A portfolio of power-trains for Europe: a fact-based analysis

Fuel Cells and Hydrogen Joint Undertaking
3rd Stakeholders General Assembly
Brussels, November 9, 2010

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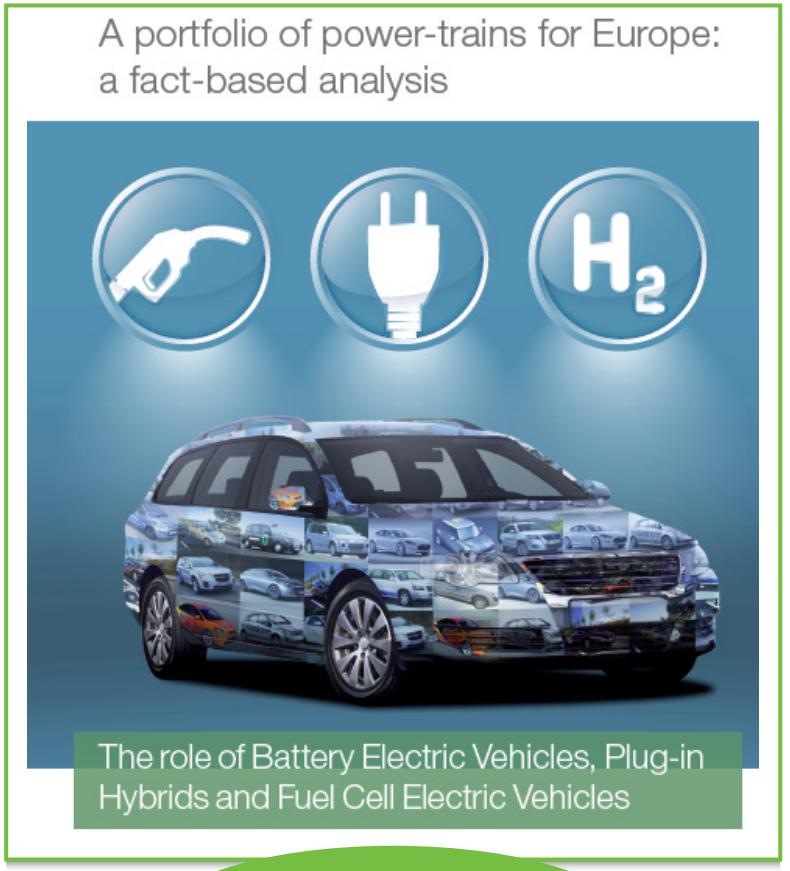
An international industry group evaluated the potential of alternative power-trains for passenger cars in Europe

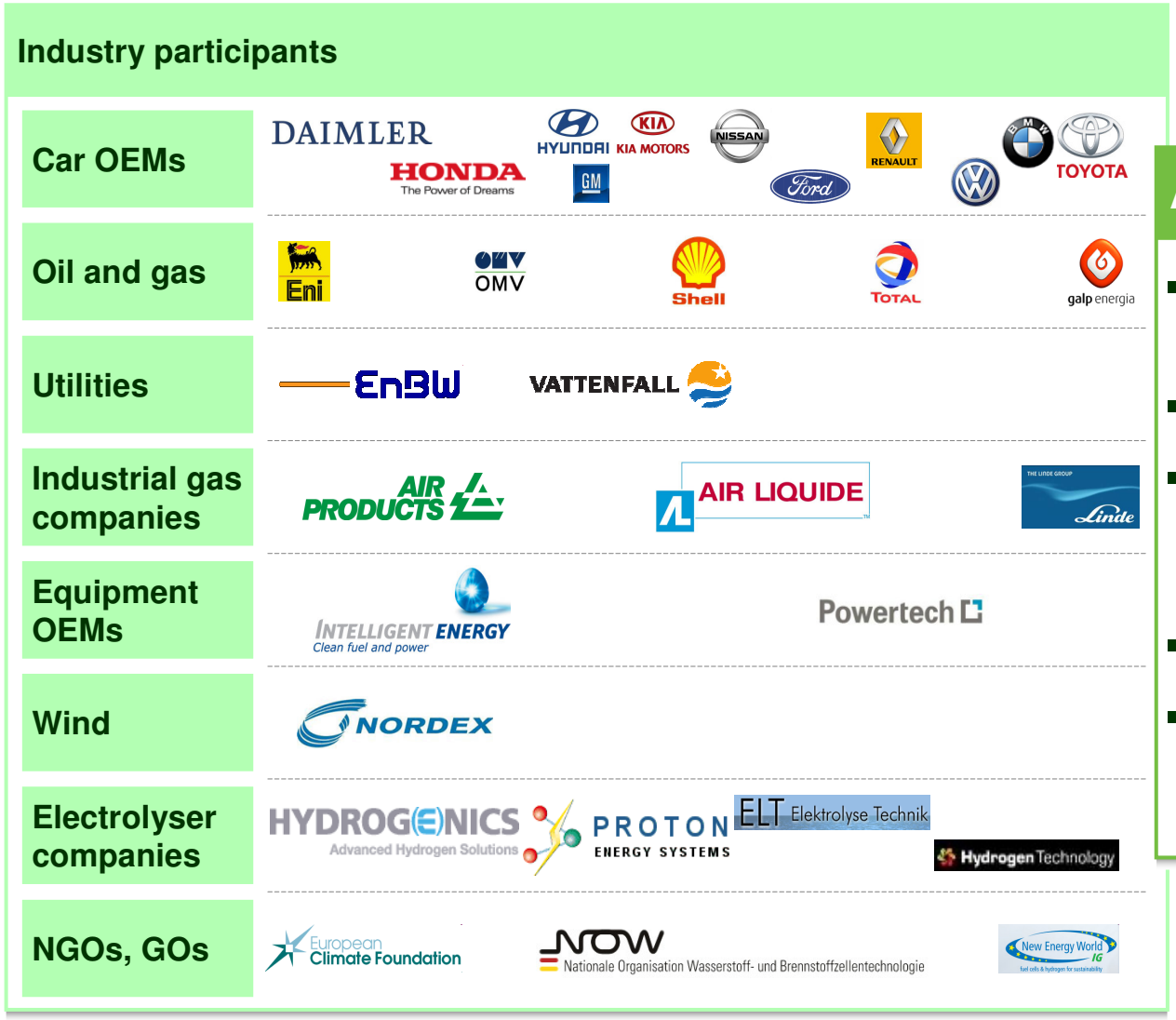
Core questions

- How do FCEVs, BEVs, and PHEVs compare to ICEs on
  - Cost
  - Emissions
  - Energy efficiency
  - Driving performance?
- What are viable production and supply pathways?
- What are the potential market segments for the different power-train technologies?



Public launch November 8, 2010

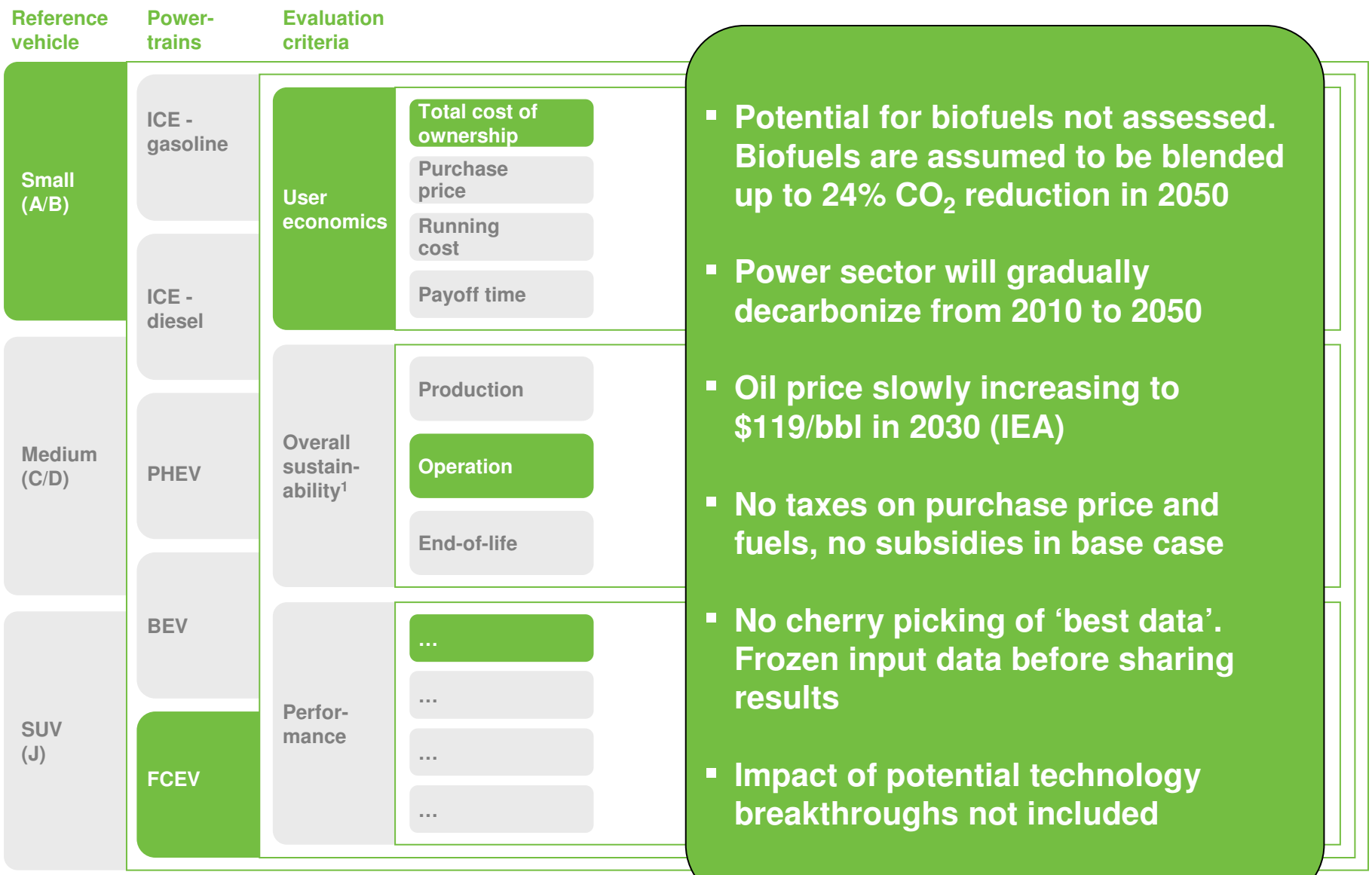
27 private companies, 1 NGO, and 2 GOs across the value chain performed a fact-based analyses in a "clean room" environment



Approach and principles

- All relevant powertrains (ICE, BEV, PHEV, FCEV)
- 3 reference car segments
- Cost, emissions, energy efficiency, driving performance
- Well-to-wheel
- >10,000 company data in a "clean room" environment

Data were collected on all drive trains and at a granular level



- Potential for biofuels not assessed. Biofuels are assumed to be blended up to 24% CO_2 reduction in 2050
- Power sector will gradually decarbonize from 2010 to 2050
- Oil price slowly increasing to $119/bbl in 2030 (IEA)
- No taxes on purchase price and fuels, no subsidies in base case
- No cherry picking of 'best data'. Frozen input data before sharing results
- Impact of potential technology breakthroughs not included

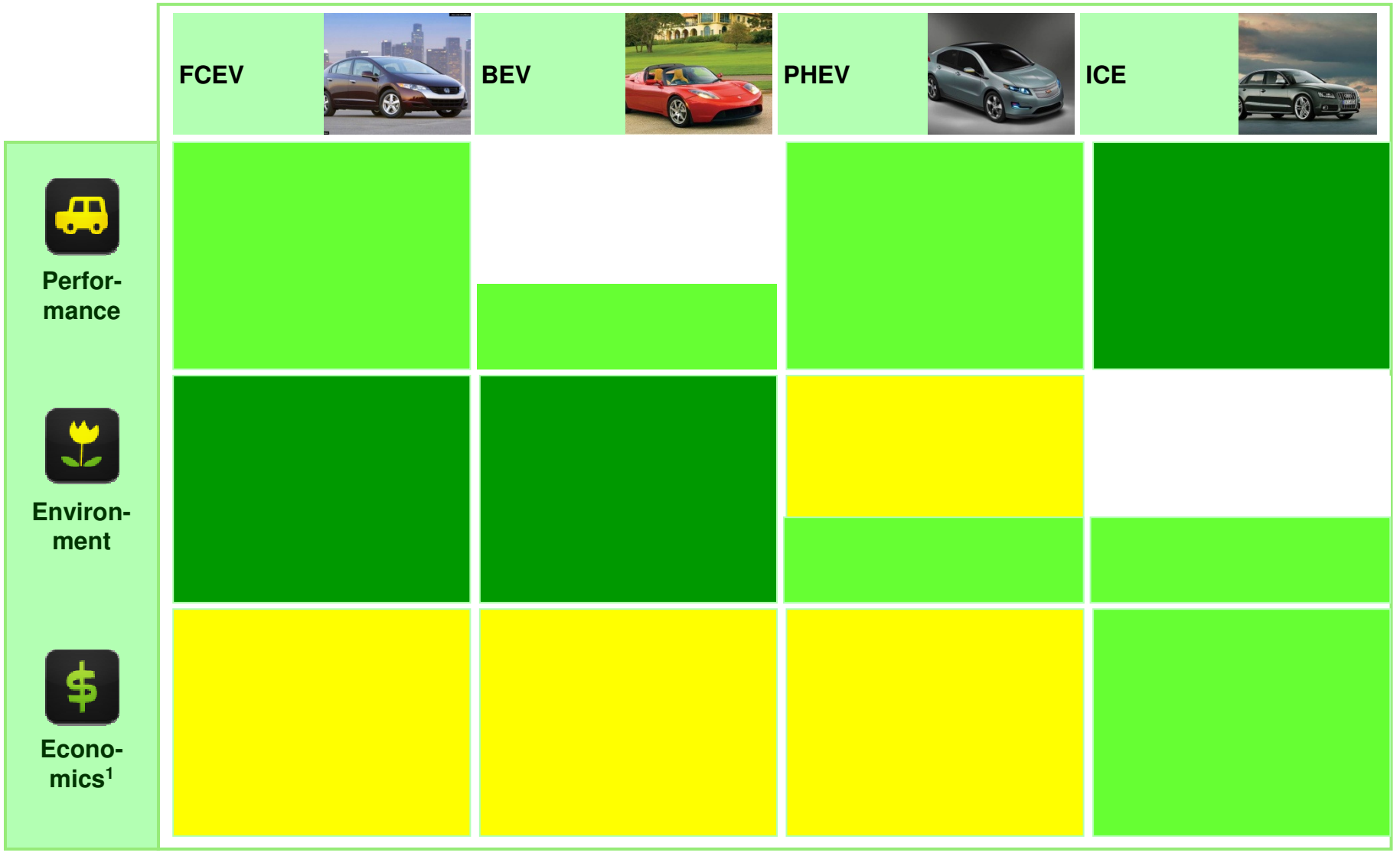
Key messages

- Electric driving has clear benefits over the combustion engine on CO_2 and local emissions, and energy efficiency
- Within electric driving, battery electric vehicles are suited for urban driving – small cars and shorter driving ranges
- Plug in hybrids and fuel cell vehicles are suitable for medium and larger cars with higher annual driving distance
- For this segment amounting for 50% of the fleet and 70% of the CO_2 emissions, fuel cell vehicles are an attractive low carbon solution
- After 2025, the total cost of ownership of electric vehicles is comparable to ICEs
- To drive the uptake of fuel cell vehicles, significant infrastructure investments are required in the first decades (~ 3 billion up to 2020 and over 40 billion up to 2030 for a region like Europe)

Passenger car powertrain technology may move from a single powertrain (ICE) to a portfolio of powertrains

C/D SEGMENT | 2030

Excellent | Good | Moderate | Challenged

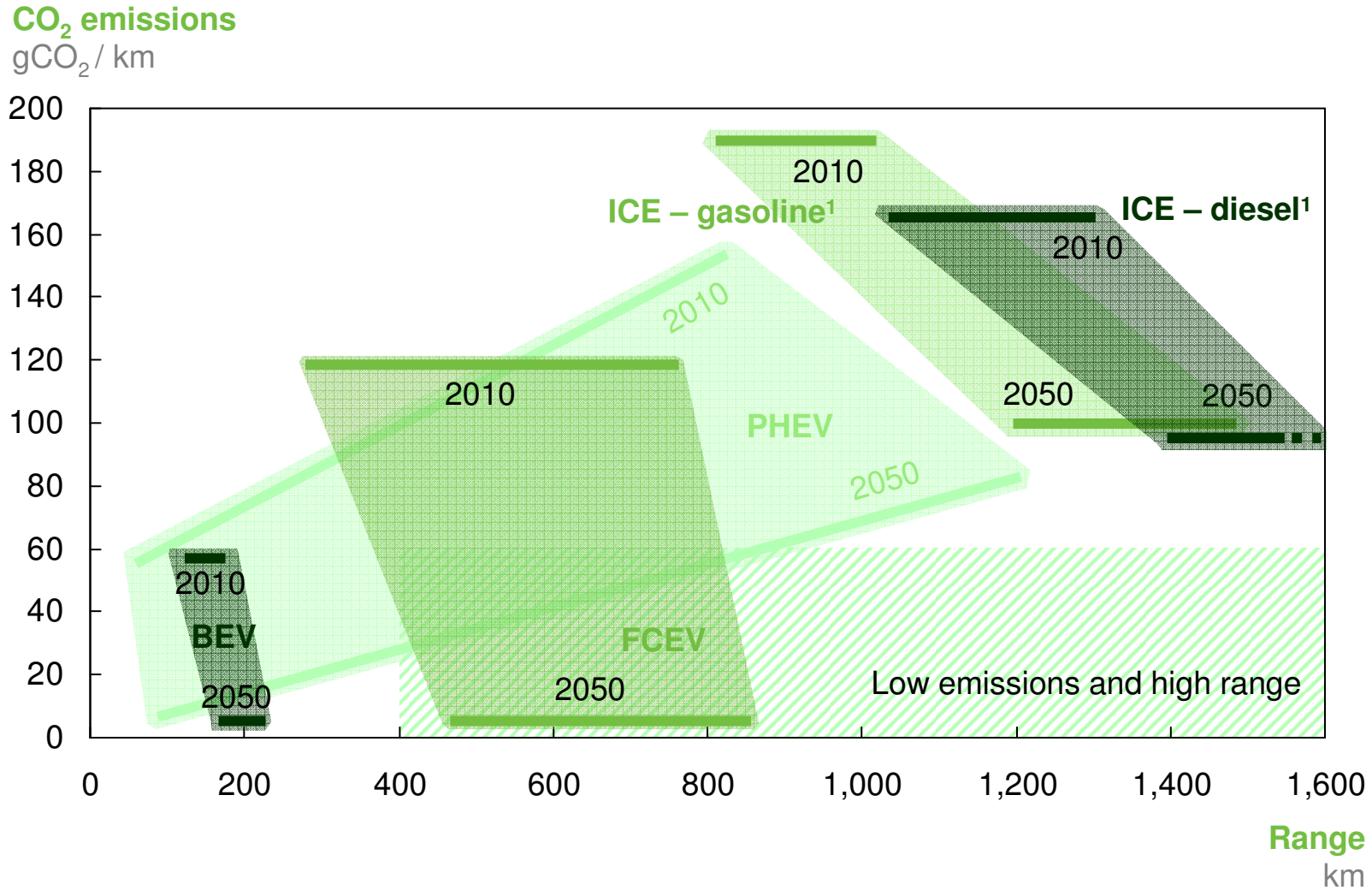


1 Consumer economics can be different, dependent on tax region
2 Fast charging for BEVs implies reduced battery lifetime, lower battery load and higher infrastructure costs than included in this study

SOURCE: Study analysis

BEVs and FCEVs can achieve significantly low CO_2 emissions, with BEVs showing limitations in driving range

C/D SEGMENT



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

FCEVs and PHEVs are comparable to ICEs on driving performance and range

C/D SEGMENT | 2015

Similar performance

- Acceleration
- Curb weight
- Payload
- Cargo volume
- Minimum starting temperature

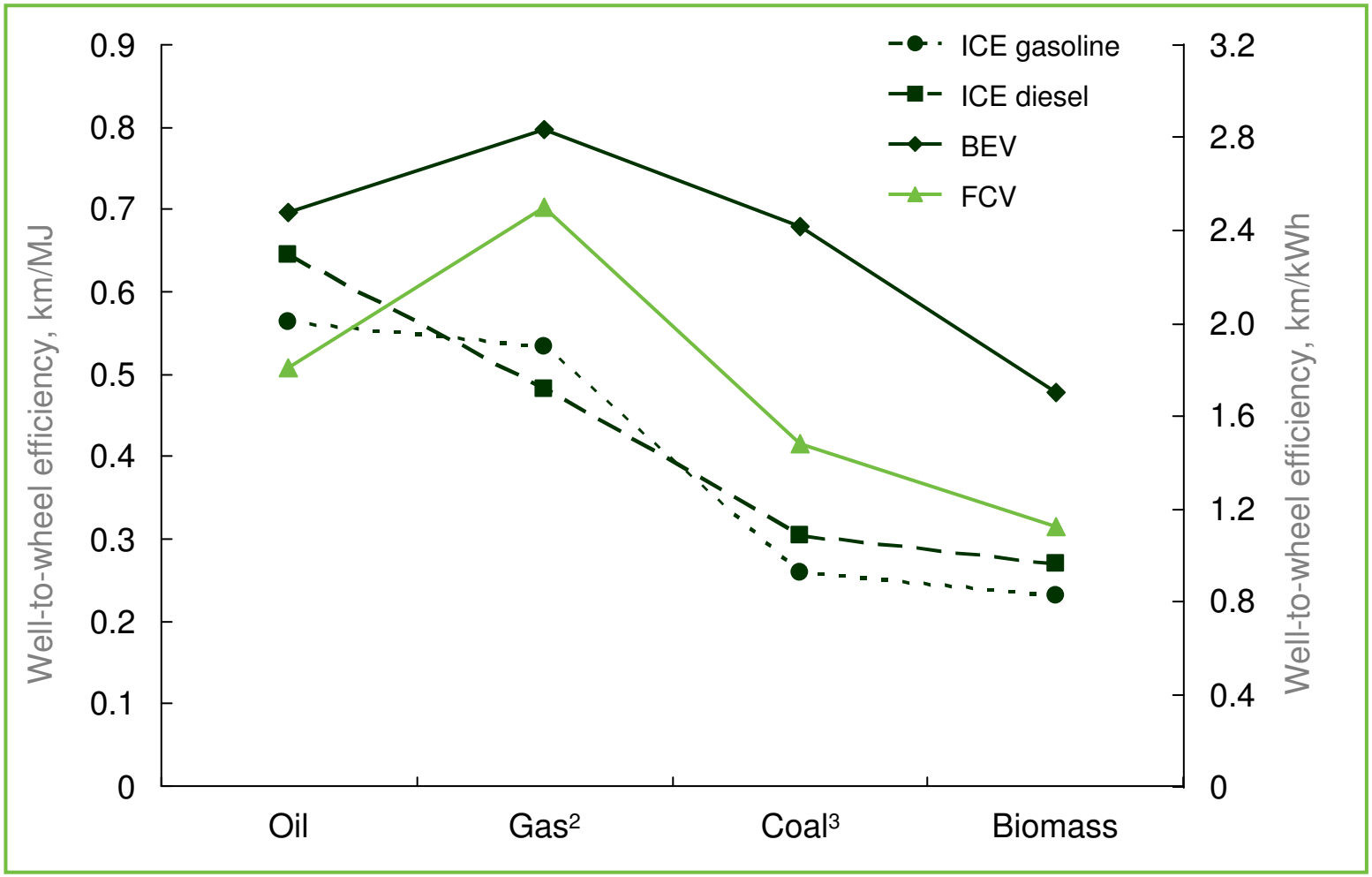
Differentiated performance1

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

Electric vehicles are more energy efficient than ICEs over a broader range of feedstocks

2020

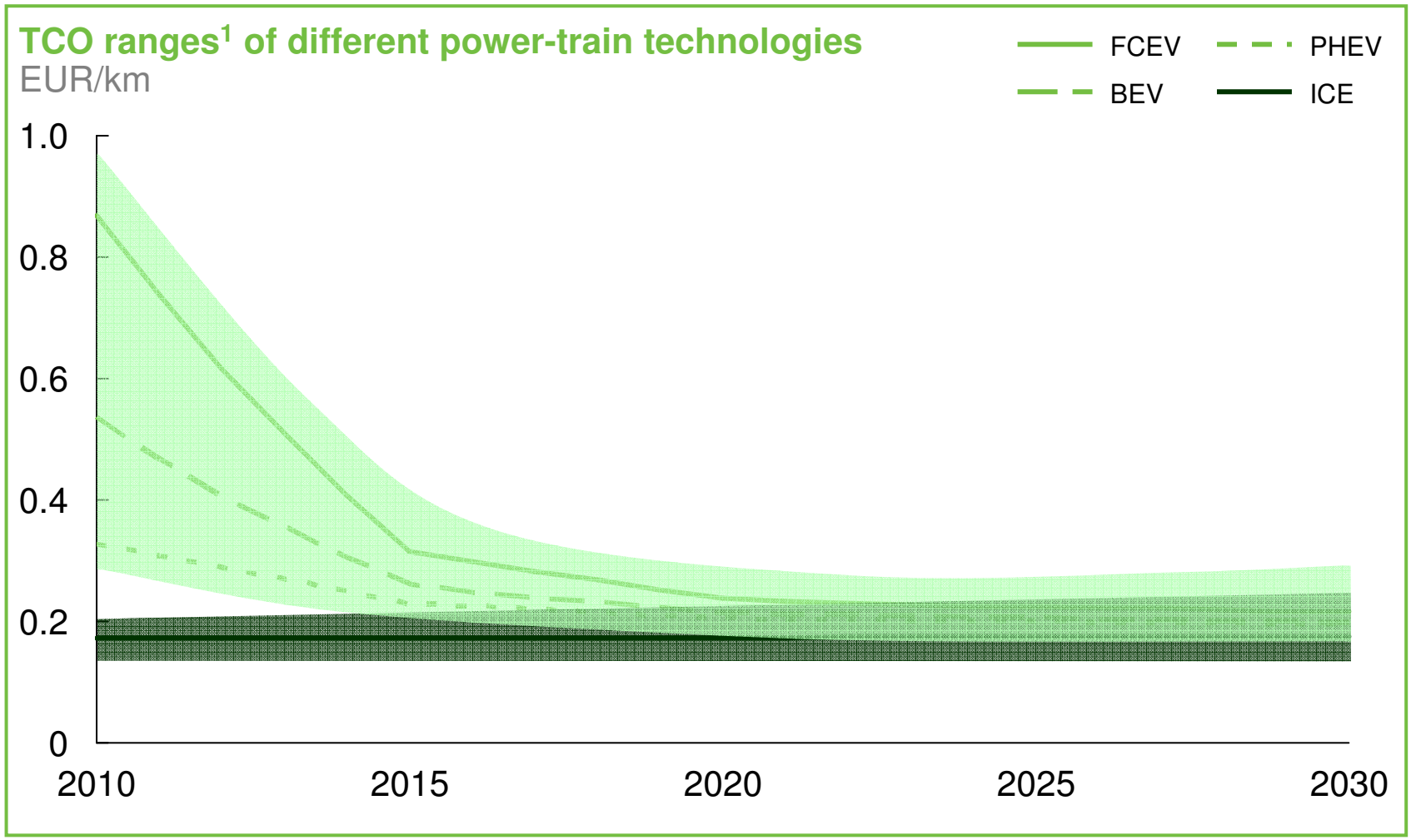


1 All power-trains have different performance criteria and therefore different driving missions
2 CNG used in gasoline ICE; diesel production from natural gas through Fischer-Tropsch process
3 Gasoline and diesel production from coal-to-liquids transformation through Fischer-Tropsch process

SOURCE: CONCAWE-EUCAR JEC-WTW study; study analysis

After 2025, the TCO of all powertrains converge

C/D SEGMENT

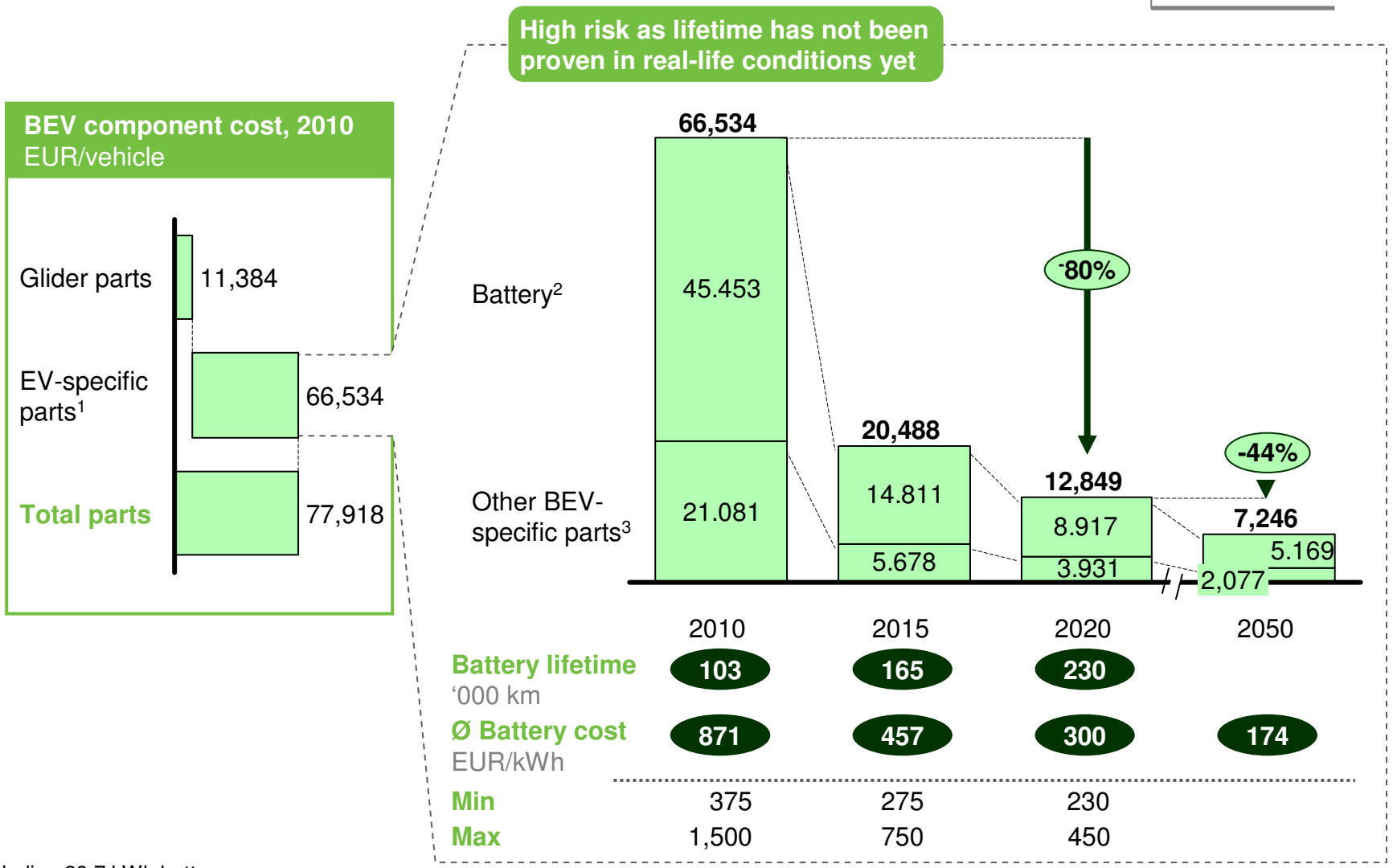


1 Ranges based on data variance and sensitivities (fossil fuel prices varied by +/- 50%; learning rates varied by +/- 50%)

SOURCE: Study analysis

BEV component costs are projected to reduce by 80% by 2020

C/D SEGMENT



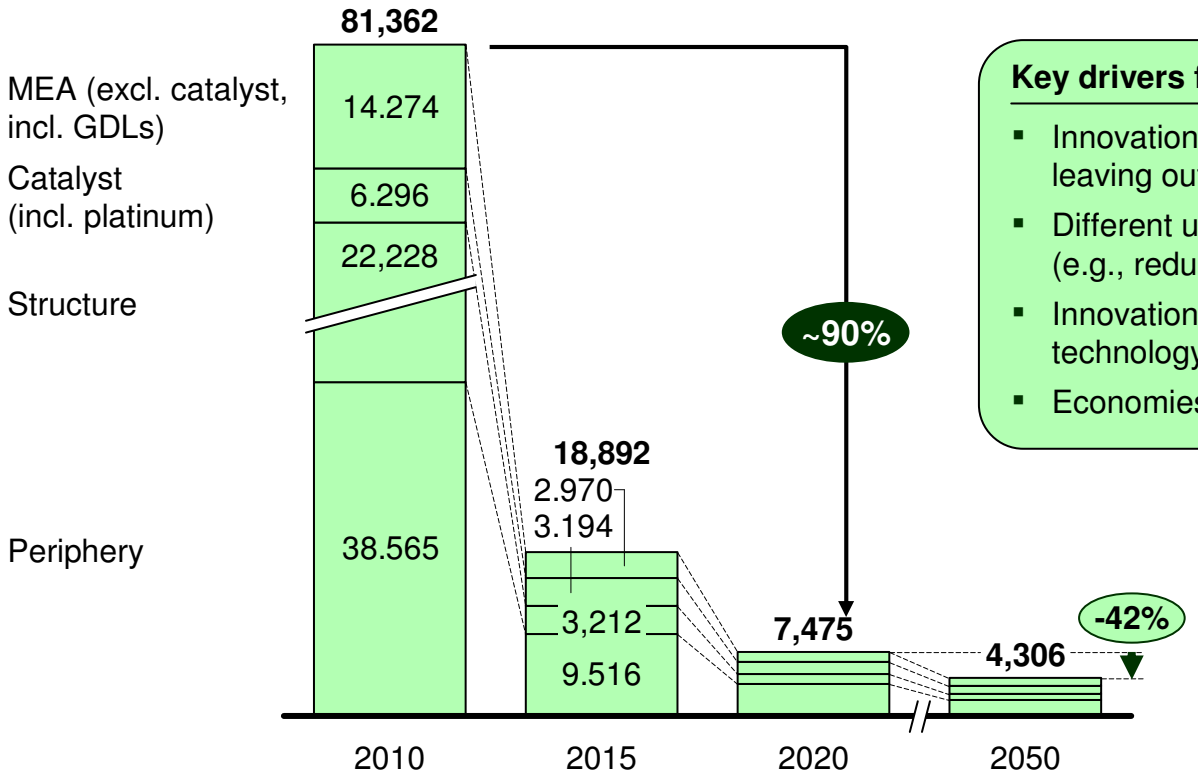
1 Including 29.7 kWh battery
2 ~1.75 batteries required over BEV lifetime in 2010; ~1.1 required in 2015; only cost of utilized battery lifetime is included
3 E.g., electric motor, transmission, inverter, wiring, controls, etc.

SOURCE: Study analysis

The cost of a fuel cell system is expected to reduce by 90% by 2020

EUR per fuel cell system

C/D SEGMENT



Key drivers for cost reduction

- Innovations in design (e.g., leaving out components)
- Different use of materials (e.g., reduced platinum use)
- Innovations in production technology
- Economies of scale

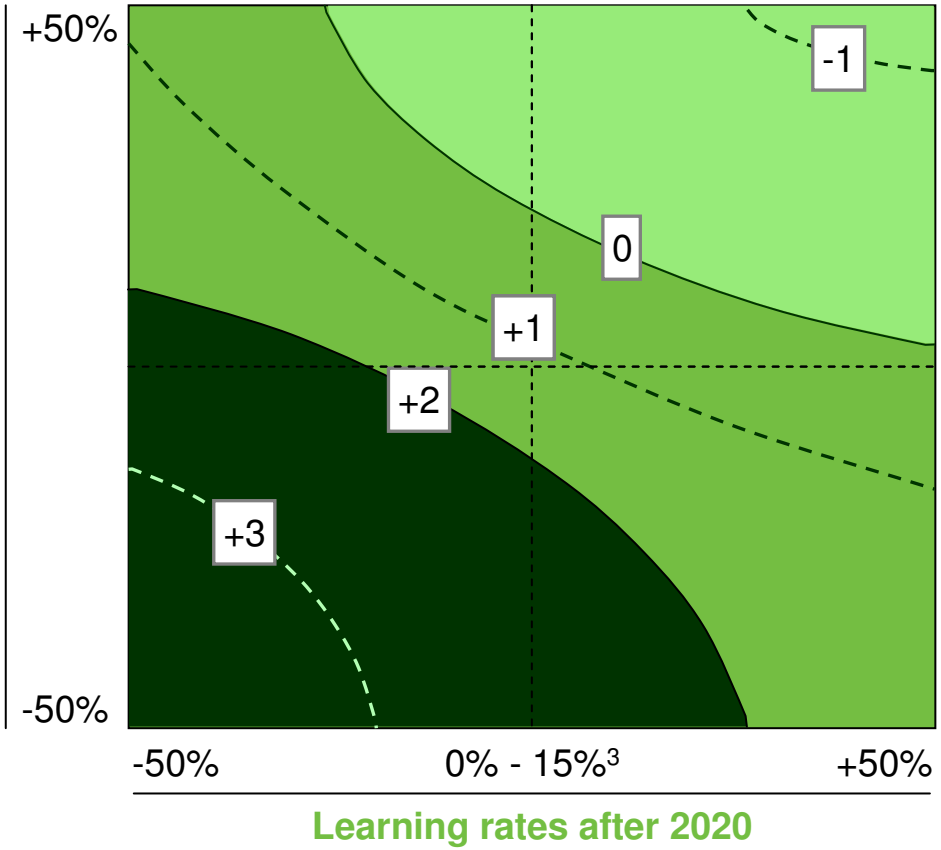
	2010	2015	2020	2050
FC stack lifetime '000 km	115	180	247	290
Platinum use g/kW	0.93	0.44	0.24	0.11
Ø Fuel cell stack cost EUR/kW	500	110	43	
Min	221	42	16	
Max	781	252	98	

SOURCE: Study analysis

Conclusions are robust to significant variations in learning rates and the cost of fossil fuels

C/D SEGMENT

TCO delta between FCEV and ICE-gasoline[1]
EURct/km, 2030



iso TCO lines

-2 Negative numbers relate to a TCO Advantage of FCEV over ICE

Fossil fuel[2]
Oil 0.58 EUR/litre,
Gas 39 EUR/MWh
Coal 88 EUR/ton

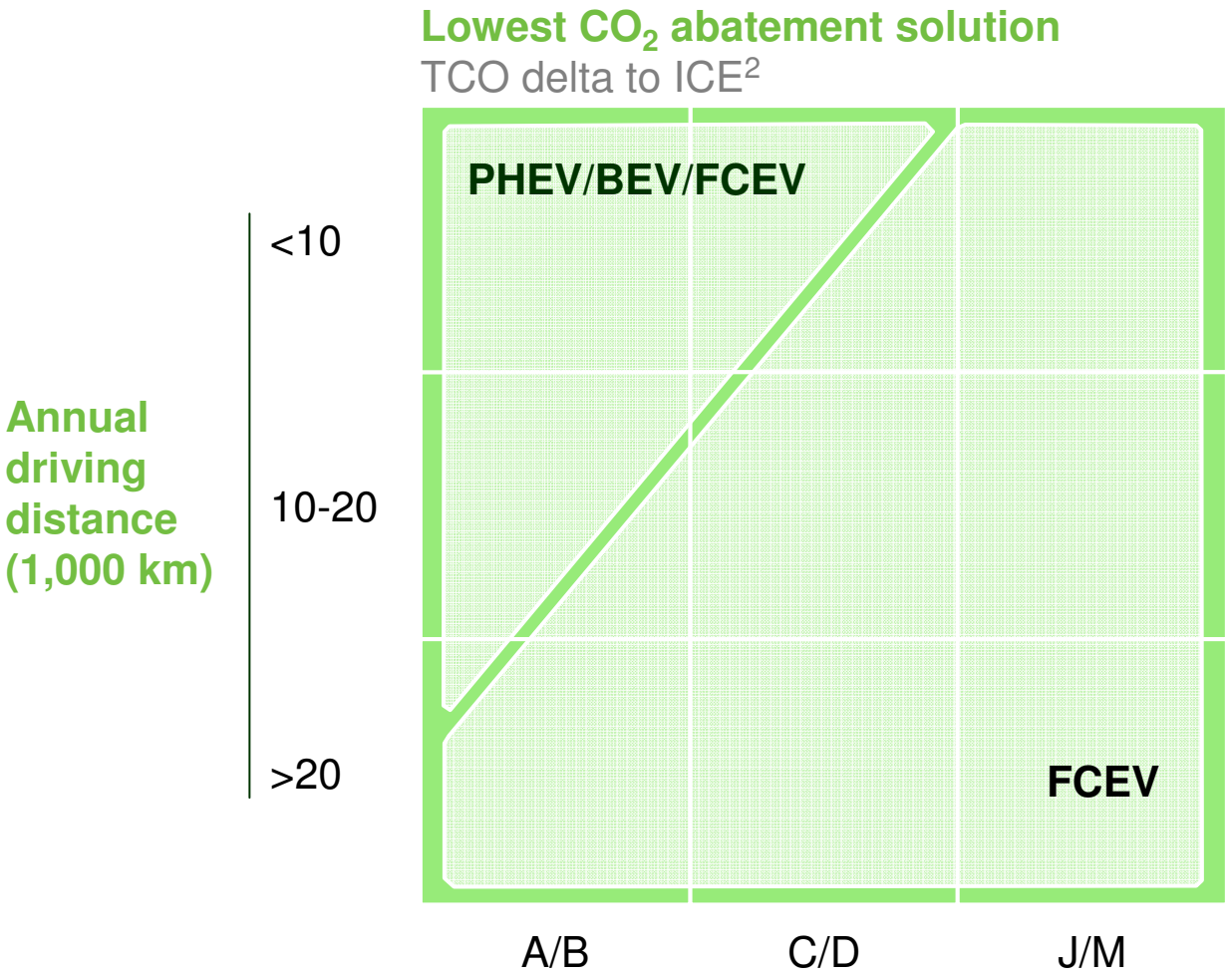
1 Assuming 15 year lifetime and annual driving distance of 12,000 km
2 No taxes included, e.g. excise tax, CO2 tax, VAT
3 Fuel cell membranes: 15% pdc (per doubling of capacity); non-platinum catalyst: 15% pdc; FC structure: 15% pdc, EV-specific parts: 4.0%/1.5% p.a.; FC periphery 4.0%/1.5% p.a.; glider cost (FCEV & ICE): 0%; ICE basic power-train parts: 0%; technology packages: 1.5% p.a.

SOURCE: Study analysis

FCEVs have a TCO advantage over BEVs and PHEVs in the larger car/long distance segments

2050

EUR/year/car[1], assuming no cost of CO_2

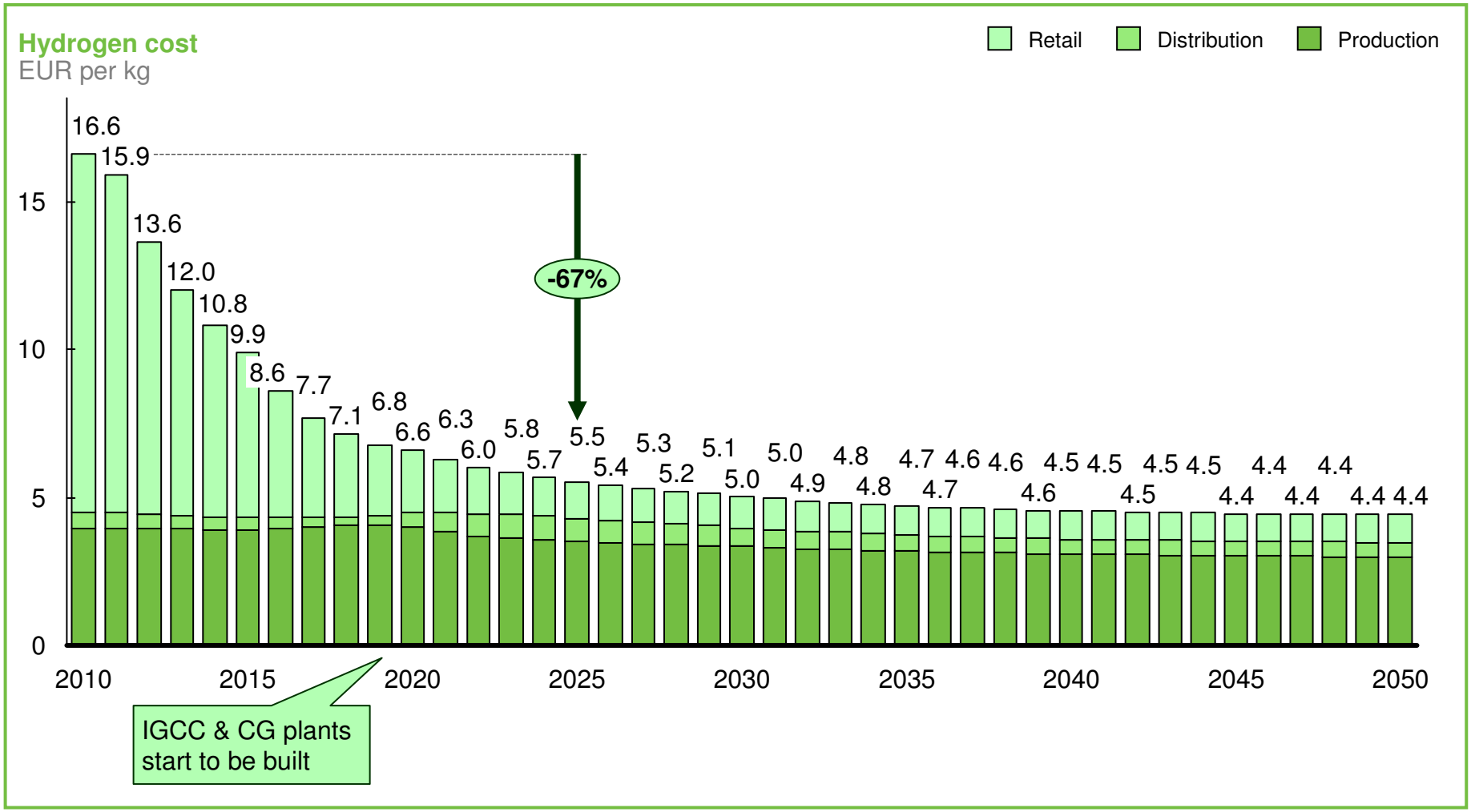


1 Constant lifetime, but different total driving distances (90,000 km; 180,000 km; 360,000 km)
2 Calculated as ICE TCO minus lowest FCEV/BEV/PHEV TCO. Negative numbers indicate a TCO advantage over the ICE

SOURCE: Study analysis

Cost of production is projected to reduce by 70% by 2025, then stays relatively flat

Delivered at pump, w/o taxes/excises

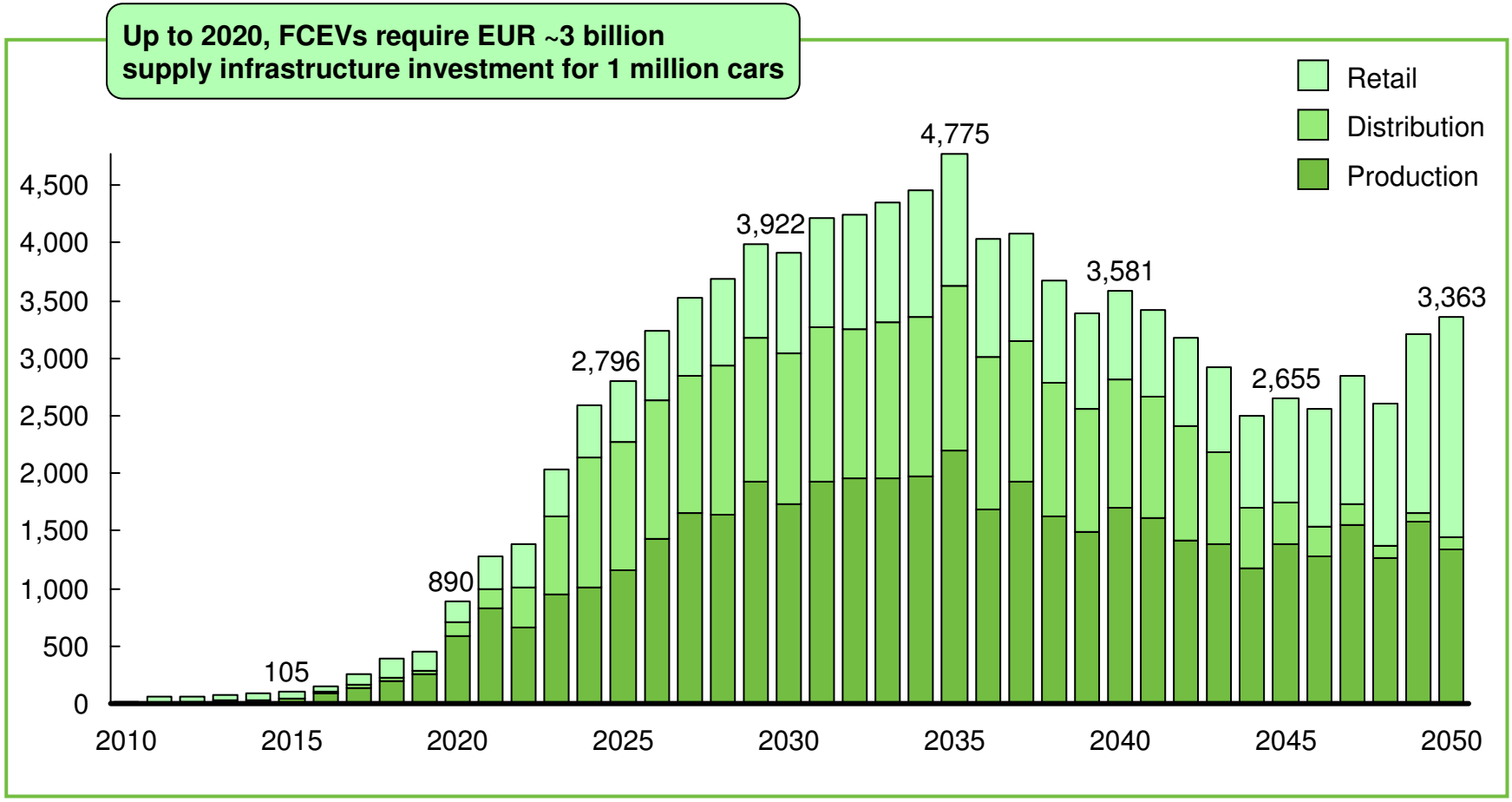


1 Coverage requirement sets area and retail station density requirements for vehicle adoption

SOURCE: Study analysis

Total capital investment for a large-scale roll-out of hydrogen supply infrastructure in Europe is estimated at EUR 100 billion over 40 years

EUR millions



1 Current annual capex requirement for the EU

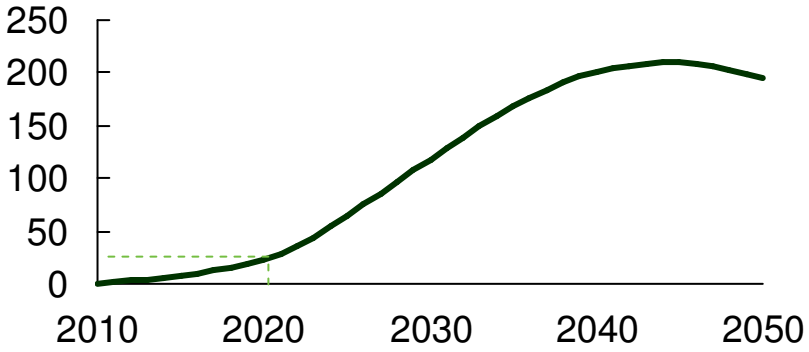
SOURCE: WIS Global Insight; OVUM; OECD / International Transport Forum; study analysis

Economic gap and infrastructure buildup require new business and funding models

25% FCEV SCENARIO

Economic gap

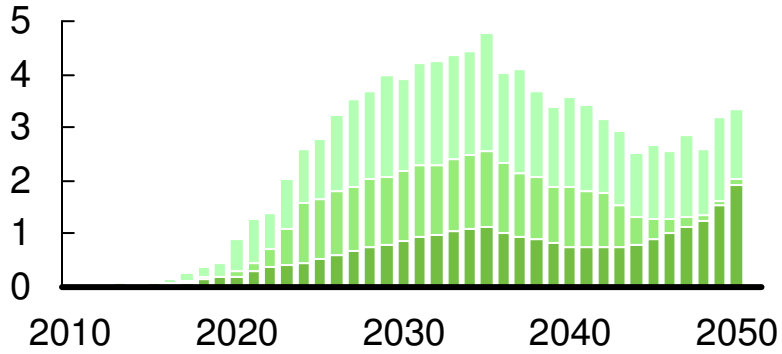
Economic gap
EUR billions cumulative



- Economic gap of about EUR 25 billion until 2020
- Gap needs to be absorbed by all stakeholders
  - Customer (price premium)
  - OEMs (investment)
  - Infrastructure industry (investment)
  - Public/regulator (taxes, subsidies, incentives)

Investment challenge

Infrastructure investment
EUR billions



- Infrastructure investment of about EUR 3 billion until 2020 required
- Industry groups with different risk profiles
- Synchronization of industry investments required
- Investments need require new integrated business models

1 E.g., selling an FCEV below its cost

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