Market uptake of battery and hybrid electric vehicles

Targets, incentives and research needs as experienced in Norway

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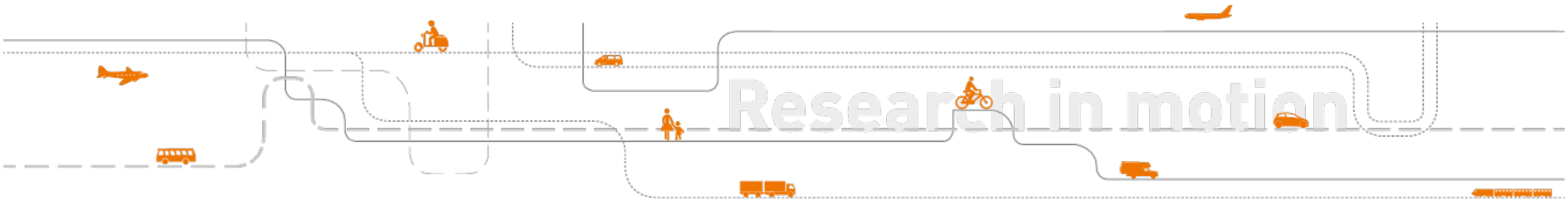
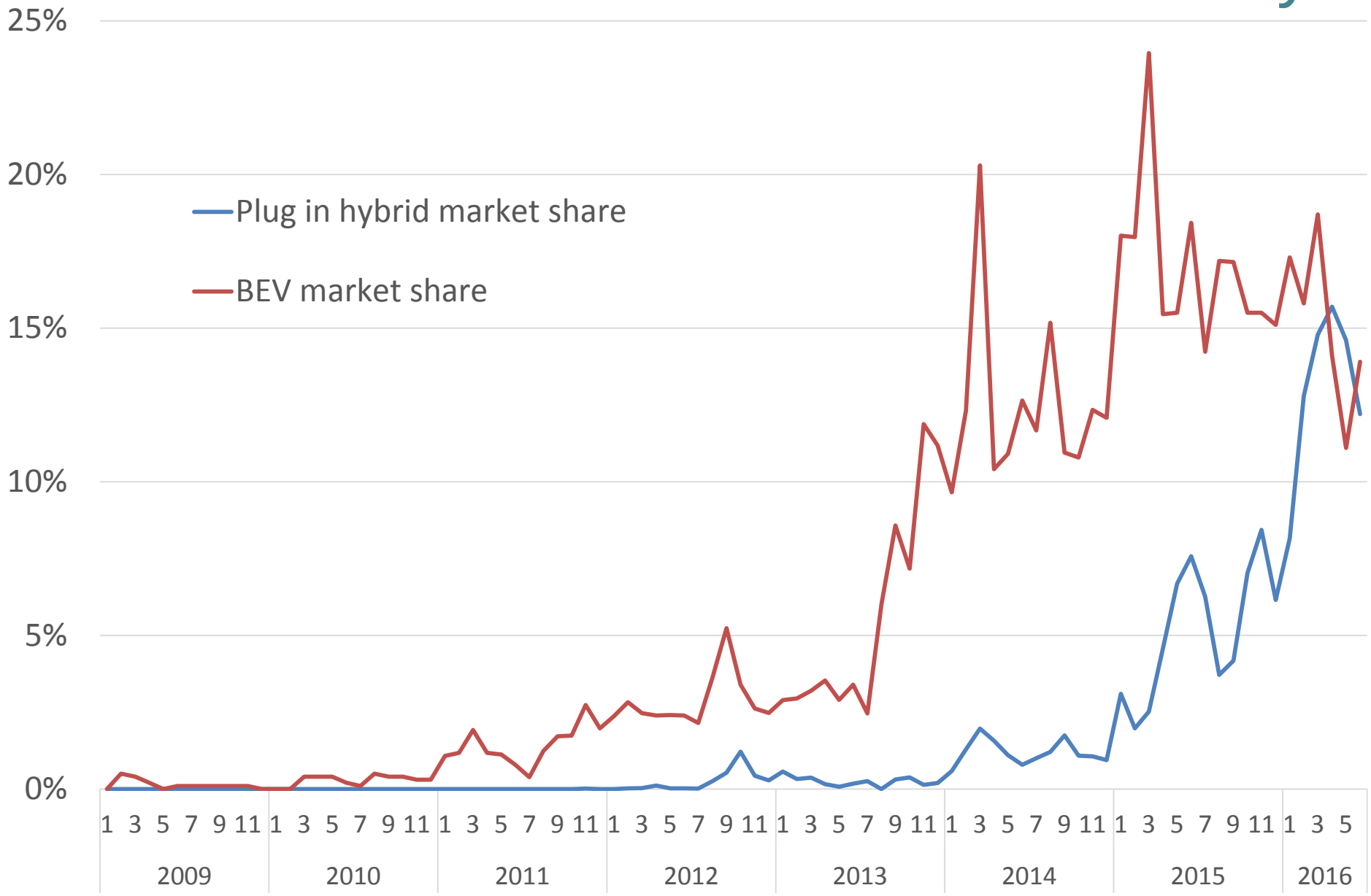


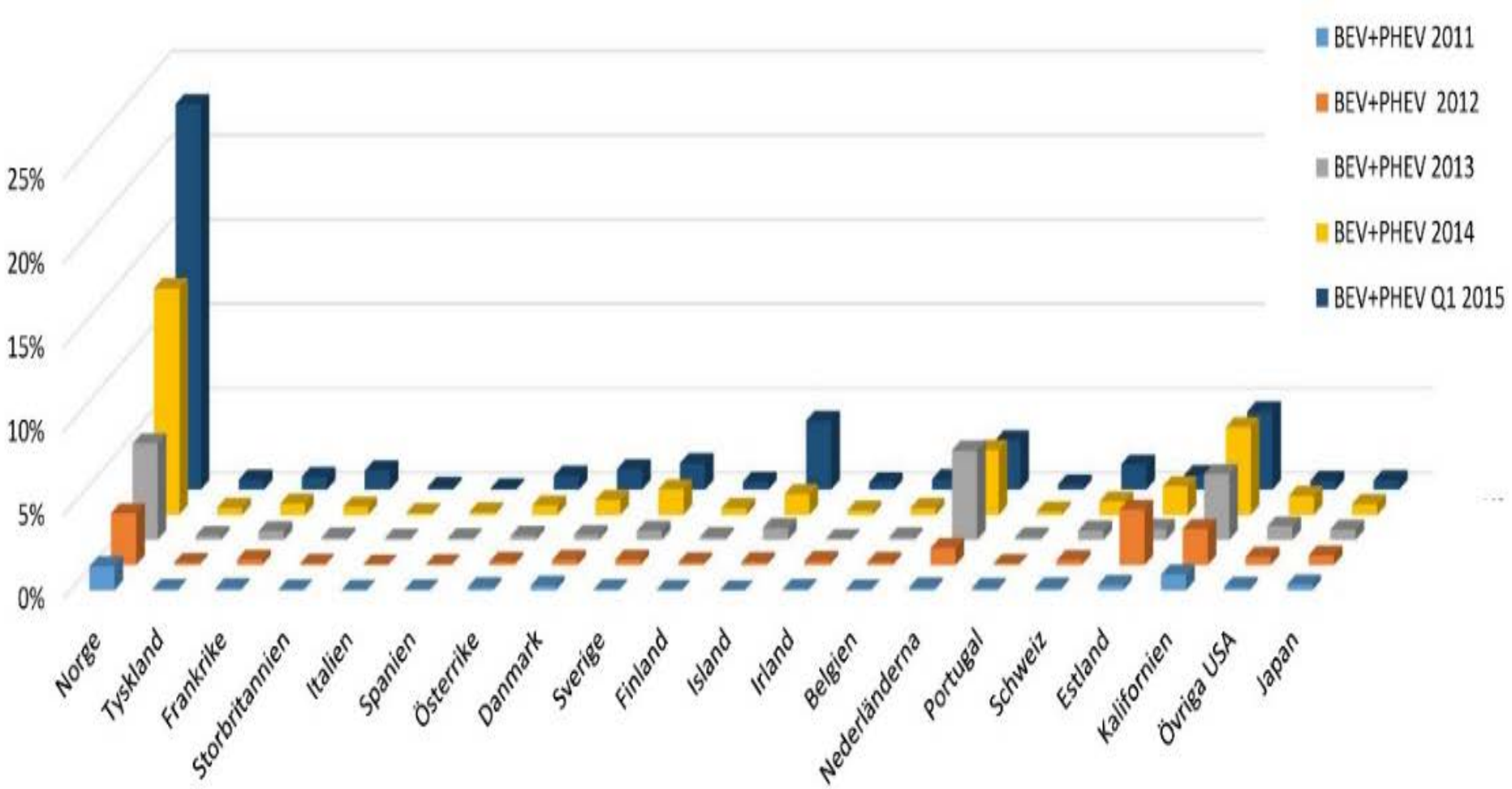
BEV and PHEV market shares in Norway



Source: Figenbaum & Kolbenstvedt (2016)

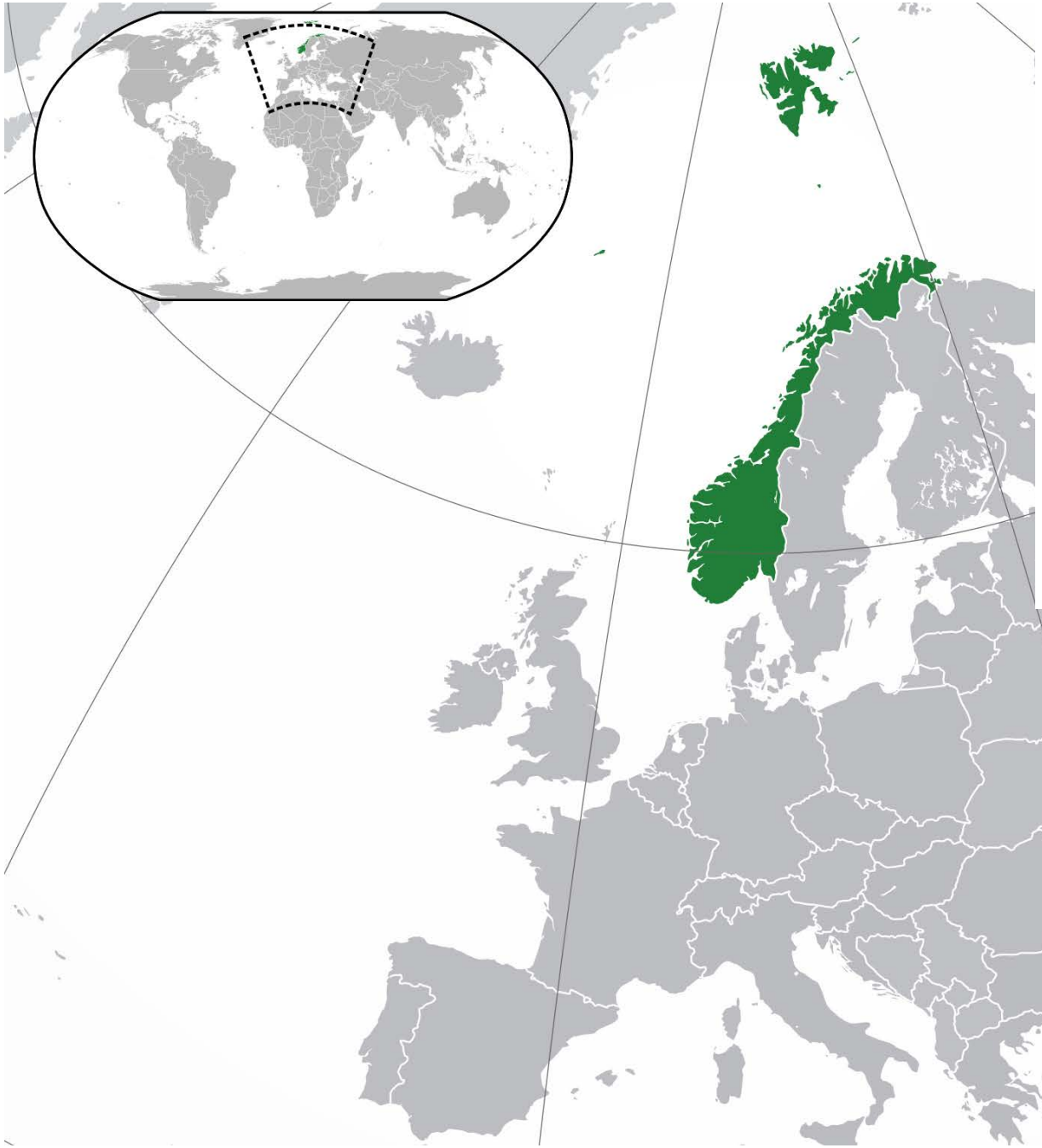
International BEV + PHEV market shares 2011-2015

Source: Figenbaum & Kolbenstvedt (2015)



Outline

1. The geography of Norway
2. Cap-and-trade
3. Ambitious GHG mitigation targets
4. Automobile taxes and charges
5. Incentives for BEVs and PHEVs
6. Stock-flow modeling of the vehicle fleet
7. Decoupling emissions from economic growth
8. Research opportunities and needs



Norway

- Pop. 5,2 million, 15,5 per km^2
- Capital: Oslo
- GDP per capita: $ 70,000
- Market economy
- EEA member (single European market)
- Annual hydropower output: 25,700 kWh per capita
- US electricity output 2014: 13,000 kWh per capita

The European cap-and-trade system (EU ETS)

- All power installations > 20 MW in EEA are covered.
- EU ETS covers roughly ½ of all CO_2 emissions in EEA.
- Fossil fuel use in transportation is not covered (except for intra-EEA aviation).
- But electricity used in transportation is!

⇒ In Europe, electrification means moving (part of) transportation into the EU ETS.

Thus, in principle, the marginal emission from a BEV is zero.

- Cap-and-trade and vehicle electrification are perfect complements.

In the absence of cap-and-trade

- In regions without cap-and-trade, GHG mitigation effect will depend on energy mix (how electricity is generated).
- With European energy mix (510 gCO_2/kWh) and 0.2 kWh/km energy use, BEV emissions come out at 102 gCO_2/km = 54 mpg.
- For maximal GHG mitigation effect, vehicle electrification should be accompanied by decarbonisation of power generation.

Emission targets in Norway

Approved by Parliament:

- A maximum of 85 gCO_2/km (by type approval test) as averaged over all new passenger cars sold in 2020 (including zero emission vehicles)
- Corresponds to a window sticker value of 64.5 mpg for a gasoline car

Proposed by Public Roads Administration – pending in Parliament:

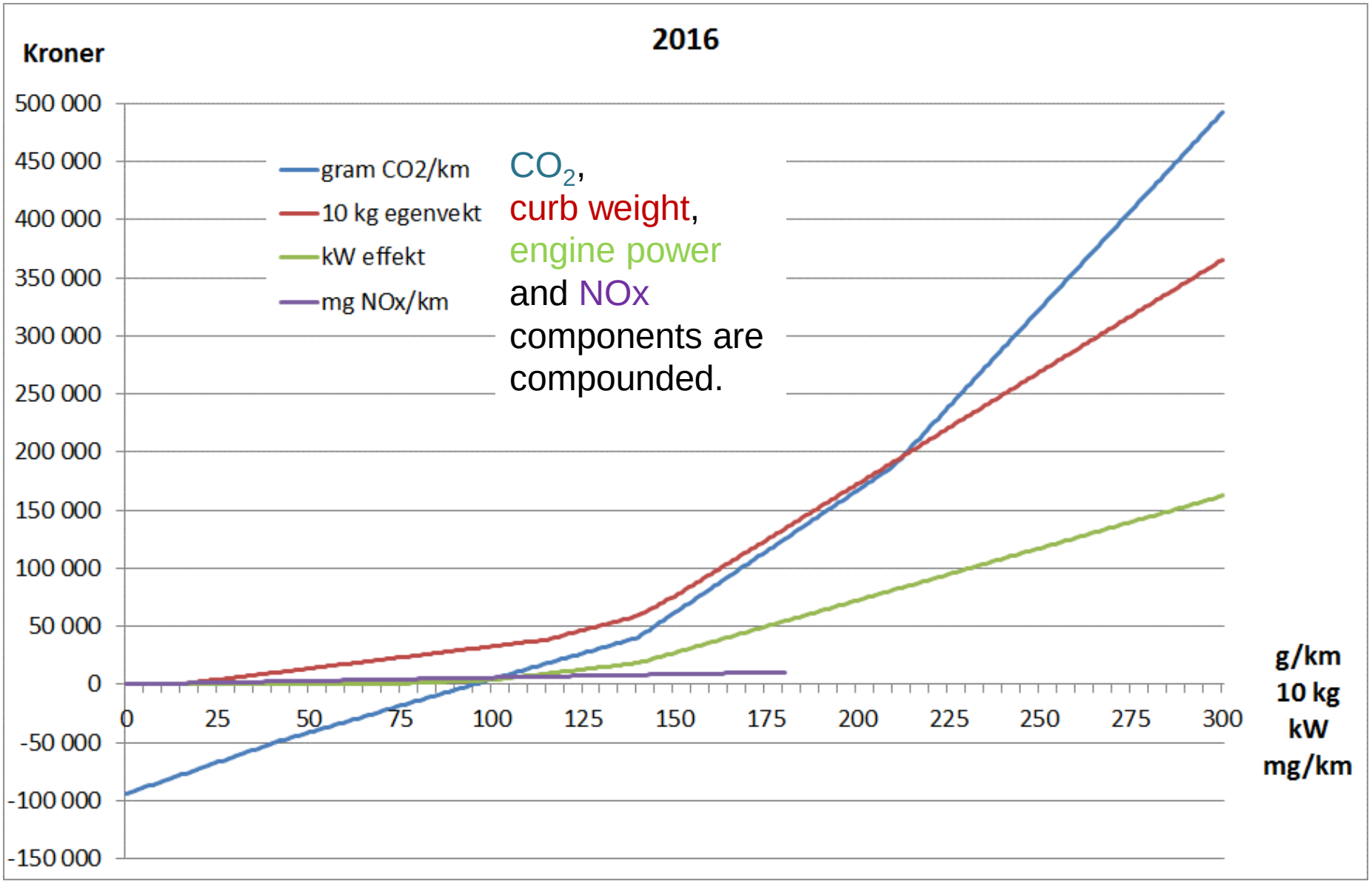
- By 2025 all new passenger cars should be zero emission vehicles
- Between 2015 and 2025 hybrids' share of new cars with ICE should grow from 16 to 100 per cent
- By 2030, all new freight vans and light trucks (< 3.5 t) should be BEVs or FCEVs.
- By 2025, all new urban buses should be BEVs or FCEVs
- By 2030, 75 % of new coaches should be BEVs or FCEVs
- By 2030, 50 % of new heavy trucks (>3.5 t) should be BEVs or FCEVs
- Between 2018 and 2030 hybrids' share of new trucks with ICE should grow from 1 to 50 per cent

Wishful thinking?

Automobile taxes and charges in Norway

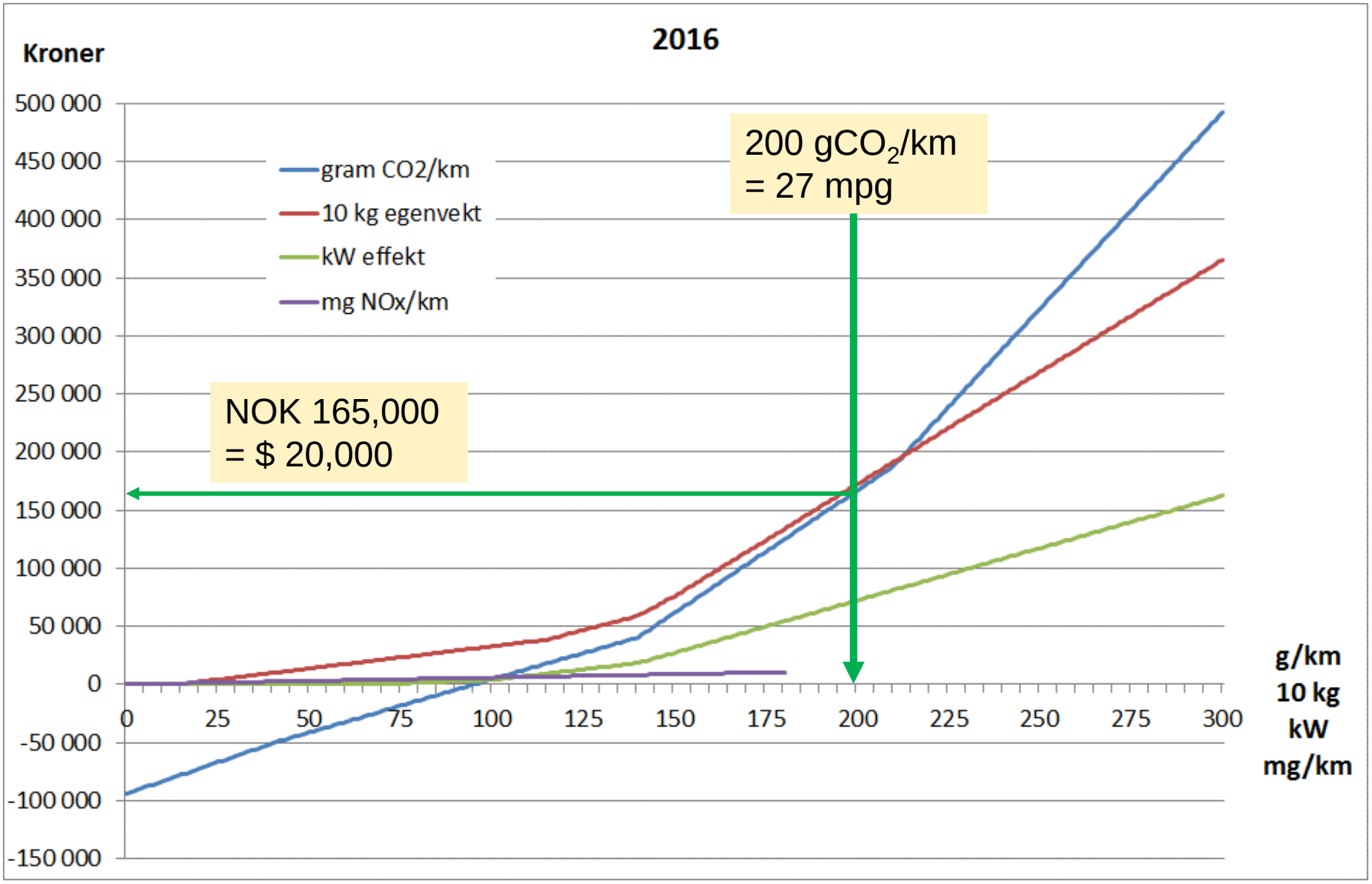
- Fuel tax: $ 2.75 + 25 % VAT = $ 3.45 per gallon gasoline
- Annual circulation tax: $ 250 per year for passenger car
- Reregistration tax: $ 185-720 per transaction
- Scrap deposit: $ 290 per car.
- Income tax on company cars: marginal income tax rate x 30 % of list price
- Commuter tax credit: above 9000 miles per annum, $ 0.08 per mile
- Toll cordons, roads, bridges, tunnels: $ 1.20 to 24 per passing
- Ferry crossings: fare depends on distance. High for cars, low for passengers
- Vehicle purchase tax (registration tax)

Purchase tax on new passenger cars in Norway 2016



As of September 20, 2016, $ 1 = NOK 8.27.

Purchase tax on new passenger cars in Norway 2016



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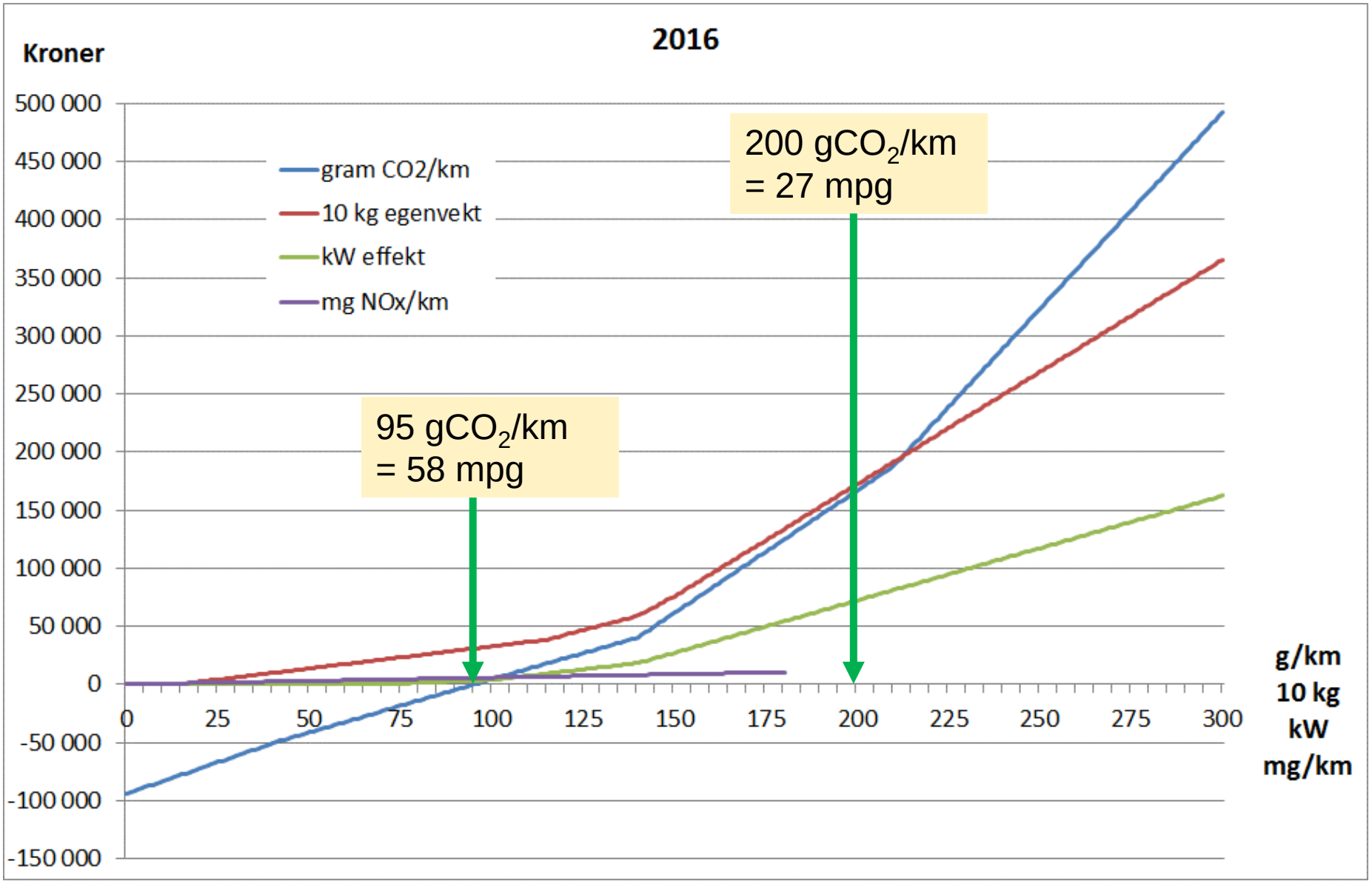
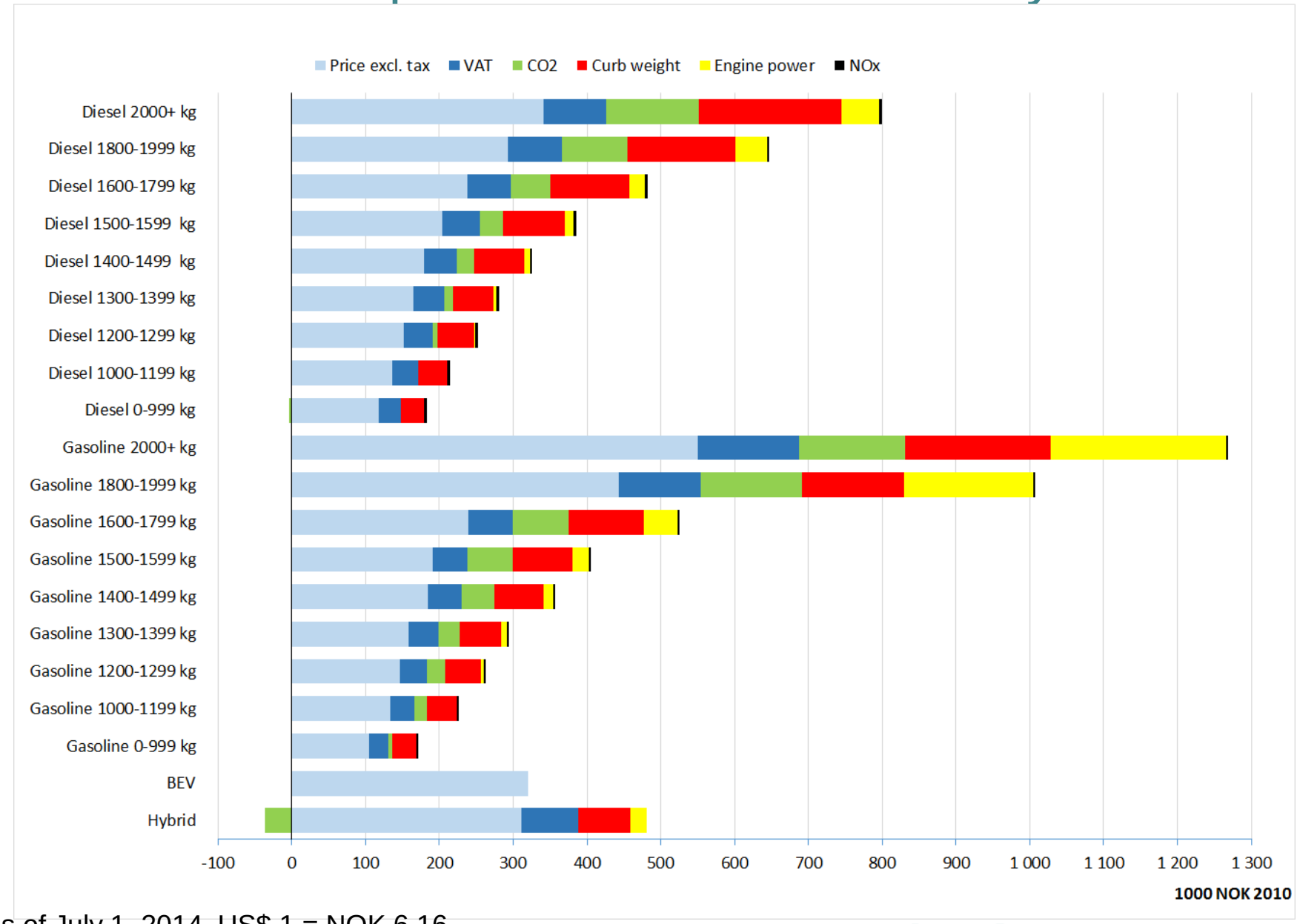
Institute of Transport Economics
Norwegian Centre for Transport Research

Purchase tax on new passenger cars in Norway 2016



As of September 20, 2016, $ 1 = NOK 8.27.

Automobile retail prices and taxes in Norway 2014



As of July 1, 2014, US$ 1 = NOK 6.16.
Source: Fridstrøm & Østli (2016b)

Incentives for zero emission vehicles in Norway

Battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEV) are exempt of

- value added tax (VAT, 25 %)
- vehicle purchase tax,
- road tolls and public parking charges.

They benefit from

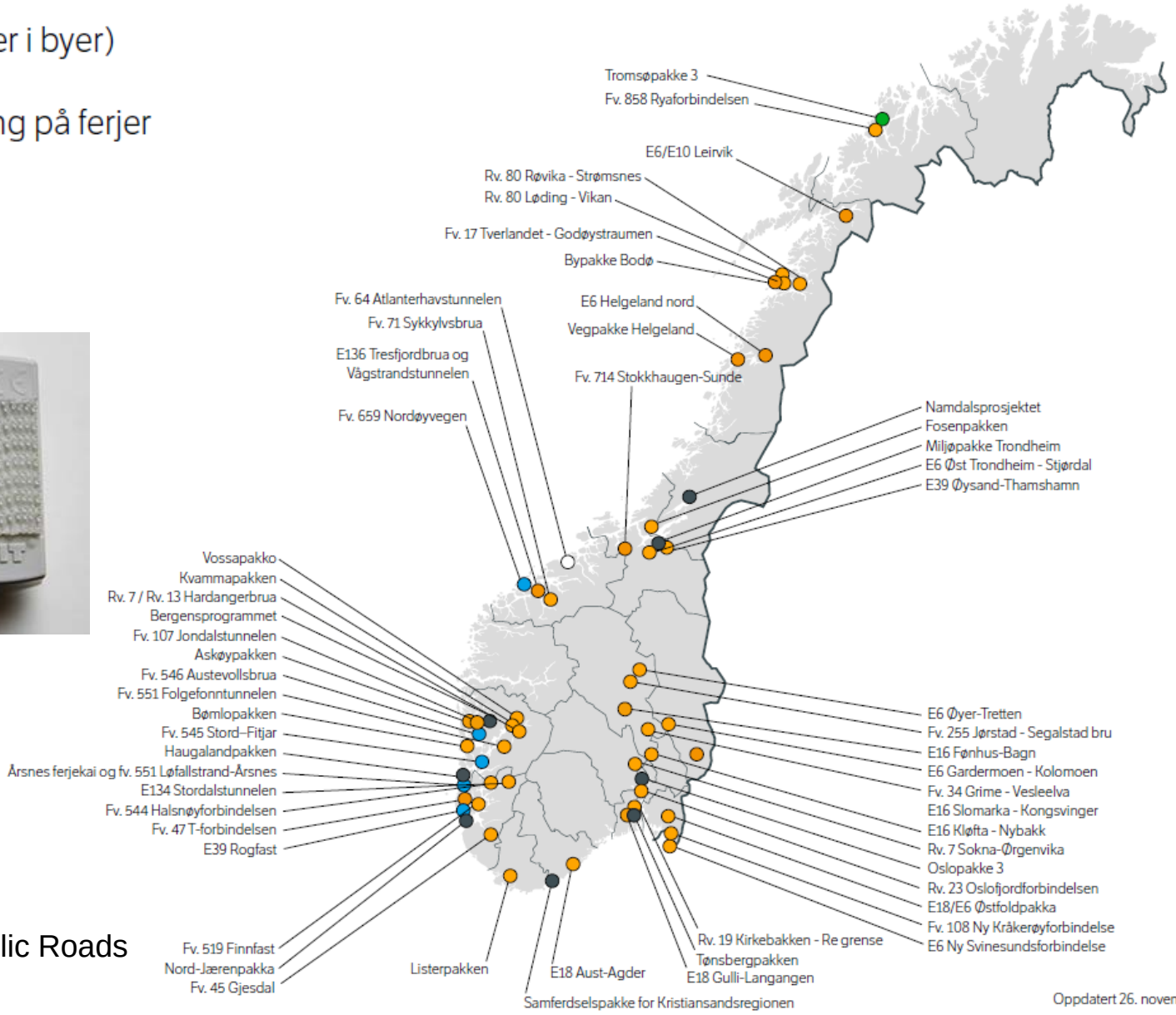
- strongly reduced annual circulation tax
- reduced income tax on company cars
- reduced ferry fares (at most equal to those payable for MCs)
- access to the bus lane (except on E18 into Oslo from west)
- free public parking, often with
- free recharging.

Incentives were intended to be temporary, until 2017, or 50,000 BEVs, whichever comes first….

Toll cordons, roads, ferries. Local fuel tax.

- Bompengeinnkreving på veger
- Bypakker (bomringer i byer)
- Bompengeinnkreving på ferjer
- Lokal drivstoffavgift
- Manuell innkreving

Automatic payment through AutoPASS tag.



Source: Norwegian Public Roads Administration

121 ferry crossings in Norway as of 2012

Source: https://no.wikipedia.org/wiki/Ferjesamband_i_Norge

20 million vehicle passages in 2012.

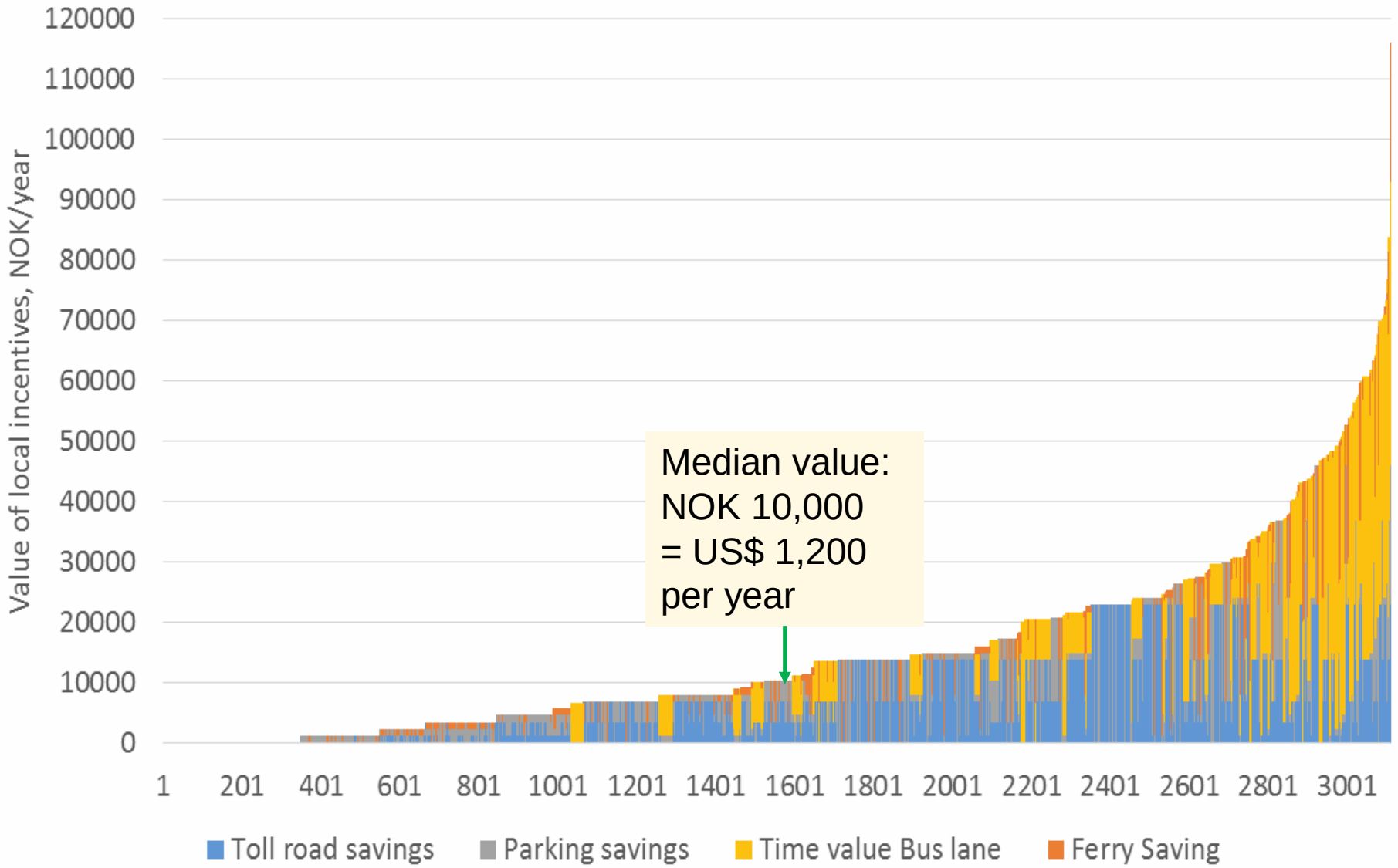
BEVs and FCEVs pay only for the driver and passengers (with some exceptions)

High visibility

Bus lane, EL number plates

Courtesy: Erik Figenbaum, TØI

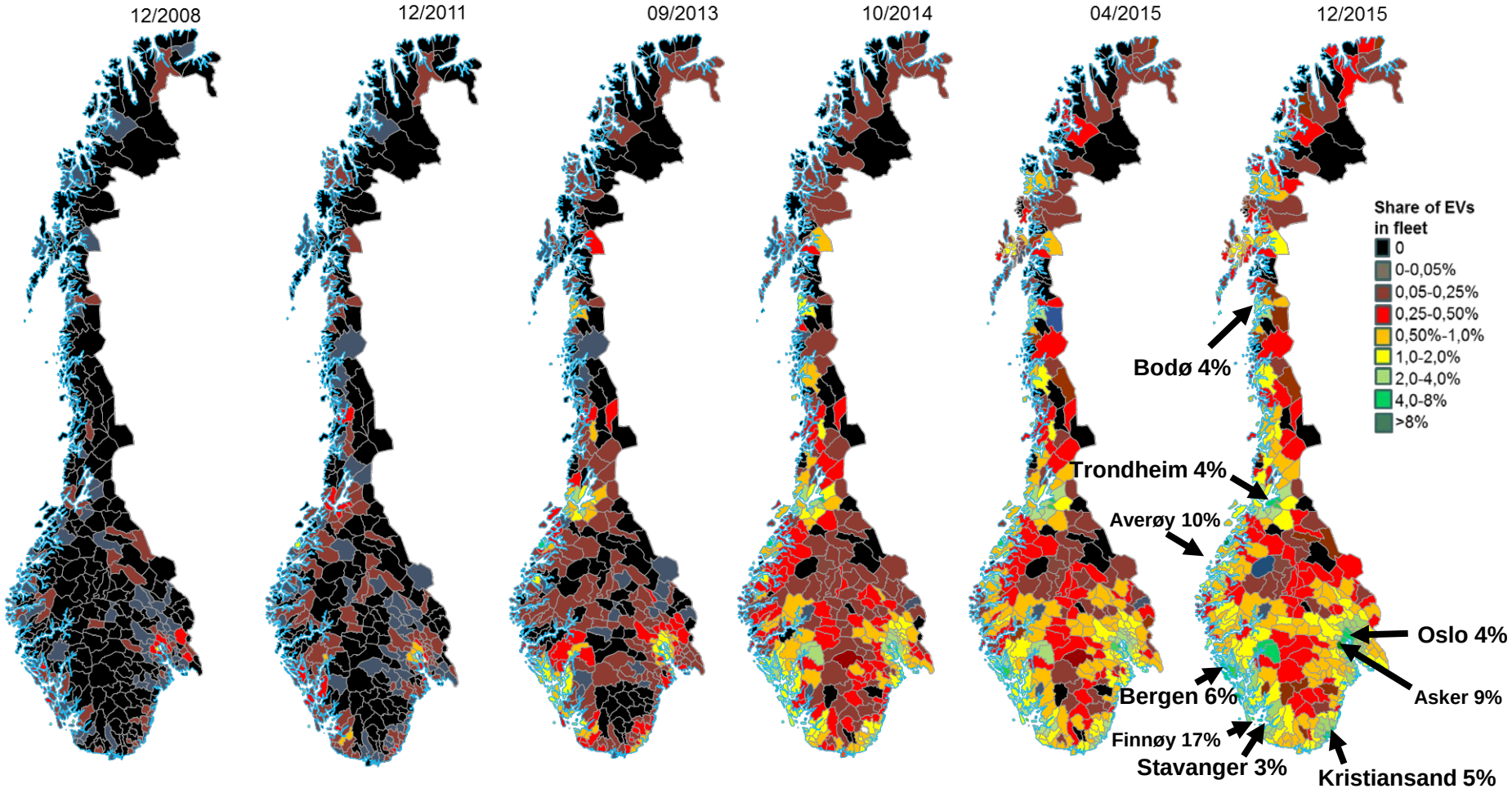
Self-reported annual value of local incentives for all BEV owners in March 2016 survey, arranged in order of increasing value per owner. N = 3111



Source: Figenbaum & Kolbenstvedt (2016)

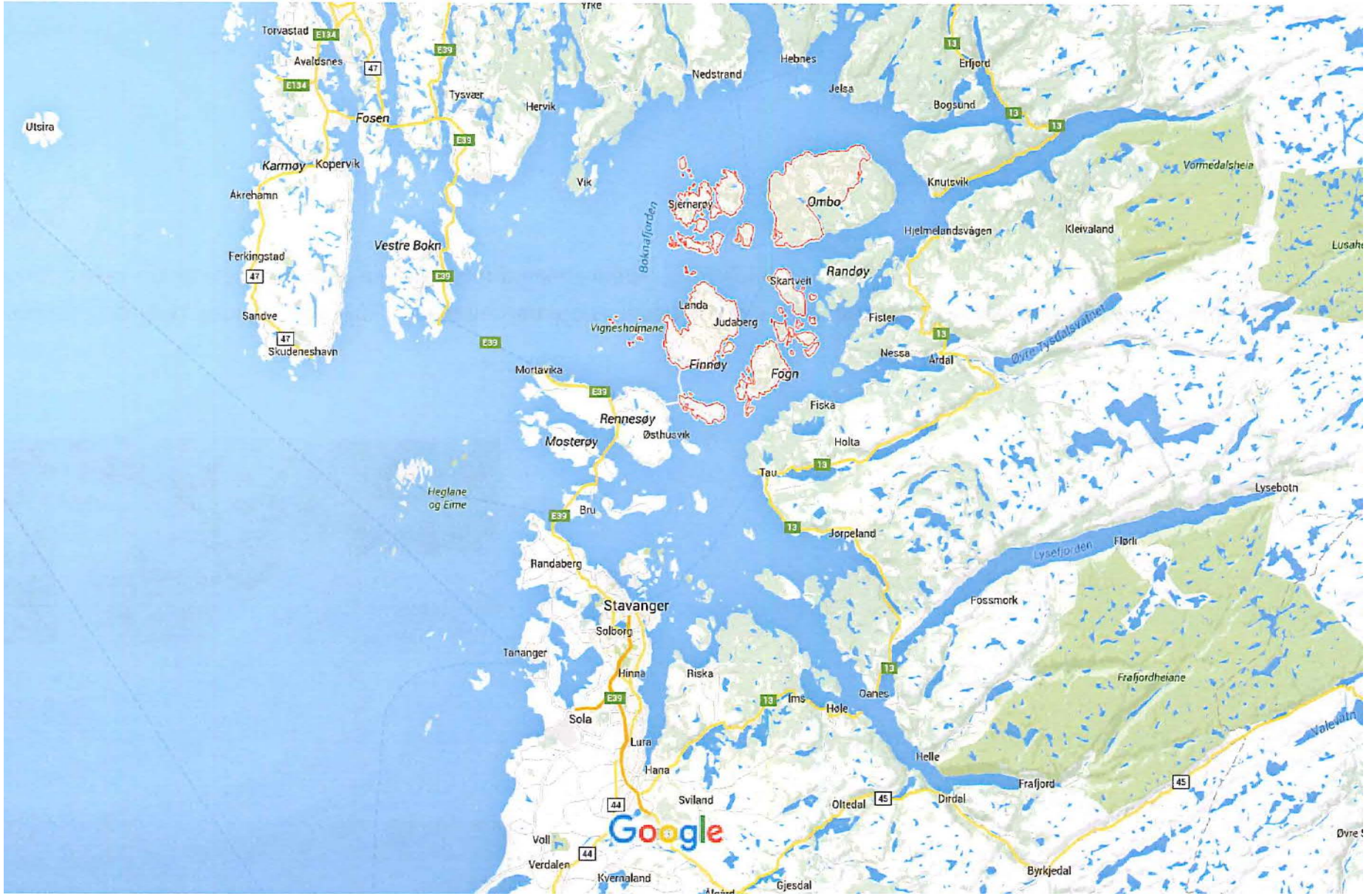
About 3.5 % of total fleet are now BEVs

August 2016: 87,000 BEVs, more than 20,000 PHEVs

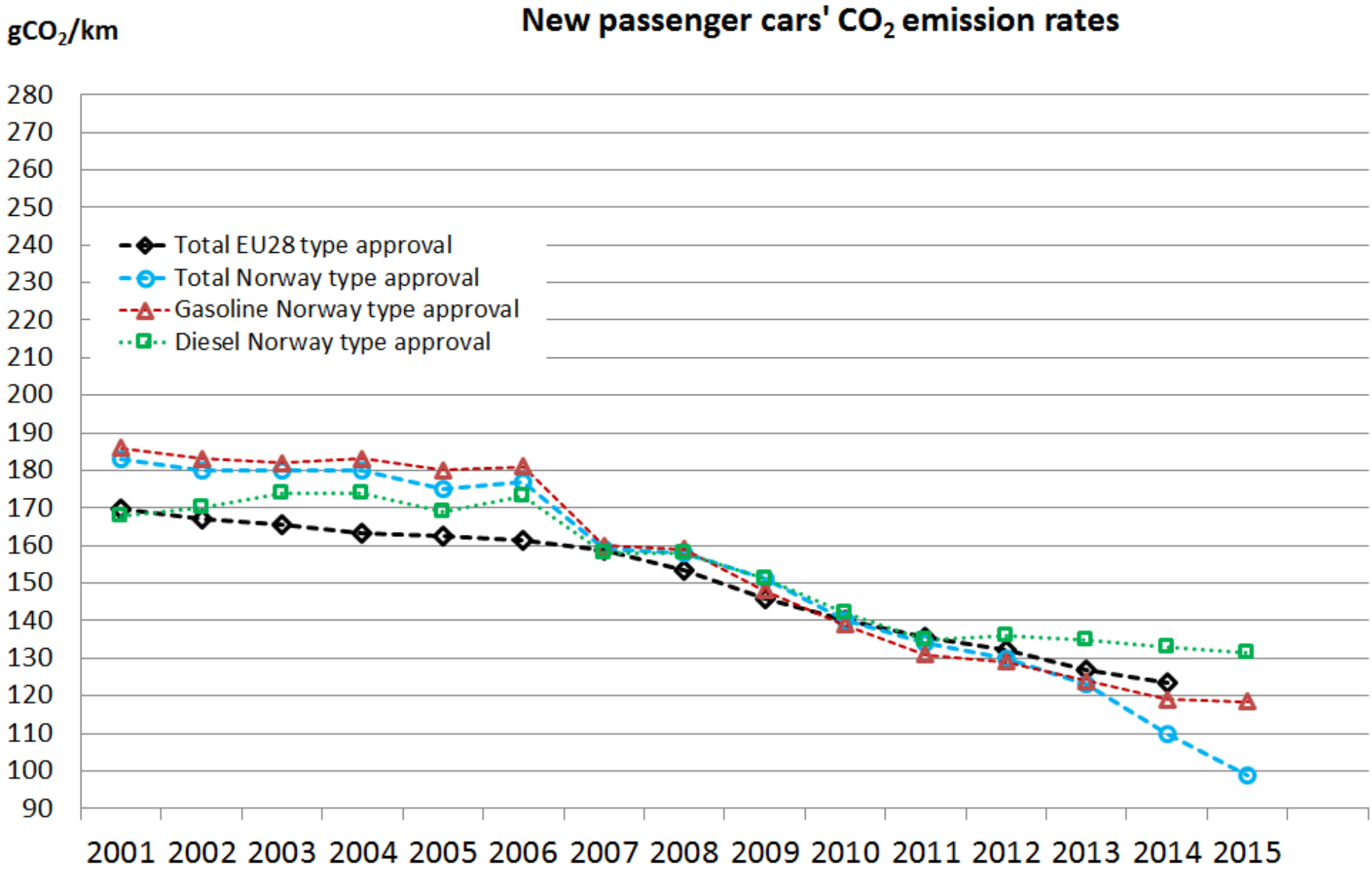


Courtesy: Erik Figenbaum, TØI

Finnøy near Stavanger. Charge: $ 24 each way!

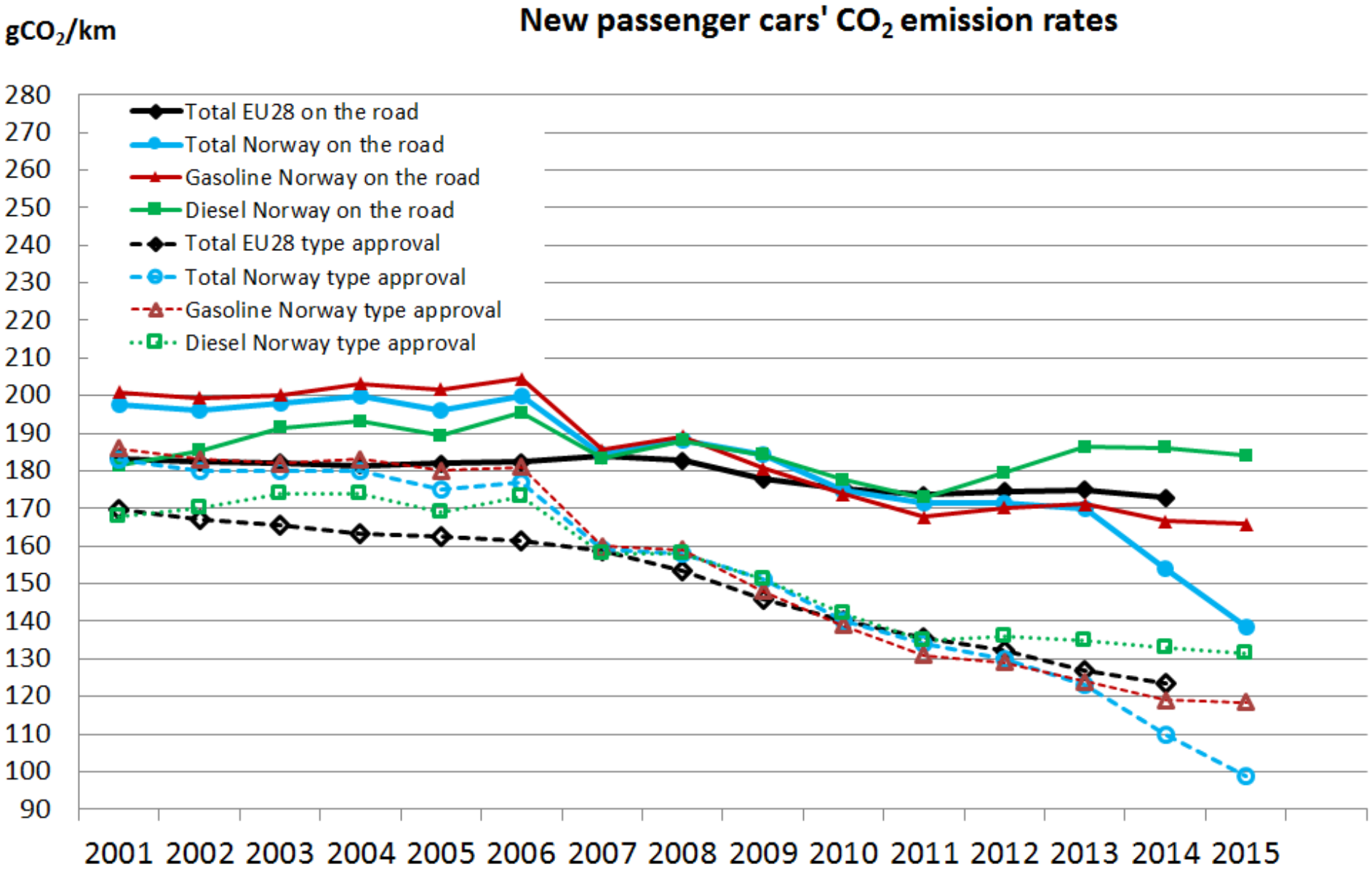


Type approval (NEDC) CO_2 emission rates



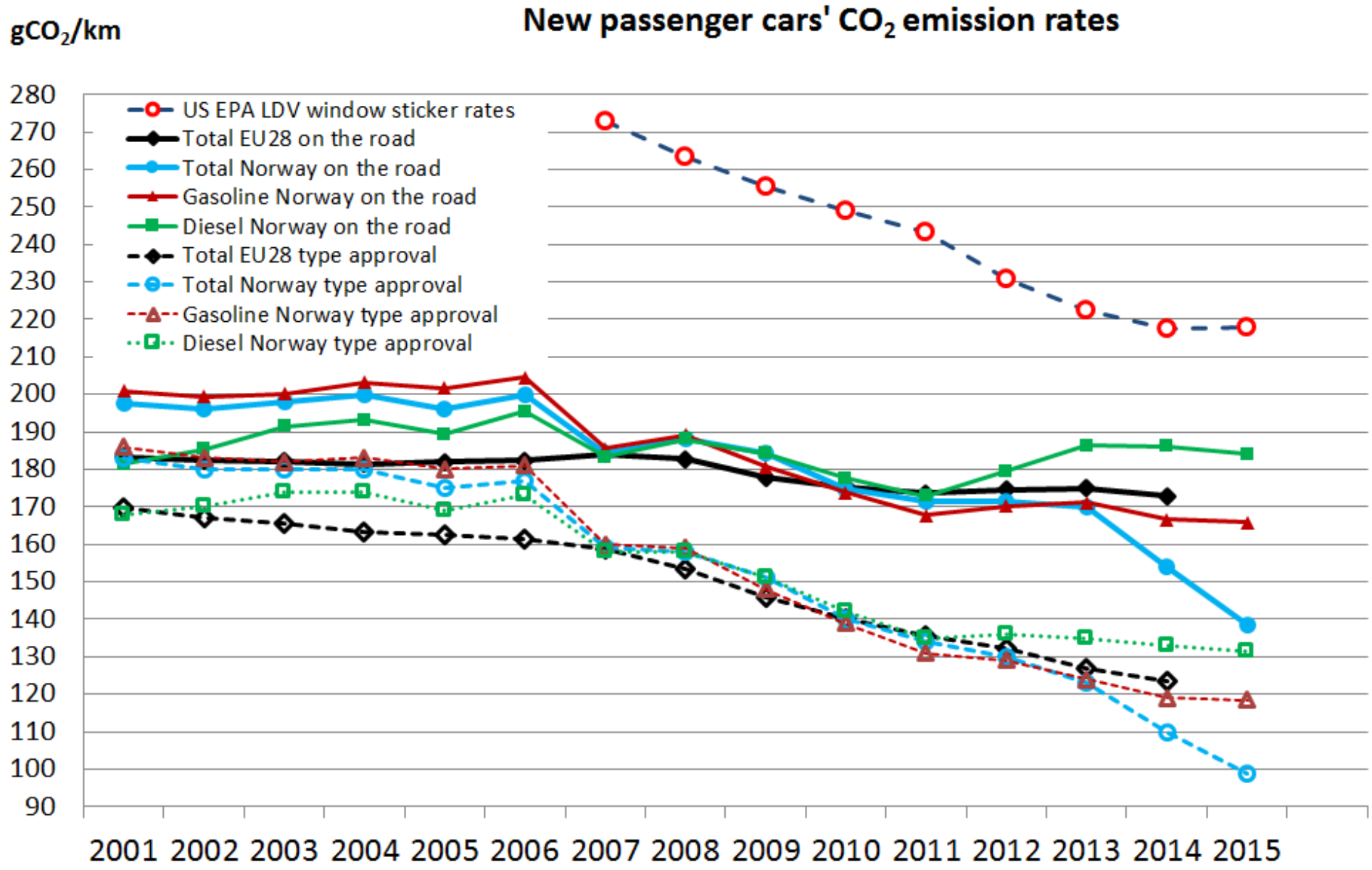
Sources: www.ofv.no, EEA (2015)

Type approval (NEDC) and real-world emissions from new cars



Sources: www.ofv.no, EEA (2015), Tietge et al. (2015)

Comparing US and European emission rates



Sources: www.ofv.no, EEA (2015), Tietge et al. (2015), Sivak and Schoettle (2016)

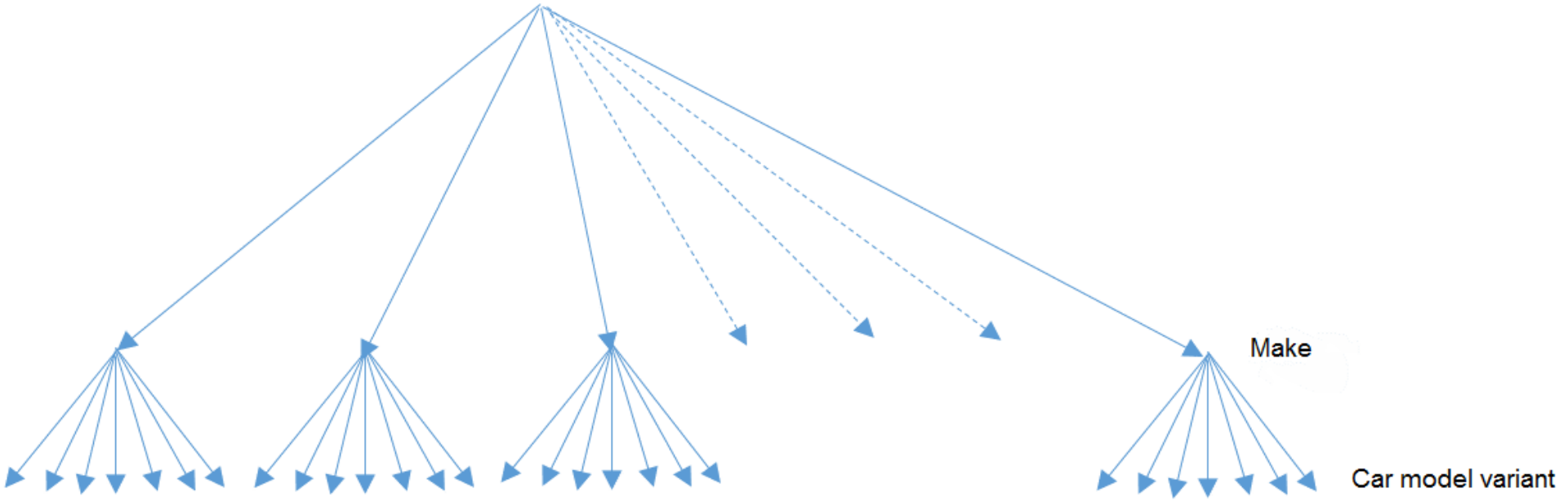
BIG: A generic nested logit model of new vehicle purchase

Estimated on complete disaggregate sales data from January 1996 through July 2011.

Model relies on objective variables only, covers the entire new car market, and contains no input on vehicle owners personal.

The upper nests consist of 20 different makes plus a residual nest assembling ‘all other makes’.

Choice model predicts the market shares of new passenger car model variants under varying tax regimes.

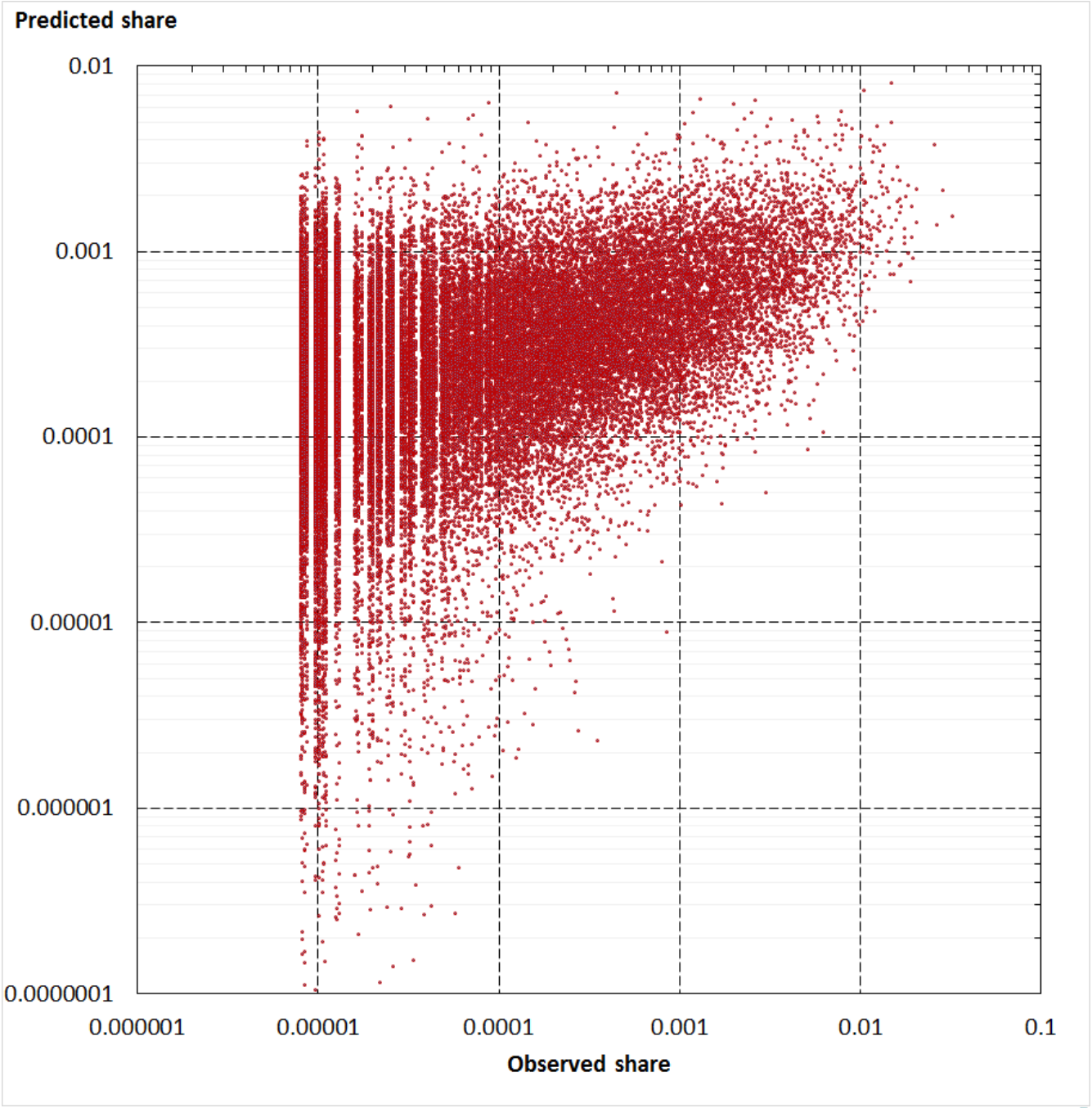


Source: Østli et al. (2016)

BIG: A discrete choice model of new passenger car purchases

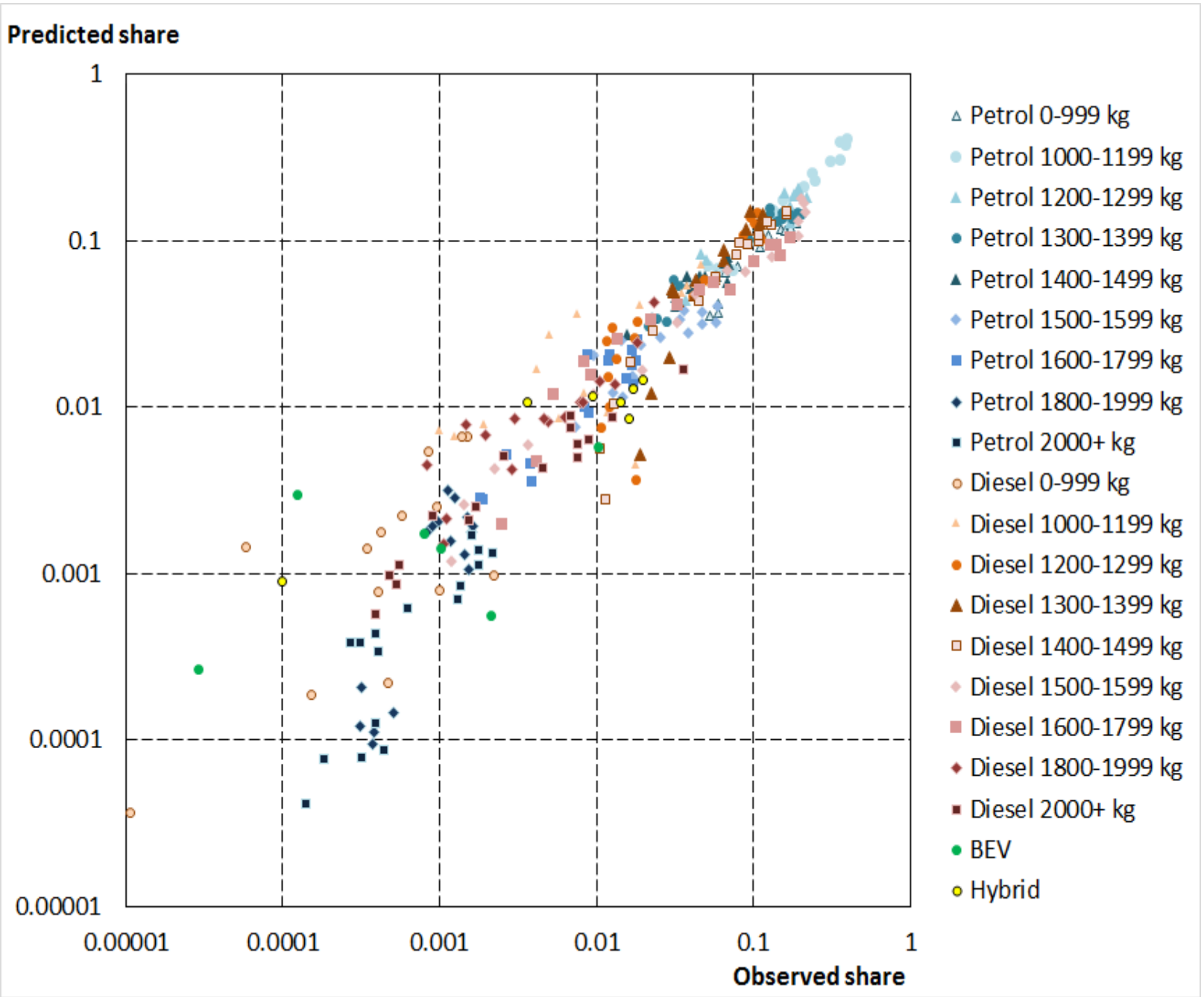
Independent variables include

- vehicle's make (dummy)
- list price (deflated)
- purchase tax amount (deflated)
- type of energy (gasoline, diesel, hybrid, battery)
- calculated kilometre cost of fuel (deflated)
- curb weight
- engine power
- number of seats and doors
- dummies for front, rear or 4-wheel drive

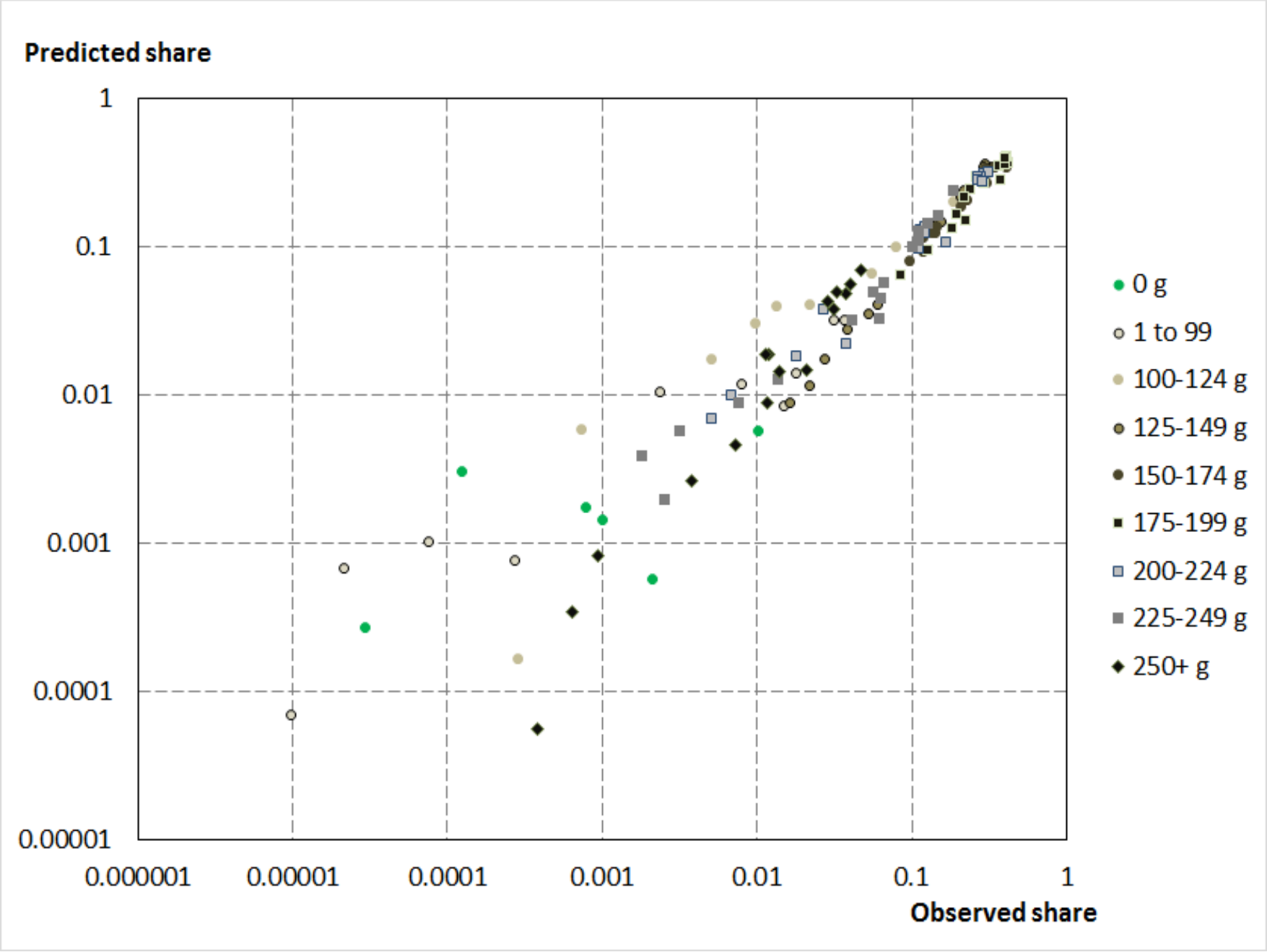


Disaggregate market shares in BIG: A generic discrete choice model of automobile choice

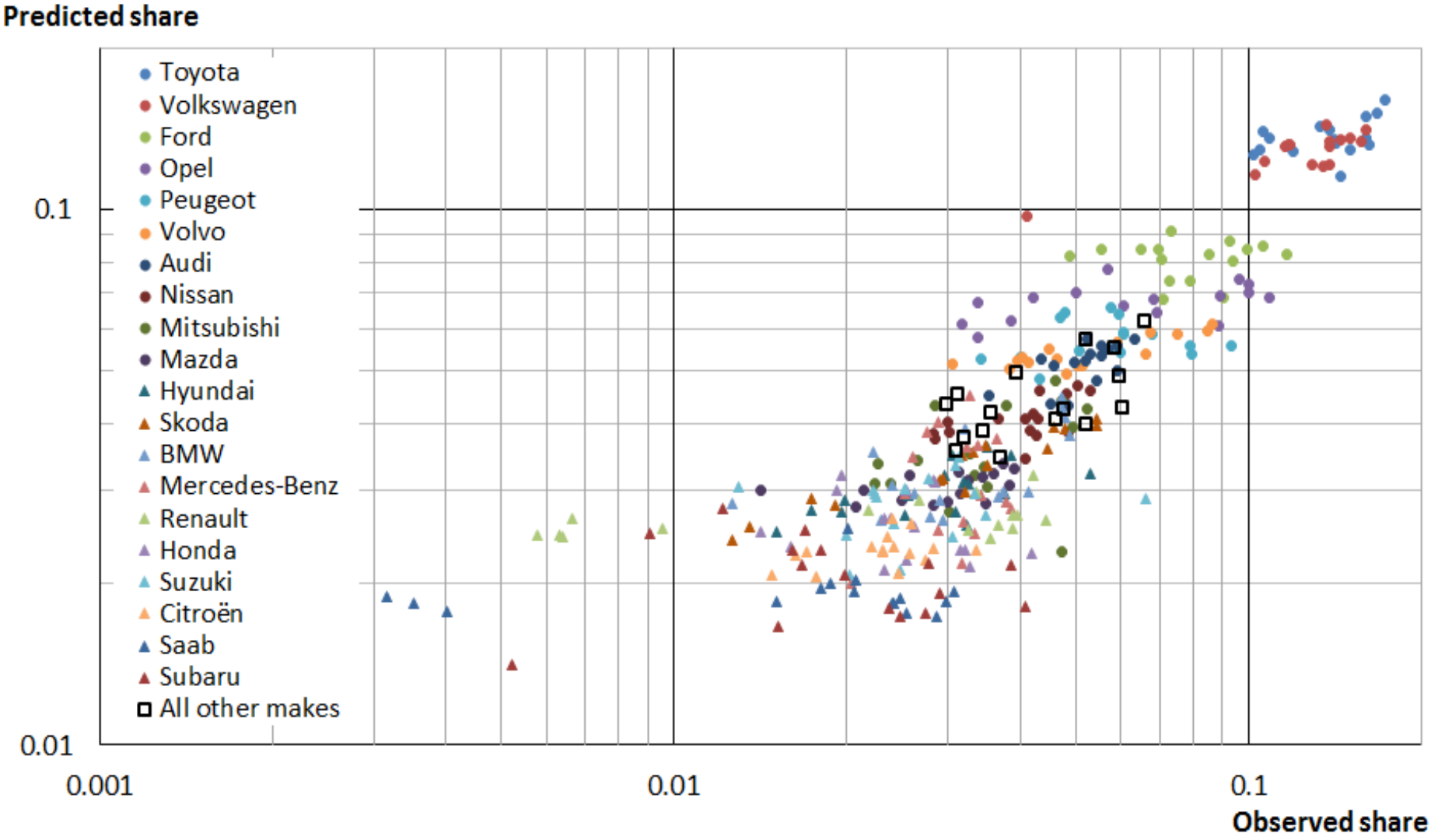
(Source: Østli et al. 2016)



Aggregation by fuel/weight. Source: Østli et al. (2016)



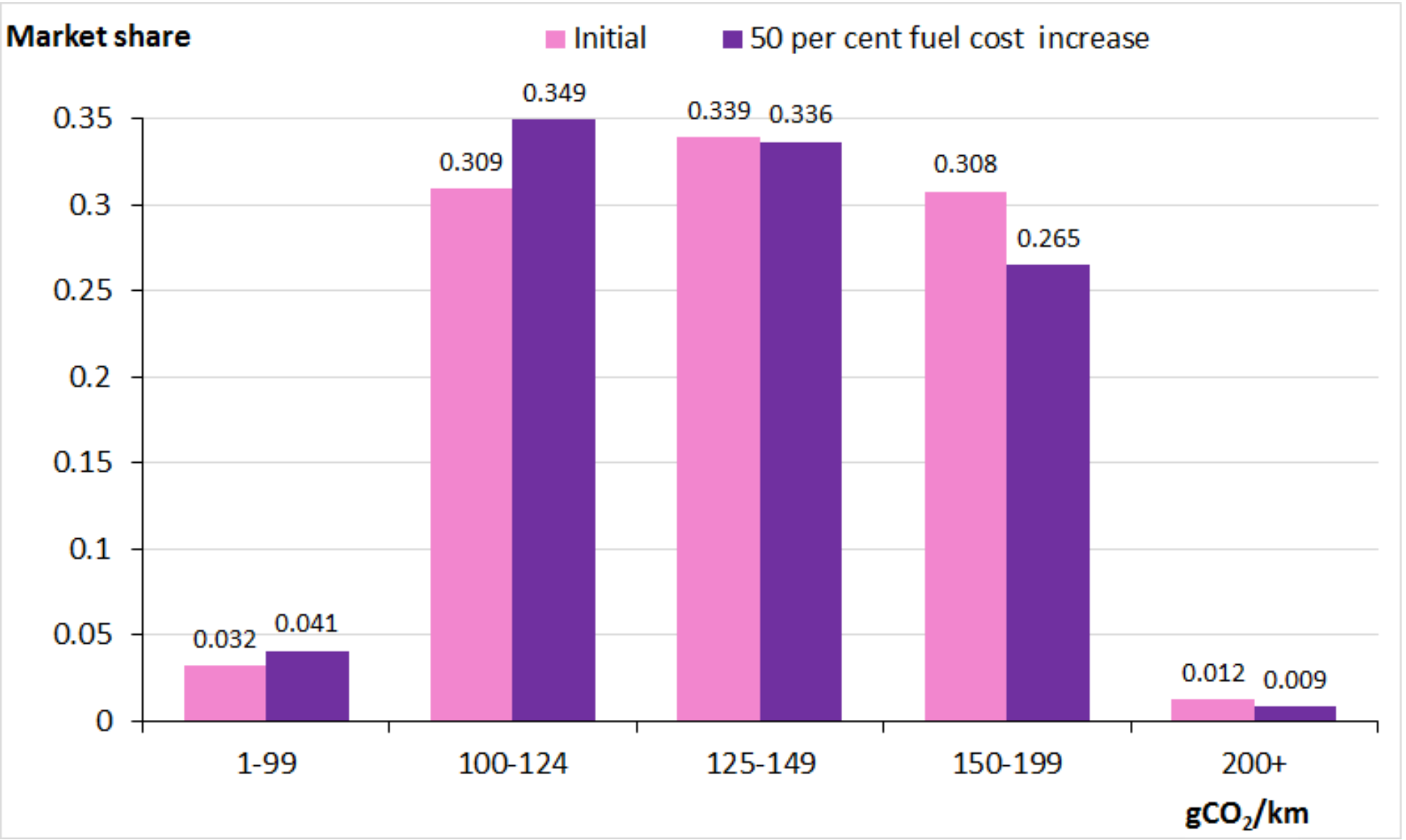
Aggregation by per km CO_2 emission level. Source: Østli et al. (2016)



Aggregation by make.
Source: Østli et al. (2016)

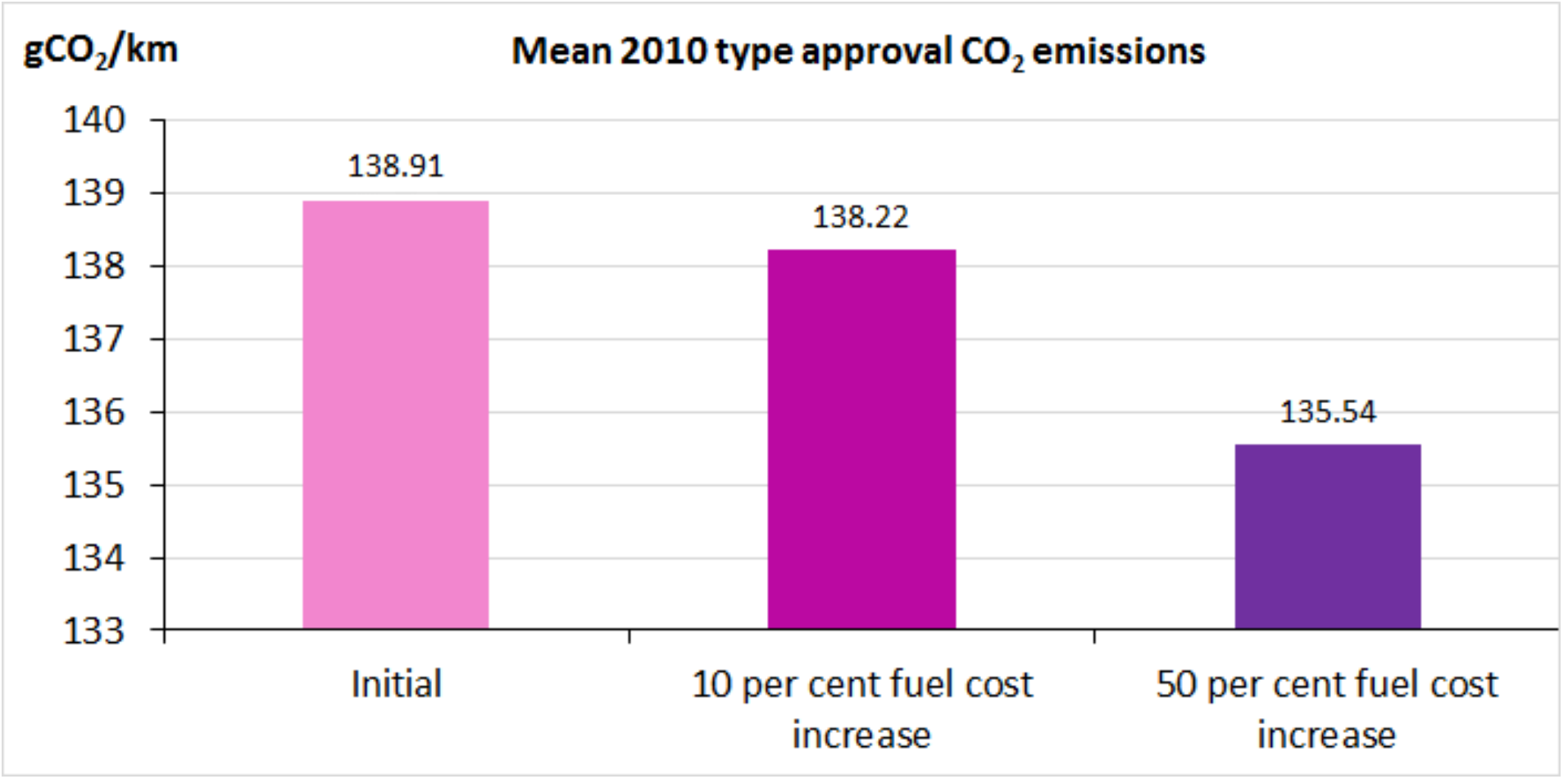
Effect of fuel cost on new vehicle sales

Source: Østli et al. (2016)



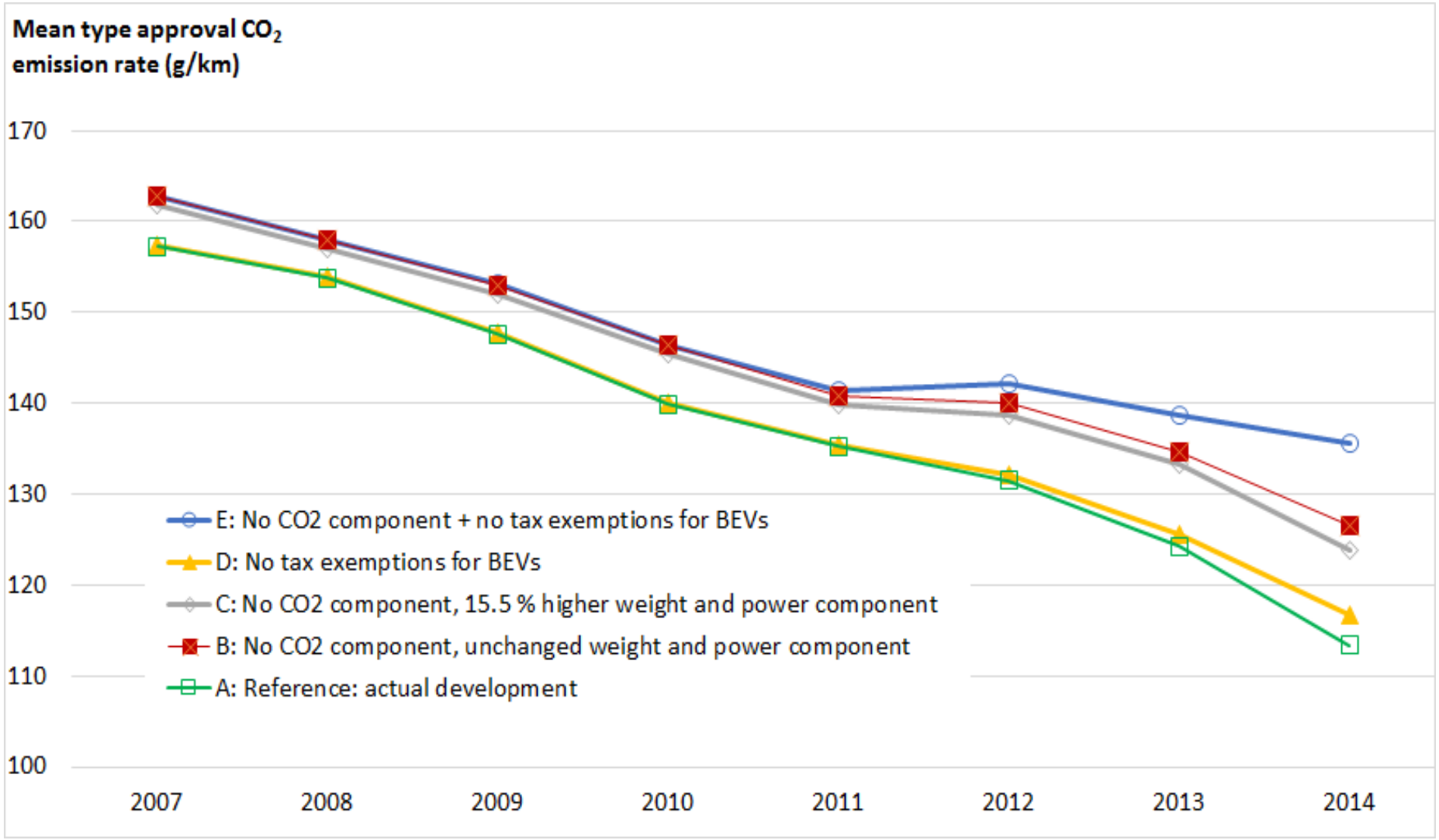
Effect of fuel cost on new automobile sales

Source: Østli et al. (2016)



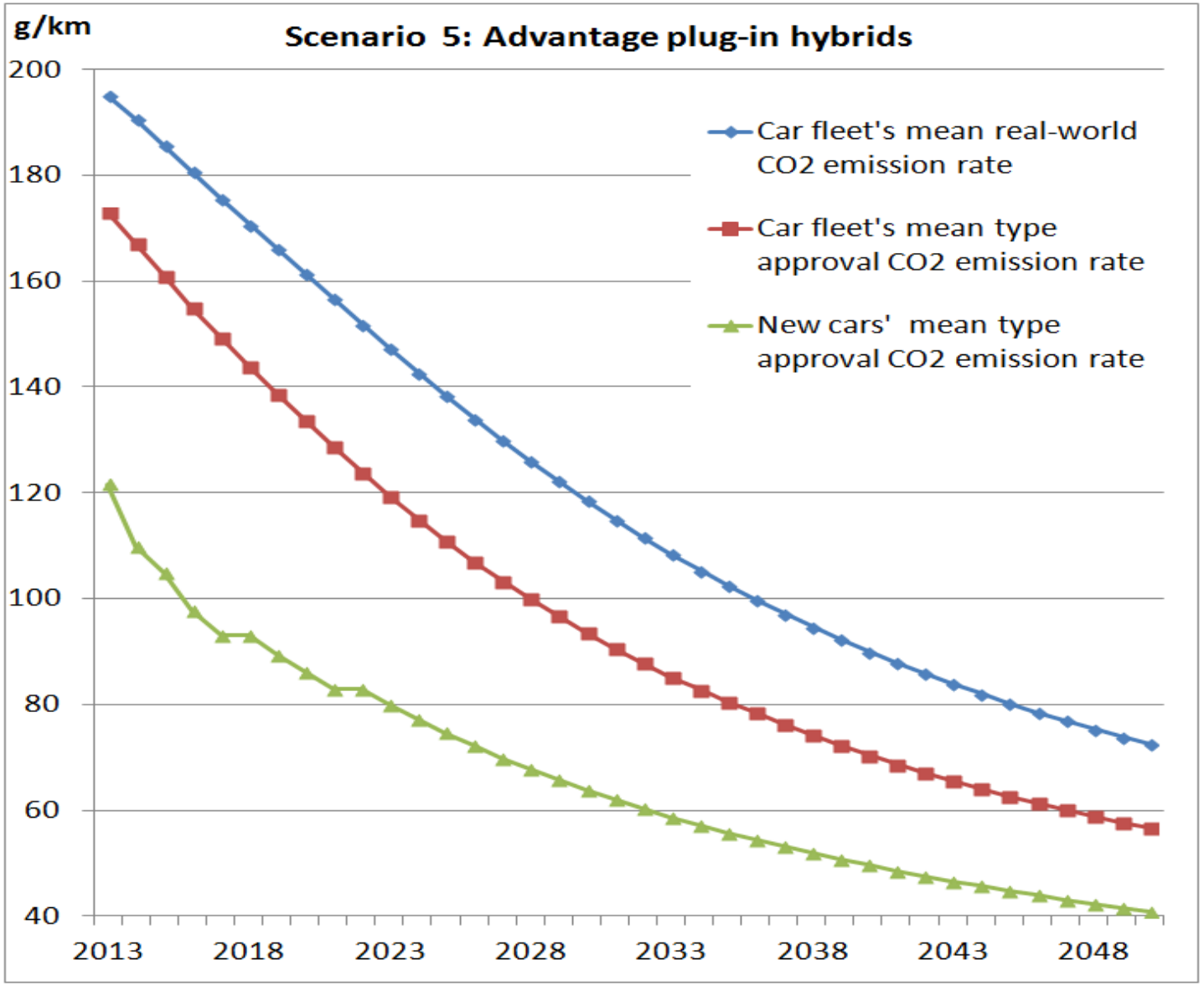
Effect of changes in purchase tax (1)

Counterfactual backcasting: 23 gCO_2/km differential in 2014 (20 %)



Source: Østli et al. (2016)

Three metrics for vehicle emissions



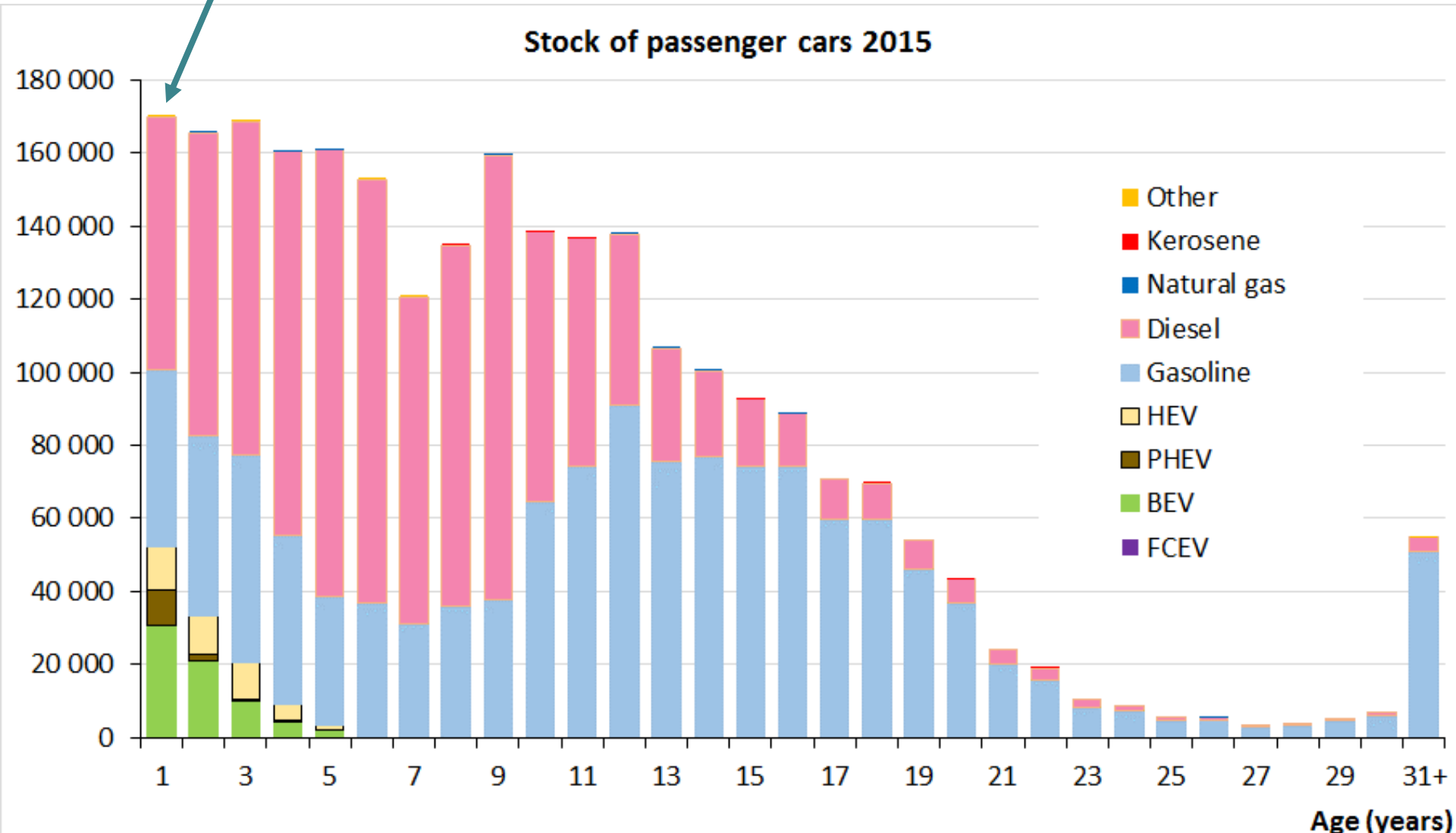
Source: Fridstrøm & Alfsen (2014)

How do we get from new vehicle sales to vehicle fleet characteristics?

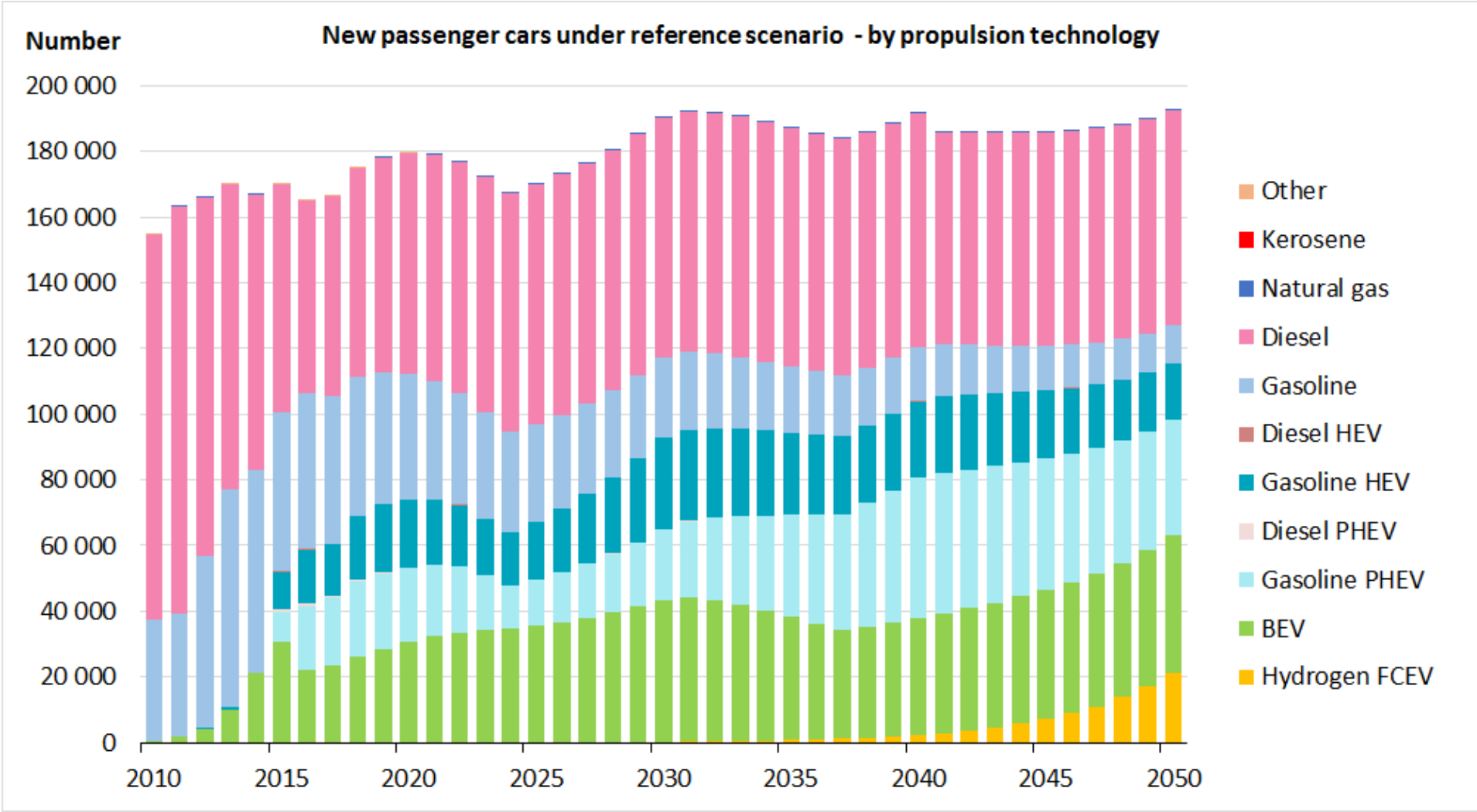
- Through bottom-up stock-flow cohort modeling!
- The Markov chain principle: Stock in year *n* follows from stock in year *n-1*, modified by flows determined by transition rates specific to each vehicle segment and age class.
- Empirical transition rates are calculable from a few years' stock data.
- Rates can be used to calculate survival curves and life expectancy by vehicle segment.
- Coefficients of interest can be assigned to cells in stock matrix: annual VMT, fuel mileage, emission rates, etc.
- Most important input is vector of new vehicles each year.
- Disaggregate discrete choice modeling (nested logit models) can be used to understand new vehicle purchases.

Automobile stock matrix as of year-end 2015 in Norway

Source: Fridstrøm & Østli (2016a)

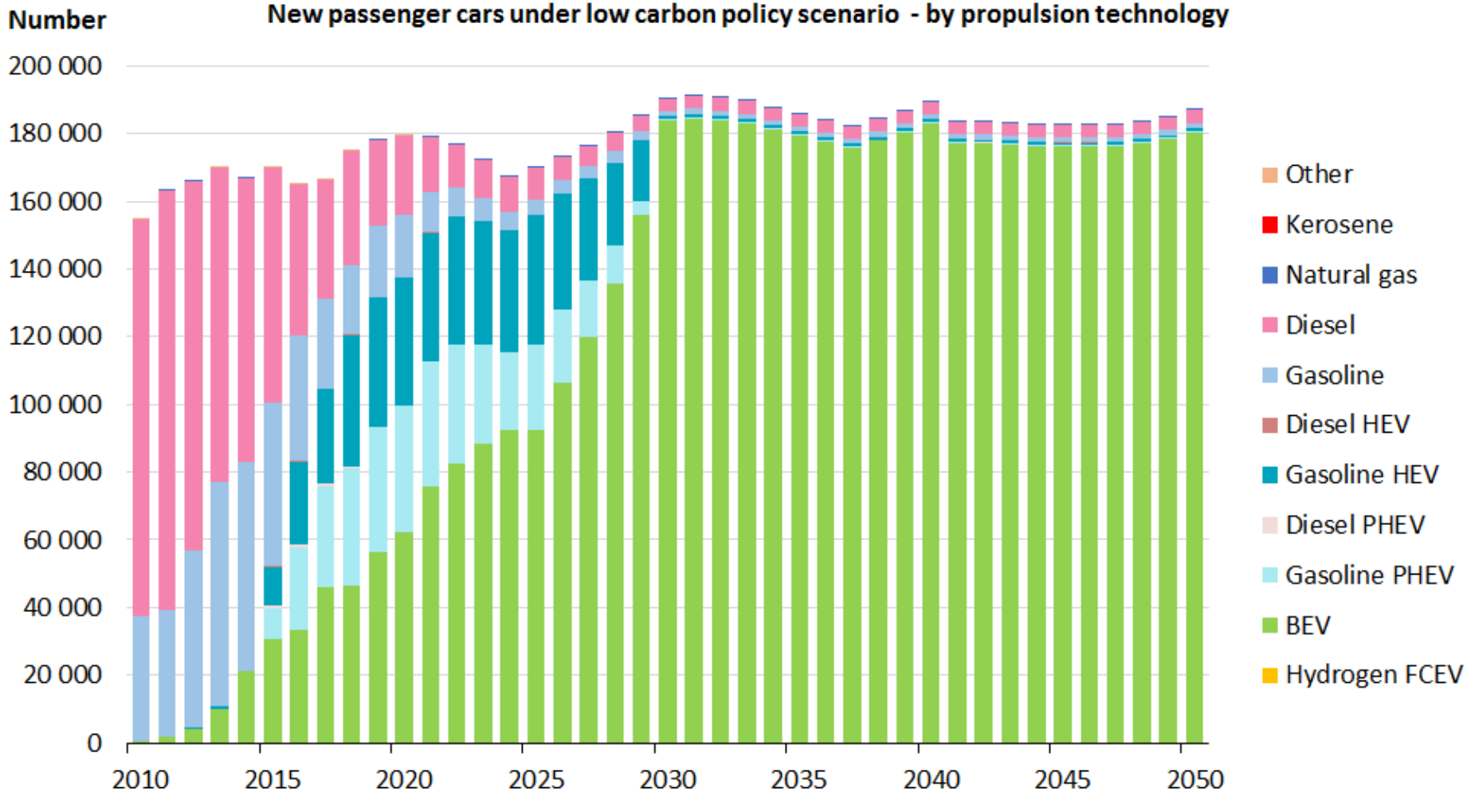


Business-as-usual (reference) scenario - flow of new passenger cars



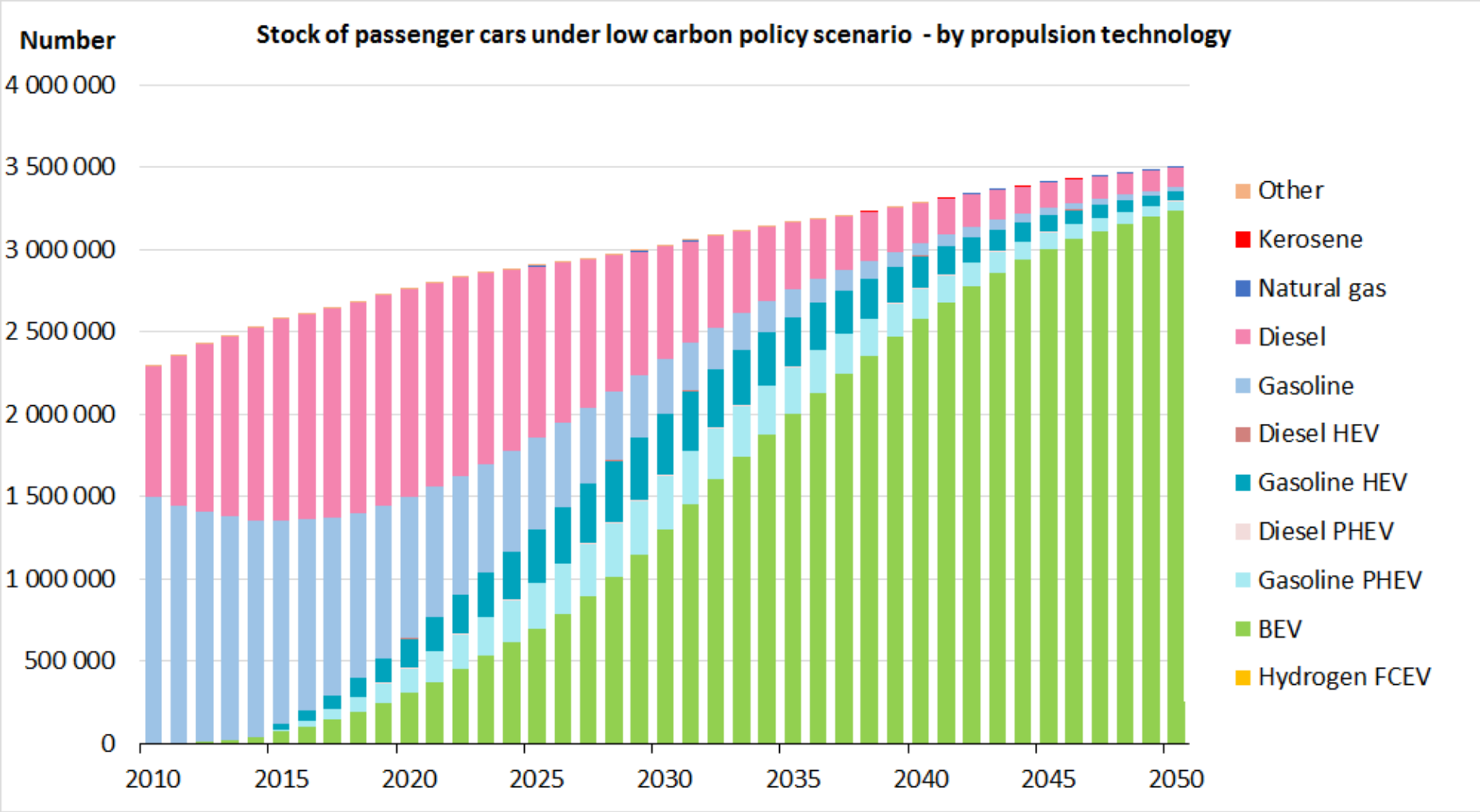
Source: Fridstrøm & Østli (2016a)

Low carbon policy scenario - flow of new passenger cars



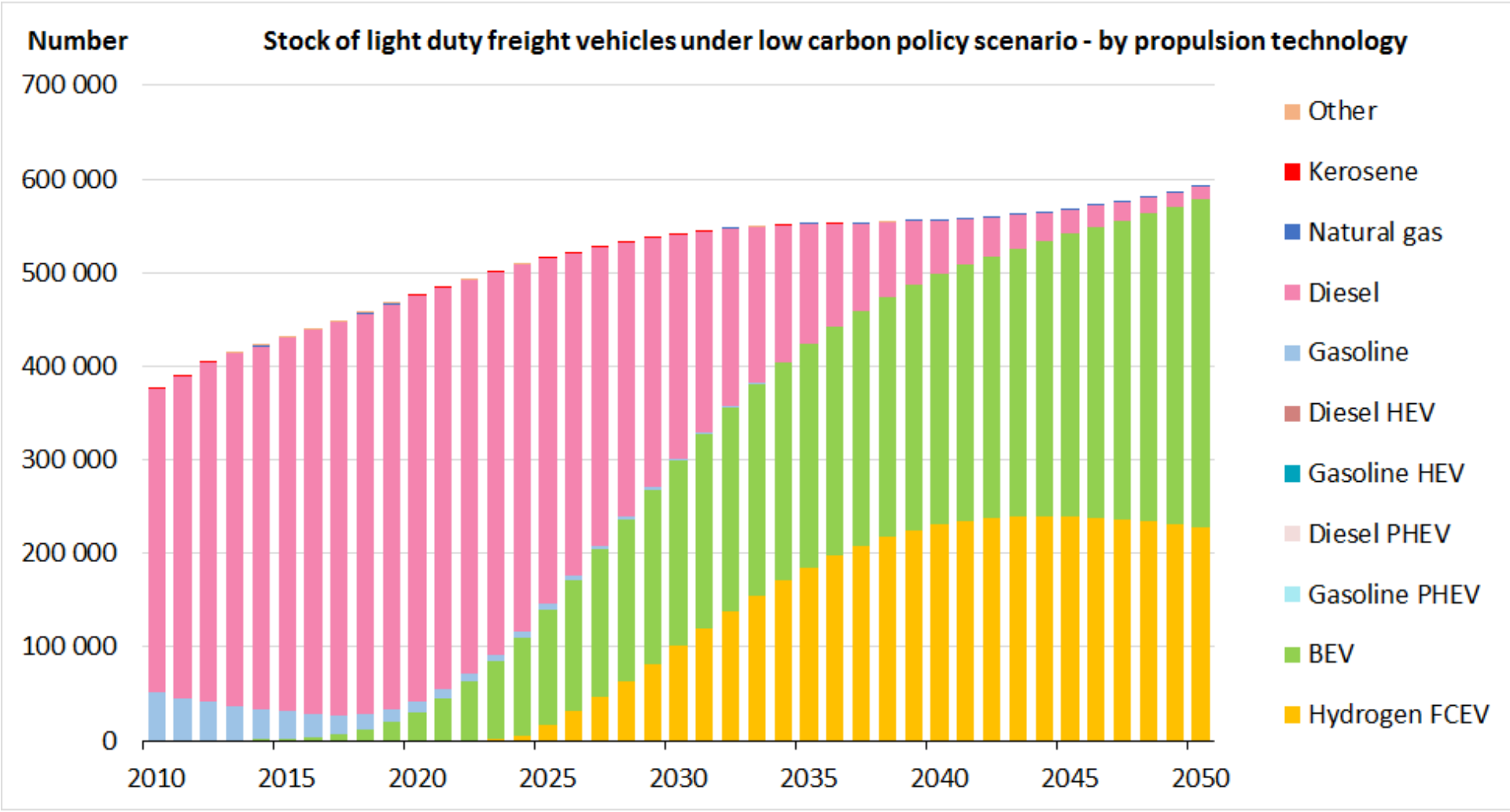
Source: Fridstrøm & Østli (2016a)

Low carbon policy scenario – stock of passenger cars



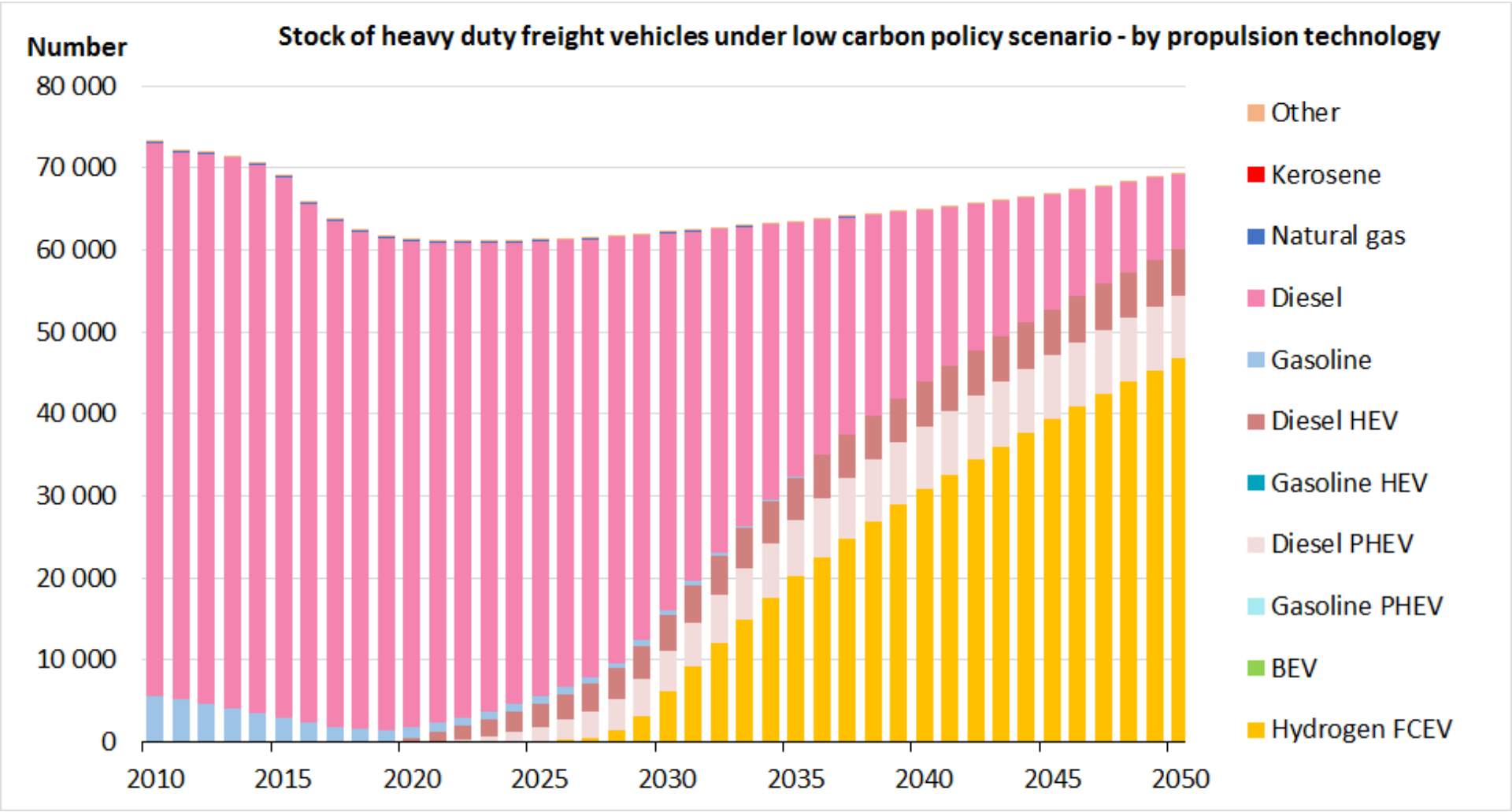
Source: Fridstrøm & Østli (2016a)

Low carbon policy scenario – stock of light trucks etc. (<3.5 t)



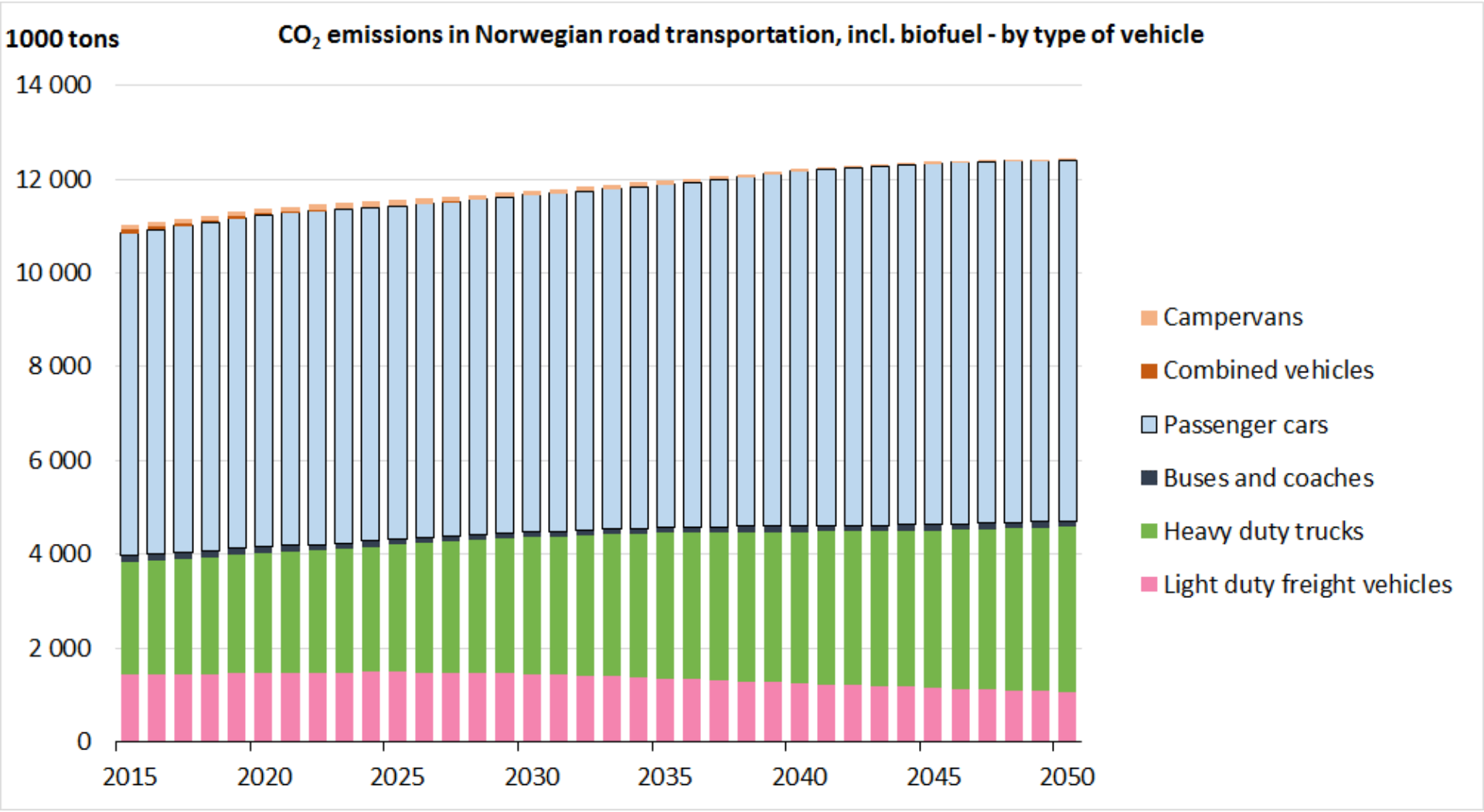
Source: Fridstrøm & Østli (2016a)

Low carbon policy scenario – stock of heavy trucks (>3.5 t)



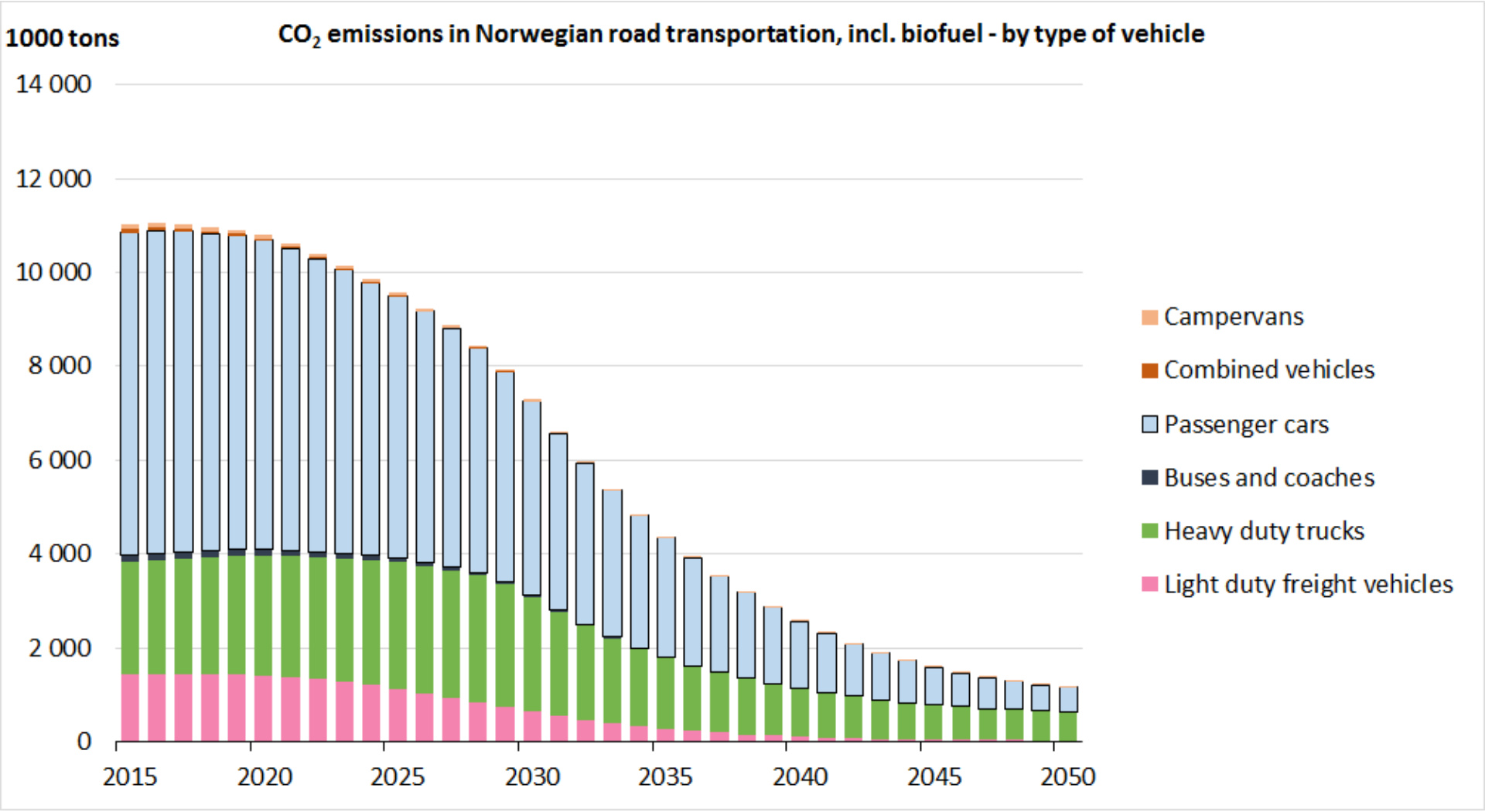
Source: Fridstrøm & Østli (2016a)

Reference scenario – CO_2 emissions



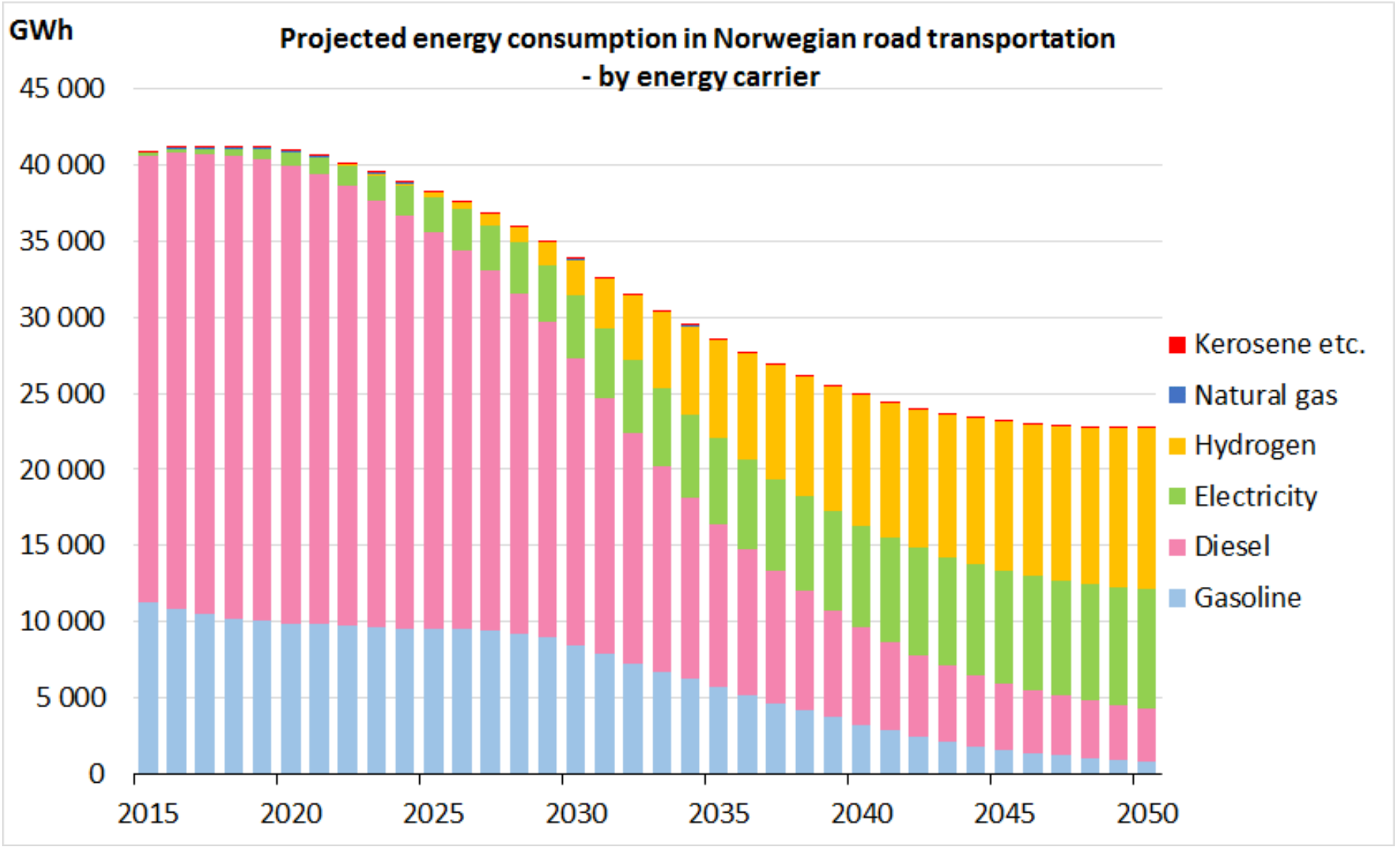
Source: Fridstrøm & Østli (2016a)

Low carbon policy scenario – CO_2 emissions



Source: Fridstrøm & Østli (2016a)

The low carbon policy scenario – energy consumption



Source: Fridstrøm & Østli (2016a)

A multiplicative decomposition

$$emissions = GDP \cdot \frac{ton/person\ miles}{GDP} \cdot \frac{vehicle\ miles}{ton/person\ miles} \cdot \frac{energy\ consumption}{vehicle\ miles} \cdot \frac{emissions}{energy\ consumption}$$

- reduced standard of living
- reduced trade and mobility
- new modal split
- improved energy efficiency
- new energy carrier

Decoupling amounts to changing certain factor(s).

The further to the left,
the higher the political and economic cost.

What have we learned? (1)

1. Economic incentives work, if they are strong enough.
2. Electrifying the automobile fleet through e. g. CO_2-graduated vehicle taxation is probably the single most effective GHG mitigation measure in transportation.
3. But it works only as fast as car fleet renewal. Stock-flow modeling is needed to estimate time lag between innovations affecting market for new cars and penetration into fleet.
4. Stock-flow models should be bottom-up, objective and exhaustive, including all relevant vehicle segments.
5. Taxing (or subsidizing) the vehicle for carbon emissions may not be as inefficient as claimed by economists. The choice of a new vehicle determines emissions 10-20 years ahead, regardless of who owns it.

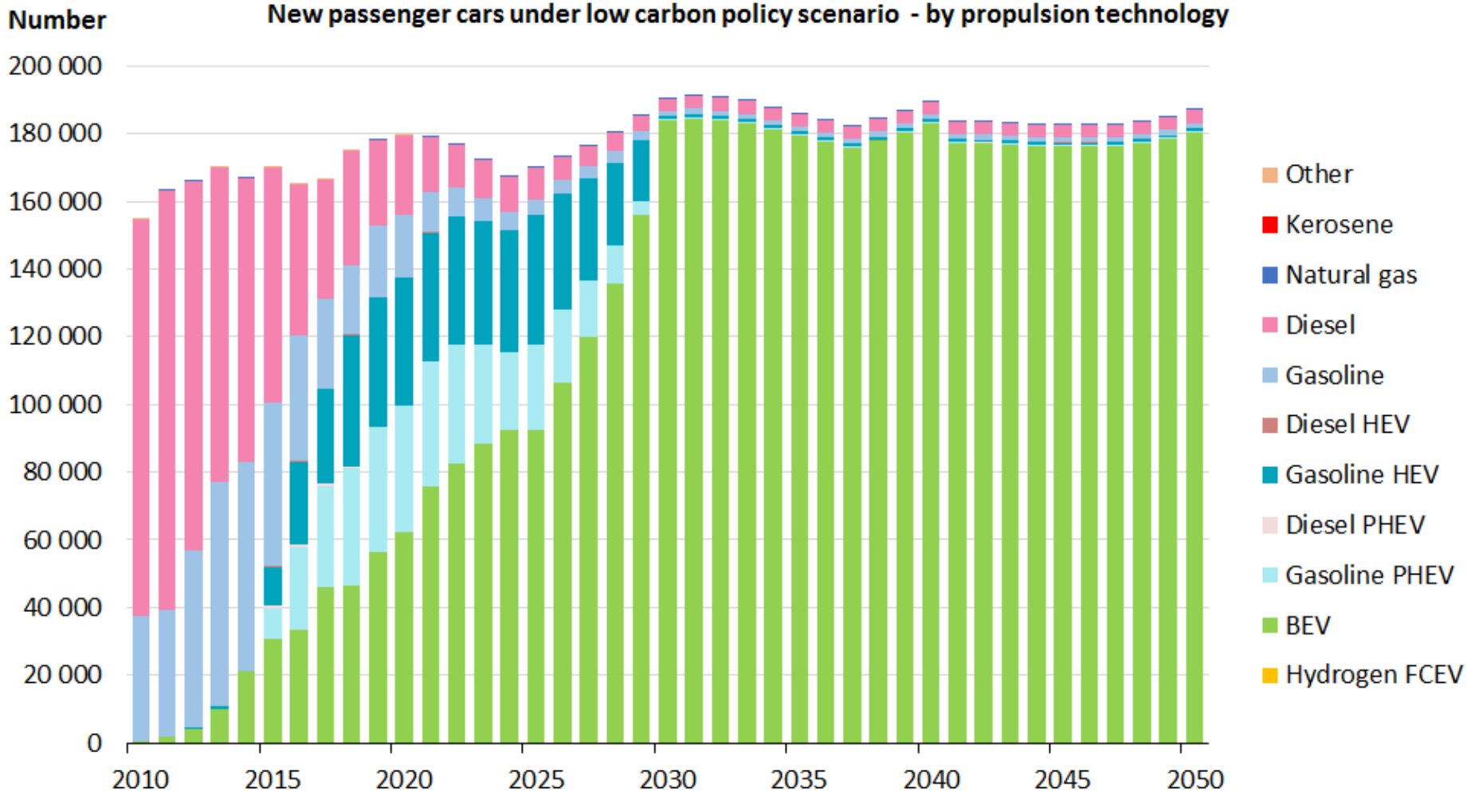
What have we learned? (2)

6. For countries without a cap-and-trade system, the effect of vehicle electrification depends on power generation mix.
7. Crucial to the cost and feasibility of electrification is how fast the manufacturing costs of BEVs, PHEVs and FCEVs will converge to those of conventional ICE vehicles.
8. Benefits will take the form of reduced (and possibly cheaper) energy use. BEVs are 3-4 times as energy efficient as ICE vehicles.
9. In the best of cases, future energy savings may outweigh extra acquisition costs. A long term economic perspective is needed.
10. The GHG mitigation potential of cheaper or improved transit is quite modest. It is hard to nudge car drivers into the bus.
11. The only promising way forward is decoupling through improved energy technology.

Research needs

1. How to make society choose this improved energy technology? It is not enough that such technologies exist – they must be competitive.
2. The everyday choices are made, not by governments, but by individual consumers and businesses.
3. Governments may influence choices by fiscal and regulatory incentives. Consumer response may be understood and predicted through behavioral economic modeling.
4. A price on carbon might help. It could apply to vehicles, energy carriers, or emissions. Policy research is crucial.
5. How to make buyers choose zero emission vehicles only by 2025 or 2030?

In short: how do we make car buyers choose like this?



Thanks for listening!

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References

1. Figenbaum E, Kolbenstvedt M (2015). Competitive Electric Town Transport. Main results from COMPETT – an Electromobility+ project. TØI Report 1422, Institute of Transport Economics, Oslo.
2. Figenbaum E, Kolbenstvedt M (2016). *Learning from Norwegian Battery Electric and Plug-in Hybrid Vehicle users – Results from a survey of vehicle owners*. TØI Report 1492, Institute of Transport Economics, Oslo.
3. EEA (2015). *Monitoring CO_2 emissions from new passenger cars and vans in 2014.* Technical Report No 16/2015, European Environmental Agency, Luxembourg.
4. Fridstrøm L, Alfsen K H (eds.) (2014). *Norway's path to sustainable transport.* TØI Report 1321, Institute of Transport Economics, Oslo.
5. Fridstrøm L, Østli V (2016a). *Vehicle fleet forecasts based on stock-flow modeling.* TØI Report 1518, Institute of Transport Economics, Oslo.
6. Fridstrøm L, Østli V (2016b). The vehicle purchase tax as a climate policy instrument. Paper under revision for *Transportation Research A: Policy and Practice.*
7. Fridstrøm L, Østli V, Johansen K W (2016). A stock-flow cohort model of the national car fleet. *European Transport Research Review* **8**: 22.
8. Østli V, Fridstrøm L, Johansen K W, Tseng Y-Y (2016). A generic discrete choice model of automobile purchase. Paper under revision for *European Transport Research Review.*
9. Sivak M, Schoettle B (2016). *Sales-weighted fuel-economy rating (window sticker) of purchased new vehicles for October 2007 through September 2016.* Transportation Research Institute, University of Michigan, Ann Arbor.
10. Tietge U, Zacharof N, Mock P, Franco V, German J, Bandivadekar A, Ligterink N og Lambrecht U (2015): *From laboratory to road: A 2015 update of official and 'real-world' fuel consumption and CO_2 values for passenger cars in Europe.* ICCT, Berlin.