Technical University of Denmark

Elbil - scenarier for dansk vejtransport : Energi, CO2 emission og økonomi?

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Publication date:
2011

Document Version
Også kaldet Forlagets PDF

Citation (APA):
Nielsen, L. H. (2011). Elbil - scenarier for dansk vejtransport : Energi, CO2 emission og økonomi? [Lyd og/eller billed produktion (digital)]., Frederiksberg (DK), 8 Mar, 01/01/2011

El til Vej-transport

Fleksible El-systemer og Vindkraft

WORKSHOP

8. marts 2011 kl. 13.30 - 16.30 hos Dansk Energi

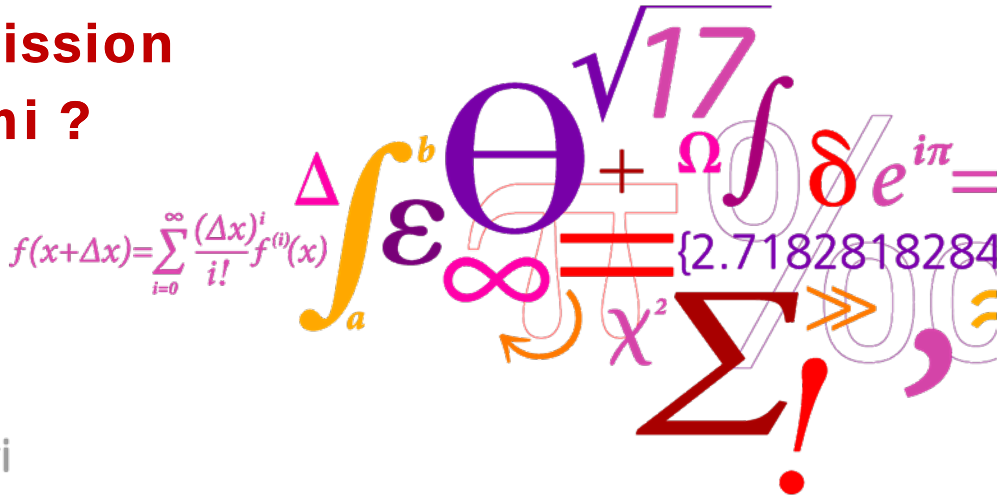
Elbil - scenarier for dansk vejtransport:

Energi

CO_2 emission

økonomi ?

Lars Henrik Nielsen
SYS Risø DTU



Risø DTU
Nationallaboratoriet for Bæredygtig Energi

Content

The project in short.

EV- technology & EV- scenarios

- **Energy substitution**
- **CO_2 emission consequences**
- **Socio-economy / cost of ownership (marginal partial analyses)**

Some conclusions

Basis for further analyses on

- overall power system aspects
- power transmission aspects
- power distribution aspects

The Project:

El til Vejtransport, Fleksible El-systemer og Vindkraft.

EFP07-II Journal nr. 33033 – 0218

Hovedsponsor: **EFP07-II**

Deltagere:

Forskningscenter Risø, DTU: SYS, VEA

ØRSTED, DTU: CET

RAM-løse edb

EnergiNet.dk

Dansk Energi

Overordnet mål:

Analyse af **mulige samspil** mellem

- **el- og kraftvarmesektoren og**
- **transportsektoren,**

dersom dele af vej-transporten baseres

- **’plug in’ hybrid- og / eller elbil-teknologi.**

Content

1) EV- technology (assumptions)

- **Energy substitution**
- **CO_2 emission consequences**
- **Socio-economy / cost of ownership (marginal partial analyses)**

2) EV- scenarios (based on EPRI scenario)

Some conclusions

Vehicles: Passenger cars and LDV < 3.5 ton

The expected '**close to average' fleet** passenger vehicles defined in versions of:

Reference: Internal Combustion Engine Vehicle (**ICEV**)

Alternative: Hybrid Electric Vehicle (**HEV**)
Plug-In Hybrid Electric Vehicle (**PHEV**)
Battery Electric Vehicle (**BEV**) (All-electric)

Vehicle data:

Ref.: COWI (2007), EPRI (2007), IEA (2009), DOE (2010)

Links assumed:

(among defined fleet average vehicles)

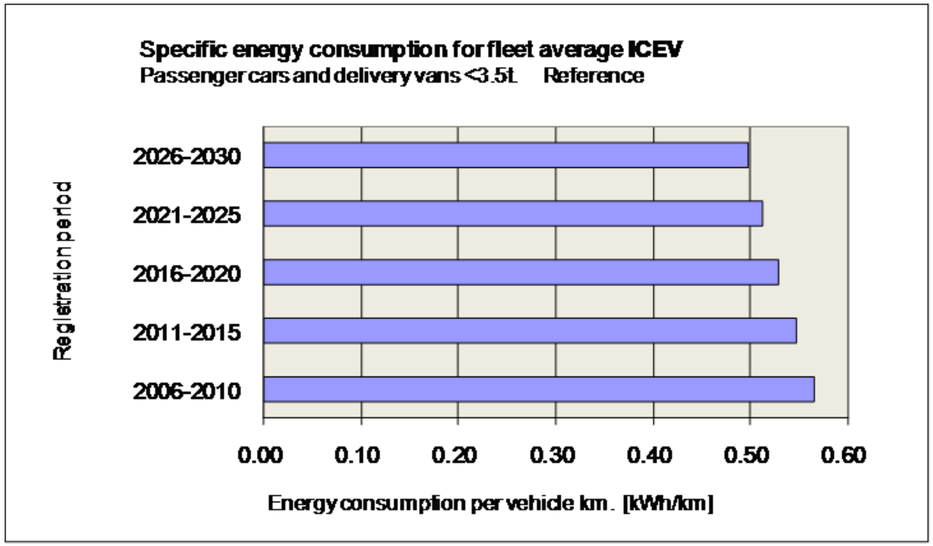
- **PHEVs operated in HEV-mode** have the same specific energy (gasoline/diesel) consumption **as the defined HEV vehicle.**

- **PHEVs operated in BEV-mode** (or charge depletion mode) have the same specific energy consumption (electricity) **as the defined BEV vehicle.**

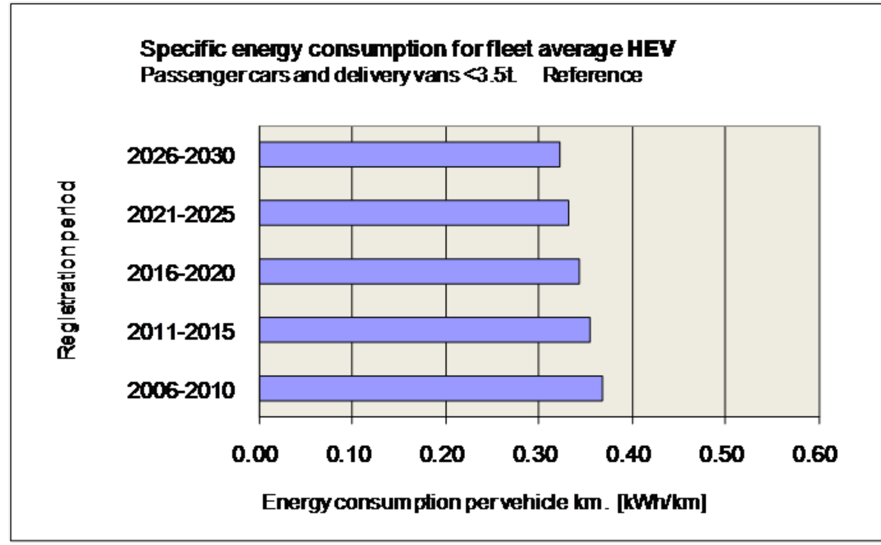
- **HEV fuel consumption equal to 65%** of the ICEV within a vintage group.

Vehicle energy consumption: kWh/km

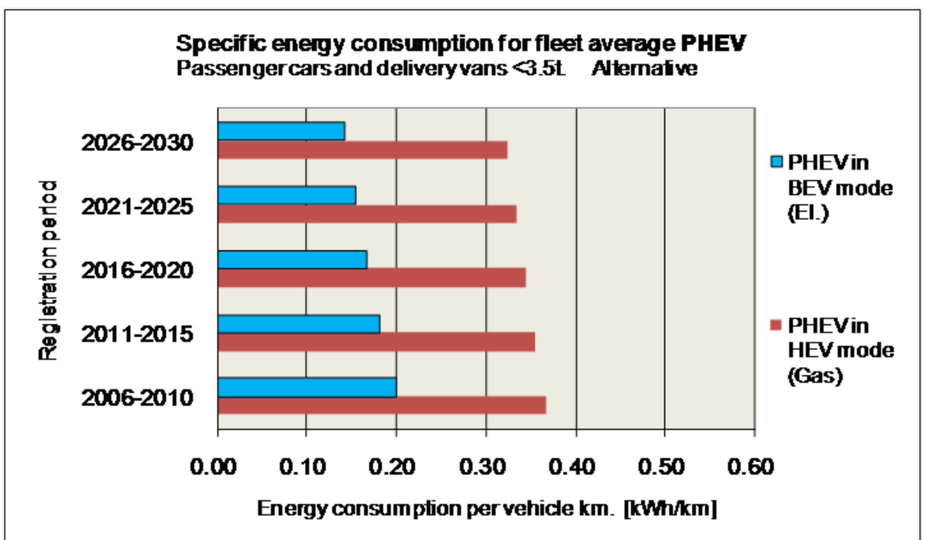
ICEV fuel consumption:



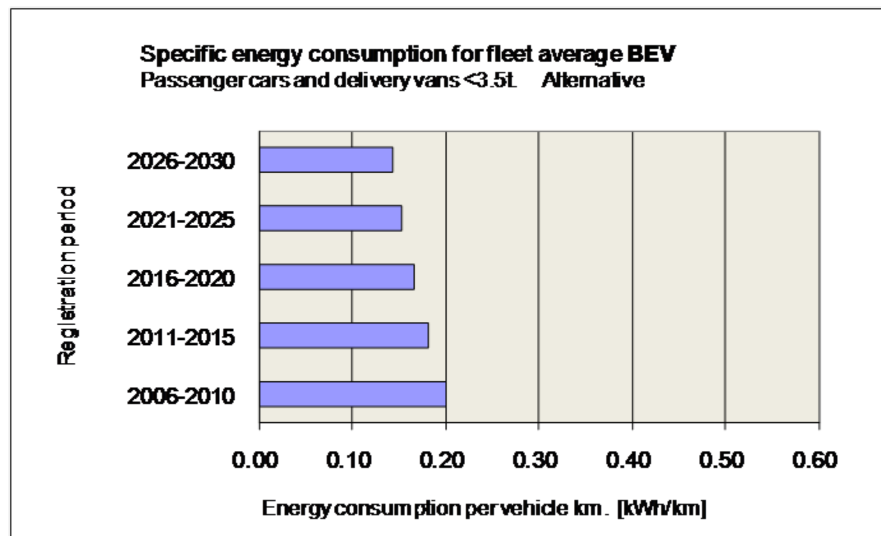
HEV fuel consumption:



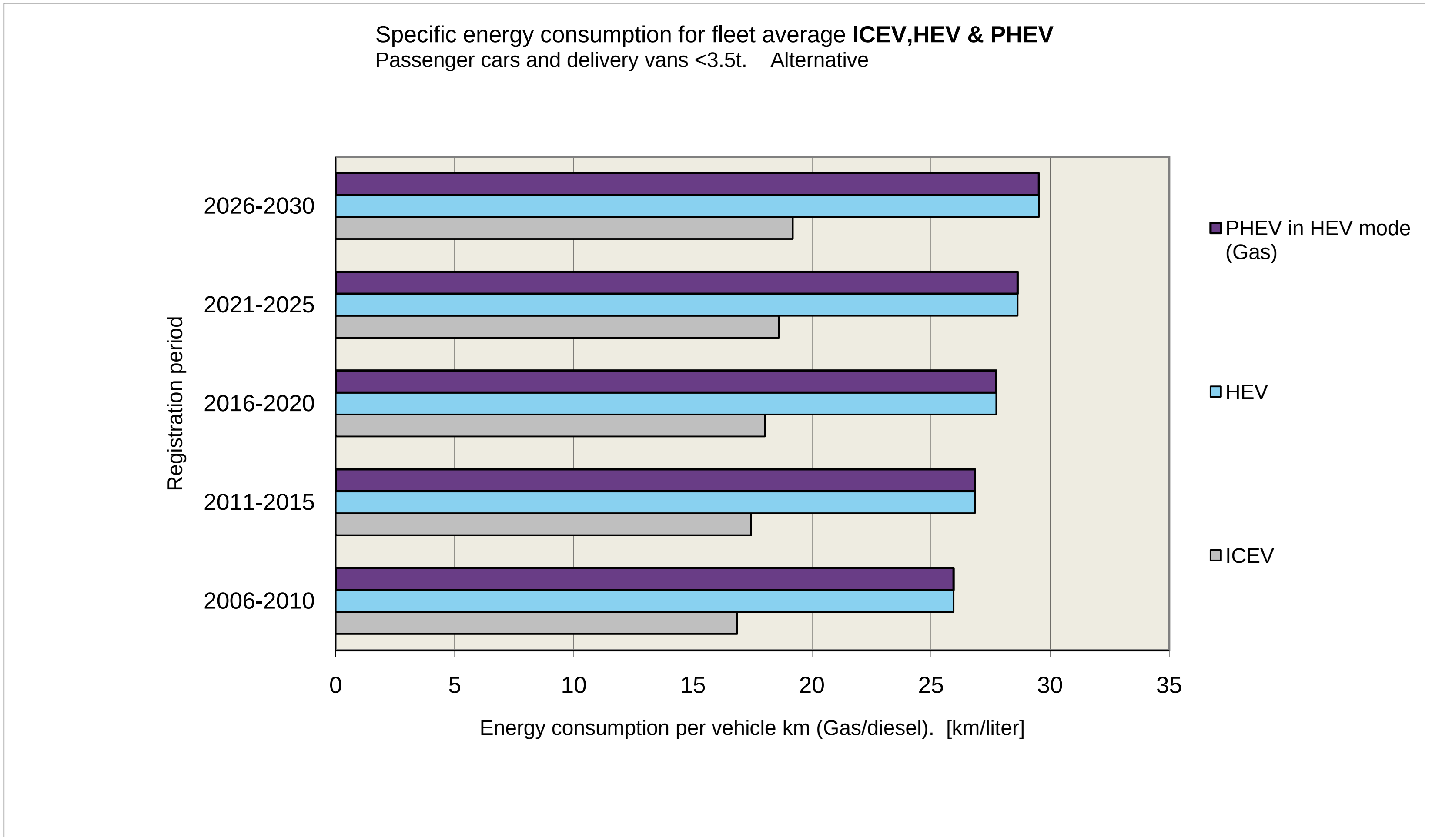
PHEV electricity and fuel consumption:



BEV electricity consumption:



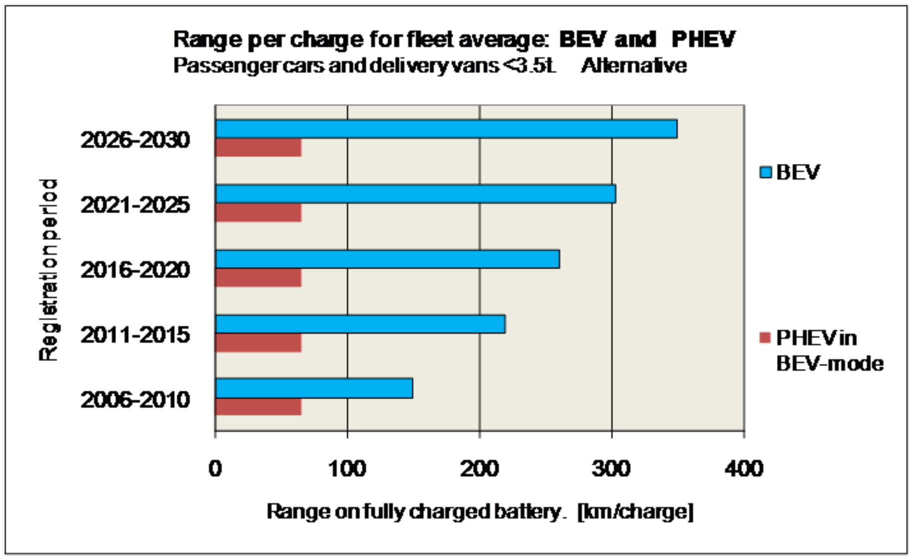
Vehicle energy consumption: km/liter



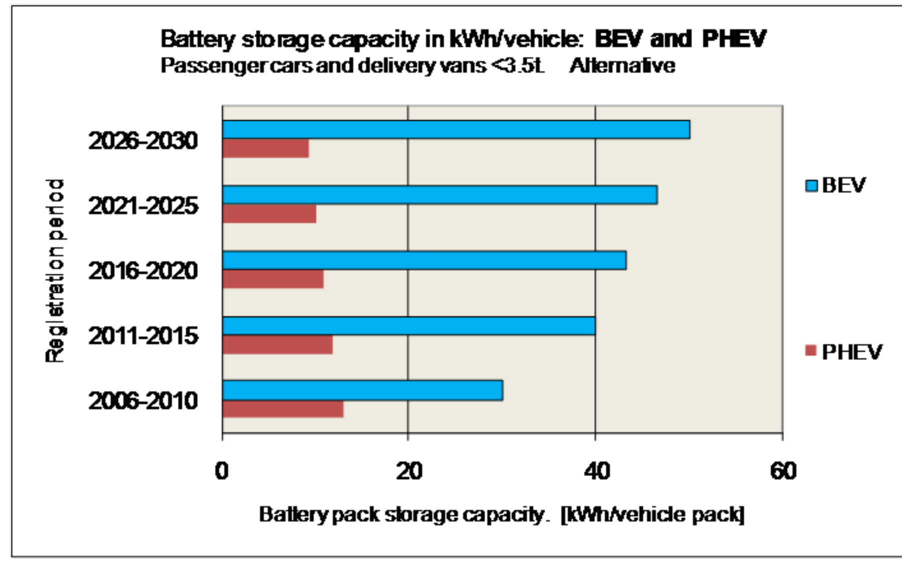
Electric Vehicle:

Battery size and range per charge

PHEV & BEV: Range [km/charge]

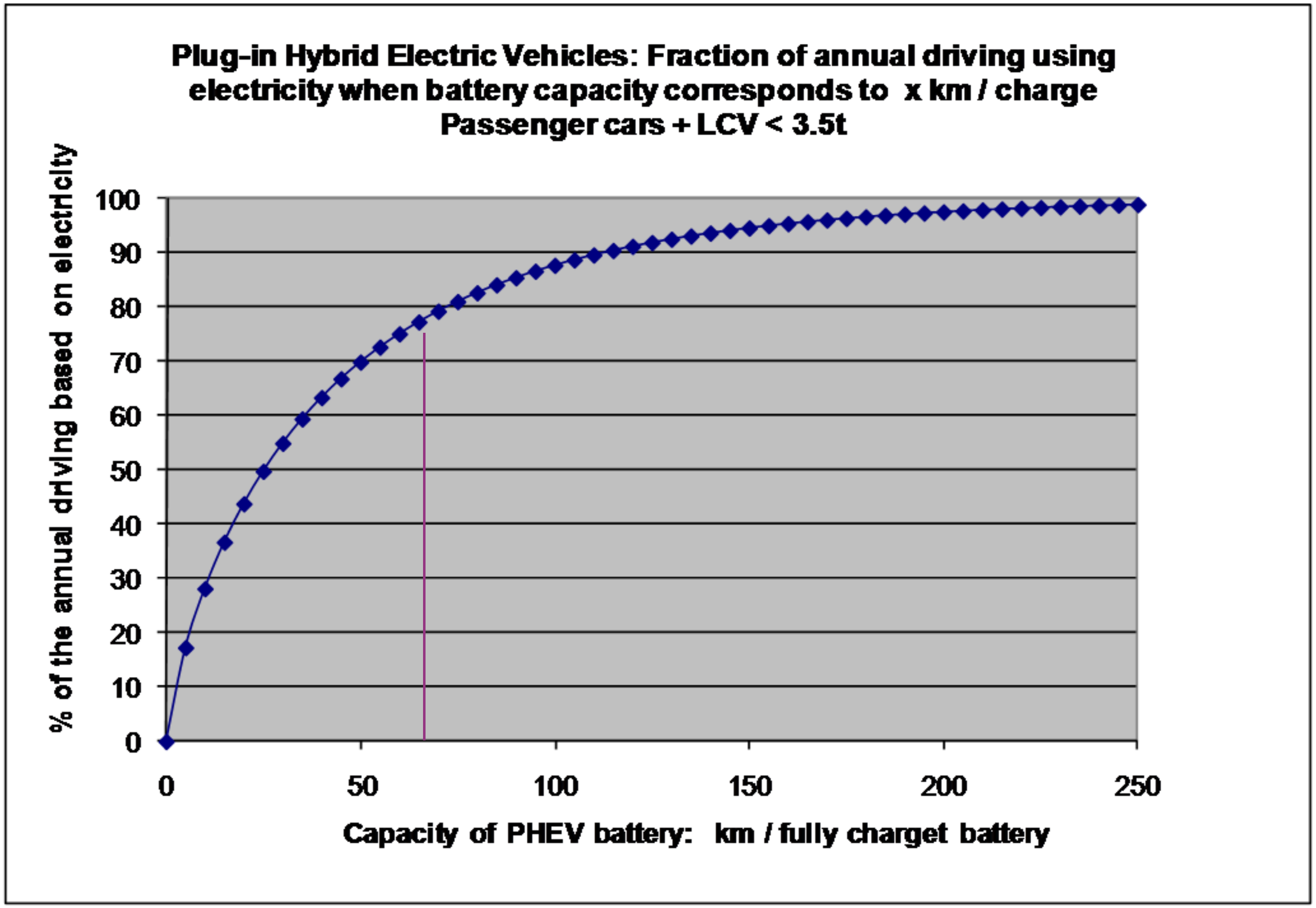


PHEV & BEV: Battery size [kWh/pack]



Plug-in Hybrid Electric Vehicles (PHEV):

% of annual driving on electricity in DK ?



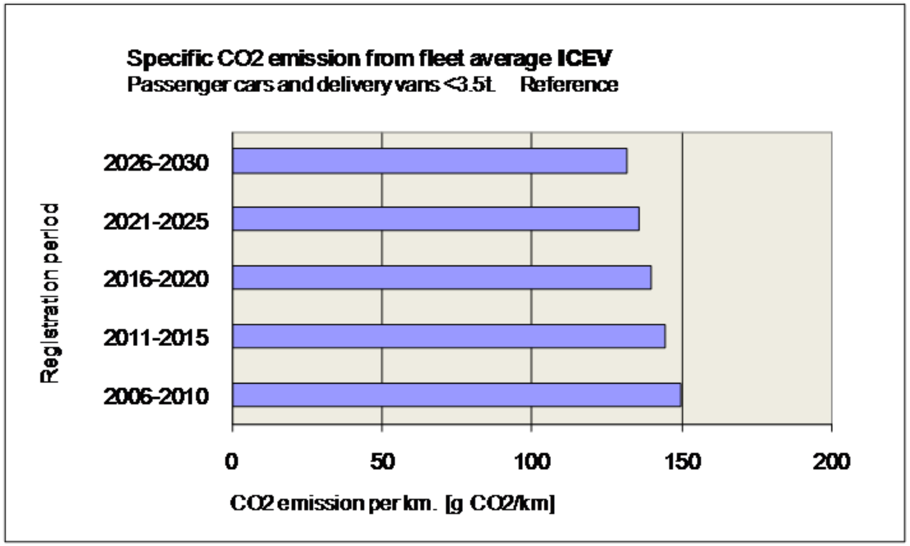
Source: Estimated (Weibull) distribution based on data from DTU Transport: 'Transport Vane Undersøgelse: 2006+2007'.

Vehicle specific CO_2 emission: g CO_2 / km

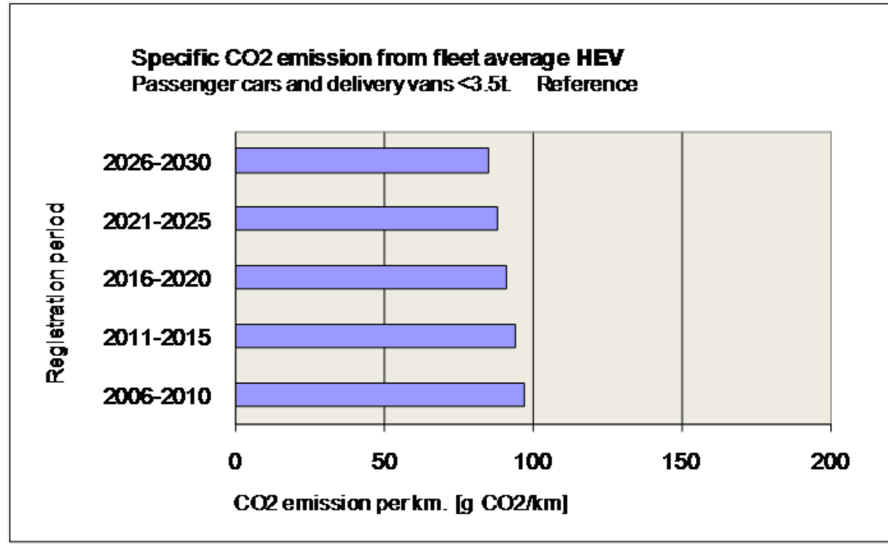
CO_2Case I : Marginal el-production in DK (coal)

Source: DEA (2010)

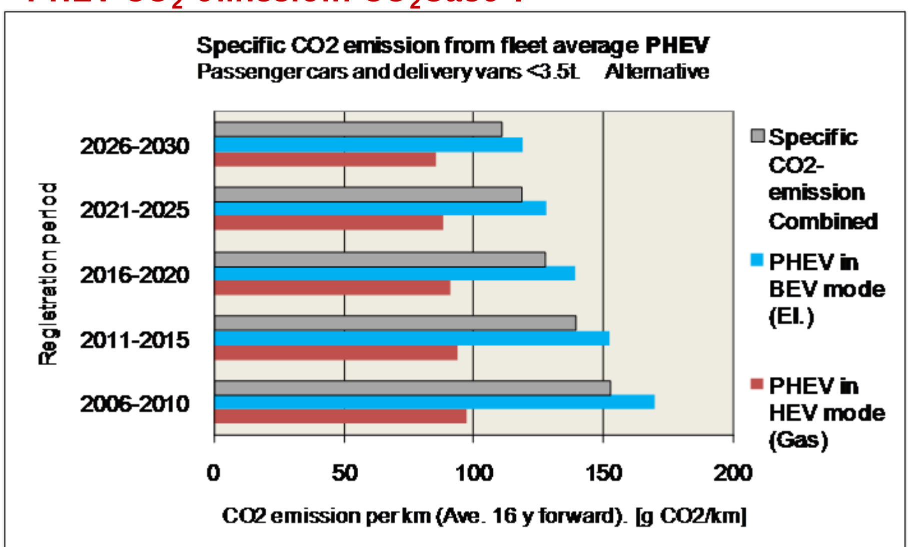
ICEV CO_2 emission:



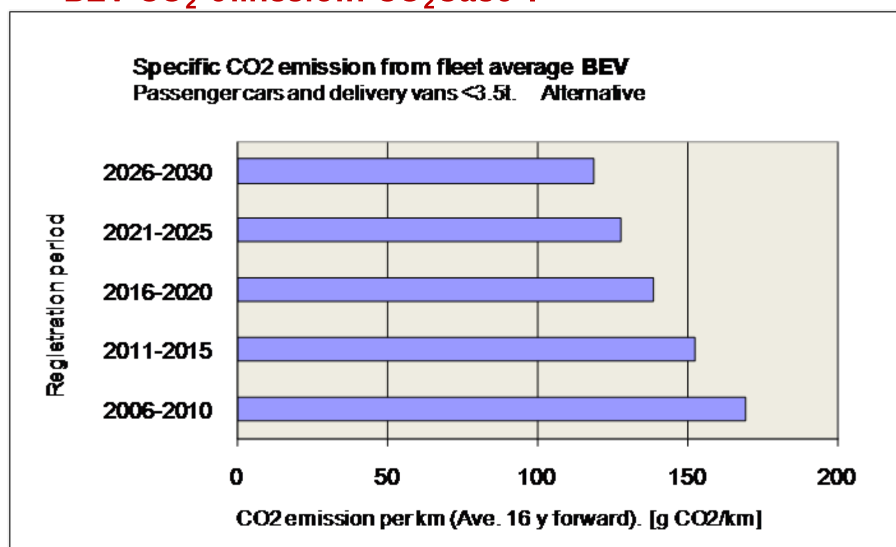
HEV CO_2 emission:



PHEV CO_2 emission: CO_2Case I



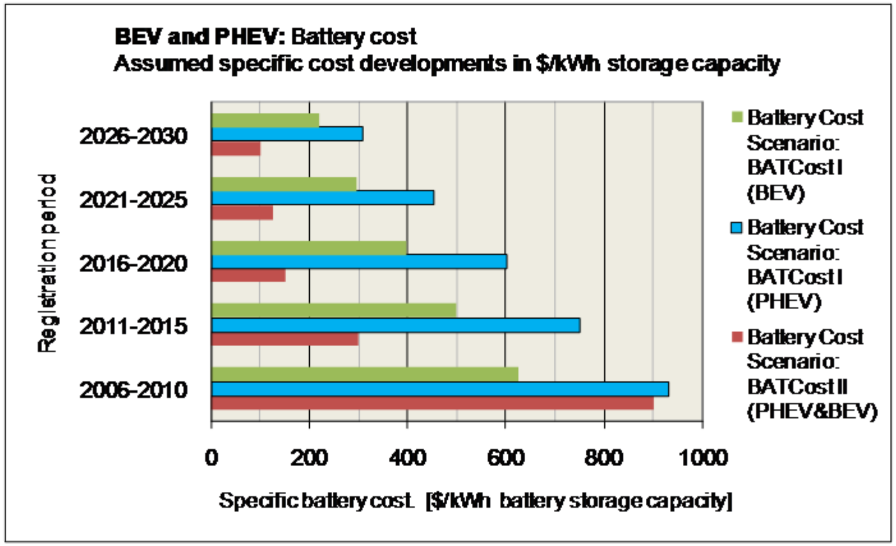
BEV CO_2 emission: CO_2Case I

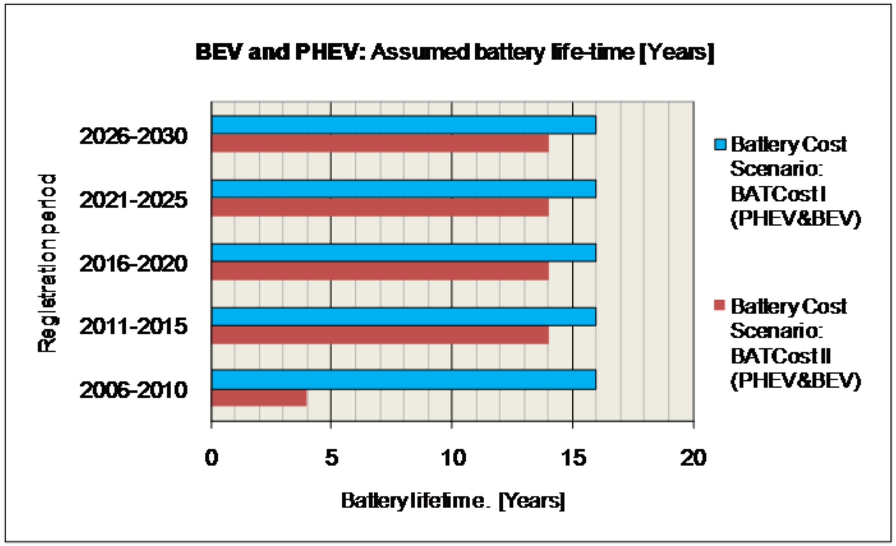


Electric Vehicle: PHEV and BEV

Battery cost and lifetime

Cost: $ / kWh battery **Lifetime: Years**





Assumptions:

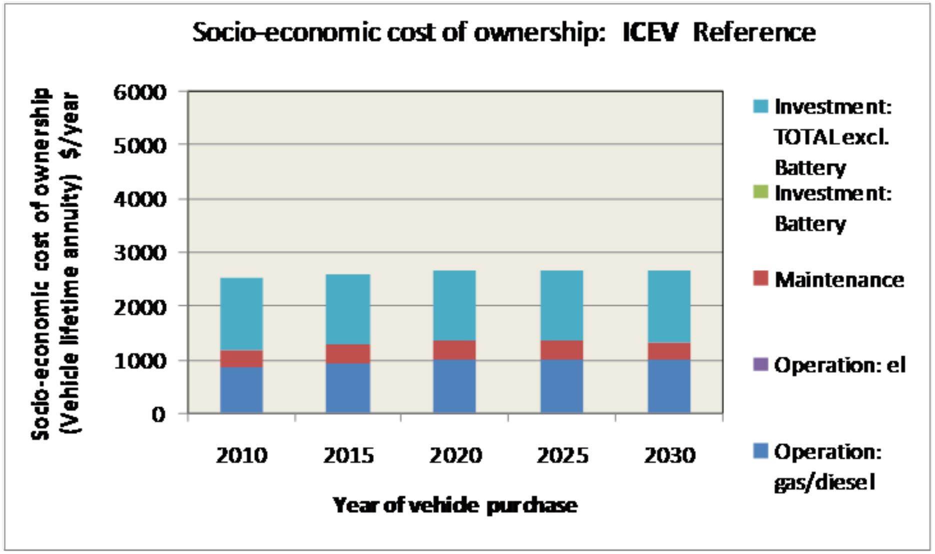
BatCost I : EV battery cost development scenario based on ref.: COWI (2007) & IEA (2009)

BatCost II: EV battery cost development scenario based on ref.: USDOE, The Recovery Act : Transforming America's Transportation Sector, Batteries and Electric Vehicles, July 14, 2010.

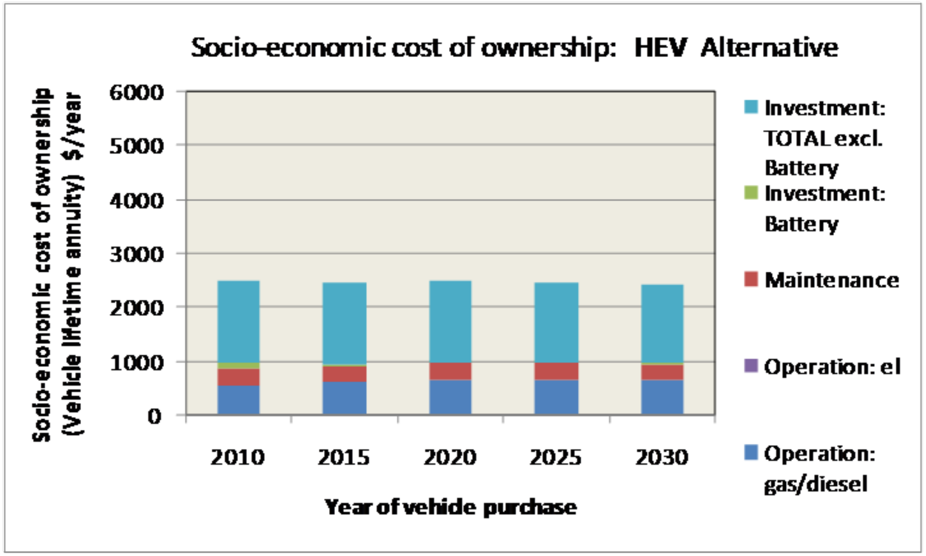
Vehicle cost of ownership: $ / year

EV battery cost: USDOE July 2010 Scenario

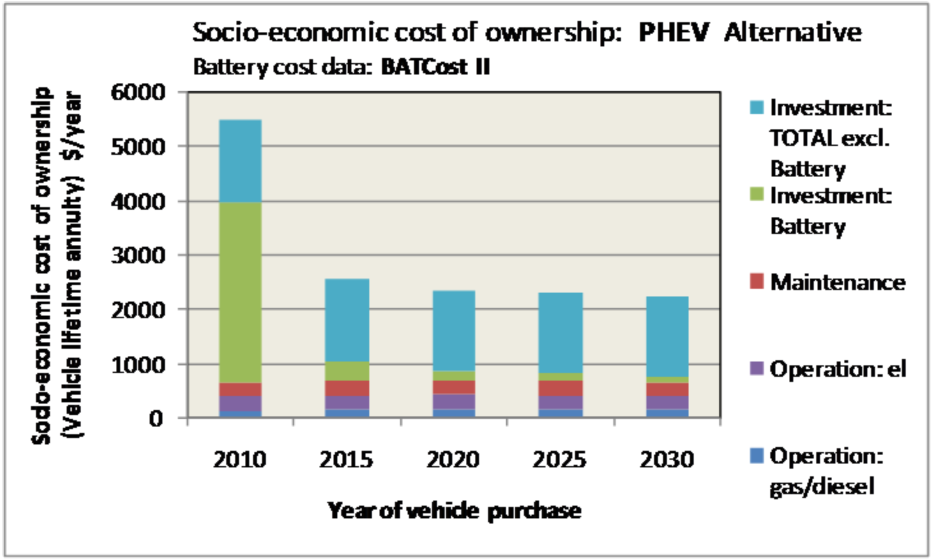
ICEV:



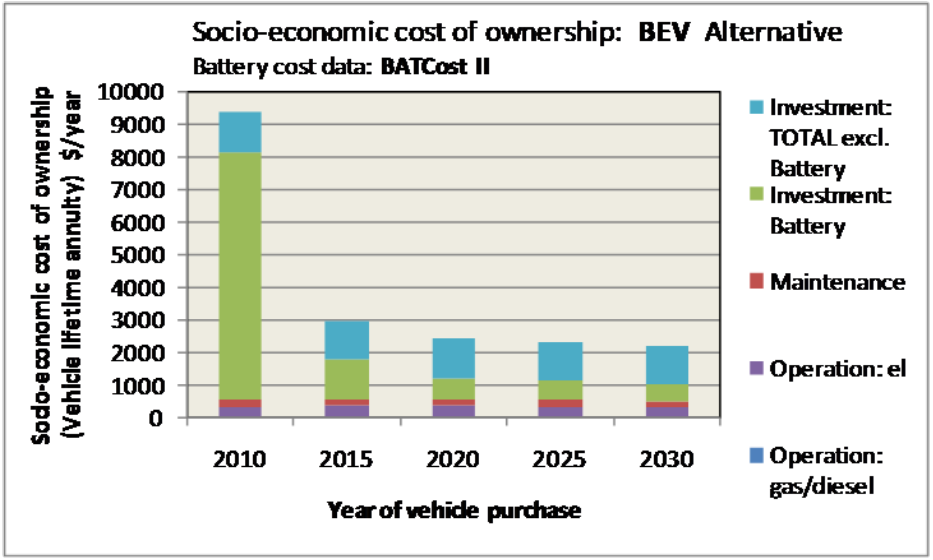
HEV:



PHEV: BatCost II , US DOE 2010 scenario



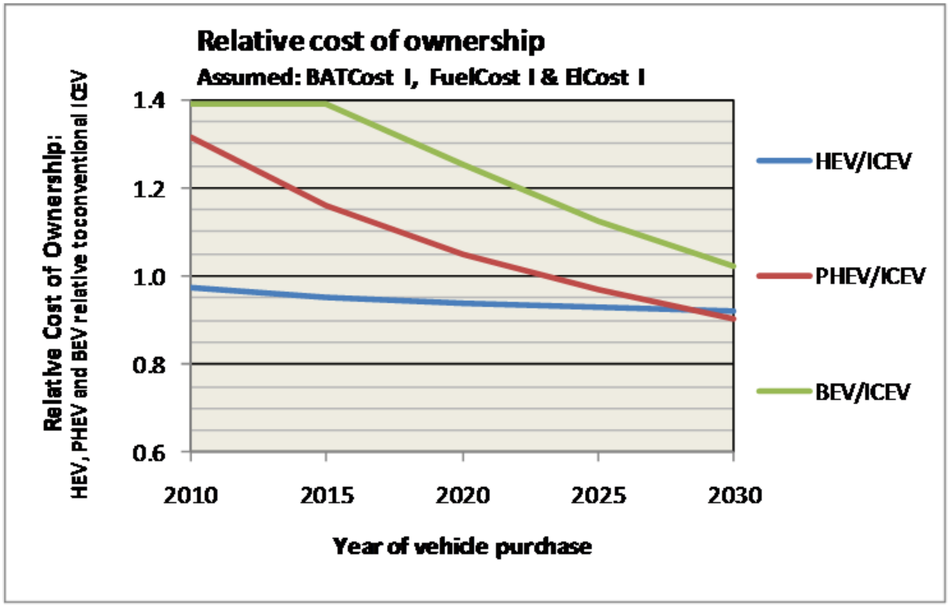
BEV: BatCost II, US DOE 2010 Scenario



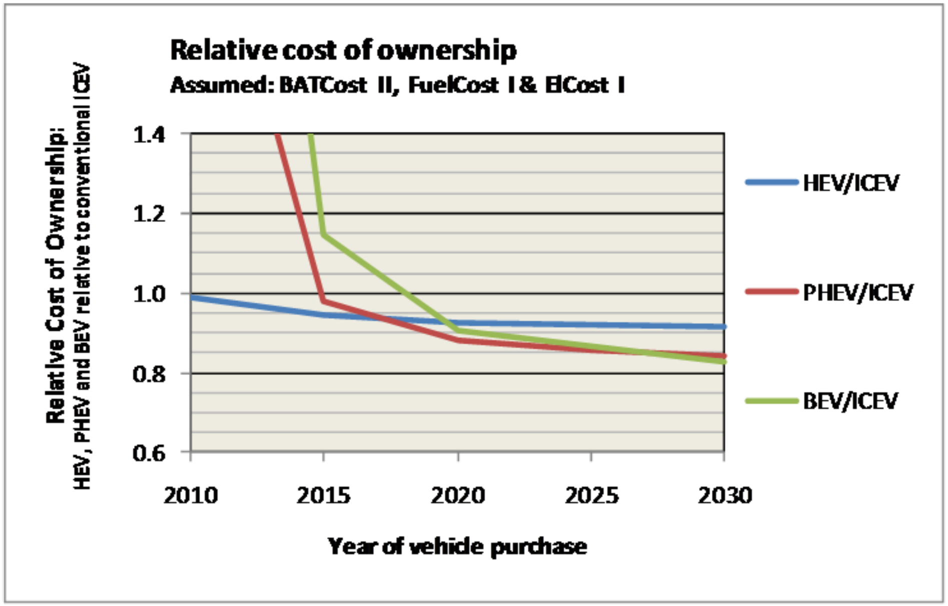
Relative cost of ownership: ($/year) / ($/year)

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.**

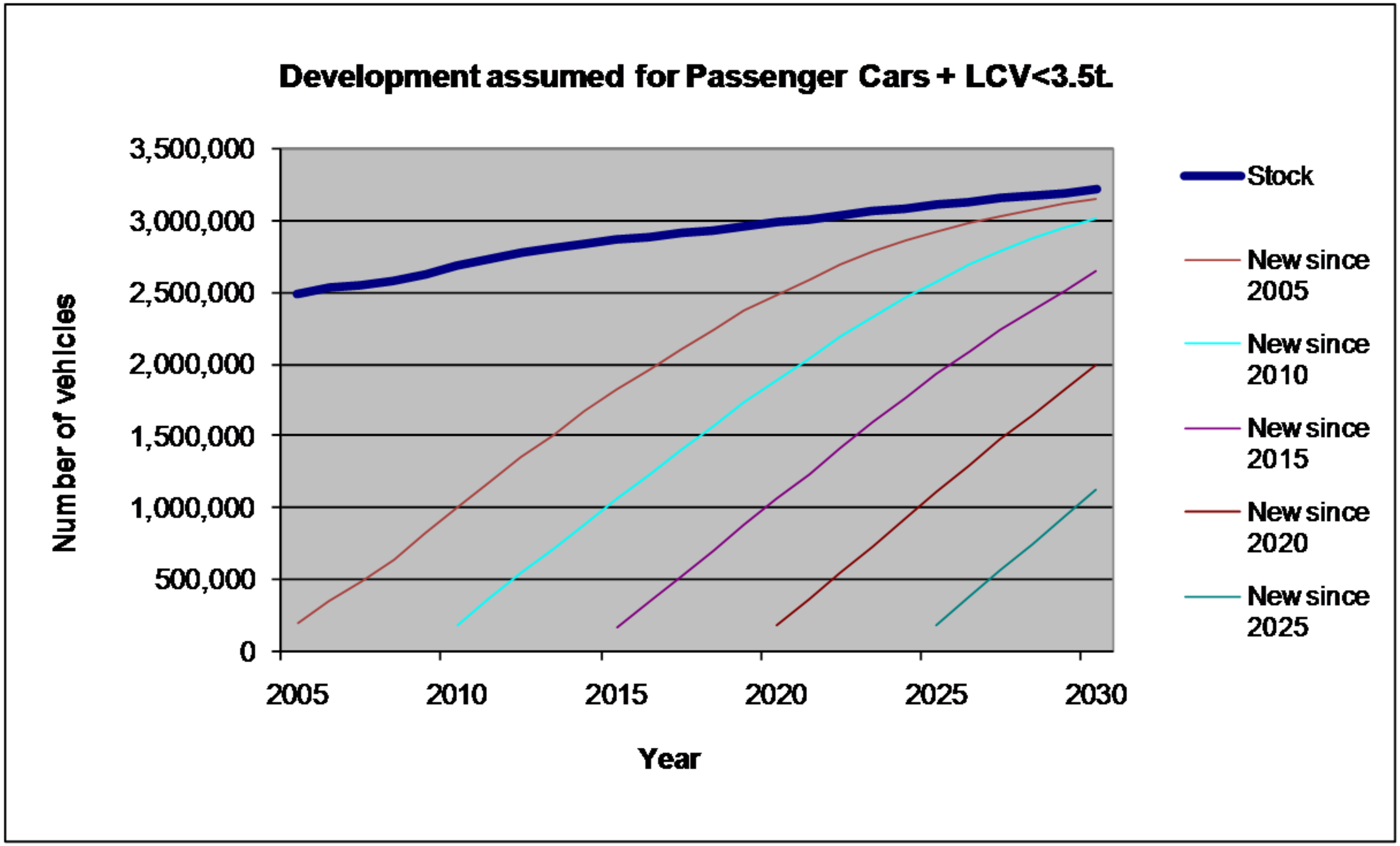
Conclusion: Individual EVs

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**.
- In **'alternative' battery cost** development **PHEVs may get break-even with the ICEV year 2015**.
- CO_2 emission allowance **costs of 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



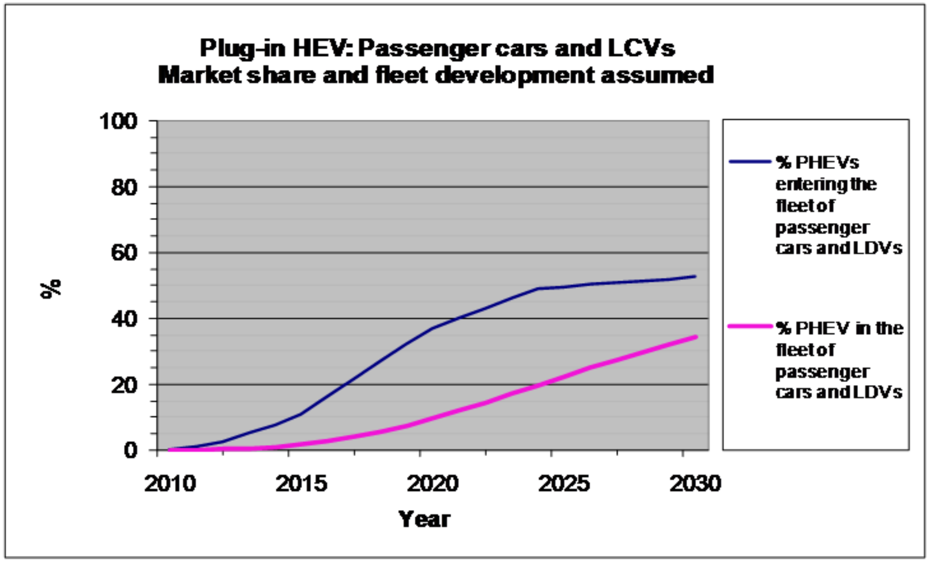
Danish fleet:

PHEV Scenario:

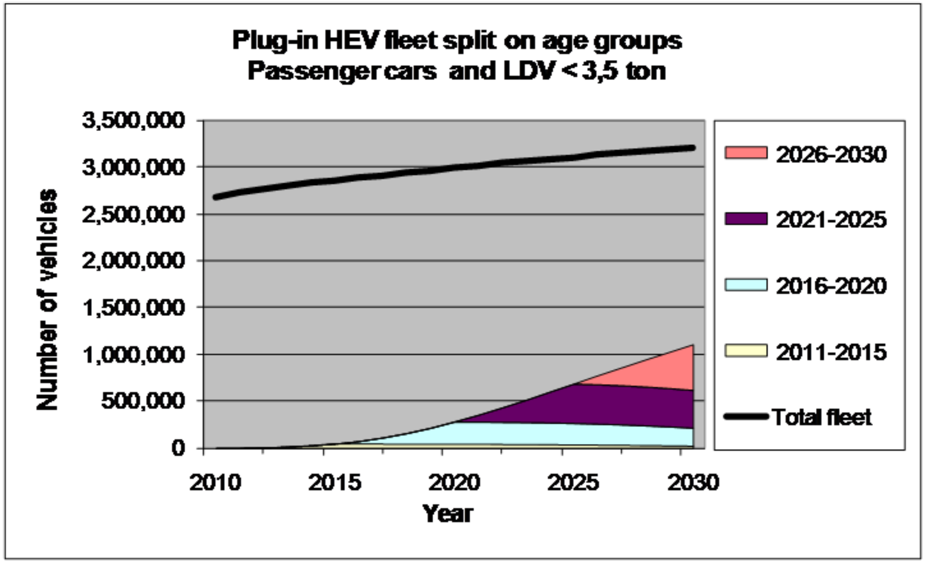
Market share & fleet development (# PHEVs)

Segment: Passenger Cars + LDV < 3.5t

PHEV Market share

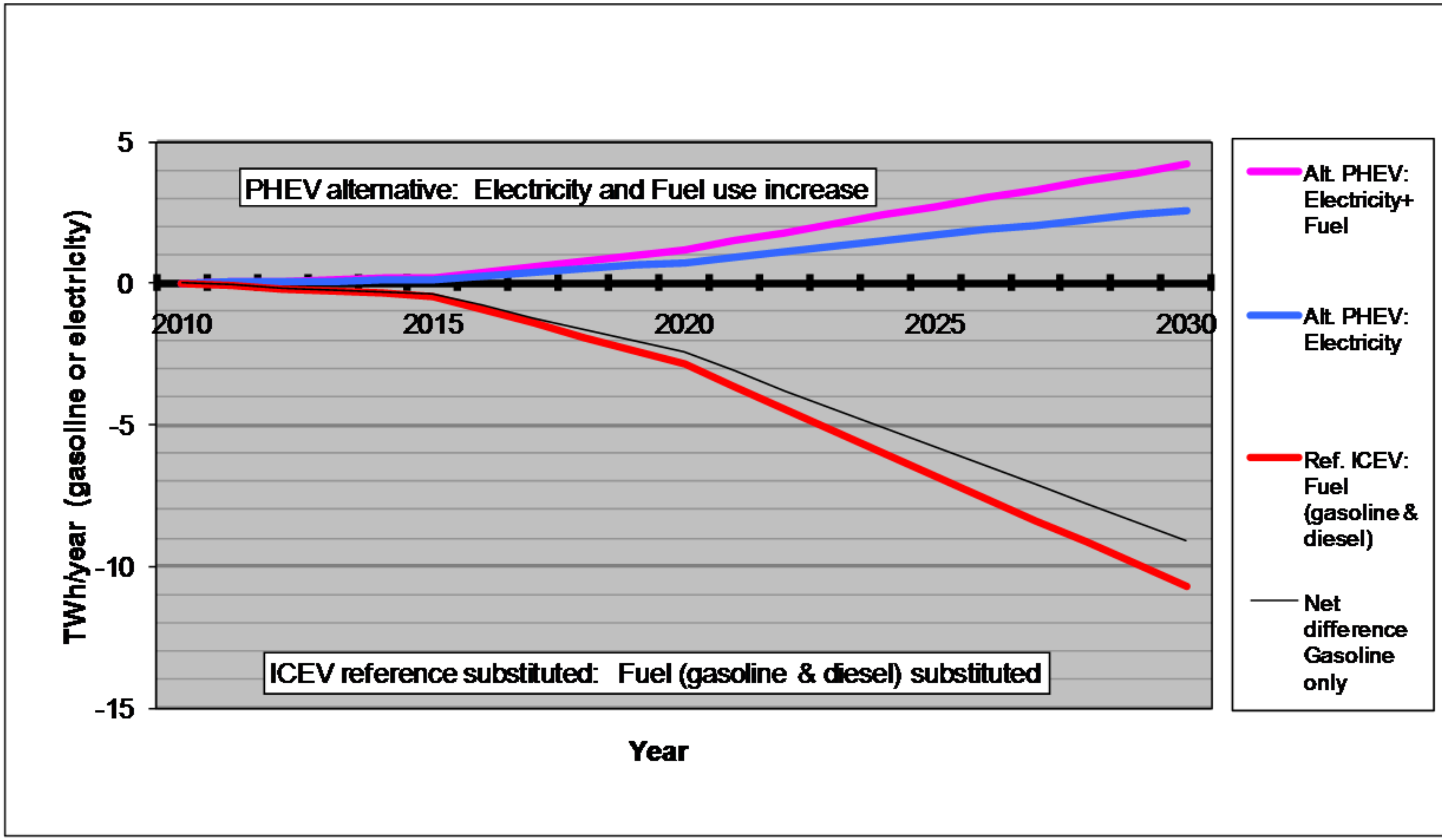


PHEV: Fleet development



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

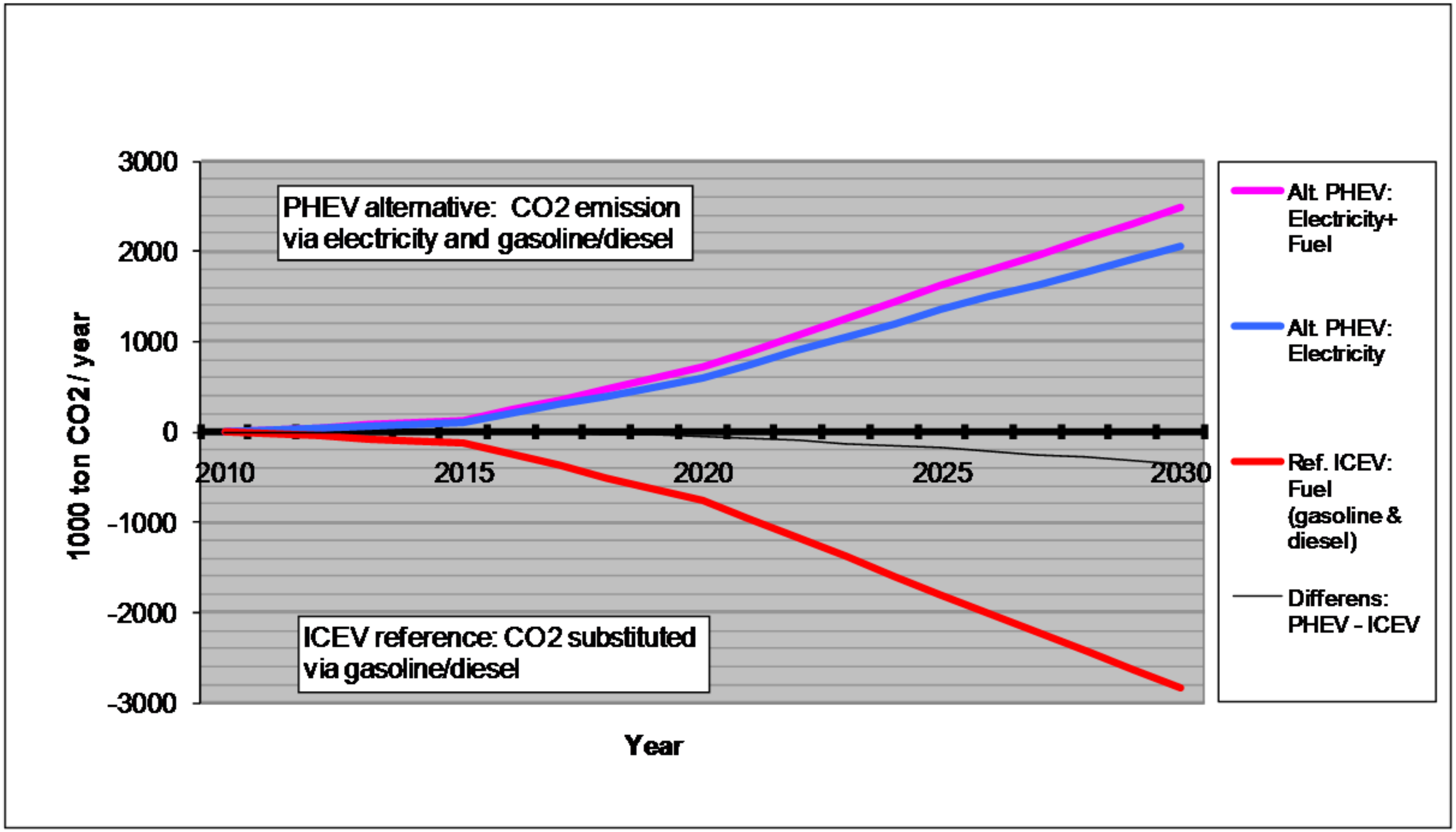
Segment: Passenger Cars + LDV < 3.5t



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

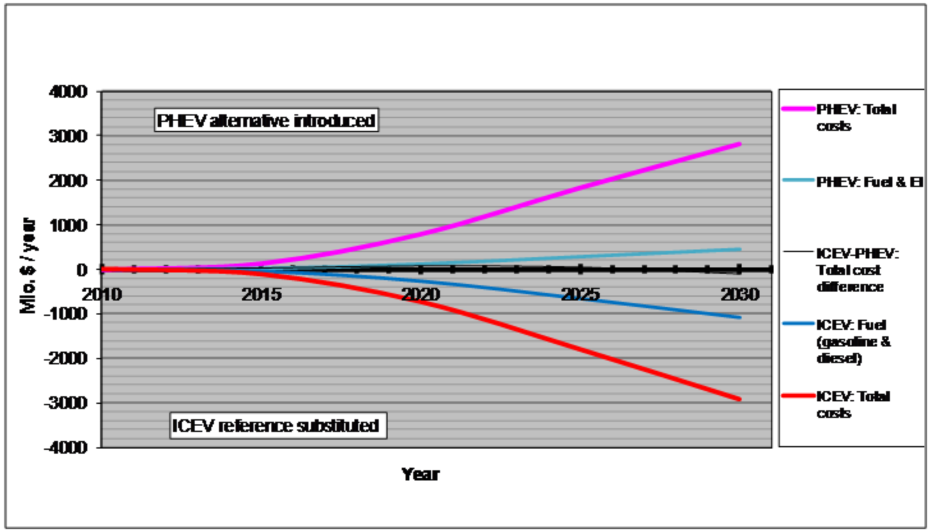
Segment: Passenger Cars + LDV < 3.5t

CO_2 Case I : Marginal (coal based) power supply (DK DEA 2010)

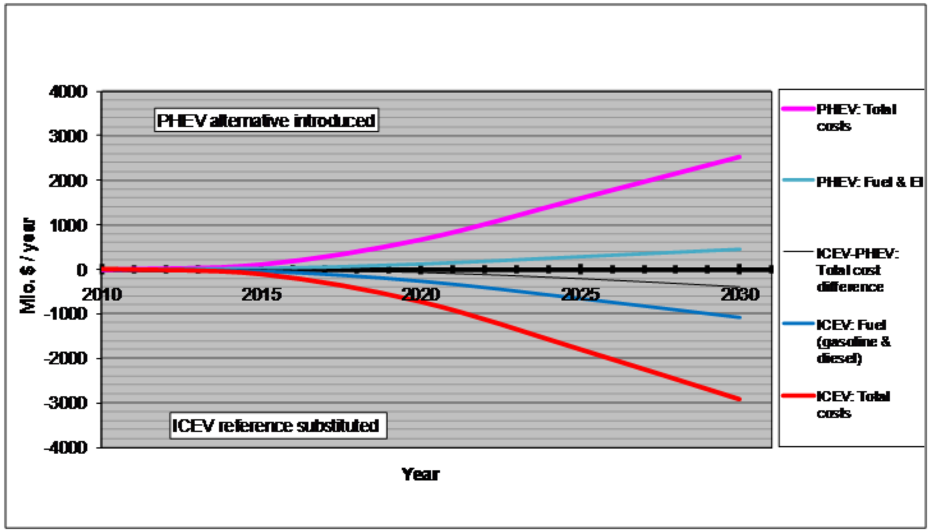


Danish fleet:
PHEV Scenario:
Socio-economic costs of ownership (Mio.$ / year)
(marginal & partial analysis)

BatCost I : Reference



BatCost II : US DOE 2010



Conclusion: PHEV (& BEV) scenario

Energy & CO_2 emission

Energy:

- **Electricity substitutes gasoline / diesel** via the PHEV and BEV scenarios. Focusing on year 2030:
  - PHEV scenario year 2030:
    - **ICEV** Fuel (gasoline/diesel) substituted: **- About 9.0 TWh_{fuel} / year**
    - **PHEV** fleet electricity consumption: **+ About 2.5 TWh electricity**
  - BEV scenario year 2030:
    - Fuel (gasoline/diesel) substituted: About 5.4 TWh_{fuel} /year.
    - Corresponding BEV fleet electricity consumption: About 1.7 TWh electricity.

  The numbers reflect the relative very high energy efficiency of EV drive trains.
- EVs in the transport sector can **diversify energy resource base** and **reduce dependency on oil** based fuels.

CO_2 emission:

- The EV scenario CO_2 emission **depends on the power supply system** charging the EV fleet.

Conclusion: PHEV (& BEV) scenario

Economy: **Based on (marginal and partial) socio-economic analysis.**

Economy:

- Cost and lifetime of **EV batteries much determine the EV economy** and outcome of the PHEV and BEV scenarios.
- In a **'reference' battery cost** development the **PHEV** scenario is close to break-even with reference development. **Beyond year 2025 annual socio-economic gains emerge**.

  The BEV scenario, however, show annual deficits throughout the period, though relatively smaller later in the period.
- In an **'alternative' battery cost** development (US DOE 2010) the **PHEV scenario is attractive from year 2015** and throughout the period. The BEV scenario becomes cost effective from beyond year 2020.
- CO_2 emission **allowance costs are small** put relative to costs of vehicle ownership and the scenario costs.