Vehicle concepts for tomorrow's demand: a European research perspective

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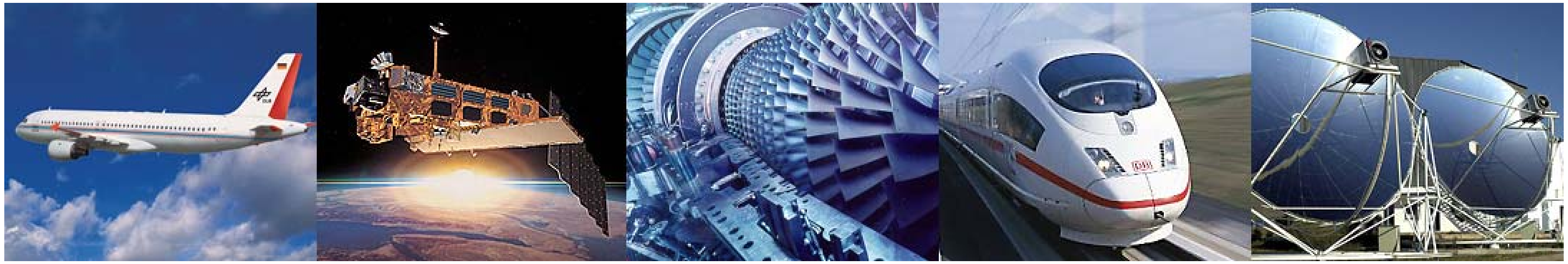
German Aerospace Center



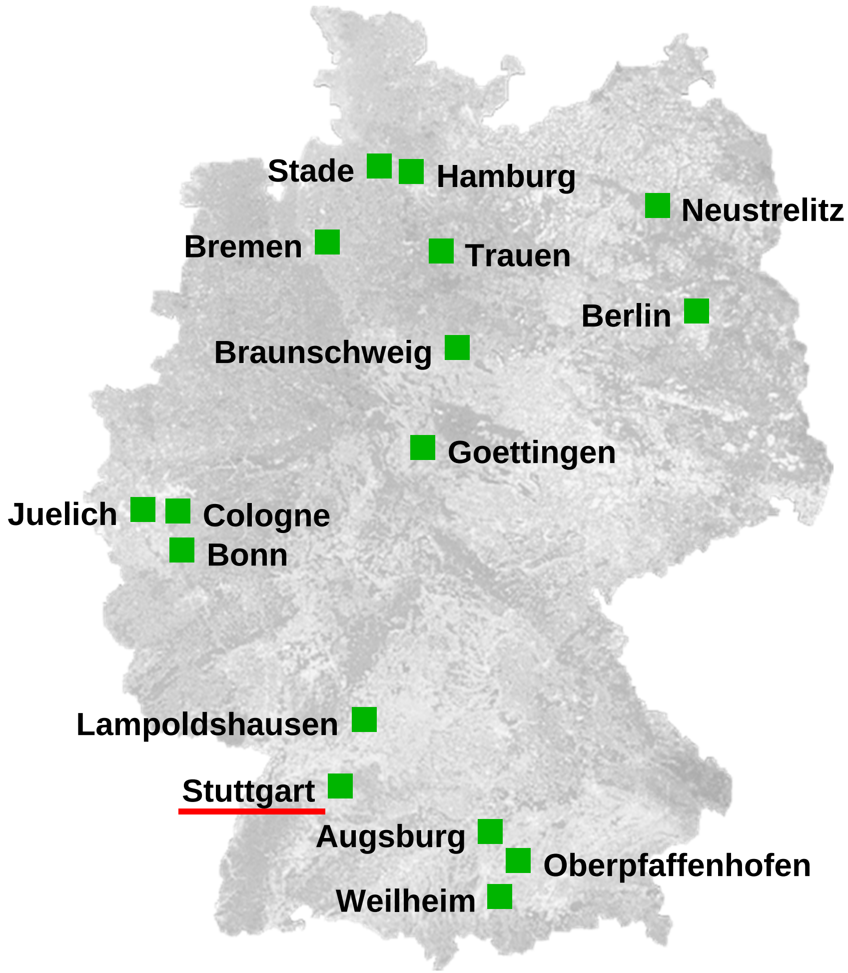
- Research Institution
- Space Agency
- Project Management Agency

Locations and employees

Approx. 8000 employees across 33 institutes and facilities at

■ 16 sites.

Offices in Brussels, Paris, Tokyo and Washington.



Research areas

- Aeronautics
- Space Research and Technology
- Transport
- Energy
- Defence and Security
- Space Administration
- Project Management Agency

Outline

- **Introduction**
    - *Drivers, CO_2 regulation in Europe, mid-term goals*
- **Today‘s EV trends in Europe**
    - Stock, new registrations
- **What about the future of vehicle electrification?**
    - European scenarios to the year 2030
    - Challenges of alternative fuels and hydrogen
- **Game changers for vehicle concepts?**
    - Automation and connectivity, other business models
- **DLR *Next Generation Car* - *vehicle concepts***
    - Concepts and technology highlights
- **Summary**

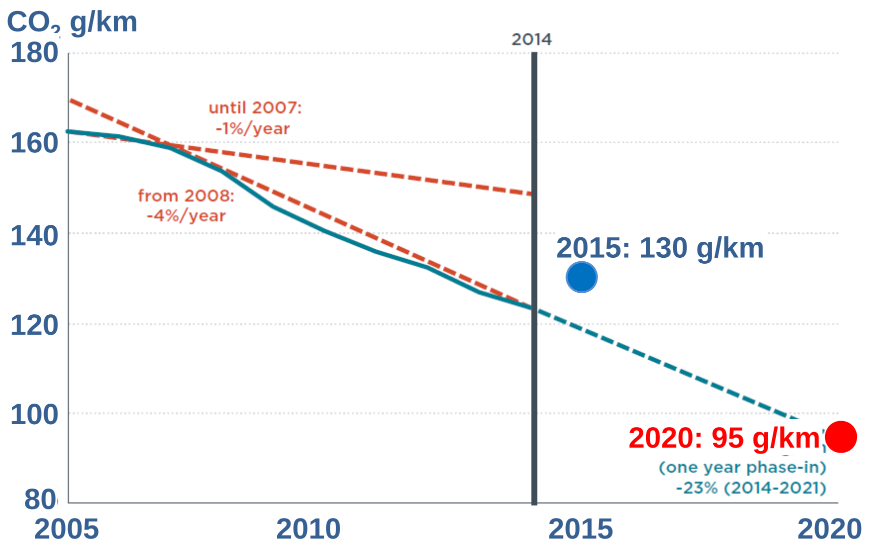
Megatrends

- Growing awareness of limited natural ressources
- Climate change in progress
- Increasing population, agglomeration in big cities and suburban areas
- Demographic change

- Increasing efficiency
- Lower fuel consumption and lower CO_2 emissions
- Alternative and regenerative power

Drivers for new developments in the automotive industry – reducing fuel consumption and emissions

- **Emission issues**
  - CO_2 legislation for passenger cars until 2020
  - Mismatch regulation / real-world
  - Local air quality



Source: ICCT

- **Emission goals, long-term,** examples
  - Netherlands: As of 2035 'zero emission' for new passenger cars
  - India: plans for 100 percent electric vehicles by 2030
  - Norway: target that in 2025 all newly-registered cars are zero emission*
  - European Union: Until 2050 60% less GHG emissions in transport compared to 1990 §
  - G7++: Until 2050 40-70% less GHG emissions worldwide compared to 2010
  - COP21**: Zero net emissions until mid-century / closed carbon cycle

* Norwegian National Transport Plan § EU Roadmap, EC White Paper 2011; ++ Final declaration G7-summit 'Schloss Elmau', 7.–8. June 2015; **COP21 2015 Paris Agreement

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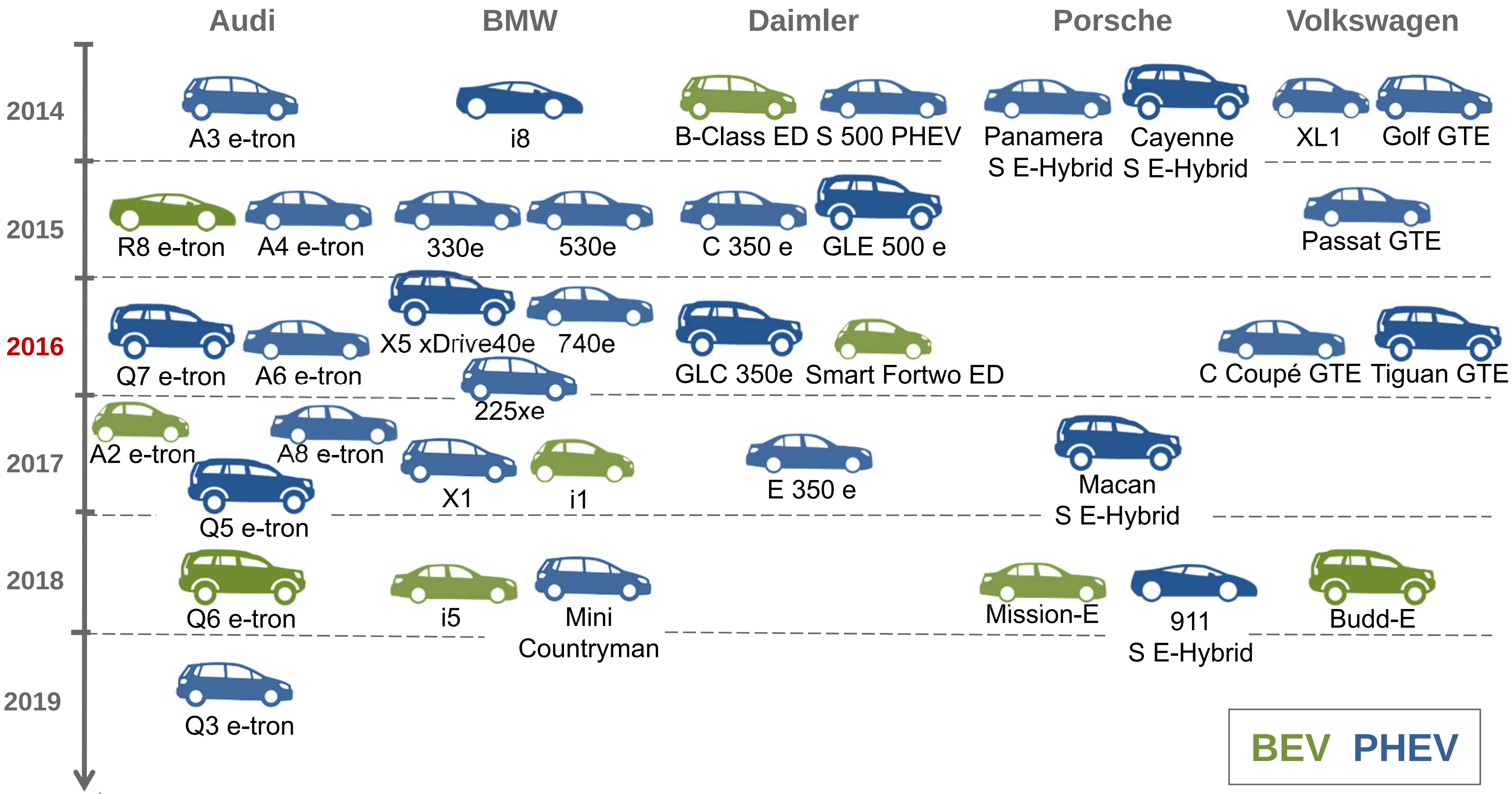
Trends in electrification of powertrains (1)
Growing number of PEVs from German carmakers

Source: Audi, BMW, Ford, Daimler, Opel, Porsche, Volkswagen

Trend in electrification of powertrains (2) - 58 models eligible for German incentives – more to come!



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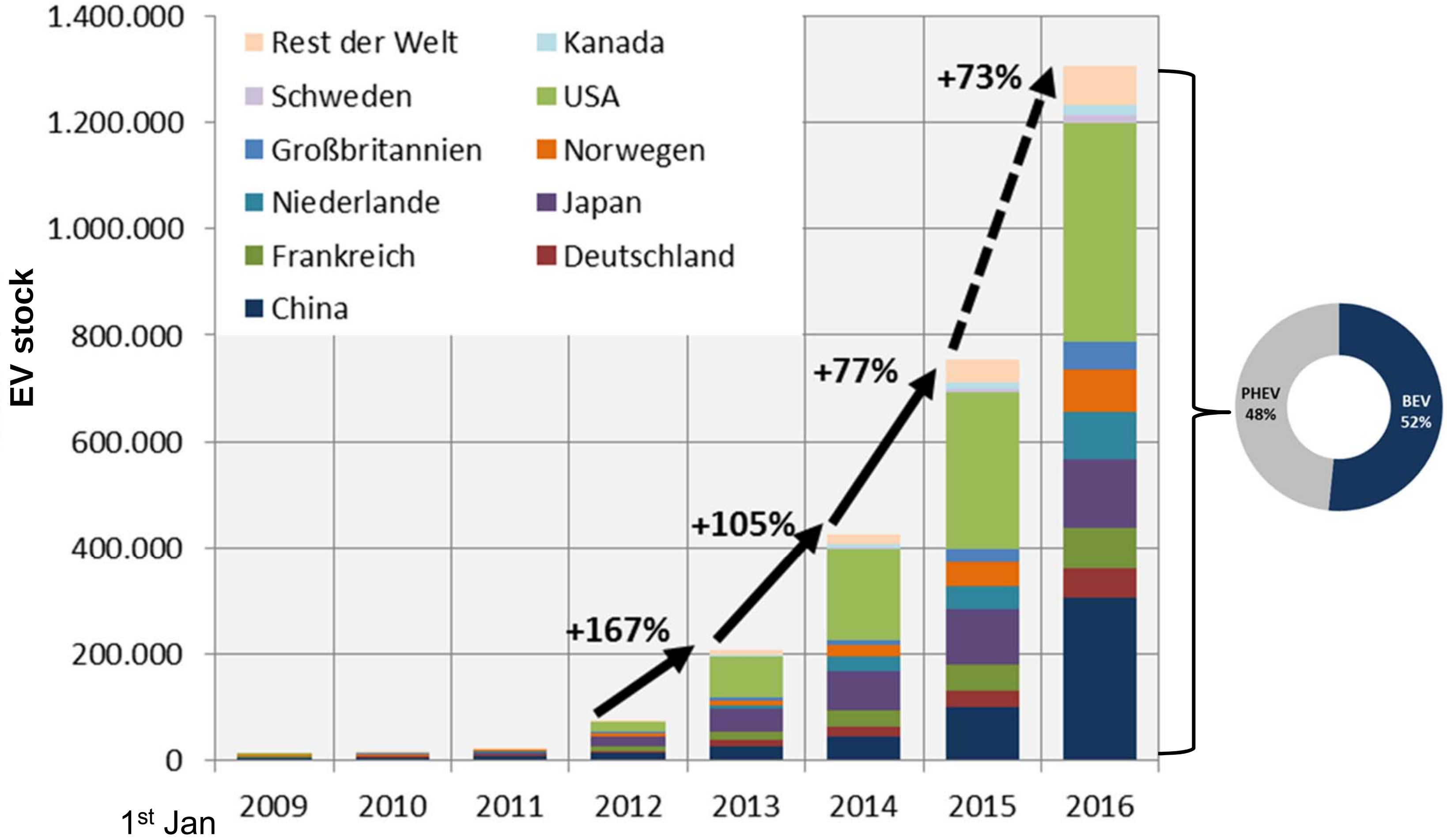
Trends in EV stock development international



Source: ZSW (2016)

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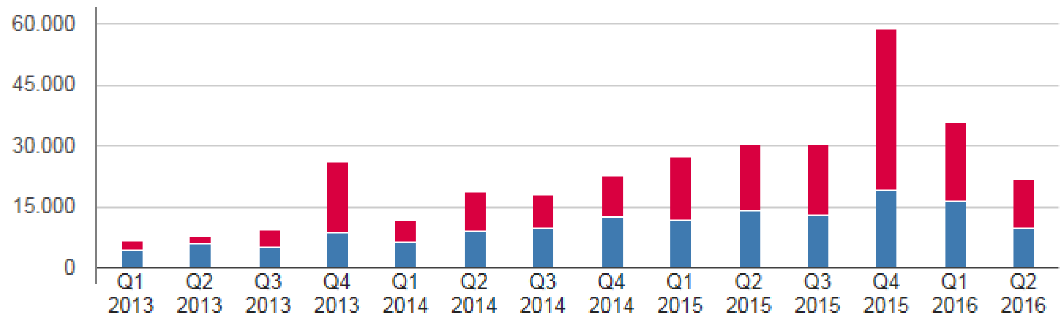
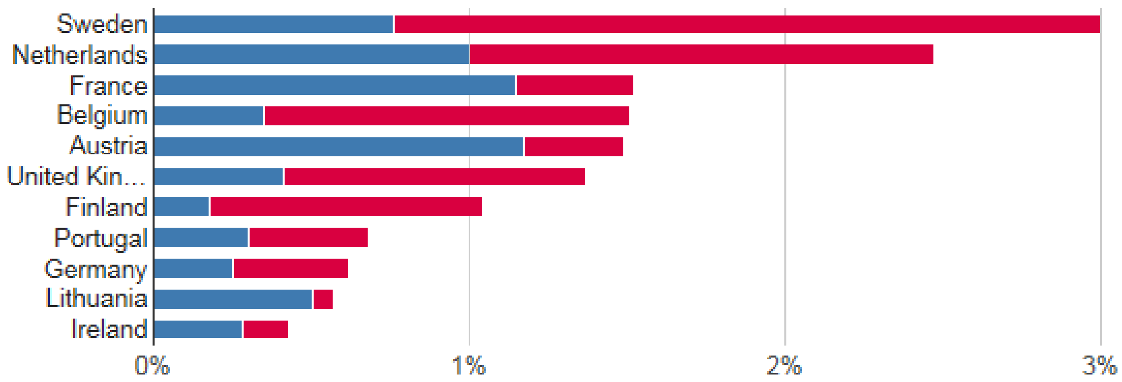
PEV trends in the European Union



New registrations for PEV (M1) in the European Union

BEV

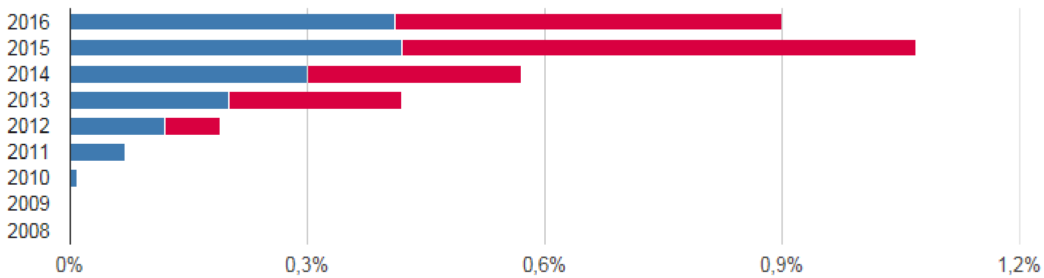
PHEV



Top PEV (M1) market share Countries in the European Union

BEV

PHEV



PEV (M1) market share in the European Union

BEV

PHEV

Source: European Alternative Fuels Observatory, www.eafo.eu

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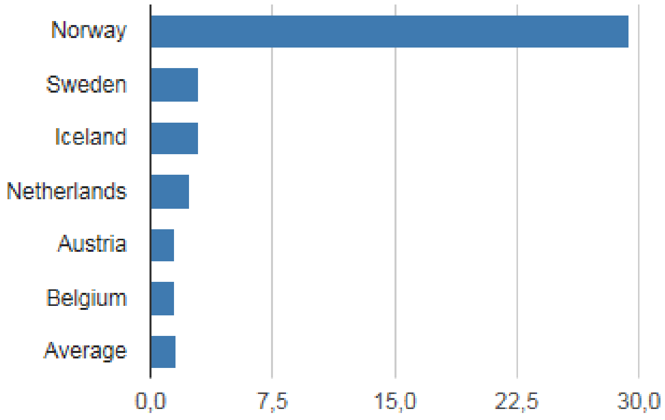
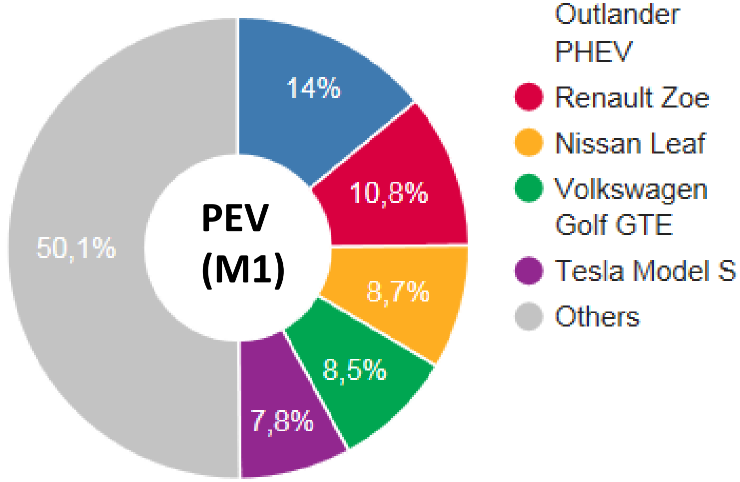
PEV trends in Europe

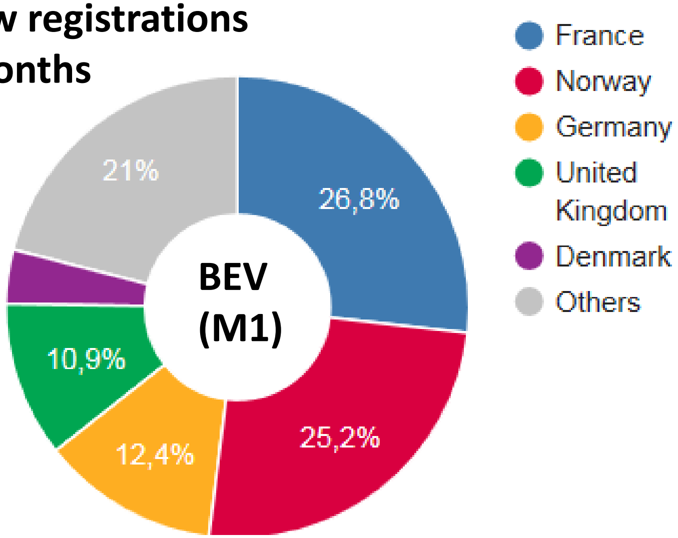
EV Market share in 2016 YTD



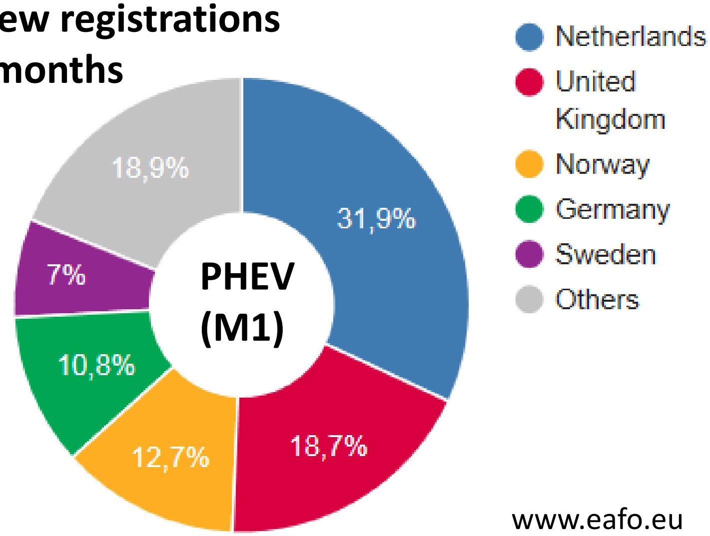
Best selling PEV models (M1) in Europe last 12 months



Share new registrations last 12 months



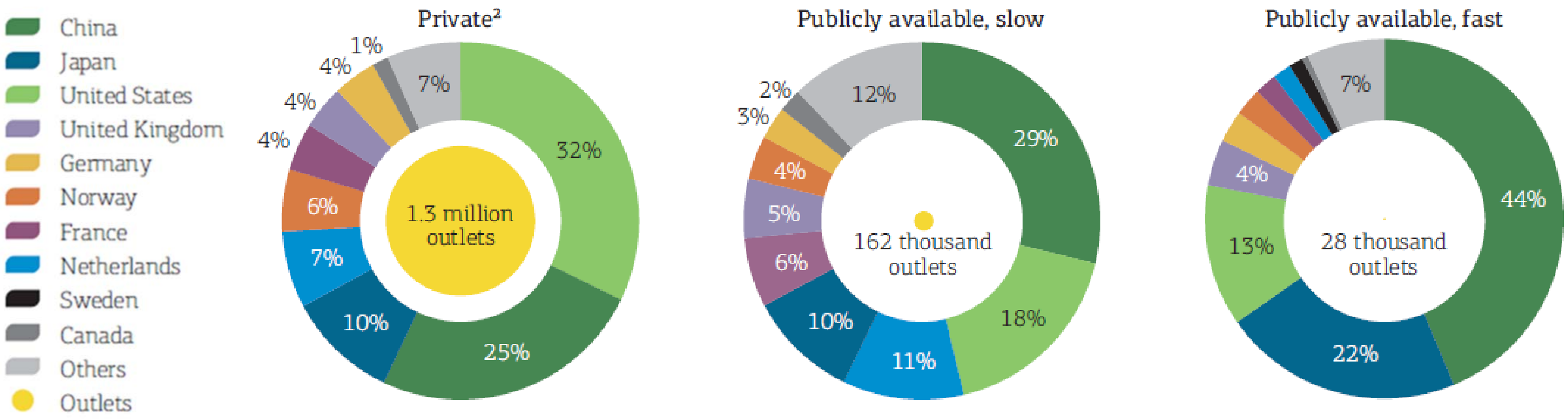
Share new registrations last 12 months



www.eafo.eu

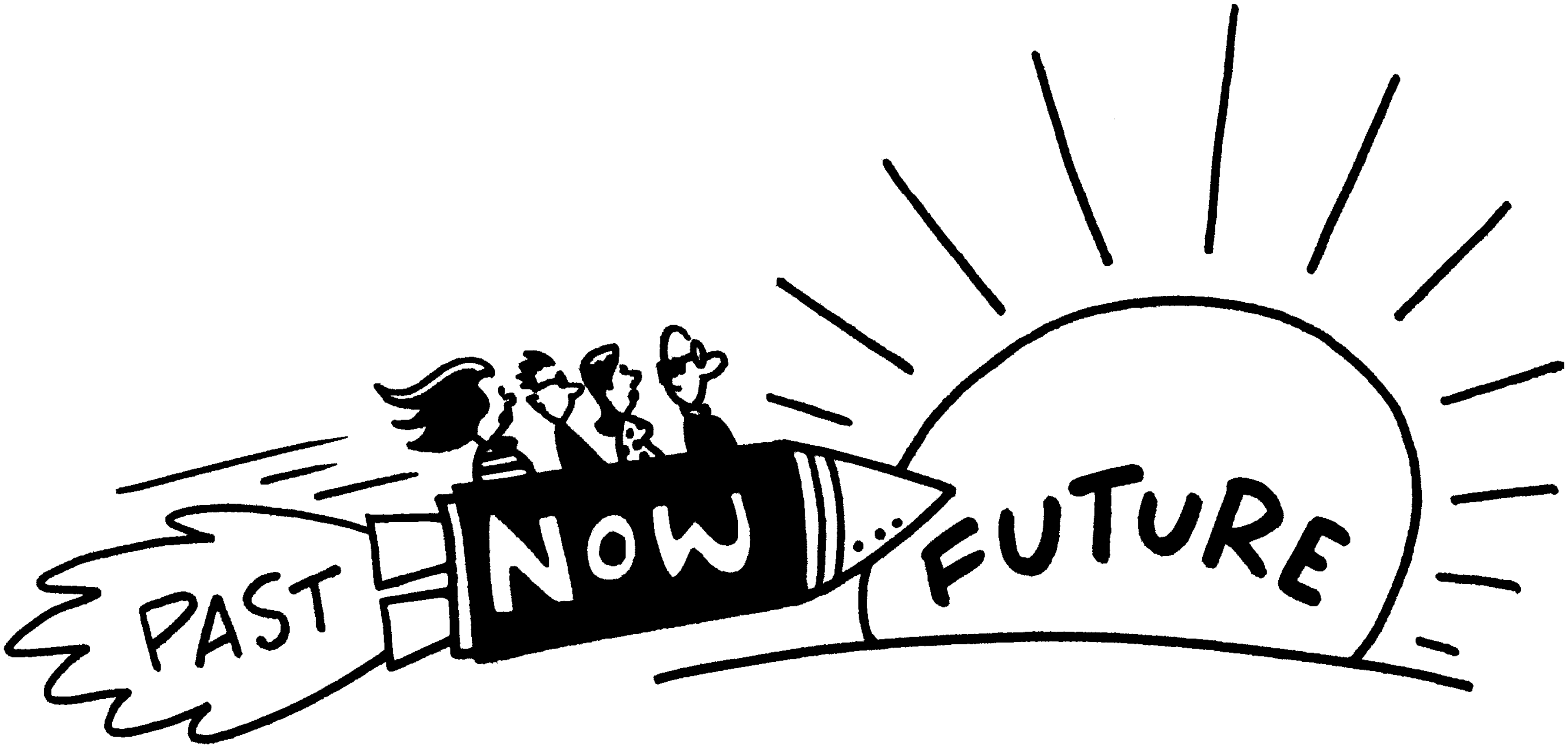
Trends in EVSE

Geographical distribution of the 2015 stock of EVSE outlets by charger type



OECD/IEA, Global EV Outlook 2016

- estimated total of 1.45 million electric car charging points worldwide in 2015
- United States and China account for more than 55% of private outlets
- China and Japan account for more than 65% of fast-charging outlets
- Problem: business models of charging infrastructure!

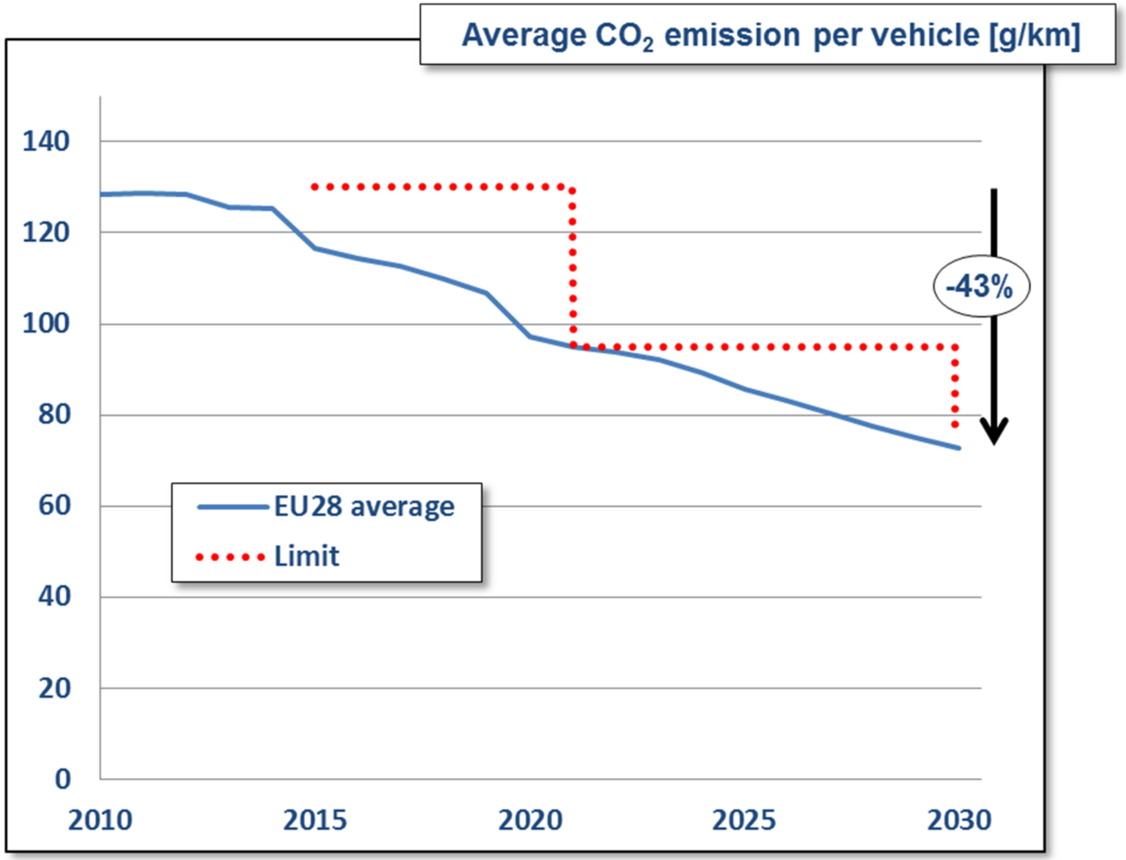


What about the future of electrified powertrains?

How to reach the EU- CO_2 target in the new vehicle fleet ? What could be the target in 2030?

Modelling results / BaU-scenario

- With the **efficiency improvements** and a slight electrification, the average CO2-emissions of new vehicles can be reduced by **24%** until 2020. Thus, the given limit of **95 g/km** will be reached
- The onward electrification comes with a reduction of **43%** until 2030 compared to 2010. So the assumed target of **75 g/km** will be achieved

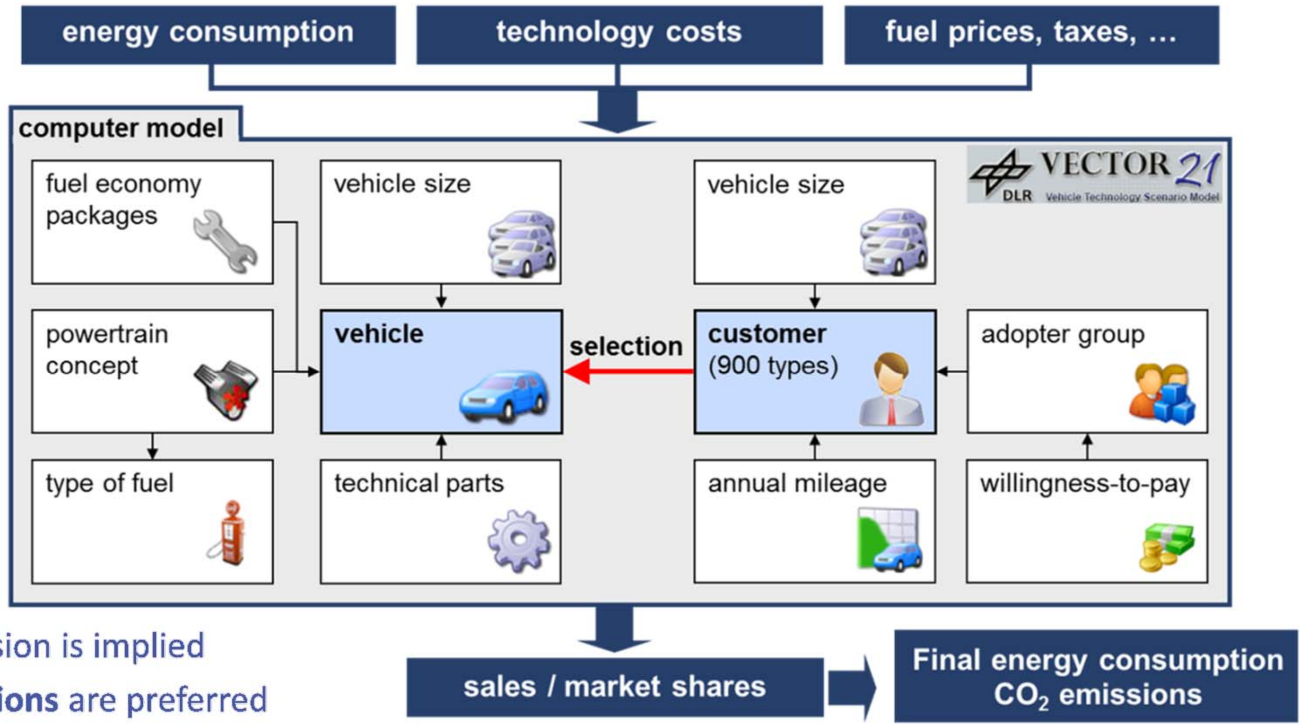


VECTOR21 scenario results for the EU

Ref. DLR, http://www.project-emap.eu/

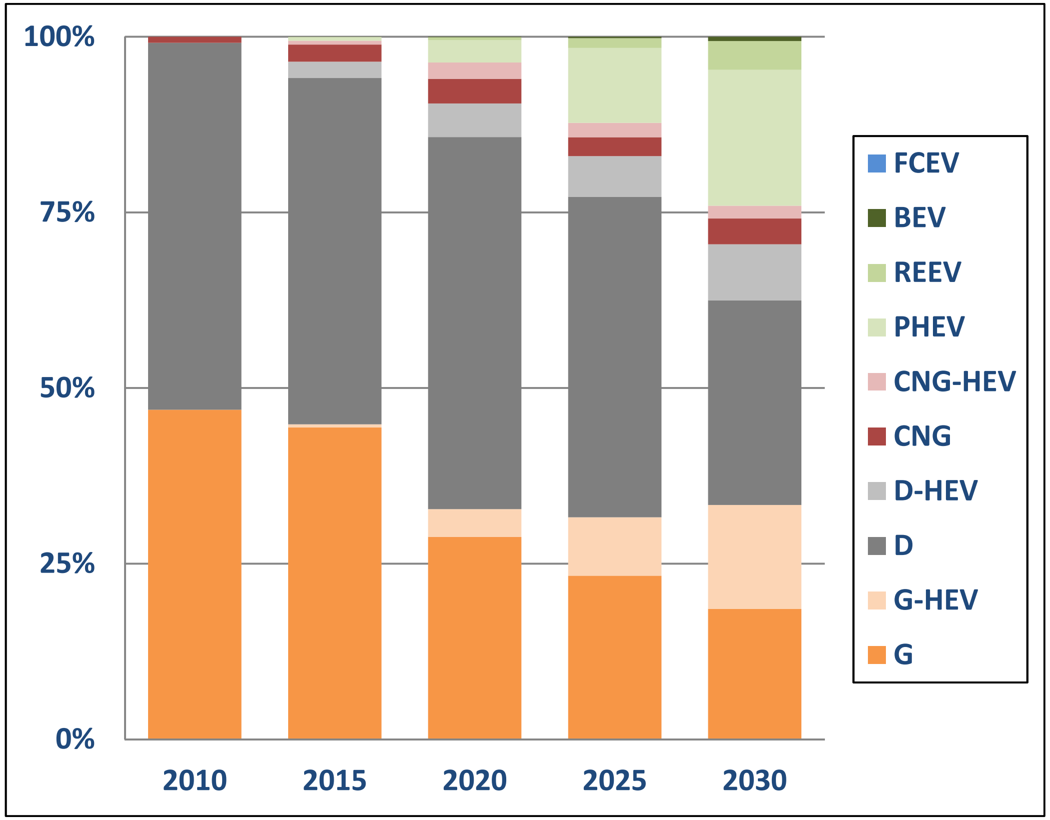
Model approach VECTOR21
Vehicle Technologies Scenario Model

- Different **customers** are specified
- **Vehicles** are technically, economically and environmentally specified
- **Political** regulations and boundary conditions are modelled
- Expected **development** and changes of key parameters can be considered
- A **RCO**[1] based purchase decision is implied
- Vehicles with less **CO_2-emissions** are preferred



Business-as-Usual scenario – EU28
New vehicle sales

- The electrification of the European market takes place. In 2030, almost 50% of the new vehicles have an electric or electrified drivetrain, of which 50% are equipped with a plug-in device.
- High efficient Diesel vehicles can have advantages in CO_2-emissions what brings a largely constant amount of new vehicles in Europe.
- The conventional vehicles are more and more replaced by electrified drivetrains after 2020.
- FCEV do not enter into the market



VECTOR21 scenario results for the EU

Ref. DLR (2015), http://www.project-emap.eu/

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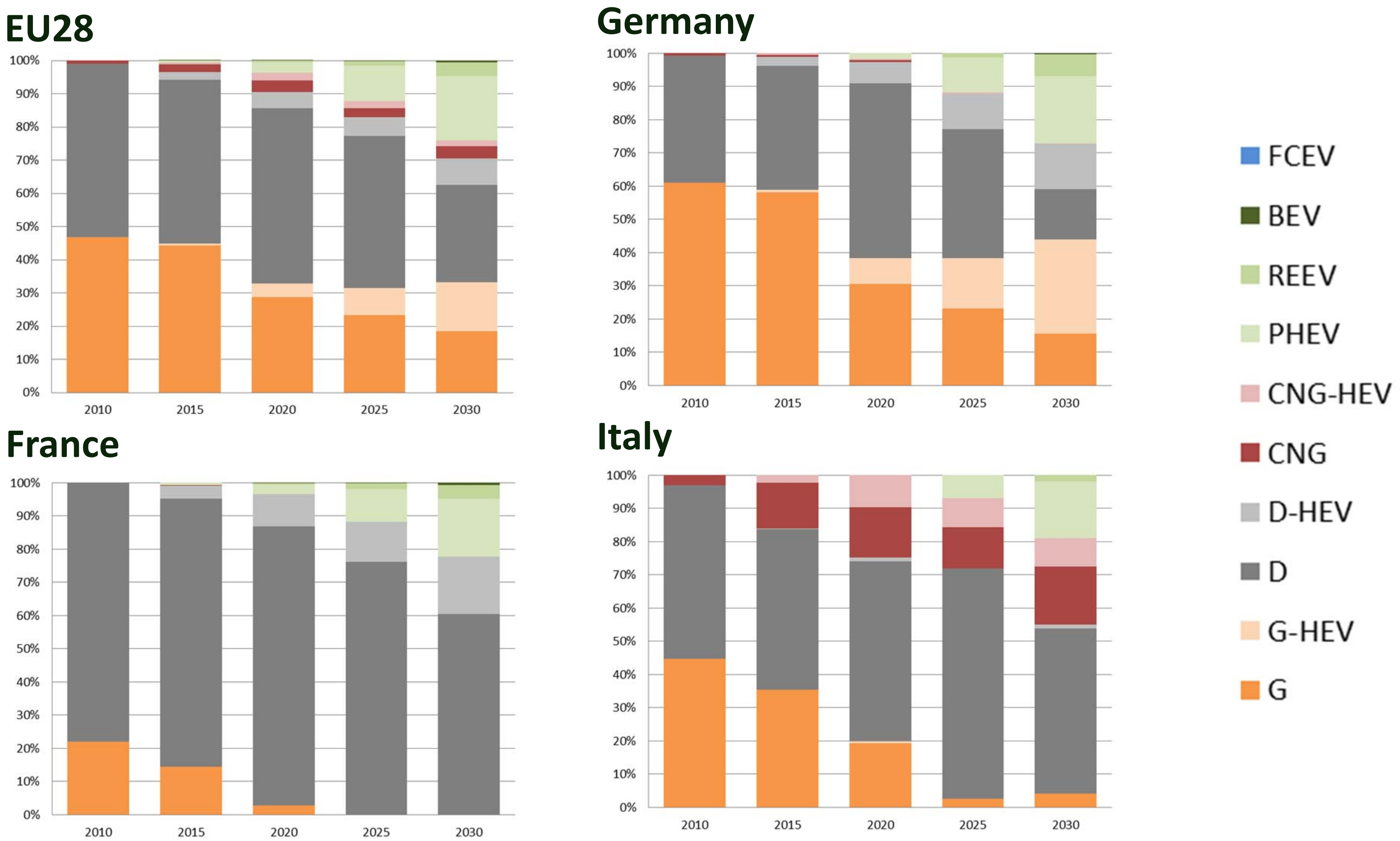
Business-as-Usual scenario – EU28
New vehicle sales – differences between countries



Ref. DLR (2015), http://www.project-emap.eu/

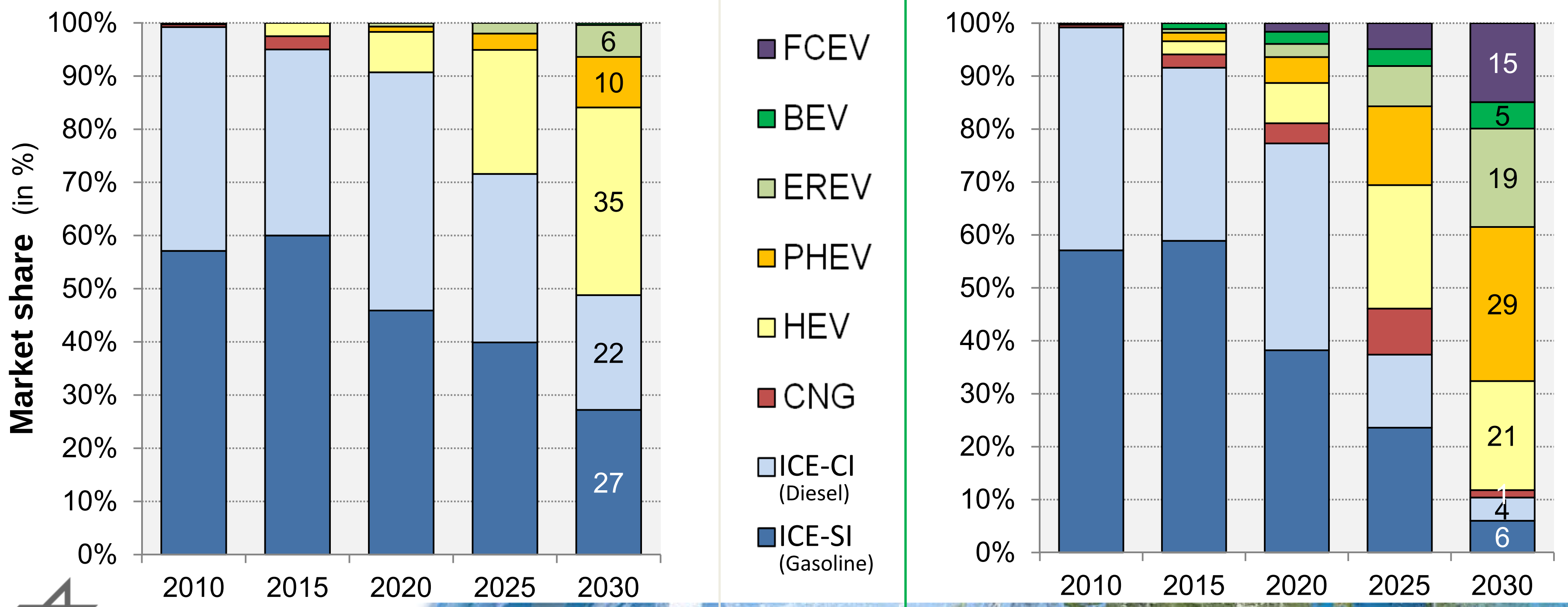
Development of the German new car market in alternative scenarios / VECTOR21 with utility function

Alternative scenario 1: *Conservative*

- Low oil price (-40% IEA Current Policy)
- CO_2 limits post 2020 constant (95g)
- No tax privileges for CNG after 2018
- Slow extension of charging/H_2 infrastructure

Alternative scenario 2: *Progessive*

- Strong increase of oil prices (+40%)
- Strict CO_2 regulation (65g in 2030)
- Continuation of tax privileges for CNG
- Fast buildup of charging /H_2-Infrastructure



Source: Redelbach, DLR

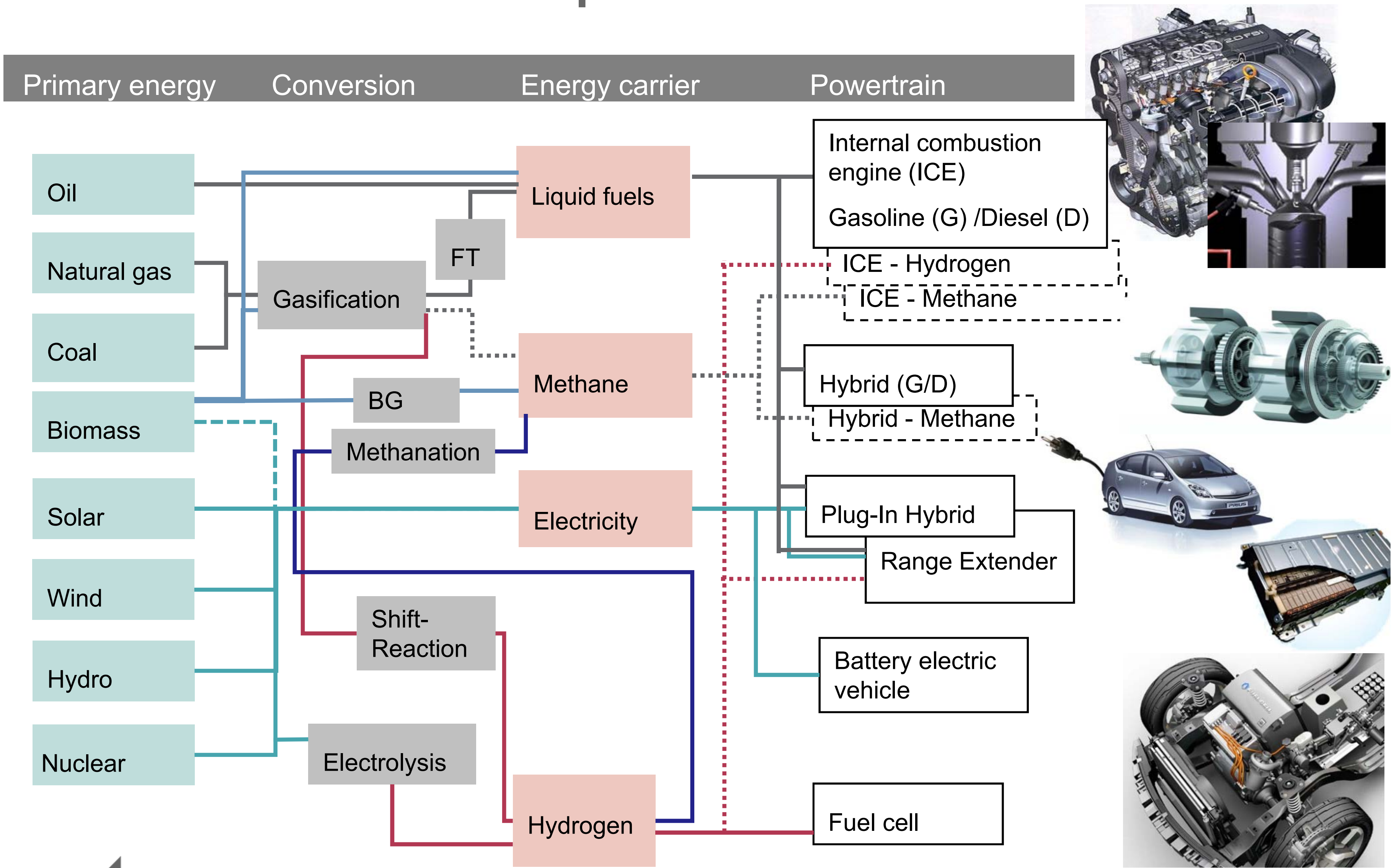
Picture: www.turneight.co.uk

Automobiles and their fuels:

All options taken into account?

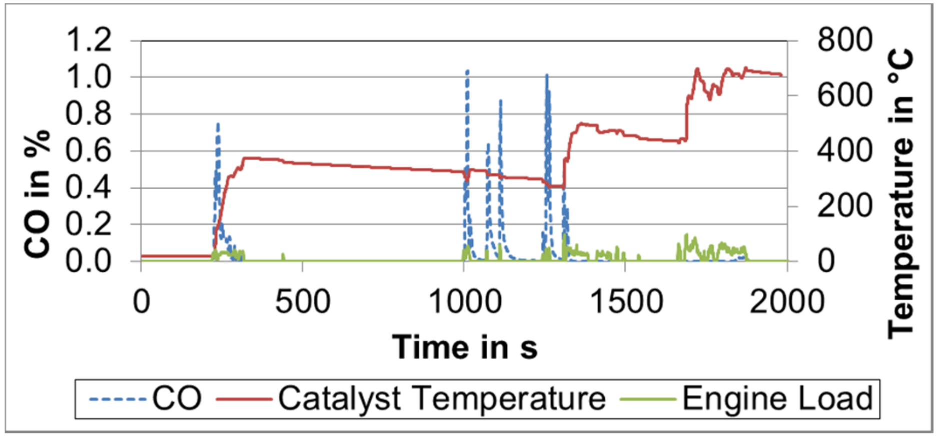
A stronger link to the energy system?

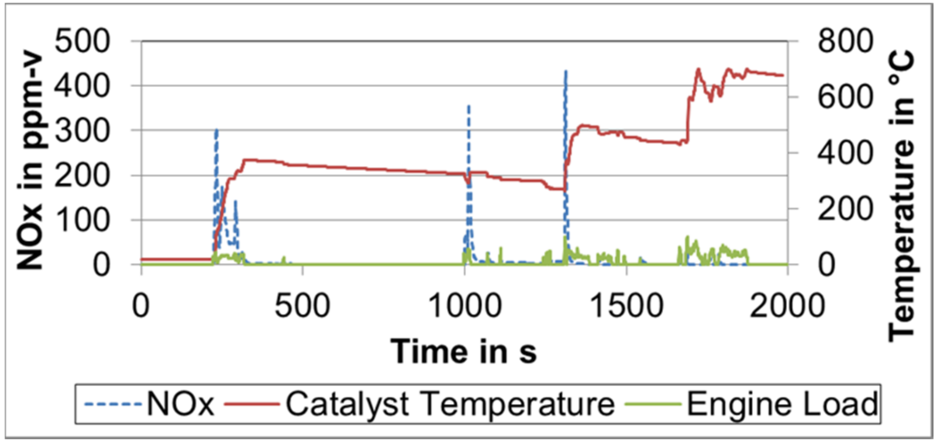
Alternative fuels and powertrains



FT: Fischer-Tropsch process
BG: Anaaerobic digestion (biogas) process and upgrading the biogas to methane
Power2gas: Electrolysis + methanation

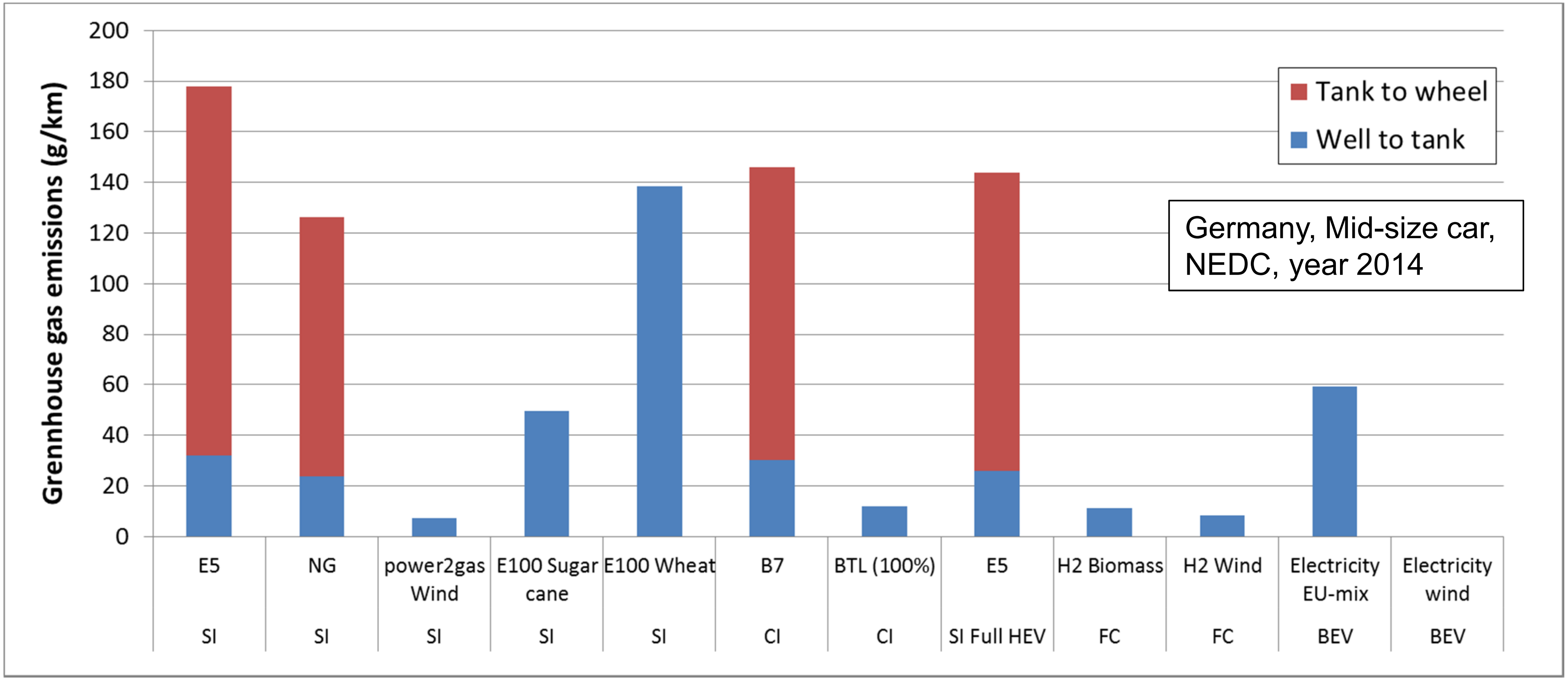
PHEV Challenges:
Emissions in "Hybrid Mode"





Catalyst cools down during WLTC resulting in several cold start peaks (23C° environment temperature, roller dynamometer measurements)

Greenhouse gas emissions (well to wheel)

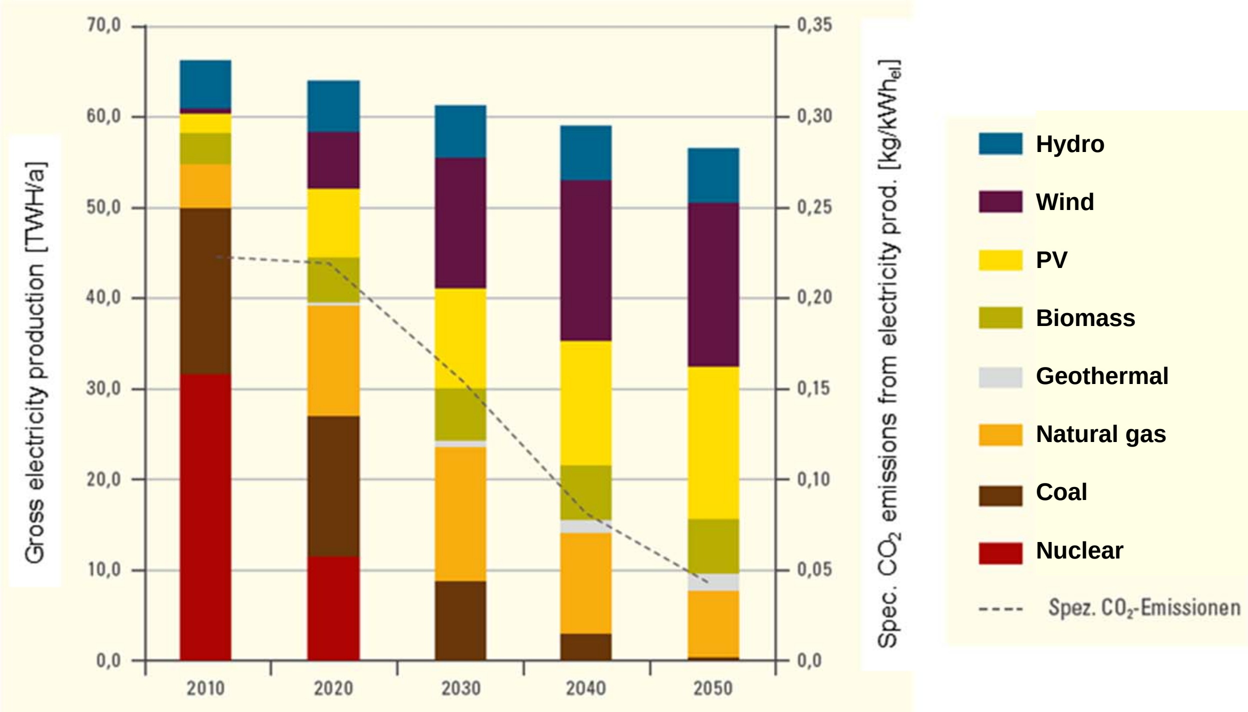


WTW analysis includes the emissions from fuel production (WTT) and driving (TTW), but not the emissions for the production of vehicles.
Biofuel tank to wheel emissions are considered as „neutral", Wind electricity production emissions are taken as zero.
SI: Spark ignition, CI: Compression ignition, HEV: Hybrid electric vehicle, FC: Fuel cell, BEV: Battery electric vehicle, E5: 5% Ethanol and 95% Gasoline, NG: Natural gas, e-gas: Methane from hydrogen (electrolysis from wind electricity), E100: 100% Ethanol, B7: 7% Biodiesel and 93% Diesel, BTL: Biomass to Liquid, H2: Hydrogen, power2gas wind: electrolysis and methanation of wind electricity

Own calculations based on Concawe (2014), DLR (2014) and DLR database

Development path renewable electricity to 2050 in Baden-Württemberg, a federal state in Germany

Gross electricity production & spec. CO_2 emissions per kWh_{el}



- How can a maximum share of renewable hydrogen be enforced in Baden-Württemberg?
- How can surplus electricity use from wind and PV plants be maximized?
- How can H_2 mobility contribute to lower (CO_2) emissions from transport sector by 2030?
- What is the possible contribution of H_2 mobility to integrate renewable energies?

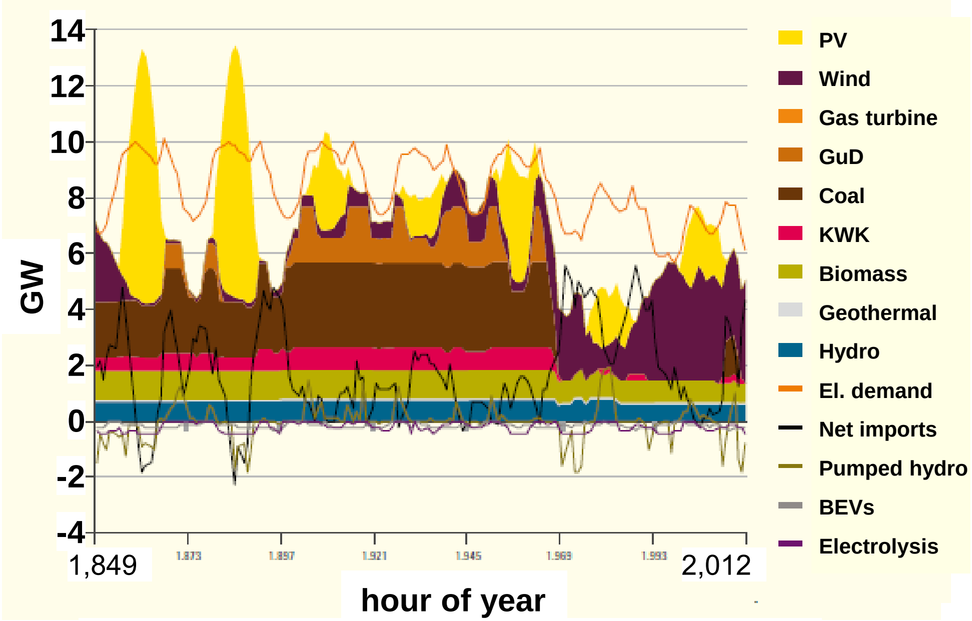
Based on IEKK (2014) – Integrated Energy- and Climate-Protection plan for Baden-Württemberg

Ref.: LBST, DLR (2016): Commercialisation of hydrogen technology in Baden-Württemberg

BW: Surplus electricity no business-case for electrification of H_2 – scenario „Flex-“

Electricity generation Baden-Württemberg [GW]

Selected period / 1 week in March



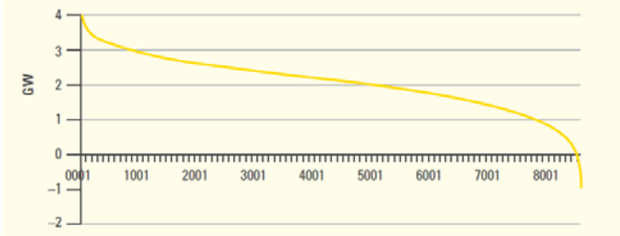
Synthetic average meteorological year / load of 2030

Simulation by REMIX-Modell, DLR-TT STB

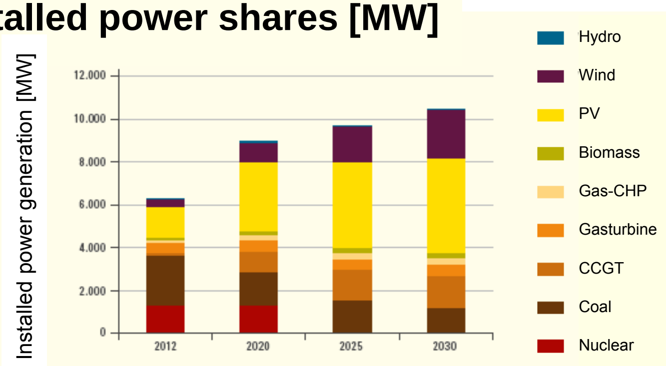
Residual load [GW]

(Annual load duration curve)

Stuttgart as example



Installed power shares [MW]



Total hydrogen demand scenario	**3.8 TWh_{el}**
Surplus electricity BaWü 2030 (ca.)	**2.9 TWh_{el}**
REL production BaWü 2030 (IEKK*)	37.6 TWh_{el}
Electricity demand BaWü 2030 (IEKK*)	74.7 TWh_{el}

Ref.: LBST, DLR (2016): Commercialisation of hydrogen technology in Baden-Württemberg

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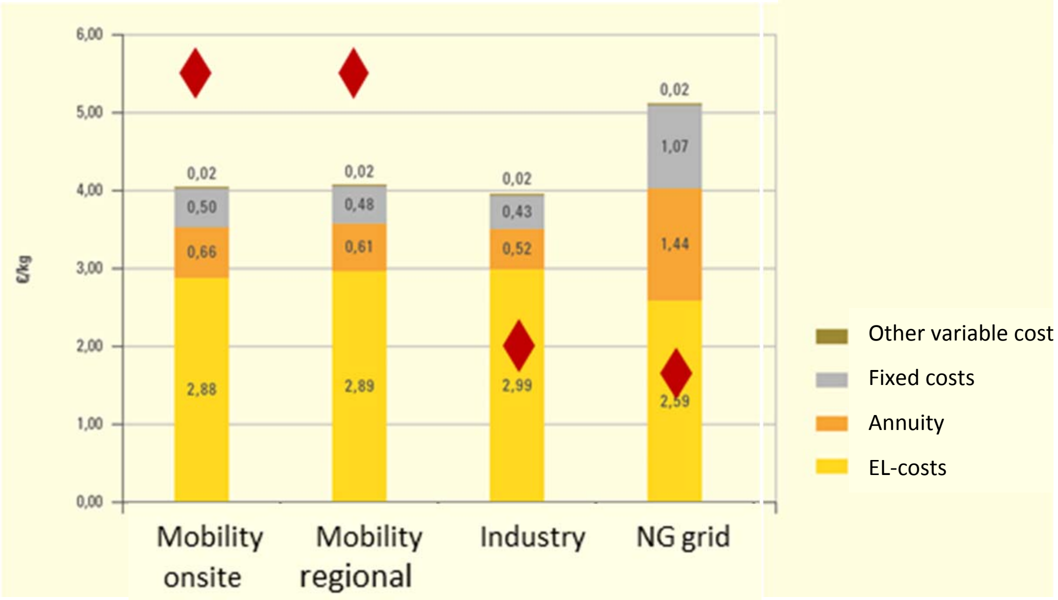
Market perspective REN H_2 – Positive business case for transport

- Significant differences in expectations of potential business cases in hydrogen market sectors
- Largest negative gap between achievable H_2 prices (1.67 €/kg) and real H_2 production costs (5.12 €/kg) for use in NG sector results from seasonal NG demand fluctuations
- Differences are caused by other electrolyzer utilization and variation of H_2-infrastructure design between sectors
- For all markets electricity makes up the highest H_2 production cost share
- Hydrogen production costs are topped by 1-2 €/kg_{H2} by (a) H_2 fuel infrastructure for mobility and (b) poor early electrolyzer utilization (out of which ca. 0.8 €/kg_{H2} attribute to refuelling stations)

→ Under current policy conditions the only sector allowing positive business cases for the development of REN-based electrolytic hydrogen in the medium term is the transport sector

Achievable sectoral H_2-sales prices
(for industry and NG grid from PlanDelyKAD project, 2015)



Ref.: LBST, DLR (2016): Commercialisation of hydrogen technology in Baden-Württemberg


GAME CHANGER
AHEAD
?
Shutterstock.com

http://www.cbsnews.com/news/beijing-issues-first-ever-red-alert-for-smo

http://nowdaily.com/wp-content/uploads/dieselgate-main.jpg?ffc0e

Growing Urbanization – the limits of individual mobility?

http://morphocode.com/global-trends-urbanisation/

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Challenges for the German transport system in numbers

Ecological damage

- **18 percent** of **CO_2 emission** attributable to transport sector
- **1.3 kg CO_2** on 4.5 km drive when looking for **parking space**

Traffic jam

- Population growth, urbanization and growth of freight transport
- Every car driver spends **38 hours** per year in **traffic jam**

Accidents

- **3,475 fatalities** and **392,744 casualties** in road traffic (2015)
- **88 percent** of accidents are caused by **drivers' mistake**

Mobility in old age

- Demography: **share of over 65 year-old** rises from today 21 percent to **27.5 percent** in 2030

Digitalization

- individual, intermodal, efficient through **information and communication**
- **business models** are changing from product- to **user-oriented**

Ref.: Prof. Karsten Lemmer, DLR, (04/2016) Presentation „Fragen zukünftiger Mobilität"; own translation

All numbers for Germany. Sources: Verkehr in Zahlen 2015/2016; Centre for Economics and Business Research 2014; APCOA PARKING Parkplatzstudie 2013; Ergebnisse der 13. koordinierten Bevölkerungsvorausberechnung, Statistisches Bundesamt
Darstellung: v.a. acatech; Bilder: shutterstock.com: Khongkit Wiriyachan, Vinogradov Illya, OliverSved, Andresr

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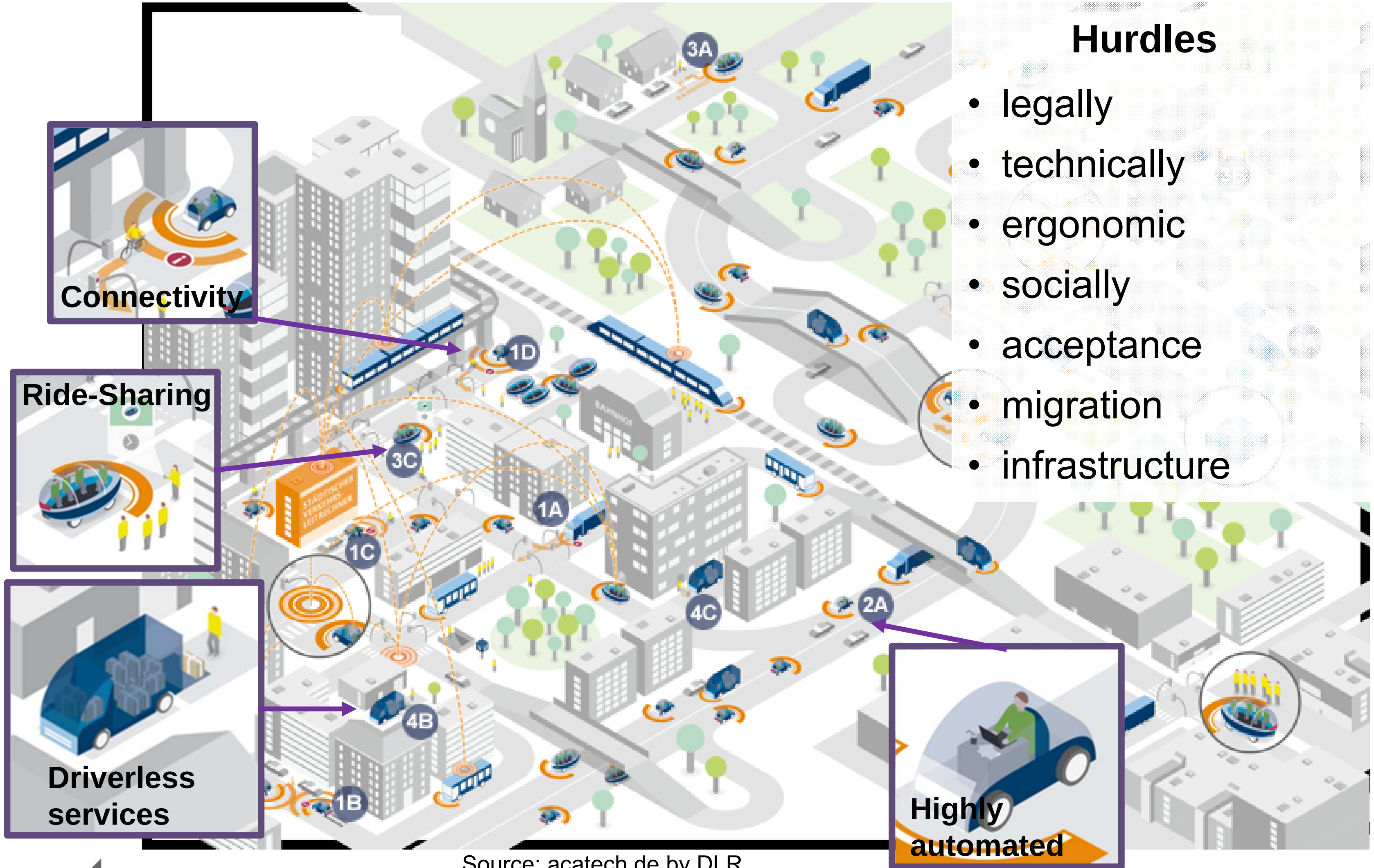
Automatisation – a dream becomes reality?

The connected transport system: possible use cases



Hurdles

- legally
- technically
- ergonomic
- socially
- acceptance
- migration
- infrastructure

Source: acatech.de by DLR

Areas where connected car technology can increase efficiency and safety

Source: Bosch

Source: Daimler

Mobility management
Functions that allow the driver to reach a destination quickly, safely, and in a cost-efficient manner

Vehicle management
Functions that aid the driver in reducing operating costs and improving ease of use

Entertainment
Functions involving the entertainment of the driver and passengers

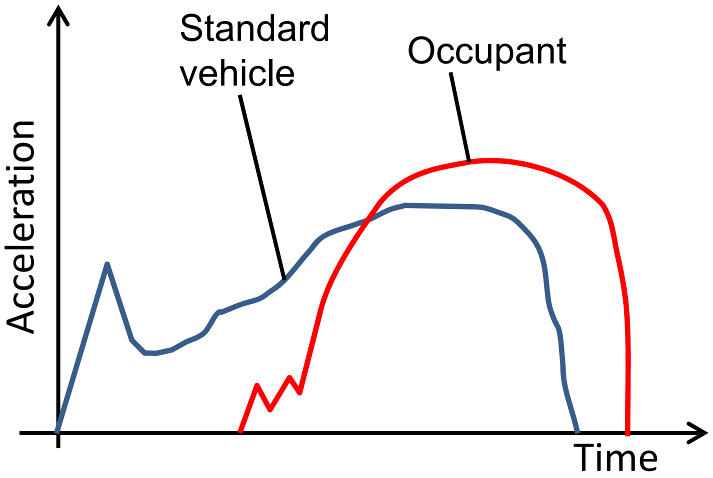
Safety
Functions that warn the driver of external hazards and internal responses of the vehicle to hazards

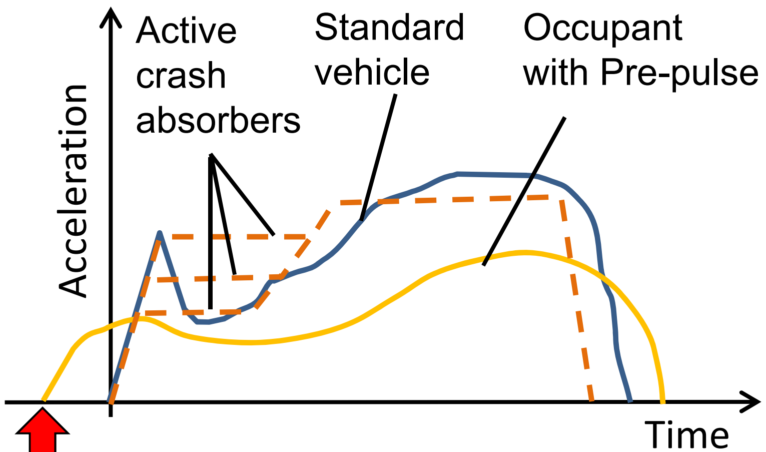
Driver assistance
Functions involving partially or fully automatic driving

Well-being
Functions involving the driver's comfort and ability and fitness to drive

Source: Management Engineers at Strategy&Analysis

Potentials of combining active and passive safety





Starts before the vehicle crash occurs

advanced sensing/ connected driving

IIHS Hyundai Tucson crash test, source: Brady Holt

- Pre-pulse (e. g. by seat movement) can significantly lower the maximum crash pulse for the front seated occupants
- Active crash absorbers can modulate crash pulses to optimize the structural behaviour for best occupant safety in each situation
- All these solutions can be utilized best in a connected traffic szenario

Source: Prof. Dr.-Ing. Rodolfo Schöneburg,
Daimler; KREISLAUF DER FAHRZEUGSICHERHEIT, 26.01.2016

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Audi‘s expectations about the future role of carmakers

„In the future carmakers have not only to build cars, but to act as agents for mobility. Our task will be, to master both worlds. One day the company will probably generate half of it‘s turnover within these fields“

Rupert Stadler, CEO Audi AG,
Handelsblatt 29.02.2016

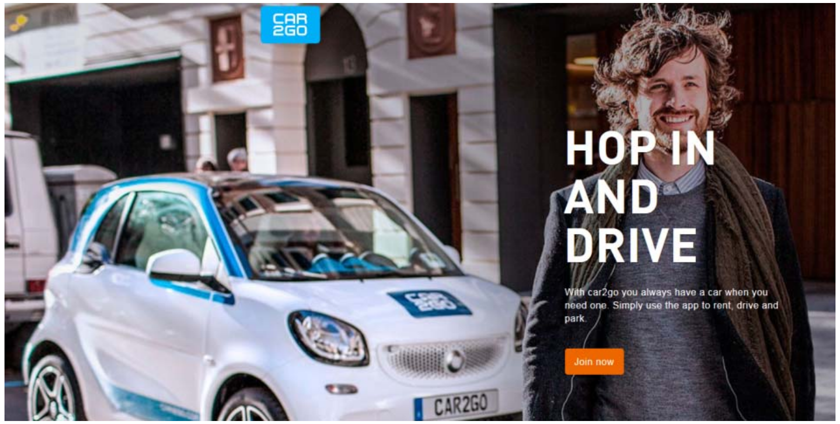
Car Sharing

BeeZero

BEEZERO
first hydrogen car sharing in the world (Munich)

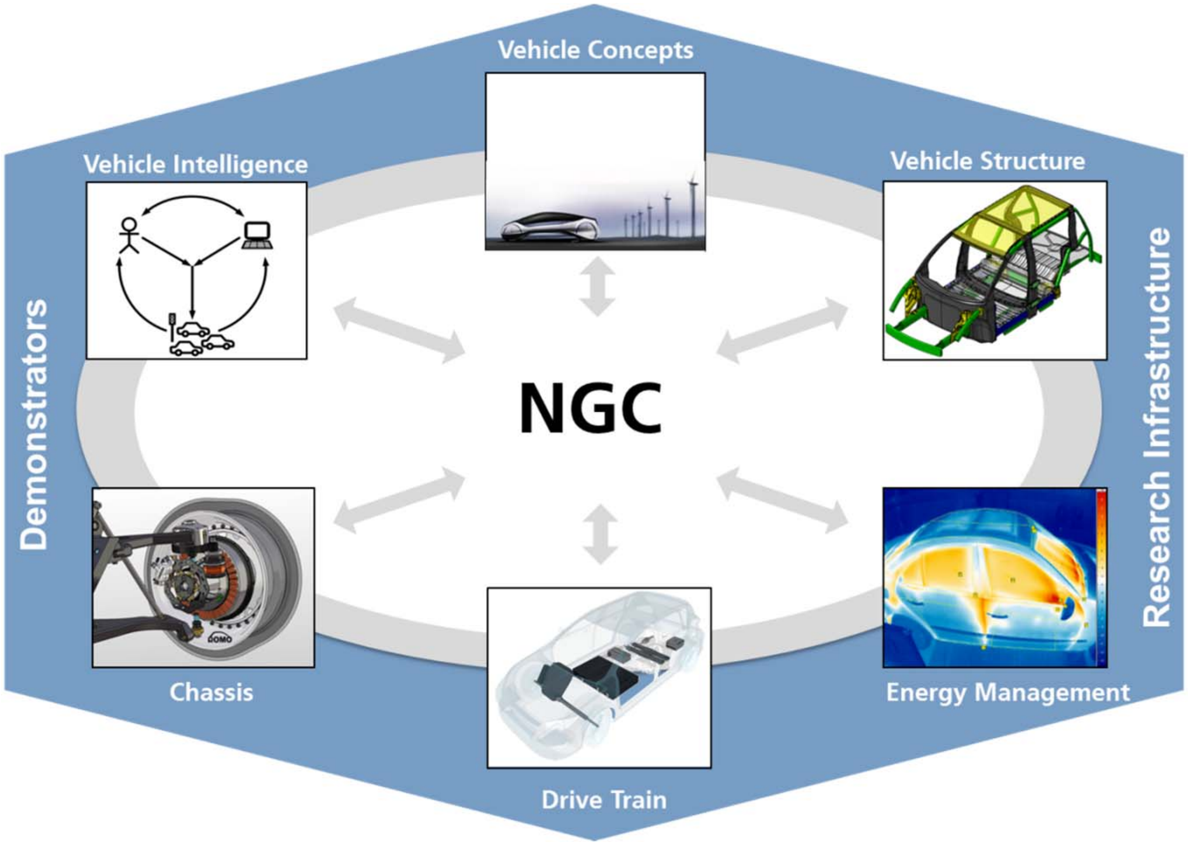
50x Hyundai ix35 Fuel Cell

car2go
BEV car sharing, more than 50 000 clients (Stuttgart)



car2go

DLR *Next Generation Car* – project



Development of novel vehicle concepts

Showcase for DLR's technological developments

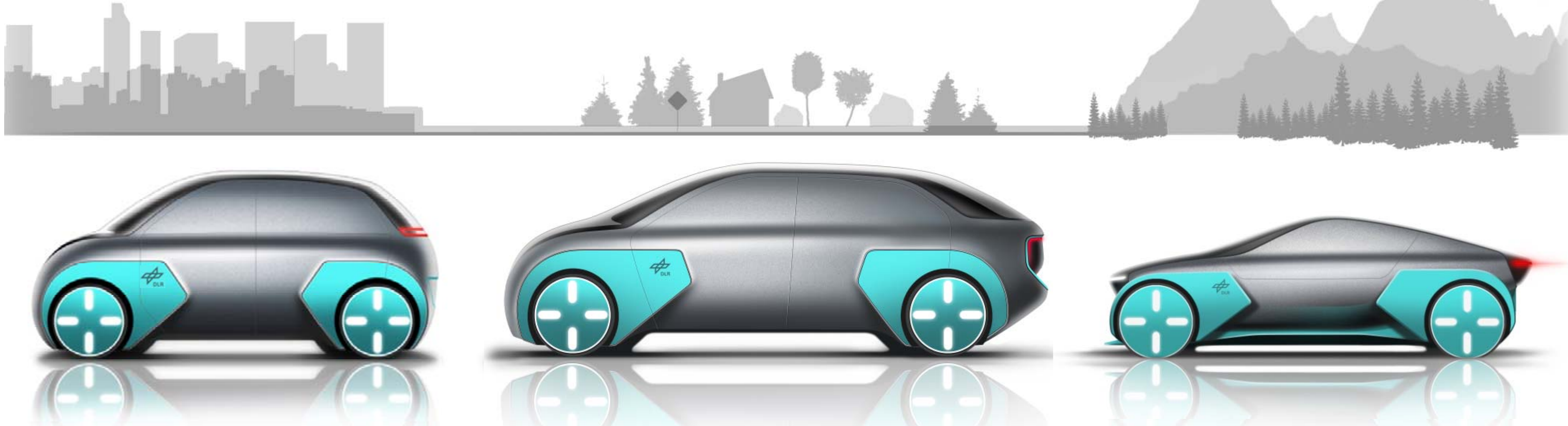
Framework for improved collaboration between different experts and infrastructure within DLR

DLR *Next Generation Car* Vehicle concepts

Urban Modular Vehicle

Interurban Vehicle

Safe Light Regional Vehicle



Electric, intelligent, modular

Comfortable fuel cell vehicle with CFRP body

Cost-effective, very light and safe vehicle, class L7e

DLR *Next Generation Car*
Concept highlights of Urban Modular Vehicle

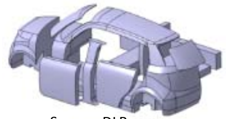
Vehicle Concepts
- Urban compact concept, intelligent, light and save
- …

Vehicle Intelligence
- Several levels of automation, assist to fully automated (SAE Level 0-5)
- 360° environment detection, C2X-networking
- Cooperation with the traffic
- …

Source: DLR

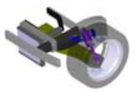
Source: DLR

Vehicle Structure
- Vehicle empty weight 680 kg
- Optimized structures specifically for battery-electric vehicle in the sense of purpose design
- …



Source: DLR

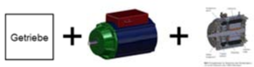
Chassis
- Modular, mechatronic, integrated lightweight chassis with innovative materials
- Steer-by-Wire-; Brake-by-wire,
- …



Source: DLR

Source: DLR

Drive Train
- The modular electric drive with 2 x 25 kW for the basic model, with high speed spreading on the rear axle
- PCM-energy storage
- …

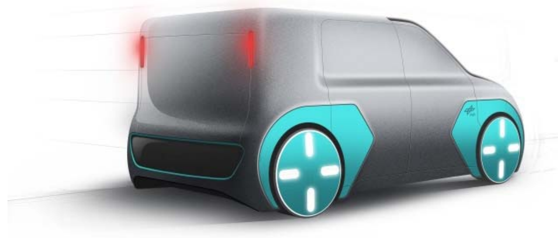


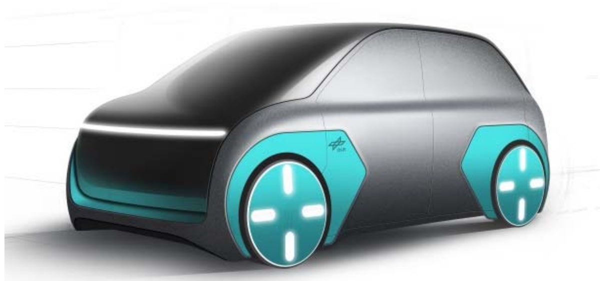
Source: DLR

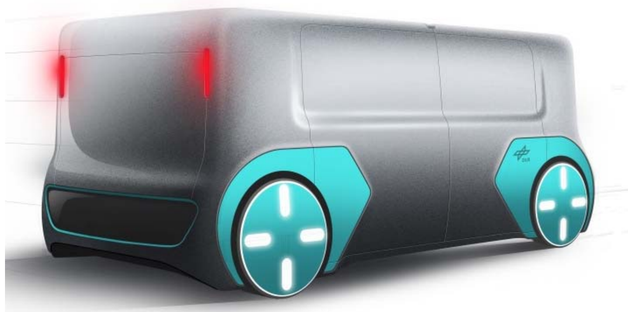
Energy Management
- Intelligent overall vehicle energy management
- Connection of heat and mass flows, Cabine-, battery-, electric motor-management
- …

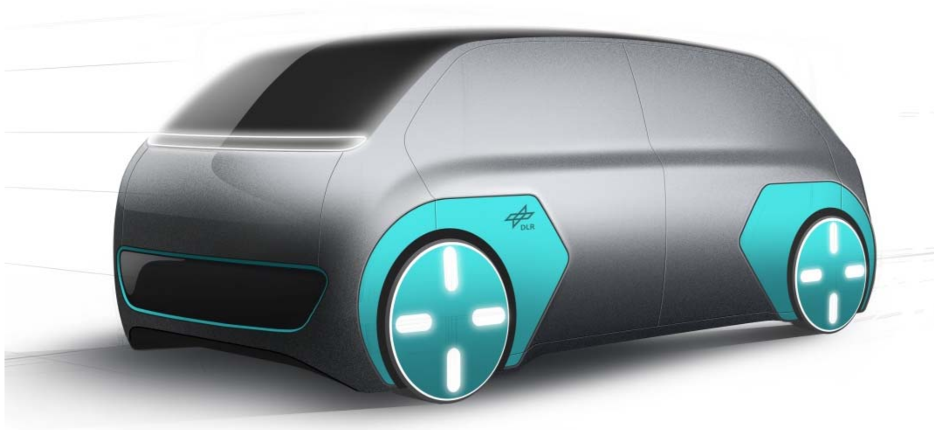
DLR *Next Generation Car*
Urban Modular Vehicle – Flexibility in future derivates

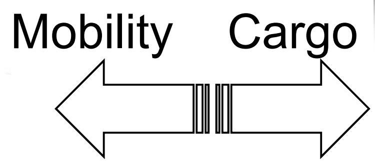
- **One platform for BEV and highly automated (SAE 4/5) during introduction phase**









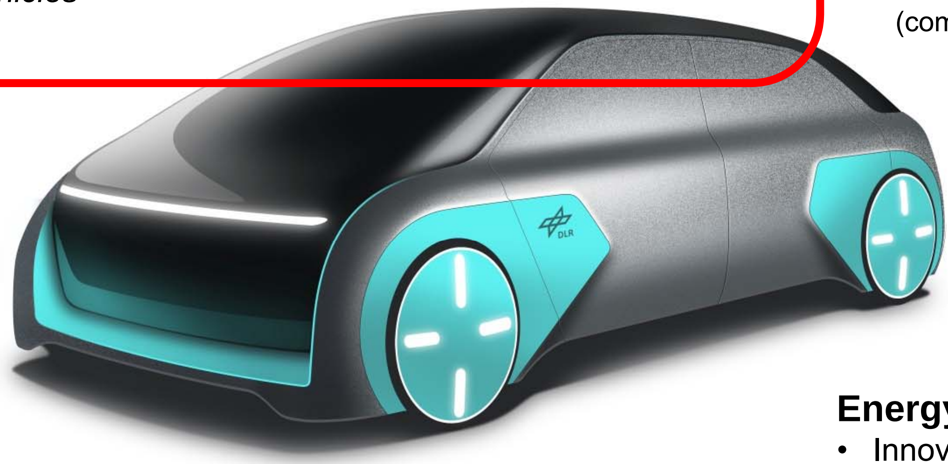


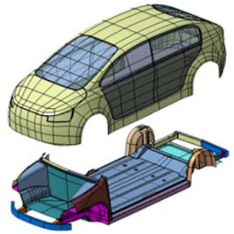
DLR *Next Generation Car*
Concept highlights of Interurban Vehicle

Vehicle Concept
- Upper-class five-seater vehicle
- Family- and business car
- Comfort as priority

Vehicle intelligence
- Up to **high automation** (SAE Level 0-4)
- ‚**Connected**': Cooperating with the traffic, *the infrastructure and other vehicles*

Vehicle Structure
- Composite-intensive structure
- Functional integration composites (e.g. structural integrated sensors)
- Additive manufacturing
- Structural weight m ≤ 250 kg (compared to MB S-Class m = 362 kg)

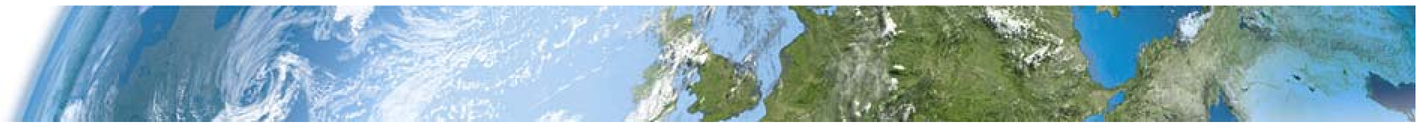




Chassis
Mechatronic chassis with integrated chassis regulation

Energy Management
- Innovative energy management
- Innovative cooling/heating system

Drive Train
- Pressure based hydrogen fuel cell system
- Hydrid energy storage



DLR *Next Generation Car* (NGC)
Concept highlights of Safe Light Regional Vehicle

Vehicle Intelligence
- Driver assistance and partial automation (SAE Level 0-2)
- Interaction with traffic lights, other traffic and traffic management
- Fully automated emergency actions with drive-by-wire
- Automatic parking

Chassis
- Front axle: Crash optimized double wishbone suspension
- Rear axle: Integration of drive motors and chassis
- Integrated chassis control

Source: DLR

Vehicle Concepts
- Lightweight, safe vehicle in the L7E class
- Empty weight max. 400 kg
- Low drag body shape
- Target quantity: 50 000 / year

Drive Train
- 2 x 7,5 kW Motors near the wheels
- Hybrid drive train with fuel-cell system and battery

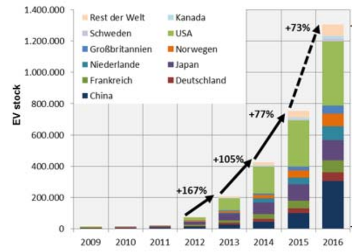
Vehicle Structure
- Metal-foam sandwich structure
- Weight of the body in white < 90 kg
- State of the art crash safety, comparable to todays M1-class

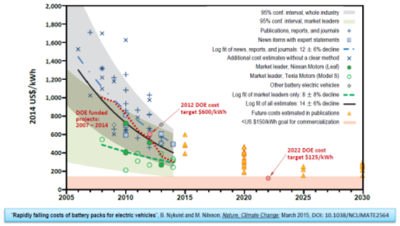
Source: DLR

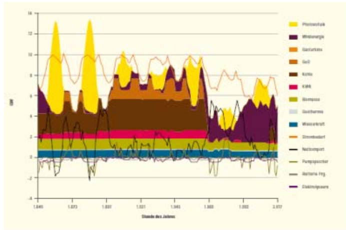
Energy Management
- Use of waste heat of the fuel cell system
- Utilisation of the Insulating properties sandwich structures
- Use of the cooling effect of thermochemical H_2 – storage systems

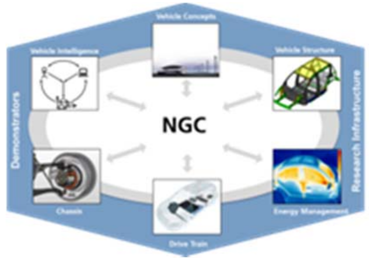
Summary

- Strong growth rate of electried powertrains (BEV, PHEV) in Europe, but still on low overall numbers
- Lower battery costs and business cases for EV-infrastructure are key for the longterm market success of PEVs
- Alternative carbon neutral fuels, e.g. hydrogen or P2L, need to be developed and we need solutions for the synergies in the renewable energy system
- Automated, assisted and connected driving will lead to several benefits e.g. various aspects of safety and comfort; this will change the vehicle concepts
- DLR is adressing various challenges by technology research in a car system perspective within the Next Generation Car (NGC)-Project









Thank you for your attention!

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