FUTURE PERSPECTIVES FOR INDIVIDUAL MOTORIZED PASSENGER TRANSPORT

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2. Historical development of transport
3. Technologies for the future?
4. Modeling future scenarios for Austria
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1. Introduction

Major motivation: Heading towards sustainable transport

- *Limited resources (oil but also renewables)*
- *Global Warming (to a significant share due to greenhouse gas emissions from transport)*
- *Insecure supply security (due to dependance from few regions/countries world-wide)*

Basic principle:

Quality of infrastructure

$$S=E*\eta$$

Service:
km driven,
Power,
speed

Fuel mix,
Fuel demand

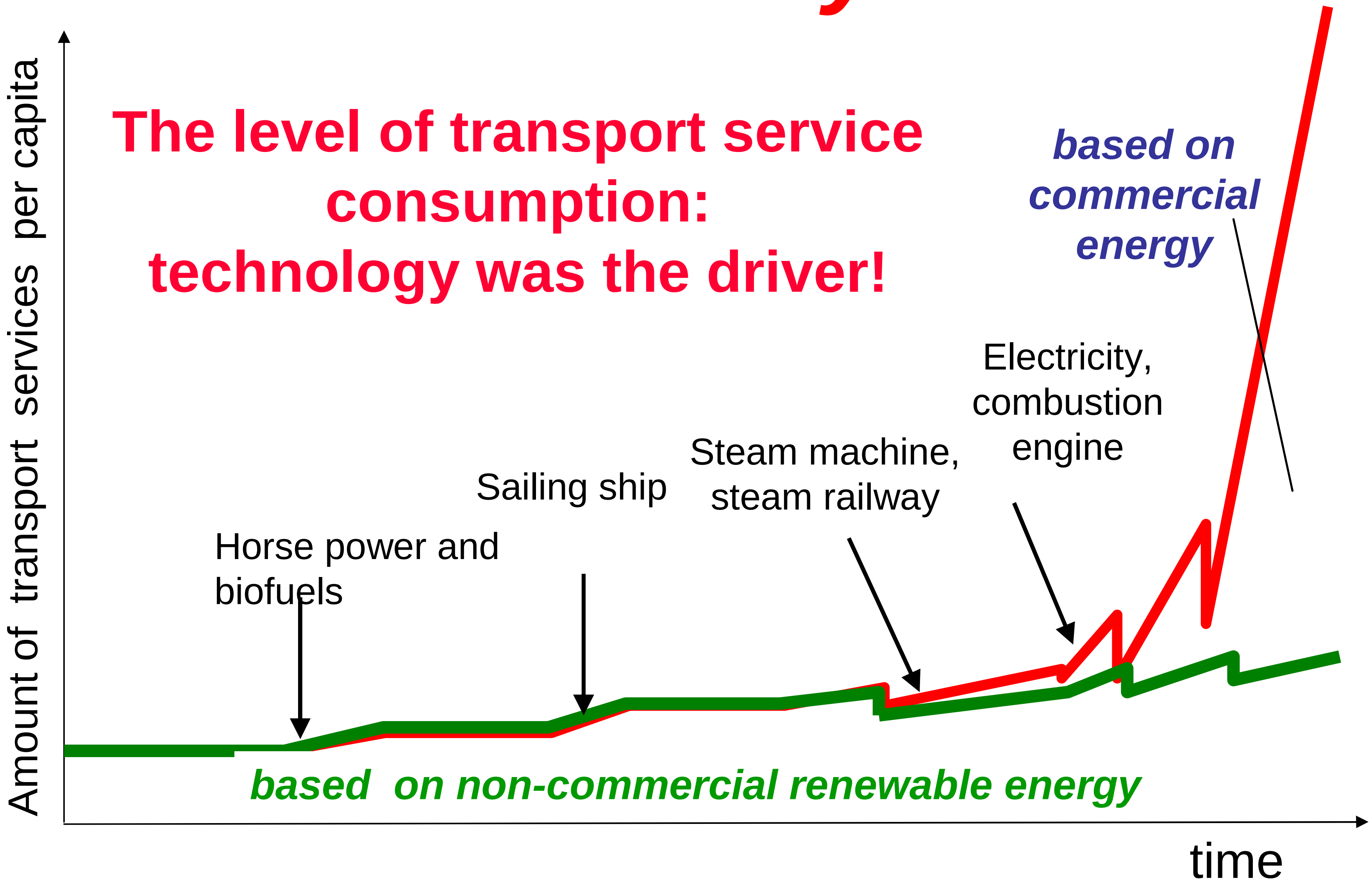
Efficiency of vehicle
(Liter/100 km)

Demand for energy service

(comfortable) mobility!

NO demand for energy!

2. History



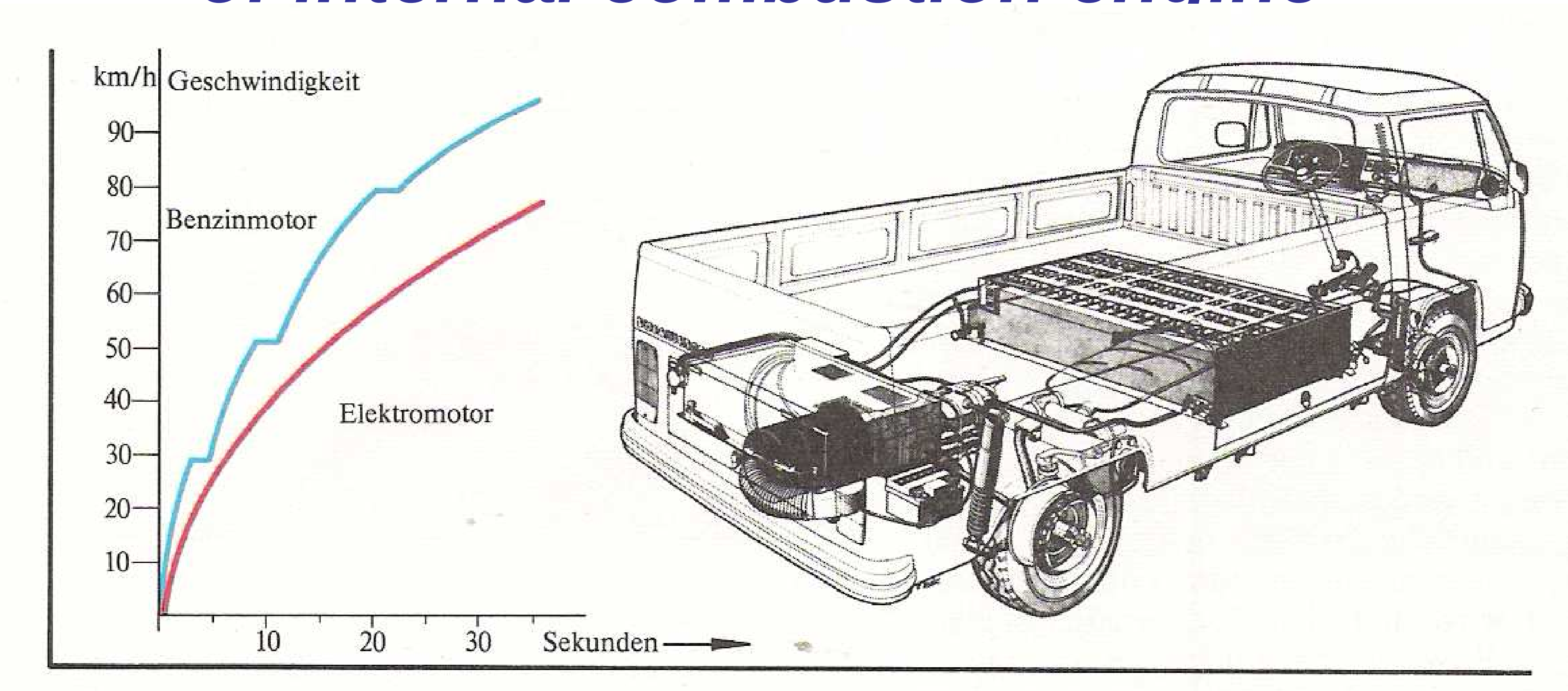
The level of transport service consumption: technology was the driver!
Amount of transport services per capita
time
based on commercial energy
Electricity, combustion engine
Steam machine, steam railway
Sailing ship
Horse power and biofuels
based on non-commercial renewable energy

2. History

The age of alternative fuels

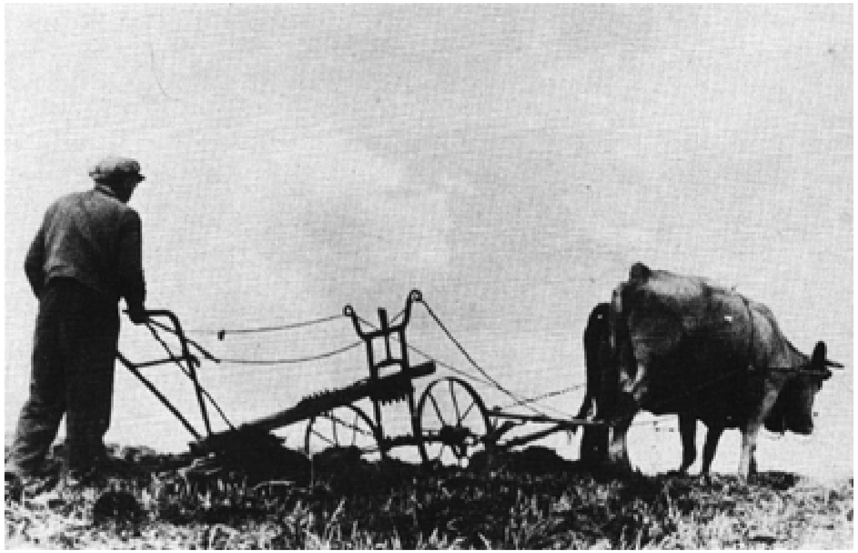
- 1807 - Isaac de Rivas makes a hydrogen gas powered vehicle - first with internal combustion power - however, very unsuccessful design
- 1826 - Samuel Morey developed an engine that ran on ethanol and turpentine.
- 1860 - German engine inventor Nicholas Otto used ethanol as the fuel in one of his engines. Otto is best known for his development of a modern internal combustion engine (the Otto Cycle) in 1876.
- In 1900, Rudolf Diesel demonstrated his compression ignition engine at the World's Exhibition in Paris. In that prototype engine he used peanut oil, the first biodiesel.

Early 20th century: The race of internal combustion engine



Before the oil age: transport sustainable but uncomfortable and exhausting!

- Farmers had to reserve 15% of farm area for „transport“ animals
- Use of tractors made these areas available for Food/feed



Biofuels in transport – a „new“ trend?

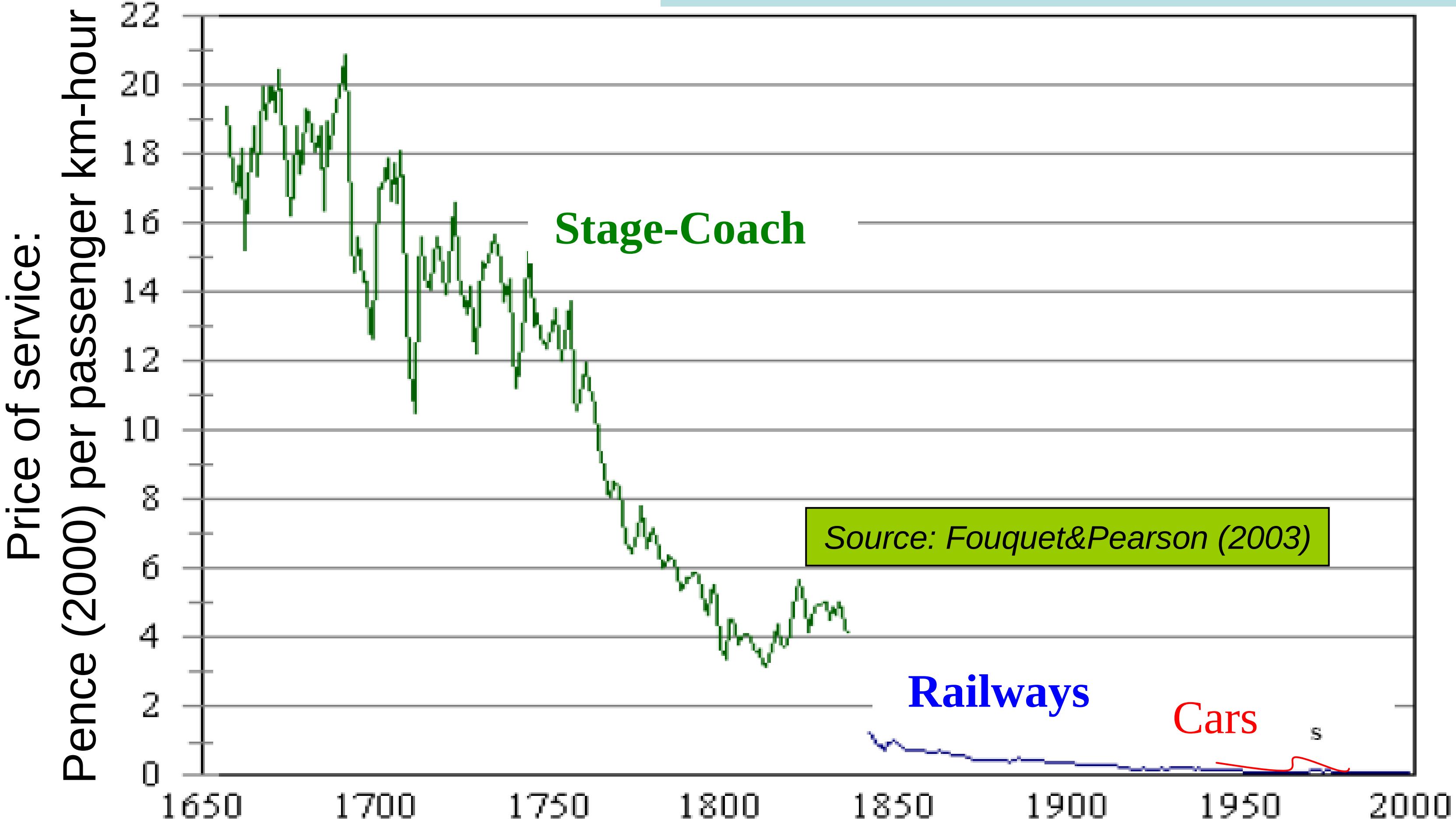
- „The fuel of the future is going to come from fruit, weeds and sawdust – almost anything. There is enough alcohol in an acre of potatoes to drive the machinery necessary to cultivate the field for a hundred years.“

- Henry Ford, 1925

2. History

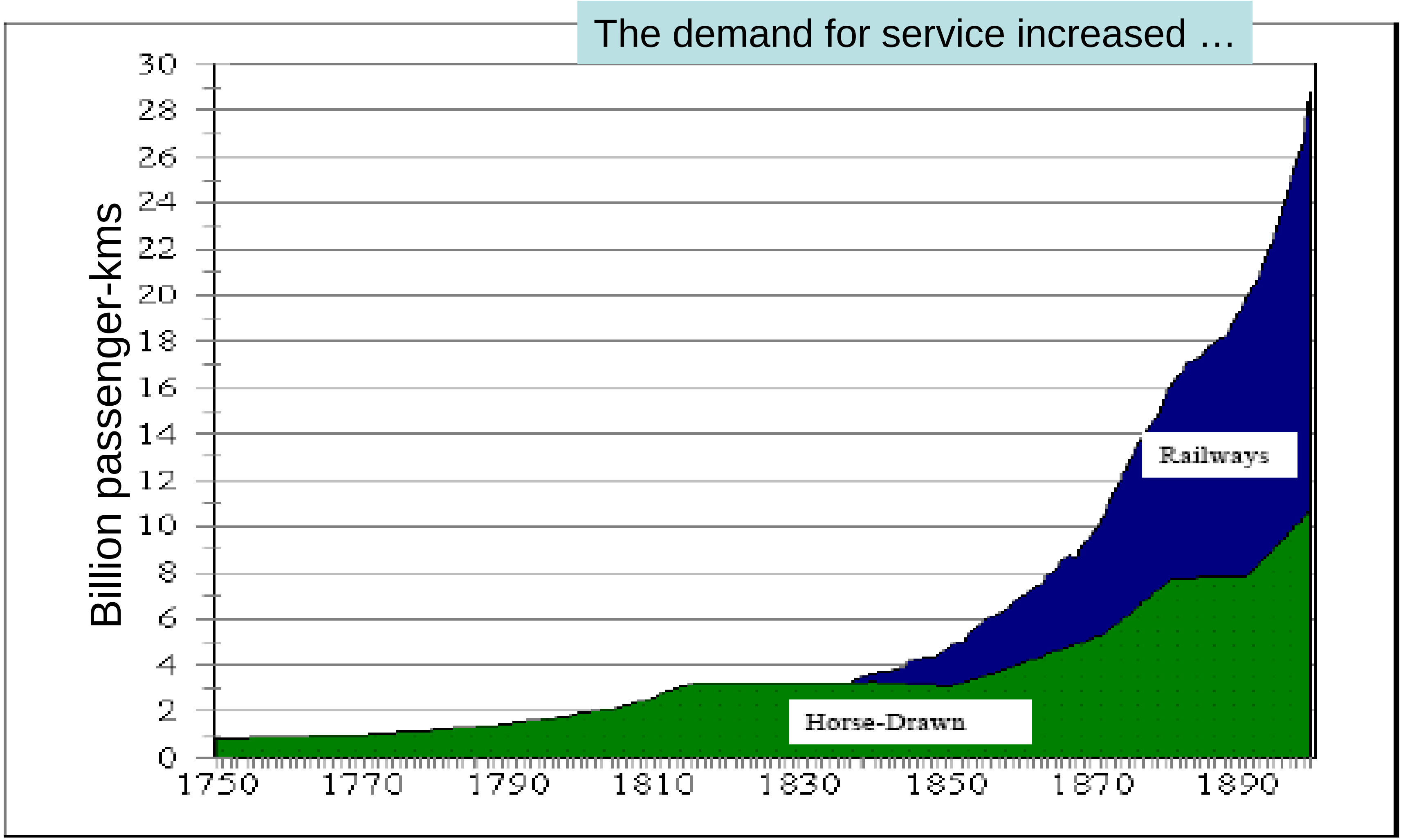
Price of Passenger Transport
(per passenger-kilometer-hour)

The price of service dropped dramatically!



2. History

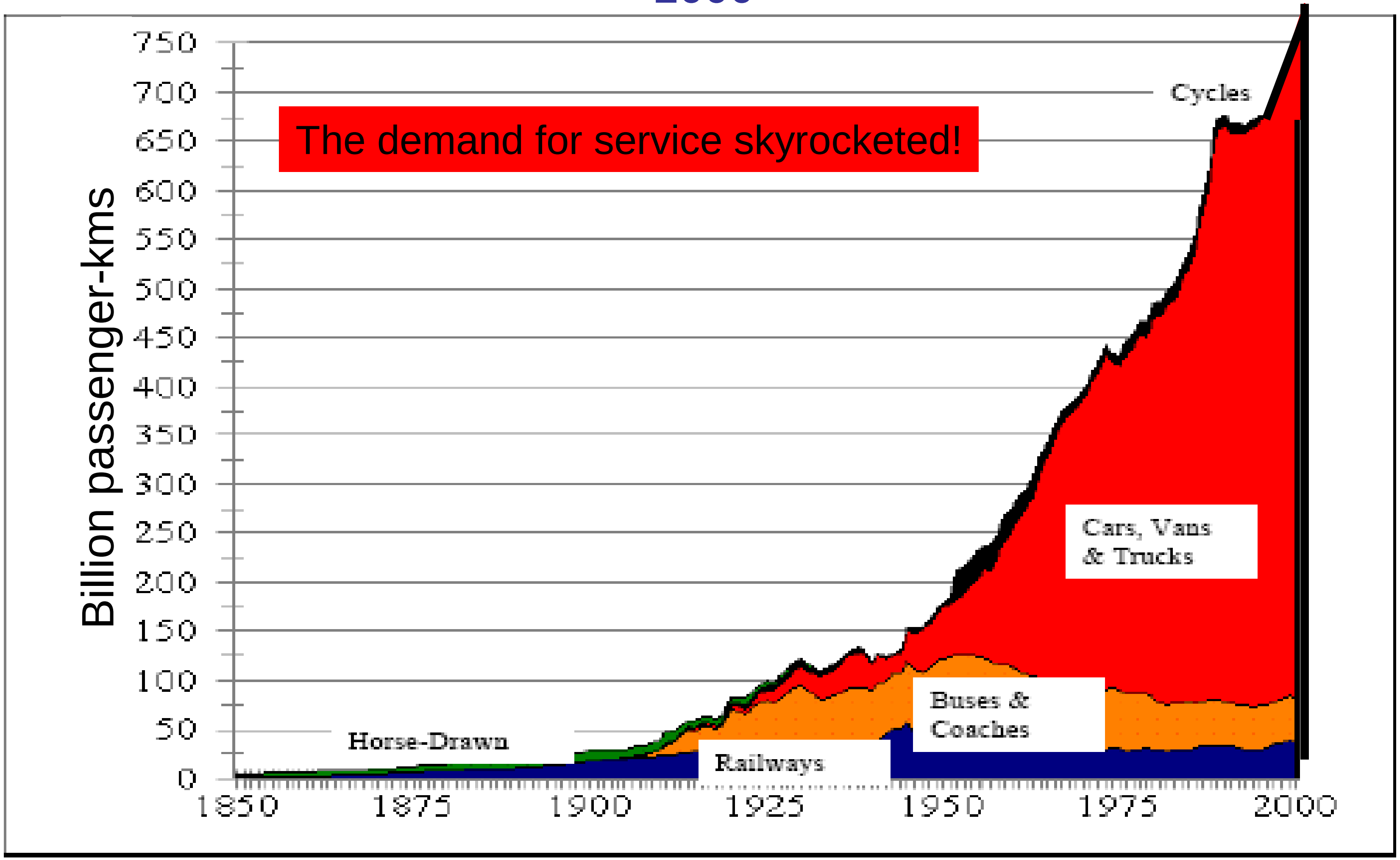
UK: The Use of Passenger Transport (per Passenger-Kilometre), 1750-1900



Source: Fouquet,2006

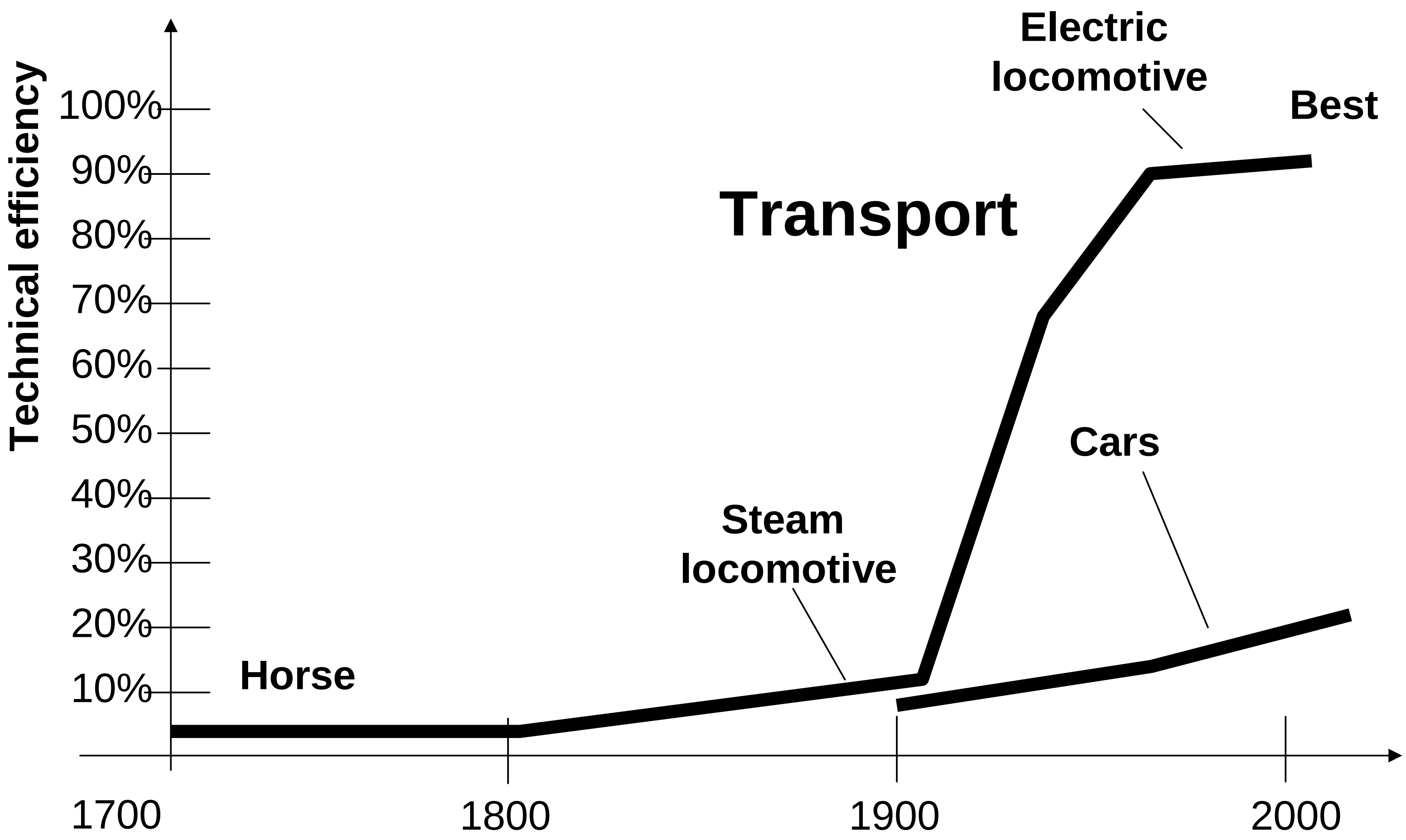
2. History

UK: The Use of Passenger Transport (per Passenger-Kilometre), 1850-2000



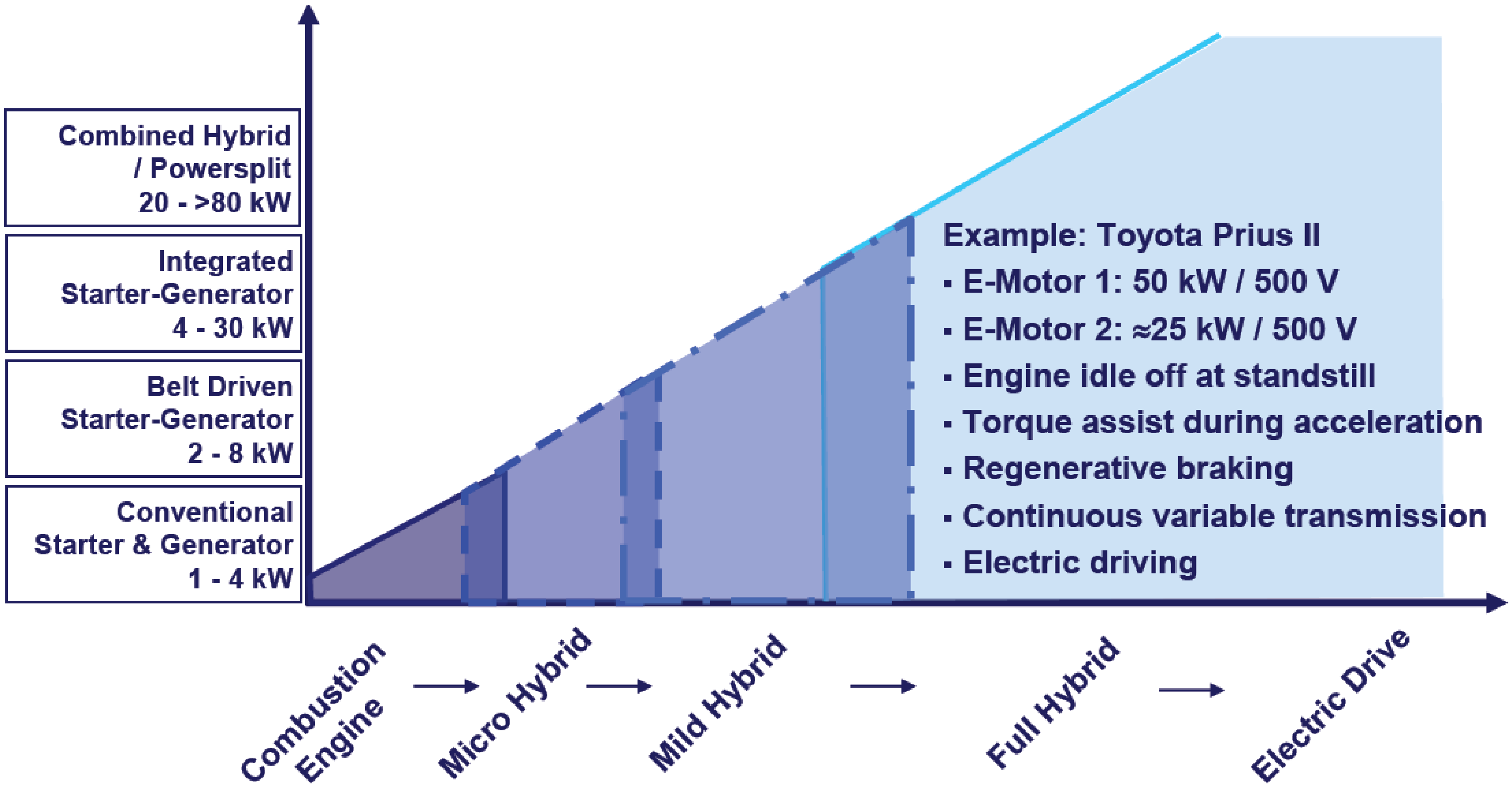
Source: Fouquet,2006

2. History: Development of efficiencies



3. Which alternatives are conceivable for the future ?

Degree of car electrification

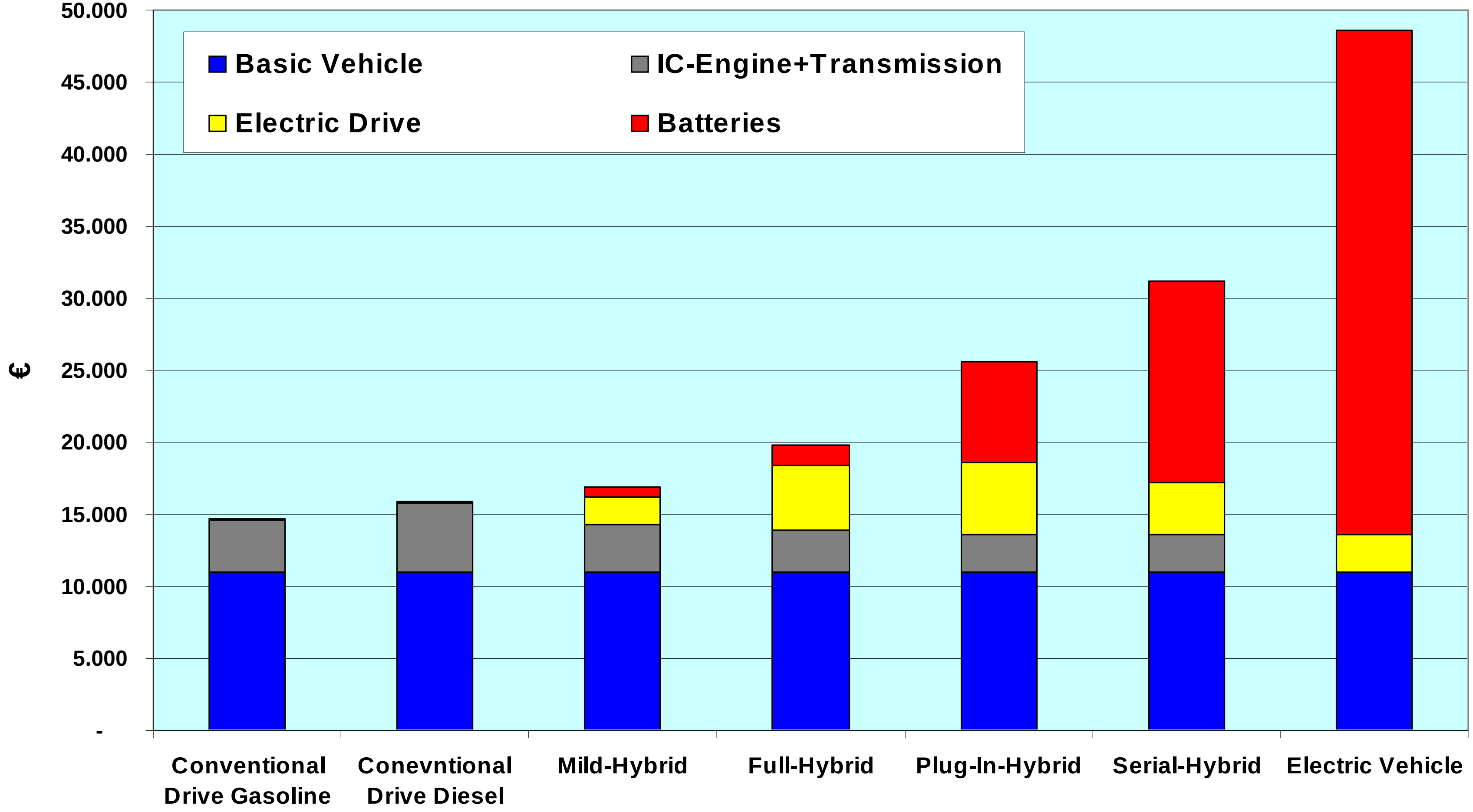


Energy storages

Volumes and mass of alternative fuels to provide the equivalent of 67 litres gasoline

Kraftstoff	Volumen (in Liter)*	Masse (in kg)*
Benzin	67	46
Diesel	60	46
Synthet. Kraftstoff	60	46
Biodiesel	67	54
Ethanol E85	95	70
Erdgas (200 bar)	245	225
Wasserstoff (700 bar)	356	190
Bleiakkus	2040	5300
Nickel-Metallhydrid-Akkus	840	2180
Lithium-Ionen-Akkus	600	1080

Netto Investment costs 2010 by component (about 75 kW)

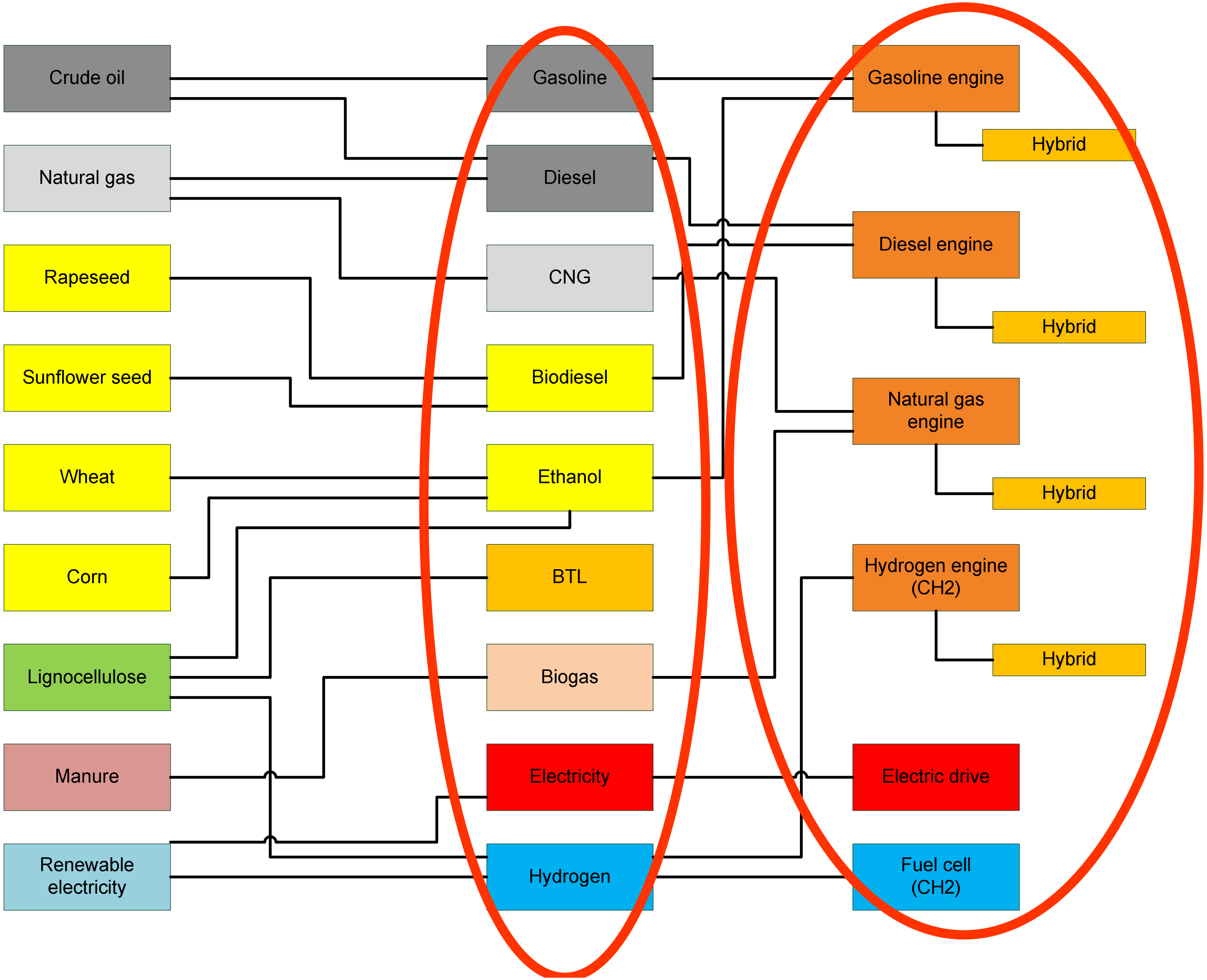


4. Future scenarios for Austria: The project ALTANKRA

Core objective

- The core objective is to analyse whether, under what boundary conditions, to what extent and when the alternative propulsion systems and fuels can be of economic relevance in Austria.
- To meeting this objective in scenarios the impact of the following key parameters is investigated:
- Possible trends in the energy price level
- Changes in demand for mobility
- Technical efficiency increases and cost reductions of specific technologies;
- Changes in policy framework conditions (taxes, subsidies, etc.).

Investigated cases



Method of approach:

- **Basic approach is an energy-economic approach based on customers WTP**
- **Decision-making criteria: Economics wrt total costs per km driven**
- **Dynamic stock change model**
- **Reference vehicle: same capacity for all powertrains,**
- **Same distance (15000 km)**
- **Distribution of usefulness and acceptance same for all powertrains**

Economic analysis

The analysed alternative automotive systems are in a different stage of development, so that total vehicle costs could be divided in two parts:

$$IC = IC^{CON} + IC^{INNOV}$$

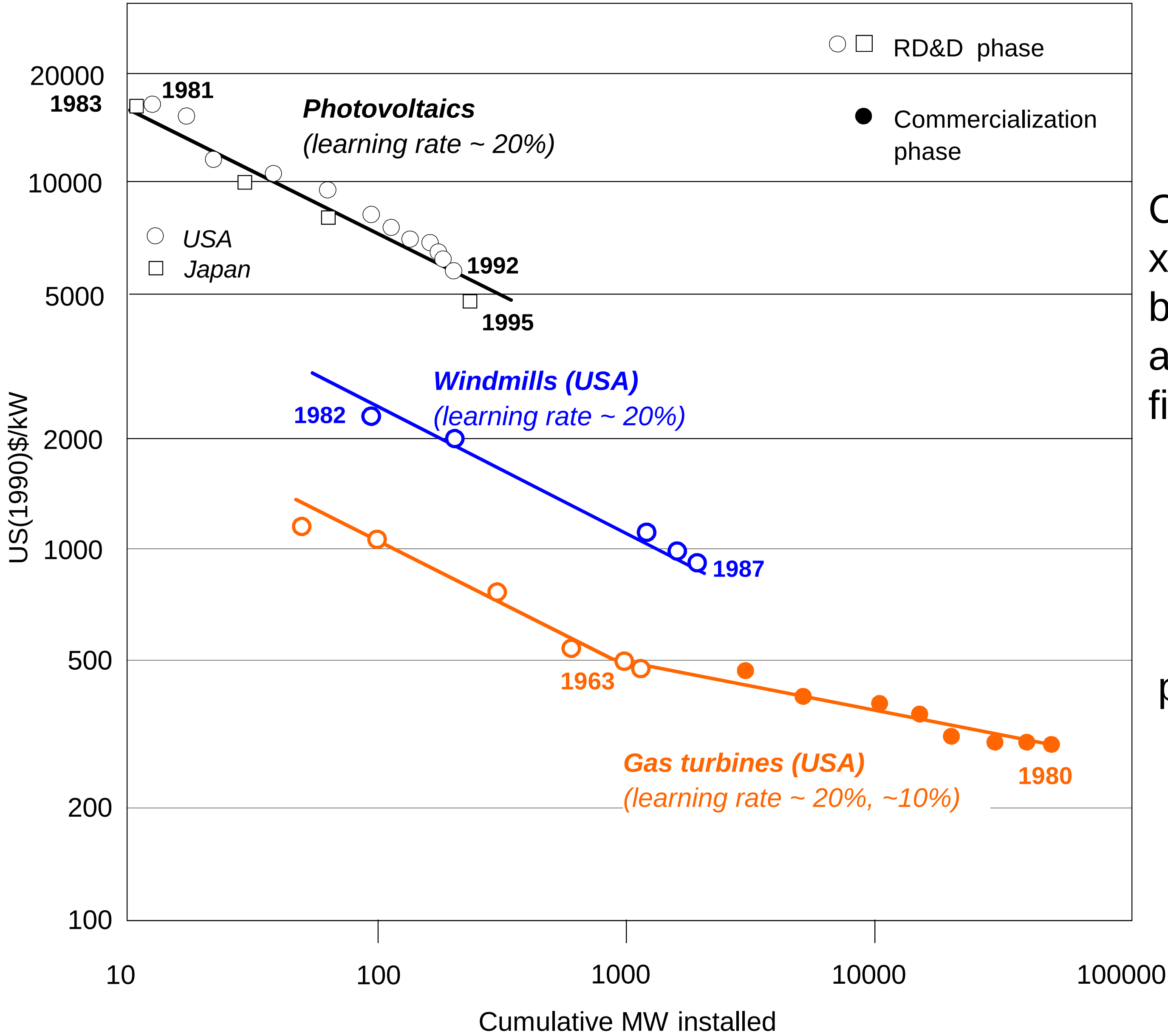
Where:
IC^{CON}: Investment costs for the conventional part of vehicle (no learning effect)
IC^{INNOV}: Investment costs for the innovative part of vehicle (learning rate 20%).

The total transport costs are dependent on the fuel cost and investment costs for vehicles:

$$TC = FC + IC_{sp}$$

Where:
TC: Transport cost (EUR/km)
FC: Fuel cost (EUR/km)
IC_{sp}: Specific investment costs for vehicle (EUR/km)

Technology learning curves



$$C(x) = a \cdot x^{-b}$$

C(x): Specific cost
x: Cumulative capacity
b: Learning index
a: Specific cost of the first unit

$$p = 2^{-b}$$

p: progress ratio

Economic analysis

The fuel cost per kilometre is calculated as follows:

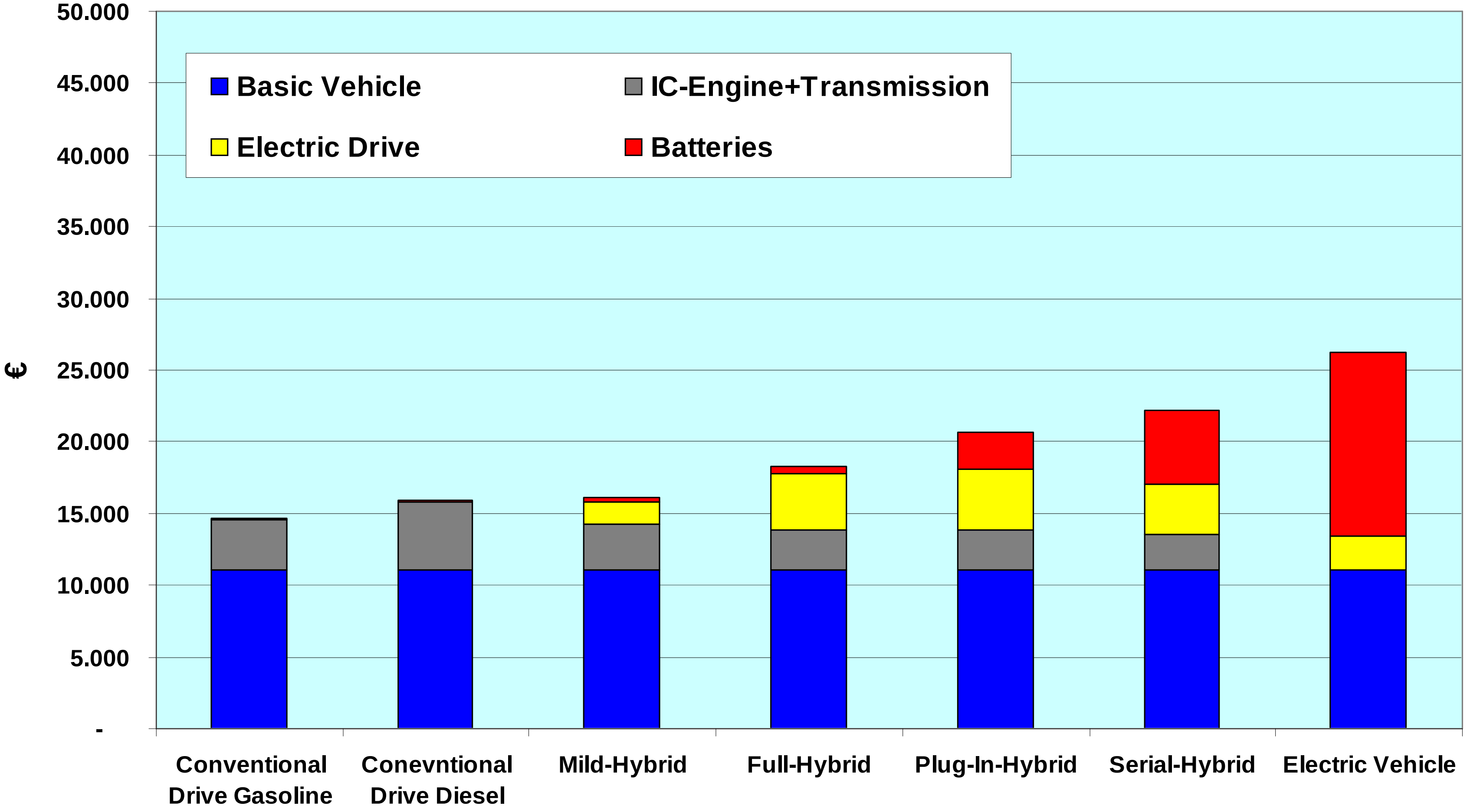
$$FC = EC \cdot FP$$

Where:
EC: Energy consumption (kWh/km)
FP: Fuel price at the refuelling station (EUR/kWh)
The total annual specific investment costs for vehicles are calculated as follows:

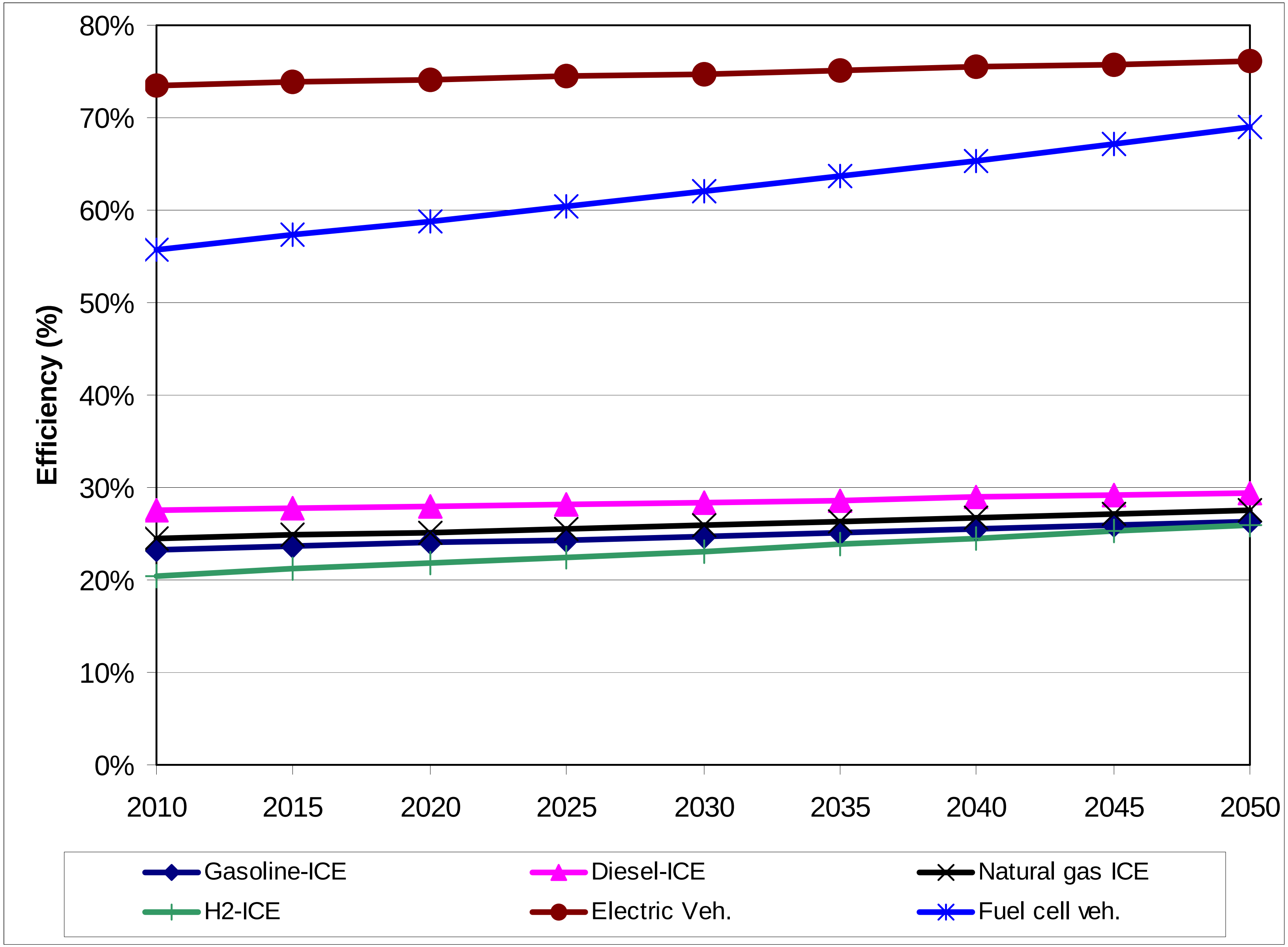
$$IC_{sp} = (\alpha \cdot (IC + NOVA) \cdot (1 + VAT)) / D_{km}$$

Where:
α: Capital recovery factor (-)
IC: Investment costs for vehicle (EUR)
NOVA: Tax on acquisition (EUR)
VAT : Value added tax
D_{km}: The annual number of kilometres driven per year (km)

Netto Investment costs 2030 by component (about 75 kW)



Increase of efficiencies



Economic analysis

$$Z_{t+1} = Z_t \cdot \left(\frac{FP_{t+1}}{FP_t}\right)^{\varepsilon_{FP}} \left(\frac{IC_{t+1}}{IC_t}\right)^{\varepsilon_{IC}} \cdot \left(\frac{GDP_{t+1}}{GDP_t}\right)^{\varepsilon_{\gamma}}$$

Elasticity of fuels price $\varepsilon_{FP} = -0{,}5$

Elasticity of vehicle price $\varepsilon_{IC} = -1$

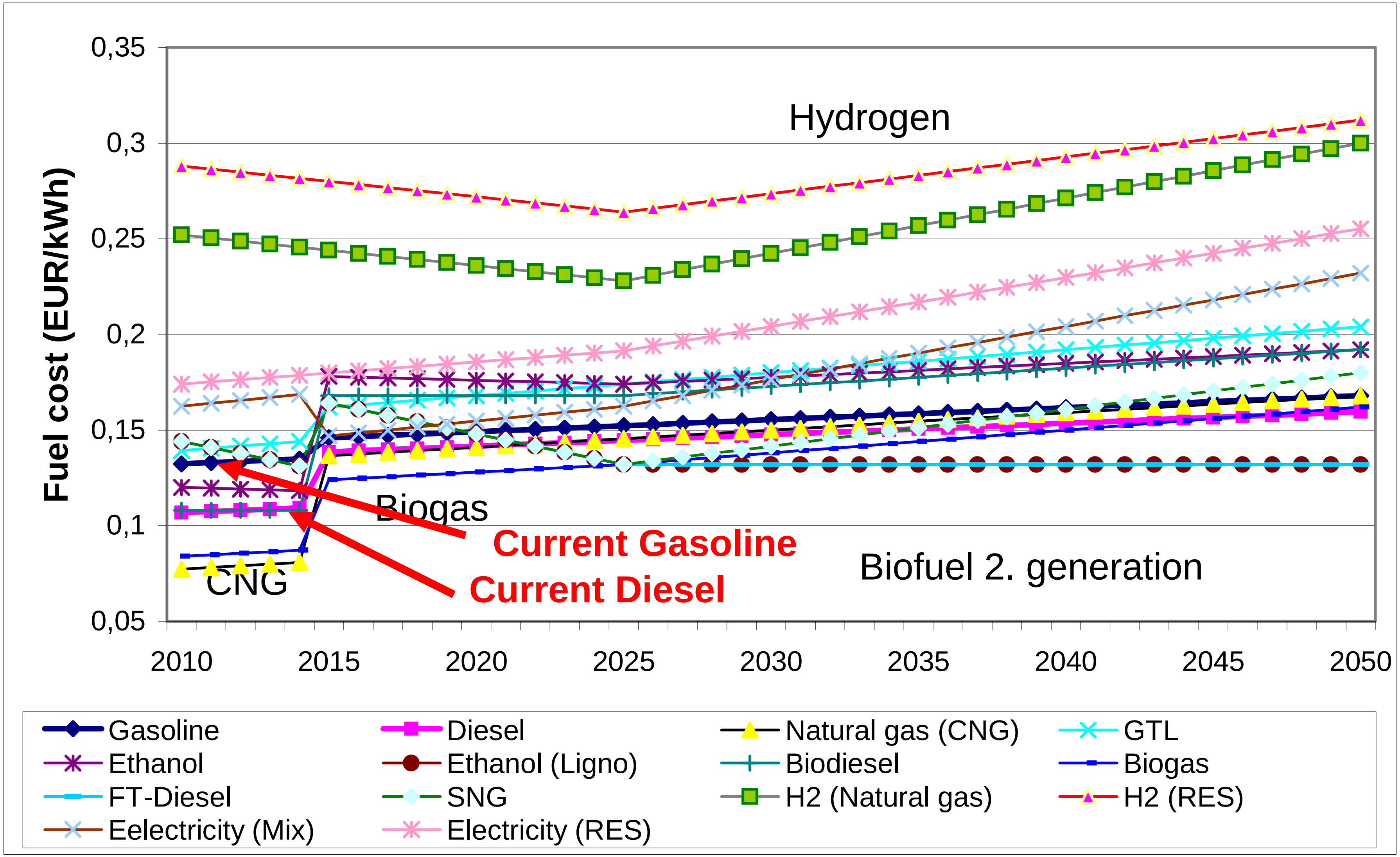
Income elasticity $\varepsilon_{\gamma} = 0{,}8$

Where:
Z: Vehicle sales per year
FP: Fuel price
IC : Investment cost
GDP: Gross domestic product

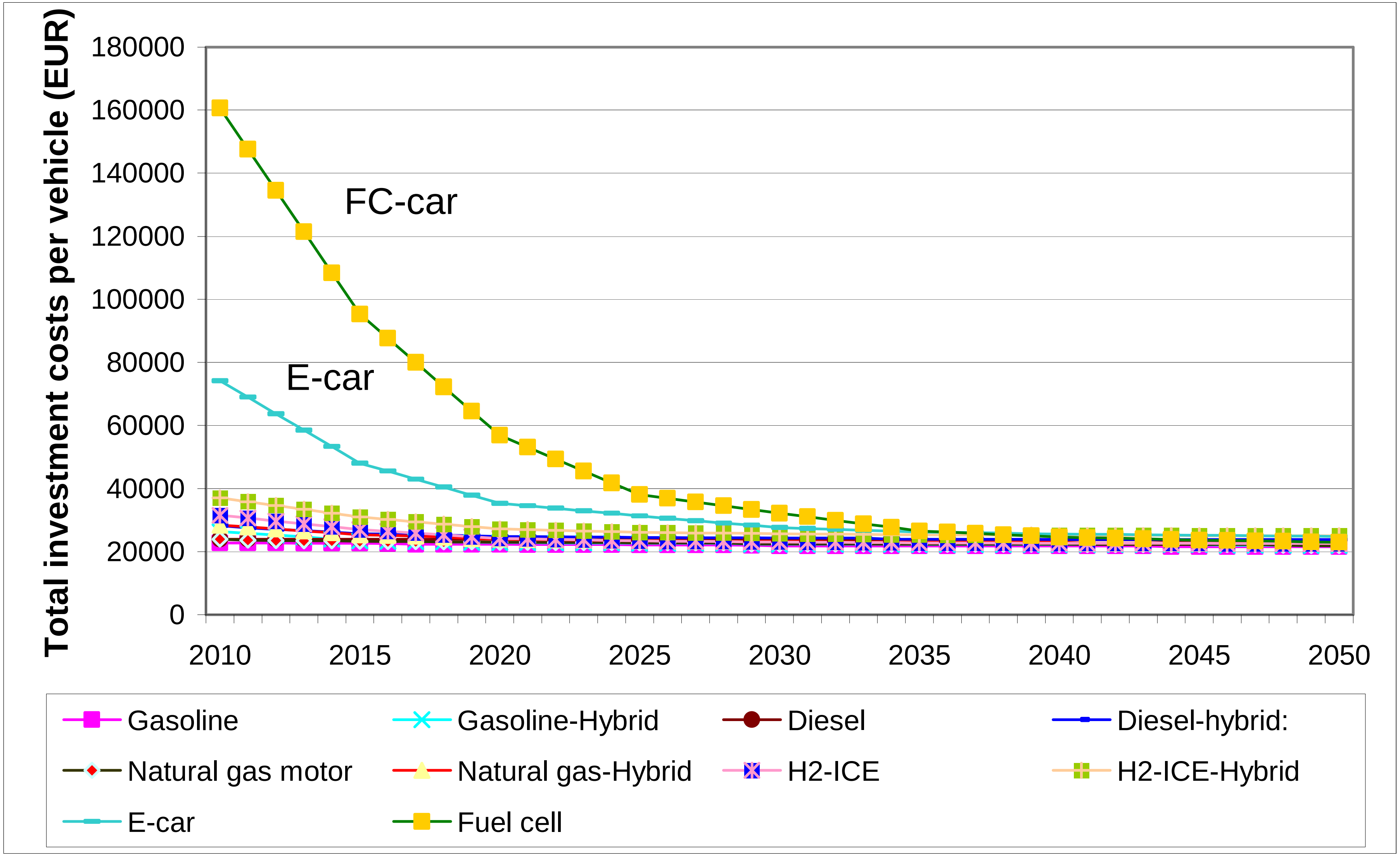
Two major scenarios

- **BAU-scenario: Low oil price and business-as-usual policy**
- **Policy scenario: High oil price and comprehensive policy measures**

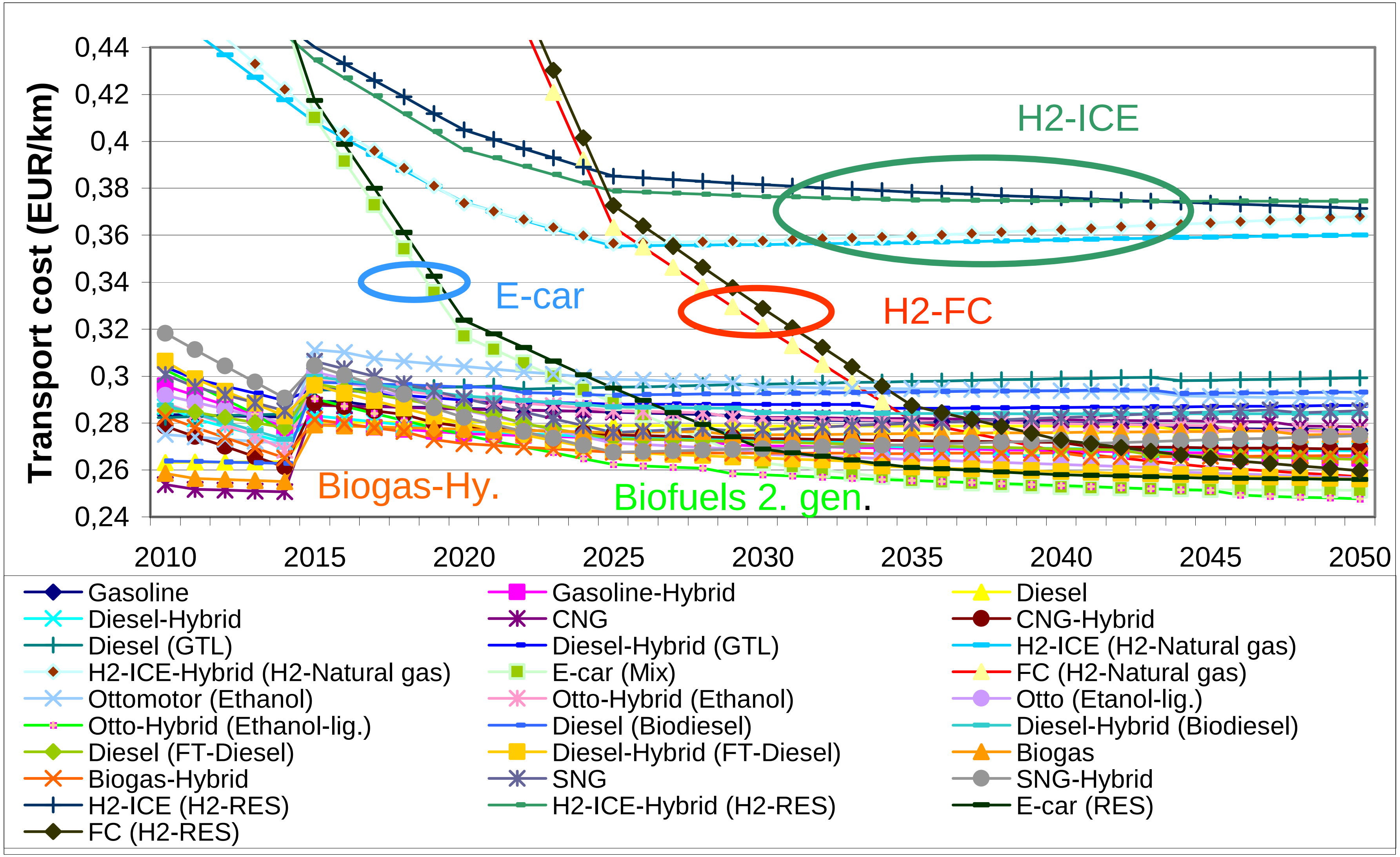
Fuel costs BAU scenario:
Low oil price and business as usual policy



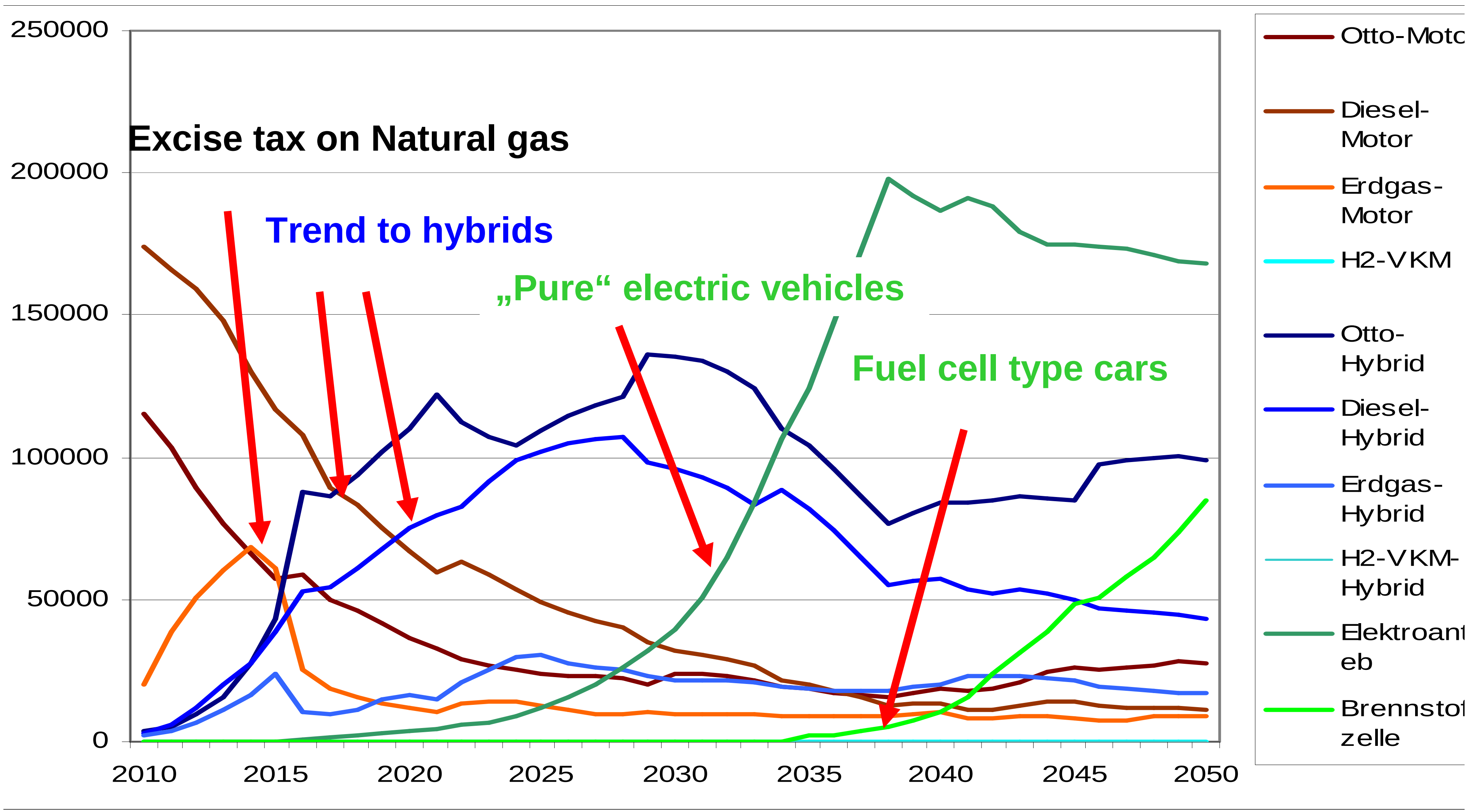
Capital costs BAU scenario:
Low oil price and business as usual policy



BAU scenario: Total transport costs (EUR/km)

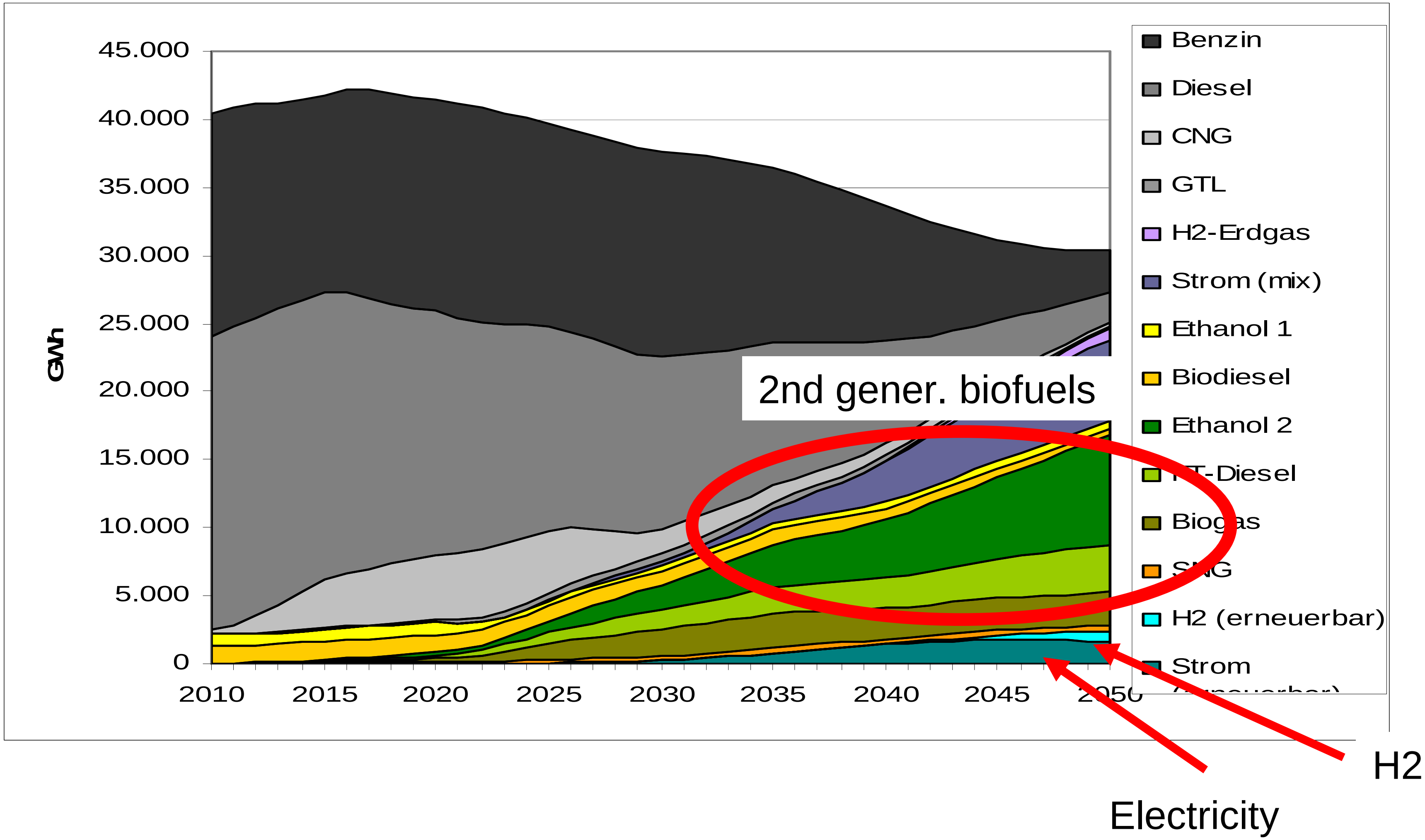


BAU- Scenario: New registrations by type of powertrain



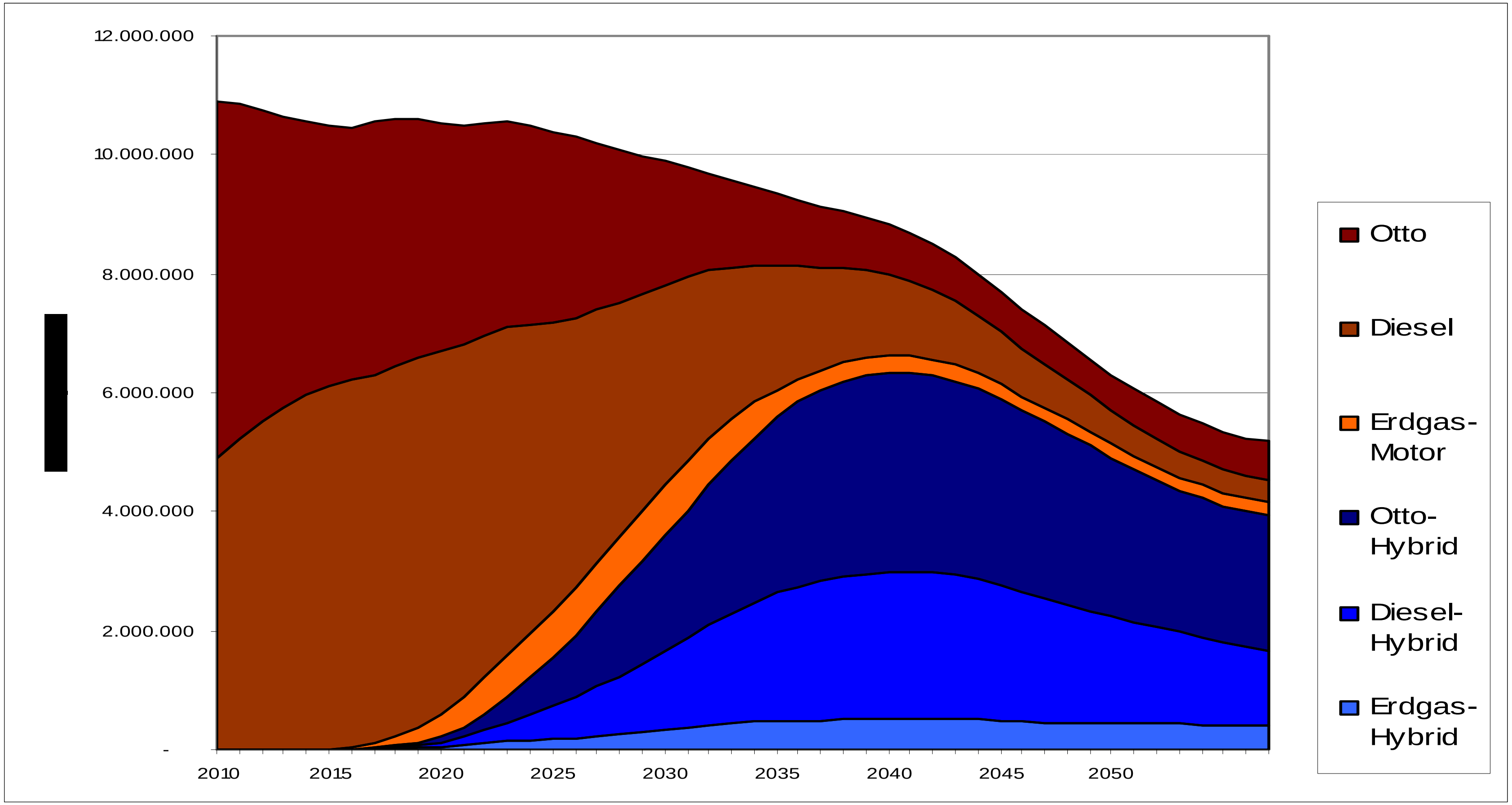
Szenario A

Verteilung des Endenergieverbrauchs:



Szenario A

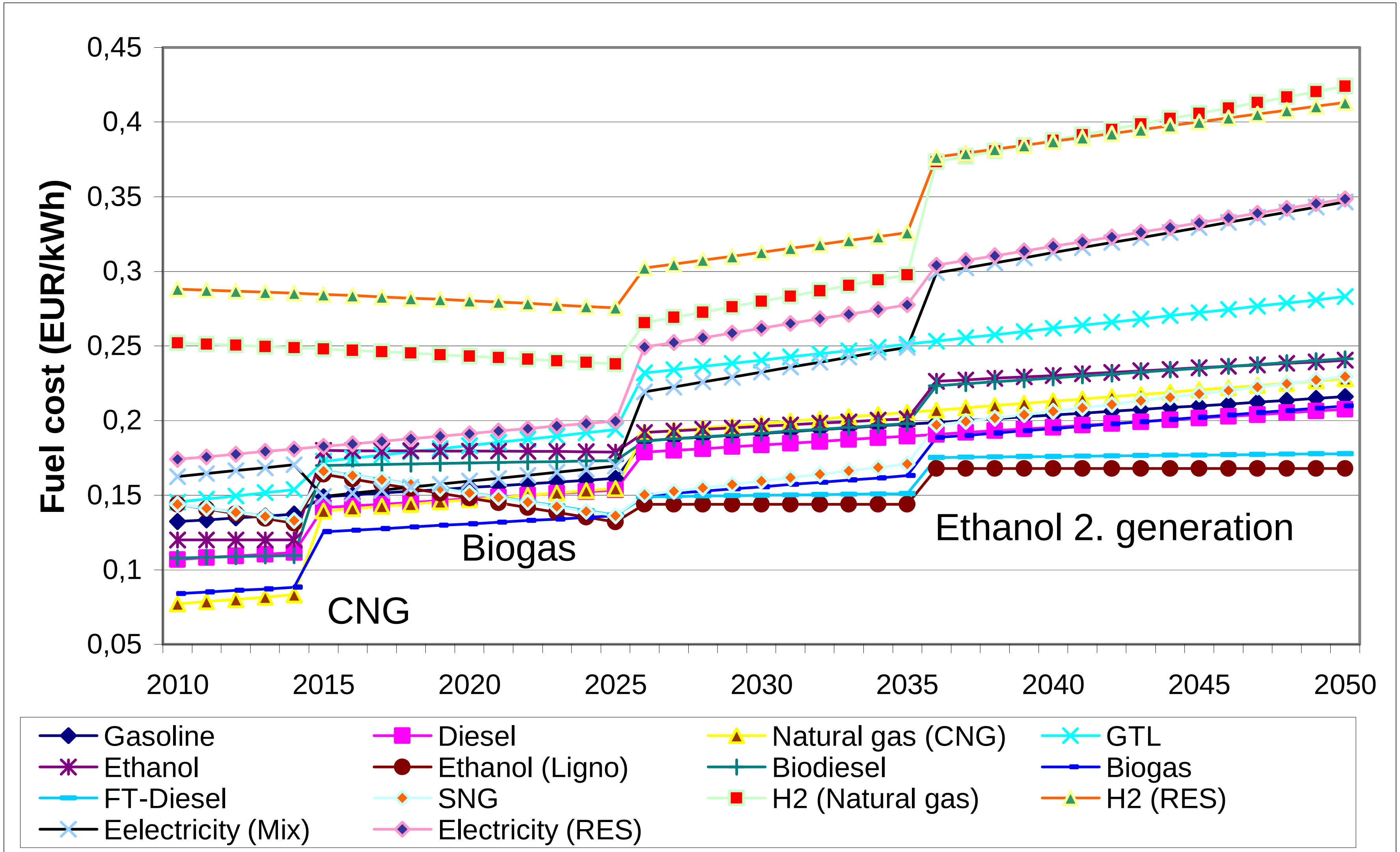
TTW – Treibhausgas – Emissionen:



Policy scenario: major features

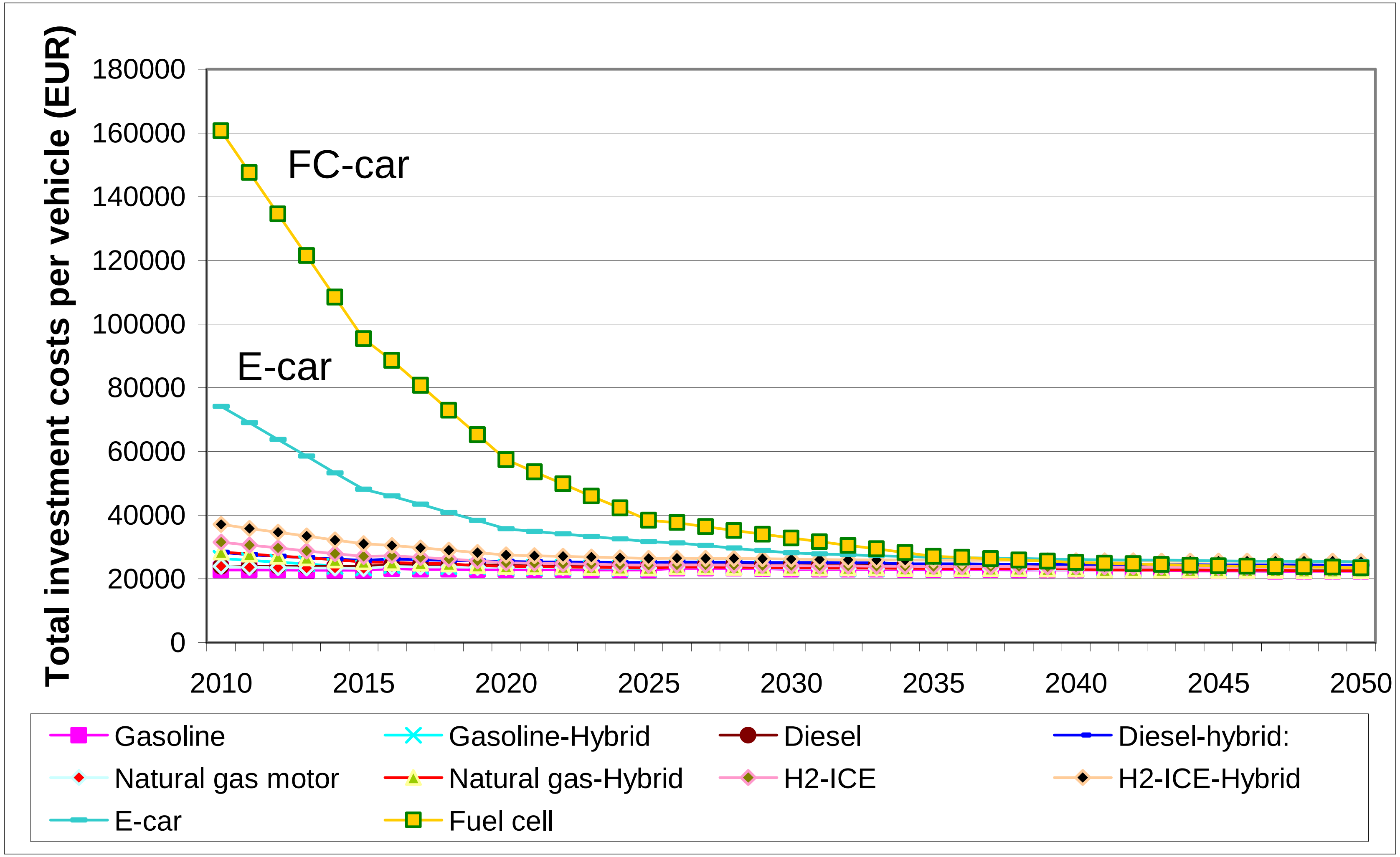
- ***Higher oil price (due to taxes and/or high price)***
- ***Quotas for Zero-emission vehicles starting in 2015***
- ***CO2-dependet increases in registration taxes***

Policy Scenario:
Fuel costs per km driven

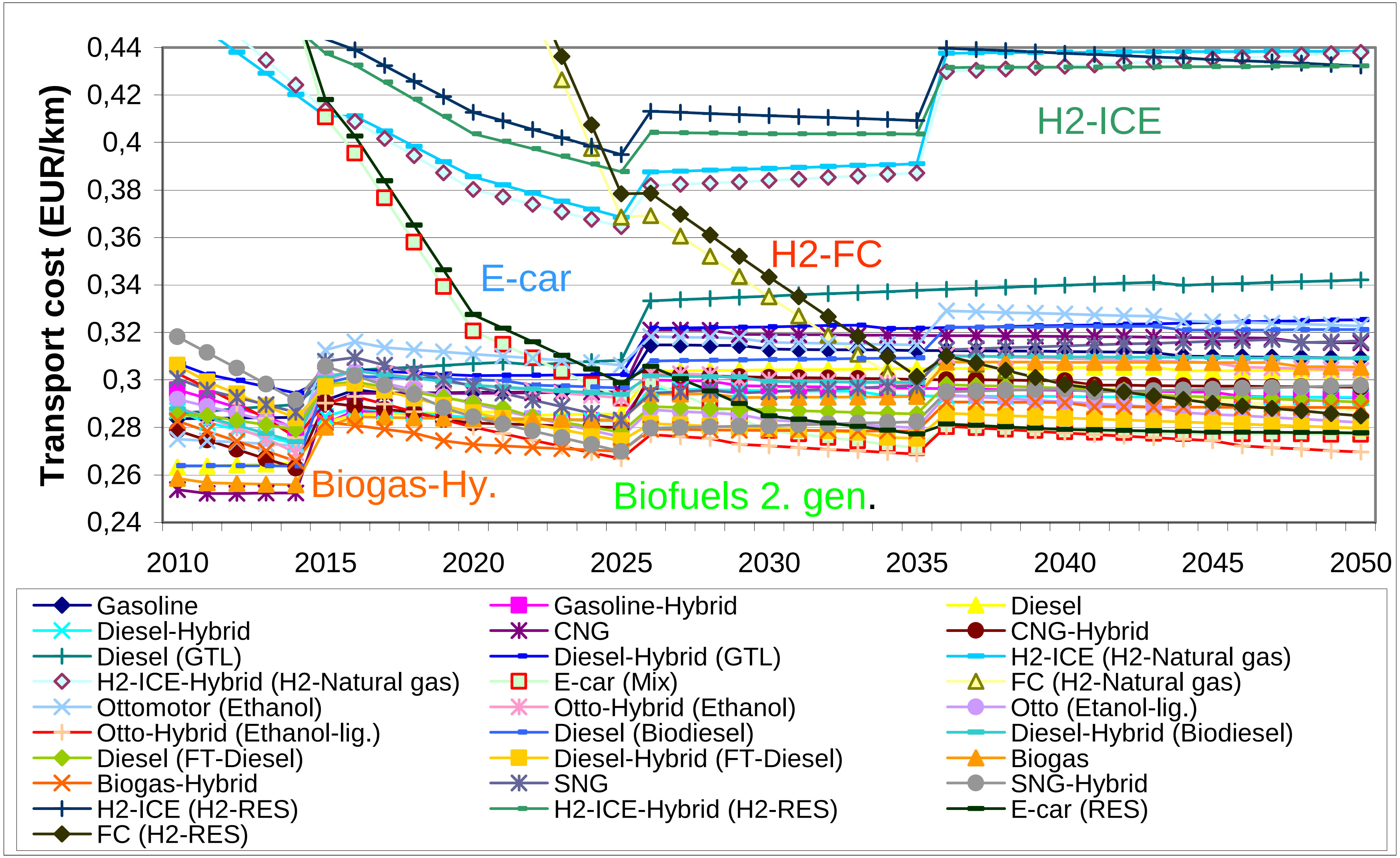


Policy Scenario:

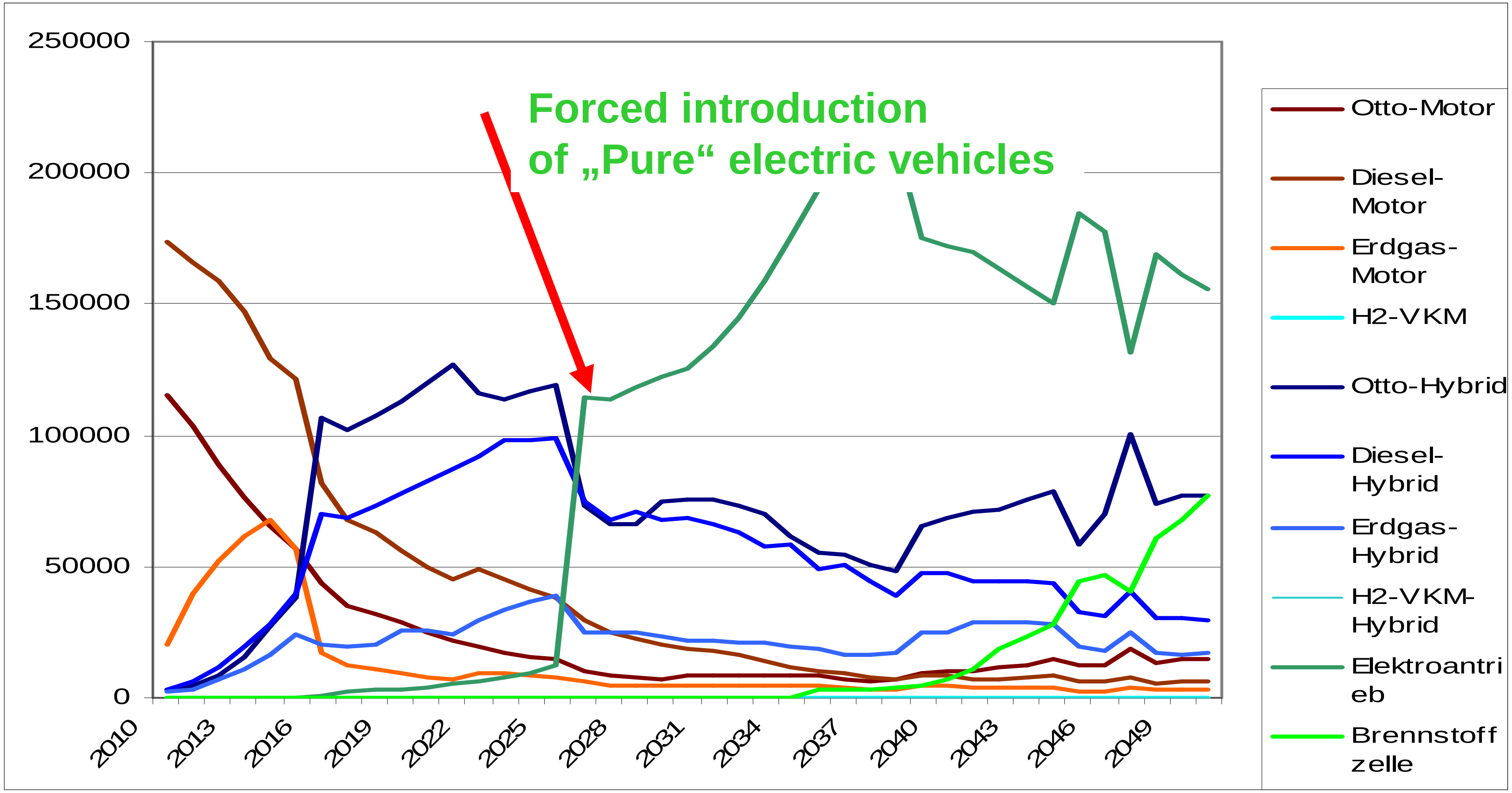
Total capital costs per km driven



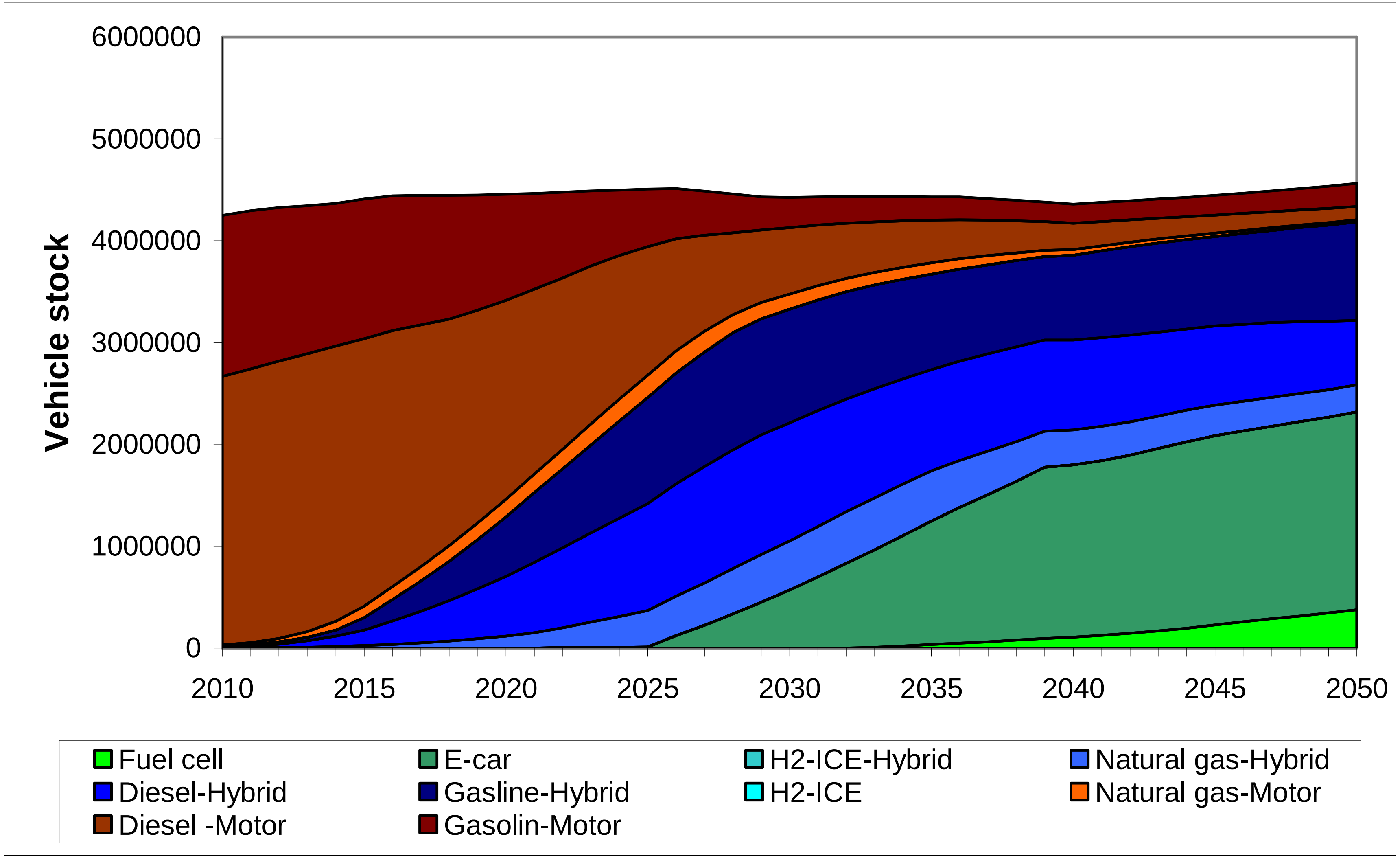
Policy Scenario:
Total transport costs per km driven



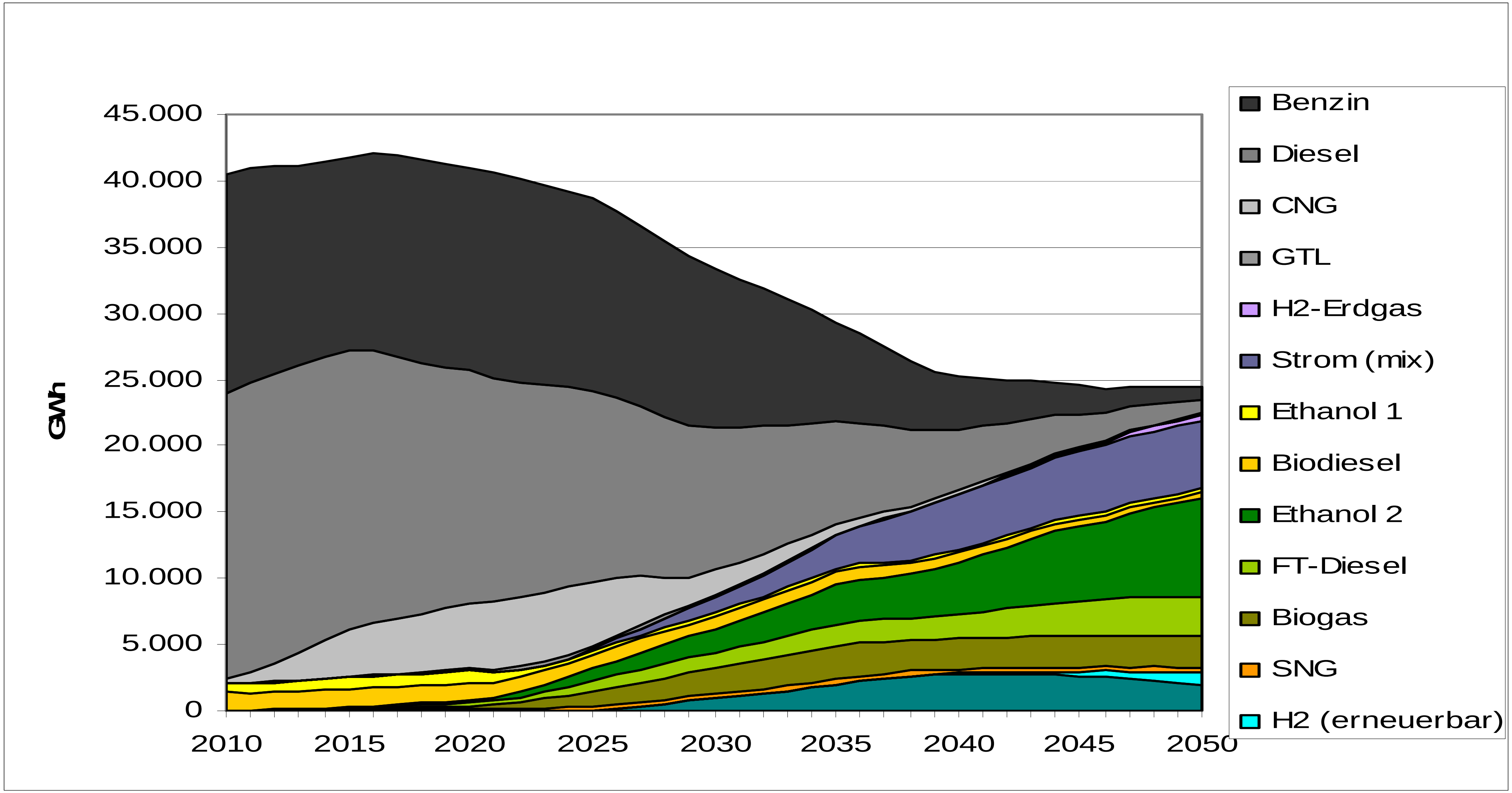
Policy - Scenario: New registrations by type of powertrain



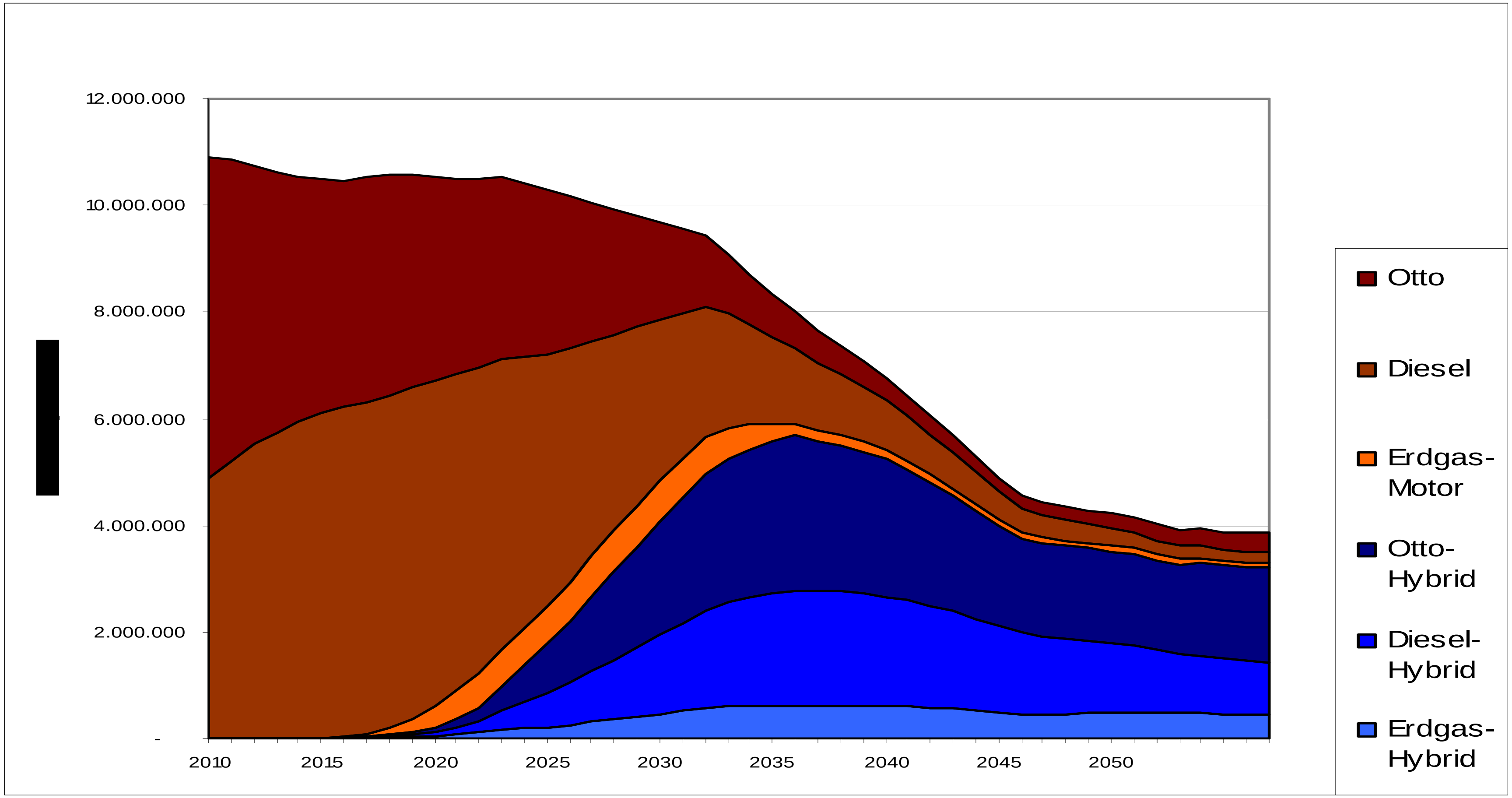
Policy Scenario:
Development of vehicle stock



Policy Scenario:
Development of energy consumption

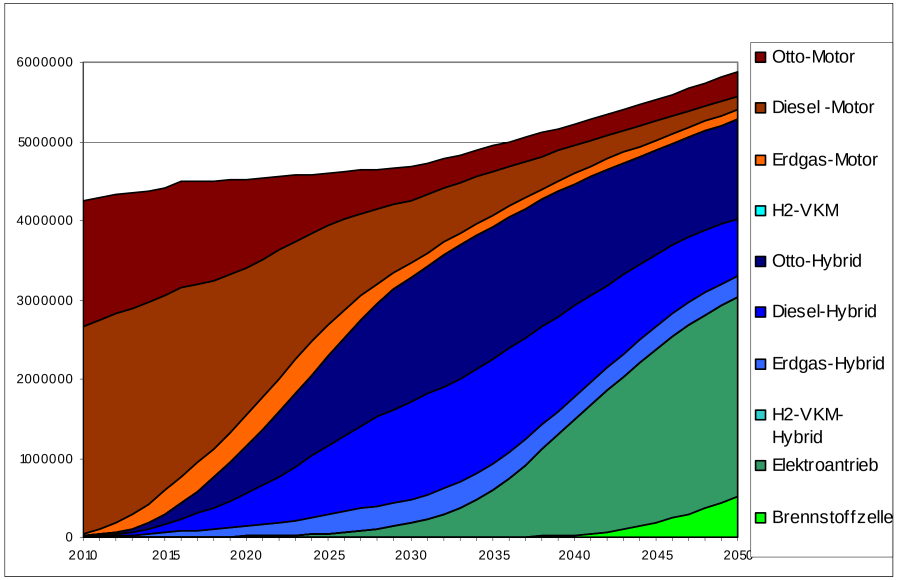


Policy Scenario:
Development of greenhouse gas emissions

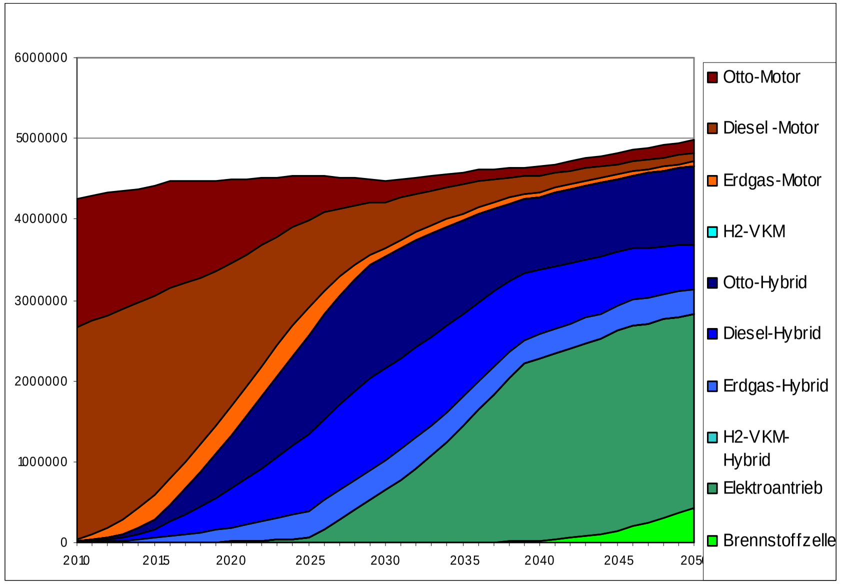


Comparison of Scenarios: Development of vehicle stock

BAU-Scenario:

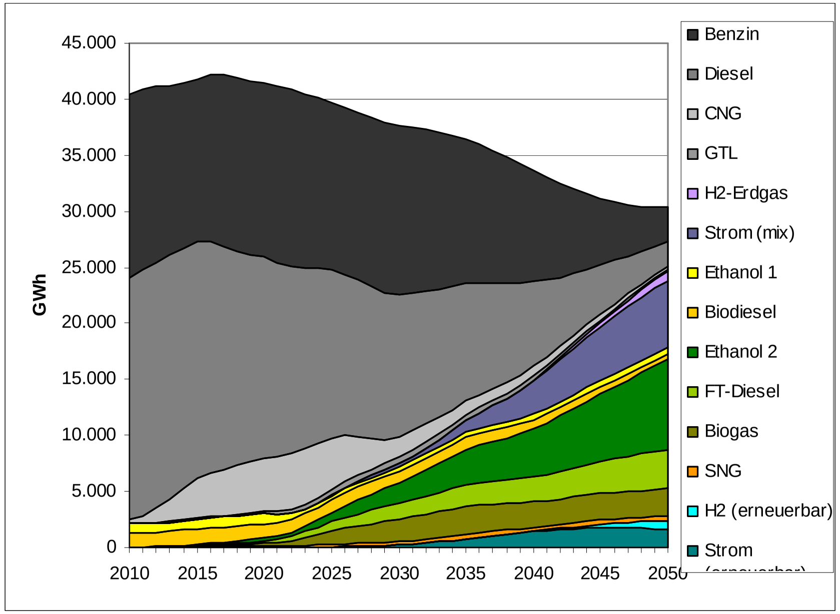


Policy Scenario:

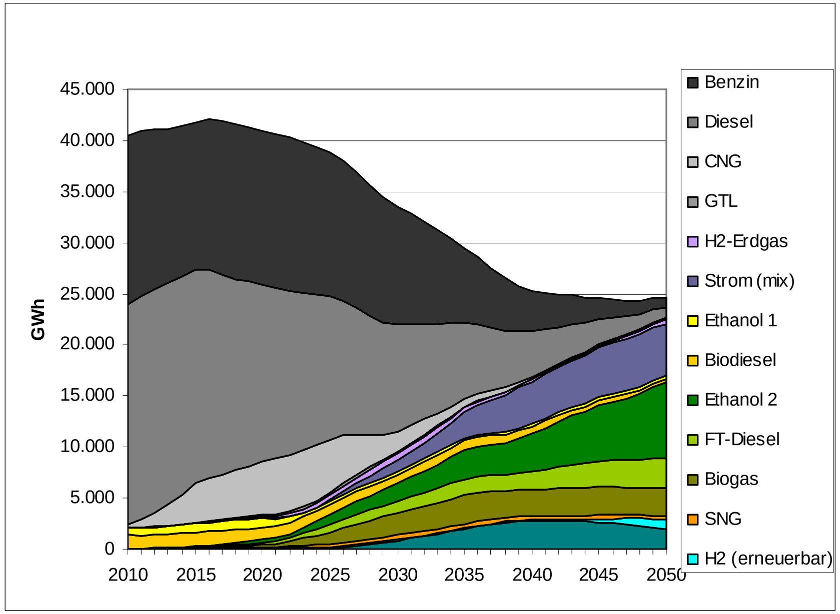


Comparison of Scenarios: Development of energy consumption by fuel

BAU-Scenario:

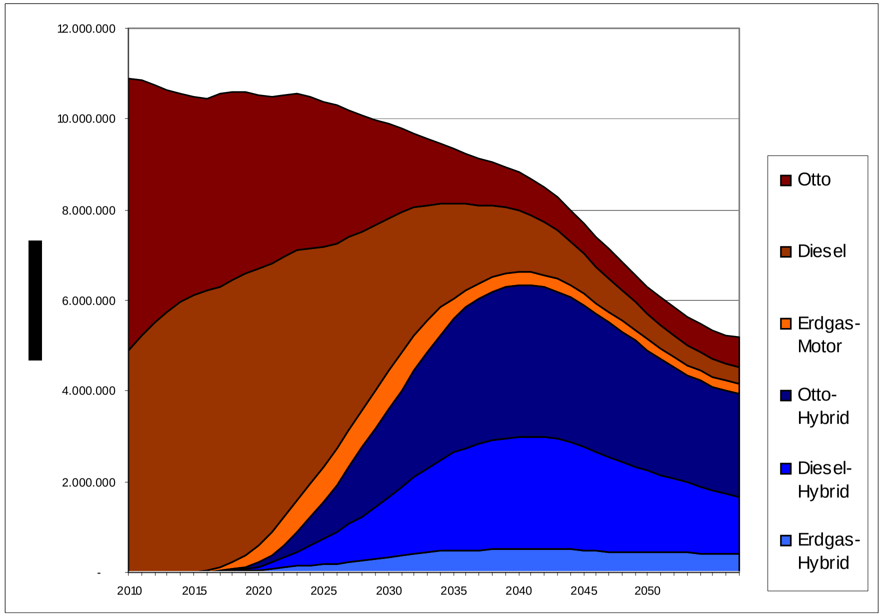


Policy Scenario:

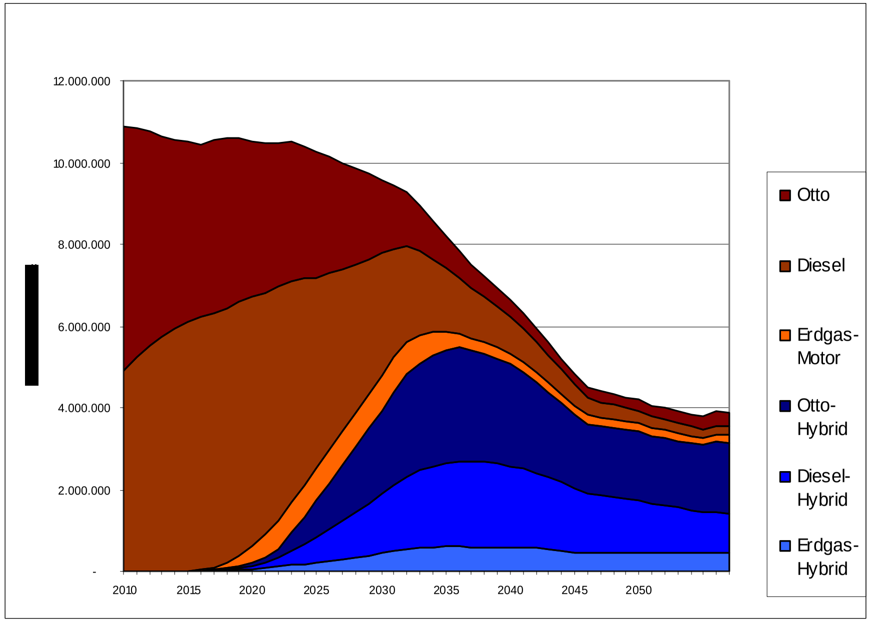


Comparison of Scenarios: Development of greenhouse gas emissions by powertrain

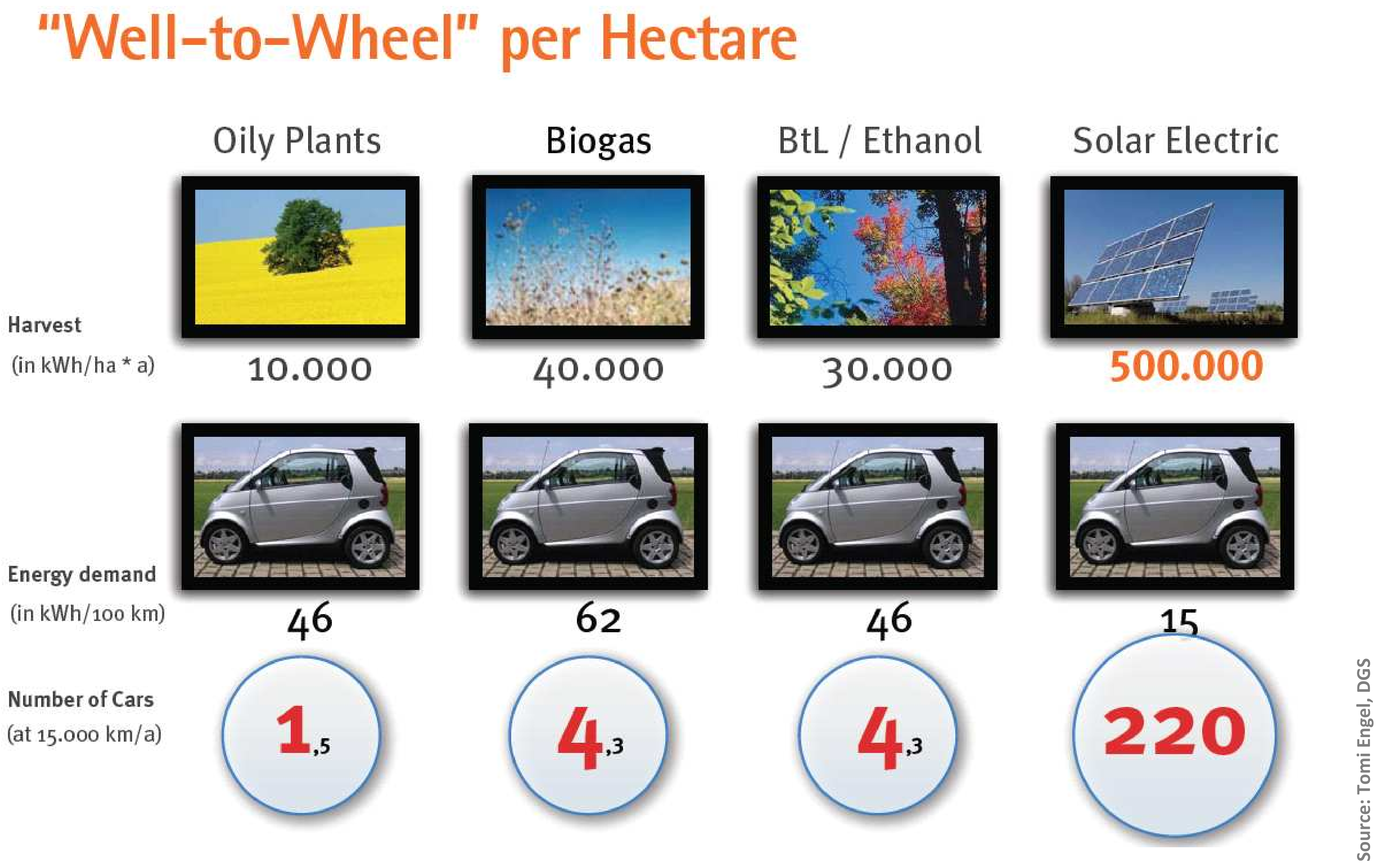
BAU-Scenario:



Policy Scenario:



Agricultural area used for transport: Competing techologies



5. Conclusions

The major conclusions of this analysis are:

- In a BAU-scenario with fuel prices increasing only moderately the stock of vehicles is increasing continuously and the major effect is a strong "hybridisation" of vehicles.
- In a scenario with high oil price and an ambitions introduction of "green" policies the total stock of vehicles stagnates or is even slightly decreasing and electric cars gain significant market shares already from 2030.
- Yet, a major characteristic of all investigated scenarios is that the manifold of propulsion systems as well as of fuels increases significantly.
- The higher decrease in energy consumption and vehicles stock can be achieved only if appropriate accompanying policies are implemented.

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