End-user flexibilities for electrical distribution grid planning

C. Yaman Evrenosoglu (ETH Zürich)

sweet swiss energy research for the energy transition

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Lunch talk series:
Flexibility provision from buildings and electromobility

1. Impacts of electric vehicles and heat pumps flexibility: European and Swiss perspectives
2. **End-user flexibilities for electrical distribution grid planning**
3. Modelling flexibility from electric vehicles: where, when, why, and how
4. Modelling flexibility from heat pumps: a bottom-up approach for Swiss buildings
5. Electrification, flexibility or both?
6. Emerging trends in recent Swiss and European policy
7. Operation and market mechanisms: from dynamic electricity tariffs to day-ahead and intraday auctions

Agenda

- Take-away messages
- Framework
- Grid planning principles
- Illustrative results
- Appendix
  - *V(P) control for tap-changing transformers*
  - *Q(V) control for solar PVs*
  - *PV feed-in limitation levels vs. loss in annual generated PV energy*

Take-aways

Prosumer- / consumer-side

- **Feed-in management of PV** systems is the most effective approach to reduce grid expansion costs.
  - 👍 Curtail excess PV statically (e.g., at 70% of kWp at all times) or dynamically
  - 👍 Shift flexible demand to high PV hours
  - 👍 Residential grid-friendly BESS
- **Voltage support by PV converter** systems with Q(V) or P(V) control is an effective method to alleviate overvoltage violations
- **Load reduction and shifting** (especially EV charging) is an effective demand-side management in dense urban areas.
  - 👍 Slow charging
  - 👍 Ripple control (i.e., Rundsteuerung) for EV charging and HPs

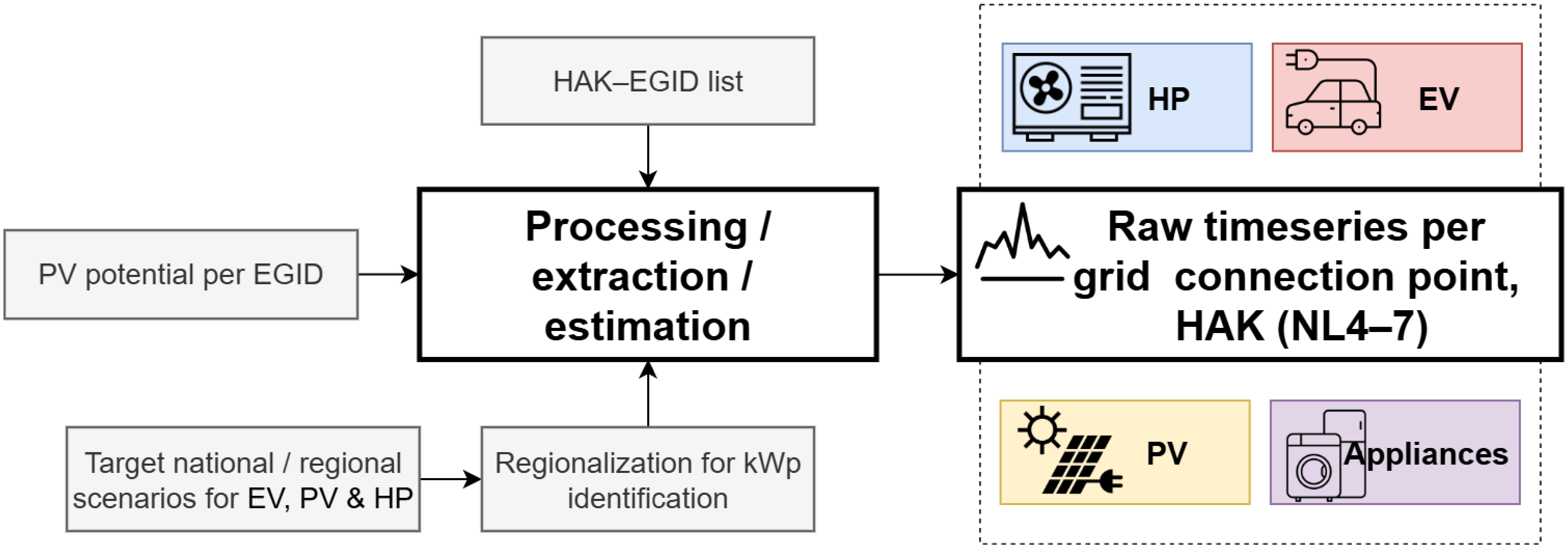
Take-aways

Grid technology

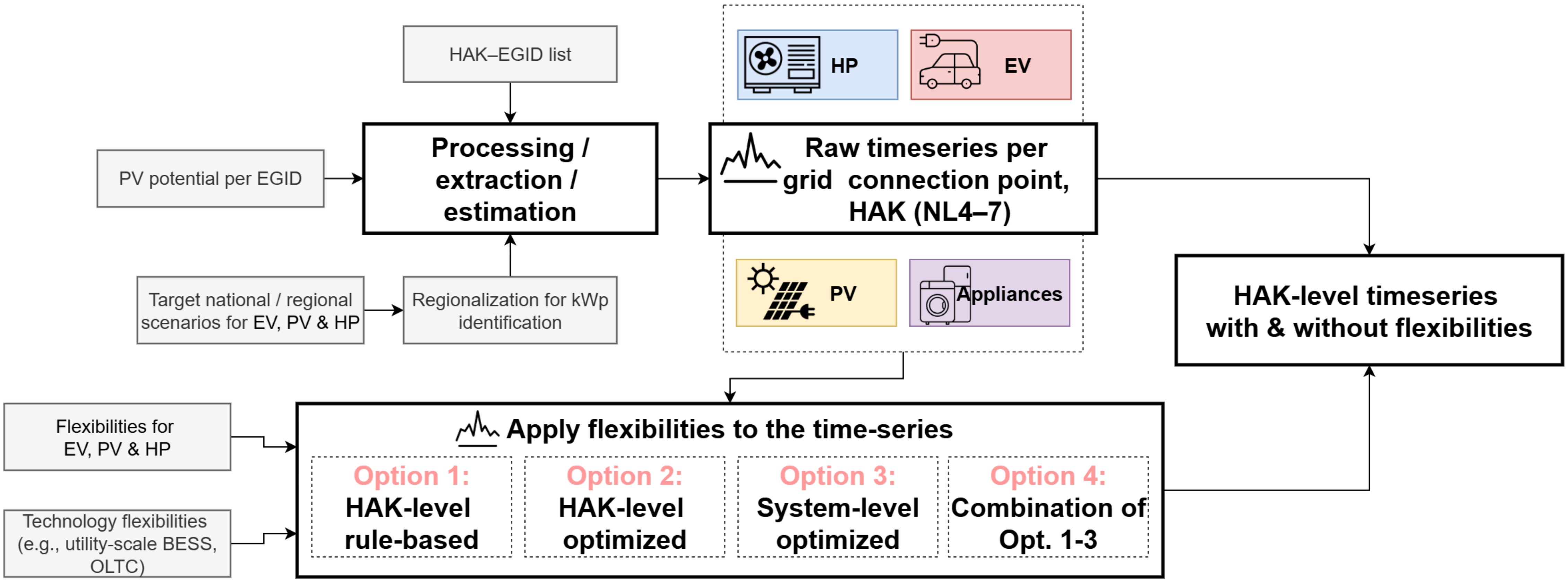
- **Tap-changing transformers**
  - at **HV-MV** shall be equipped with V(P) control rather than V(V).
  - at **MV-LV** (if deployed), shall be equipped with V(P) control rather than V(V).
    - ✍ **The current industry practice of adjusting the rated voltage of the MV-LV transformers to the values higher than nominal voltages must be revisited** in the future with high PV proliferation, to prevent unnecessary overvoltages during daytime when excess PV generation is the highest.

Framework

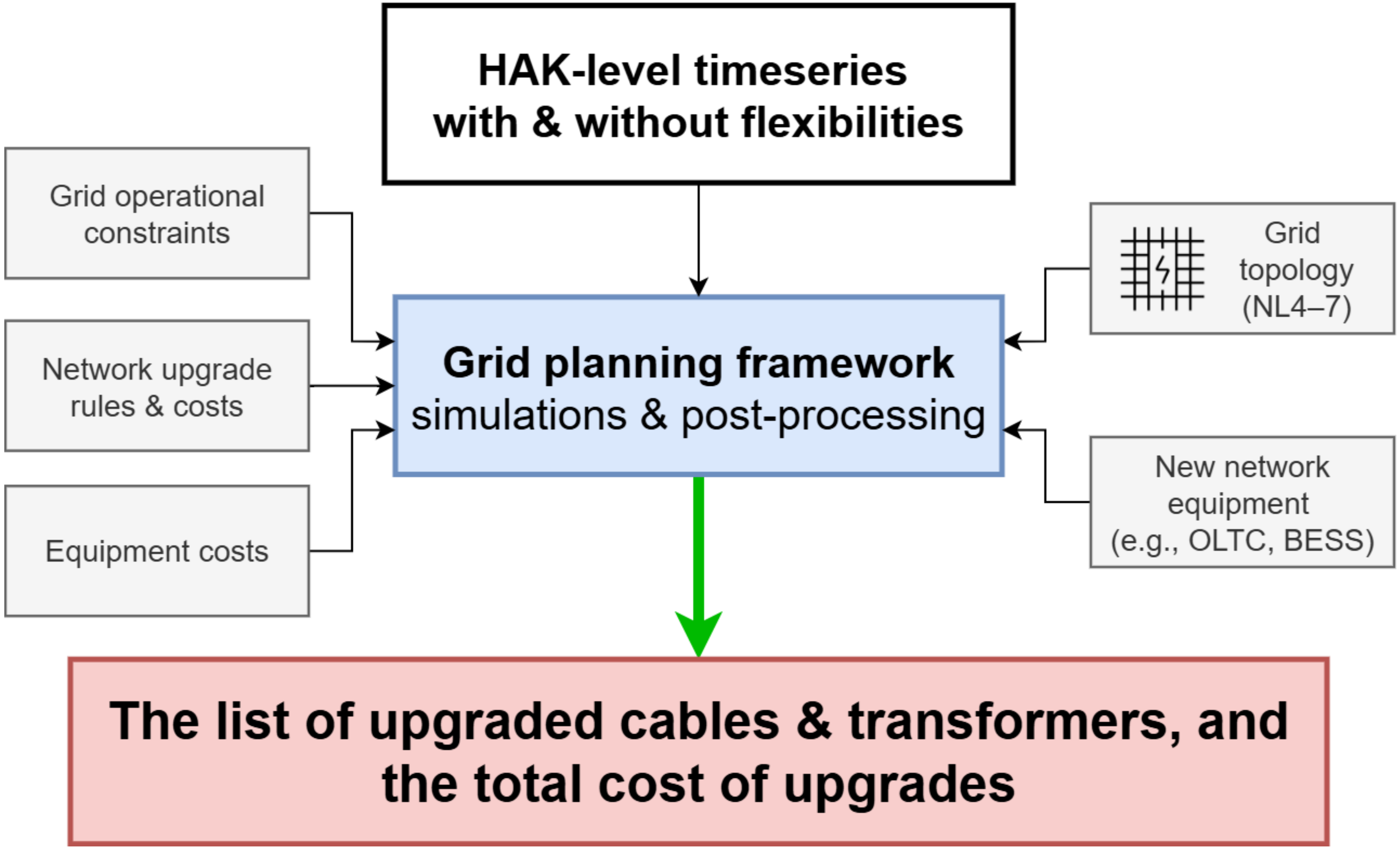
Framework
Flexibility-aware distribution grid planning



Framework
Flexibility-aware distribution grid planning



Framework
Flexibility-aware distribution grid planning



Grid planning principles

Grid planning principles

Traditional

- **cable reinforcement** by adding parallel cables or increasing the cross-sectional area, including the digging-trenching costs,
- **transformer reinforcement** by adding parallel transformer(s) or increasing the capacity, including the building costs

with grid flexibilities

- **OLTC** at HV-MV (network layer 4) substations with **V(P) characteristics**
- **VRDT** at MV-LV (network layer 6) stations with **V(P) characteristics**

OLTC: on-load tap-changing transformer; VRDT: voltage-regulating distribution transformer

with prosumer/consumer flexibilities

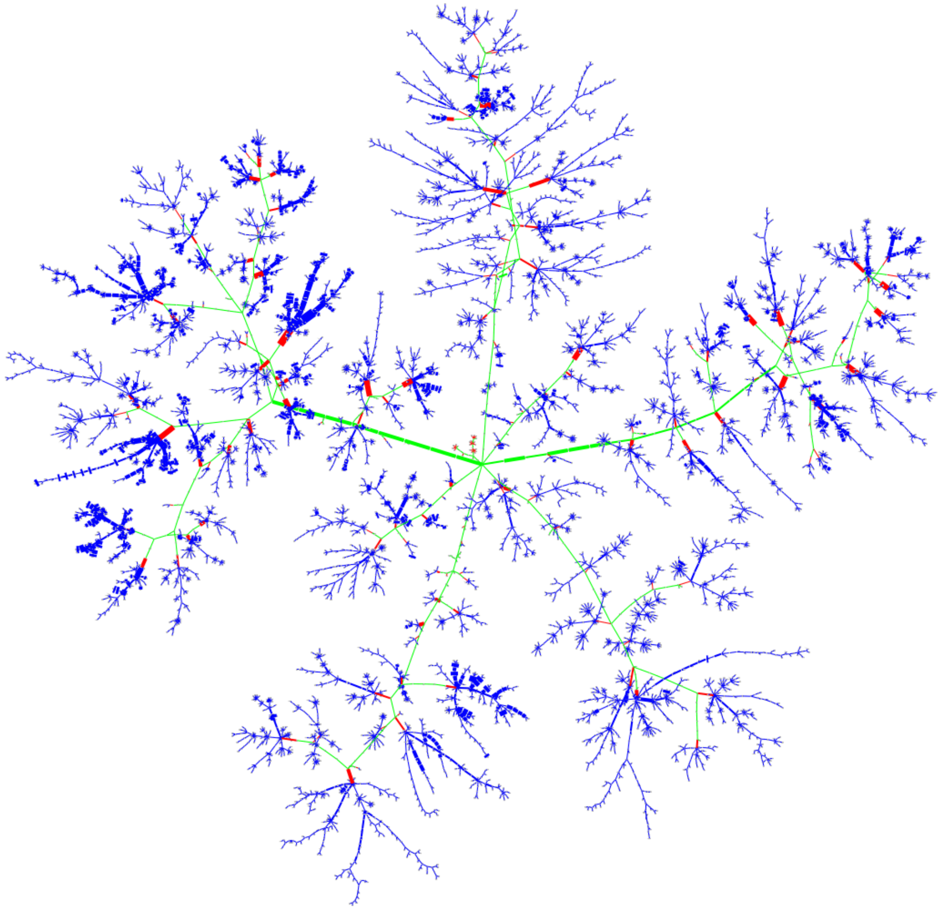
- **Limiting** solar PV production (e.g., maximum generation is reduced by 30%, shifting flexible demand, grid-friendly BESS)
- **Voltage support** by solar PVs
- **Limiting** the capacity of EV charging and HP
- **Smart charging** (e.g., night-time charging for residential EVs)
- **Shifting** HP operations

Illustrative results

Real Swiss networks
NE4-7

- Results for the **NE4-7** of multiple **Swiss** utilities, a mix of **rural**, **semi-rural** and **urban**
- Total of **>60** HV-MV substations with all network layers downstream
- Each HV-MV substation is simulated with all downstream grids connected (NE4-7)
- **2’000 – 7’000 HAKs** (i.e., Hausanschlusskasten – grid connection point) per substation
- **4’000 – 11’000 nodes** and **4’000 – 11’000** cables, served per HV-MV substation
- Grids are imported from the commercial software (e.g., NEPLAN, PowerFactory, CYME, Integral), the format conversion is performed and in-house tool, **FlexDyn** is used, benchmarked with the utility’s commercial software.

One selected substation and downstream grids **today**



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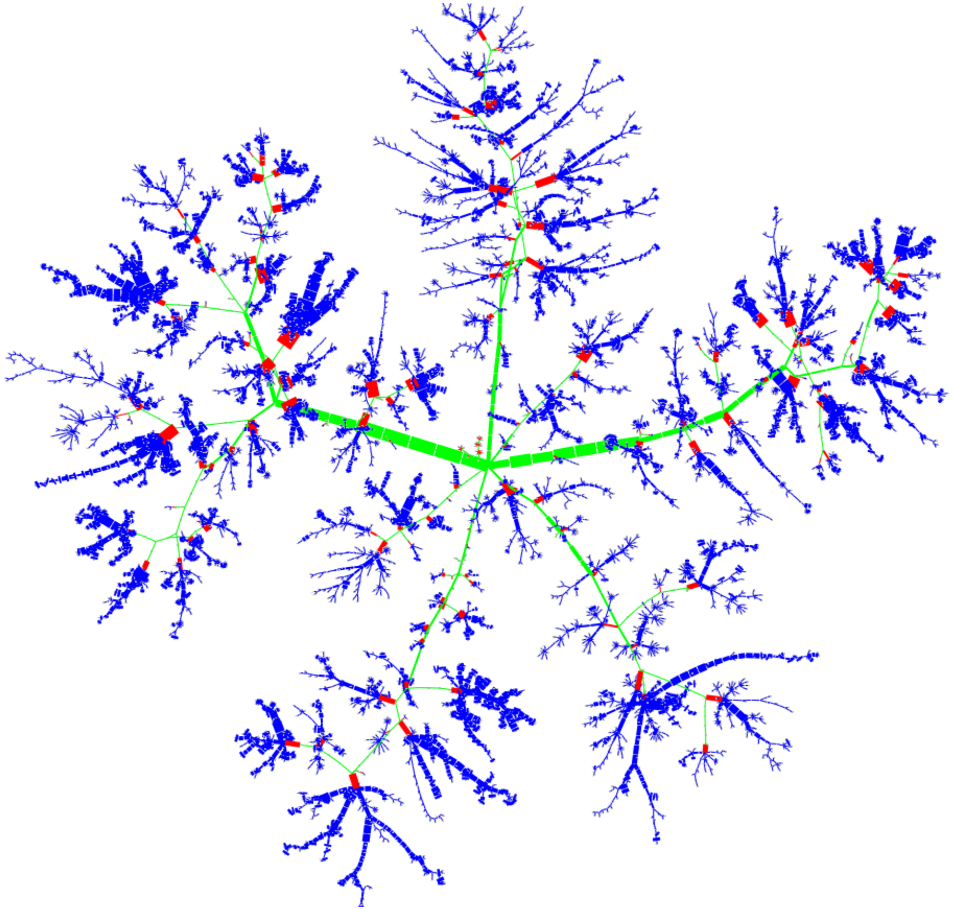
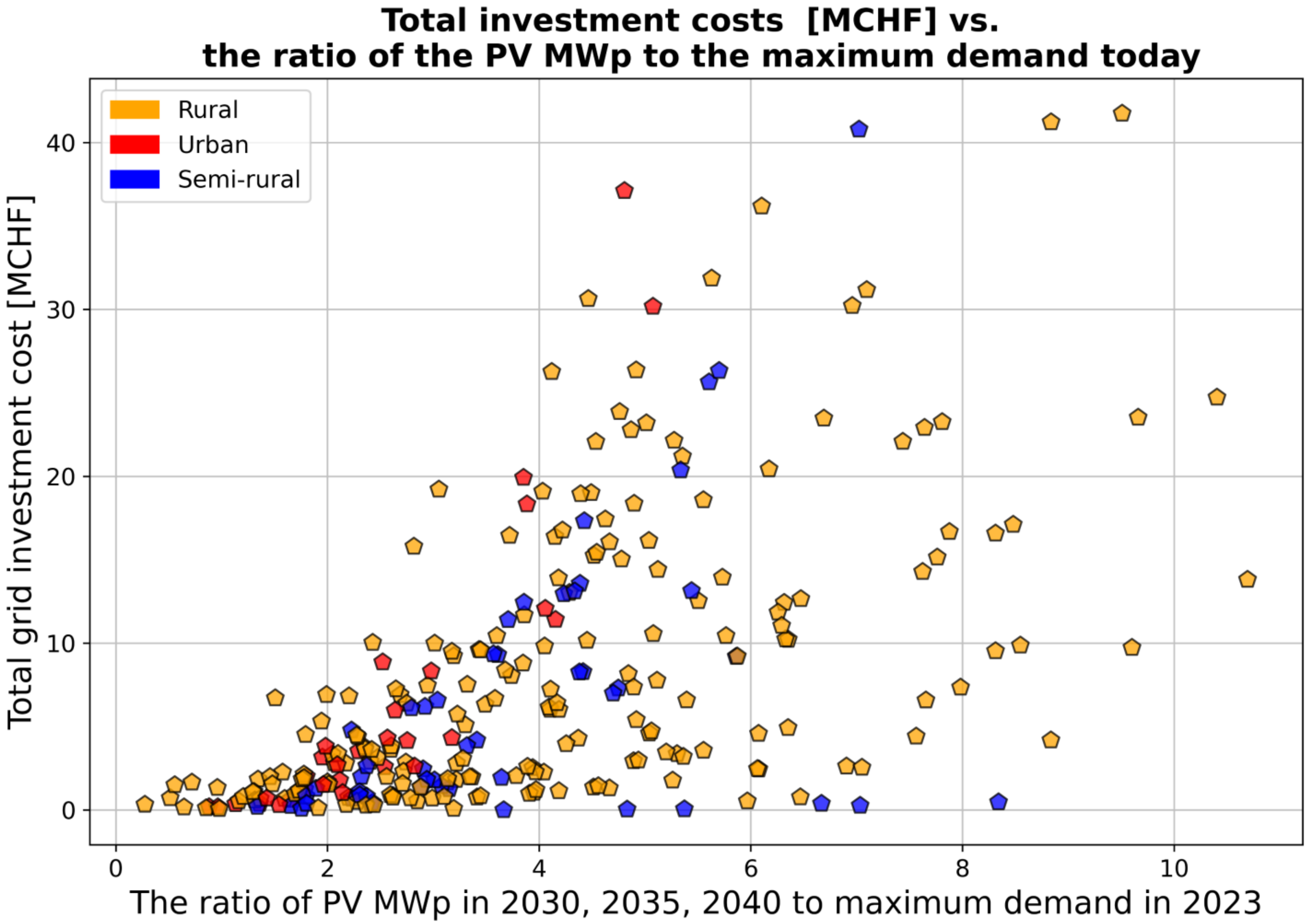
One selected substation and downstream grids **2040**

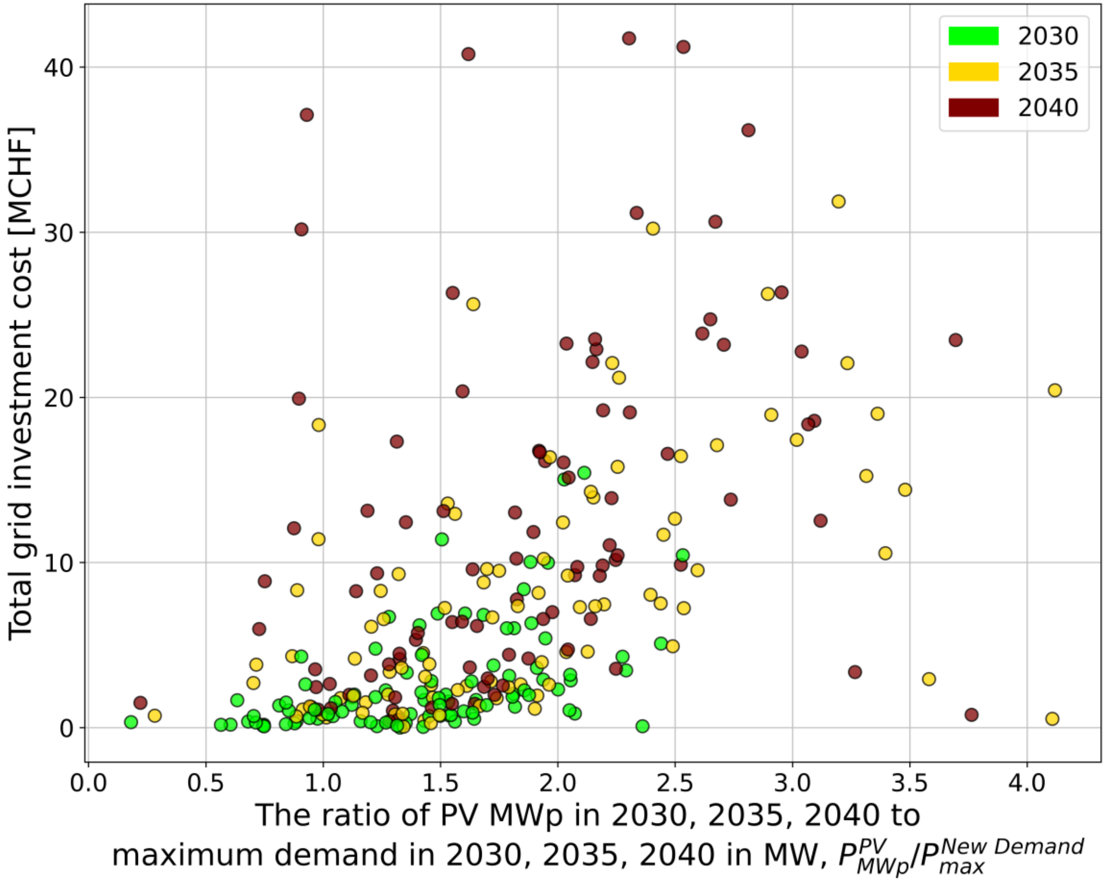


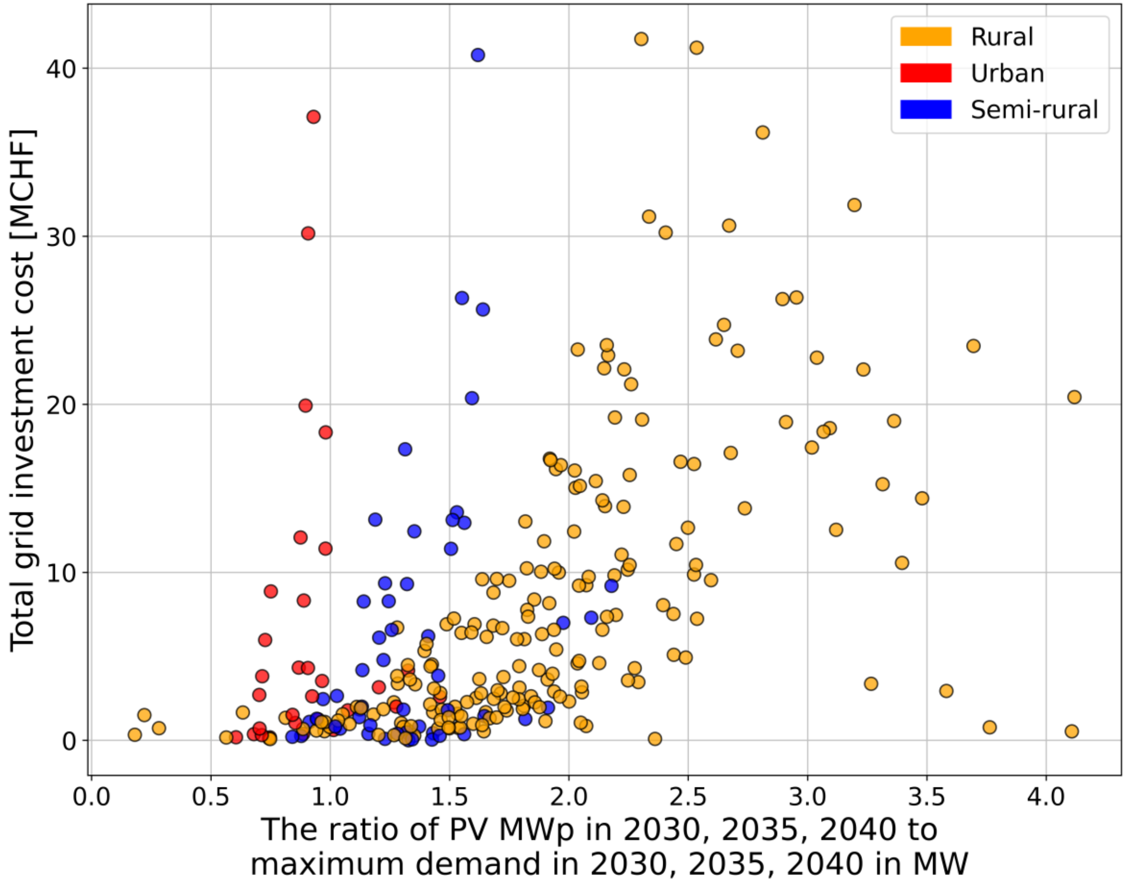
Future PV MWp vs. **today's maximum demand *without any measures***

- Total grid investment costs
- The ratio of PV installed capacity in 2030, 2035 and 2040 to the maximum demand today, respectively



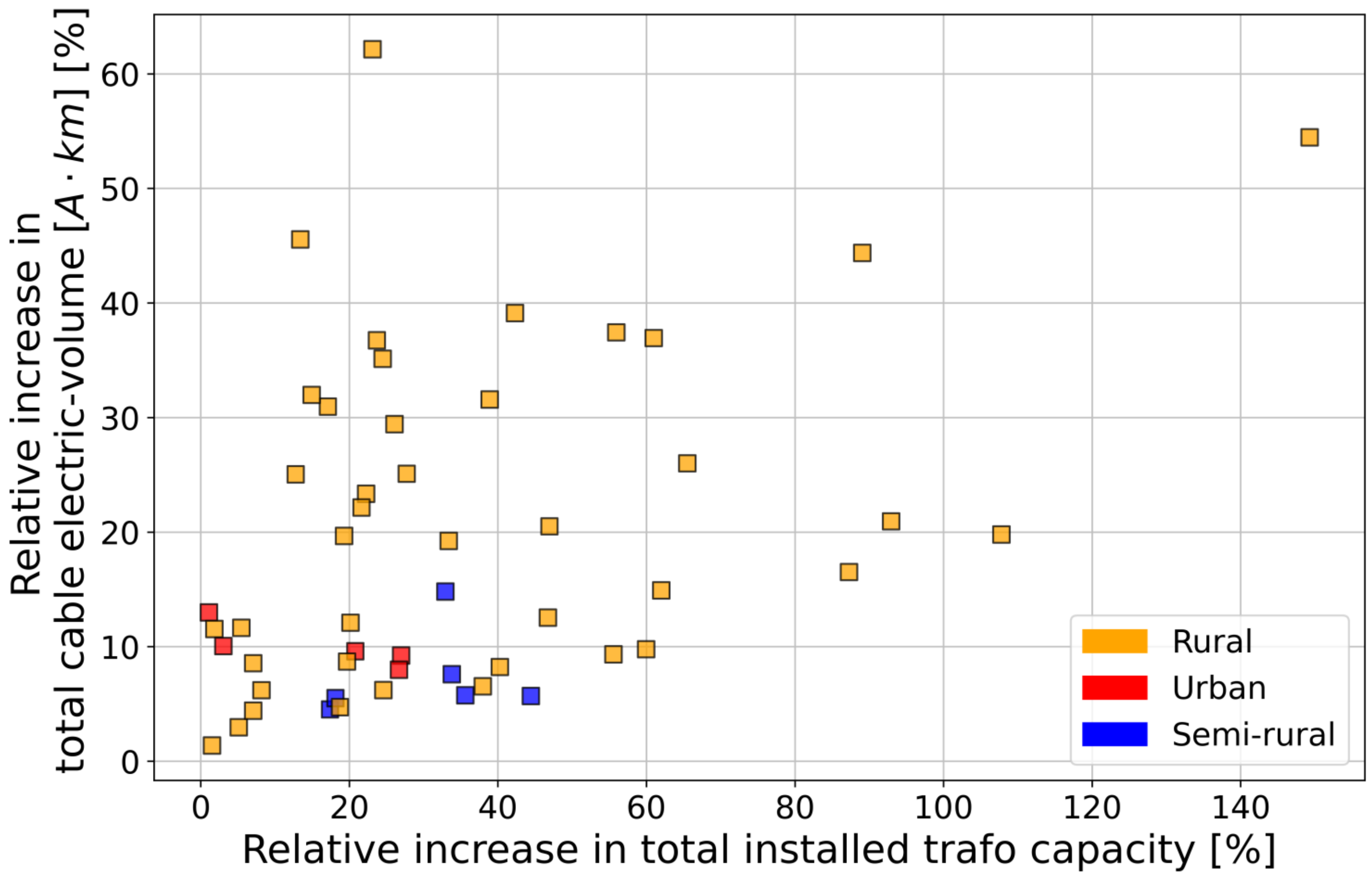
Future PV MWp vs. **future maximum new demand *without any measures***





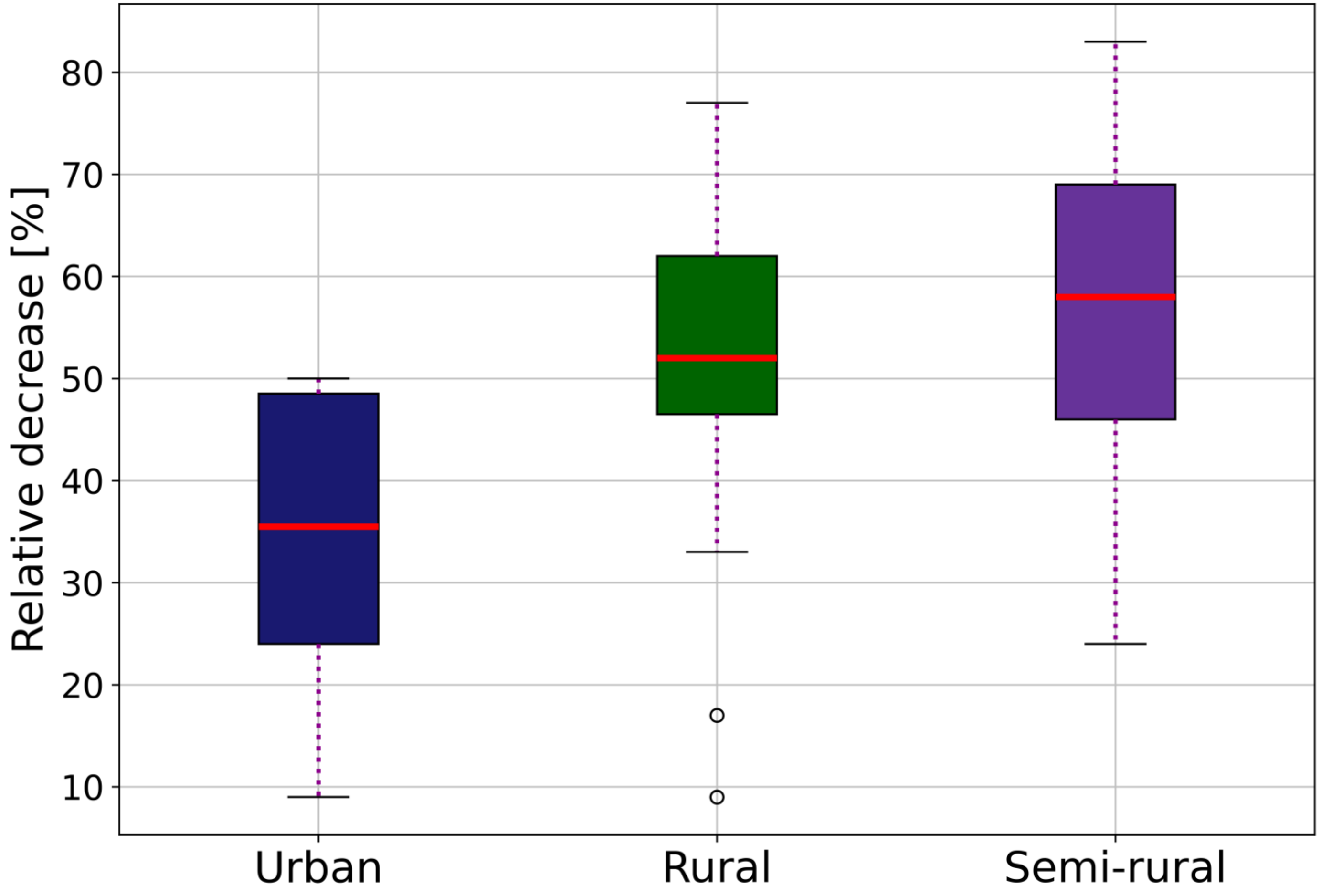
Grids in 2040 for the Mantelerlass Strom VG/EnG
without any measures

- Relative increase in total transformer capacity (NE4 & NE6)
- Relative increase in electric-volume:
  - Current capacity × Length



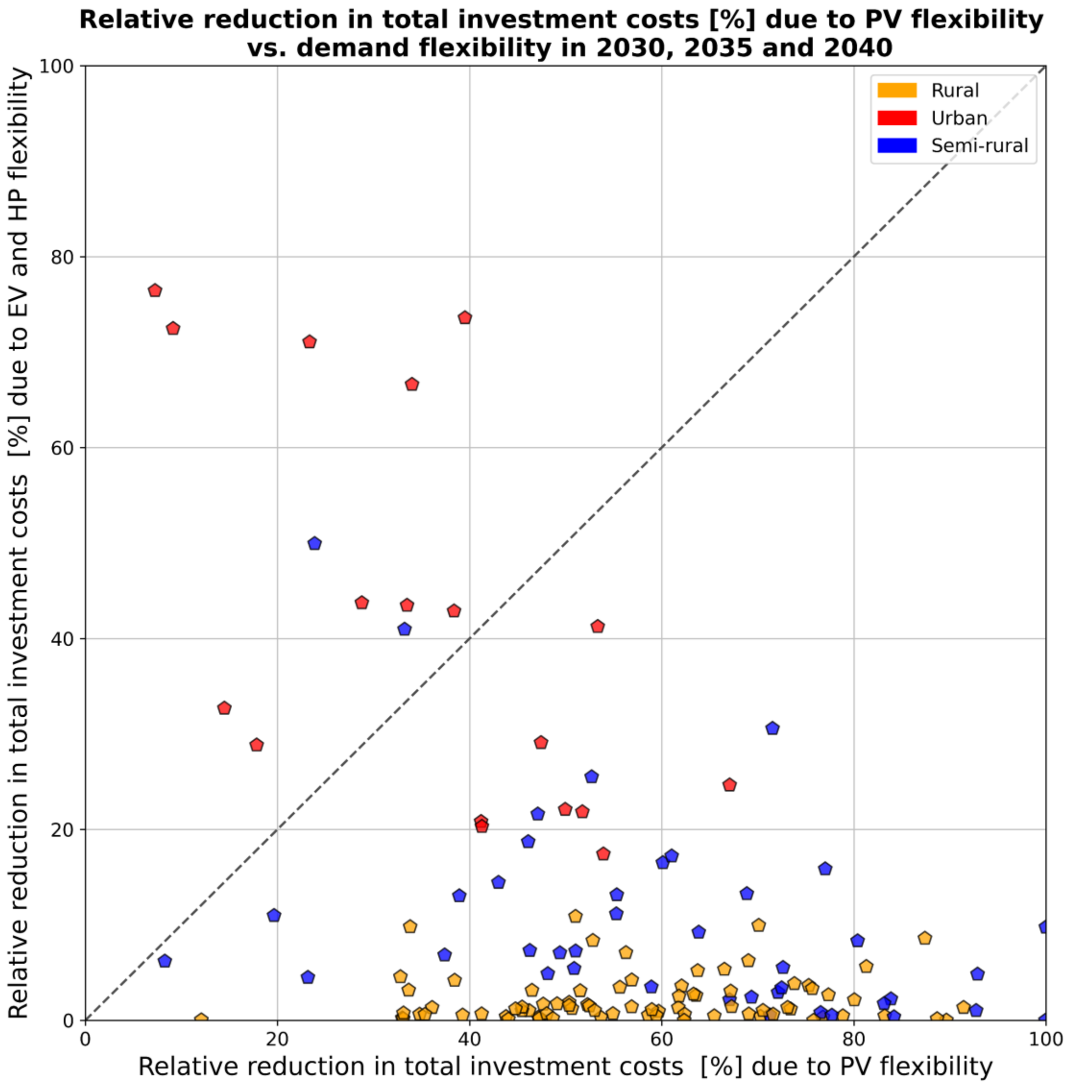
Grid investments in 2040 for Mantelerlass Strom VG/EnG

Impact of limiting the PV feed-in on total investment costs
relative decrease w.r.t. the results of traditional planning



Impact of **flexibilities** on the grid investment costs

- Relative reduction in total investment costs due to PV feed-in management
- Relative reduction in total grid investment costs due to EV and HP flexibility



Take-aways

- **Sizing the grids for kWp installed capacity of the PVs does not make sense**, since the peak production seldom occurs
- **Local flexibilities must be unlocked and be considered in grid planning processes**
  - Spatially differentiated **dynamic tariffs** for demand and production make sense
  - **Curtailing PV** makes sense, and it can be static or dynamic
  - Providing incentives to **shift the non-stiff demand** to high PV hours makes sense
- **Simultaneity factor estimation** for new demand and PV production (especially composite simultaneity factors) in grid planning is **complex**

  → Using **time-series** in grid planning for new demand and generation at the HAK-level is very insightful

  → **Stochastic methods** for the location (e.g., which buildings), amount (e.g., kWp installed) and the profiles of the new demand and generation in various **target years** and for various **scenarios** are ideal, but are not easily scaling up sweet swiss energy research for the energy transition

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FEN experts in **PATHFNDR**

Demiray | Fuchs | Marinakis | Buchecker | Savvopoulos | Bellé

C. Yaman Evrenosoglu
evrenos@fen.ethz.ch
ETH Zürich
Forschungsstelle Energienetze (FEN) [*Research Center for Energy Networks*]

FEN Website

FEN Linkedin

PATHFNDR: www.sweet-pathfndr.ch

ETH zürich | Empa | PAUL SCHERRER INSTITUT PSI | zh aw | HOCHSCHULE LUZERN | UNIVERSITÉ DE GENÈVE | EPFL | TU Delft

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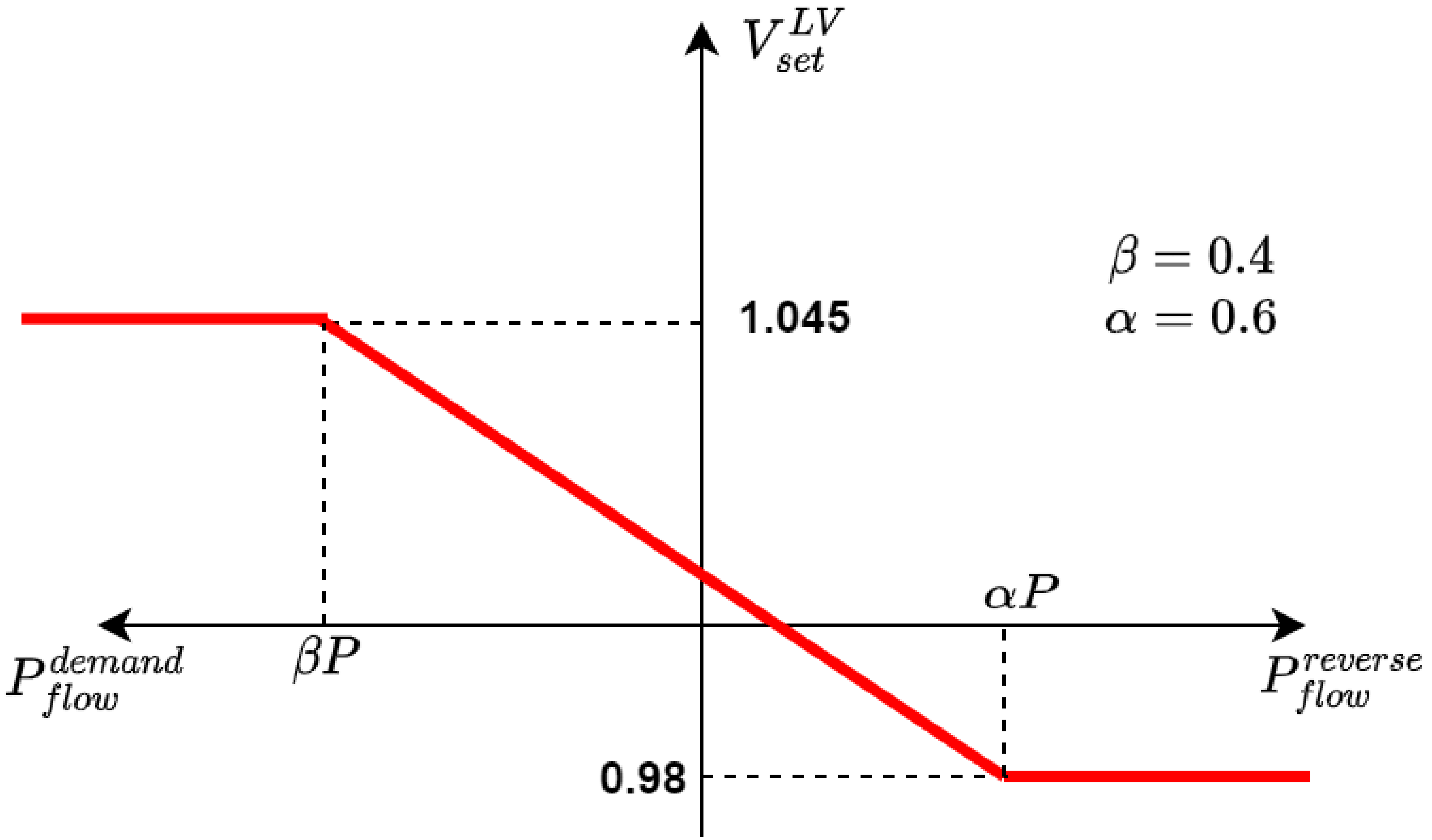
Appendix

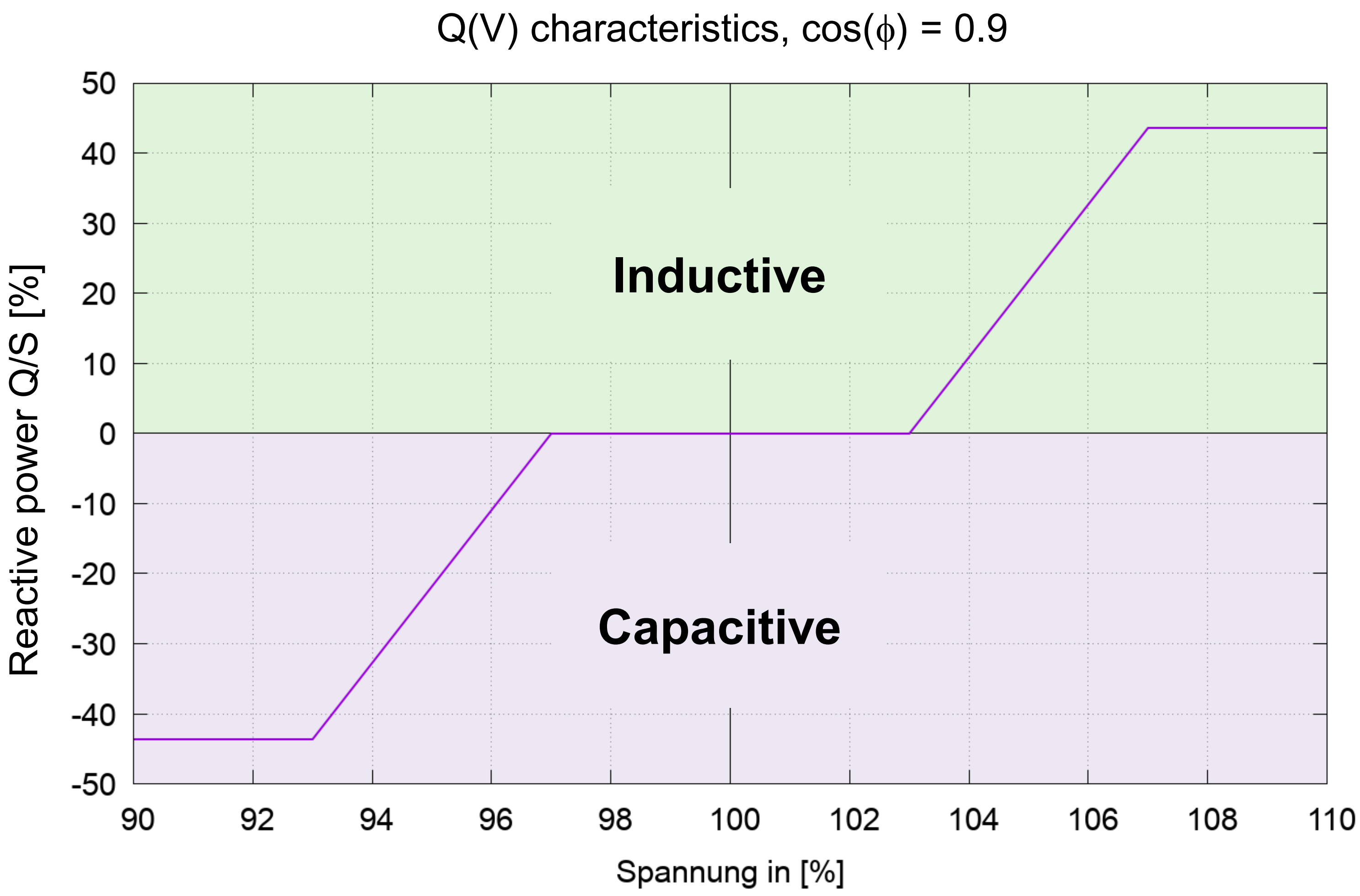
– V(P) control for tap-changing transformers
– Q(V) control for solar PVs
– PV feed-in limitation levels vs. loss in annual generated PV energy

V(P) Control for OLTCs & VDRTs

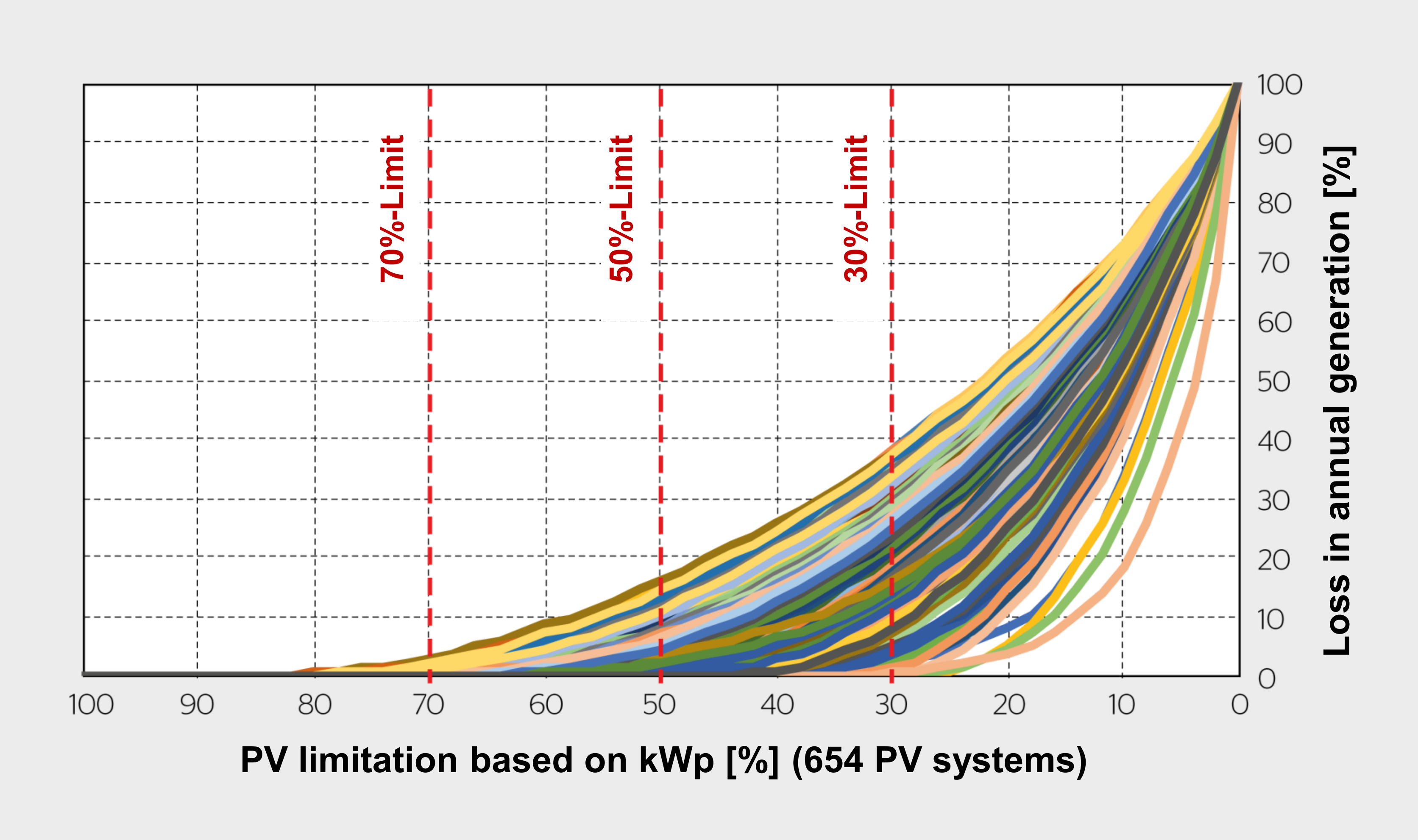
OLTC: on-load tap-changing transformer; VRDT: voltage-regulating distribution transformer



Q(V) control of solar PVs



PV limitation vs. loss in annual generated PV energy



Peter Cuony, Helena Todorov and Christof Bucher, “**Ohne Leistungsregelung von PV geht es nicht, Bulletin Electrosuisse**”, December 2024.