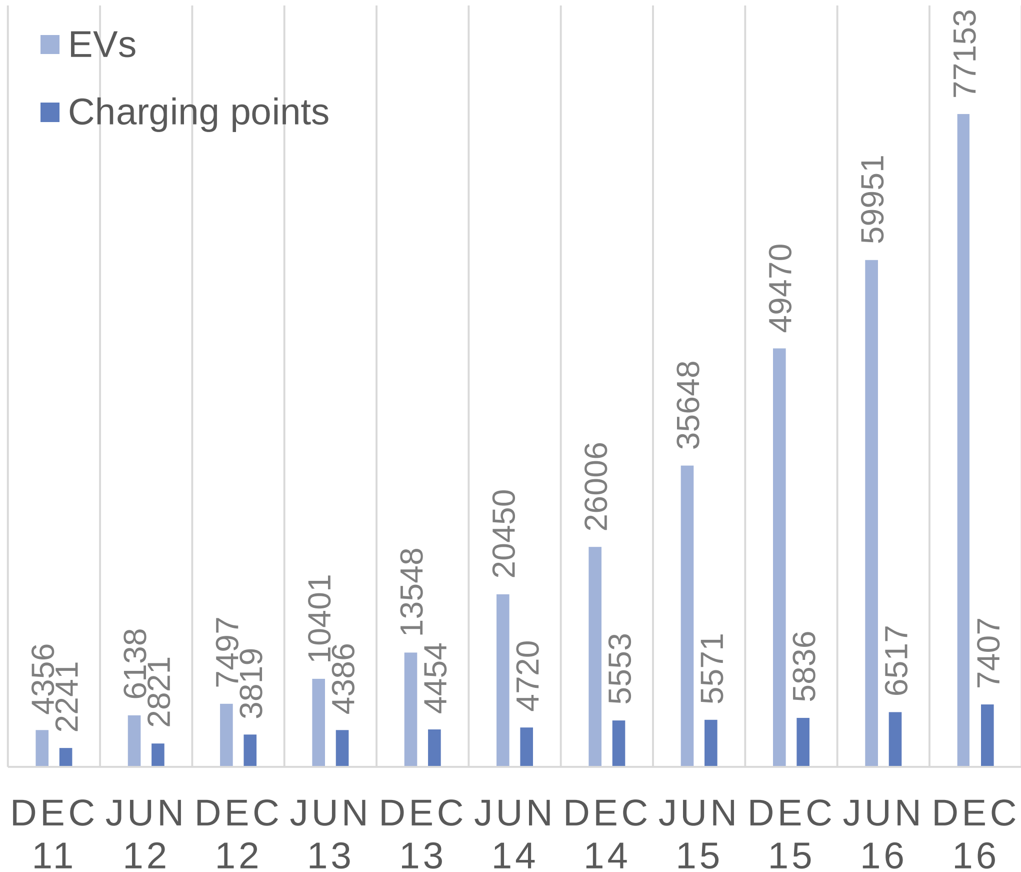
Determination of the integration and influencing potential of rapid-charging systems for electric vehicles in distribution grids

Marcel Kurth, M.Sc.

Introduction

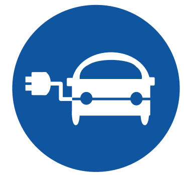
Motivation

Current development of EVs in Germany



1)

National goal



2020: 1 Mio. EVs

Charging infrastructure

Need for countrywide rapid charging infrastructure

1) BDEW, *Inquiry on charging Infrastructure*

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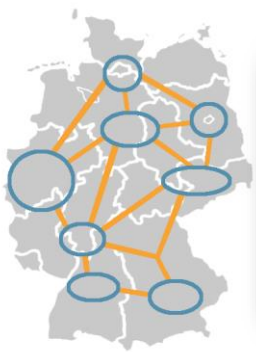
SLAM – Project goal



Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

SLAM

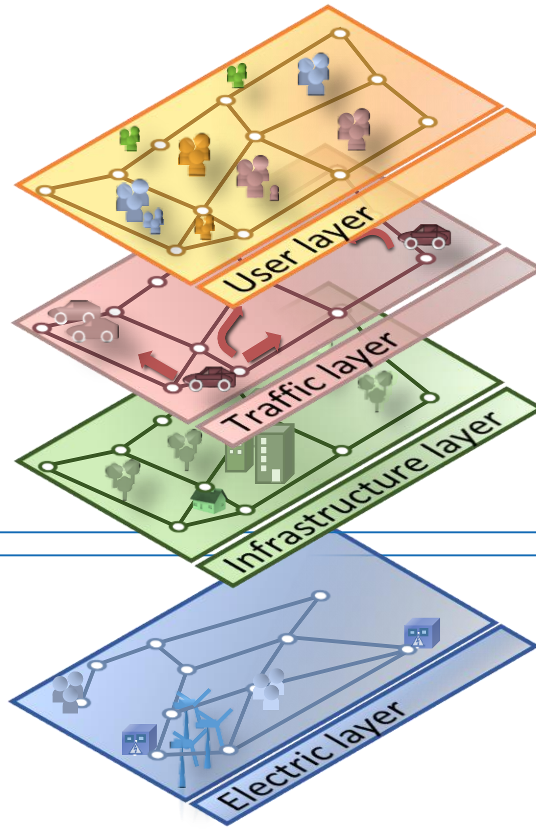
Schnellladenetz für Achsen und Metropolen

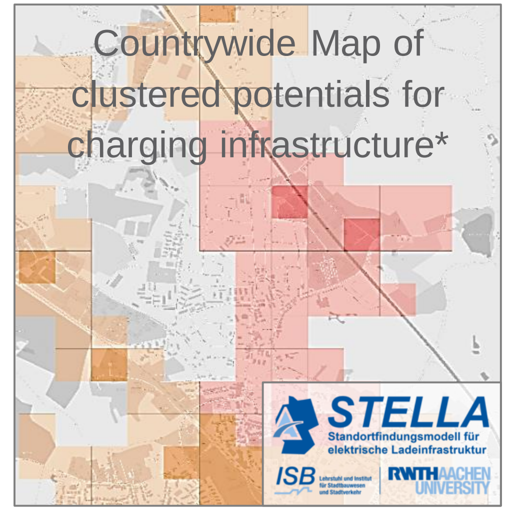
Countrywide rapid-charging station network for traffic axes and metropolitan areas in Germany

www.slam-projekt.de/

Multi-objective site assessment and selection model

Identification of suitable and sustainable locations for rapid-charging infrastructure





Determination of suitable sites for rapid-charging stations in distribution grids of Düsseldorf and Stuttgart

*http://www.isb.rwth-aachen.de/cms/ISB/Forschung/Projekte/~mdac/STELLA/

Agenda

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Methodology

Investigation scope and assumptions

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Methodology

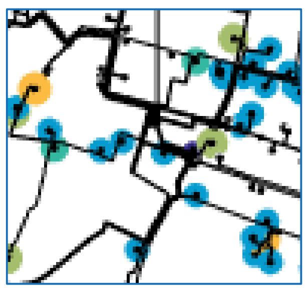
From grid data to potential maps

Preparation of grid data for power flow calculation

Initial worst case load assumption

- Drag indicators of MV/LV distribution transformer
- LV load modeling based on standard load profiles

Nodal integration and influencing potential

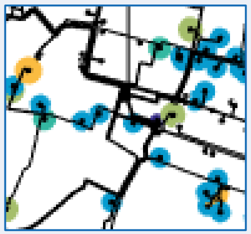
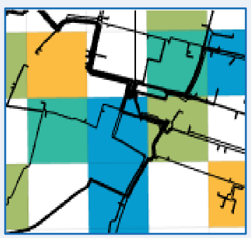


Clustered integration and influencing potential

Electric layer

Methodology

Integration and influencing potential

	Integration potential $IntP_i^0$	Influencing potential $InfP_i$
 Nodal potential	***What is the individual IntP at all gird connection points?*** $IntP_i^0$: maximum additional installable power to one node i considering ▪ Max. DT loading ▪ Max. cable loading ▪ Voltage constrains MV grid investigations: installation of rapid-charging station at LV busbar; considering DTs' apparent power	***Where in the grid are sites with sufficient IntP (e.g. >100 kW) and at the same time with small influence on the InfP of all other sites?*** Influencing potential of a rapid-charging station at node i ($InfP_i$) equals the sum of the integration potential reductions of all other (n-1) nodes $InfP_i = \sum_j IntP_j^0 - IntP_j^{new}, j \epsilon N \backslash i, N = [1 \dots n]$
 Clustered potential	***What is the max. installable charging power within a clustered square area?*** Clustered square area values equal the maximum IntP value of all nodes inside that area	***When searching for site with a certain IntP (e.g. > 100 kW), what is the lowest InfP within a clustered square area?*** Clustered square area values equal the minimum InfP value of all nodes inside the respective square area

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Investigation scope and assumptions

MV grid of South Düsseldorf

Grid data

- 18.8 km HV cable grid
- 2 HV/MV substations
- 234 km 10 kV and 25 kV MV cable grid
- 463 MV/LV distribution transformers (DT)

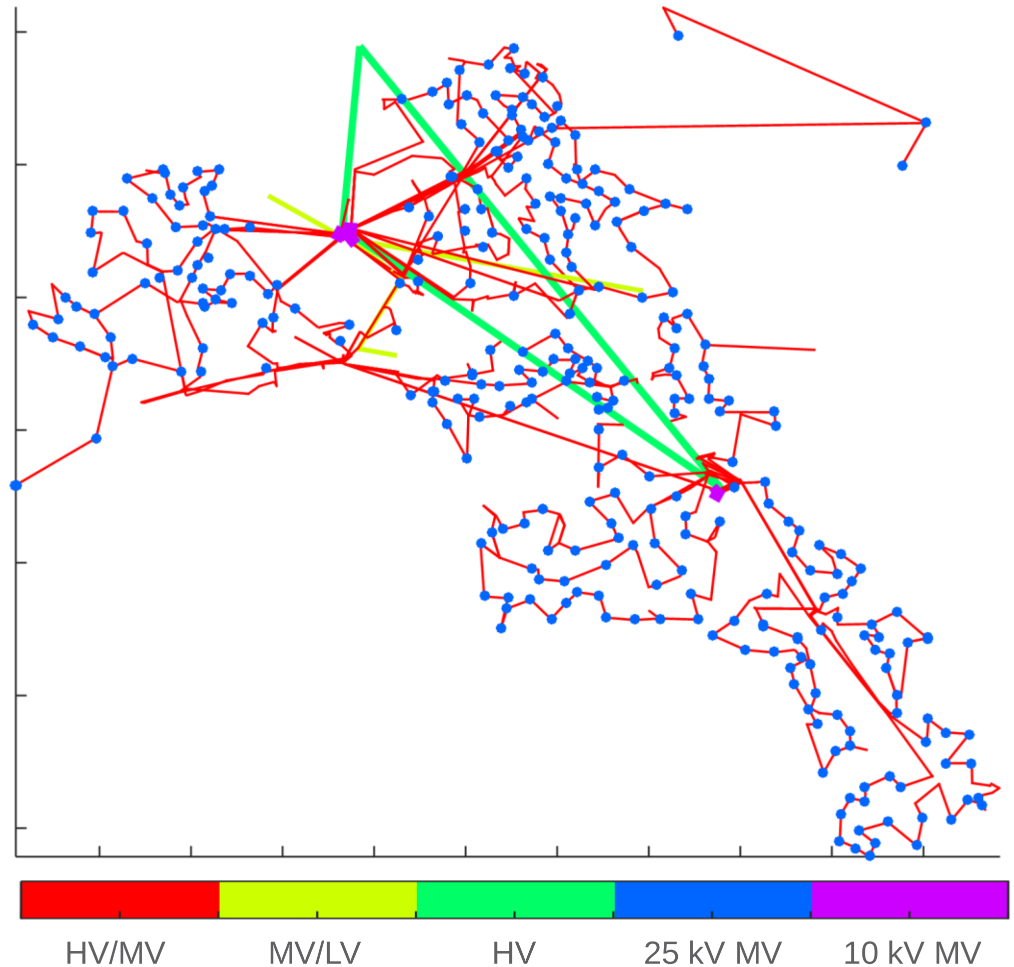
Load

- $\sum S_{DT,i} = 114\ MVA$

Constraints

- Max. Transformer loading: 100%
- Max. cable loading: 80%
- Voltage constrains:

Voltage level	U_{min}
110 kV	1.00 p.u.
25 kV	0.96 p.u.
10 kV	0.97 p.u.



Investigation scope and assumptions

MV grid of Stuttgart

Grid data

- 23 public HV/MV transformer substations (2150 MVA)
- 2,522 km 10 kV MV gird
- 2,239 DTs

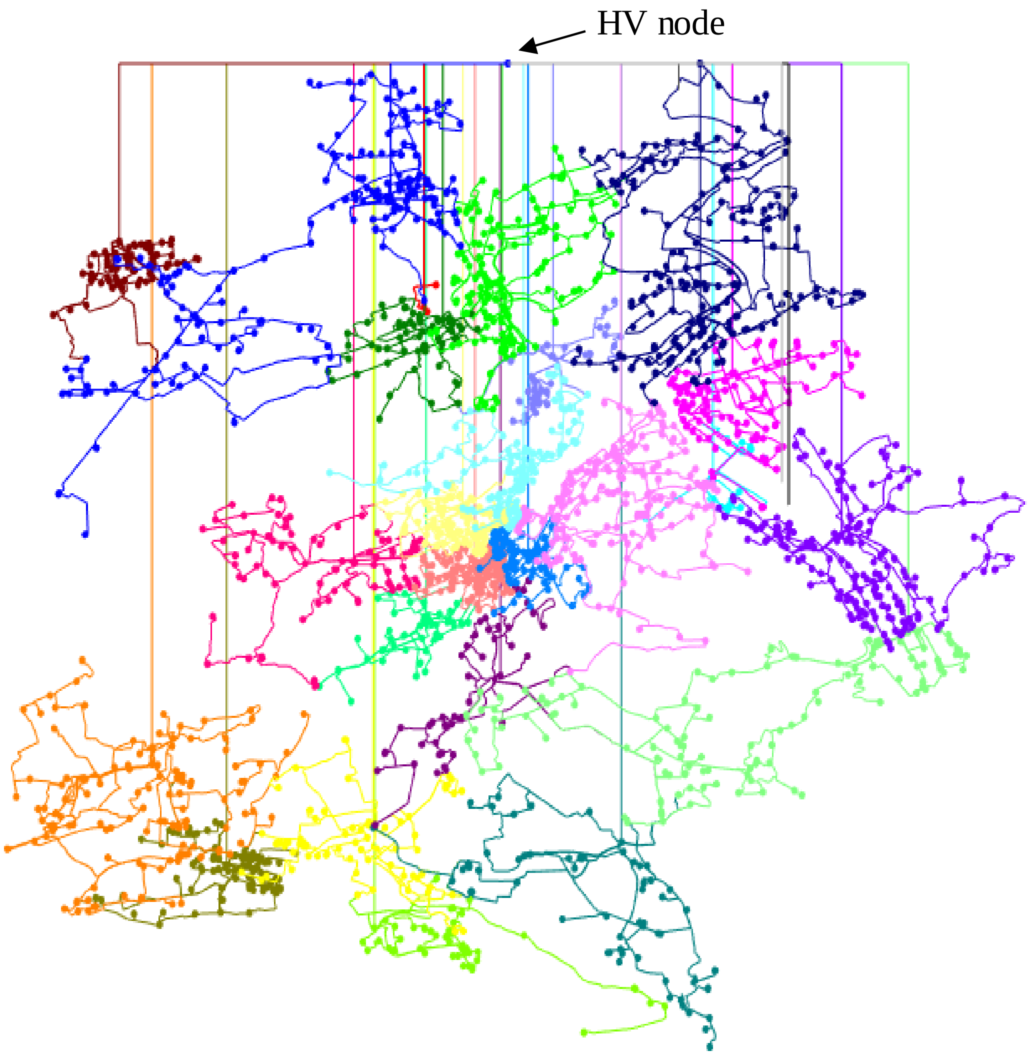
Load

- $S_{DT,i}$= *drag indicator value* OR $0.7 \cdot S_{DT,i}$
- $\sum S_{DT,i} = 974\ MVA$

Constraints

- Max. transformer loading: 100%
- Max. cable loading: 100%
- Voltage constrains:

Voltage level	U_{min}
110 kV	1.00 p.u.
10 kV	0.96 p.u.



Investigation scope and assumptions

LV grid of Stuttgart-Hausen

Grid data

- 3 separate LV grids
- DTs' apparent power: 2 x 800 kVA, 1 x 630 kVA
- 328 loads (mainly households)

Load

- $P_i = p_{SLP,max,i} \left[\frac{W}{Wh}\right] \cdot W_{annual,i}[kWh] \cdot CF$
- coincidence factor:

$$CF = \frac{\sum S_{DT,max}}{\sum p_{SLP,max,i} \cdot W_{annual,i}} \approx 74\%$$

- $P_i = 2.8 \; ... 24 \; kW, \sum P_i = 903 \; kW$

Constraints

- Max. transformer loading: 100%
- Max. cable loading: 100%
- Min. voltage limit: 0.9 p.u.

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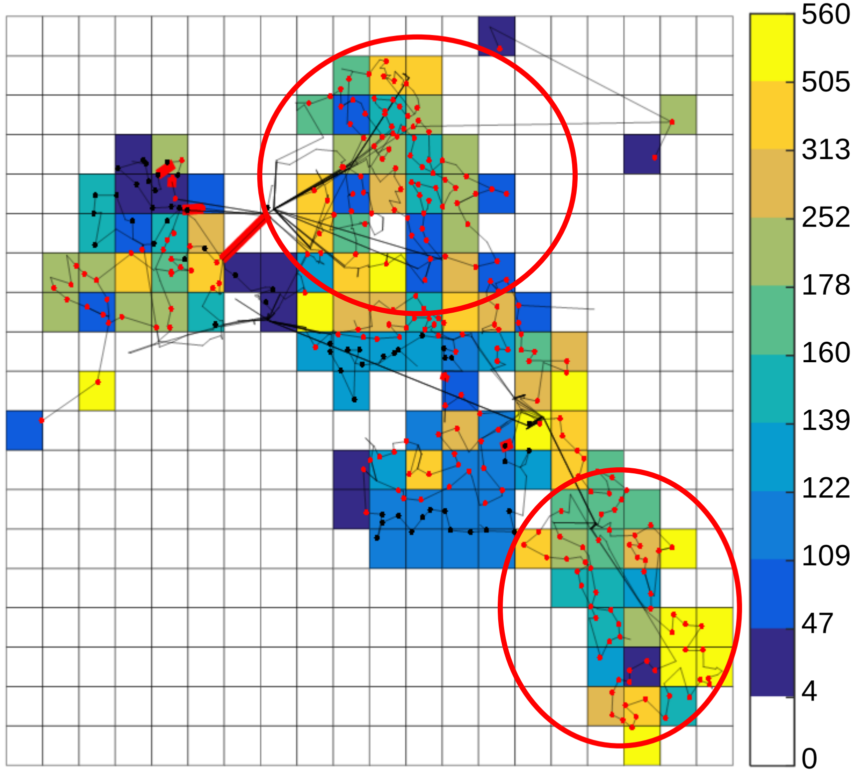
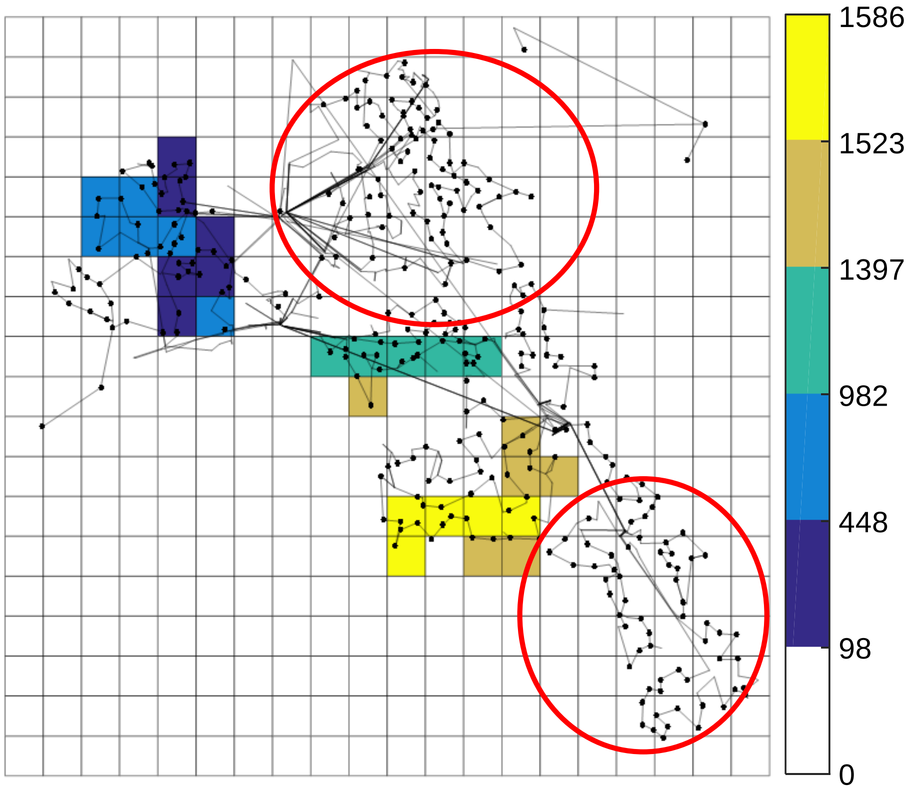
MV grid of South Düsseldorf

Integration potential [kW]



Influencing potential [kW]



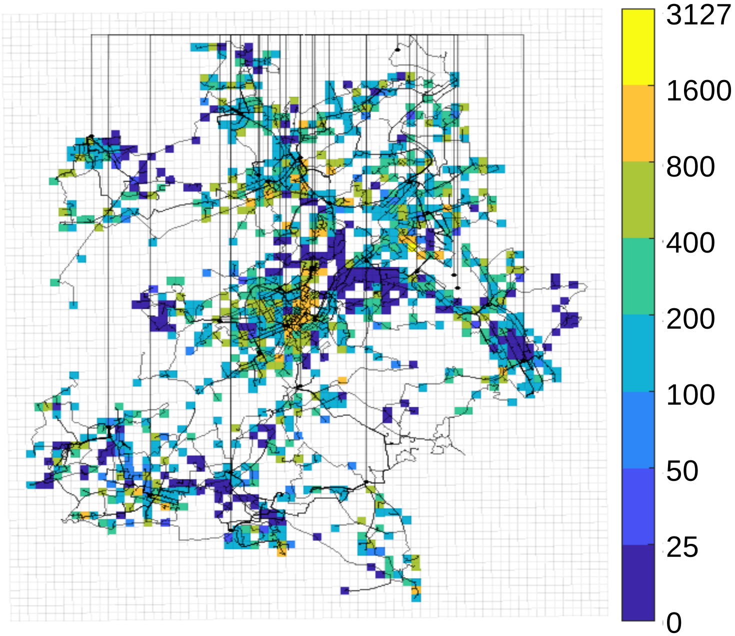
- IntP mainly limited by DT overloading
- Large parts of the grid have suitable sites for 100 kW rapid-charging stations (high IntP, small InfP)

Square area size: 400 m x 400 m

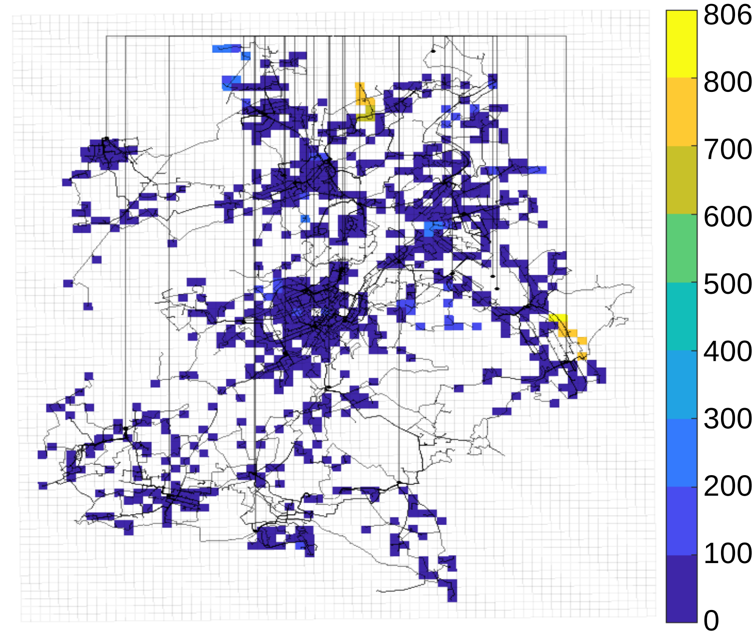
Results

MV grid of Stuttgart

Integration potential [kW]



Influencing potential [kW]



<table>
<tr><td rowspan="2">IntP</td><td>$0\ kW$</td><td>$0\ ...100\ kW$</td><td colspan="3">$\geq 100\ kW$</td></tr>
<tr><td>7.9%</td><td>28.2%</td><td colspan="3">63.9%</td></tr>
<tr><td rowspan="2">InfP</td><td colspan="2">$0\ kW$</td><td>$0\ kW$</td><td>$0\ ...100\ kW$</td><td>$\geq 100\ kW$</td></tr>
<tr><td colspan="2">36.1%</td><td>57.0%</td><td>2.4%</td><td>4.5%</td></tr>
</table>

- IntP mainly limited by DT overloading
- 59.4% of the DTs are suitable sites for 100 kW rapid-charging stations

Square area size: 250 m x 250 m

LV grid of Stuttgart-Hausen

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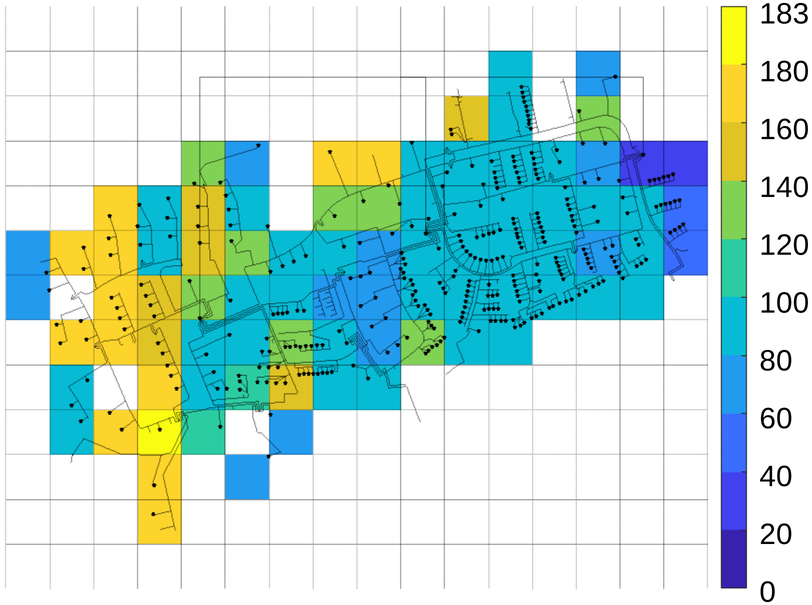
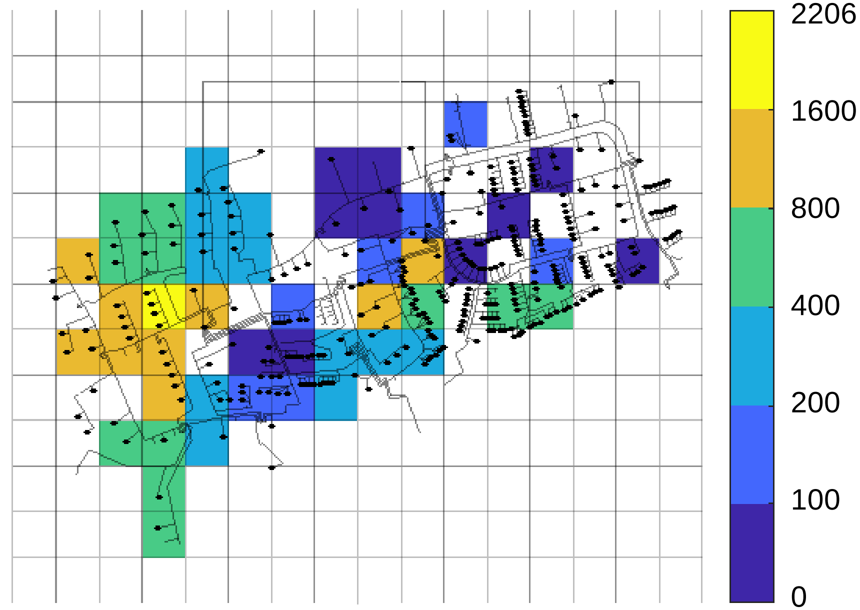
Integration potential [kW]



Influencing potential [kW]



<table>
<tr><td rowspan="2">IntP</td><td>$0\ kW$</td><td>$0\ ...100\ kW$</td><td colspan="3">$\geq 100\ kW$</td></tr>
<tr><td>0%</td><td>61.0%</td><td colspan="3">39.0%</td></tr>
<tr><td rowspan="2">InfP</td><td colspan="2">$0\ kW$</td><td>$0\ kW$</td><td>$0\ ...100\ kW$</td><td>$\geq 100\ kW$</td></tr>
<tr><td colspan="2">61.0%</td><td>0.9%</td><td>3.4%</td><td>34.8%</td></tr>
</table>

- IntP mainly limited by house connection cables
- 4.3% of the builings are suitable for 100 kW rapid-charging stations

Square area size: 50 m x 50 m

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Results – MV grid of Düsseldorf and Stuttgart

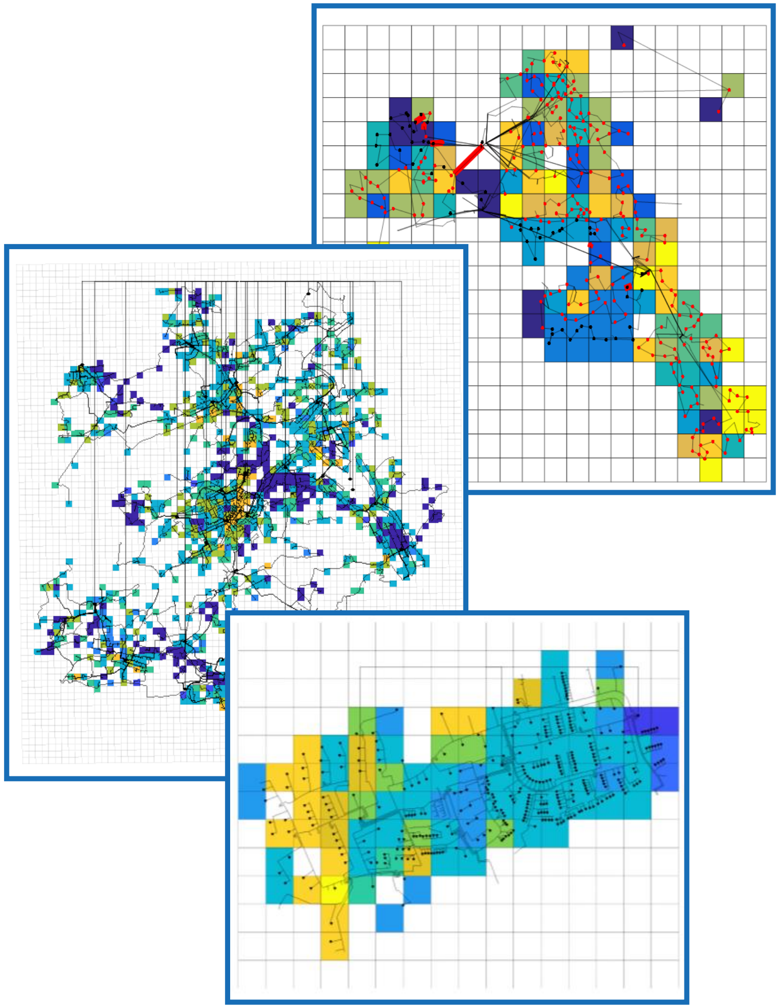
- Large number of suitable sites for 100 kW rapid-charging stations despite a worst-case load modelling assumption
- Main limiting factor for integration potential in case of installation at the DT's busbar: DTs' apparent power

Results – LV grid of Stuttgart-Hausen

- Connection cables of most households and buildings not suitable for 100 kW rapid-charging stations
- Rare suitable sites for 100 kW rapid-charging stations (4.3%)

Next steps

- Electric layer has to be added to the multi-objective assessment model
- Further investigations for the integration of home charging systems (11 kW) into LV girds



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Thank you for your attention

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