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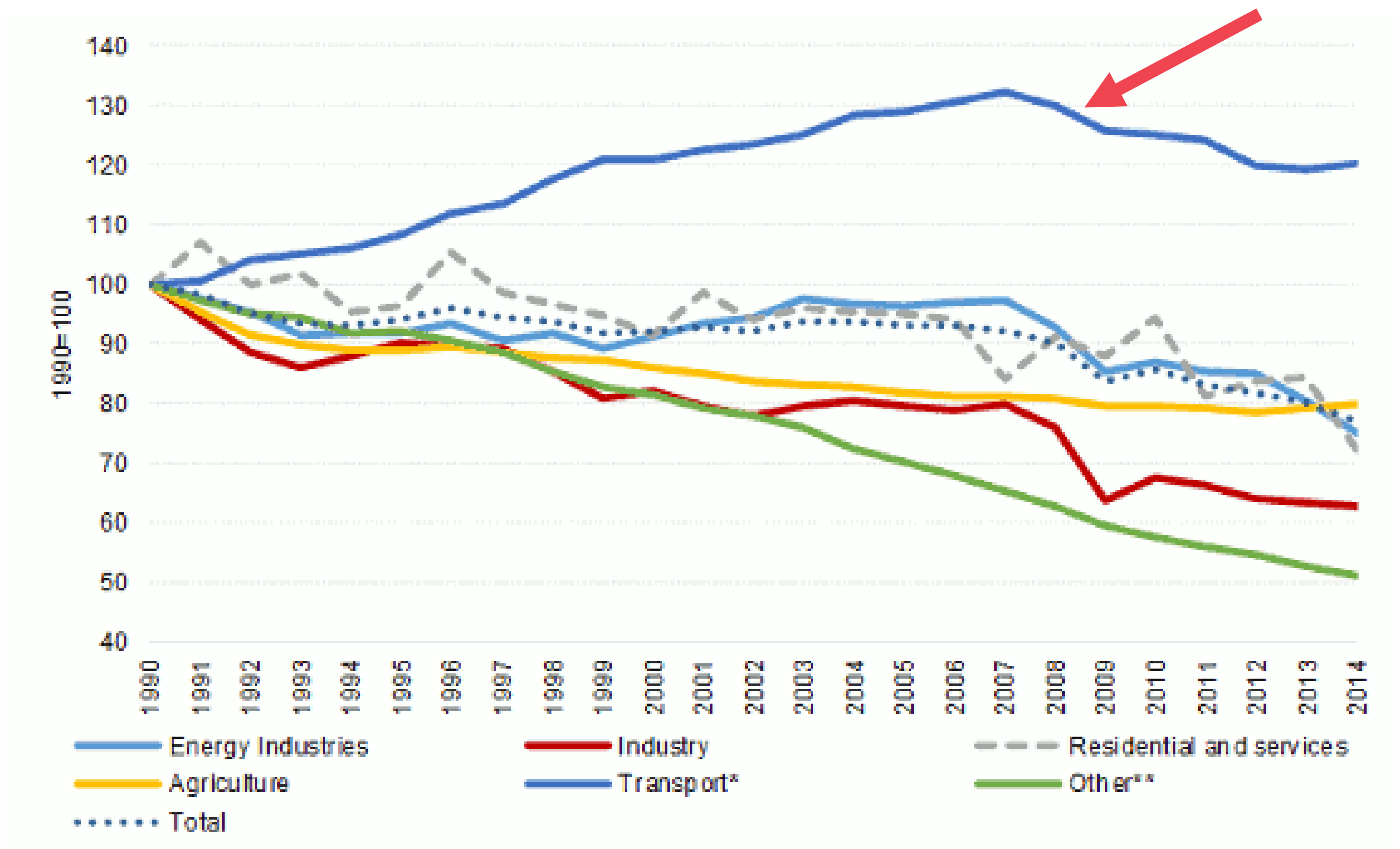
GOOD CAUSES. BETTER EFFECTS.

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



Source: European Environment Agency (EEA), see: https://ec.europa.eu/clima/policies/transport_en

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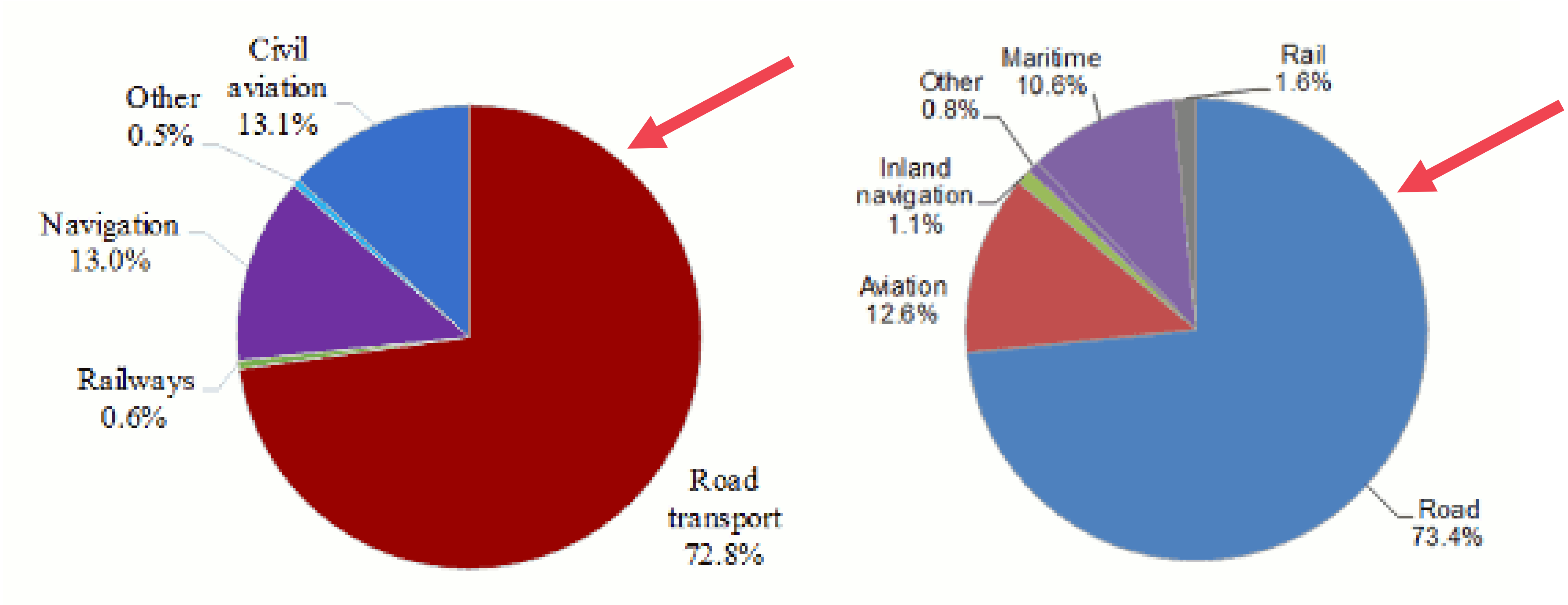
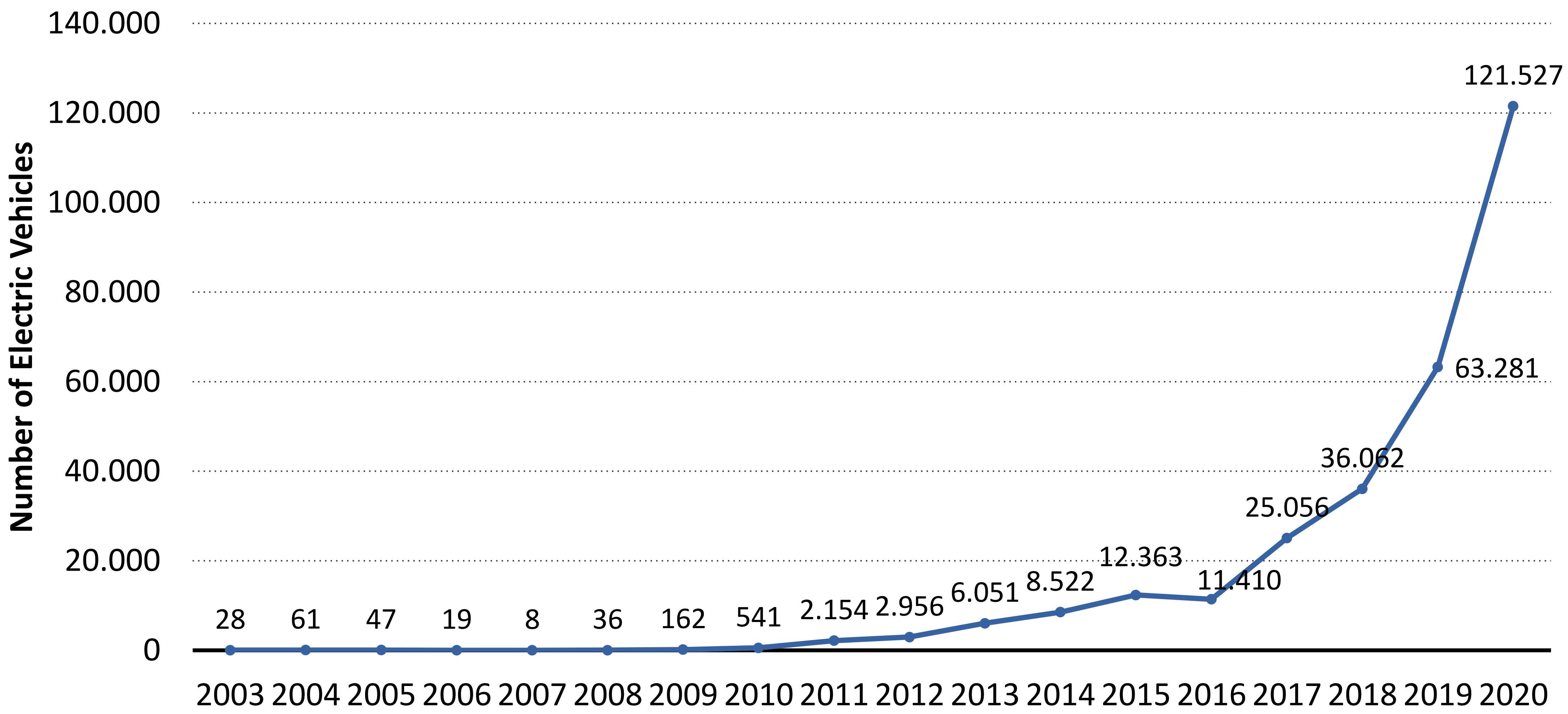


Source: European Environment Agency (EEA), see: https://ec.europa.eu/clima/policies/transport_en

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/.

heute

Ausbau der Elektromobilität

E-Autos bringen Stromnetz ans Limit

Strommasten und Windraeder heben sich wie Scherenschnitte vom farbenpraechtigen Abendl

Wirtschaft 〉 Energiepolitik 〉 Deutsches Stromnetz in einem kritischen Zustand

Frankfurter Allgemeine

Wirtschaft

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

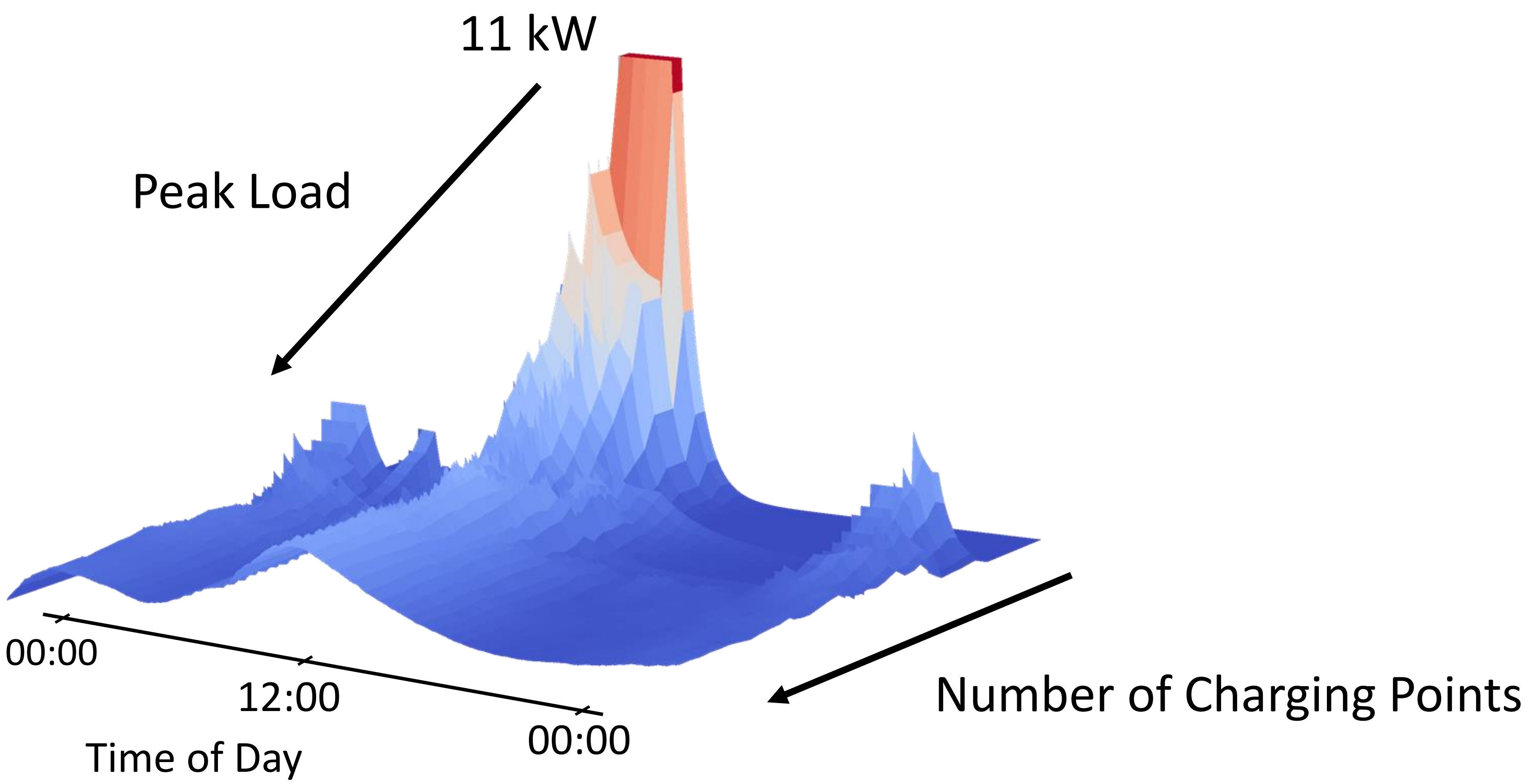
These des Monats: Stromnetz nicht fit für Elektromobilität?!

These des Monats

NEWSLETTER

Abonnieren Sie „electrive.n
bequem per E-Mail. Unser N
erscheint werktäglich gege
kurz, kompakt und kost

Concept of concurrency for EV charging



How to approach modelling the grid impact?

Measured Data

Simulation

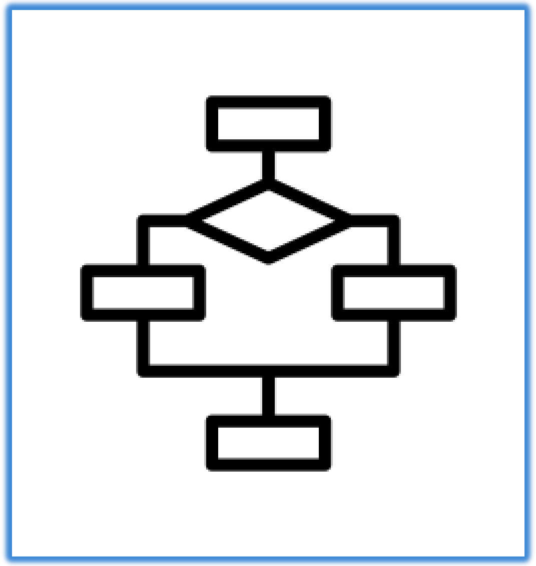
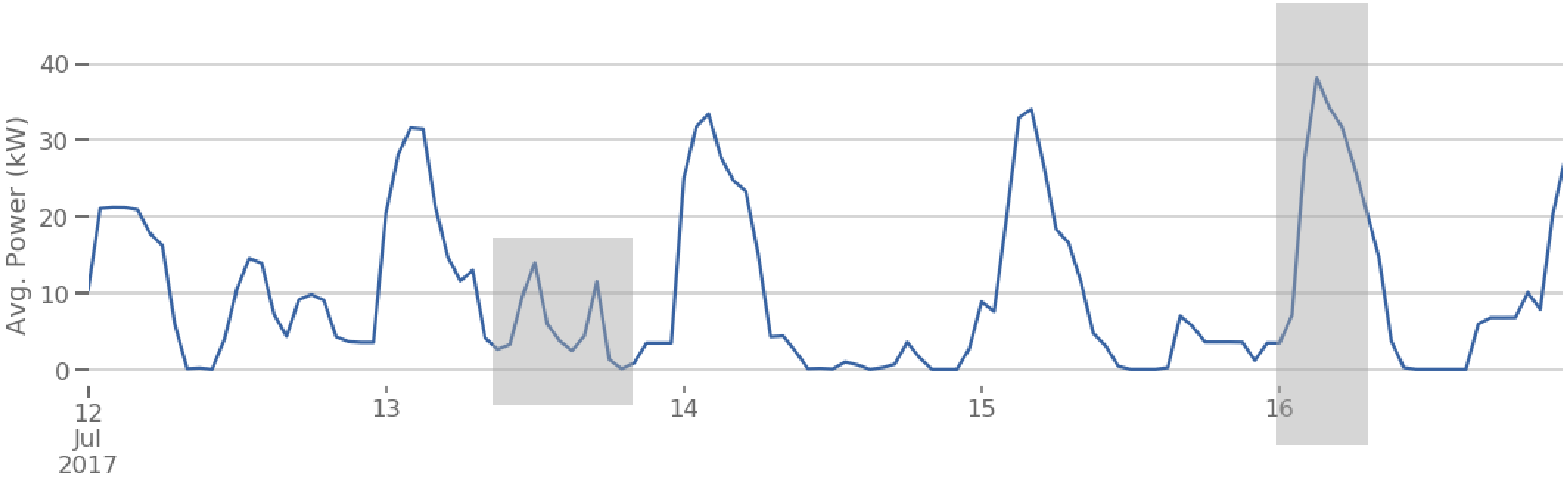


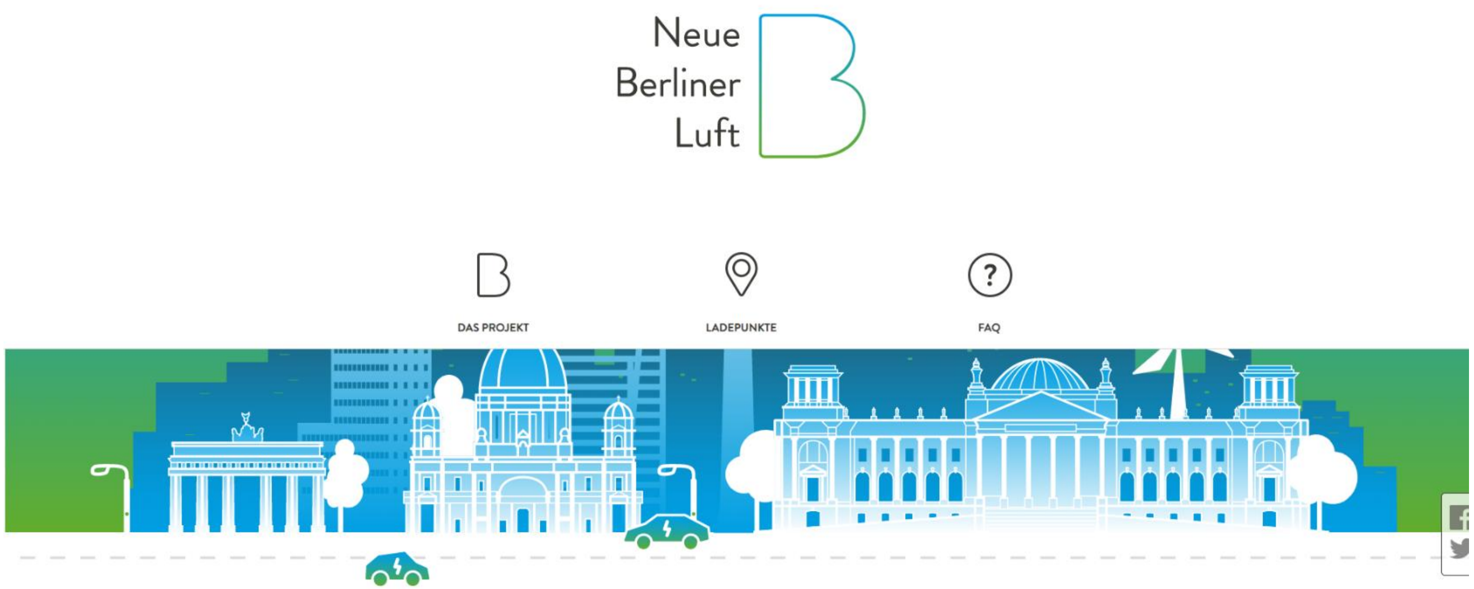
Image sources: https://commons.wikimedia.org/wiki/File:Smart-meter-gateway.jpg/ (left), CC (right)

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

Saturday night?



Example Measured Data: Project Neue Berliner Luft



be Berlin
Senatsverwaltung
für Umwelt, Verkehr
und Klimaschutz

ubitricity

DAI-Labor
TU Berlin

GASAG
SOLUTION +

HUBJECT

REINER LEMOINE
INSTITUT

Gefördert durch:

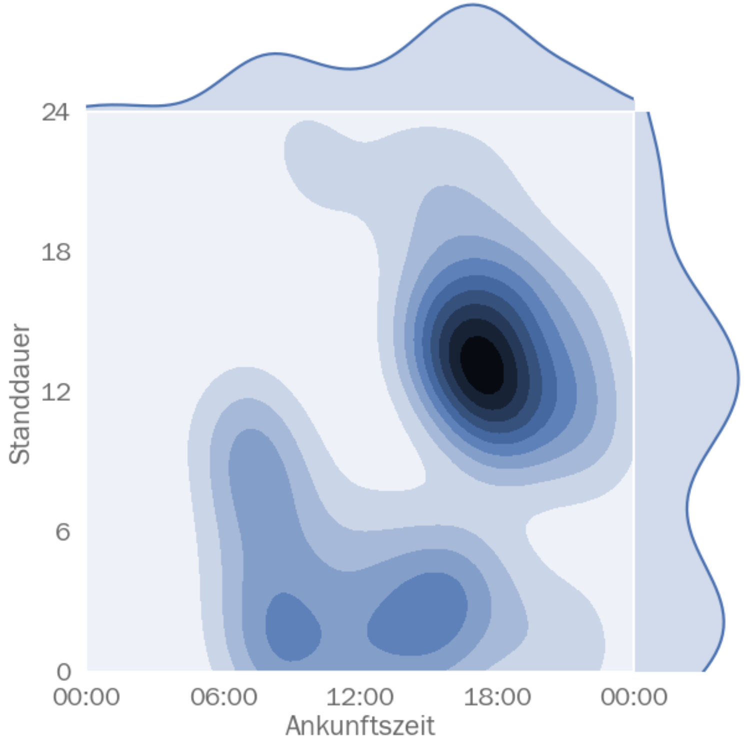
Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
des Deutschen Bundestages

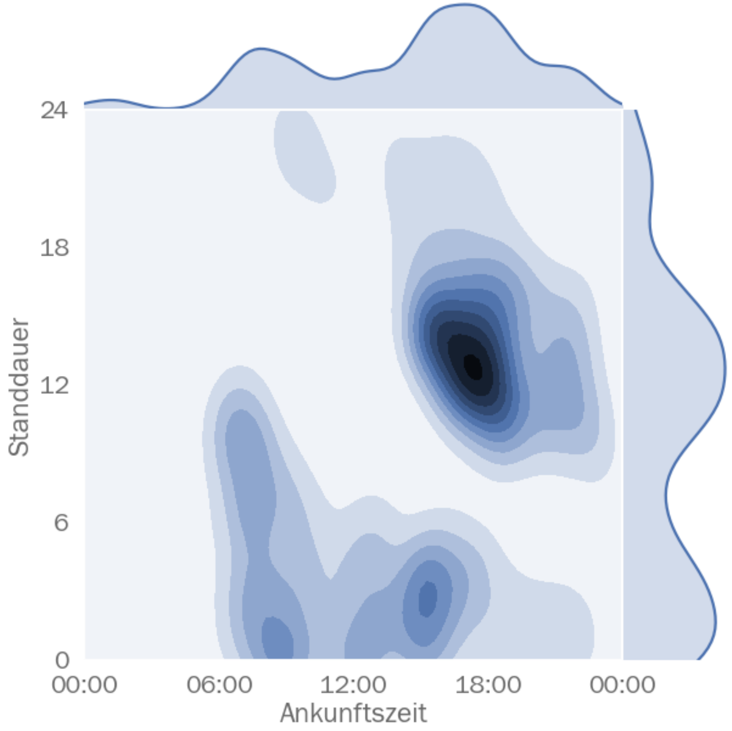
More info: https://www.neueberlinerluft.de/

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

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

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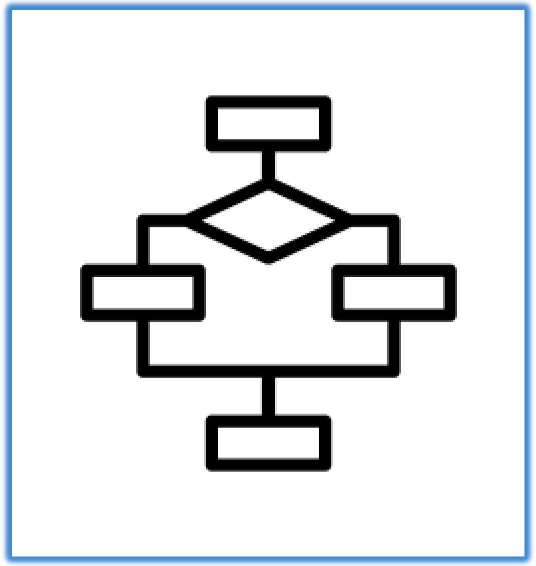

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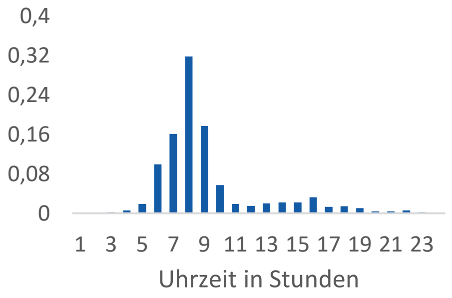
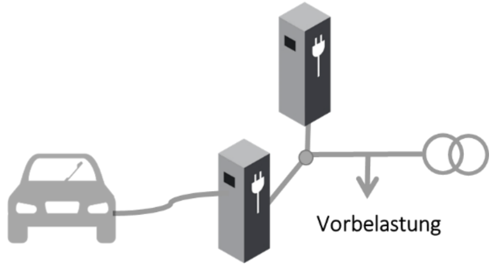
Assumptions

Mobility Behavior



Charging Infrastructure Configuration



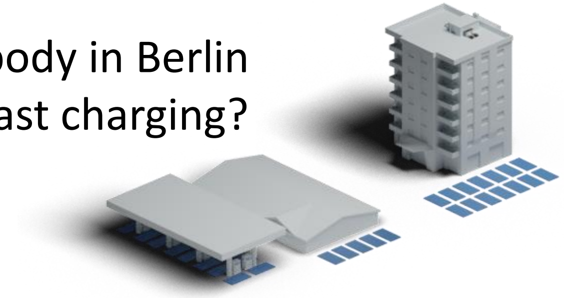
Simulation

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?

pandapower

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

scikit learn TensorFlow PYOMO

A Simple Abstract Pyomo Model

We repeat the abstract model from the previous section:

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

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

```
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)
```

More info: https://pyomo.readthedocs.io/en/stable/index.html/

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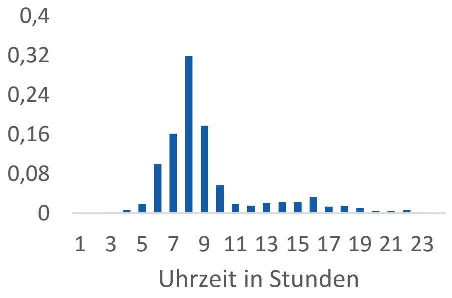

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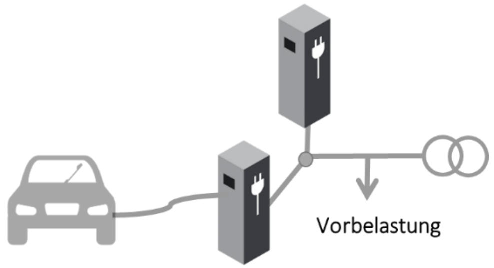


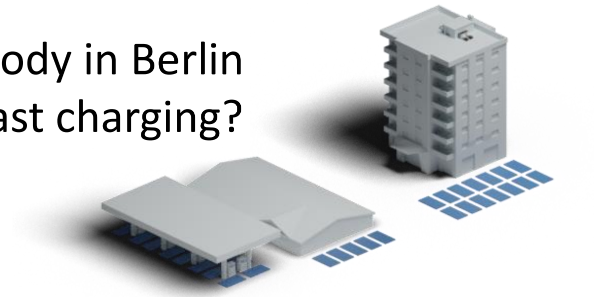
Simulation

elvis

electric vehicle infrastructure simulator

python™

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



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How will low-voltage grids cope with EV charging?

pandapower

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

scikit learn TensorFlow PYOMO

```
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.)
```

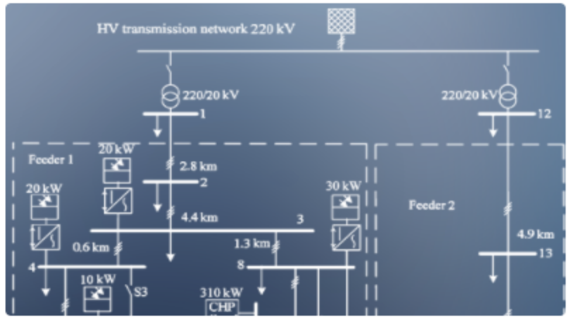
3. Run a power flow:

```
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!



open source initiative

Electric Modeling **Power System Analysis** **Free and Open**

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

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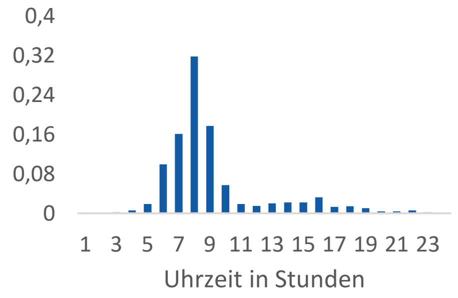

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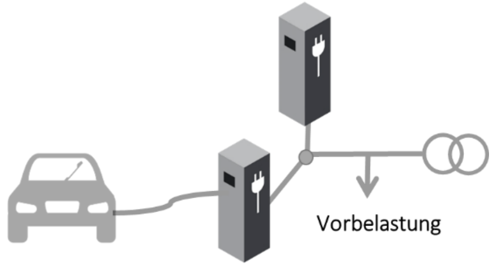

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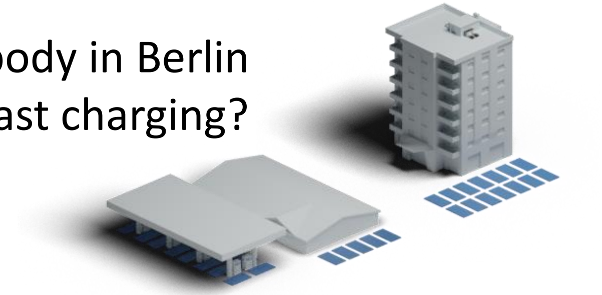

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PYOMO

scikit learn

TensorFlow

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

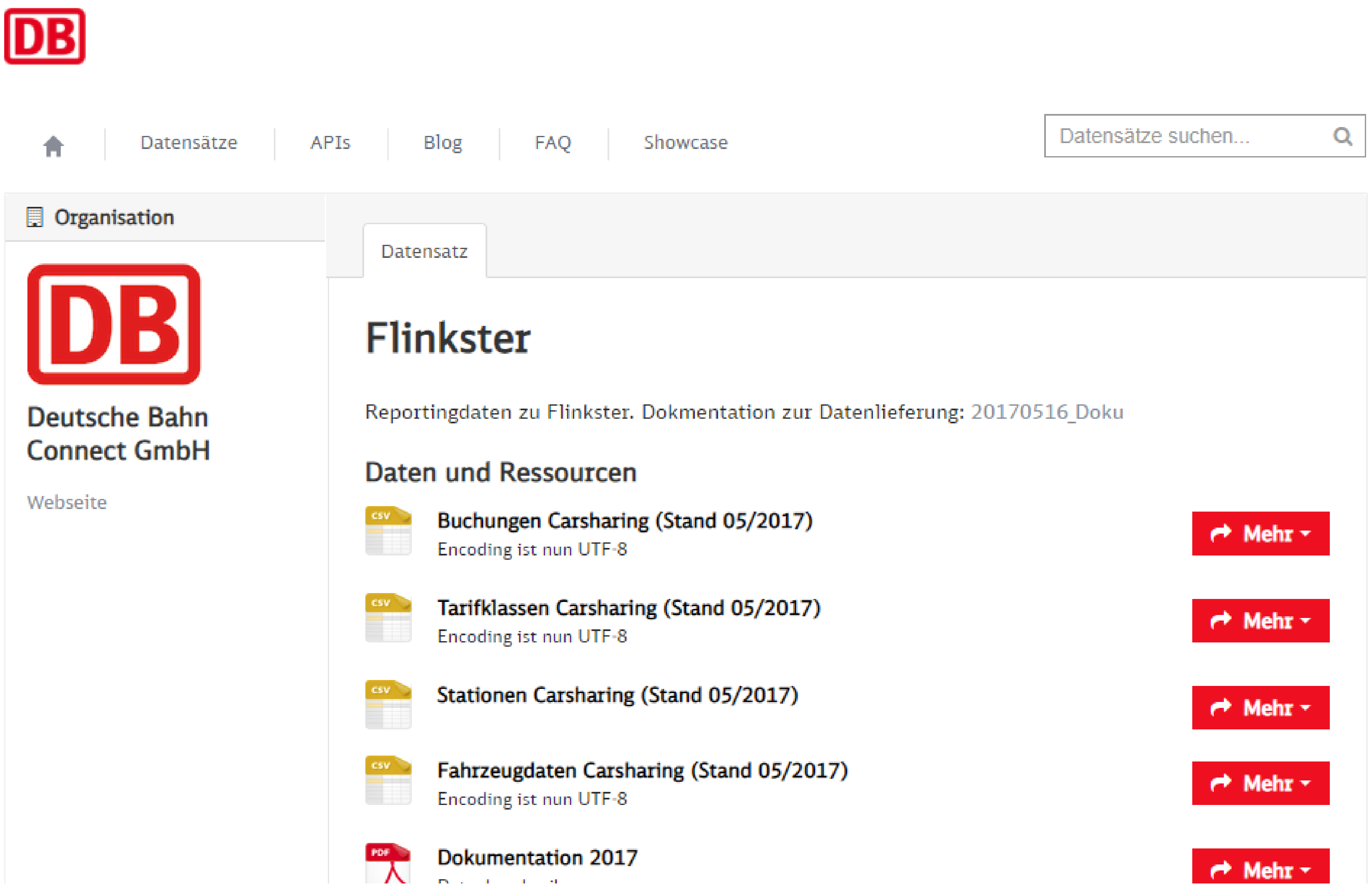
Fast Charging

Charging at central hubs in cities or next to highways.

Typical charging power:
43 kW – 350 kW

Image sources: https://www.neueberlinerluft.de/partner/ubitricity/ (left), CC0 (middle), https://commons.wikimedia.org/wiki/File:Nissan_LEAF_got_thirsty (right)

Example Car Sharing Open Data



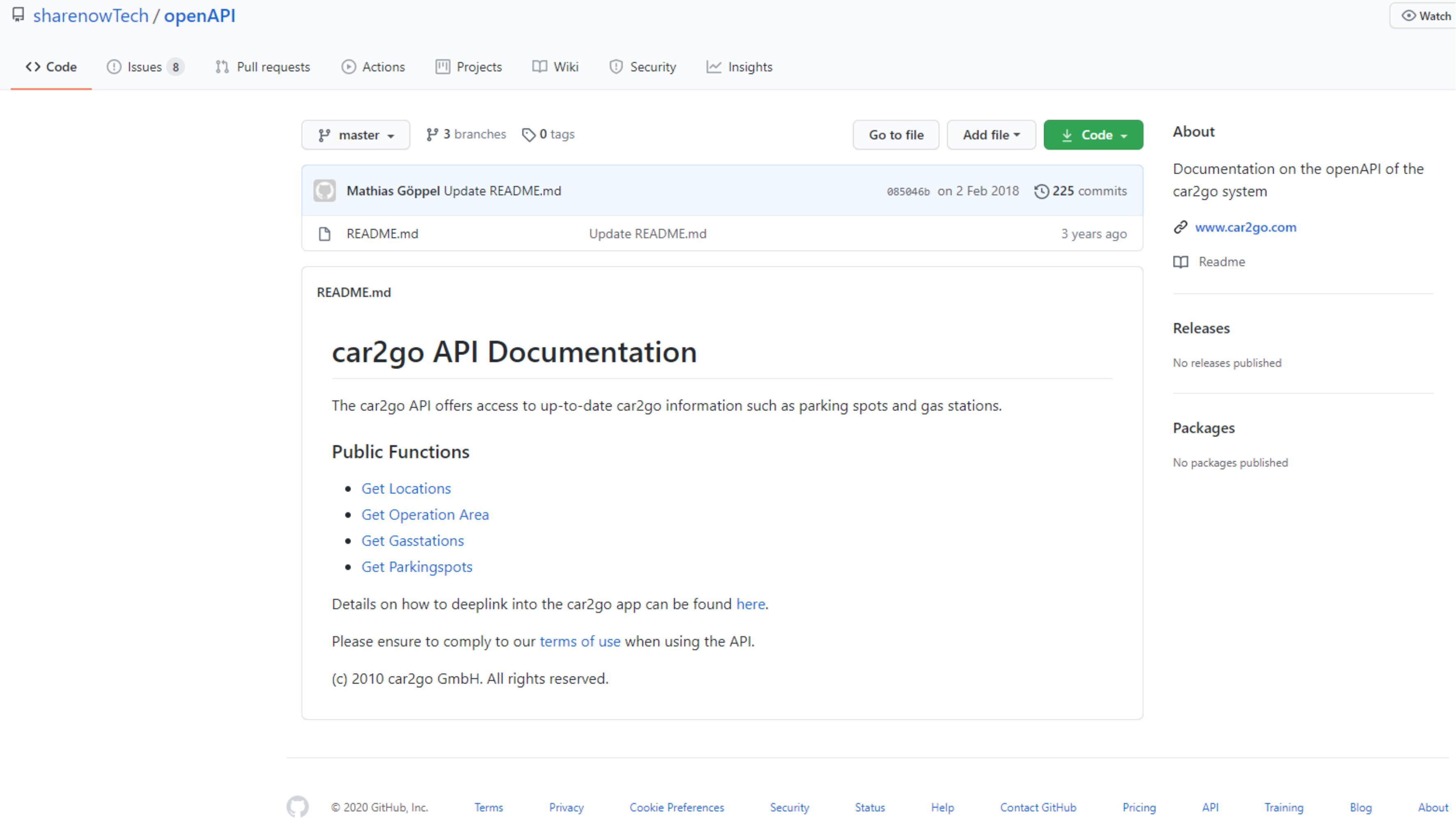
More info: https://data.deutschebahn.com/dataset/data-flinkster

Example Car Sharing Web Scraping

→ **Web Scraping**

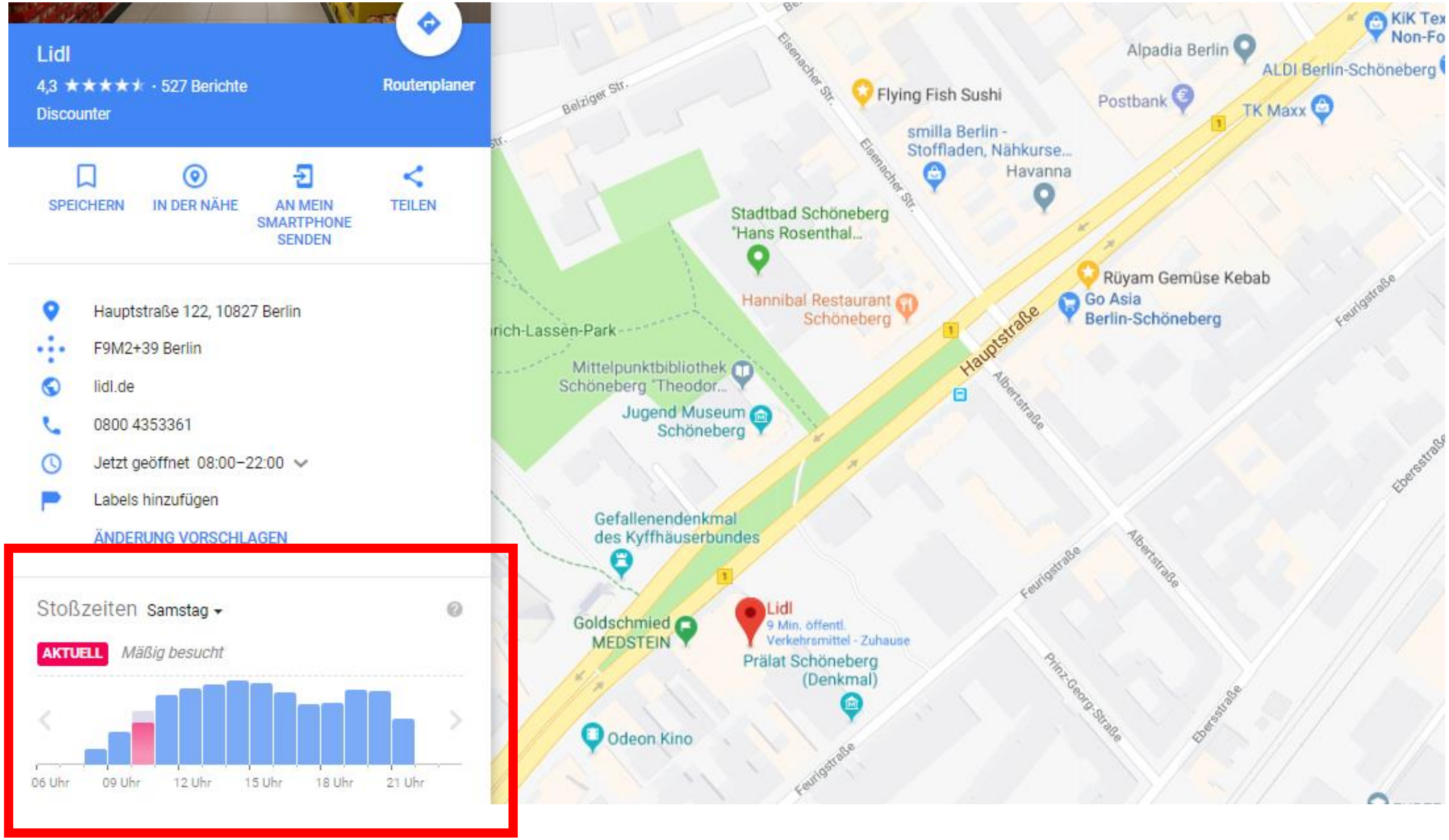
Image Source: https://www.citroen.de/citroen-markenwelt/aktuelles-und-events/multicity-carsharing-erweitert-geschaeftsgebiet.html

Example Car Sharing Open API



More info: https://github.com/sharenowTech/openAPI

Example Google Popular Times



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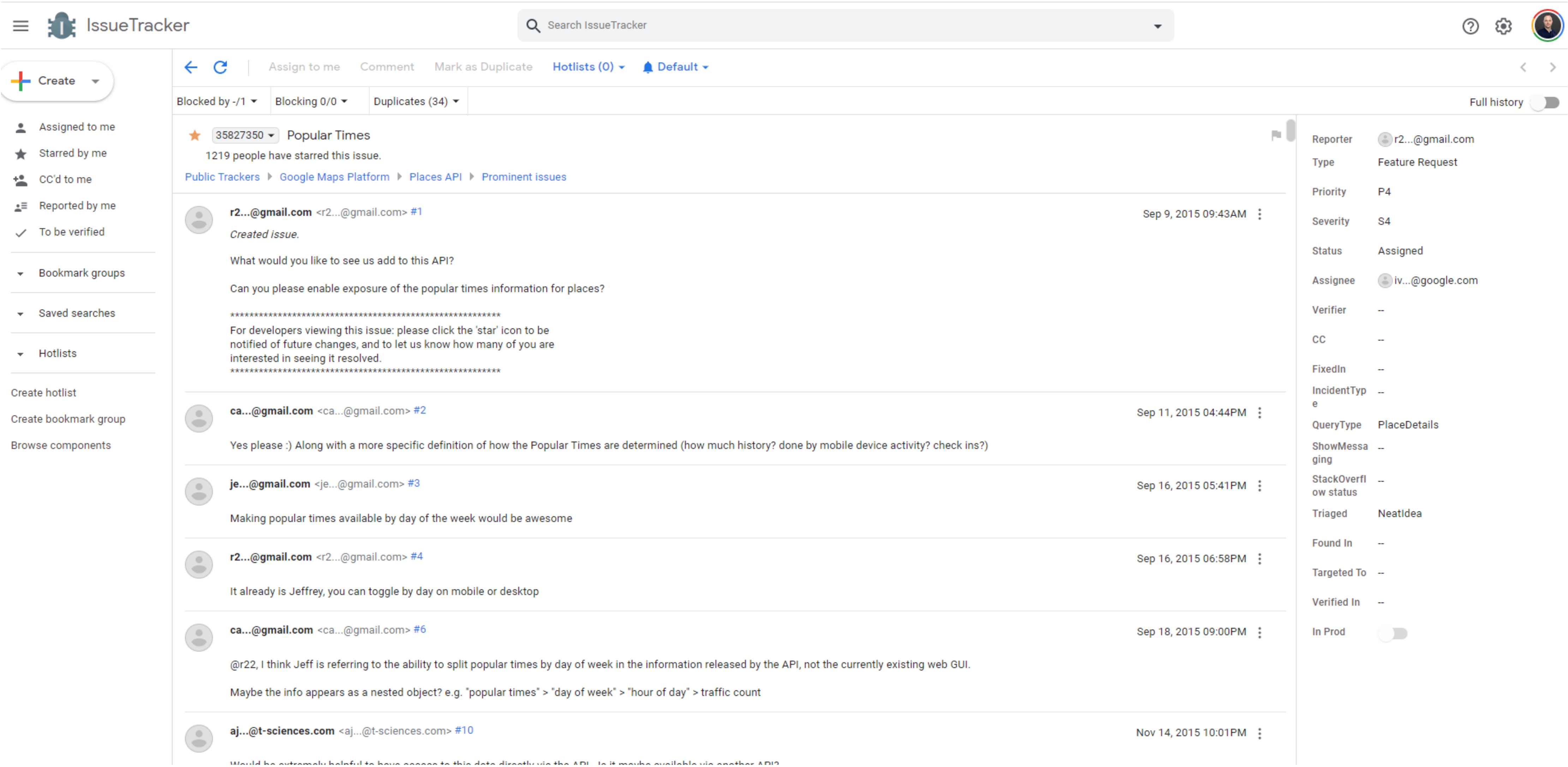
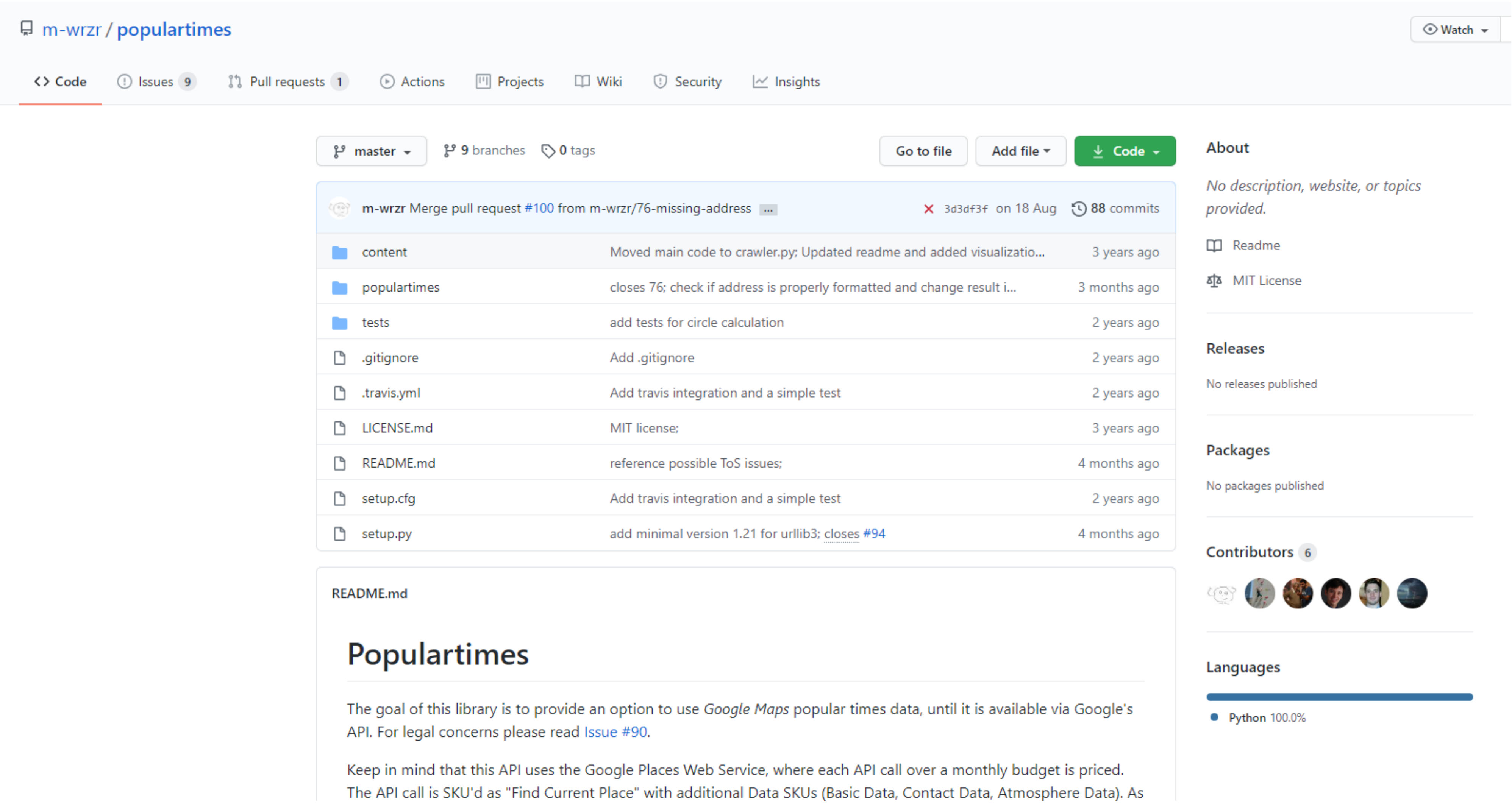


More info: https://issuetracker.google.com/issues/35827350

Example Google Popular Times



More info: https://github.com/m-wrzr/populartimes/

Example Google Popular Times

federicotallis commented on 30 Jul

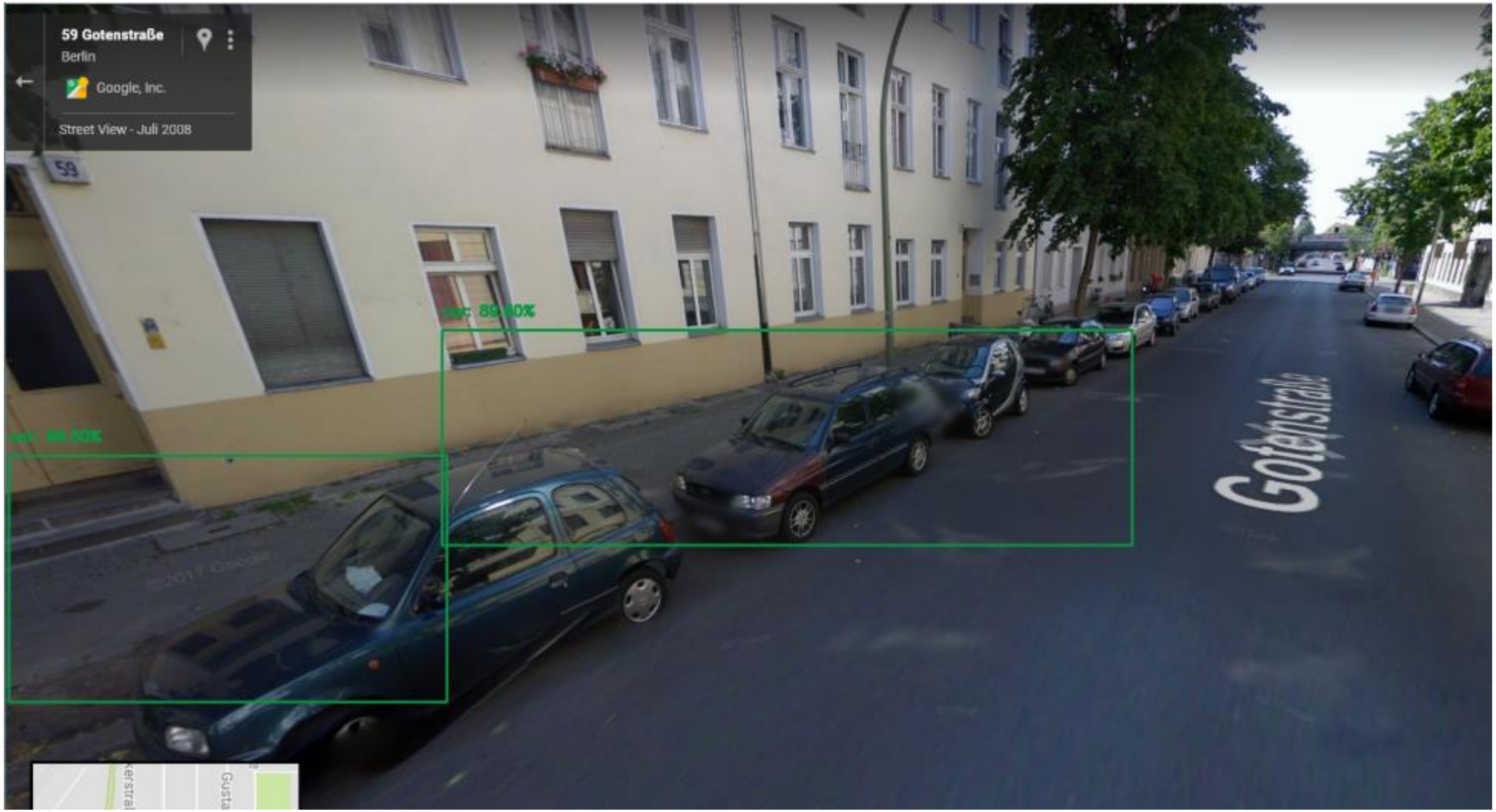
Appealed my case to Google and they responded:

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.

👍 2

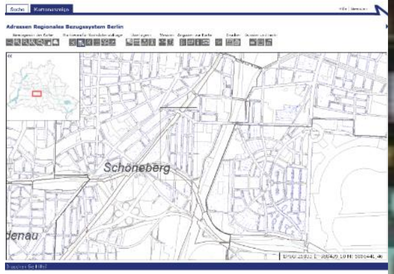
More info: https://github.com/m-wrzr/populartimes/issues/90

Example Google Streetview (Hackathon Idea)

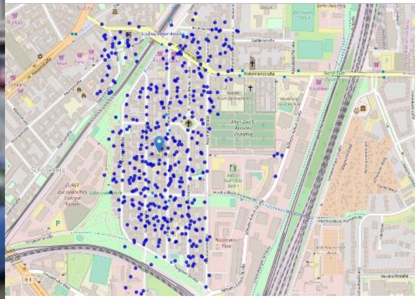


Example Google Streetview (Hackathon Idea)

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)

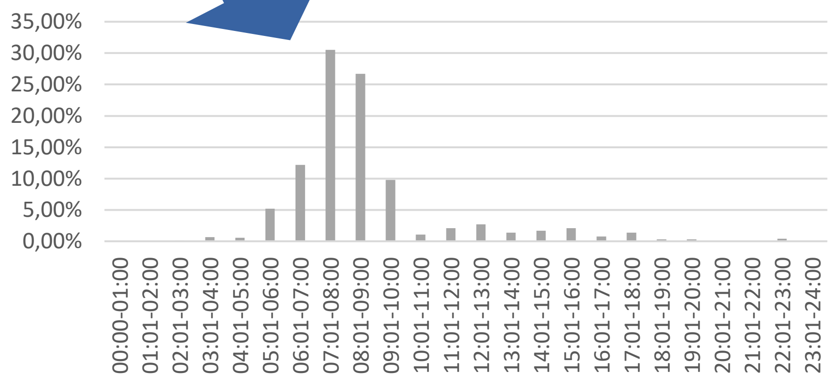
Gefördert durch:

Bundesministerium
für Wirtschaft
und Energie

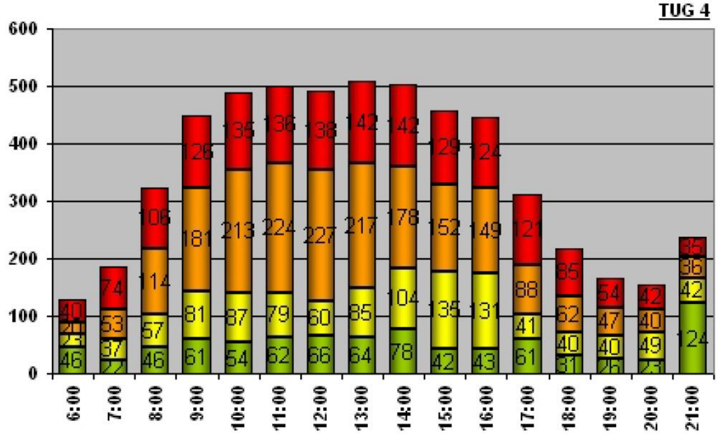
aufgrund eines Beschlusses
des Deutschen Bundestages

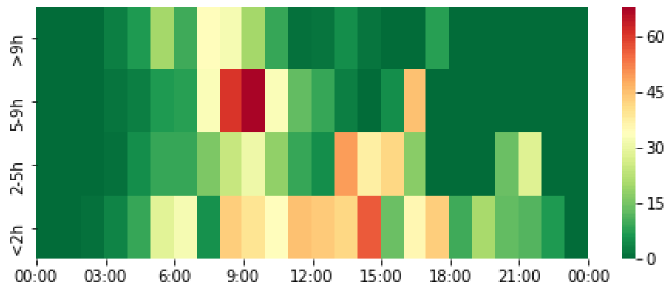
Example Data from Mobility Studies (PDF!)

Beginn des Weges	Anteil an Wegen der Hauptverkehrsmittelgruppe				
Uhrzeit	Zu Fuß	Fahrrad	MIV	ÖPV	Gesamt
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 %	0,0 %
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



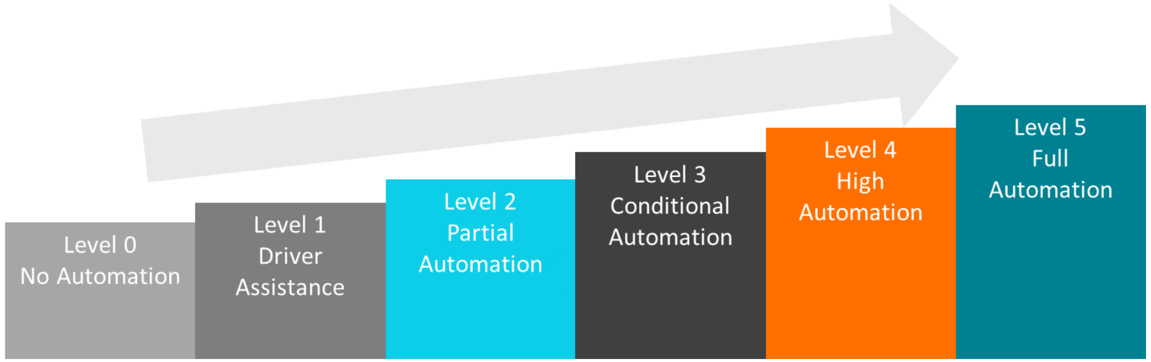


Number of parked cars per hour, from: „Studie zum Ruhenden Verkehr Adlershof“ (2009)

Example Data from Mobility Studies

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.



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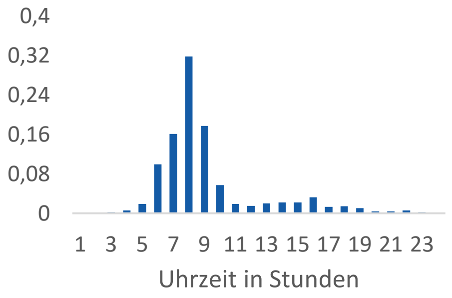

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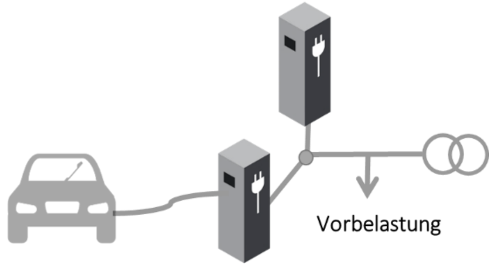

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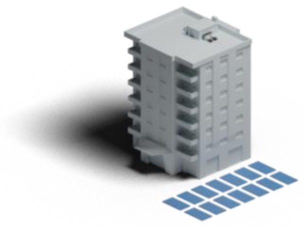
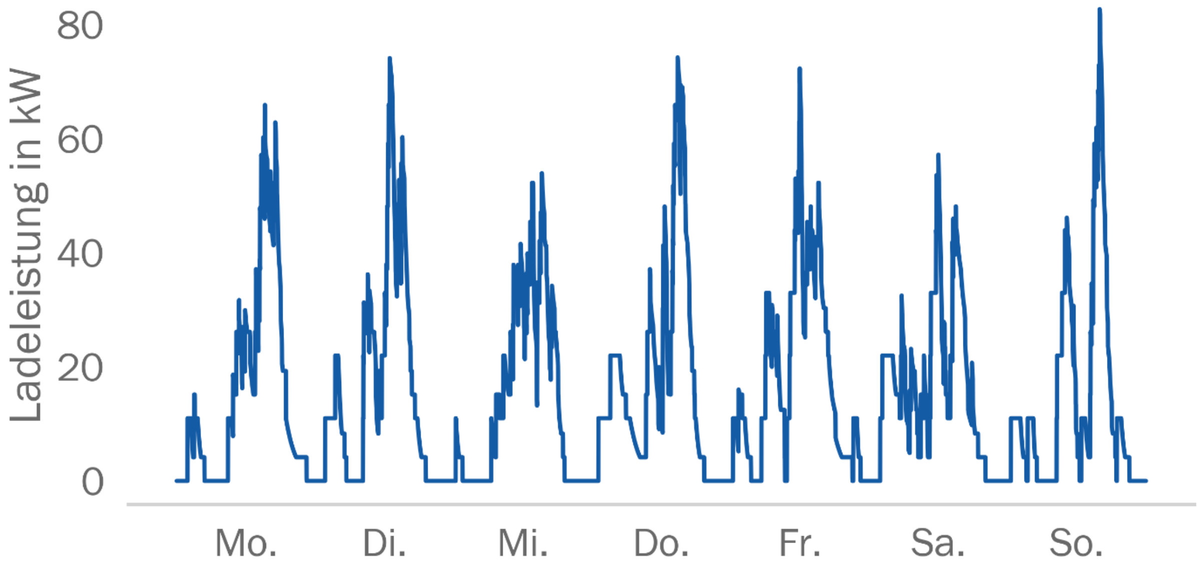
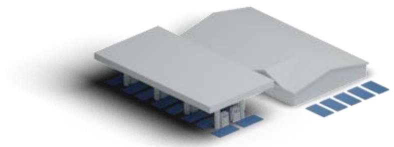
Comparison of Residential Building and Fast Charging Hub



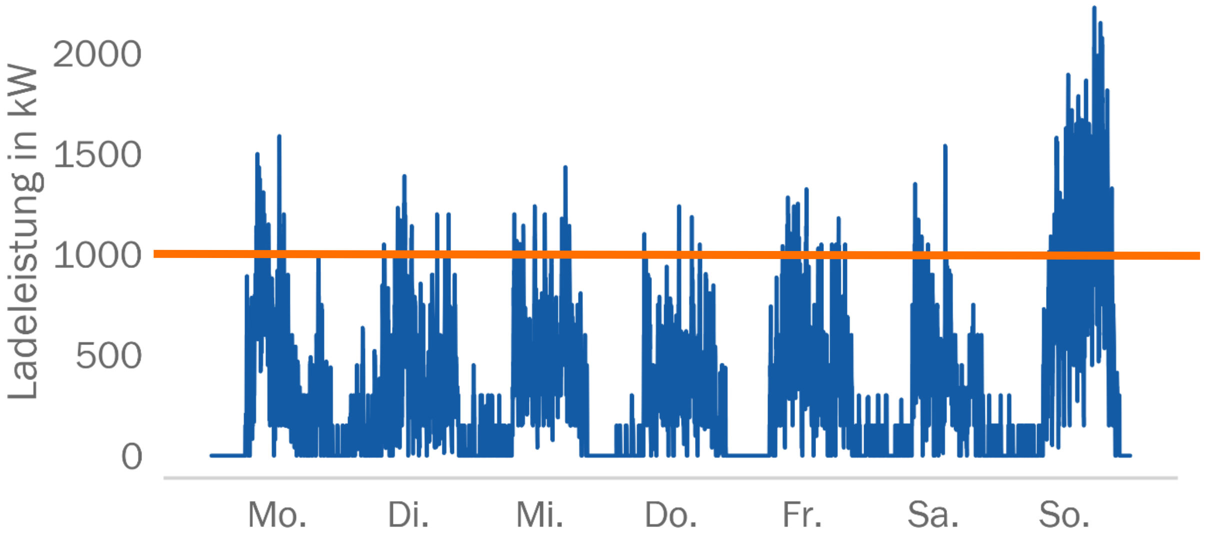
Residential Building



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



Fast Charging Hub



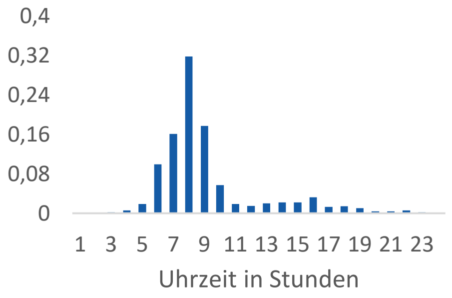
Annahmen	
Anzahl Ladepunkte	20
Ladeleistung	150 kW
Anzahl Ladeevents	125 je LP je Woche

Overview of Simulation Approach

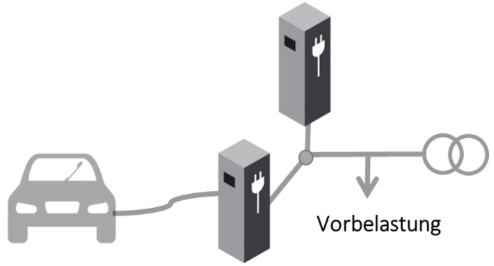
We use a stochastic, „bottom-up“ simulation of EV charging based on mobility scenarios to model expected impacts on the electric power grids and opportunities as distributed storage.

Assumptions

Mobility Behavior



Charging Infrastructure Configuration



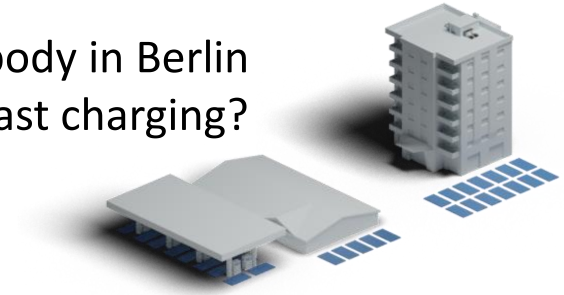
Simulation

elvis

electric vehicle infrastructure simulator

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?

pandapower

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

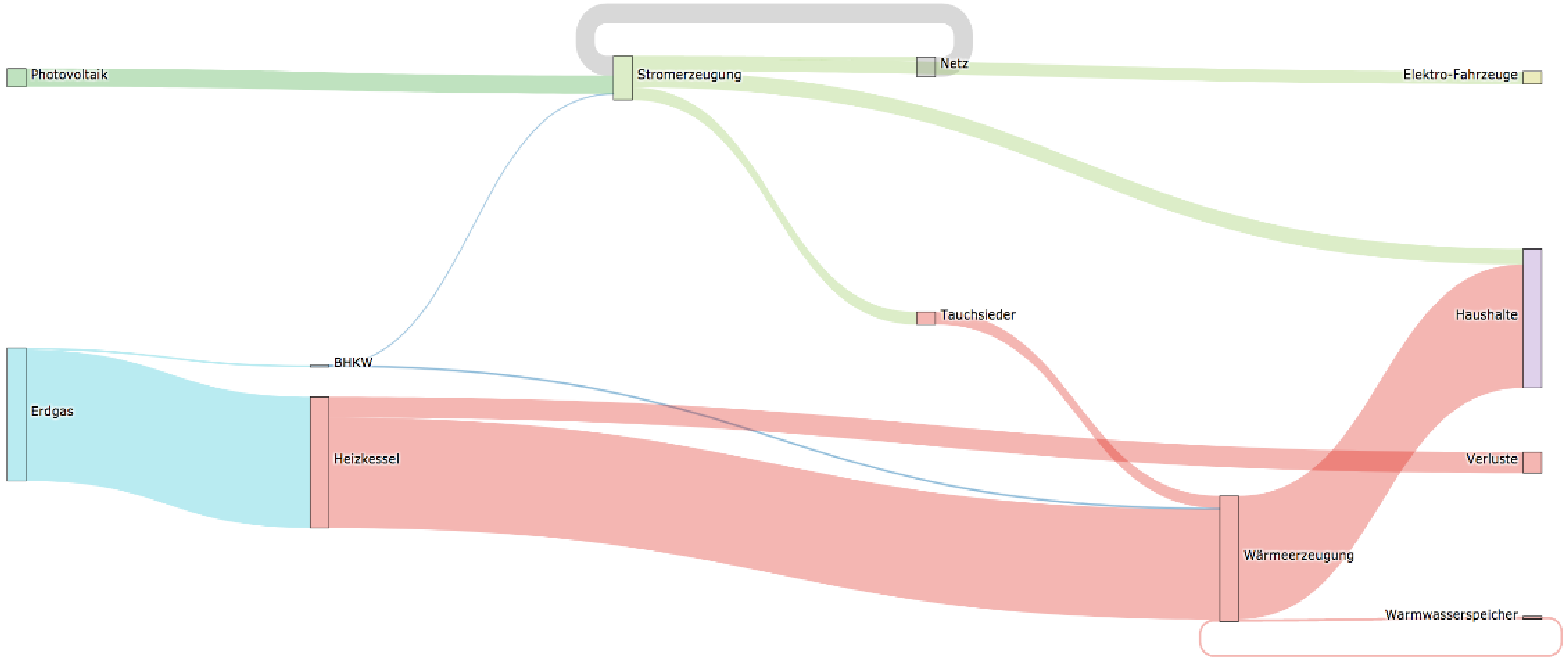
PYOMO

scikit learn

TensorFlow

Increasing self-consumption using electric vehicle batteries

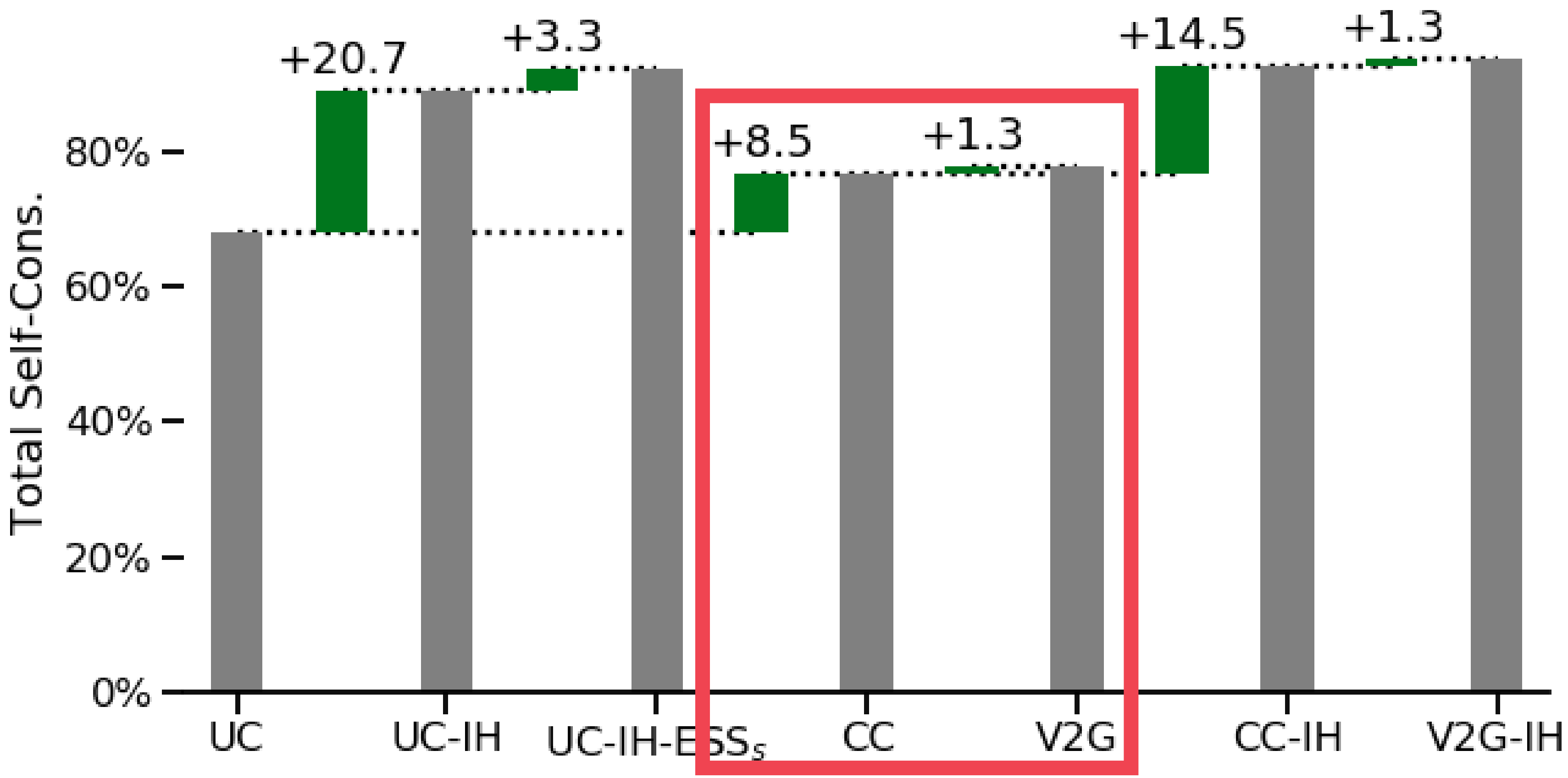
Sankey-Diagramm für den Energieaustausch

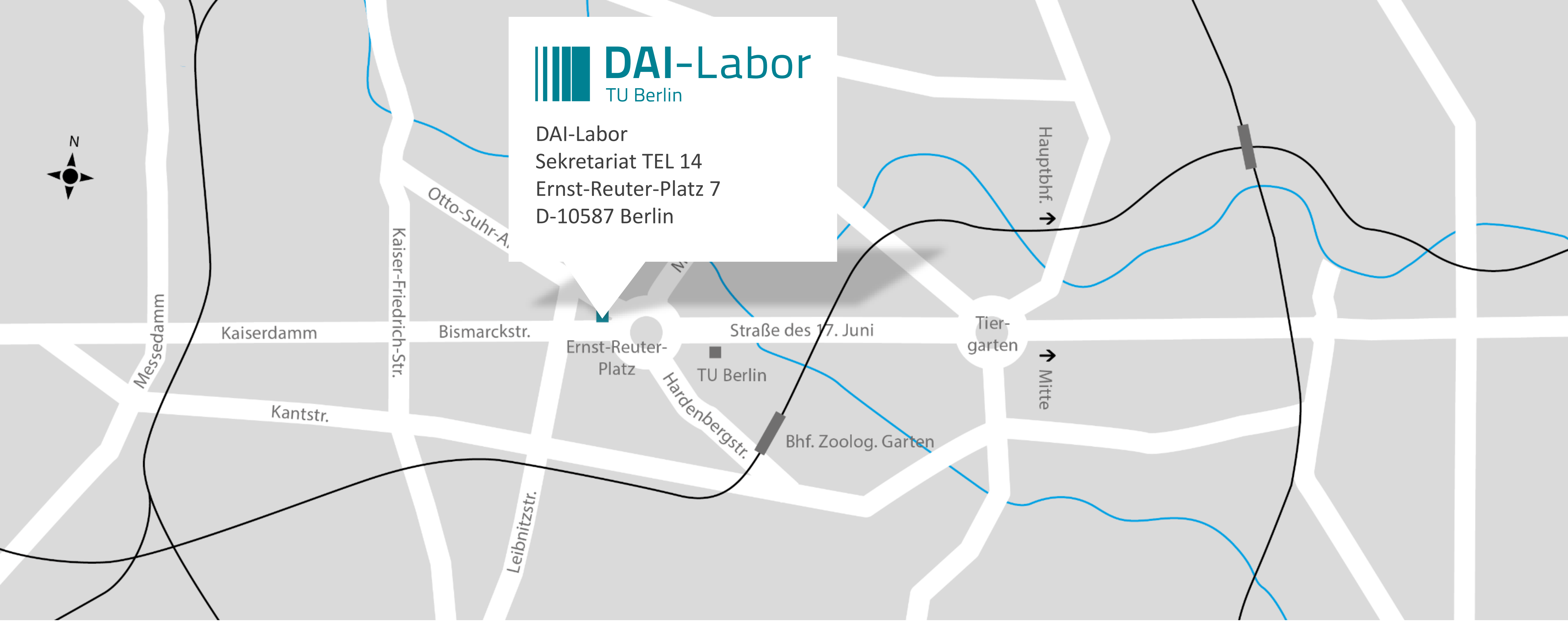


Increasing self-consumption using electric vehicle batteries

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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