Summary Review of the Technical Results from the McKinsey & Company Report: "A Portfolio of power-trains for Europe: a fact-based analysis; The role of Battery Electric Vehicles, Plug-in Hybrids and Fuel Cell Electric Vehicles"

Presented the DOE Hydrogen and Fuel Cell Technical Advisory Committee (HTAC)

February 18, 2011

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Study Participants

- 10 OEMs ⟵ Proprietary Cost data
- 5 Energy Companies
- One Utility
- 3 Industrial Gas Companies
- One Wind Energy Company
- 4 Electrolyzer Companies
- One non-government agency
- 2 Government agencies

New Results/Perspectives

- An overall 80% reduction in GHGs will require a 95% reduction in road transport GHGs
- Larger vehicles represent 50% of all cars in the EU and they generate 75% of all road transport GHGs.
  - [therefore FCEVs will play a large role, since they alone can provide long range and fast refilling for larger vehicles.]

Road Transport will require 95% GHG reduction to achieve over-all 80% reduction

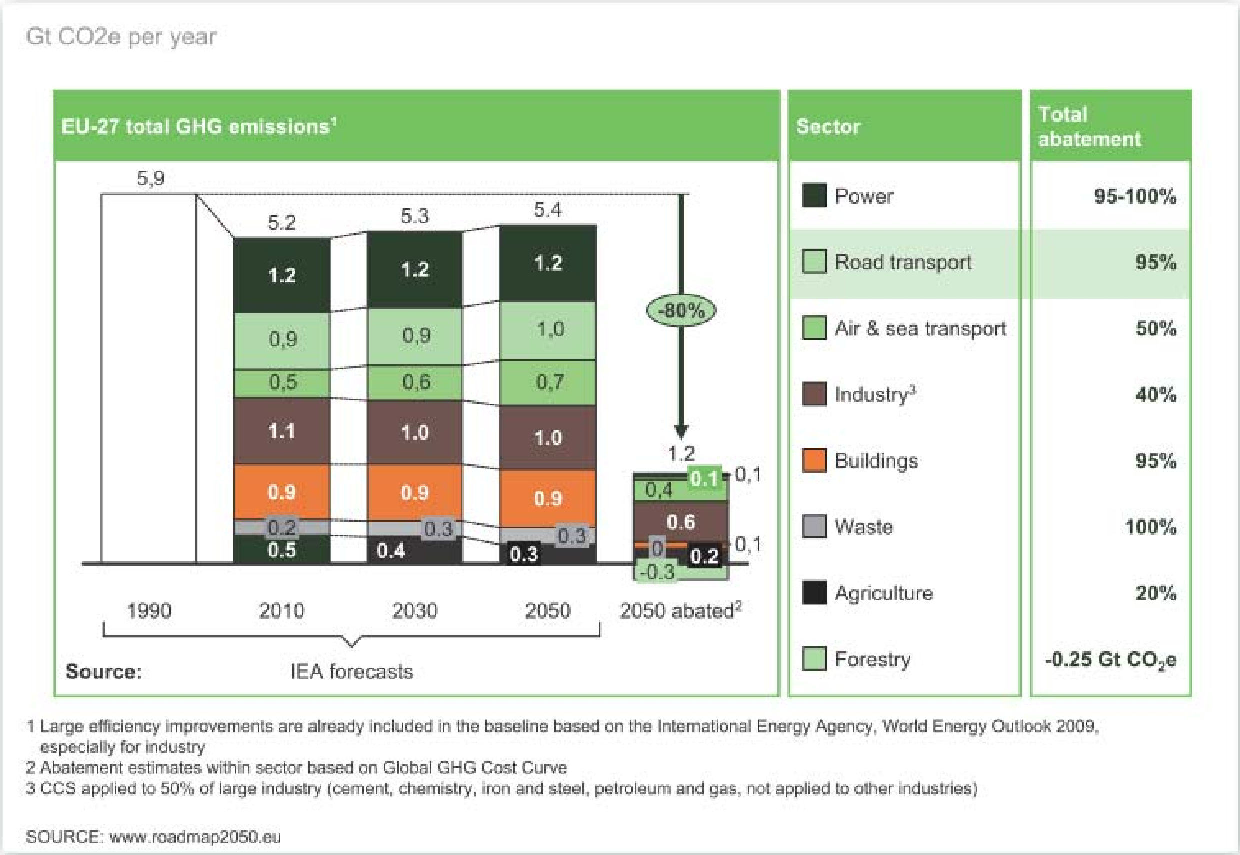
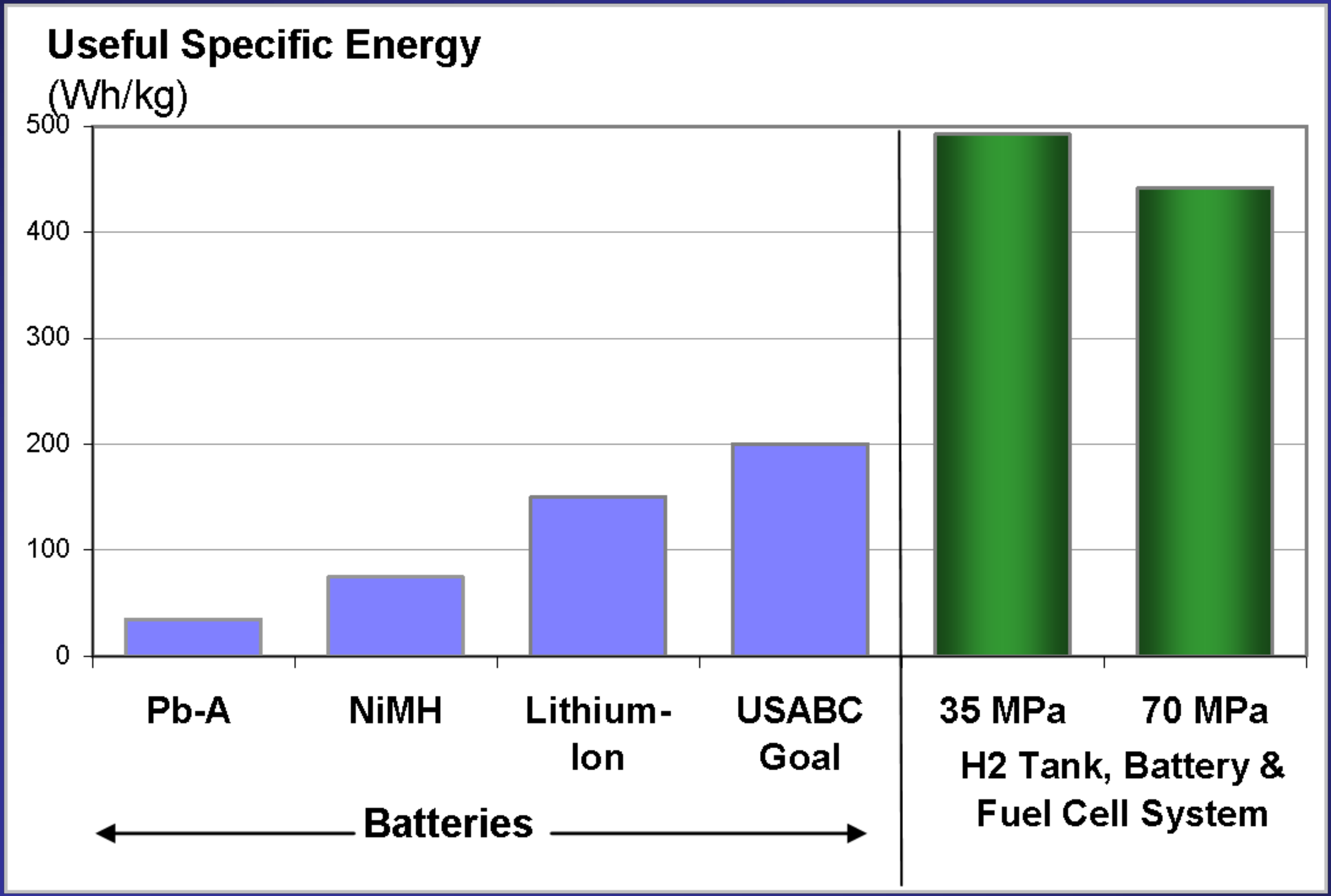


Exhibit 1: In order to achieve EU CO_2 reduction goal of 80% by 2050, road transport must achieve 95% decarbonisation

Key Results

- FCEVs are ready for commercialization and FCEVs “are the lowest carbon solution for medium/larger cars and longer trips.”
- BEV’s “are ideally suited to smaller vehicles and shorter trips.”
- PHEVs will help to cut GHGs, particularly if combined with biofuels (although biofuel resources are limited.)
- ICEs efficiency can be improved 30%, which will help cut GHGs with biofuels (see above)

Specific Energy Comparison

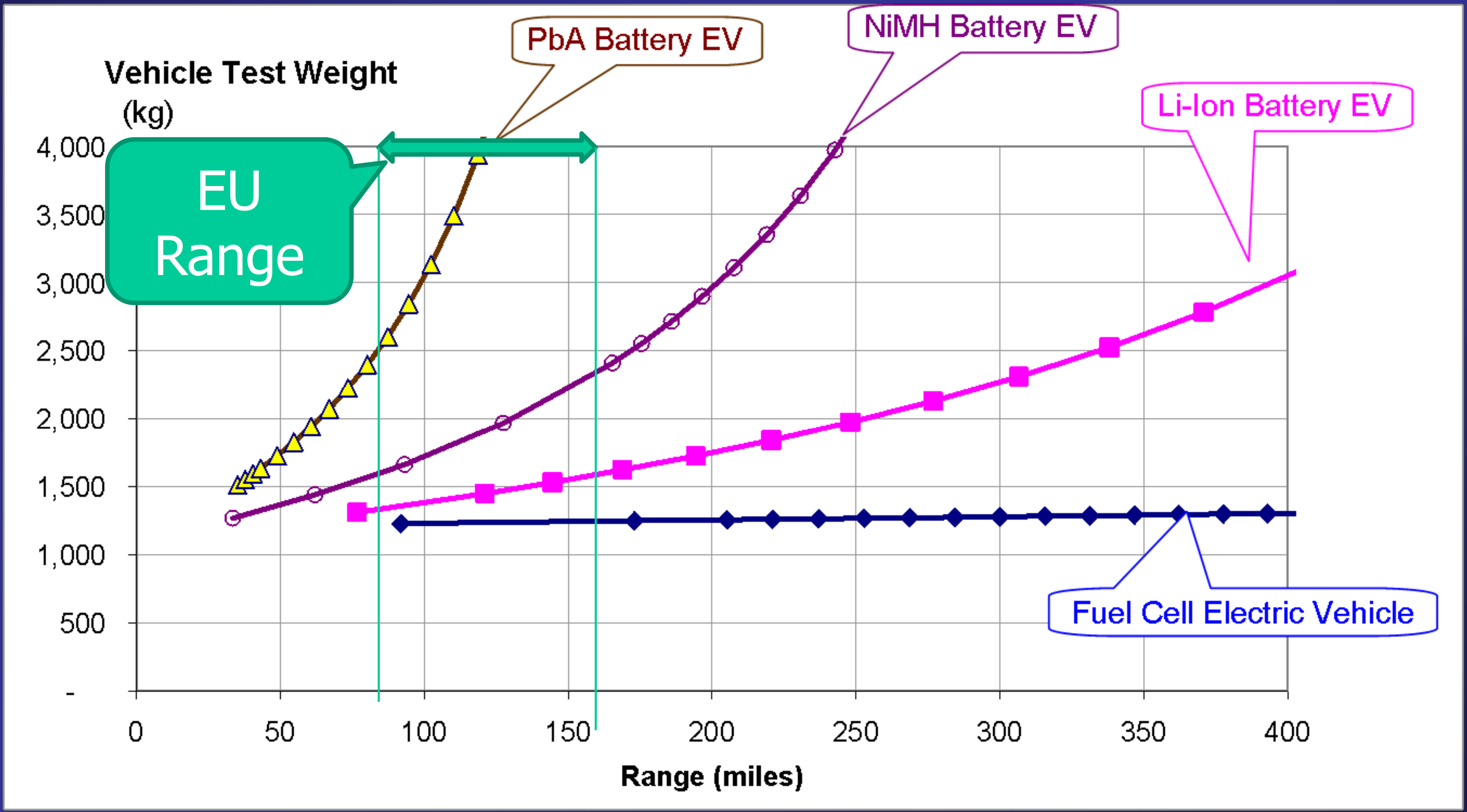


H2Gen: Wt_Vol_Cost.XLS; Tab 'Battery'; S60 - 7 / 14 / 2010

Note: The Chevy Volt Li-ion battery has 44.1 Wh/kg of useful specific energy. (although PHEVs require much less energy than BEVs)

Batteries Weigh More than Fuel Cell Systems

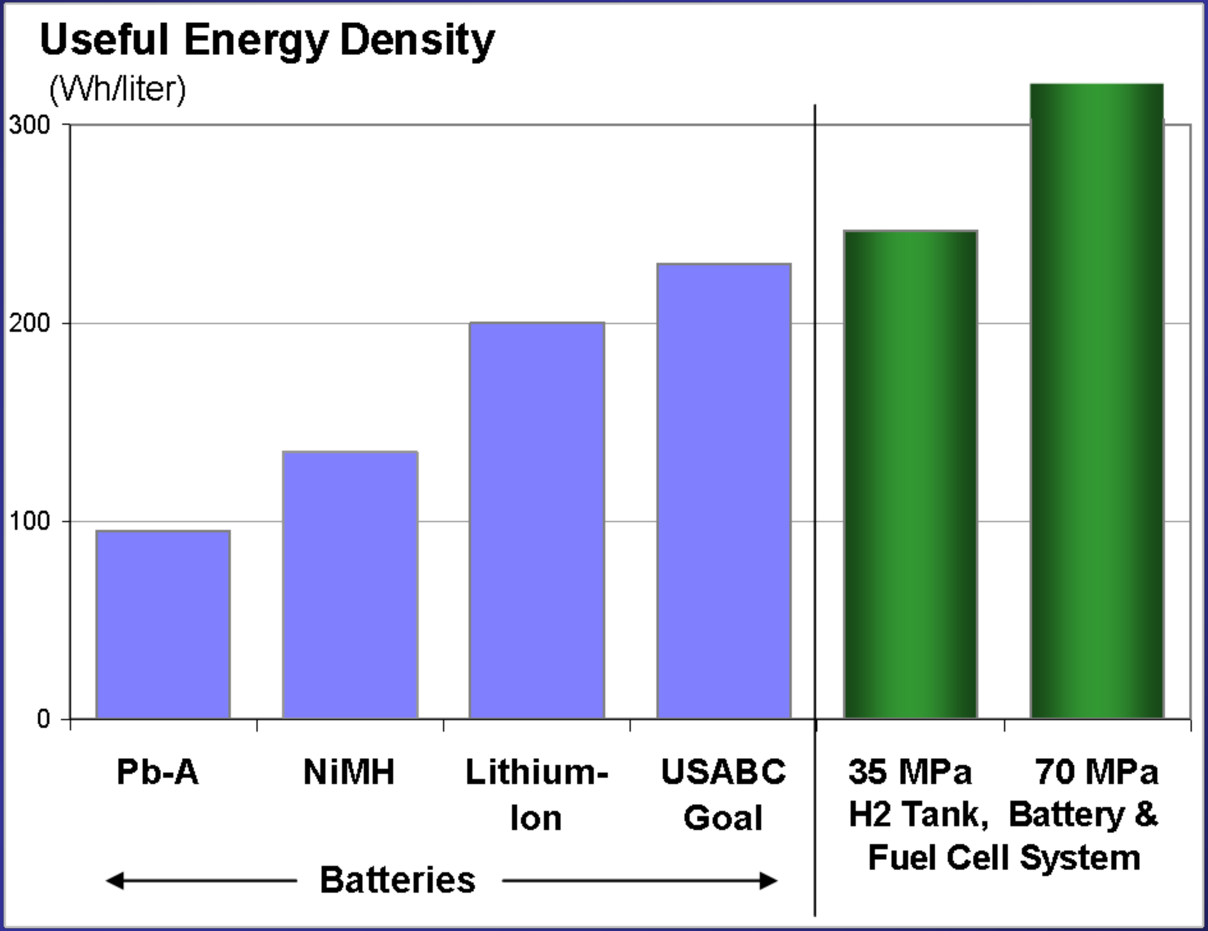
(Effects of mass compounding)



Structural weight addition: 15%

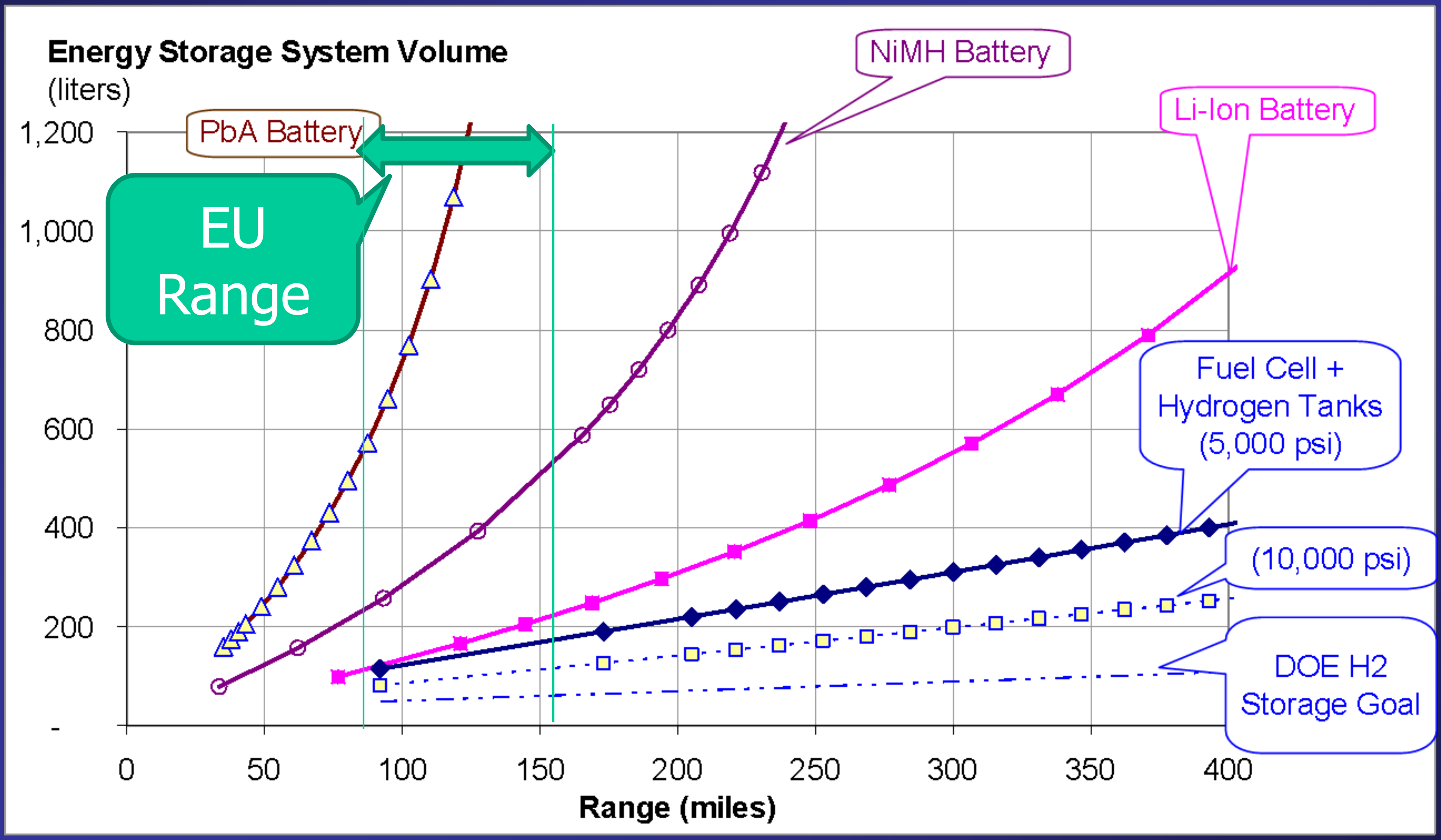
BPEV.XLS; 'Compound' AF142 3/14 /2009

Useful Energy Density



Battery & H2 Tank Wt_Vol_Cost.XLS; Tab 'Battery'; S36 - 7 / 15 / 2010

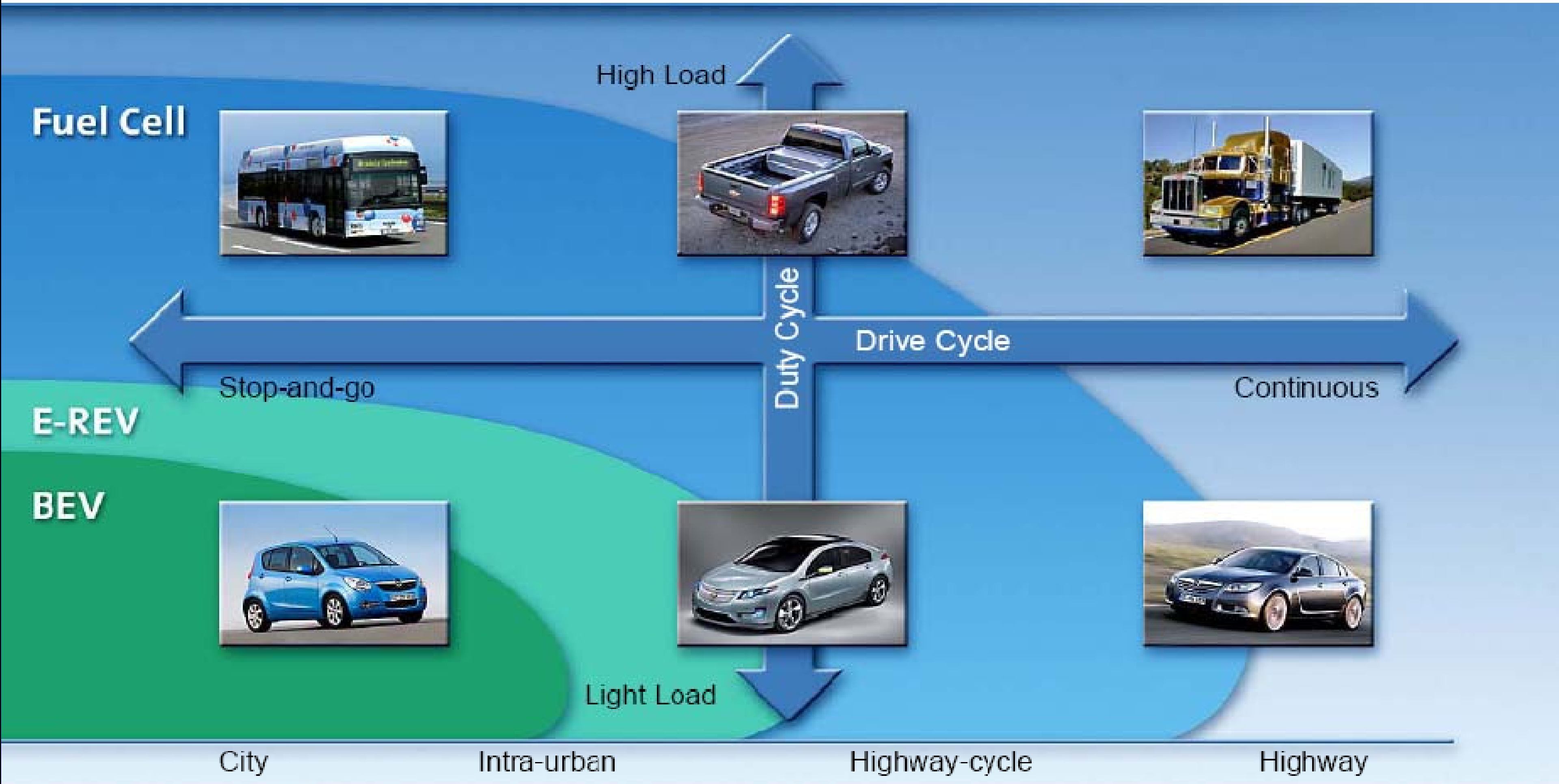
Batteries also take up more space:



DOE Storage Goal: 2.7 kWh/Liter

BPEV.XLS; 'Compound' AF114 3/14 /2009

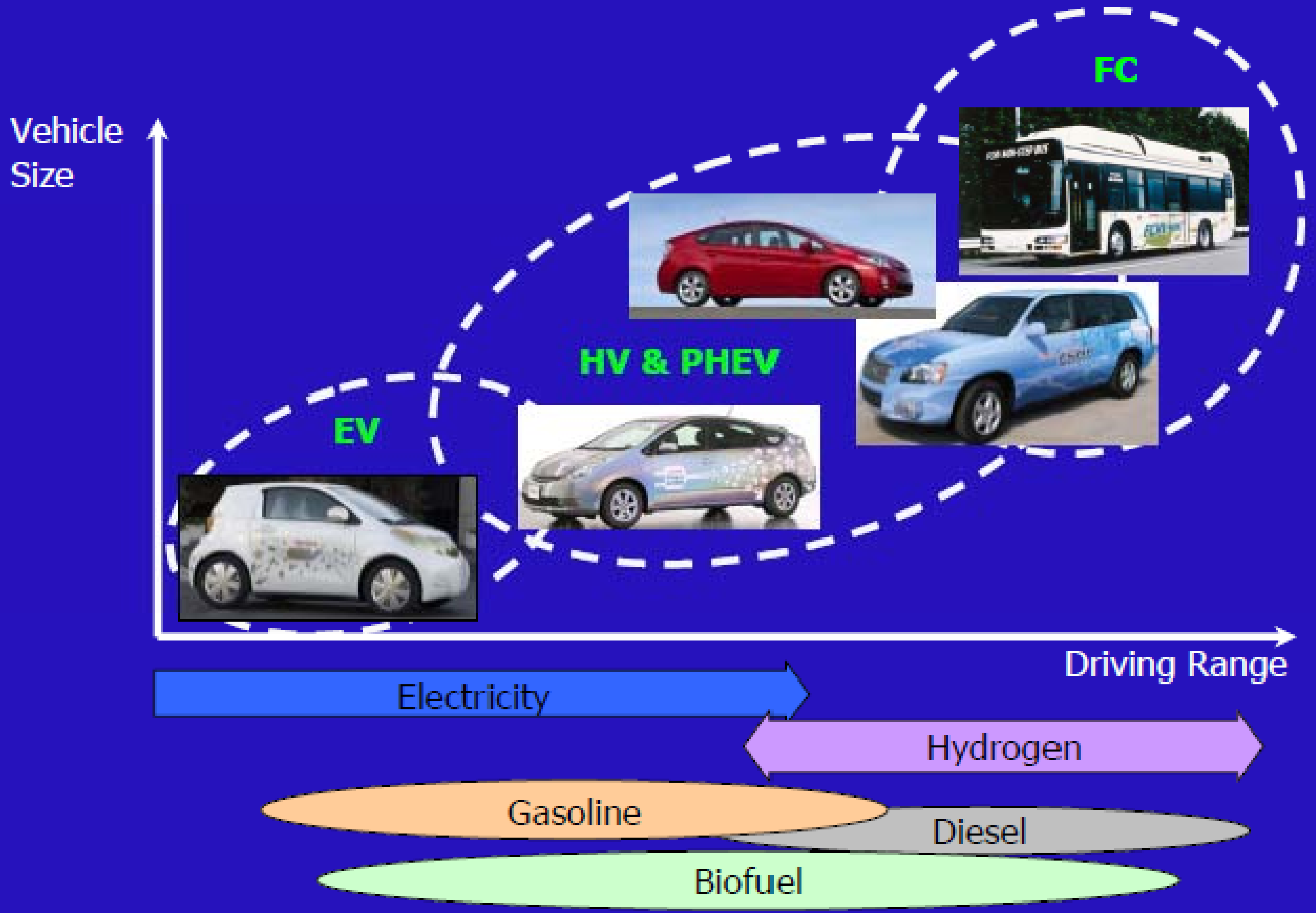
Application Map for Electric Vehicle Technologies



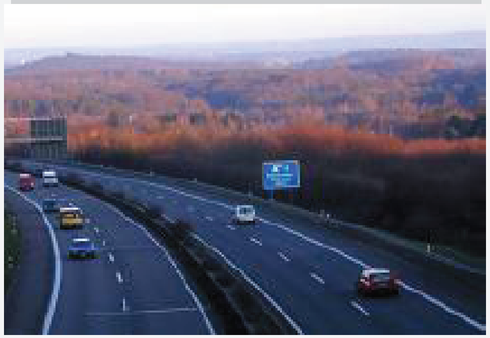
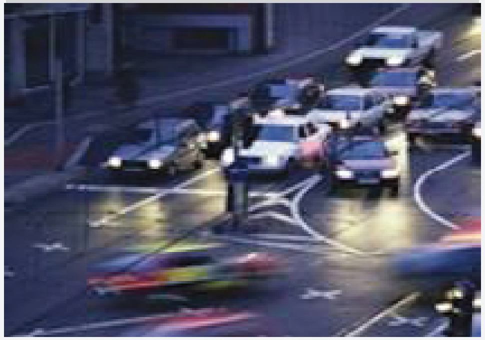
No Silver Bullet !!!

Toyota View of Alternative Vehicle Space:

Market Segments for Each Technologies



Drivetrains for Various Driving Cycles

Long Distance	Suburban	Urban
		

Combustion Engine

Hybridization

Plug-In/Range Extender

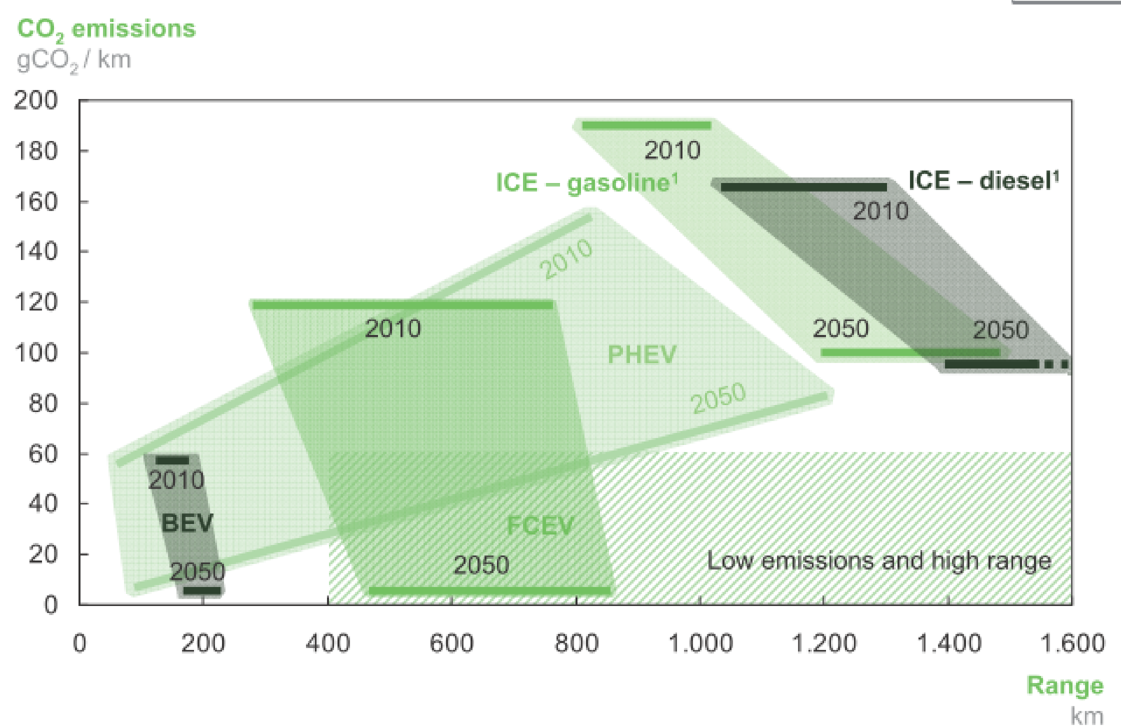
Electric Drive with Battery

Electric Drive with Fuel Cell

➢ **Only fuel cell technology is suited equally for both, short and long distance mobility**

CO2 emissions vs. range
from McKinsey Report

b. BEVs are ideally suited to smaller cars and shorter trips



1 ICE range for 2050 based on fuel economy improvement and assuming tank size stays constant. Assuming 6% CO2 reduction due to biofuels by 2020; 24% by 2050

SOURCE: Study analysis

Exhibit 18: BEVs and FCEVs can achieve significantly low CO_2 emissions, with BEVs showing limitations in range

FCEVs are ready for Commercialization

- Over 500 FCEVs have been road-tested
- 15 million km (9.3 million miles)
- 90,000 refuelings
- 700-bar storage acceptable for long range
- -25C temperature (or lower) achieved
- Durability improving

FCEVs &PHEVs have ICV-like performance

1 Bars represent range of performance across reference segments

2 Fast charging; implies higher infrastructure costs, reduced battery lifetime and lower battery load

3 The gas tank of a PHEV has the same refueling time as a conventional vehicle

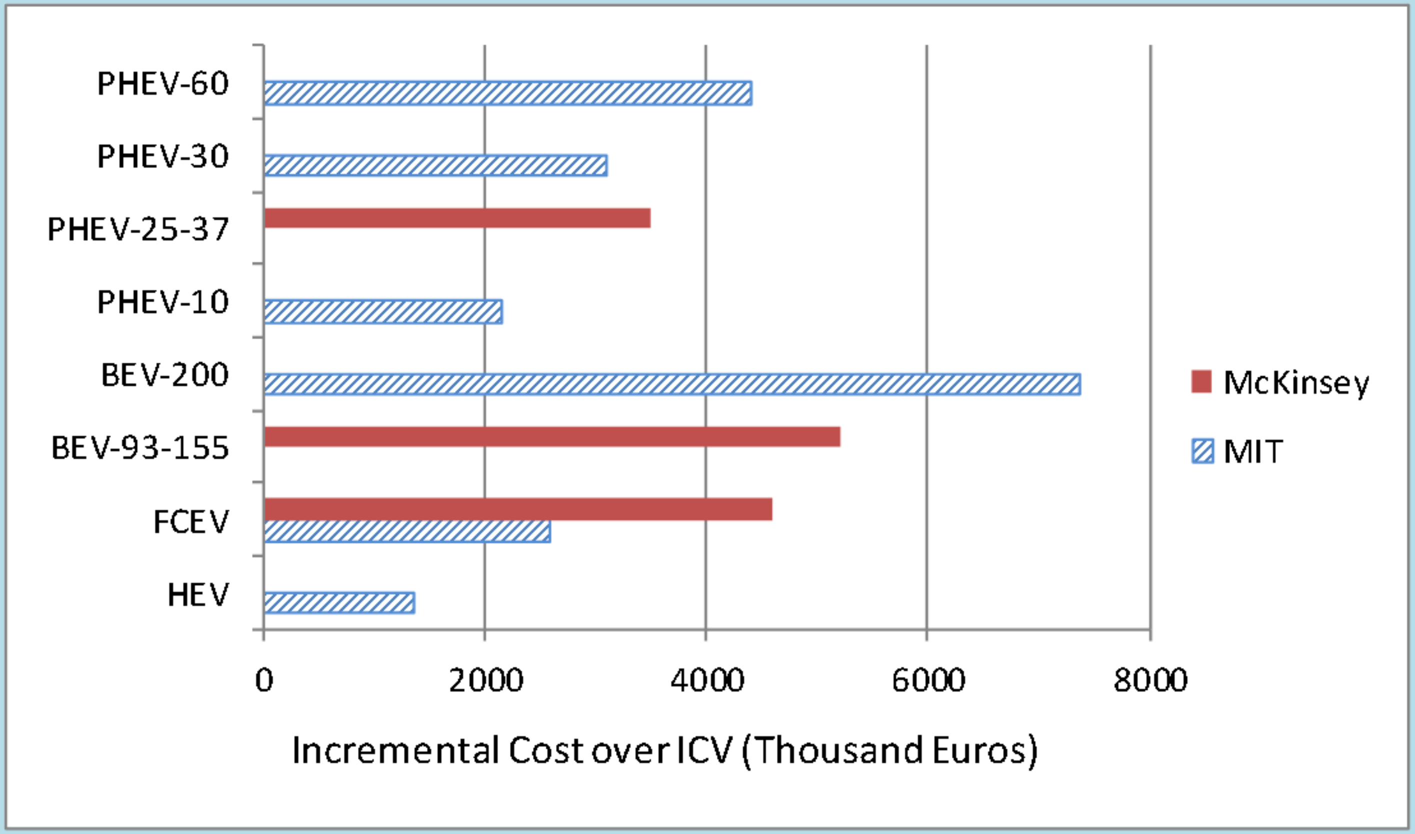
SOURCE: Study analysis

Alternative Vehicle Mixes Considered:

	FCEVs	BEVs	PHEVs	ICEs
ICE Case	5%	10%	25%	60%
EV Power Train	25%	35%	35%	5%
FCEV Case	50%	25%	20%	5%

Incremental Cost of Alternative vehicles in 2030

(Kromer & Heywood [MIT] vs. McKinsey C/D segment)

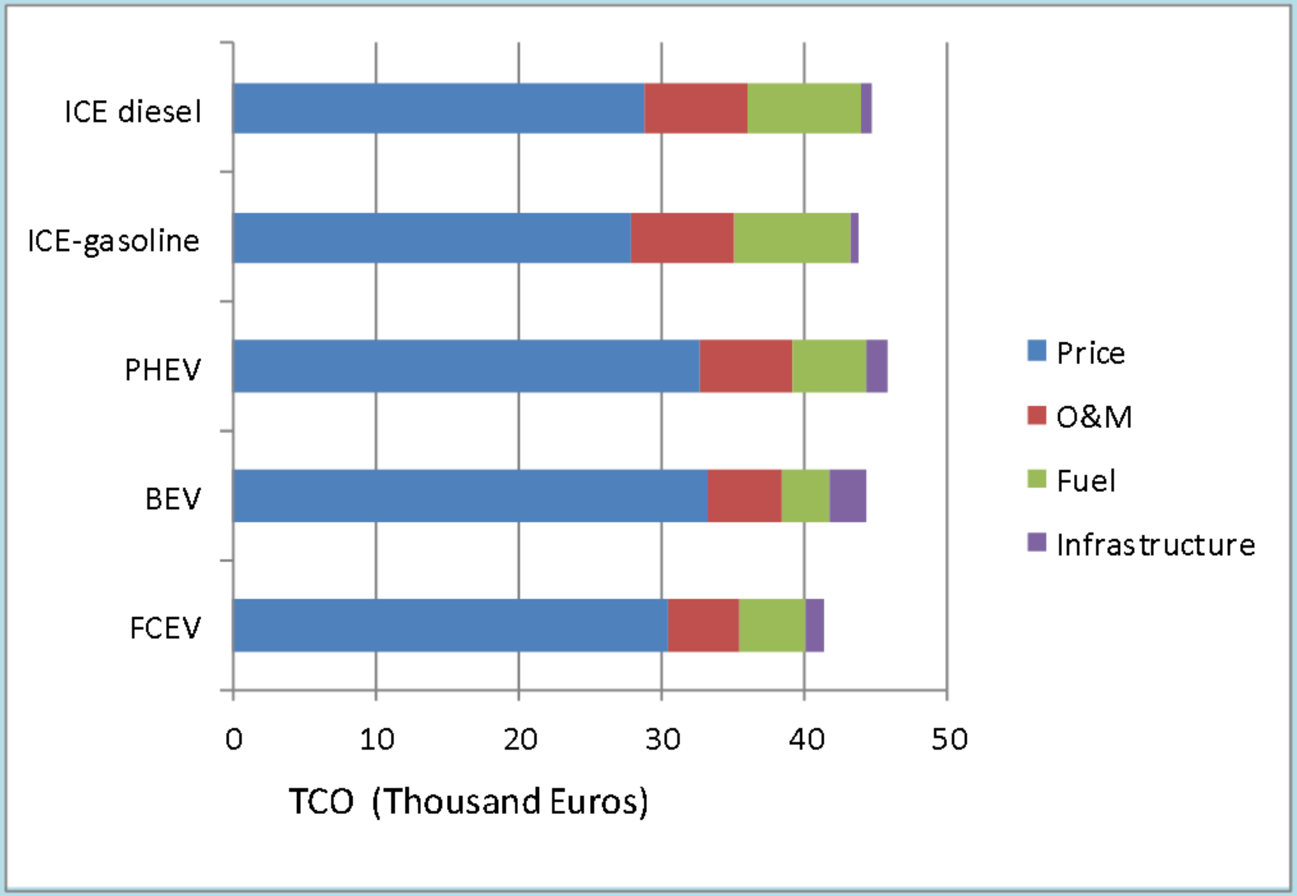


McKinsey EU Data.xls; Tab 'Detaila'; AH 9 12/3/2011

Ref: Kromer & Heywood, "Electric Powertrains: Opportunities & Challenges in the U.S. Light-Duty Vehicle Fleet Report # LFEE 2007-03RP, MIT, May, 2007, Table 53

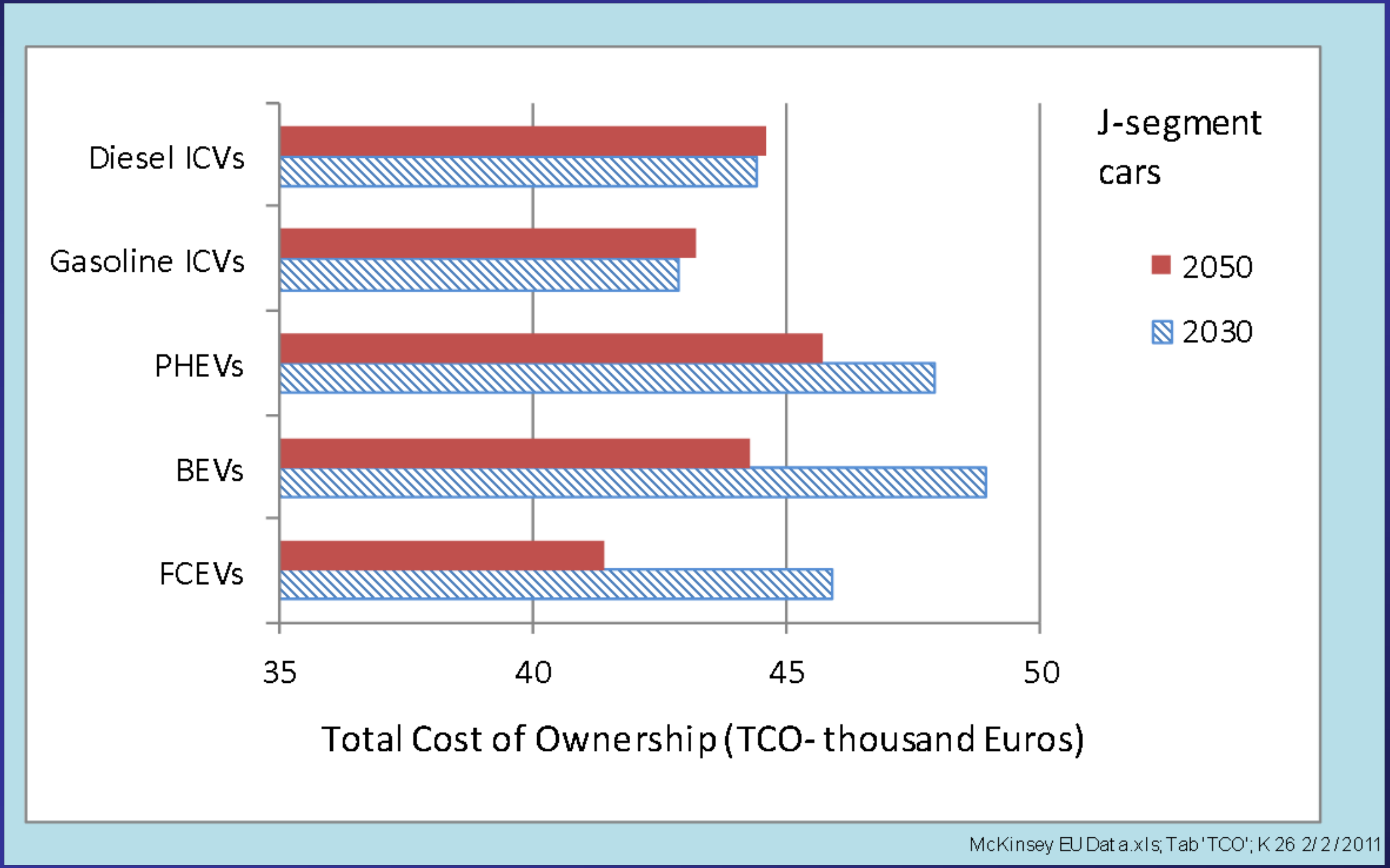
($1 =€0.7245)

J-Segment (SUV) total cost of ownership in 2050



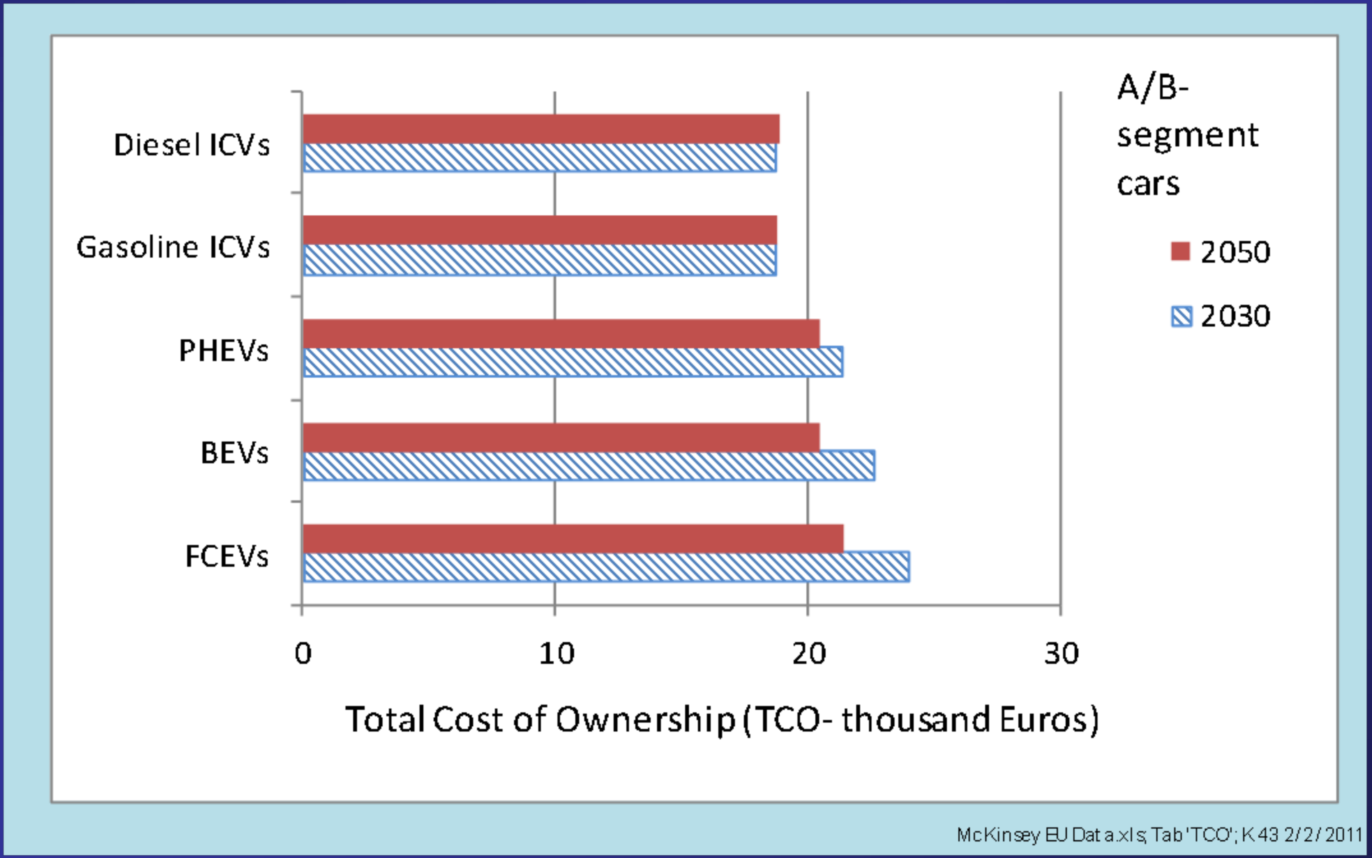
McKinsey EU Data.xls; Tab 'Detaila'; X92 2/2/2011

TCO 2030 & 2050 for J-segment (SUVs)



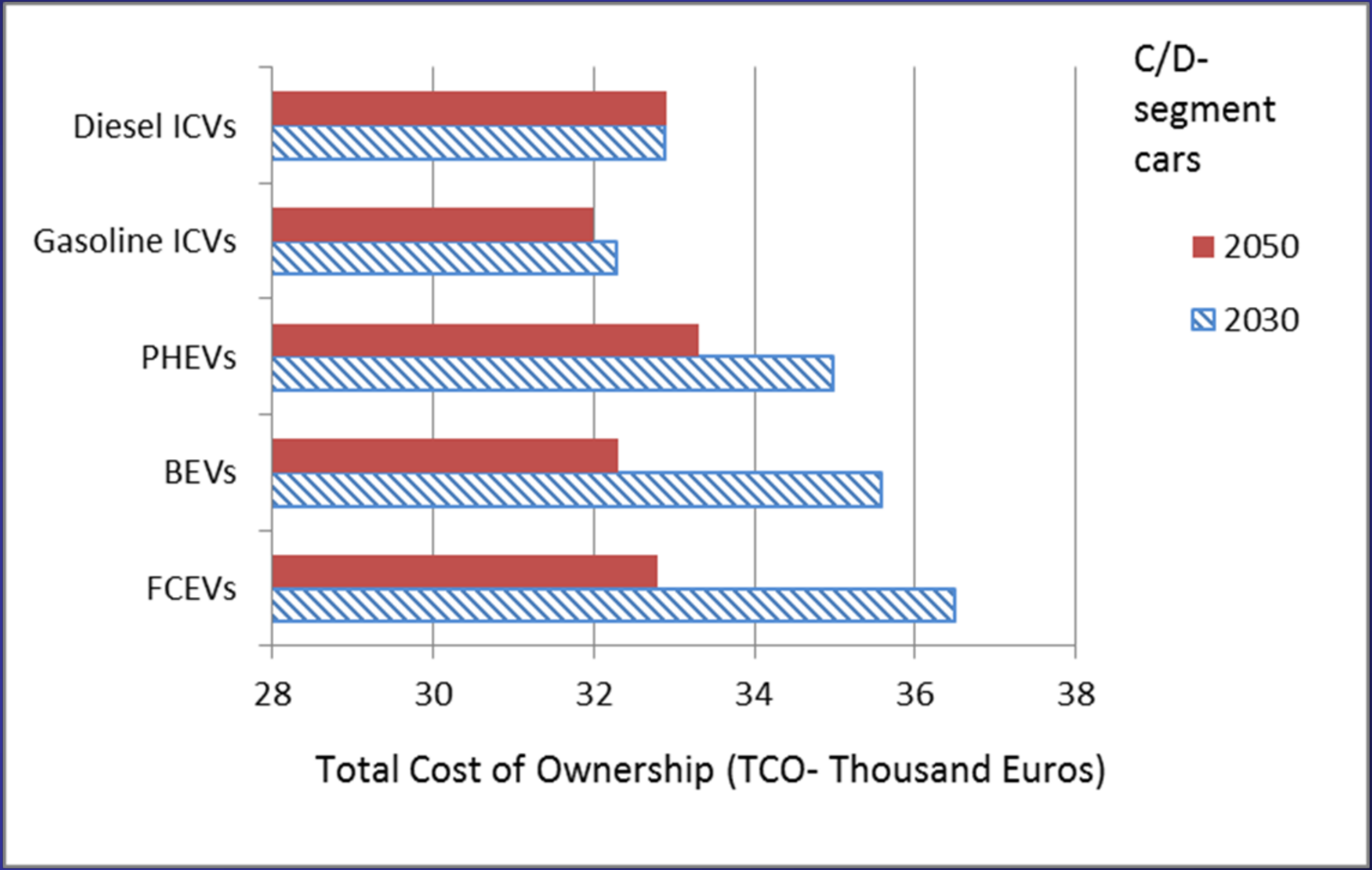
Total Cost of Ownership (TCO) – small cars

A-Cars =City Cars (Smart & Hyundai ilo)
B-cars = Super-mini (Toyota Yaris &Mercedes A)

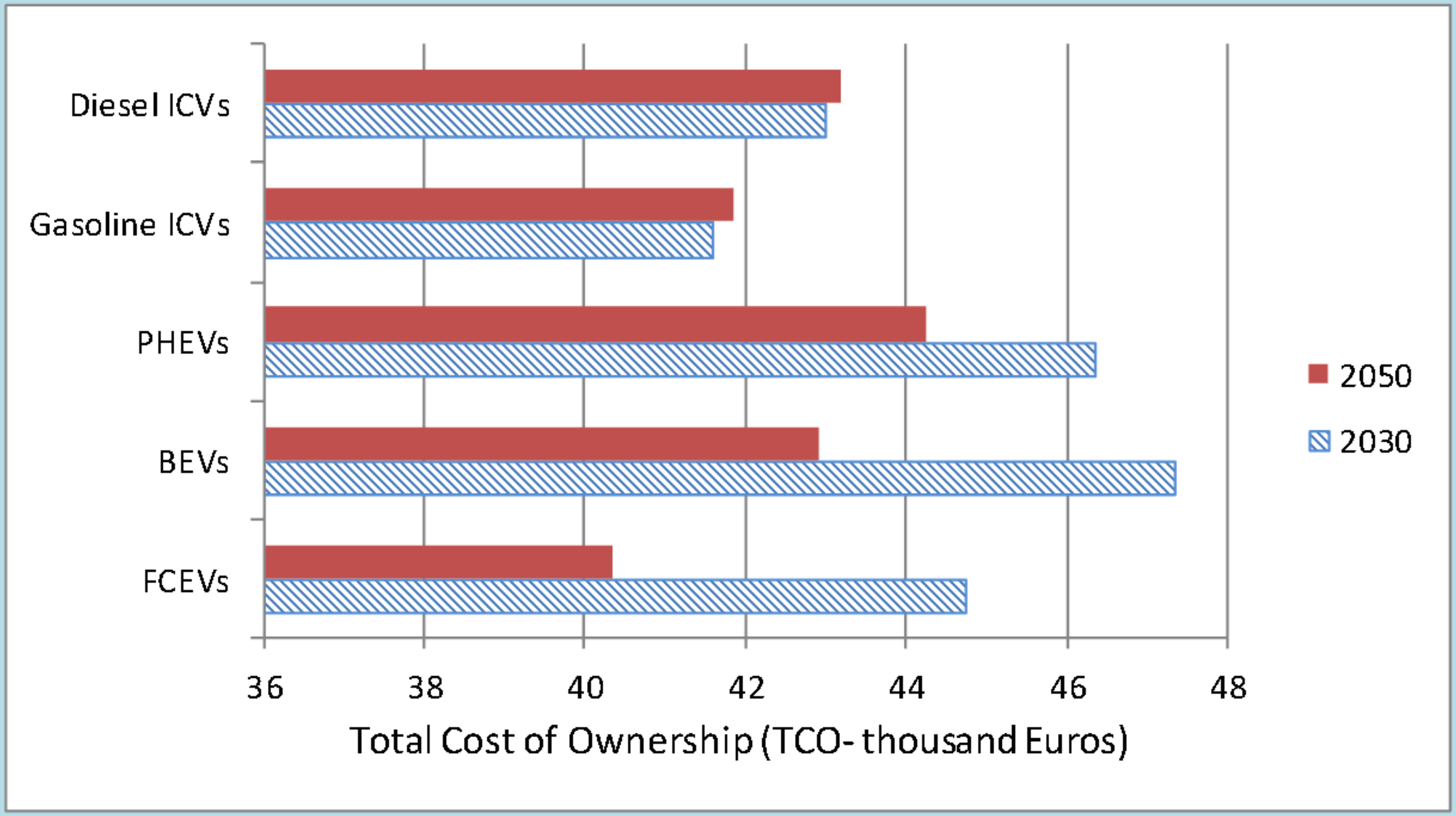


Total Cost of Ownership (TCO) – Medium cars

C-Cars =Medium Cars (Honda Civic & Ford Focus)
D-cars = upper Medium (Hondas FCX, Renault Laguna & Mercedes C)



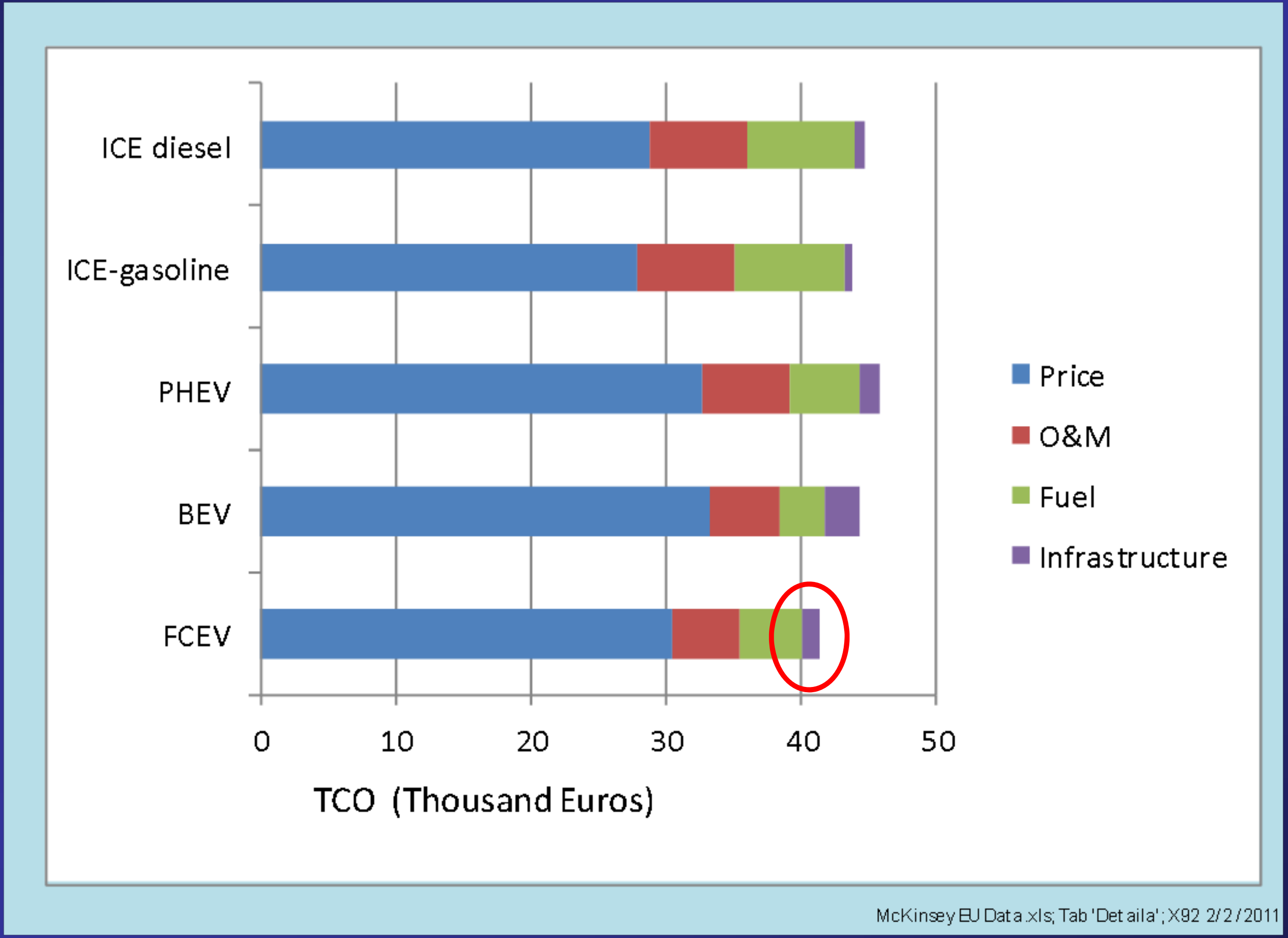
Total Cost of Ownership for Mixture of 2.1% A/B; 7.5% C/D & 90.4% J
(accounting for 50% of vehicles and 75% of GHGs)



Daimler thinks FCEV will not cost more than diesel HEV by 2015

- By 2015, we think a fuel cell car will not cost more than a four-cylinder diesel hybrid that meets the Euro 6 emissions standard. By 2013-2014, we want to bring a four-digit-number of fuel cell vehicles to market.
- Source: Herbert Kohler, head of e-drive and future mobility at Daimler, recently told Automotive News Jan 30th 2011 at 8:15AM

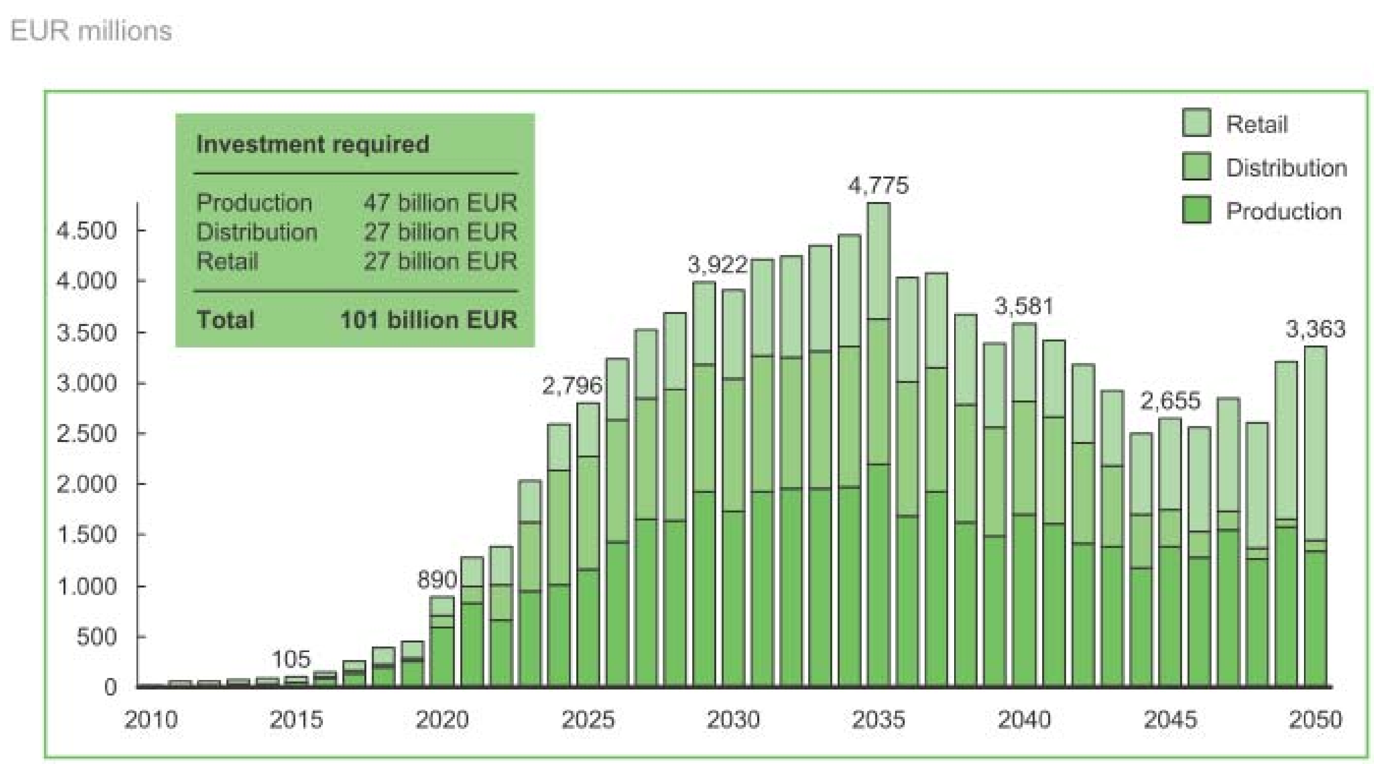
J-Segment (SUV) total cost of ownership in 2050



Hydrogen Infrastructure cost is small and Manageable

- H2 infrastructure is ≈5% of FCEV cost or €1,000 to €2,000 per FCEV
- H2 Infrastructure is €3 billion first decade and €2 billion/year to €3 billion/year thereafter
- Other EU infrastructure: €150 to 180 B/year:
  - Oil & gas infrastructure
  - Telecommunications
  - Roads: each €50 to €60 billion per year
- Cost to decarbonize electricity: €20 to €30 billion per year and €1.3 Trillion total

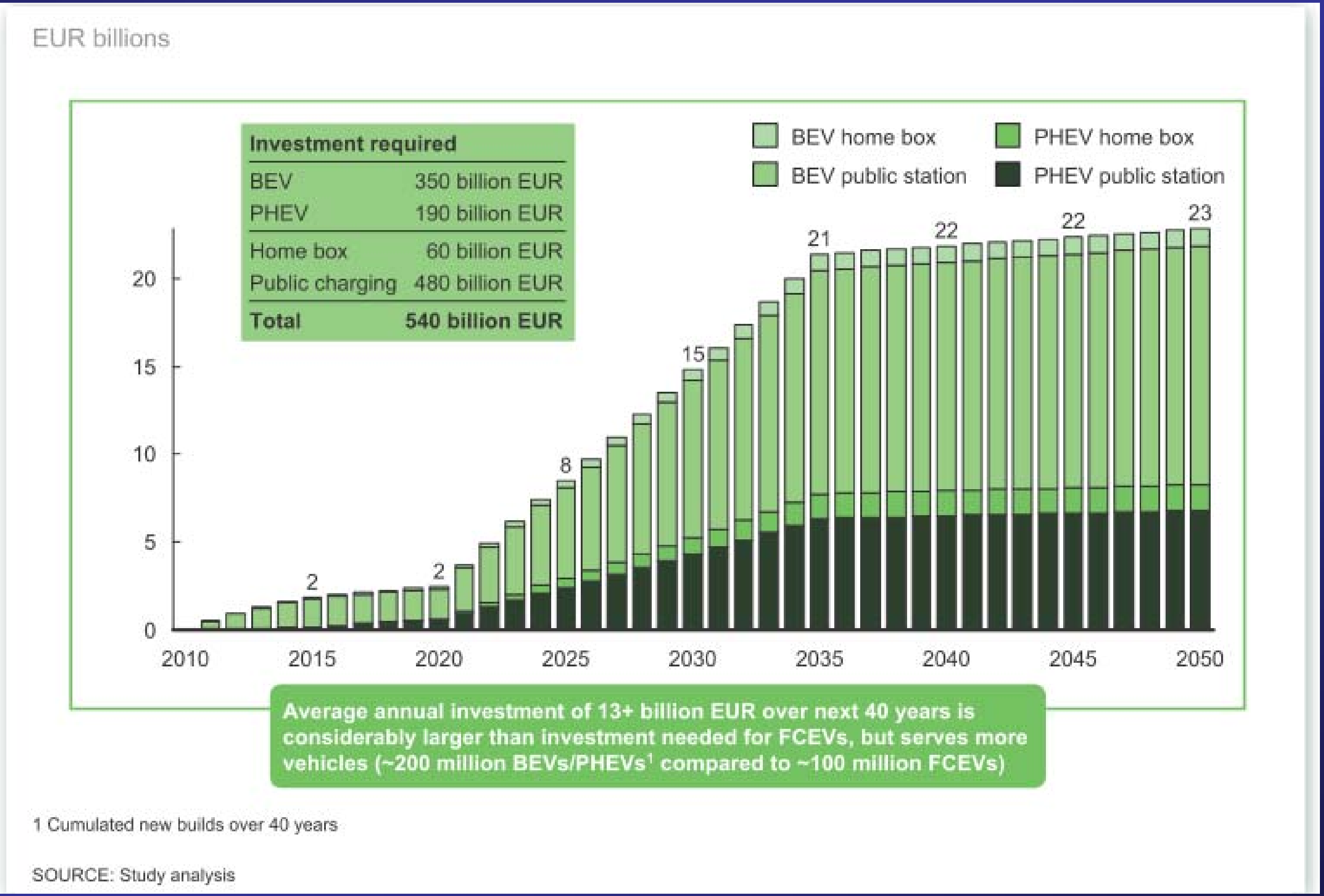
H2 Infrastructure: €101 Billion over 40 years



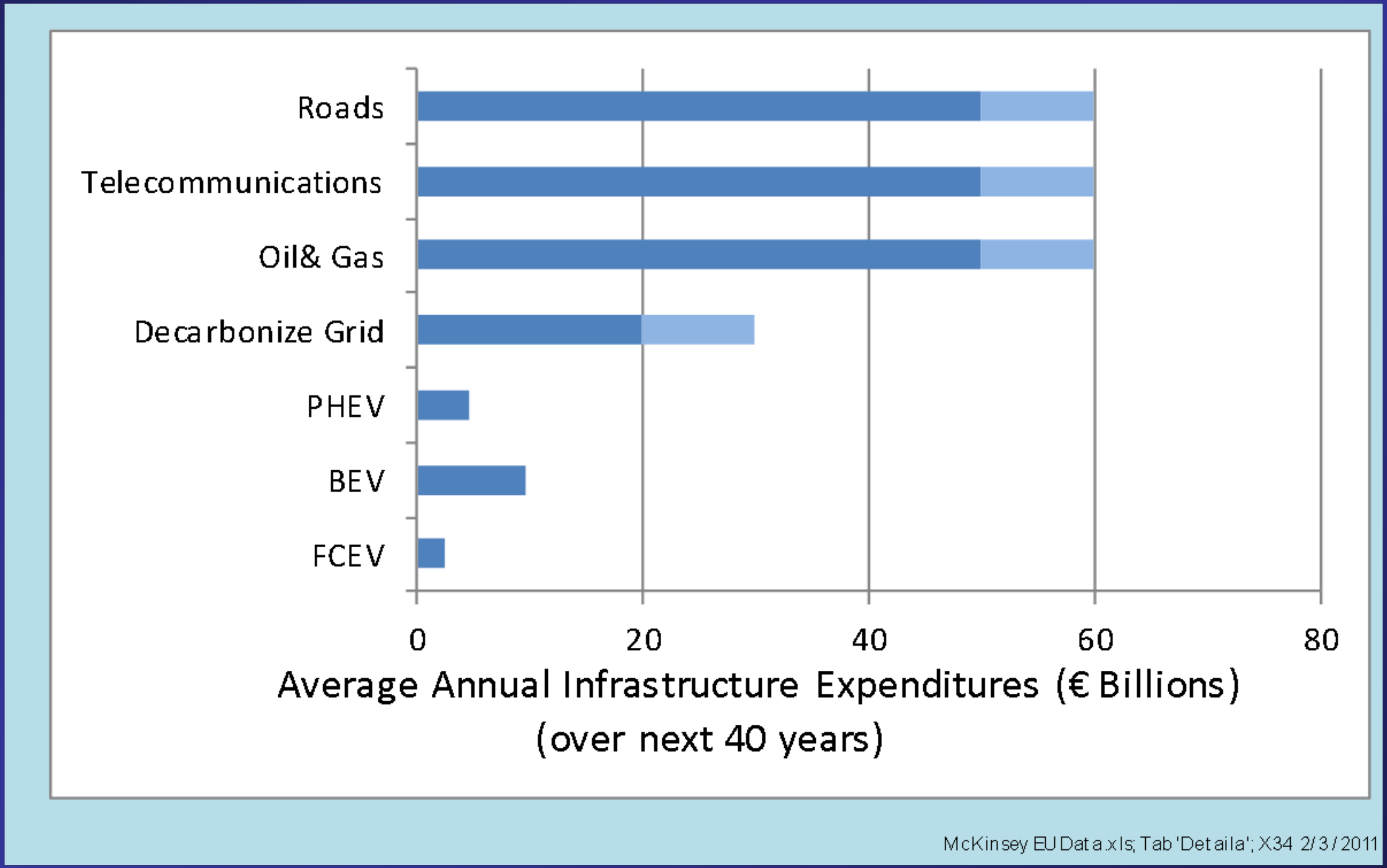
1 Current annual capex requirement for the EU

SOURCE: WIS Global Insight; OVUM; OECD / International Transport Forum; study analysis

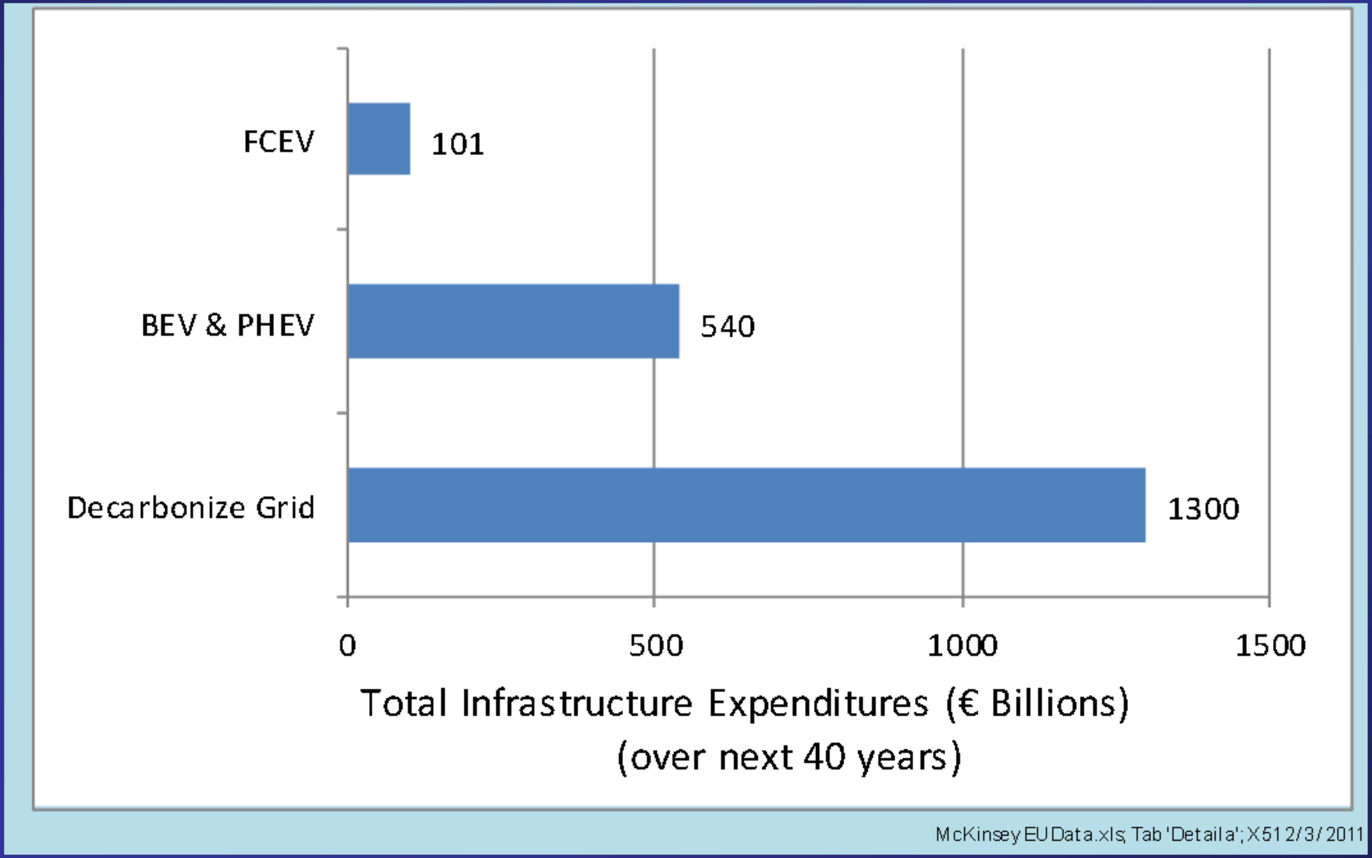
Electric charging infrastructure: €540 Billion over 40 years



Average Annual EU Infrastructure Costs over next 40 years

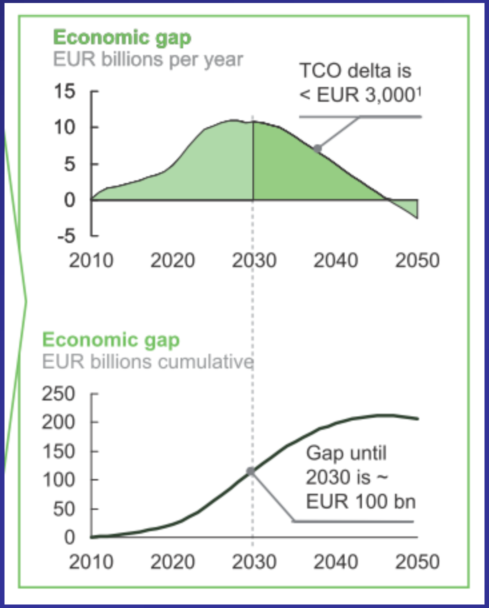


Total Cumulative Infrastructure Costs over 40 years



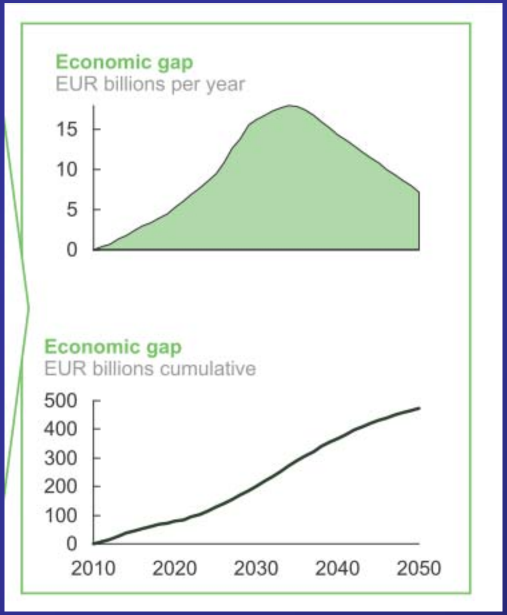
Annual Economic Gaps
(Vehicles & Infrastructure)

FCEV Gaps



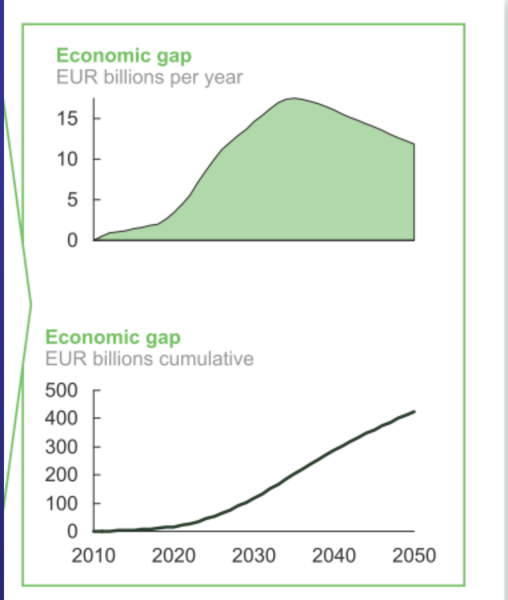
€202B by 2050

BEV Gaps



€502B by 2050

PHEV Gaps

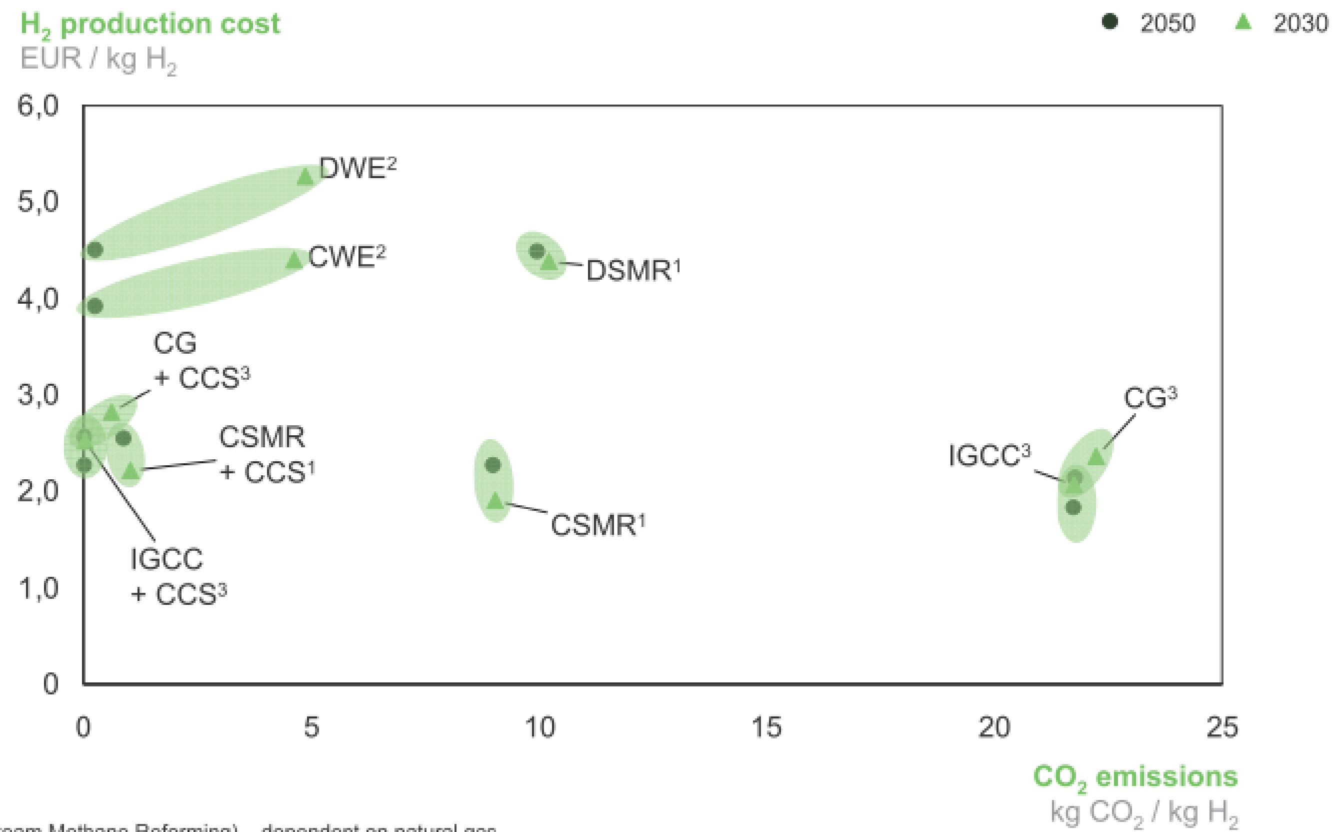


€420B by 2050

Surprise: GHGs Not total well-to-wheels

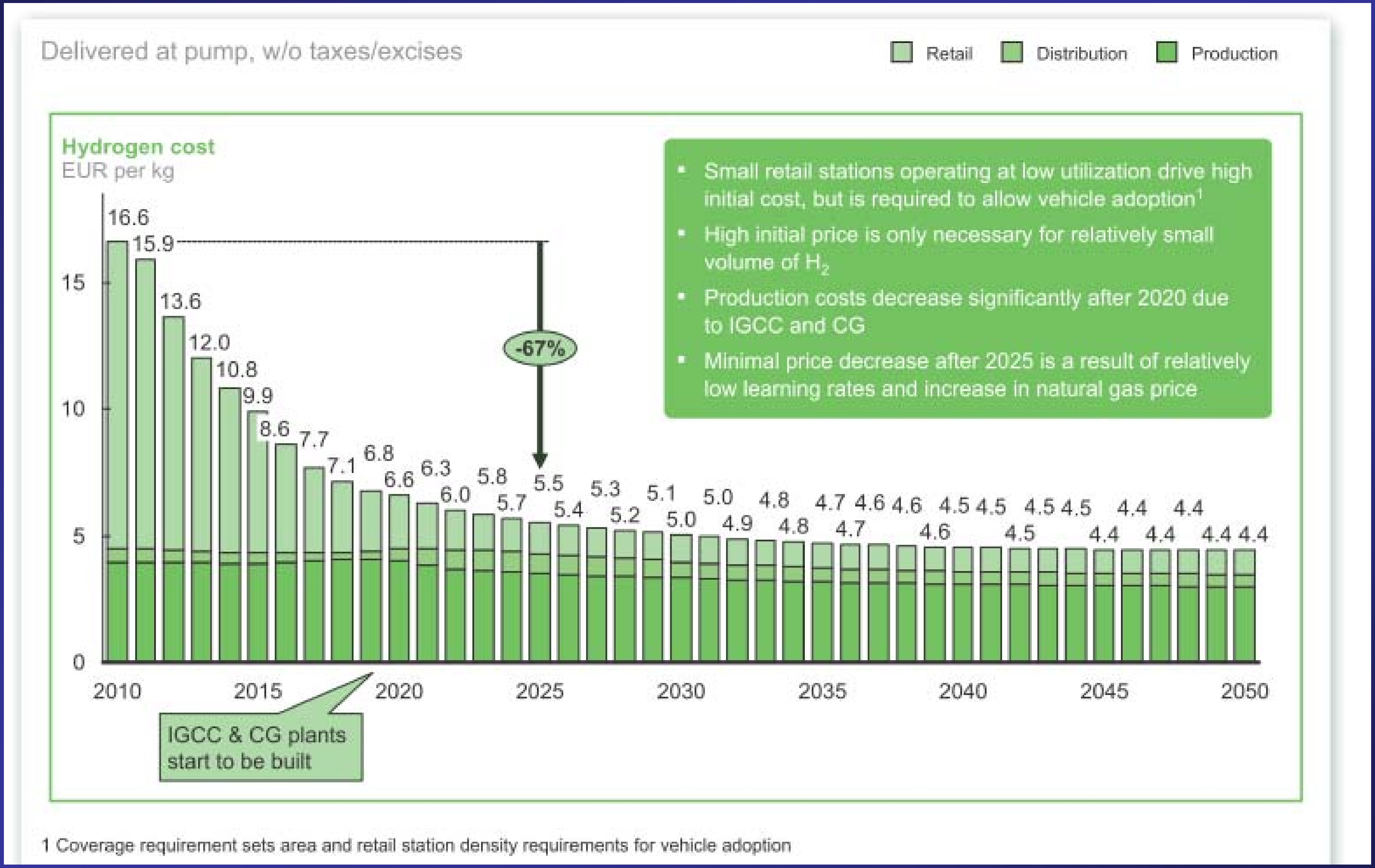
- They did NOT include "indirect GHG emissions" from:
  - Feedstock exploration & infrastructure buildup, including
    - Mining activities
    - Power plant buildup
  - Nor "so-called CO2-equivalent emissions"

CCS = near-zero GHGs



1 SMR (Steam Methane Reforming) – dependent on natural gas
2 WE (Water Electrolysis) – uses 80% RES pathway for electricity and can offer additional grid stabilisation load leveling benefits
3 CG (Coal Gasification) – relies on domestic coal and when combined with CCS is assumed to be co-fired with 10% biomass

H2 costs decrease from €16.6/kg to €4.40/kg



31% of technology improvements for BEVs and PHEVs also apply to FCEVs

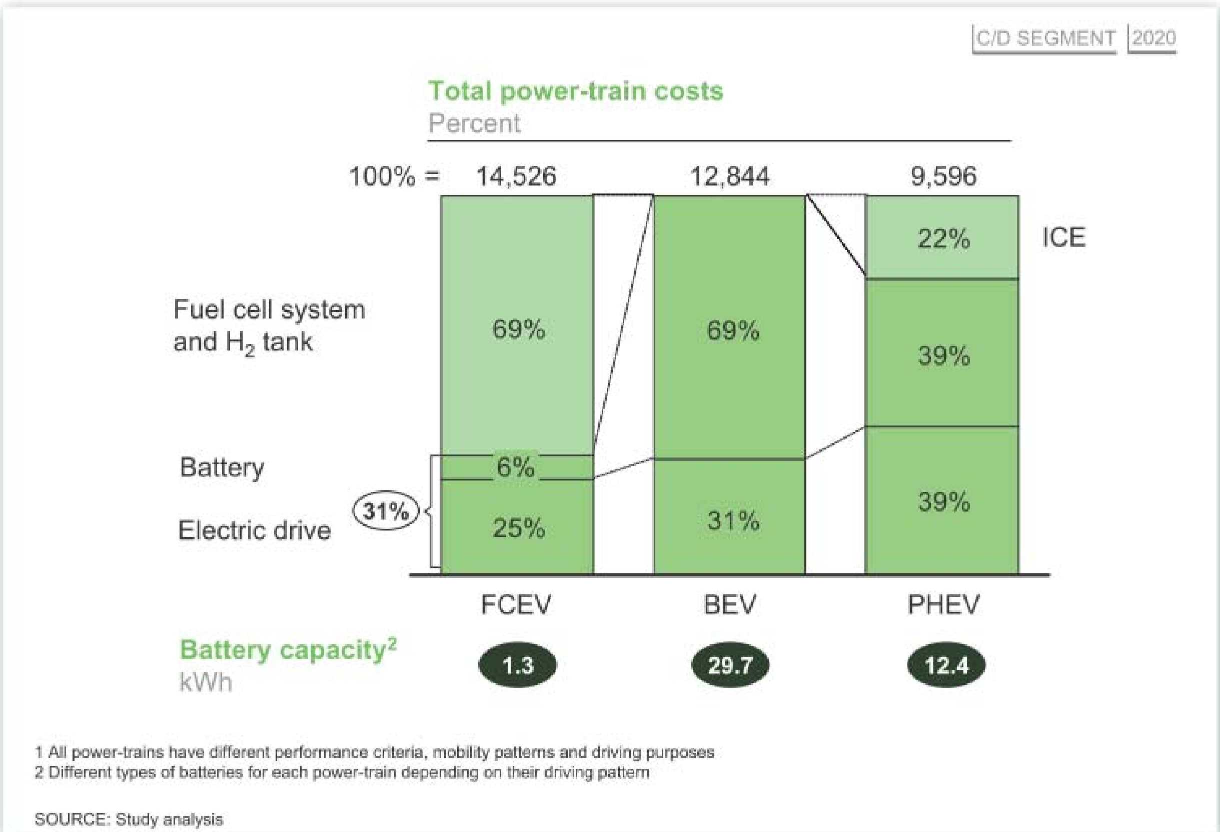


Exhibit 23: In 2020, 31% of technology improvements in BEVs and PHEVs also apply to FCEVs

Thank You

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