Demand-Side Management

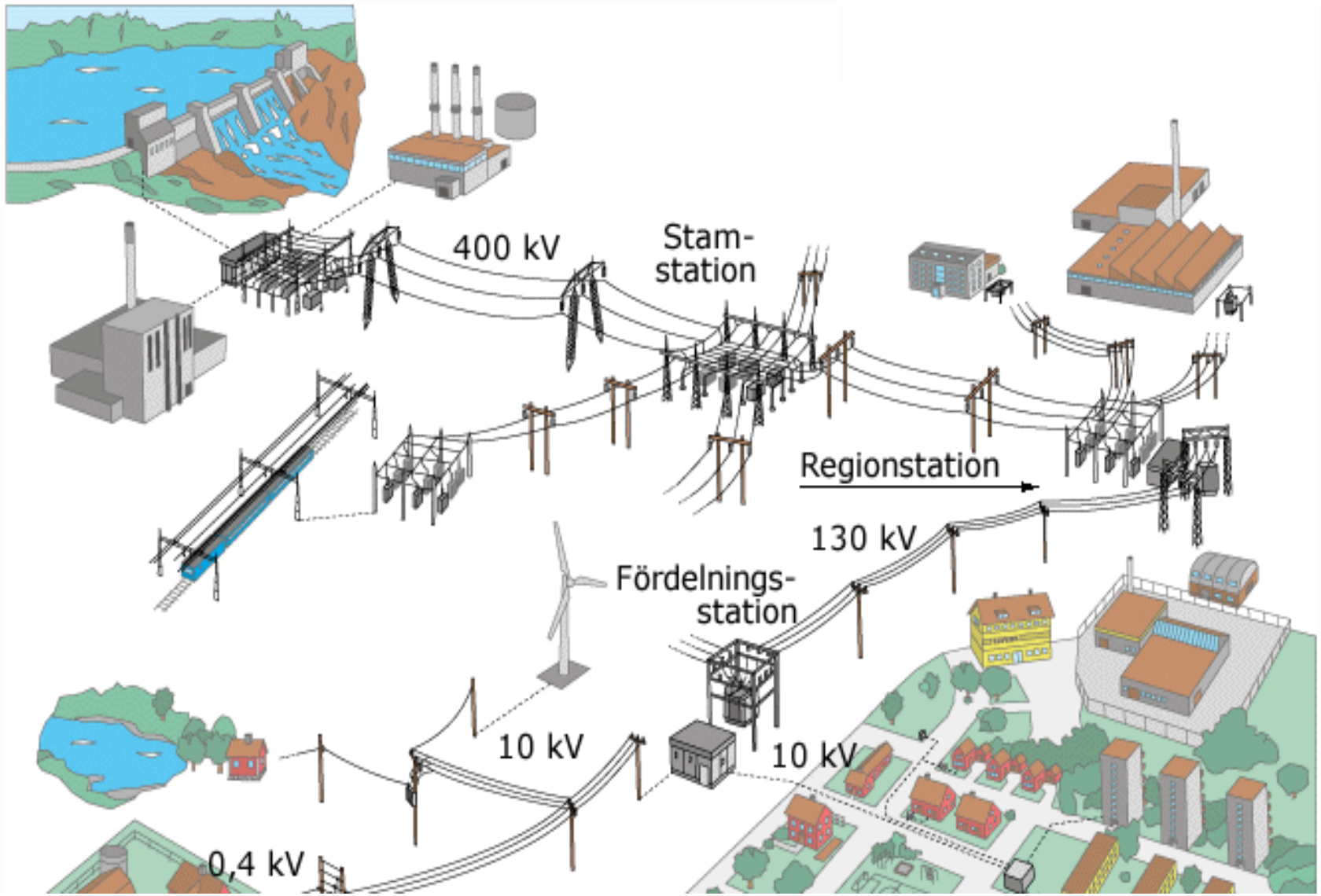
Dr. Paschalis Gkaidatzis , CERTH

CERTH SmartWins Summer School: Day 4
07 July 2023
Thessaloniki

Funded by the European Union

This project has received funding from the European Union's Horizon research and innovation programme under grant agreement No 101078997

T5.1 Smart Grids Concept – Traditional Power System



T5.1 Smart Grids Concept – Smart Grid Concept

pp – power plant, 1– large hydro pp, 2– wind farm on-shore, 3– small hydro pp, 4–concentrated solar thermal pp, 5 –biofuel pp, 6- wind farm off-shore, 7– low emission fossil pp , 8 – high voltage DC transmission, 9– control center, 10 – micro- grid, 11 – wave pp, 12 – photovoltaic plants, 13 – underground power transmission,14 – solar heating, 15 – hydrogen filling station, 16 – small electric batteries,17 – thermal storage,18 – electricity storage,19 – cogeneration of heat and power, 20 – fuel cells

T5.1 Smart Grid challenges in EU

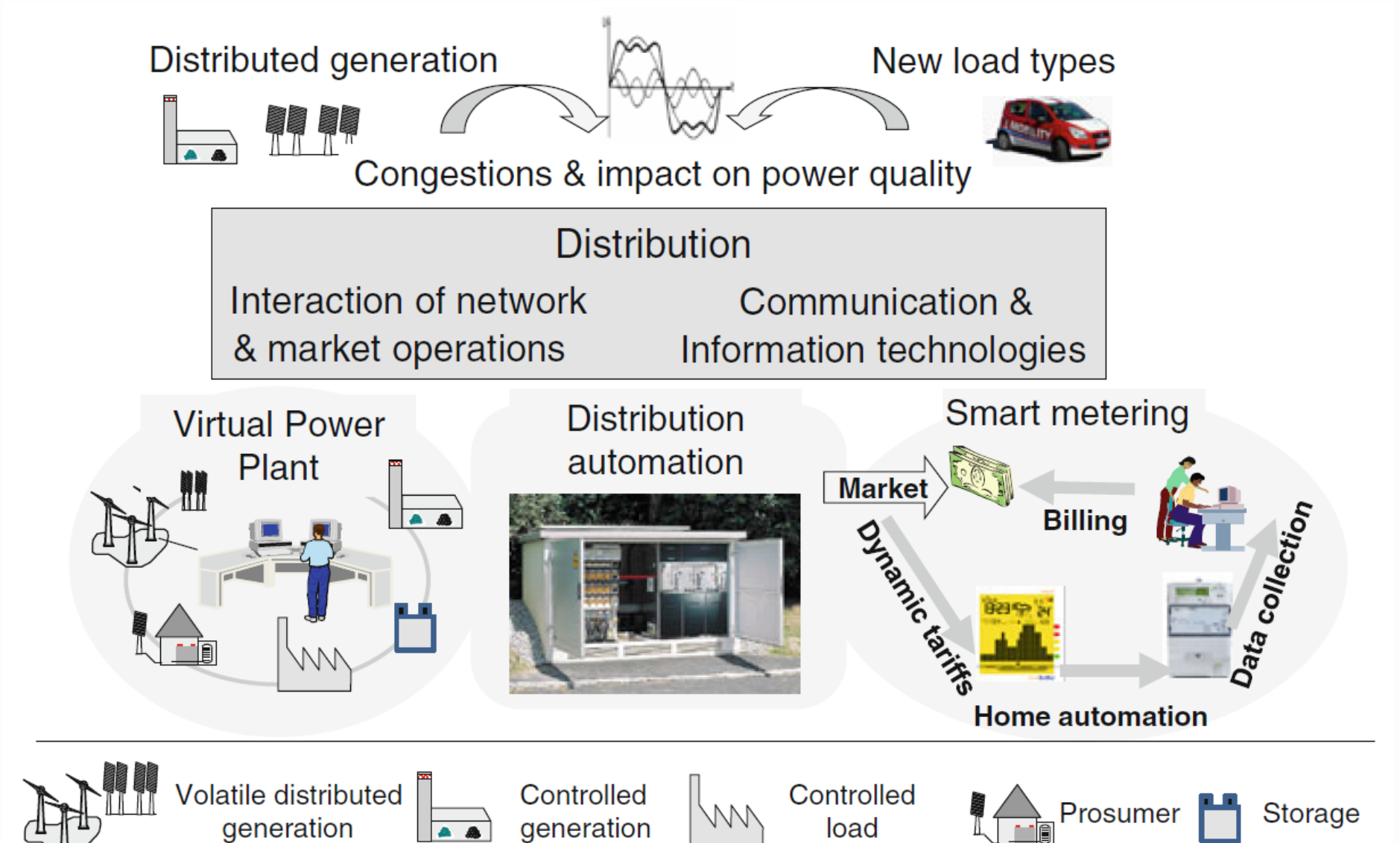
- Decreasing availability of fossil fuel and nuclear primary energy sources (PES),
- Accordingly, their rapidly increasing prices,
- the 70% dependency of Central Europe on imported PES,
- The increasing impact of greenhouse emissions on the environment

- 20, 20, 20 by 2020 (30, 30, 30, by 2030 etc…)

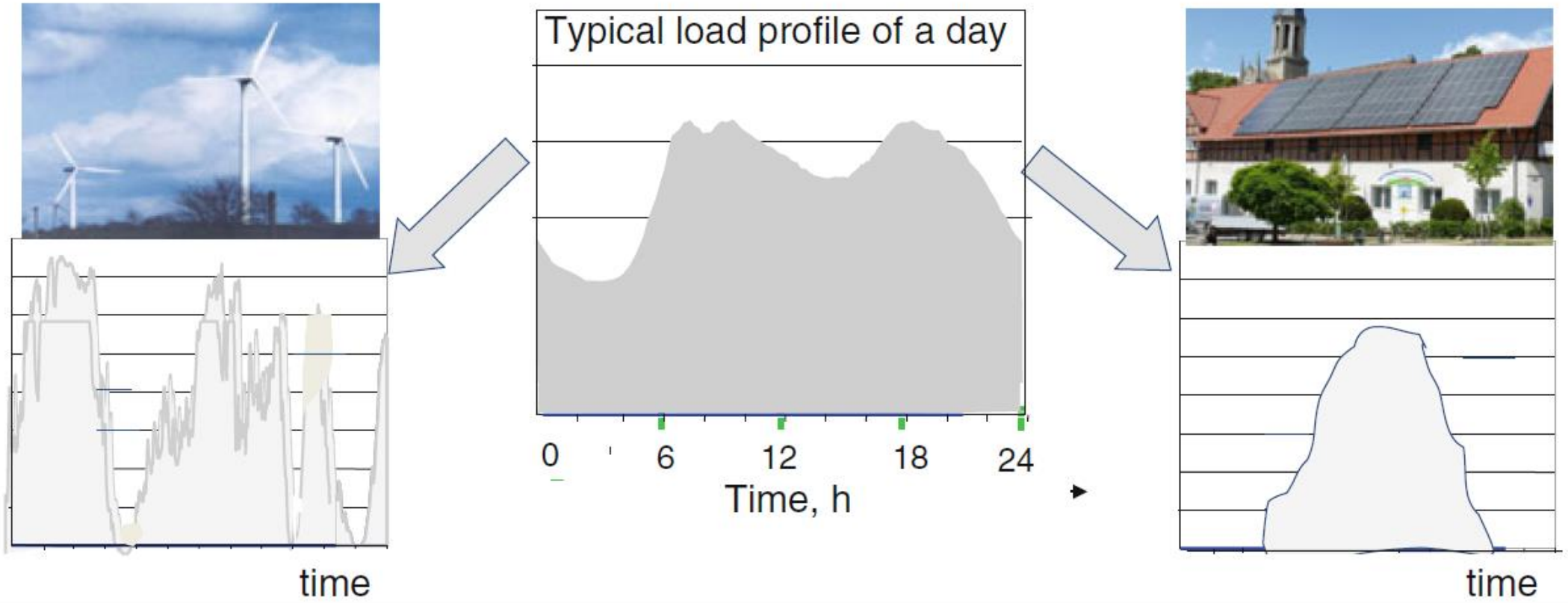
T5.1 Smart Grid challenges in EU – solution core elements

- toolbox of proven technical solutions,
- establish Interfacing capabilities,
- Ensure Harmonization of regulatory and commercial frameworks,
- Establish shared technical standards and protocols that will ensure rapid share of knowledge via open access routes
- develop information, computing and telecommunication systems

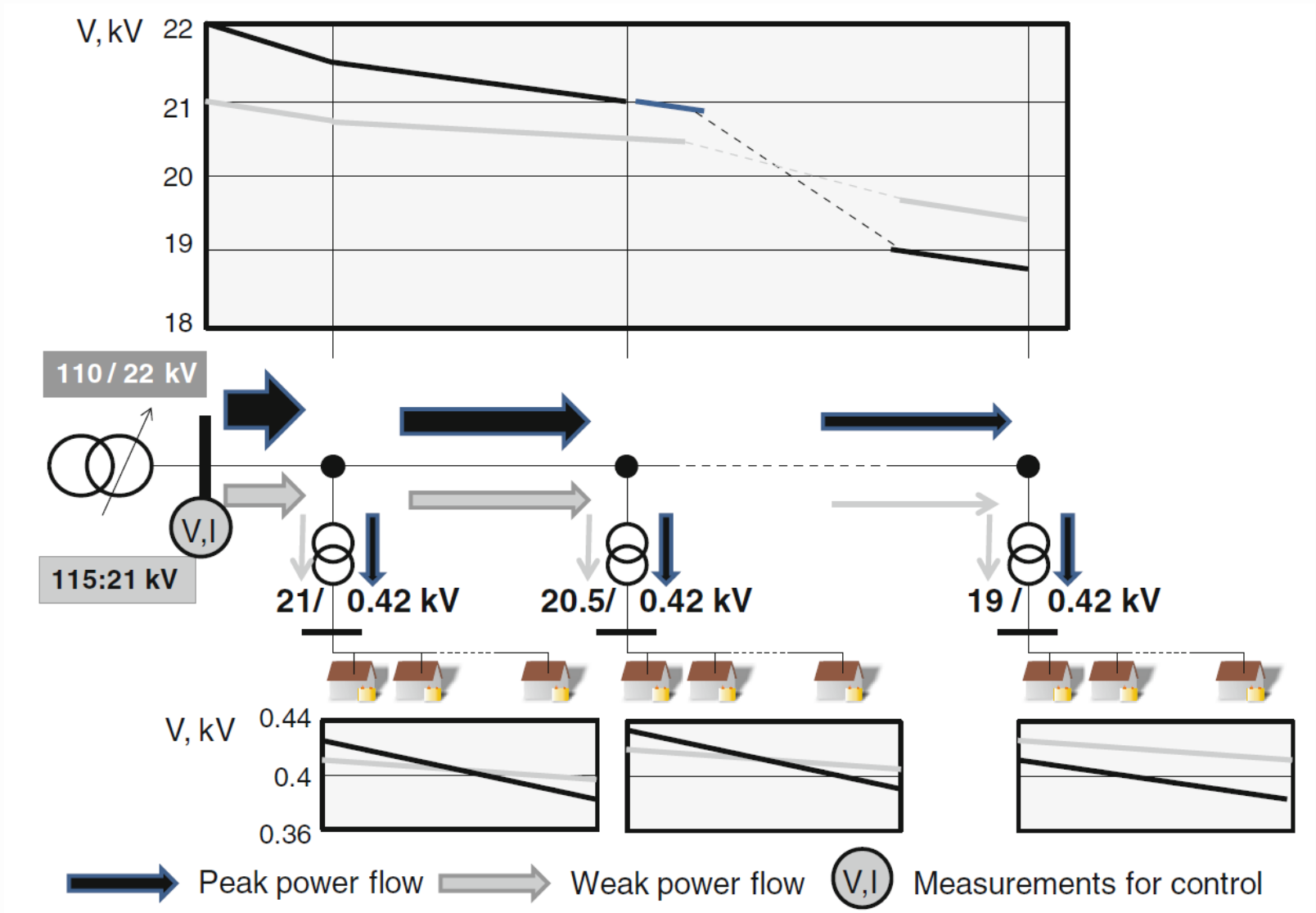
T5.1 Smart distribution Network



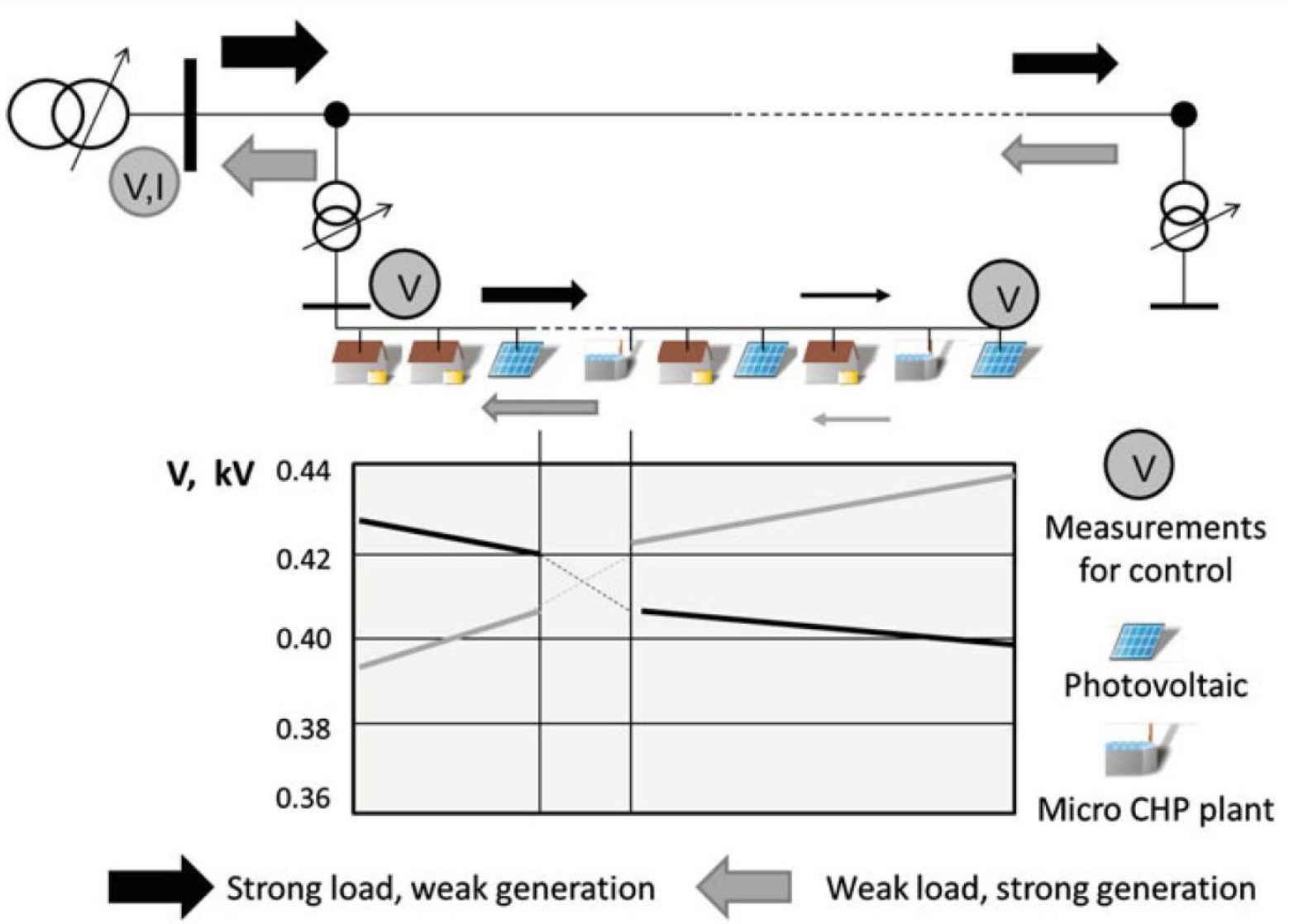
T5.1 Smart Distribution Network challenges #1



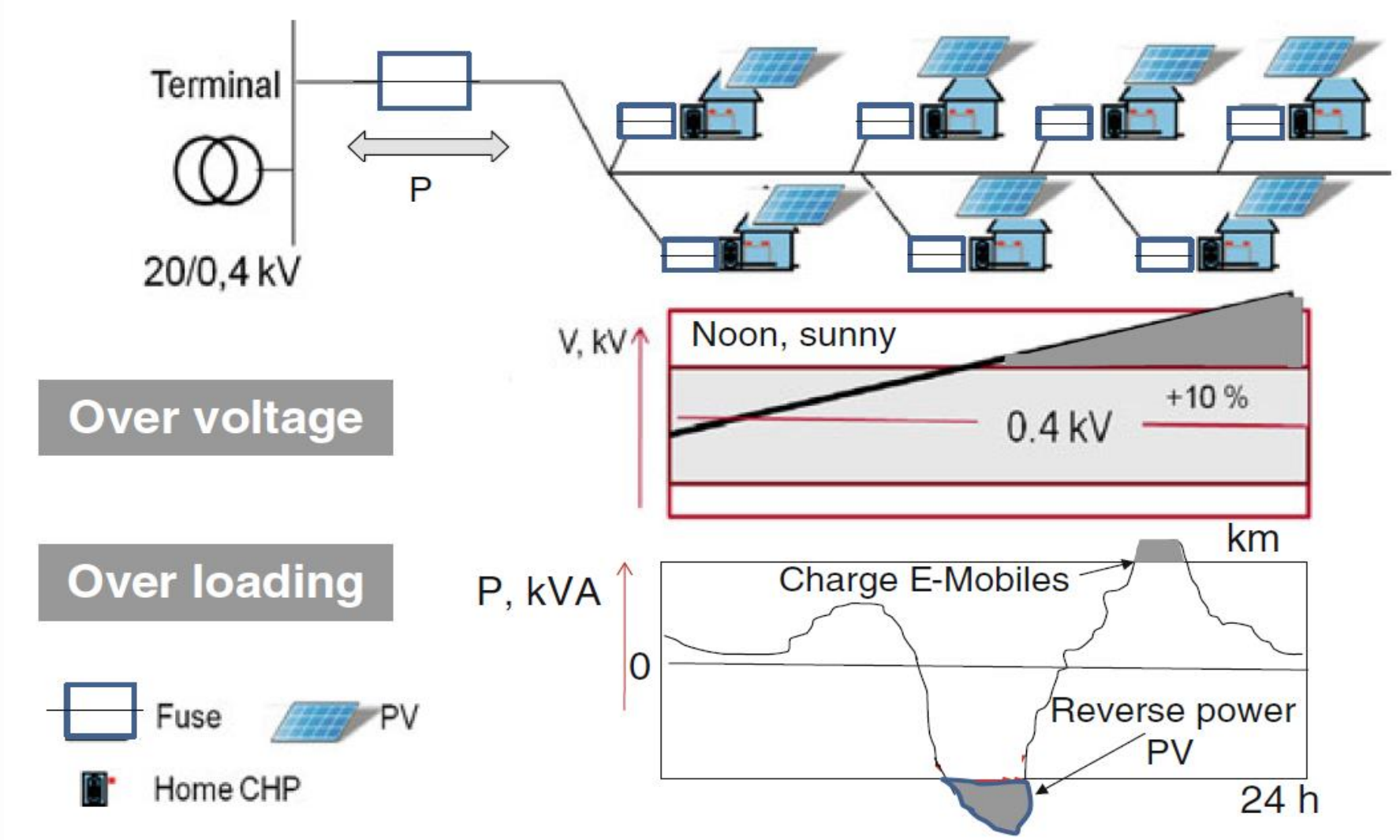
T5.1 Smart Distribution Network challenges #2a



T5.1 Smart Distribution Network challenges #2b

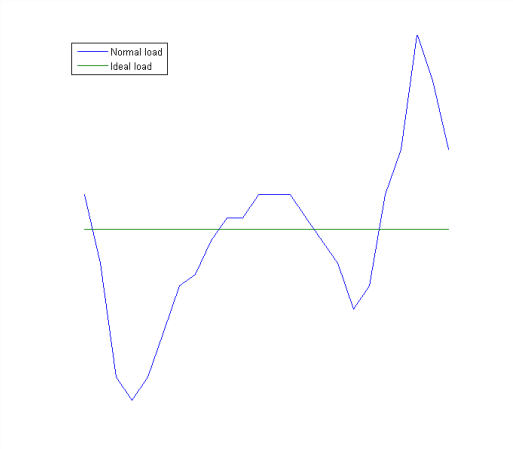


T5.1 Smart Distribution Network challenges #2c

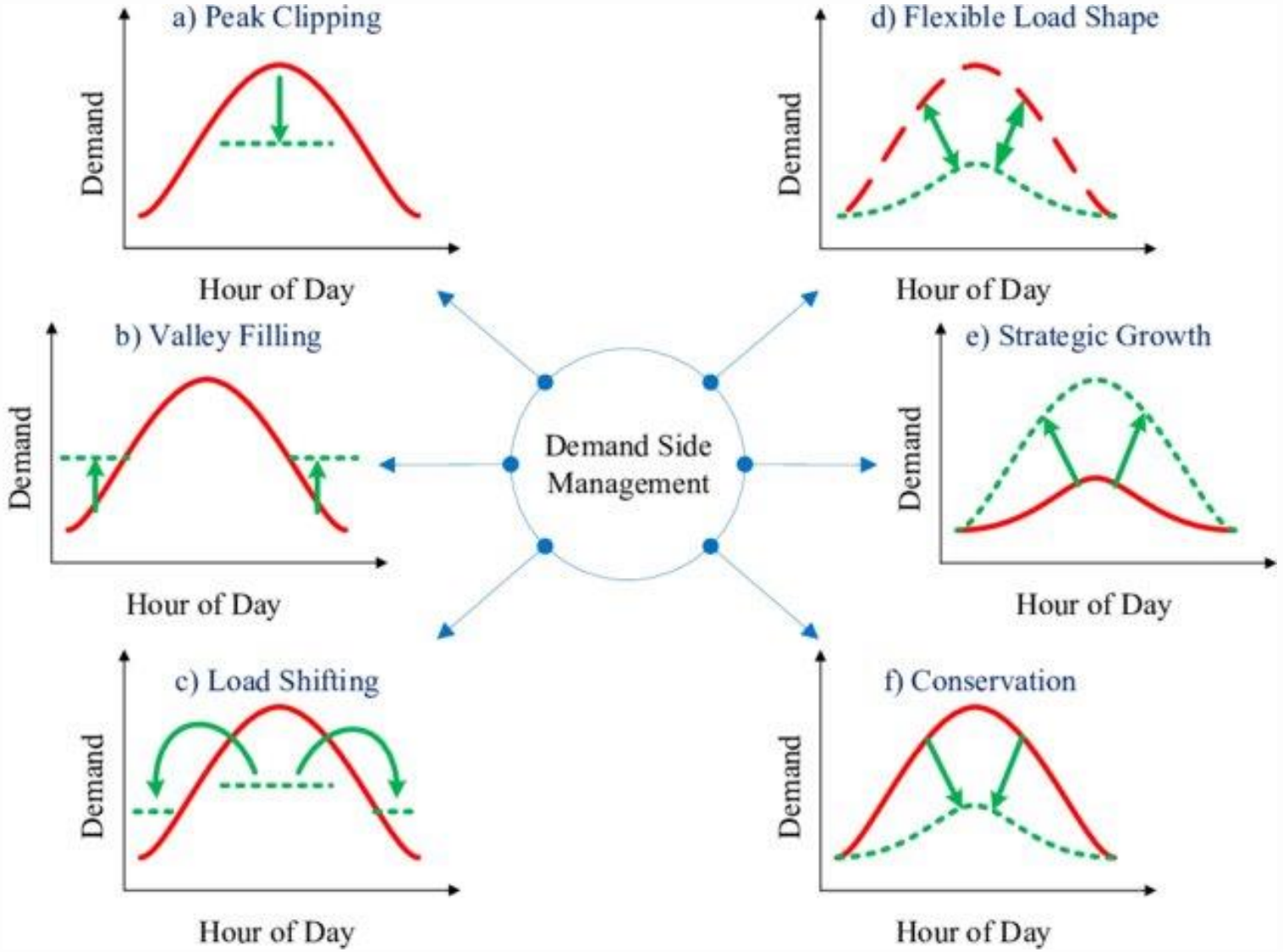


T5.1 Demand-Side Management – DSM - General #1

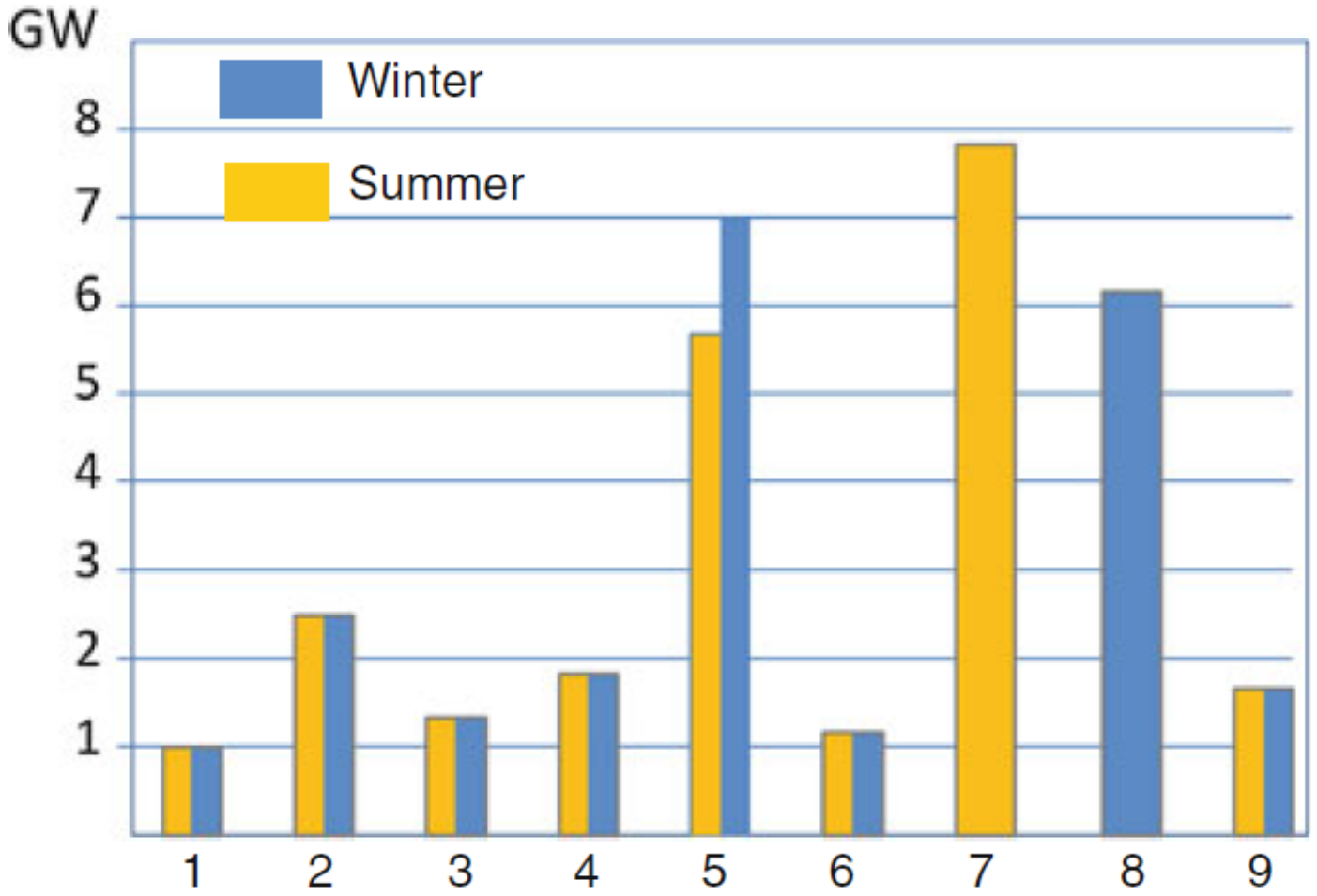
- In developed countries residential users account for 25% of the annual electricity consumption
- Peak times exceed 50%
- The most volatile consumption type compared to Industry, commercial services, transport and agriculture
- Thus, the greatest margin for manipulation and harmonization



T5.1 Demand-Side Management – DSM - General #2



T5.1 Demand-Side Management – DSM - General #3



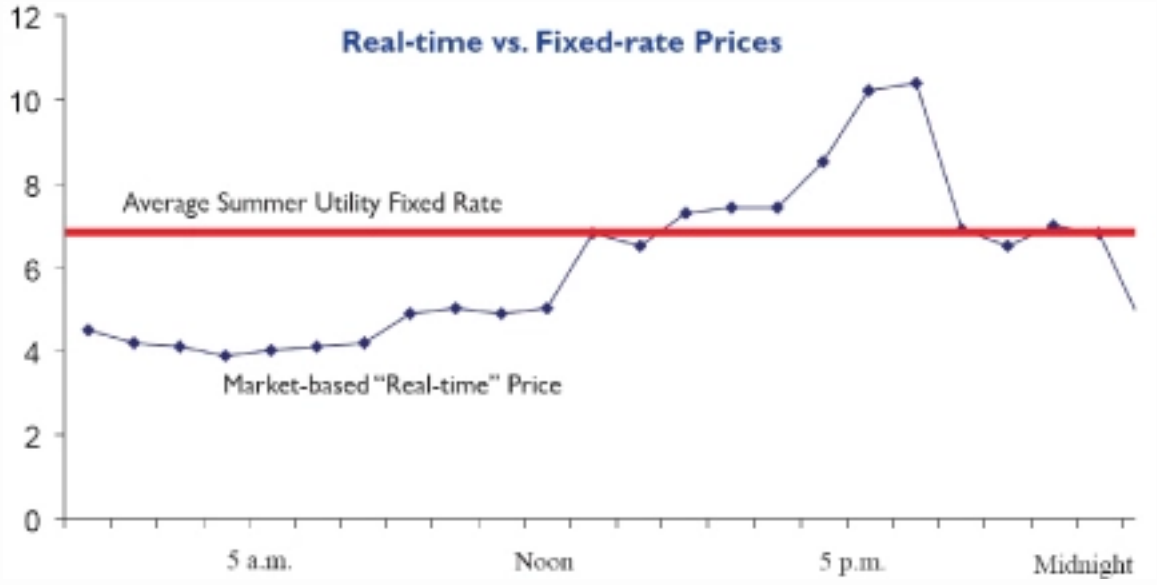
1– Refrigerator, 2– Dish washer, 3– Washing, 4- Dryer, 5 – Water heating,
6– Fridge, 7- Air conditioning, 8- Heat pumps, 8- Restaurants

T5.1 Demand-Side Management – Demand Response #1

- Modifying residential consumption -> consumers' willingness -> public awareness
- Demand Response programs (DR)
  - The end-user can select a more economic offer,
  - Turn them to active players, rather than passive ones,
- Transition from a fixed electricity price to a dynamic one

T5.1 Demand-Side Management – Demand Response #2

- **Fixed pricing:**
  - Same price all year around,
  - Simple and easy to apply,
  - Low risk



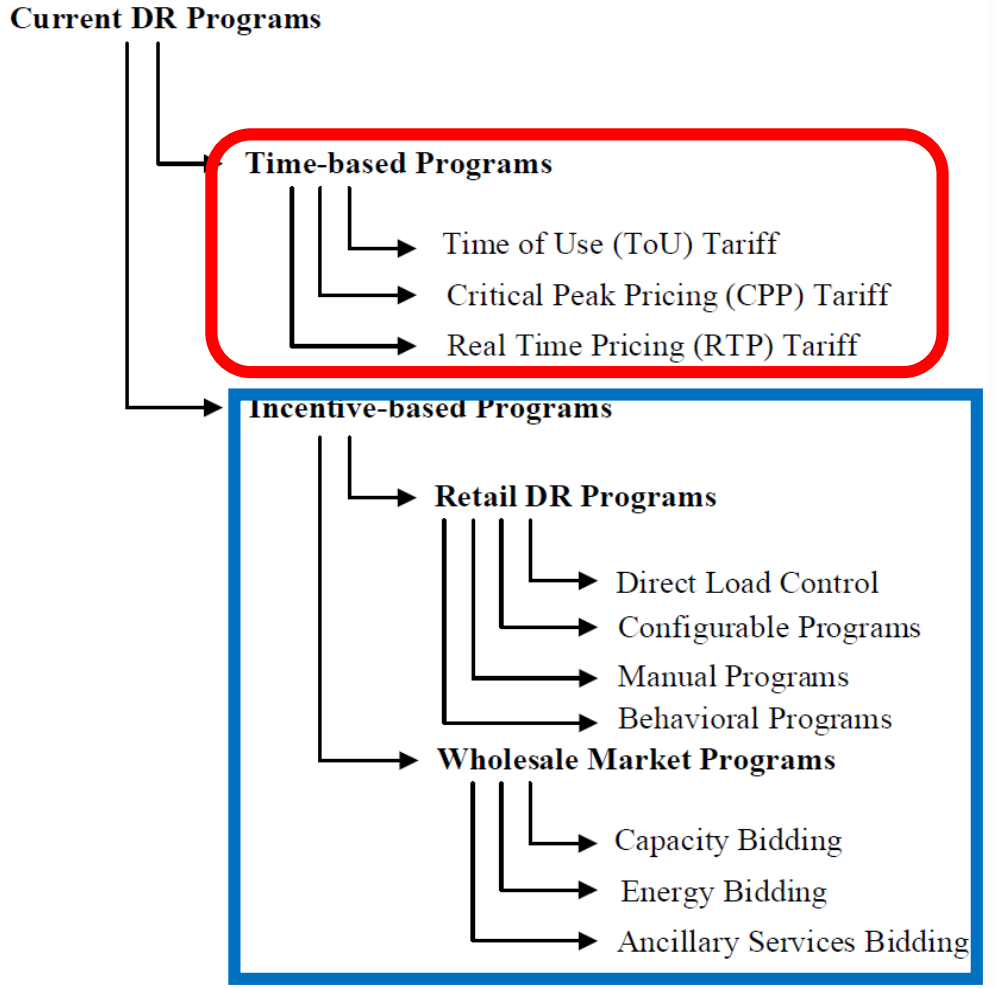
- **dynamic pricing:**
  - Different rate at different times of the year, day etc.
  - Reflects the changes in demand,
  - Promotes consumption reduction during peak times,
  - Bill reduction,
  - Network congestion reduction,
  - Whole-sale market price reduction,
  - Distributed Energy Resources (DERs) benefits
  - More environmental benefits

T5.1 Demand-Side Management – Demand Response #3

- **2014 USA:**
  - **9.3 million user participated**
  - **Saved 1.4 MWhs,**
  - **Peak load reduction by 12.7 GW,**

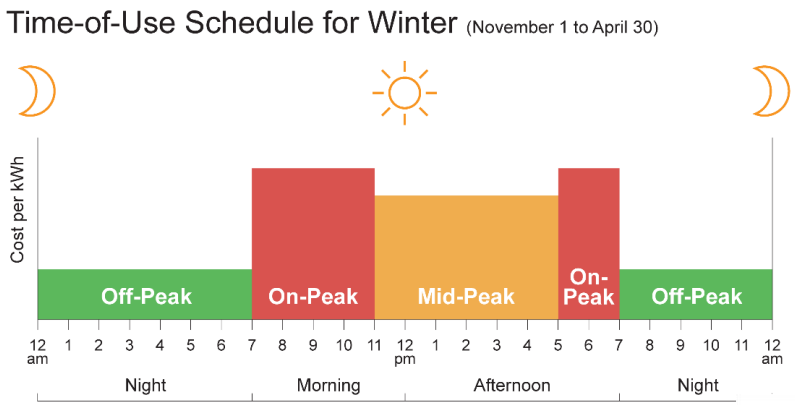
T5.1 Demand-Side Management – Demand Response #4

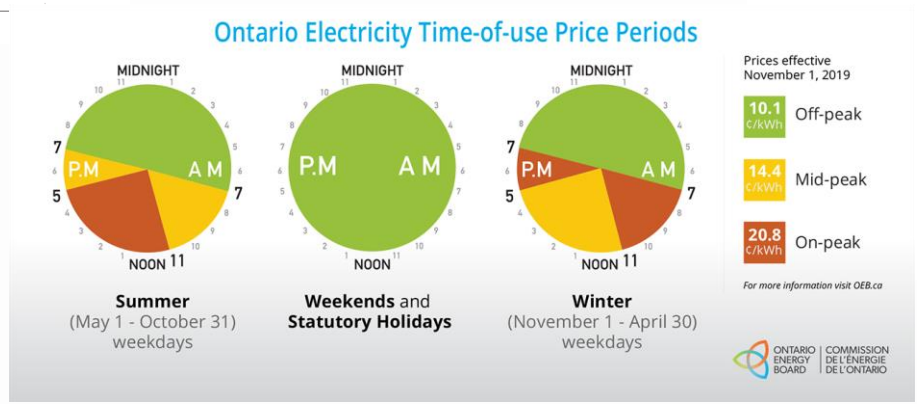
- Time-based – Implicit DR
  - Responding to electricity prices
- Incentive-based – Explicit DR
  - Agreed load reduction on demand

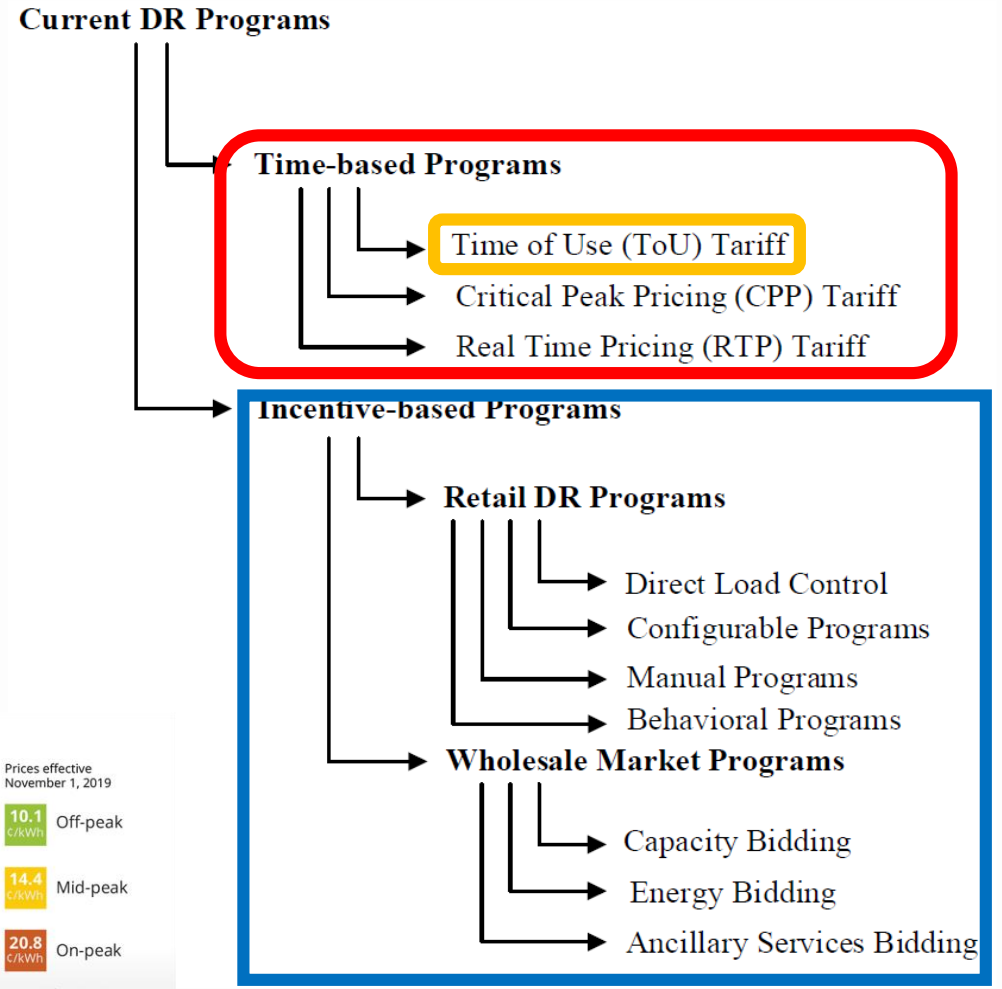


T5.1 DSM – DR – Implicit #1

- Time-based – Implicit DR
  - Time-of-Use (ToU)
    - Different pricing in different periods of the day

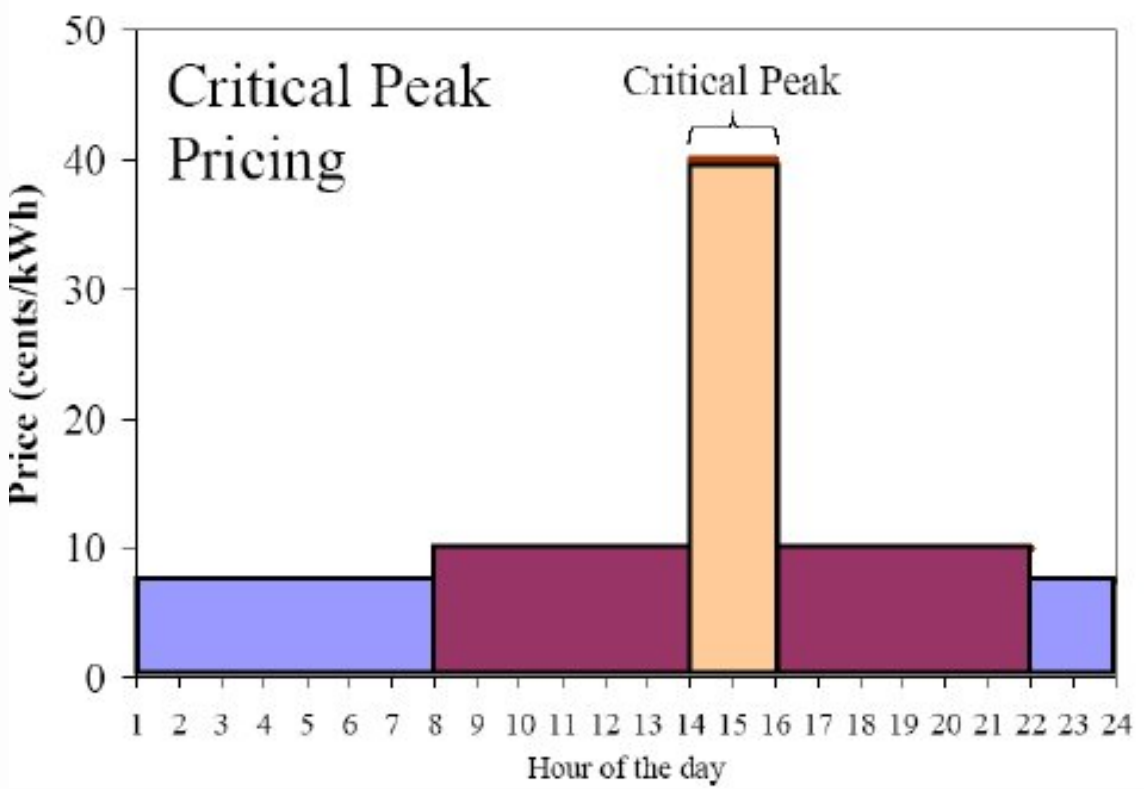


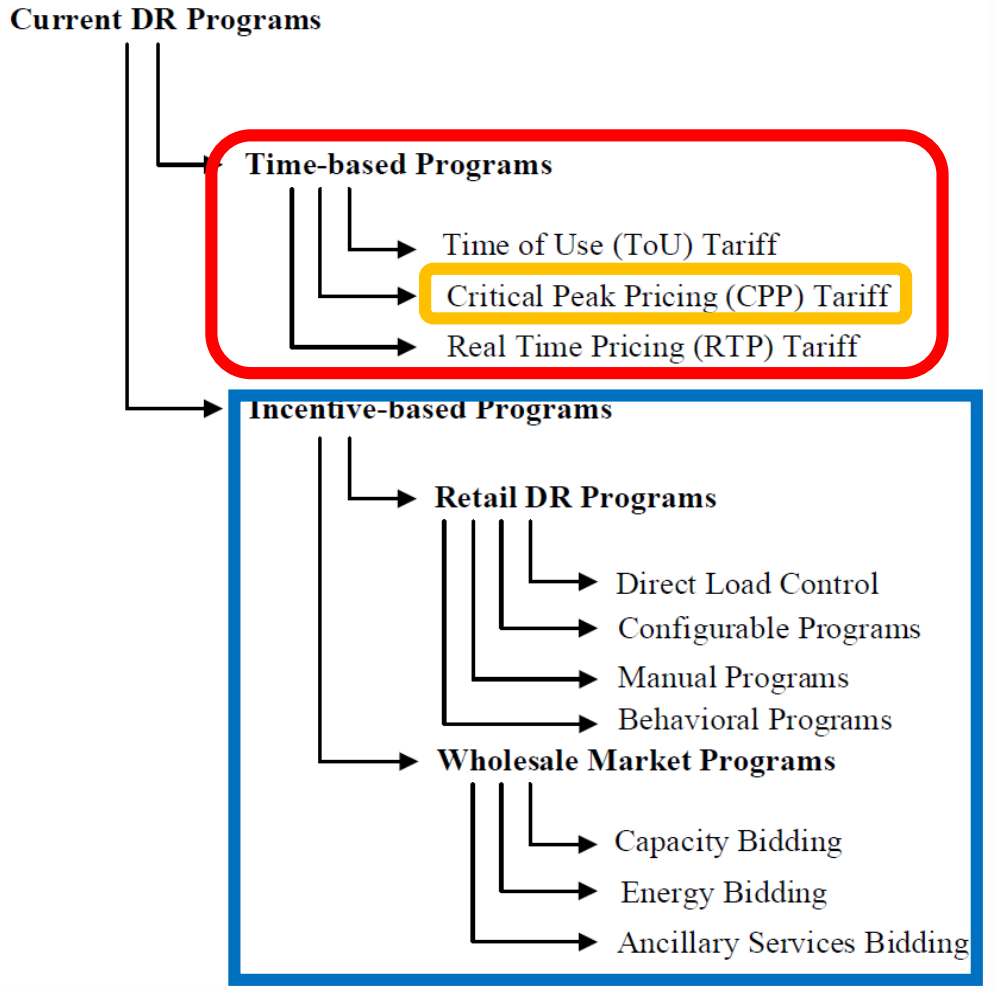




T5.1 DSM – DR – Implicit #2

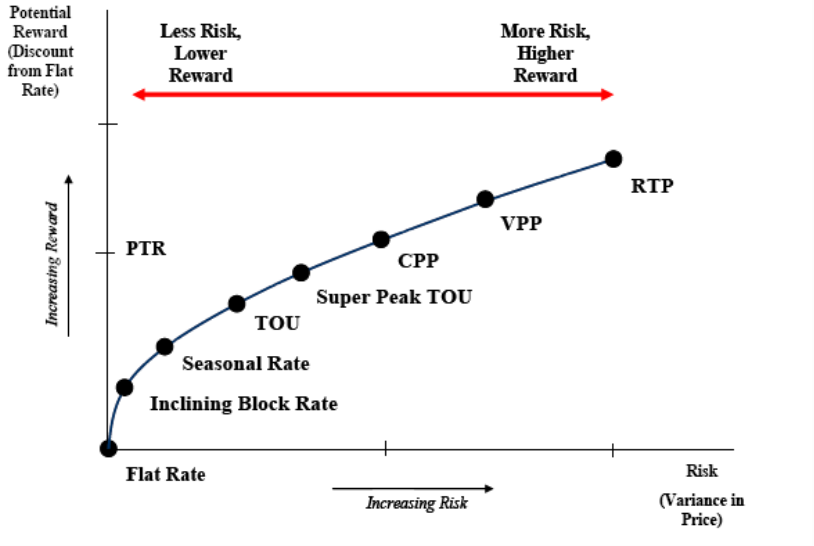
- Time-based – Implicit DR
  - Critical Peak Pricing (CPP)
    - High pricing in peak times
    - Several days a year

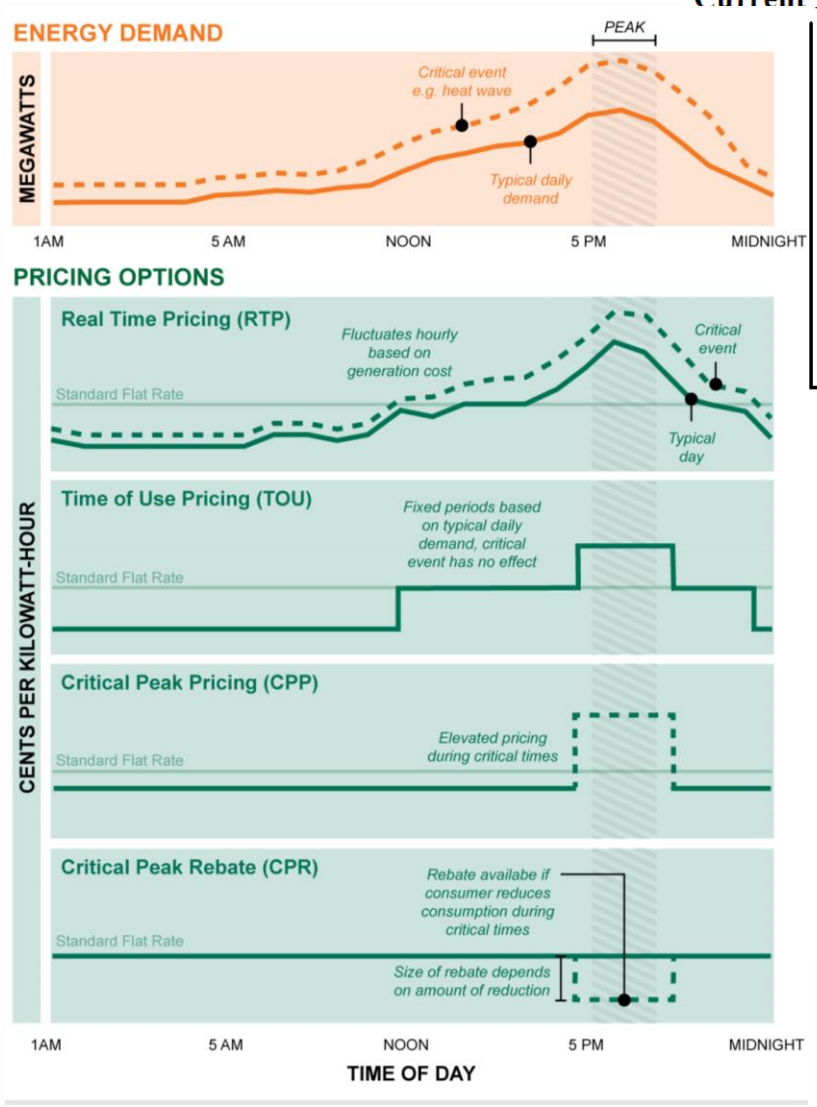


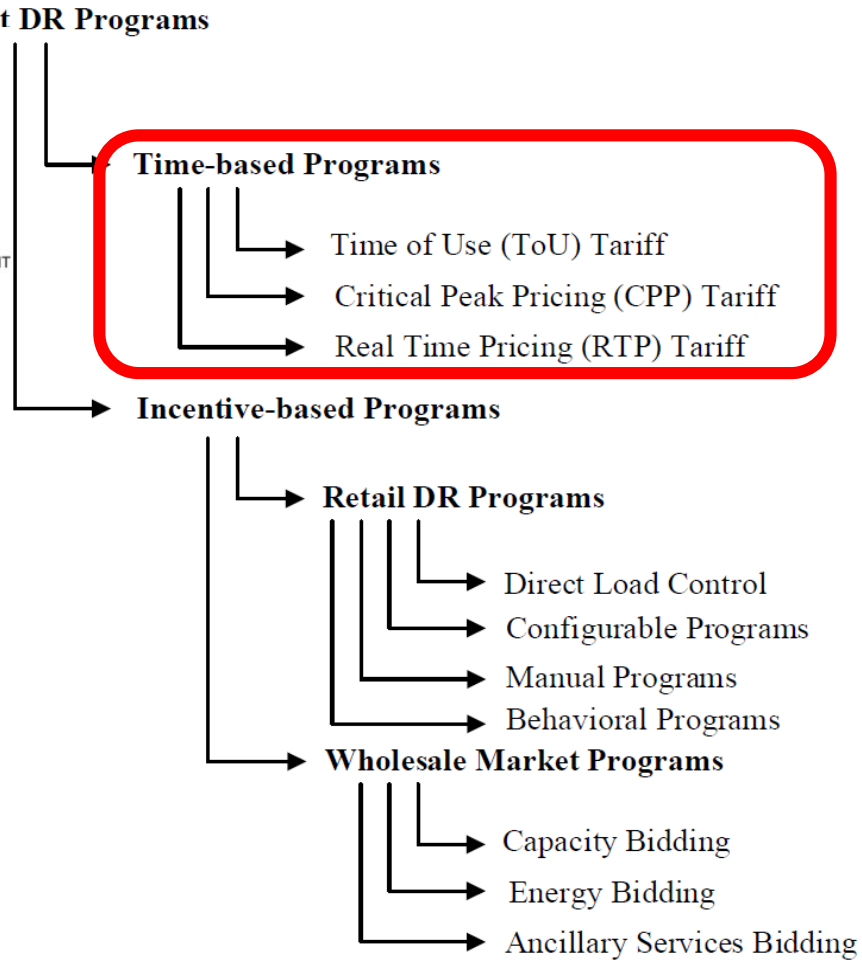


T5.1 DSM – DR – Implicit #3

- Time-based – Implicit DR

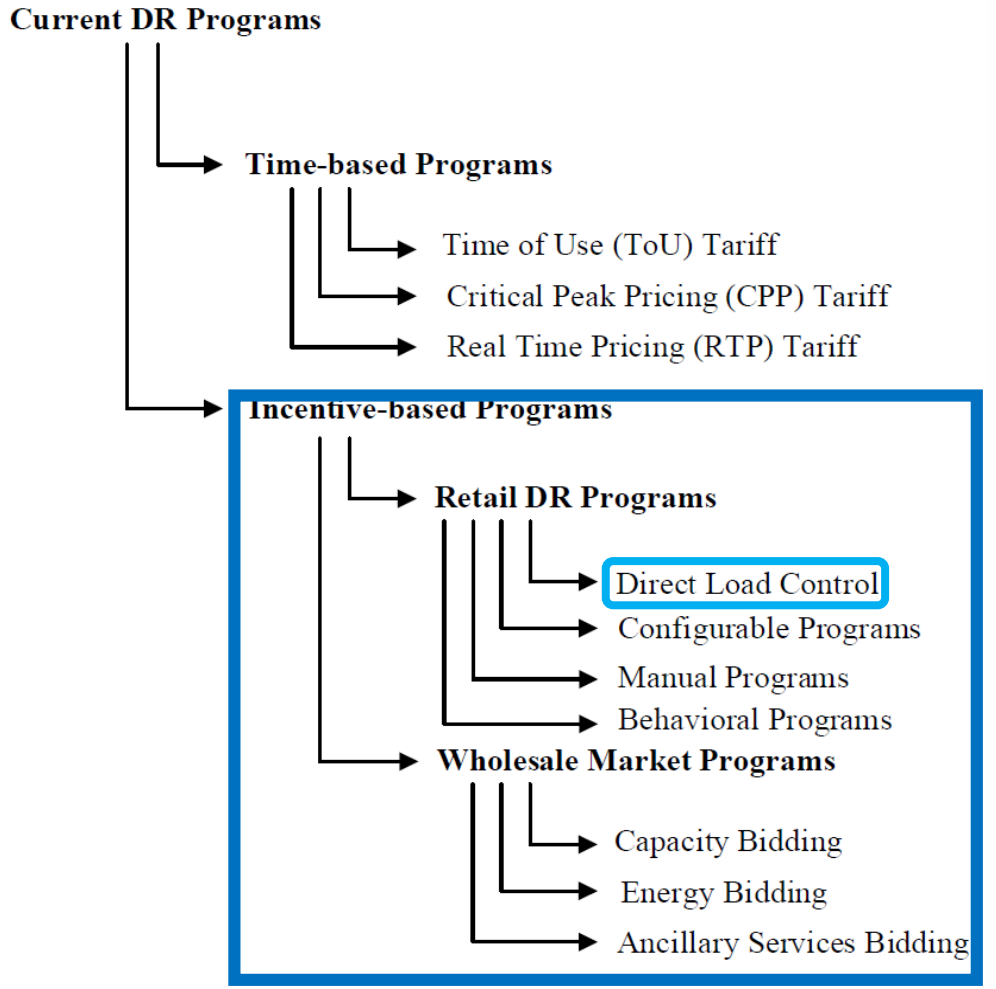






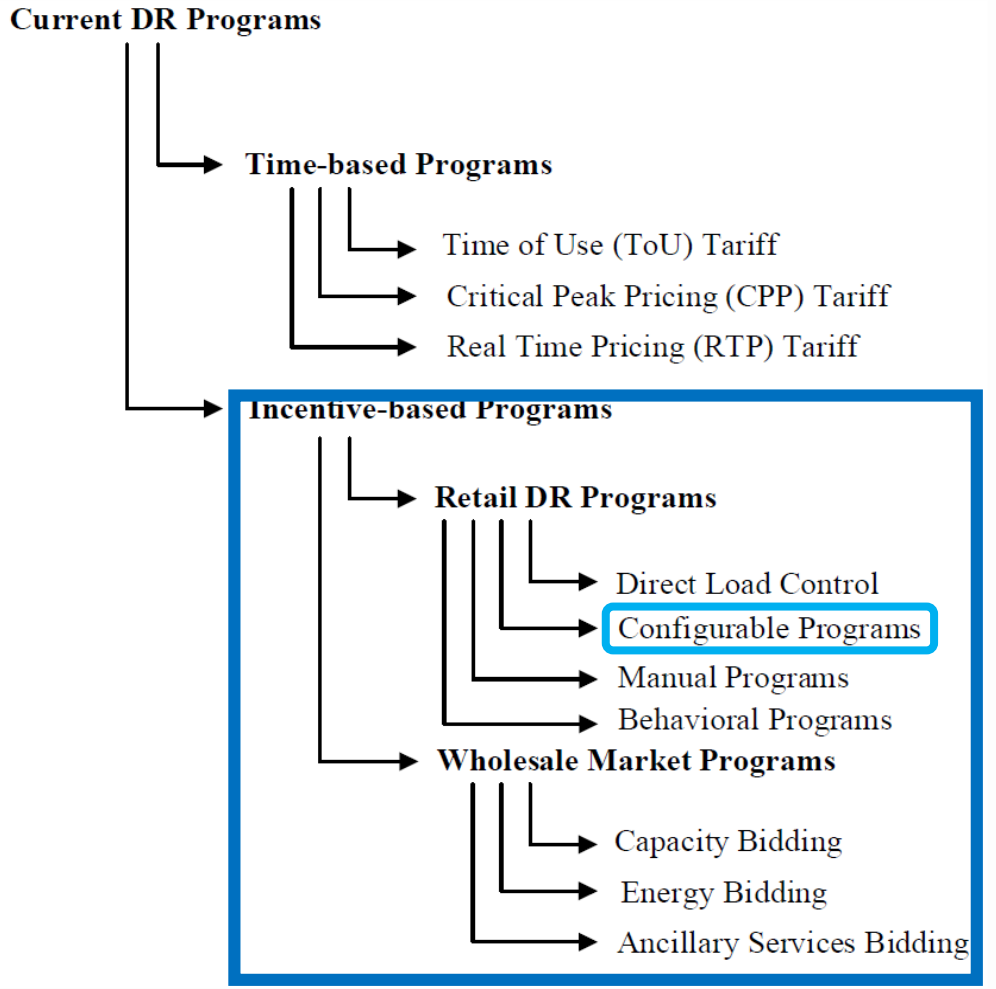
T5.1 DSM – DR – Explicit #1

- Incentive-based – Explicit DR
  - Direct Load Control (DLC)
    - Offering control of particular assets directly to third-party, e.g. Aggregator, DSO



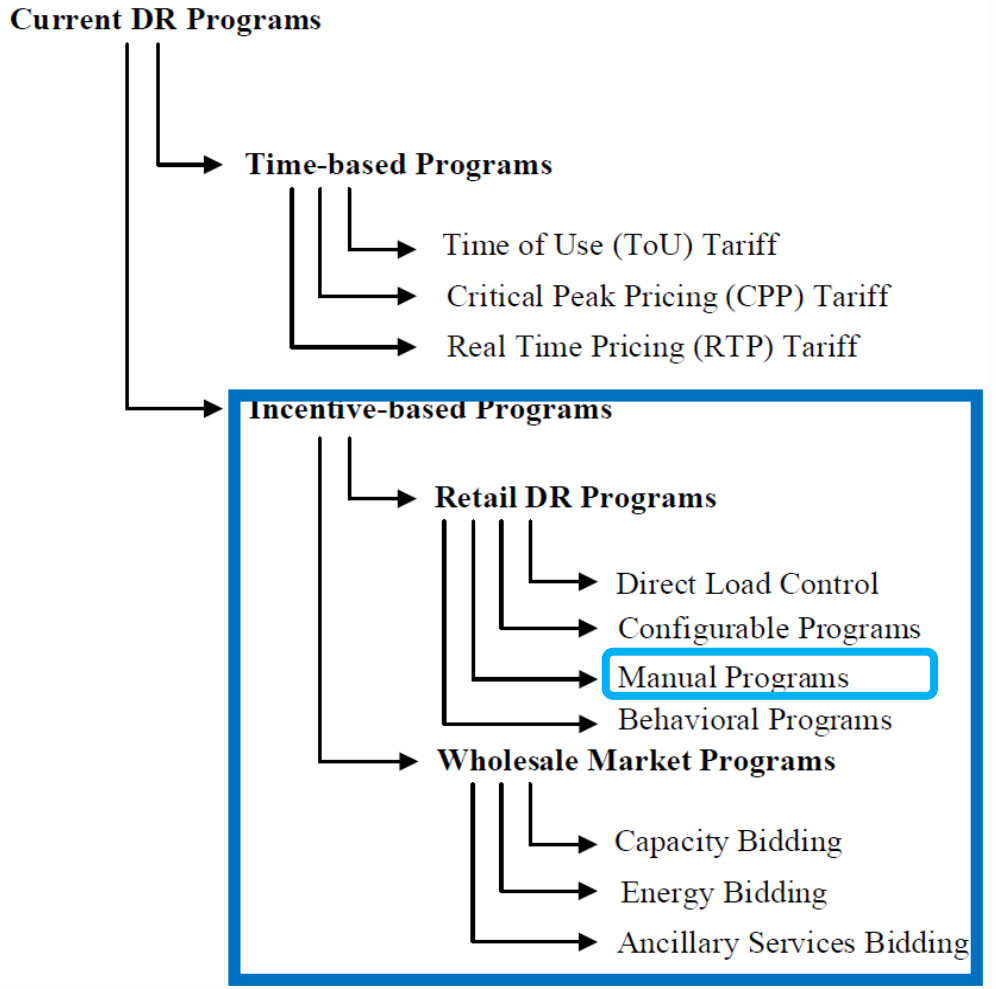
T5.1 DSM – DR – Explicit #2

- Incentive-based – Explicit DR
  - Configurable Loads
    - Similar to DLC
    - End-users participating in the control scheme with assets configuration
    - Most popular program so far



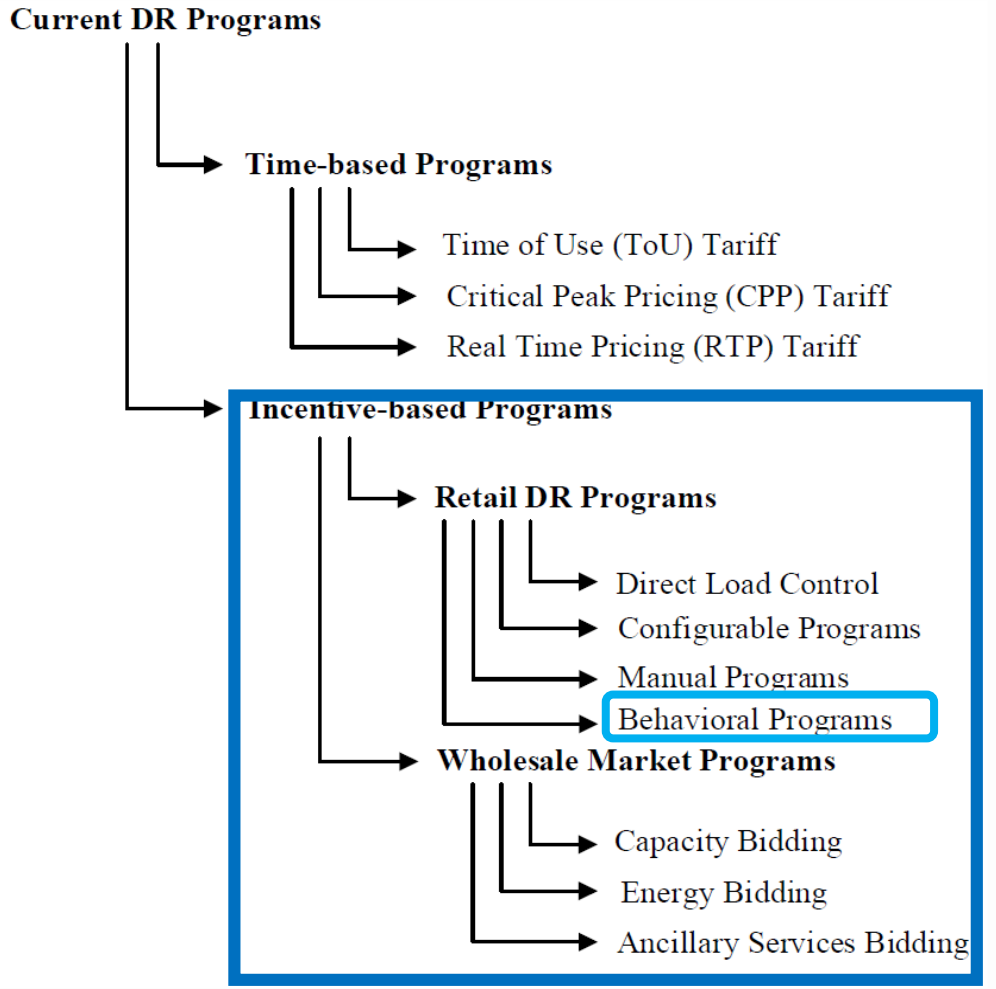
T5.1 DSM – DR – Explicit #3

- Incentive-based – Explicit DR
  - Manual Programs
    - Manually controlling the assets
    - Notification (sms, email, app etc.)
    - Low cost
    - 1st step to DR



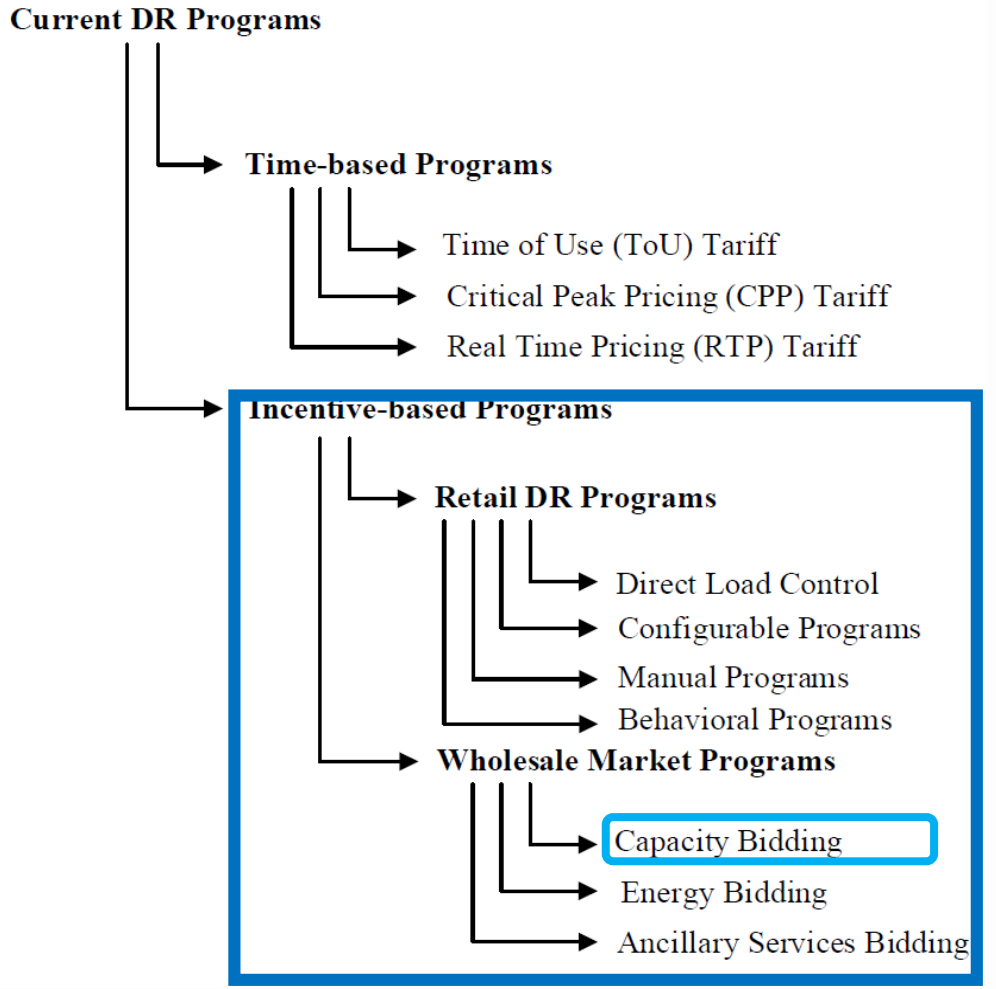
T5.1 DSM – DR – Explicit #4

- Incentive-based – Explicit DR
  - Behavioral Programs
    - Based on end-user load profile
    - Social motivation for reduction or participation
    - Combined with other DR programs



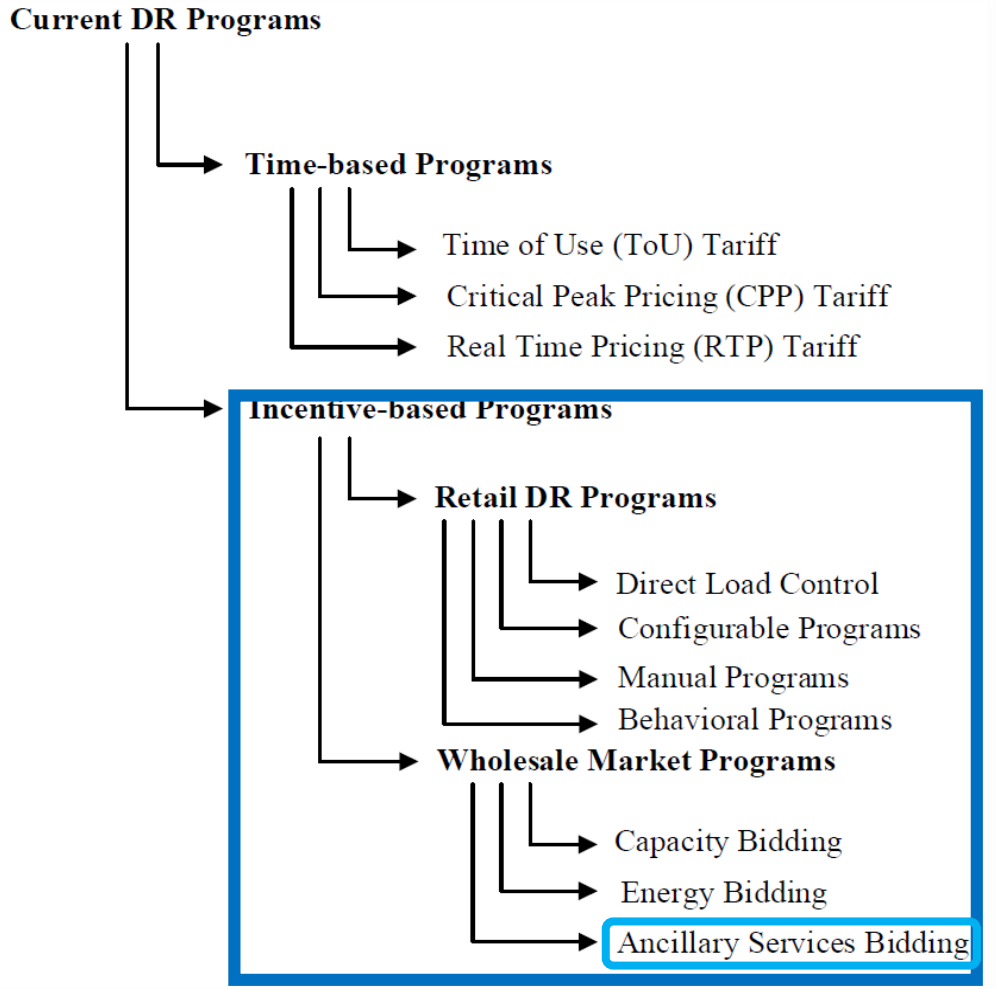
T5.1 DSM – DR – Explicit #5

- Incentive-based – Explicit DR
  - Capacity biddings
    - When the Distribution Network constraints are about to be violated.
    - Reward/penalty approach



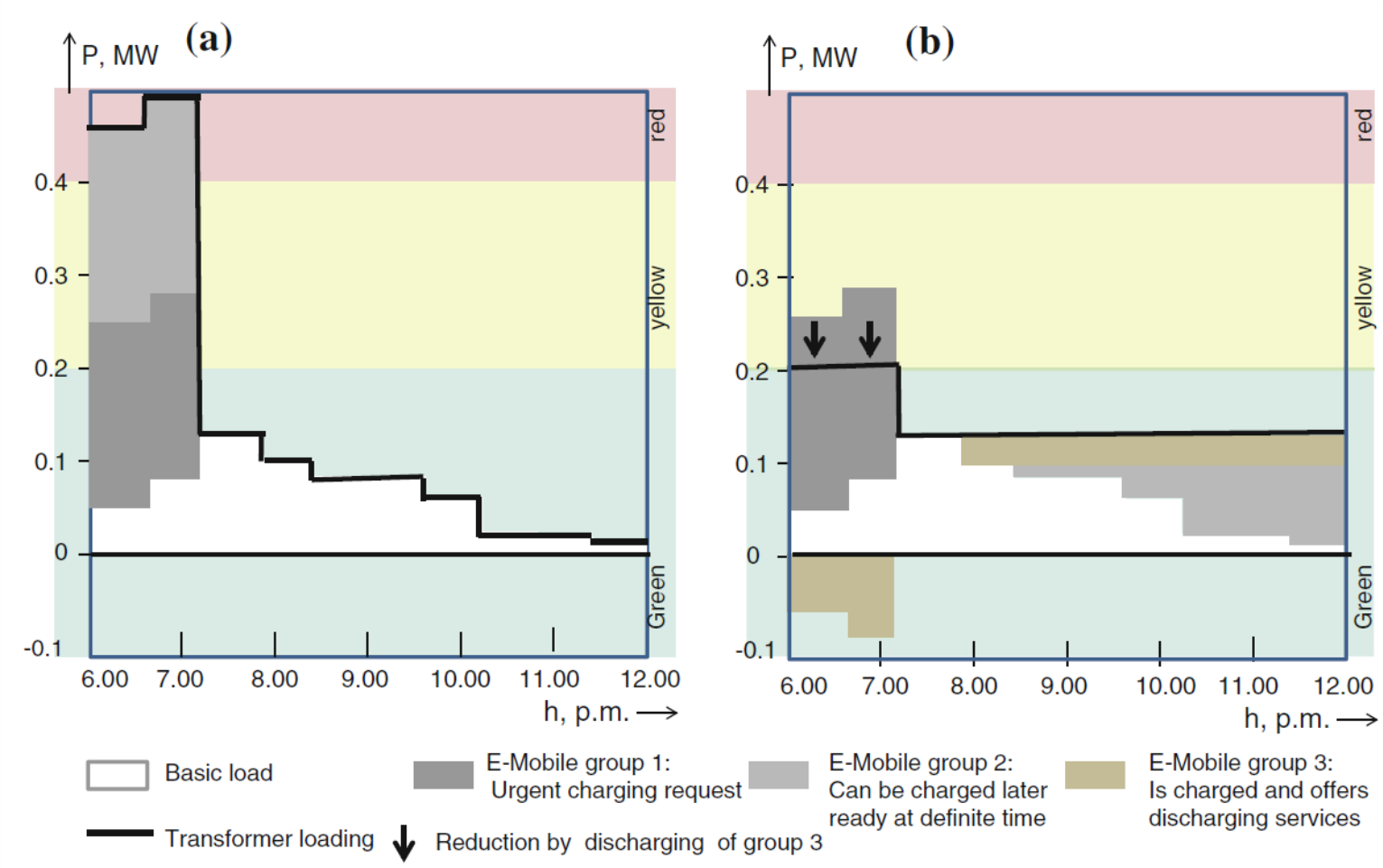
T5.1 DSM – DR – Explicit #6

- Incentive-based – Explicit DR
  - Ancillary Services Bidding
    - Reserves,
    - Frequency/Voltage support,
    - Rapid Response
    - Short periods

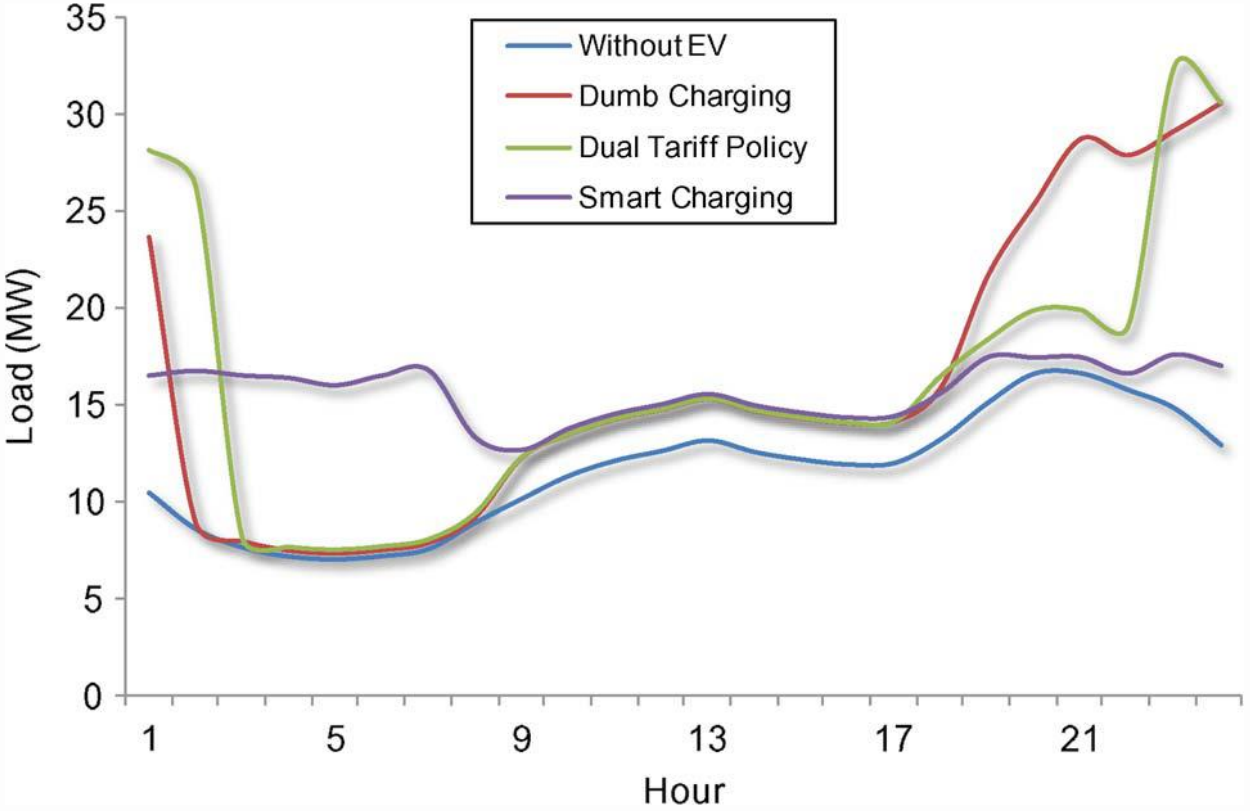


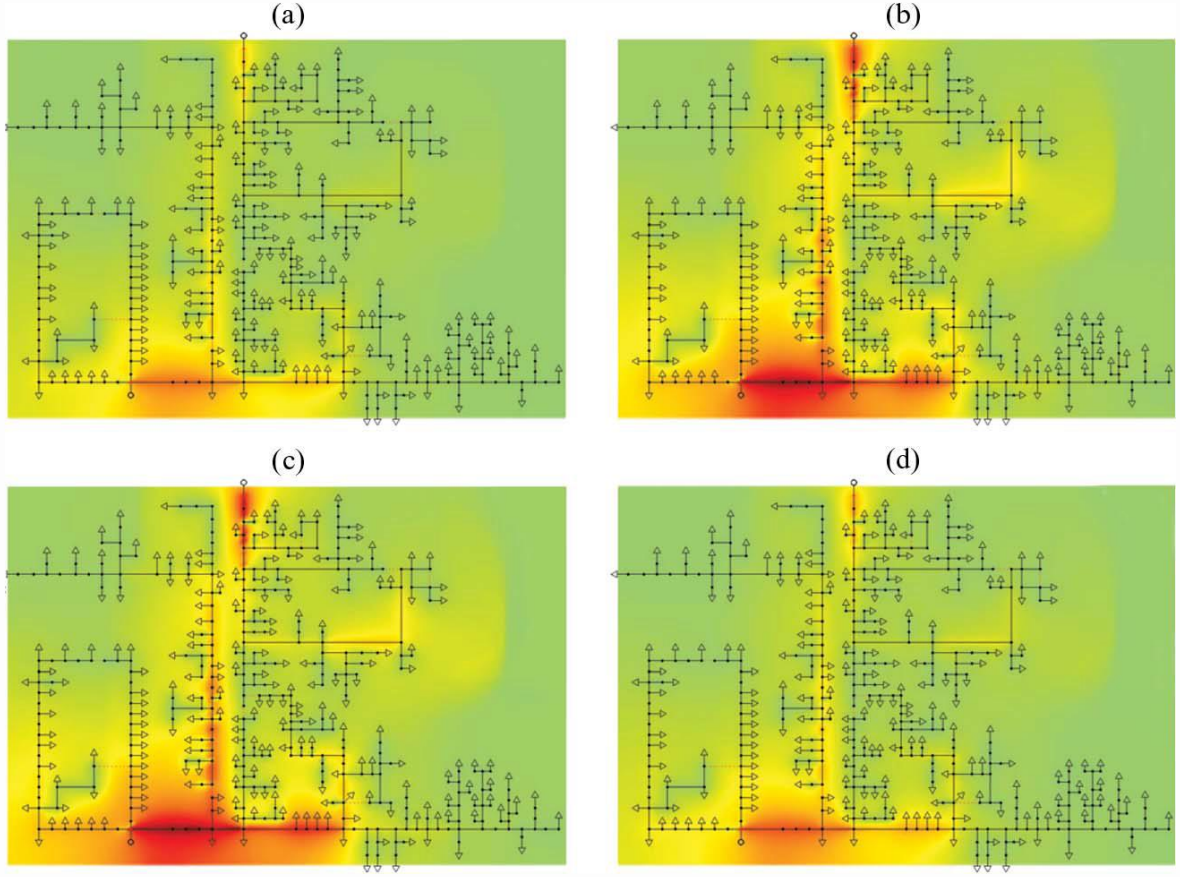
T5.1 DSM – Electric Vehicles #1

- “Traffic light” approach
- Red: Network equipment is overstressed.
- Yellow: Network operation is critical
- Green: everything is ok.



T5.1 DSM – Electric Vehicles #2





T5.1 DSM – implementations #1a

(a) European Project Web2Energy
(A, CH, D, NL, PL, RU)

200 pilot consumers
Traffic lights via Web or SMS

(b) E-Energy Project MEREGIO
(D)

1000 pilot consumers
Inhouse display

T5.1 DSM – implementations #1b

(a) Web2Energy

Day-ahead Forecast of red & green time periods

Demand is compared to a reference profile

Bonus system for saving in red and exceeding in green intervals

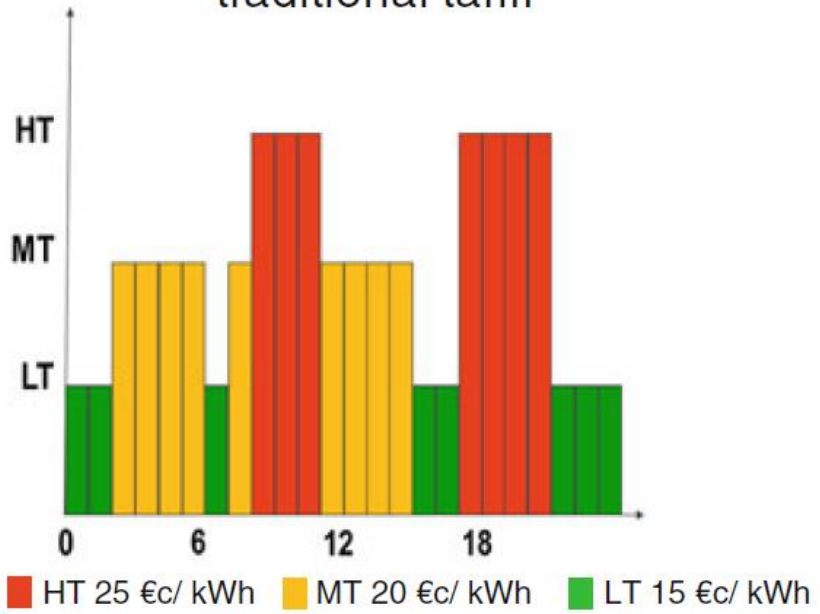
(b) MEREGIO

3 fixed tariffs: HT, MT, LT

their duration varies every day

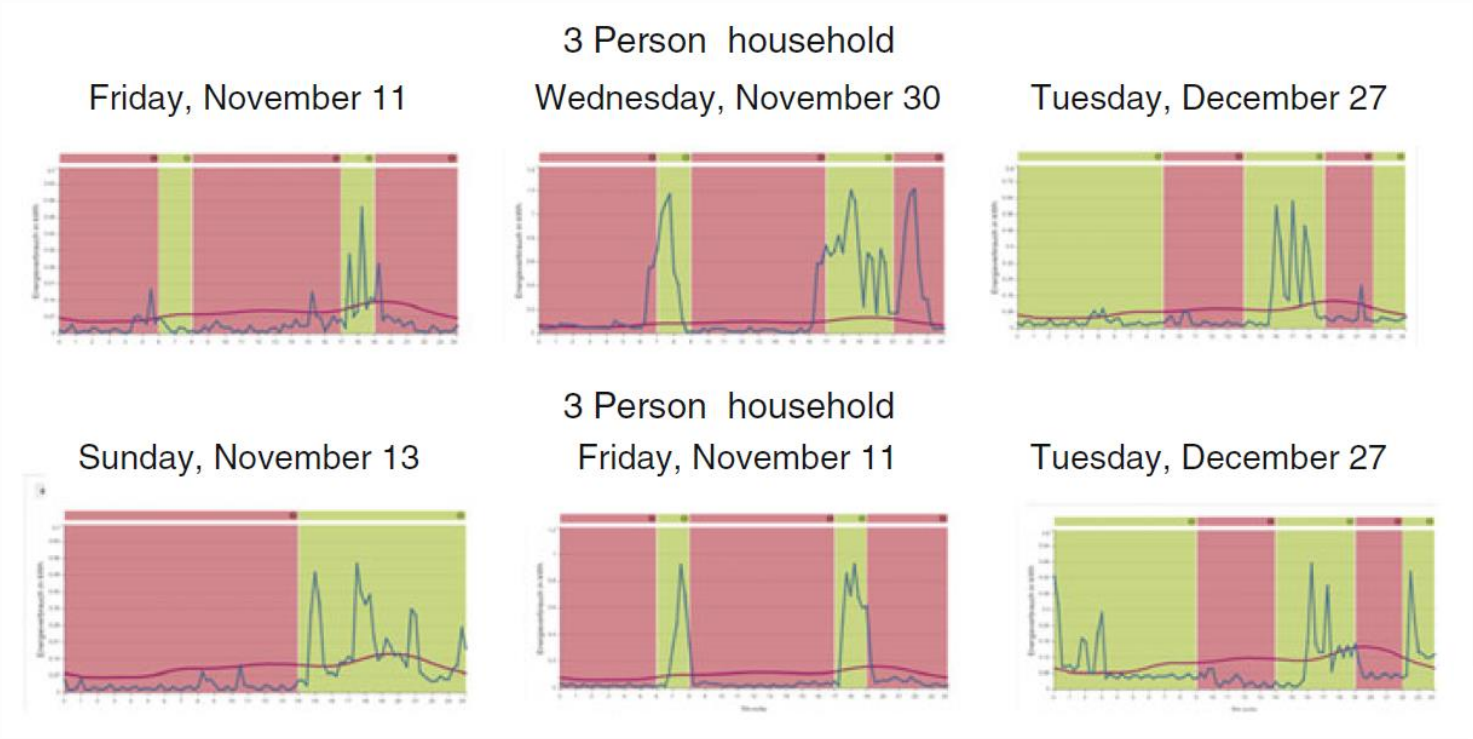
The forecasts are shown on a display

The consumer can decide about the billing according to the new or the traditional tariff

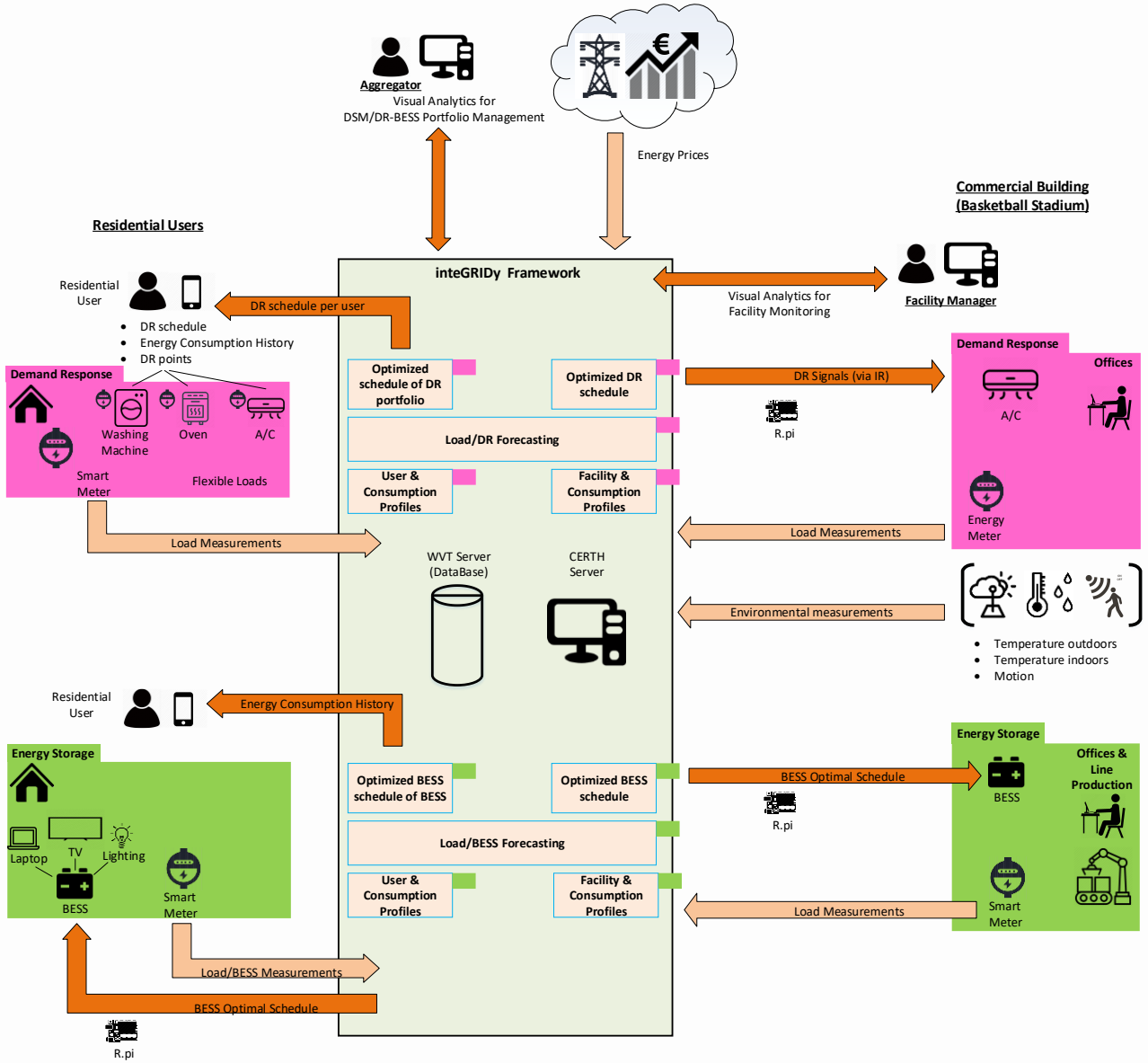


T5.1 DSM – implementations #1c

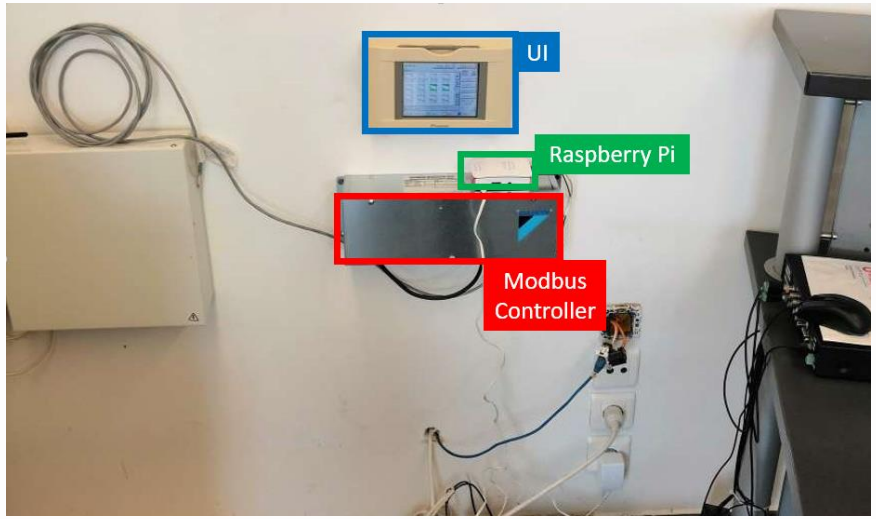
- Only presenting consumption and pricing for raising awareness
- 3% in average reduction (0.3 kWh/day)
- End-user engagement 60 out of 200
- The end-user engagement was decreasing over-time. Requirement for automation



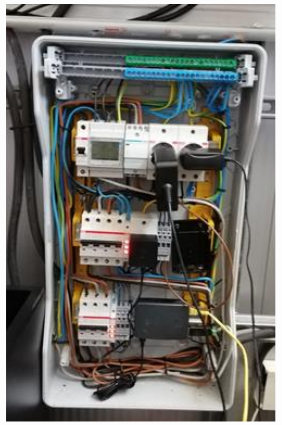
T5.1 DSM – implementations #2a



T5.1 DSM – implementations #2b

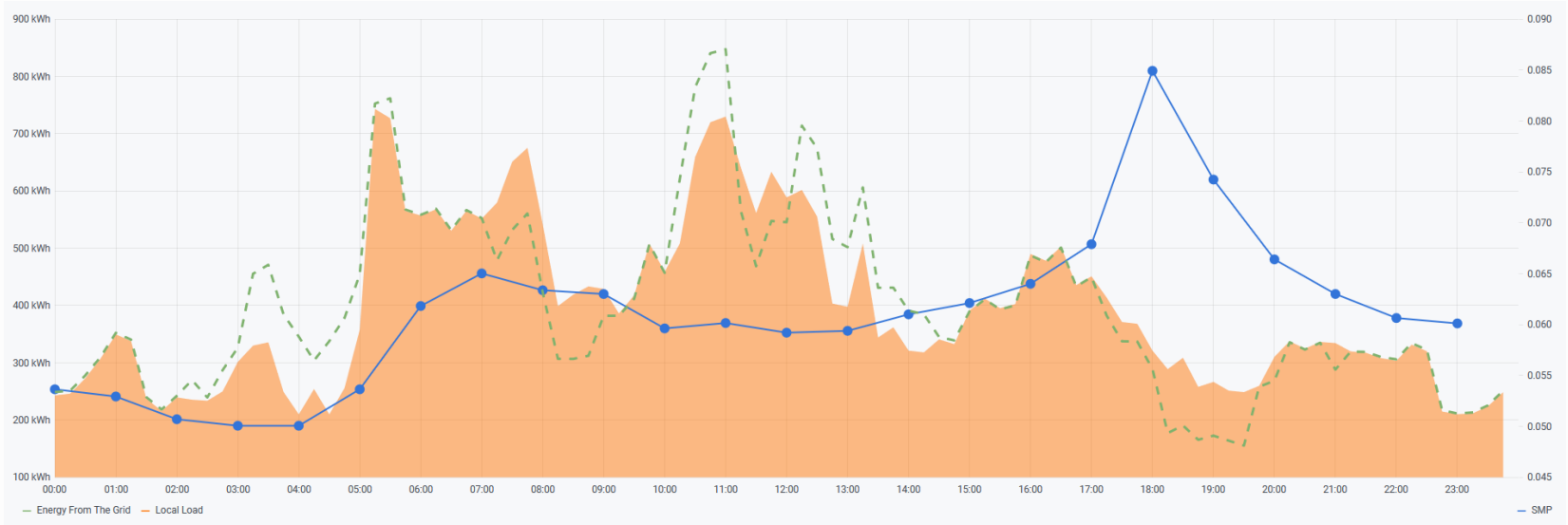


T5.1 DSM – implementations #2c



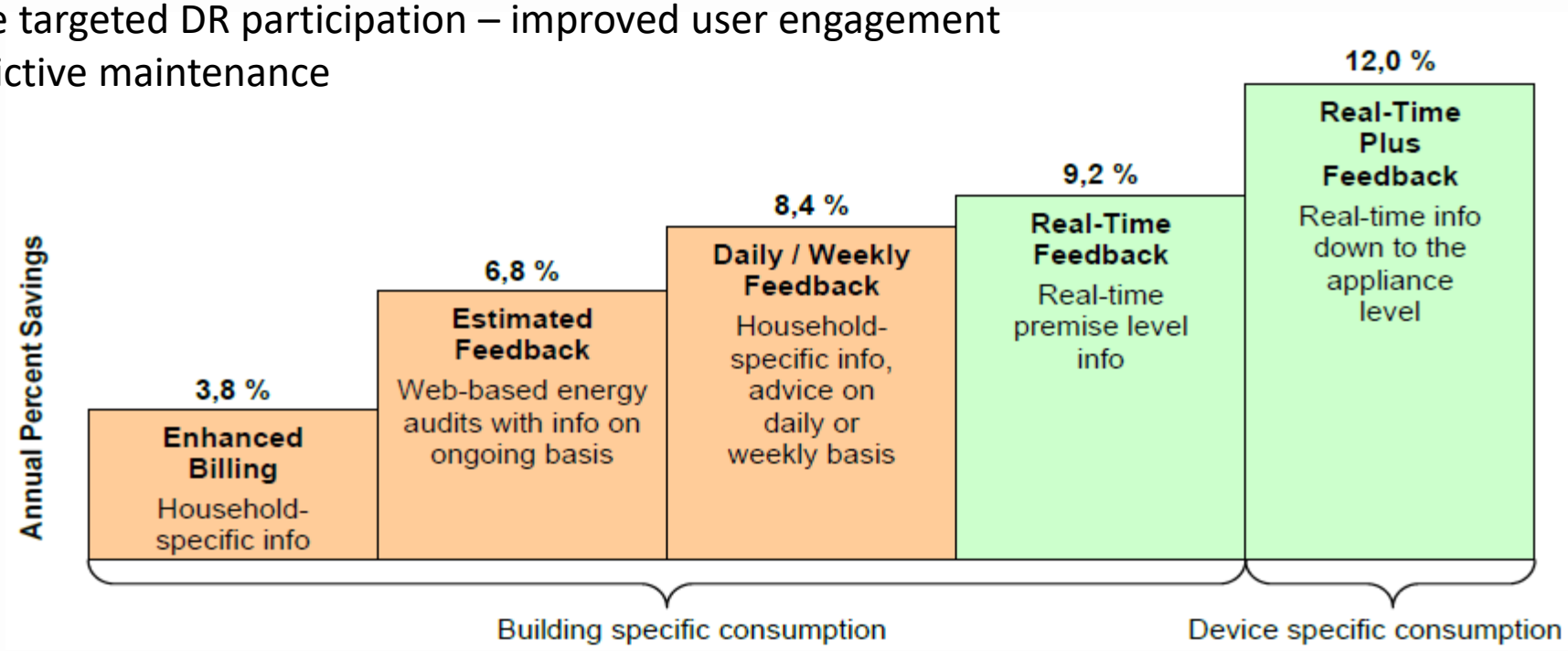
T5.1 DSM – implementations #2d

- Circa 80 end-users participated
- ~40% Peak load reduction



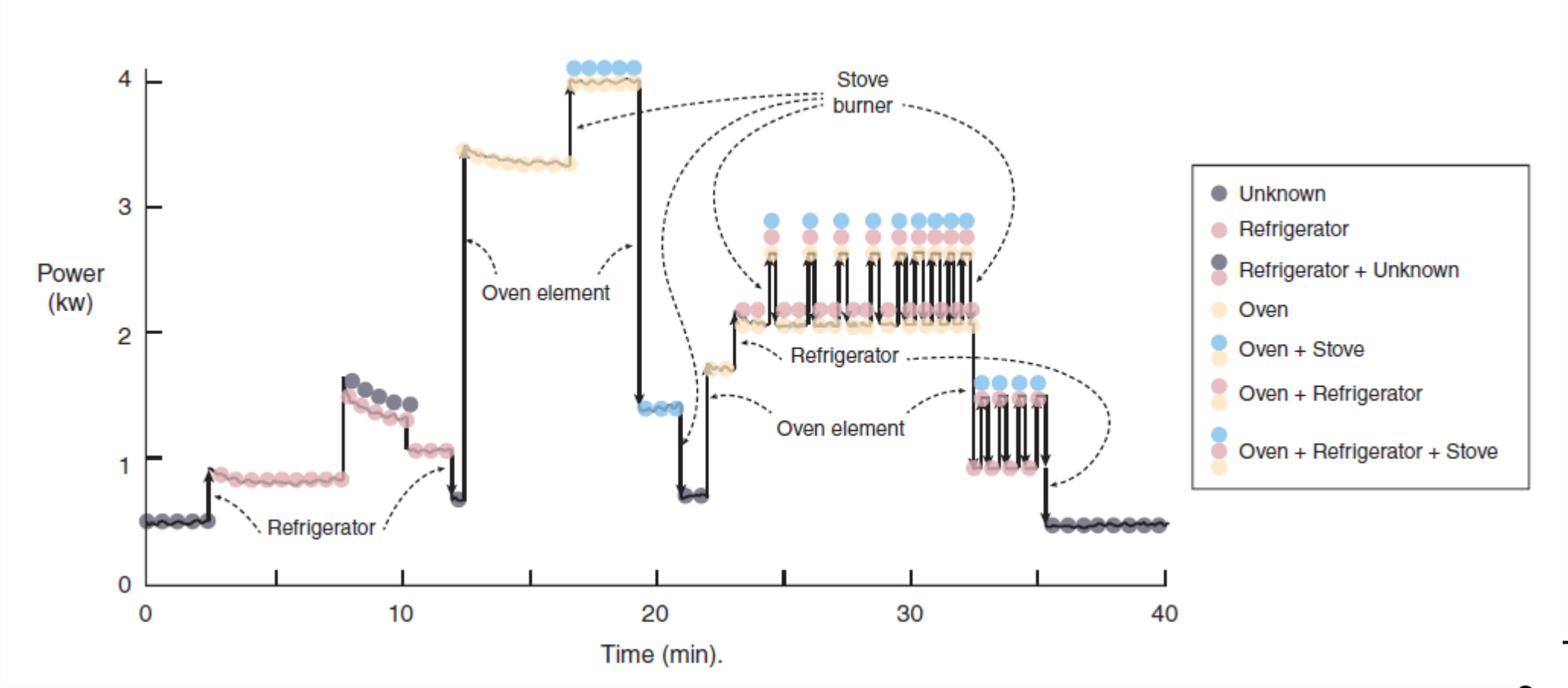
T5.1 DSM – NILM #1

- Energy savings improving margin
  - Load disaggregation – detecting appliances/devices
    - Detecting heavy energy consuming devices
    - Detecting non-active devices
    - Predicting flexibility consumption
    - More targeted DR participation – improved user engagement
    - Predictive maintenance



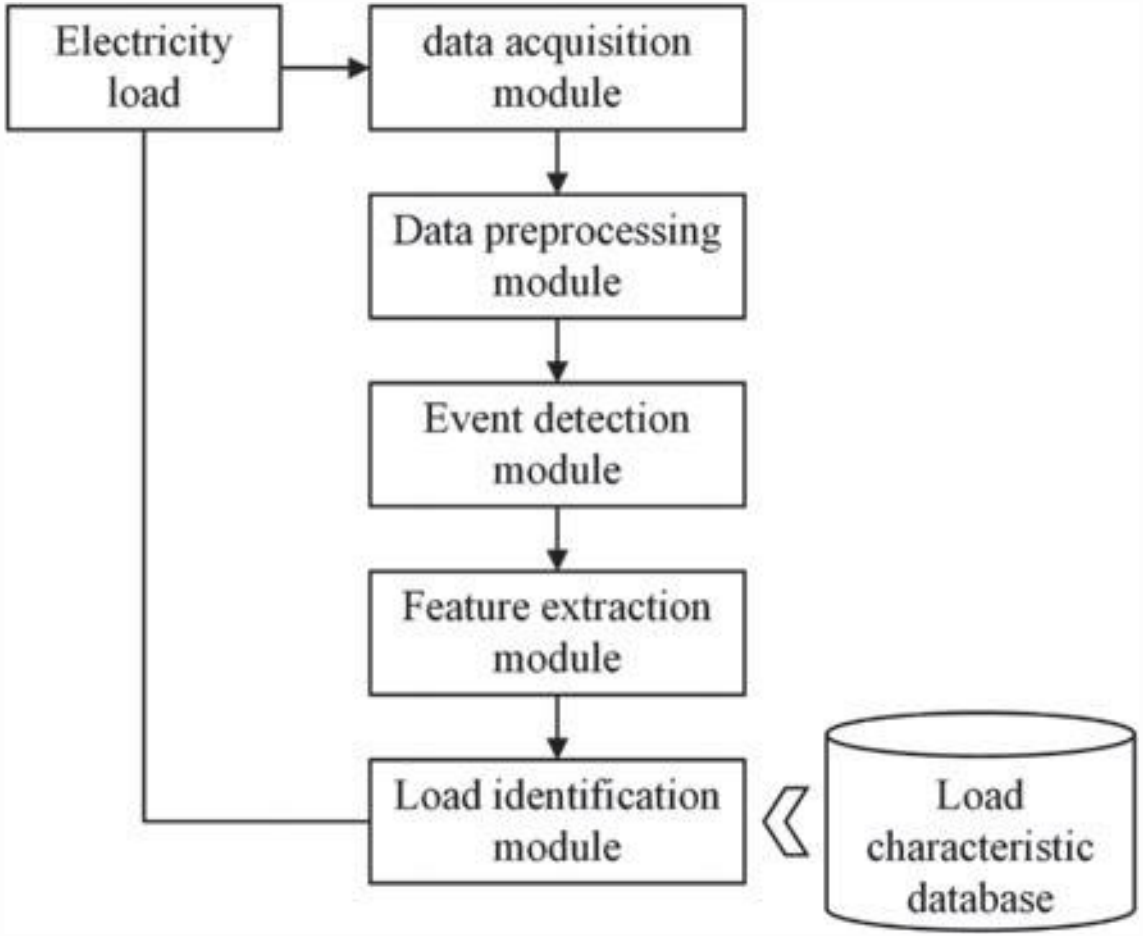
T5.1 DSM – NILM #2

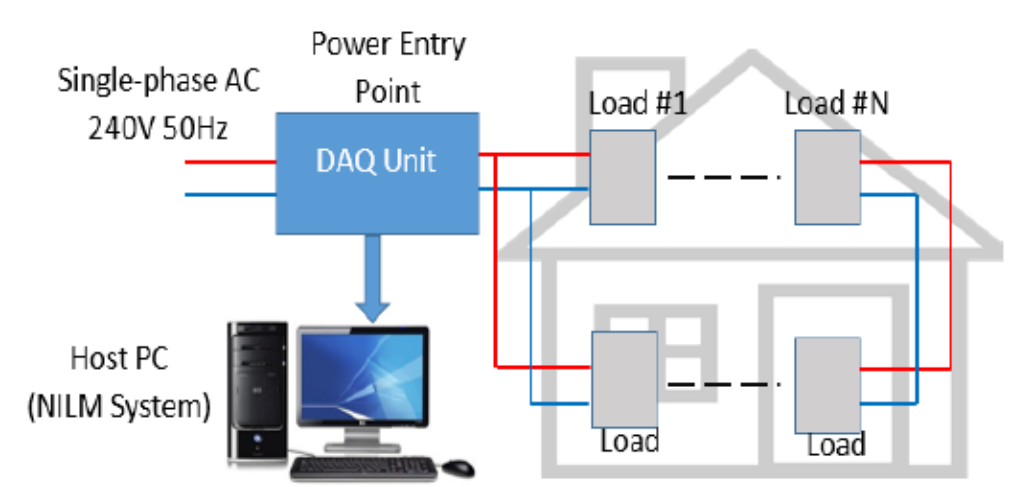
- Load Disaggregation – Non-Intrusive Load Monitoring (NILM)

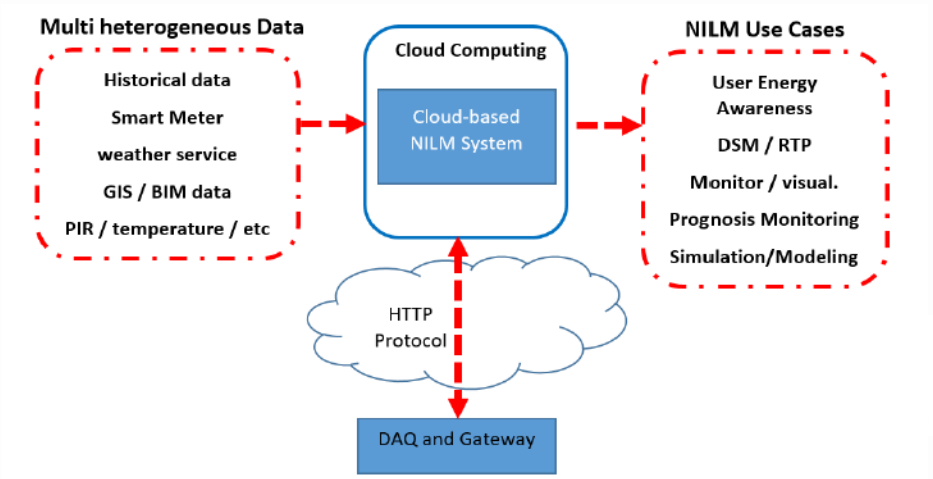


T5.1 DSM – NILM #3

- Load Disaggregation – Non-Intrusive Load Monitoring (NILM)



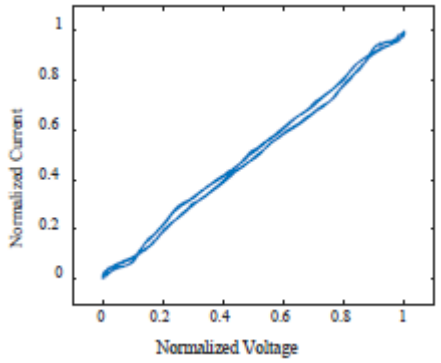




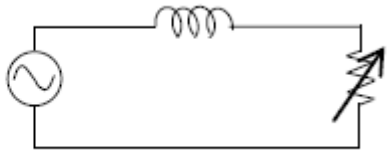
T5.1 DSM – NILM #4

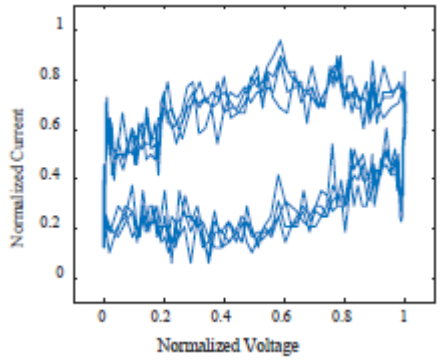
- Load Disaggregation – Non-Intrusive Load Monitoring (NILM)

Resistive load

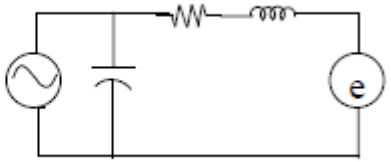


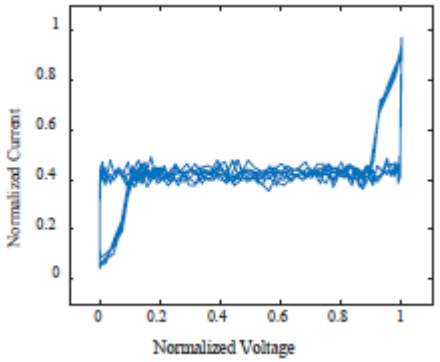
Inductive load



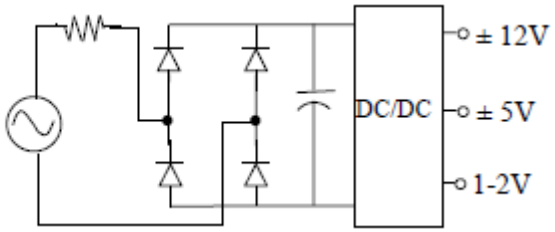


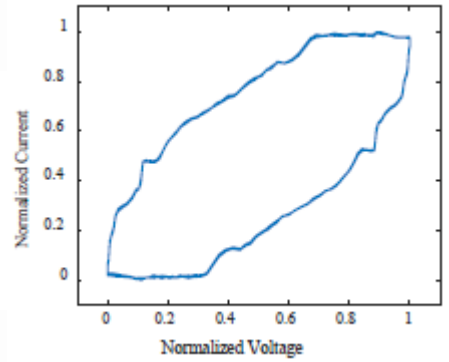
Motor load





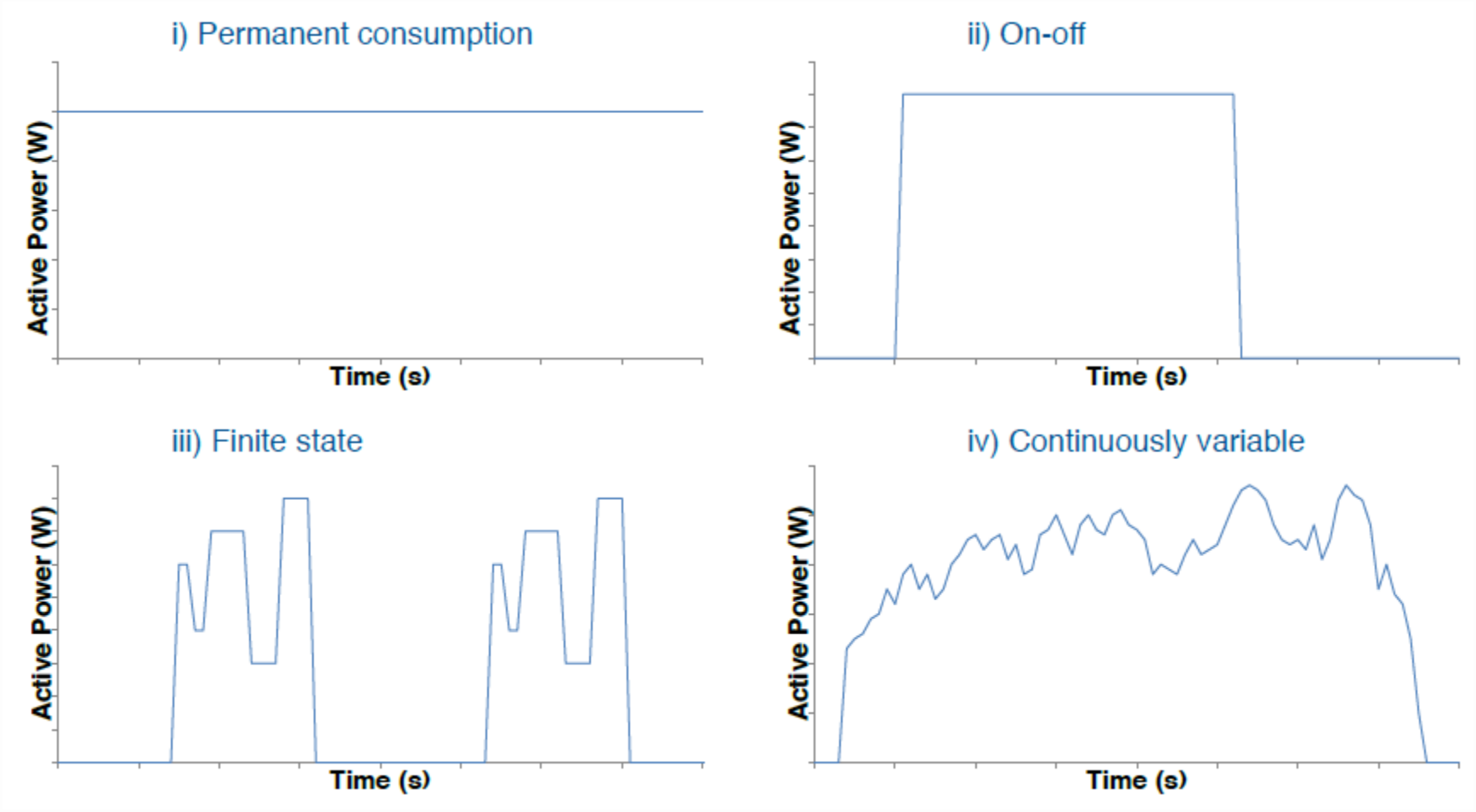
Rectifier load





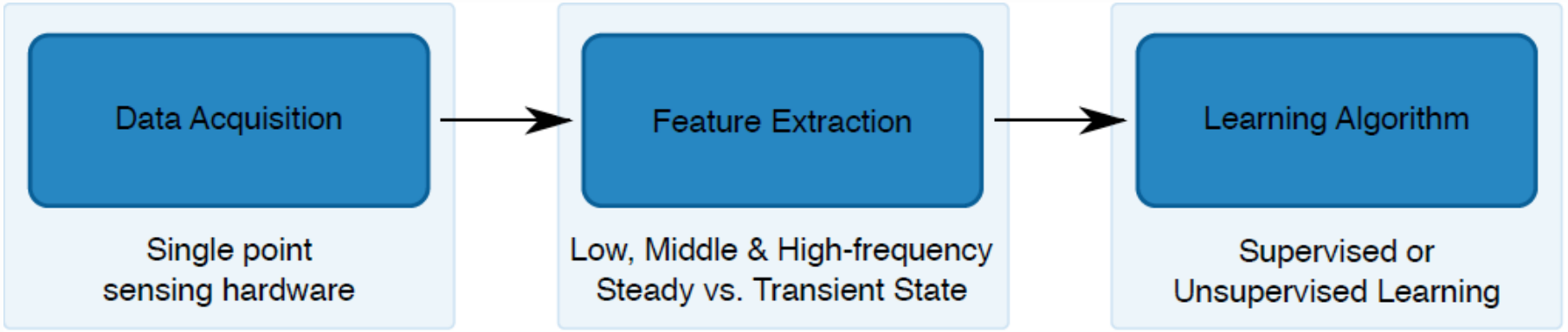
T5.1 DSM – NILM #5

- Load Disaggregation – Non-Intrusive Load Monitoring (NILM)



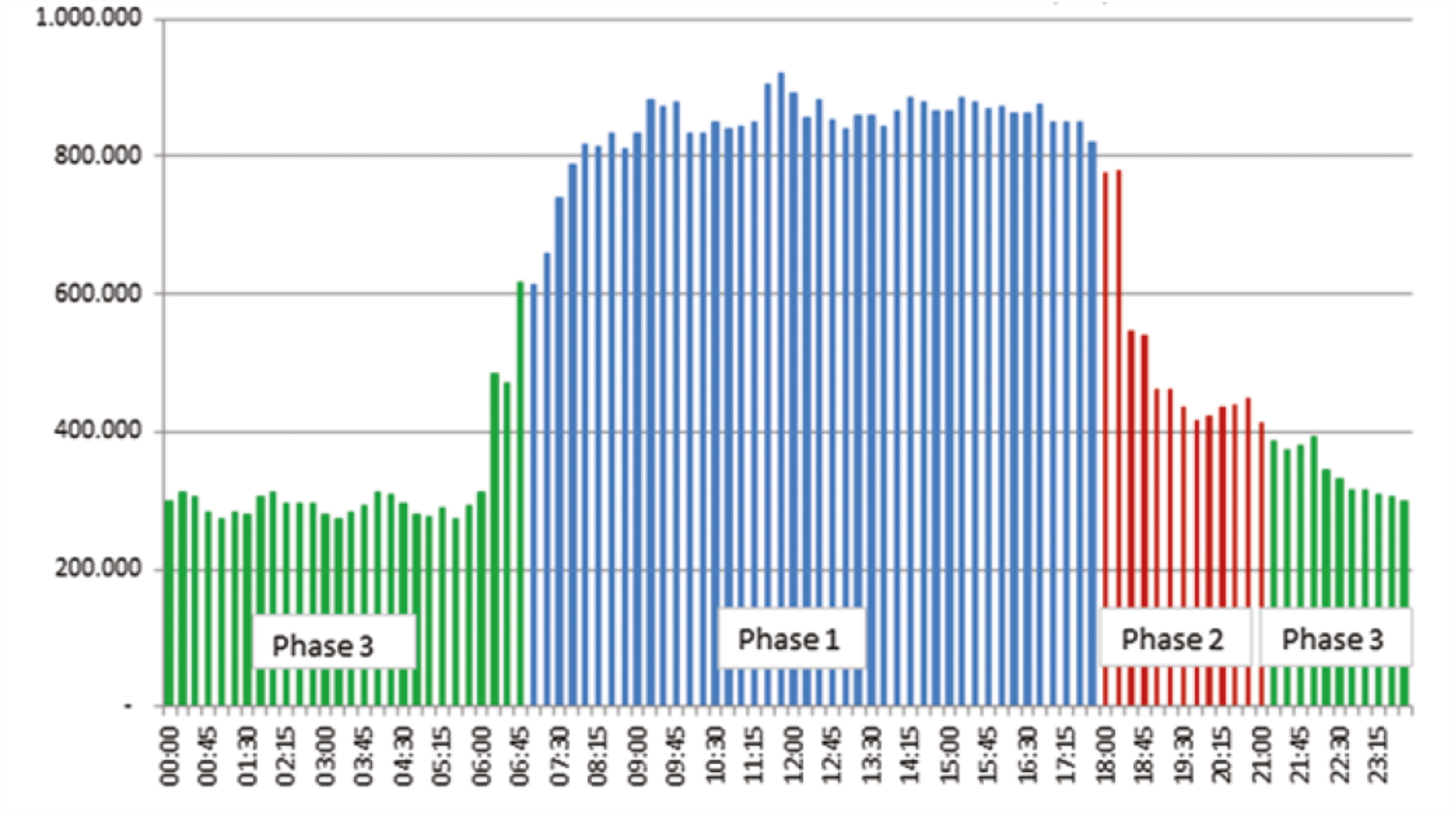
T5.1 DSM – NILM #6

- Load Disaggregation – Non-Intrusive Load Monitoring (NILM)

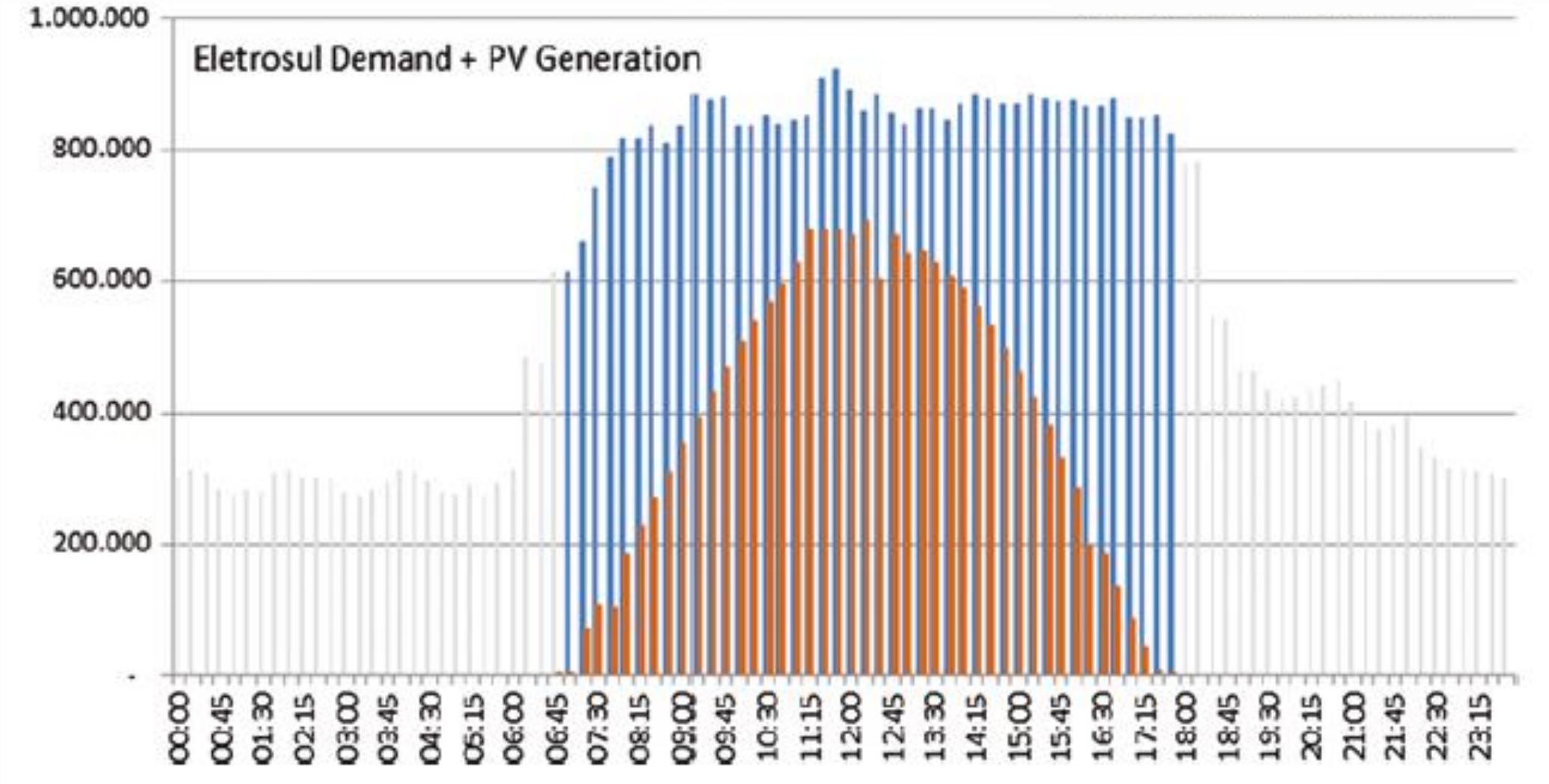


- **Supervised**: Support Vector Machine (SVM), Hidden Markov Models (HMM), Artificial Neural Networks (ANN), k-nearest neighbors (k-NN), Deep learning
- **Semi-supervised**: smaller training stage
- **Unsupervised**: no training stage

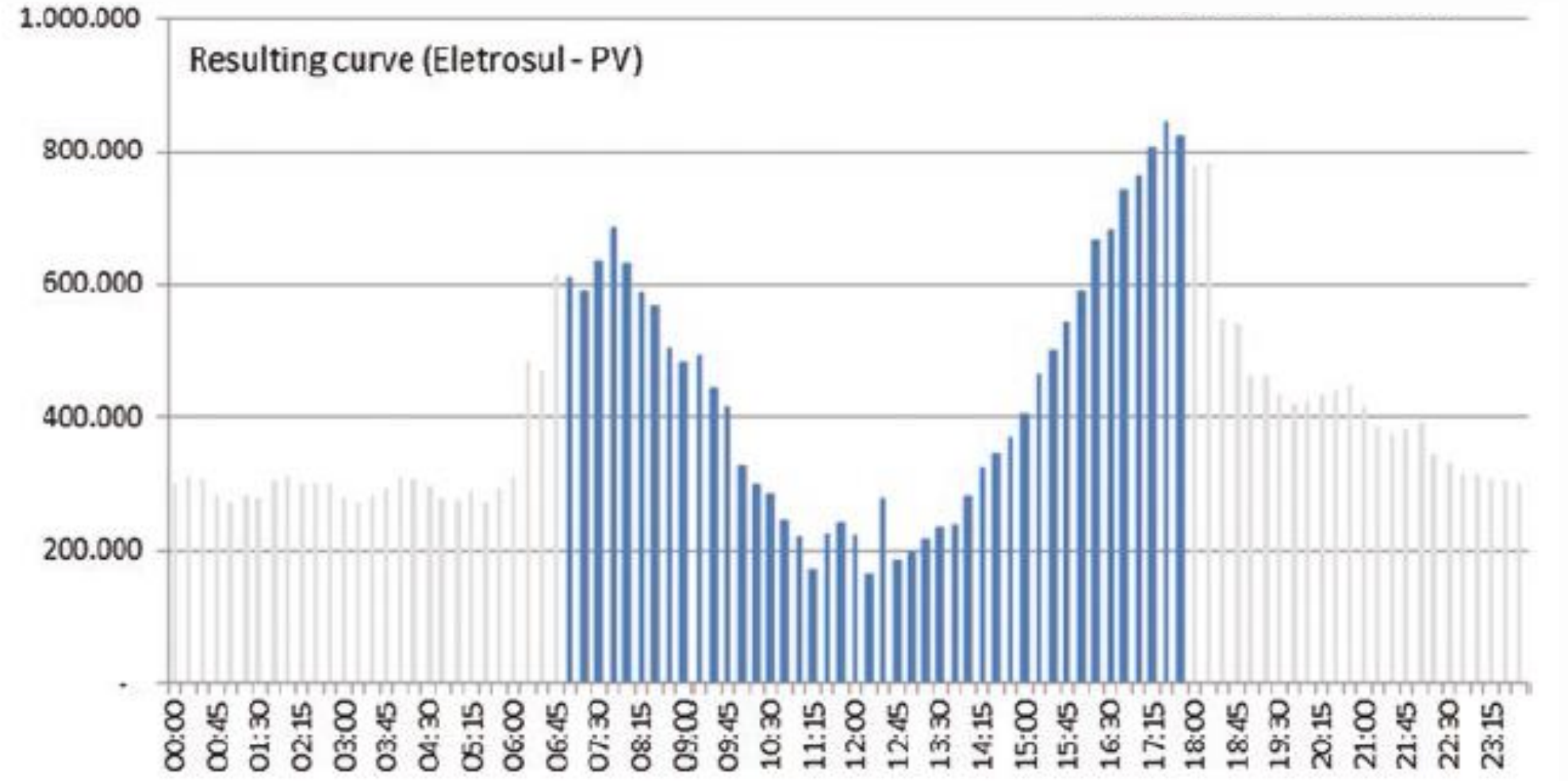
T5.1 DSM – implementations #4a



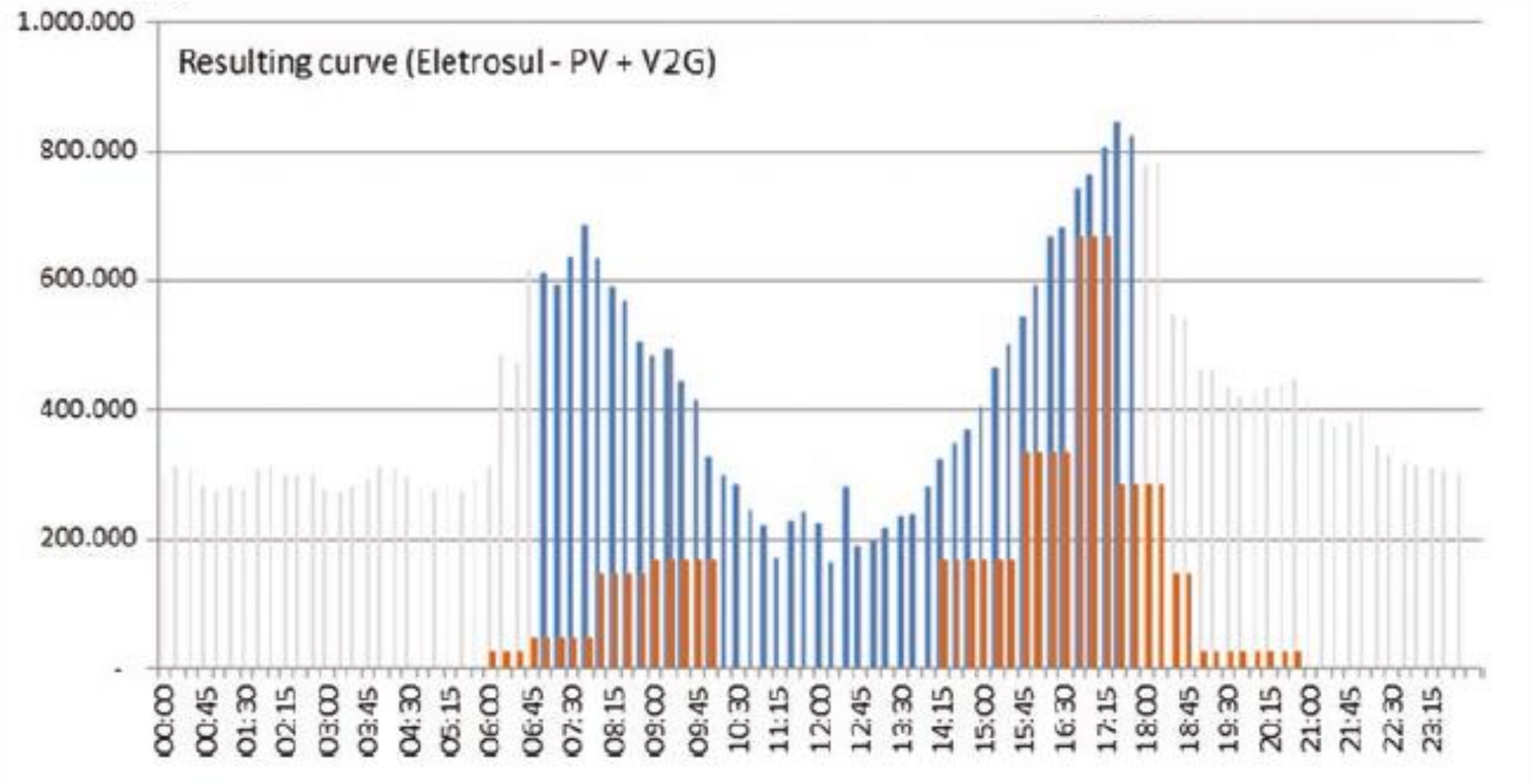
T5.1 DSM – implementations #4a



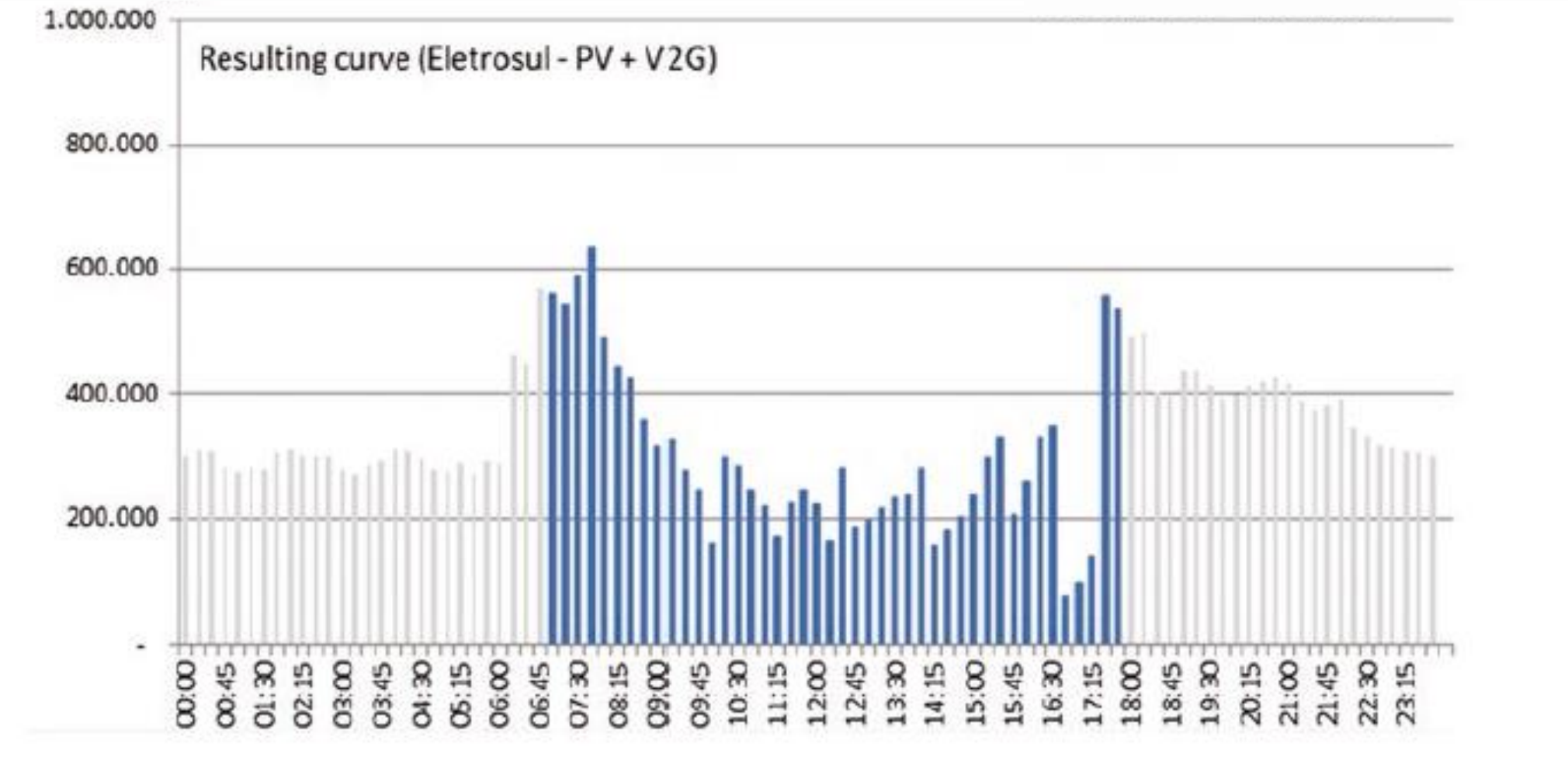
T5.1 DSM – implementations #4a



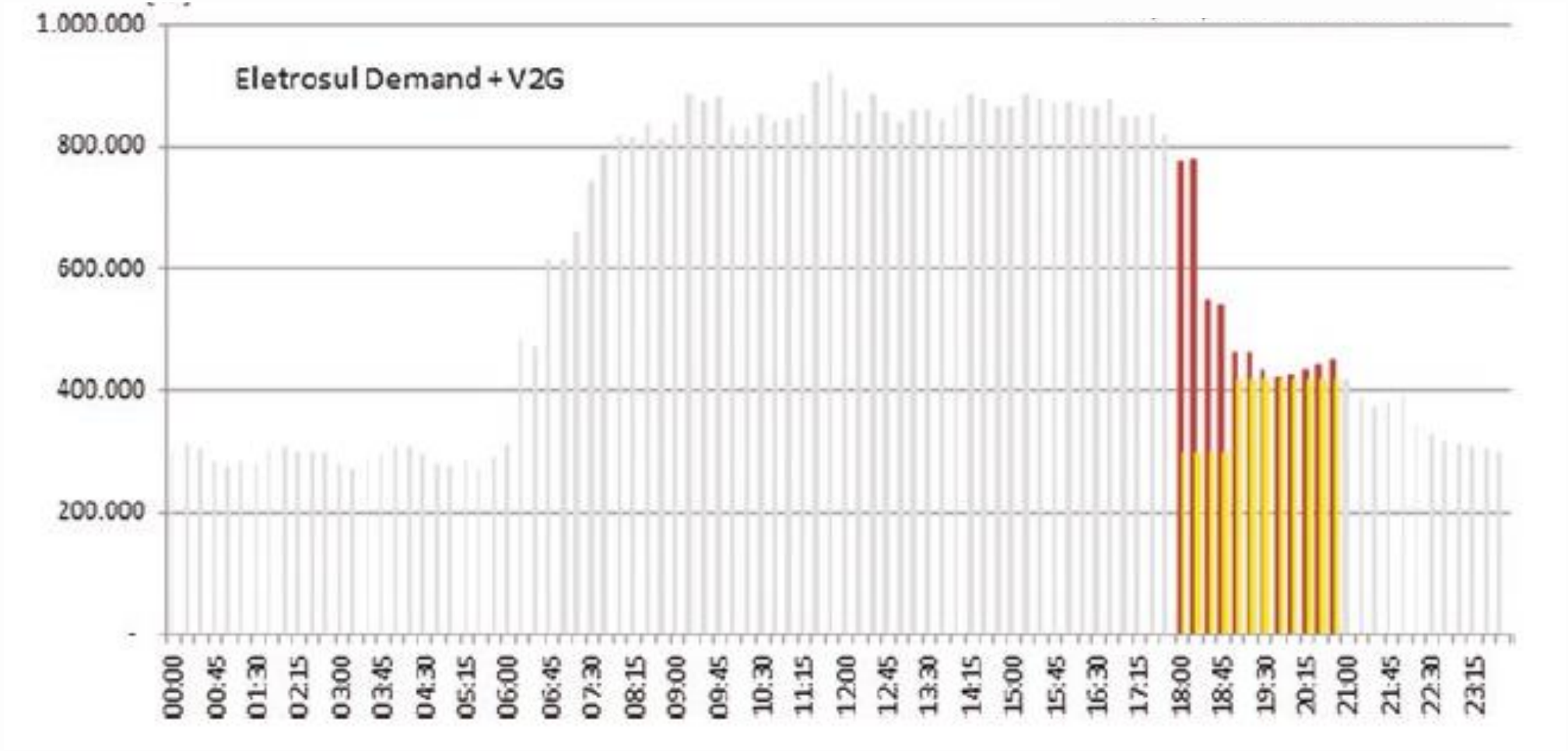
T5.1 DSM – implementations #4a



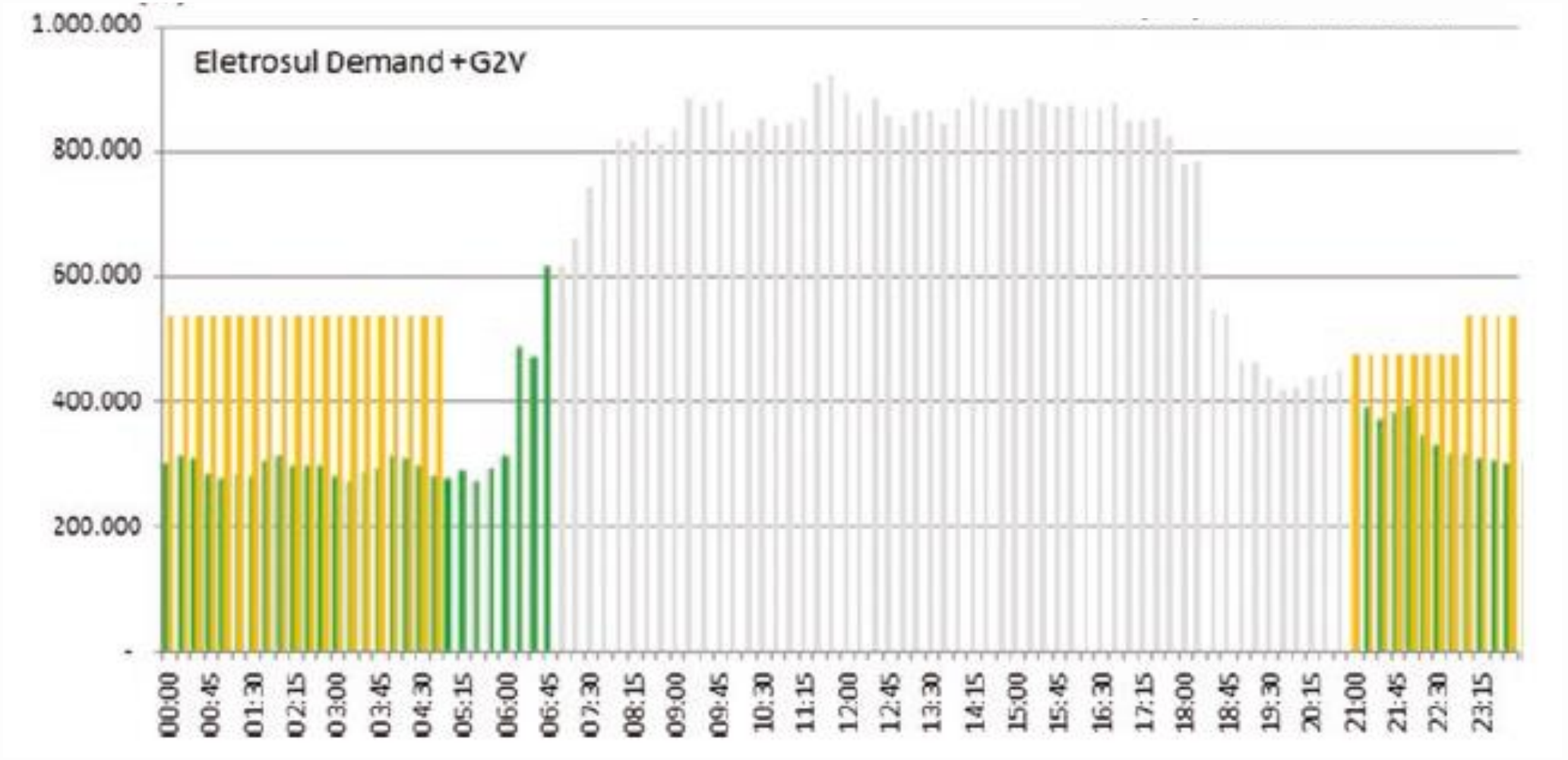
T5.1 DSM – implementations #4a



T5.1 DSM – implementations #4a

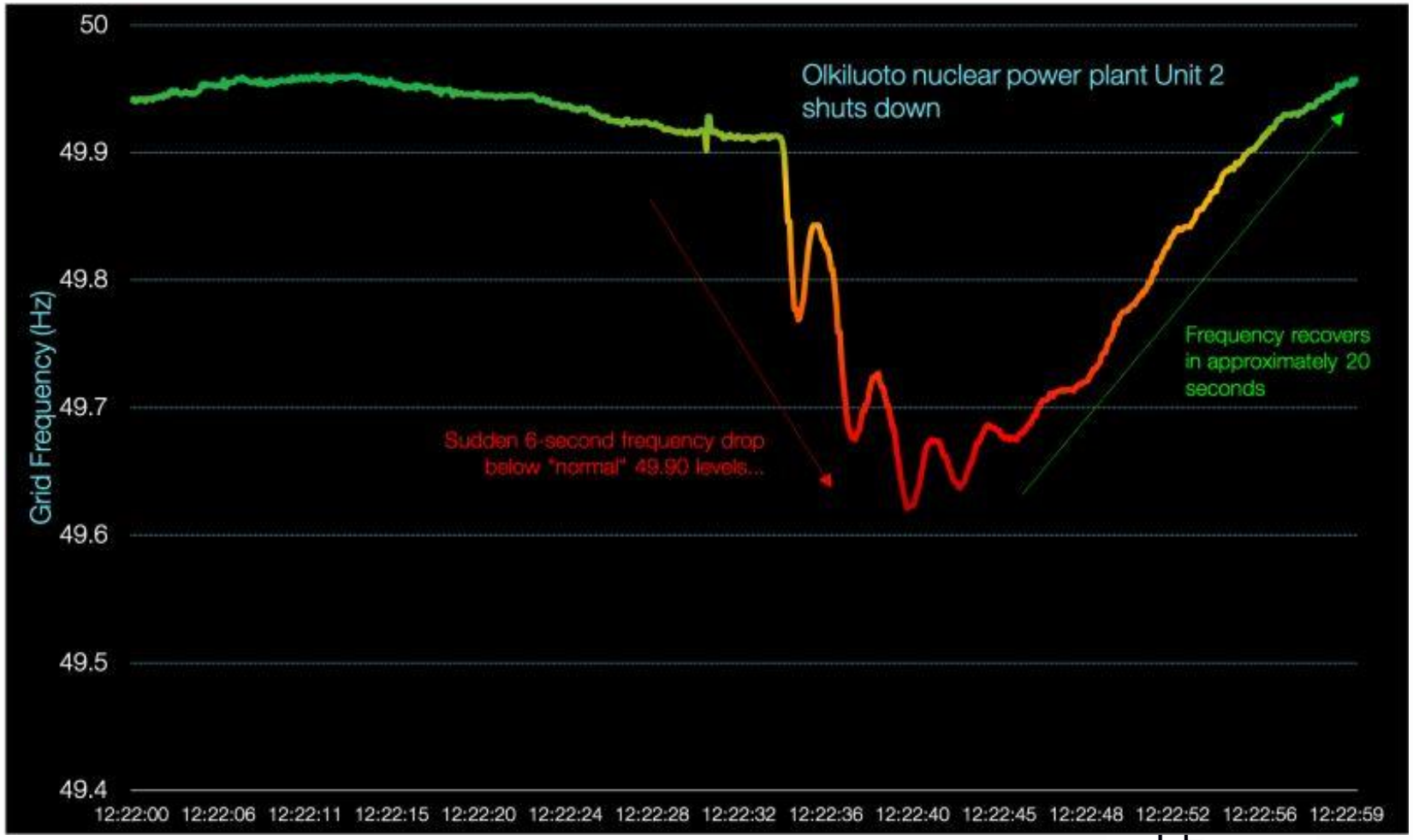


T5.1 DSM – implementations #4a

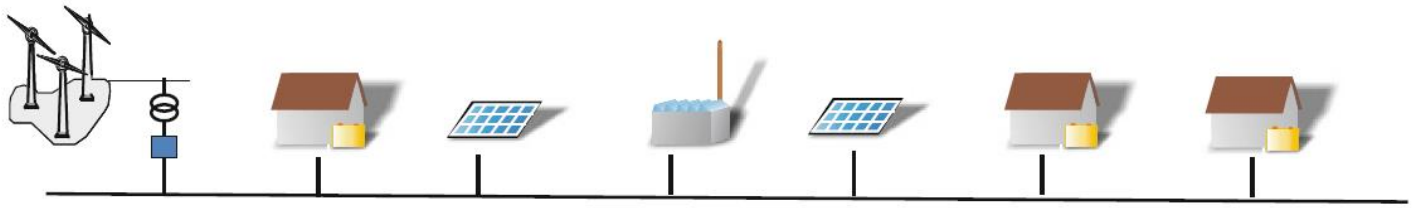


T5.1 DSM – Impact

- 12-12-20 – 12:22 the nuclear power plant at Olkiluoto, Finland disconnects, due to serious disturbance
- Frequency drop within 6 sec
- restore in 20 sec.
- Some end-users have been called to participate in DR



T5.1 3 pillars of Smart Distribution



Distribution Automation	Smart Aggregation	Smart Metering
		
Information content for communication		
Metered values ¼ h, Measurements I, V, P, Q, Switch status/ command, Short circuit indications & reset command, alarms, Tap changer position/ command, Voltage control settings, Remote/ local control status	Metered values ¼ h, Measurements I, V, P, Q ,Pth, Ets, ϑ, Target values P, Q, Schedules (P, Q ¼ h), Switch commands, Plant Status	<u>Consumer integration:</u> Metered values ¼ - 1h, Tariff signals, forecasts day- ahead, intraday, Current demand/ costs, savings, <u>Vehicle management</u> Driver information/ order, SOC, charging schedule

I- current, V- Voltage, P – Real Power, Q – Reactive Power, Pth- thermal power,
E –Energy, ts–thermal storage, ϑ –Temperature heating water, SOC – State of charge

Thank you

Questions?

Project Partners

ktu kaunas university of technology 1922

CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

POLITECNICO MILANO 1863

Contecht

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Funded by the European Union

This project has received funding from the European Union's Horizon research and innovation programme under grant agreement No 101078997

SmartWins