Infraday: The Future of E-Mobility

Fabian Kley, Fraunhofer ISI

October 9th, 2009

Fraunhofer ISI

Fraunhofer ISI is actively researching the field of e-mobility with focus on system analysis

Fraunhofer ISI

- …researches **how innovations are created**, which players need to be included and how they can be supported
- **…evaluates profitability, social and political potential** as well as technical barriers
- …helps decision makers in commerce, academia and politics with strategic analysis
- …uses the latest theories, models, social-economic methodologies, as well as databases and develops these continuously
- …works on approx. 250 projects p.a.
- …leads the German innovation landscape like no other research institute for more than 35 years

Current E-Mobility Projects

Flottenversuch Elektromobilität	▪ System integration of renewable energies ▪ Together with VW, E.ON
Meregio Mobil (Pilot Karlsruhe)	▪ Business models, control and customer acceptance ▪ Focus on Smart Homes
Fraunhofer Systemforschung Elektromobilität	▪ Socio-economic and sys-tem profitability evaluation ▪ E-Mobility association
LIB 2015	▪ Evaluation of Li-Ion development ▪ Roadmapping
Other	▪ Transport studies for EU ▪ IEKP-Monitoring

Fraunhofer ISI

E-Mobility is seen as a key lever for efficiency, reduced emissions, and renewable integration in transport

Key Levers for E-Mobility

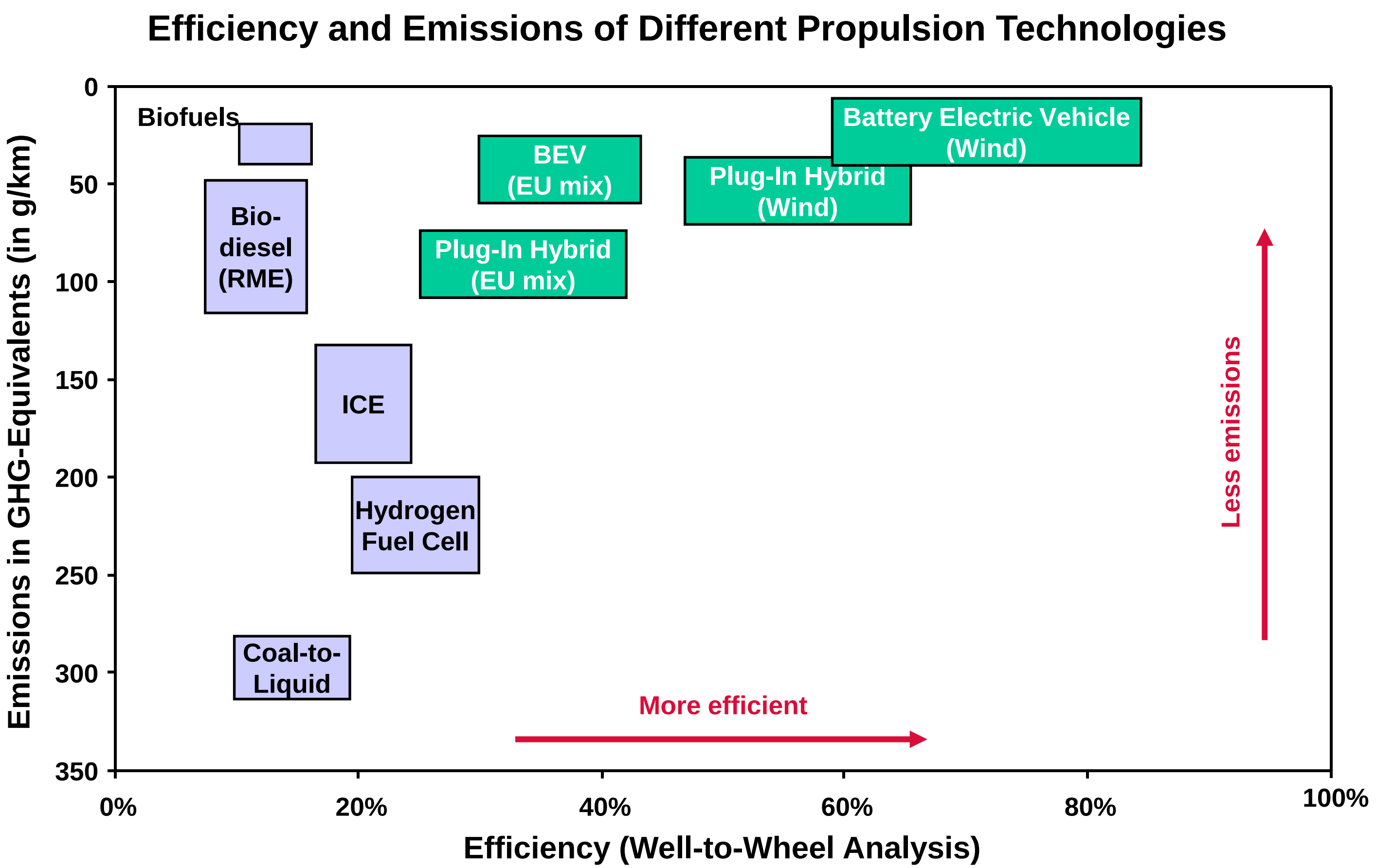
Efficiency Increase
- EVs are the most efficient propulsion technology
- Centralization of energy conversion

Emission Reductions
- Reduction of CO_2-emissions in transport
- Avoidance of further local emissions such as noise or particulate matter

Renewable Integration
- Shift from oil towards other energy sources
- EV battery storage capacity is an important lever for the built-up of further intermittent renewable capacities

Fraunhofer ISI

EVs are the most efficient propulsion technology and can help to reduce CO_2-emissions in transport

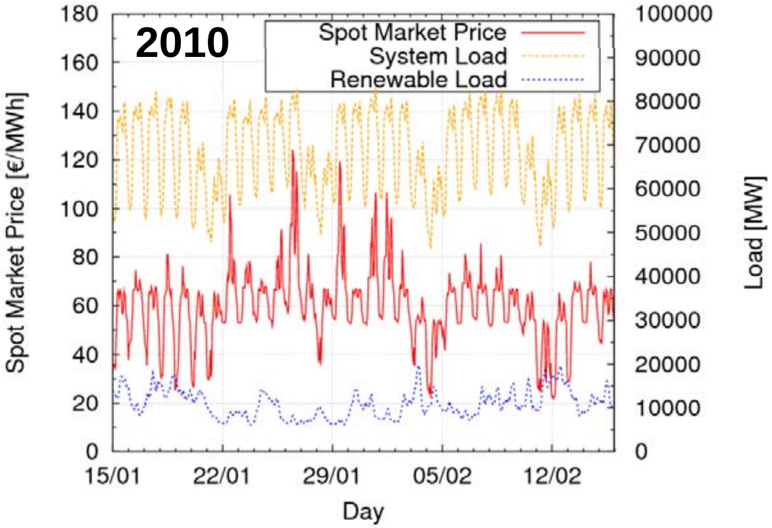


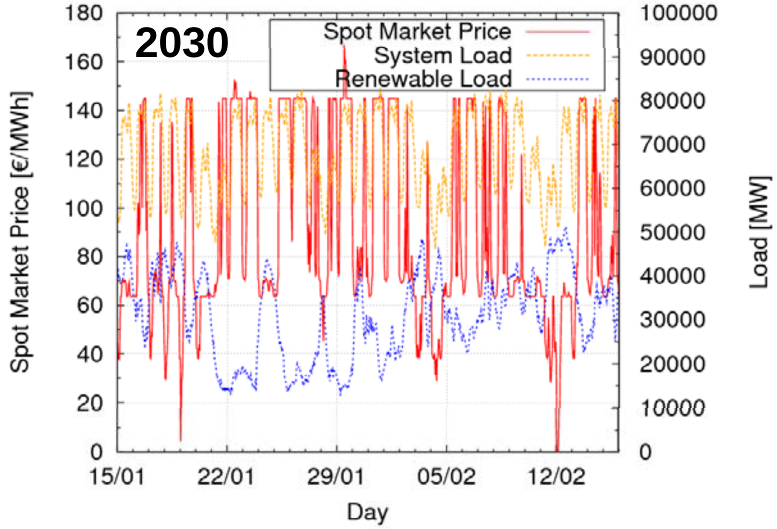
Note: BEV: Battery Electric Vehicle; RME: Raps-Methyl-Ester

Source: Own calculations and LBST

With the built-out of wind in the next years, additional storage capacity is needed

Price Variations in Different Wind Built-Out Scenarios





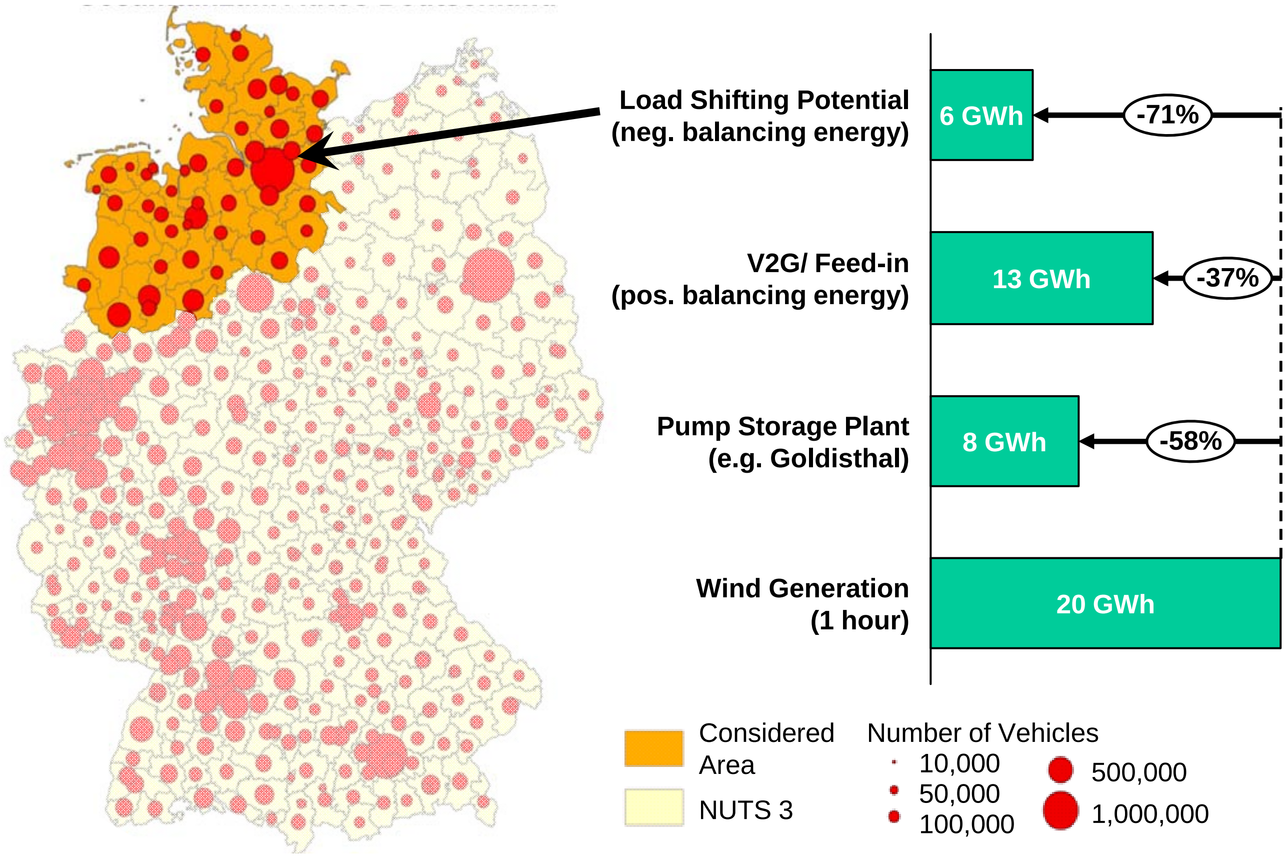
- Share of wind generation relatively low
- Here, renewable load never exceeds the system load
- Prices between 20-80 €/MWh
- Some extreme peaks occur when peak demand is combined with weak wind hours

- Higher wind generation share
- Multiple hours where the renewable load exceeds the system load
- Prices more volatile between 0-150 €/MWh

Source: Power ACE Simulation

EVs are a part of the solution, but other measures still needed - V2G usage economically questionable

Storage Capacity - 2030



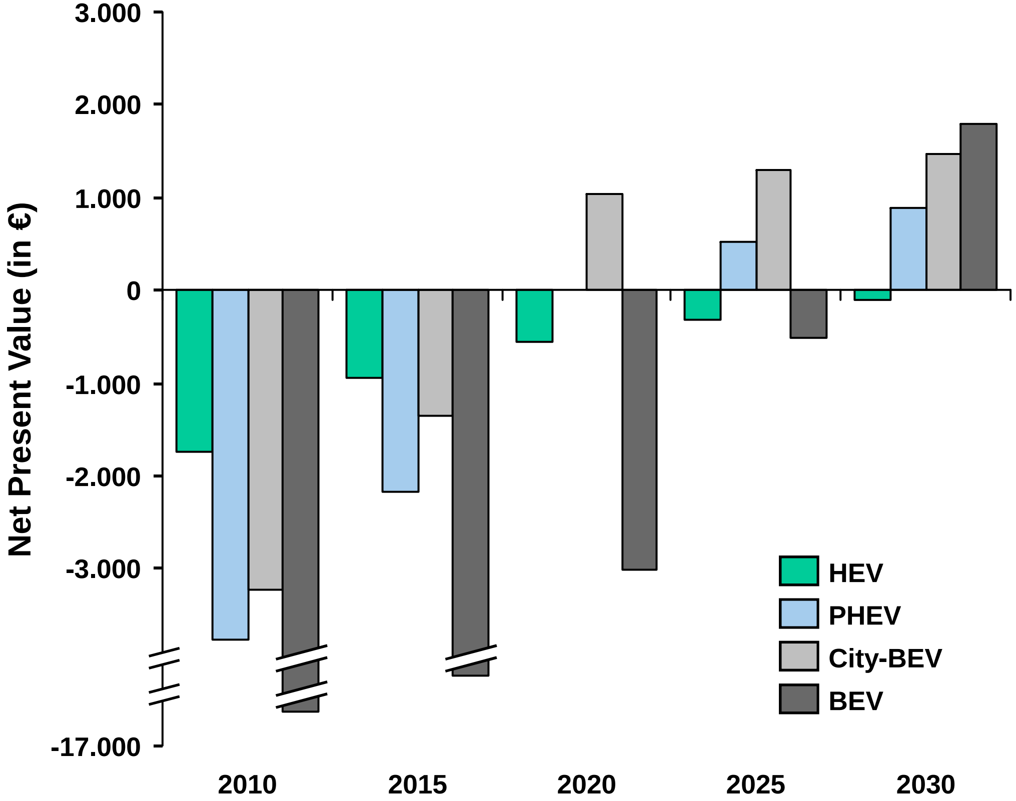
- In the Fraunhofer ISI „dominance“ scenario 25% (1 mio.) EV share by 2030
- **EVs just part of the solution**, other measures still needed:
  - Better transmission
  - Other storage cap.
  - Flexible power plants
- **Load shifting economically viable**
- **Positive balancing energy questionable** due to battery cycle life implications

Source: Own calculations

Fraunhofer ISI

Today, electric vehicles are far more expensive than ICEs - future cost reductions expected

Cost Parity: EVs vs. ICEs



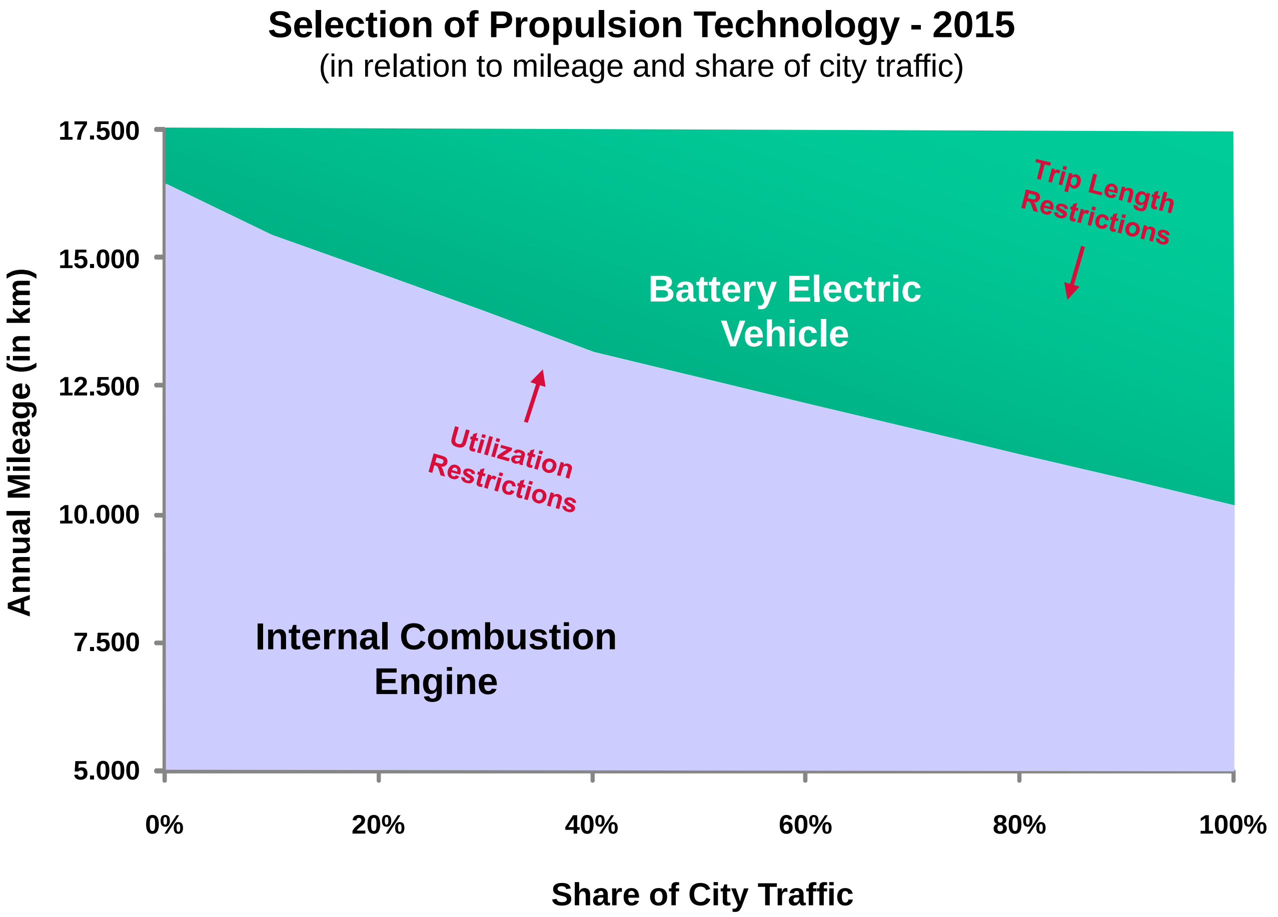
Note: HEV: Hybrid-Electric Vehicles, PHEV: Plug-in Hybrids, BEV: Battery Electric Vehicle
Source: Own calculations

Main Sensitivities

- **Battery costs** - need to drop from $1,000/kWh to almost $300/kWh
- **Energy costs** - question remains if power costs can be decoupled from crude oil prices, esp. levels beyond $80/bbl needed
- **Taxation and support schemes** - today EVs profit from less taxes on power than on fuel, same taxation would defer cost parity by 5-10 years
- **Additional revenue** - e.g. from V2G services

Fraunhofer ISI

In the beginning, electric vehicles will mainly target a niche market



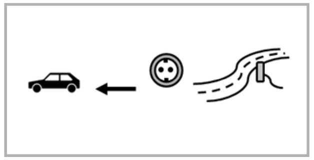
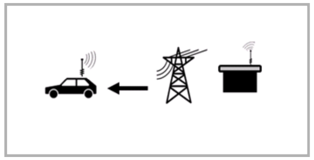
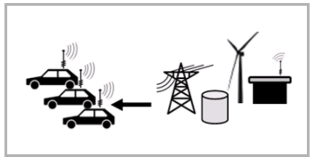
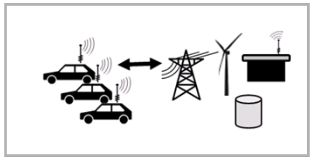
Source: Own calculations

- EVs **only in some segments** profitable
- Attractive first user segments
  - **Commuters**
  - **Second-car users**
  - Full time employees from areas with less than 100,000 inhab.
- Potential of up to 4% of car users (2015) in existing infrastructure - equivalent to 1.6 mio.

Fraunhofer ISI

Depending on future market penetration, charging infrastructure has to provide additional functionalities

Grid Integration with Increasing Market Penetration

Charging Infrastructure	Innovators´ Market	Niche Market (e.g. commuters, business clients)	Market Penetration	Mass Market
Grid Integration				
Infrastructure	• Norms and standards • Mainly private infrastructure	• Expansion of semi public charging infrastructure • Smart Metering	• Expansion of high power charging concepts	• Widespread private and public charging infrastructure • Smart Grids
Control		• Time-of-use rates	• Demand Side Management (Dynamic rates)	• Bi-directional connection
System Services			• Load shift (negative supply of balancing power)	• Load shift and active load leveling (positive & negative balancing power)

Time →

Fraunhofer ISI

Separate charging points or switching stations will be hardly economic

FIRST ESTIMATE

Profitability of Different Charging Infrastructure Concepts

Charging Infrastructure	Costs per Charging Point (€, w/o replacement)	/ Vehicles per Charging Point (in pieces)	= Infrastructure Costs per Vehicle (in €)	/ Profit Margin per Vehicle (at 5%, in €/a)	= Amortisation Period (in years)
Private Connection	100-200 €	1	100-200 €	12 € (Total: 240 €[6])	8-16 years
Semi-private Connection	100-200 €	1-2	50-200 €		4-16 years (possibly free of charge)
Public Charging Point	2,000-8,000 €[1]	12[4]	170-670 €		14-55 years
Battery Switching Station	~750,000 €[2] + 1,450,000 € batteries[3]	2,750[5]	~800 €		67 years[8]
Conventional Filling Station	~750,000 €[2]	2,750[5]	~272 €	39 € (Total: 780 €[7])	7 years (not including shops)

Note: Vehicle consumption 12 kWh/100km, annual mileage 10,000 km; **(1)** Costs should be estimated as being at the higher end of the range because of protection against vandalism etc.; **(2)** Costs of an average conventional filling station according to experts; **(3)** Approx. 700 cars arrive every day spread evenly across 12 h (see also (5)), i.e. ~180 batteries have to be charged at the same time, a battery costs approx. 8,000 €, equivalent to ~1,450,000 €; **(4)** Max. 3 charges per day due to longer standing time, vehicles have to be charged every 4 days, i.e. 12 vehicles can be charged at charging points; **(5)** 14,500 filling stations in Germany to about 40 million vehicles; **(6)** Sale price of 0.20 €/kWh at a total consumption of 1,200 kWh; **(7)** Gasoline price of 1.30 €/l at a consumption of 6 l/100km; **(8)** Esp. replacement of battery would greatly extend amortization period

Fraunhofer ISI

In summary…

- **E-Mobility is one of the kex technologies to make transport more sustainable** by
  - Improving efficiency ratios
  - Reducing overall emissions
  - Diversifying energy sources from oil towards renewable energies
- EVs help to integrate renewables, but other measures need still to be followed
- For a mass market application, however, **EVs need to overcome today's deficiencies**
  - High battery costs for stacks with high energy content and manageable weight
  - Short battery cycle life/ lifetime
  - Long charging times
- Today, **EVs mainly target niche markets**, e.g. city-BEVs or electric scooters
- **Step-wise integration** of e-mobility **in the electricity infrastructure**
  - Private connections and charging points are economically more attractive than public charging points or even switching stations and reach large initial customer segments
  - A question remains: **Which kind of infrastructure is best to support market penetration?**

Thank you for your attention…

Fraunhofer

ISI

Fabian Kley

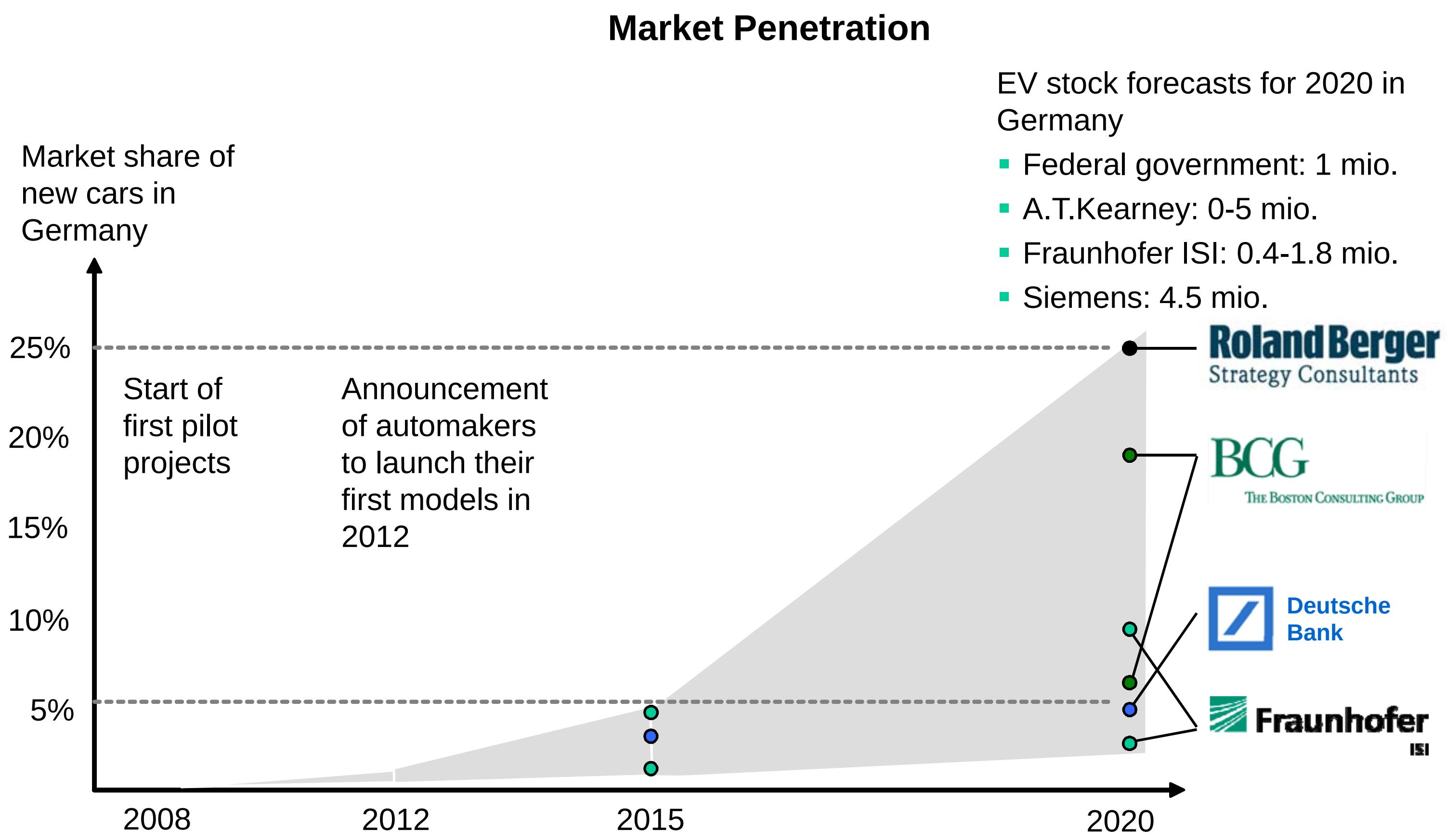
M.Sc., MBA
Competence Center for Energy Policy and Energy Systems
Fraunhofer Institute for Systems and Innovation Research ISI

Breslauer Strasse 48 | D-76139 Karlsruhe | Germany
Phone +49 721 6809-430 | Fax +49 721 6809-272
fabian.kley@isi.fraunhofer.de

…please feel free to reach out to me for questions!

Market penetration scenarios for e-mobility are probably to bullish

APPENDIX



Separate charging points will be hardly economic

APPENDIX

Details: Charging Points

- High costs for charging stations (w/o grid connection)
- Investments of 1,000-7,000 € and maintenance of 150 € annually
- Charging stations at home with investment costs of 50-350 €
- Low revenue levels
  - Annually approx. 1,200 € - based on 2-3 hours charging time and three charges per day
  - Realization of tailored business models

Charging Point, Project Better Place

Fraunhofer ISI

Switching stations will be hardly economic

APPENDIX

Details: Switching Station

- **Advantages**
  - „Gas station“ concept stays in place
  - Quick „charges“ possible
  - Easier grid integration possible, e.g. to enable load balancing
- **Disadvantages**
  - High capital intensity due to additional batteries (roughly 1,4 per vehicle)
  - Standard battery packs jeopardizes the automakers agenda, e.g.
    - Loss of value creation
    - Identification over driving power and uniqueness
    - Curtailing the design of different vehicles
  - Battery production is the bottleneck
  - Switching machines/ tools are costly
  - Safety issues at high voltage

Battery Switching, Project Better Place

Fraunhofer ISI