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PV and Storage in Communities: Challenges and Solutions

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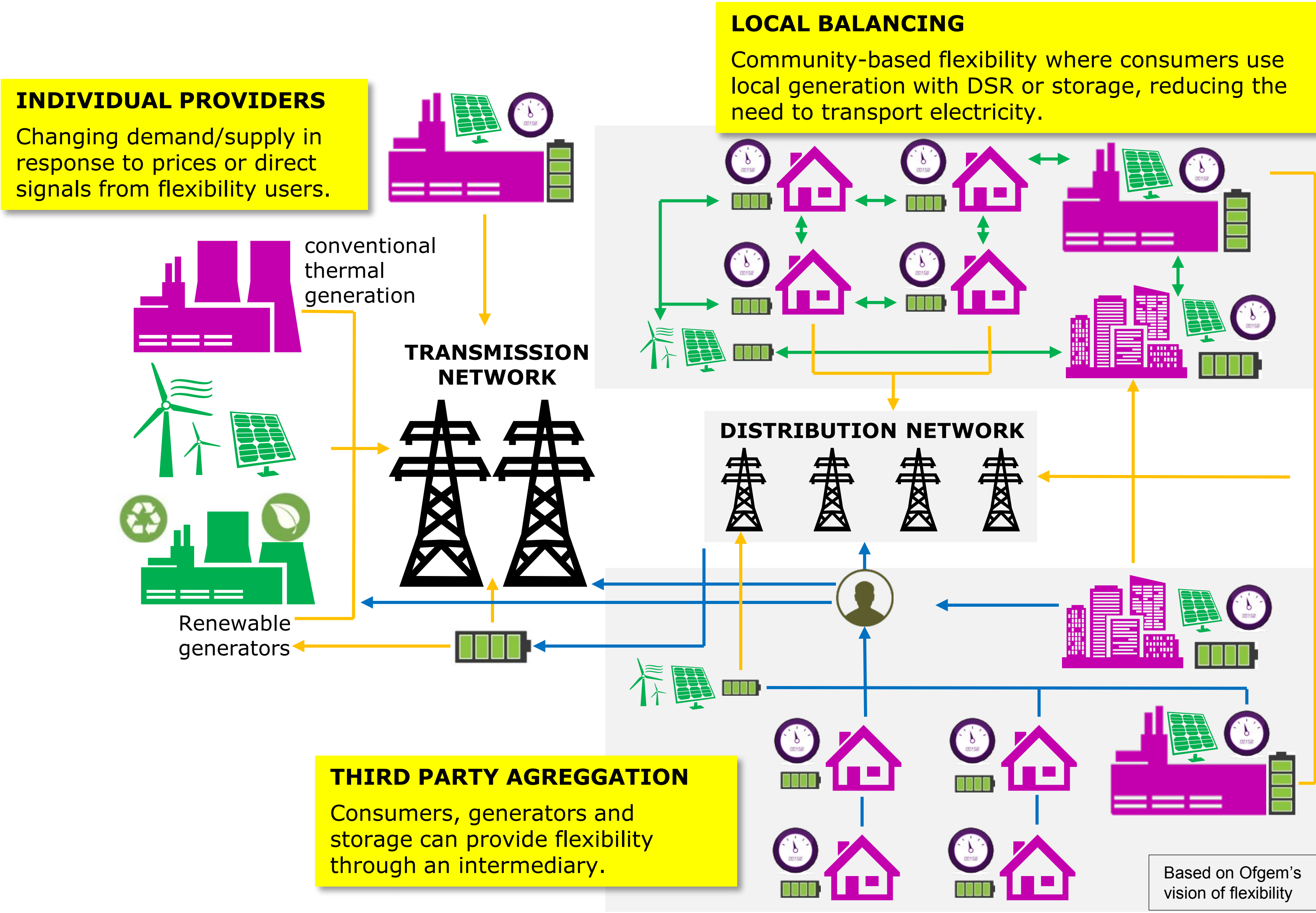
Outline

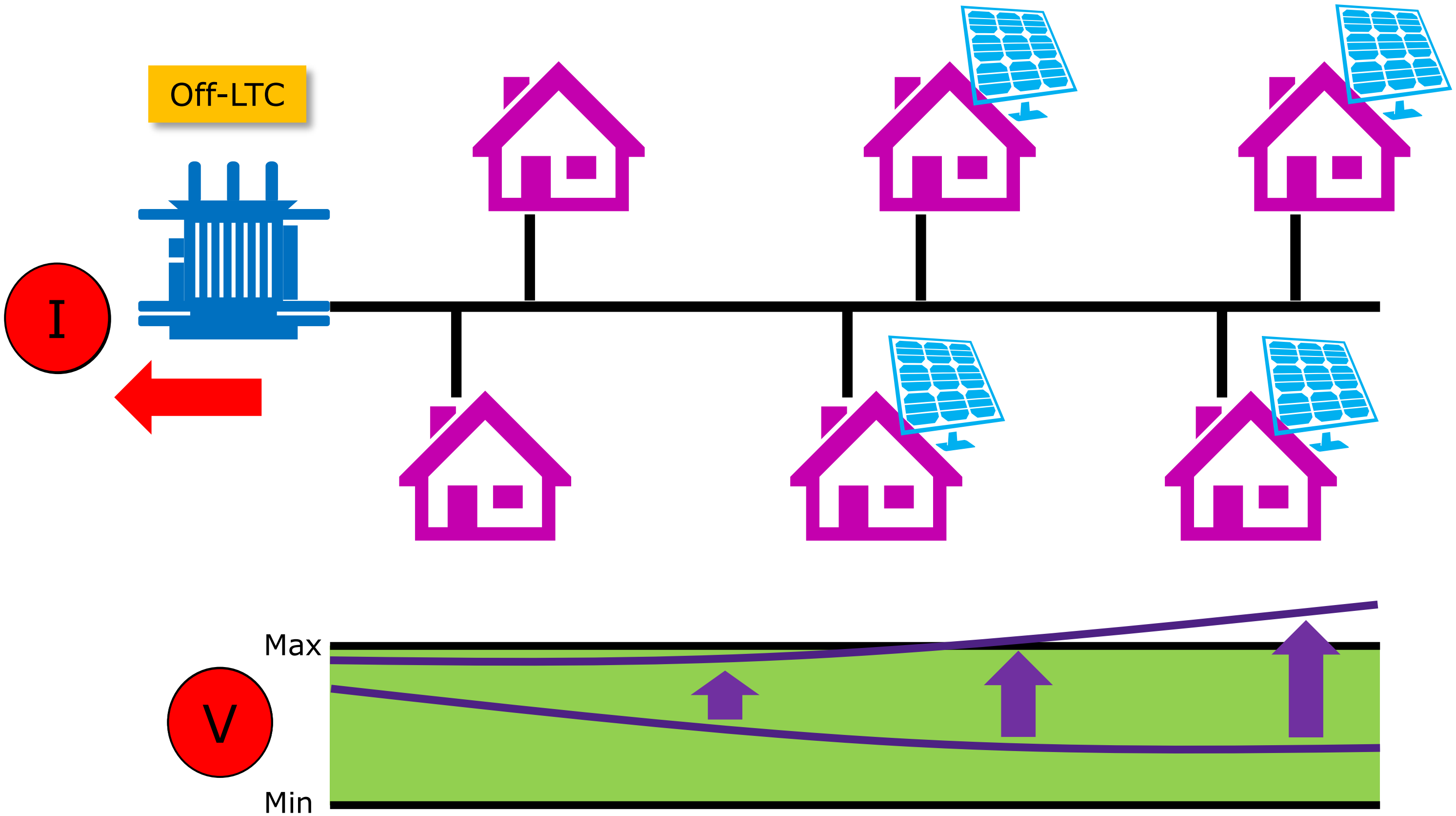
- Context: Flexibility
- Challenges in PV-Rich LV Networks (Communities)
  - PV, Battery storage
  - Case Study, Control strategies
  - Effects on the LV Network and Customers
- Future DSOs and Community-Based Flexibility
- Conclusions

Flexibility Vision (UK Regulator)



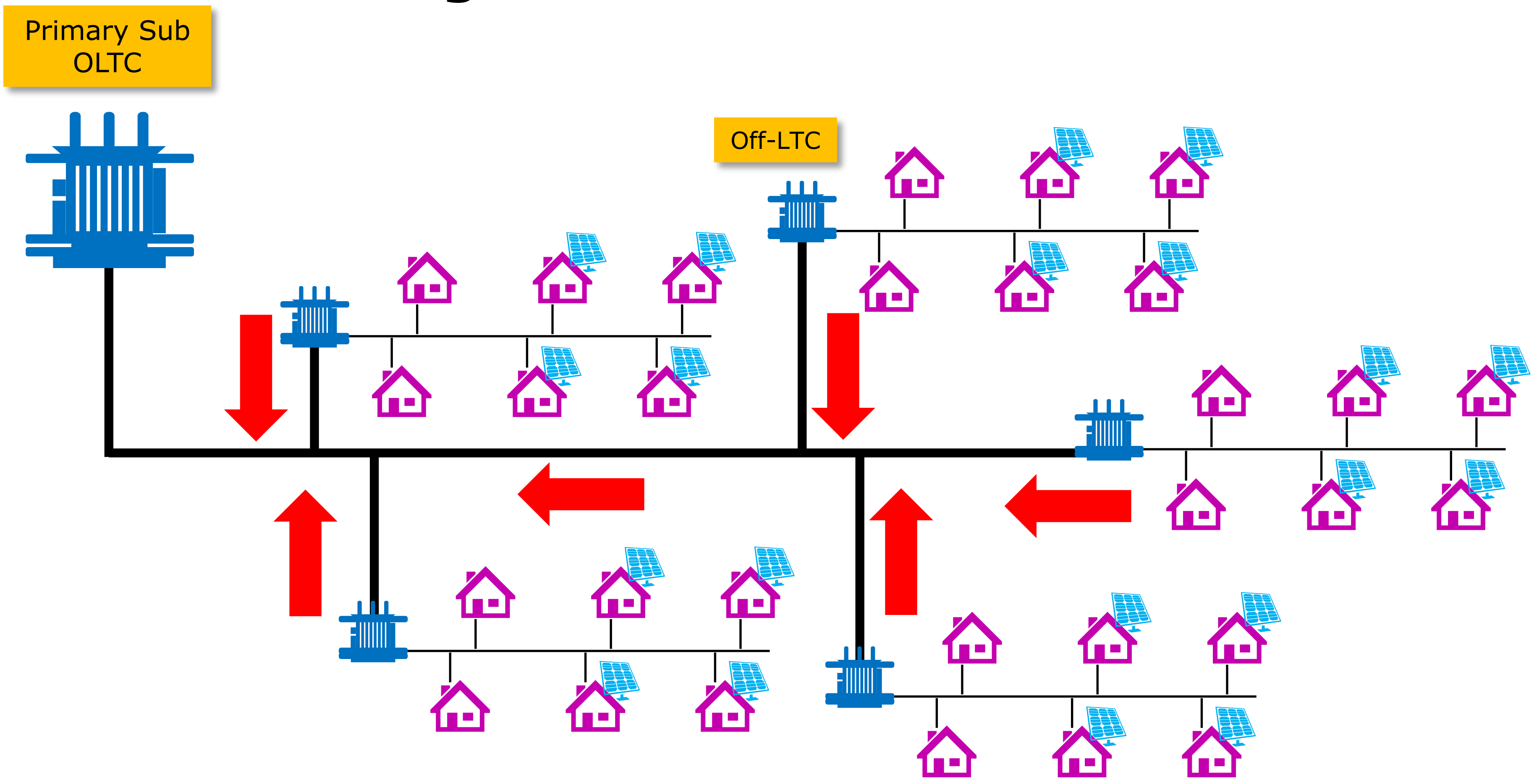
But before we get there…

Challenges in PV-Rich LV Networks



PV generation happens during the day, when many people are not at home → Problems

Challenges in PV-Rich MV Networks



V

Wide-spread PV adoption → Challenges to HV networks
How can we address this?

… but people will buy storage.

Surely, this will sort it out (?)

Challenges in PV-Rich LV Networks

- For Distribution Network Operators (DNOs)
  - **PV impacts**: voltage rise and thermal overload
  - Networks need to be reinforced

- For householders
  - Little or **no incentive to export** PV power
  - **PV export limits** are being adopted in some countries (e.g., 70% of PV installed capacity is the limit in Germany)
  - **Falling prices** for household **storage** devices makes it more viable

store the **surplus** during the day to **use** it **later** in the night!

Residential PV + Storage Systems

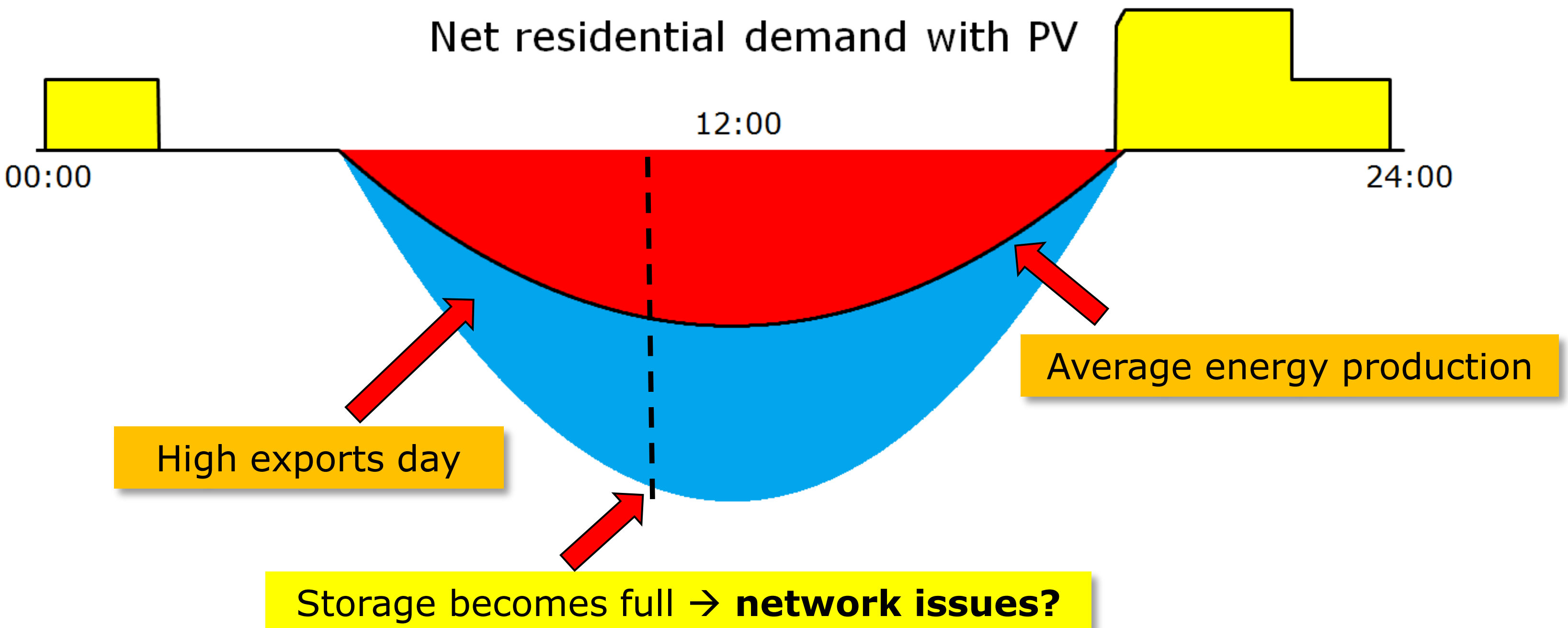
- For householders
  - interested in their **own benefits**
  - want to **save money** with the PV + storage system
  - want to use as much **low carbon energy** as possible
  - **do not care about the DNO's** technical problems!

- For DNOs
  - storage creates **opportunities** to mitigate technical issues and **avoid/defer investments**
  - concerned with less grid dependency, **lower revenue**

… very different objectives

Storage – Basic Control and Sizing

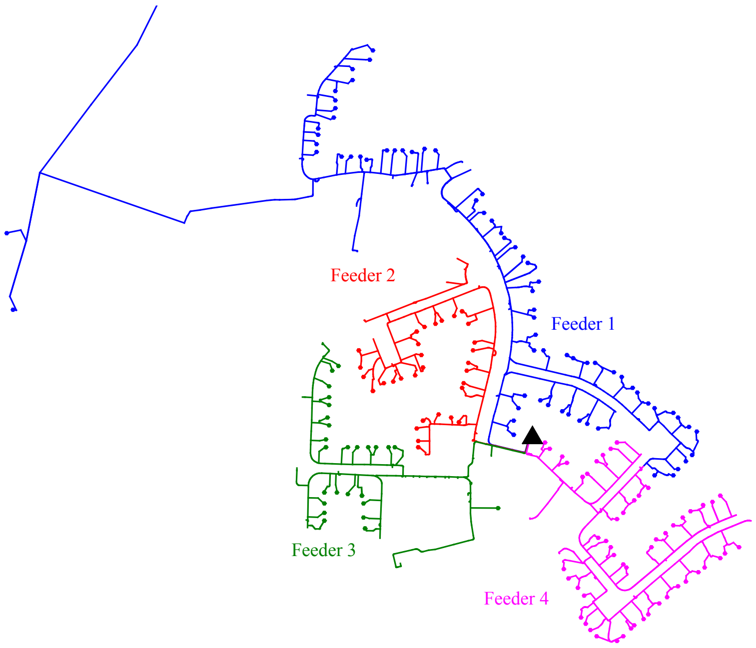
- Day (generation) → Store the exports until full
- Night (no generation) → Supplies the house load until empty
- Size of battery → Enough to meet the average exports



… Does residential storage help mitigating PV impacts?

LV Network Impacts – Case Study

- Real UK LV Network (NW England)
  - Residential, underground
  - Tx 800 kVA, 11/0.4 kV, 4 feeders
  - 200 single-phase customers
  - Voltage limit of 1.10 pu (253 V)
- Summer, Weeklong
- Storage
  - Similar to Tesla Powerwall
  - 2 kW, 10 kWh, 20 < SoC < 90%
  - Round trip efficiency of 87%

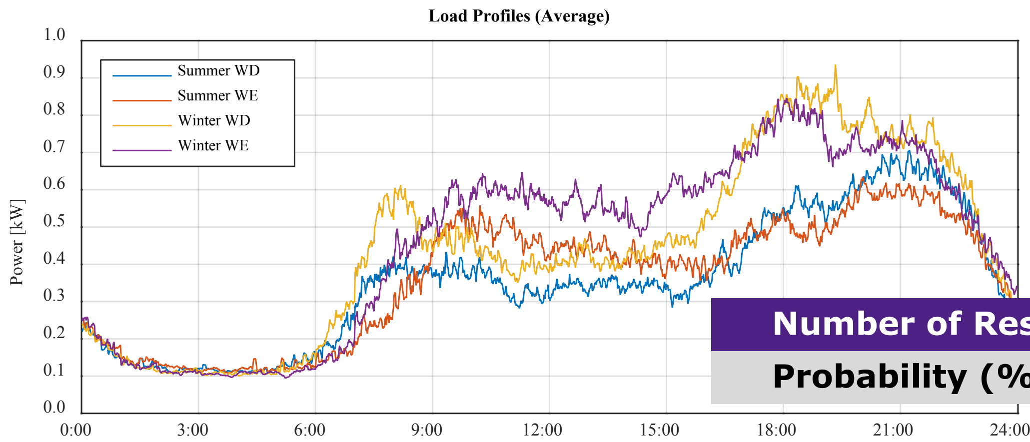


Probabilistic Approach 1/2

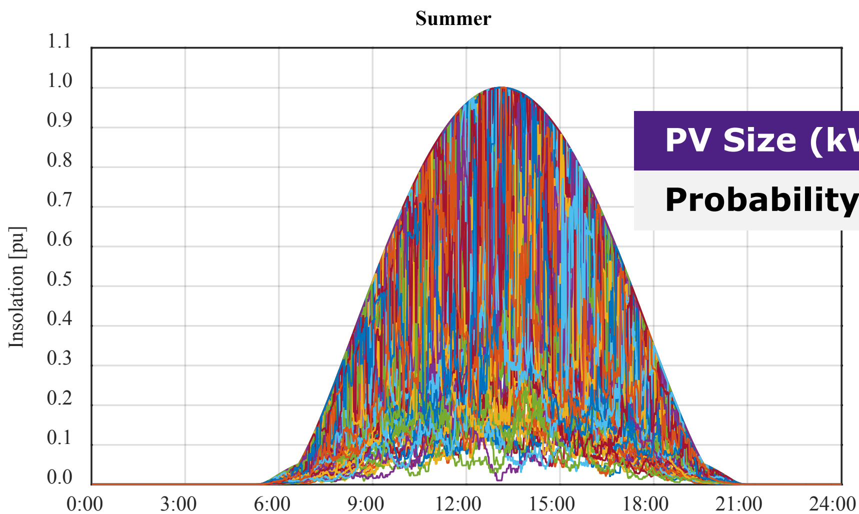
- Monte Carlo Analysis
  - To cope with **uncertainties** (load/PV behaviour, location)
    - Sets of 1,000 residential demand profiles (season/type of day)
    - Sets of 1,000 PV profiles (season)
  - Unbalanced, time-series power flows (OpenDSS)
  - Different **PV penetrations** and **storage control strategies**
  - 100 **week-long simulations** per scenario
- Key Metrics
- **Voltage**: EN50160 non-compliant customers
- **Thermal**: Feeder utilisation (1-hour moving avg)
- **Effects on Customers**: Grid Dependency, Self Consumption

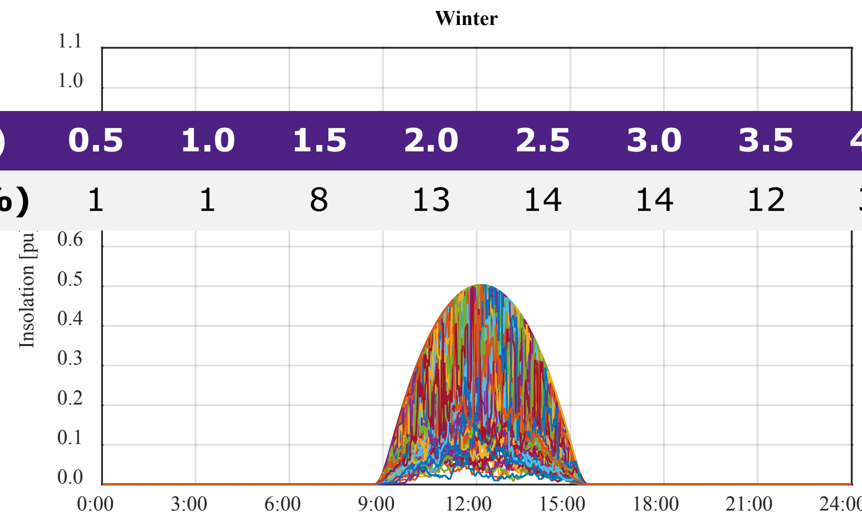
Probabilistic Approach 2/2

Tool developed by CREST (Loughborough Univ.)
1-min resolution



Number of Residents	1	2	3	4+
Probability (%)	29	35	16	20

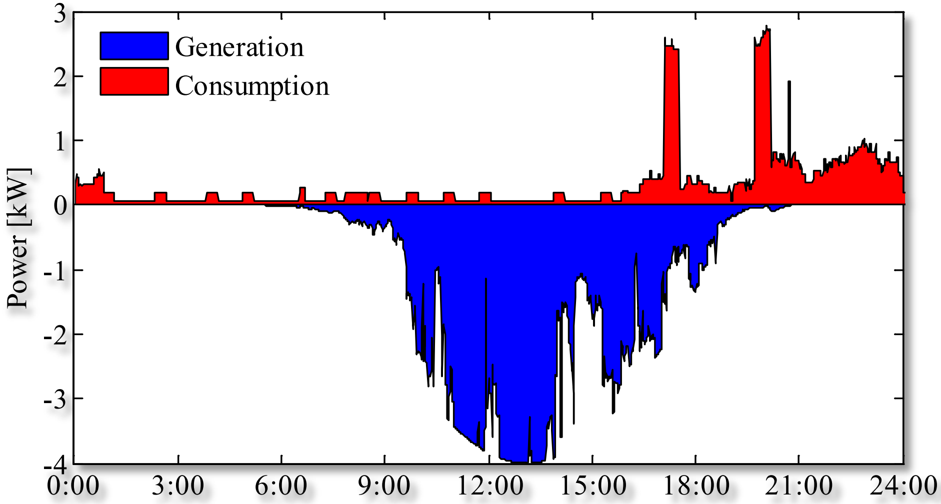


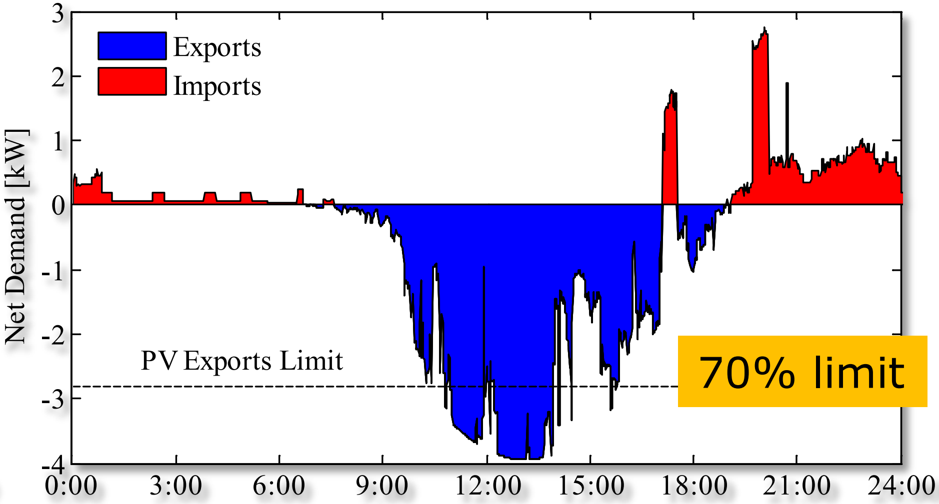


PV Size (kWp)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Probability (%)	1	1	8	13	14	14	12	37

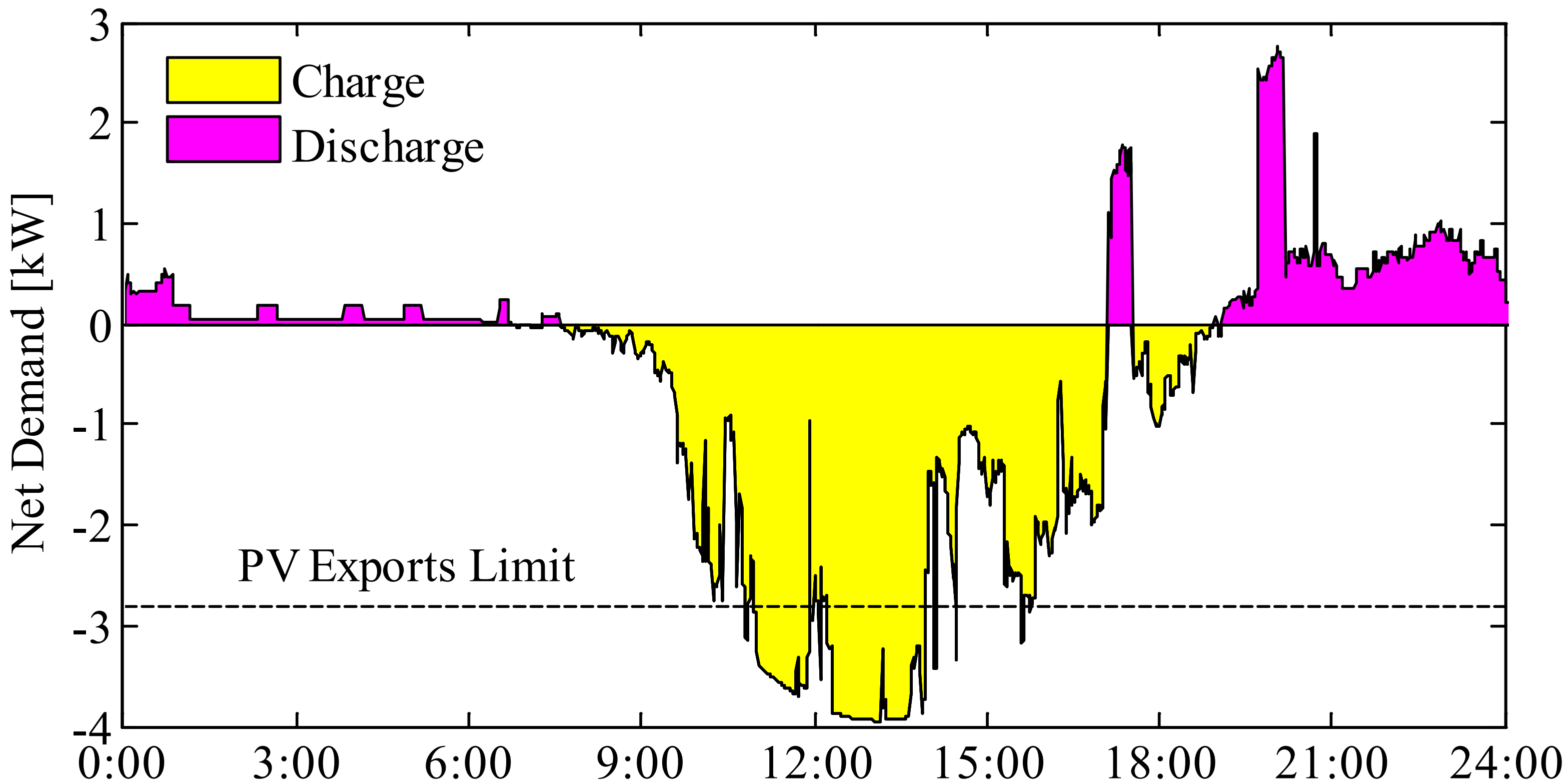
Control Strategies

1. **Optimal for the Customer**
   – All PV surpluses (negative net demand) are stored
2. **Delayed Charging**
   – Surpluses are stored if the power export limit is reached
3. **Store the Excess**
   – Only PV generation beyond the export limit is stored





Mode: Optimal for the Customer

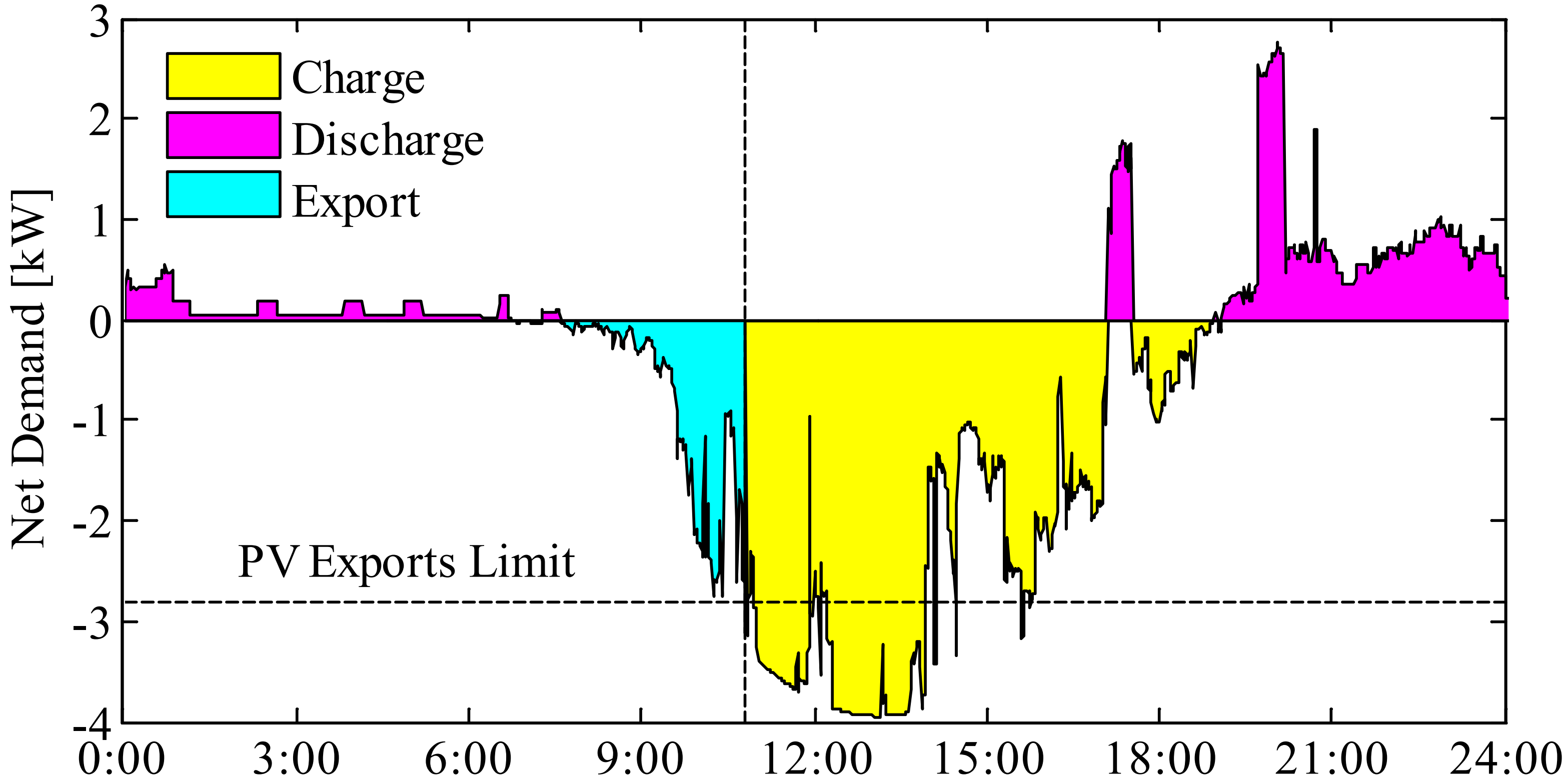


Even small surpluses early morning are stored

→ **More energy for the customer**

→ **Battery is likely to be full before PV impacts**

Mode: Delayed Charging

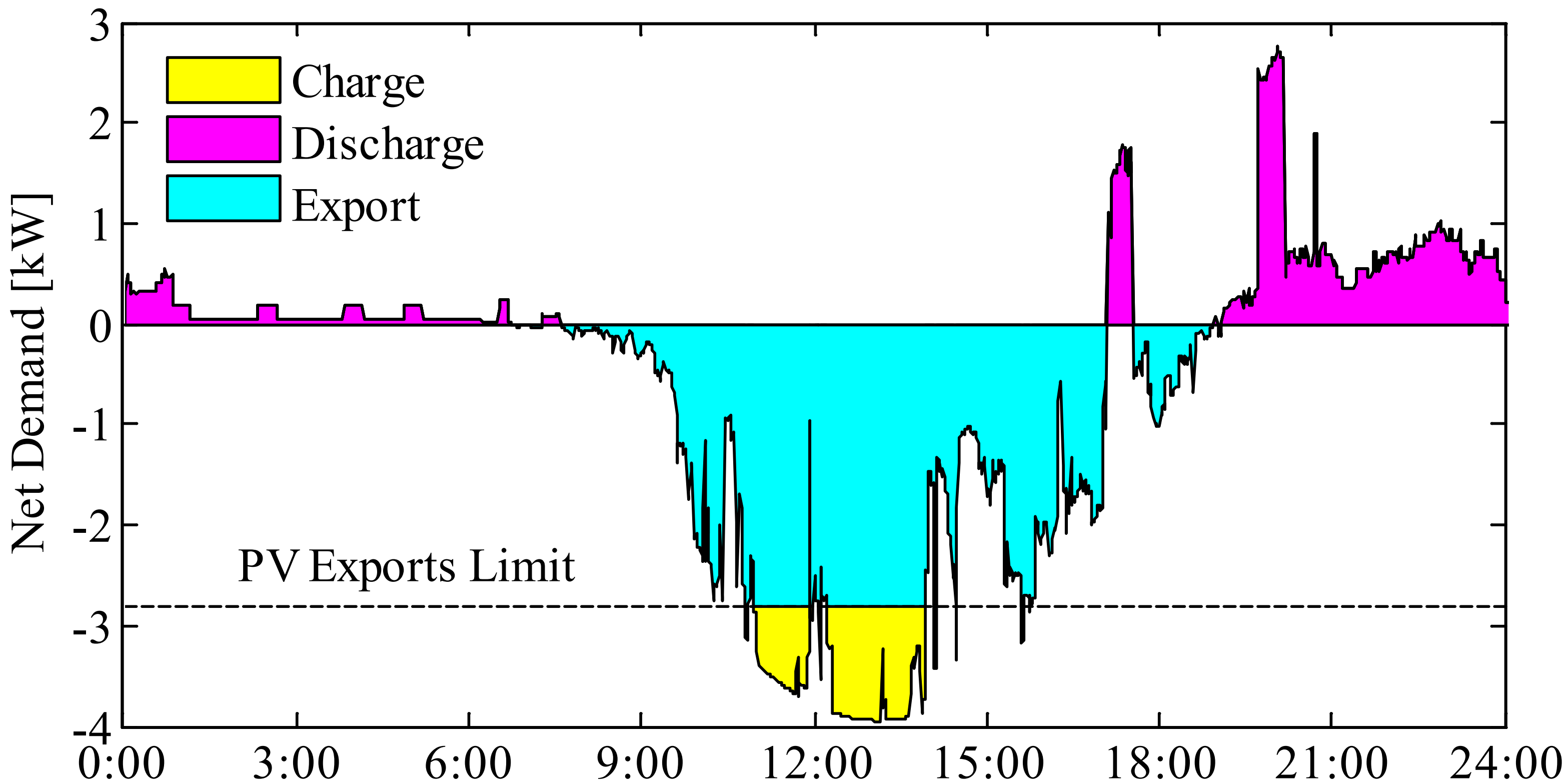


Charging starts closer to peak generation

→ **Battery is likely to have room during PV impacts**

→ **Not necessarily making the most of PV generation for the customer**

Mode: Store the Excess

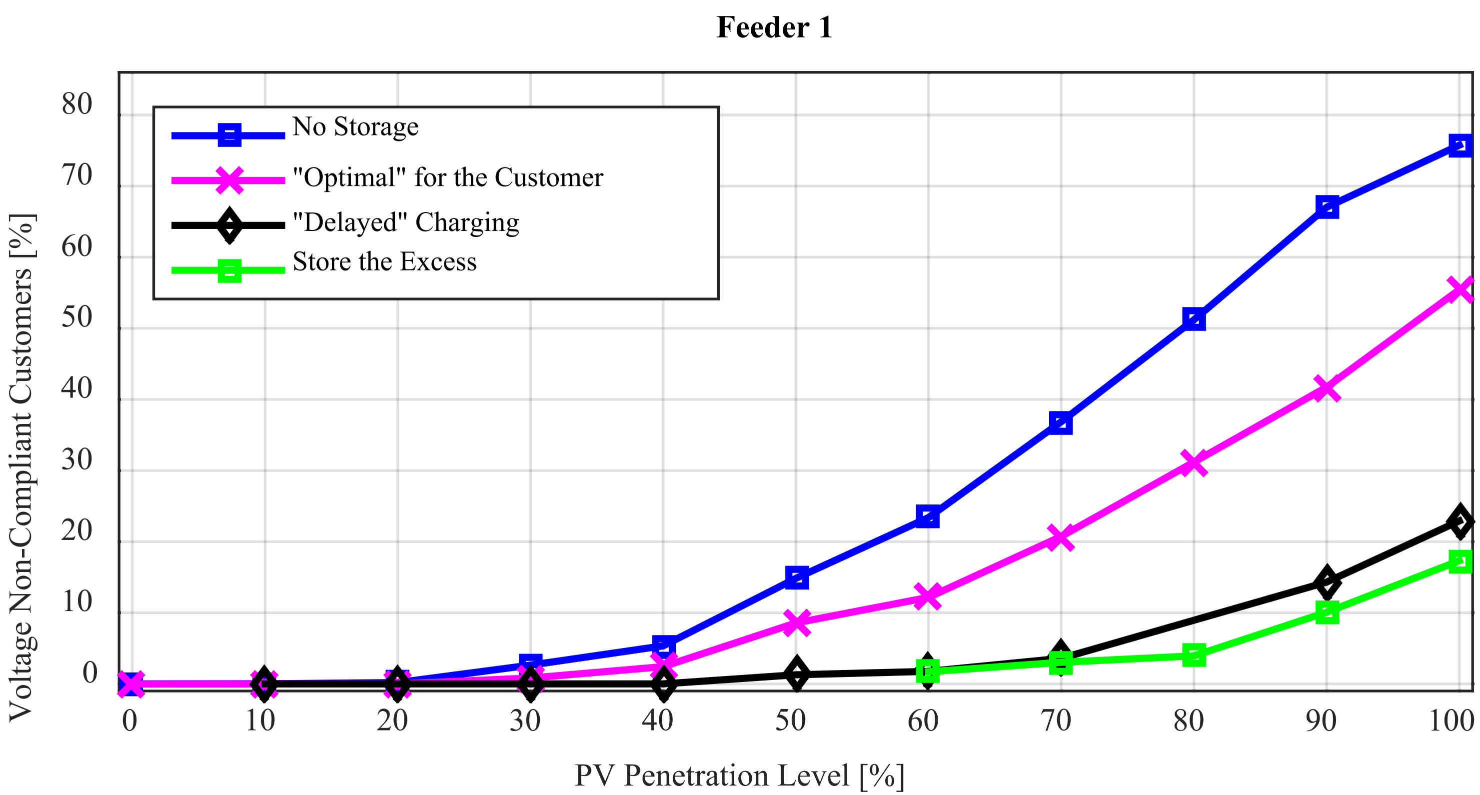


Charging only PV generation beyond the export limit

→ **Battery will significantly help reducing PV impacts**

→ **Does not make the most of PV generation for the customer**

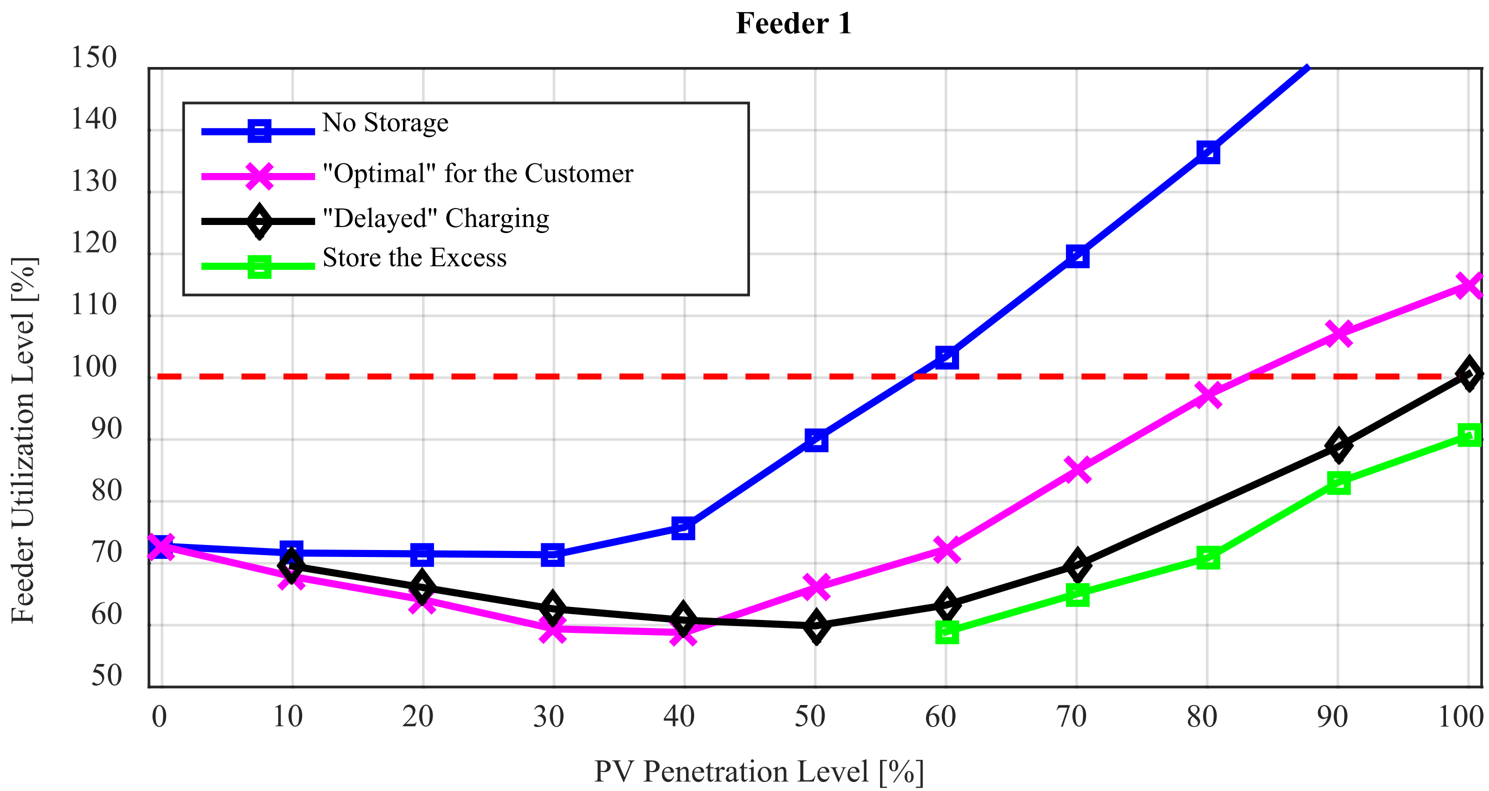
Results: Voltage Issues



Optimal for the customers → Largest network impacts

Store the excess → Significant mitigation of impacts

Results: Thermal Issues



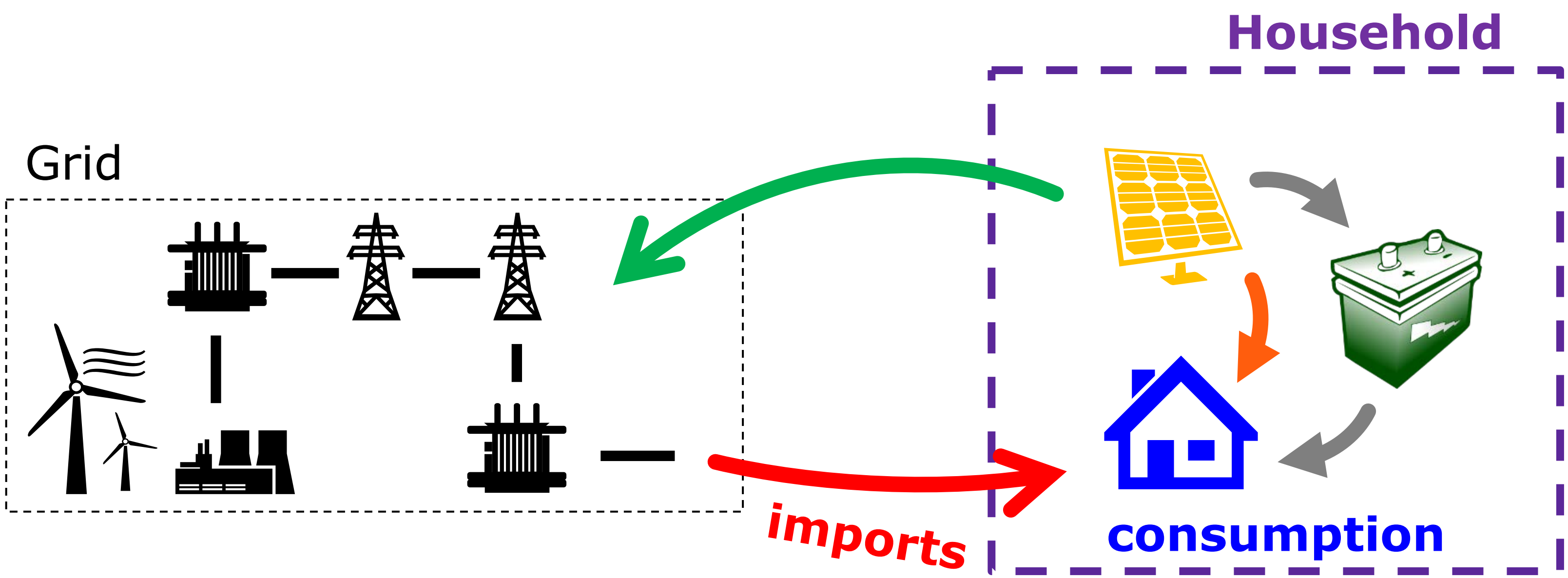
Optimal for the customers → Largest network impacts

Store the excess → No thermal issues

… Do all control strategies benefit customers?

Index of Grid Dependence (IGD)

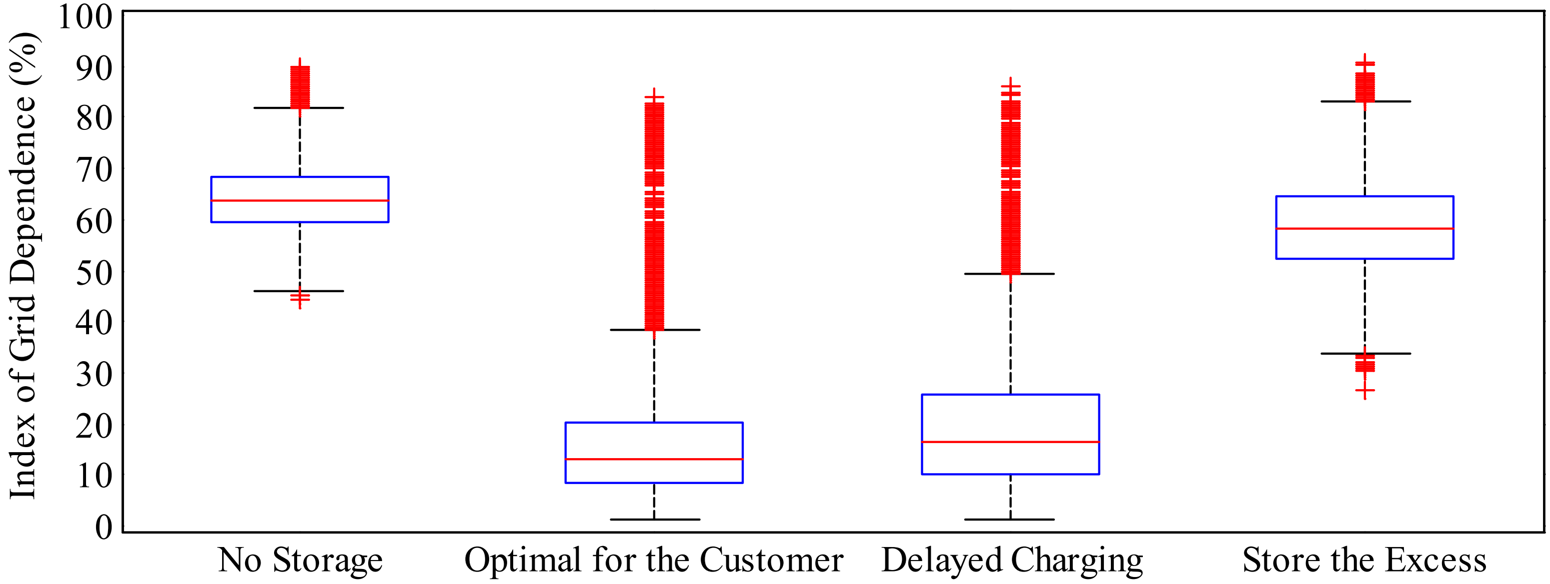
- Effect of using storage on the electricity bill



$$IGD = \frac{imports}{consumption}$$

- 100% - household totally **grid dependent** (normal bill)
- 0% - household totally **grid independent** (no bill)

Grid Dependency



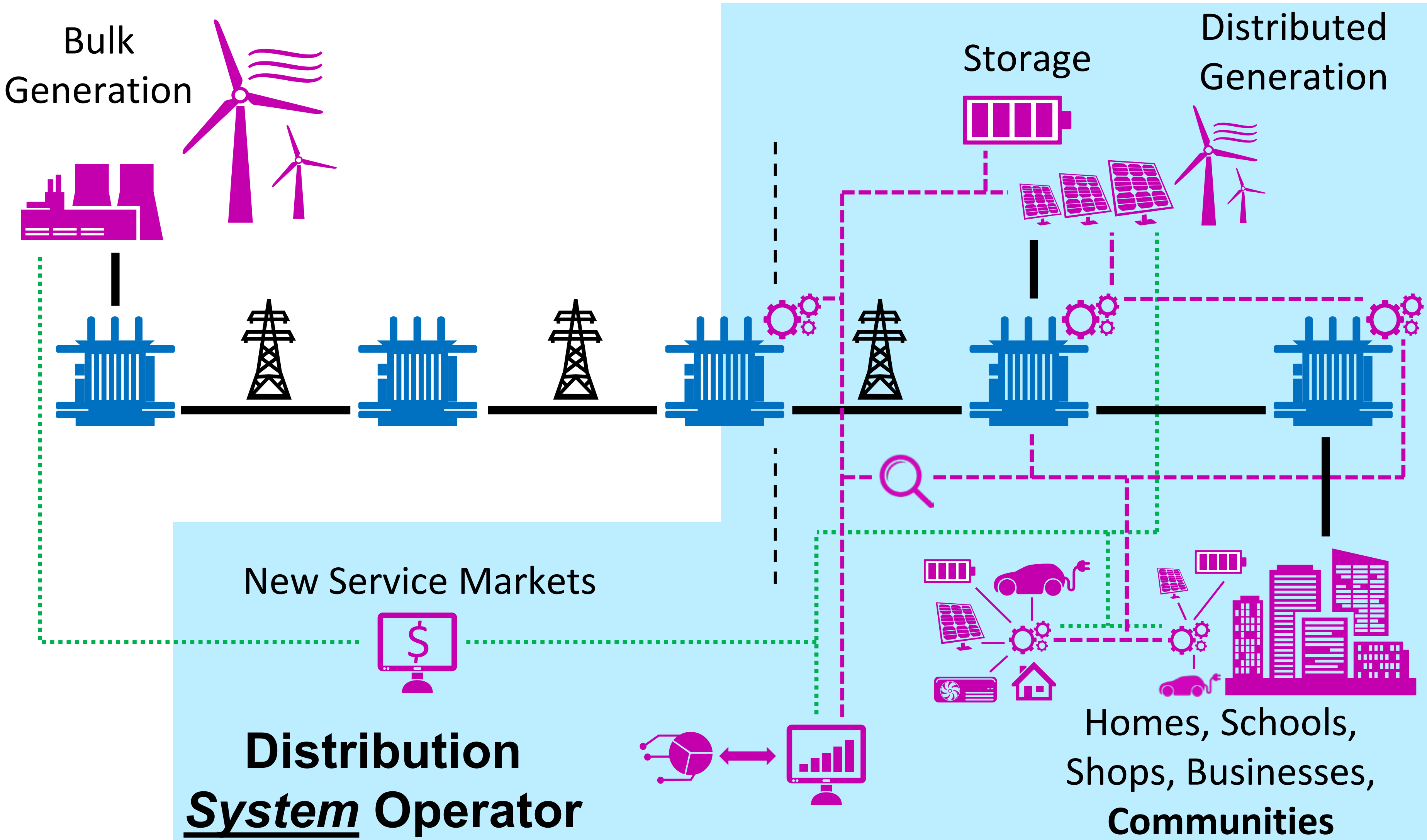
- PV w/o storage → Produces savings but not large
- *Optimal for the Customer* and *Delayed Charging* → Greatest benefits, small electricity imports
- ***Store the Excess* → Almost as not having storage!**

… so, it is just a matter of

‘smart’ storage control ☺

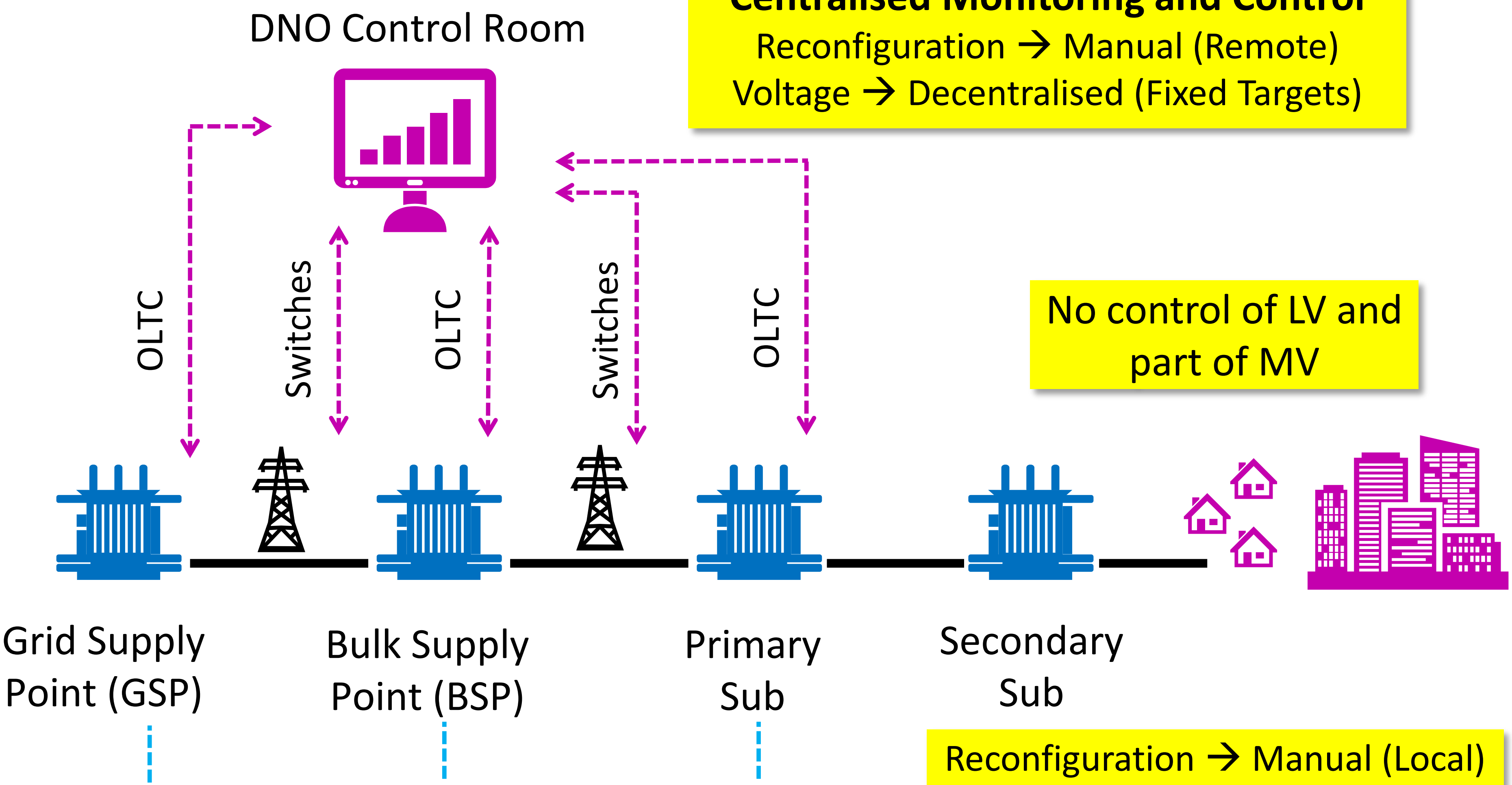
… not really

Smart & Low Carbon



Current Control Philosophy (Distribution)

Centralised Monitoring and Control
Reconfiguration → Manual (Remote)
Voltage → Decentralised (Fixed Targets)



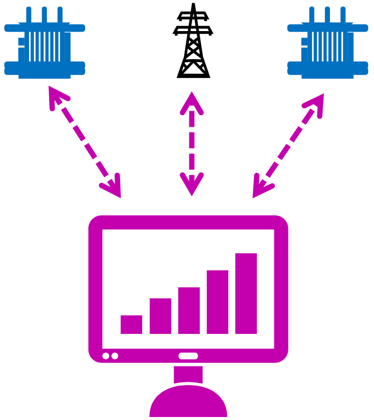
No control of LV and part of MV

Reconfiguration → Manual (Local)
Voltage → Off-load taps

OLTCs → Coordinated Decentralised Control

Fully Centralised vs. Coordinated Decentralised

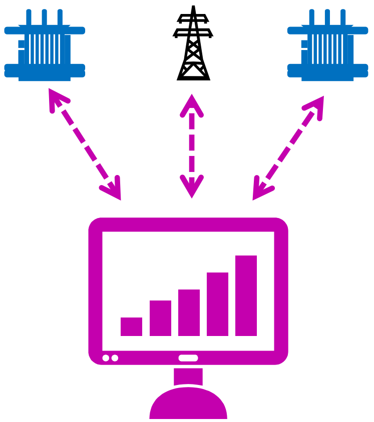
- **Fully Centralised**
  - Opportunity for holistic ‘optimisation’
  - Full flexibility
  - Increased reliance on monitoring/comms
  - Increased complexity due to scale
  - High deployment time



- **Coordinated Decentralised**
  - More localised ‘optimisation’ (static areas)
  - Flexibility exists to <u>centrally react</u> to problems
  - Less <u>centralised</u> monitoring/comms
  - Less complexity due to reduced scale
  - Less deployment time

… but there are many other barriers

- Defining **Distribution Markets**
  - Voltage management, congestion management
  - Near or post fault management (enabling islanding/microgrids)



- DSOs should be capable of
  - **Quantifying operational needs and constraints**

    → wide-scale observability, forecasting
  - **Exchanging data** with the TSO and third parties (service providers)

… all this requires advanced management systems, investment, time, training, etc.

Conclusions 1/2

- Residential **PV + storage** might become more viable
  - Lower capital cost, lower electricity bills → less grid dependent
- However, **customer-focused storage control strategies do not reduce PV impacts**
  - Storage gets full before critical periods (around midday)
- **New storage control strategies** can mitigate network impacts from PV without affecting customers
  - Customers can achieve similar levels of grid dependency

Conclusions 2/2

- **Complexity will increase** with more controllable elements and the need for more flexibility
  - Computational/data complexity shouldn't be an issue in ~15 years
- Regulators need to **define the roles of potential future players and technologies** in the provision of flexibility
  - E.g.: aggregators, storage
  - This will prevent new business models being hindered by regulatory barriers
- This transition of DNOs to ***DSOs*** in the next few years will bring exciting new regulatory environments where the envisioned smart grids are likely to finally emerge ☺

Technical Reports and Publications

- Technical Reports (most publicly available):

  https://sites.google.com/site/luisfochoa/publications/technical-reports

- List of Publications (most publicly available):

  Journal Papers

  https://sites.google.com/site/luisfochoa/publications/journals

  Conference Papers

  https://sites.google.com/site/luisfochoa/publications/conferences

Thanks!

Questions?

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