Foto: Martin Braun

IFHT Institute for High Voltage Technology
RWTH AACHEN UNIVERSITY

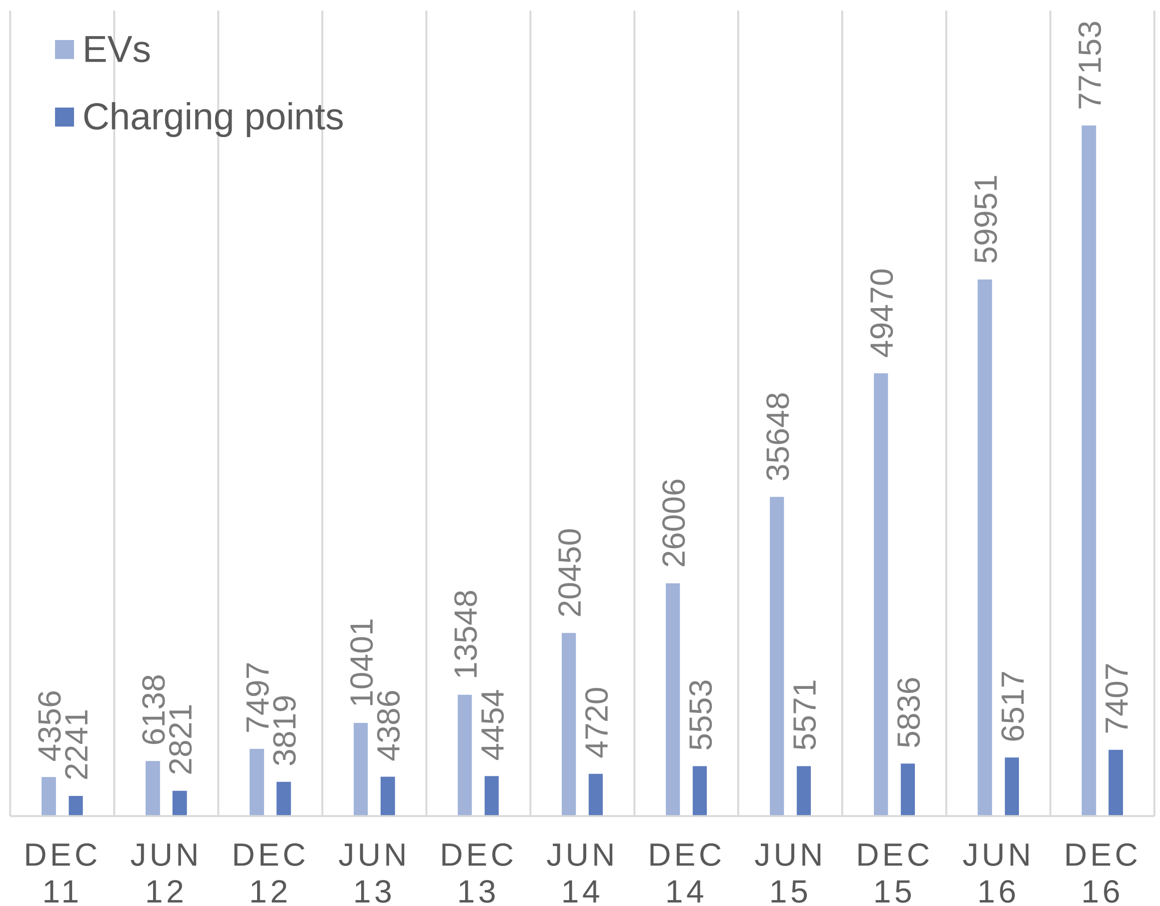
Development of rapid-charging infrastructure for electric vehicles in Germany

Marcel Kurth, M.Sc.

Rapid-charging infrastructure

National goal

Current status



National Goal

2020

1 Mio. EVs

charging systems

70,000 AC
7,100 DC

Source: BDEW-inquiry on charging Infrastructure (BDEW-Erhebung Ladeinfrastruktur); Number of automobile registrations: KBA/ VDA

Agenda

- Institute for High Voltage Technology at RWTH Aachen University
- Goal of SLAM
- Simulation tools at RWTH Aachen University
- Lessons learned
- Outlook and current reseach questions

44.517 Students

154 Subjects

540 Professorships

2.175 Research assistants

1.976 Non-scientific personel

3 Excellence clusters

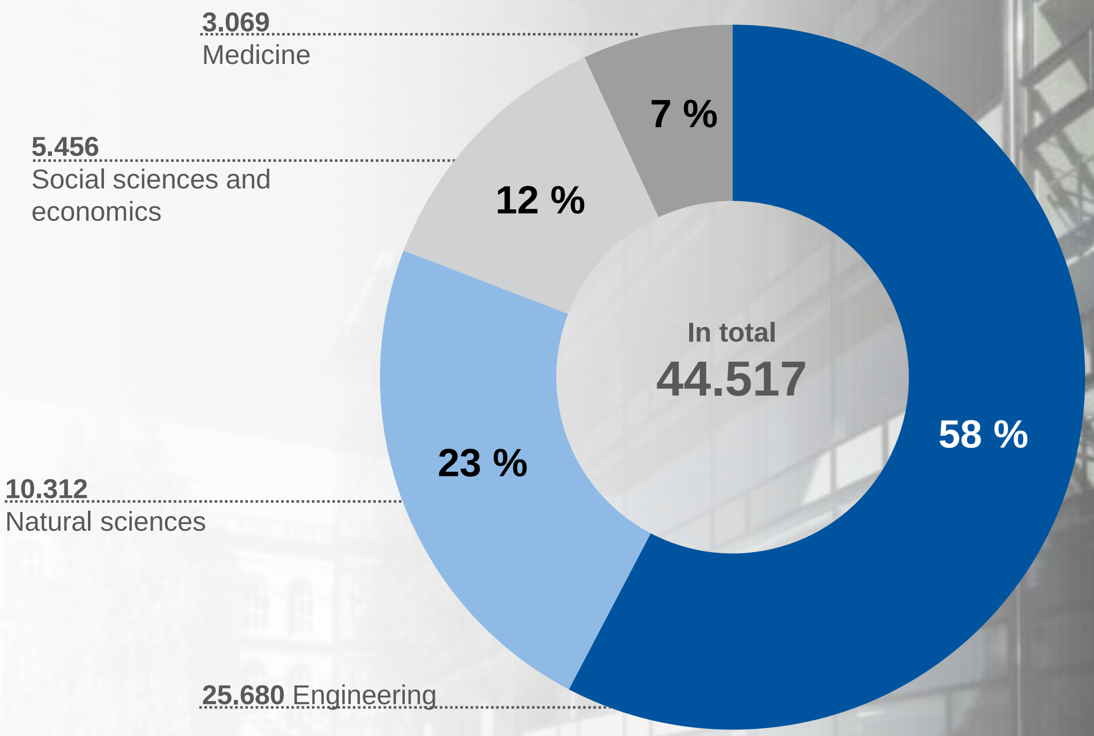
29 Graduate programs

14 Special research areas

15 Affiliated institutes

5 Fraunhofer institutes

900 Mio. Euro financial volume



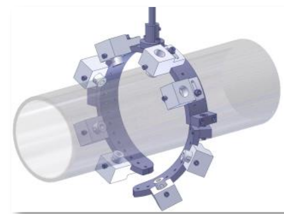
Status: May 2017

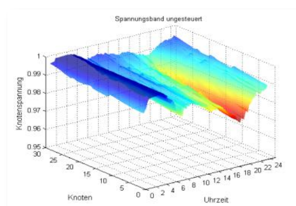
ca. 300
Researchers

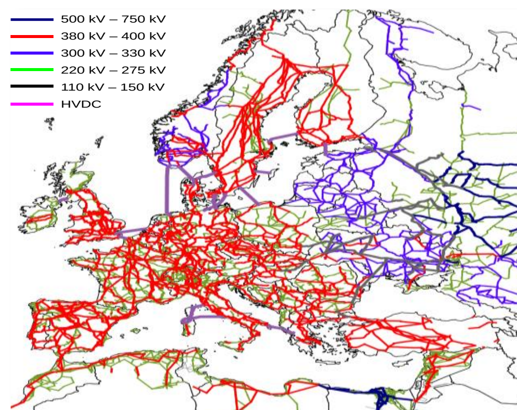
Power
Engineering
Aachen

Competence

„Largest energy research cluster in Europe“







ca. 85
Employees

High Voltage
Technology
Aachen

4 Departments

„From the materials, to the components to the system“

Institute for High Voltage Technology

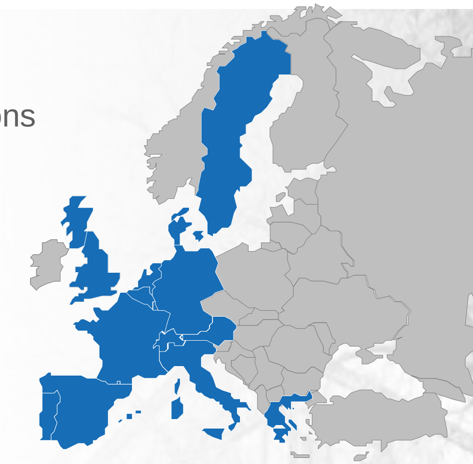
In Numbers – Projects

Over **50** research projects

- Research cooperation
- Basic & accompanying research

International activities

- International cooperations
- International projects
- EU research



Over **25** service projects

- Asset- & material testing
- Scenario analyses
- Grid studies

More than **85** employees

- 65 scientific staff
- 18 non-scientific staff
- 3 honorary staff (teaching staff)

Over **€ 6.1 million** of third-party funds

- € 3.7 million public research
- € 1.8 million contract research
- € 0.6 million services

Over **90** student employees

- Supervision of scientific experiments
- Preparation of data

Map: project locations over the last 3 years; status: 2017

Institute for High Voltage Technology

In Numbers – Teaching

13 Lectures

- High-Voltage topics
- Power engineering components
- High-voltage direct-current transmission
- Cross-cutting issues

Over **750** Practical courses

- Basic electrical engineering
- Power engineering courses
- Power engineering seminars

166 Final theses

- Bachelor and Master thesis
- Wide range of topics
- Links to existing projects

source: Mario Irrmischer

source: Martin Braun

Status: 2017

Institute for High Voltage Technology

In Numbers – Labs & Equipment

Center for grid integration and storage technologies

- 3,000 m² laboratory with power rating of more than 4 MW
- Configurable distribution grid (10 kV / 0.4 kV) with field assets as well as information and communication technology and control room
- Current research fields: grid integration, e-Mobility, IT-Security, …

Labs & test stands

- High-voltage laboratory
- Medium-voltage laboratory
- Circuit breaker laboratory
- Partial discharge laboratory
- Insulation material laboratory
- Climate test stands

Quelle: Martin Braun

High performance calculator for fast parallel simulation calculations

- 500 own cores with 4.5 TB working memory in the high-performance computers of the RWTH Aachen IT Center
- IFHT server for 70 core kernel development and 768 GB of memory

Institute for High Voltage Technology

Organigram

Deputy Director of Institute
Dr. Regina Oertel

Director of Institute
Prof. Dr. Armin Schnettler

Deputy Director of Institute
Dr. Ralf Puffer

Finance *Norbert Horndt*	**Head of Department** *Dr. Michael Andres*	**Head of Department** *Dr. Sebastian Wetzeler*	**Head of Department** *Moritz Mittelstaedt*	**Head of Department** *Felix Glinka*
Infrastructure	**Electrical Equipment and Diagnostics**	**Switchgear and DC Technologies**	**Sustainable transmission systems**	**Sustainable distribution systems**
Human Resources *Dr. Regina Oertel*	**Cables, Overhead Lines and Insulation Systems** *Tobias Frehn*	**DC Control and Protection** *Cora Petino*	**Stationary Grid Analysis and System Assessment** *Christoph Müller*	**Distributed Energy Systems** *Tobias Falke*
Controlling *Norbert Horndt*	**Components and Secondary Equipment** *Pascal Köhn*	**AC and DC Switchgear** *Michael Weuffel*	**System Stability** *Janek Massmann*	**Grid planning and Operation** *Moritz Cramer*
Test Center/ Services *Dr. Michael Andres*				**Protection and Stability** *Philipp Erlinghagen*

Status: April 2017

Agenda

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SLAM

Schnellladenetz für Achsen und Metropolen

Rapid-Charging Network for Traffic Axes
and Metropolitan Areas

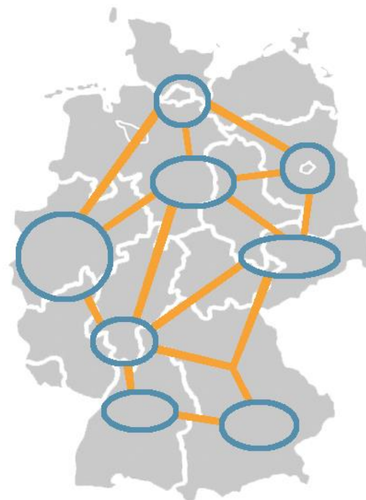
Jan. 2014 - Aug. 2017

www.slam-project.de

Supported by:

Federa Ministry
for Economic Affairs
and Energy

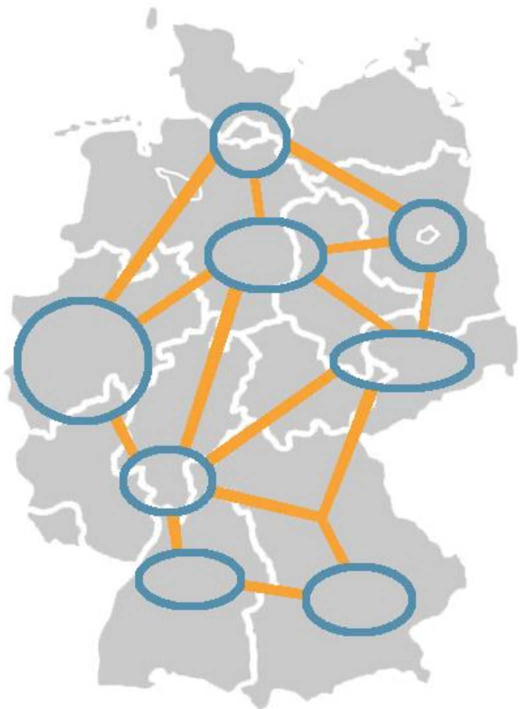
on the basis of a decision
by the German Bundestag



SLAM

Goals

Goals



Integration of a country-wide rapid-charging network

Development of a simulation tool for the potential analysis of sites for rapid-charging stations

Unification of interfaces for authentication and billing

Analysis and development of business cases

Conformance tests of electric vehicles with charging stations

RTWH Aachen University

Agenda

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SLAM

Simulation tools

STELLA site selection modell for electric charging infrastructure | ISB Lehrstuhl und Institut für Stadtbauwesen und Stadtverkehr | RWTH AACHEN UNIVERSITY

User layer

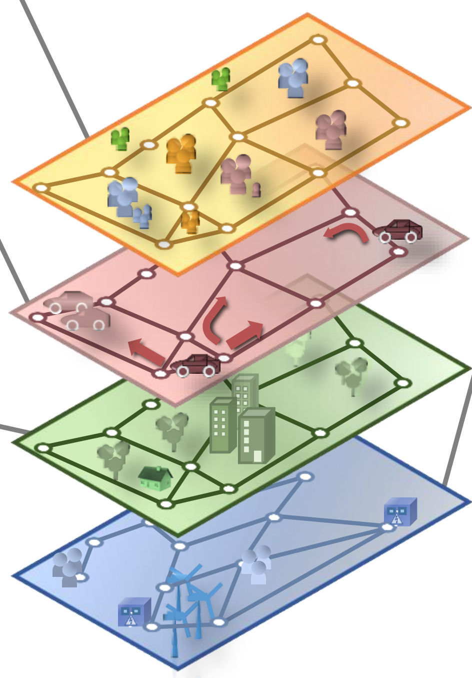
- Local user's demand
- Local density of EVs
- Local EV forecasts

Traffic layer

- Traffic grid / nodes
- Traffic

Infrastructure layer

- Settlement structures
- Existing charging infrastructure from other/earlier projects
- Points of interest



IFHT Institute for High Voltage Technology | RWTH AACHEN UNIVERSITY

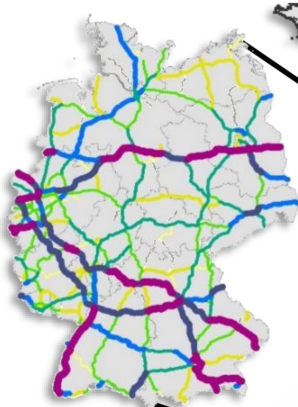
Electrical layer

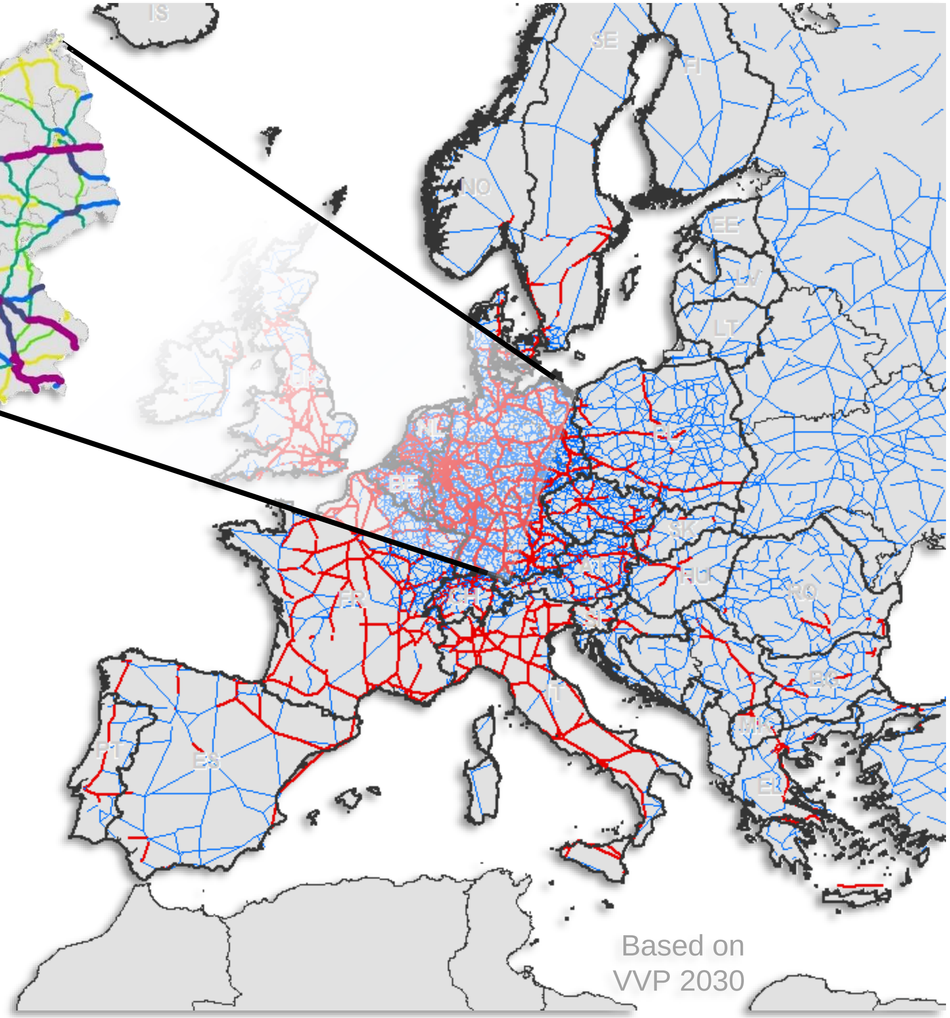
- Integration potential of rapid-charging stations in distribution girds
- Influencing potential of rapid-charging stations in distribution grids

STELLA

Transport network

Traffic layer





- Germany is a transit country
- Traffic modelling of Germany
- Traffic data covers all of Europe and is increasingly simplified the further away it is from Germany
- Axes are linked with international traffic
- Consideration of international connections and traffic

ISB – Institute of Urban and Transport Planning

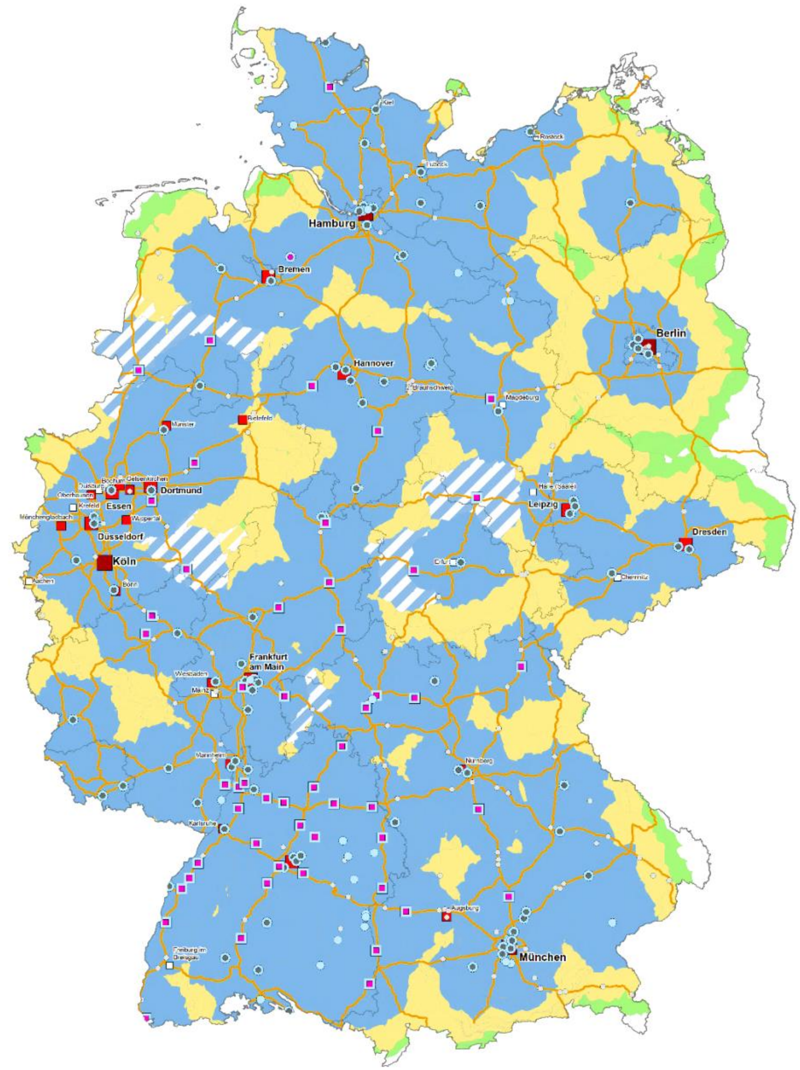
STELLA

Accessibility analysis

Infrastructure layer

- Accessibility radii from existing rapid-charging stations
- High potential for rapid-charging infrastructure at high way sites in the yellow and green area
- Resolution: Urban quarter

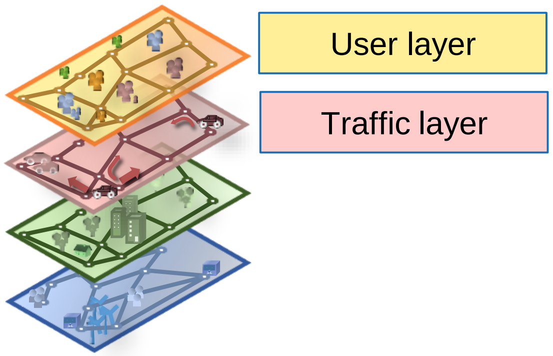
100 km
80 km
50 km



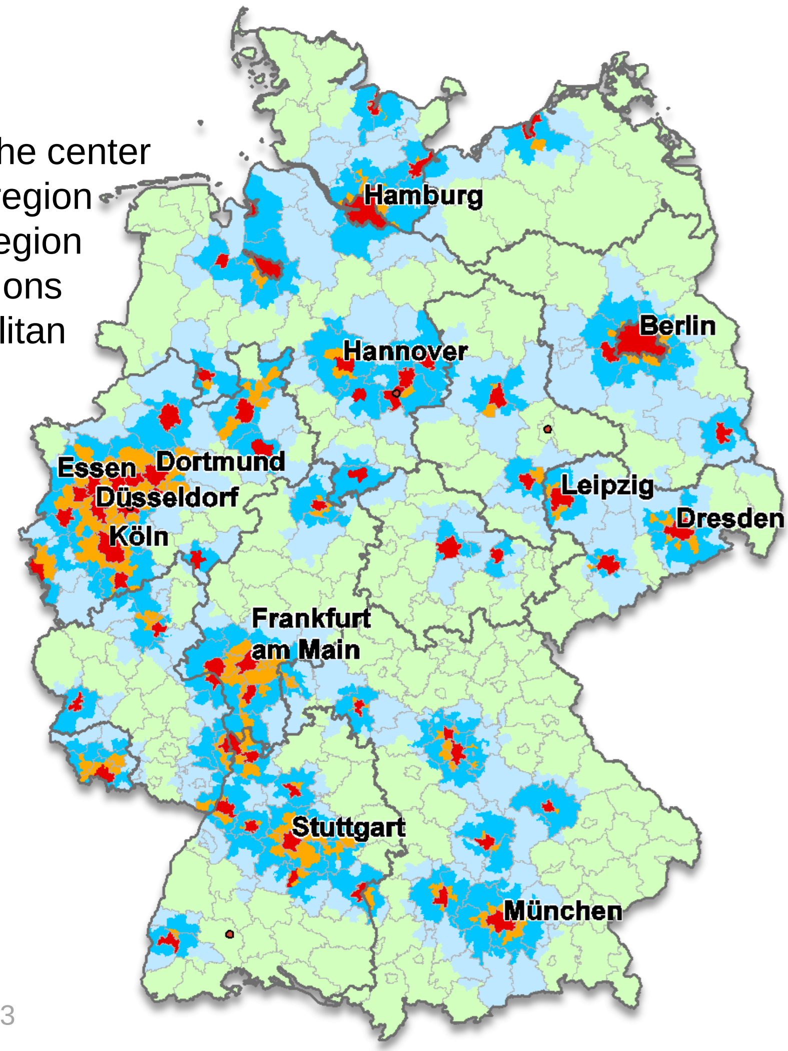
ISB – Institute of Urban and Transport Planning

STELLA

Spatial distribution



- Center
- Area surrounding the center
- Closer connected region
- Wider connected region
- Municipal associations outside of metropolitan areas



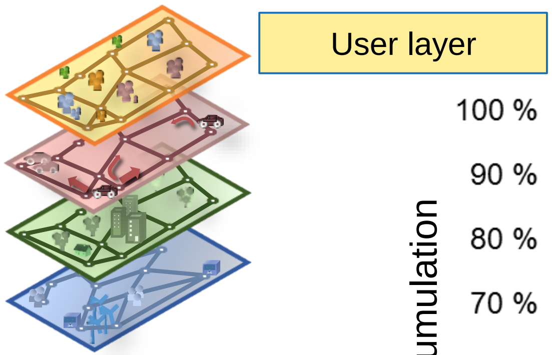
- Commuting towards centers
- Connection between the municipal associations
- Linkages independently from administrative boundaries
- Municipality resolution

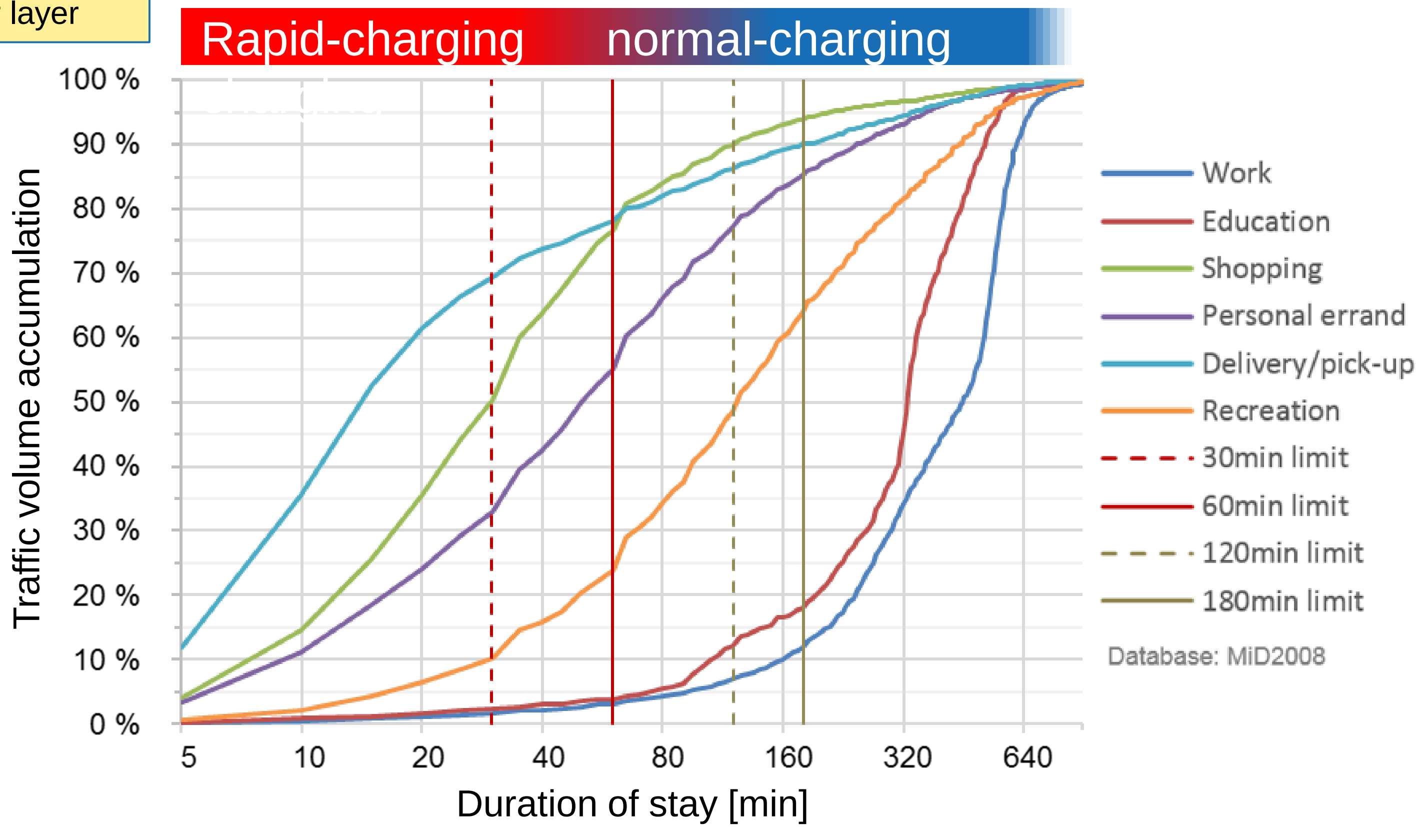
Database: continuous spatial monitoring by the BBSR
Geometrical Basis: BKG, municipal associations/ urban-rural-regions 31. Dec 2013
Editing: P. Kuhlmann

ISB – Institute of Urban and Transport Planning

STELLA

Duration of stay





High potential for …

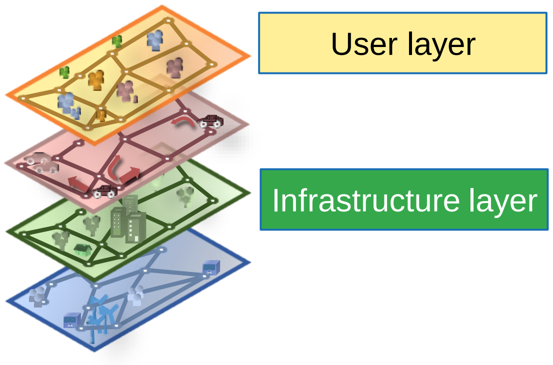
… Rapid-charging stations at shopping facilities and train stations (pick-up)

… normal-charging stations at workplaces, education facilities and recreation locations

ISB – Institute of Urban and Transport Planning

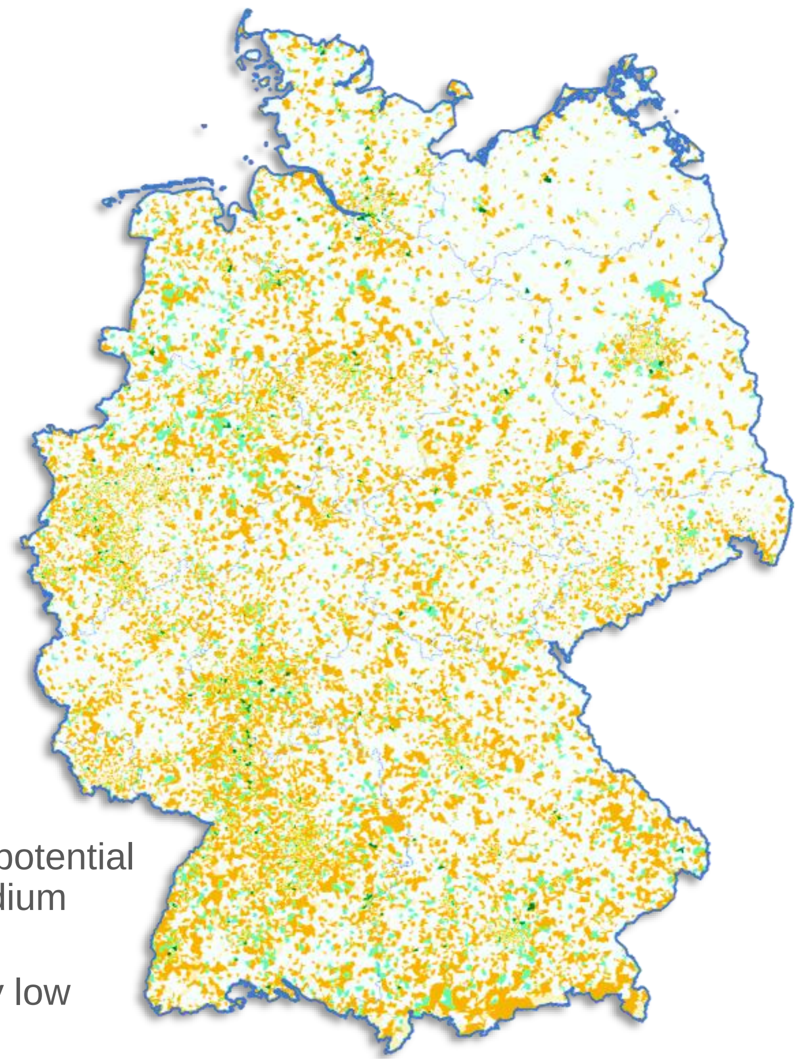
STELLA

Settlement structure



- Analysis of population structure accounts **local demand**
- Analysis of quarter type accounts **local offers**
- potentials for charging infrastructure at existing developed areas

high potential	medium potential
very high	medium
high	low
medium	very low



ISB – Institute of Urban and Transport Planning

STELLA

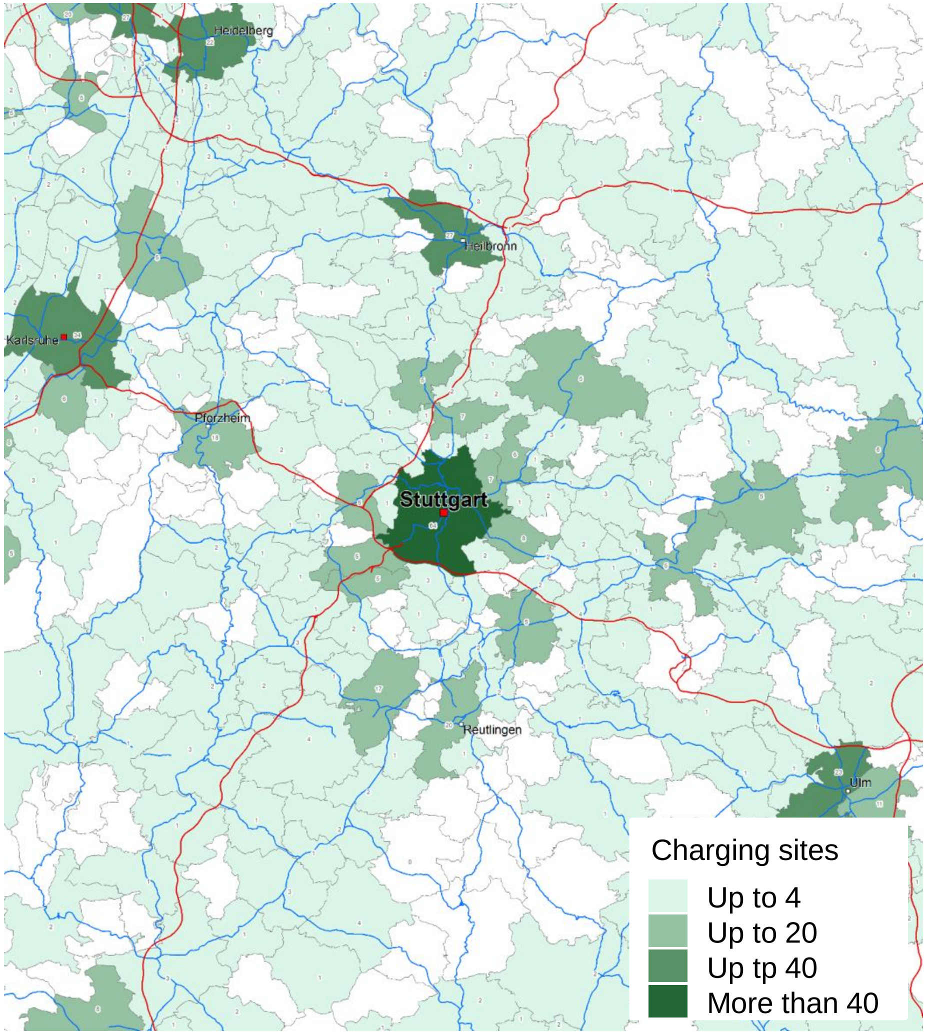
Potential forecast

User layer

Traffic layer

Infrastructure layer

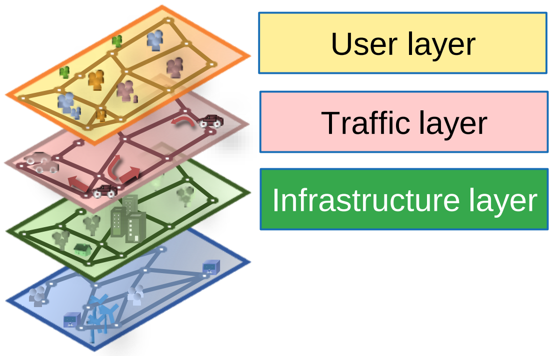
- Number rapid-charging points
- 1 Mio EVs in 2020 based on settlements
- Resolution: municipal



Map basis:
BKG; BVWP; BASt; DDS; OSM
Bundesverflechtungsprognose;
Projekt SLAM; GoingElectric;
RWTH Aachen University

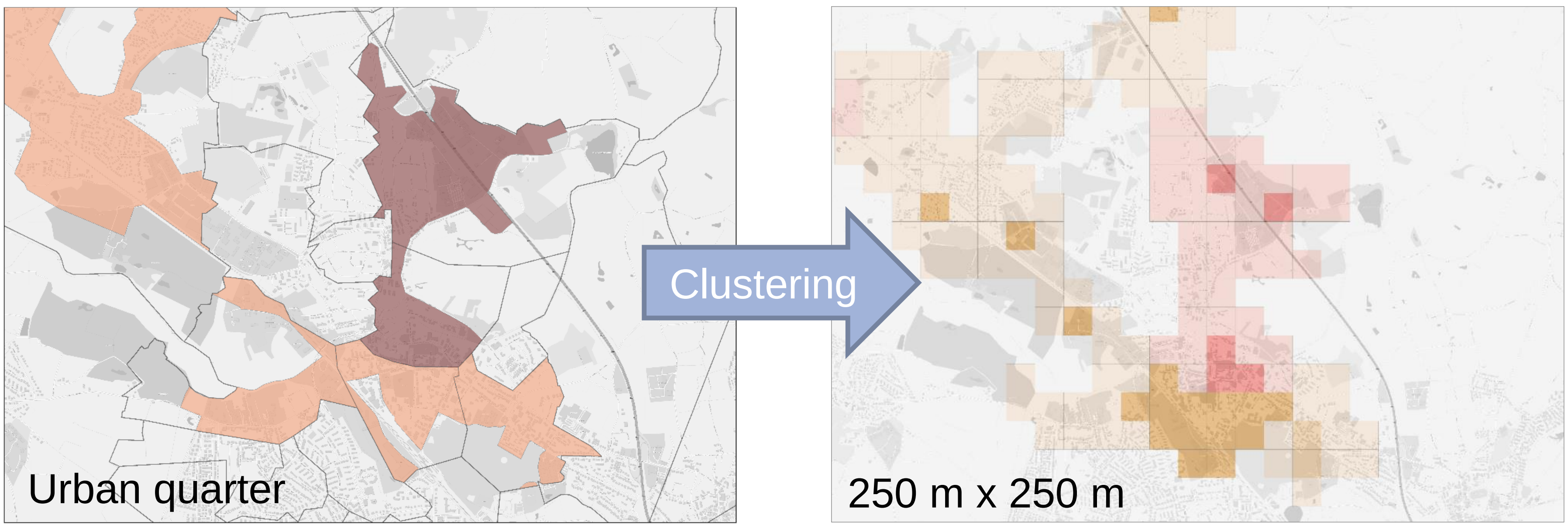
ISB – Institute of Urban and Transport Planning

Disaggregation and clustering



high potential
- very high
- high
- medium

medium potential
- medium
- low
- very low



ISB – Institute of Urban and Transport Planning

STELLA

Simulation tools

STELLA
site selection modell for
electric charging infrastructure

SLAM
WEBTOOL

STELLA	WebTool

Expert tool

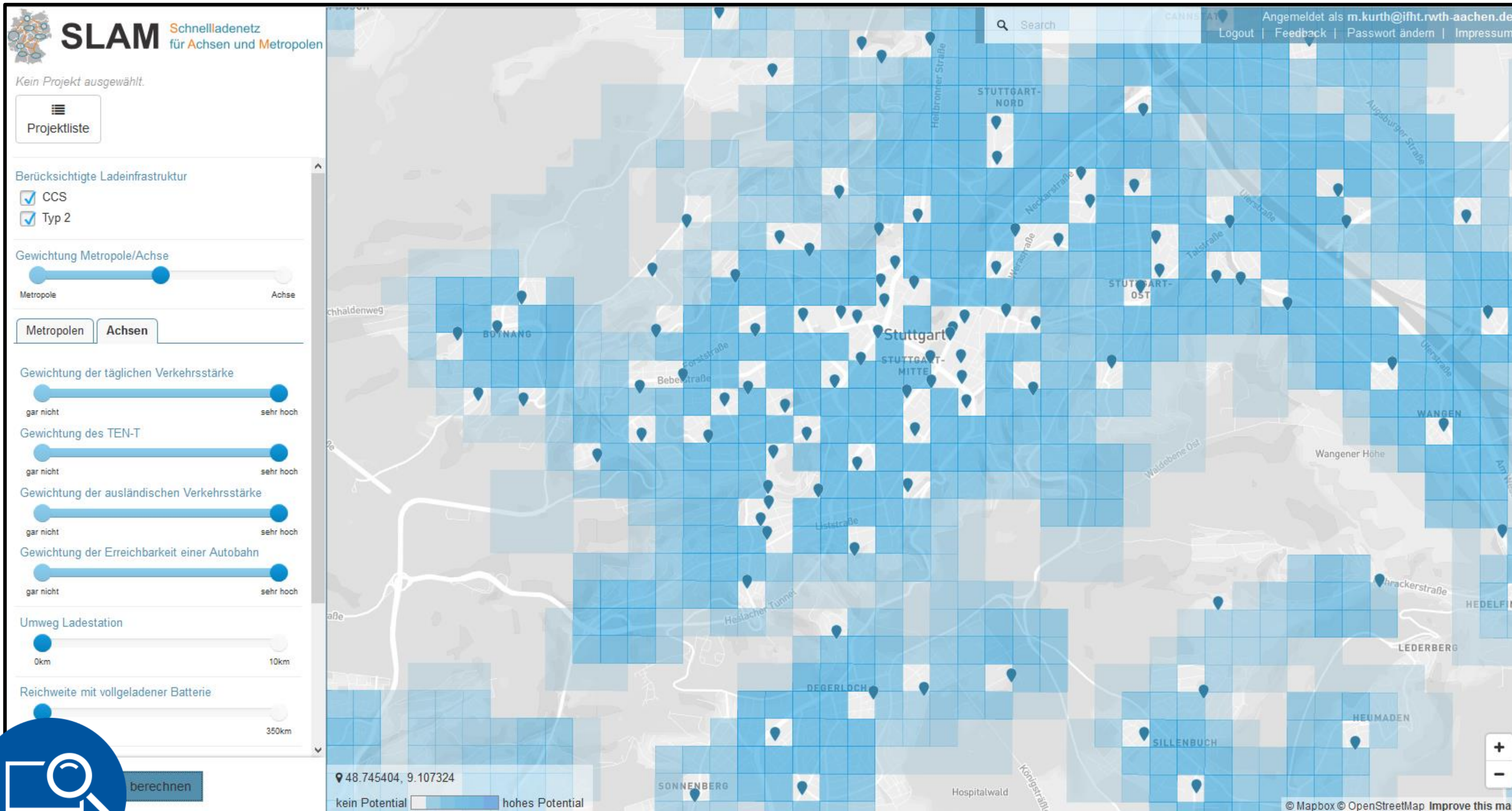
- Variety of indicators
- Individual parameterize of values
- Creation of individual scenarios
- Detailed location assessment with quantification of the charging points

WebTool

- Optimized for fast calculation
- Management of LIS building projects
- Integration of individually compiled scenarios from the holistic modell
- Planning tool
- Content Management System

SLAM

WebTool



https://webtool.slam-projekt.de/main

ISB – Institute of Urban and Transport Planning, IKA – Institute for Automotive Engineering

Distribution grid analysis

Electrical layer

- Identification of suitable sites for rapid-charging stations
- Use case study: Medium voltage grid of the city of Stuttgart

Grid and load modelling → Calculation of integration potential → Calculation of influencing potential → Generation of potential maps

Distribution grid analysis

City of Stuttgart – Grid and load modelling

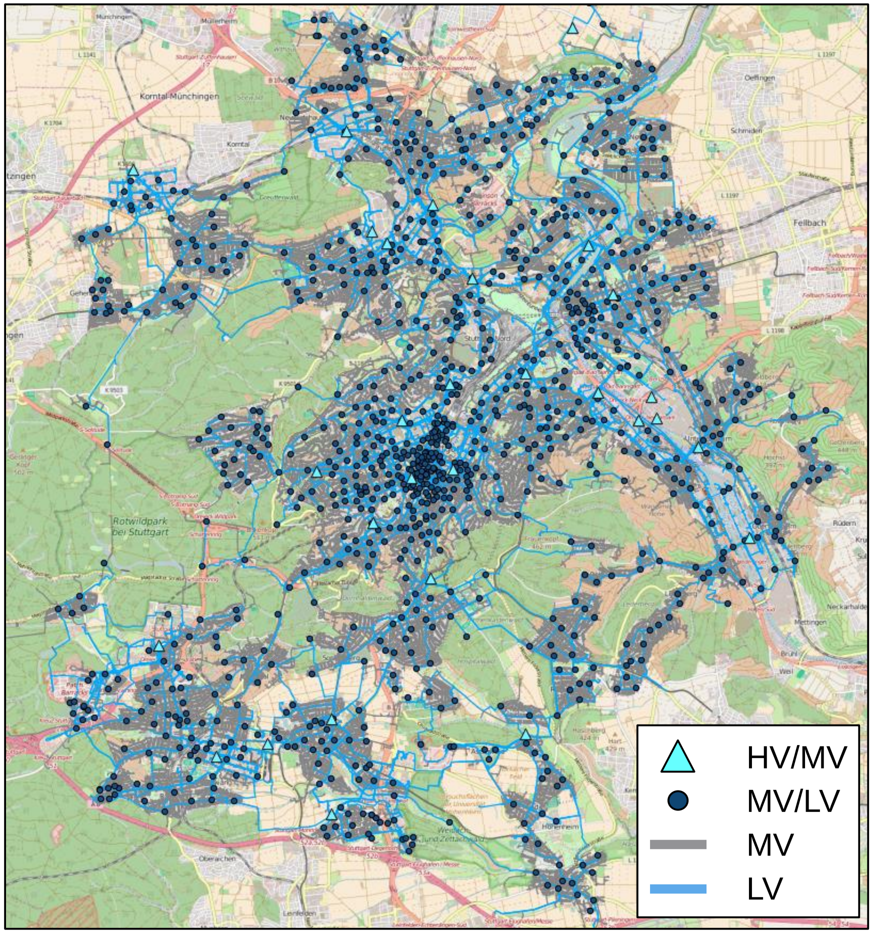
- 23 public **HV/MV transformer stations**
- 2.239 **distribution transformers** (DT)
- 87.630 households (HH)
- Ca. 170.000 **cable branches**

+

- Asset data
- trailing pointer values of DTs
- Year energy demand of loads

=

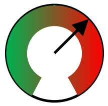
Matlab grid model



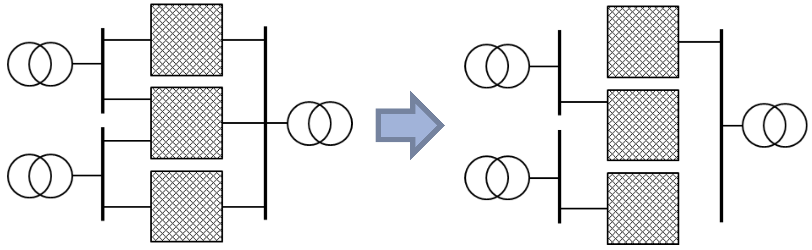
IFHT – Institute for High Voltage Technology

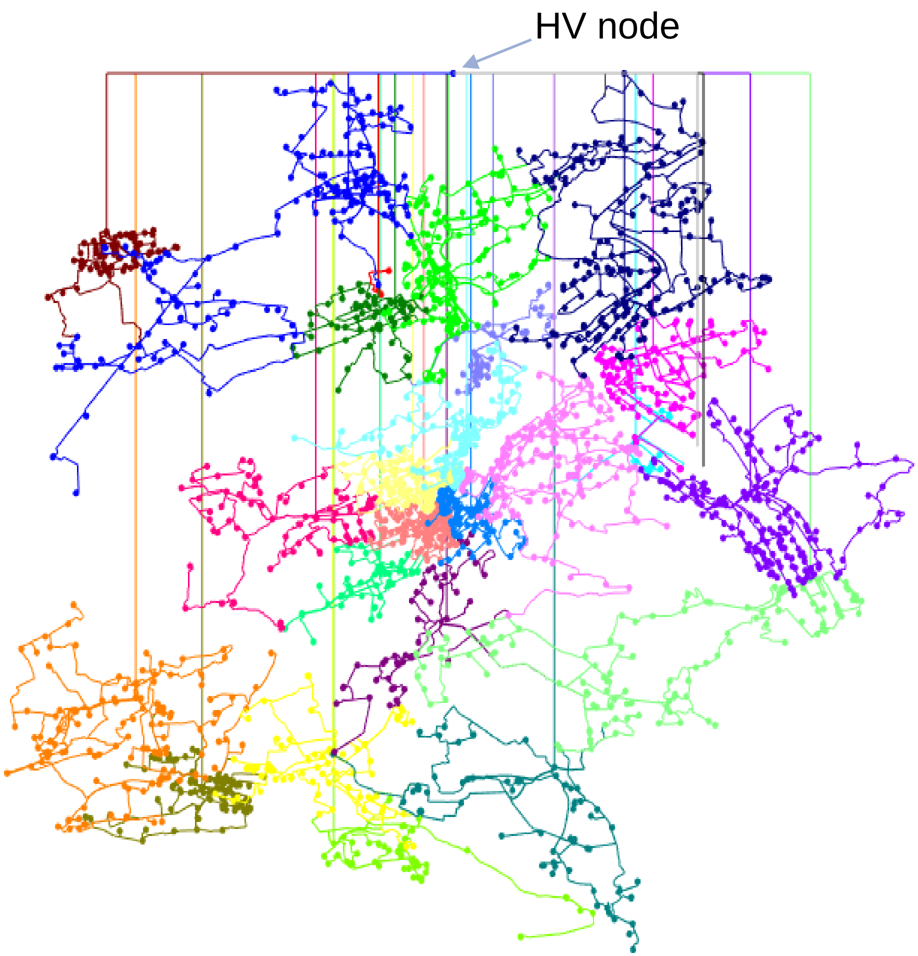
Challenges with modelling the **MV distribution grid**

- No load DT profiles available
- → Worst case assumption: DT trailing pointer values



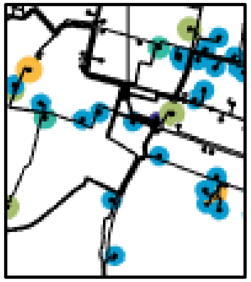
- No information about the switching stages of disconnectors
- → Finding switching stage combination leading to even loading of HV/MV transformers
- → MV grid sections shall be connected to only one HV/MV transformer





Distribution grid analysis

Method – Integration and Influencing Potential



Potential calculation at DT nodes

Integration potential (IntP) considering

- Max. DT loading
- Max. cable loading
- Voltage band: 0.96 p.u. to 1 p.u.

Golden section search algorithm

Influencing potential (InfP)

- A 100 kW load at one single node leads to a reduction of integration potential at other nodes
- influencing potential equals the **sum of the integration potential reductions** of all these other nodes

Clustering of results

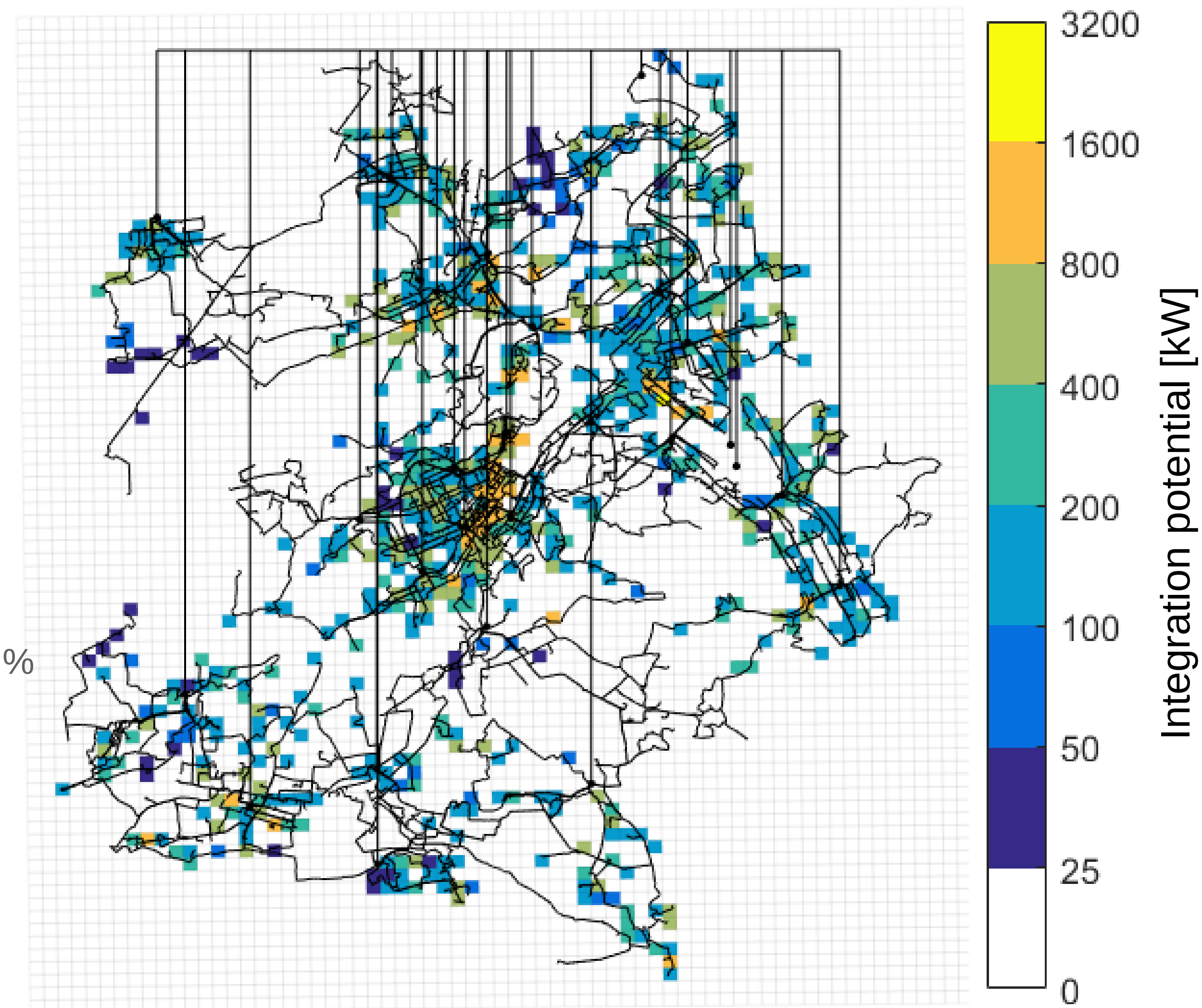
- Clustering all nodes in 250 m x 250 m squares
- Value of a squares equals maximum value of a calculated potential

Distribution grid analysis

City of Stuttgart – Results

Clustered Integration potential

- Nodes/DTs: 2239
- IntP > 0 kW: 95.4 %
- IntP > 100 kW: 55 %
- Limiting factor for IntP
  - Max. DT loading: 58.6 %
  - Max. cable loading: 40.8%
  - inadmissible low voltage: 0.6 %



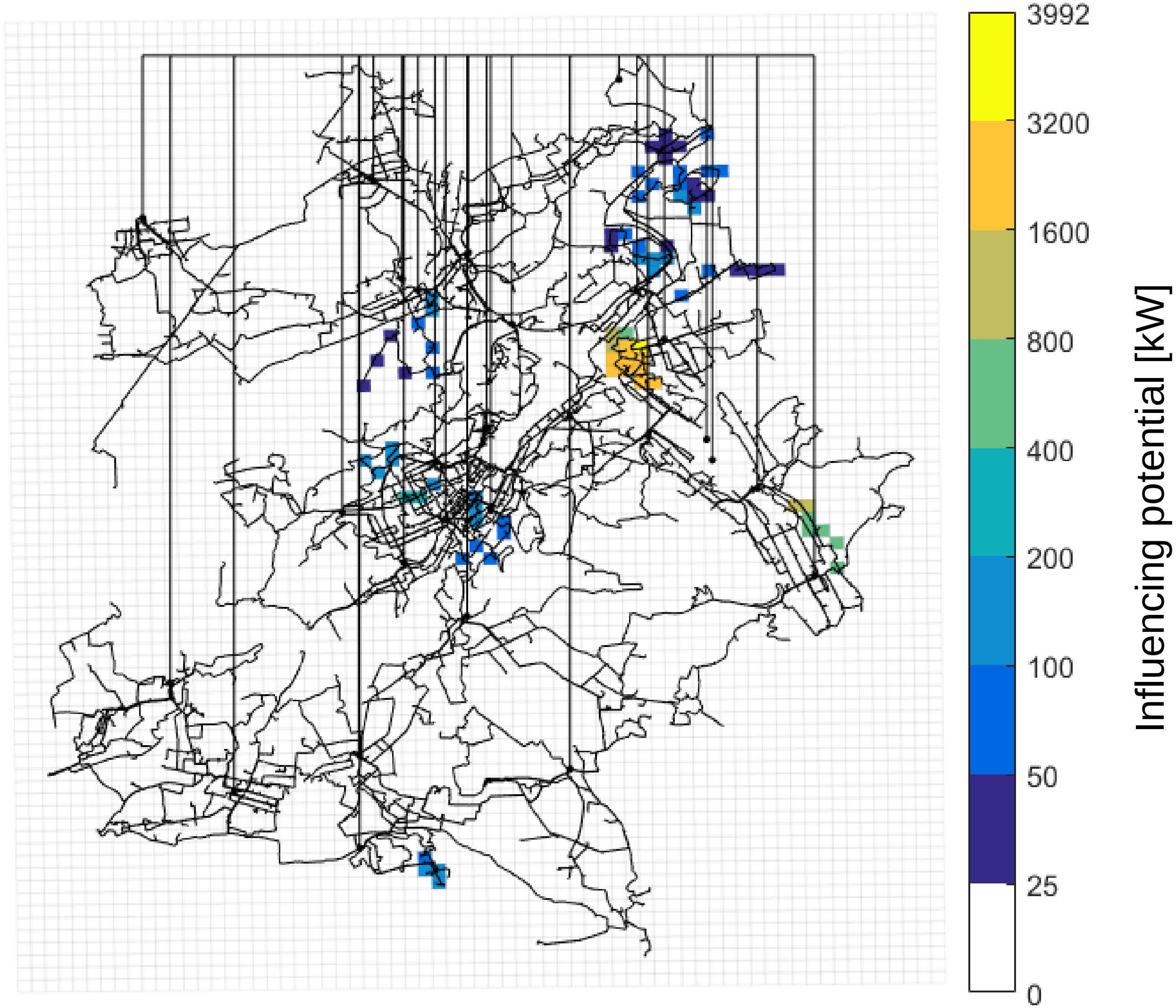
IFHT – Institute for High Voltage Technology

Distribution grid analysis

City of Stuttgart – Results

Clustered Influencing potential

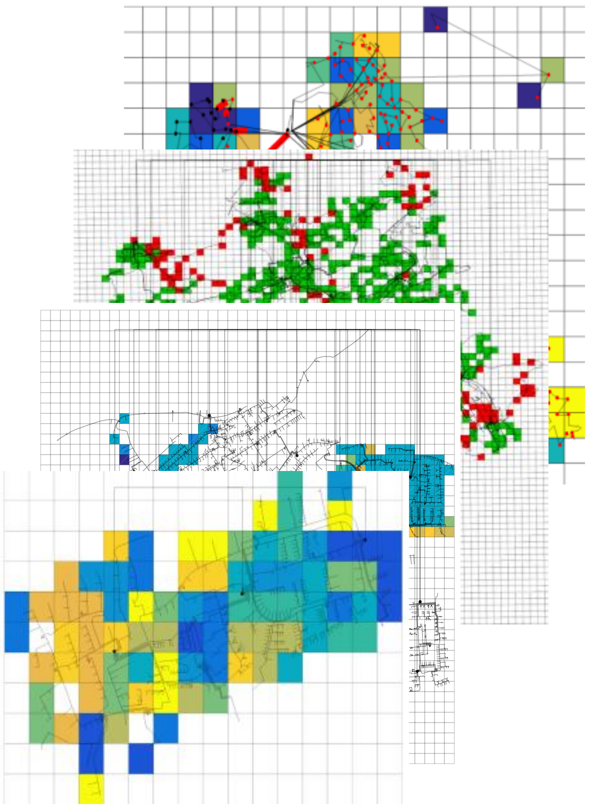
- IntP < 100 kW: 45 %
  → No InfP
- IntP > 100 kW & InfP < 100 kW: 51,7 %
  → Preferable for rapid-charging stations
- IntP > 100 kW & InfP > 100 kW: 3,2 %
  → Not preferable for rapid-charging stations
- Highest InfP: 4 MW



IFHT – Institute for High Voltage Technology

Results – City of Stuttgart

- Worst case scenario leads to high cable loading
- Charging points of 100 kW or higher can be installed at 51,7 % of all nodes (DTs)



Obstacles

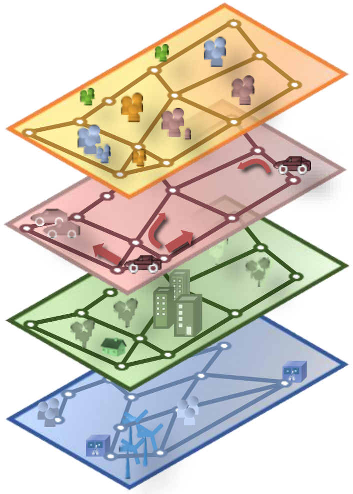
- Acquisition of grid data from DSOs
- Preparation of grid data for load flow calculations
- Load assumptions

Further studies and results

- MV distribution grid of the city of Düsseldorf
- LV distribution grid of the city of Stuttgart

Simulation tools

Conclusion



Model output

- **STELLA**
  user layer + traffic layer + infrastructure layer (by ISB): Spatially detailed sites for charging infrastructure throughout Germany (250m)

- **Electrical layer (by IFHT):** Sufficient capacity for rapid-charging stations even for a worst case load assumption

Next steps

- Further development of a stepwise **charging station expansion plan**

- Development of a mathematic optimization procedure for **optimal siting** of rapid-charging stations

ISB – Institute of Urban and Transport Planning; IFHT – Institute for High Voltage Technology

Agenda

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- ▷ Lessons learned
- Outlook and current reseach questions

SLAM

Lessons learned

Result

- Stations by the consortium: 100 (installed) + 22 (under construction)
- Stations by investors: 62 (installed) + 25 (under construction)
- 90 locations each with 1 to 4 charging points

Obstacles

- **Small investors** have often problems with planning and implementation of the business case but less problems with the process of approving of location as small investors mostly own the location
- **Big investors** have problems with finding suitable locations
- No approval by the DSO due to bottlenecks in distribution grids
- Unexpected high costs for grid connection
- Inhibited willingness to invest even with subsidization of 75%
- High amortization times for charging station with costs of 75.000 ± 30.000 €

Source: Universität Stuttgart

- Institute for High Voltage Technology at RWTH Aachen University
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Outlook – Electric mobility

Past – **Present – Future**

Optimal placement of public charging infrastructure

Integrated consideration of several layers
- Traffic-flow
- Grid capacities
- Processes of town-planning
- Technology options

Charging infrastructure for commercial fleets

Optimization of economic viability
- Charging management
- Procurement optimization
- Bidirectional charging
- Charging infrastructure sharing

Changeover to electrical public traffic

Development of integrated charging concepts
- High power demand
- Optimization of timetables
- Placement of charging stations

Commercialization of flexibility

Integration into virtual and / or topological power plants
- Marketing on the spot market
- Offer of system services
- Consideration of uncertainties

High Power Charging

System integration for charging capacities up to 350 kW
- Selection of locations
- Connection concepts
- Use of storage

Current research question – Electric mobility

Congestion management – Houshold with EVs

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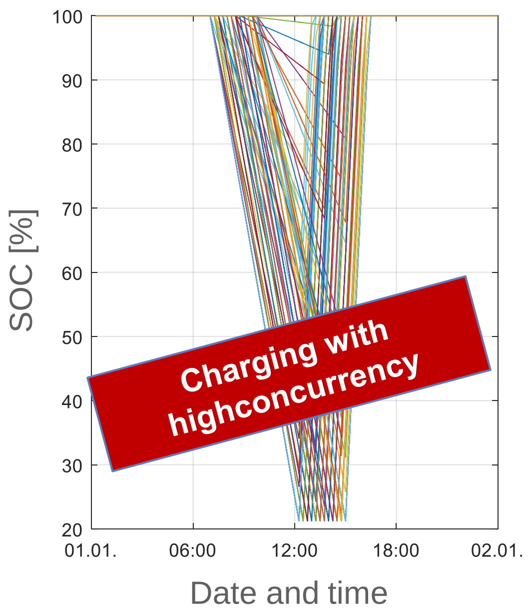

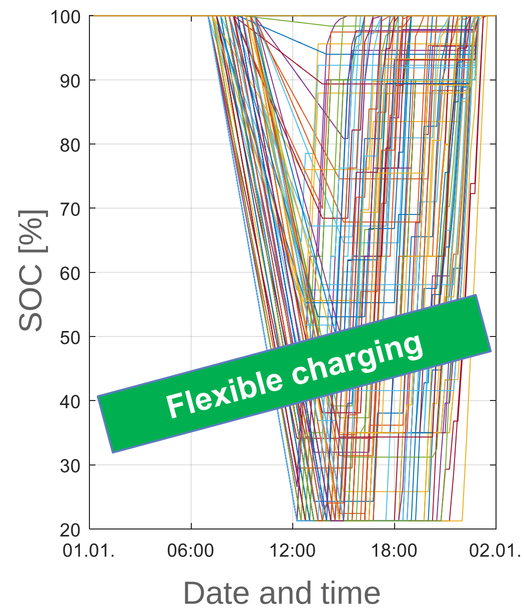

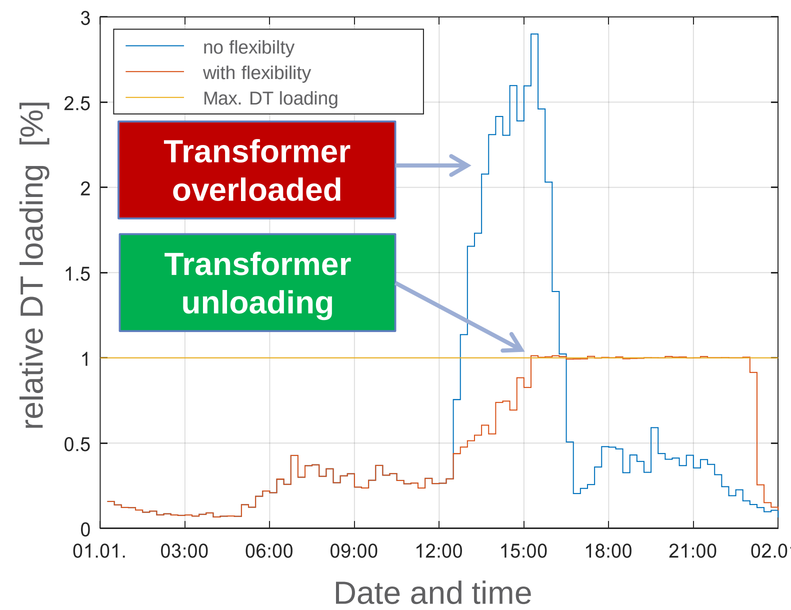

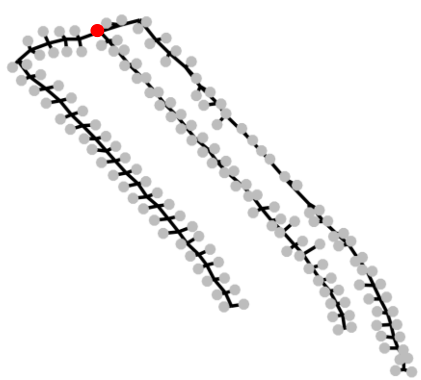

- 250 kVA distribution transformer
- LV distribution gird with 100 EV charging station with a power of 11 kW
- Identification of flexibility for unloading the distribution transformer

Obrigado & Thank you for your attention

Marcel Kurth, M.Sc.

Sustainable Distribution Systems

Expertise:
Grid expansion planning, Smart Grid concepts, Electric mobility

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Team Leader
Transport Modelling und e-Mobility

Expertise:
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