Global Fuel Economy Initiative
A fresh perspective

INTERNATIONAL TRANSPORT FORUM

LEIPZIG, 1 June 2017

Global Fuel Economy Initiative
A fresh perspective

INTERNATIONAL TRANSPORT FORUM

LEIPZIG, 1 June 2017

Introductions and update on GFEI
Sheila Watson, Deputy Director, FIA Foundation

Electric Vehicles, prospects and progress
Lew Fulton, Director STEPS, UC Davis

The Real Urban Emissions Initiative (TRUE)
Peter Mock, Europe Managing Director / EU Lead, ICCT

Discussion

Close

Global Fuel Economy Initiative
A fresh perspective

INTERNATIONAL TRANSPORT FORUM

LEIPZIG, 1 June 2017

Sheila Watson

FIA Foundation

Global Fuel Economy Initiative
A fresh perspective

INTERNATIONAL TRANSPORT FORUM

LEIPZIG, 1 June 2017

Global Fuel Economy Initiative
A fresh perspective

INTERNATIONAL TRANSPORT FORUM
LEIPZIG, 1 June 2017

Lew Fulton
UC Davis

GFEI Session, ITF Leipzig, May 31 2017

Modeling the future of electric vehicle adoption

Lew Fulton, Director
Alan Jenn, Postdoctoral Researcher
Gil Tal, Research Scientist

UCDAVIS

www.steps.ucdavis.edu

What will electric vehicle adoption look like in the future?

- The primary objective of this research is to investigate future international scenarios of electric vehicles (EVs) deep into the future. The broad set of questions we are interested in studying:
  - How many electric vehicles will be on the road in 2030? 2040? 2050?
  - When will we see 100 million EVs cumulatively in the world?
  - What sorts of vehicle pricing and attributes are required to boost adoption?
  - Which policies can be implemented in different countries to promote EVs in the most effective manner?

- Our work is unique for several reasons:
  - we leverage a massive dataset of EV sales across 39 markets
  - our focus is on international trends rather than a single country set of vehicle sales
  - We test three different forecast techniques

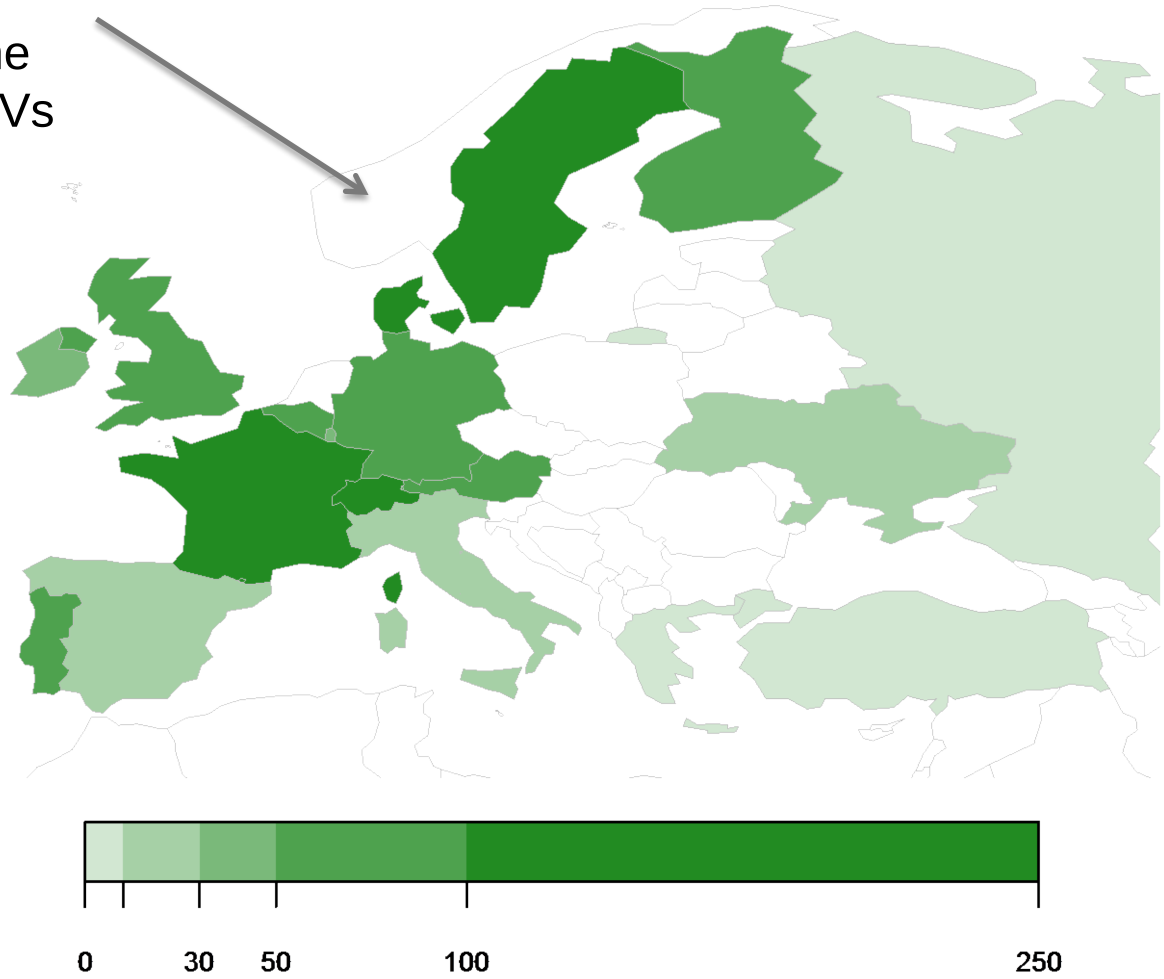
Our project leverages an extremely detailed dataset

- We are using a large dataset of new vehicle registrations from IHS Automotive.
- The data were cleaned and expanded in cooperation with the International Energy Agency.
- A quick summary of the dataset
  - Number of countries: 39
  - Years: 2005, 2008, 2010-2015
  - Unique vehicle models: 4,771
  - Unique vehicle manufacturers: 503
  - Total registrations: 509,194,651
  - Vehicle attributes: Axles, drive, engine size, # of cylinders, engine power, fuel type, transmission, turbo, price, segment, curb weight, footprint, fuel efficiency (NEDC/WLTP), and emissions (NEDC/WLTP)

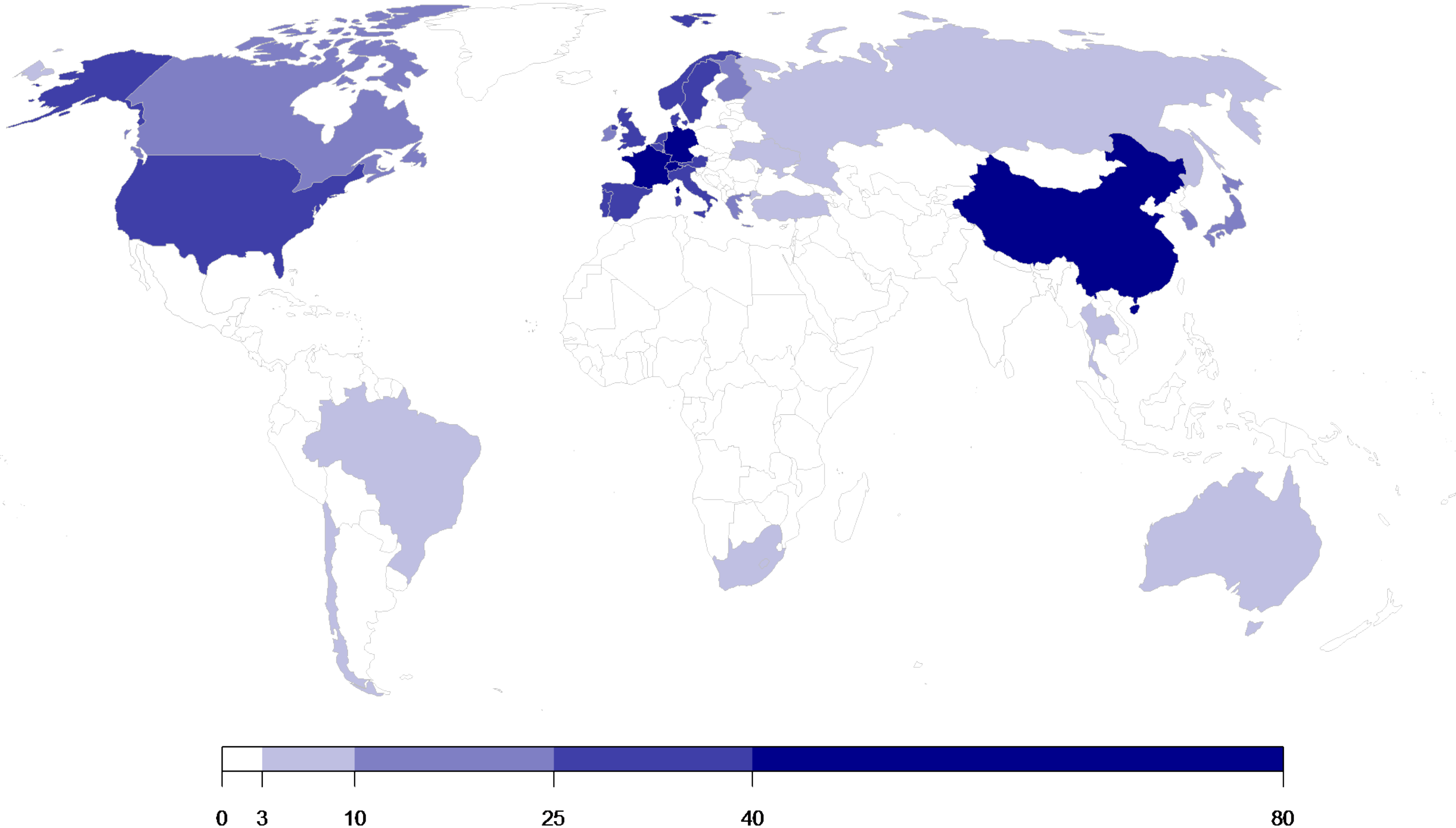
INTERNATIONAL MARKETS

European sales of electric vehicles (EVs per 10000 conventional vehicles sold)

Norway is significantly off the charts at 1,900 EVs sold per 10,000 vehicles sold

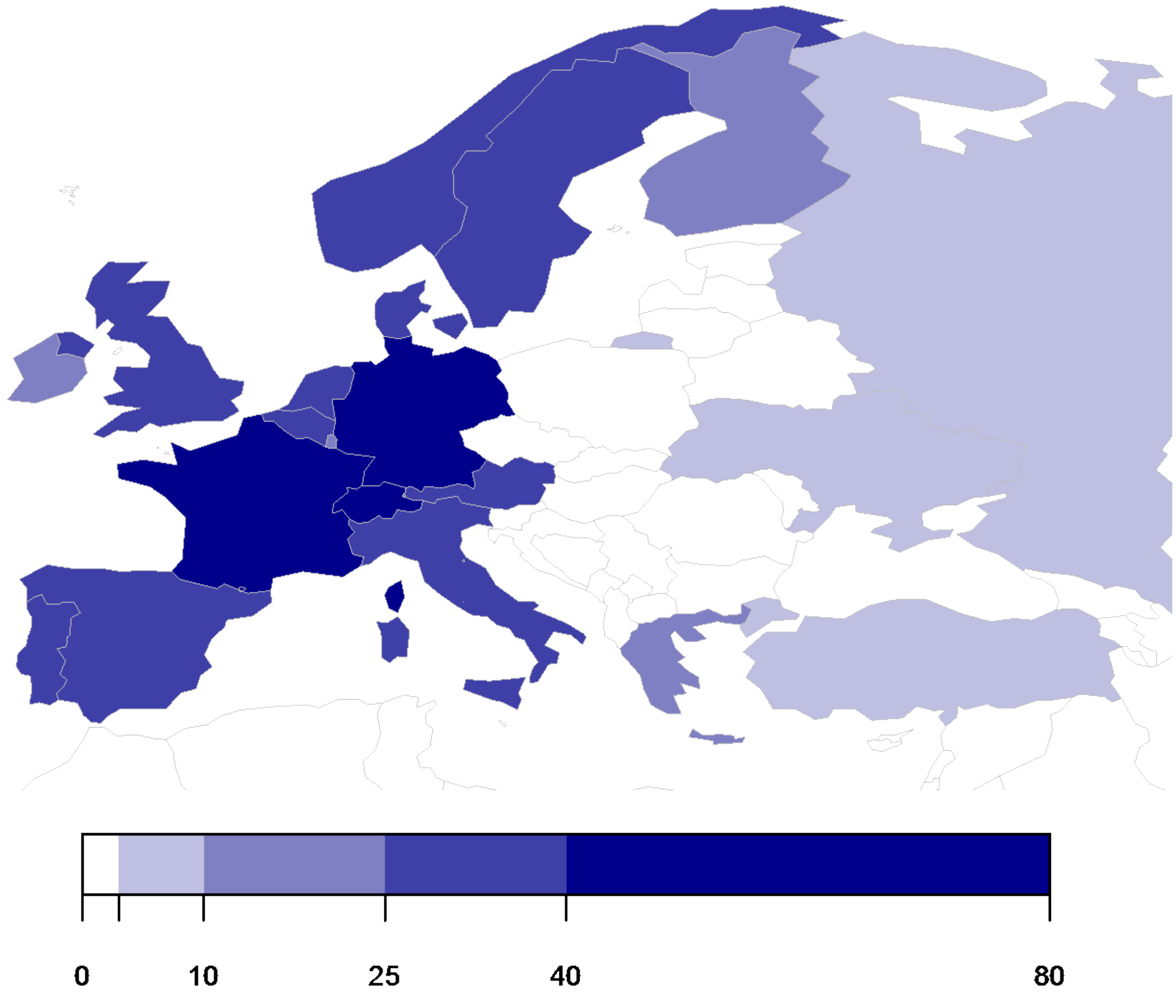


Number of electric vehicle models available

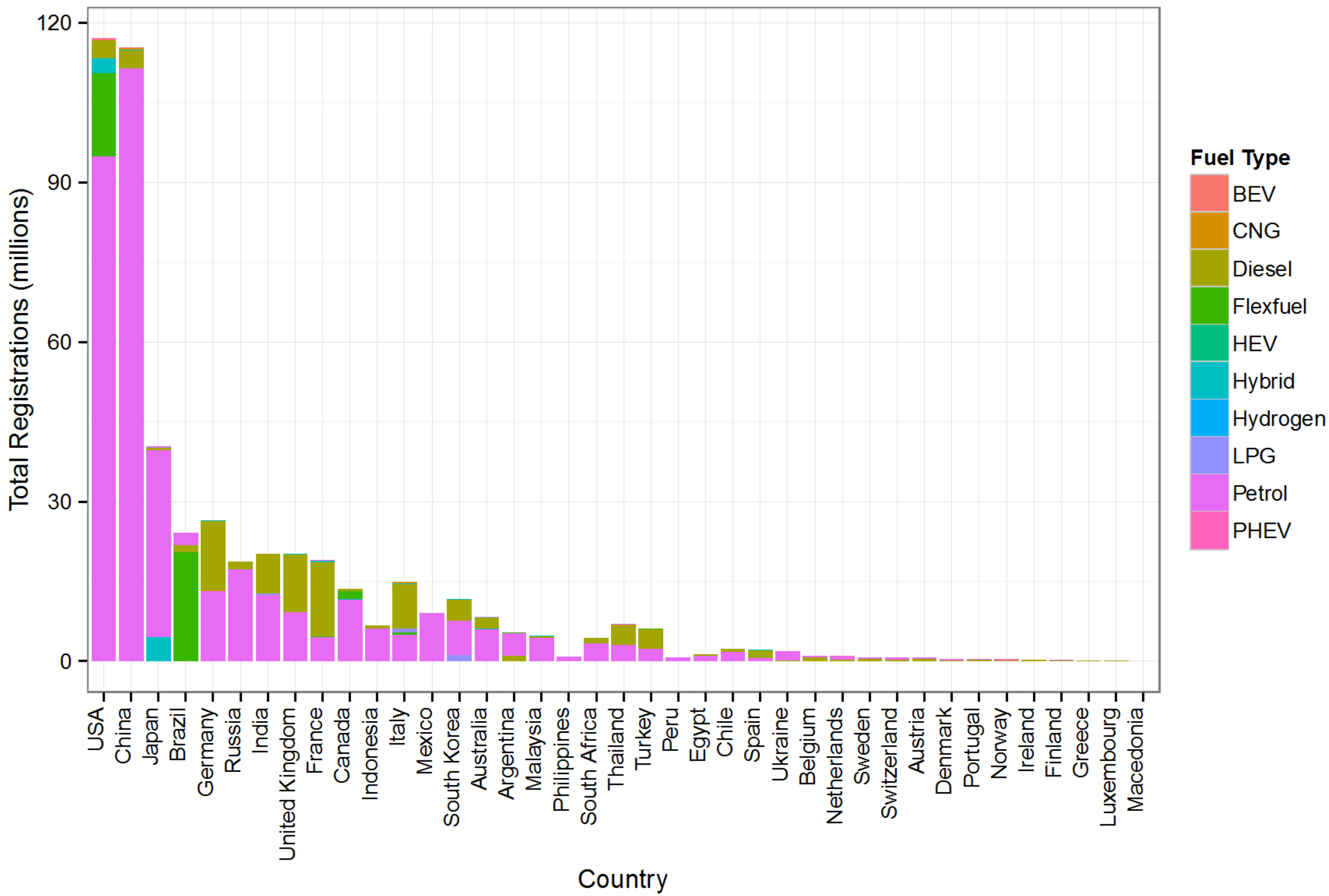


UCDAVIS
SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

Number of electric vehicle models available

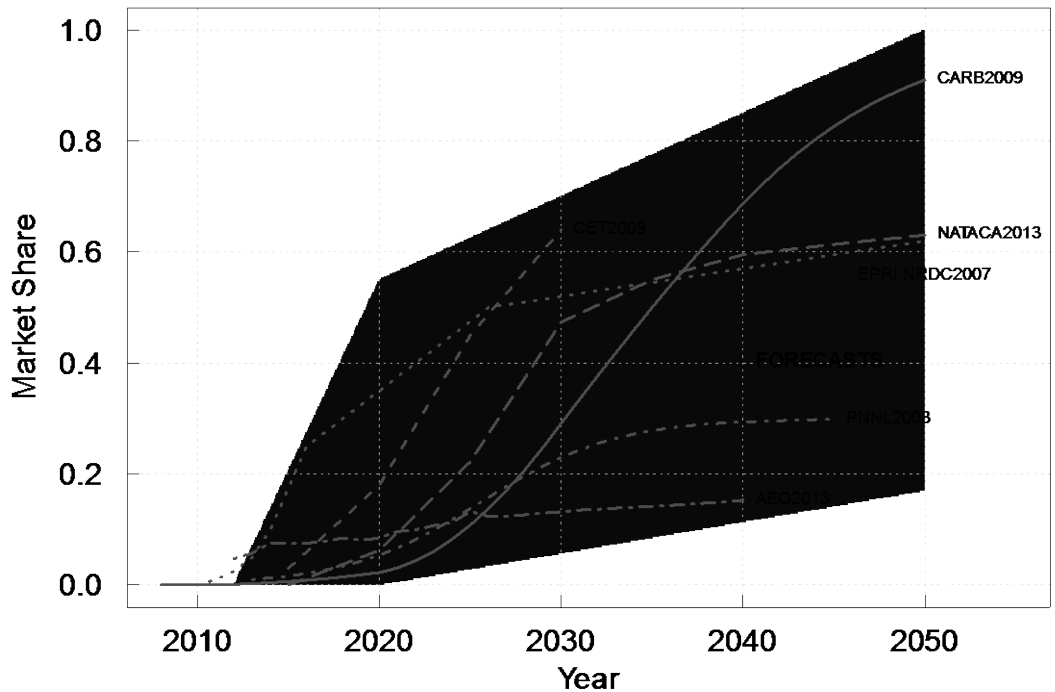


International vehicle registrations by fuel technology (cumulative 2010-2015)



Deep forecasts of electric vehicle sales

- Forecasting is very uncertain, especially going deep into the future!
- In the literature, there is a huge range of future EV market shares in the future
- We aim to update these studies with more current data as well as examining a range of possible futures

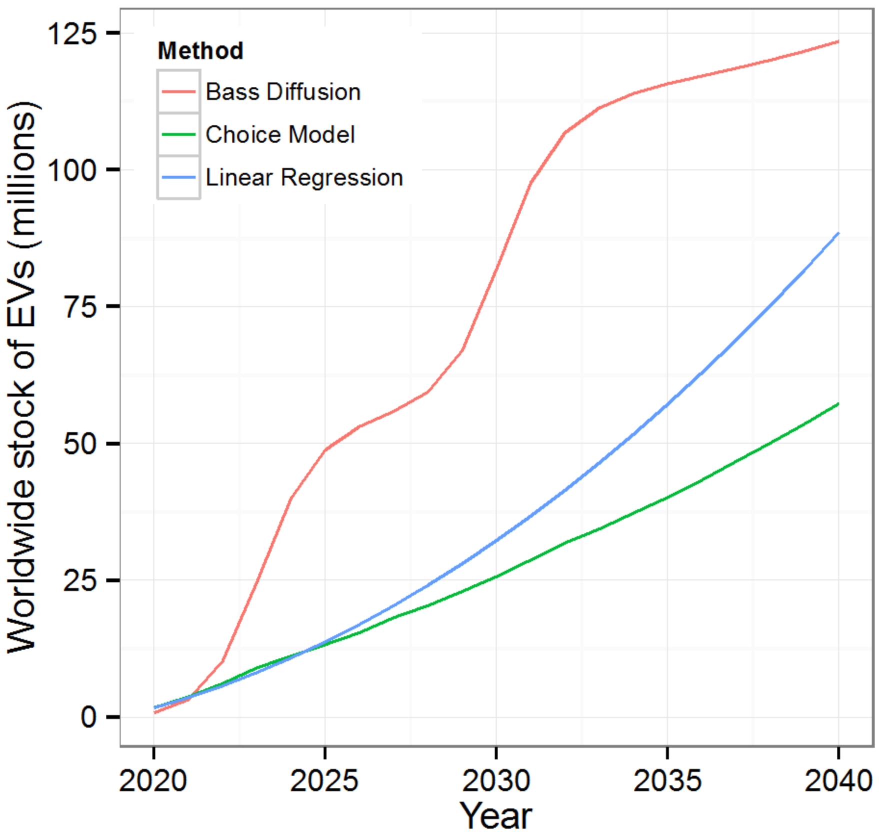


Taking a three-pronged approach to forecasting

- Using the IHS registration data, we attempt to inform the construction of three separate models to forecast the sales of electric vehicles
    1. Discrete choice modeling approach
    2. Diffusion of innovation modeling approach
    3. Regression of trends approach
- This multi-model approach attempts to use strengths and assumptions of each model to understand different aspects of adoption
- Help to minimize errors and assumptions inherent in each respective model by capturing commonalities across all three

How do the different model projections compare?

- Discrete choice model yields the lowest adoption, this is sensible as the models reflect current consumer preferences
- Shape of diffusion curve due to addition of demand due to exceeding vehicle lifetime
- Different models vary in estimation across the same inputs by an order of 2 (from 60 million vehicles in 2040 up to 120 million vehicles)



Discrete choice model

- We simulate consumers' decision making process about selecting a product among a set of discrete choices
- An individual is more "attractive" based on its comparative value compared to other vehicles
- Vehicle attributes inform "attractiveness"

Vehicle Brands

Fuel Efficiency

Engine Size, Power

Vehicle Classes

Vehicle Sales

Basics of discrete choice modeling

- **In discrete choice models, we attempt to simulate consumers' decision making process about selecting a product among a set of discrete choices**.
  1. A consumer chooses based on attributes of the product in comparison to other products (e.g. higher price all else equal is worse, higher efficiency is better)
  2. With a large enough sample of consumers and a diverse enough set of products, we are able to measure the "desirability" of each of the attributes
  3. Once the importance of each attribute is determined, we can freely introduce products with different levels of attributes to determine how the market will respond (assuming preferences don't change and that the "desirability" was modeled correctly)

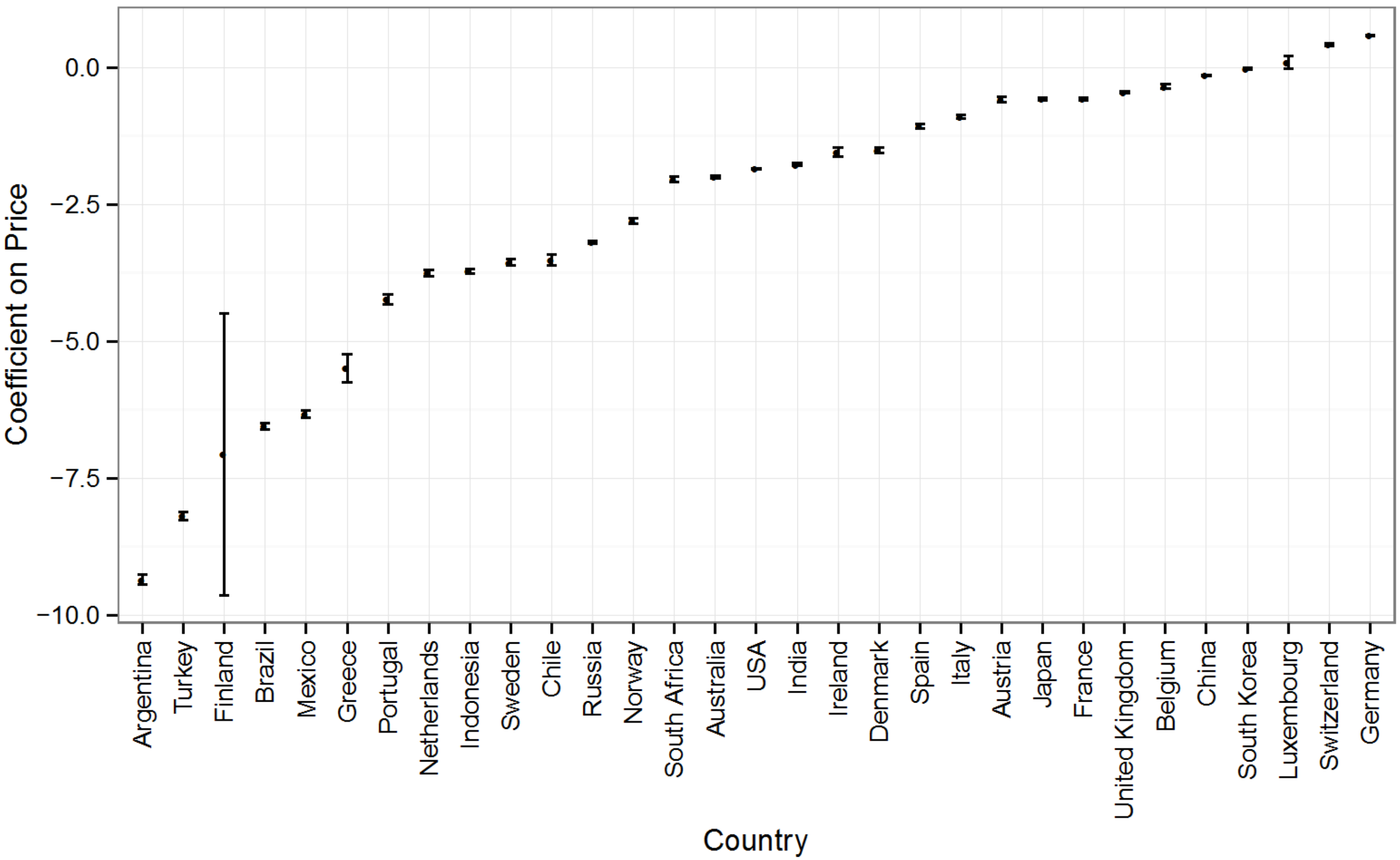
Structure of our choice model

- The utility for choices in our model is defined as:

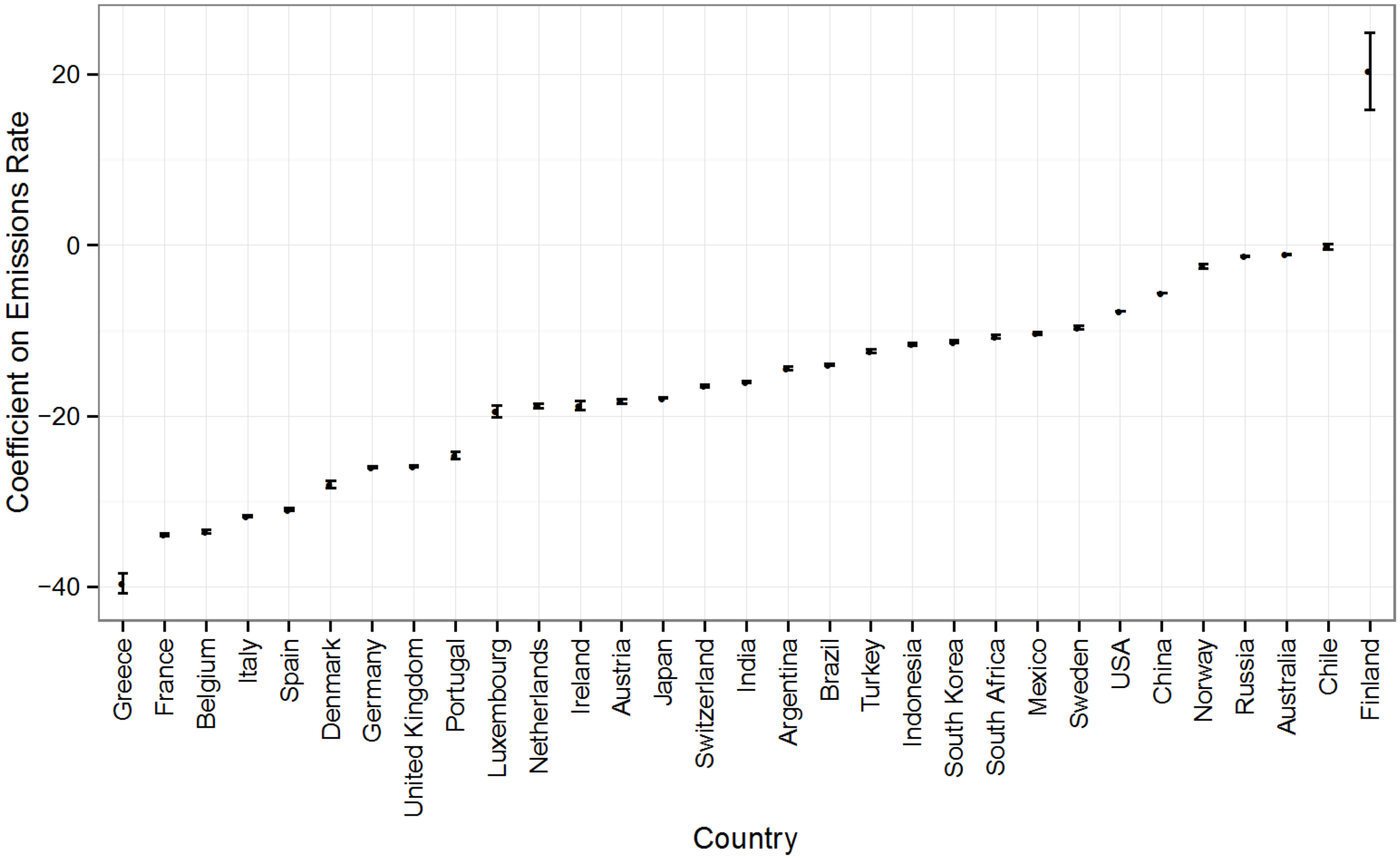
$$u_i = \beta_1 \text{price}_i + \beta_2 \text{em.rate}_i + \beta_3 \text{manufacturer}_i + \beta_4 \text{fuel.type}_i + \beta_5 \text{segment}_i + \varepsilon_i$$

- We run our model independently for each of the 39 countries, each of which has approximately several hundred models available each year in the market
- While our regression is trained on a vehicle model level, our confidence on such small market shares is relatively small and therefore we choose to aggregate to less granular levels
- Prices are standardized to euros for uniform comparison purposes, likewise the emission rates are based on the New European Driving Cycle (NEDC)

Cross-country comparison of price coefficients

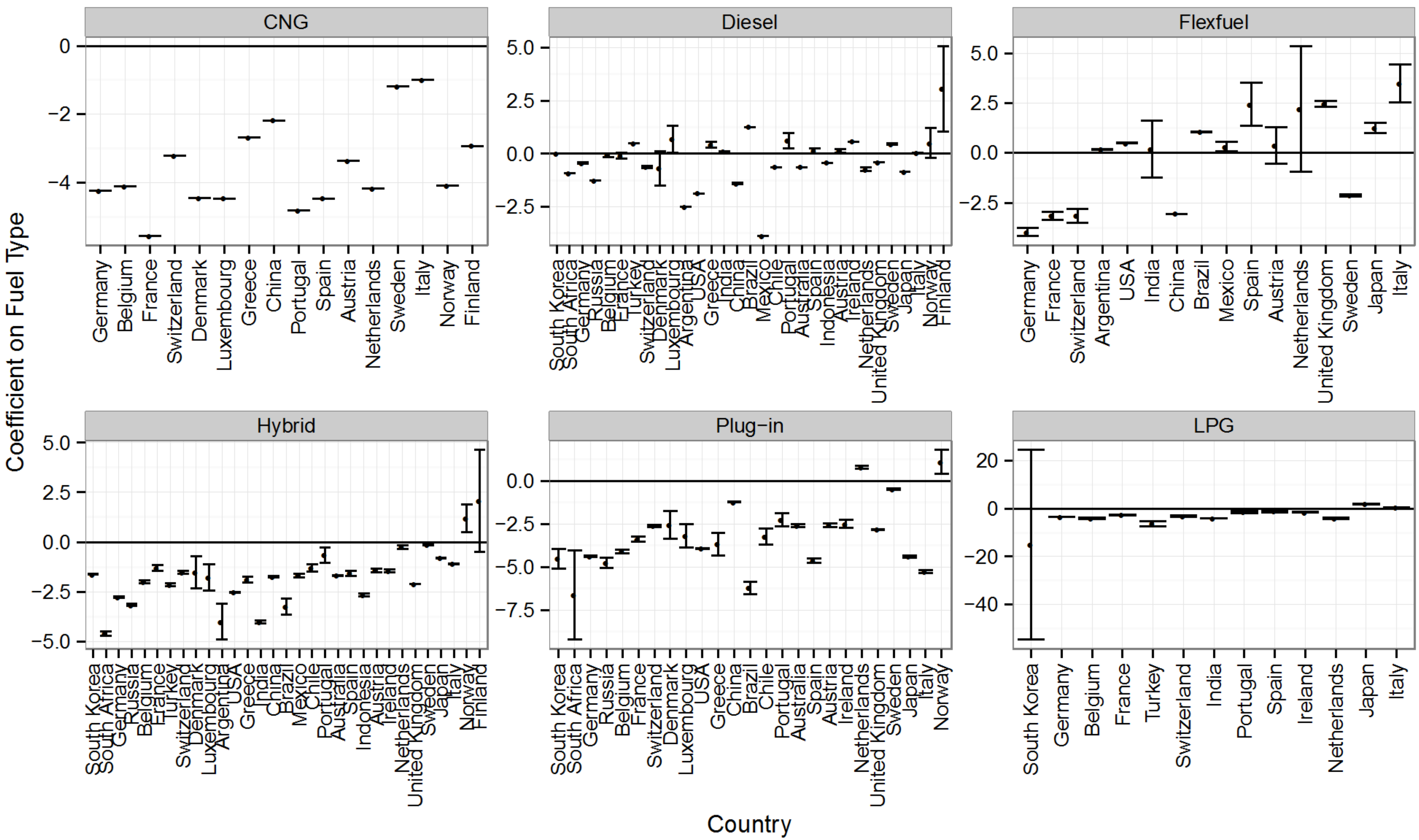


Cross-country comparison of fuel economy (CO_2 emission) coefficients



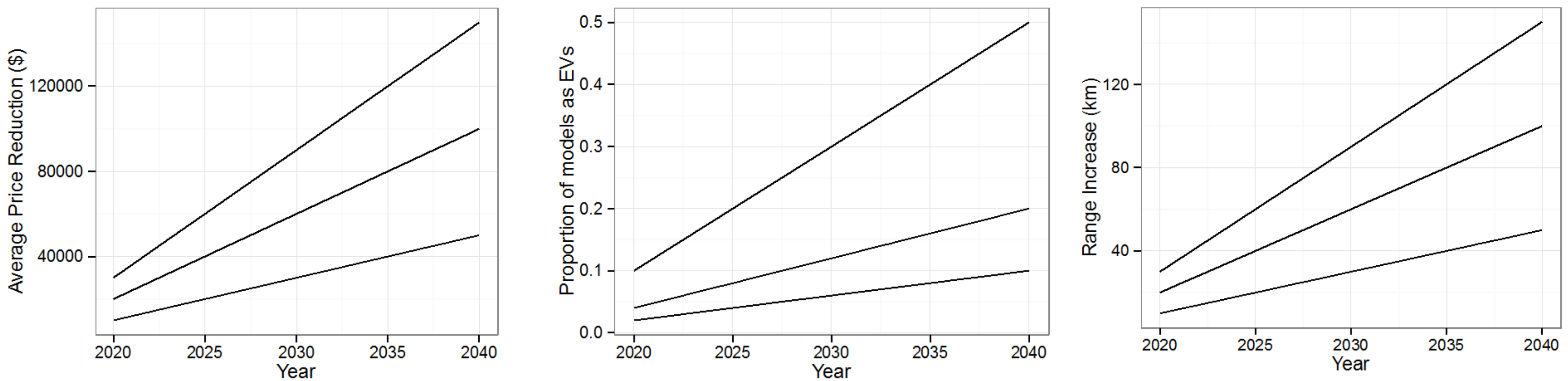
UCDAVIS
SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

Cross-country comparison of fuels (relative to gasoline)

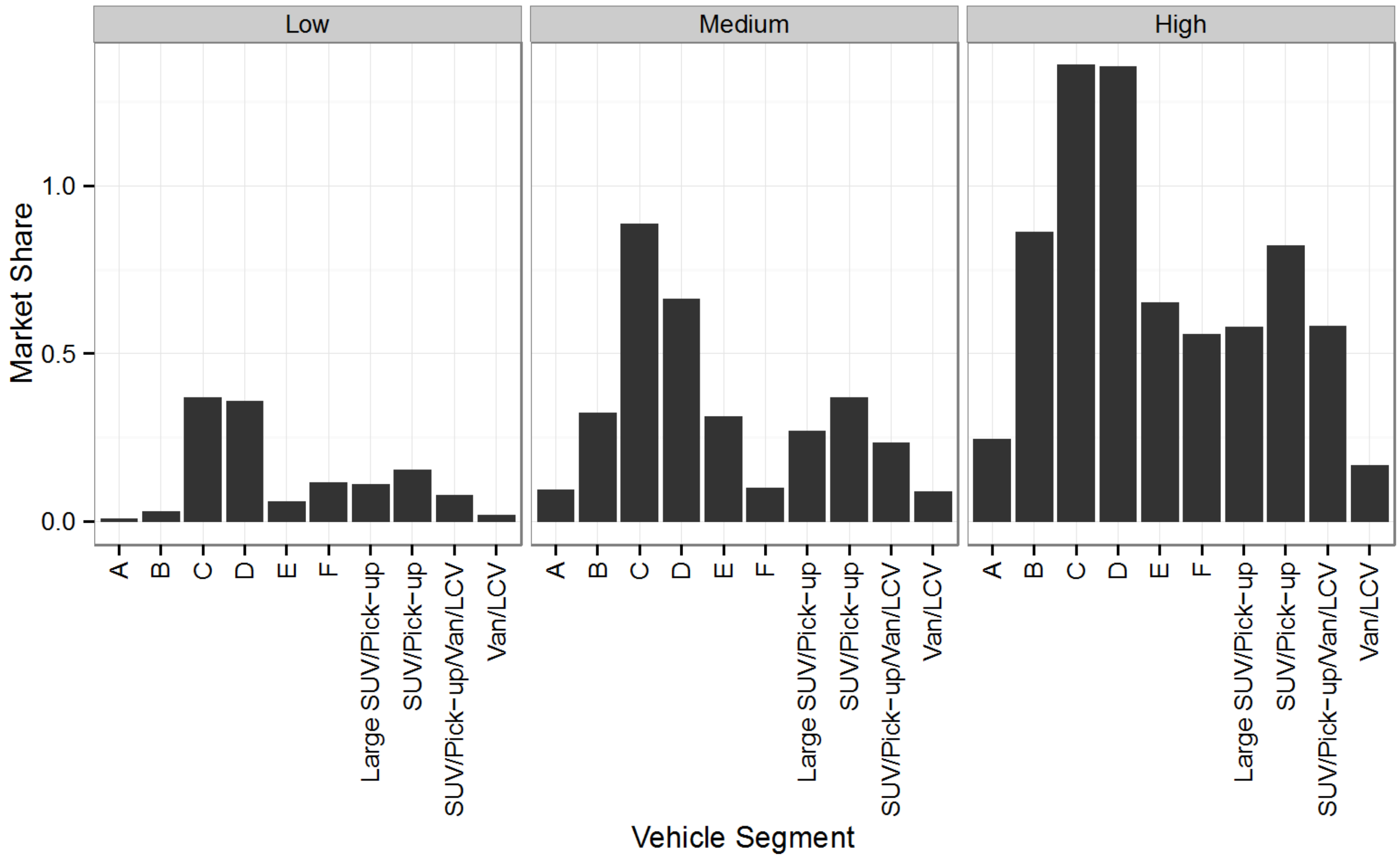


Assumptions for forecasting

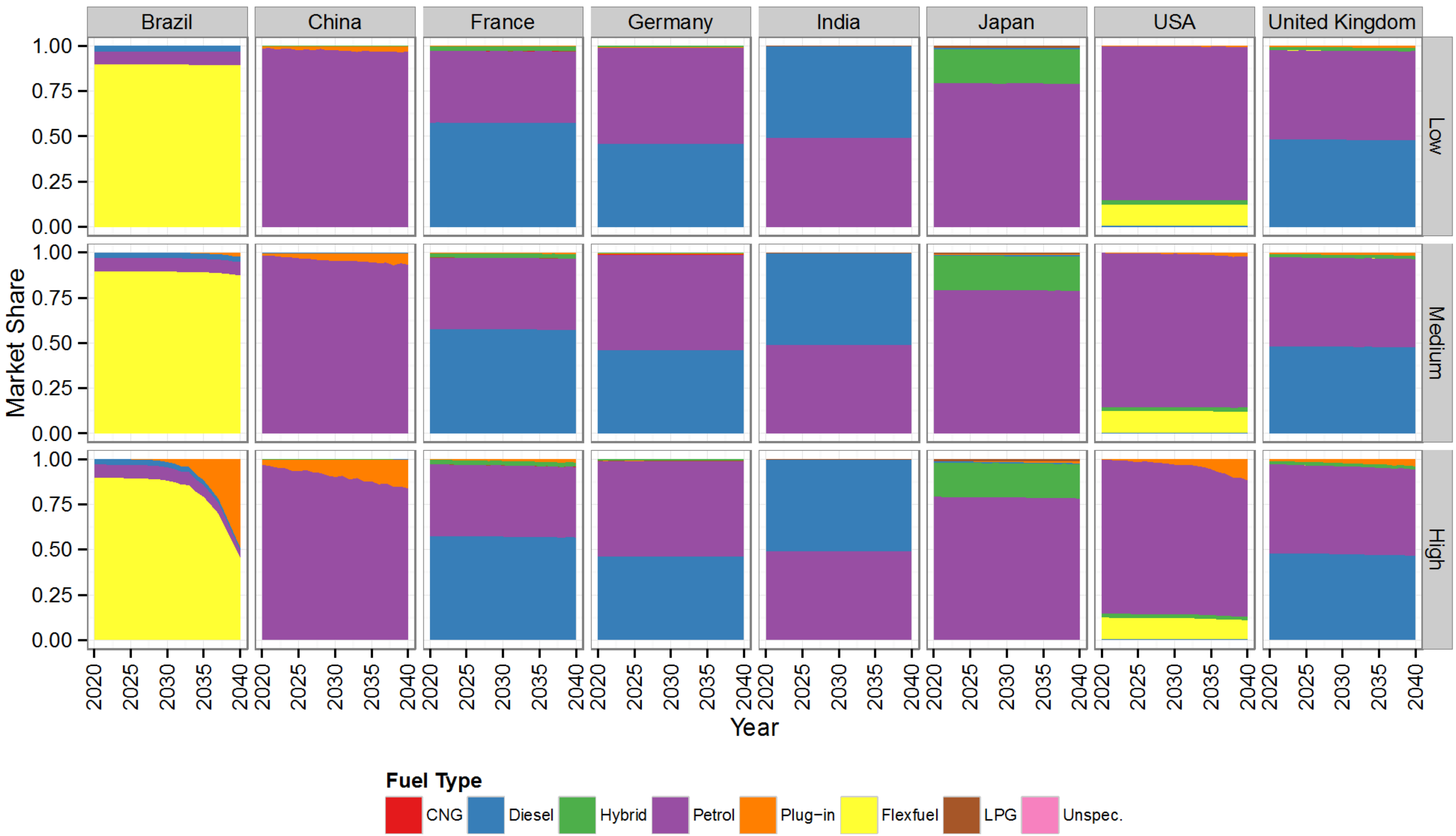
- We examine three basic scenarios for forecasting, each scenario assumes different prices and model availabilities for electric vehicles.
  – Price reductions are exogenous, their mechanisms are not explicitly stated but include learning-by-doing, competition, and policy incentives.
  – Model availability refers to the coverage of EVs in the market of vehicle models.
  – Range of EVs are increased over time to allay issues of range anxiety



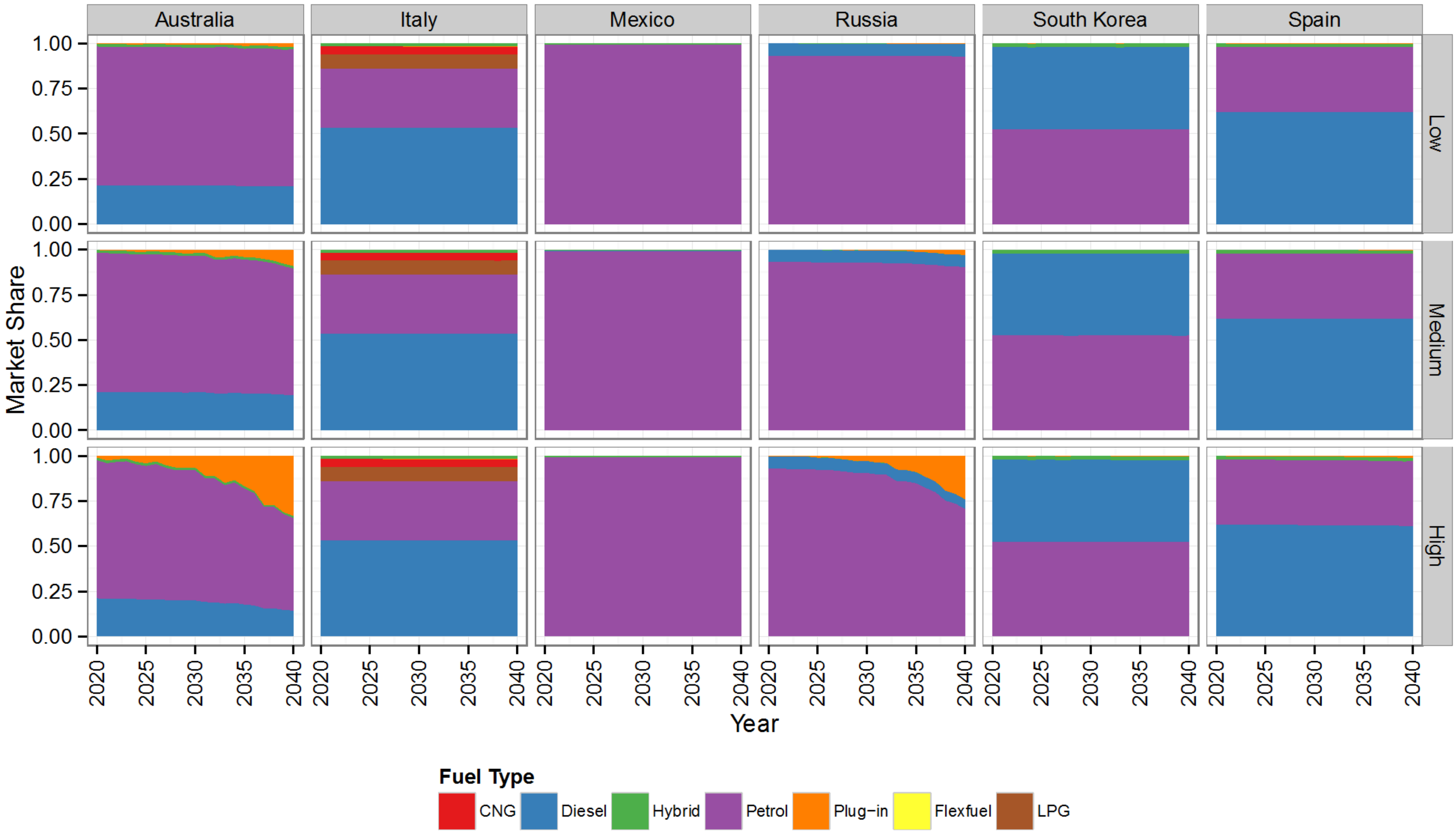
Segment breakdown of electric vehicles



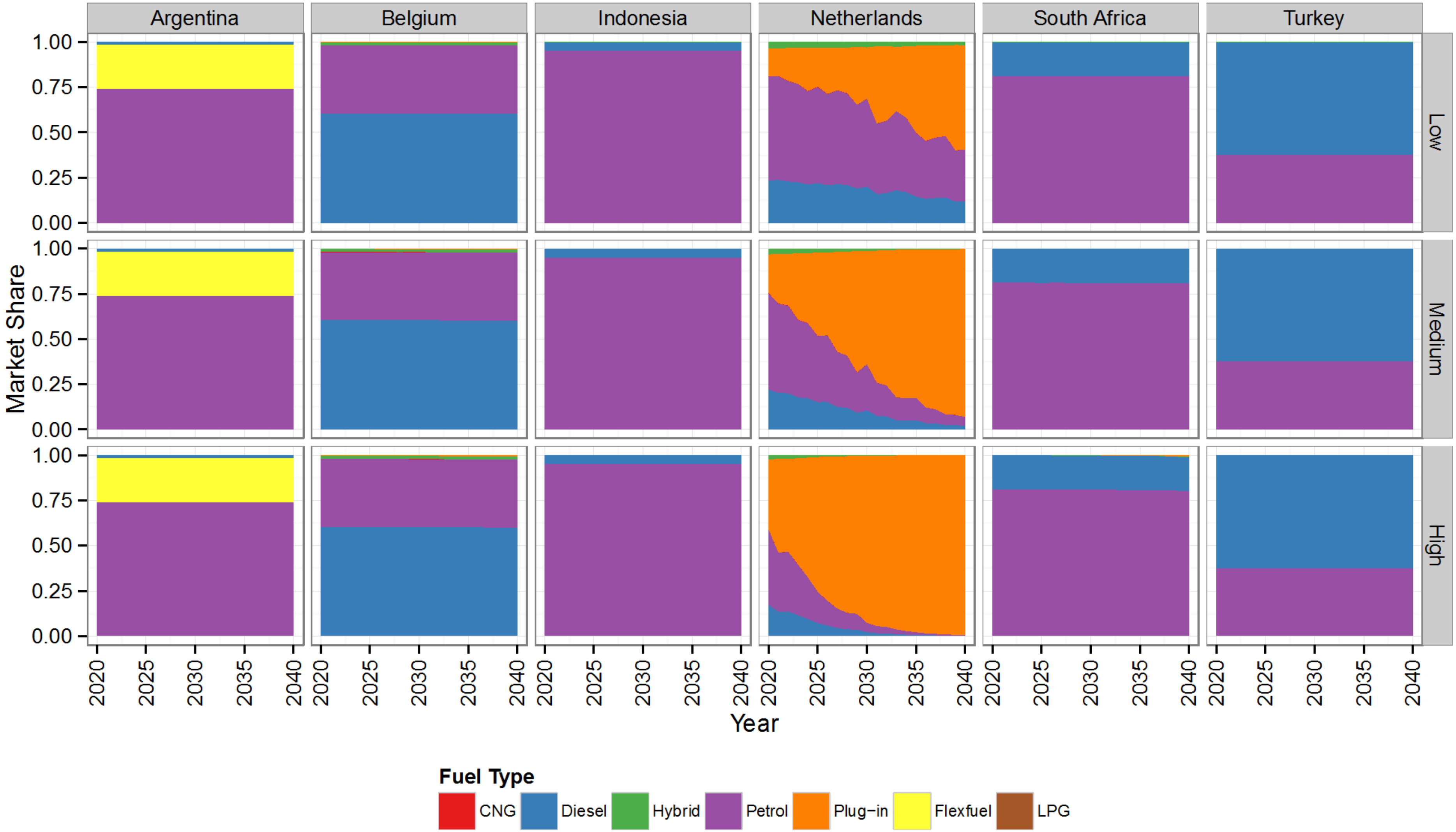
Large market (>200,000) scenario predictions



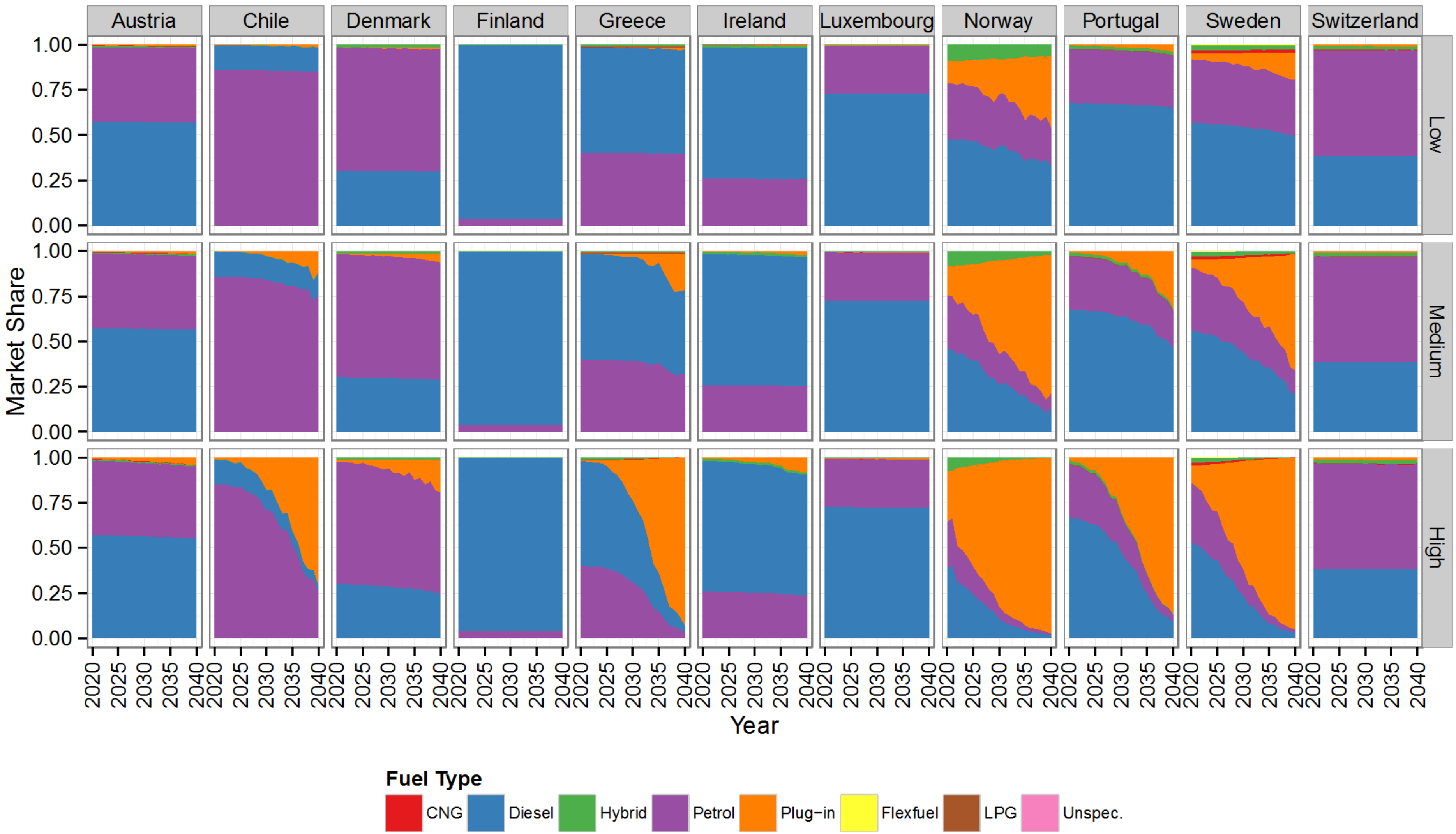
Medium market (100,000-200,000) scenario predictions



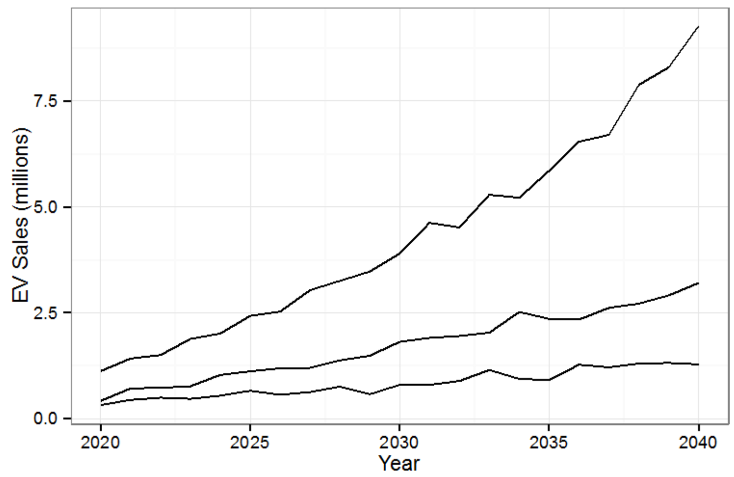
Small market (50,000-100,000) scenario predictions

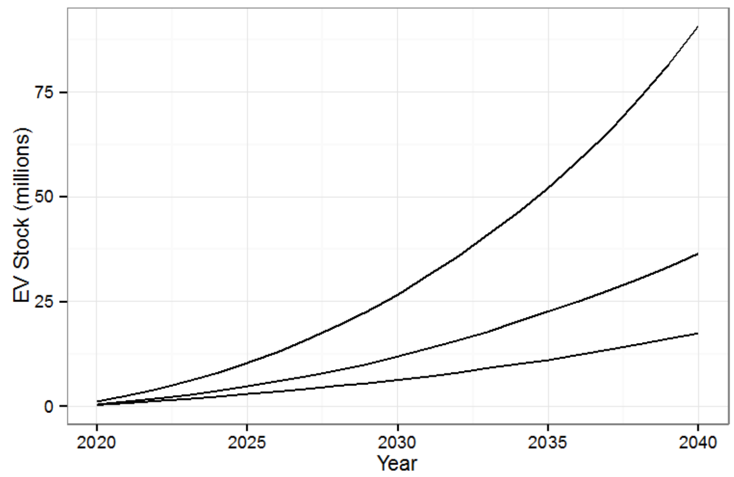


Tiny market (<50,000) scenario predictions



Forecasted sales





- Vehicle sales continue to grow annually (left) but at drastically different rates depending on the scenario. By 2040, sales range between 1.2 million to 9 million annually across 38 countries.
- The cumulative stock of EVs (right) also follows significantly different levels. By the end of the modeling period of 2040, adoption reaches just under 100 million EVs in 2040 (high scenario) down to around 20 million in 2040 (low scenario).

Discussion

- Despite consistency in model inputs, there are significant differences in outputs. The choice of model matters!
- 100 million vehicles by 2040 is an optimistic projection for choice and regression models but is achieved in the diffusion model.
- International factors are vital to consider and lead to stark differences in adoption potential across all three models.

Ongoing work

- Further calibration of models is needed:
  - Data cleaning
  - Investigating combinations of different variables
- Incorporating more variables and scenarios (e.g. charging infrastructure)
- Focusing on policy impacts and integrating existing policies
- Investigate uncertainty in each modeling scenario

Global Fuel Economy Initiative
A fresh perspective

INTERNATIONAL TRANSPORT FORUM

LEIPZIG, 1 June 2017

Global Fuel Economy Initiative
A fresh perspective

INTERNATIONAL TRANSPORT FORUM

LEIPZIG, 1 June 2017

Peter Mock

ICCT

The Real Urban Emissions Initiative

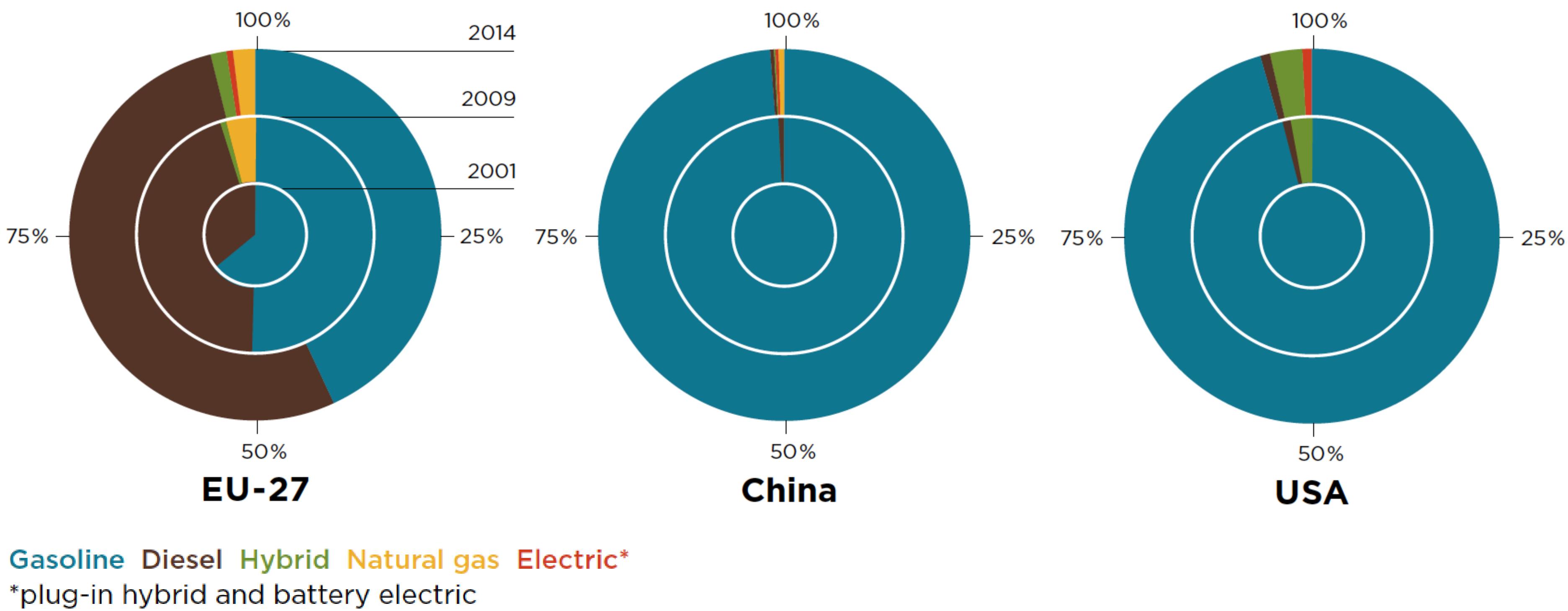
Peter Mock, Yoann Bernard, Rachel Muncrief

Global Fuel Economy Initiative (GFEI): A Fresh Perspective
June 1, 2017 – International Transport Forum, Leipzig

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

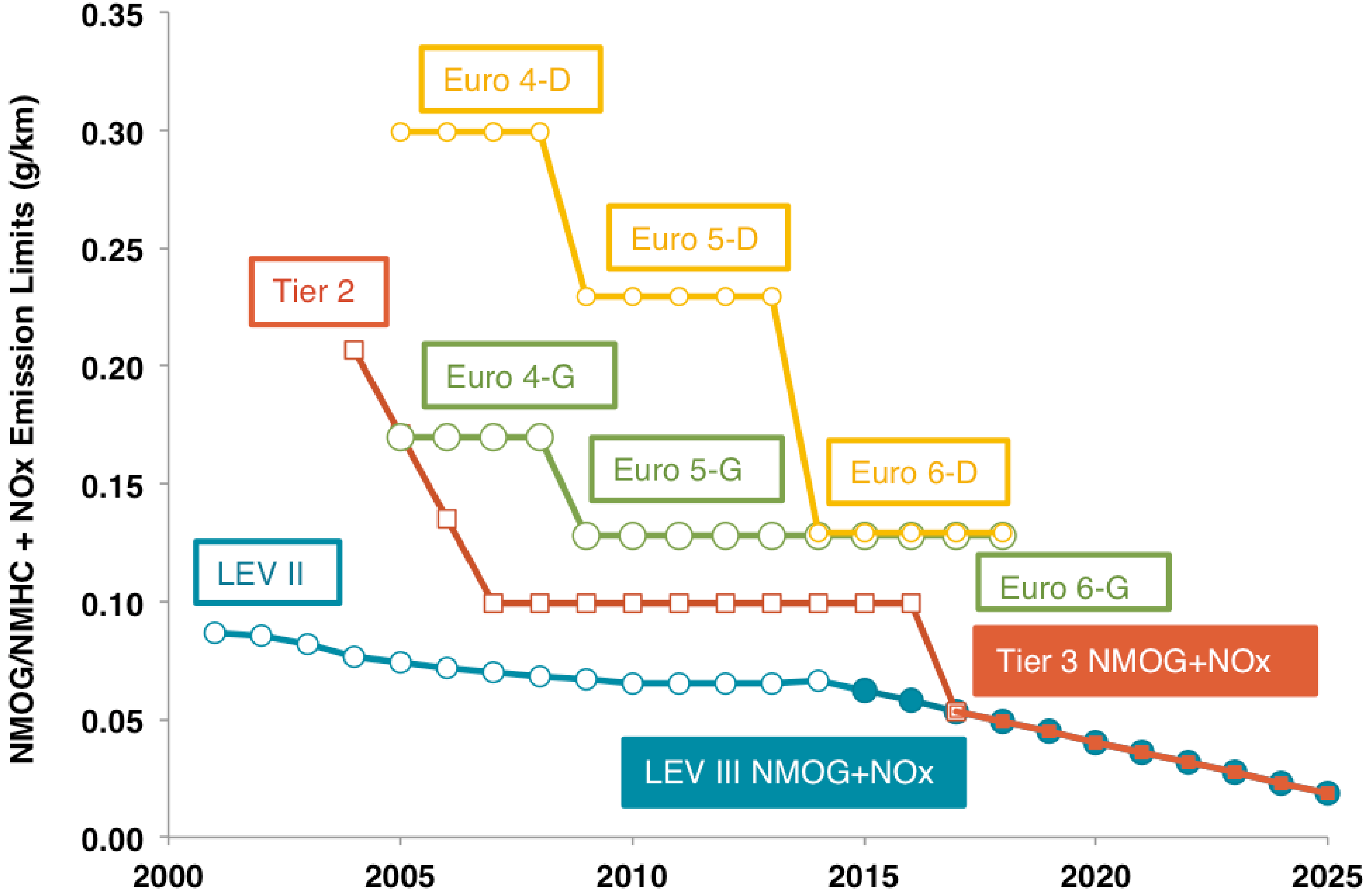
The problem

More than half of new cars in Europe have a diesel engine, unlike in most other major vehicle markets



Source: http://eupocketbook.theicct.org

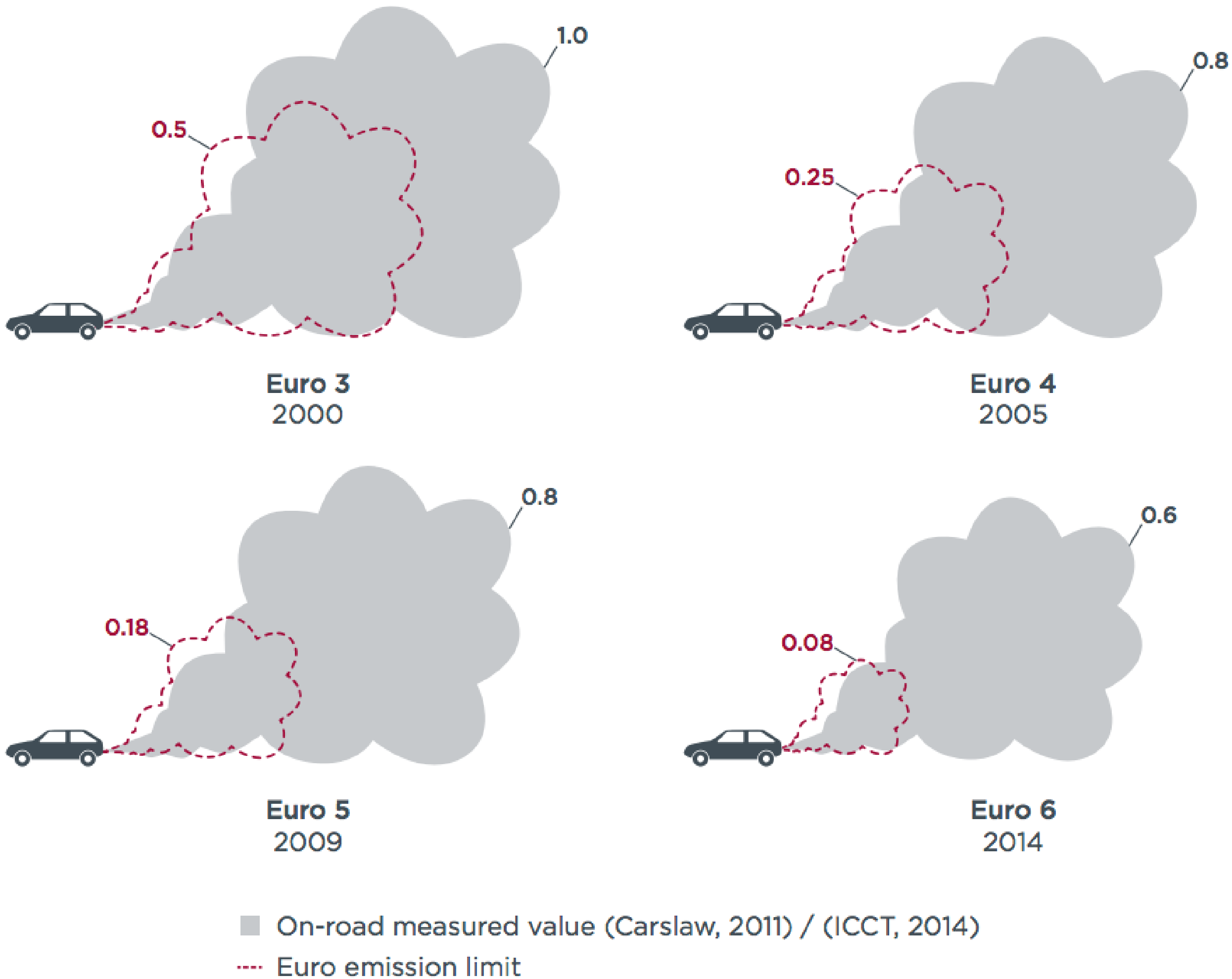
Emission limits for gasoline (G) and diesel (D) cars in the EU and US have converged in recent years



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: http://transportpolicy.net/

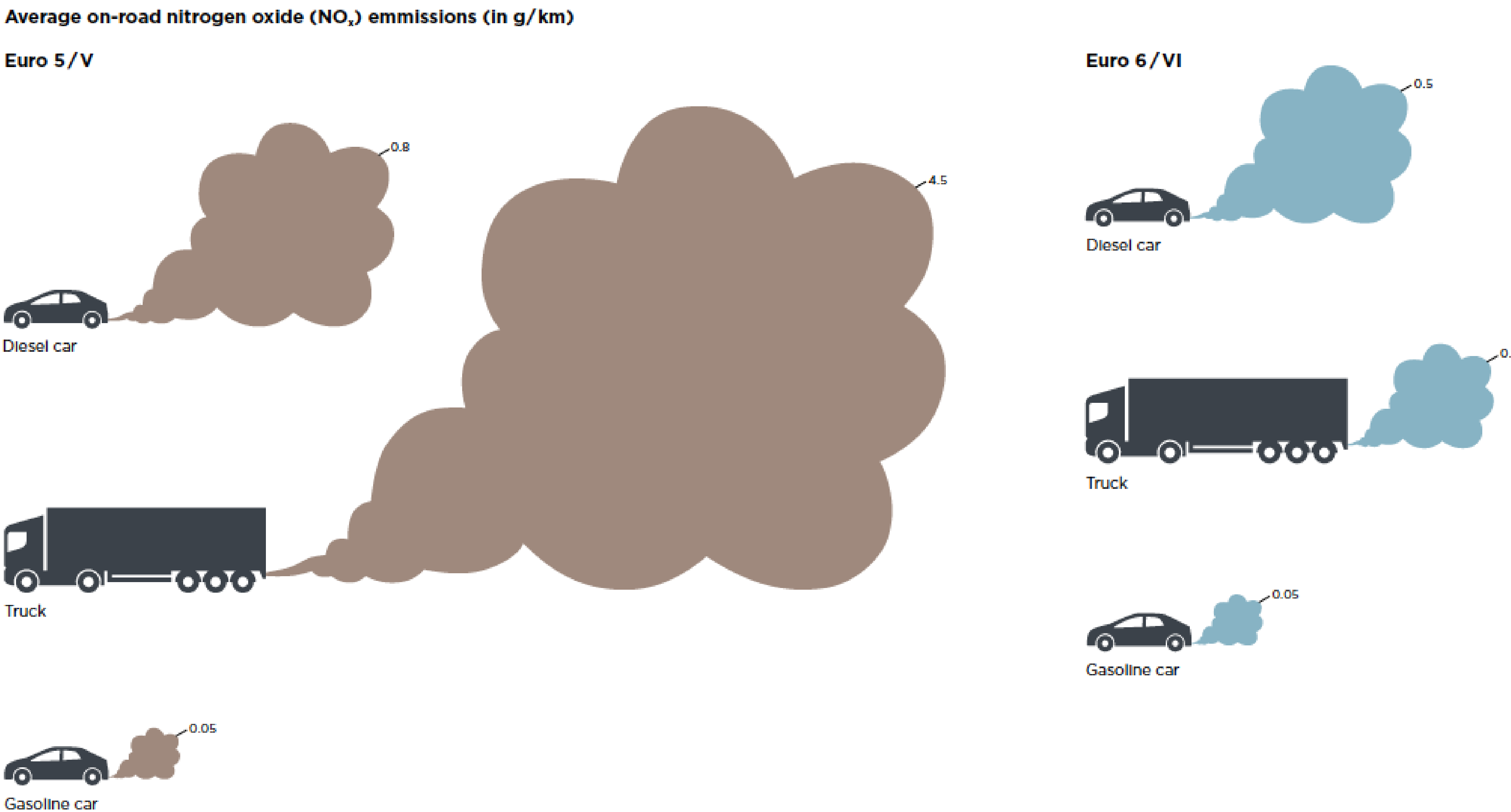
In reality, nitrogen oxides emissions from diesel cars in Europe have not decreased as expected



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: http://eupocketbook.theicct.org

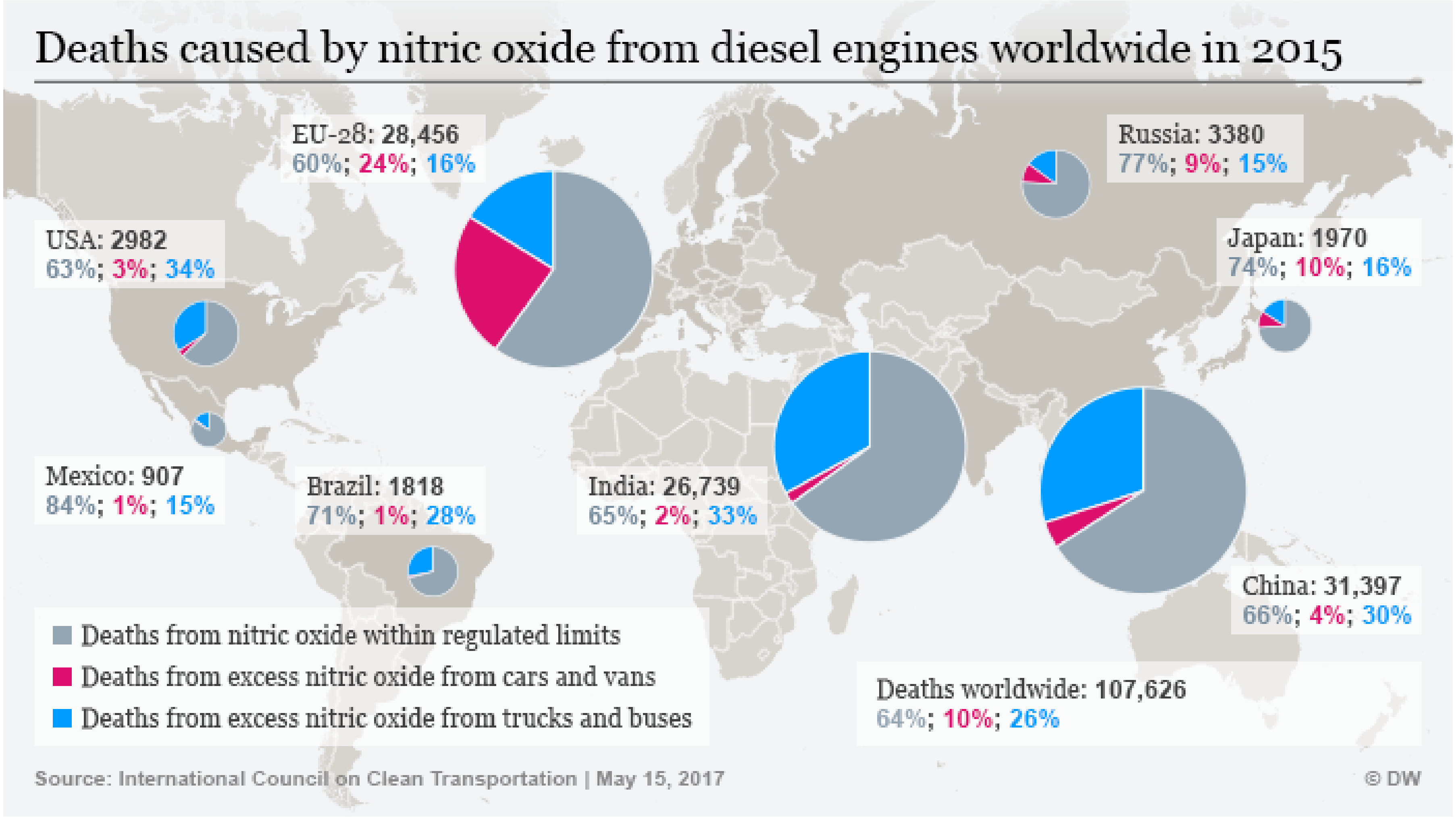
In fact, a modern heavy-duty truck emits less nitrogen oxides emissions than a small diesel car



icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: http://eupocketbook.theicct.org

In Europe, more than 11,000 people die early because of excess diesel NO_x emissions, every year



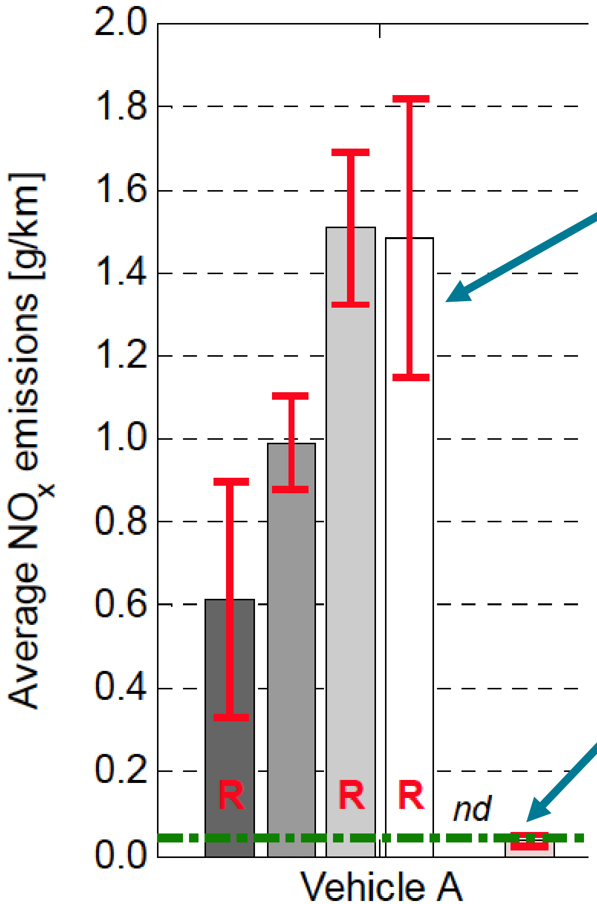
icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: Deutsche Welle

The reason

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

A comparison of laboratory vs. on-road test results for 3 diesel cars in the US triggered "Dieselgate"



On-road test

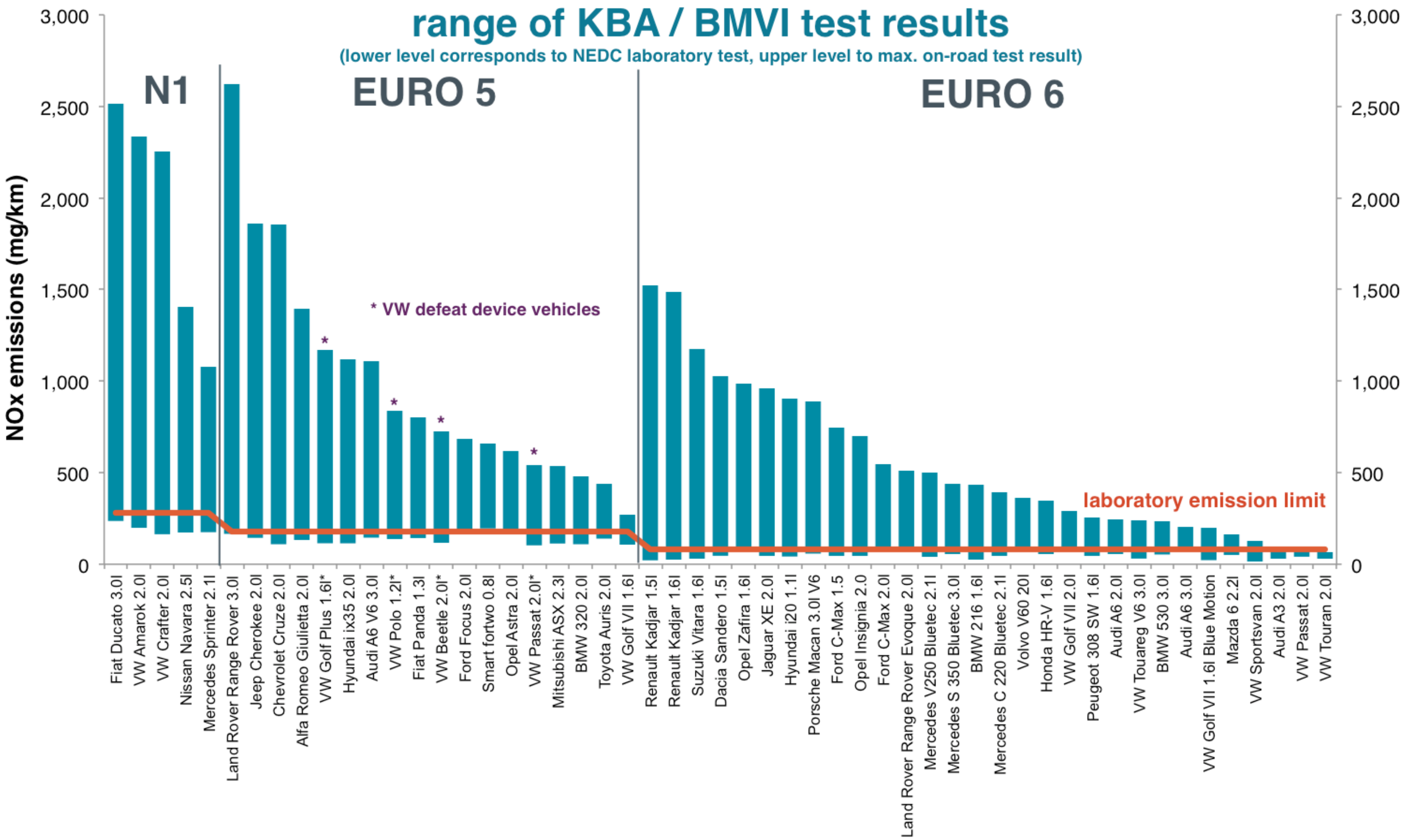
Laboratory test

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source for photos: AVL / ERMES
Vehicles shown on photos are not related to test results shown

Source: http://www.theicct.org/use-emissions-testing-light-duty-diesel-vehicles-us

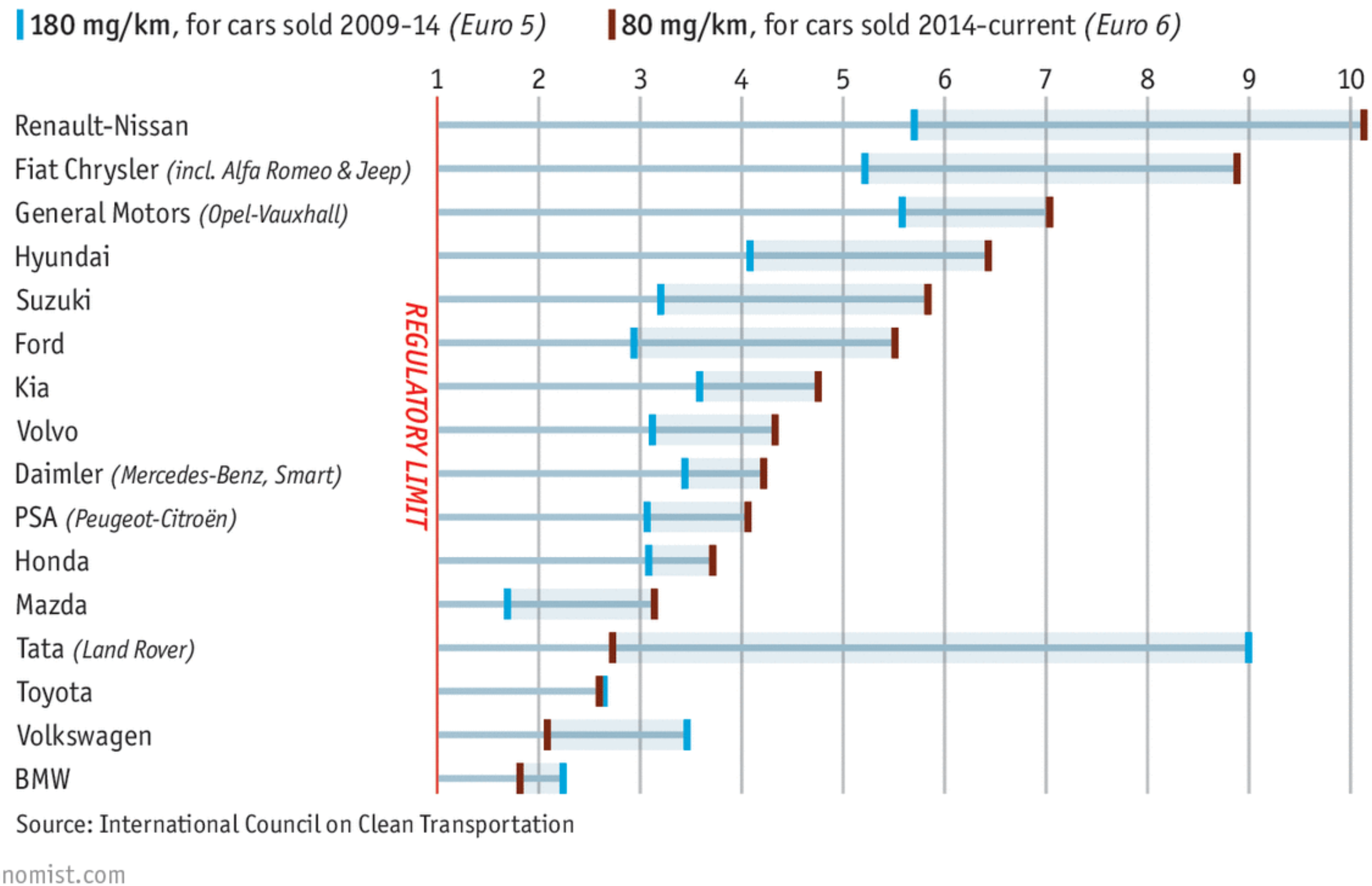
Government testing has confirmed earlier findings and points to numerous other defeat devices



icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: http://theicct.org/blogs/staff/first-look-results-german-transport-ministrys-post-vw-vehicle-testing

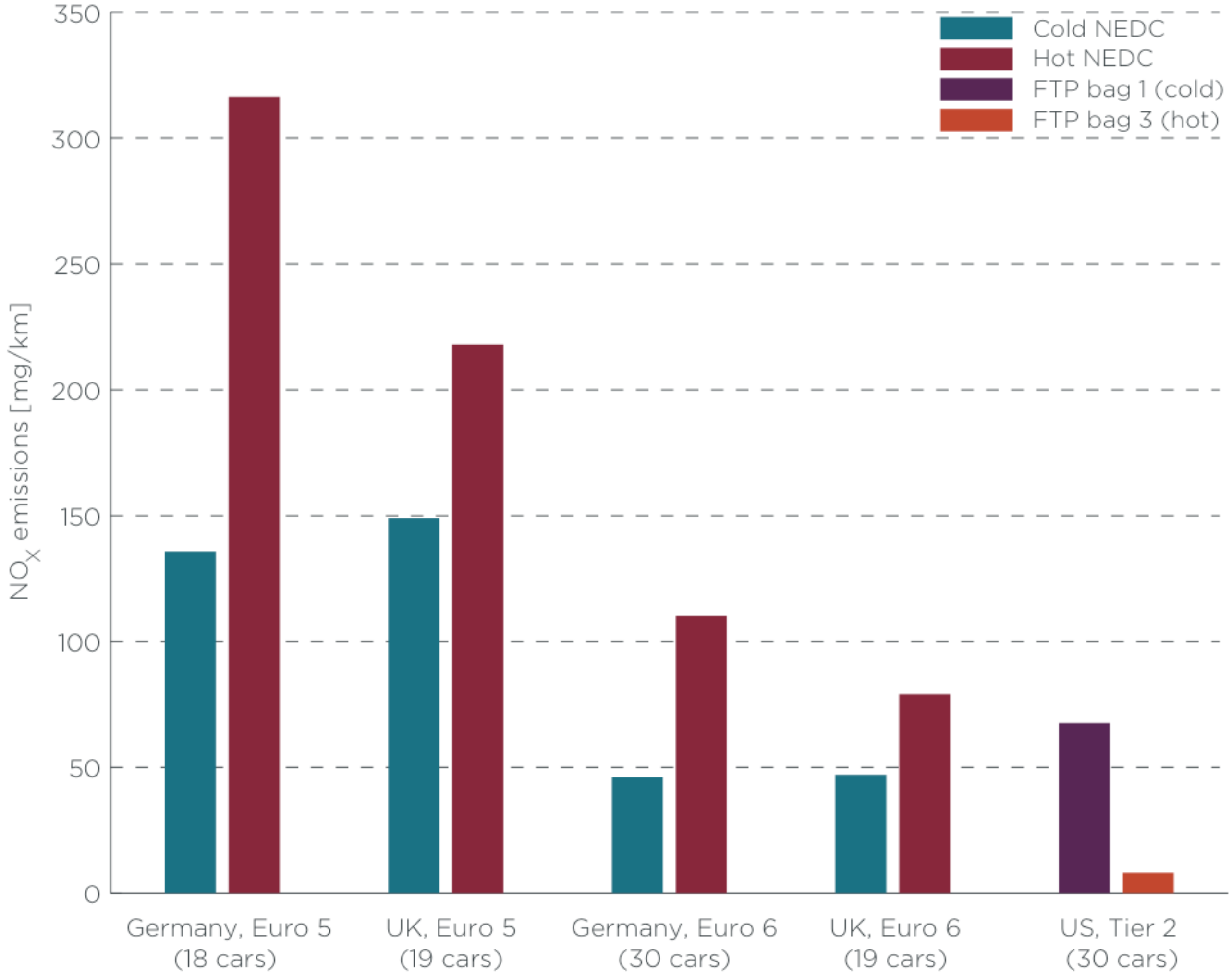
Using on-road vehicle testing (PEMS), it is possible to determine the worst offenders



icct THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: http://www.economist.com/blogs/graphicdetail/2017/01/daily-chart-13

A popular type of defeat device is recognizing cold start conditions as type approval testing



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: http://www.theicct.org/blogs/staff/emissions-test-defeat-device-problem-europe-not-about-vw

Nearly all manufacturers in the EU make use of the “thermo-window” defeat device

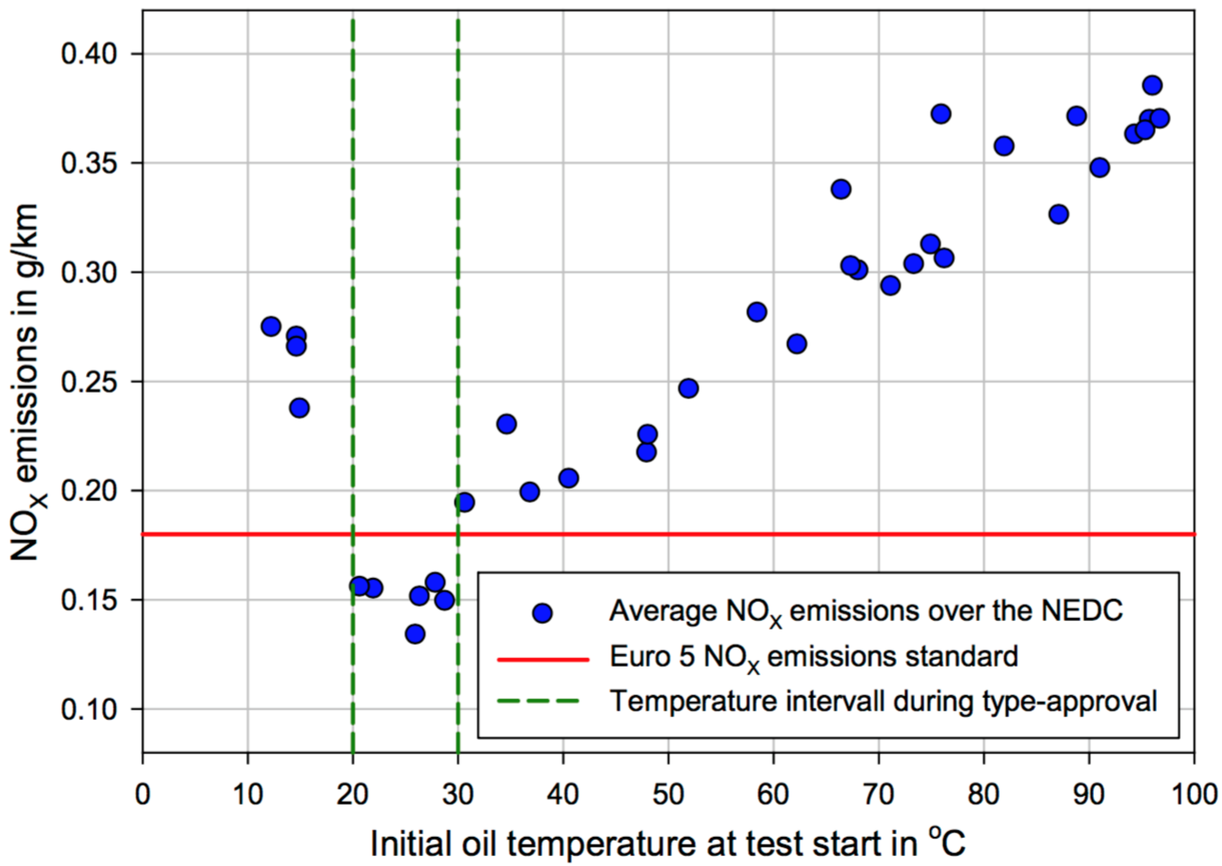


Figure 9: Average NO_X emissions of a Euro 5 diesel vehicle over the NEDC at various initial engine temperatures (Data source: Kühlwein, 2012)

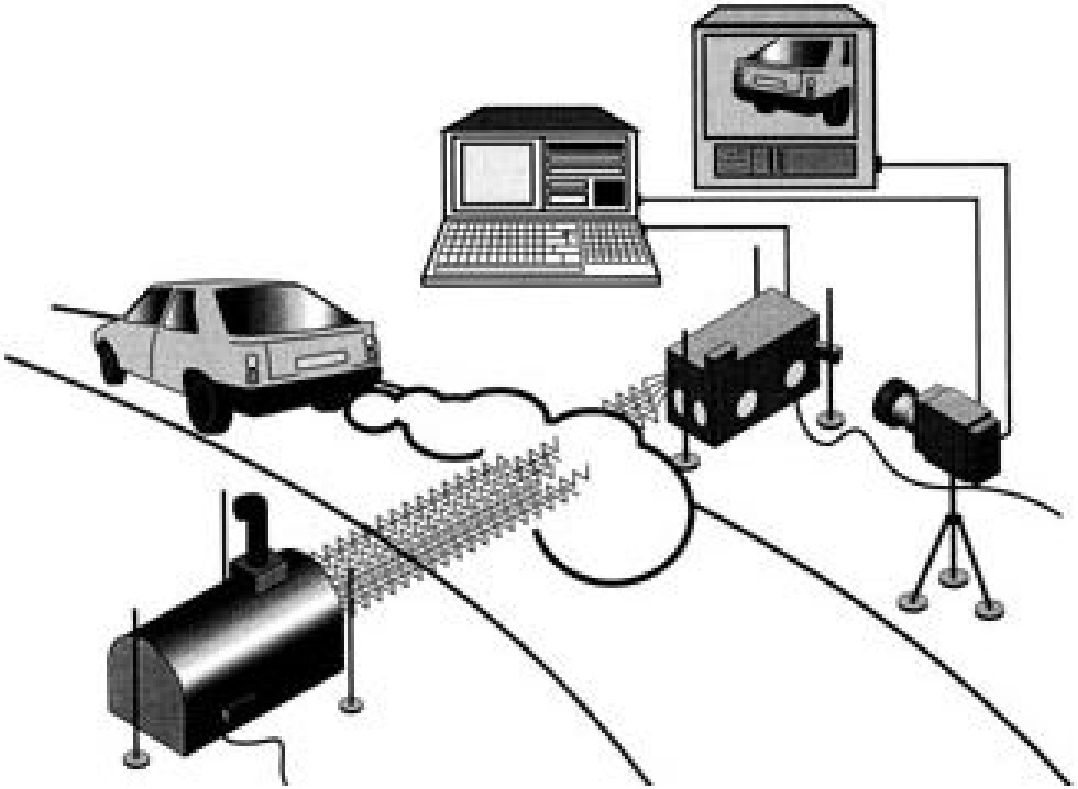
icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC75998/ld-na-25572-en-n_online.pdf

The future

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

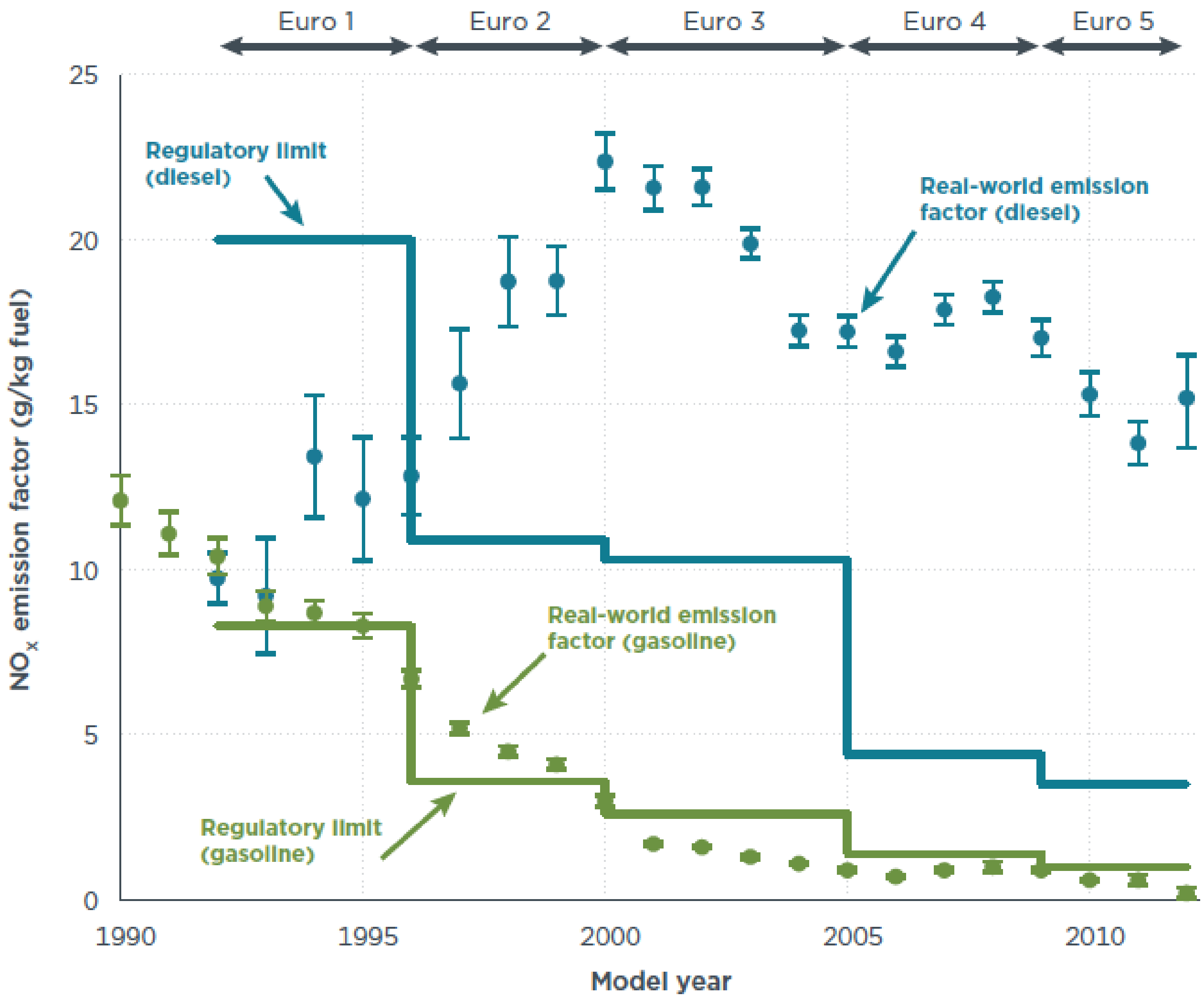
Remote sensing allows measuring the real-world emissions of thousands of vehicles – remotely!



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: Kanton Zürich, Amt für Abfall, Wasser, Energie und Luft

Remote sensing indicated large-scale problems with recent diesel cars, long before Dieselgate



THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: http://www.theicct.org/environmental-risks-diesel-passenger-vehicles-brazil-2016, based on Chen and Borken-Kleefeld (2014)

TRUE will help to inform city administrations and citizens about real-world emissions of vehicles

ENVIRONMENT | Wed Mar 29, 2017 | 10:44am EDT

Paris and London mayors announce scheme to gauge car emissions

London Mayor Sadiq Khan (L) and Paris Mayor Anne Hidalgo attend a meeting on air pollution in Paris, France, March 29, 2017. REUTERS/Gonzalo Fuentes 1/2

true
THE REAL URBAN EMISSIONS INITIATIVE

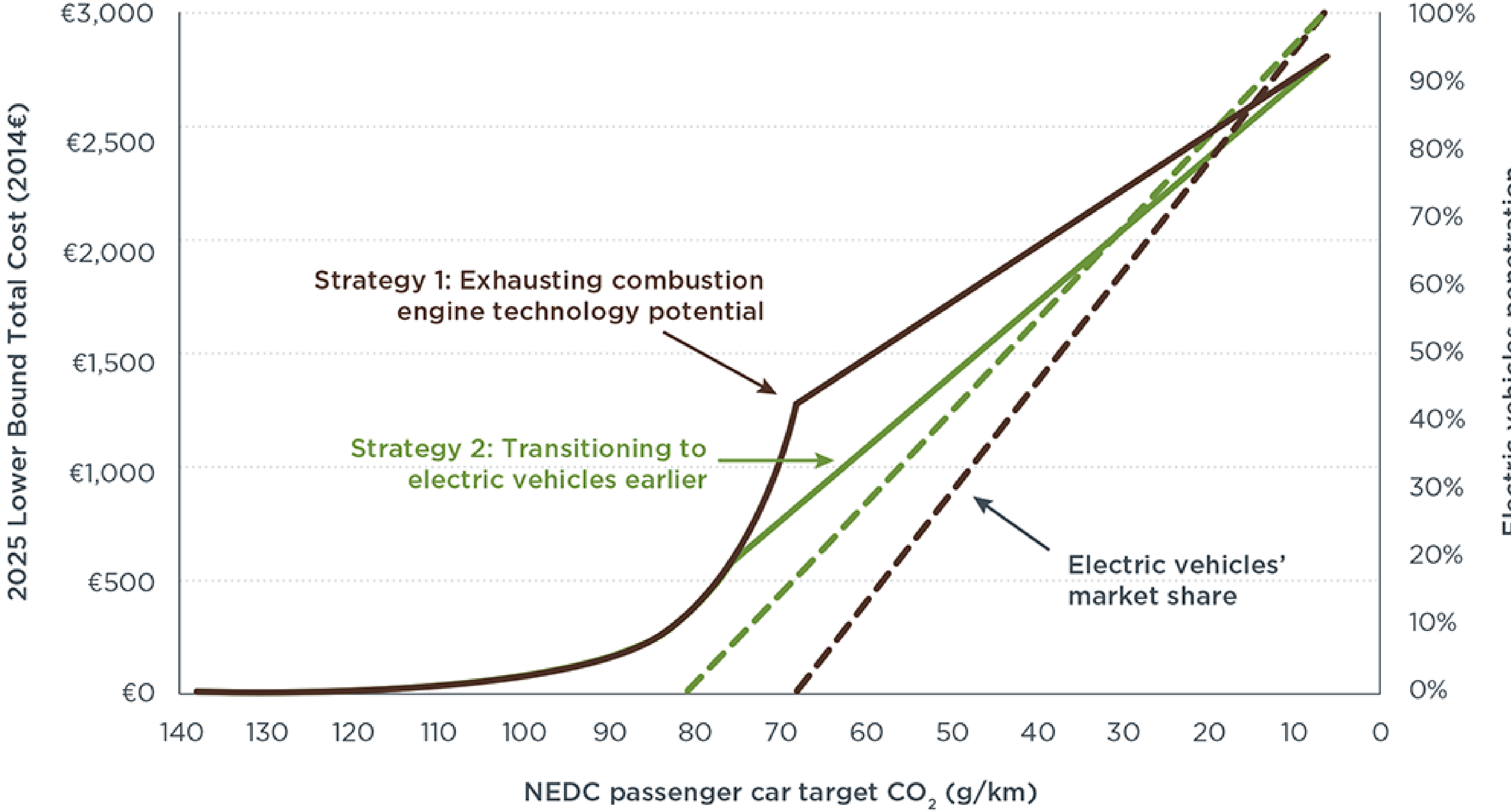
icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Sources: Reuters; Kodjak

The threat

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

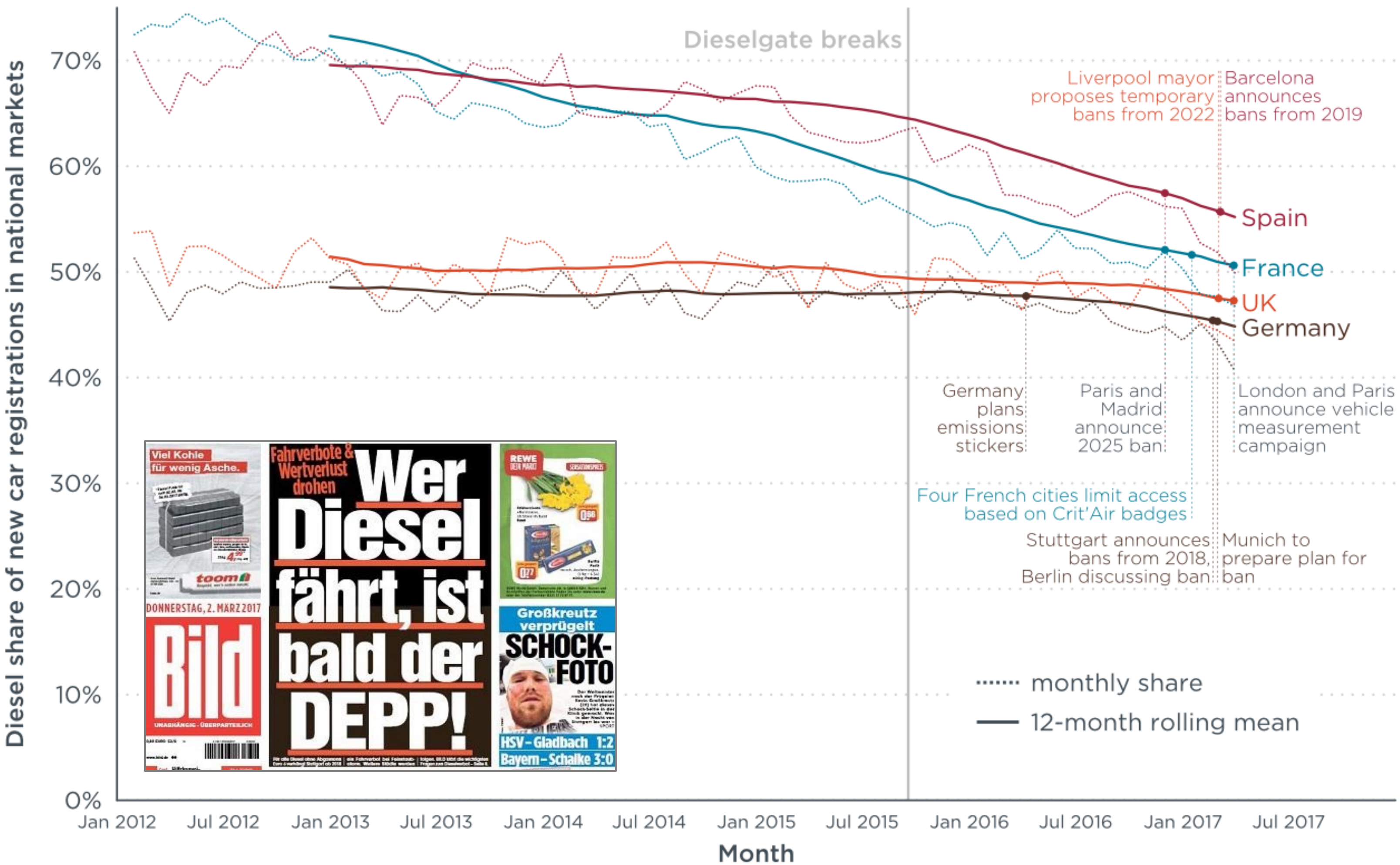
Diesel cars are under more and more economic pressure, with electric vehicles becoming cheaper



icct THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Source: http://www.theicct.org/2020-2030-co2-standards-cars-lcvs-eu-briefing-nov2016

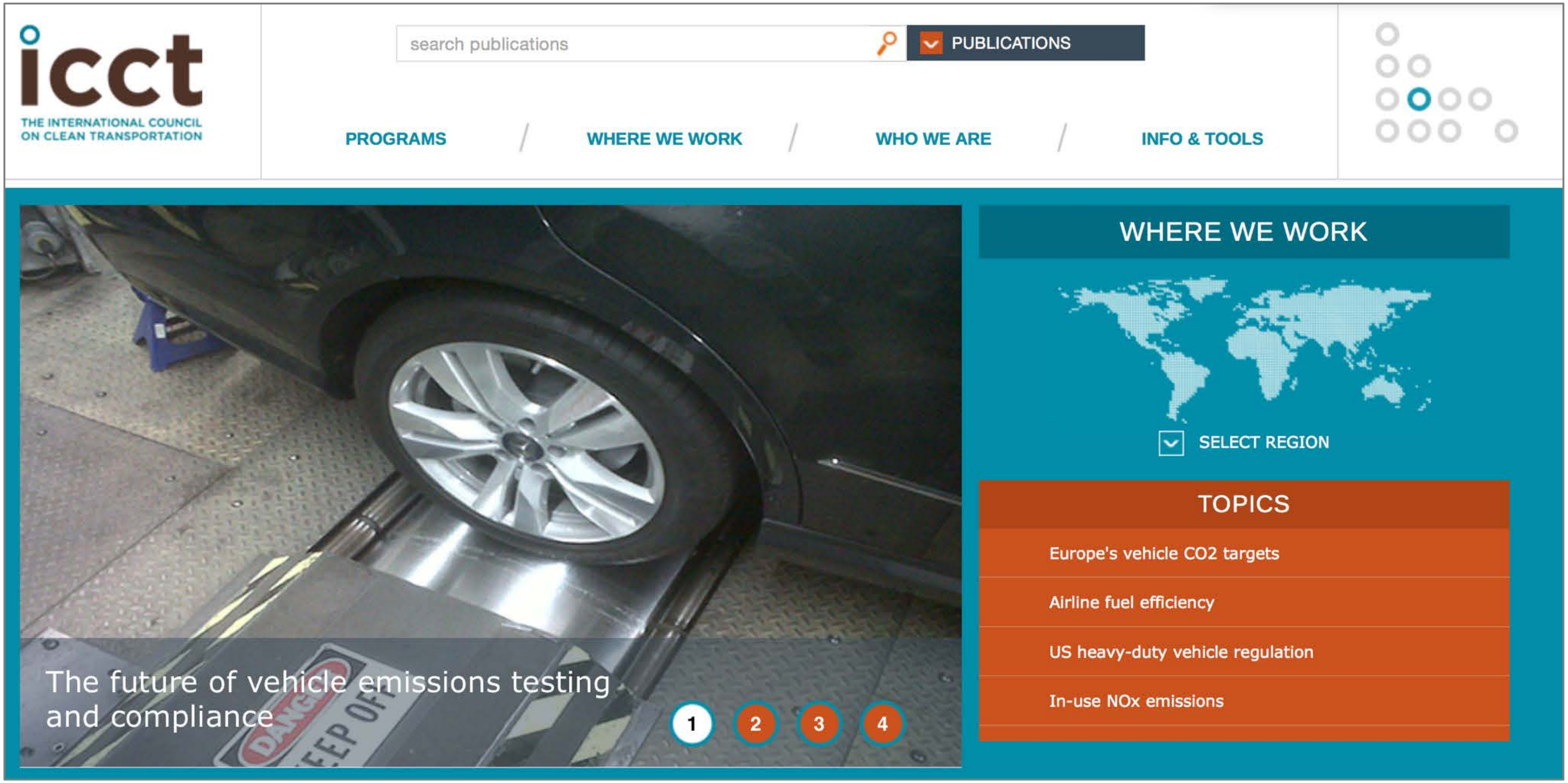
Without a trustworthy emissions testing and enforcement scheme, Diesel car sales will implode



icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

Sources: BILD; http://www.theicct.org/blogs/staff/cities-driving-diesel-out-european-car-market

For more detail, please visit our ICCT website



Peter Mock
peter@theicct.org
www.theicct.org

Global Fuel Economy Initiative
A fresh perspective

INTERNATIONAL TRANSPORT FORUM

LEIPZIG, 1 June 2017

Global Fuel Economy Initiative
A fresh perspective

INTERNATIONAL TRANSPORT FORUM

LEIPZIG, 1 June 2017

Wei-Shiuen Ng

ITF

International Transport Forum

Low Carbon Global Road Freight

Wei-Shiuen Ng

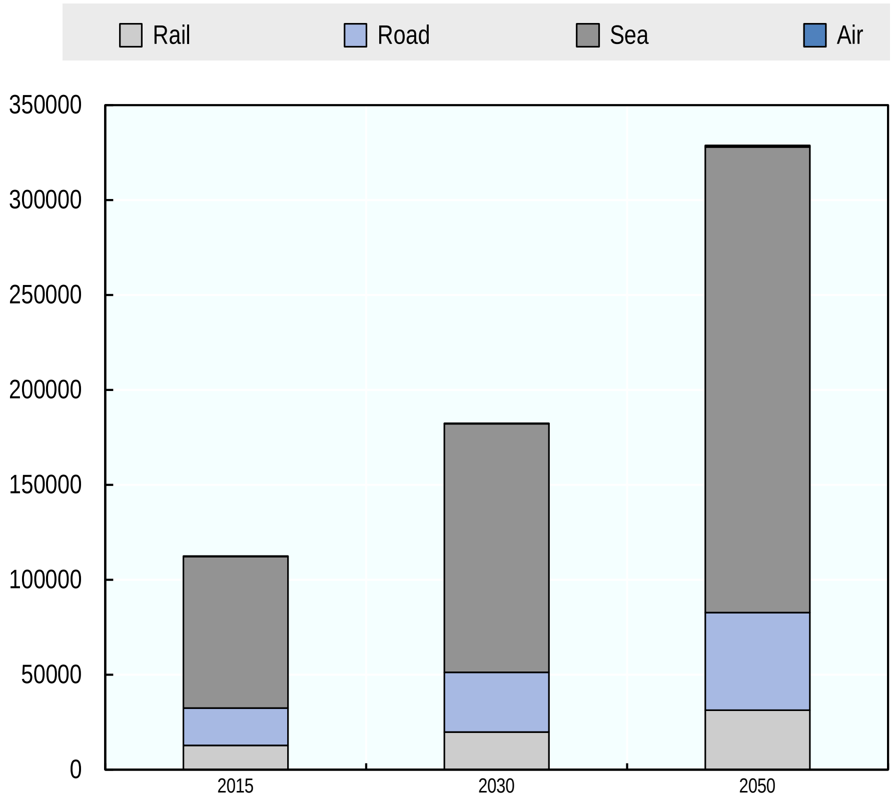
GFEI Side Event, ITF Summit 2017

June 1, 2017

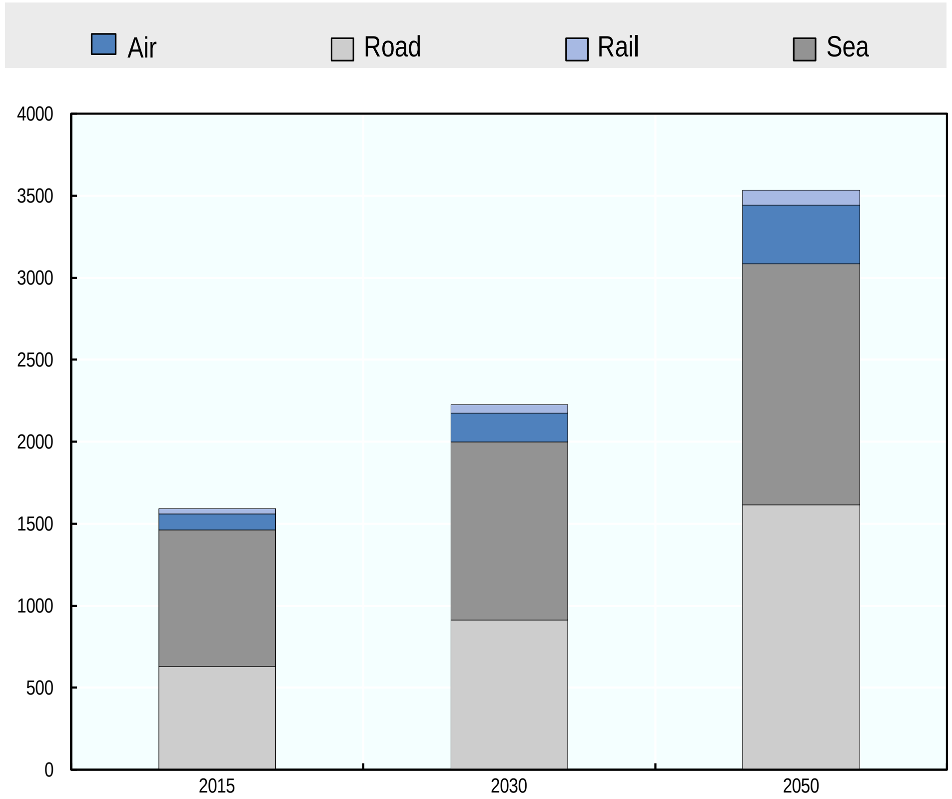
OECD

International Transport Forum

Global Freight Demand and CO_2 Emissions will Continue to Grow



Freight Transport Volumes
Business as usual
Billion tkm, 2015-2050



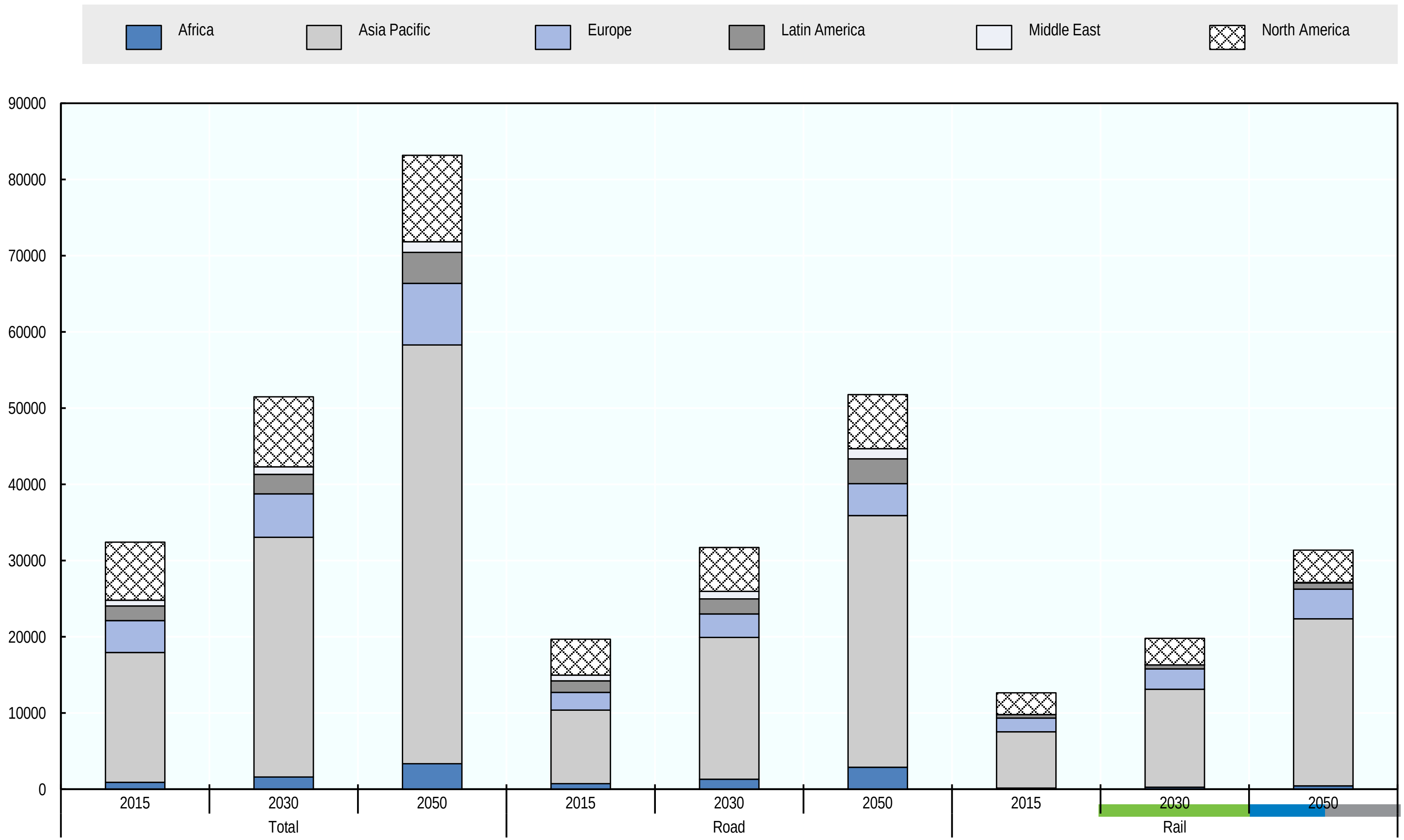
Freight CO_2 Emissions
Business as usual
Million tonnes, 2015-2050

Source: ITF Transport Outlook 2017

International Transport Forum

Surface freight tonne-kilometres by region

Baseline scenario, billion tonne-kilometres



Source: ITF Transport Outlook 2017

International Transport Forum

New Study on Low Carbon Road Freight Scenarios

Fuel Efficiency Scenarios (Emissions per vkm)	Vehicle Optimization Scenarios (Total vkm)
Scenario 1: Rapid expansion of existing fuel efficiency standards to five new markets (South Korea, Mexico, Brazil, India, and the EU)	**Scenario 3:** Non-technological measures will be implemented, • vehicle optimization measures, changes in average load factor and number of empty runs • operational measures • modifications to regulations on the weight and dimensions of vehicles • asset sharing • route optimisation
Scenario 2: Existing fuel efficiency standards in Canada, China, Japan, and the US will be improved at a regular interval till 2030 and 2050	

Scenario 4: Combines improvements in and expansion of fuel efficiency standards together with non-technological measures to capture the cumulative impact of these different policies on the reduction of global road freight CO_2 emissions

Global Fuel Economy Initiative
A fresh perspective

INTERNATIONAL TRANSPORT FORUM

LEIPZIG, 1 June 2017