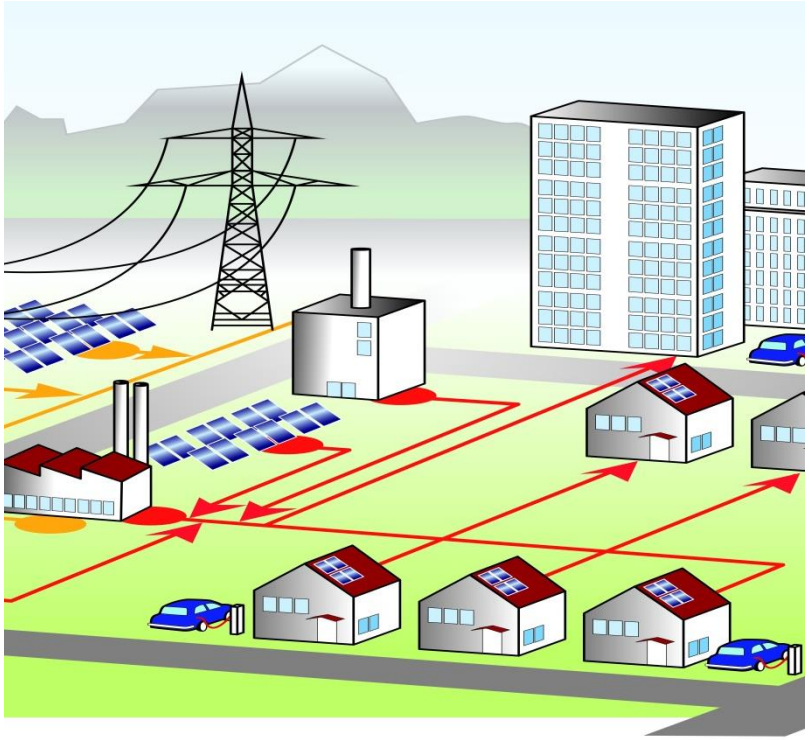
Energy System Analysis and Electric Mobility within Energy Systems

Bangkok | 26.04.2017

Dr.-Ing. Stefan Lösch | stefan.loesch@ifam.fraunhofer.de



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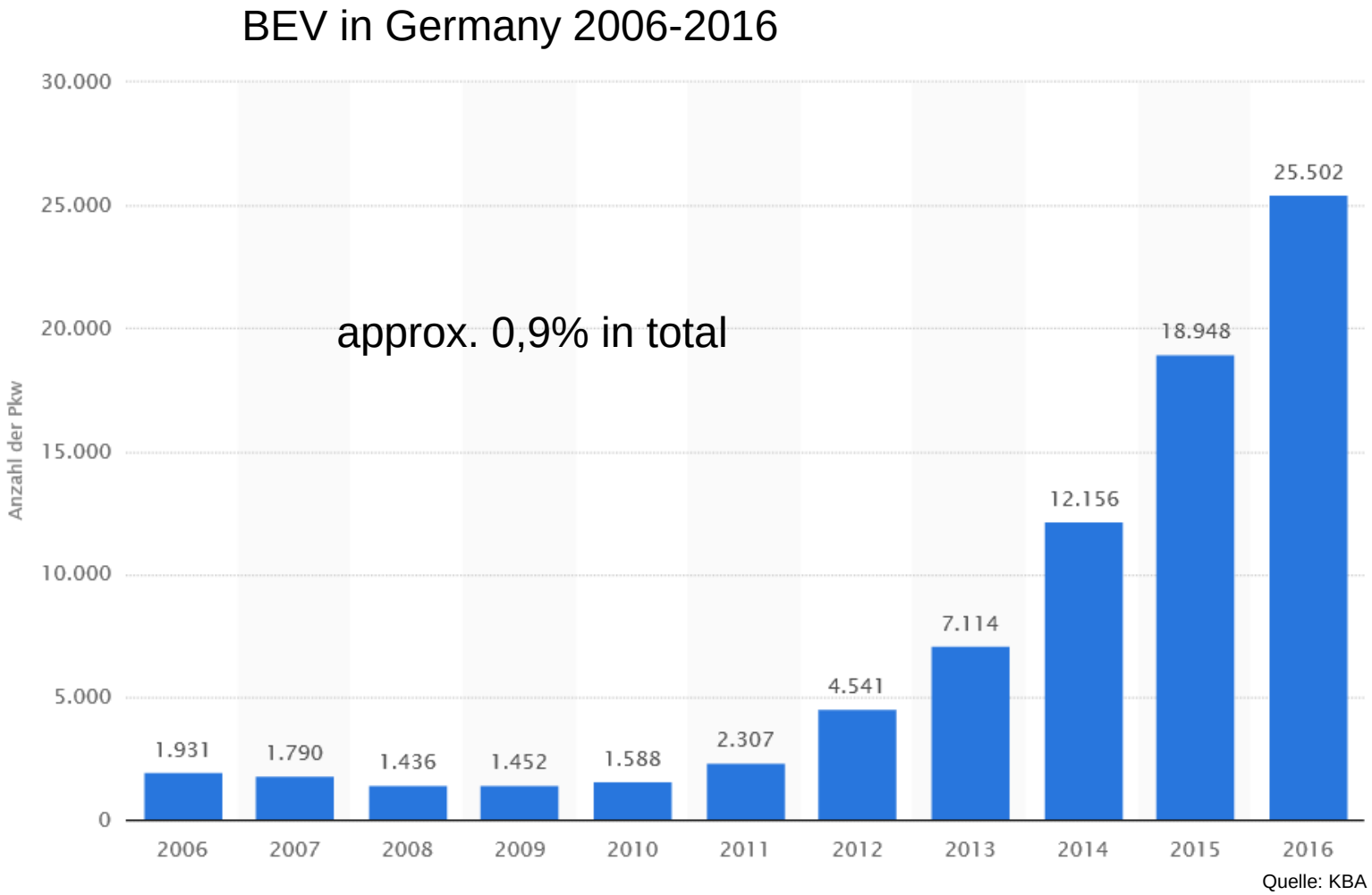
Electric vehicles in Germany



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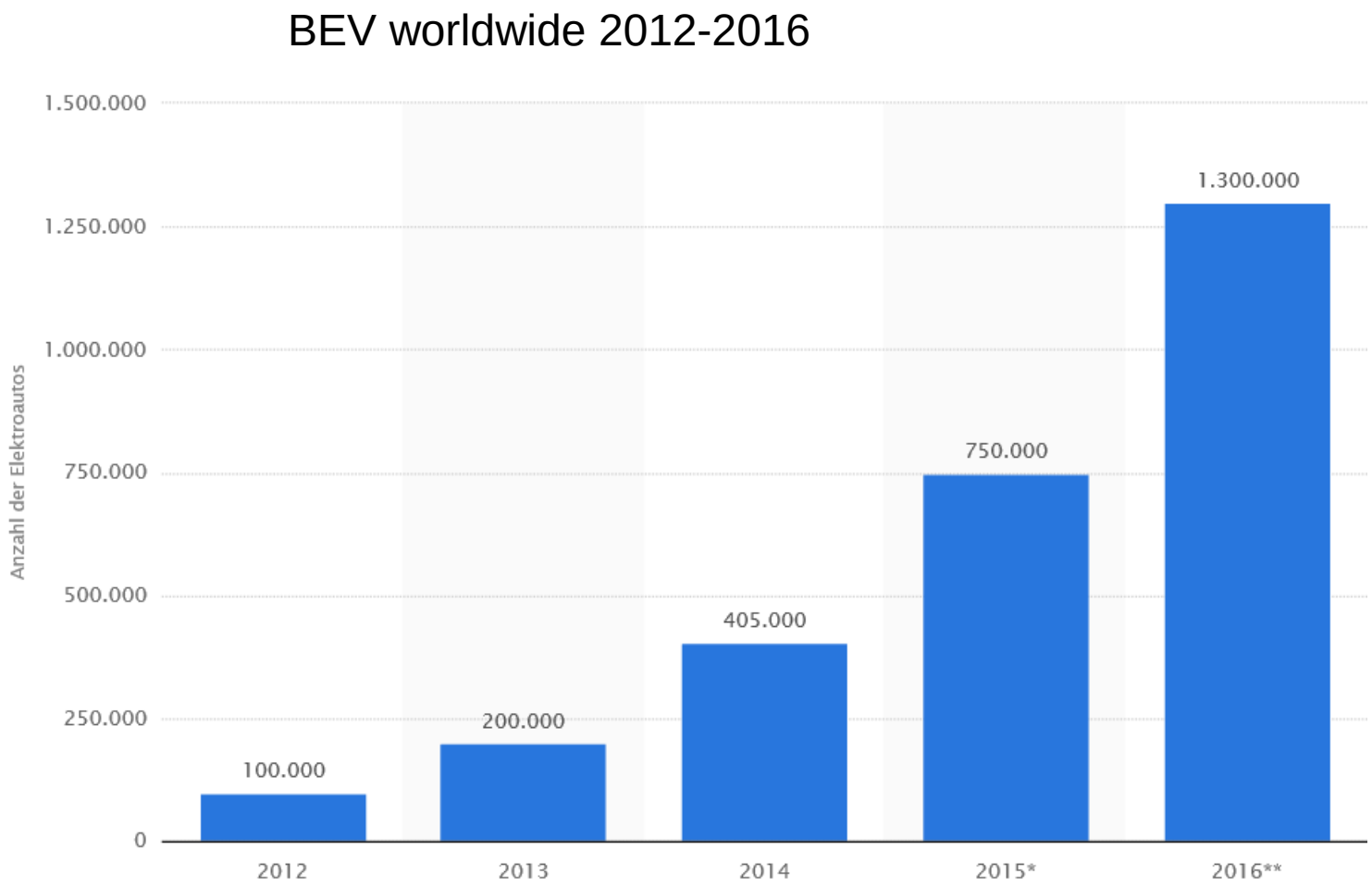
Electric vehicles world-wide



Quelle: KZSW

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Forecast Electric vehicles

- Batteries will base on Li-Ion technology
- Prices of PHEV/BEV will fall continously (Scale effects, „Gigafactory“)

  2008: approx. 900€/kWh at 140Wh/kg (cell level)

  2016: approx. 250€/kWh at 180Wh/kg

  2030: <100€/kWh at 300Wh/kg (Fraunhofer ISI)

  Electric vehicles economic in general less 150€/kWh
- Ranges 200-400km
- Battery sizes 20-60kWh
- Politics and environment will push the market

=> Excellent future for the EV

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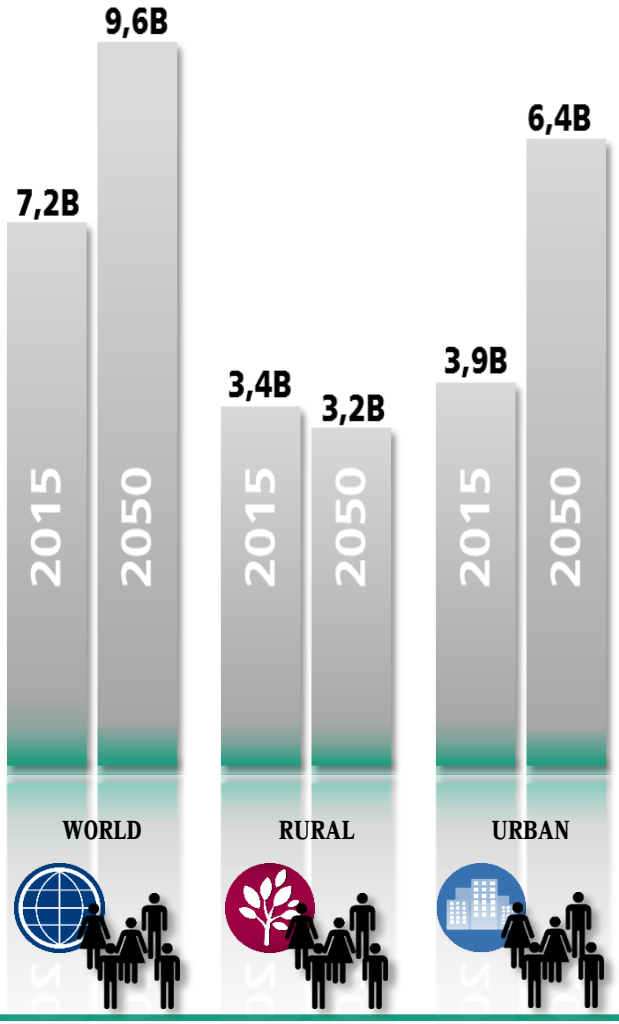
Forecast Electric vehicles



- 1950: 3M Cities
  → 2030: 480M Cities
- Every week more than 1M people worldwide move from rural regions to the cities
- 80% of the Gross Domestic Product (GDP) is generated in cities
- Establishing new work, lifestyle and living models is a process that requires participation

Urban space & resources (mobility) are needed for additional 2.5B people!

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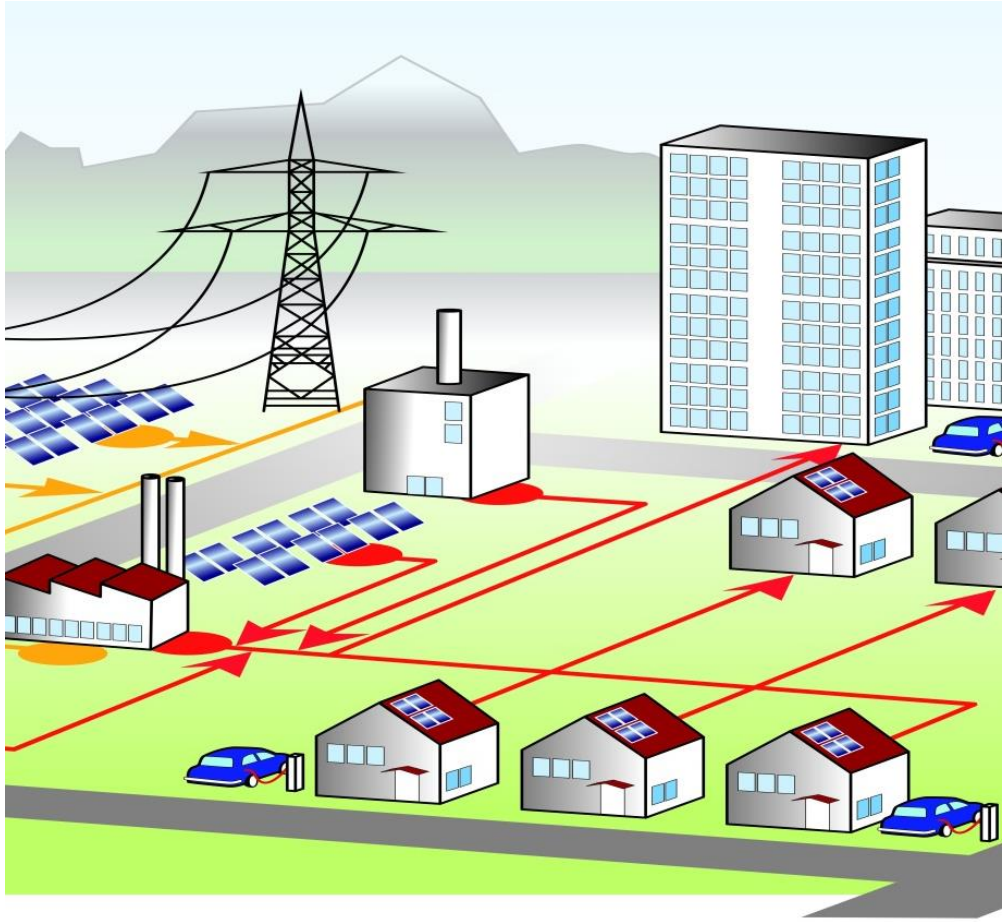
Charging infrastructure



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Charging infrastructure

- How long does it take
- How can I charge my car?
- Where do I charge my car?
- Which charging technic is for which vehicle?

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How long does it take?

- assuming 50kWh battery => realistic range of approx. 250km
- Charging up to SOC 80% = 40kWh = range for additional 200km

3kW	**=> 13h**	**@ home**
22kW	**=> 1,8h**	
50kW	**=> 0,8h (48min)**	**@ public**
100kW	**=> 0,4h (24min)**	
350kW	**=> 0,1h (7min) => target for highway-stations**	

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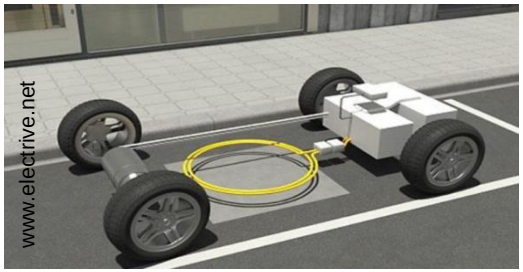
How can I charge my car?

1. Cable

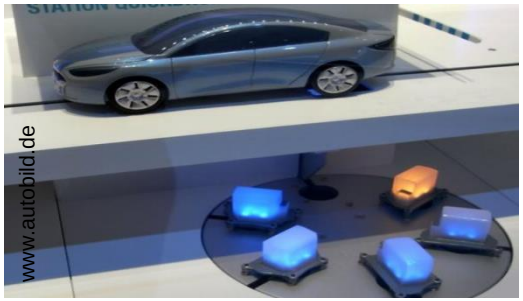
IFAM - hardware

2. Contactless



IFAM - hardware

3. Battery exchange



4. Trolley

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Power source AC

Plug „Schuko“ => up to 3kW

Plug Typ1 => up to 3,8/5,8/7,2 kW

Plug Typ2 => up to 3,6/11/22/43kW

Power source DC

CCS Combo 2 => 50kW approx. 570 pupblic stations/Germany

CHAdeMO => 22/50kW approx. 440 public stations/Germany

Supercharger => 135kW approx. 378 public stations/Germany

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Examples for conductive charger

www.ebg-compleo.de

www.tank.rast.de

www.bmw.de

www.renault.de

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Examples for conductive charger

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Charging infrastructure – Cable

advantages:

- High efficiency (up to 97%)
- No exact positioning of vehicle is required
- Standard exist (CHAdeMO, CCS, Typ 2)
- Cost friendly solutions

disadvantages:

- No protection against vandalism
- Charging can be stopped by others
- Not comfortable for user
- Billing
- Discrimination regarding standards
- Charging just stationary

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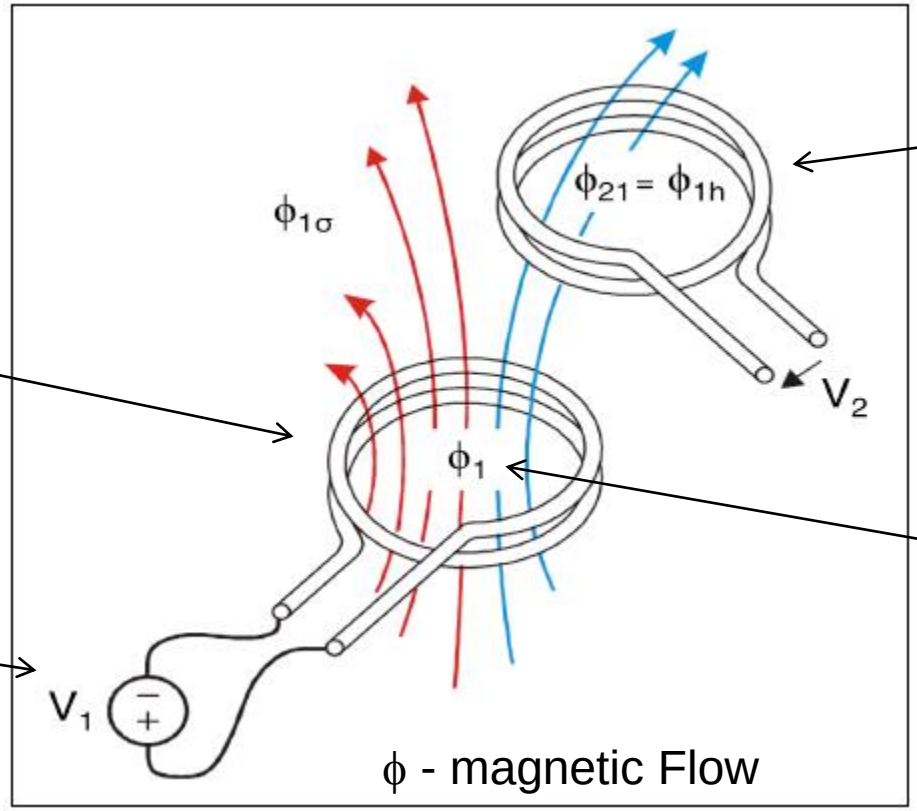
Basics of inductive energy transfer



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Interessting for vehicles

- „Cableless“ gives the advantage to recharge any vehicle during moving!

Inductive charging

stationary **mobil**

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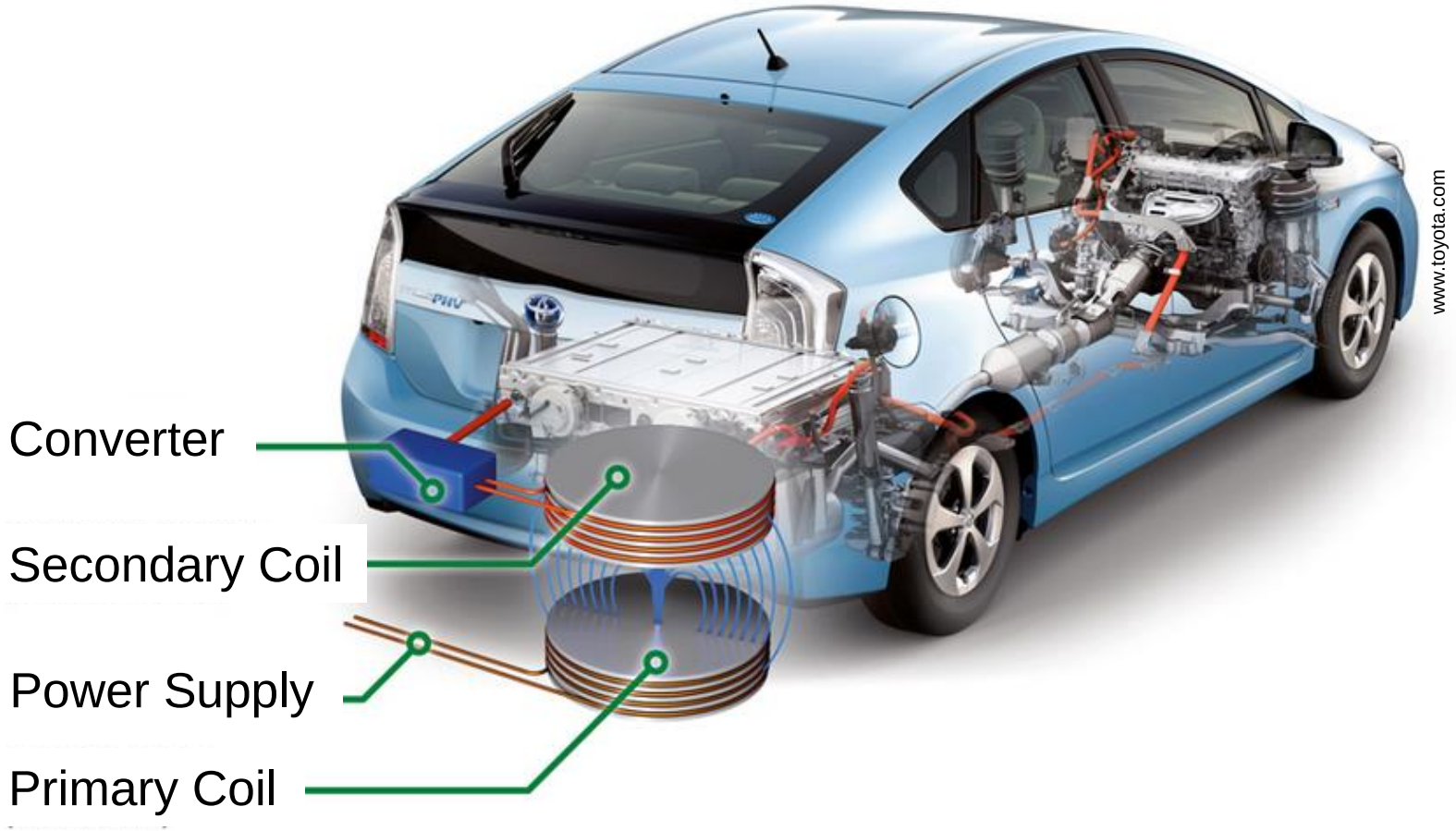
Charging infrastructure – Contactless

Stationary – vehicle does not move



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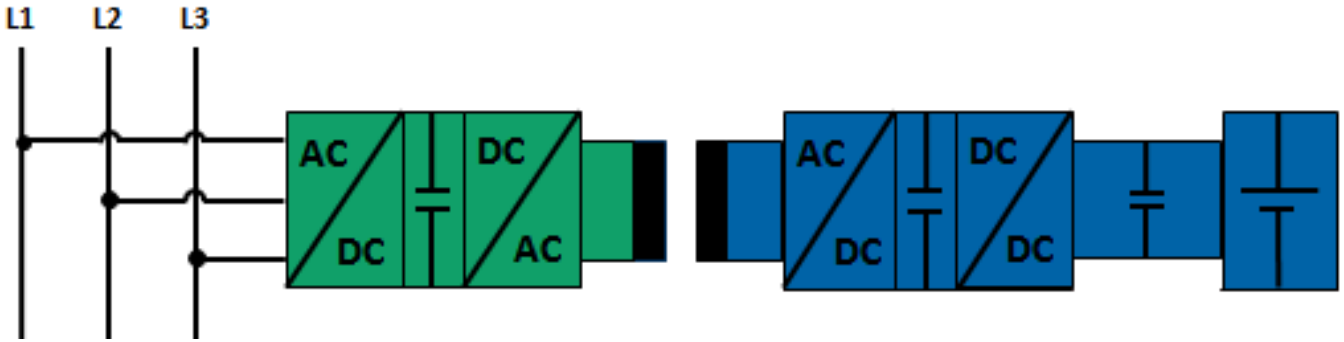
Stationary – vehicle does not move



- for 3,7kW-Systems: 60x60cm (Coils) und 10-20cm (Air gap)
- Starts at 4000EUR

Power source in general AC

Charging power up to 30kW (Car) and 200kW (Bus)

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Examples for stationary inductive charging - cars

www.mein-elektroauto.com

www.autobild.de

www.reevolt.de

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Examples for stationary inductive charging - bus

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Examples for stationary inductive charging - bus

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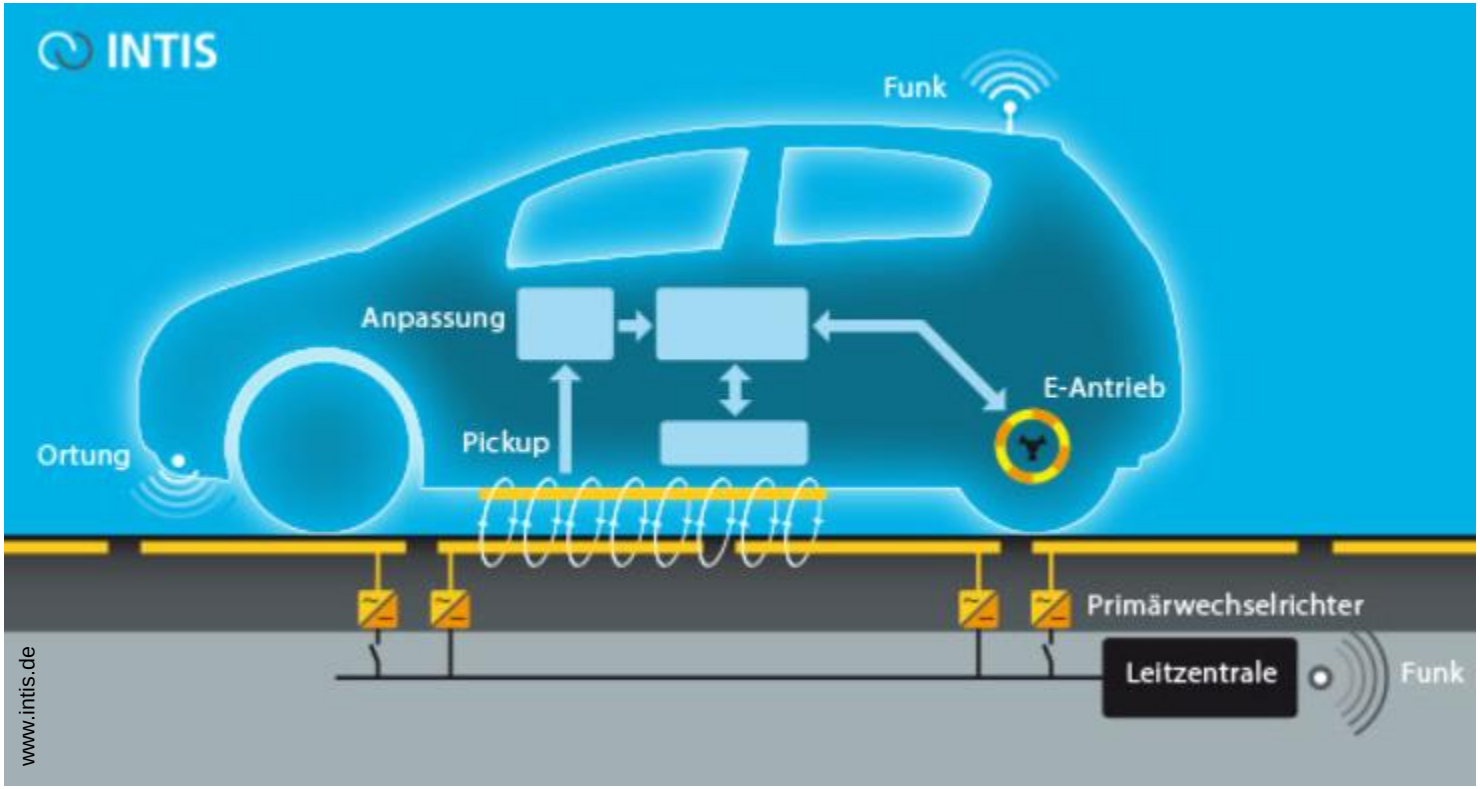
Charging infrastructure – Contactless

mobil – vehicle can move



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Charging infrastructure – Contactless

mobil – vehicle can move

advantages against stationary inductive charging:

- Battery protection during operation
- Minimization of traction battery => interesting for trucks
- No range-fear on highway and minimization of stopping time for recharging

disadvantages against stationary inductive charging:

- Still very expensive! => no mass market

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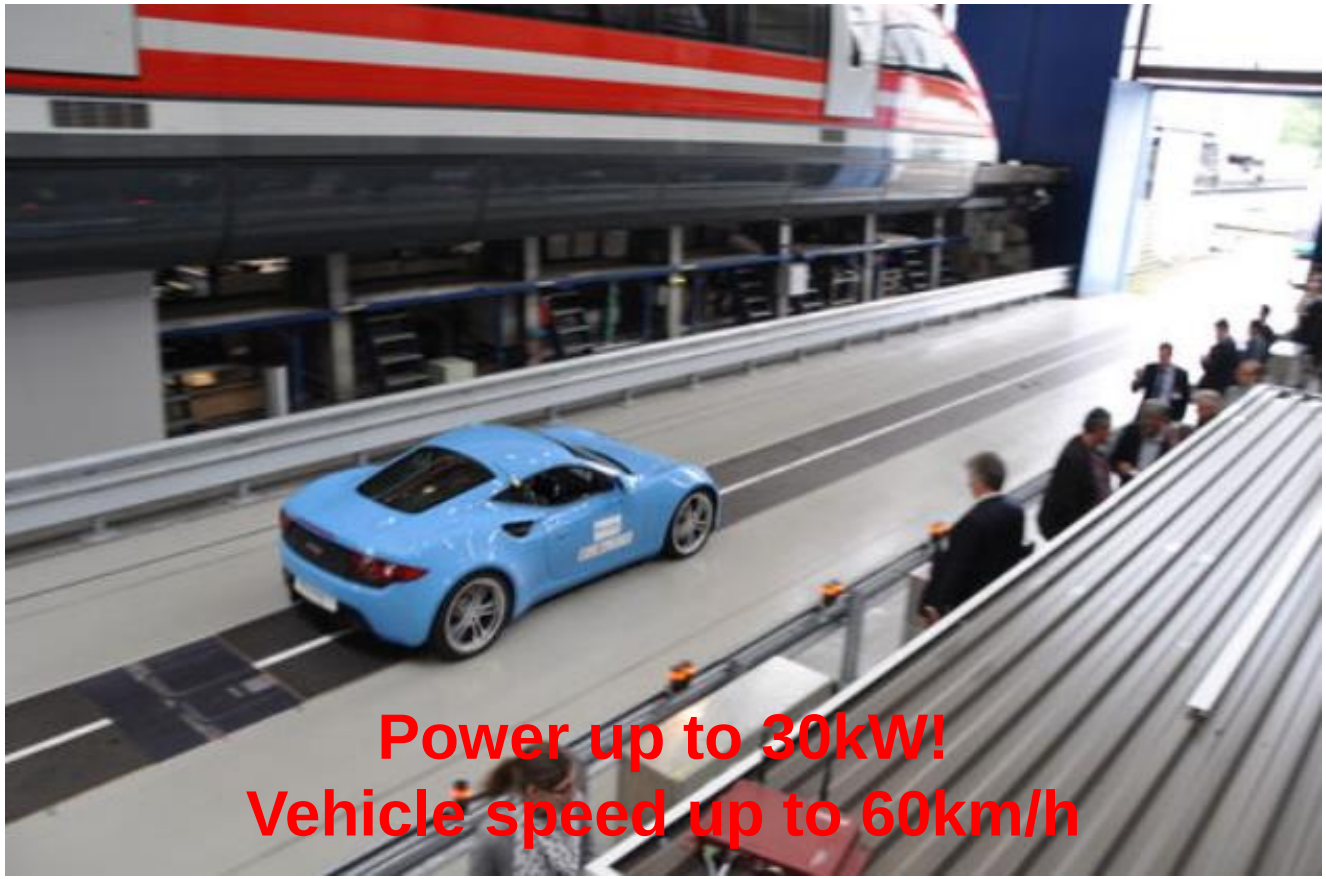
Examples for mobile inductive charging - car



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Examples for mobile inductive charging - car

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Examples for mobile inductive charging - trucks

www.primove.de

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Charging infrastructure – Contactless

advantages:

- High efficiency (up to 90%)
- No physical interruption during charging caused by others
- User-friendly
- Safe against vandalism
- No risk of stumpling
- **Charging during operation!**

disadvantages:

- Expensive (3,6kW charger starts at 4000EUR)
- Positioning of vehicle necessary
- No binding standards
- Security (EMC, foreign matters)

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Generation of sustainable energy

Energy Harvest 2014: 4521kWh (5kWp, South, 45°, Bremen)

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Generation of sustainable energy

η = 5-30%
2000-5000€/kWp

η = 25-50%
800-2000€/kWp

Energy Harvest 2014: 2250kWh (3,5kWp, horiz., 5m/s, Bremen)

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Energy Harvest 2014: 4521kWh (5kWp, South, 45°, Bremen)

vs

Energy Harvest 2014: 2250kWh (3,5kWp, horiz., 5m/s, Bremen)

=> our focus are Photovoltaic-systems

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Storage of sustainable energy

www.quadrex-solar.de

www.sonnewindwaerme.de

www.comfortliving.com

www.pv-magazin.de

www.kreiselelectric.com

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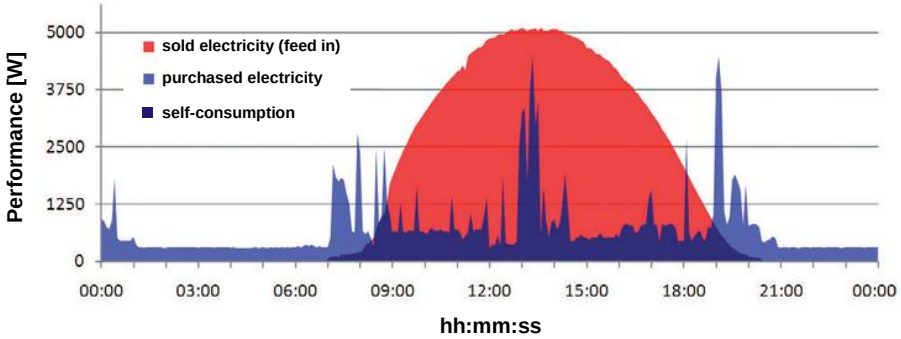
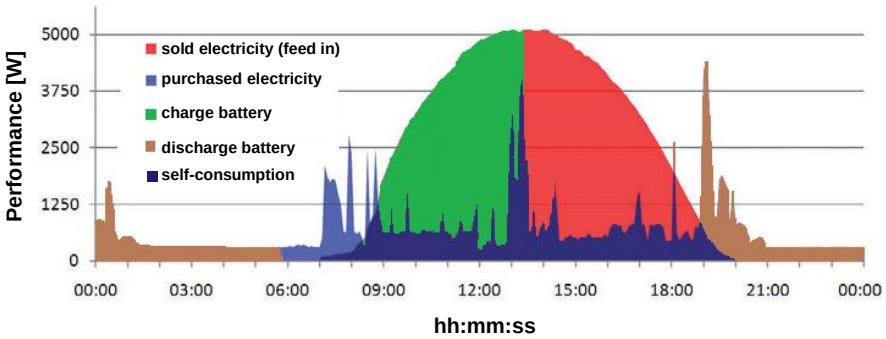
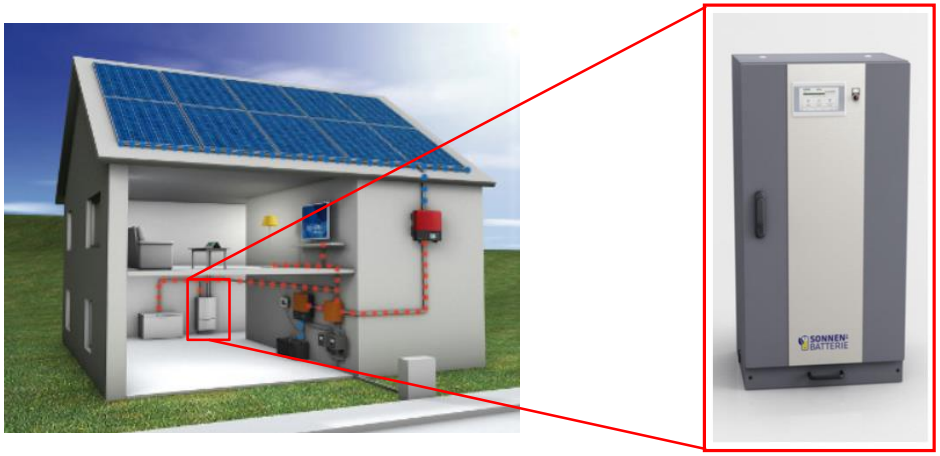
Storage of sustainable energy

without battery



with battery





type	Pb	Li-Ion
cycles	1000-3000	3000-10000
DOD [%]	40	5-10
η [%]	85	95
Costs [€/kWh]	400-1000	800-2000

Energy consumption of 4-person-household compared to harvest-profile of Photovoltaic-System for 24 hours

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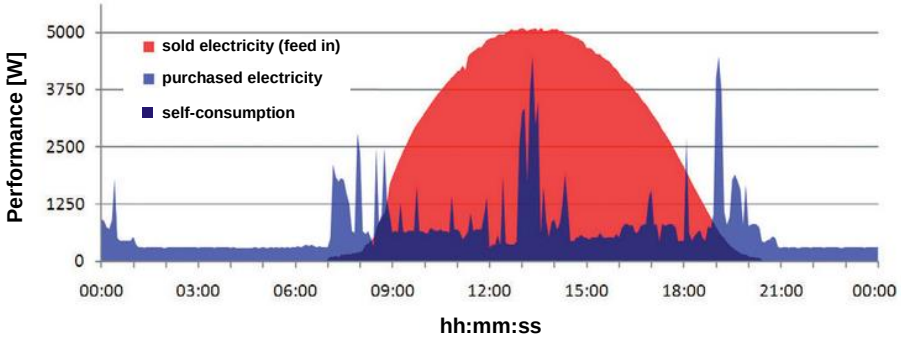
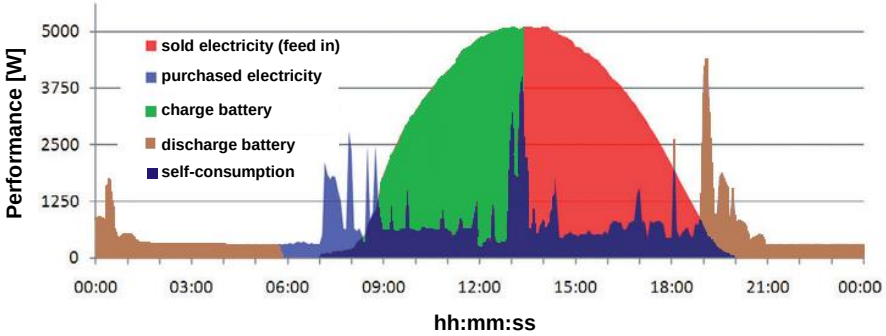
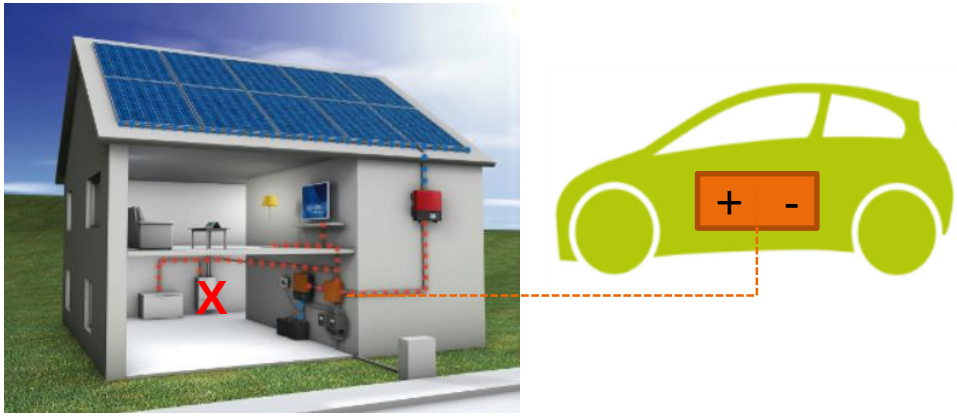
Storage of sustainable energy

without battery



with BEV





Energy consumption of 4-person-household compared to harvest-profile of Photovoltaic-System for 24 hours

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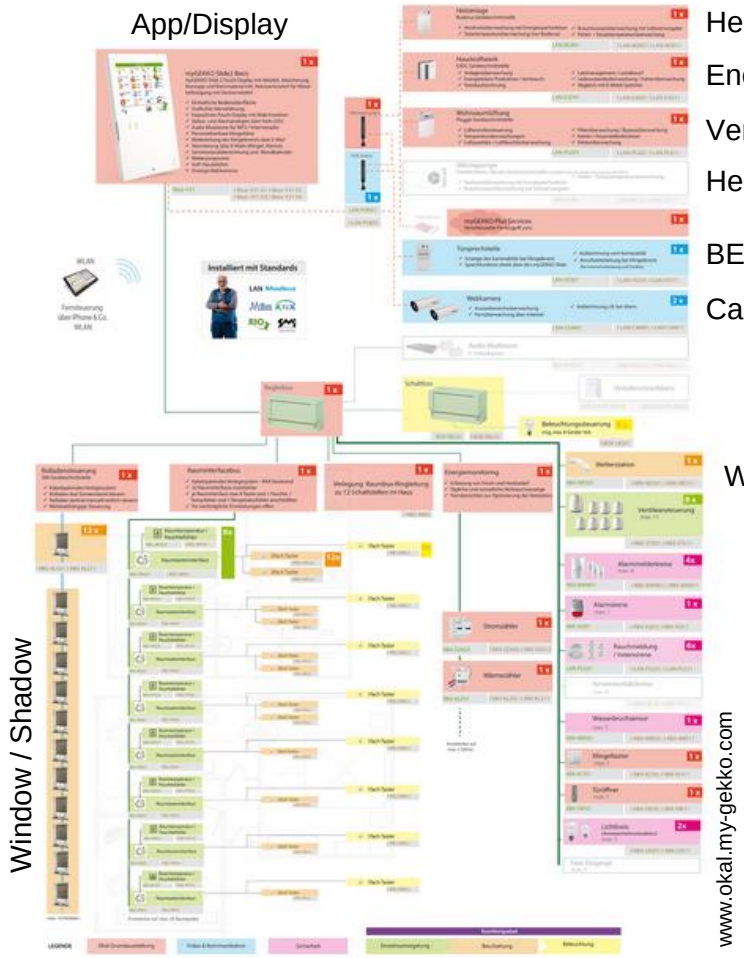
Distribution of sustainable energy

Energy management



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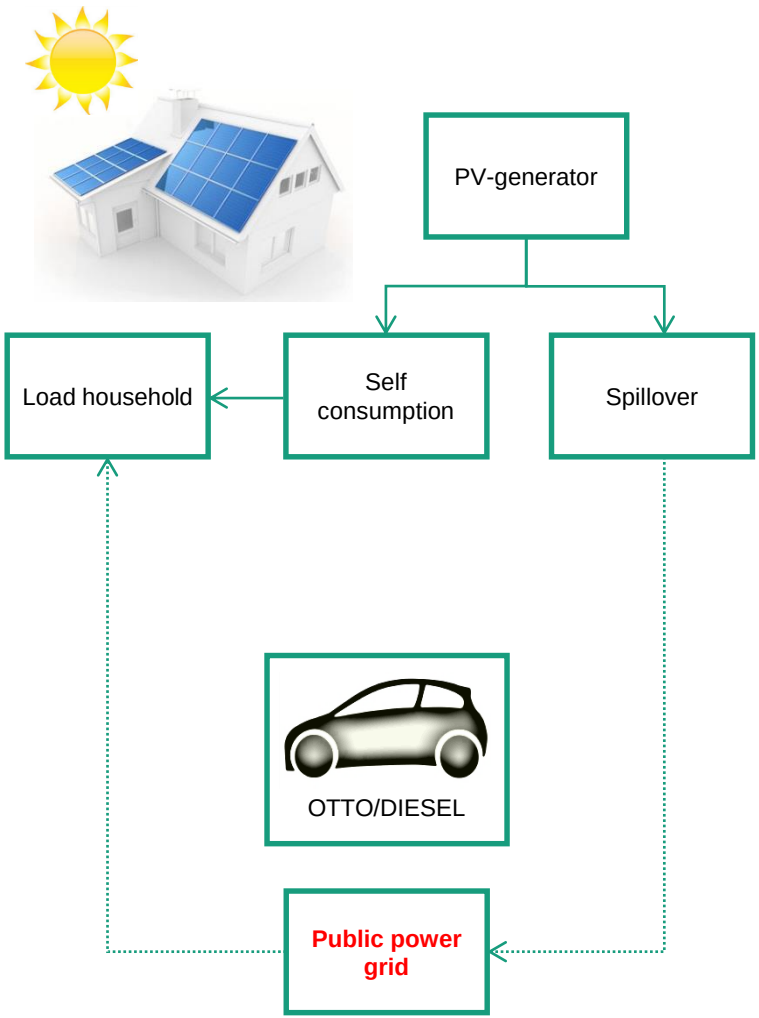
Distribution of sustainable energy



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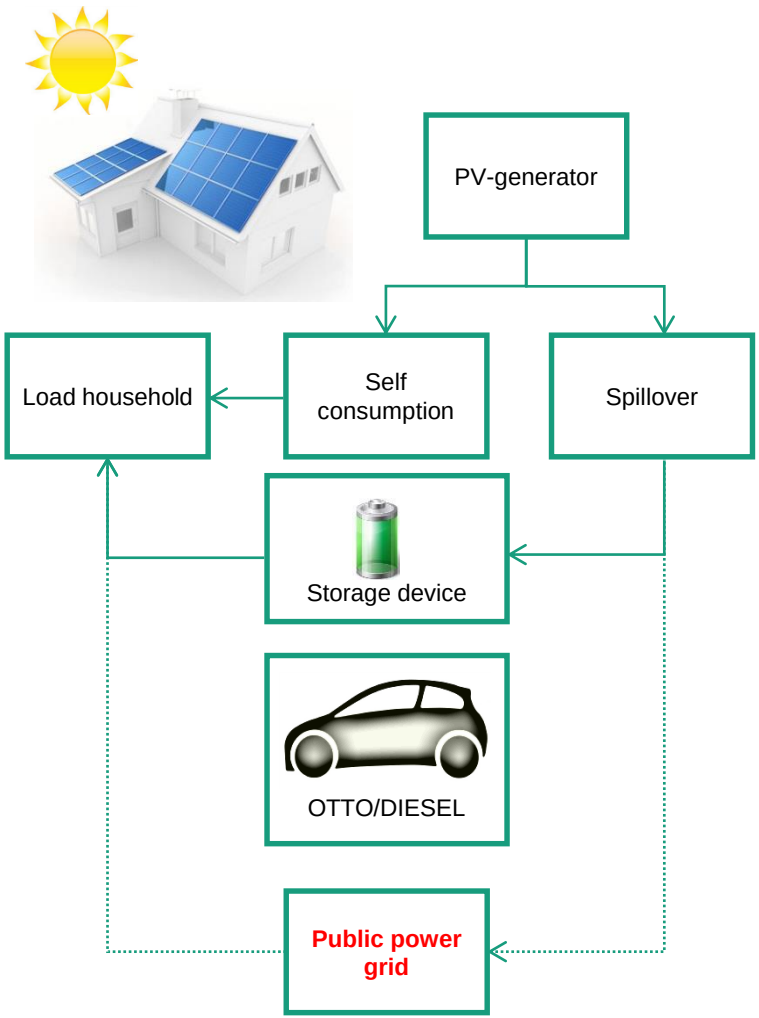
Distribution of sustainable energy



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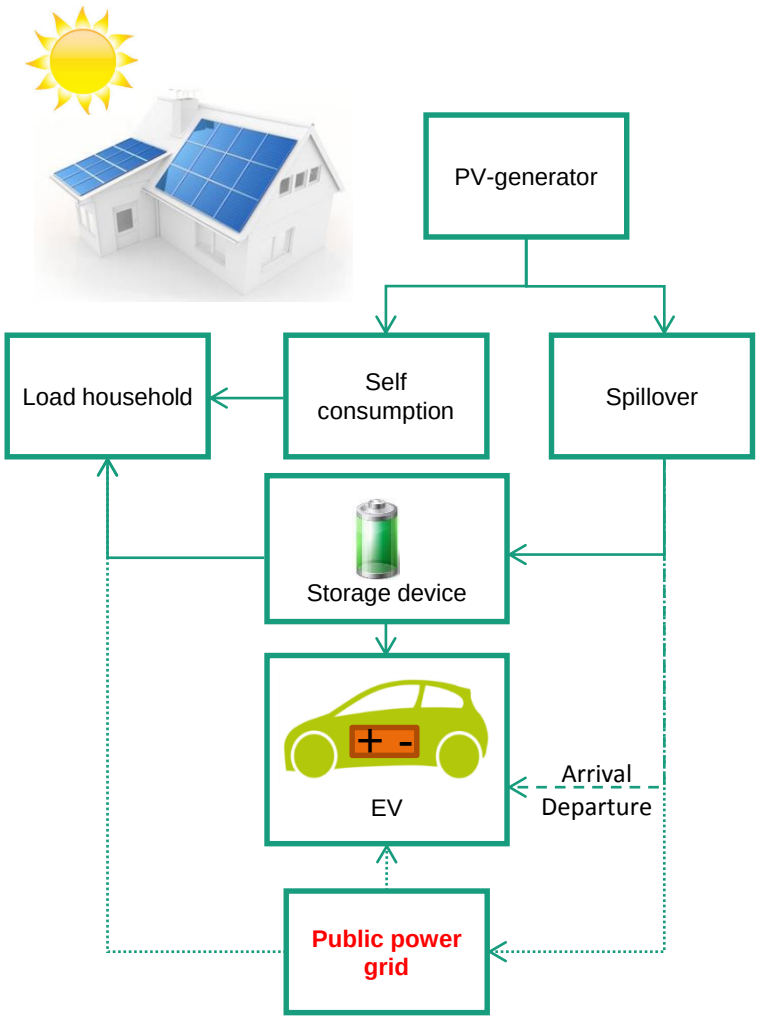
Distribution of sustainable energy



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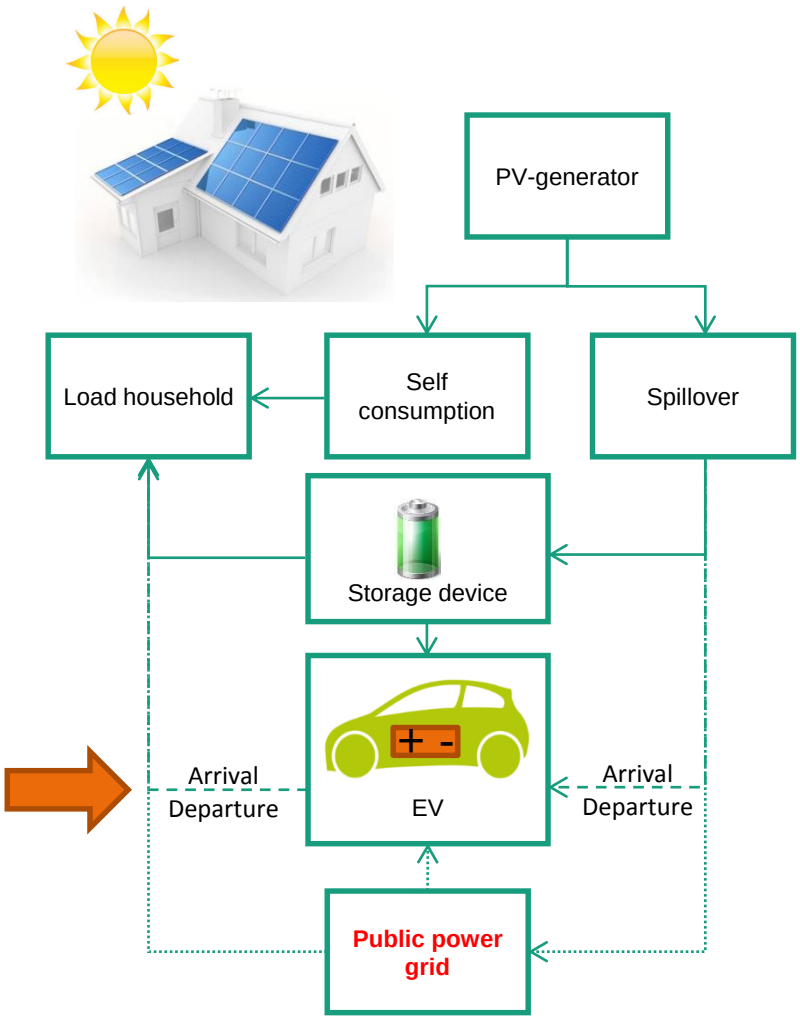
Distribution of sustainable energy



Bi-directional charging

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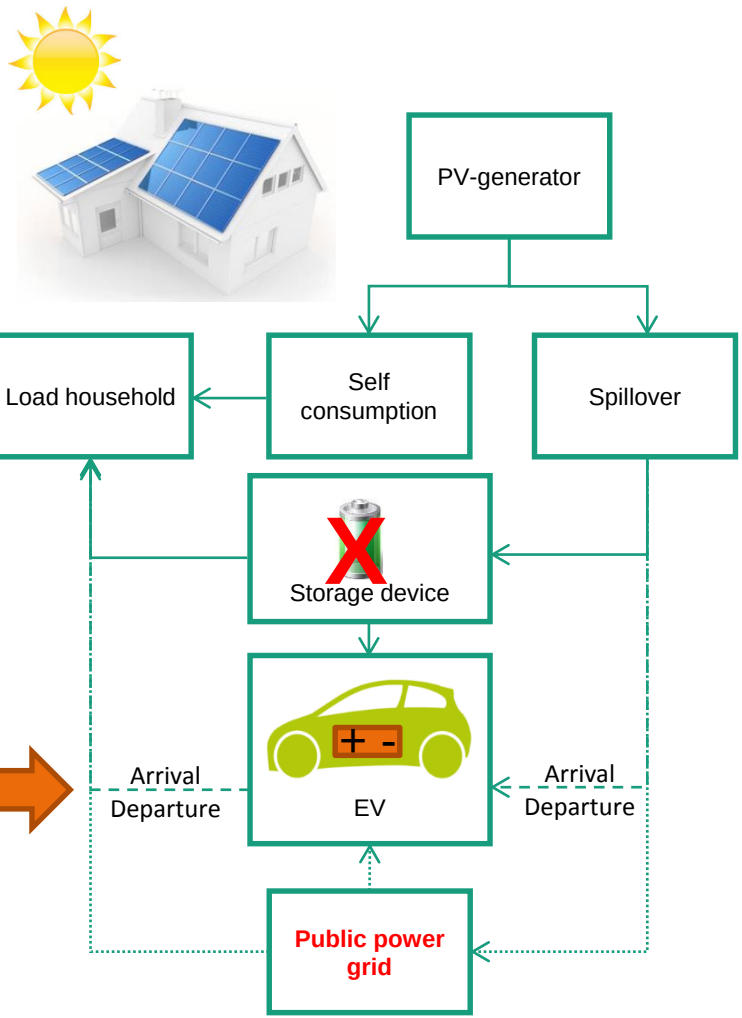
Distribution of sustainable energy



Bi-directional charging

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Using scenario: private

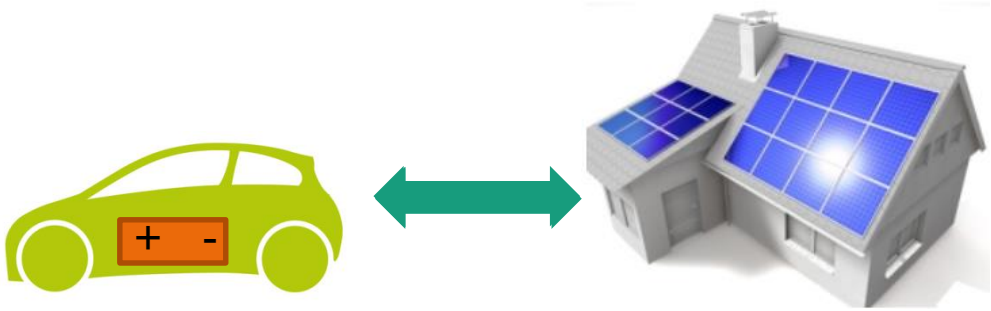
a) distance > 100km/day => battery will be empty

b) distance < 30km leaving 6am; arriving 8pm => no buffering

c) distance < 30km leaving 8am; arriving 1pm => buffering + providing

d) No travelling the whole day => buffering + providing

e) …



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Advantages of **bidirectional charging:**

- V2G, V2L
- Buffering / providing spillover of regenerative energy
- Reducing / Elimination stationary battery
- Speed up ROI
- Reducing CO2-emissions

Disadvantages of **bidirectional charging:**

- Increase of battery cycles
- Reducing battery lifetime for mobile application
- Charging infrastructure
- Still expensive

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How much energy can be transfered by a bidirectional EV to a building by using a photovoltaic system??

Main Input data:

load profile

mobility profile

power profile

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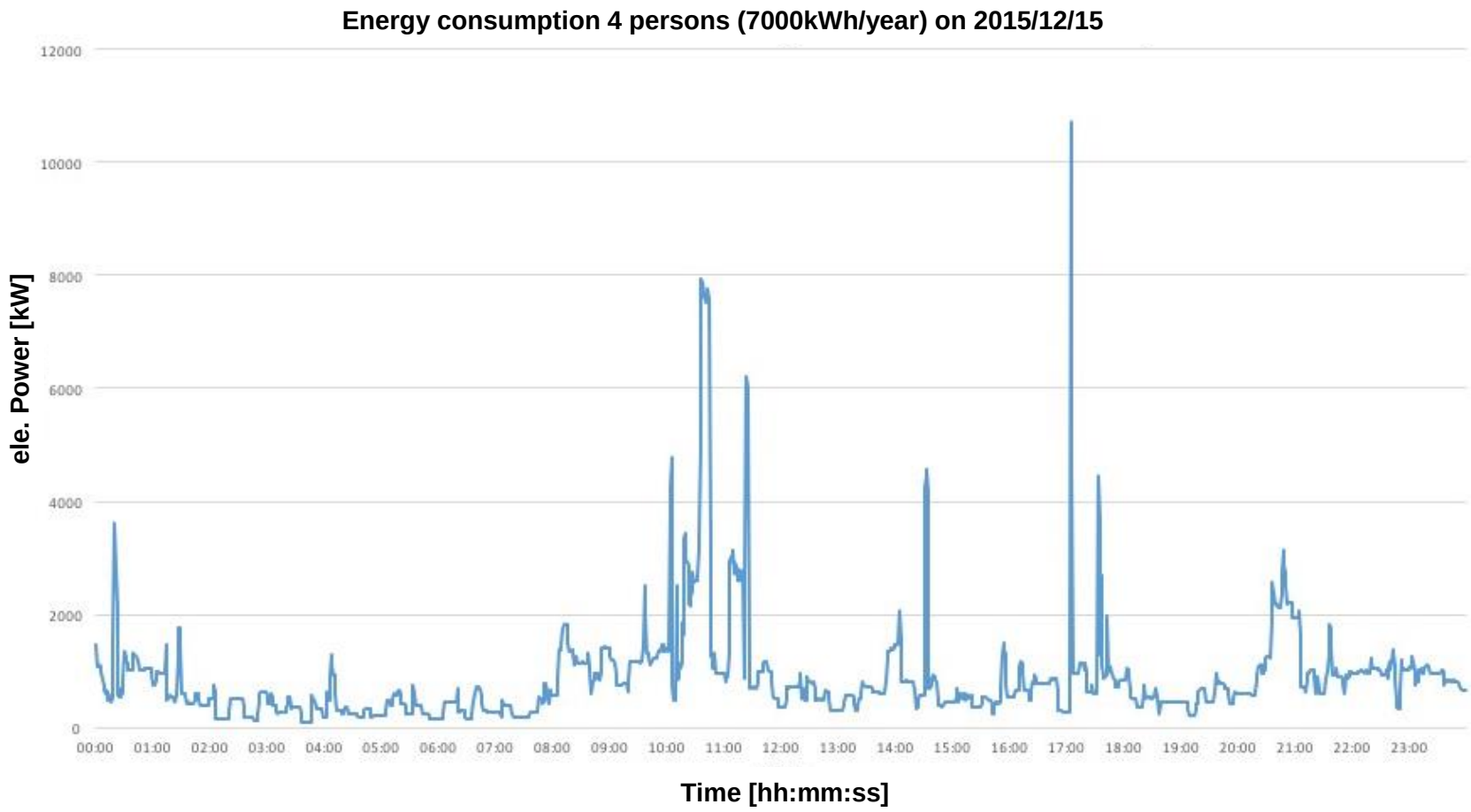
Distribution of sustainable energy – bidirectional EV

Input: load profile



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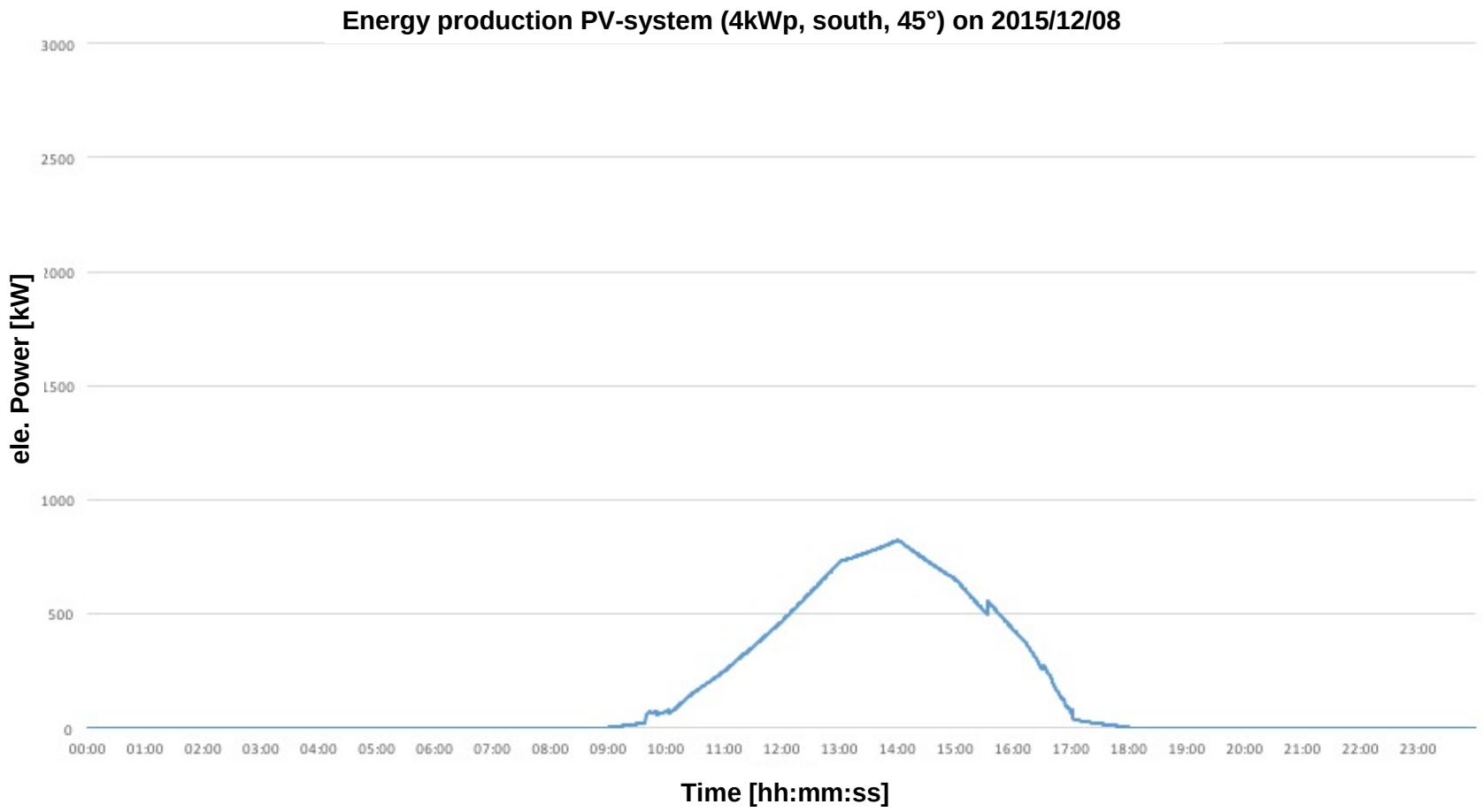
Distribution of sustainable energy – bidirectional EV

Input: power profile



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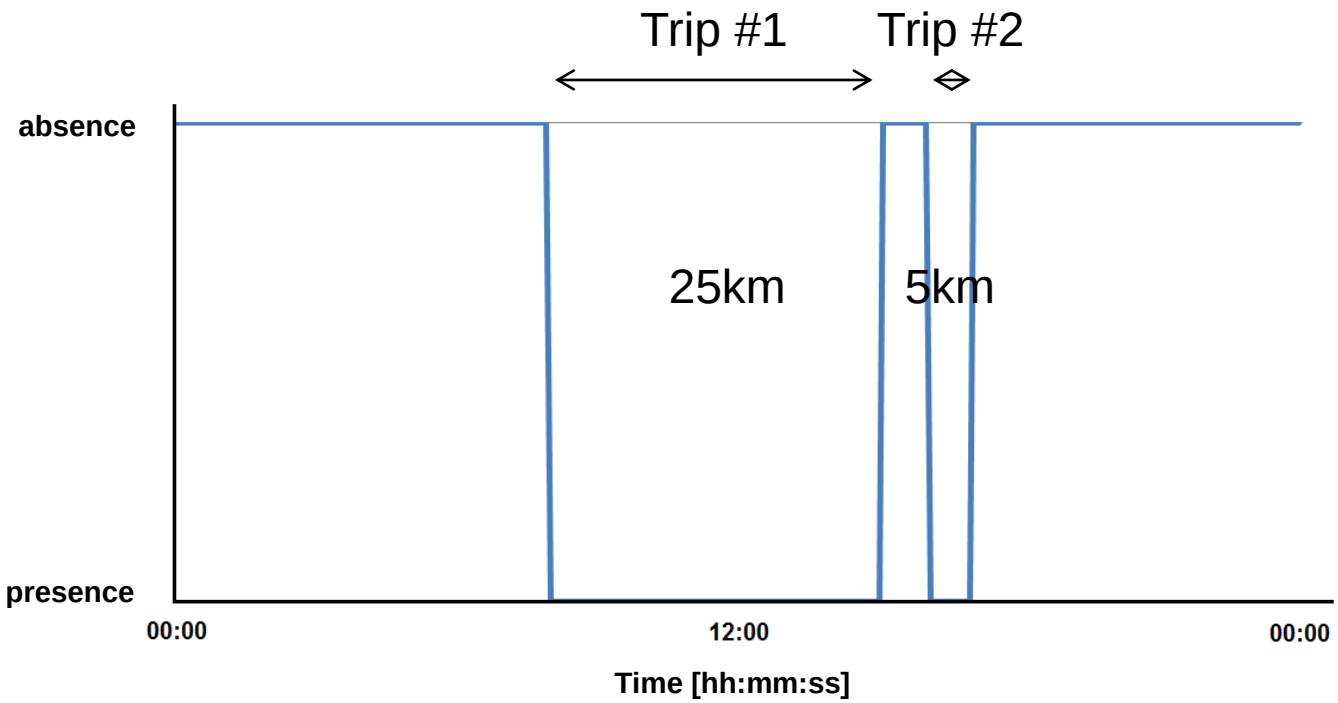
Distribution of sustainable energy – bidirectional EV

Input: mobility profile



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Distribution of sustainable energy – bidirectional EV

Input: parameter of components

- ✓ Battery size EV
- ✓ Charging power EV
- ✓ Discharging power EV
- ✓ Performance ratio PV-modules
- ✓ Efficiency PV-modules
- ✓ …

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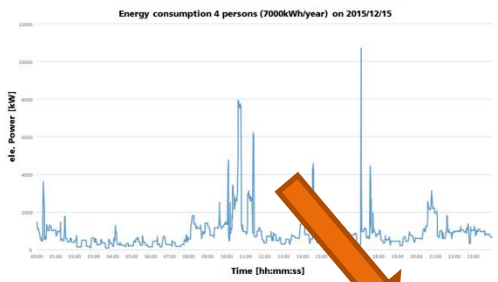
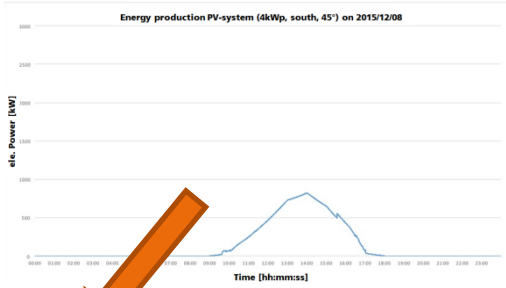
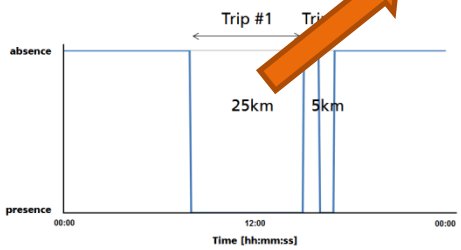
Distribution of sustainable energy – bidirectional EV

calculation: energy flow







- ✓ Battery s EV
- ✓ Charging power EV
- ✓ Discharging power EV
- ✓ Performance ration PV-modules
- ✓ Efficiency PV-modules
- ✓ …

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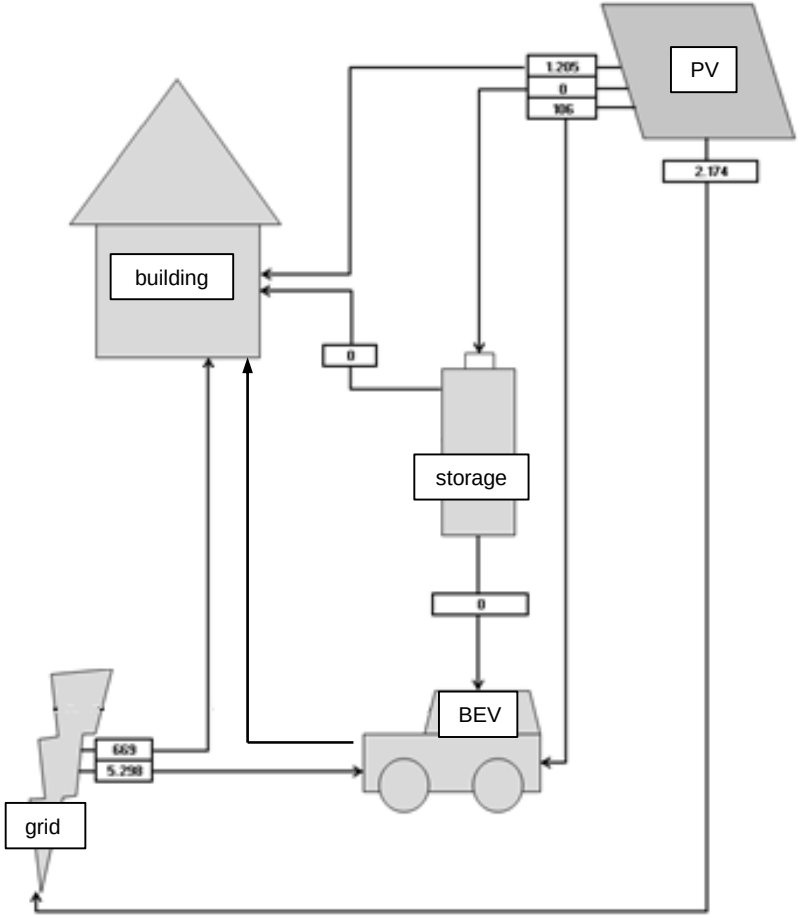
Distribution of sustainable energy – bidirectional EV

Output: energy flow



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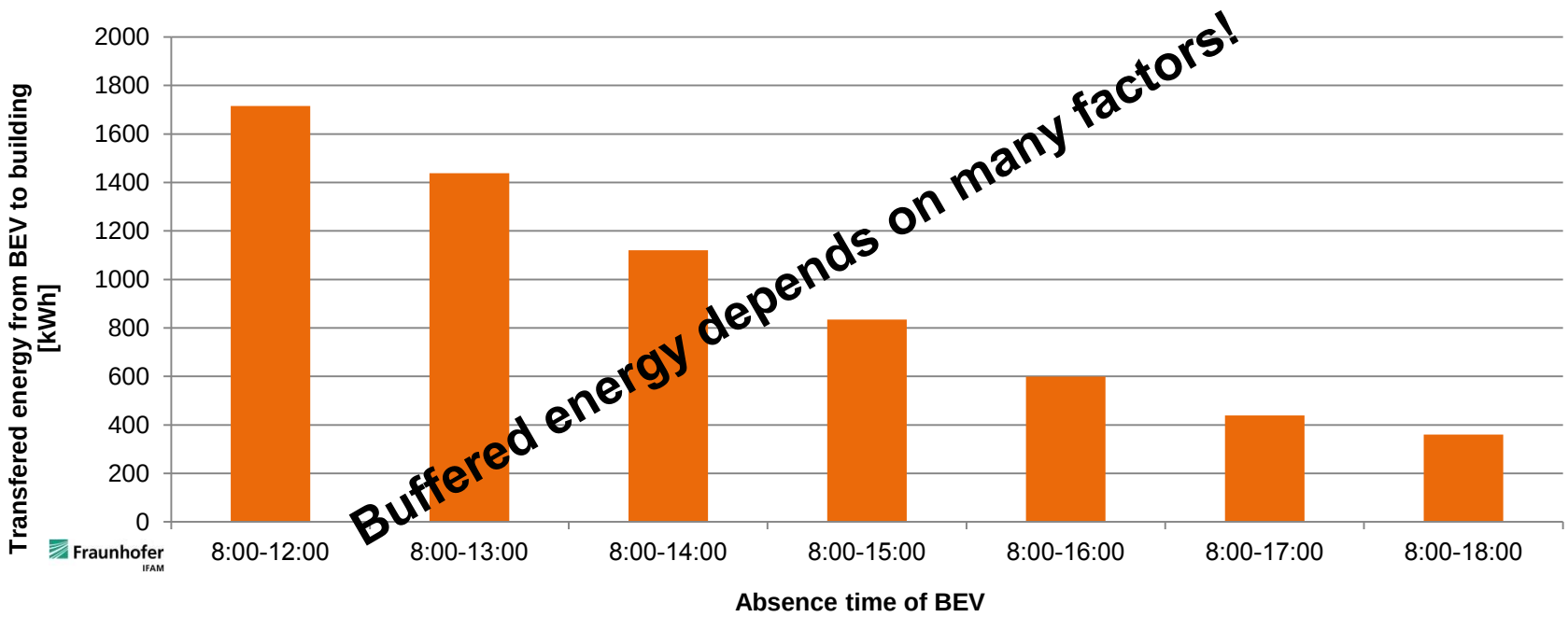
Distribution of sustainable energy – bidirectional EV

Output: energy flow (example for building with 4 person, bidirectional EV, PV-system)



Capacity BEV-batterie	36 kWh	Trip length on weekend	25 km/day
BEV-absence on weekend	10 - 14 Uhr	Photovoltaic-System	5 kWp
Trip length within week	25 km/day	consumption household	7.000 kWh/a

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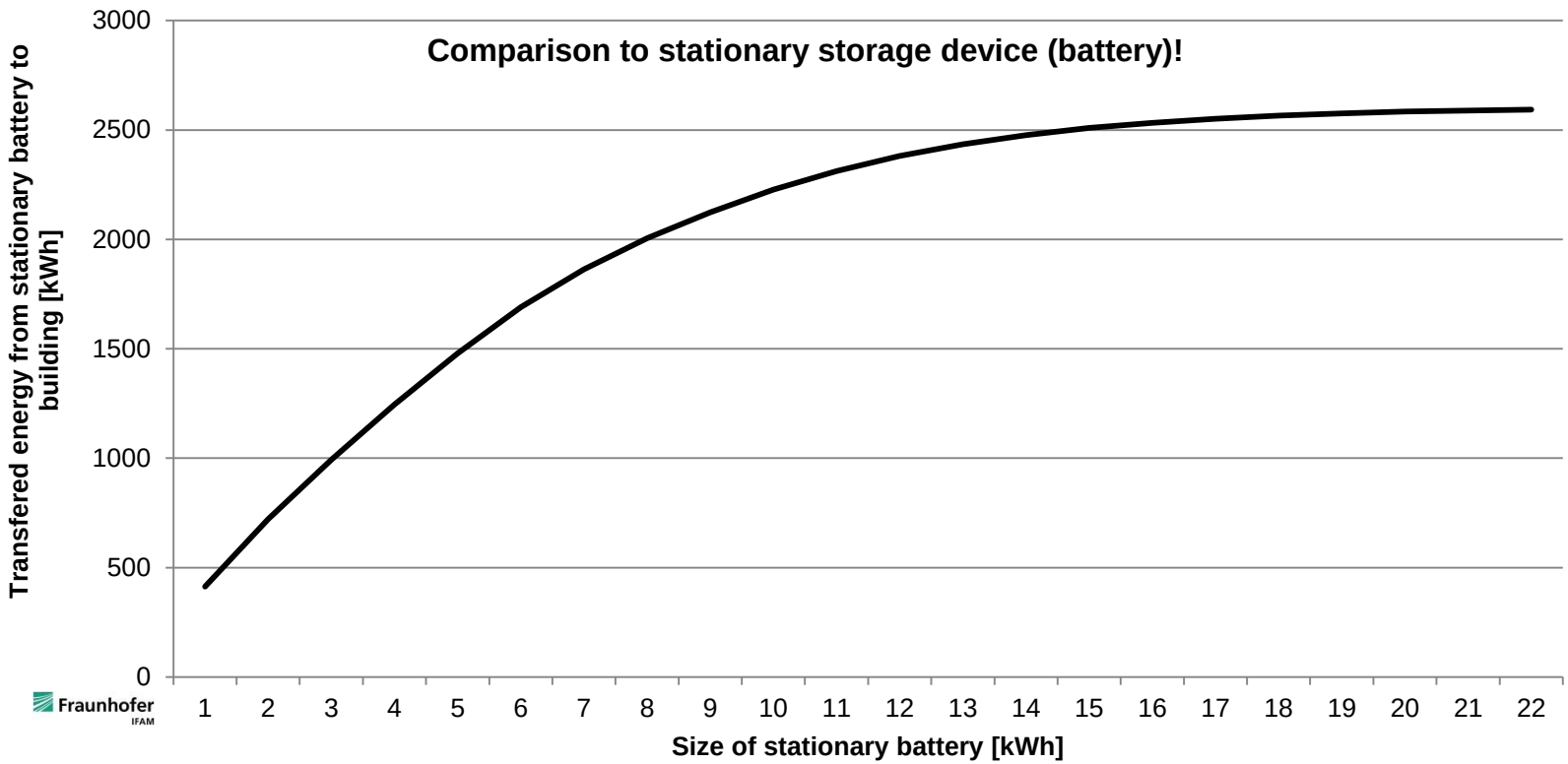
Distribution of sustainable energy – bidirectional EV

Output: energy flow (example for building with 4 person, conventionel vehicle, PV-system)



Photovoltaic-System	5 kWp
consumption household	7.000 kWh/a
Charging/discharging rate	1C

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Distribution of sustainable energy – bidirectional EV

Output: energy flow

	V2H EV	stat. battery
Capacity [kWh]	36	4
Absence within week	8am– 12am	never
Absence on weekend	10am – 2pm	never
Trip length each day [km]	25	0
PV-System [kWp]	5	5
Load of household[kWh]	7000	7000
Buffered energy [kWh]	**1680**	**1250**

Now you can do economical calculations!

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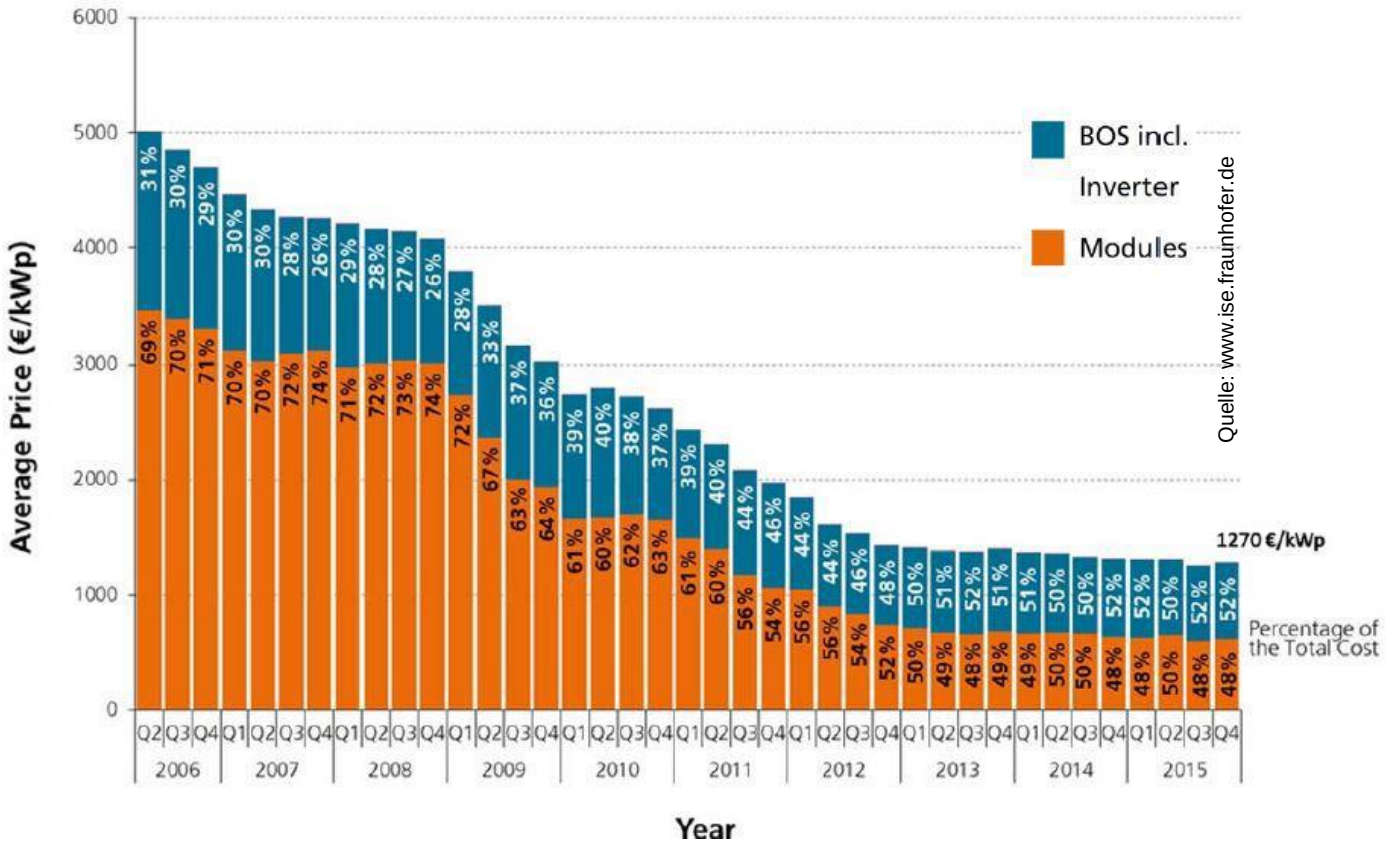
Techno–economical estimation of EV within energy systems

End-user-prices of PV-systems between 10 and 100 kWp (**orange**: prices modules, **blue**: others, e.g.: cables, hardware, inverter)



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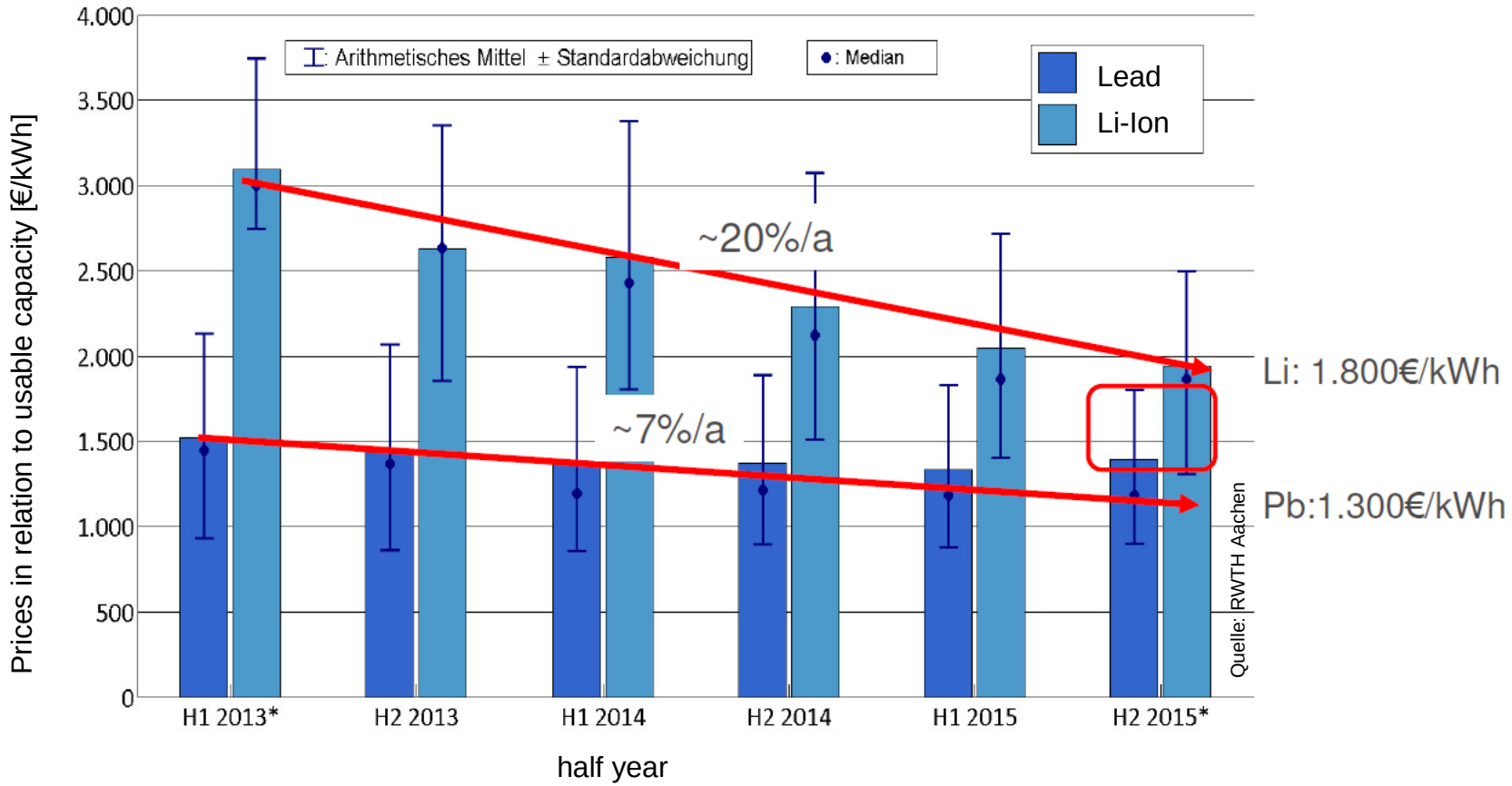
Techno-economical estimation of EV within energy systems

prices for PV-battery systems



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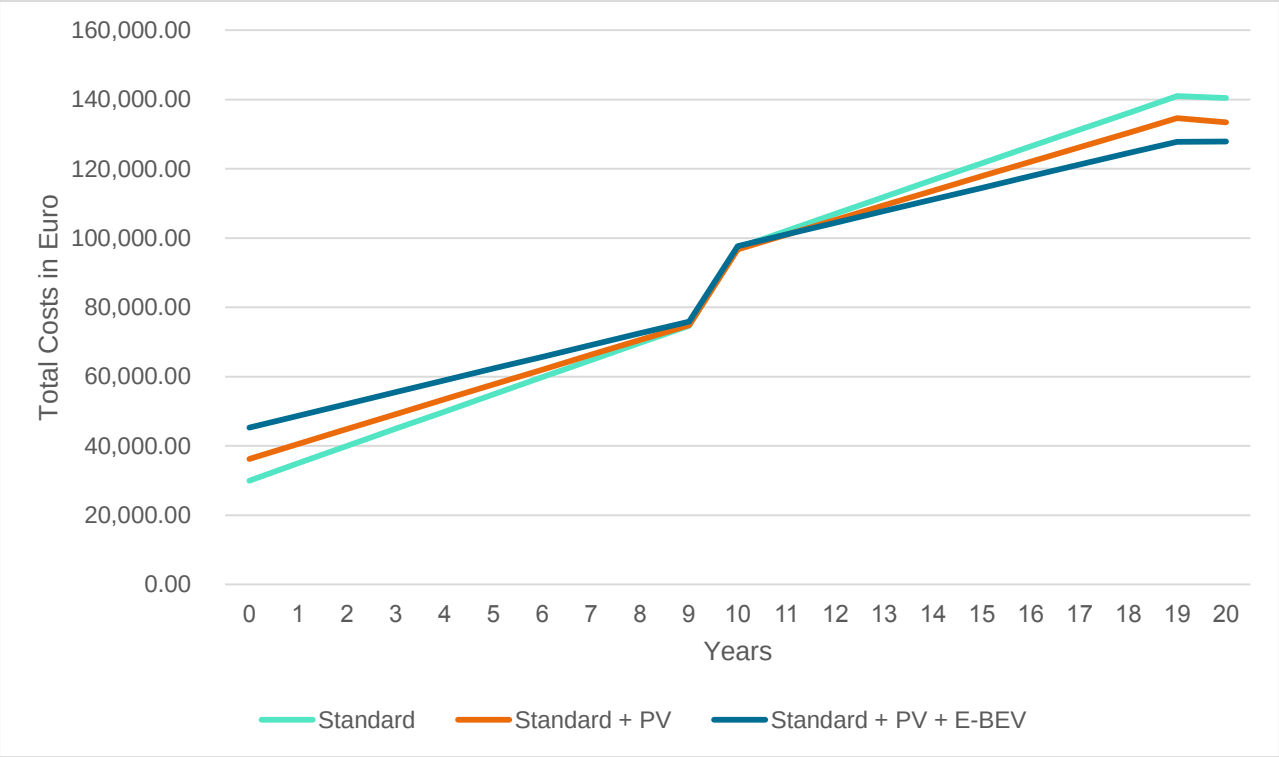
Techno-economical estimation of EV within energy systems

Total costs (invest + running costs) of 4-person household, 140m² building, 15.000km/year within 20 years



Standard: no photovoltaics, combustion driven vehicle, gas heating system

Standard + PV: 5kW photovoltaic (south, 40°), combustion driven vehicle, gas heating system

Standard + PV + E-BEV: 5kW photovoltaic (south, 40°), electric vehicle, gas heating system

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Techno–economical estimation of EV within energy systems

Reducing ROI of BEV by:

- Time-regulated charging => low-cost charging rates
- Grid-regulated charging => low-cost charging rates
- Home-regulated charging => Maximization of self-consumption-rate – Minimization of purchased electricity

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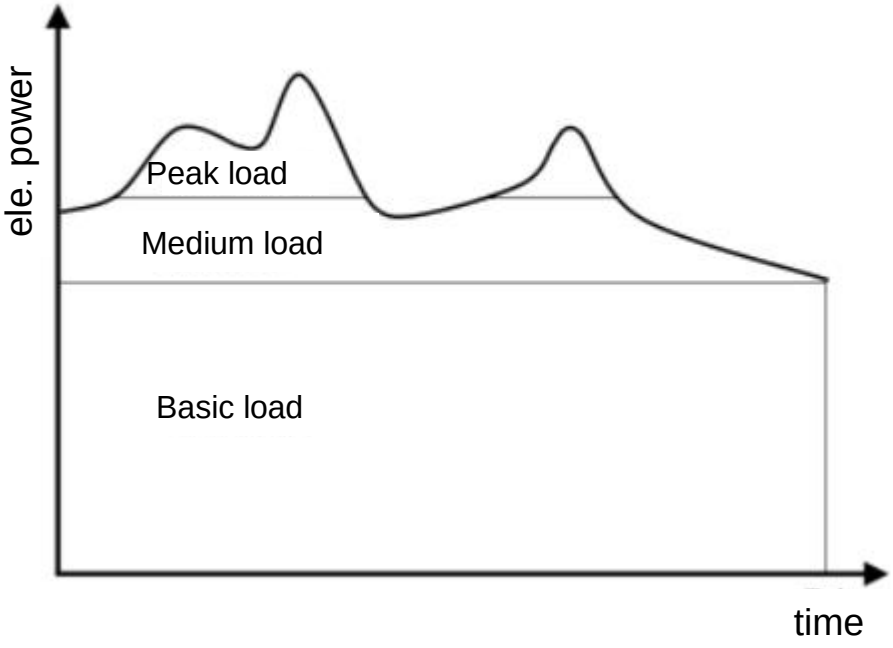
Further applications of EV within energy systems

Participation on grid-market

required electrical power within puplic grid during one day



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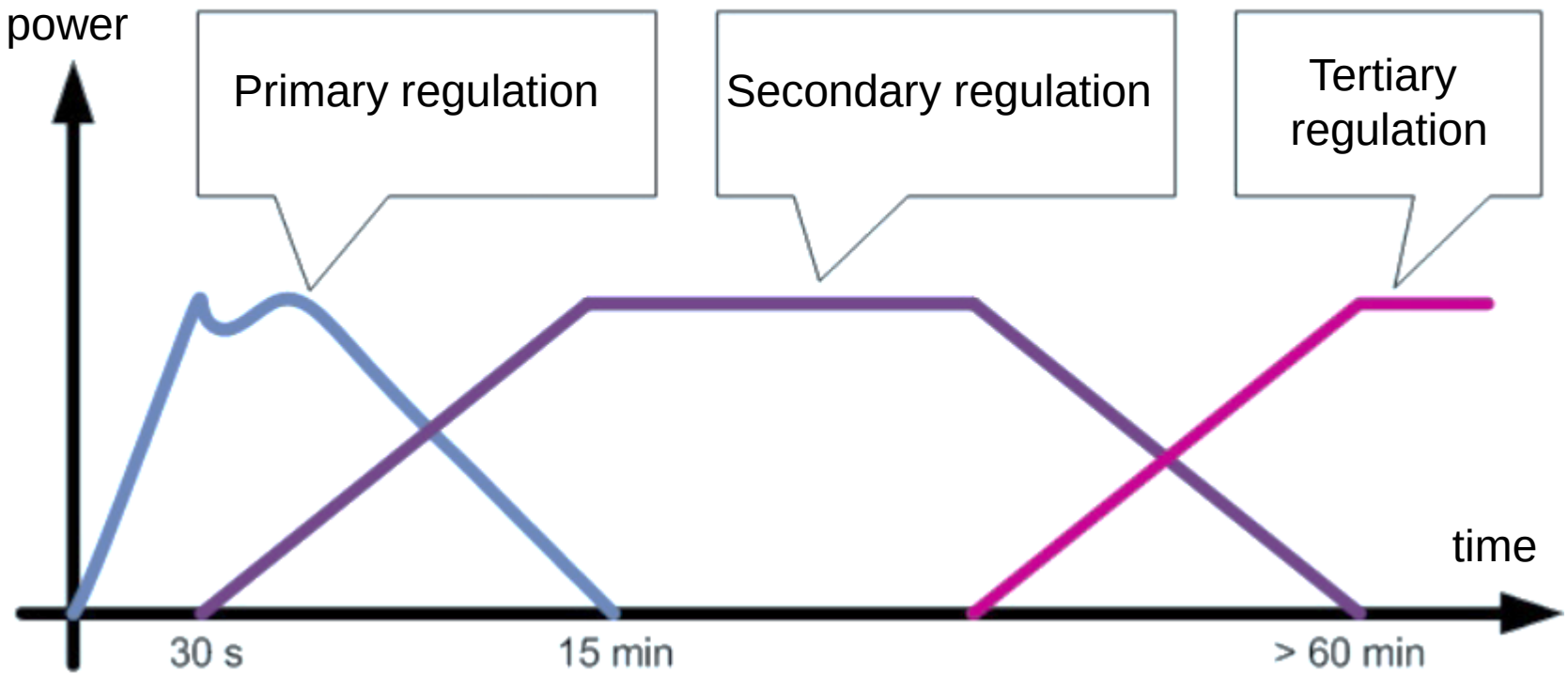
Further applications of EV within energy systems

Participation on grid-market



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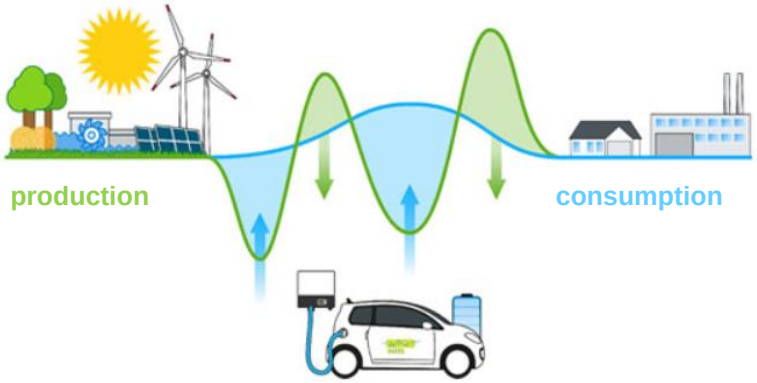
Further applications of EV within energy systems

Participation on grid-market

Primary regulation
Secondary regulation
} perfect match with batteries



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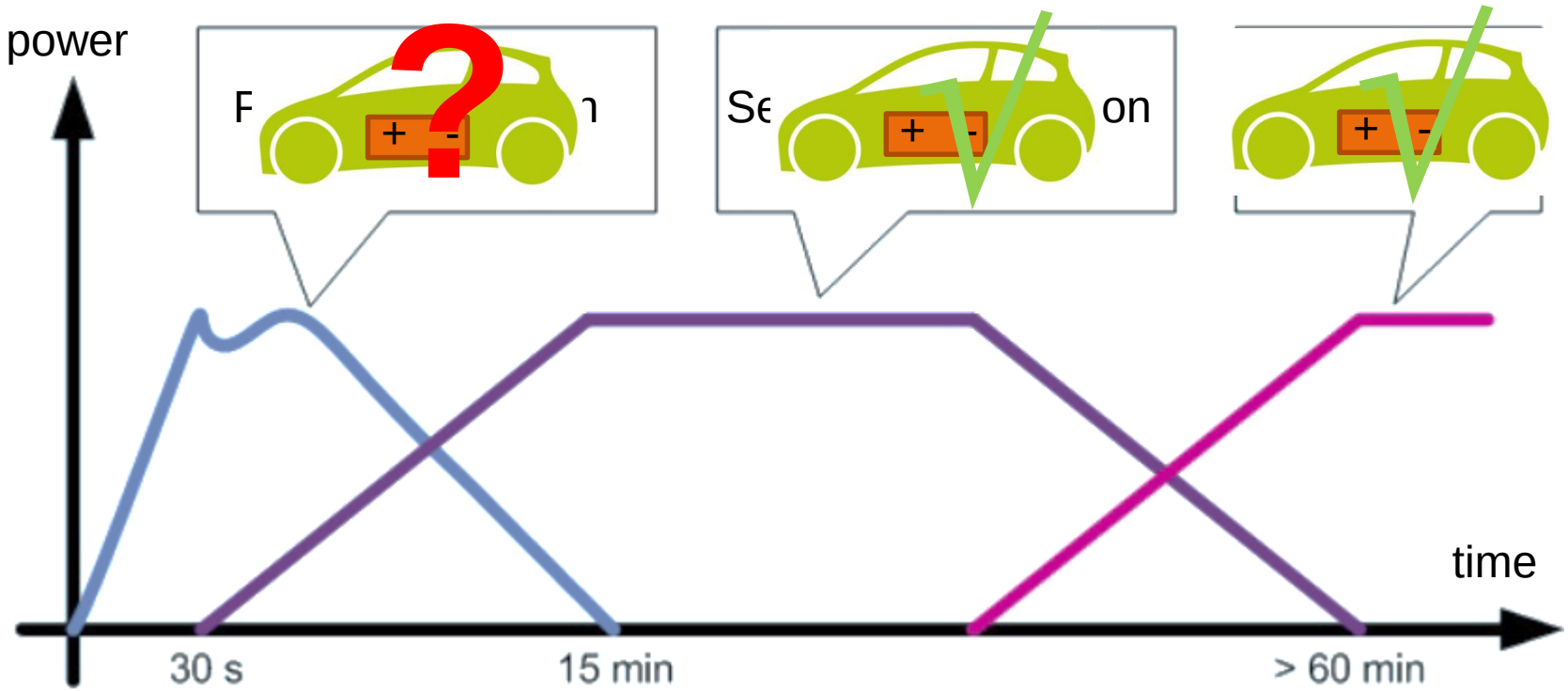
Further applications of EV within energy systems

Participation on grid-market



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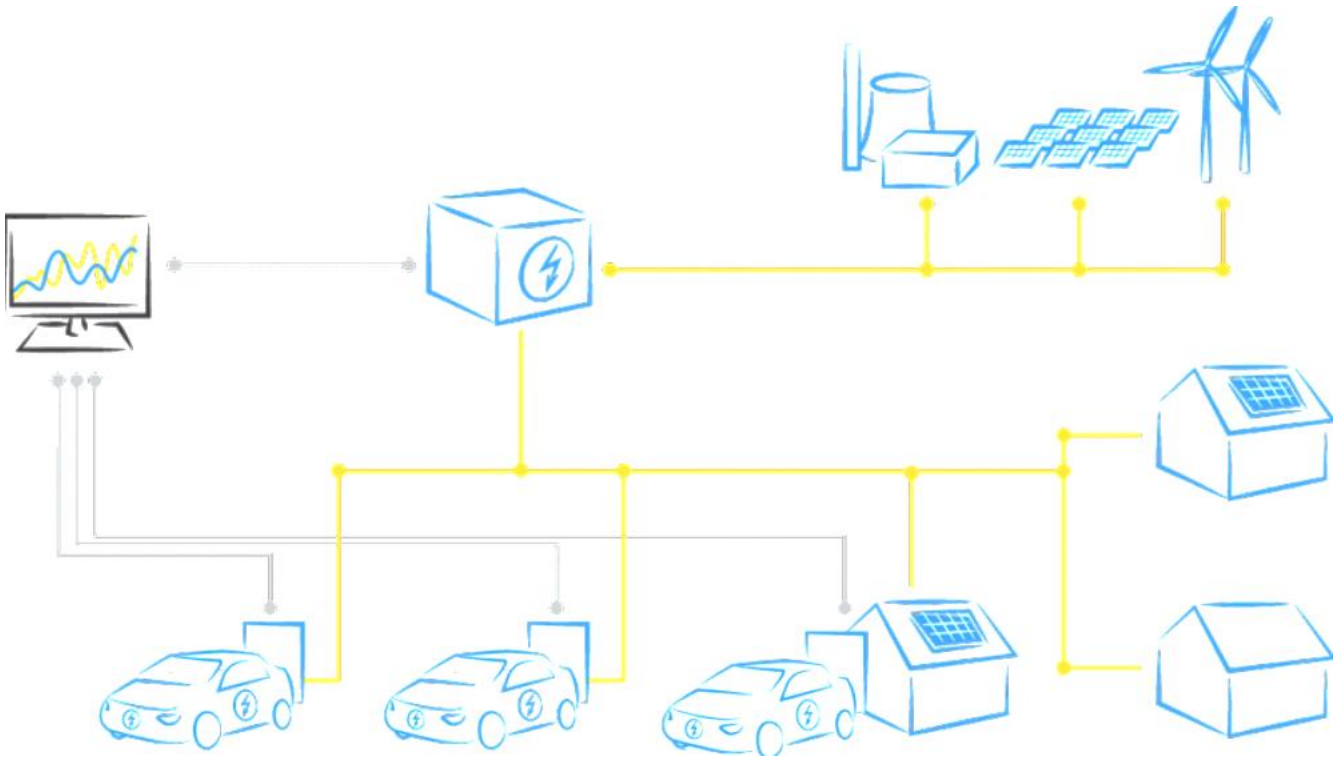
Further applications of EV within energy systems

Participation on grid-market – with V2X- and Standard-EV possible



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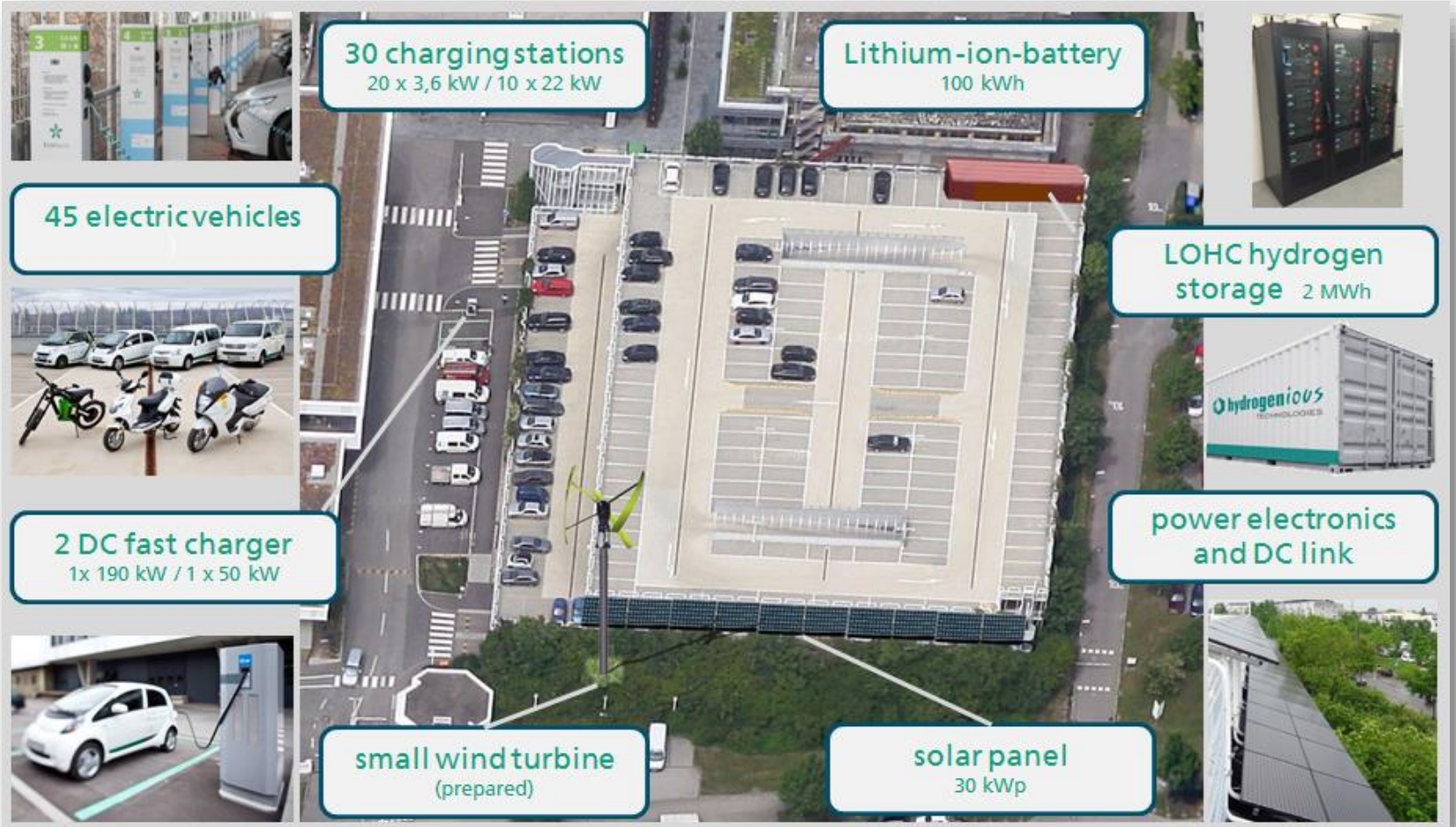
Further applications of EV within energy systems

Participation on grid-market – with V2X- and Standard-EV possible



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Summary

- EVs can be operated ecomomical already today depending on scenario
- The invest for EVs and storage devices will degrease year by year (scale-effect, politics, environmental aspects)
- The integration of EVs into energy systems has advantages:
  - Speeding up ROI
  - Stabilization of public power grid
  - Reduction CO2-emissions

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Thank you for paying attention!

Dr.-Ing. Stefan Lösch

Fraunhofer-Institut für Fertigungstechnik und
Angewandte Materialforschung IFAM

Wiener Straße 12 | 28359 Bremen | Germany
Phone + 49 421 2246-202

loesch@ifam.fraunhofer.de
www.ifam.fraunhofer.de

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