Technical University of Denmark

Electricity for Road-transport, Flexible Power Systems and Wind Power

Nielsen, Lars Henrik

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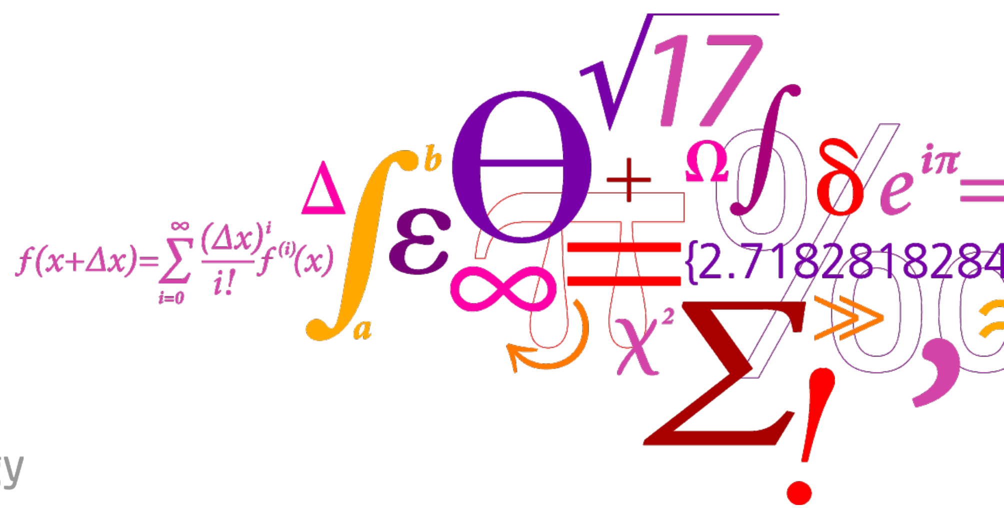
Results from a study on:

Electricity for Road-transport
Flexible power systems and wind power
http://www.risoe.dtu.dk/en/Research/sustainable_energy/energy_systems/projects/SYS_G2V2G.aspx

Lars Henrik Nielsen
Senior scientist
SYS Risø DTU
Denmark



Project title:

Electricity for Road Transport Flexible Power Systems and Wind Power

Project aim:

To analyse the **potential synergistic interplay** that may arise between the **power sector and the transport sector**,
if segments the road transport are based on
plug-in hybrid electric vehicles and pure electric vehicles,
for integrating fluctuating power production, such as wind power.

Partners:

- Risø National Laboratory for Sustainable Energy. Technical University of Denmark (DTU) **Systems Analysis Division** and the IES Programme.
- Technical University of Denmark (DTU). Centre for Electric Technology, Department of Electrical Engineering.
- RAM-løse edb (expertise on optimisation models / Balmorel)
- Energinet.dk, Planning & Scenarios and Analysis & Methods (Danish **TSO**)
- Danish Energy Association (Includes Danish **DSOs**)

Main sponsor: EUDP (Danish Energy Development and Demonstration Programme)

Project duration: 3.5 years

Content: Touch upon

- **EV technology development assumptions**

  (Segment:Passenger cars and delivery vans < 3.5 ton)

- **Scenarios set up for Denmark** (population of about 5.5 mio.)

  (via EPRI medium scenario assumptions from 2007 for market penetration. **Mainly focus on PHEVs**.)

- **Power Distribution system aspects (DSO)**

- **Power Transmission system issues (TSO)**

- **Overall (north European) power system: Future development with EVs ..**

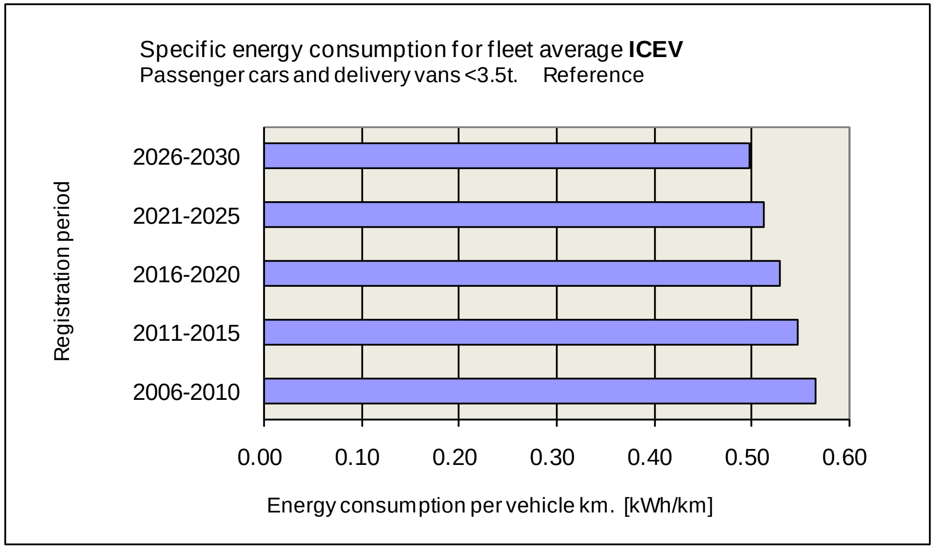
  Results via the power system optimisation models (including transport modules)

  Balmorel (market, system operation and development (investments)) and

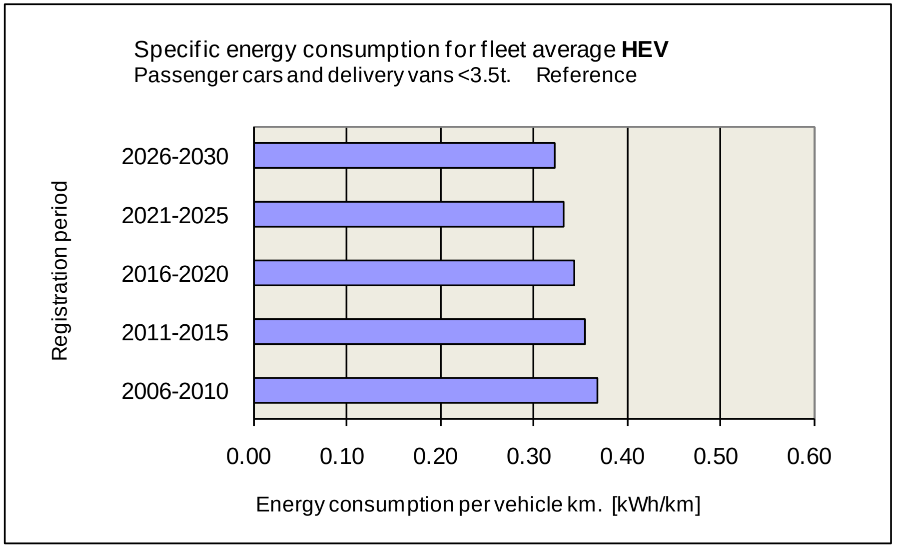
  Wilmar (spot and intraday markets, system operation, stochastic production)

Vehicle energy consumption: kWh / km

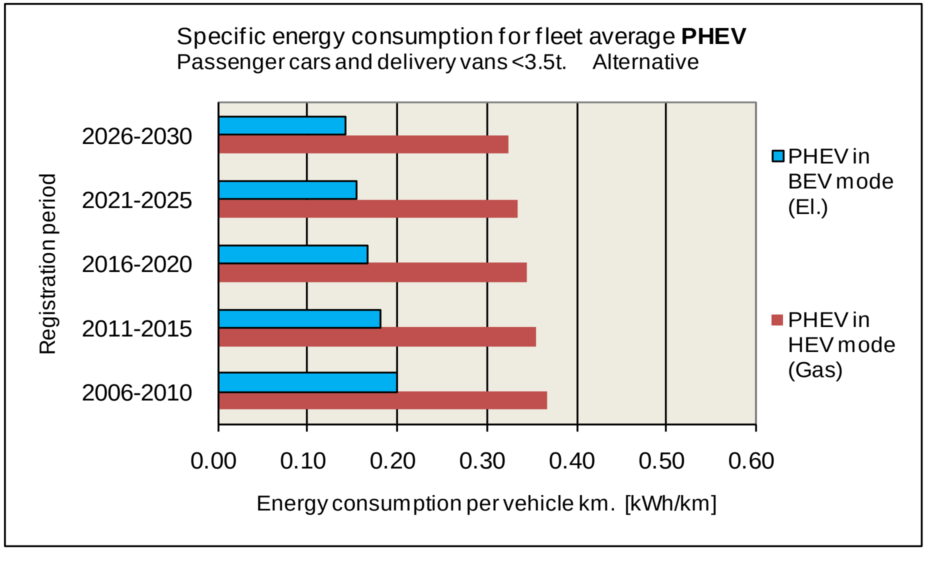
ICEV fuel consumption:



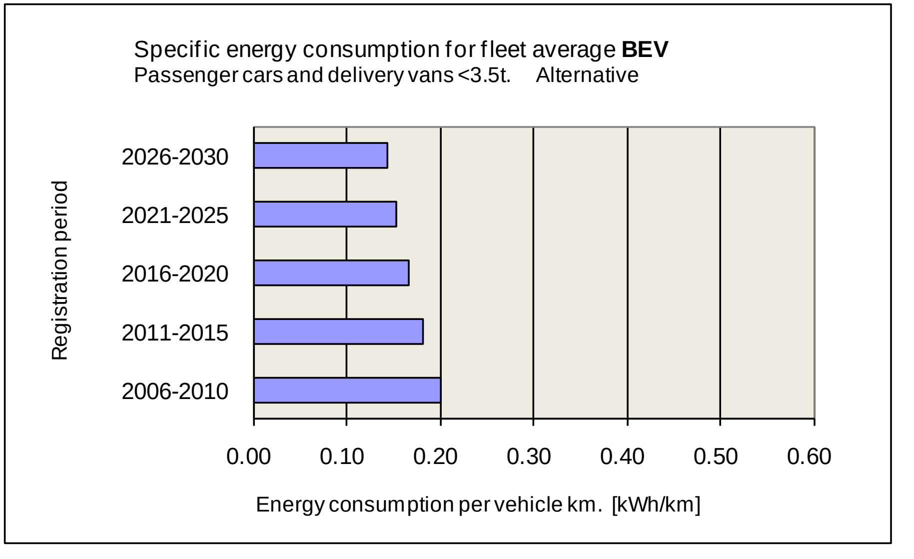
HEV fuel consumption:



PHEV electricity and fuel consumption:



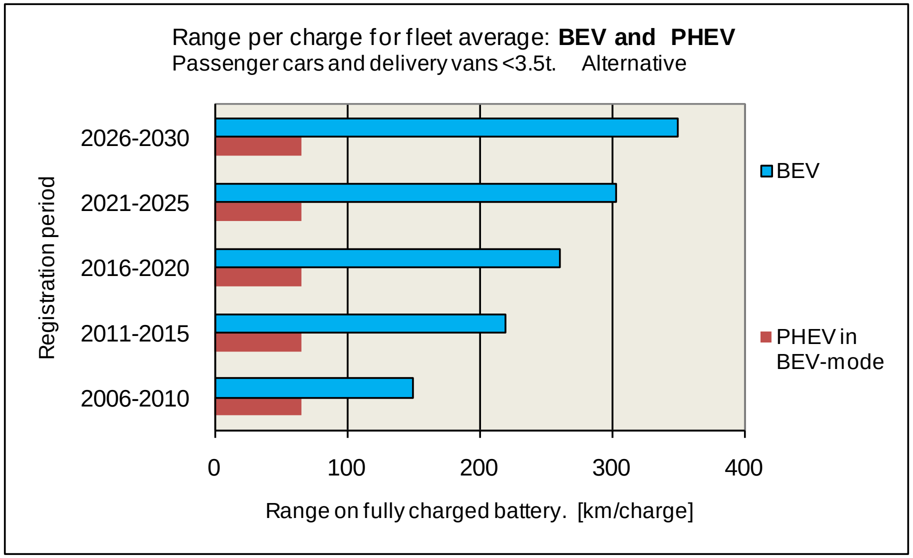
BEV electricity consumption:



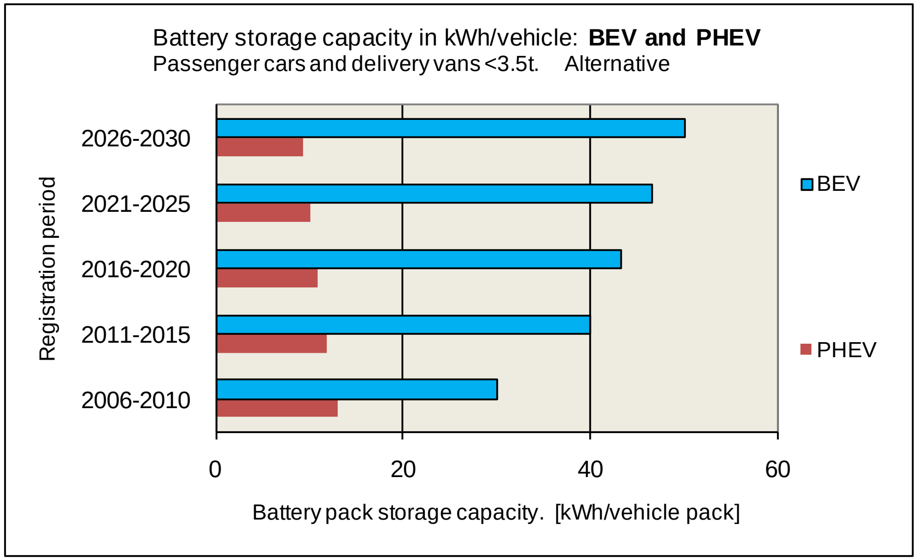
Electric Vehicle:

Battery size and range per charge

PHEV & BEV: Range [km/charge]



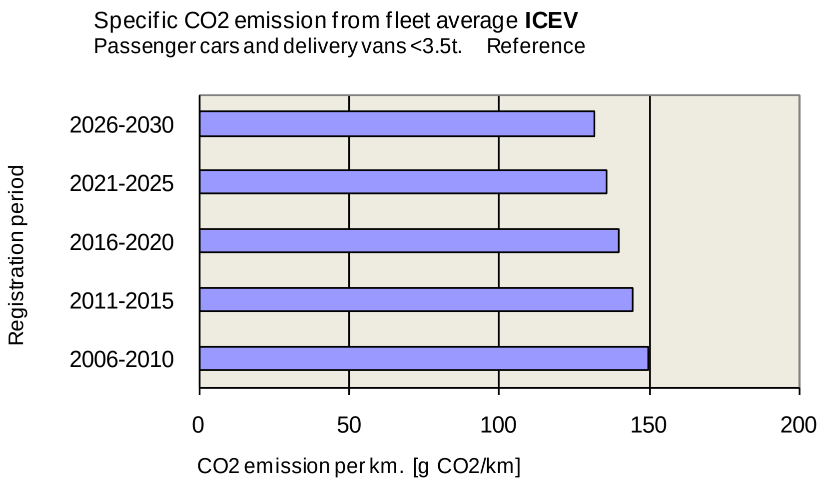
PHEV & BEV: Battery size [kWh/pack]



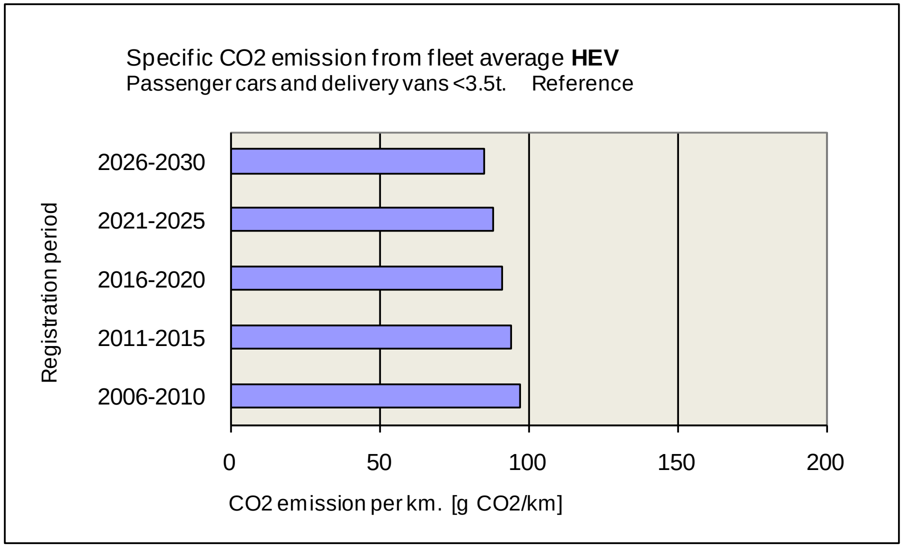
Vehicle specific CO_2 emission: g CO_2 / km

CO_2Case I : Marginal el-production in DK (coal) Source: DEA (2010)

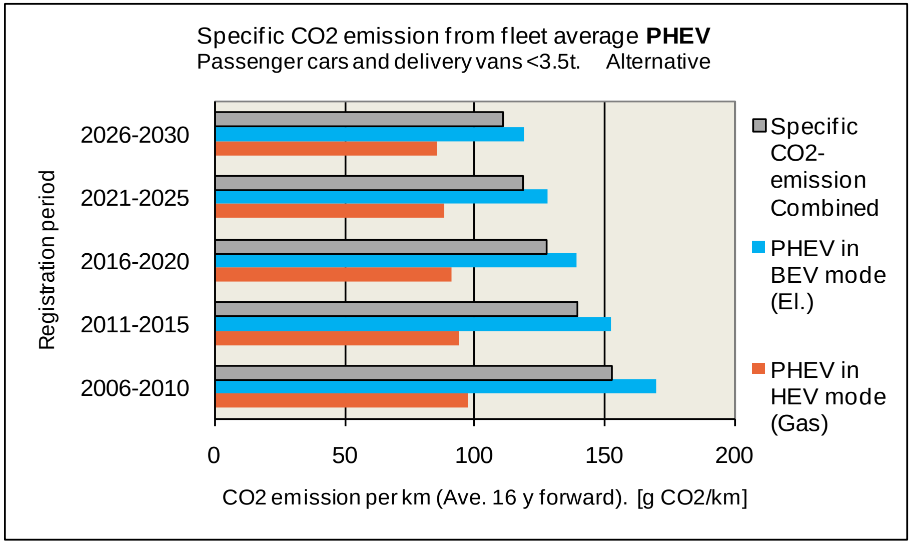
ICEV CO_2 emission:



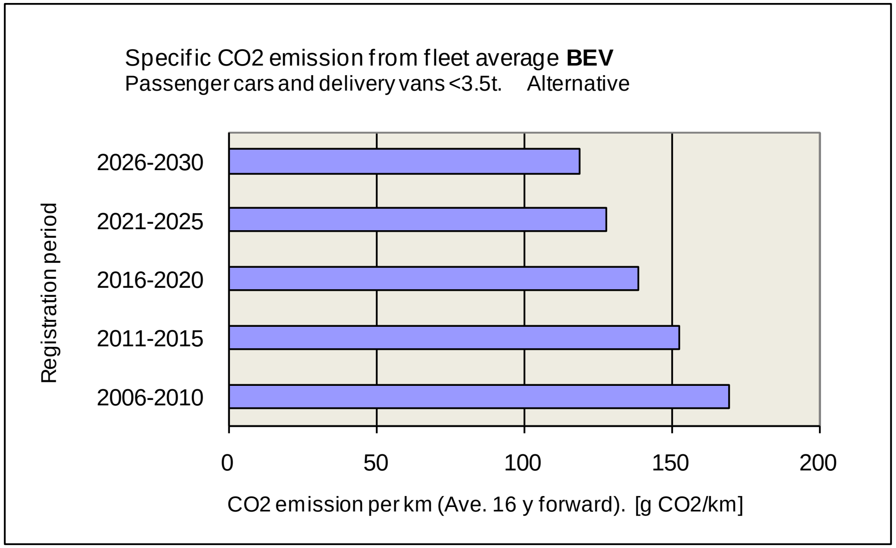
HEV CO_2 emission:



PHEV CO_2 emission: CO_2Case I



BEV CO_2 emission: CO_2Case I

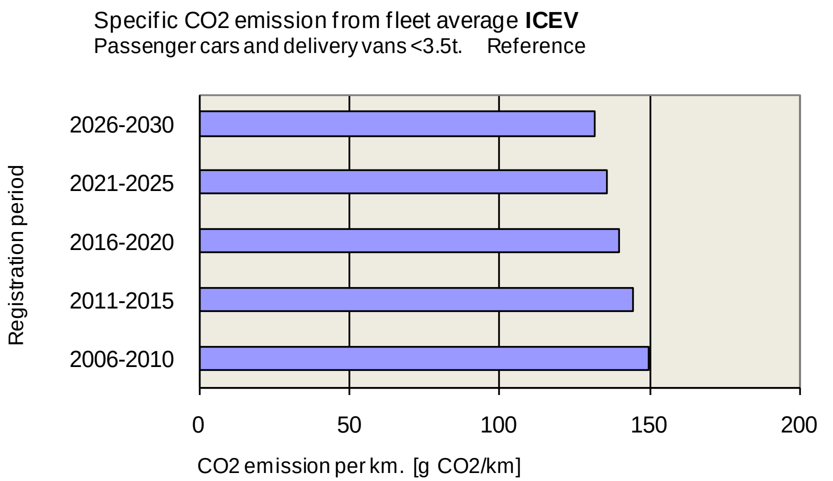


Vehicle specific CO_2 emission: g CO_2 / km

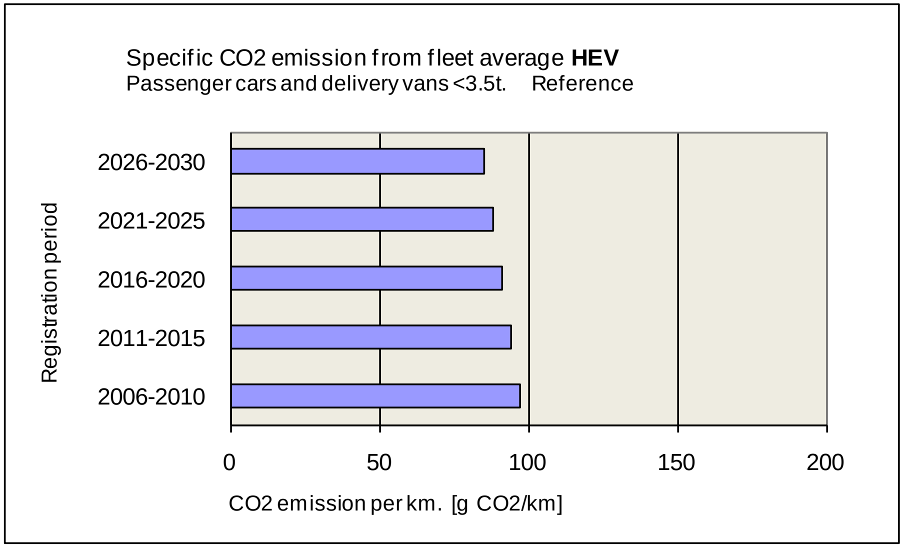
CO_2Case III : Average power system CO_2-characteristics.

And linear phasing out to zero of all fossil fuels by 2050. (Stated Danish aim, October 2010.)

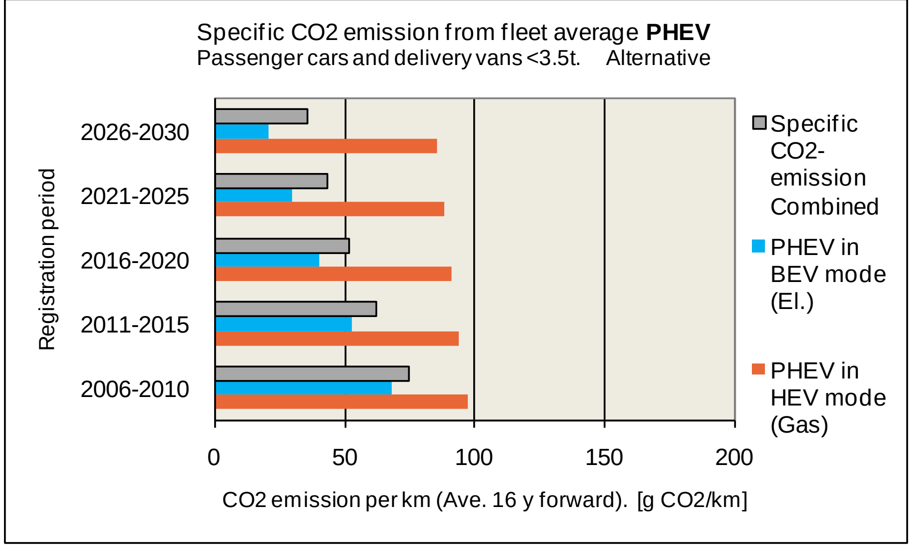
ICEV CO_2 emission:



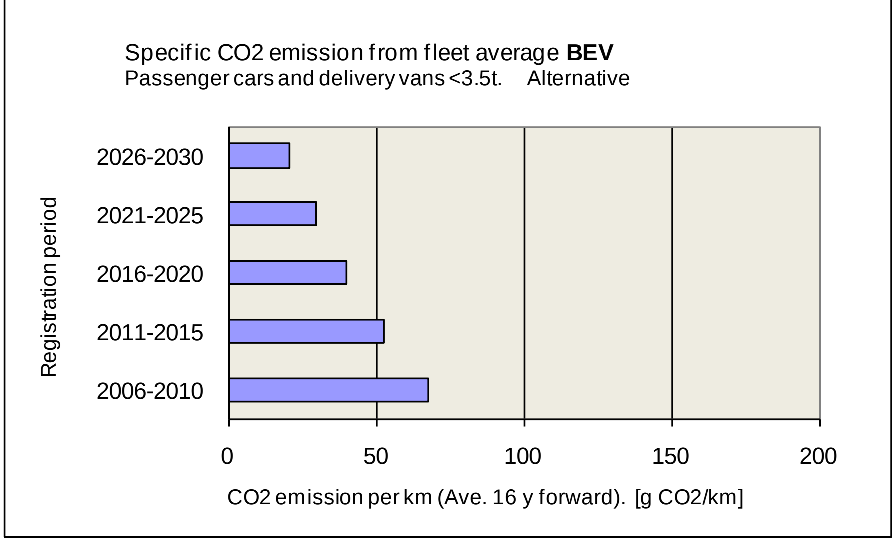
HEV CO_2 emission:



PHEV CO_2 emission: CO_2Case III

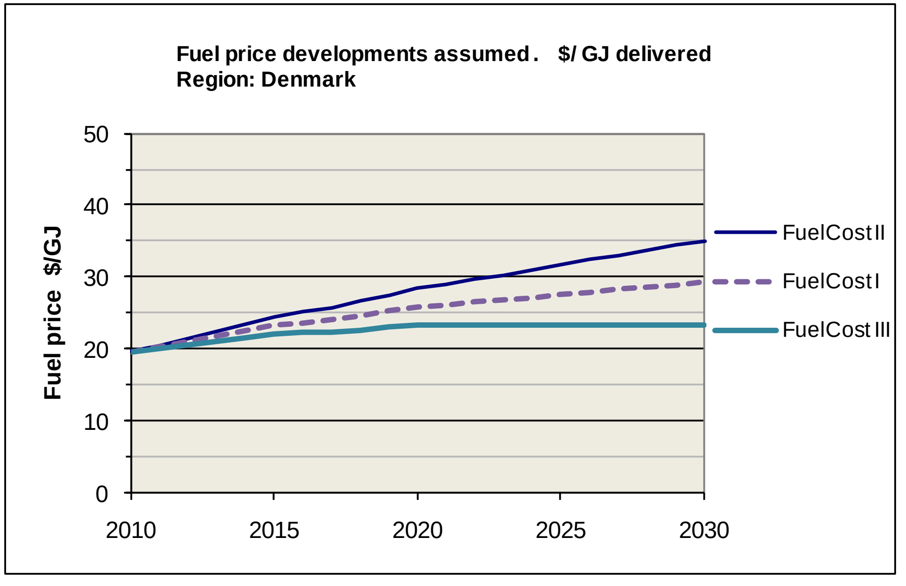


BEV CO_2 emission: CO_2Case III

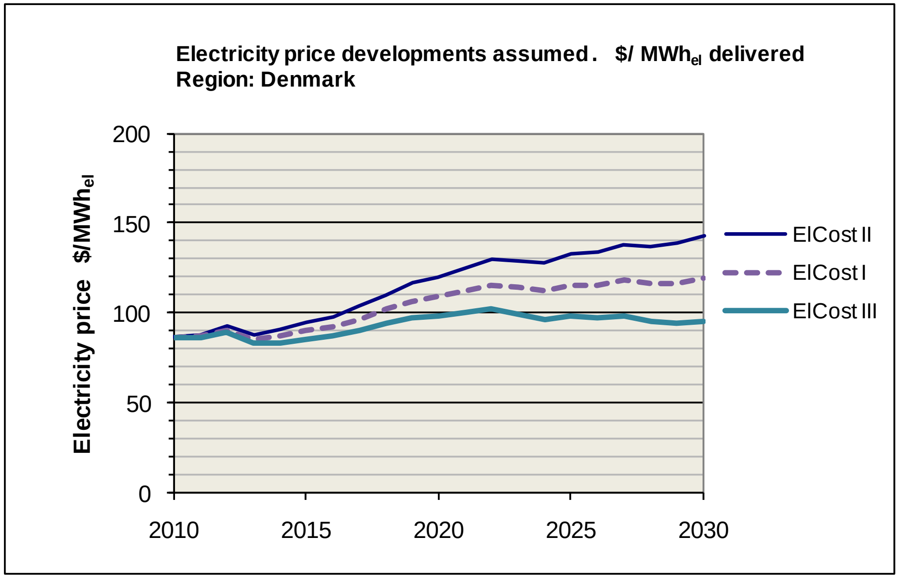


Energy price developments assumed for fuel (gasoline / diesel) and electricity.

Fuel-Cost I, II and II I



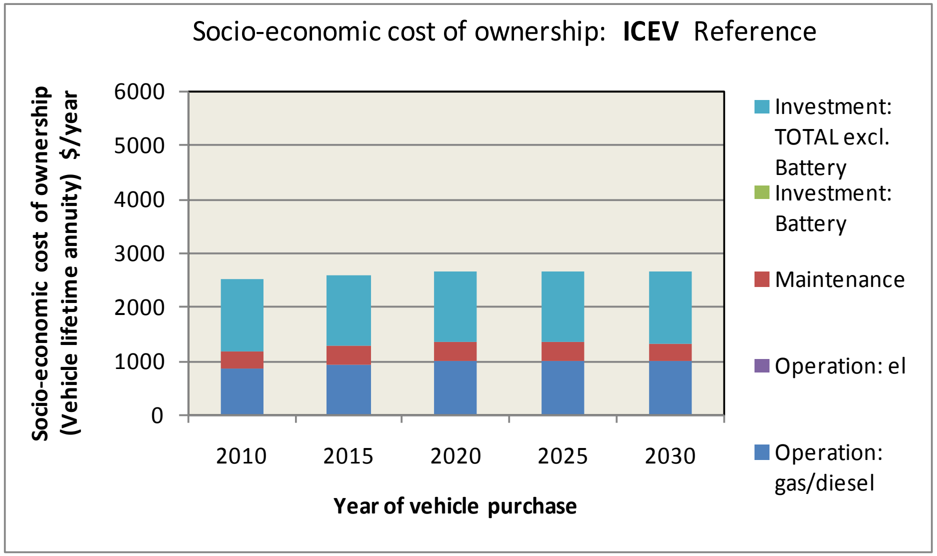
El-Cost I, II and III



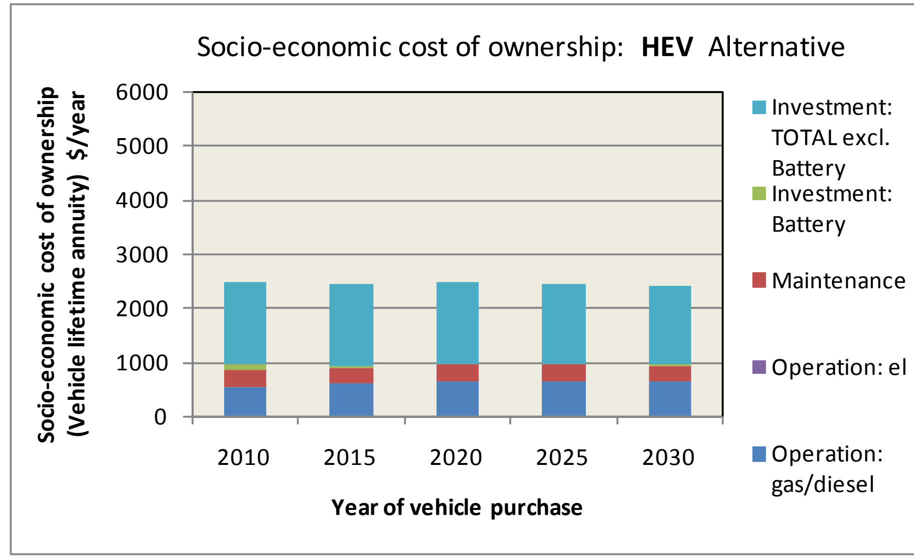
Vehicle cost of ownership: $ / year

EV battery cost: USDOE July 2010 Scenario

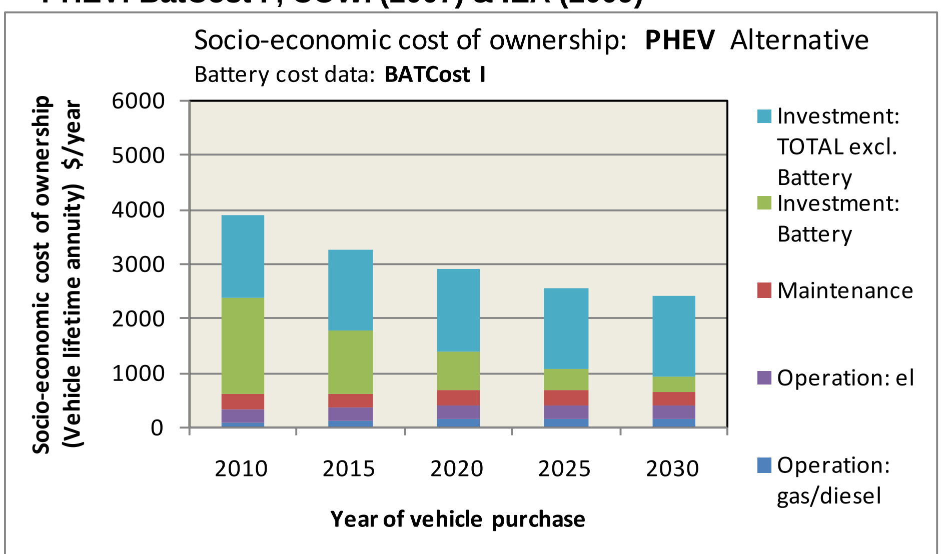
ICEV:



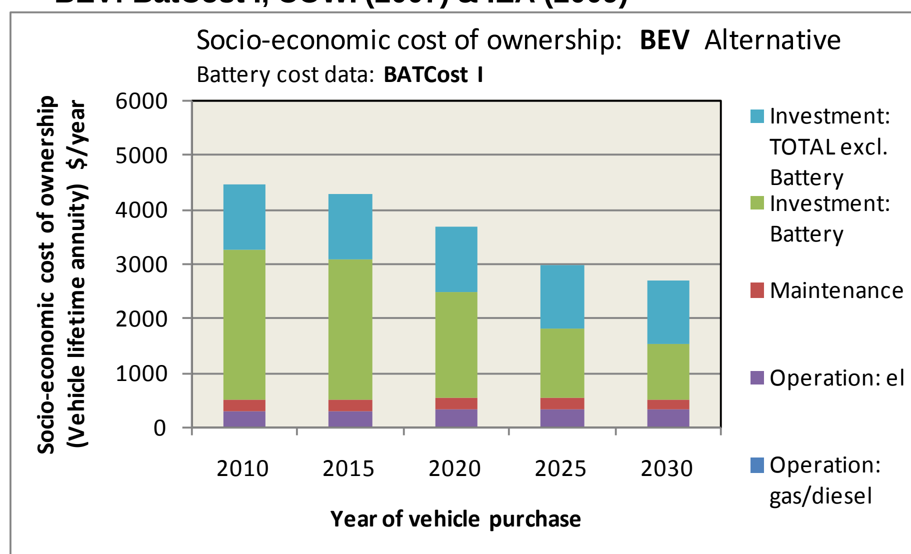
HEV:



PHEV: BatCost I , COWI (2007) & IEA (2009)

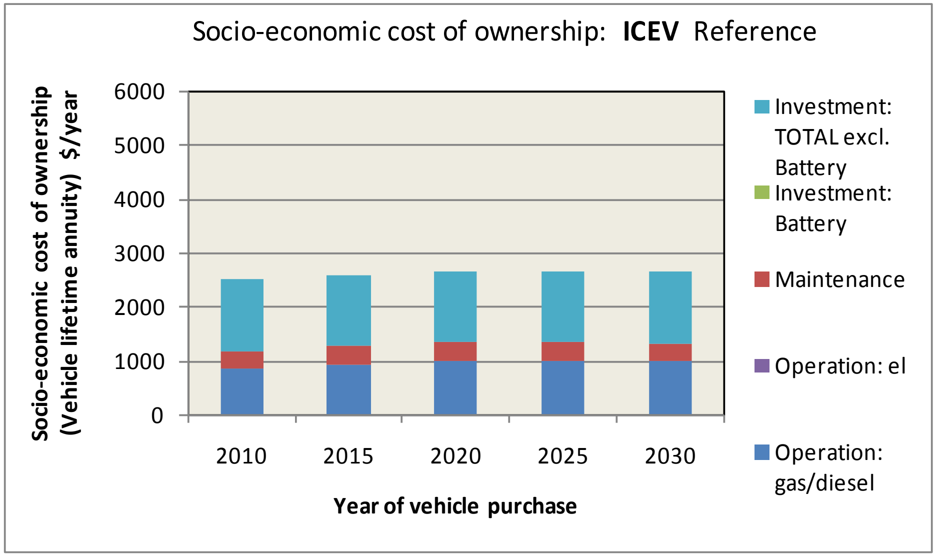


BEV: BatCost I, COWI (2007) & IEA (2009)

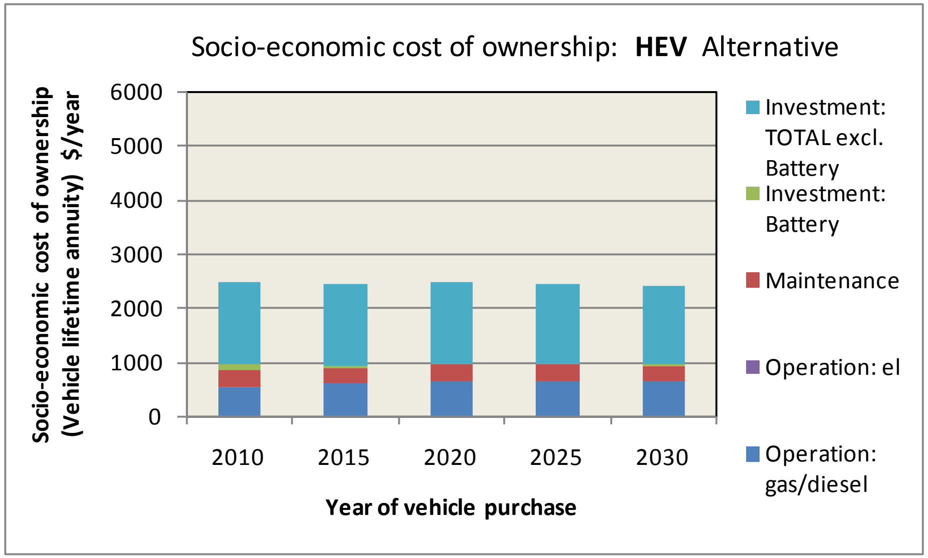


Vehicle cost of ownership: $/year
EV battery cost: USDOE July 2010 Scenario

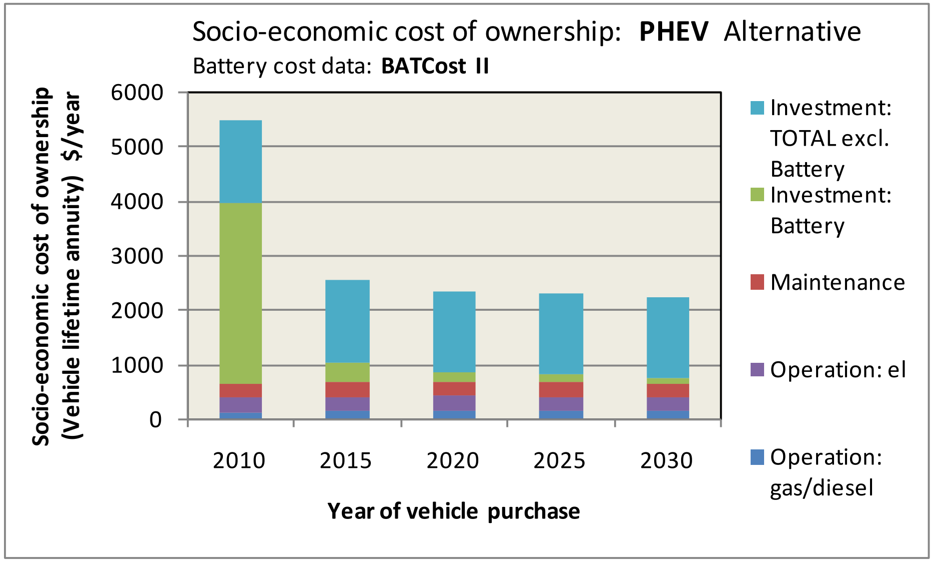
ICEV:



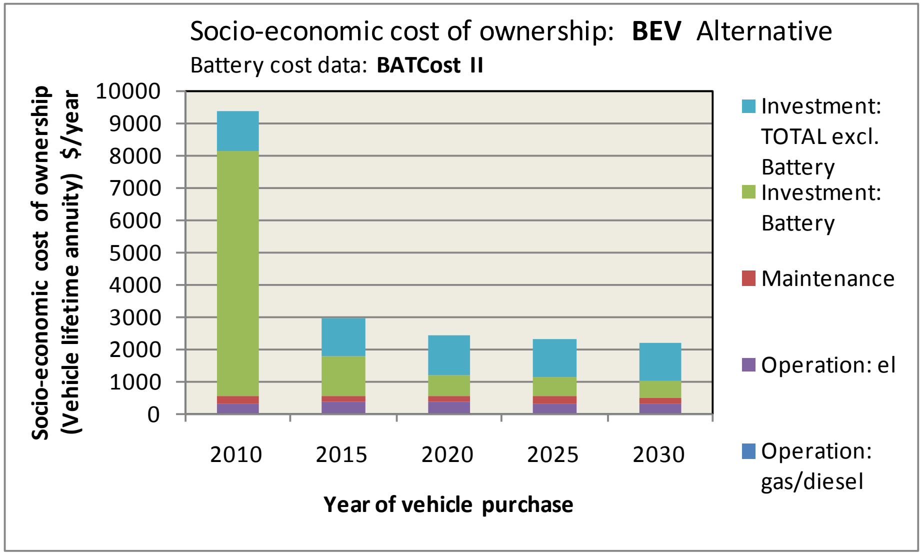
HEV:



PHEV: BatCost II , US DOE 2010 scenario

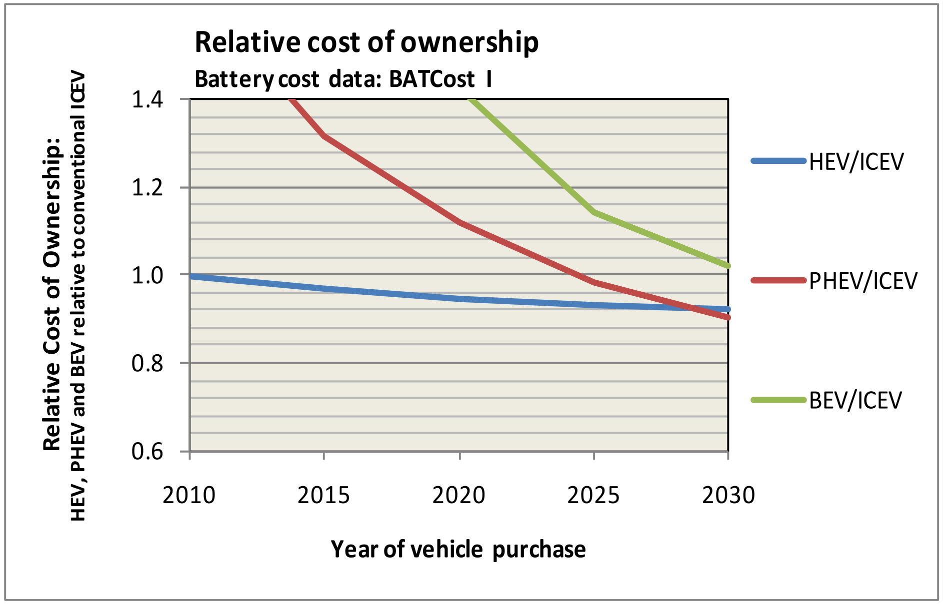


BEV: BatCost II, US DOE 2010 Scenario

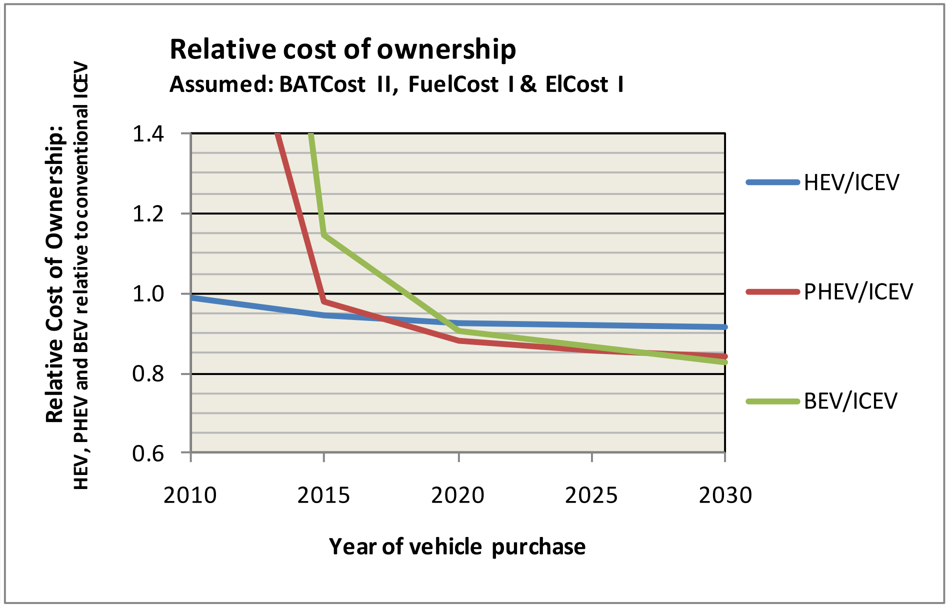


Relative cost of ownership: ($/year) / ($/year)
BEV, PHEV, HEV / ICEV

BatCost I : DK DEA 2010 scenario



BatCost II: US DOE 2010 Scenario



Conclusion: Individual EVs

Energy & CO_2 emission

Energy:

- **Electricity substitutes gasoline / diesel** via the EV.
- **EV drive trains** have potential for being very **energy efficient**.
- 3000 kWh electricity may sustain about 20.000 km average vehicle driving.
- Via EVs segments of the transport sector can **diversify its energy resource base** and reduce dependency on oil based fuels.

CO_2 emission:

- **EV CO_2 emission relates to the power supply** system charging the vehicles. The EV footprint of the individual vehicle change in accordance with the power supply.
- According to the Danish 'reference' development for the marginal power supply EVs bring almost **insignificant CO_2 reduction (due to coal dominated marginal power production).** However, assuming linear descend to zero CO_2 emission in 2050 for the power supply substantial CO_2 reduction is achieved via EVs substituting ICEVs. Ultimately EVs may provide zero CO_2 emission road transport.
- The individual ICEV of today may emit **about 2-3 ton CO_2 / year. This equals max achievable EV CO_2 reduction.**

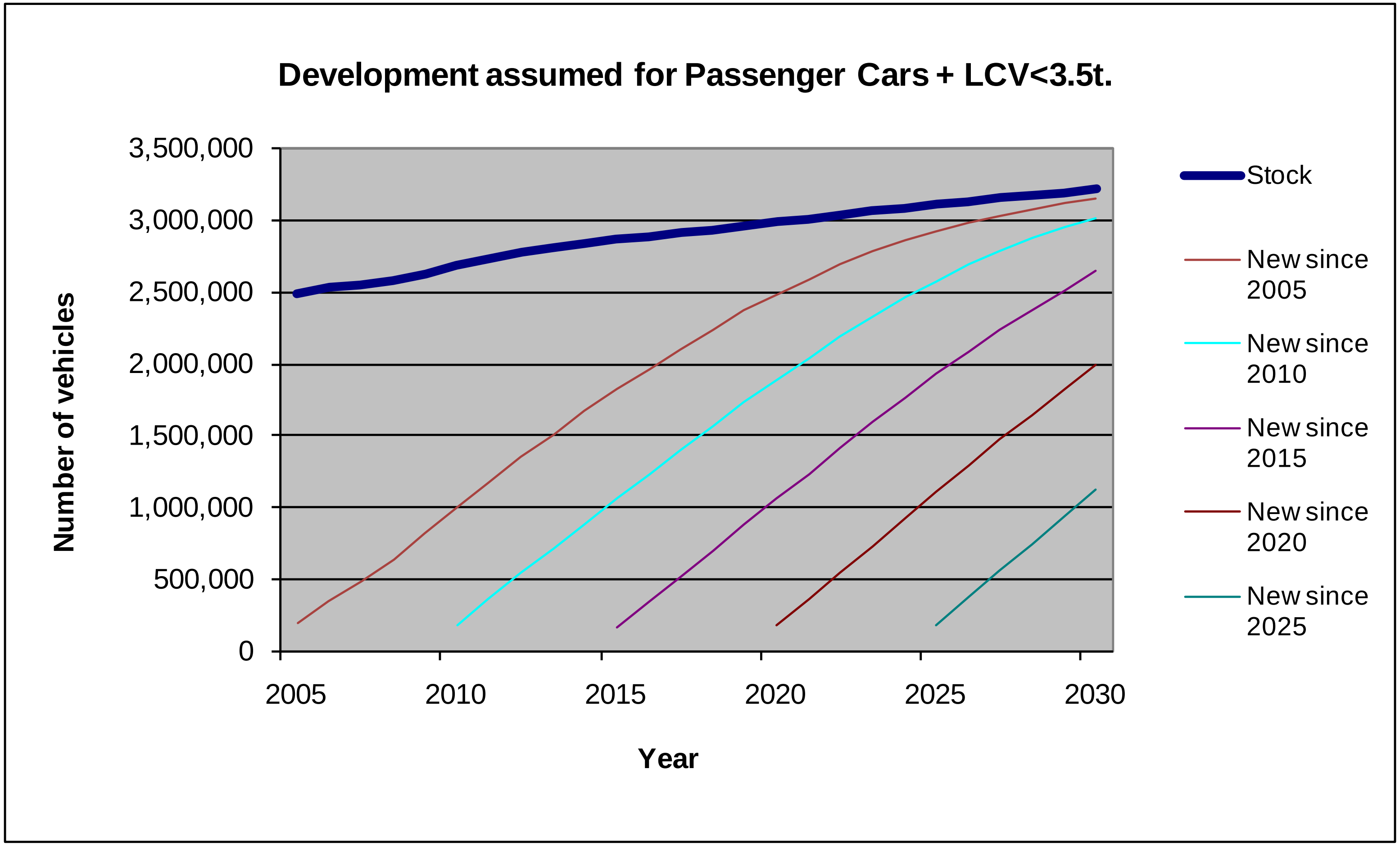
Conclusion: Individual EVs

Economy:

- Cost and lifetime of **EV batteries much determine the EV economy**. Based on (marginal and partial) socio-economic costs of ownership.
- In **'reference' battery cost** development: **PHEVs may get break-even with the ICEV beyond year 2020**. (COWI (2007) & IEA (2009))
- In **'alternative' battery cost** development: **PHEVs may get break-even with the ICEV year 2015**. (DOE, The Recovery Act: Transforming America's Transportation Sector, Batteries and Electric Vehicles, July 14, 2010.)
- CO_2 emission allowance **costs for 2-3 ton CO_2 are small put relative to costs of vehicle ownership**. May not constitute incentive for vehicle purchase.

Danish fleet:
Vehicle / fleet renewal

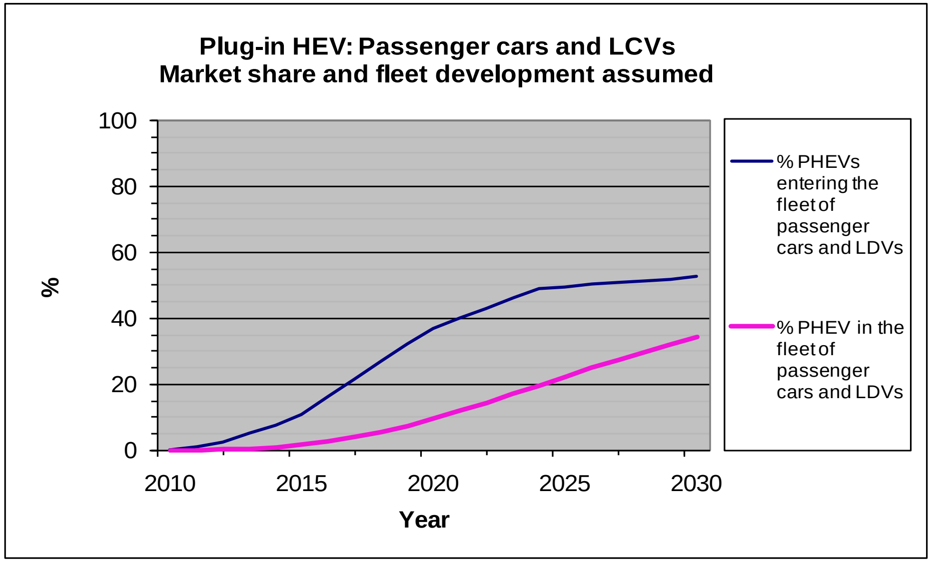
Segment: Passenger Cars + LDV < 3.5t



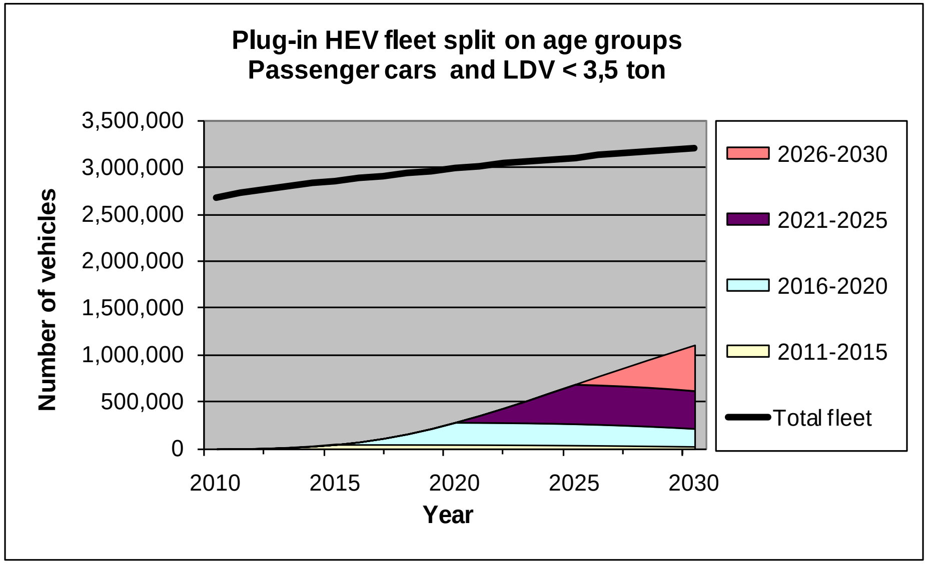
Danish fleet:
PHEV Scenario:
Market share & fleet development (# PHEVs)

Segment: Passenger Cars + LDV < 3.5t

PHEV Market share

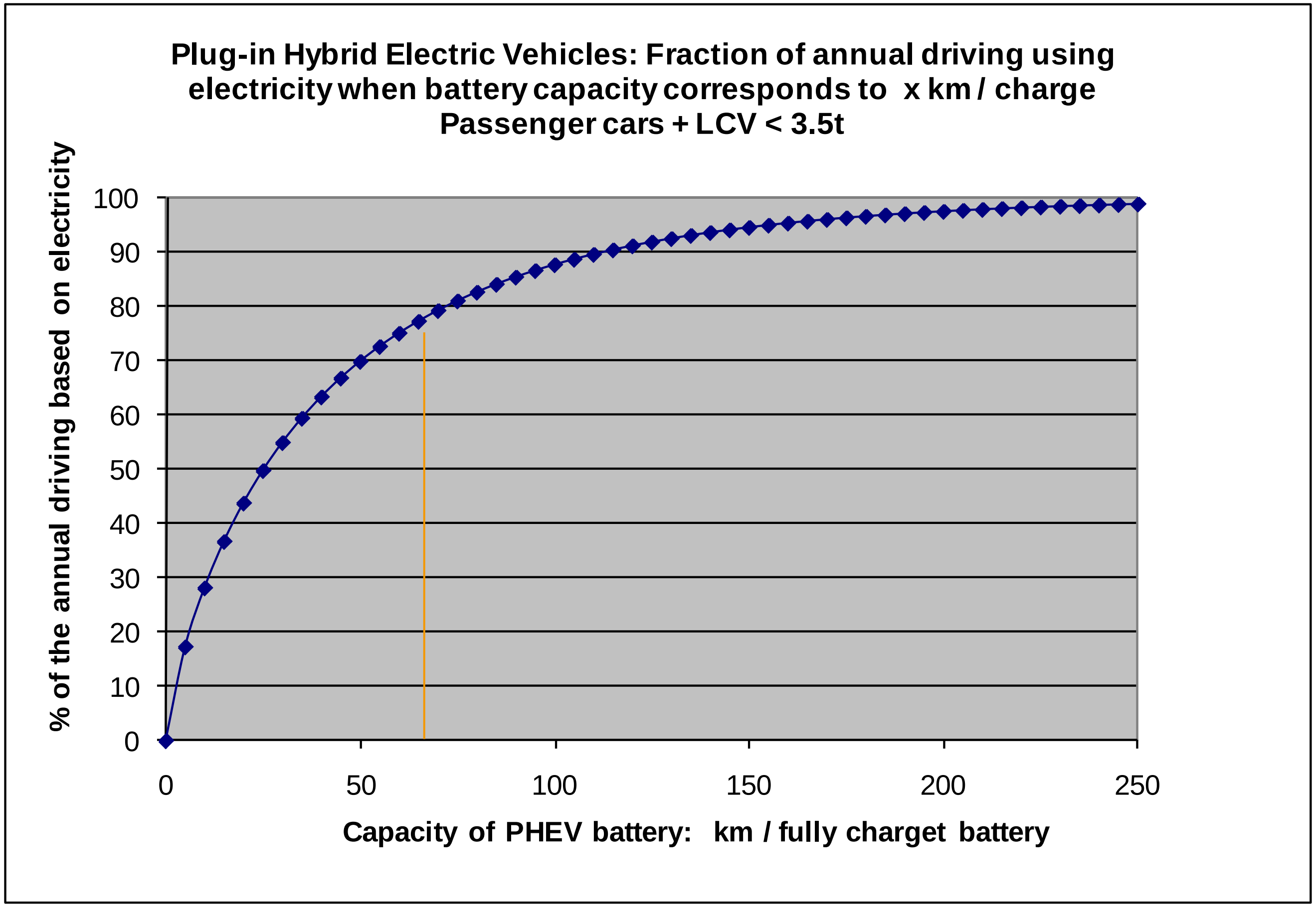


PHEV: Fleet development



Plug-in Hybrid Electric Vehicles (PHEV):

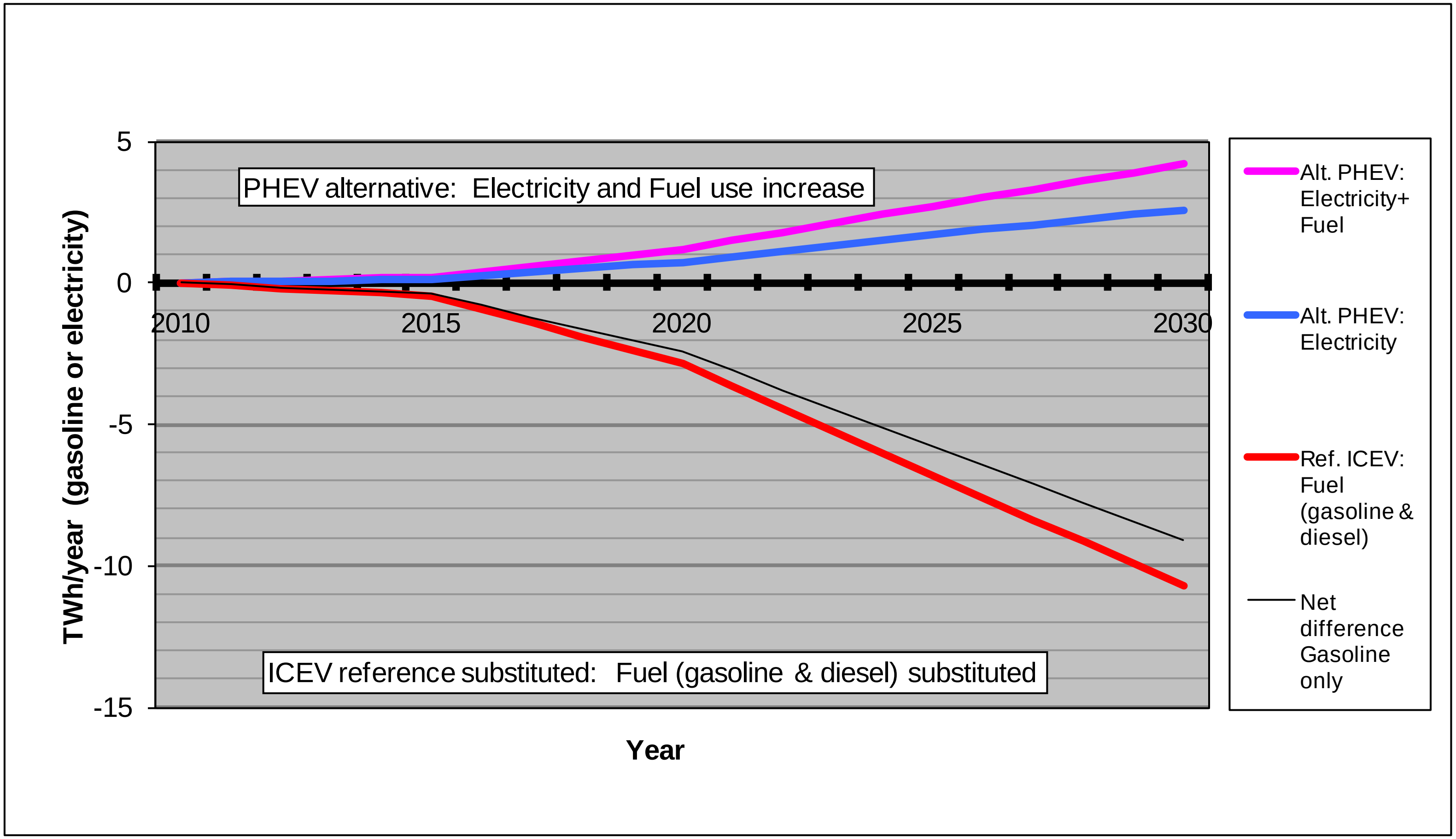
% of annual driving on electricity in DK ?



Source: Estimated (Weibull) distribution based on data from DTU Transport: 'Transport Vane Undersøgelse: 2006+2007'.

Danish fleet:
PHEV Scenario:
Energy substitution (TWh / year (fuel or el.))

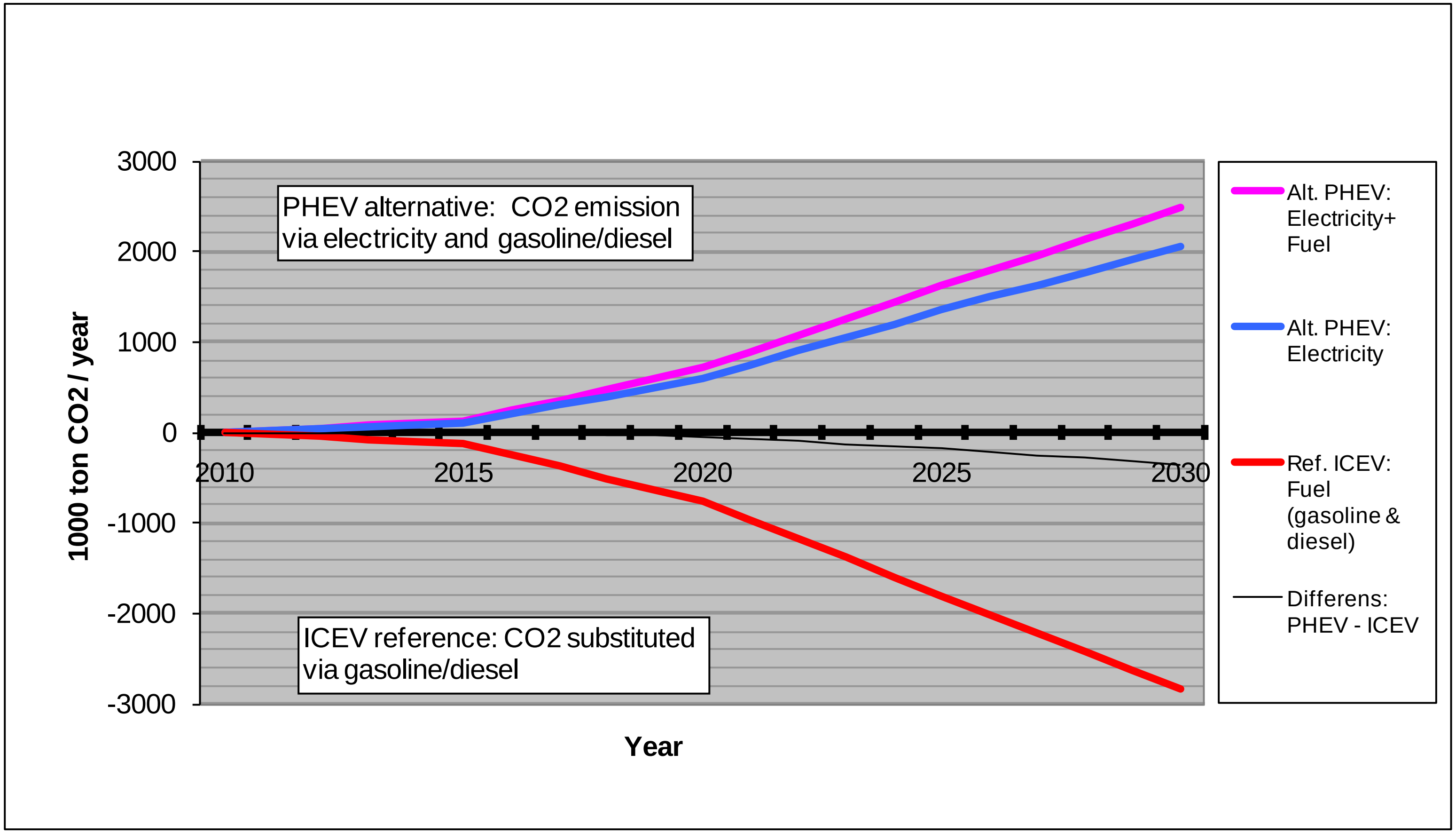
Segment: Passenger Cars + LDV < 3.5t



Danish fleet:
PHEV Scenario:
CO_2 emission (1000 ton CO_2 / year)

Segment: Passenger Cars + LDV < 3.5t

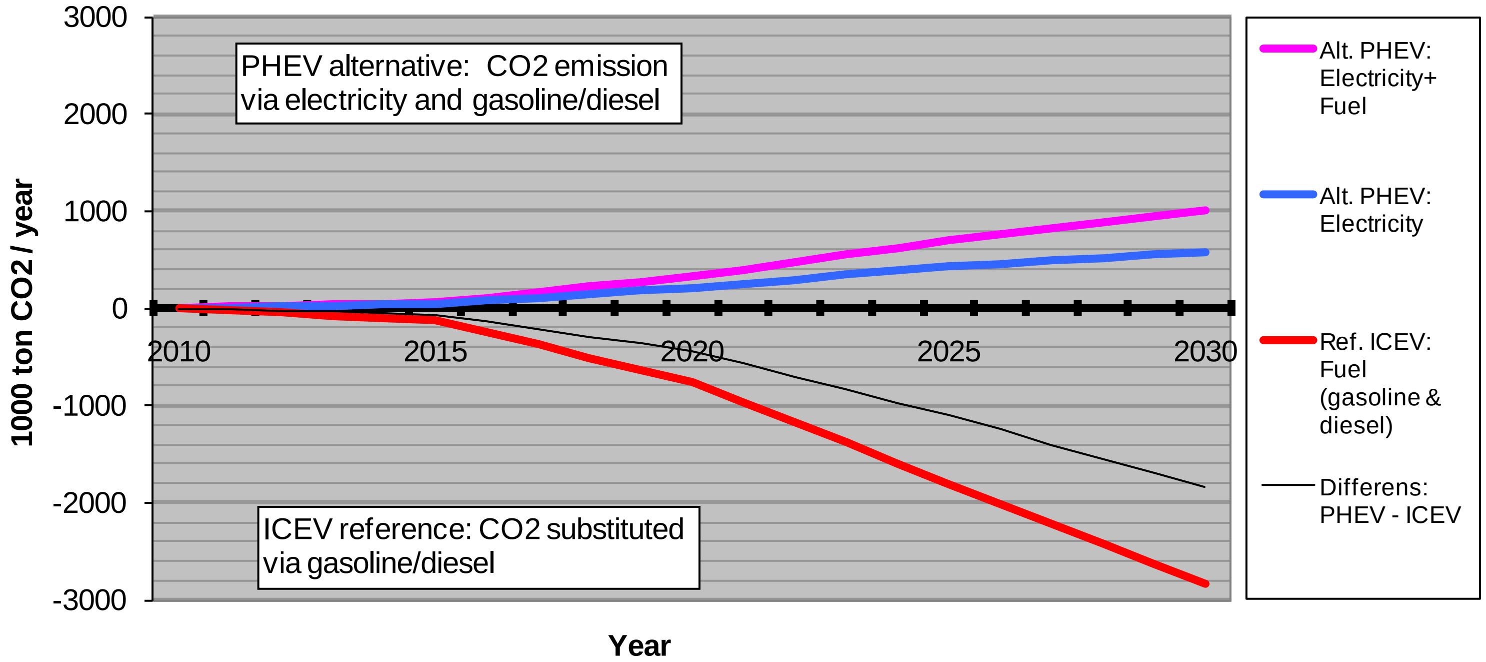
CO_2Case I : Marginal (coal based) power supply (DK DEA 2010)



Danish fleet:
PHEV Scenario:
CO_2 emission (1000 ton CO_2 / year)

Segment: Passenger Cars + LDV < 3.5t

CO_2Case III : **Average power system CO_2-characteristics.**
And linear phasing out to zero of all fossil fuels by 2050.



Danish fleet:

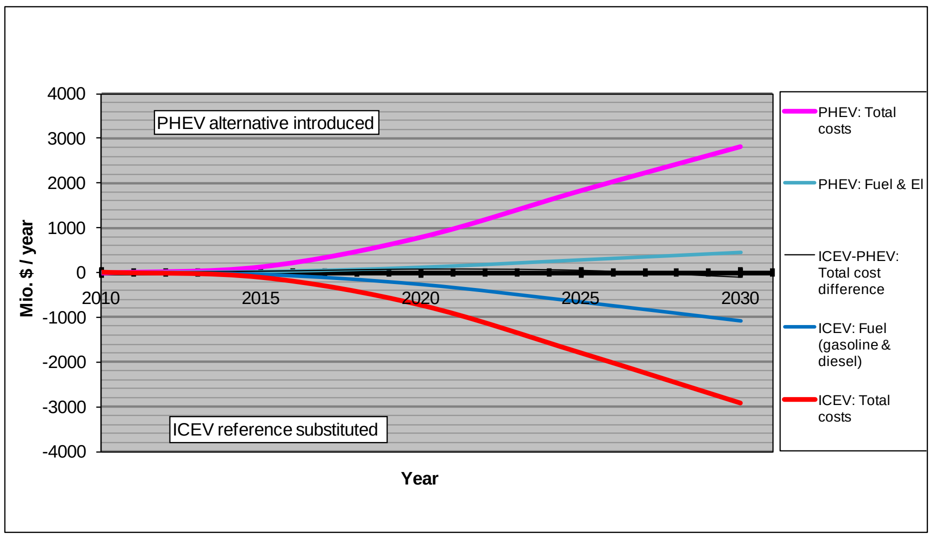
PHEV Scenario:

Socio-economic costs of ownership (Mio.$ / year)

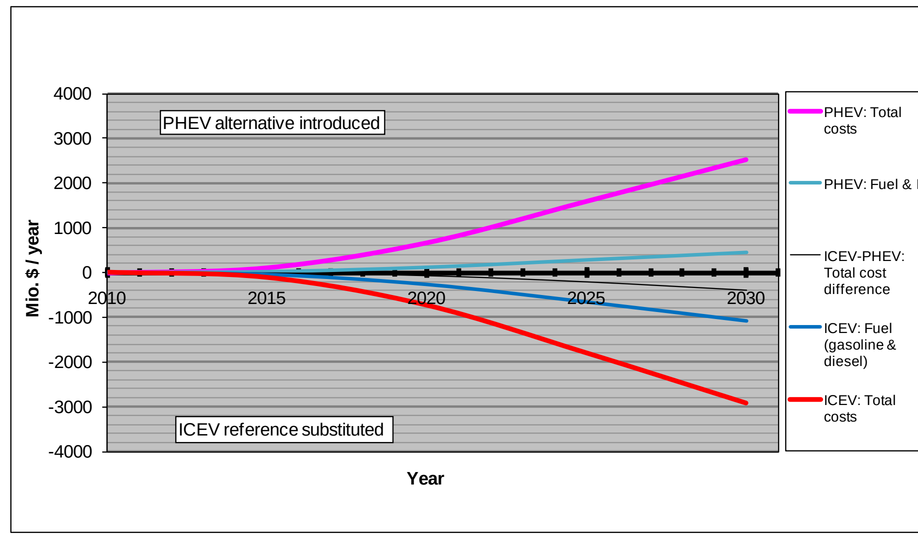
(marginal & partial analysis)

Battery cost development: Important for BEVs , less for PHEVs

BatCost I : Reference



BatCost II : US DOE 2010



Socio-economic PHEV and BEV scenarios: Limitations and assumptions made

- **Issues NOT taken into account:**
  - Infrastructure costs
  - Insurance costs
  - Power system flexibility gains (power system regulation capabilities, postpone investments in production/grids etc.)
- **Externalities NOT taken into account:**
  - Reduced local pollution and reduced noise
  - Opportunities for industry and future employment (‘first mover’ effects)
  - Oil substitution (reduced dependency on oil)
  - EVs effect on hedging for increasing oil prices (and rising transport costs).
  - System robustness and flexibility. Security of energy supply (diversified transport energy basis).

Most externalities NOT taken into account tend to act in favor of the EV

Note, however, infrastructure costs for EVs relative to the ICEVs are not addressed in the present analysis.

Thank you for your attention

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Lars Henrik Nielsen
SYS, Risø DTU
Danish Technical University