On the prospects of increasing energy efficiency in car transport by promoting electric and hydrogen vehicles

Reinhard Haas, Amela Ajanovic
Energy Economics Group
Vienna University of Technology

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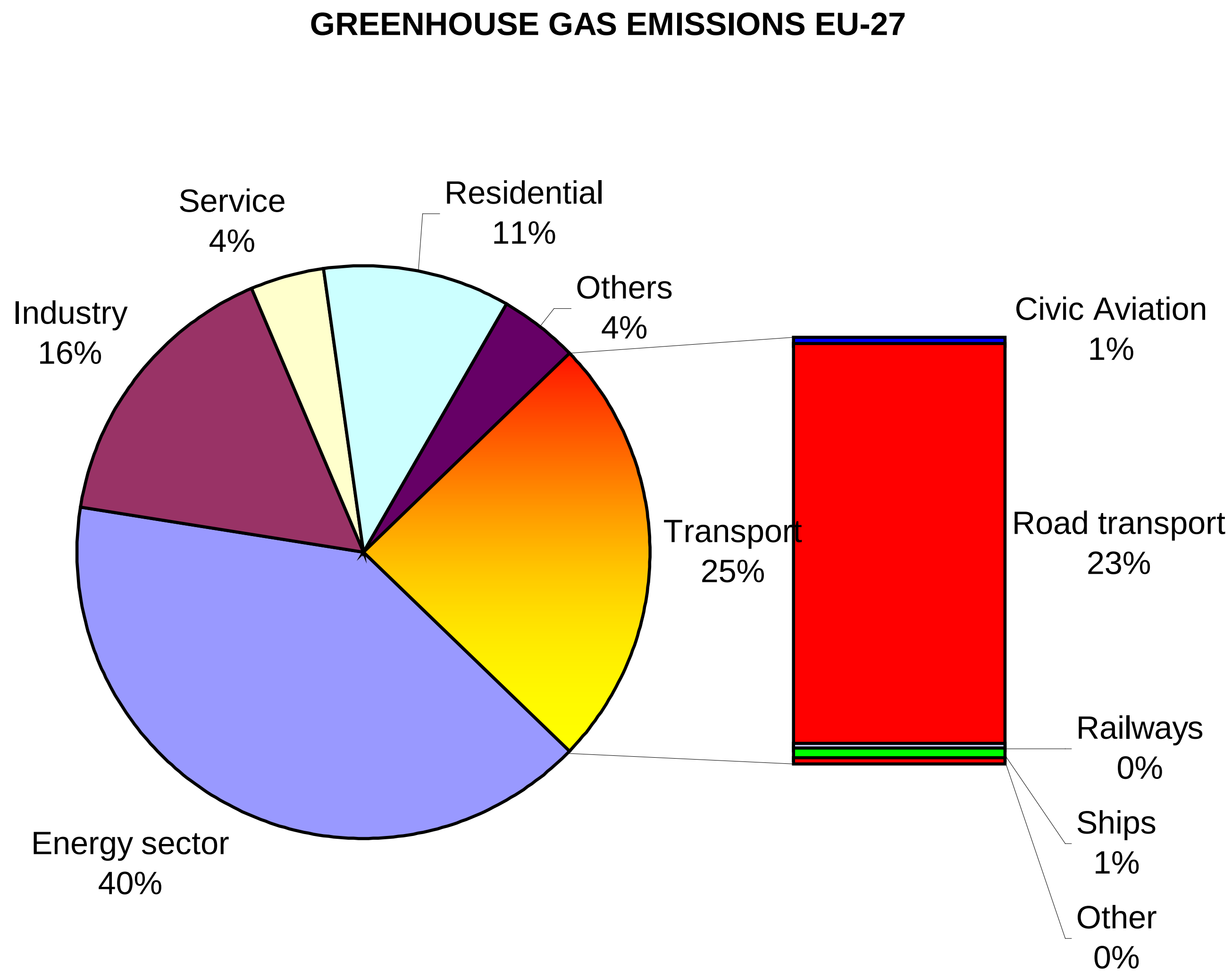
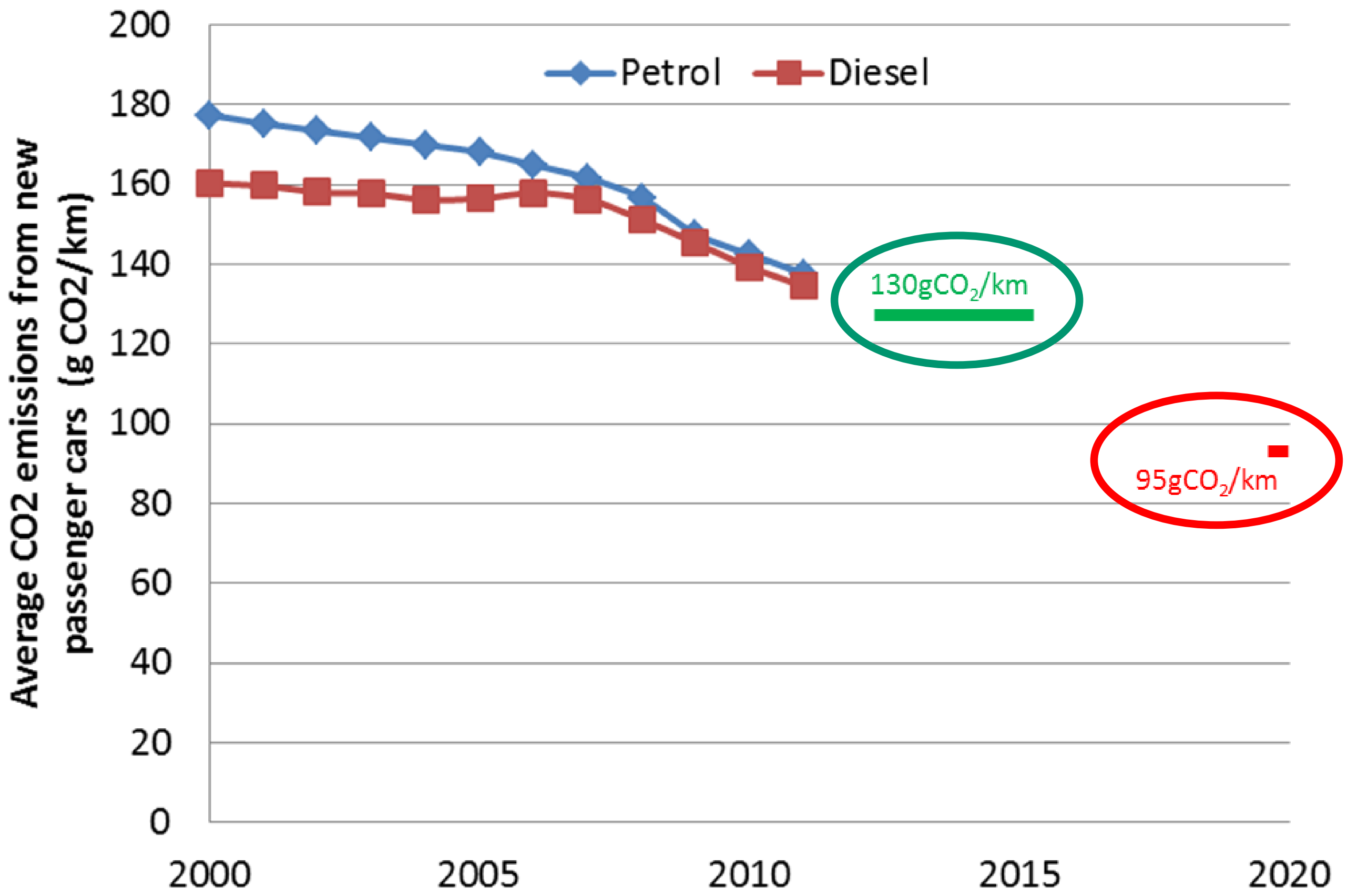
1. Introduction: Motivation



CO_2 emissions from new cars



Targets and average CO_2 emissions from new passenger cars by fuel in EU countries

2. Core objective:

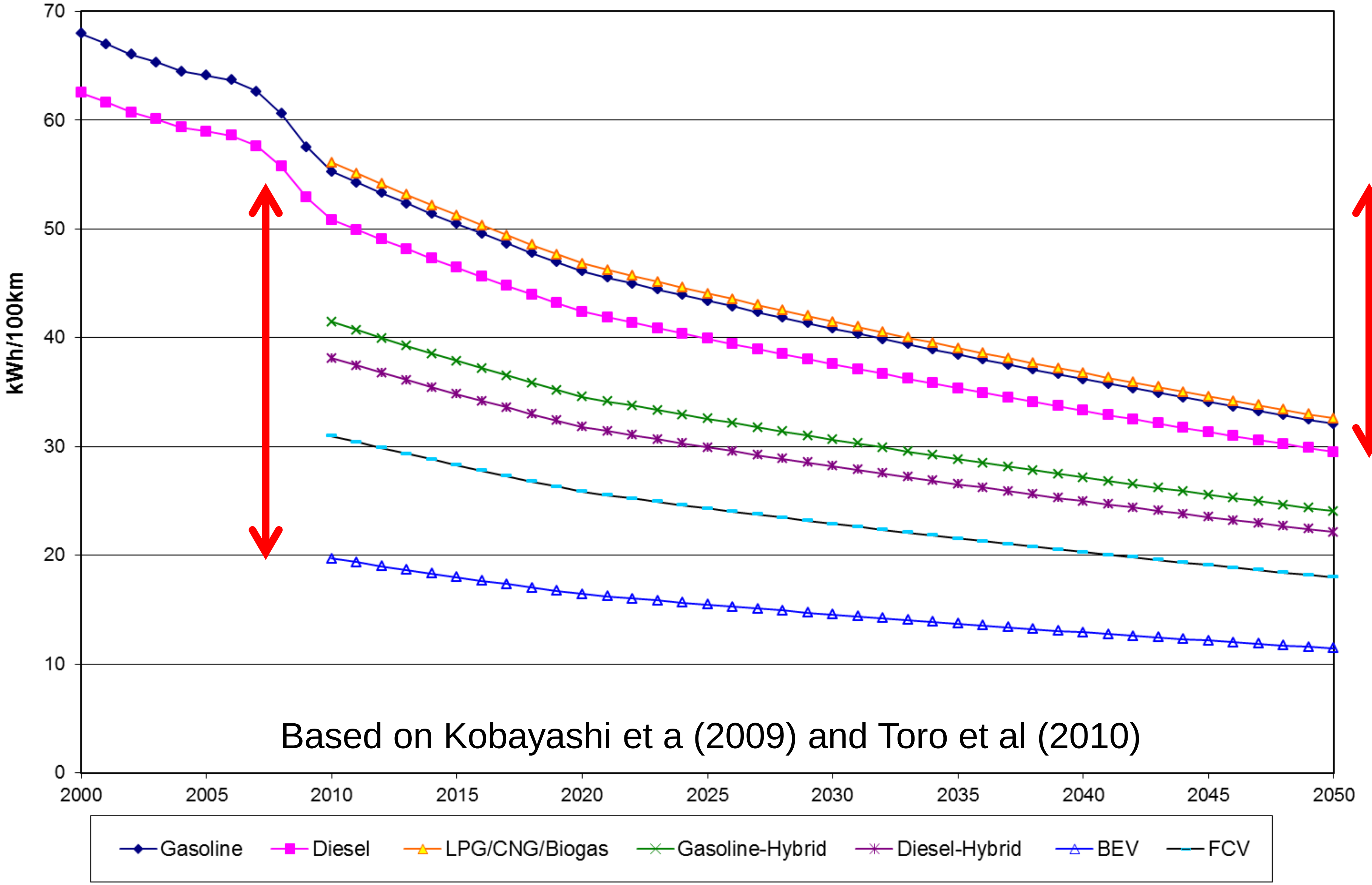
... to investigate the market prospects of increasing energy efficiency in car transport by promoting battery electric, hybrid and fuel cell vehicles...

...from an environmental and an economic point-of-view...

...in a dynamic framework up to 2050 ...

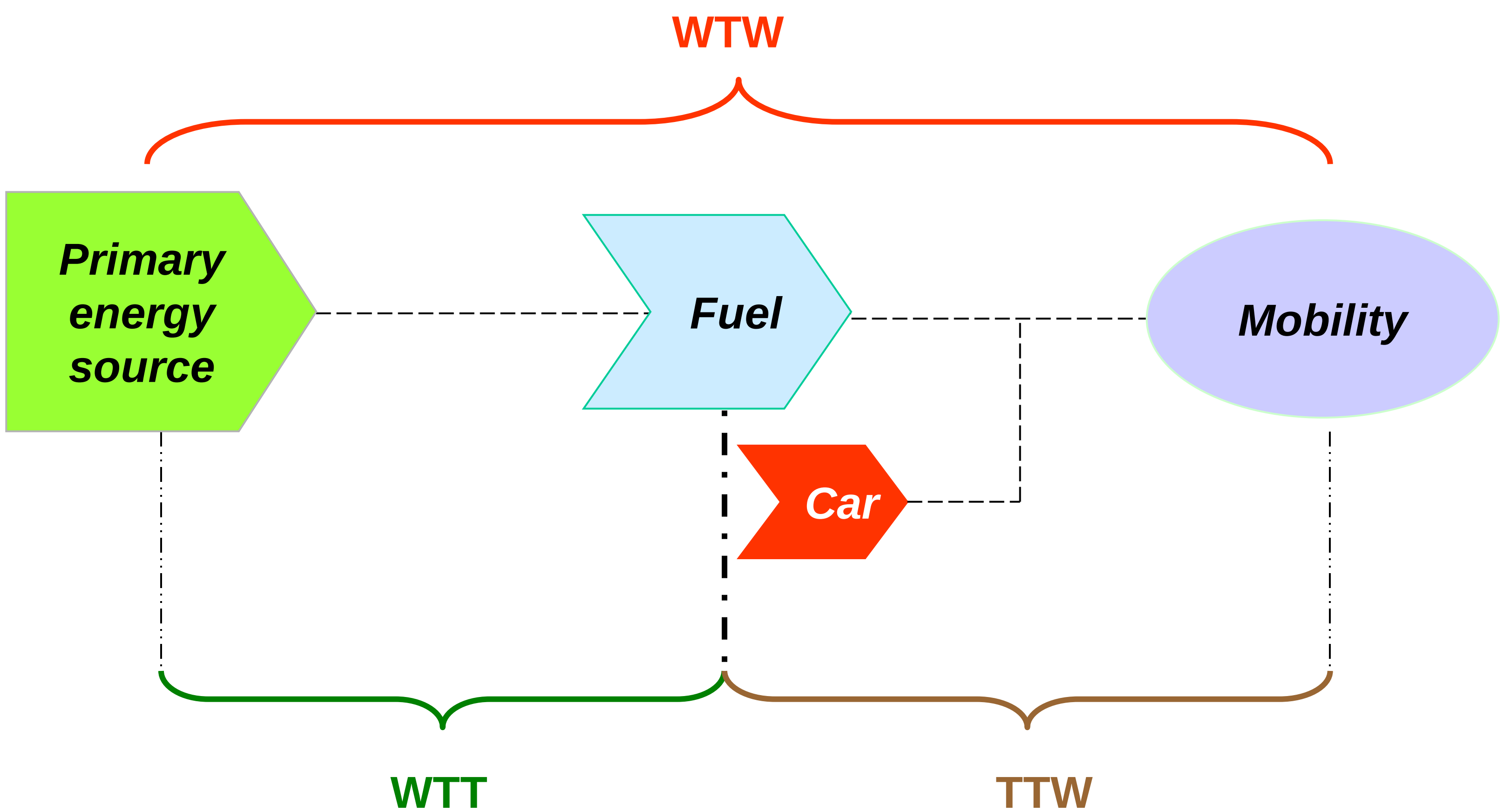
...in an optimistic scenario in comparison to conventional passenger cars

Fuel intensities of new cars: Optimistic scenario 2012-2050



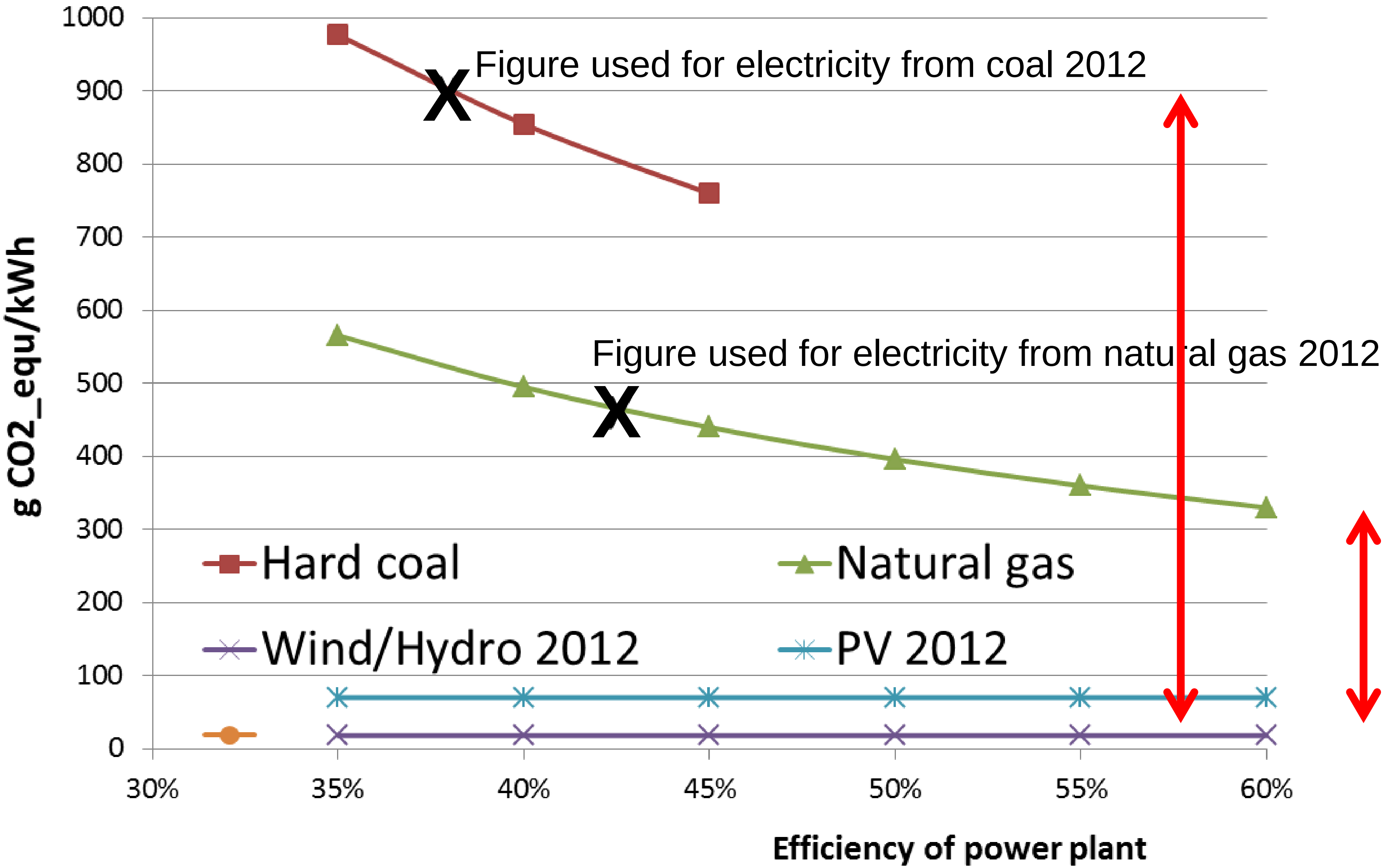
3. Environmental assessment

Method of approach (environment)



Energy service providing chain

Electricity generation (environment)



Method of approach (environment)

Total emissions e_{ij} , g CO2/km:

$$e_{WTW\_ij} = + e_{WTT\_Fuel\_ij} + e_{TTW\_Fuel\_i} + e_{LCA\_Car\_sp\_i} \quad [gCO2/km]$$

i … Type of car (EV, conv. Vehicle…)
j … Type of primary fuel (PV or coal for electricity generation)

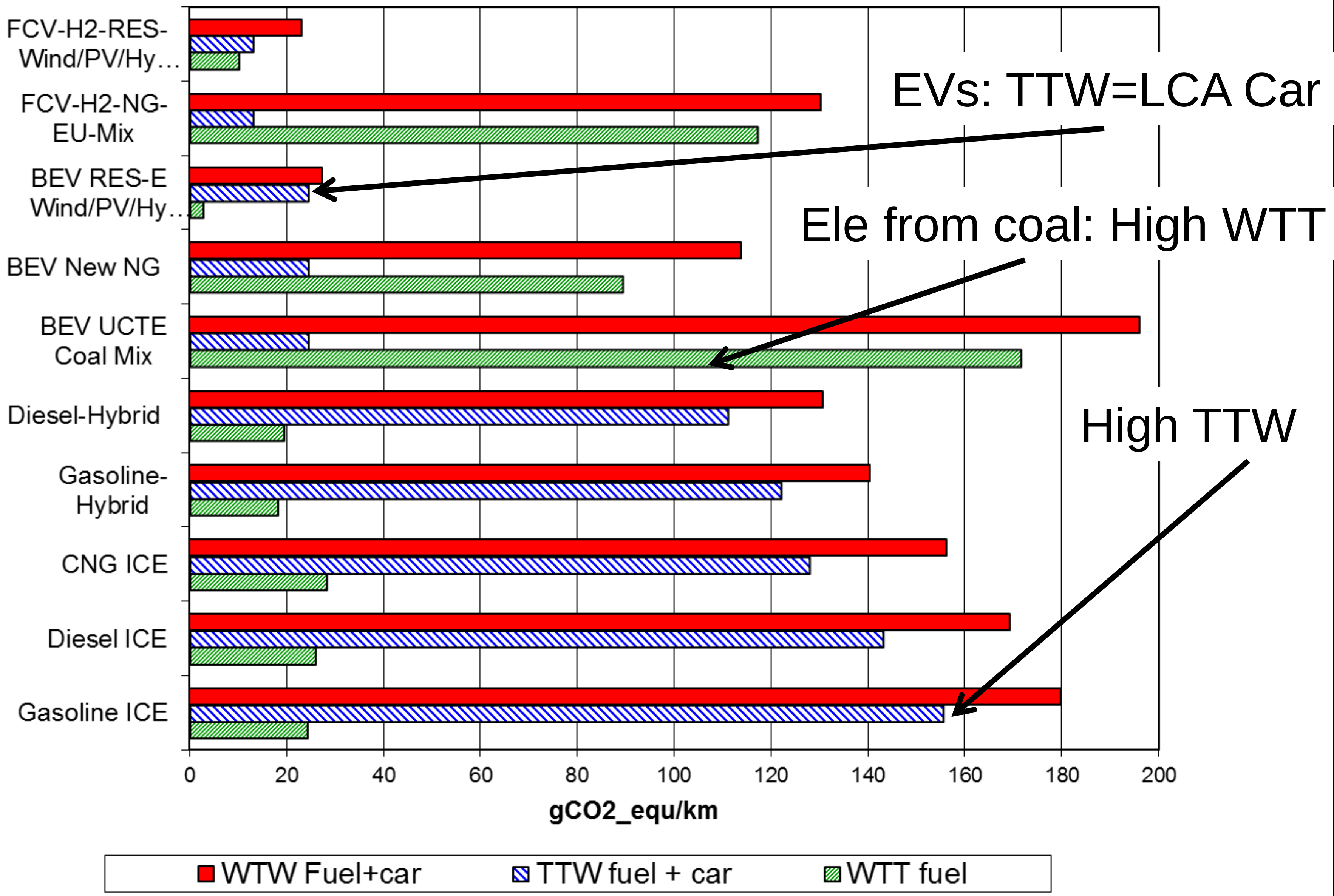
$$e_{WTT\_Fuel\_ij} = e_{PRI\_spj} / \eta_j / skm_i$$

$$e_{TTW\_Fuel\_i} = e_{TTW\_SP\_Car\_i} * FI_i / skm_i$$

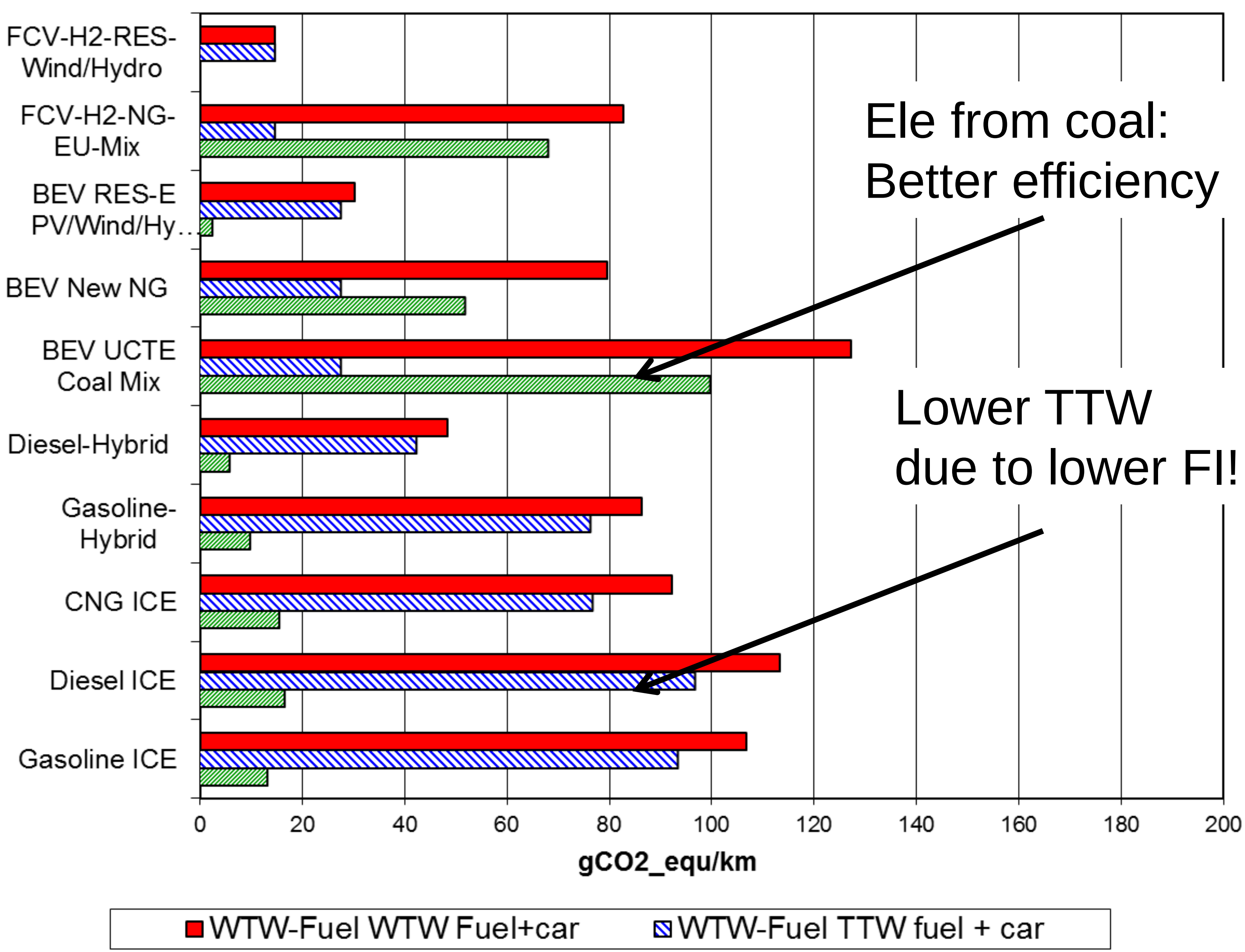
$$e_{LCA\_Car\_sp\_i} = e_{LCA\_Car\_i} / LT_i / skm_i$$

$e_{TTW\_SP\_Car\_i}$ ……specific emissions in operation
$e_{pri\_sp\_j}$… specific emissions electricity generation
skm…..specific km driven per car per year [km/(car.yr)]
FI……..fuel intensity [litre/100 km]

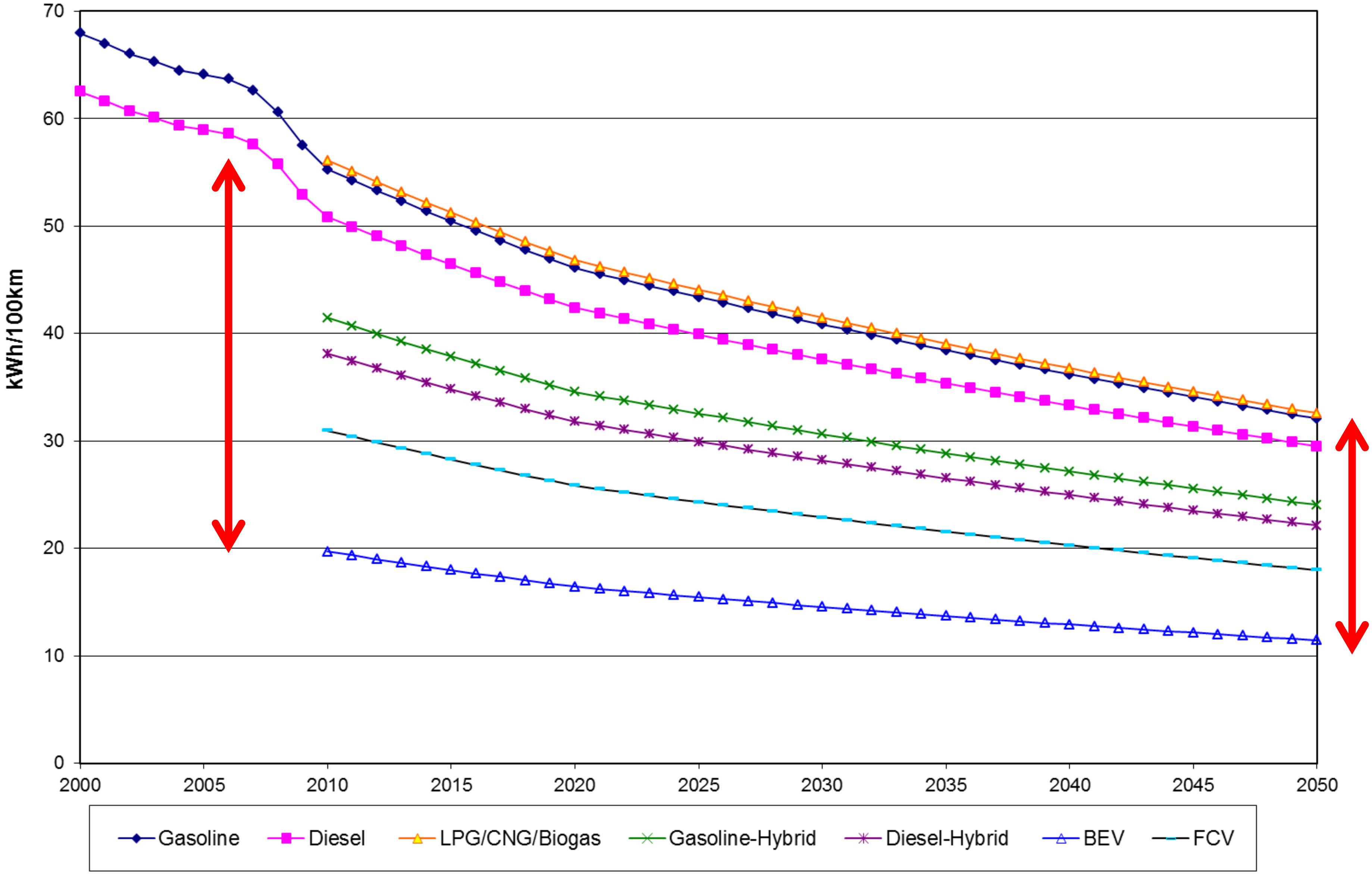
Environmental assessment 2012



Environmental assessment 2012



Fuel intensities of new cars: Optimistic scenario 2012-2050



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4. Economic assessment

Method of approach

Total driving costs C_{drive} per year:

$$C_{drive} = IC\ \alpha + P_f FI\ \ skm + C_{O\&M}$$ [€/car/year]

The costs per km driven Ckm are calculated as:

$$C_{km} = \frac{IC \cdot \alpha}{skm} + P_f \cdot FI + \frac{C_{O\&M}}{skm}$$ [€/100 km driven]

IC……investment costs [€/car]
α……..capital recovery factor
skm…..specific km driven per car per year [km/(car.yr)]
Pf……..fuel price incl. taxes [€/litre]
$C_{O\&M}$…operating and maintenance costs
FI……..fuel intensity [litre/100 km]

The fuel price depends on the cost of fuel C_f, and possible VAT, excise and CO2 taxes:

$$P_f = C_f + \tau_{CO_2} + \tau_{VAT} + \tau_{exc}$$

Technological learning

$$IC_t(x) = IC_{Con\_t}(x) + IC_{New\_t}(x)$$

IC_{Con_t}(x)…specific investment cost of conventional mature technology components (€/kW)
IC_{New_t}(x)…specific investment cost of new technology components (€/kW)

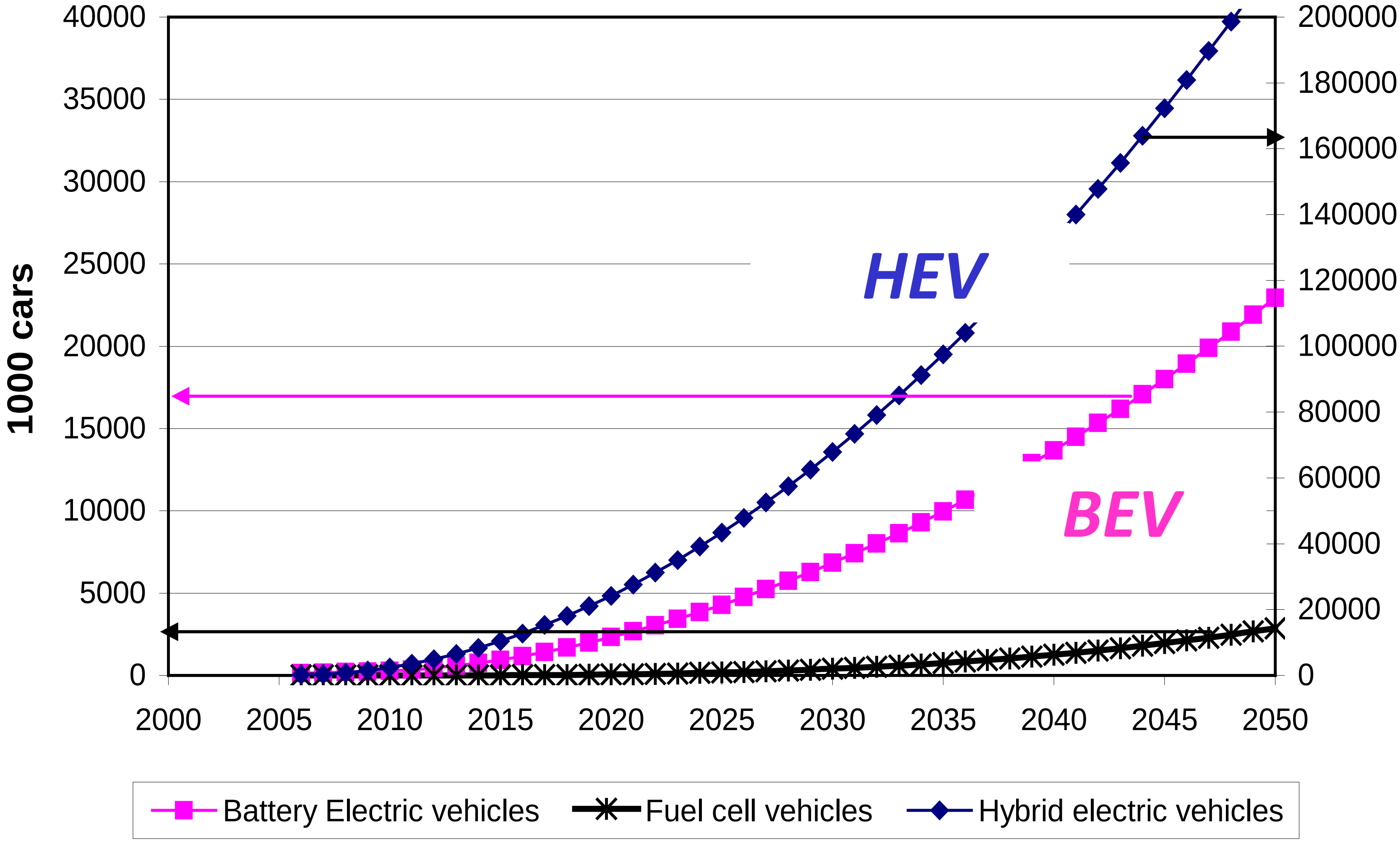
$$IC_{New\_t}(x) = IC_{New\_t}(x_{nat\_t}) + IC_{New\_t}(x_{\mathrm{int}\_t})$$

ICNew_t(xnat_t)…specific national part of ICNew_t(x) of new technology components (€/kW)
ICNew_t(xint_t)…specific international part of ICNew_t(x) of new technology components (€/kW)

$$IC_{New\_t}(x) = a \cdot x_t^{-b}$$

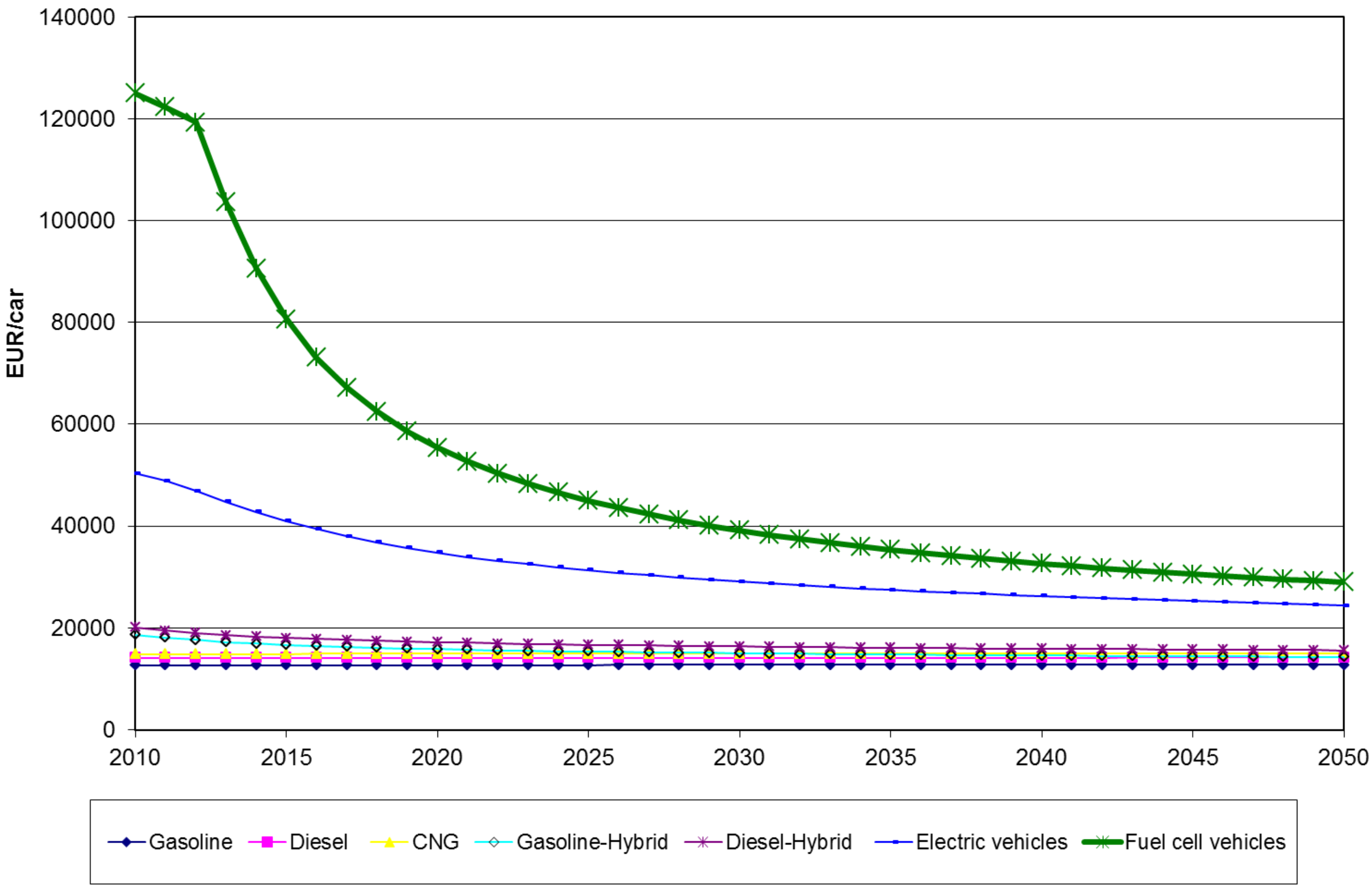
b………..learning rate
x ……….cumulative capacity up to year t (kW)

Stock of vehicles world-wide

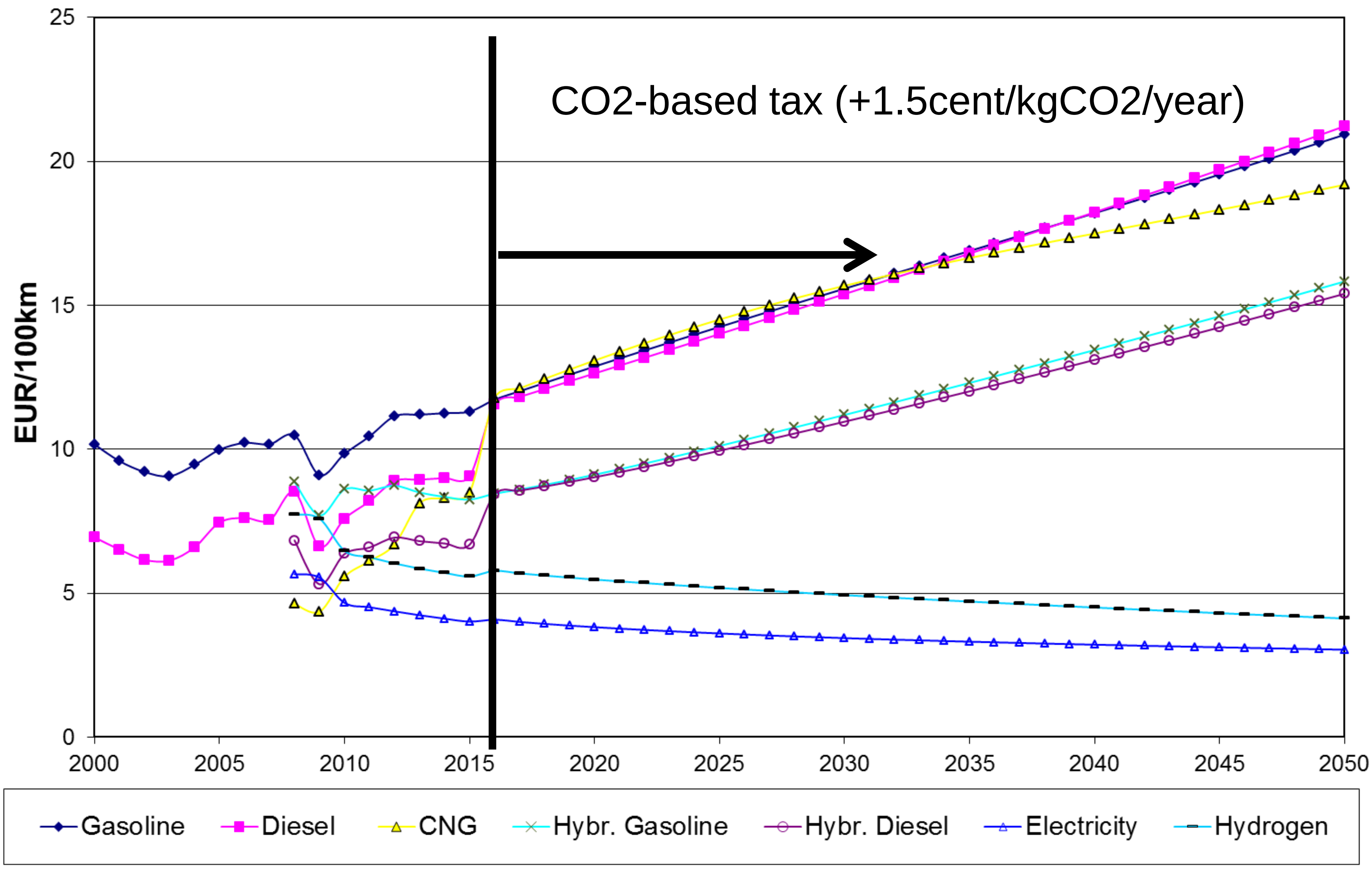


Overall scenarios for world-wide market diffusion of HEV, BEV and FCV

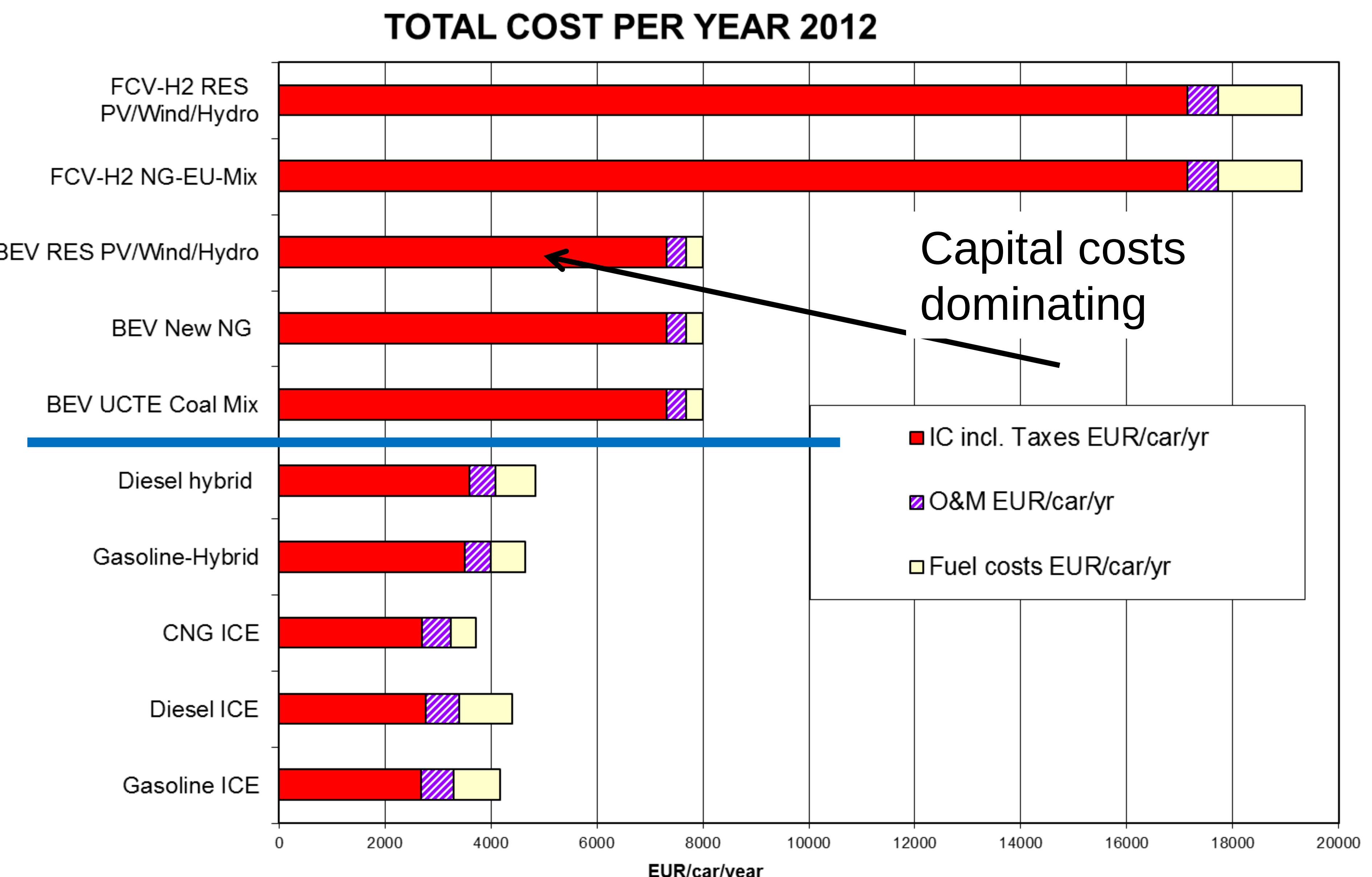
Investment costs of convent and alternative vehicles: Scenario 2013-2050



Fuel costs of driving: 2012 to 2050 Scenario



Total costs of driving in 2012



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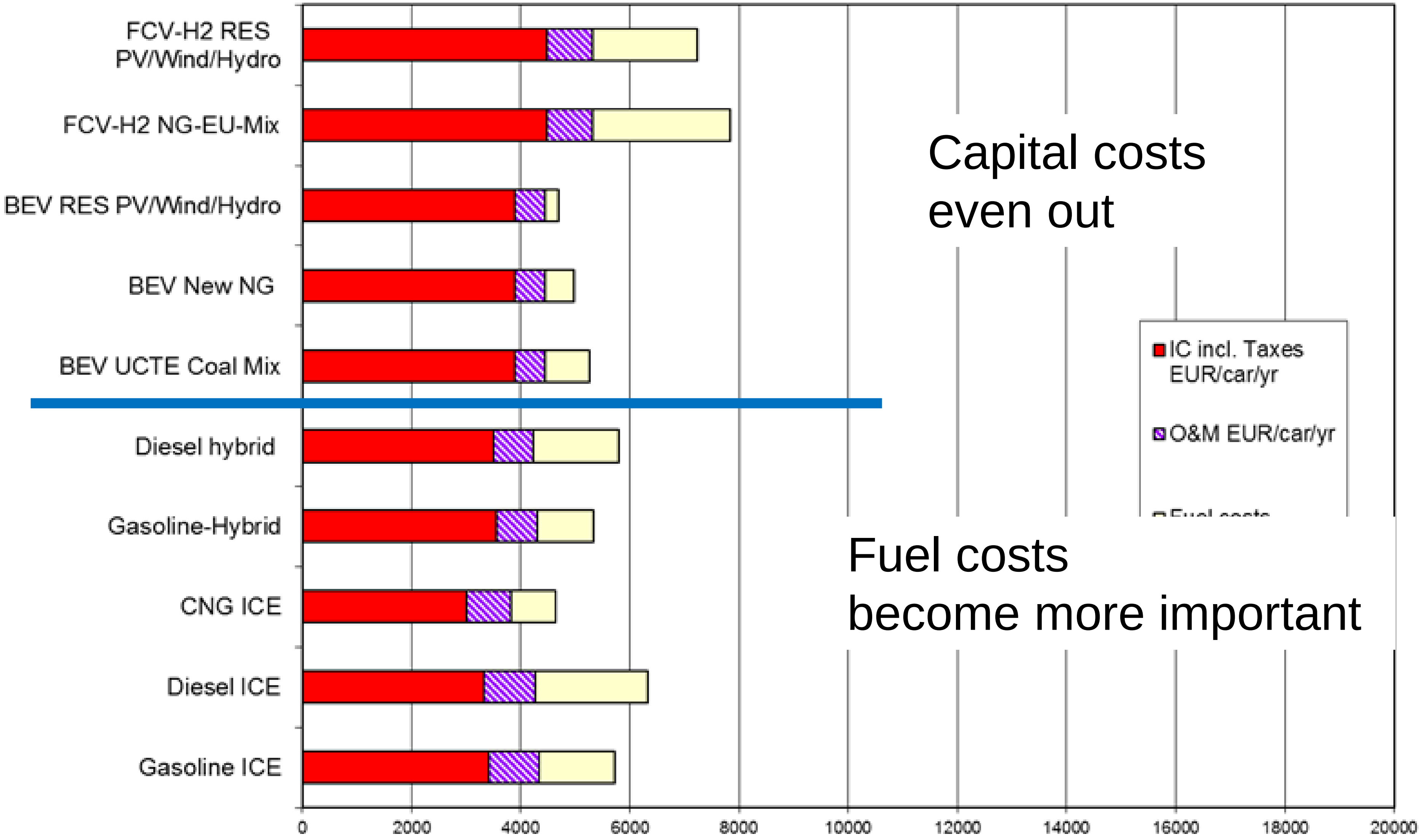
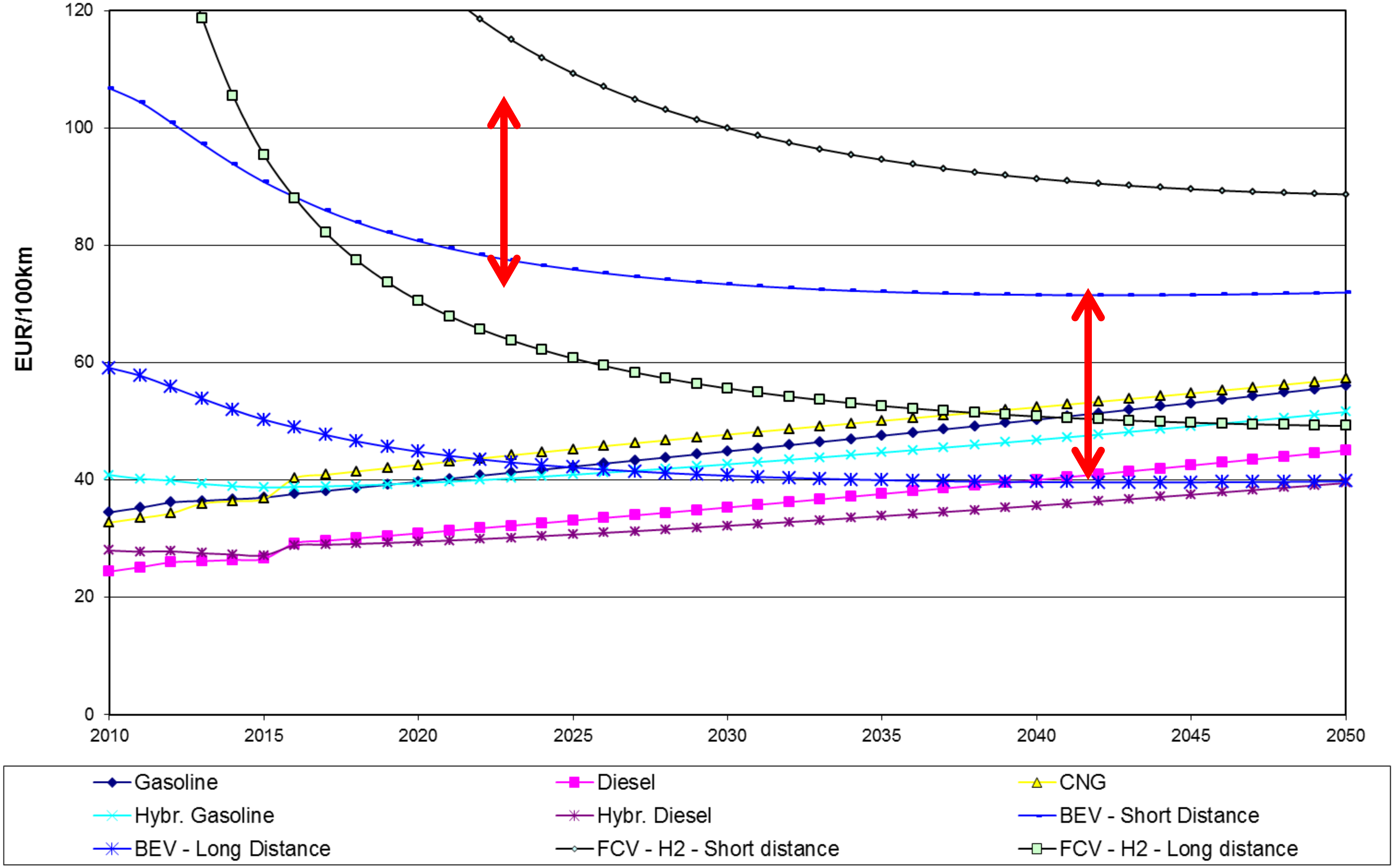
TOTAL COST PER YEAR 2050

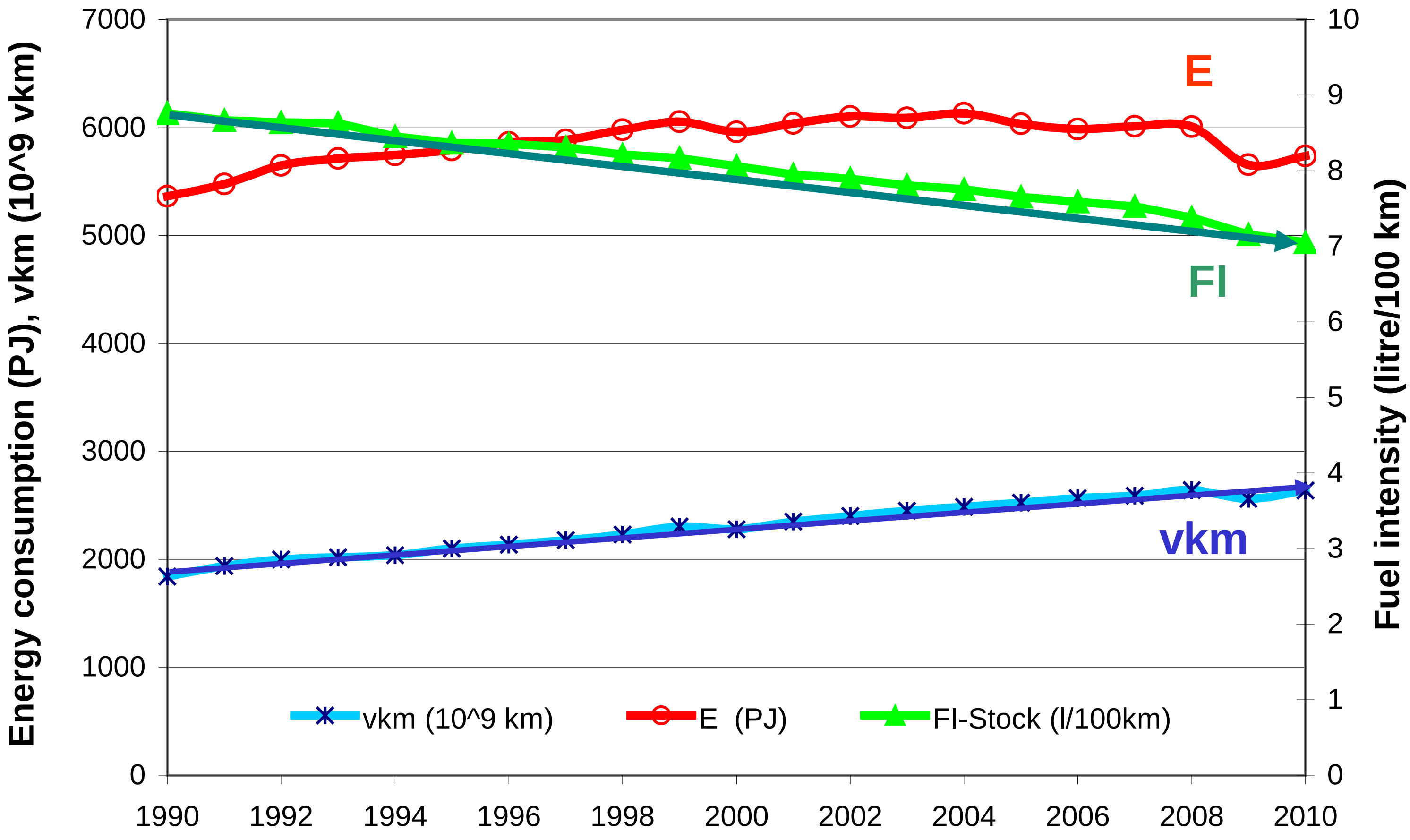


Total costs of driving: 2012 to 2050 Scenario



5. Future: Rebound effects?

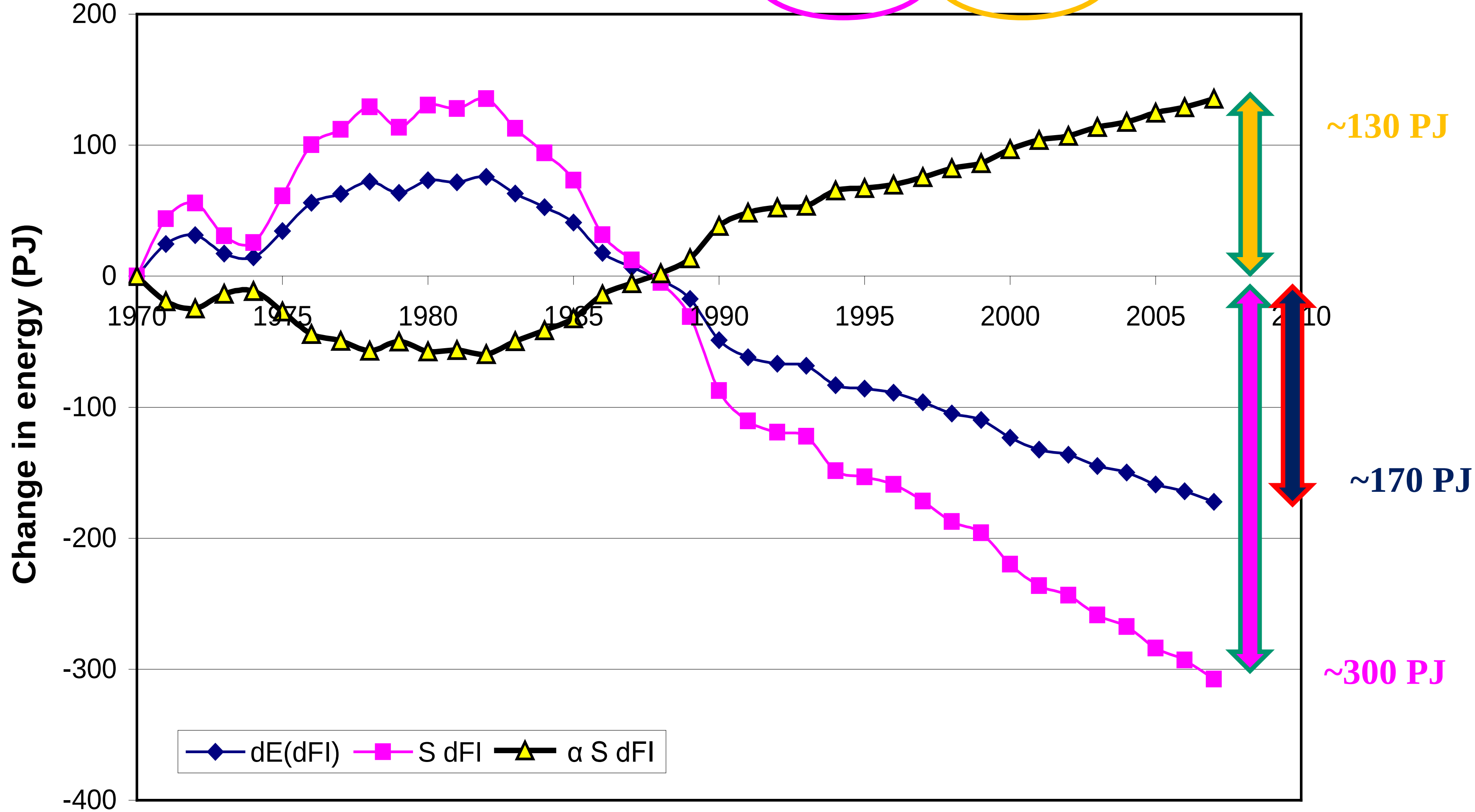
Rebound due to driving longer distances



Development of vehicle km driven (vkm), energy consumption and the fuel intensity of the stock of vehicles in EU-15 from 1990 to 2010

The impact of fuel intensity

$$dE(dFI) = S(1+\alpha)dFI = SdFI + \alpha SdFI$$



The change of energy consumption due to changes in fuel intensity for EU-6, base 1970

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Fuel intensity vs Car size

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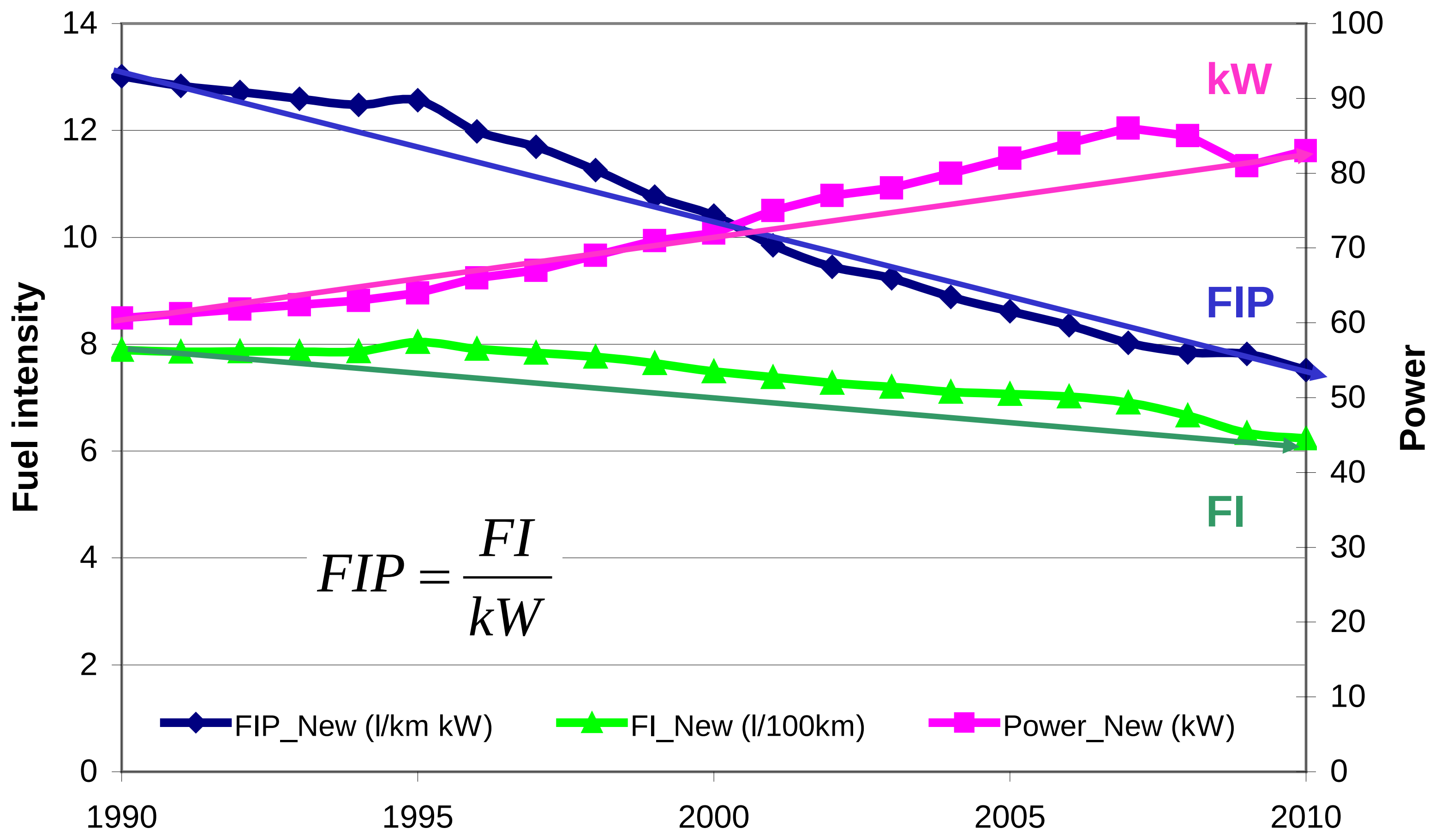
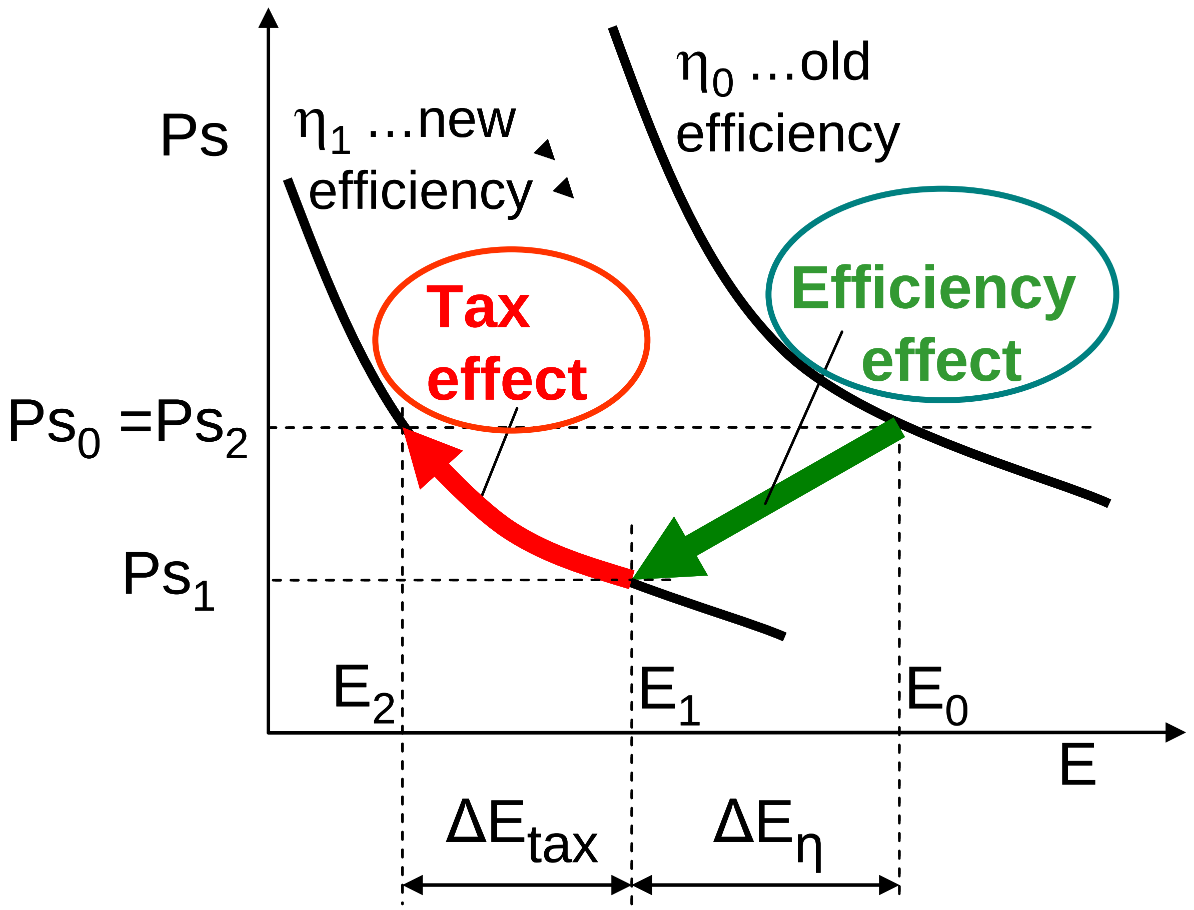


Development of fuel intensity, power-specific fuel intensity and power (kW) of new vehicles in EU-15 from 1990 to 2009

Standards & taxes



How taxes and standards interact and how they can be implemented in a combined optimal way for society

6. Conclusions

- From an environmental point-of-view BEV and FCV are currently clearly preferable to conventional cars if the electricity is generated from renewable energy sources
- With respect to the economic competitiveness of alternative powertrains compared to conventional vehicles in the most favourable – long distance driven – case BEV will enter the market by about 2025.
- By 2050 total overall driving costs of most analysed fuels and powertrains will almost even out.
- The major uncertainty remaining regarding BEV and FCV is how fast technological learning will take place especially for the battery and the fuel cells.

ajanovic@eeg.tuwien.ac.at