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Potenciál elektromobility pro řízení flexibility v energetice za využití umělé inteligence

Ing Ondřej Štogl, Ing. Marek Miltner MPhil

Kolokvia Vize výzvy mobility
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Authors

		
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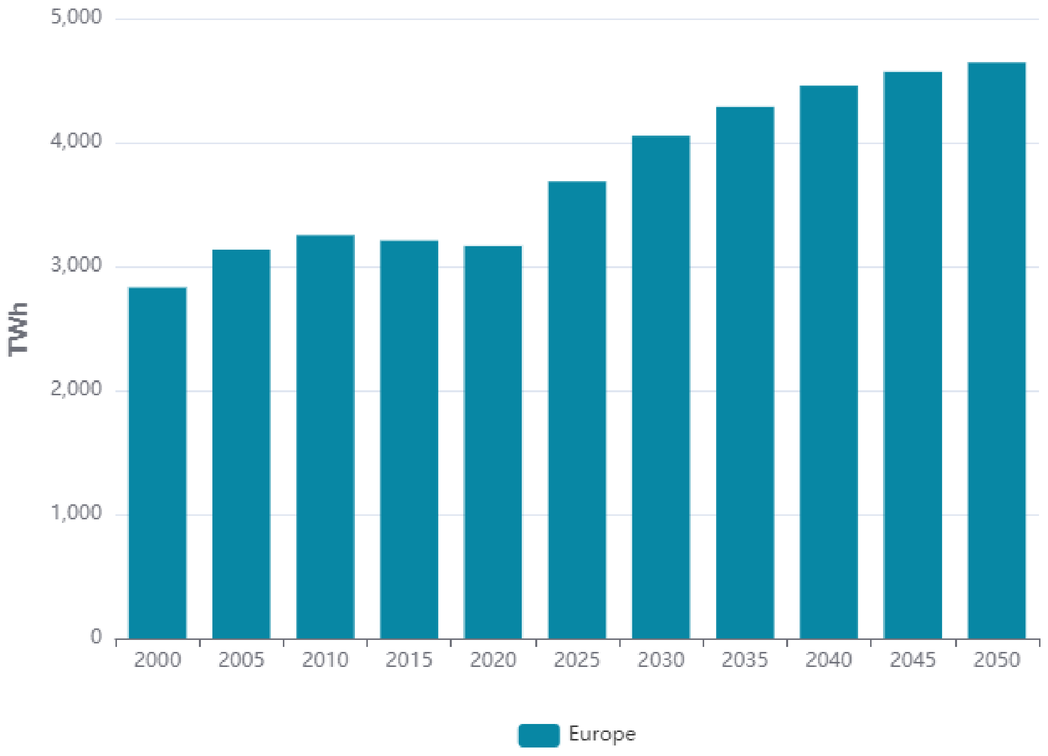
Current focus	Vehicle to Grid and flexibility	AI applications for the sustainable transformation of power grids
Previous experience	Electric racecar development	Autonomous electric vehicles

Energy flexibility potential of V2G

Ing. Ondřej Štogl

Energy context

- **Energy sector transformation**
  - Electricity consumption growth



Share of renewables in EU energy consumption

- 2022 – 23 %
- 2030 – 32 % (2018)
- 2030 – 42,5 %

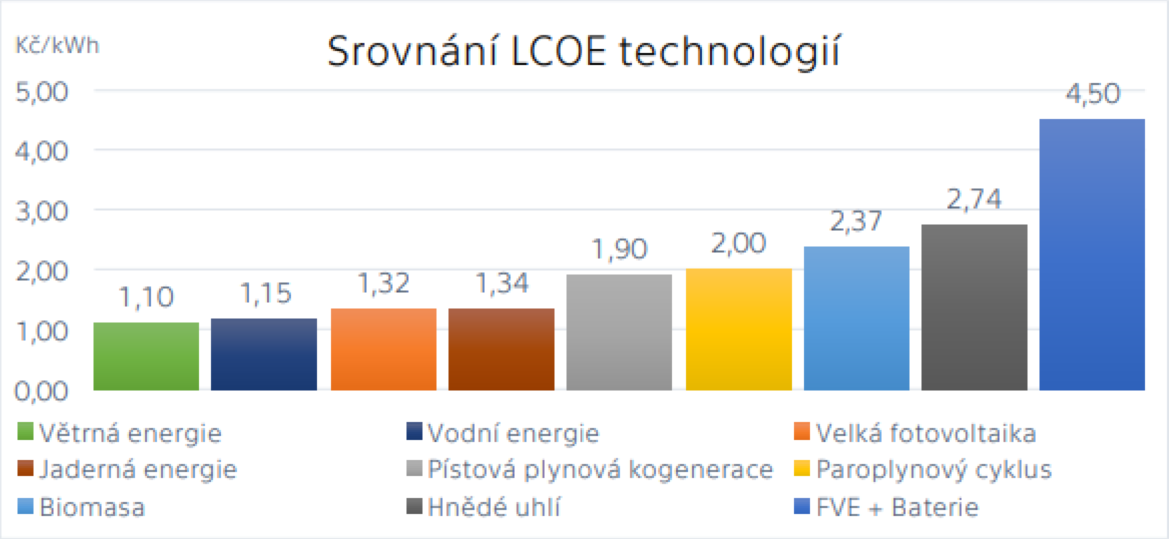
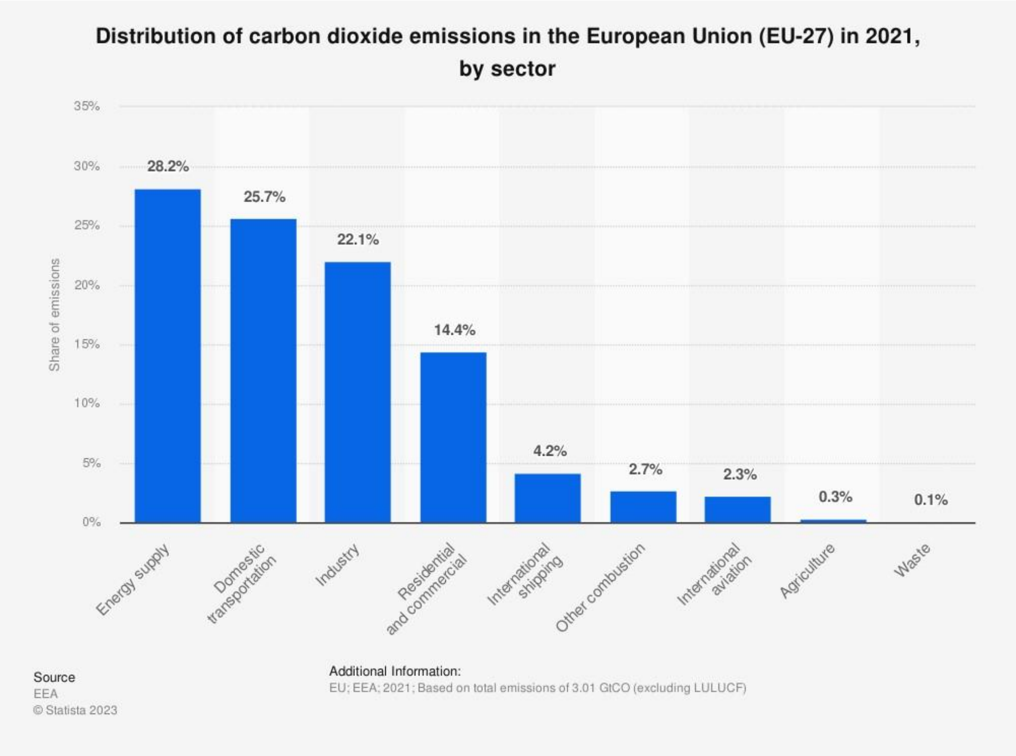


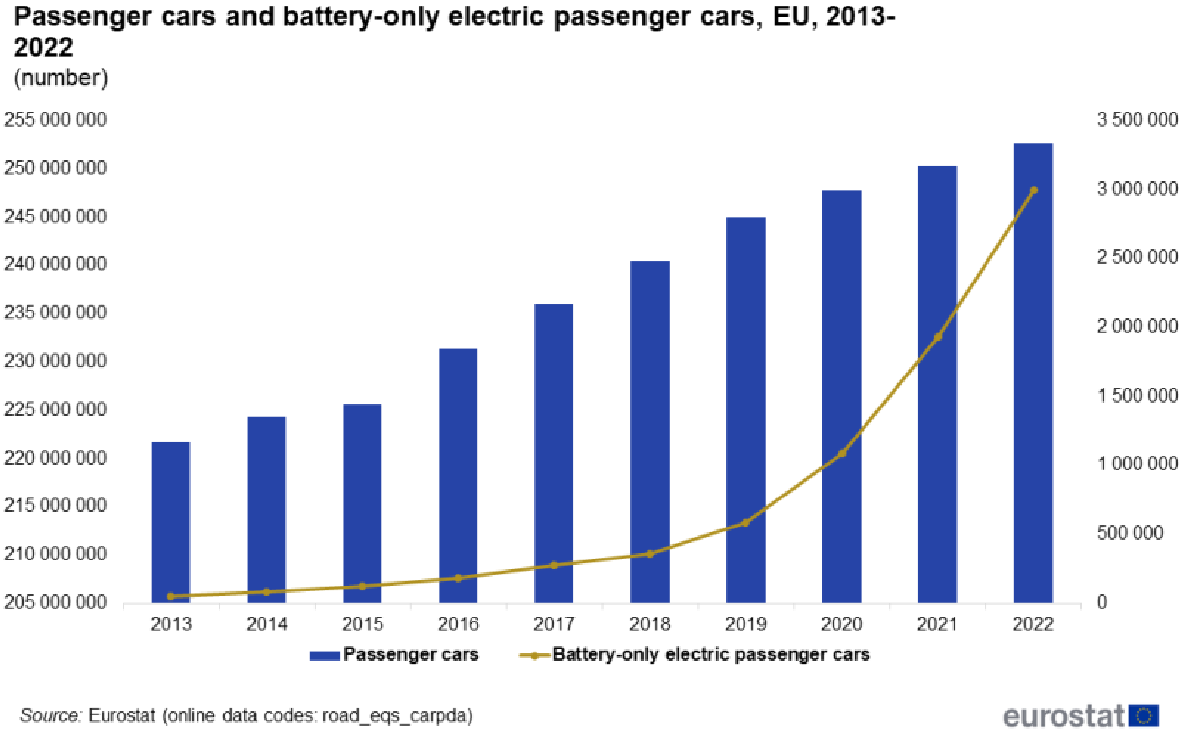
Image source: https://eneroutlook.enerdata.net/forecast-world-electricity-consumption.html

EU Renewables data source: 'Renewable energy targets - European Commission'. Accessed: Apr. 20, 2024. [Online]. Available: https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-targets_en

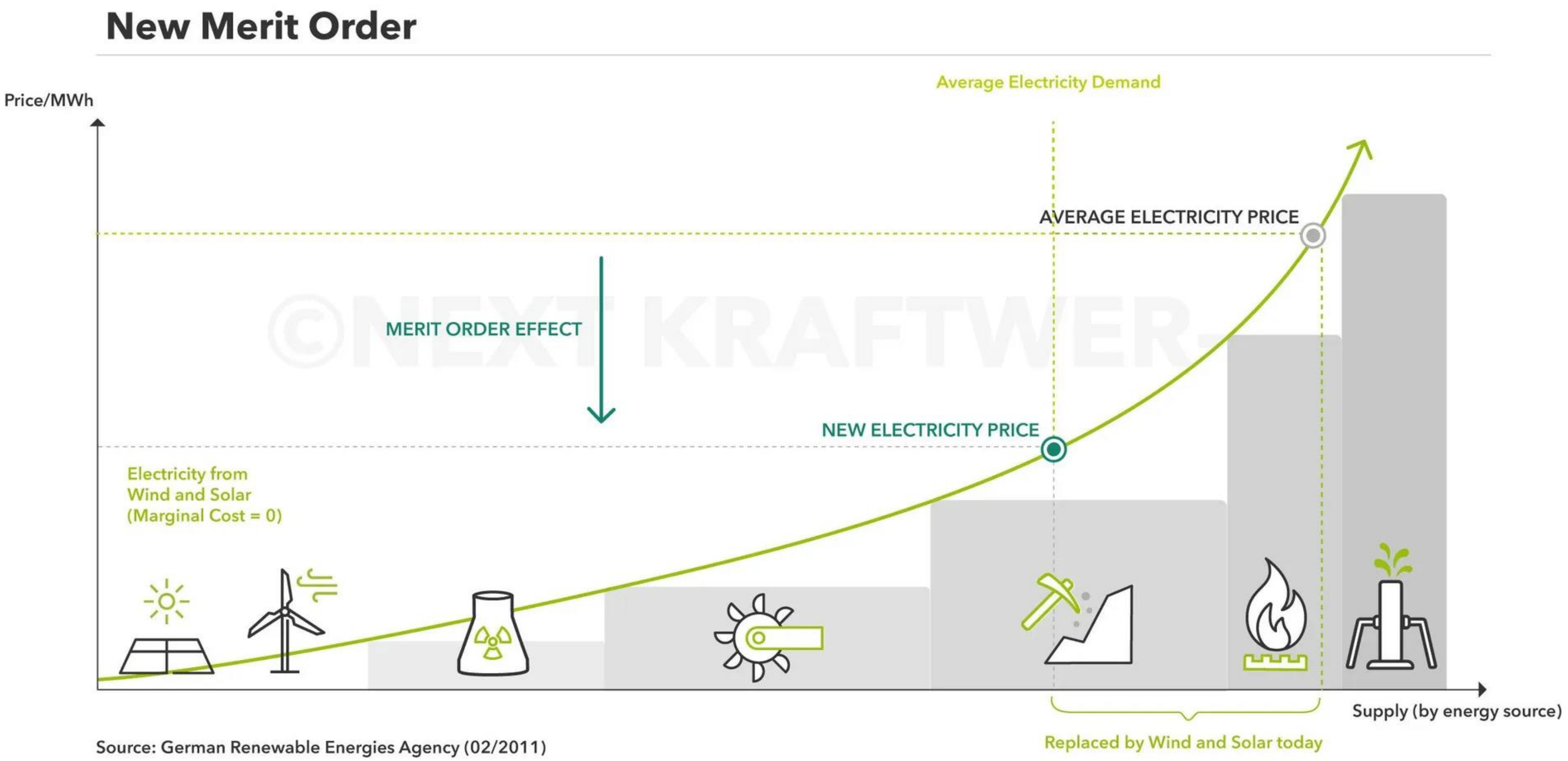
Energy context

- **Energy sector transformation**
- **Transportation sector transformation**
    - EU goal – 30 million zero emission cars until 2030

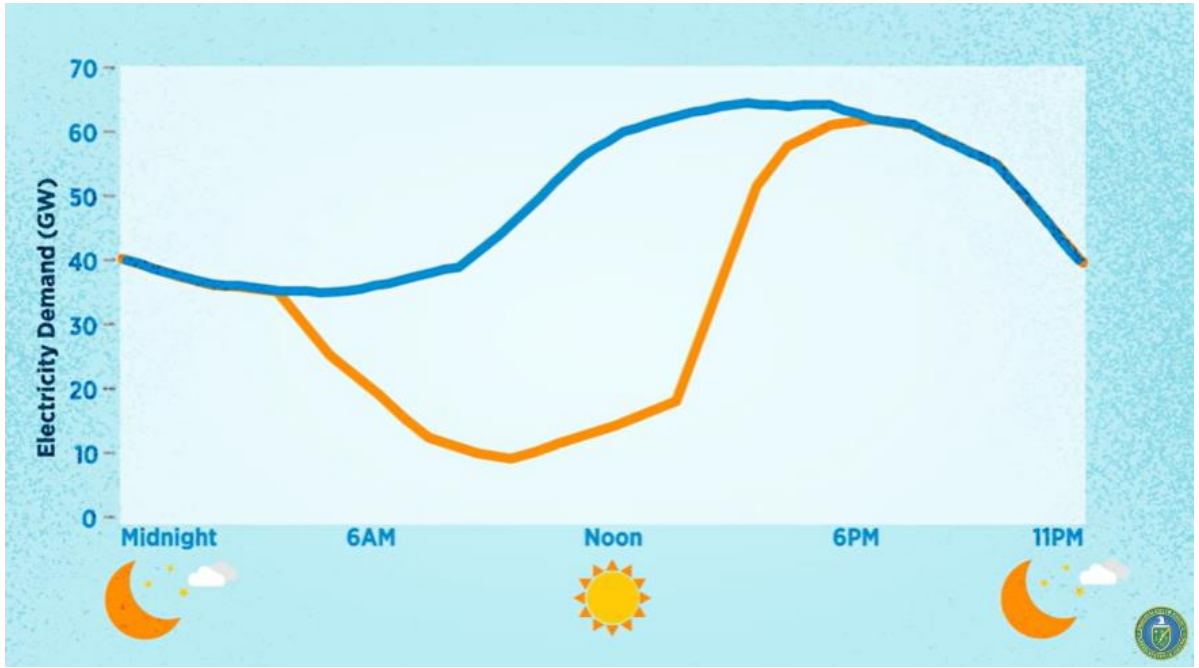


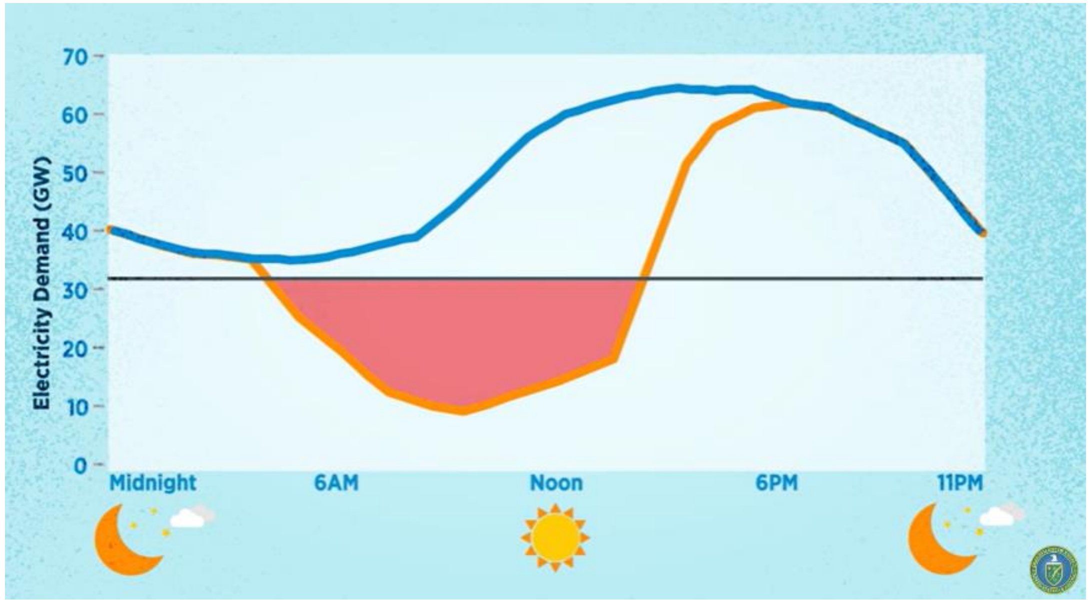


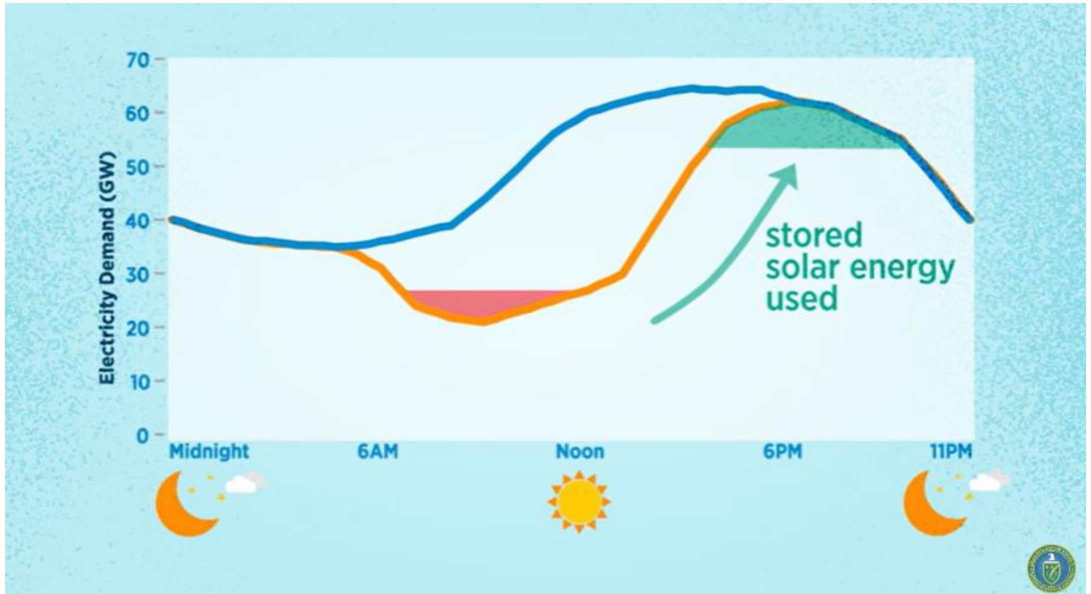
Electricity price



The duck curve

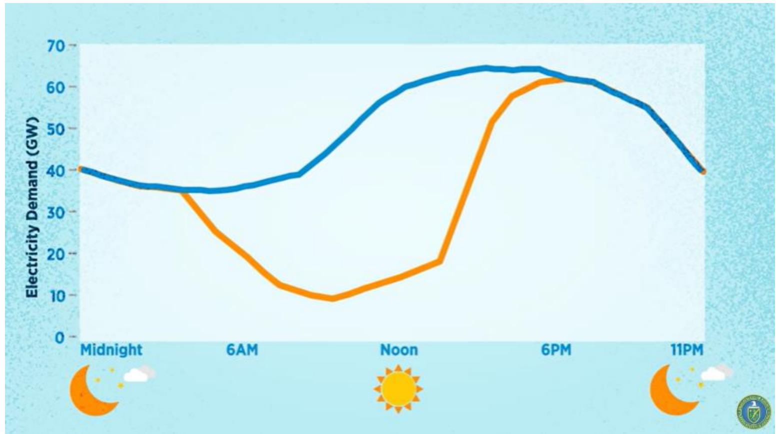


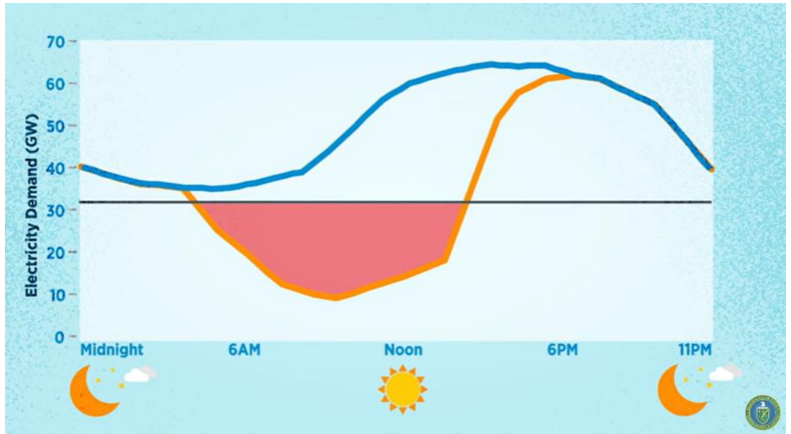


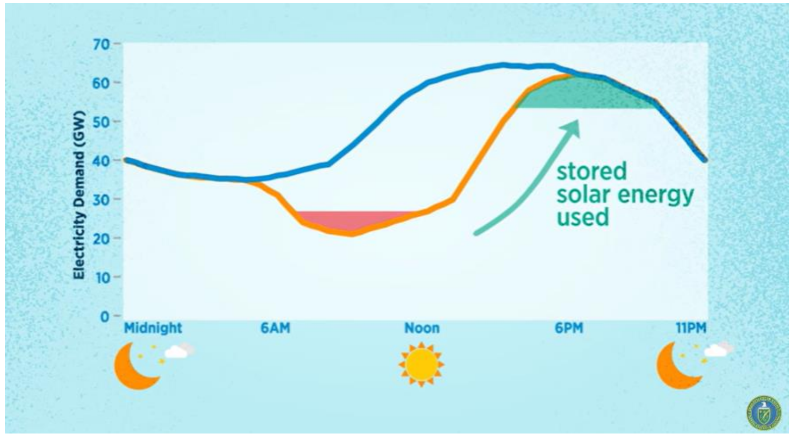


Images source: https://www.youtube.com/watch?v=KwA44fr7apw

The duck curve – solutions







- **Energy storage and use at another time**
- **Increase/decrease production**
- **Increass/decrease consumption**

Images source: https://www.youtube.com/watch?v=KwA44fr7apw

Why flexibility?

- *„Shift of consumption and production over time“*
- **Nature of the electricity grid**
- **Renewables intermittency**

Flexibility control

- **Upward flexibility**
  - Reducing consumption or increasing production
- **Downward flexibility**
  - Increasing consumption or decreasing production
- **Electricity storage**
  - Day, week, season

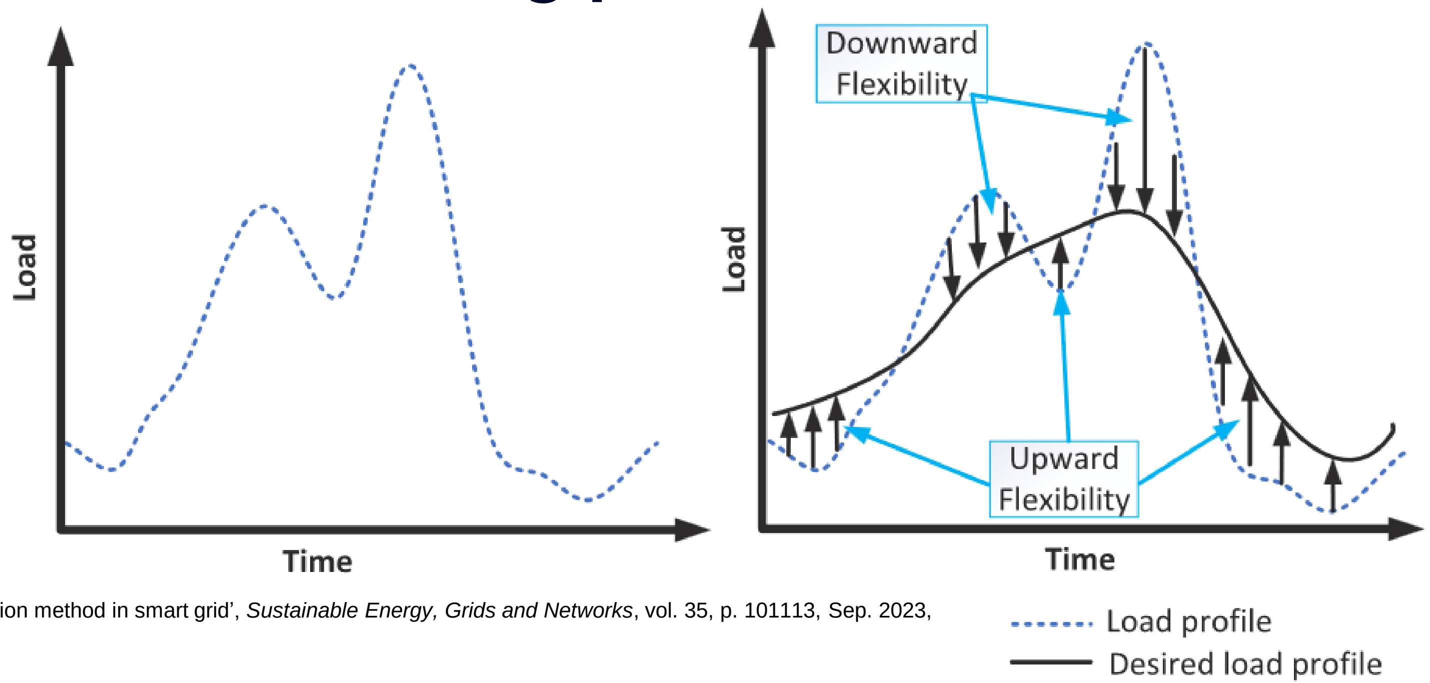
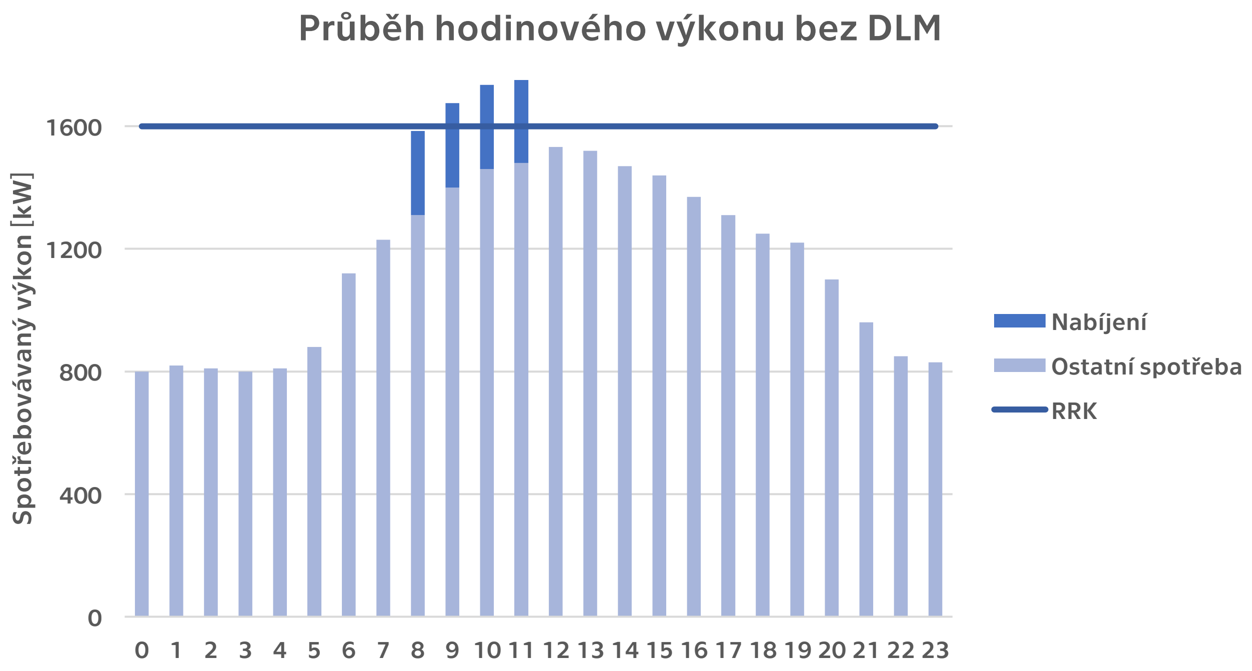
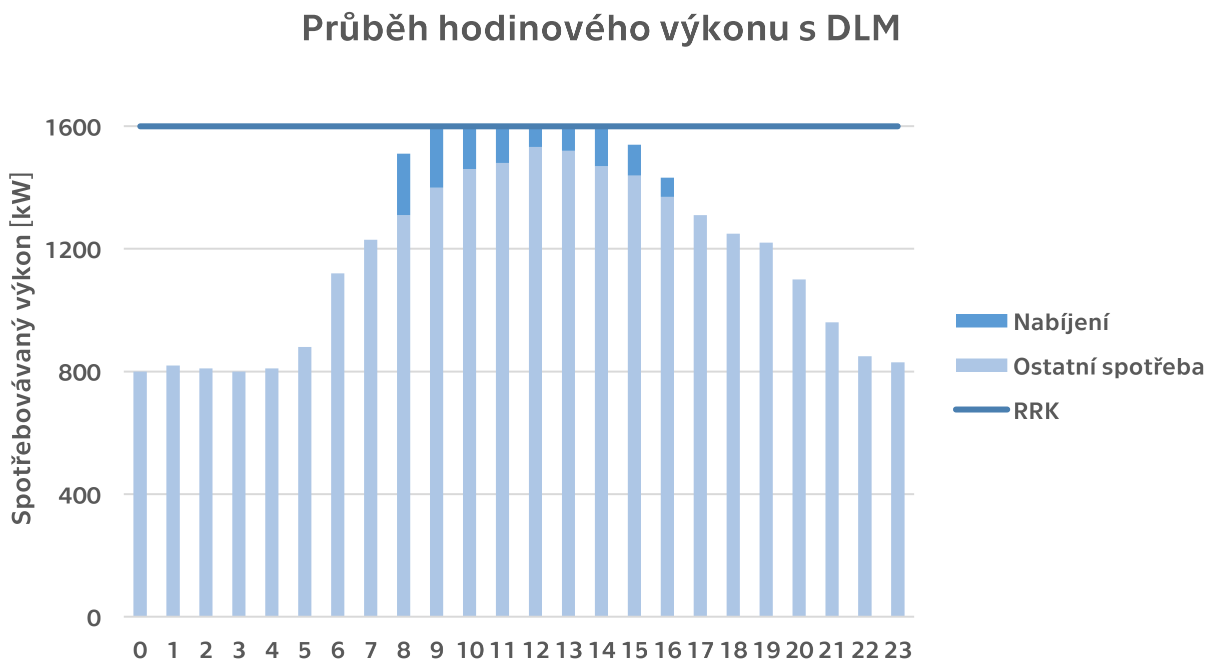


Image source: S. Hussain, C. Lai, and U. Eicker, 'Flexibility: Literature review on concepts, modeling, and provision method in smart grid', *Sustainable Energy, Grids and Networks*, vol. 35, p. 101113, Sep. 2023, doi: 10.1016/j.segan.2023.101113

Dynamic load management (levels)

- **Local grid limitations**





- **Transformer station**
- **Large distribution areas**

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EV as flexibility provider

- **Smart grid**
  - Solving the unpredictibility
- **Smart charging**
- **Vehicle-to-Grid**

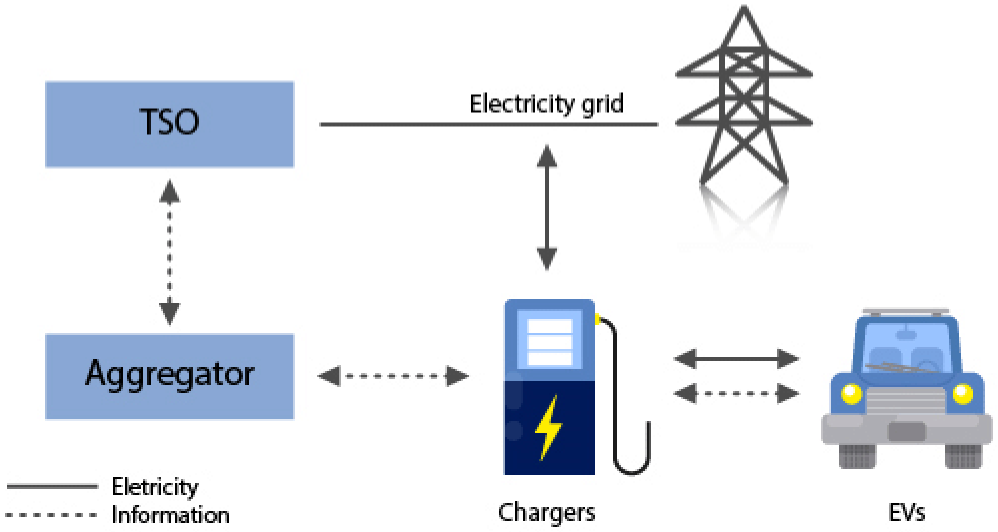
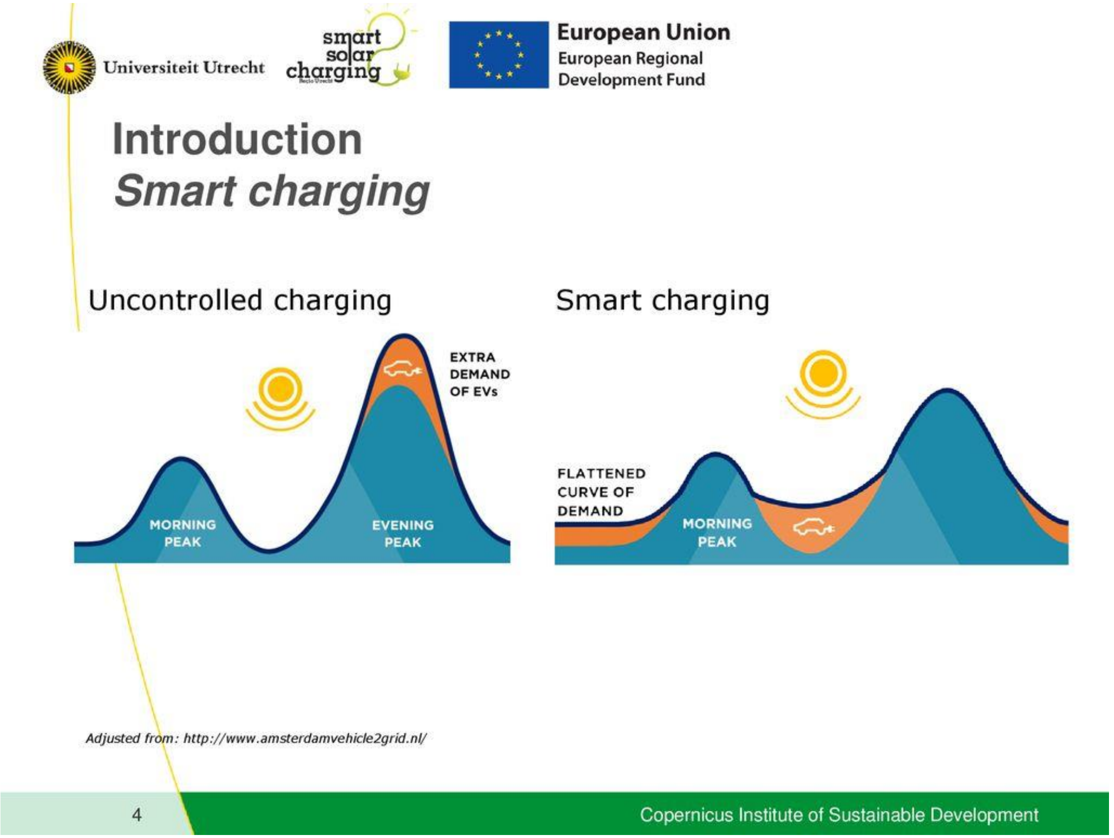


Image source: G. Ala et al., ‘Different Scenarios of Electric Mobility: Current Situation and Possible Future Developments of Fuel Cell Vehicles in Italy’, Sustainability, vol. 12, p. 564, Jan. 2020, doi: 10.3390/su12020564.



V2G hierarchy

- Generation Company
- DSO
- TSO
- Car
- End user
- Aggregator

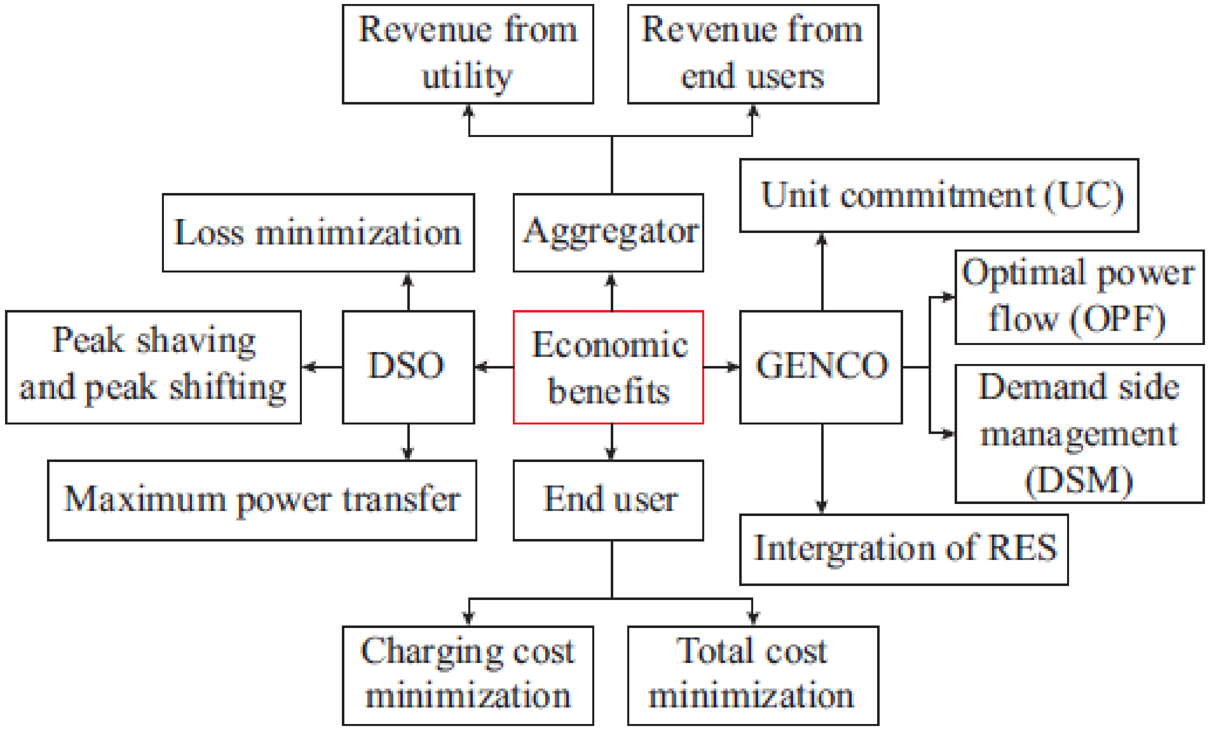


Image source: H. Patil and V. N. Kalkhambkar, 'Grid Integration of Electric Vehicles for Economic Benefits: A Review', Journal of Modern Power Systems and Clean Energy, vol. 9, no. 1, pp. 13–26, Jan. 2021, doi: 10.35833/MPCE.2019.000326

Challenges to overcome

- **Technical solution**
  - Common standard ISO 15118
  - Battery degradation
- **Legislative solution**
  - Privacy issue
  - Responsibility issue
- **Economical solution**
  - Beneficial for all stakeholders

Flexibility project

- Využívání „volné kapacity“ velkých bateriových systémů pro podpůrné služby (ČEPS)
- Návrh, vývoj a praktické ověření IT systému k optimalizaci využití volné kapacity distribuční sítě pro dobíjení elektromobilů (LEEF technologies, PREdi)
- …
- Využití technologie Vehicle to Grid pro poskytování energetické flexibility – ČVUT, PREdi, (Škoda Auto, ERÚ, ČEZ, Valeo)
  - Ekonomicky udržitelné využití elektromobilů pro poskytování služeb výkonové rovnováhy

Applying Machine Learning approaches for EV charging sessions and flexibility modelling

Ing. Marek Miltner MPhil

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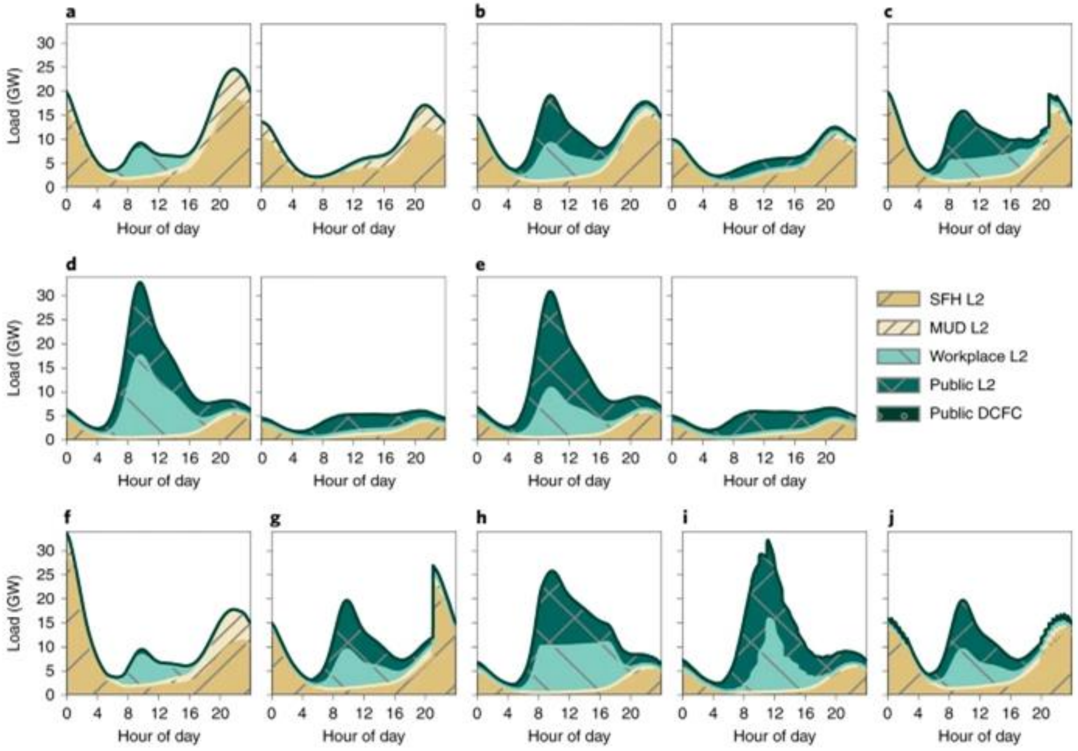
Building on previous work at Stanford

Following slides and research are building on paper in Nature Energy: *"Charging infrastructure access and operation to reduce the grid impacts of deep electric vehicle adoption"*
by Powell, S. et al.

Stanford University

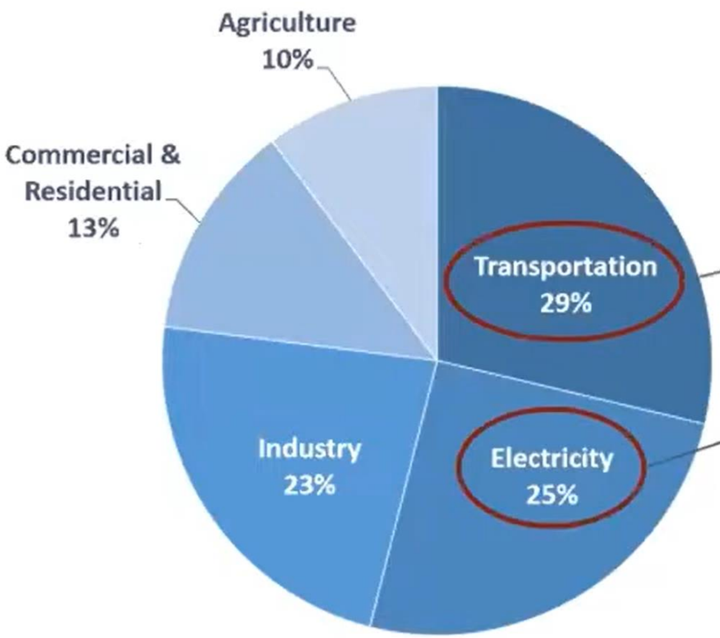
Stanford | ENERGY
Bits & Watts Initiative

Stanford | Sustainable Systems Lab



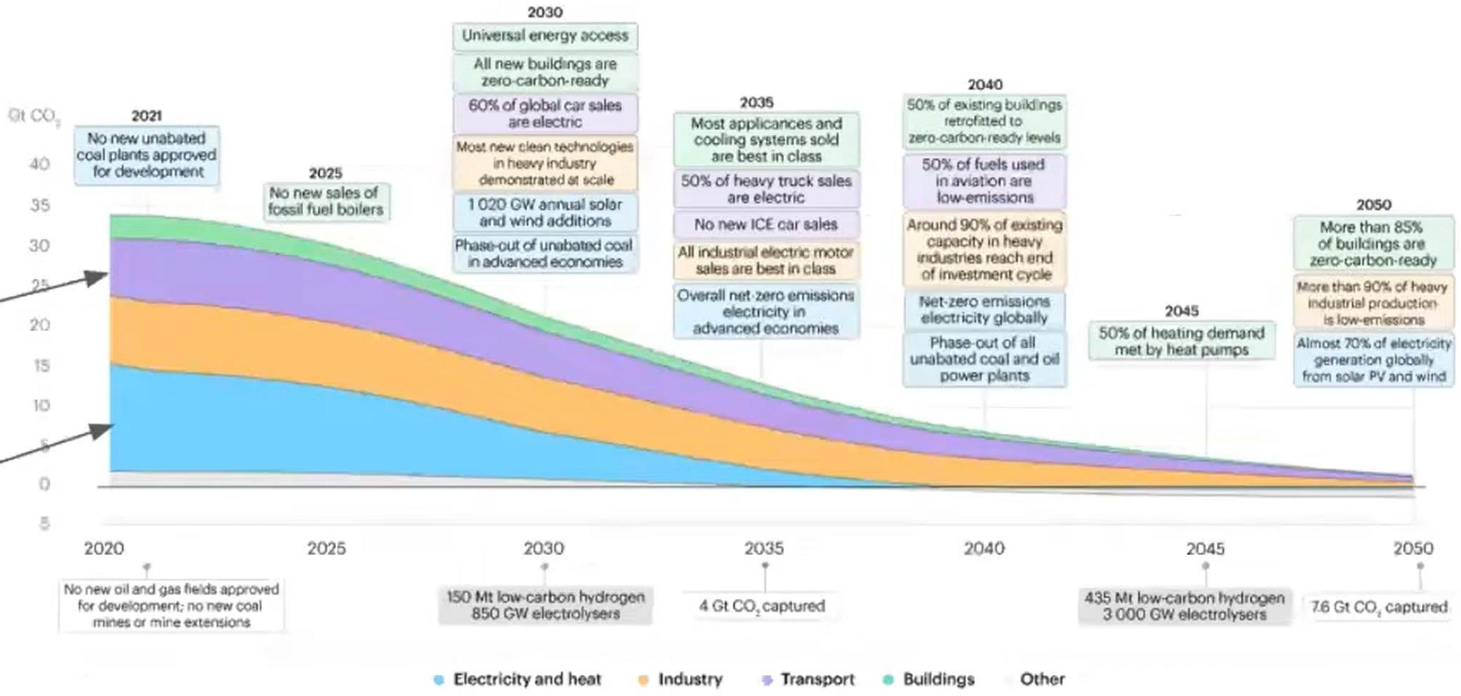
Grid and mobility are undergoing rapid transformations

2019 snapshot of US emissions:



Source: US EPA
https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

Global net zero pathway:



Source: IEA “Net Zero by 2050”
https://www.iea.org/reports/net-zero-by-2050

The transformations impact each other

The Grid

- Provide enough electricity and stations[1]
- Reliability[4]
- Electricity prices[1]

- Equipment aging + capacity upgrades [2,3,4]
- Generation resource mix [3,4]
- Grid services [4]

Vehicle Travel

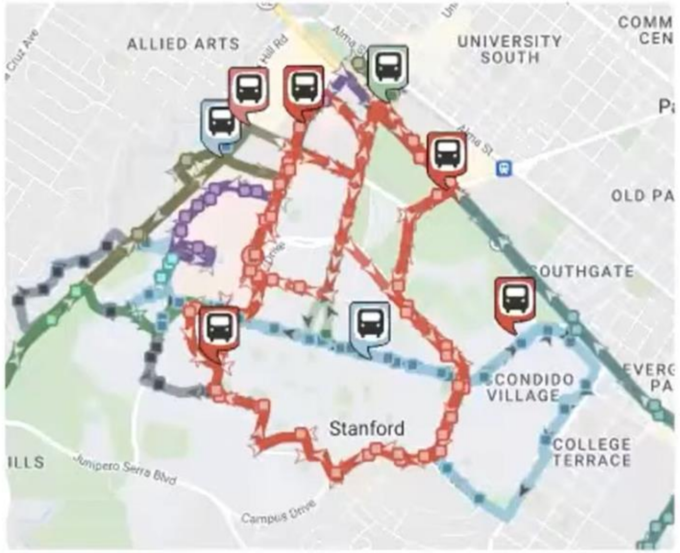


Image Source: Stanford Marguerite Live Map
http://supublic.etaspot.net/

[1] Hardman, S., & Tal, G. (2021). Understanding discontinuance among California's electric vehicle owners. Nature Energy, 6(5), 538-545.
[2] Coignard, J., MacDougall, P., Stadtmueller, F., & Vrettos, E. (2019). Will electric vehicles drive distribution grid upgrades?: The case of California. IEEE Electrification Magazine, 7(2), 46-56.
[3] Brinkel, N. B. G., Schram, W. L., AlSkaif, T. A., Lampropoulos, I., & Van Sark, W. G. J. H. M. (2020). Should we reinforce the grid? Cost and emission optimization of electric vehicle charging under different transformer limits. Applied Energy, 276, 115285.
[4] Anwar, M. B., Muratori, M., Jadun, P., Hale, E., Bush, B., Denholm, P., ... & Podkaminer, K. (2022). Assessing the value of electric vehicle managed charging: a review of methodologies and results. Energy & Environmental Science.

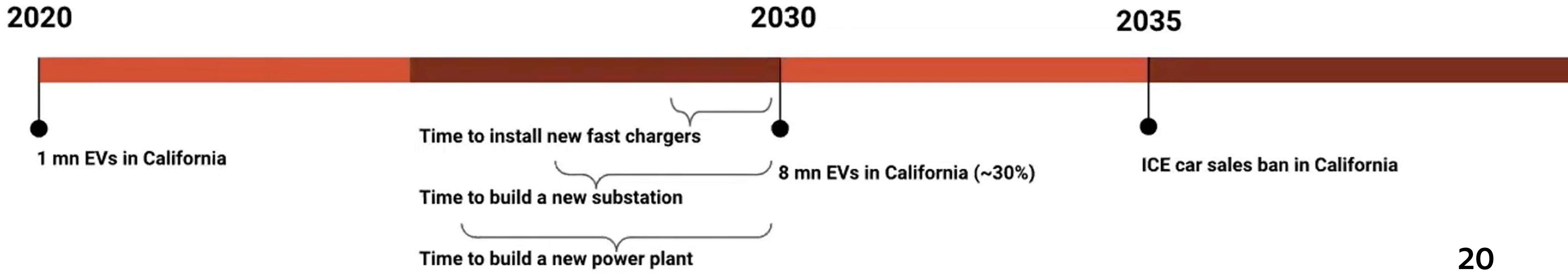
What is at stake?

Planning

- Grid operators: Will we have enough generation capacity?
- Policy makers: How many stations need to be installed?
- Utilities: Which equipment needs upgrading and when?

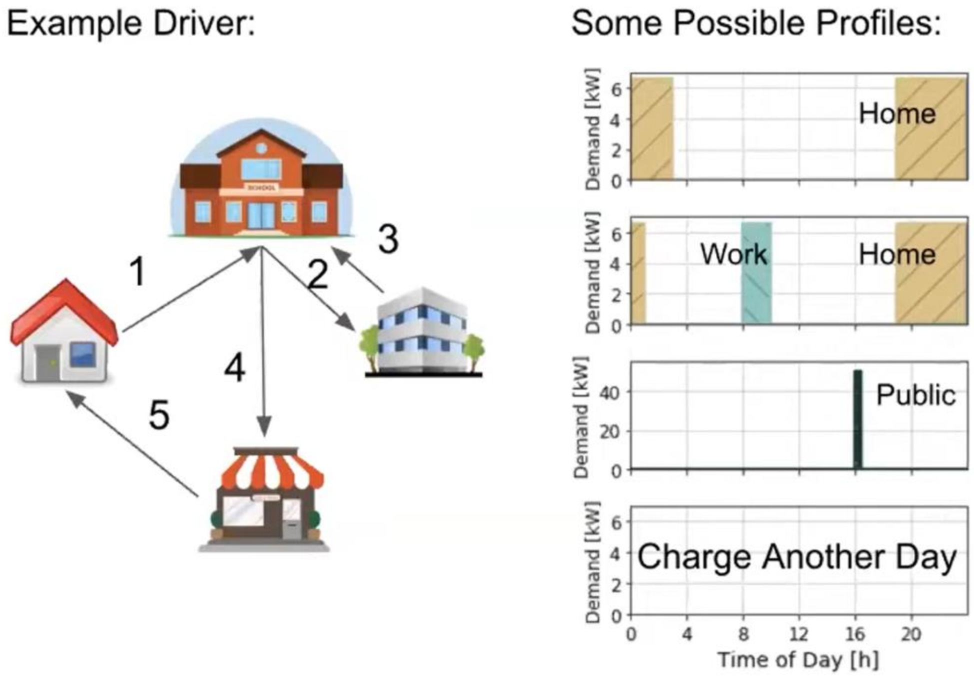
Operation

- Given equipment, EV adoption, and driver decisions, how should the grid and charging be managed hour by hour/day by day?



EV Charging behaviour

- **Mobility needs are heterogenous**
- **Charging access and decisions increase complexity further**



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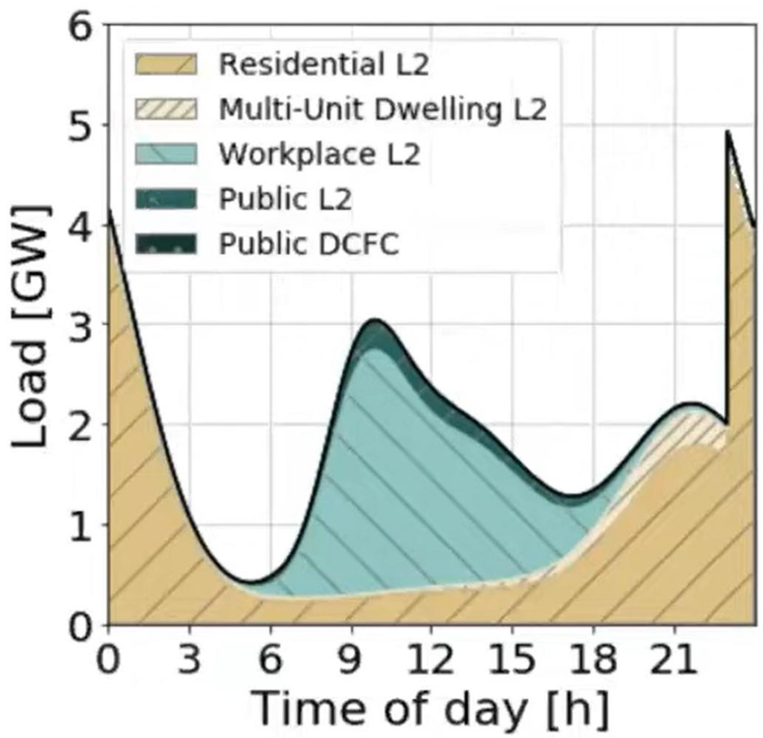
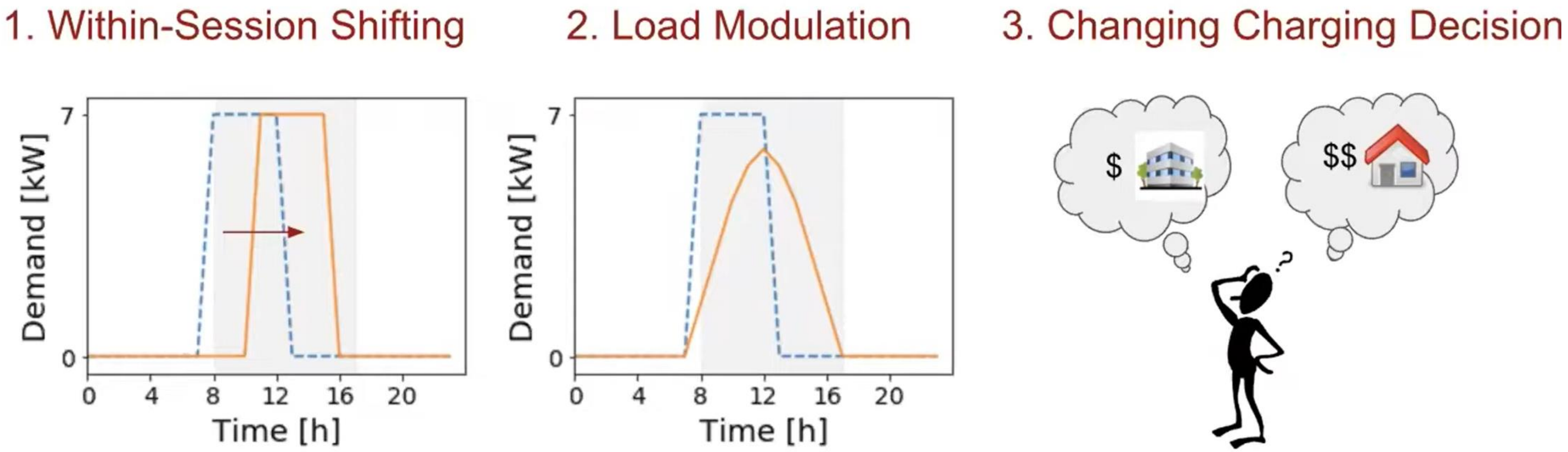


[1] Powell, S., Cezar, G.V., Min, L. *et al.* Charging infrastructure access and operation to reduce the grid impacts of deep electric vehicle adoption. *Nat Energy* **7**, 932–945 (2022). https://doi.org/10.1038/s41560-022-01105-7

Fortunately, charging is a flexible load

- Most drivers do not charge every day and most charging includes idle time, which introduces flexibility
- Main types of flexibility include[1]:



[1] Anwar, M. B., Muratori, M., Jadun, P., Hale, E., Bush, B., Denholm, P., ... & Podkaminer, K. (2022). Assessing the value of electric vehicle managed charging: a review of methodologies and results. Energy & Environmental Science.

Motivation

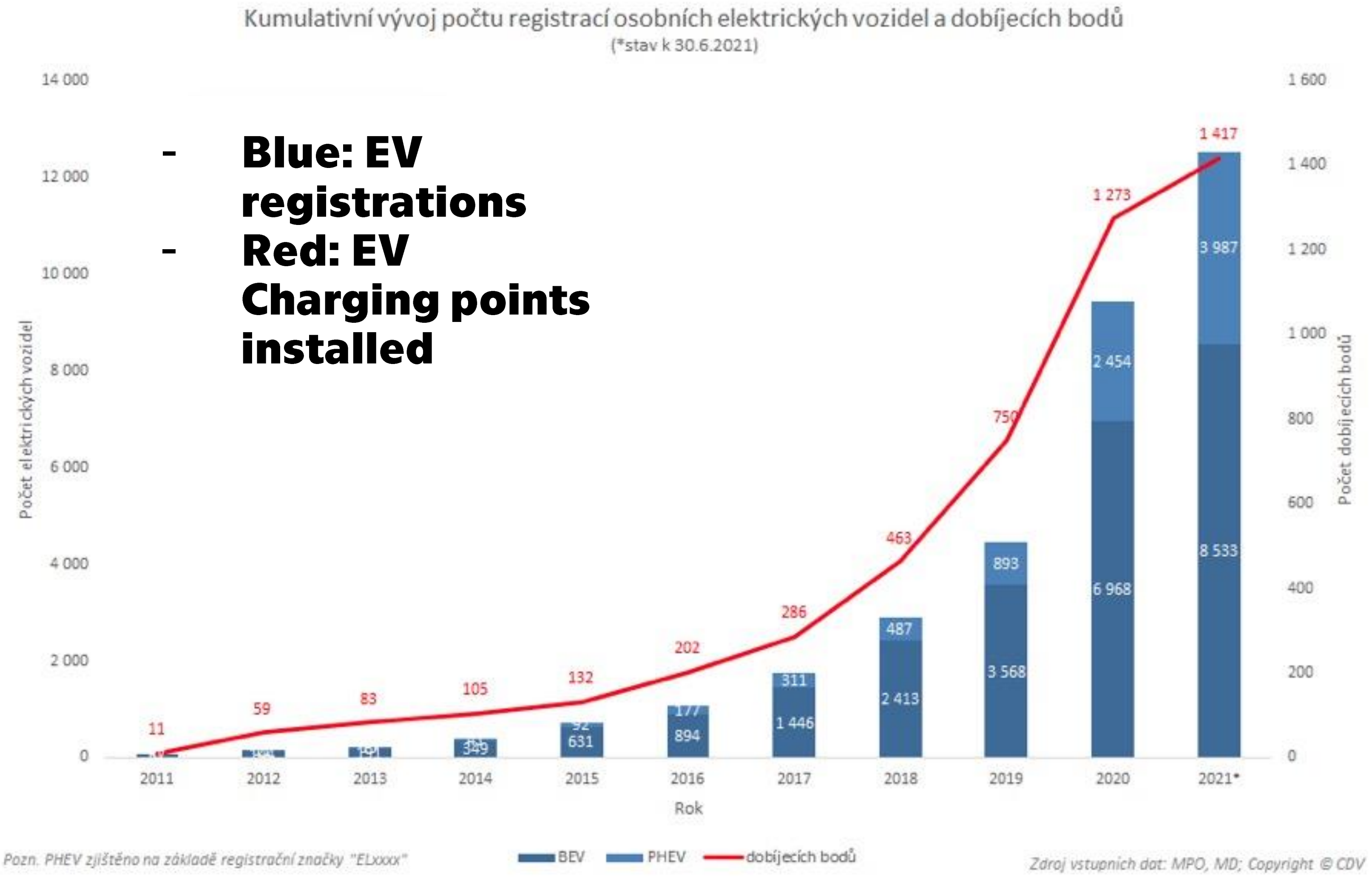
- Electric vehicles are becoming more common
- With them comes demand for chargers and charging itself
- Infrastructure for charging is not easy or quick to build

- Conflicting trends:
  - Charging demand is accelerating
  - It is more and more difficult to build charging stations

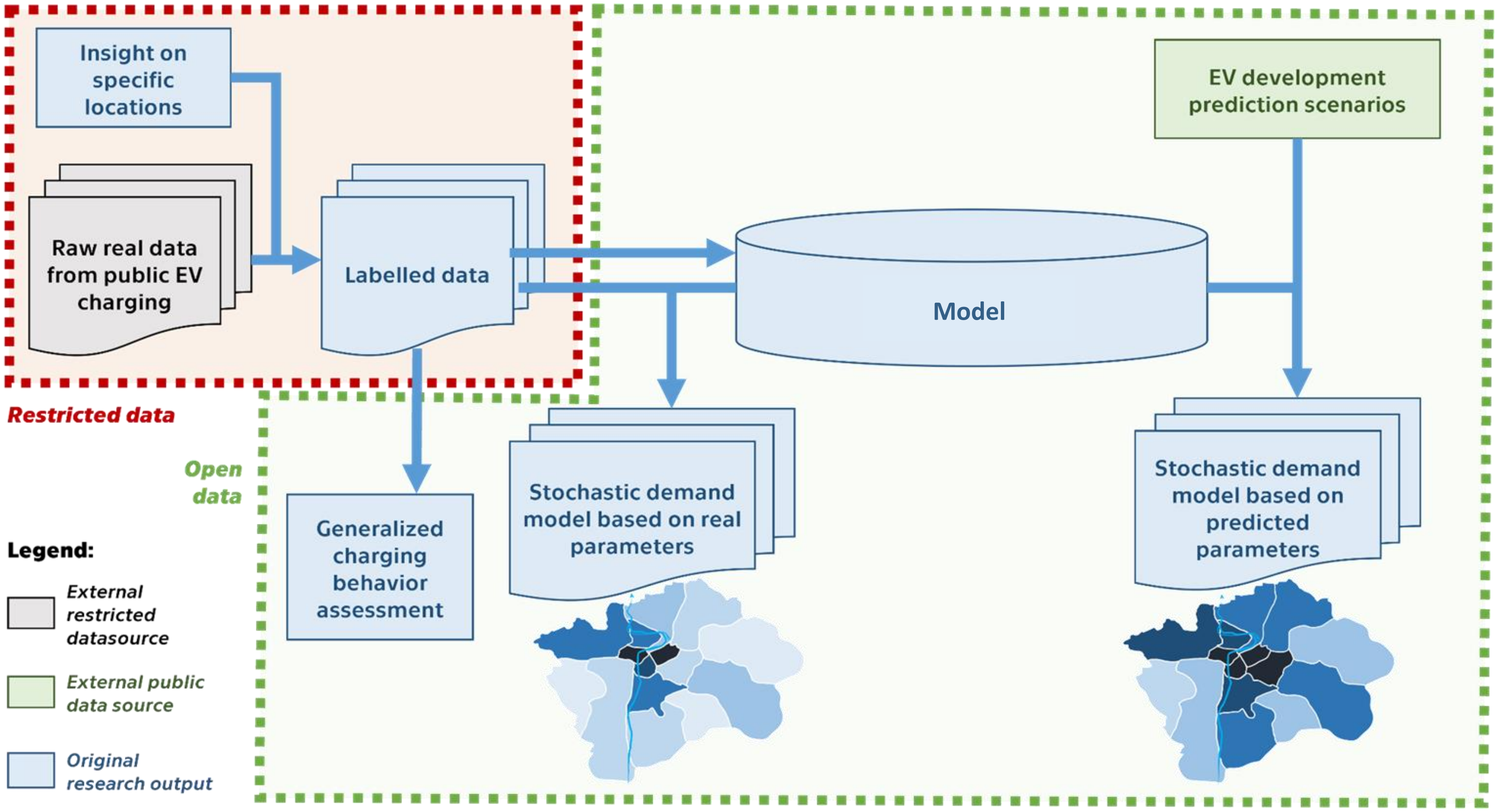
- Can we predict where demand will be?
  - To build infrastructure efficiently
  - To detect systemic challenges in capacity

Current situation: reaching an inflection point

- **Blue: EV registrations**
- **Red: EV Charging points installed**

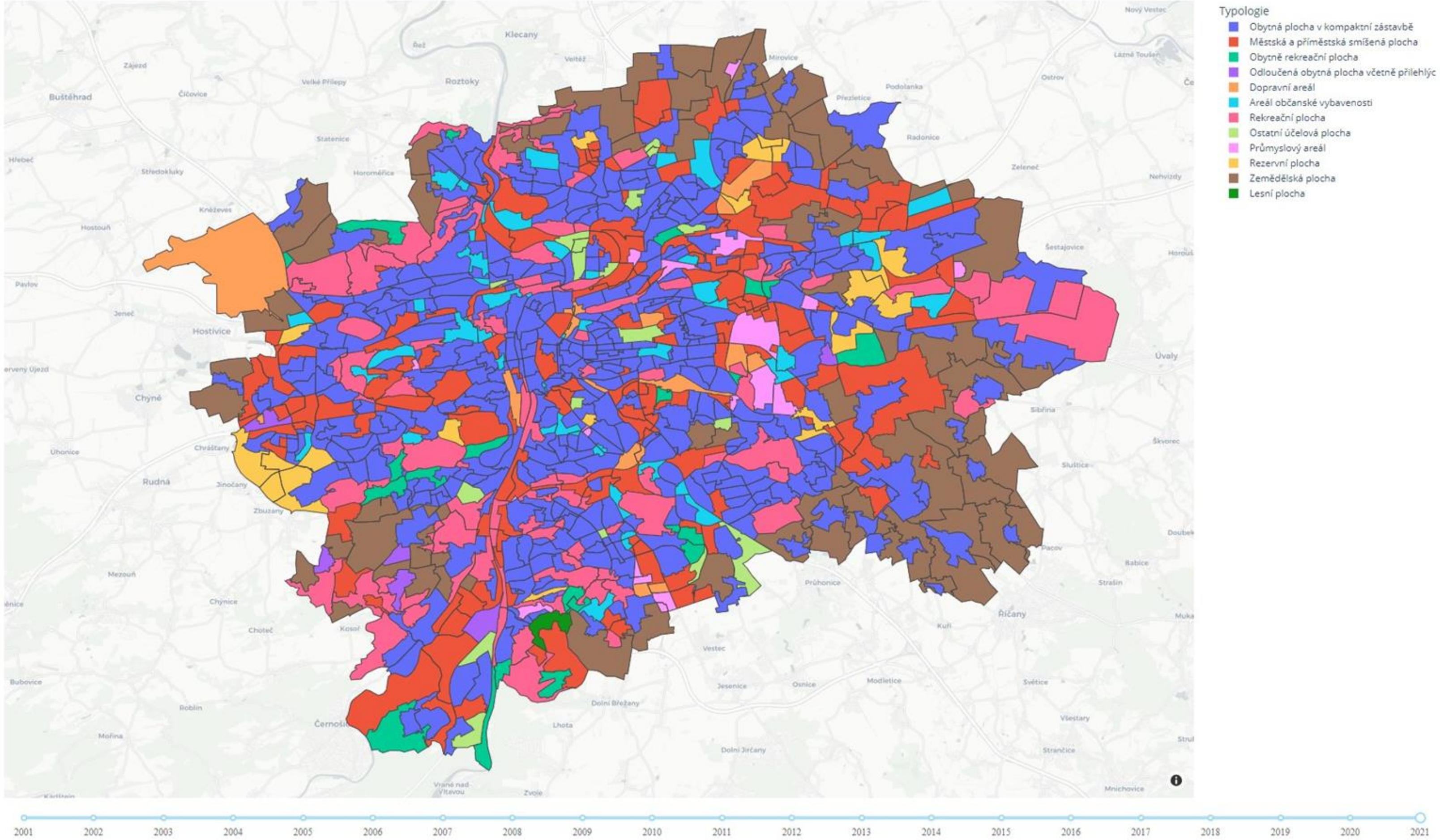


General work data flow scheme



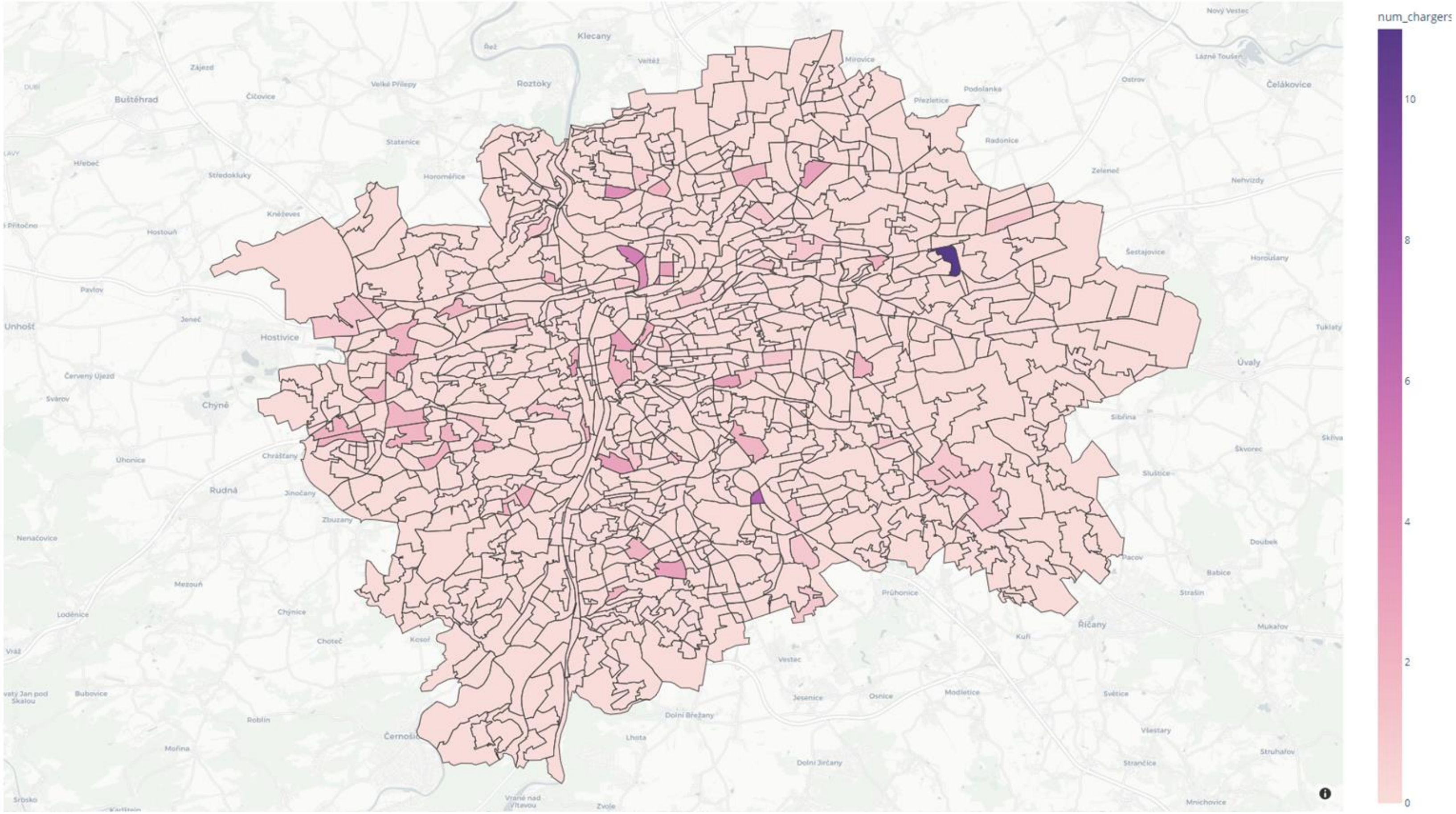
Data showcase - Area typology

Charging point count per ZSJ / BAU



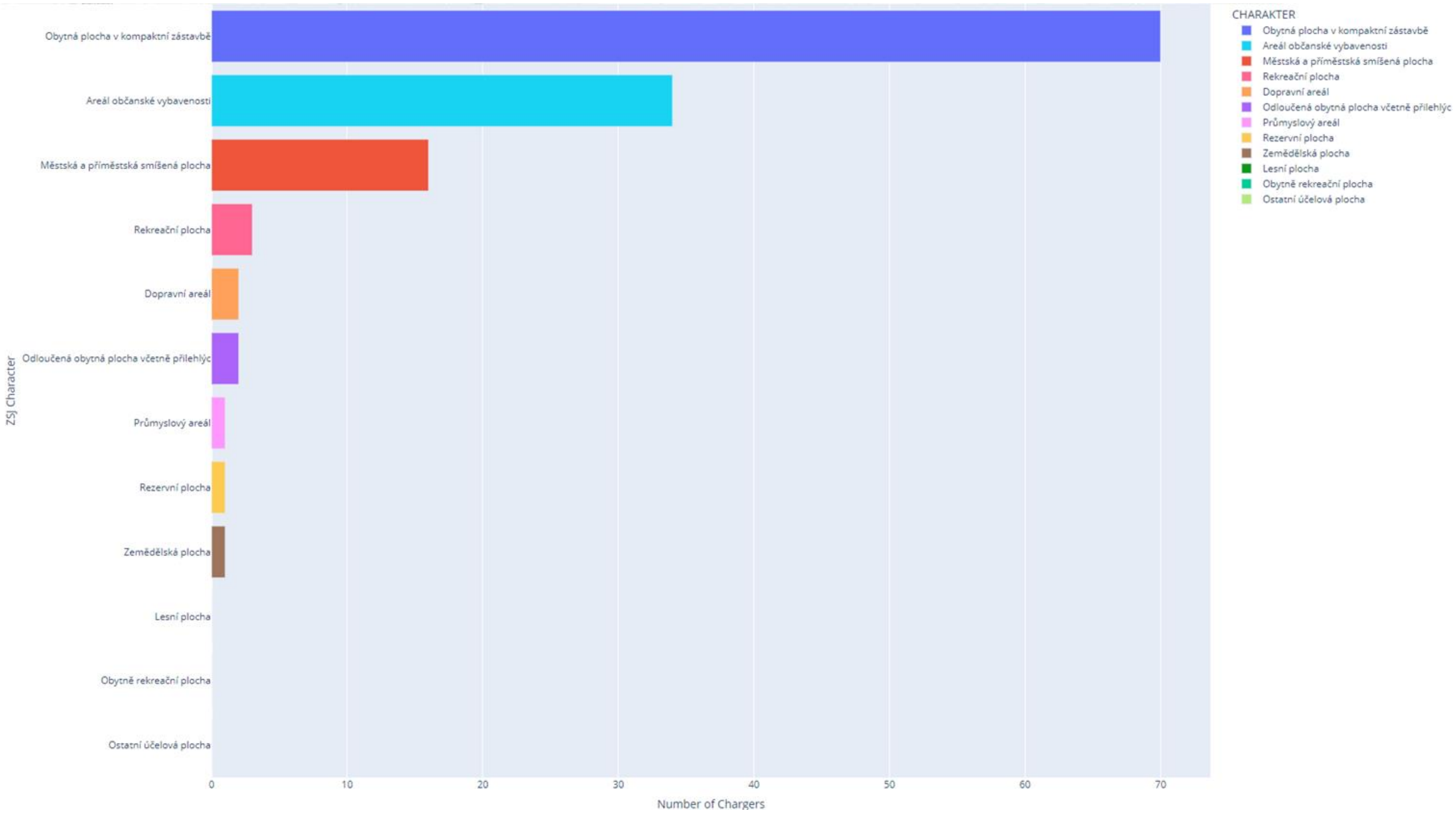
Data showcase: Charging points

Charging point count per ZSJ / BAU



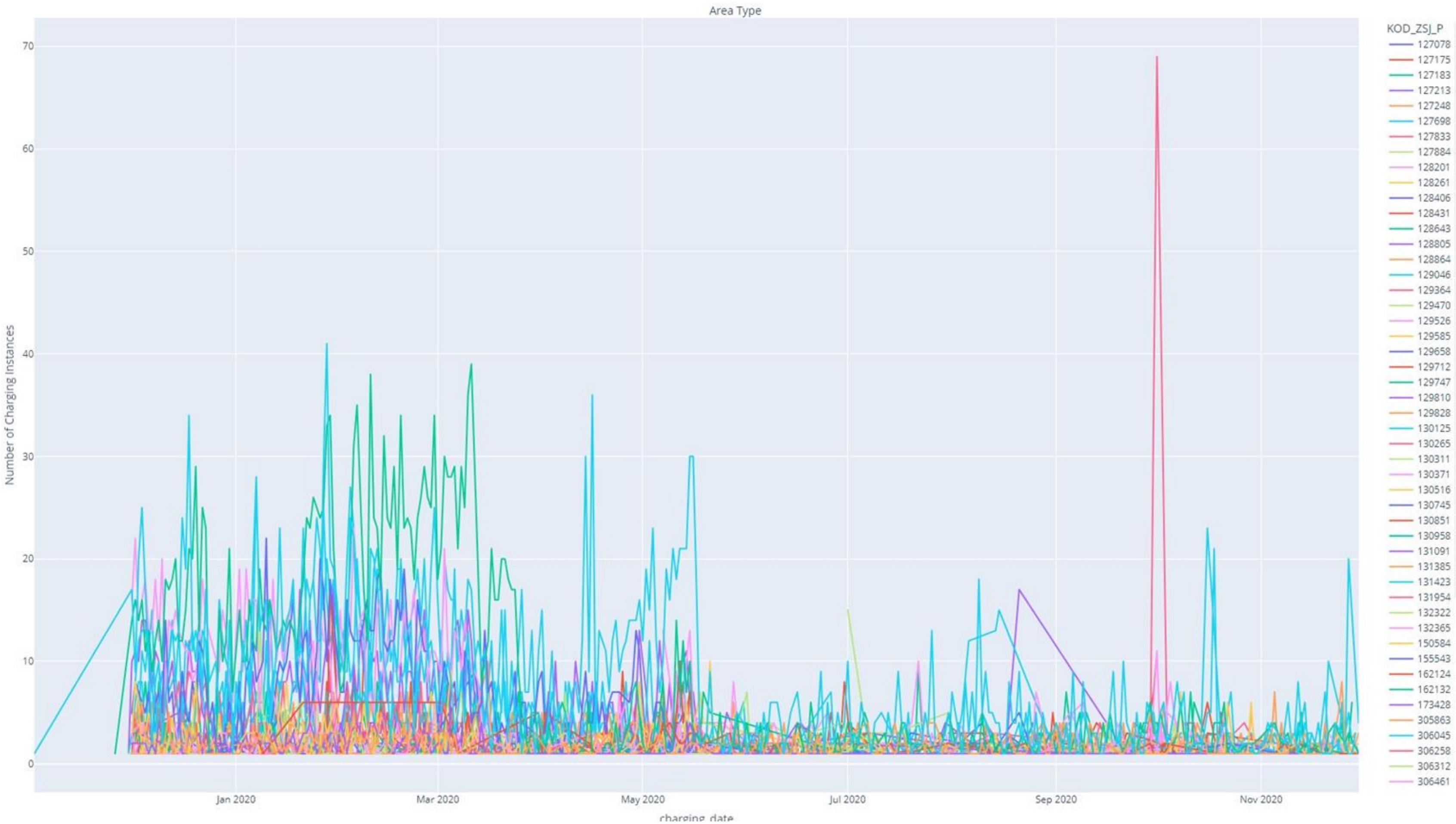
Data showcase: Charging

Charging point count per ZSJ / BAU type



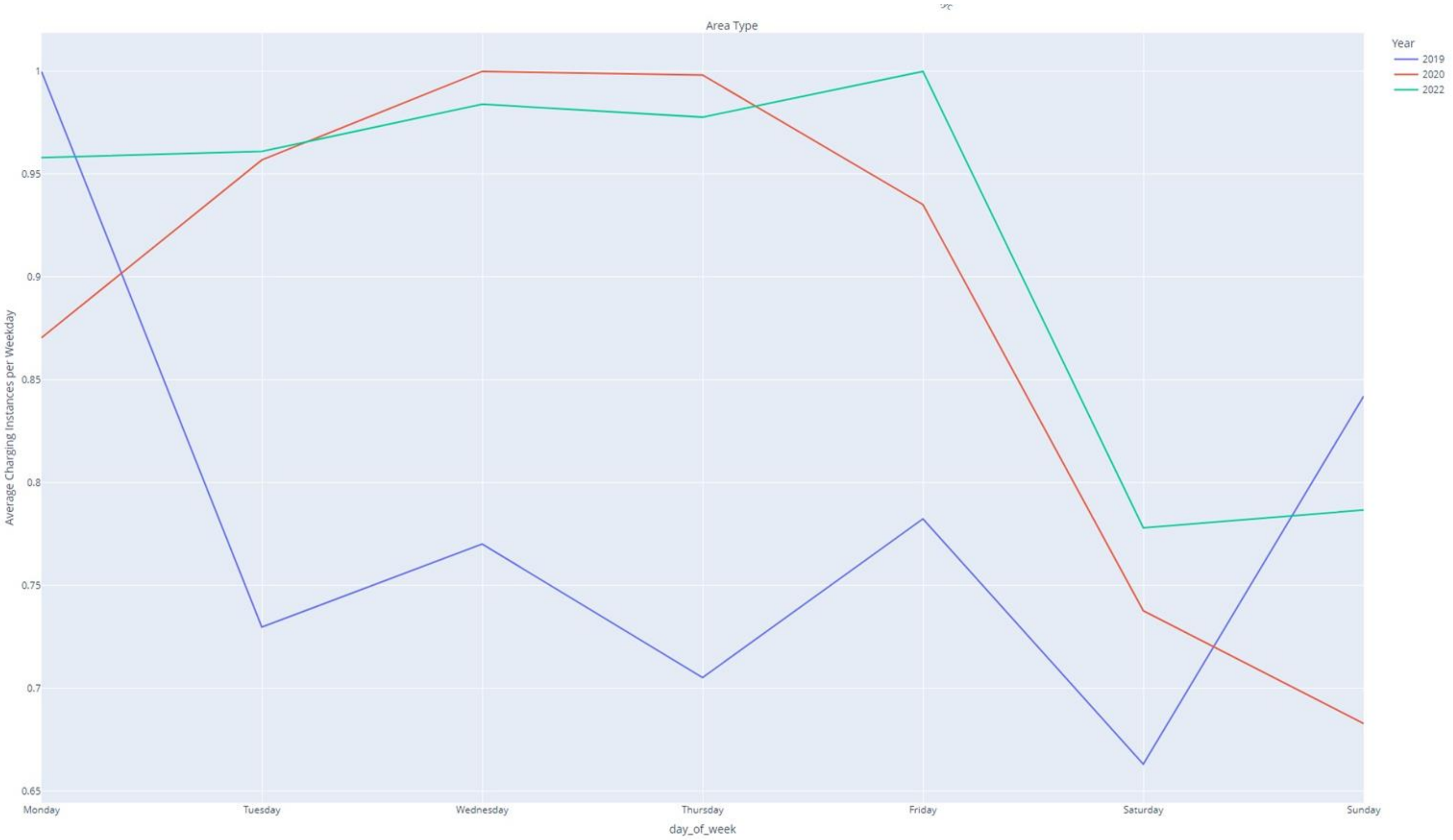
Data showcase: Charging

Raw data is somewhat noisy but detailed



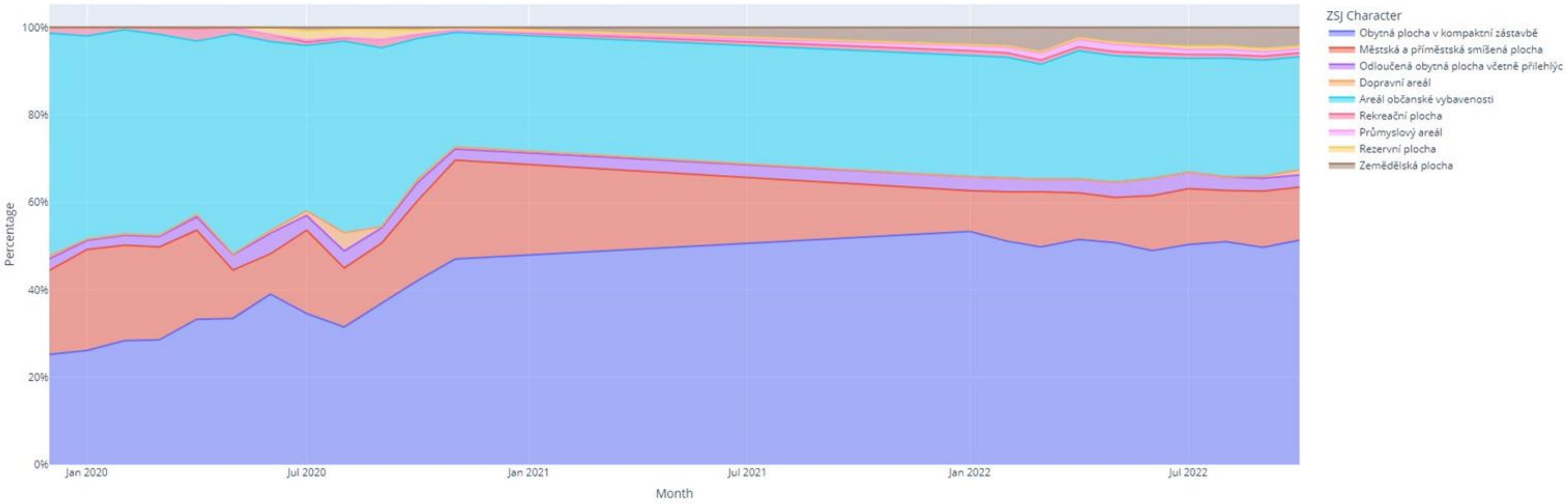
Data showcase: Charging

Showcase: more charging Mo-Fri, ca 20% less demand on weekend

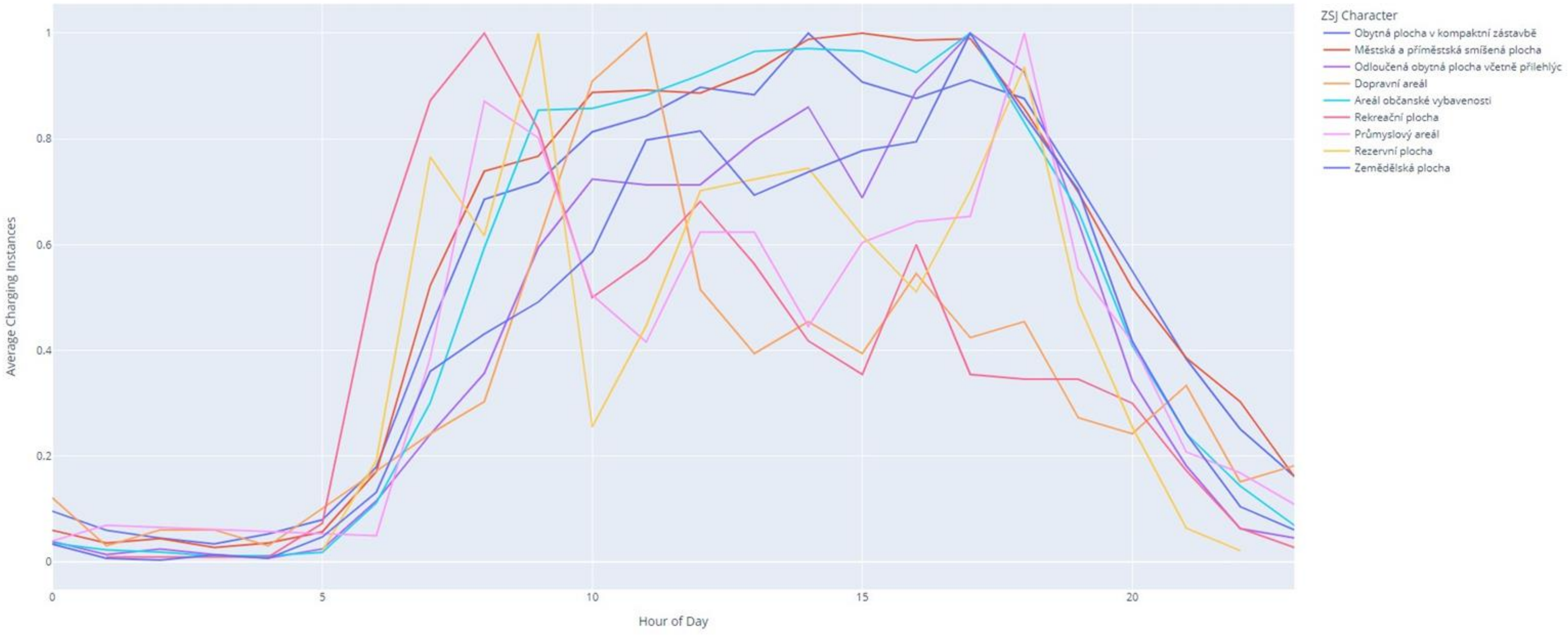


Data showcase: Charging share per ZSJ type

Residential and rural areas increase vs. public area decrease



Load curves per area (ZSJ) type



Data overview - linkage

EV number data

EV Registrations
- Time granularity: yearly
- Area granularity: region
- Range: up to 2023
- Contents
  - Region/kraj
  - Type of EV
  - Private/commercial
  - Count

Population dynamics
- Time granularity: custom
- Area granularity: MČ/KU
- Range: only Dec19+Apr22

Česko v pohybu - survey of from-to journeys
- Time granularity: daily
- Area granularity: TBD
- Range: TBD
- Contents
  - list of anonymised journeys

Telco pop density
- Time granularity: specific days in month
- Area granularity: 20x20m
- Range: only 4 months

Processing

Processing

Processing

Charging data

PREdi charging 19-20
- Time granularity: seconds
- Area granularity: address
- Range: Dec19-Nov20
- Contents
  - ID of charger
  - Charger plug type
  - Address
  - Timestamp start, end
  - Energy Consumption

Linked

PREdi charging 22
- Time granularity: seconds
- Area granularity: address
- Range: Jan22-Oct22
- Contents
  - ID of charger
  - Charger plug type
  - Address
  - Timestamp start, end
  - Energy Consumption

Linked

Demographic data

ZSJ database
- Time granularity: yearly
- Area granularity: up to BAU / ZSJ
- Range: Up to 2022
- Contents
  - Geospatial data
  - Name
  - Population
  - Nr of apartments
  - …

Point of interest map
- To be acquired if needed

Model draft

The model should predict charging profile at a specific charging point.
This means the distribution of charging counts during average day.

Inputs

Charging point features
- Geospatial
  (type of the neighborhood - ZSJ)
- Sociodemographic
  (population movement, relative to overall local population)

$x_1, \dots, x_p$

Absolute local counts
- Overall population
- Density of charging points

$y_1, \dots, y_q$

PyTorch

Latent output

Probabilities of the individual charging profiles

$f(x_1, \dots, x_p) \rightarrow p_1, p_2, \dots, p_k$

Overall charging demand

$g(x_1, \dots, x_p, y_1, \dots, y_q) \rightarrow n$

Charging profiles
- Trainable parameters

$prof_1, prof_2, \dots, prof_k$

where

$prof_j = (q_{j,1}, \dots, q_{j,m})$

Final output

Charging profile

$(prof_1 * p_1 + \cdots + prof_k * p_k) * n$

Training
- MSE or some density distance loss
- Against real charging profile

Estimating EVs in Prague: datasets

Vehicle registrations
Number of newly registered vehicles (including EVs) in Czechia

- Time granularity: yearly
- Area granularity: region
- Range: up to 2023
- Contents
  - Region/kraj
  - Type of EV
  - Private/commercial
  - Count
- Source: the Central Vehicle Register, Ministry of transport
- Data availability: publicly available PowerBI dashboard

Registrace všech čistých vozidel v ČR dle NAP ČM | Centrum dopravního výzkumu, v. v. i.

Population dynamics
Tracked mobility of people via Mobile network operators.

- Time granularity: per month (potentially more granular)
- Area granularity: MČ/KU
- Range: only Dec19+Apr22
- Contents:
  - Trip source
  - Trip destination (MČ)
  - Number of people

Data availability: CSV

https://golemio.cz/data/data-mobilnich-operatoru

Česko v pohybu - survey of from-to journeys

Survey of 50.000 journeys

- Time granularity: daily
- Area granularity: TBD
- Range: 2017 - 2019
- Contents
  - list of anonymised journeys
  - transportation type

Data availability: CSV

https://www.ceskovpohybu.cz/

Open questions being worked on

1 Creating the EV commuting model, finding the right model to predict demand curve in individual locations

2 How to include external factors - private charging, charger accessibility, etc

3 Deciding to use data for locations outside of Prague (available)

Thank you.

We are looking forward to the discussion and potential collaboration

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