MARKET DIFFUSION OF ELECTRIC VEHICLES IN GERMANY

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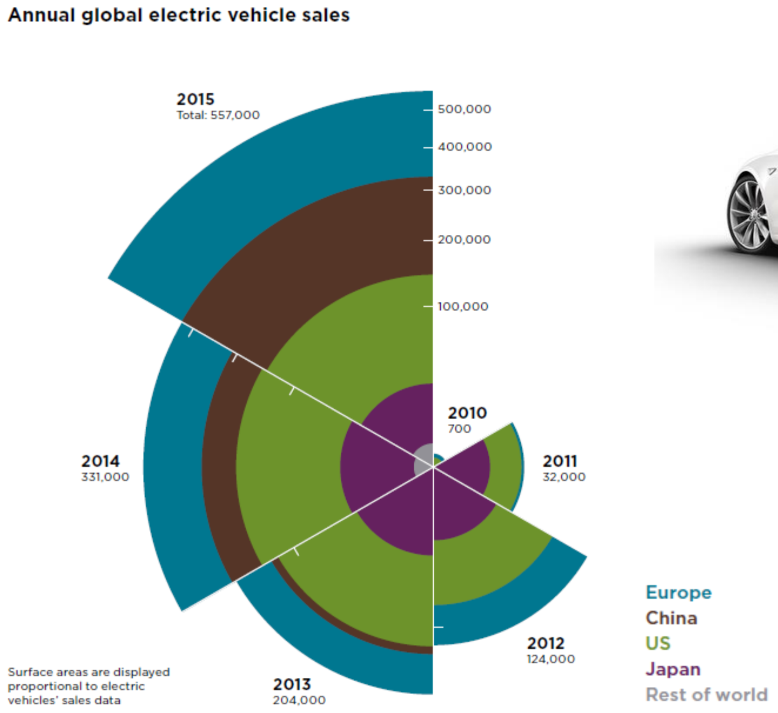
Workshop Electro Mobility in Northwestern Germany – Experiences and Perspectives
Delmenhorst, March, 31st, 2017



Sources:
http://www.theicct.org/european-vehicle-market-statistics-2016-2017
https://www.tesla.com/models
http://www.mennekes.de/index.php?id=aktuell_details&tx_ttnews[tt_news]=608&cHash=78756603b971f6891ad935a0fdb579a3

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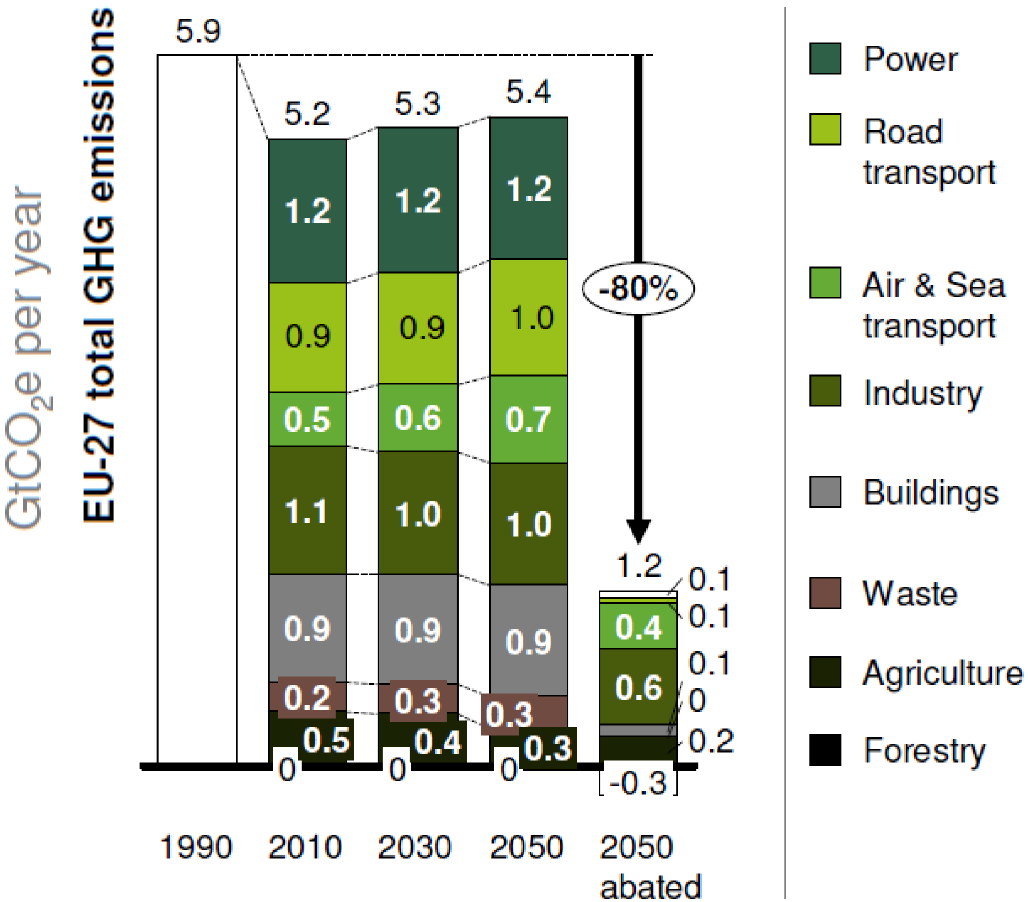
AGENDA

- **Motivation for (research in) electro mobility**
- Market diffusion of plug-in electric vehicles as passenger cars
  - Status quo
  - Market projections
  - Policy options
  - Impact on the energy system
- Outlook: What‘s next?

To achieve Europe's climate targets, a drastic reduction in transport CO_2-emissions is needed



- The EU's long term goal is to reduce GHG emissions by 80%
- Power production and road transport have to become almost CO_2 free
- This is **impossible with** efficiency gains in **combustion engines**
- New technologies and concepts are clearly needed.
- **Electric vehicles powered by renewable energies** can contribute significantly

Source: www.roadmap2050.eu

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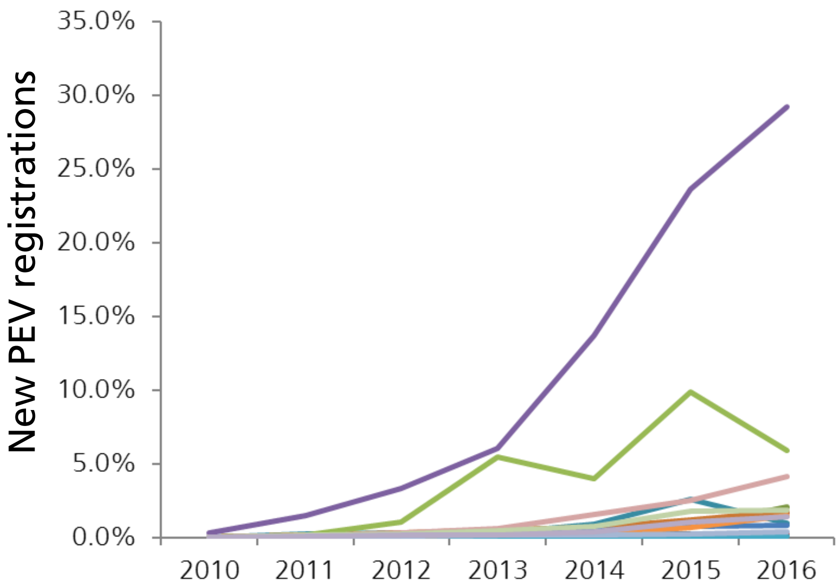
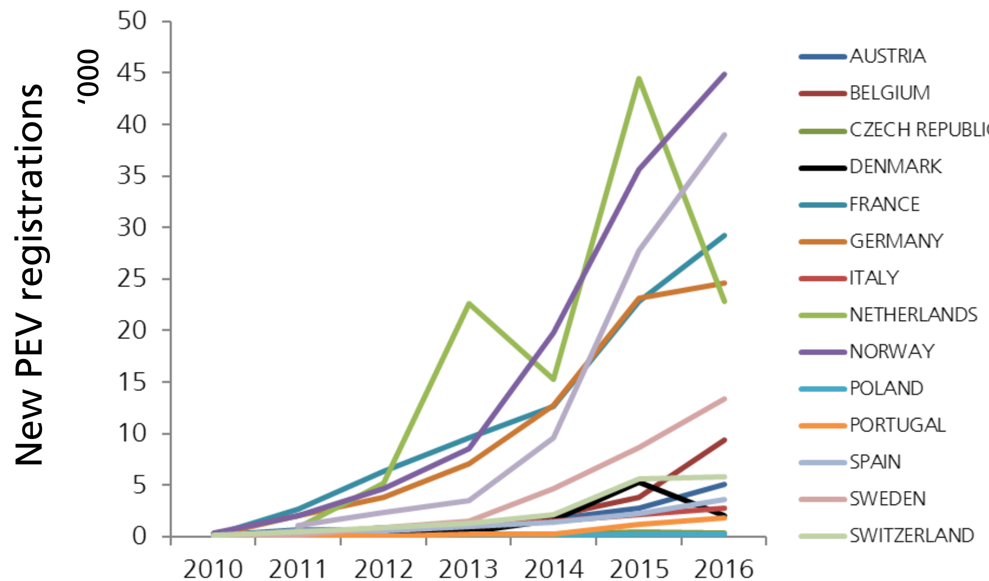
PEV market diffusion in Europe

- Historical **new PEV registrations** in Europe:





- Norway, The Netherlands and Sweden with market shares above 3%
- Yet, large car markets with higher number of PEVs: Norway, Spain, France, Germany and The Netherlands above 15,000 PEVs

Data sources: de.statista.com, eafo.eu und EUROPEAN VEHICLE MARKET STATISTICS Pocketbook

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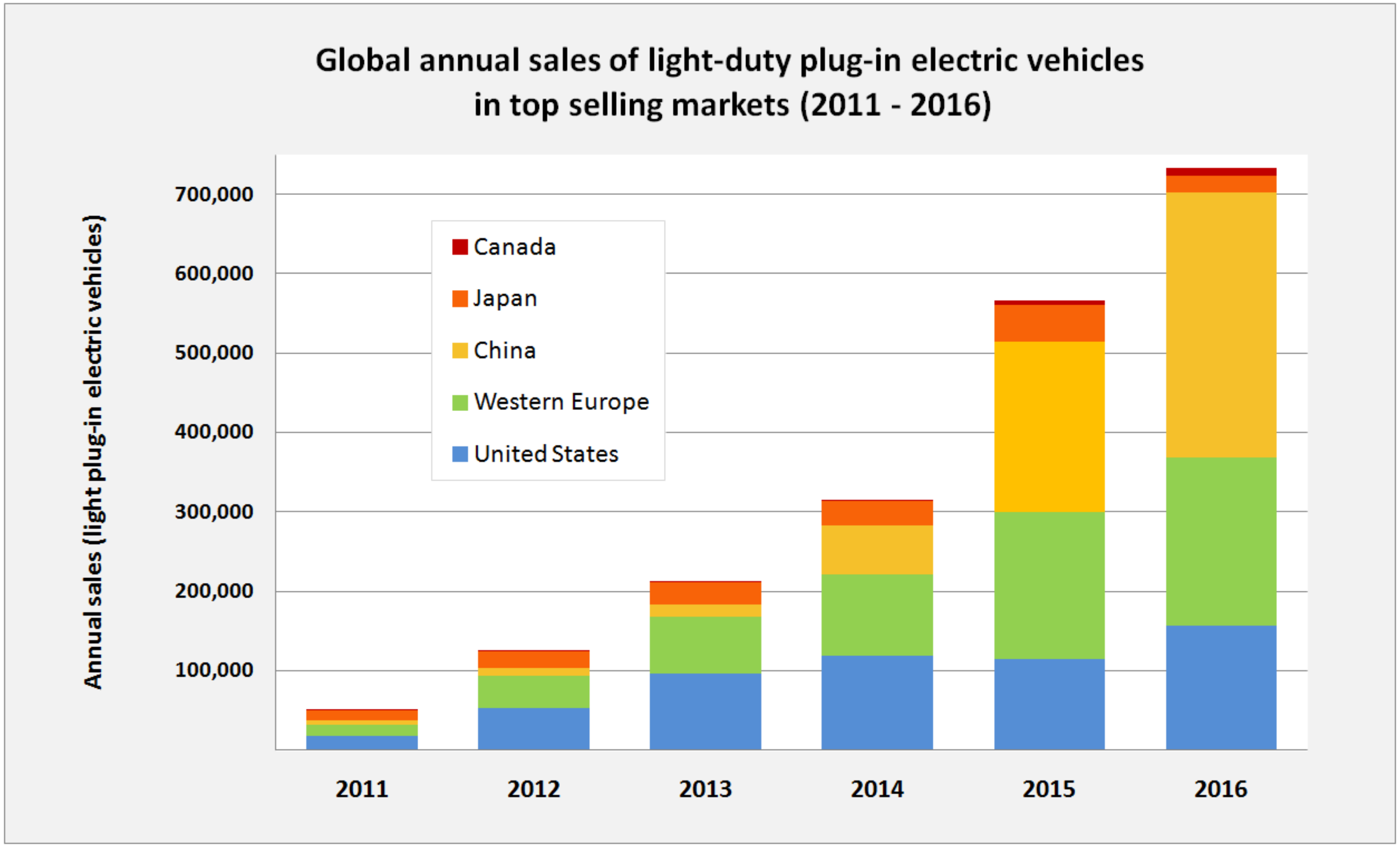
China will dominate global PEV sales…



…but will the national government hold on to this plan in the next years?

How will PEV market diffusion evolve in other countries?

And, what determines the diffusion?

Source: https://en.wikipedia.org/wiki/Electric_car_use_by_country

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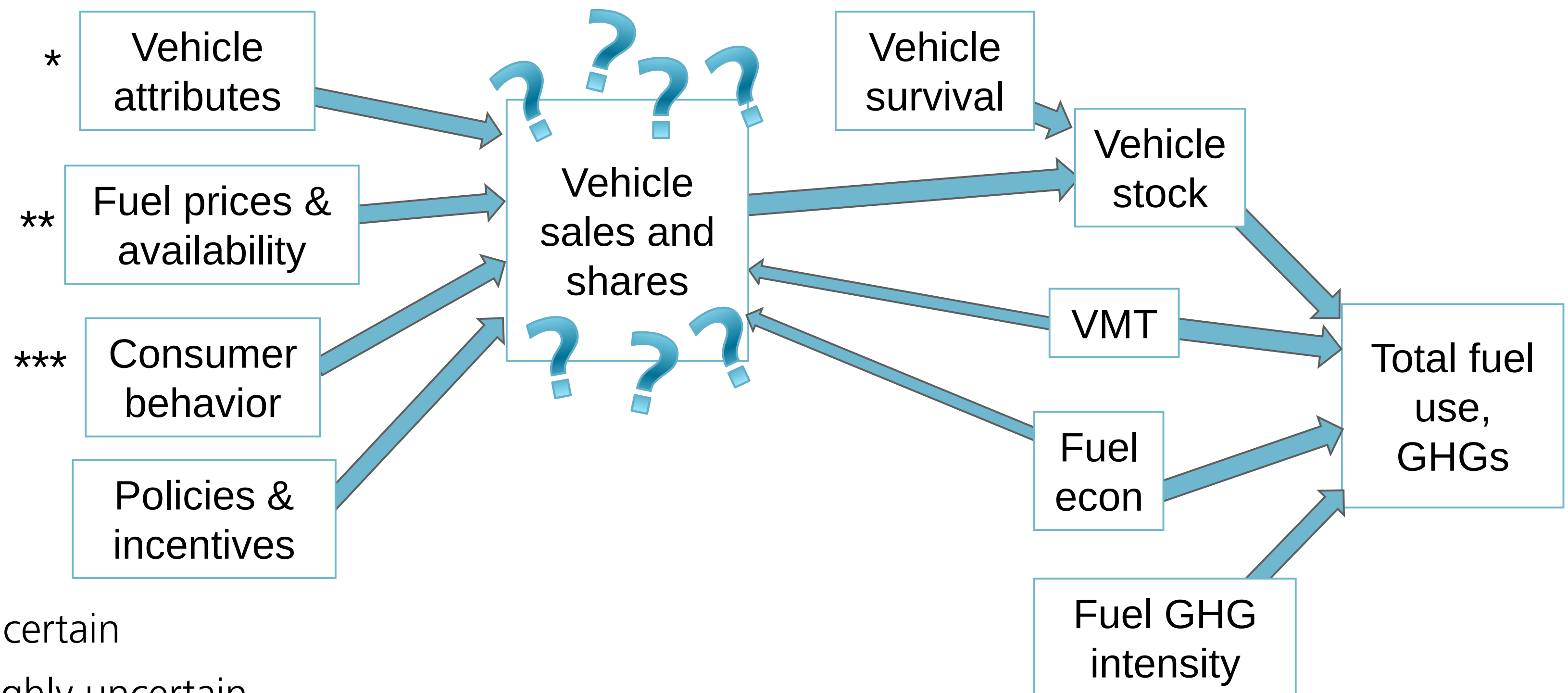
Vehicle sales of new technologies are hard to estimate but very important



* Uncertain

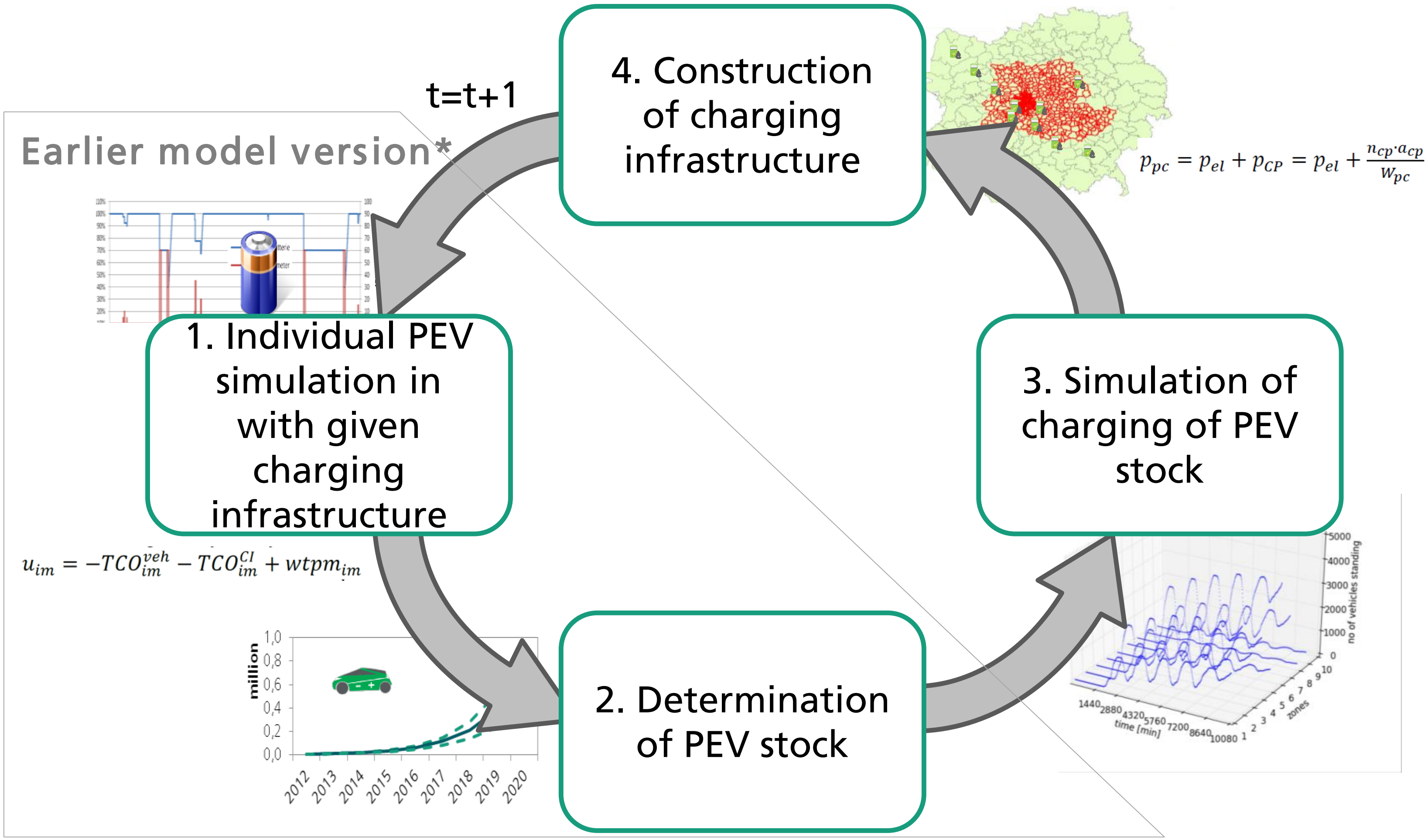
** Highly uncertain

*** Extremely uncertain

Idea: Compare market diffusion models and determine how they differ.

Source: Gnann, T.; Stephens, T. S.; Lin, Z.; Plötz, P.; Liu, C.; Brokate, J.: What drives the market for plug-in electric vehicles? Proceedings to the European Electric Vehicle Congress (EEVC), 14th – 16th March 2017, Geneva, Switzerland.

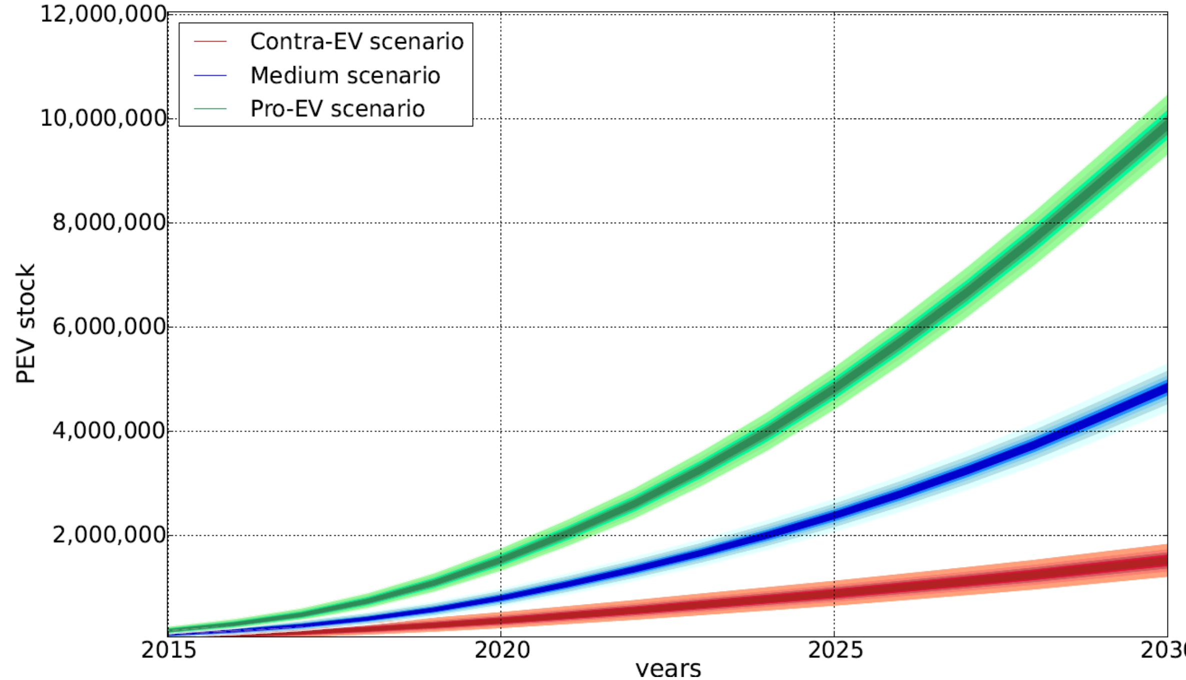
The model ALADIN (Alternative Automobiles Diffusion and Infrastructure



* Plötz, P.; Gnann, T.; Kühn, A.; Wietschel, M.: Markthochlaufszenarien für Elektrofahrzeuge - Langfassung. Studie im Auftrag der acatech - Deutsche Akademie der Technikwissenschaften und der Arbeitsgruppe 7 der Nationalen Plattform Elektromobilität (NPE). Fraunhofer ISI, Karlsruhe, 2013.

Market diffusion of PEVs in Germany

Future PEV stock based on simulations with ALADIN (Alternative Automobiles Diffusion and Infrastructure



Assumptions for 2030 (all prices with VAT in $€_{2014}$)	Contra-EV	Medium scenario	Pro-EV
Gasoline price [€/l]	1.50	1.75	2.00
Diesel price [€/l]	1.42	1.65	1.90
Electricity price private [€/kWh]	0.35	0.32	0.27
Battery price [€/kWh]	295	266	235

Important results

- No lock-in for PEVs in Germany if there is no public charging infrastructure
- High shares of PHEV in next years
- Large influence of framework conditions

Source: Gnann, T. (2015): Market diffusion of plug-in electric vehicles and their charging infrastructure. Fraunhofer-Verlag Stuttgart,http://publica.fraunhofer.de/eprints/urn_nbn_de_0011-n-364342-15.pdf

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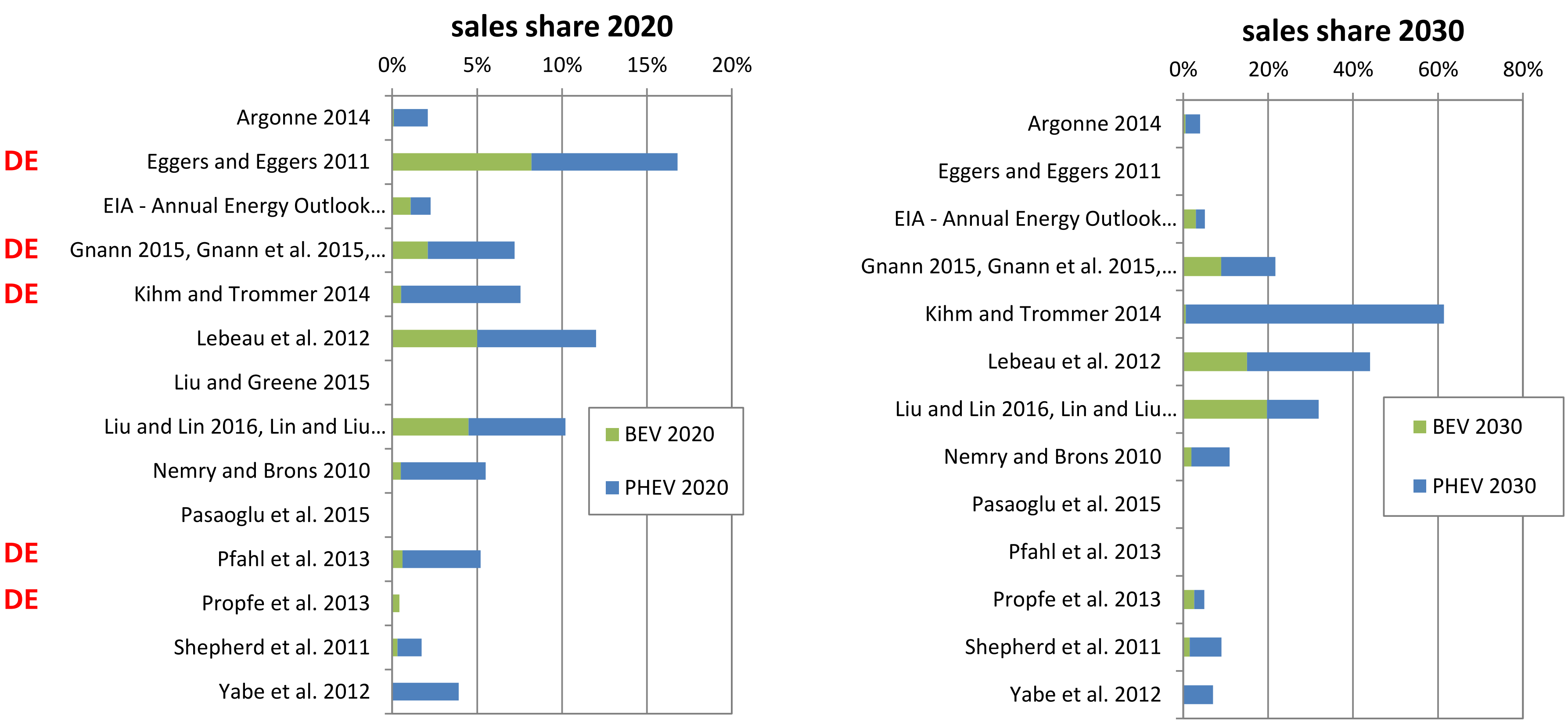
Comparison of 40 papers from 11 regions shows variety of results and higher PHEV market shares in the short-term



Source: Gnann, T.; Stephens, T. S.; Lin, Z.; Plötz, P.; Liu, C.; Brokate, J.: What drives the market for plug-in electric vehicles? Proceedings to the European Electric Vehicle Congress (EEVC), 14th – 16th March 2017, Geneva, Switzerland.

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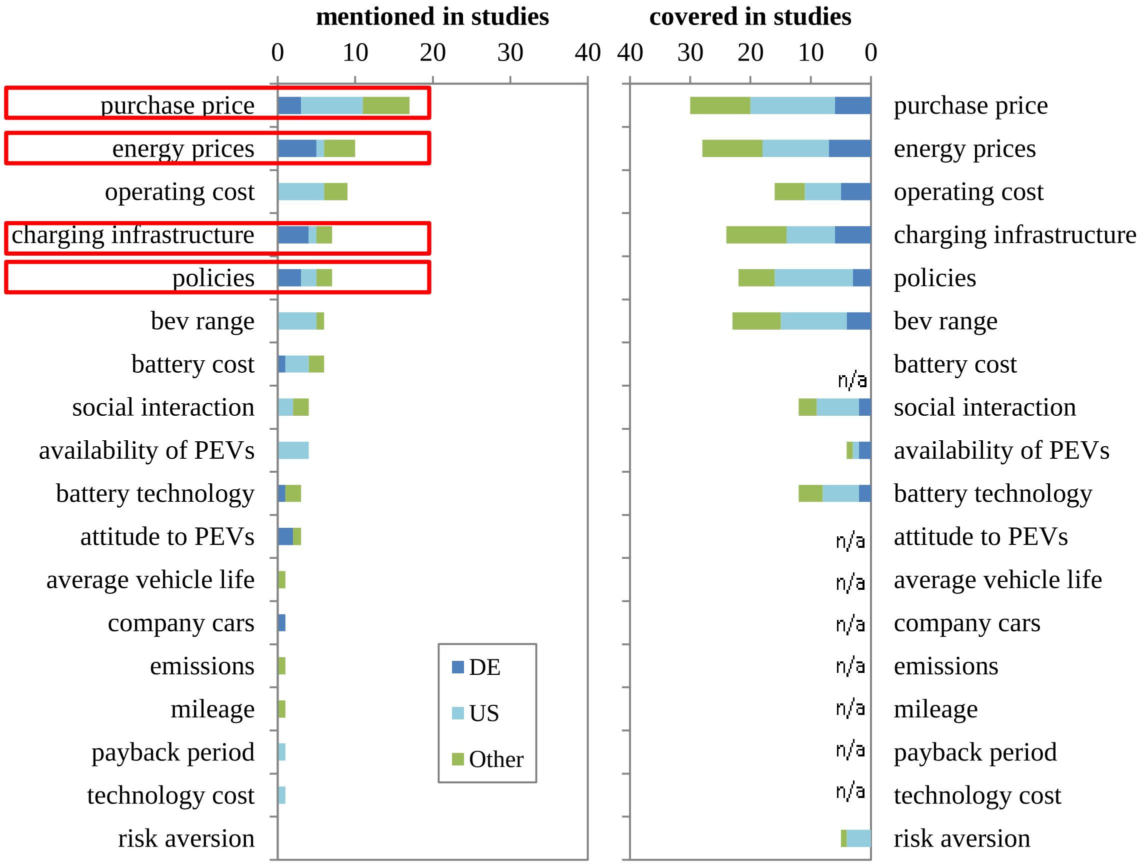
What were "important factors stated" by authors and do they differ in countries?



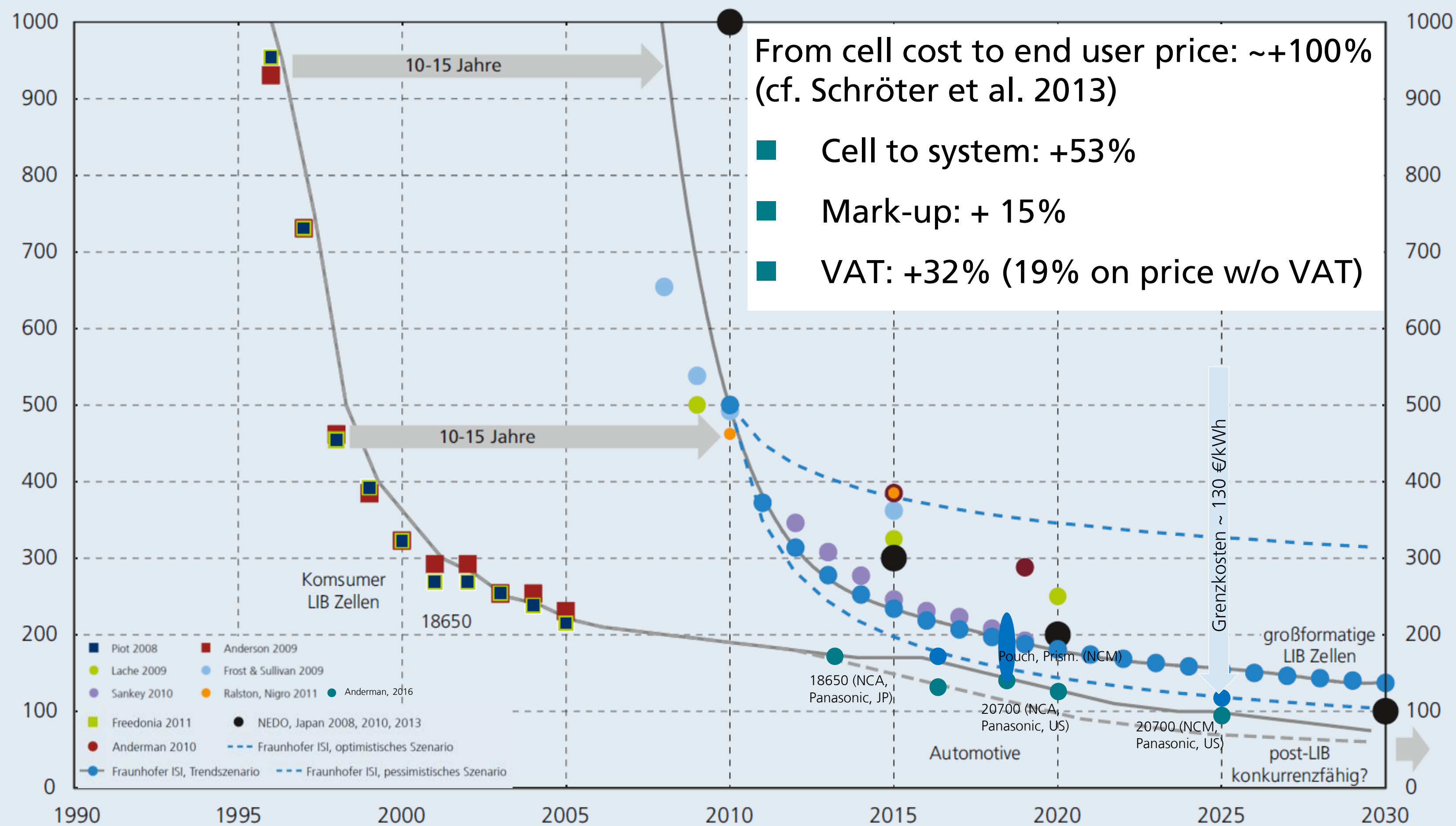
Main findings:

- A lot of factors are stated to be important after the analysis (16 different factors in 40 models)
- factors with "n/a" were not investigated by us
- Some country-specific differences:
  - For the US vehicle cost seems to be most important
  - For Germany, energy prices and other factors tend to be more important
  - Very heterogeneous in other countries

Source: Gnann, T.; Stephens, T. S.; Lin, Z.; Plötz, P.; Liu, C.; Brokate, J.: What drives the market for plug-in electric vehicles? Proceedings to the European Electric Vehicle Congress (EEVC), 14th – 16th March 2017, Geneva, Switzerland.

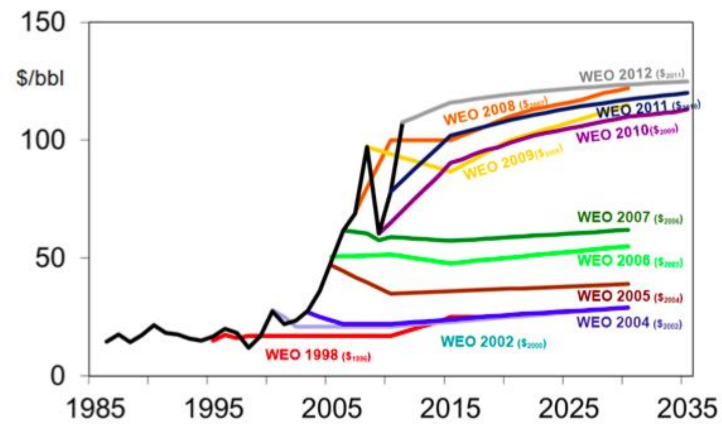
How do battery prices evolve?

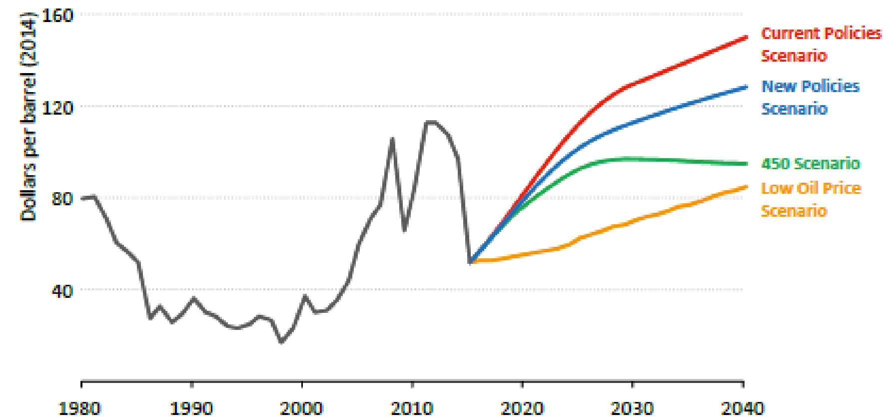
Development of cell cost in €/kWh



Source: Thielmann et al. 2015 – Gesamtroadmap Energiespeicher für Elektromobilität (incl. Aktualisierung) ; Schröter et al. 2013 - Energiespeicher Monitoring für die Elektromobilität (EMOTOR) - Nachhaltigkeitsbericht Teil 1;

How will the oil price evolve in the next years?





- Until 2007, the oil price was projected to stay stable in the future (until 2030 / 2035)
- Increase of oil price developments thereafter until 2013:
  - WEO2013: 128$/bbl in 2035
  - WEO2014: 128$/bbl in 2040
  - WEO2015: 128$/bbl in 2040)

→ Future development unclear, but a higher price than today can be assumed.

Source:
Left panel: Ludwig-Bölkow Systemtechnik (Werner Zittel) with data from IEA (1998-2012)
Right panel: IEA 2015 – World Energy Outlook 2015.

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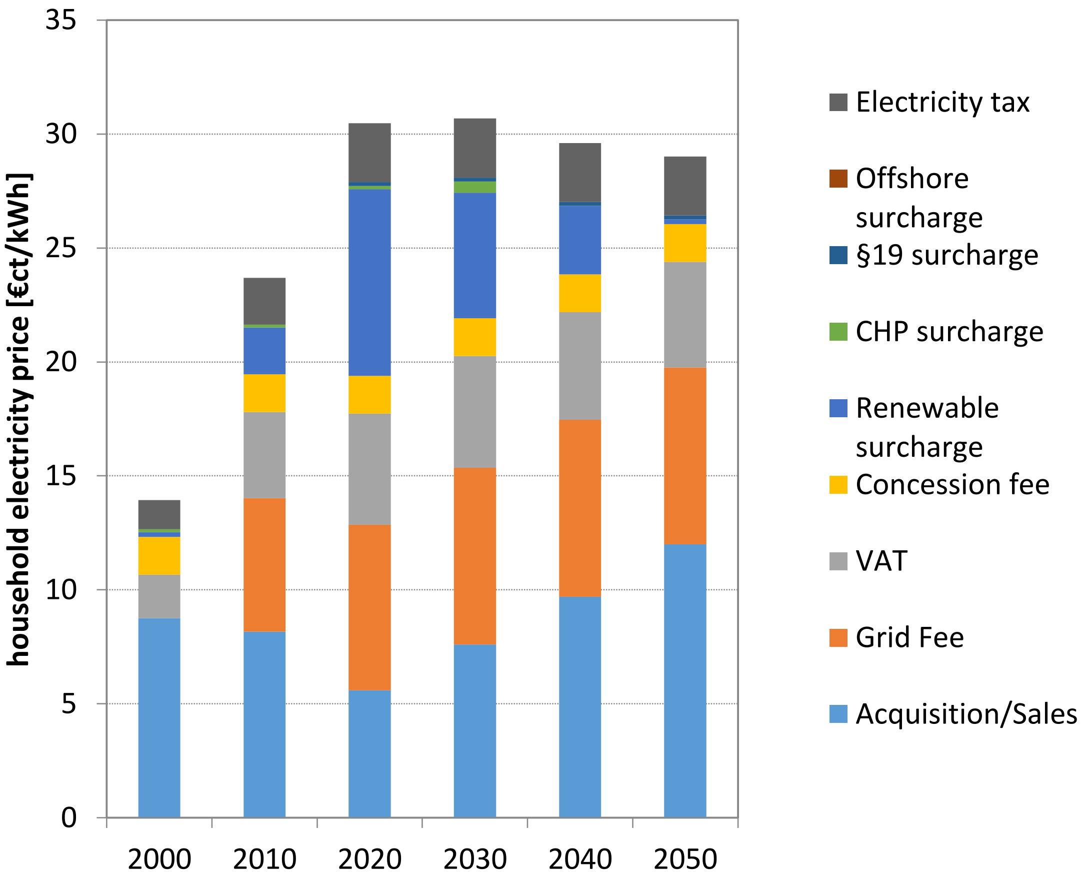
Future evolution of electricity prices



Sources: BDEW (2015) HH electricity prices (for values until 2010); UBA (2015): Klimaszenarien 2050 (after 2020)

Electricity price is largely dependent on surcharges:

- Decrease and phase out of renewable surcharge from 2020 on as renewables become economical
- Cost for grid construction assumed to be at 1€ct/kWh
- Stabilization / decrease of end user prices after 2030

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Motivation

- Major policy attempts world-wide to foster electric vehicle adoption
- Yet, little empirical evidence on effect and efficiency of policies
- Question: **What is the impact of direct and indirect incentives on EV adoption?**

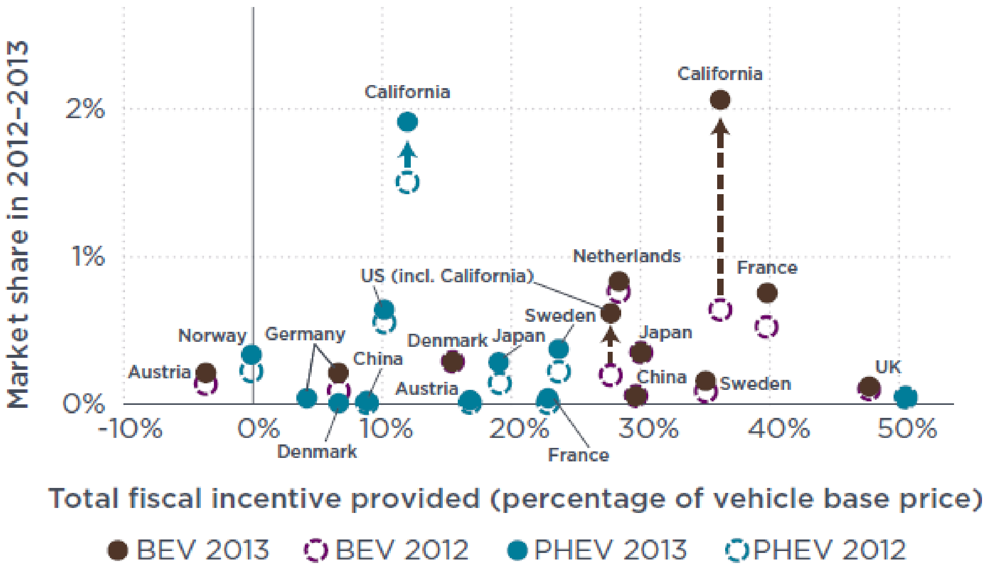


Figure source: Mock, P., & Yang, Z. (2014). Driving electrification: A global comparison of fiscal incentive policy for electric vehicles. *The International Council on Clean Transportation (ICCT).*

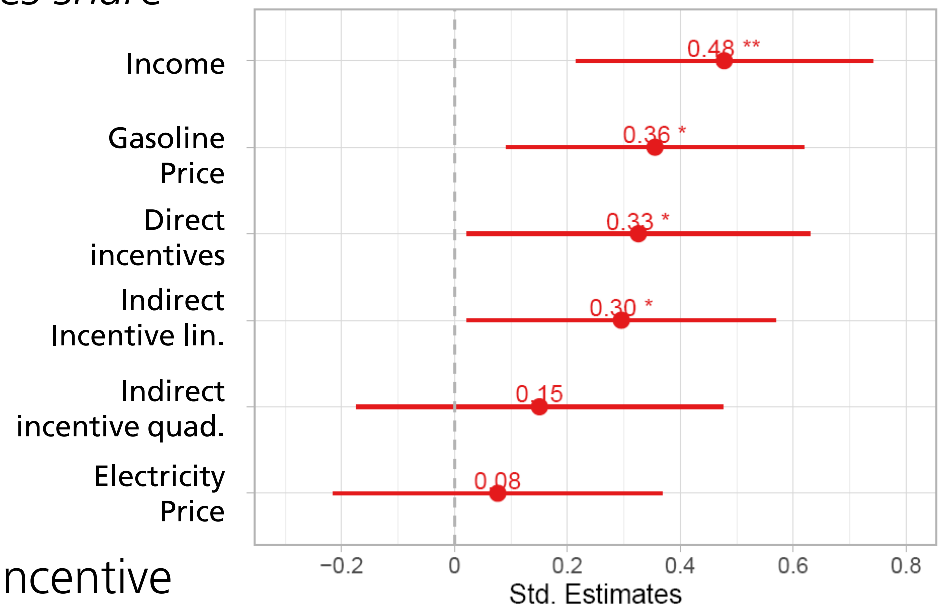
Source: Plötz, P.; Gnann, T.; Sprei, F.: Can policy measures foster plug-in electric vehicle market diffusion? Presented at EVS29, International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium & Exhibition, Montreal, Canada, 19-22 June, 2016.

Results on PEV sales shares

- Data: Mainly European markets
- Dependent variable: log *PEV sales share*

Variable	Est.	SE
(Intercept)	-13.5	1.8
Income ('000 €)	0.083**	0.023
Electricity price	2.439	4.73
Gasoline price	2.813*	1.064
Direct incentive ('000 €)	0.164*	0.078
Indirect incentives (lin.)	0.712*	0.336
Indirect incentives (quad.)	0.541	0.594

Standardized coefficients:



- +16% PEV sales share per 1,000 € incentive
- Similar results for separate regression on PHEV or BEV sales shares

➢ **Positive effect of direct & indirect incentives**

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05; **N = 35**; F(6,29)= 5.583; Prob > P = 0.001; $R^2 = 0.54$; Adj-$R^2 = 0.44$

Source: Plötz, P.; Gnann, T.; Sprei, F.: Can policy measures foster plug-in electric vehicle market diffusion? Presented at EVS29, International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium & Exhibition, Montreal, Canada, 19-22 June, 2016.

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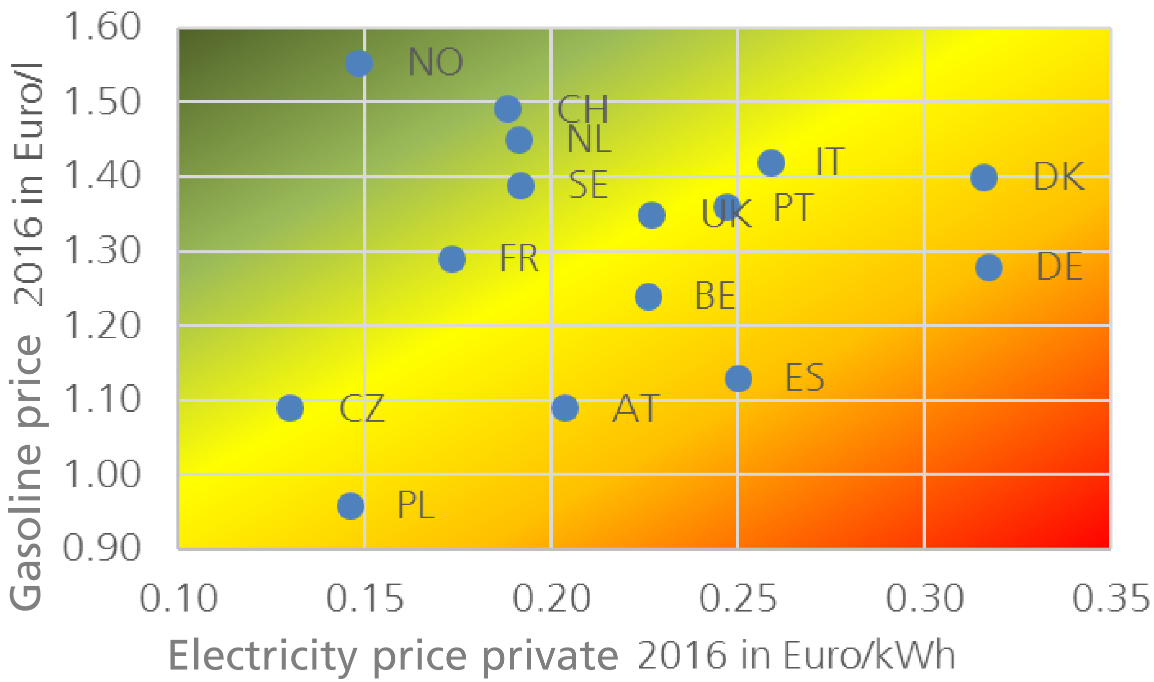
Framework conditions in Germany not advantageous

- high gasoline and low electricity prices make PEVs economical during use



- Norway and The Netherlands provide high subsidies, but their energy prices also favor PEVs
- These conditions are not very favorable in Germany and Denmark

Source: Preliminary values from „EU Transport and Figures“ https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2016_en

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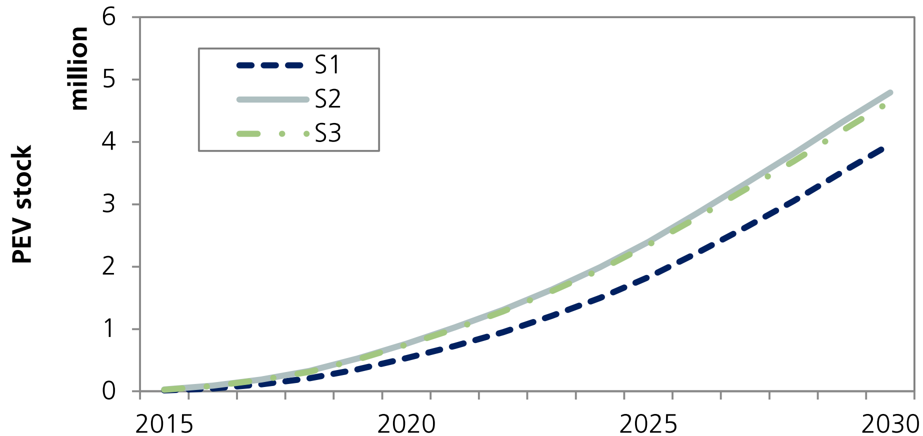
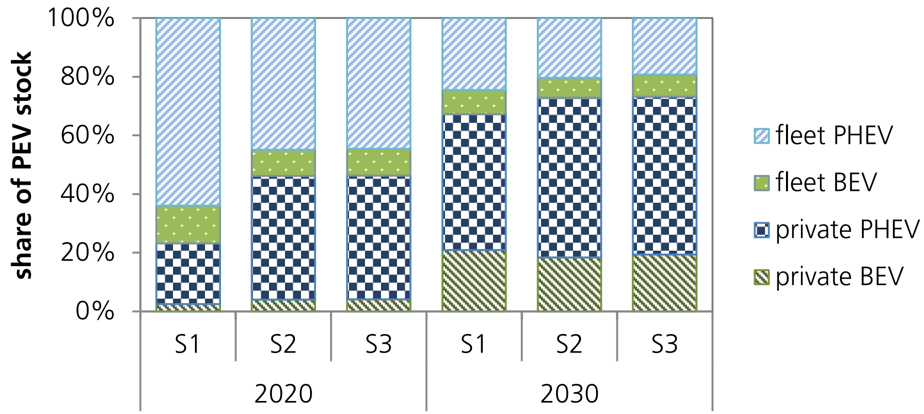
Case study
PEV market penetration

Scenario	Domestic	Work	Public
S1	√		
S2	√	√	
S3	√	√	√

- Substantial PEV market penetration possible with only **domestic/ commercial** charging infrastructure
- Charging **@work** (S2) increases market shares and PEV stock
- **Public** slow charging has no impact



- **User groups**
  - **2020**: PEV stock dominated by commercial fleet users
  - **2030**: larger shares for private PEVs 2030 (former fleet vehicles)
- **PEV types**
  - **PHEVs** dominate in 2020 and 2030



Source: Bossmann, T., Gnann, T., Michaelis, J.: Future load shift potentials of electric vehicles in different charging infrastructure scenarios : Paper presented at Enerday, Dresden, 08. April 2016

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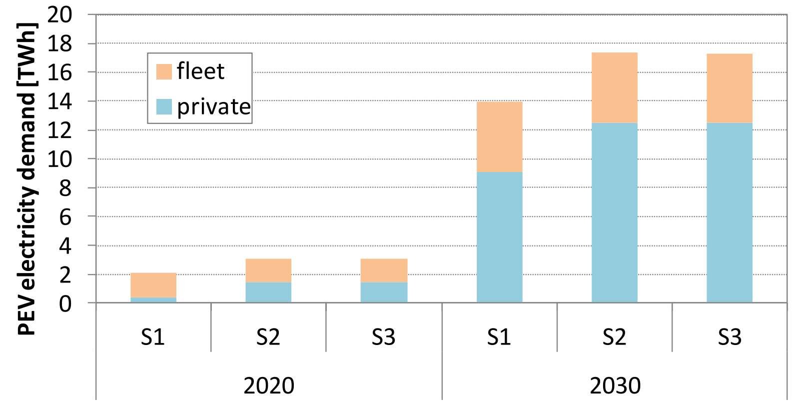
Case study
Electricity demand

Scenario	Domestic	Work	Public
S1	√		
S2	√	√	
S3	√	√	√

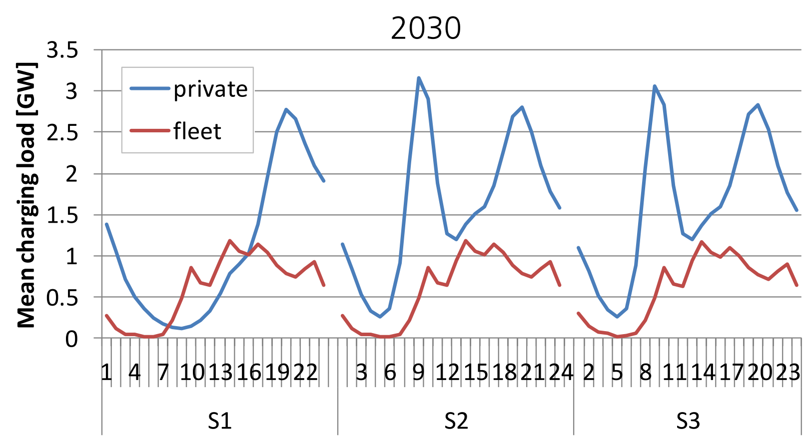
Additional electricity demand

- **Private**
  - @work raises 2030 demand by 3.5 TWh
- **Fleet PEVs** same demand in all scenarios
- **Total:** +2-3 TWh (2020) = +0.6%
  - +14-17 TWh (2030) = +3-4%



Uncontrolled charging

- Charging **@home**:
  - Private PEVs in evening hours: +3 GW
  - Fleet PEVs charge during the day => less impact on system load peaks
- Charging **@work**: additional morning peak
- Public charging has no impact



Source: Bossmann, T., Gnann, T., Michaelis, J.: Future load shift potentials of electric vehicles in different charging infrastructure scenarios : Paper presented at Enerday, Dresden, 08. April 2016

Scenario	Domestic	Work	Public
S1	√		
S2	√	√	
S3	√	√	√

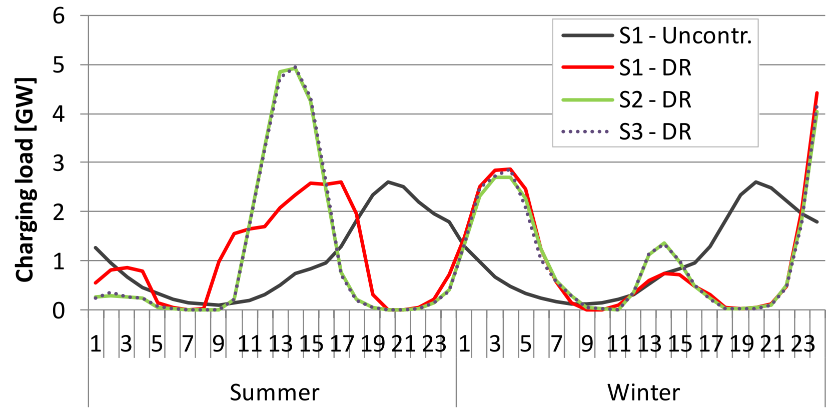
Case study
Flexibility potentials

Results for 2030

Impact on charging profile

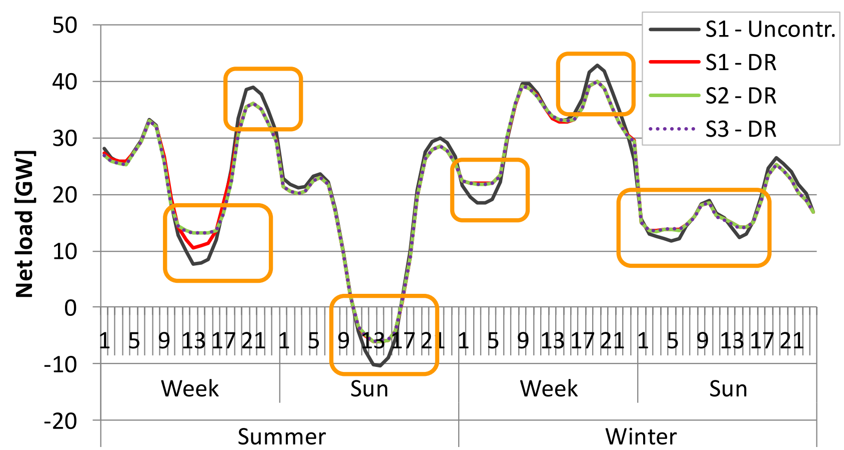
- Shiftable load of smart charging **@home**:
  - In midday hours limited to 3 GW for private PEVs
- **@work/public**: +5 GW for private PEVs; no impact on comm. PEVs

Private PEVs, weekday, compared to S1



Impact on peak load and curtailment

- Smart charging **@home:**
  - Max. net load: -2.4GW / -3.6%
  - Curtailment: -1.6 TWh / -26%
- **+ @work:** Curtailment: -1.8 TWh / -30%; but no further peak load reduction
- **+ @public:** No additional impact



Source: Bossmann, T., Gnann, T., Michaelis, J.: Future load shift potentials of electric vehicles in different charging infrastructure scenarios : Paper presented at Enerday, Dresden, 08. April 2016

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Summary on market diffusion, charging infrastructure and load shifting potentials

- **PEV market uptake** already **takes place** with charging infrastructure **at home**
- PEV stock is dominated by **PHEV**s (80% in 2020 and 70% in 2030 in all scenarios)
  - However, reduced DR potential due to smaller batteries and lower electricity demand
- **Commercial fleet vehicles** have significant shares but low impact on system peak load
- **Smart charging** facilitates the **integration** of **private** PEVs in the system

- **Charging** infrastructure **at work facilitates** PEV market penetration and increases flexibility potential
- **Public charging** infrastructure has **no additional benefit** on PEV diffusion AND load shifting potential.
- **Smart charging** smoothens the net load but may imply **new** system load **peaks locally** that may additionally challenge the grid.

- Consider impact of smart PEV charging on **power market and prices**
- Compare **flexibility potential** of PEVs with other flexiblity options

Source: Bossmann, T., Gnann, T., Michaelis, J.: Future load shift potentials of electric vehicles in different charging infrastructure scenarios : Paper presented at Enerday, Dresden, 08. April 2016

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HEAVY-DUTY VEHICLES NEED MORE ATTENTION AND RESEARCH

Source: Siemens AG

How do heavy duty vehicles differ from passenger cars?

Attributes	Passenger car	40t heavy-duty truck
Vehicle stock	40 million	180,000
Average annual vehicle mileage	14,000 km	115,000 km
Annual CO_2 emissions	~80 m tons CO_2/a total ~2 ton CO_2/a per vehicle	~20 m tons CO_2/a total ~110 ton CO_2/a per vehicle
Daily usage	~1 hour/day	~4-6 hrs/day (for 115,000 km/year)

Currently no optimal technical solutions and research is far behind passenger cars...

Studies on alternative drive trains for heavy duty vehicles to be published soon...

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SUMMARY

- Motivation for research in electro mobility → necessity to decarbonize road transport, regulations force car makers to act
- Market diffusion of plug-in electric vehicles as passenger cars
  - Status quo → China will dominate the PEV market (in the next years?)
  - Market projections → Tendency to more PHEV in the short term, ab-solute evolution uncertain because of energy prices and consumer adoption
  - Policy options → Impact of incentives also depends on market conditions, probably regulations more helpful
  - Impact on the energy system → Rising load shift potential with higher availabilty of charging infrastructure at work
- Outlook: What‘s next? → Think about strategies to decarbonize heavy road transport

Thank you for your attention!

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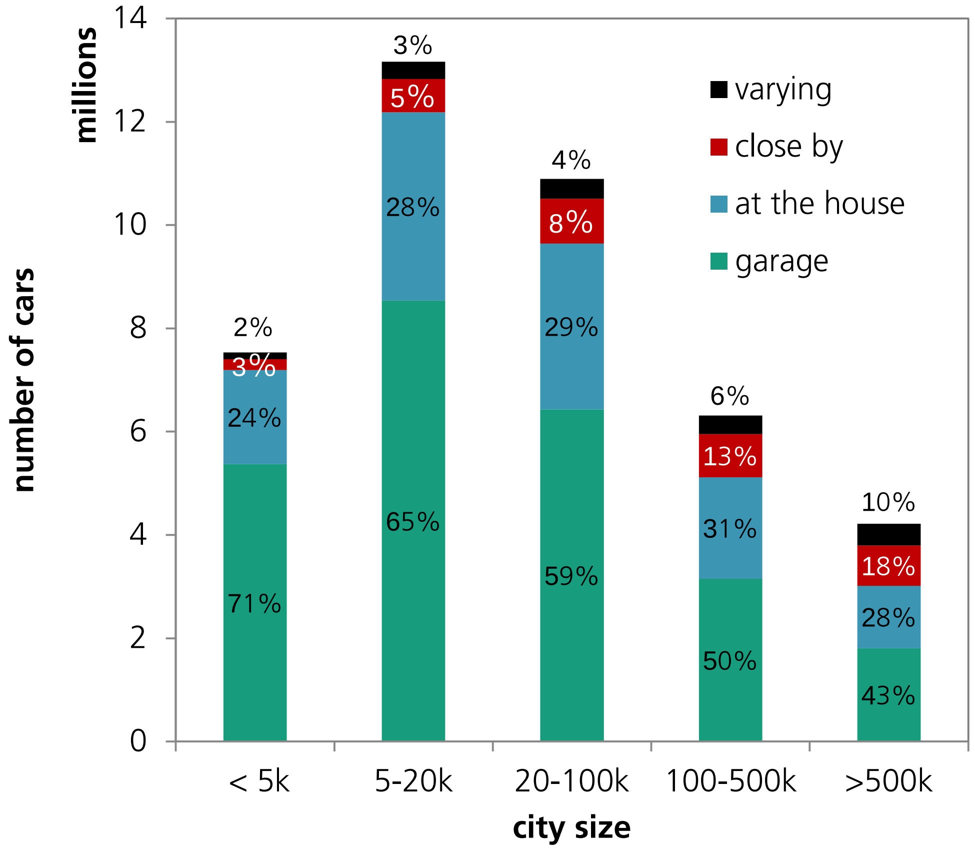
www.profilregion-ka.de

BACKUP

Lots of users could easily charge at home.

German passenger vehicle stock subdivided into typical parking spots and city sizes.*



- 60% of all users leave their car in garages overnight
- Another 30% park their cars close by
- Only 10% of so-called lantern parkers

→ Initial charging infrastructure can be provided rather simple

- **But:** Not sure if all garages do have electricity connection.

Source: Own display based on: infas and DLR (2002): Mobility in Germany 2002; Federal Motor Transport Authority (KBA) (2012): German passenger car stock; *Shown in:* Gnann, T., Plötz, P., and Haag, M. (2013). What is the future of public charging infrastructure for electric vehicles? - A techno-economic assessment of public charging points for Germany. In Proceedings of the 2013 ECEEE summer study, Toulon, France.

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