# InitiativE-BW – Real-world driving, energy demand, user experiences and emissions of EV-fleets

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**H. Dittus**, U. Kugler, D. Özdemir, M. Schmitt

German Aerospace Center, Institute of Vehicle Concepts

# Background: The Project InitiativE-BW

## *Elektrische Flottenfahrzeuge für Baden-Württemberg*

InitiativE-BW

<u>InitiativE-BW</u>

- investigates real life operation of electrified vehicles
- project duration: 01/2014 to 12/2016
- project goal: up to 500 electrified vehicles on road in BW
- vehicles are equipped with data loggers
- user experiences are assessed with structured surveys

<u>Status</u>

- 358 contracts signed, 114 in negotiation (by 08/2016)
- more than 90% battery electric vehicles (BEV)
- 88% of vehicles are in commercial applications
- 64 vehicles are equipped with data loggers

Gefördert durch:

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit

Aufgrund eines Beschlusses des Deutschen Bundestages

Förderprogramm:

Erneuerbar mobil

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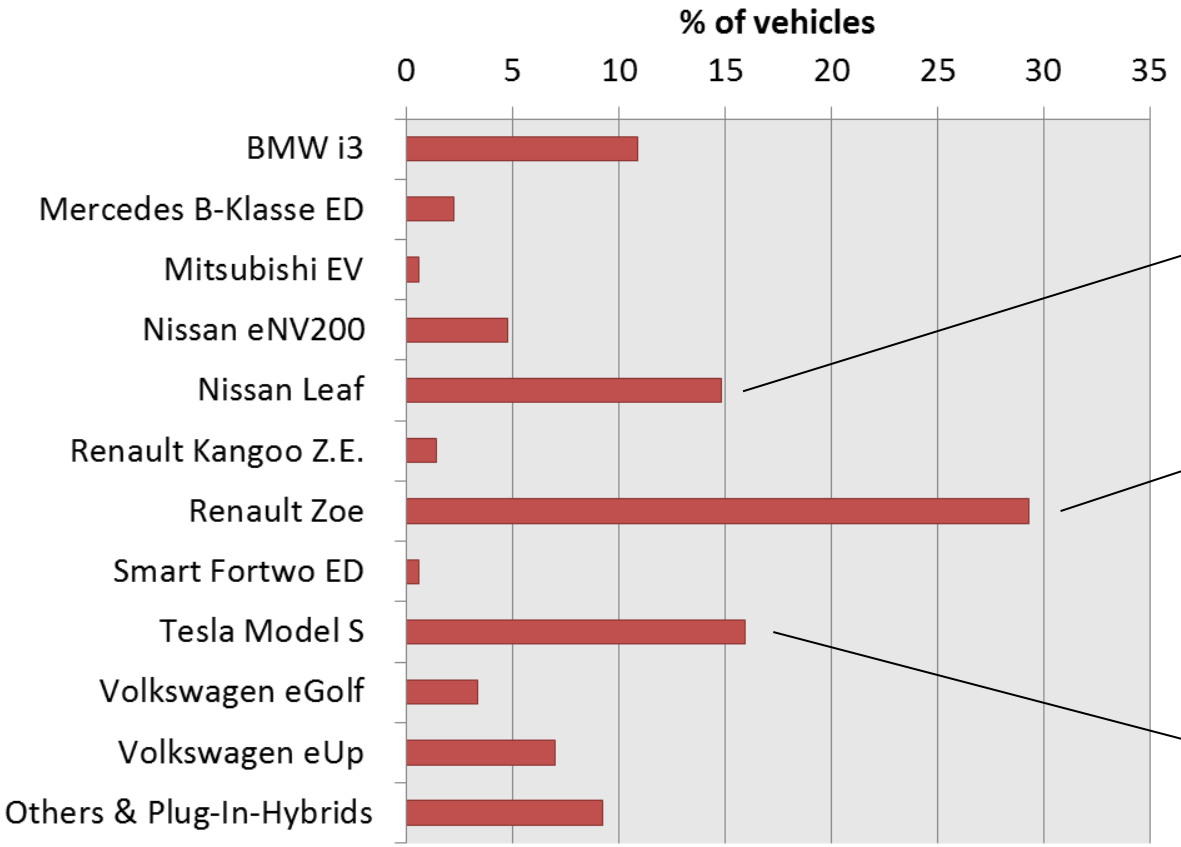
# Background: The Project InitiativE-BW

## Distribution of vehicle types




15%

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# Background and Objectives of this study

InitiativE-BW

## Background

- EU Regulation limits tank-to-wheel emissions to 95 g $CO_2$/km by 2021
- No tank-to-wheel $CO_2$ emissions from battery electric vehicles (BEV), but during generation and distribution of electric energy
- Energy costs are important for the total costs of ownership of BEV

## Objectives

- Analyse specific use case for a BEV charged by power from electricity grid and local photovoltaic (PV) system
- Consider temporally resolved data of German electricity production mix combined with the BEV use case to derive 2015 $CO_2$ emissions
- Determine economic and ecologic impact of PV power usage in 2015:
  - reduction of specific emissions in g $CO_2$/km
  - energy cost reduction

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# Data sources for the study

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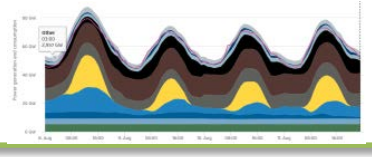
## Data logger of local PV System
Average power, 15-min intervalls

## BEV data logger
Charging events, secondly

## Agorameter Database, German Electricity Production Mix
Average power per source with hourly resolution



## Icha and Kuhs (UBA)
Emission factors by source, yearly

$CO_2$

## BDEW e.V.
Price of electricity, per year

€

## Ecoinvent Database
Emissions of vehicle manufacturing

$CO_2$

## Bundesnetzagentur
Earnings for PV electricity fed to grid

€

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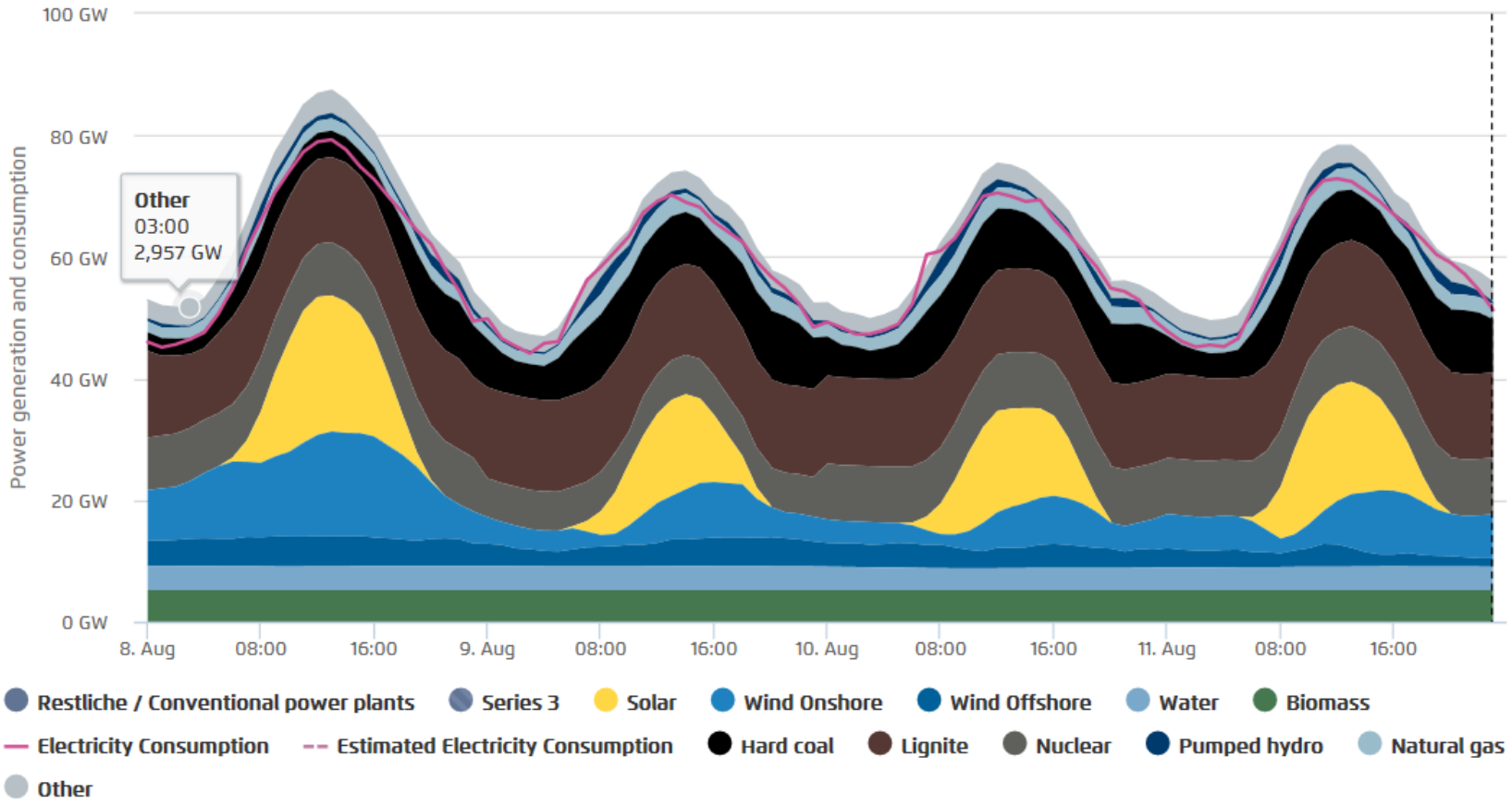
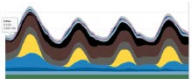
# Agorameter Database

## German electricity production with hourly resolution




Agora Energiewende; Current to: 11.09.2016, 20:45

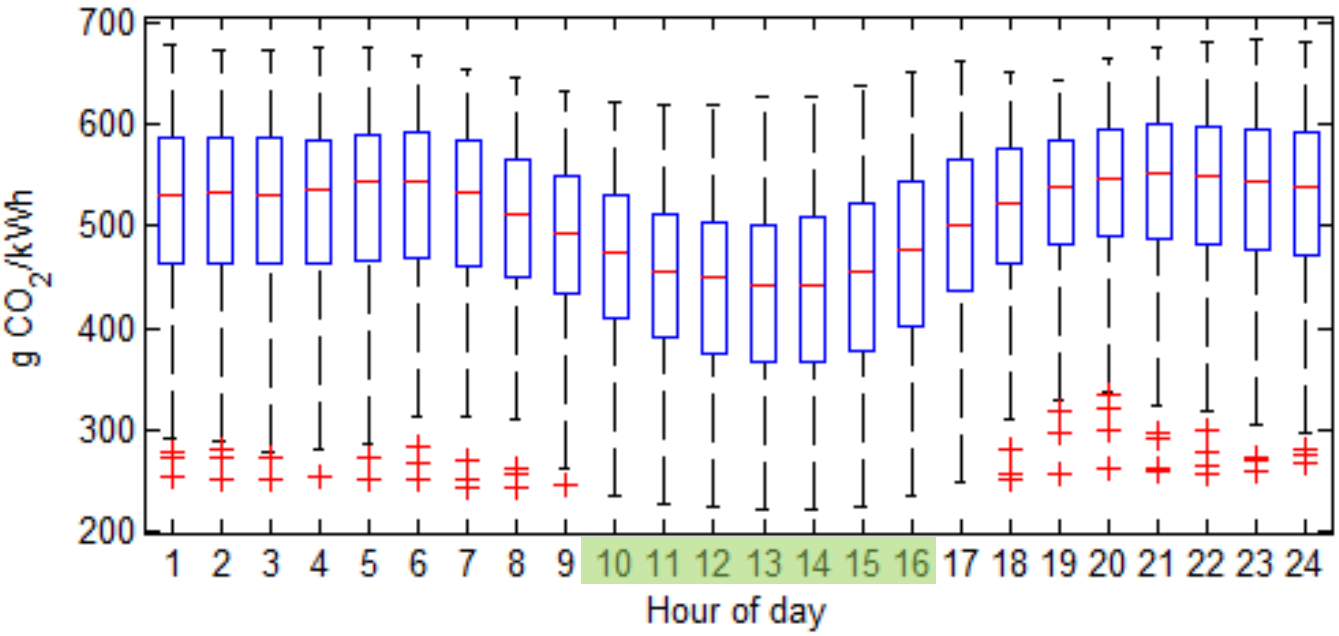


$CO_2$

# German electricity production mix

## Specific $CO_2$ emission statistics for 2015

| Electricity source | g $CO_2$/kWh |
|---|---|
| Lignite | 1,136 |
| Hard Coal | 888 |
| Natural Gas | 370 |
| Others[1] | 1,057 |
| Biomass, Hydro, Wind, PV, Nuclear, Pump | 0 |



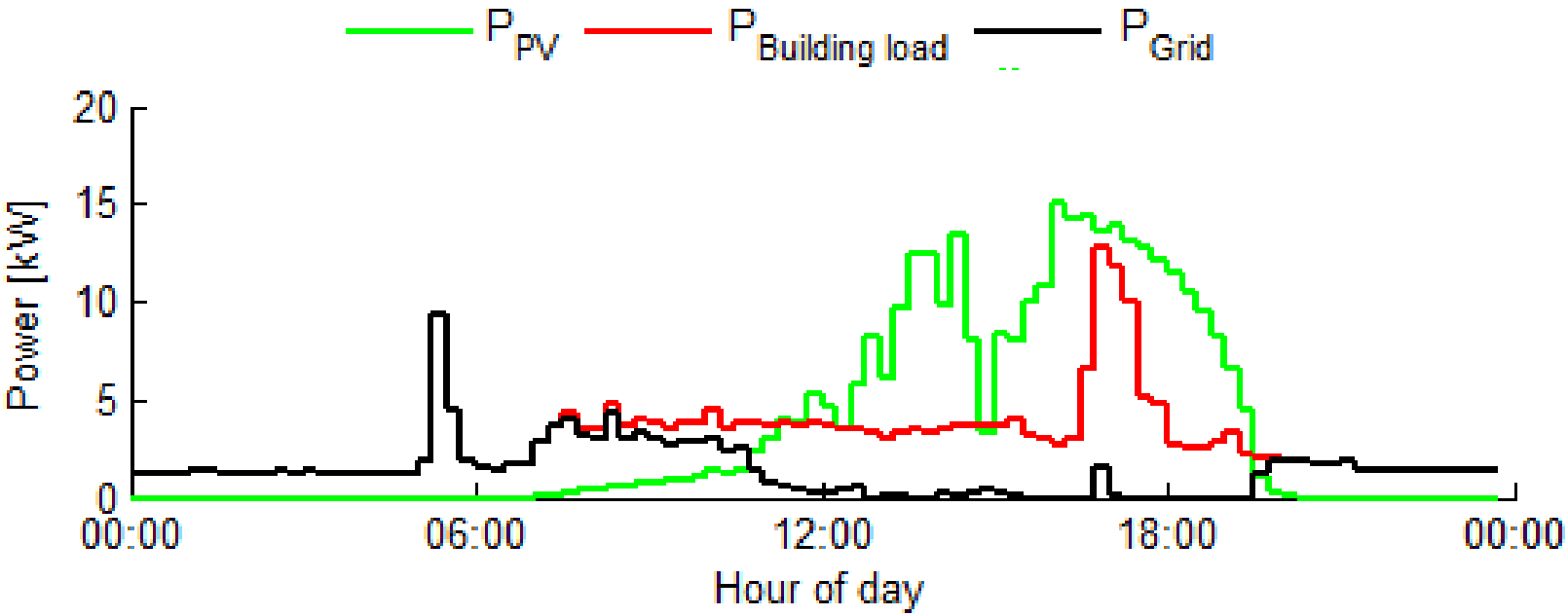

*Source: Icha and Kuhs (2016)*

➔ **On average $CO_2$ emissions are lower during daytime**

[1] Others: Mineral oil plants, waste incineration plants and unspecified sources

# Local PV system

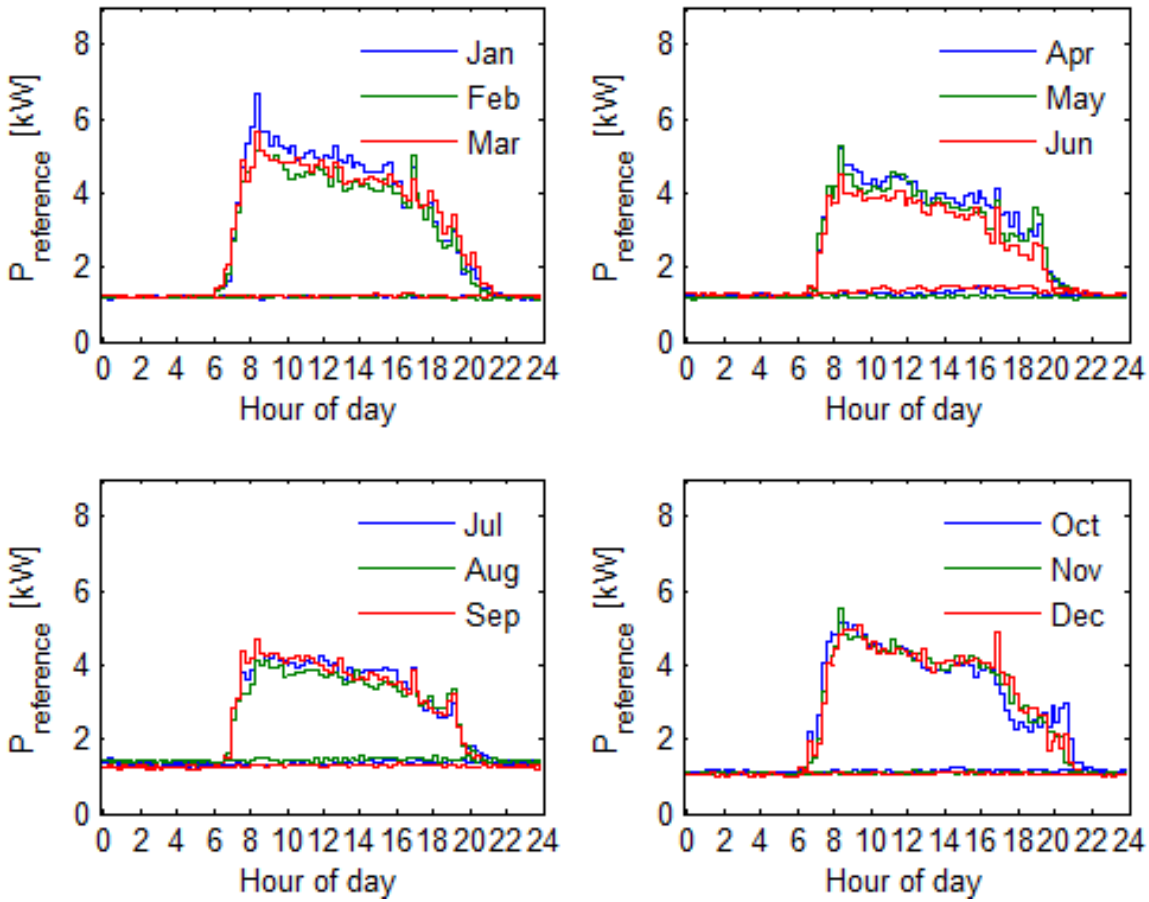
## 15-min average power of PV, building load and grid




➔ Building load includes BEV charging events. But how to identify them?

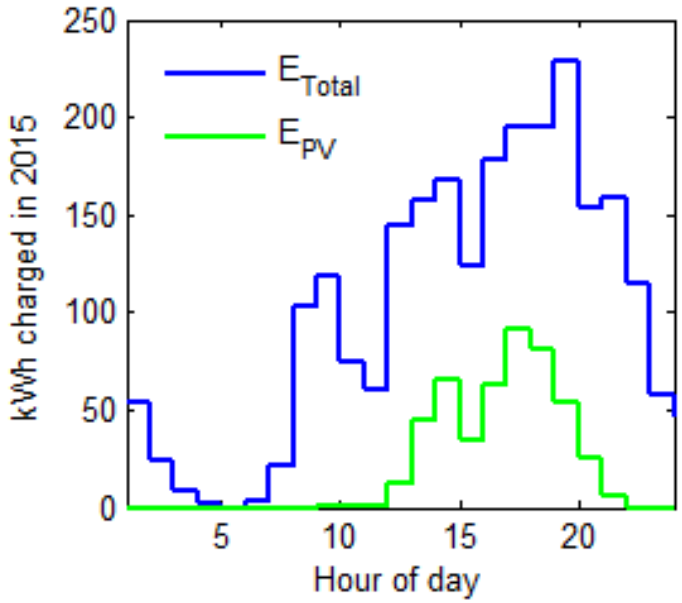
# Local PV system

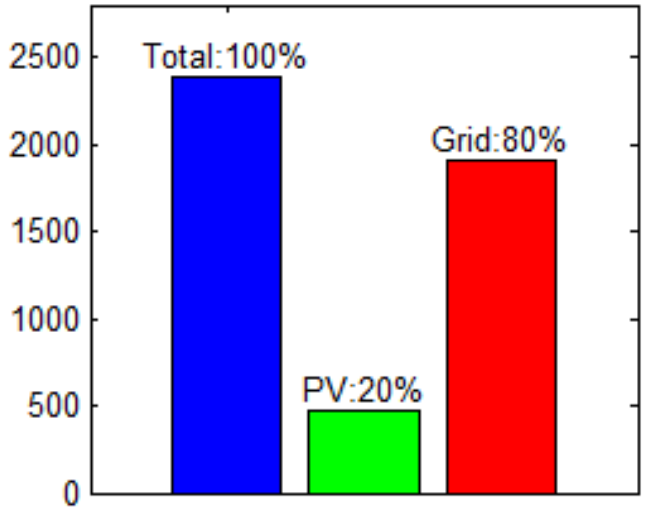
## Building base load – reference curves per month




# Local PV system

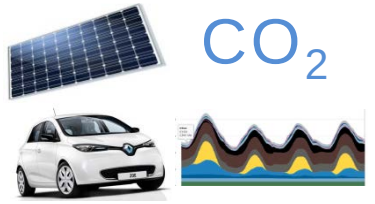
## Charging energy and PV share in 2015




→ Suitable charging behaviour needed for a notable PV share

➔ **In 2015 the PV system covered 20% of BEV energy demand**




# Impact of PV system on $CO_2$ emissions

## Comparison of reference and BEV use case

| | kg $CO_2$ | Yearly average g $CO_2$/kWh |
|---|---|---|
| **Reference case without PV** | | |
| $CO_2$ emissions from grid charging | 1,235.8 | 517.5 |
| **BEV use case with PV** | | |
| $CO_2$ emissions from grid charging | 1,010.2 | 528.8 |
| Avoided $CO_2$ emissions by PV charging | 225.6 | 472.4 |
| Overall $CO_2$ emissions in use case | 1,010.2 | 423.0 |
| **Use case $CO_2$ reduction** | **18.3 %** | |

→ PV provides 20% of charging energy, but $CO_2$ reduction only 18.3%

→ PV substitutes “clean” grid energy

➔ **mileage based emissions due to electricity production 96 g $CO_2$/km**

$CO_2$

# Ecoinvent Database

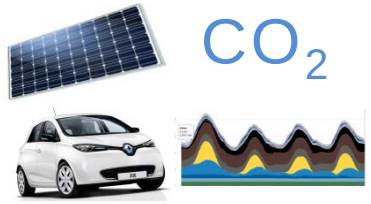
## $CO_2$ emissions related to BEV manufacturing

| | Unit | $CO_2$ |
|---|---|---|
| **Vehicle data: lifetime 12 years, 175,000 km** | | |
| Vehicle mass without battery | kg | 1213 |
| Battery mass | kg | 435 |
| **Emission factors** | | |
| Ecoinvent BEV without Battery | kg/kg vehicle | 7.00 |
| Ecoinvent Battery | kg/kg battery | 5.41 |
| **Results: $CO_2$ emissions related to BEV manufacturing** | | |
| BEV without battery | kg | 8,491 |
| Battery | kg | 2,353 |
| **Total manufacturing emissions** | kg | 10,844 |

*Source: ecoinvent Center (2016)*

➔ **mileage based emissions due to manufacturing 62 g $CO_2$/km**

[1] Original battery mass 290 kg, multiplied by 1.5 to account for replacement after 8 years




# BEV CO2 emissions - summary

## 2015 BEV use case with PV system

The mileage based $CO_2$ emissions
of that respective BEV in 2015 amount to

**158 g $CO_2$/km**

including vehicle manufacturing, electricity production and
emission benefits from PV system usage

Emissions without PV system: 179 g CO2/km ➔ 12% savings

# Business case 2015

## Impact of PV system on BEV energy cost in Germany

BEV use case

| First operation of PV system: | | 2012-07 | 2013-07 | 2014-07 | 2016-07 |
|---|---|---|---|---|---|
| Earnings for PV energy fed to grid excl. VAT | Ct/kWh | 17.95 | 14.30 | 12.22 | 11.97 |
| Electricity price in 2015 | Ct/kWh | 24.10 | | | |
| Cost for EV charging with PV-system | Ct/kWh | 22.87 | 22.14 | 21.72 | 21.67 |
| **Energy cost reduction** | **%** | **5.10** | **8.13** | **9.86** | **10.06** |

*Sources: BDEW (2016), Bundesnetzagentur (2016)*

→ Significant impact of PV charging on energy costs in BEV use case

→ Impact of PV on energy costs increases with rising electricity prices

➔ **Recently built PV systems have a higher impact on BEV energy costs**

# Main Conclusions and Outlook

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## Use Case 2015

- PV system provided 20% of BEV charging energy:
  - 18% of $CO_2$ emission reduction
  - 9.9% energy cost reduction

## Local PV system & BEV in Germany

- Impact of PV on BEV energy costs increases with rising electricity costs
- Recently built PV systems have a higher cost reduction potential

## Outlook

- Analysis of BEV & PV system use case for 2016
- Evaluation of temporally resolved $CO_2$ emissions for further BEVs

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# Contact

German Aerospace Center, DLR e.V.
Institute of Vehicle Concepts
Pfaffenwaldring 38-40
70569 Stuttgart
Holger Dittus
holger.dittus@dlr.de


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