



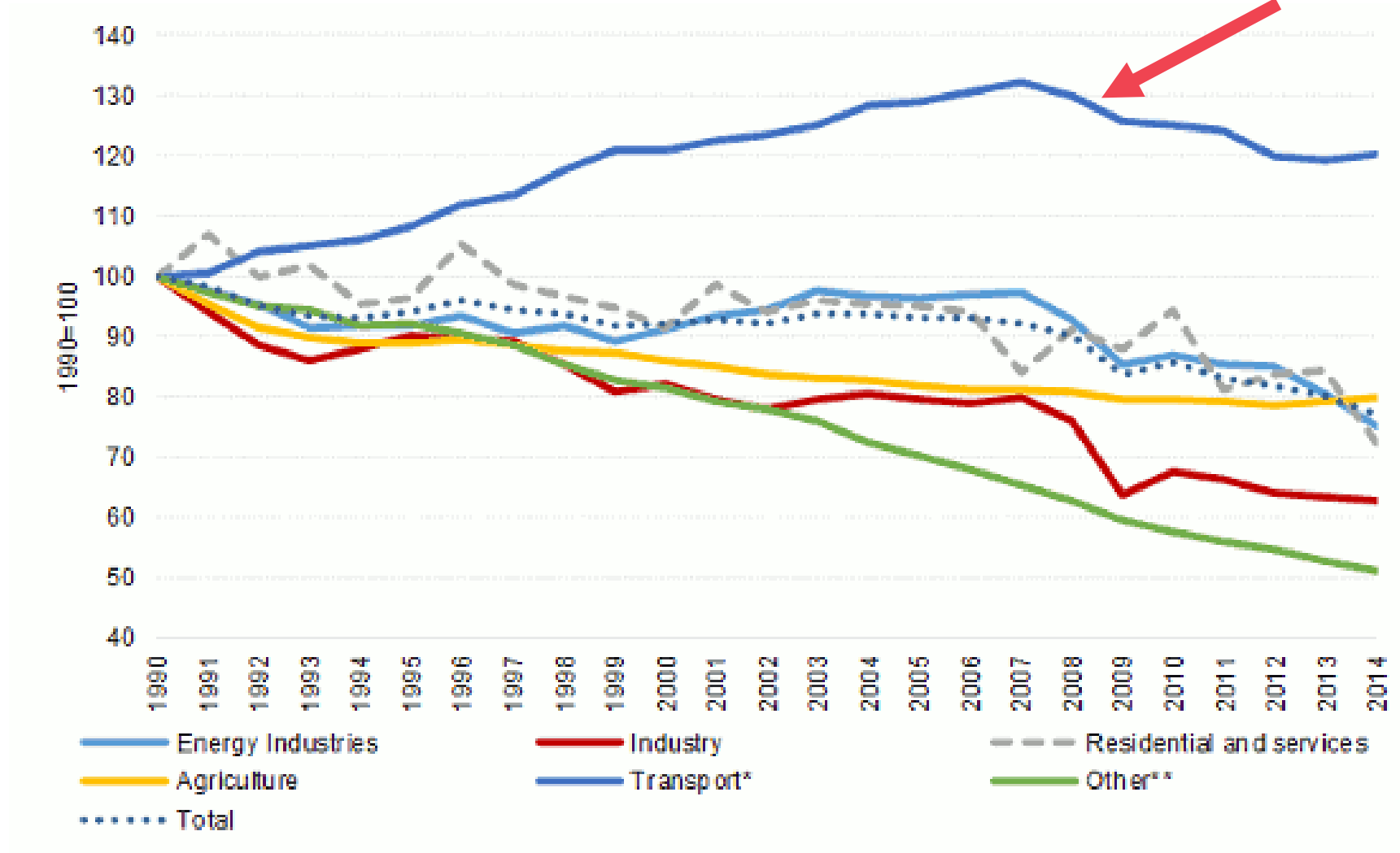
CORRELAID
GOOD CAUSES. BETTER EFFECTS.

Using Mobility Data to Simulate the Impact and Opportunities of Electric Vehicles in the Smart Grid

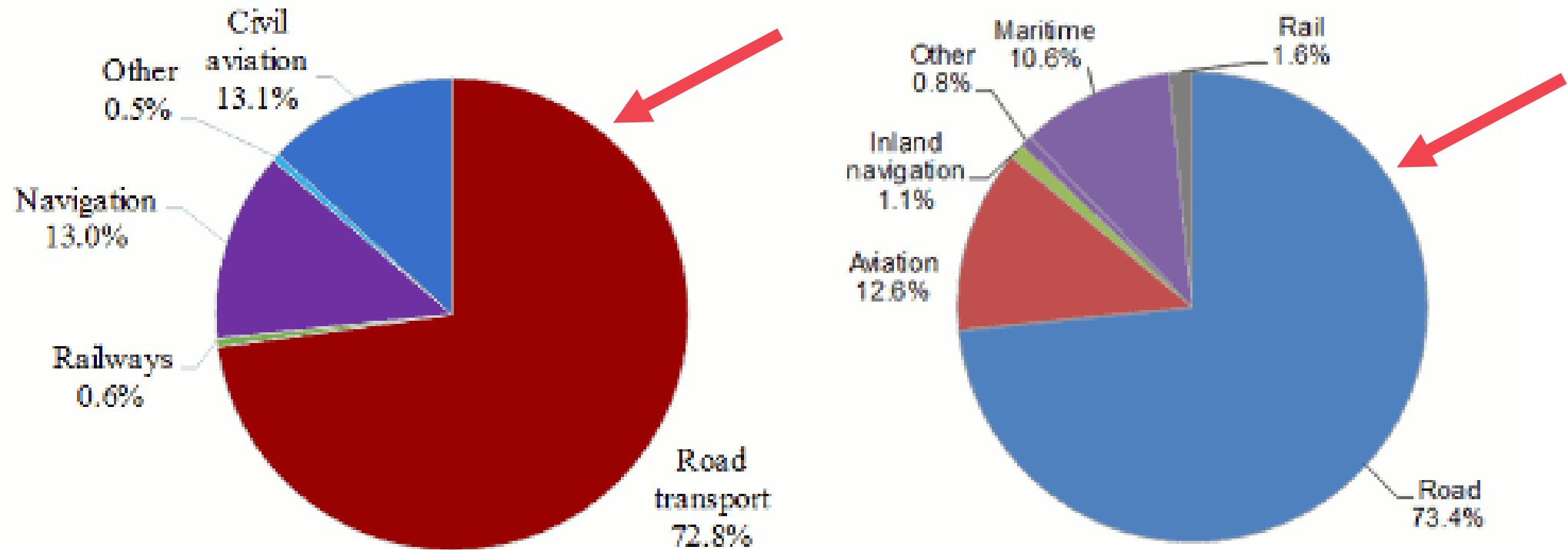
6th Open Online Data Meetup on Mobility Data

M. Sc. Marcus Voß, 2. December 2020

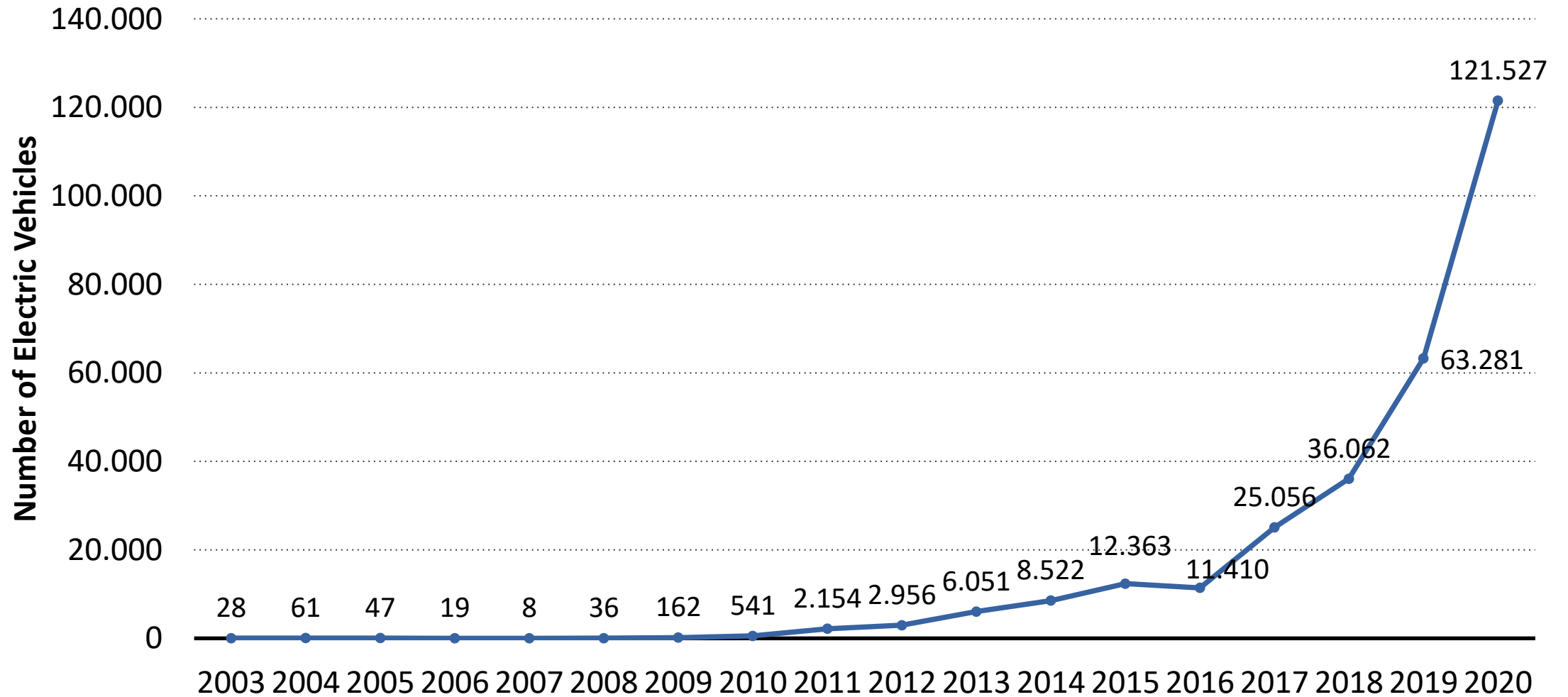
The Impact of the Mobility Sector on Green House Gas Emissions



The Impact of the Mobility Sector on Green House Gas Emissions



Registration of Electric Vehicles (EV) in Germany up to October 2020



Source: KBA. (2020) Anzahl der Neuzulassungen von Elektroautos in Deutschland von 2003 bis Oktober 2020. In *Statista - Das Statistik-Portal*. Zugriff am 25. November 2019, von <https://de.statista.com/statistik/daten/studie/244000/umfrage/neuzulassungen-von-elektroautos-in-deutschland/>.

Ausbau der Elektromobilität

E-Autos bringen Stromnetz ans Limit



Strommasten und Windraeder heben sich wie Scherenschnitte vom farbenpraechtigen Abend

F.A.Z.-INDEX ▲ 2.475,00 +0,02 % DAX [®] ▼ 12.592,35 -0,06 % DOW JONES ▼ 22.349,59 -0,04 % EUR/USD ▲ 1,19

ENERGIEWENDE

Stromnetz kurz vor dem Zusammen

VON ANDREAS MIHM , BERLIN - AKTUALISIERT AM 09.06.2017 - 14:39



electrive.net
Branchendienst für Elektromobilität

- Nachrichten
 - Terminkalender
 - Studienführer
 - Jobmarkt
 - IKT EM III
- Nachrichten
 - Projekte
 - These des Monats
 - Videos
 - Termine

IKT EM III >

01.09.2017

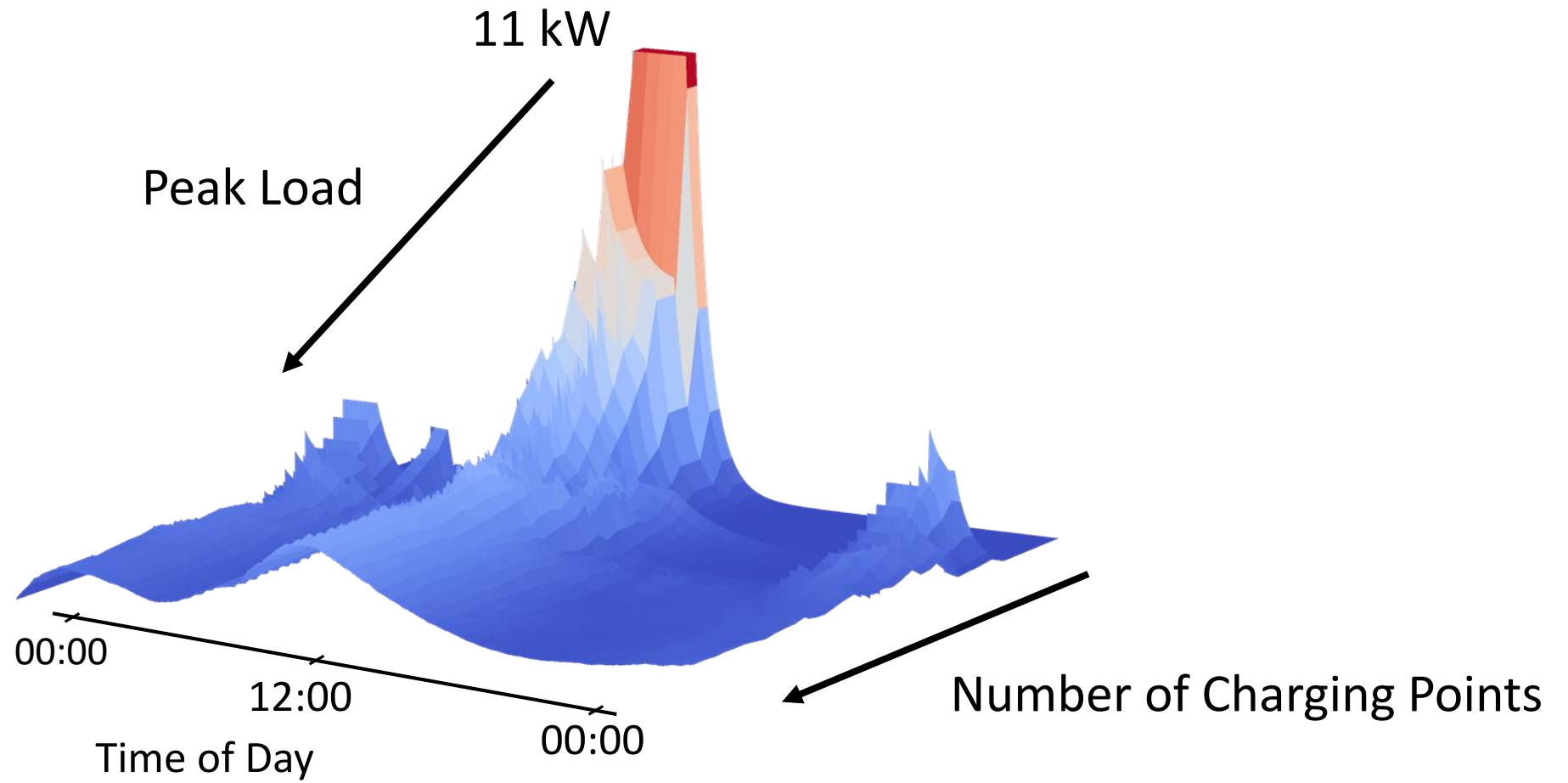
These des Monats: Stromnetz nicht fit für Elektromobilität?!

These des Monats

NEWSLETTER

Abonnieren Sie „electrive.net“ bequem per E-Mail. Unser Newsletter erscheint werktäglich gegen 12 Uhr mittags, kurz, kompakt und kostenlos.

Concept of concurrency for EV charging

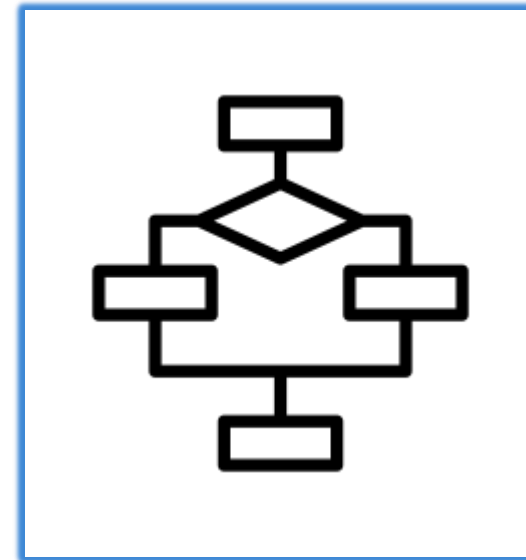


How to approach modelling the grid impact?

Measured Data

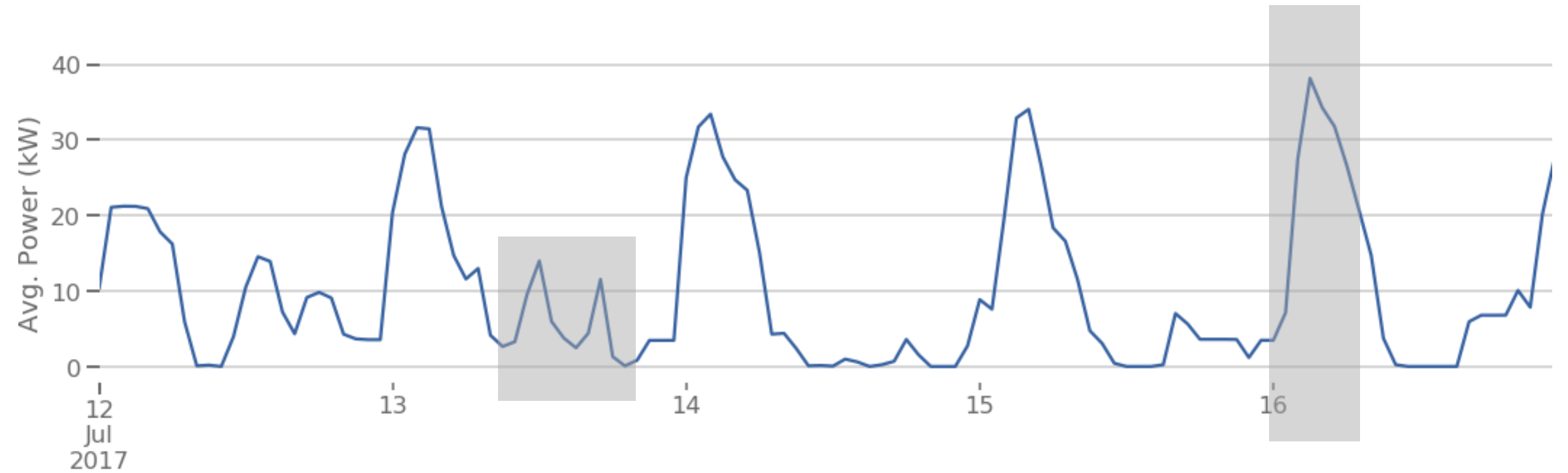


Simulation



Example Measured Data: Charging Stations at EUREF campus in Berlin Schöneberg

Saturday night?



Example Measured Data: Project Neue Berliner Luft

Neue
Berliner
Luft 



DAS PROJEKT



LADEPUNKTE



FAQ



HUBJECT



More info: <https://www.neueberlinerluft.de/>



Gefördert durch:



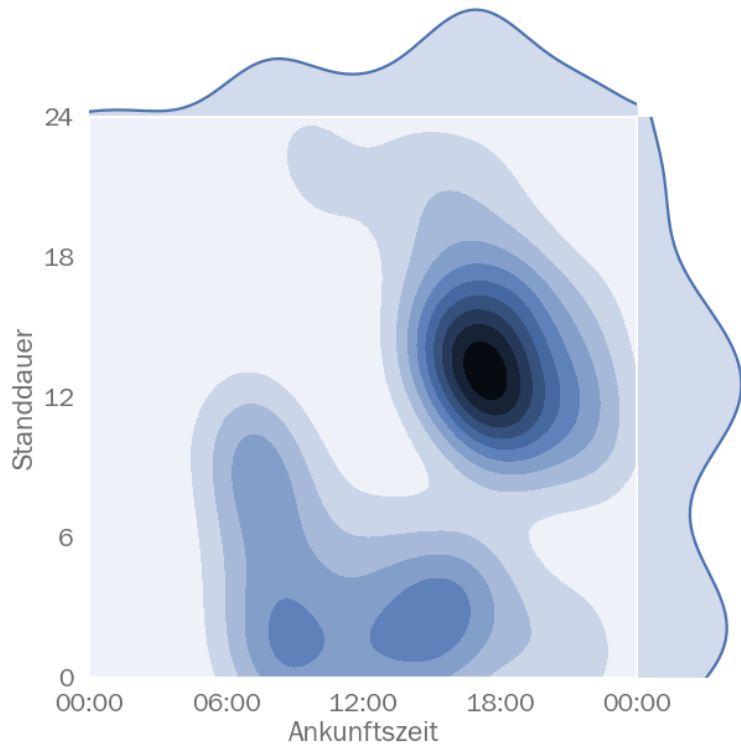
Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
des Deutschen Bundestages

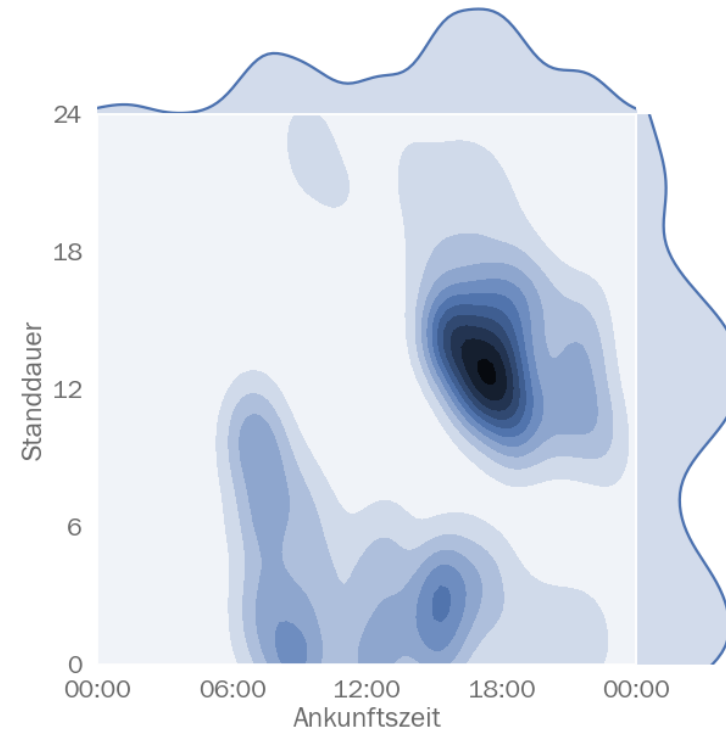


Example Measured Data: Project Neue Berliner Luft

Kernel Density Estimation with Gaussian Kernel to model conditional dependency of arrival time and parking time.



500 measured events



10.000 sampled events

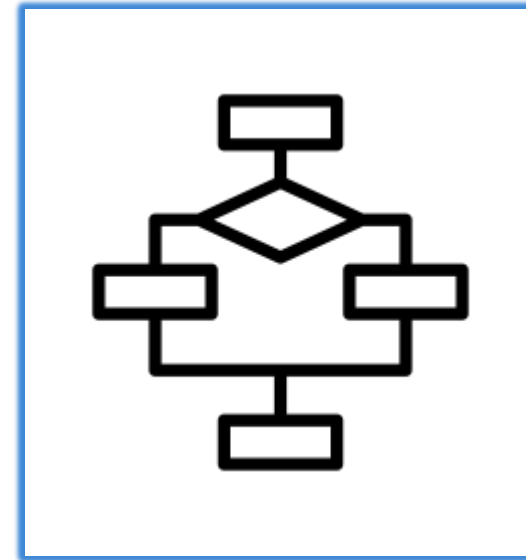


How to approach modelling the grid impact?

Measured Data



Simulation

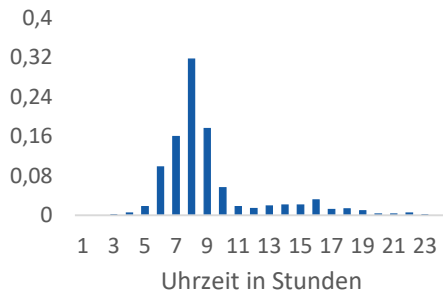


Overview of Simulation Approach

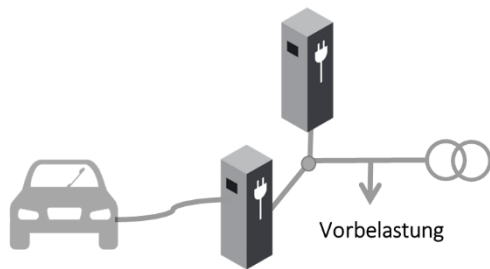
We use a stochastic, „bottom-up“ simulation of EV charging based on mobility scenarios to model expected impacts on the electric power grids and opportunities as distributed storage.

Assumptions

Mobility Behavior



Charging Infrastructure Configuration



Simulation



elvis

electric vehicle
infrastructure
simulator

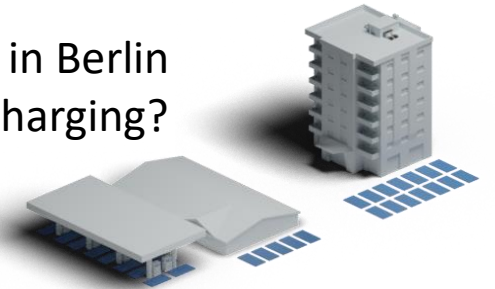


What if everybody in Berlin uses slow vs. fast charging?

How will different coupling points change with EV charging?

How will low-voltage grids cope with EV charging?

How much can EV batteries increase solar energy self-consumption?



A Simple Abstract Pyomo Model

Overview of Simula

We use a stochastic, „bot
on the electric power grid

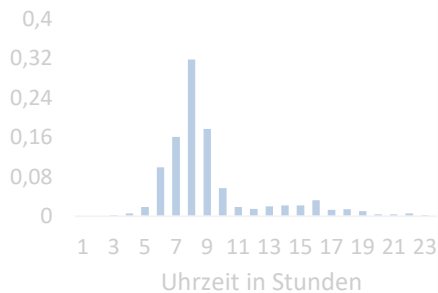
We repeat the abstract model from the previous section:

$$\begin{aligned} \min \quad & \sum_{j=1}^n c_j x_j \\ \text{s.t.} \quad & \sum_{j=1}^n a_{ij} x_j \leq b_i \quad \forall i = 1 \dots m \\ & x_j \geq 0 \quad \forall j = 1 \dots n \end{aligned}$$

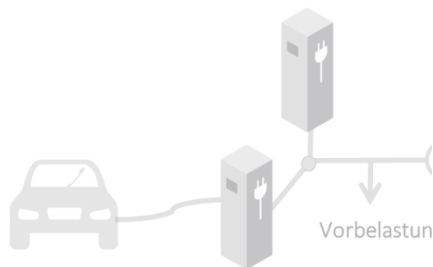
One way to implement this in Pyomo is as shown as follows:

Assumptions

Mobility Behavior



Charging Infrastructure Config



```
from __future__ import division
import pyomo.environ as pyo

model = pyo.AbstractModel()

model.m = pyo.Param(within=pyo.NonNegativeIntegers)
model.n = pyo.Param(within=pyo.NonNegativeIntegers)

model.I = pyo.RangeSet(1, model.m)
model.J = pyo.RangeSet(1, model.n)

model.a = pyo.Param(model.I, model.J)
model.b = pyo.Param(model.I)
model.c = pyo.Param(model.J)

# the next line declares a variable indexed by the set J
model.x = pyo.Var(model.J, domain=pyo.NonNegativeReals)

def obj_expression(m):
    return pyo.summation(m.c, m.x)

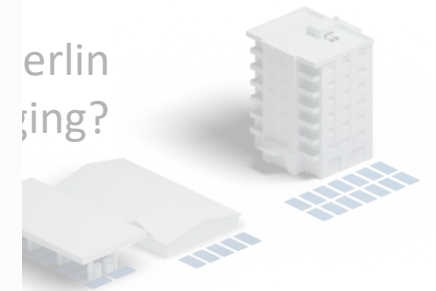
model.OBJ = pyo.Objective(rule=obj_expression)

def ax_constraint_rule(m, i):
    # return the expression for the constraint for i
    return sum(m.a[i,j] * m.x[j] for j in m.J) >= m.b[i]

# the next line creates one constraint for each member of the set model.I
model.AxbConstraint = pyo.Constraint(model.I, rule=ax_constraint_rule)
```

expected impacts

erlin
ing?



rids



ase



A Simple Abstract Pyomo Model

Overview of Simula

We use a stochastic, „bot
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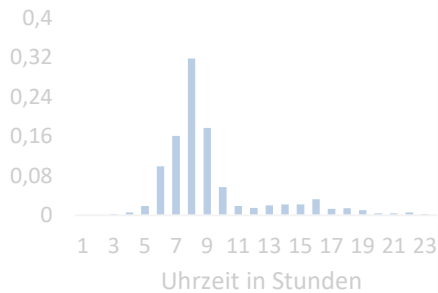
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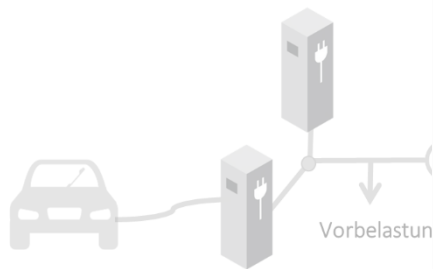
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Assumptions

Mobility Behavior



Charging Infrastructure Config



expected impacts

erlin
ging?



rids



ase

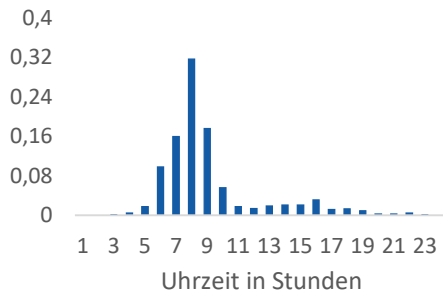


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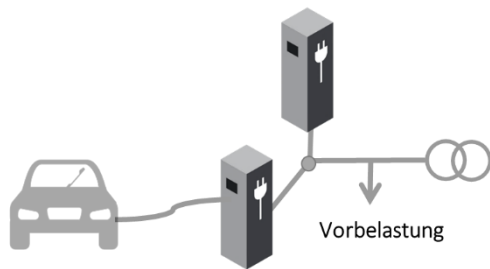
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Assumptions

Mobility Behavior



Charging Infrastructure Configuration



Simulation



elvis

electric vehicle
infrastructure
simulator



What if everybody in Berlin uses slow vs. fast charging?

How will different coupling points change with EV charging?

How will low-voltage grids cope with EV charging?

How much can EV batteries increase solar energy self-consumption?



Or
W
or

```
net = pp.create_empty_network()
b1 = pp.create_bus(net, vn_kv=20.)
b2 = pp.create_bus(net, vn_kv=20.)
pp.create_line(net, from_bus=b1, to_bus=b2, length_km=2.5, std_type="NAYY 4x50 SE")
pp.create_ext_grid(net, bus=b1)
pp.create_load(net, bus=b2, p_mw=1.)
```

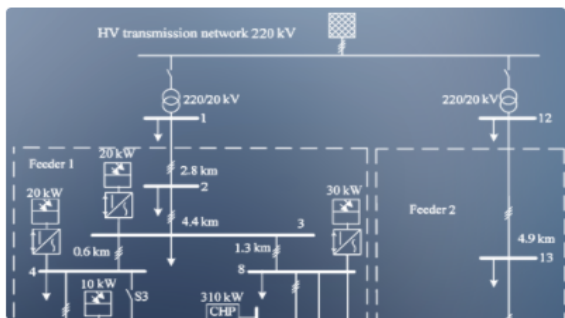
3. Run a power flow:

```
pp.runpp(net)
```

4. And check the results:

```
print(net.res_bus.vm_pu)
print(net.res_line.loading_percent)
```

But of course pandapower can do much more than that - find out what on this page!



Electric Modeling
Vorbereitung



Power System Analysis



Free and Open

More info: <https://www.pandapower.org/>

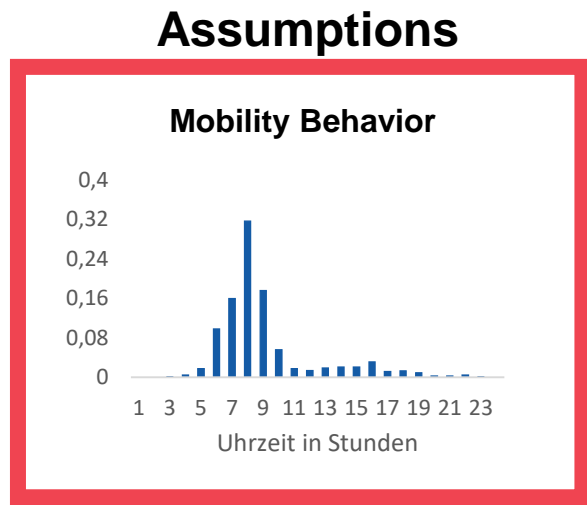


cts

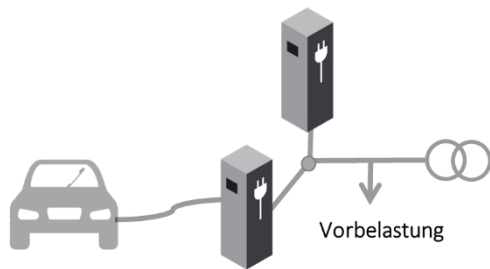


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Charging Infrastructure Configuration



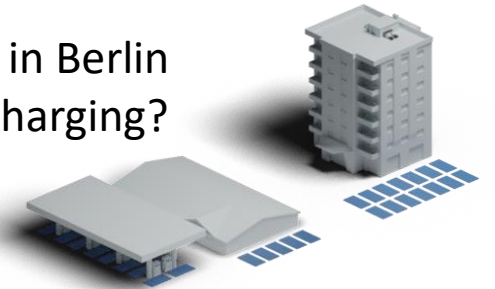
Simulation

elvis

electric vehicle infrastructure simulator

python™

What if everybody in Berlin uses slow vs. fast charging?



How will different coupling points change with EV charging?



How will low-voltage grids cope with EV charging?



How much can EV batteries increase solar energy self-consumption?



Different Types of EV charging

Periodic Charging



Charging, where one parks regularly (home or work).

Typical charging power:
3.7 kW – 11 kW

Additional Charging



Charging, where one temporarily stops anyhow.

Typical charging power:
11 kW – 22 kW

Fast Charging



Charging at central hubs in cities or next to highways.

Typical charging power:
43 kW – 350 kW


Example Car Sharing Open Data



↑ | Datensätze | APIs | Blog | FAQ | Showcase

Datensätze suchen... 🔍

Organisation





**Deutsche Bahn
Connect GmbH**
Webseite

Datensatz

Flinkster

Reportingdaten zu Flinkster. Dokumentation zur Datenlieferung: 20170516_Doku

Daten und Ressourcen

-  **Buchungen Carsharing (Stand 05/2017)**
Encoding ist nun UTF-8 [↩ Mehr ▾](#)
-  **Tarifklassen Carsharing (Stand 05/2017)**
Encoding ist nun UTF-8 [↩ Mehr ▾](#)
-  **Stationen Carsharing (Stand 05/2017)**
[↩ Mehr ▾](#)
-  **Fahrzeugdaten Carsharing (Stand 05/2017)**
Encoding ist nun UTF-8 [↩ Mehr ▾](#)
-  **Dokumentation 2017**
[↩ Mehr ▾](#)



Example Car Sharing Web Scraping



Web Scraping



Example Car Sharing Open API

The screenshot shows a GitHub repository page for 'sharenowTech/openAPI'. The repository is on the 'master' branch, has 3 branches, and 0 tags. A commit by Mathias Göppel is shown, titled 'Update README.md', with commit hash 085046b, dated Feb 2, 2018, and 225 commits. The README content is as follows:

car2go API Documentation

The car2go API offers access to up-to-date car2go information such as parking spots and gas stations.

Public Functions

- [Get Locations](#)
- [Get Operation Area](#)
- [Get Gasstations](#)
- [Get Parkingspots](#)

Details on how to deeplink into the car2go app can be found [here](#).

Please ensure to comply to our [terms of use](#) when using the API.

(c) 2010 car2go GmbH. All rights reserved.

The right sidebar contains sections for 'About' (Documentation on the openAPI of the car2go system, with a link to www.car2go.com), 'Releases' (No releases published), and 'Packages' (No packages published).



Example Google Popular Times

Lidl
4,3 ★★★★★ · 527 Berichte
Discounter

Routenplaner

SPEICHERN IN DER NÄHE AN MEIN SMARTPHONE SENDEN TEILEN

Hauptstraße 122, 10827 Berlin
F9M2+39 Berlin
lidl.de
0800 4353361
Jetzt geöffnet 08:00–22:00
Labels hinzufügen
ÄNDERUNG VORSCHLAGEN

Stoßzeiten Samstag ▾
AKTUELL Mäßig besucht

Uhrzeit	Stoßzeit
06 Uhr	Niedrig
09 Uhr	Niedrig
12 Uhr	Mittel
15 Uhr	Hoch
18 Uhr	Mittel
21 Uhr	Niedrig

The map shows the Lidl store at Hauptstraße 122, 10827 Berlin. The bar chart indicates that the store is 'Mäßig besucht' (moderately visited) on Saturday, with a peak in traffic around 15:00. The chart shows a significant increase in traffic starting around 12:00, peaking at 15:00, and then gradually decreasing towards 21:00. The store is highlighted with a red pin and a red box around the popular times section.



Example Google Popular Times

The screenshot shows the Google IssueTracker interface for issue 35827350, titled "Popular Times". The issue is a "Feature Request" with a priority of P4 and a severity of S4. It was reported by r2...@gmail.com and assigned to iv...@google.com. The issue description asks for the exposure of popular times information for places in the Google Maps API. The comments section shows a discussion about the definition of popular times and the ability to toggle by day on mobile or desktop. The interface includes a left sidebar with navigation options like "Assigned to me", "Starred by me", and "Bookmark groups". The top navigation bar includes a search bar and various utility icons. The right sidebar displays the issue's metadata, including the reporter, assignee, and various status indicators.

Issue Details:

- Issue ID: 35827350
- Title: Popular Times
- Type: Feature Request
- Priority: P4
- Severity: S4
- Status: Assigned
- Reporter: r2...@gmail.com
- Assignee: iv...@google.com

Comments:

- r2...@gmail.com** (Created issue, Sep 9, 2015 09:43AM):
What would you like to see us add to this API?
Can you please enable exposure of the popular times information for places?

For developers viewing this issue: please click the 'star' icon to be notified of future changes, and to let us know how many of you are interested in seeing it resolved.

- ca...@gmail.com** (Sep 11, 2015 04:44PM):
Yes please :) Along with a more specific definition of how the Popular Times are determined (how much history? done by mobile device activity? check ins?)
- je...@gmail.com** (Sep 16, 2015 05:41PM):
Making popular times available by day of the week would be awesome
- r2...@gmail.com** (Sep 16, 2015 06:58PM):
It already is Jeffrey, you can toggle by day on mobile or desktop
- ca...@gmail.com** (Sep 18, 2015 09:00PM):
@r22, I think Jeff is referring to the ability to split popular times by day of week in the information released by the API, not the currently existing web GUI.
Maybe the info appears as a nested object? e.g. "popular times" > "day of week" > "hour of day" > traffic count
- aj...@t-sciences.com** (Nov 14, 2015 10:01PM):
Would be extremely helpful to have access to this data directly via the API. Is it maybe available via another API?

Example Google Popular Times

The screenshot shows the GitHub repository page for `m-wrzt/populartimes`. At the top, there are navigation links for Code, Issues (9), Pull requests (1), Actions, Projects, Wiki, Security, and Insights. Below the navigation, there are buttons for 'Go to file', 'Add file', and 'Code'. The main content area displays a pull request from `m-wrzt/76-missing-address` with commit `3d3df3f` on August 18, containing 88 commits. Below the pull request is a file list:

File	Description	Time
content	Moved main code to crawler.py; Updated readme and added visualizatio...	3 years ago
populartimes	closes 76; check if address is properly formatted and change result i...	3 months ago
tests	add tests for circle calculation	2 years ago
.gitignore	Add .gitignore	2 years ago
.travis.yml	Add travis integration and a simple test	2 years ago
LICENSE.md	MIT license;	3 years ago
README.md	reference possible ToS issues;	4 months ago
setup.cfg	Add travis integration and a simple test	2 years ago
setup.py	add minimal version 1.21 for urllib3; closes #94	4 months ago

Below the file list is the README content:

Populartimes

The goal of this library is to provide an option to use *Google Maps* popular times data, until it is available via Google's API. For legal concerns please read [Issue #90](#).

Keep in mind that this API uses the Google Places Web Service, where each API call over a monthly budget is priced. The API call is SKU'd as "Find Current Place" with additional Data SKUs (Basic Data, Contact Data, Atmosphere Data). As

On the right side of the repository page, there are sections for 'About' (No description, website, or topics provided), 'Releases' (No releases published), 'Packages' (No packages published), 'Contributors' (6 contributors), and 'Languages' (Python 100.0%).



Example Google Popular Times



federicotallis commented on 30 Jul



Appealed my case to Google and they responded:

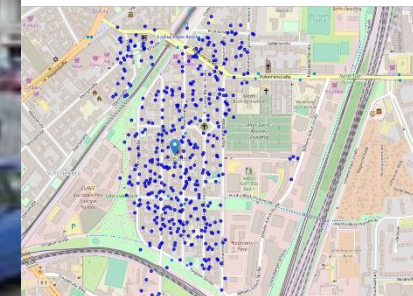
We can understand the interest in using Google Maps data to do research. Unfortunately, Google does not have the data rights to allow this use case as we do not own all the images that our API's serve. Additionally, creating new insights from imagery or data within the Google Maps API is creating a derivative work out of the data, which even for research purposes is against the Google Maps Terms of Service as outlined in Sections 3.2.2 and 3.2.3.



Example Google Streetview (Hackathon Idea)

Download
Adresses from FIS
Broker [1]

View on
Map
Application



[1] http://fbinter.stadt-berlin.de/fb/?loginkey=showMap&mapId=k_rbsadressen@senstadt

[2] <https://developers.google.com/maps/documentation/streetview/?hl=de>

Example Google Streetview (Hackathon Idea)



Gefördert durch:

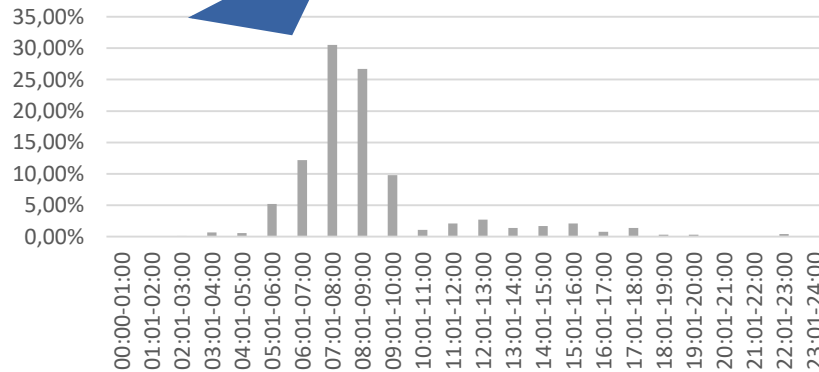


aufgrund eines Beschlusses
des Deutschen Bundestages

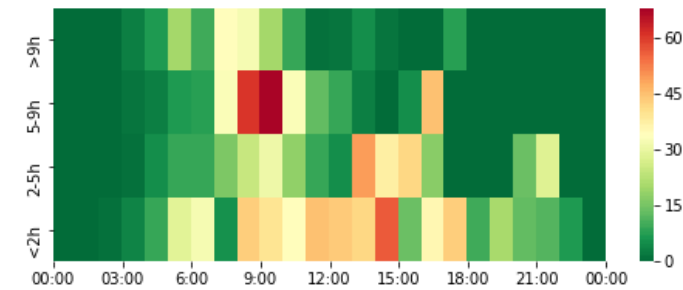
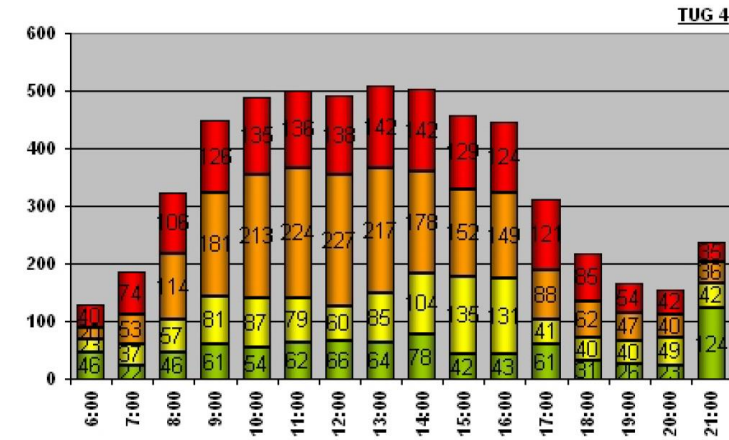


Example Data from Mobility Studies (PDF!)

Beginn des Weges Uhrzeit	Anteil an Wegen der Hauptverkehrsmittelgruppe				Gesamt
	Zu Fuß	Fahrrad	MIV	ÖPV	
00:00 - 01:00	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %
01:01 - 02:00	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %
02:01 - 03:00	0,0 %	0,0 %	0,0 %	0,1 %	0,1 %
03:01 - 04:00	0,0 %	0,0 %	0,1 %	0,1 %	0,1 %
04:01 - 05:00	0,1 %	0,3 %	0,4 %	0,5 %	0,3 %
05:01 - 06:00	0,4 %	0,6 %	2,1 %	1,9 %	1,3 %
06:01 - 07:00	1,5 %	1,9 %	4,0 %	5,5 %	3,4 %
07:01 - 08:00	6,8 %	10,0 %	9,0 %	11,4 %	9,1 %
08:01 - 09:00	6,5 %	8,9 %	7,0 %	7,4 %	7,2 %
09:01 - 10:00	5,8 %	6,1 %	5,7 %	5,0 %	5,6 %
10:01 - 11:00	6,3 %	4,0 %	5,0 %	4,0 %	5,0 %
11:01 - 12:00	6,6 %	3,6 %	4,9 %	4,0 %	5,0 %



Distribution of Departures at Home in Berlin, from: PROJEKT MOBILITÄT IN STÄDTEN SRV



Number of parked cars per hour, from: „Studie zum Ruhenden Verkehr Adlershof“ (2009)

Example Data from Mobility Studies

MiD 2008 MiD 2002

Mobilität in Deutschland

Wissenschaftlicher Hintergrund Regionale Erhebungen Ablauf der Erhebung Publikationen MiD 2017 MIT 2017



Wissenschaftlicher Hintergrund



Mobilität in Deutschland (MiD) ist eine bundesweite Befragung von Haushalten zu ihrem alltäglichen Verkehrsverhalten im Auftrag des **Bundesministeriums für Verkehr und digitale Infrastruktur (BMVI)**. Sie wurde bereits in den Jahren 2002 und 2008 erhoben. Die aktuelle Studie wurde 2017 durchgeführt. Die Ergebnisse stehen ab Ende Juni 2018 schrittweise zur Verfügung. Bereits verfügbare Projektinformationen finden Sie [hier](#).

Ähnliche Umfragen fanden bereits 1976, 1982 und 1989 unter dem Namen "KONTIV" (Kontinuierliche Erhebung zum Verkehrsverhalten) statt. Die in diesen Studien erhobenen Daten dienen sowohl als Basis für die Verkehrsplanung der Bundesrepublik Deutschland als auch für wissenschaftliche Untersuchungen zur Alltagsmobilität.

Die zentrale Aufgabe der Studie besteht darin, repräsentative und verlässliche Informationen zur Soziodemographie von Personen und Haushalten und ihrem Alltagsverkehr (z.B. Wege nach Zwecken und Verkehrsarten) für ein ganzes Jahr zu erhalten. Sie dient, gewichtet und hochgerechnet, als Rahmen und Ergänzung für andere Verkehrserhebungen, wie die Verkehrsbefragungen in einzelnen Städten (z.B. SrV oder das **Mobilitätspanel**).

Die Studie Mobilität in Deutschland bietet darüber hinaus aktuelle Datengrundlagen zu wichtigen Einflussgrößen der Mobilität und bildet die Basis für Verkehrsmodelle. Nicht nur für die Verkehrsplanung, für Forschung und das wissenschaftliche Erkenntnisinteresse sind Ergebnisse der Studie von Bedeutung, auch für konkrete politische Entscheidungen liefern sie die quantitativen Hintergrundinformationen.

Weitere Materialien und Informationen zu den Erhebungen


Publikationen MiD 2017 Auswertungstool MIT 2017 – Publikationen MiD 2008

eine Studie des:



Bundesministerium für Verkehr und digitale Infrastruktur

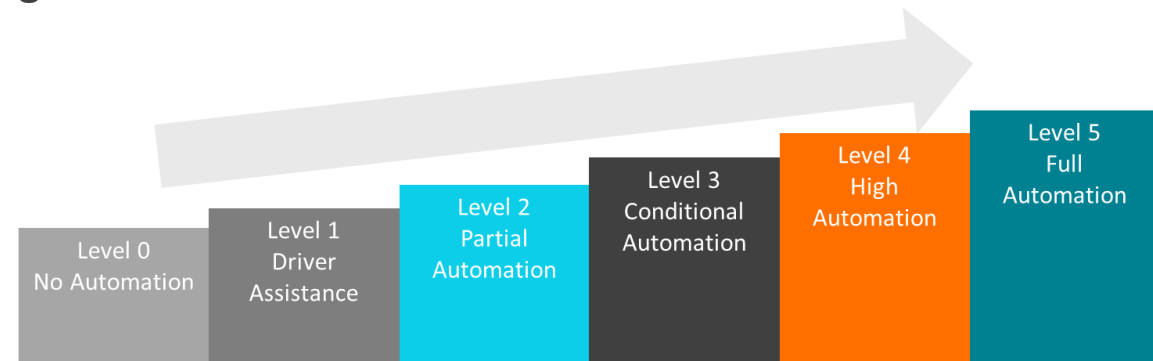
durchgeführt von:



Kontakt

Conclusions on mobility data

- ▶ Due to **sector coupling of mobility and the electric grid**, mobility data is relevant input to assessing impacts on the grids and hence necessary for accurate planning of the infrastructure.
- ▶ Existing (German) **e-mobility data does not yet generalize** well enough, as mostly from car-sharing, fleets and early adopters.
- ▶ Publicly funded mobility studies are giving useful input, but **data is often not shared in easily accessible formats** (e.g. only PDF) for further use or access is cumbersome. They are typically **based on combustion engine cars**.
- ▶ **Private companies have valuable data**, but access is only possible in restricted ways or for restricted use cases, or not at all.
- ▶ In general there exist **long-term uncertainties** in the assumptions regarding the long-term changes in mobility and charging behavior that affect grid planning now.

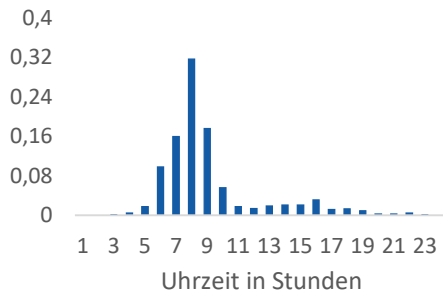


Overview of Simulation Approach

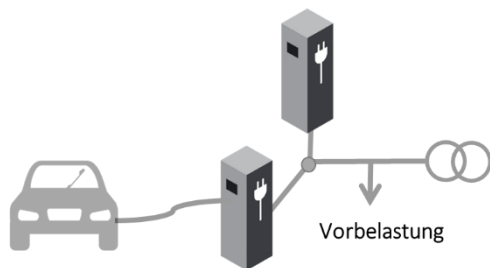
We use a stochastic, „bottom-up“ simulation of EV charging based on mobility scenarios to model expected impacts on the electric power grids and opportunities as distributed storage.

Assumptions

Mobility Behavior



Charging Infrastructure Configuration



Simulation



elvis

electric vehicle
infrastructure
simulator



What if everybody in Berlin uses slow vs. fast charging?



How will different coupling points change with EV charging?



How will low-voltage grids cope with EV charging?



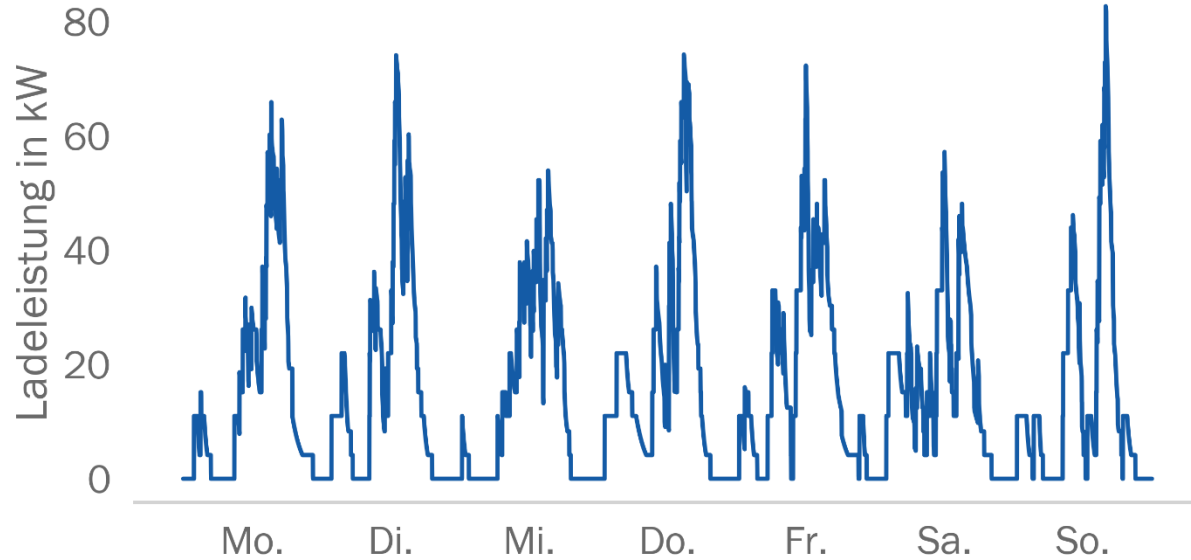
How much can EV batteries increase solar energy self-consumption?



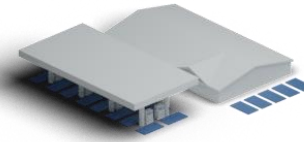
Comparison of Residential Building and Fast Charging Hub



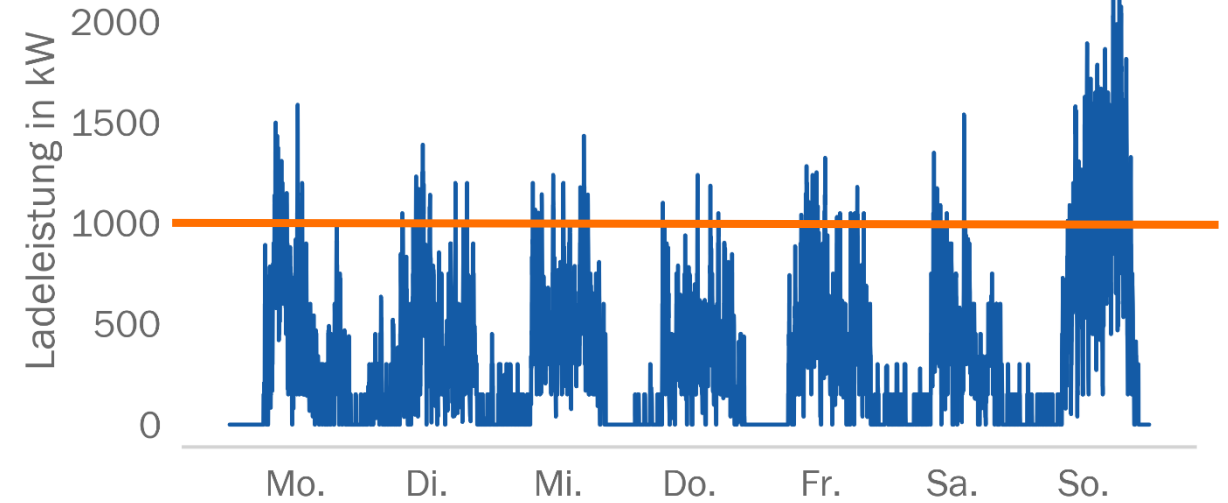
Residential Building



Annahmen	
Anzahl Ladepunkte	20
Ladeleistung	11 kW
Anzahl Ladeevents	10 je LP je Woche



Fast Charging Hub



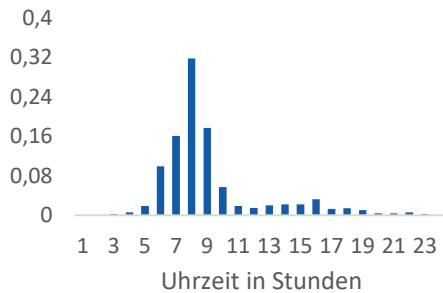
Annahmen	
Anzahl Ladepunkte	20
Ladeleistung	150 kW
Anzahl Ladeevents	125 je LP je Woche

Overview of Simulation Approach

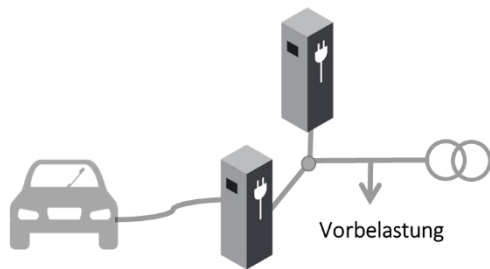
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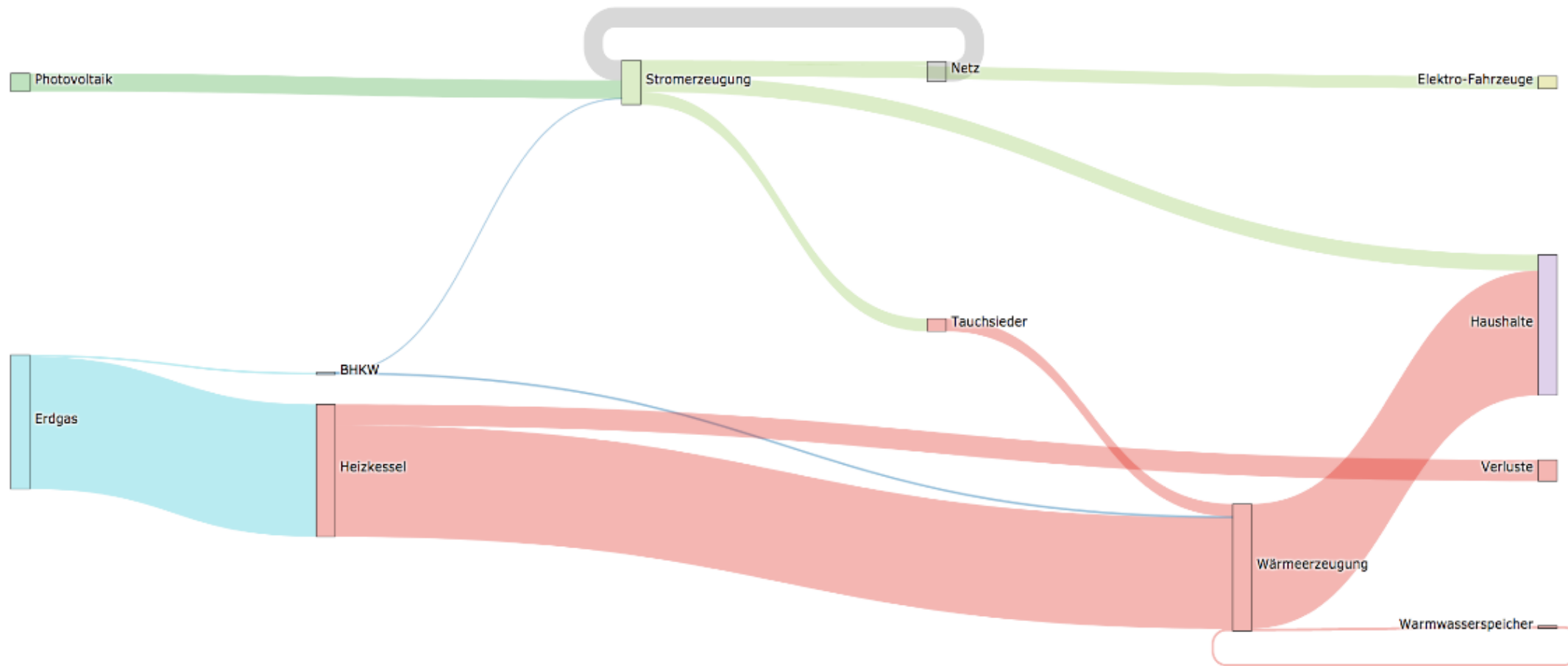
How will low-voltage grids cope with EV charging?

How much can EV batteries increase solar energy self-consumption?



Increasing self-consumption using electric vehicle batteries

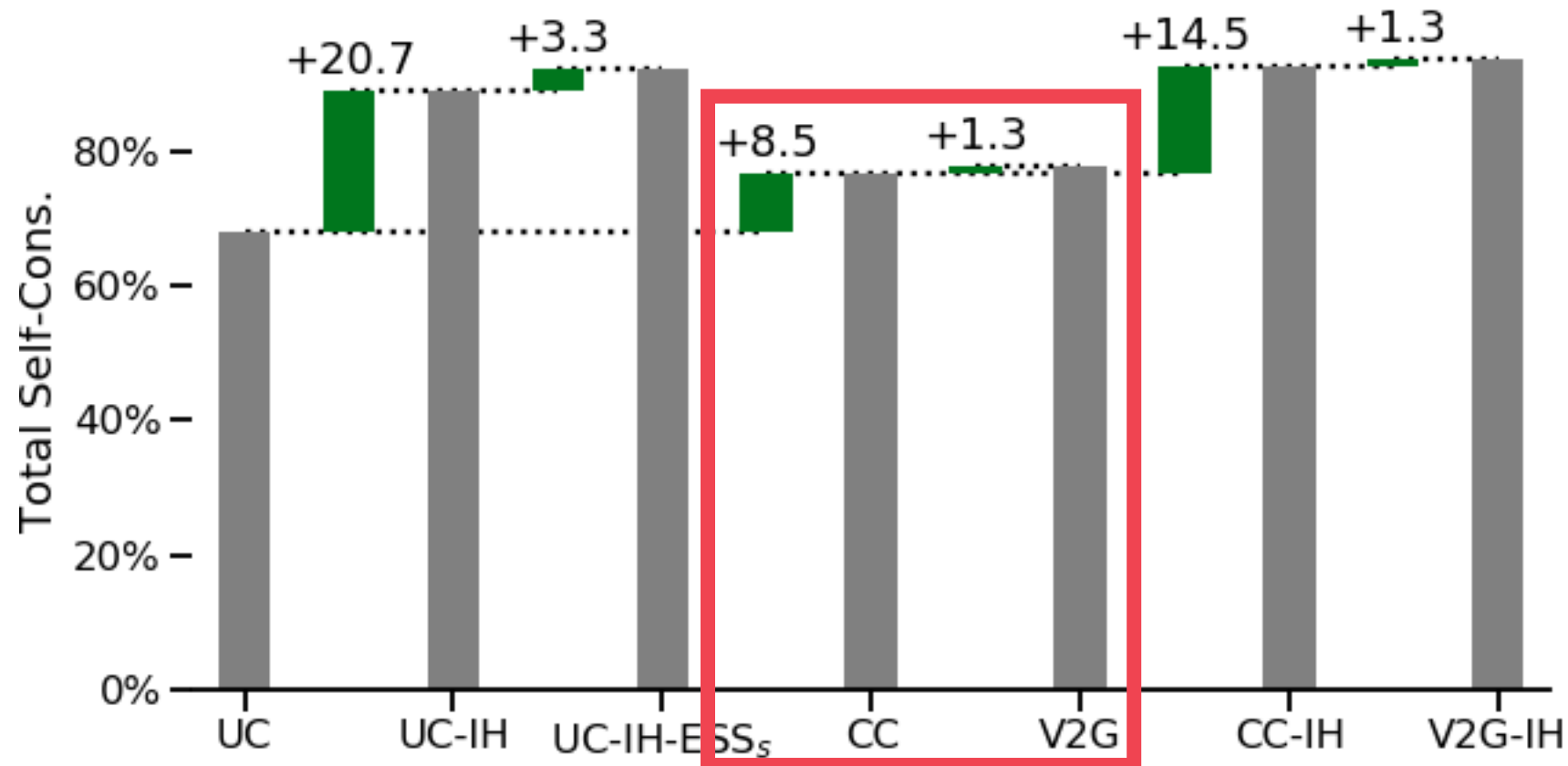
Sankey-Diagramm für den Energieaustausch

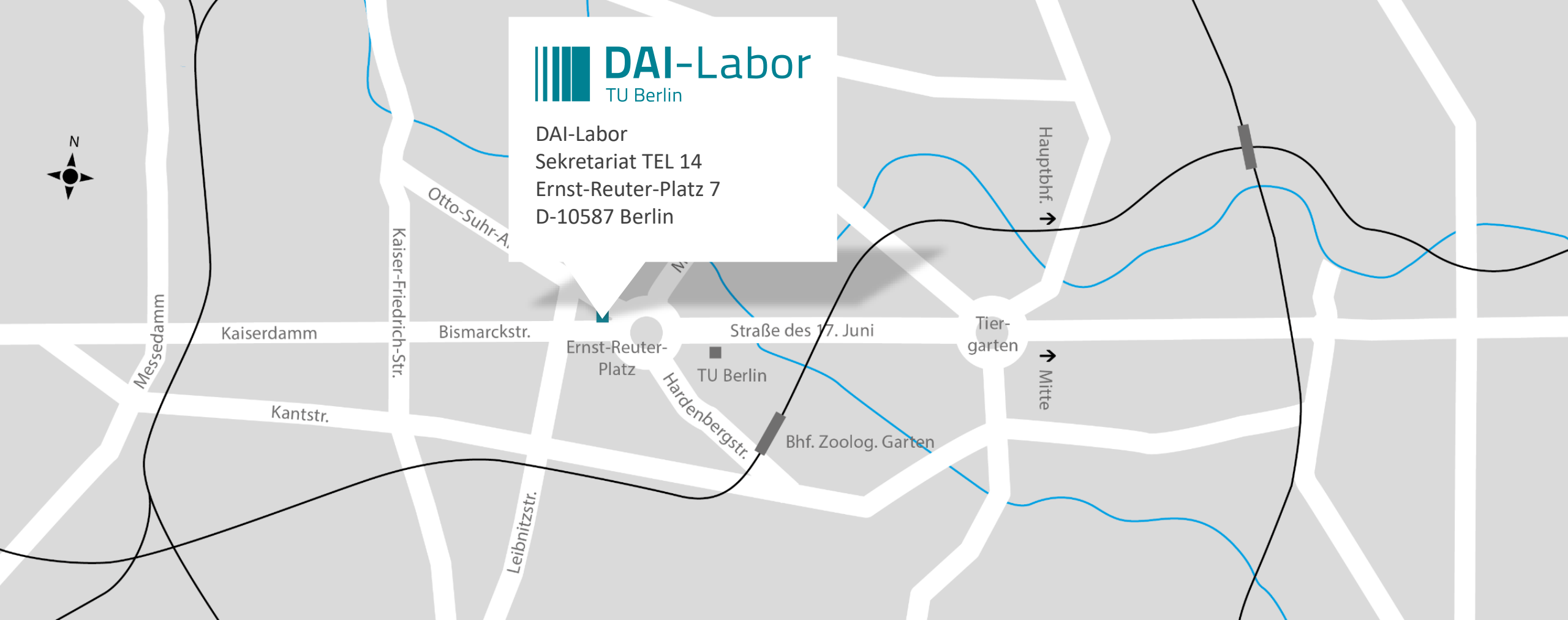


Increasing self-consumption using electric vehicle batteries

Example Case Study:

- By using intelligent controlled charging (CC), the **self-consumption** of the PV and combined heat and power is **increased from 68% by 8.5 percentage points**.
- By allowing feeding back energy („Vehicle-to-Grid“) it can increase by another 1.3%.





Get In Touch



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