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ICCT PHEV Webinar, June 2022

Real-world usage of plug-in hybrid electric vehicles in Europe

A 2022 update on fuel consumption, electric driving, and CO_2 emissions

Fraunhofer ISI: **Patrick Plötz**, Steffen Link, Hermann Ringelschwendner, Marc Keller, Cornelius Moll
ICCT: Georg Bieker, Jan Dornoff, Peter Mock

Summary: Analysis of 100,000 PHEVs confirms high deviation fro official fuel efficiency and CO_2 values.

2020 study

Background and study

- Plug-in hybrid electric vehicles (PHEVs) use electricity as well as conventional fuel for driving.
- They offer environmental benefits if they are mainly driven on electricity.
- The present study is the first large international and systematic study of real-world usage of PHEVs.

Findings

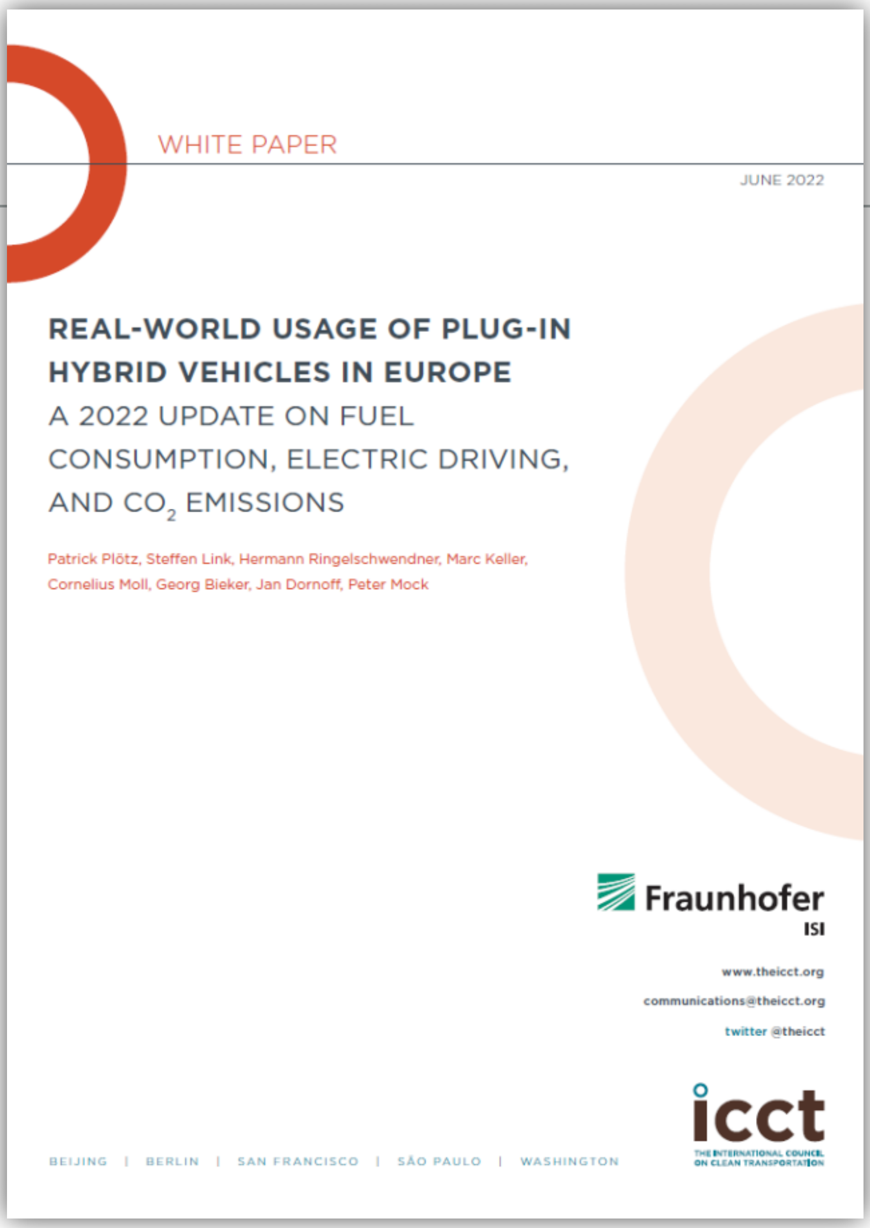
- PHEV **fuel consumption & tail-pipe CO_2 emissions are two to four times higher than type-approval**.
- Real-world **share of electric driving** of PHEVs **is about half the share in type-approval** values.
- PHEVs are **not charged every day**.
- PHEVs show **high annual mileage and many long-distance trips**.
- PHEVs **electrify many kilometers** per year.
- **Decrease engine power and increase range** to improve real-world fuel consumption & CO_2 emissions of PHEVs.

Source: ICCT/Plötz et al. (2020): Real-world usage of plug-in hybrid electric vehicles: Fuel consumption, electric driving, and CO2 emissions. ICCT White paper. Sept. 2020. https://theicct.org/publications/phev-real-world-usage-sept2020

This new PHEV study

- Update of 2020 study with new data
- Focus on Europe and WLTP certified vehicles
- Collection of new primary data
- Publication freely available:

  https://theicct.org/publication/real-world-phev-use-jun22/


WHITE PAPER

JUNE 2022

REAL-WORLD USAGE OF PLUG-IN HYBRID VEHICLES IN EUROPE

A 2022 UPDATE ON FUEL CONSUMPTION, ELECTRIC DRIVING, AND CO_2 EMISSIONS

Patrick Plötz, Steffen Link, Hermann Ringelschwendner, Marc Keller, Cornelius Moll, Georg Bieker, Jan Dornoff, Peter Mock

Fraunhofer ISI

www.theicct.org

communications@theicct.org

twitter @theicct

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Collection of PHEV real-world fuel consumption data

Data Collection:

- Collection of primary fuel consumption data from a large sample of PHEV in Europe
- No direct measurement of single vehicles but collection of data from large number of vehicles from
  - online fuel consumption diaries
  - company car fuel card data
  - online surveys
- Only results with new primary data are shown, no data from 2020 study used

Observed variables:

- long-term average fuel consumption in litres/100km
- annual mileage
- Make, model, variant and construction year
- Official test procedure fuel consumption $FC_{combined}$ (NEDC or WLTP assigned from make, model, variant, and year)

Derived variables:

- Deviation from test values: FC_{real} / $FC_{combined}$
- Electric drive share (e-km / total-km) (EDS)

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Data: New primary data from almost 9,000 individual PHEV from all of Europe covering 2013 – 2021.

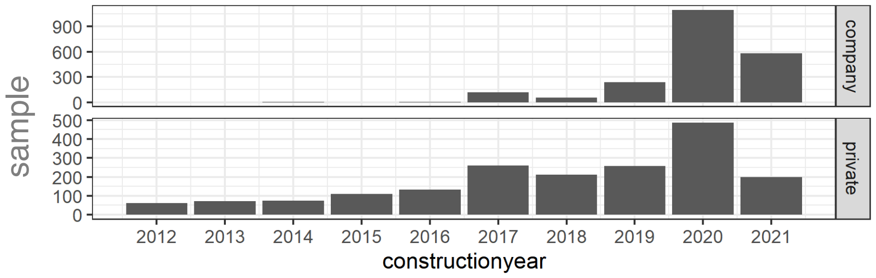
- **PHEV from Germany**
  - online fuel log diary Spritmonitor.de (N = 2,666)
  - DLR survey for Germany (N = 1,531)
  - from 13 companies in Germany (N = 2,924)
- **Rest of Europe**
  - *Private*: non-German Spritmonitor users and other online fuel log sources (carbuyer.co.uk, honest-john, fiche-auto, MILE21)(N = 1,609;
    UK 370; FR 261; AT 226; 50 – 100 in NL, CH, FI, HU, IT, BE, DK)
  - *Company cars*: N = 119 in AT + 4 from survey
- **PHEV model years** 2012–2021, mainly 2017–2021

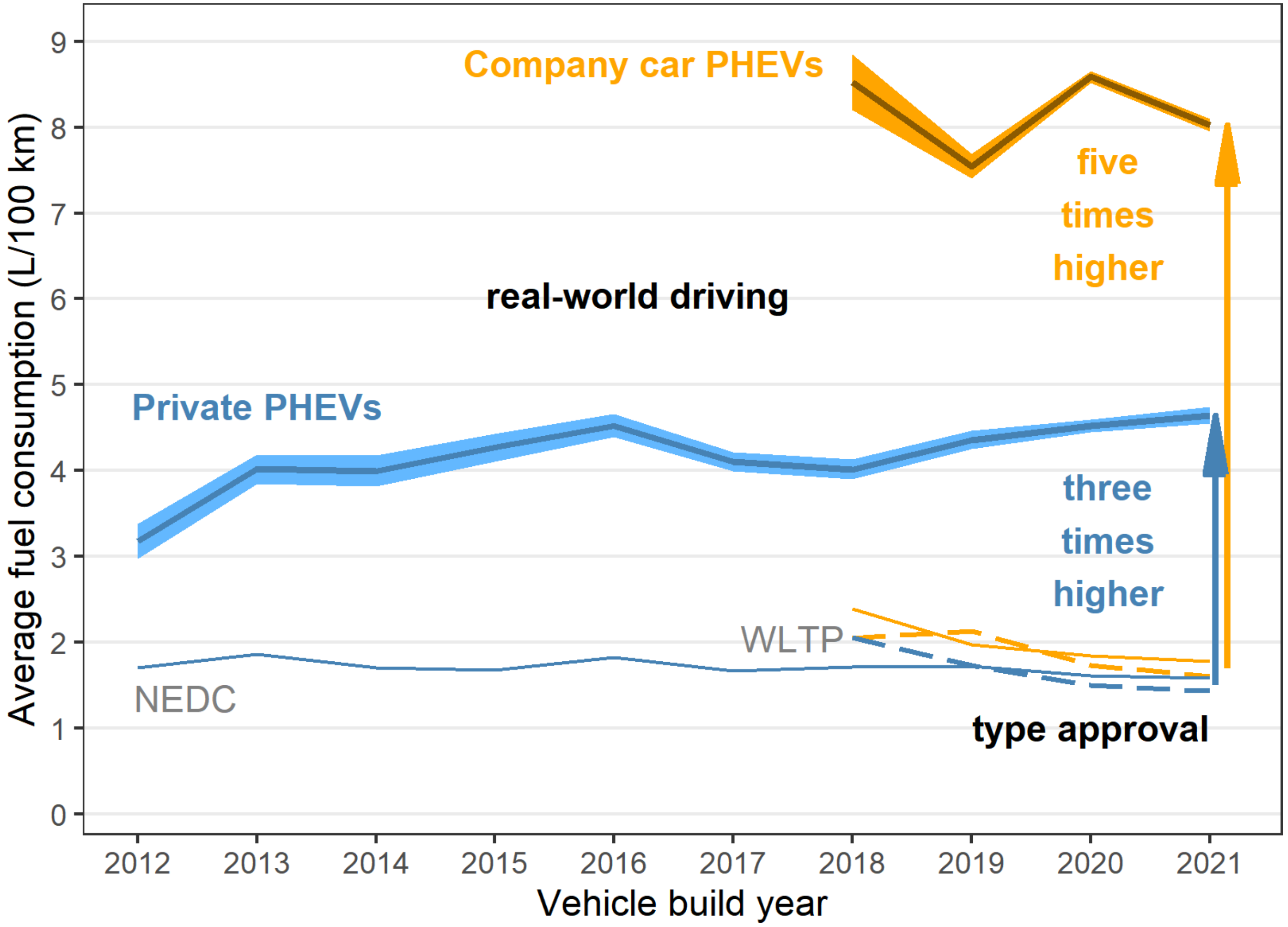
PHEV in sample	Germany	Rest of Europe	Total
Private	4,199	1,609	5,808
Company car	2,924	123	3,047
Total	**7,123**	**1,732**	**8,855**

PHEV in sample	Only NEDC	Only WLTP	NEDC & WLTP
Private	2,536	25	3,242
Company car	229	0	2,817
Total	**2,765**	**25**	**6,059**

Real-world fuel consumption of private PHEV is growing but fuel consumption is even higher for company cars.

- Shown is the mean (± one standard error) fuel consumption of PHEV by vehicle build year
- The sample mean WLTP fuel consumption is shown as dashed line (NEDC mean is thin solid)
- Deviation between type approval and actual fuel consumption is increasing for private PHEVs and high for company cars





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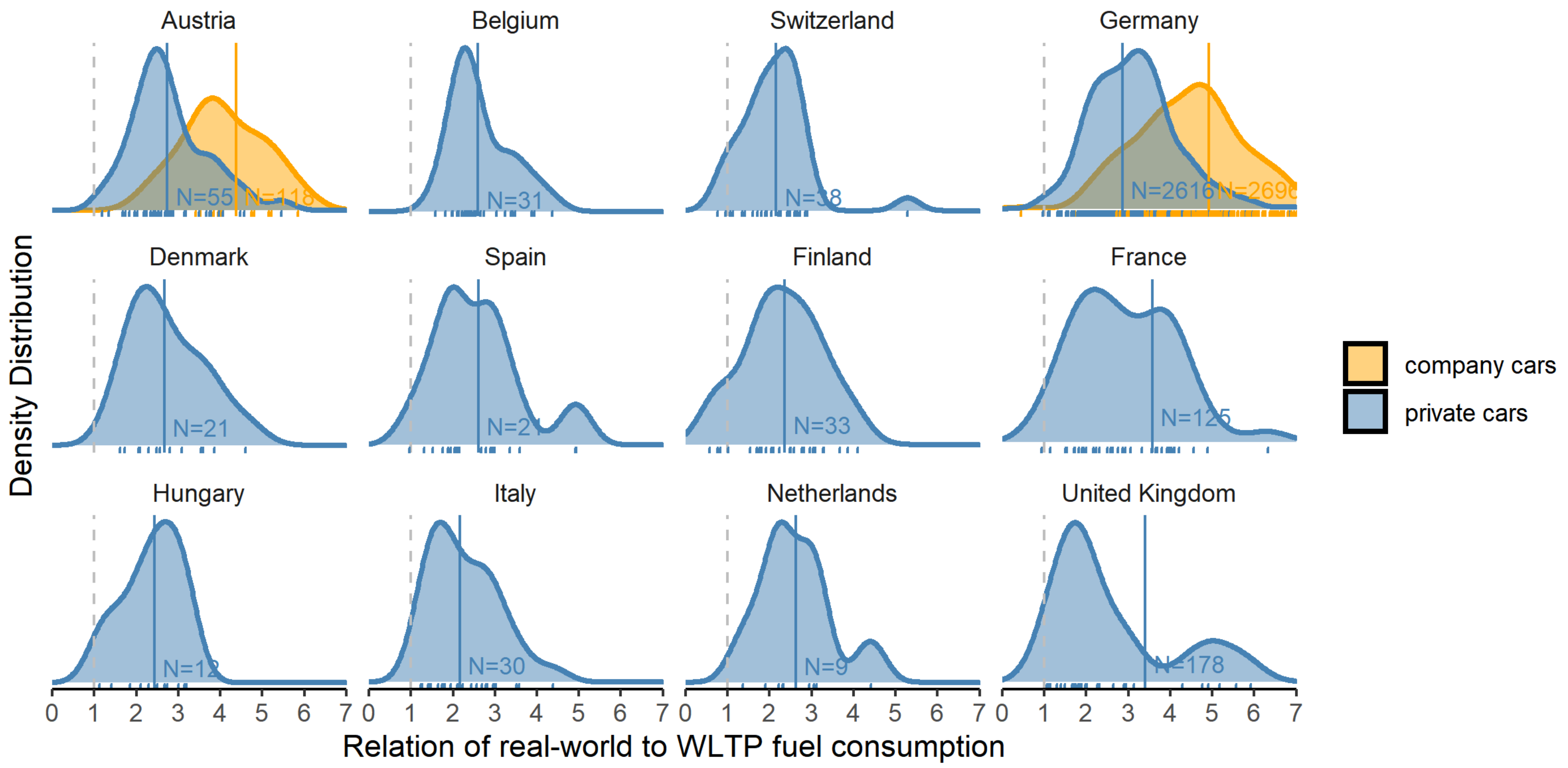
Real-world fuel consumption is ca. 3 times higher than WLTP for private & ca. 5 times higher for company cars.



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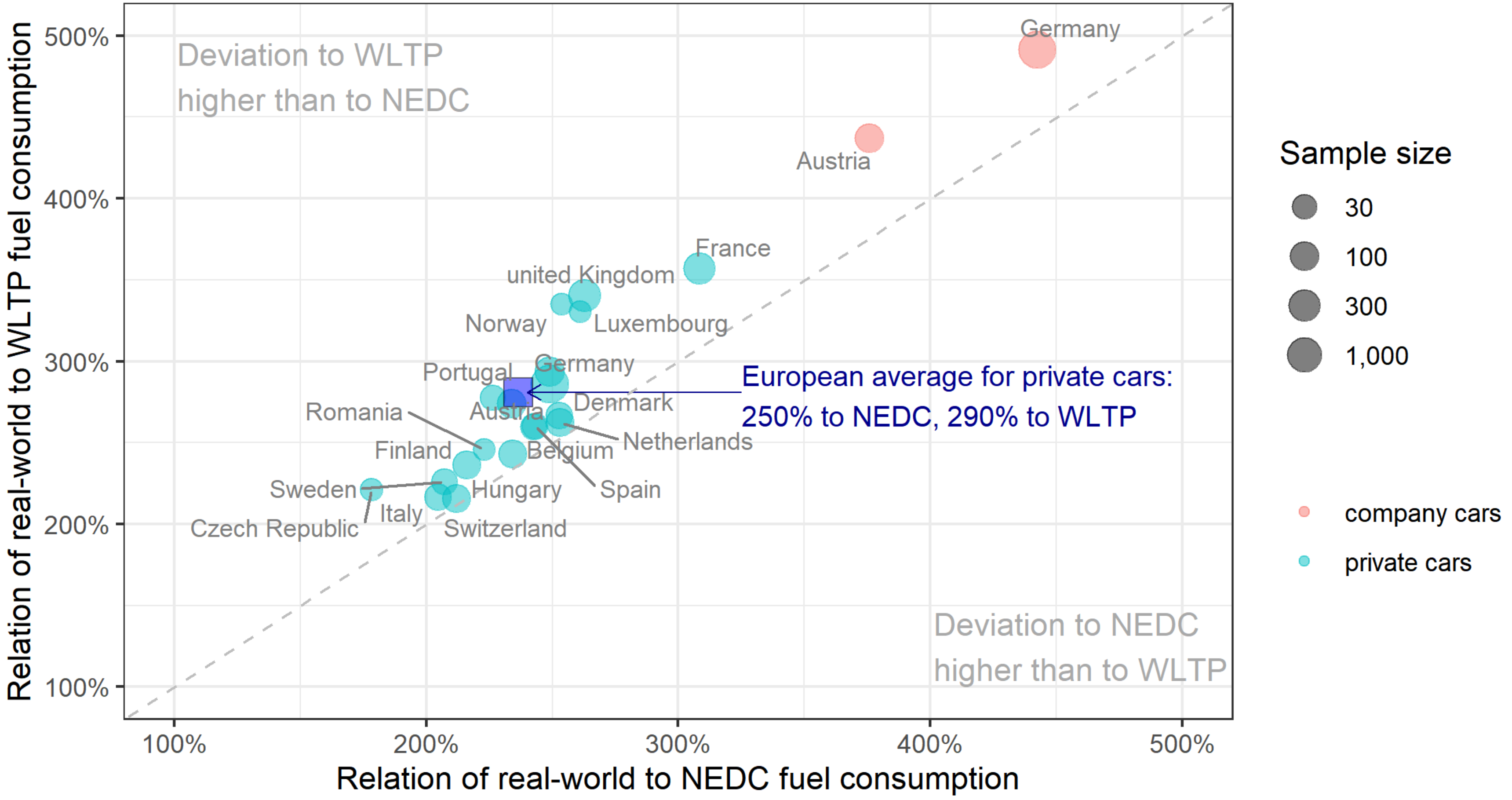
Deviation to real-world is larger for WLTP than NEDC in all countries indicating robustness.

Weighted mean deviation for **private vehicles**

- **270–310 % from WLTP → about 3 times higher**
- 240–260 % from NEDC for → ca. 2.5 times higher

Weighted mean deviation for **company cars**

- **455–520 % from WLTP → about 5 times higher**
- 420–460 % from NEDC → almost 4.5 times higher



Deviation is 220–240 % from NEDC for only NEDC certified private vehicles → ca. 2 times higher
Deviation is 360–410 % from NEDC for only NEDC certified company car vehicles → almost 4 times higher

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Technical factors and user behavior impact real-world PHEV fuel consumption.

- Regression results on individual vehicle level confirm earlier results on range, power, mass and user group but with an additional increase over time

Shown are regression results with (log of) fuel consumption and electric driving share (quasi-binomial logit regression) as dependent variable. We used sample size weighted regression with robust standard errors and the regression contains additional controls variables (country, mileage etc.). No noteworthy collinearity present. Ranges are from sample and model uncertainty. Results for electric driving shares are marginal effects.

Change in factor	Change in real fuel consumption	Change in electric driving share
+ 10 km WLTP range	–12% to –15%	+1 to +7 pp
+ 50 kW system power*	+3% to +8%	insignificant
+ 100 kg vehicle mass	+4% to +6%	Insignificant
+ 1 vehicle build year	+6% to +8%	Insignificant
User group: Company car	+45% to +55%	–39 to –25 pp

* System power = engine power + electric motor power, engine power > electric motor power in almost all models, main effect from engine power

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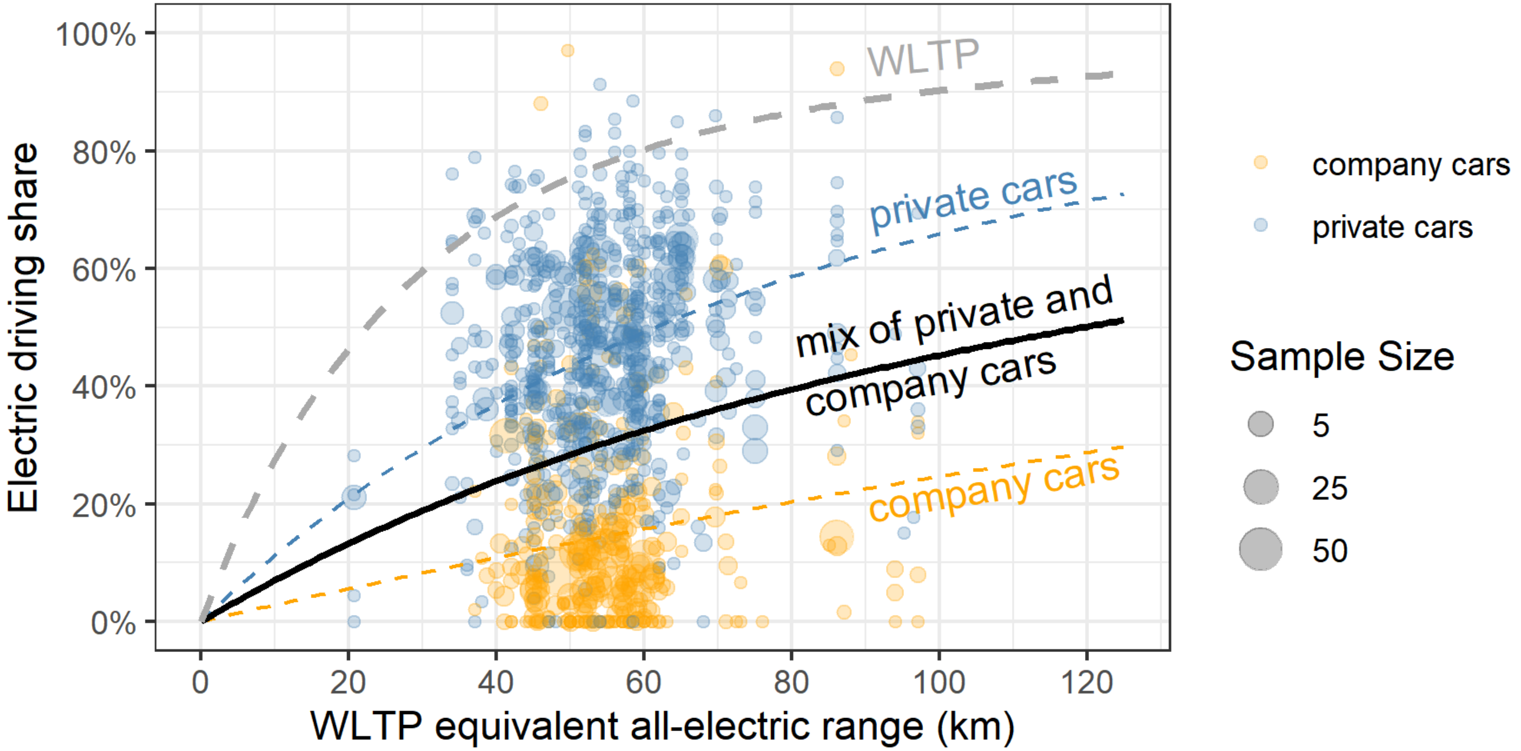
Realistic WLTP UF are possible with modified parameters.

- The UF in WLTP has a special mathematical form that can be modified to be more realistic
- We treat the WLTP constant $d_n = 800$ km as free parameter and fit it to the real-world data



- Real-world electric drive shares are higher for private vehicles than for company cars
- Assumptions needed for private & company car mixture to derive single parameter value
- Best estimate for mixture with ½ private + ½ company cars is $d_n = 4260 \pm 1100$ km

Compare also: Plötz & Jöhrens (2021): Realistic Test Cycle Utility Factors for Plug-in Hybrid Electric Vehicles in Europe. https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cce/2021/BMU_Kurzpapier_UF_final.pdf

$$\mathrm{UF}(\mathrm{R_{CDC}}, d_n) = 1 - \exp\left[-\sum_{i=1}^{10} c_i \left(\frac{\mathrm{R_{CDC}}}{d_n}\right)^i\right],$$

where $\mathrm{R_{CDC}}$ is the WLTP charge depleting range in km and the numerical constants c_i and d_n for Europe are $d_n = 800$ km, $c_1 = 26.25, c_2 = -38.94, c_3 = -631.05, c_4 = 5964.83, c_5 = -25095, c_6 = 60380.2, c_7 = -87517, c_8 = 75513.8, c_9 = -35749, c_{10} = 7154.94$ according to (EC 2017)

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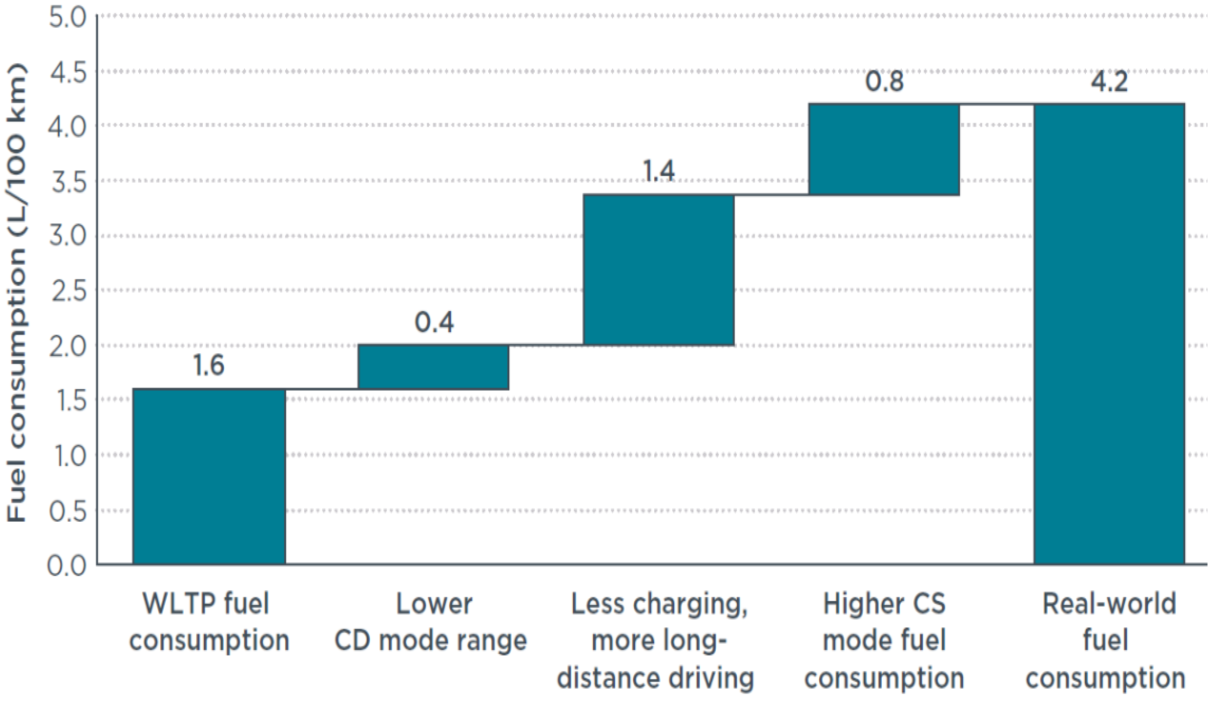
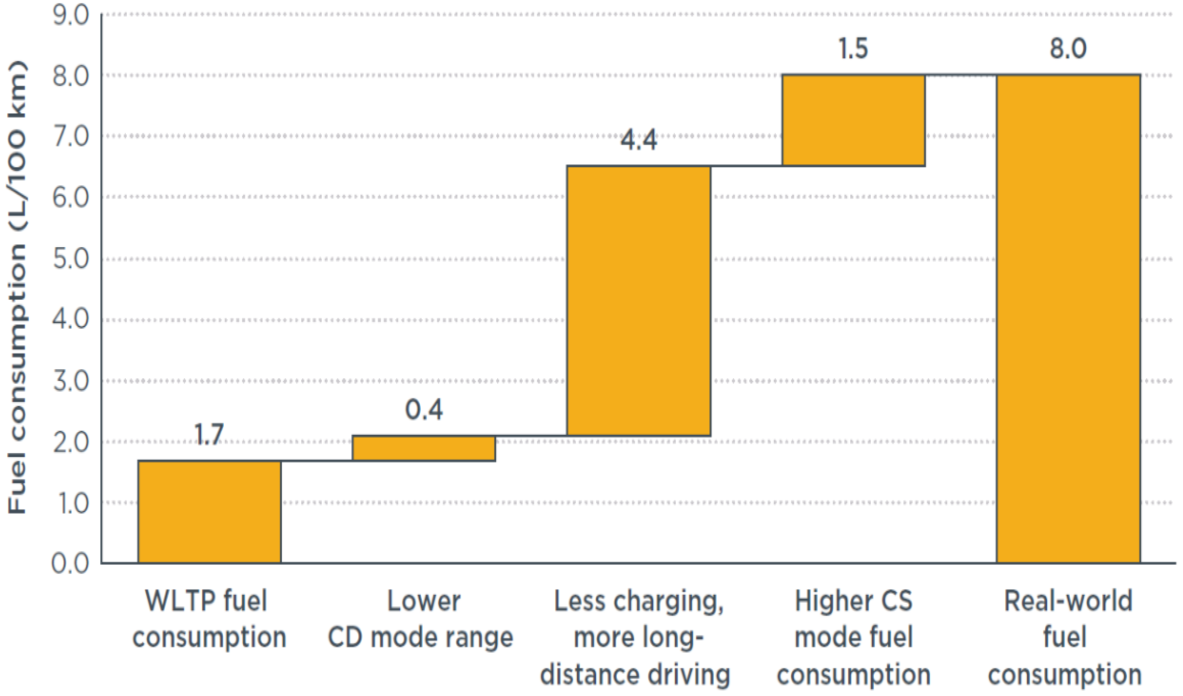
Limited charging and long-distance driving are the main factors for the deviation from type-approval.

Private car PHEVs



Company car PHEVs



Typically, about 1/3 of annual driving (of 15,000 km) from long-distance driving yielding, for example, an electric driving share of 2/3 * 100% + 1/3*10% = 70% even when charging every day (10% = 40 km range / 400 km distance).

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Conclusion: New plug-in hybrids deviate even more from test cycle fuel consumption than older vehicle models.

Discussion

- Sample small for most individual countries but general results similar in all countries
- Results consistent with findings from 2020 study but show increase in deviation to real-world
- Deviation has increased with build year but reasons unclear
  - potentially due to larger engines, larger vehicles and new buyers with less environmental concern or less charging or faster driving)
  - simultaneous changes in mass, power, range have been controlled for

Findings

- Results from 2020 ICCT & Fraunhofer ISI study largely confirmed
- PHEV fuel consumption and **emissions three to five times higher** than WLTP type approval
- Deviation higher for WLTP than for NEDC and higher for company cars than private cars
- **Deviation has been increasing** for private PHEVs by 0.1–0.2 L/100 km with every build year
- Real-world electric driving shares are 45% – 49% for private and 11% – 15% for company car instead of 70% – 85% in WLTP

Thank you for your attention!

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Dr. Patrick Plötz

Competence Center Energietechnologien und Energiesysteme
Fraunhofer-Institut für System- und Innovationsforschung ISI

Breslauer Straße 48 | 76139 Karlsruhe
Telefon +49 721 6809-289
patrick.ploetz@isi.fraunhofer.de

Real-World Usage of Plug-in hybrid vehicles in Europe: A 2022 update

Policy recommendations

Fraunhofer ISI: Patrick Plötz, Steffen Link, Hermann Ringelschwendner, Marc Keller, Cornelius Moll

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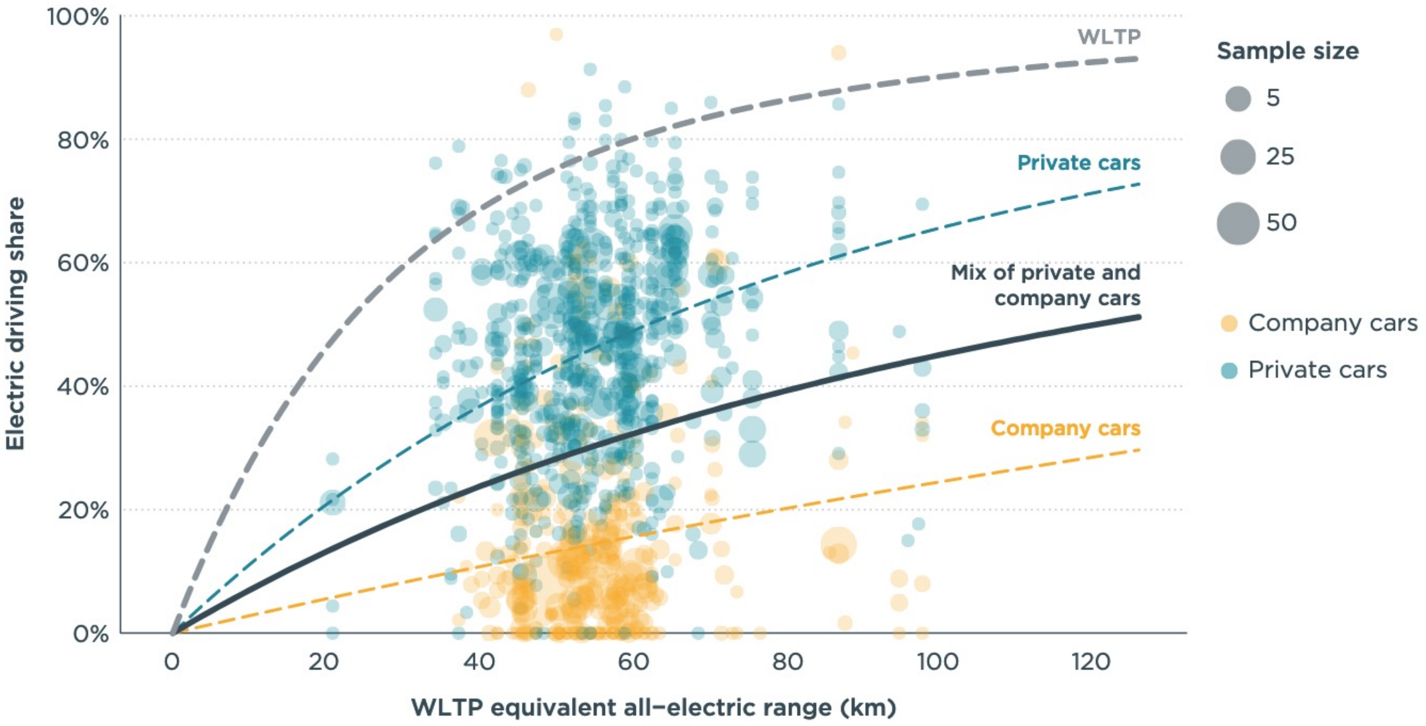
1) Adjust WLTP Utility Factor

PHEV electric driving share assumption in WLTP type approval should be adjusted to empirical evidence.

➡ Adjust d_n parameter in WLTP Utility Factor formula: d_n = 4260 km

The usage assumptions can be further refined based on fleet-wide data obtained from on-board fuel consumption monitoring (OBFCM) devices, but such data will not become available for several years.

Real-world electric driving share compared to WLTP assumption on charge-depleting mode driving share



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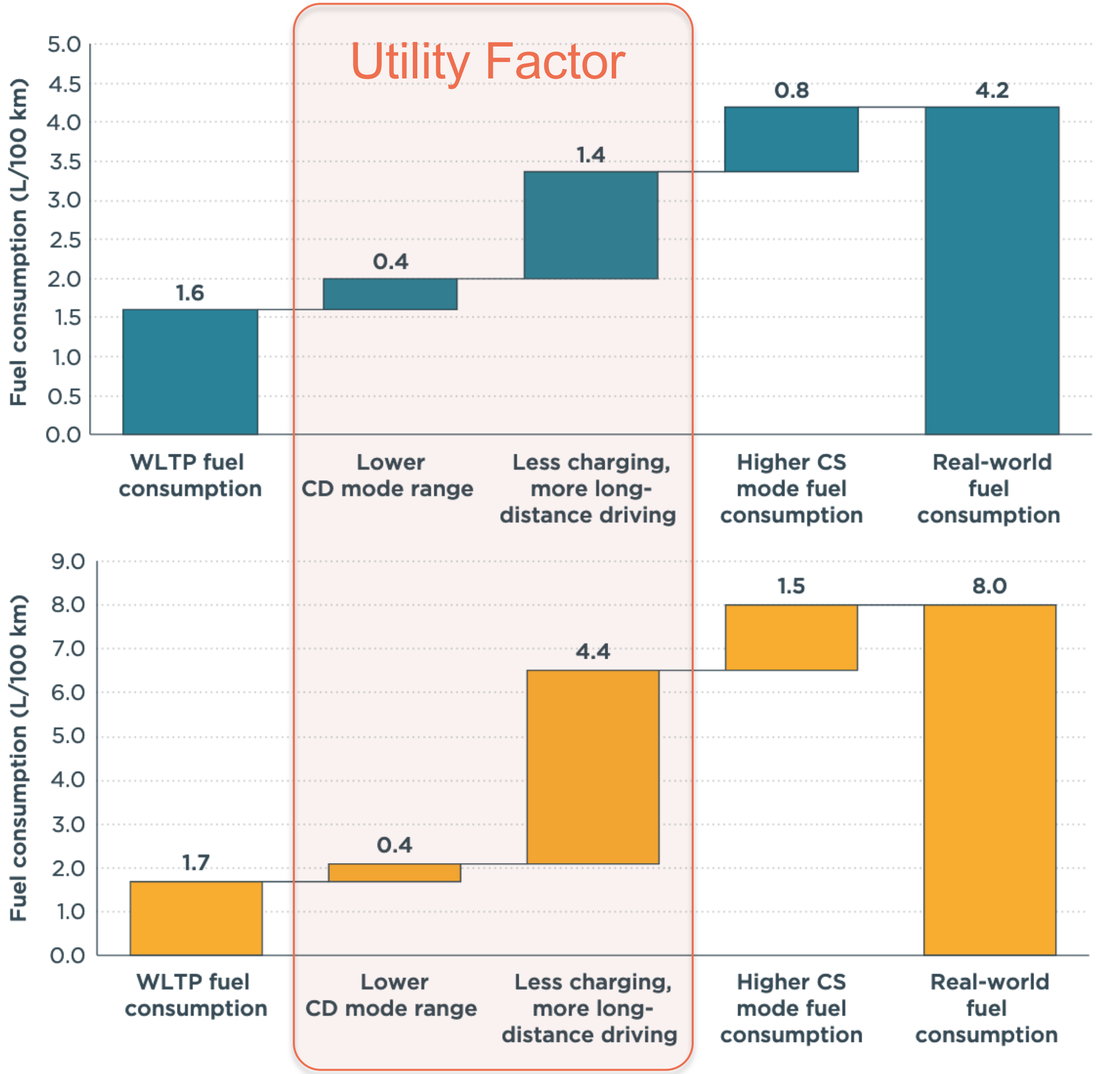
1) Adjust WLTP Utility Factor

Four factors impact the difference between WLTP and real-world fuel consumption:

1) Lower electric range
2) Vehicles are charged less frequently
3) More long-distance driving
4) Higher fuel consumption when driving on fuel

Adjusting the Utility Factor only covers factors 1) to 3).

The remaining gap is similar to hybrid electric vehicles and slightly higher as for conventional gasoline or diesel cars.



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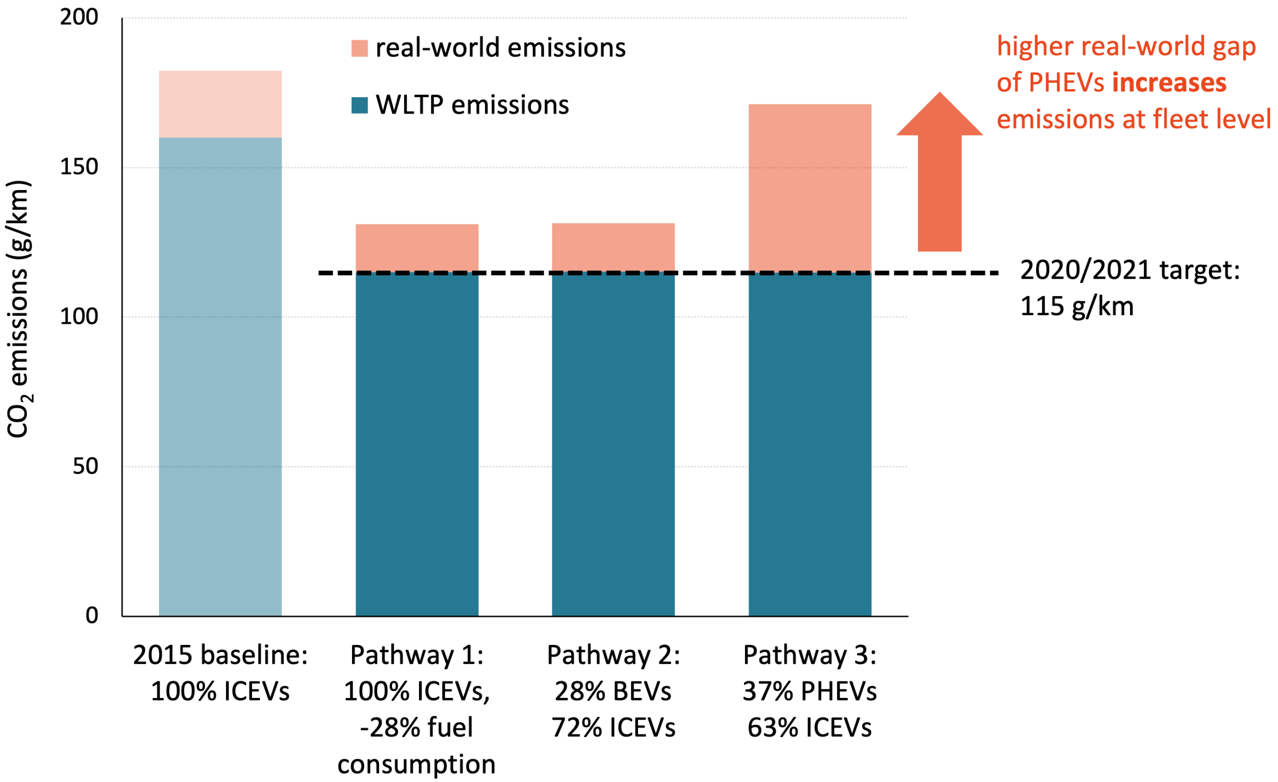
2) Purchase subsidies and tax incentives

With 3-5 times higher CO_2 emissions, meeting the CO_2 emission standards with PHEVs **increases real-world emissions** at the fleet level.

Purchase subsidies and fiscal incentives for PHEVs should either
be abolished or limited to users that demonstrate **< 2 L/100 km** and/or **> 80%** electric driving share
– close to WLTP values.

An electric driving share of only 50% results in 2-3 times higher emissions than in WLTP.

Real-world CO_2 emissions of meeting the CO_2 emission standards with improving ICEVs, with BEVs, or with PHEVs (illustration).



Compared to improving the fuel efficiency of ICEVs and/or partially replacing them by BEVs, meeting the CO_2 emission standards with PHEVs increases real-world emissions at the fleet level.

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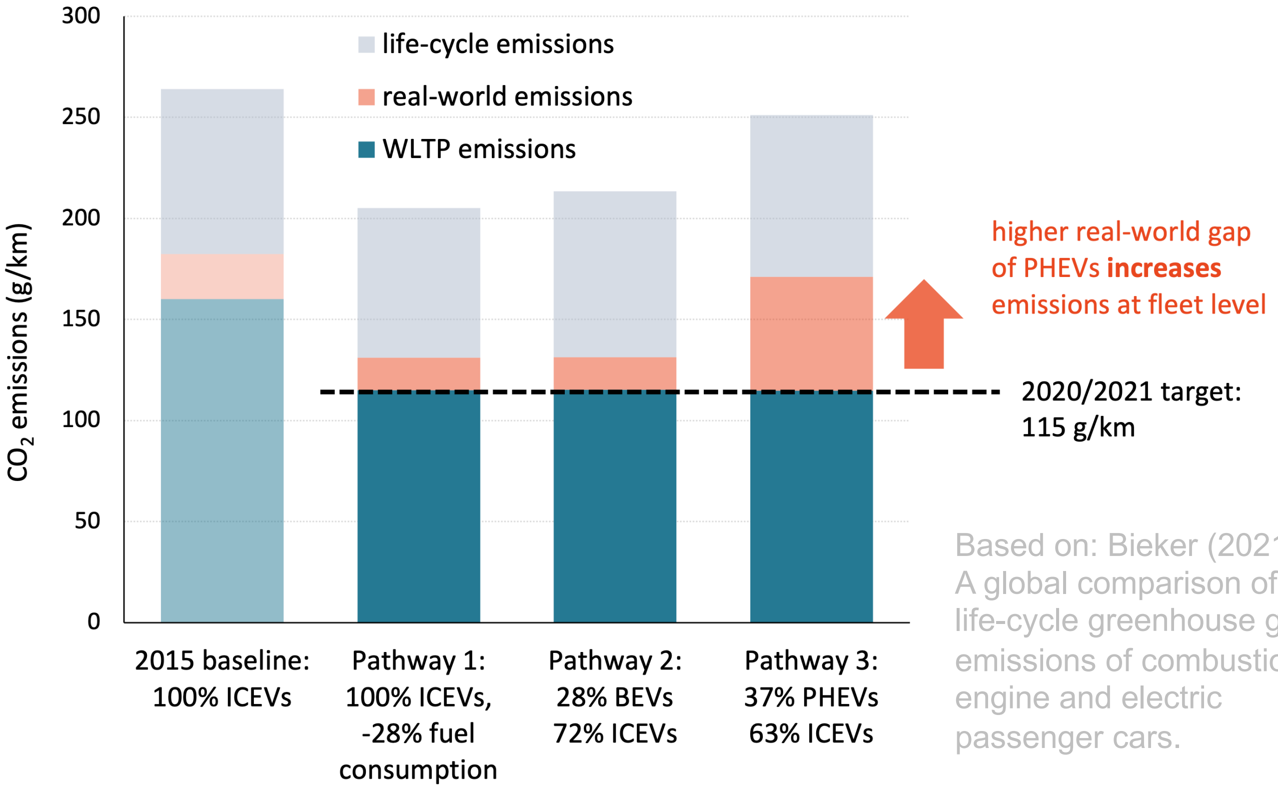

Based on: Bieker (2021). A global comparison of the life-cycle greenhouse gas emissions of combustion engine and electric passenger cars.

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Only vehicle models that allow users to realize a low fuel consumption and high electric driving share should be supported:

- Electric range of at least 90 km allows high electric driving share also a cold weather and high velocities
- Minimum ratio of electric motor versus combustion engine power of > 40%-50% to allow more purely electric driving.
- Fast charging capability

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3) Incentivize charging over fossil fuel

Incentivize charging:

- **Home charging:** Reduce legal and financial barriers to installing home charging points
- **Workplace charging**: Limit company car incentives to companies that provide workplace charging or support employers in home or public charging
- **Public charging**: Non-discriminatory access to public charging stations

Disincentivize fossil fuel usage:

- Higher energy tax rates and/or CO_2 price on fossil fuels
- Abolishing or limiting free fuel cards for company cars
- Limiting tax-deductibility of spendings for fossil fuels

4) More transparency for consumers

- Manufacturers should be obligated to disclose the charge-depleting and charge-sustaining mode fuel consumption

- Manufacturers should clearly display the realized electric driving share on the dashboard

Thank you!

g.bieker@theicct.org

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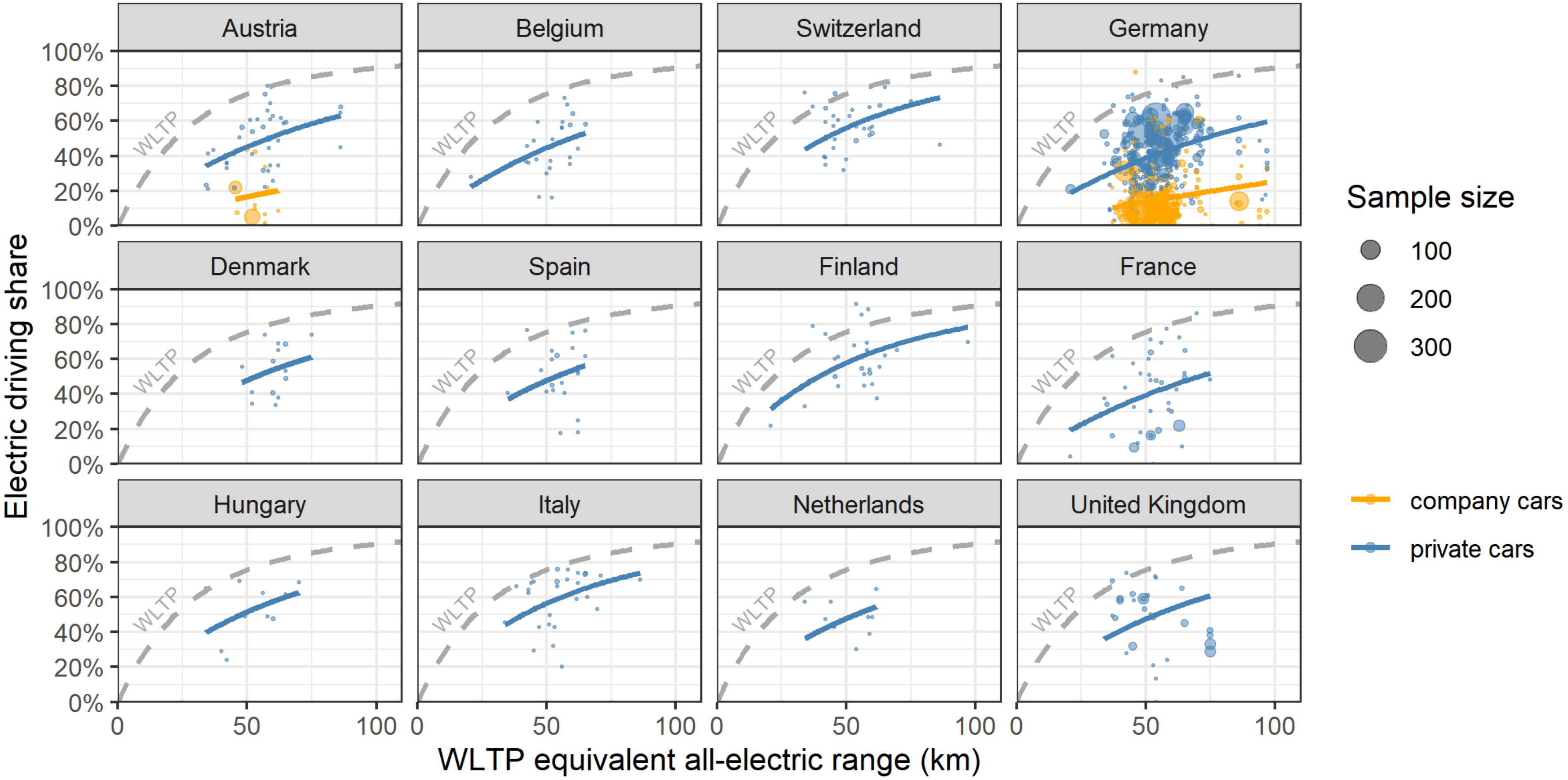
Actual UF is smaller than test cycle in all countries

- Shown are mean UF by PHEV model from private vehicles
- Shown are countries with N > 50
- Legend:
  - Dashed line: NEDC
  - Dot-dashed: WLTP
  - Solid line: local average
- Actual UF is smaller than NEDC in all countries



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