Energy Storage

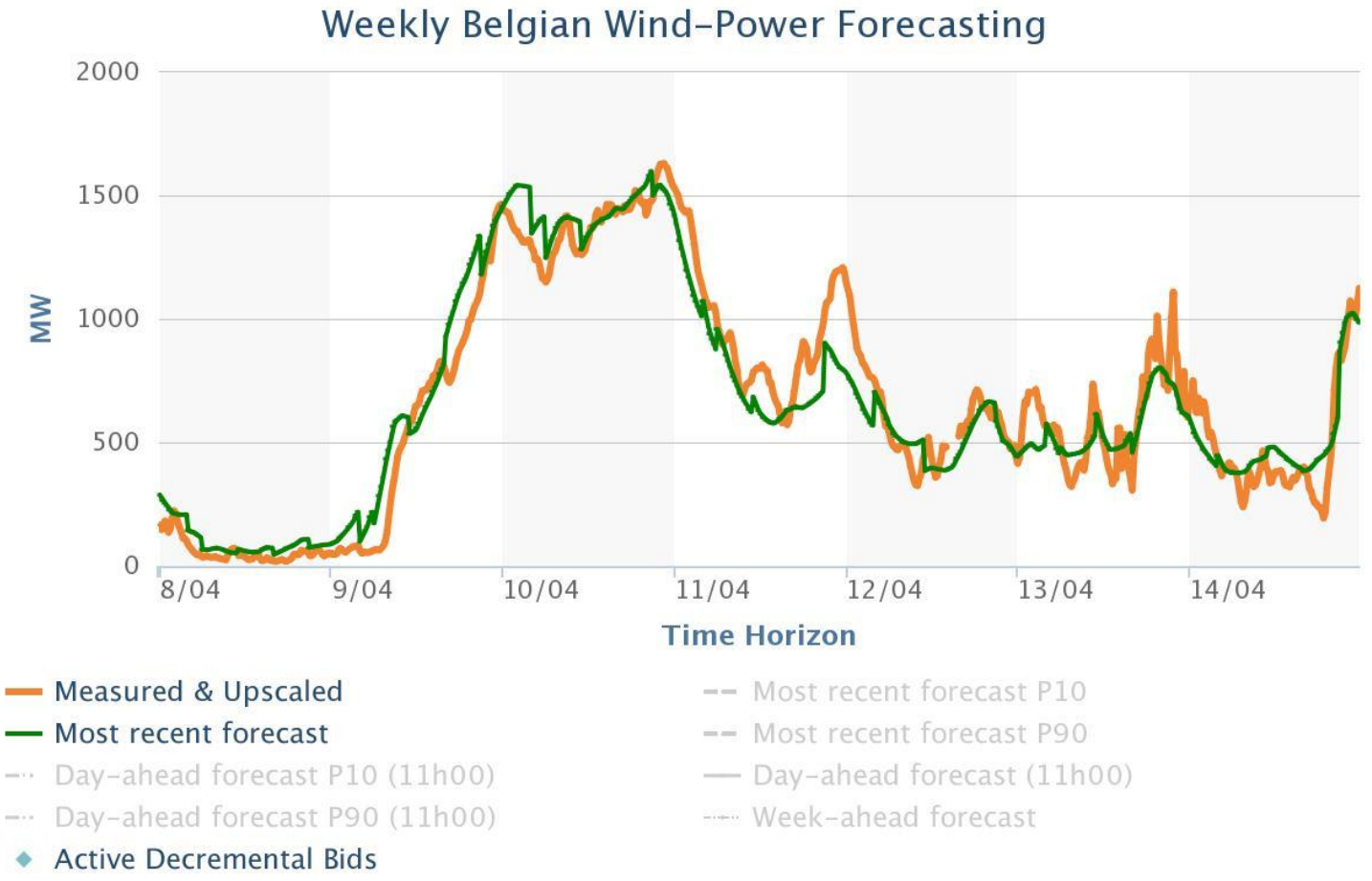
Demand Response

Assoc. Prof. Hrvoje Pandžić
Marija Miletić, mag. ing.

Contents

- Introduction
- Definitions
  - Types
- Participants
  - Enablers
  - Users
  - Providers
- Real world examples

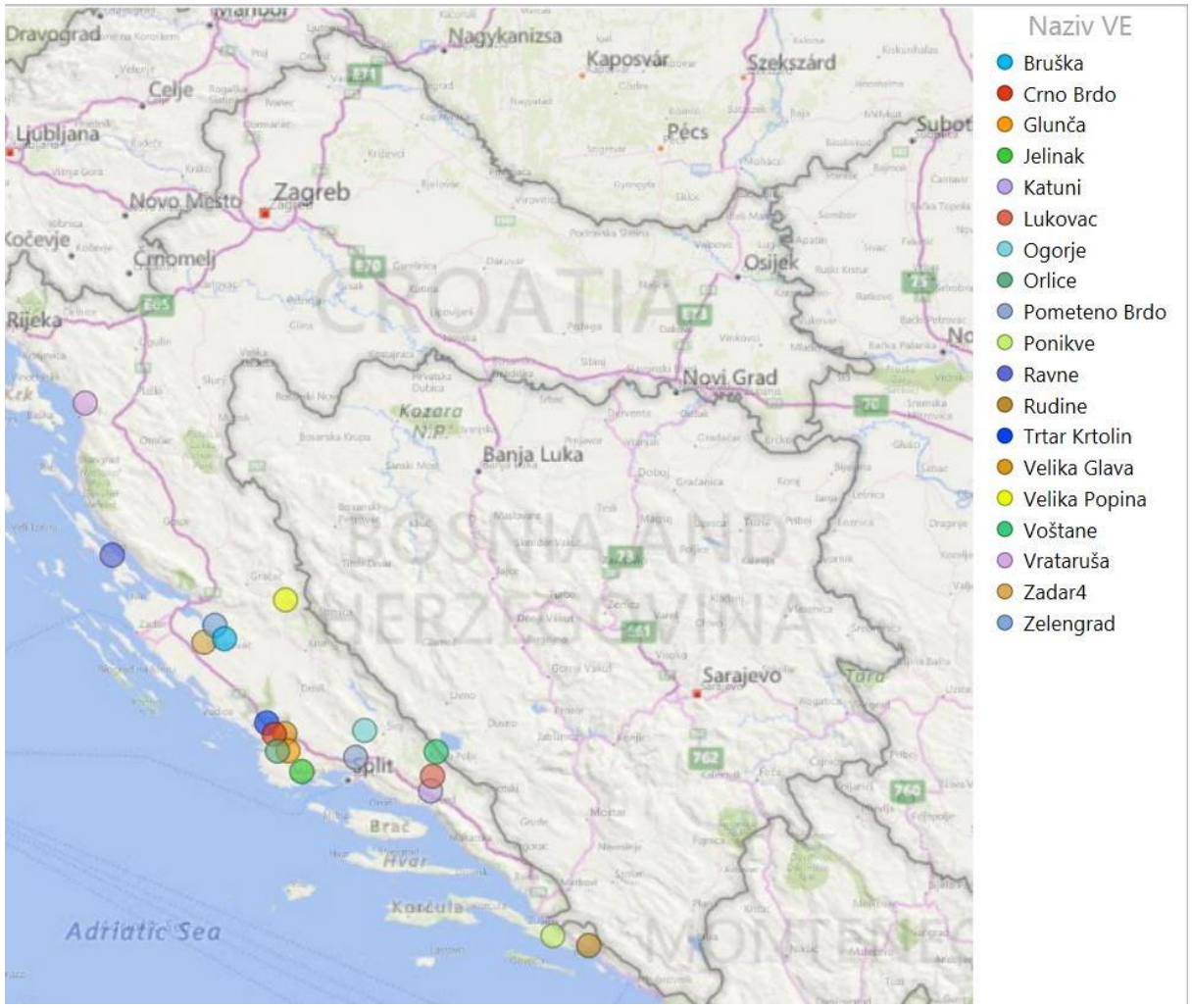
Variable Wind Production



www.elia.be/en/grid-data/power-generation/wind-power

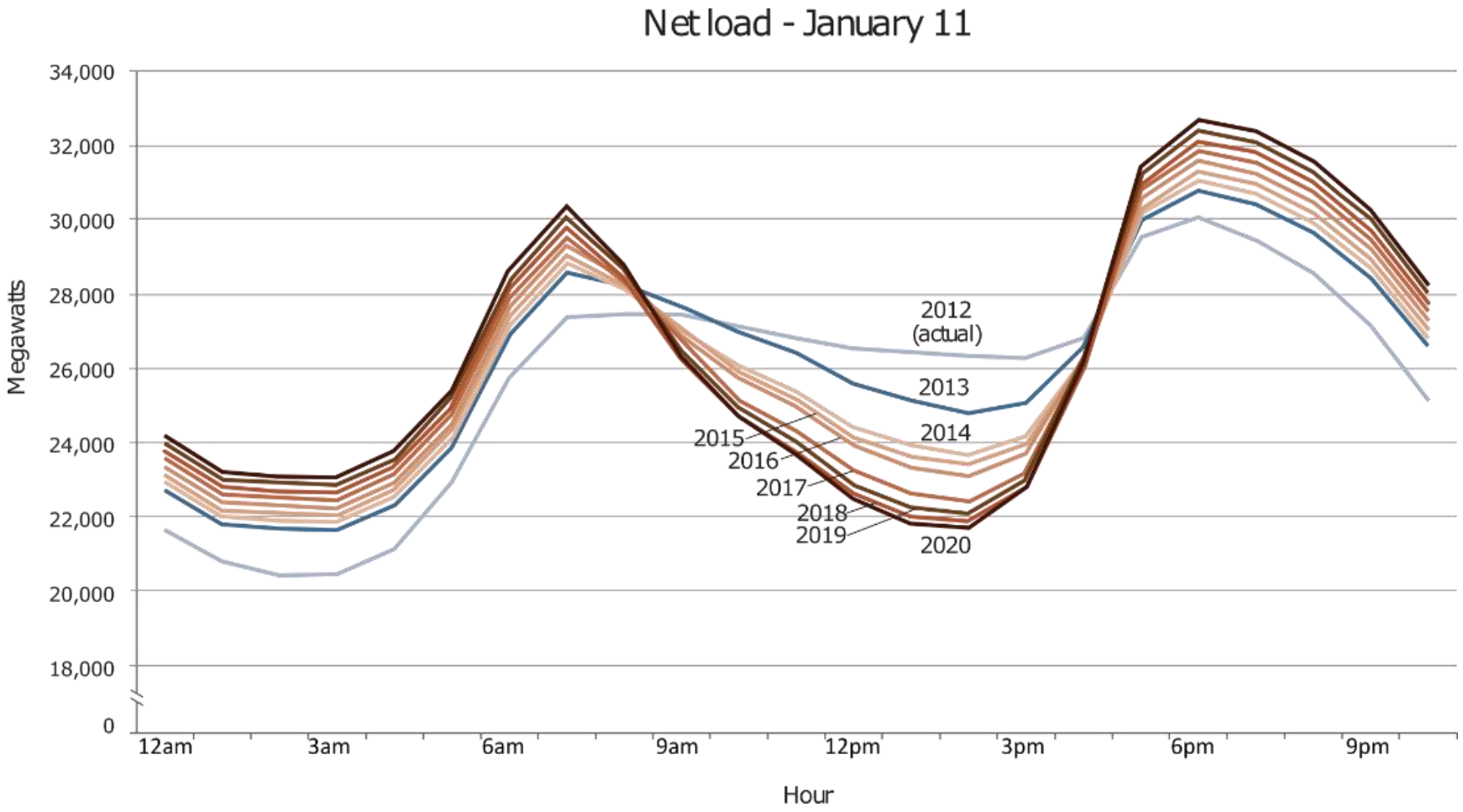
Wind Farms in Croatia

- 16 out of 19 wind farms, whose installed capacity is 75% of the overall wind farm capacity in Croatia, is located in a square 110 x 70 km^2



Source: CIGRE Roundtable: T. Plavšić, HOPS

Duck Curve



https://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf

Demand side management

„Power providers have two main choices to respond to the disruption caused by the mass adoption of solar-generated electricity. One option is to adapt to a more curvaceous duck, by investing in fast-ramping power plants to help the grid withstand sharp variations in its load. The other is to **put the duck on a diet**, by adjusting electricity pricing with hourly rates to encourage customers to shift their power usage from high-demand to low-demand times, smoothing out unwanted fluctuations.”

The Economist

https://www.economist.com/graphic-detail/2018/03/28/what-a-ten-year-old-duck-can-teach-us-about-electricity-demand?fsrc=scn/tw/te/bl/ed/whatatenyearoldduckcanteachusaboutelectricitydemanddailychart

Clean energy for all Europeans

Consumers will be able to **participate actively, individually or through communities**, in all markets, either by generating electricity and then consuming, sharing or selling it, or by providing storage services.

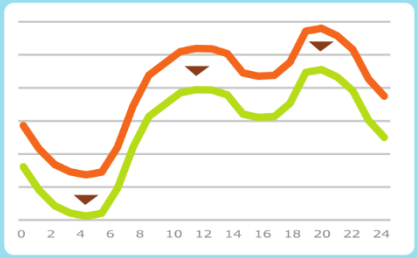
For the first time, consumers will have the right to request a smart meter and a dynamic price contract that allows them **to be rewarded for shifting consumption to times when energy is widely available and cheap**.

European Commission

https://ec.europa.eu/energy/sites/ener/files/documents/electricity_market_factsheet.pdf

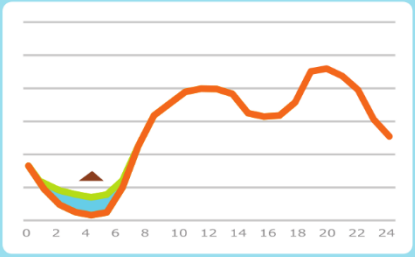
Measures

1 Reduction in consumption



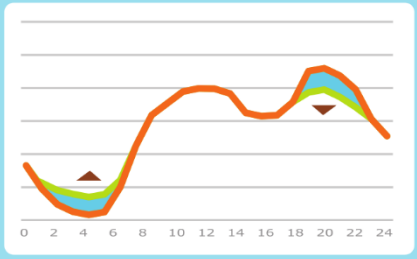
- Improving efficiency of equipment and processes
- Energy saving awareness

3 Filling valleys



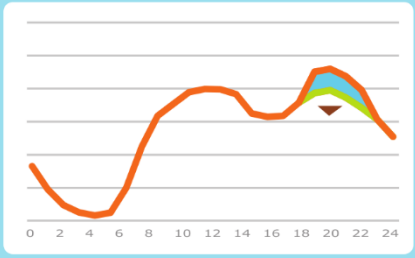
- Pumped storage stations
- Energy storage technologies
- Charging of electric vehicles

2 Shifting consumption from peak hours to valley hours



- Time-of-use tariffs
- Response to electricity market prices

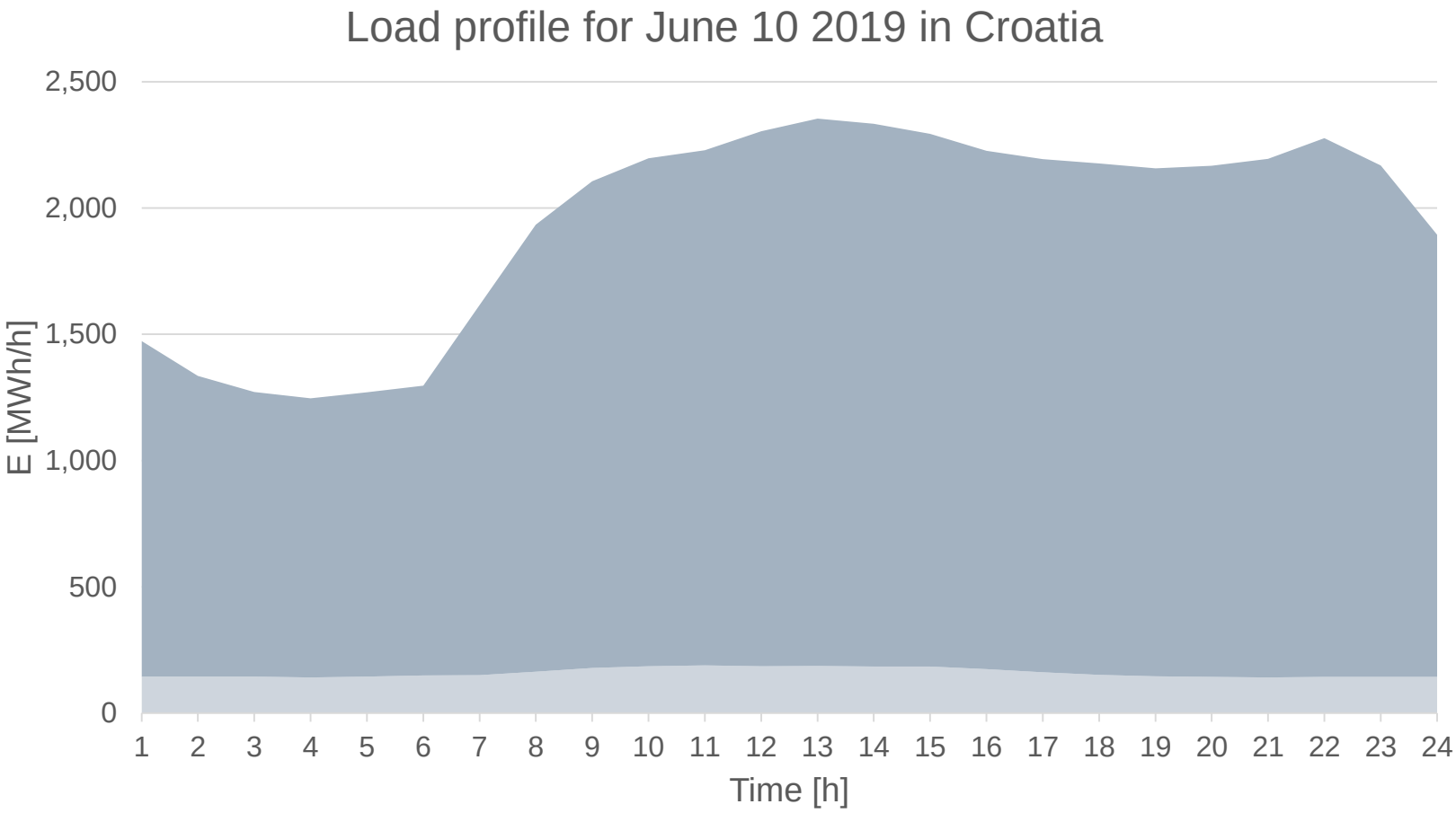
4 Reduction in consumption during peak hours of the system



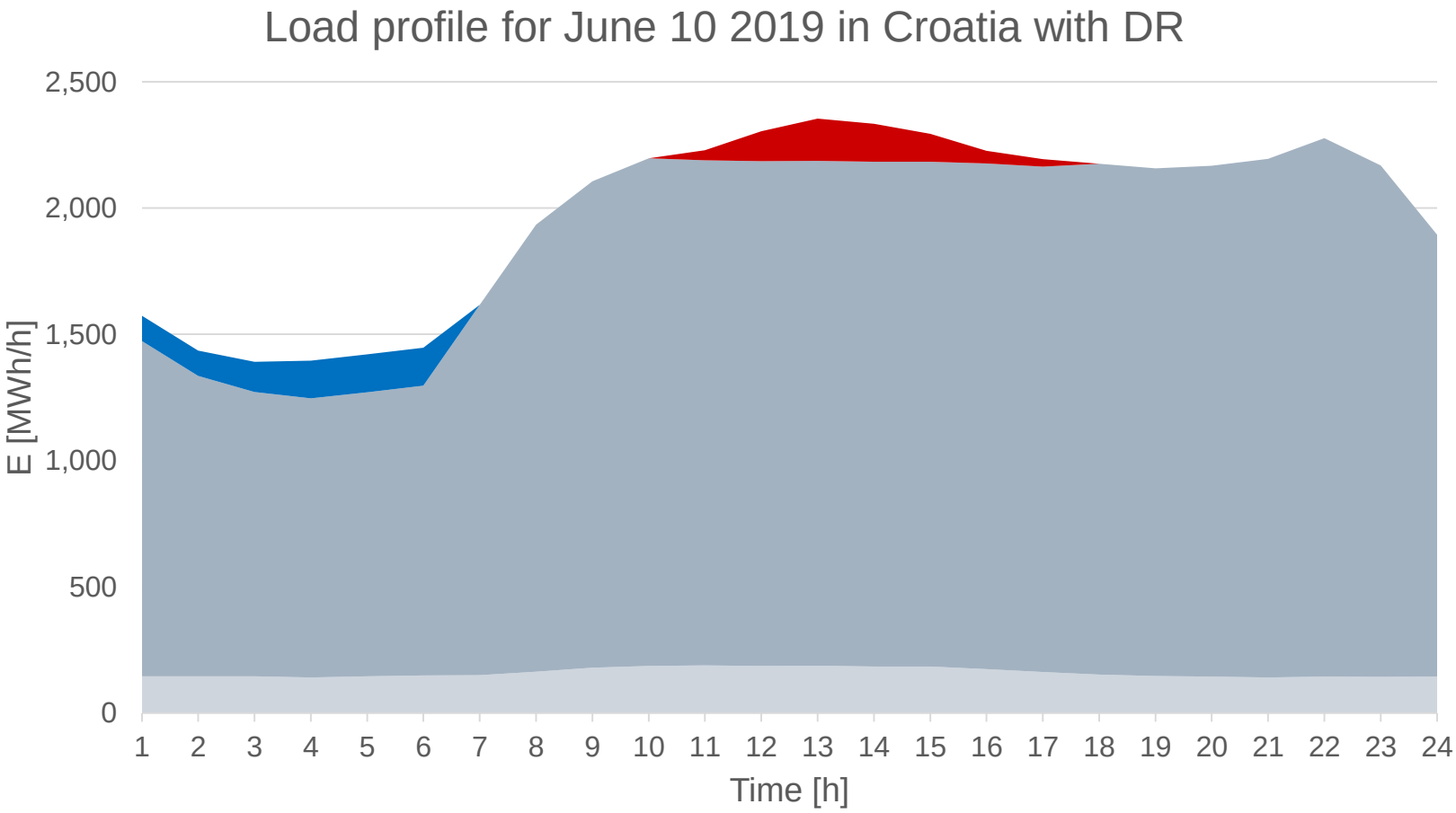
- Interuptibility service
- Automatic load management

https://www.ree.es/sites/default/files/go15_web.pdf

Example #1


Load profile for June 10 2019 in Croatia
2,500
2,000
1,500
1,000
500
0
E [MWh/h]
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time [h]

Example #1


Load profile for June 10 2019 in Croatia with DR
E [MWh/h]
2,500
2,000
1,500
1,000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time [h]

Flexibility providers

Technology	Congestion	Electricity production	Reserve provision	Positive impact on emissions
FACTS devices	+	-	-	-/+
Gas power plants	-	+	+	-
Grid reconfiguration	+	-	-	-/+
Energy storage	+	-/+	+	-/+
Demand response				

Flexibility providers

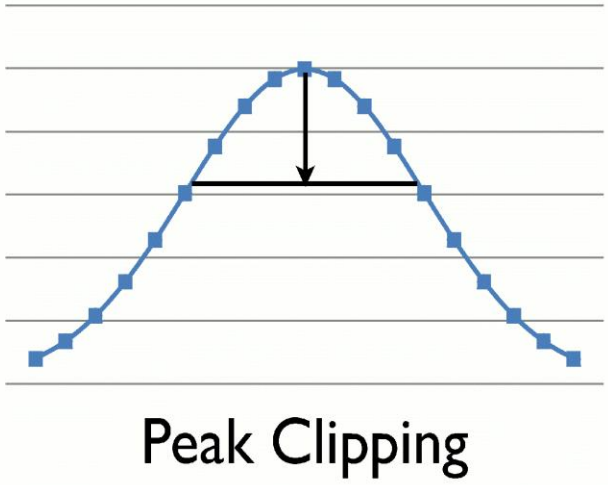
Technology	Congestion	Electricity production	Reserve provision	Positive impact on emissions
FACTS devices	+	-	-	-/+
Gas power plants	-	+	+	-
Grid reconfiguration	+	-	-	-/+
Energy storage	+	-/+	+	-/+
Demand response	+	-/+	+	-/+

Demand Response

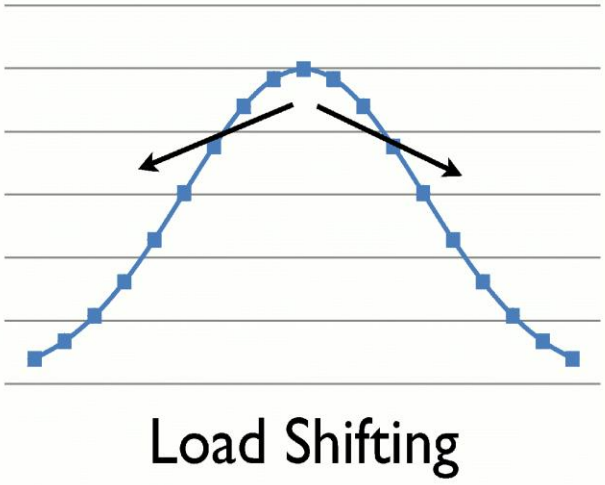
DEFINITIONS

Demand Response

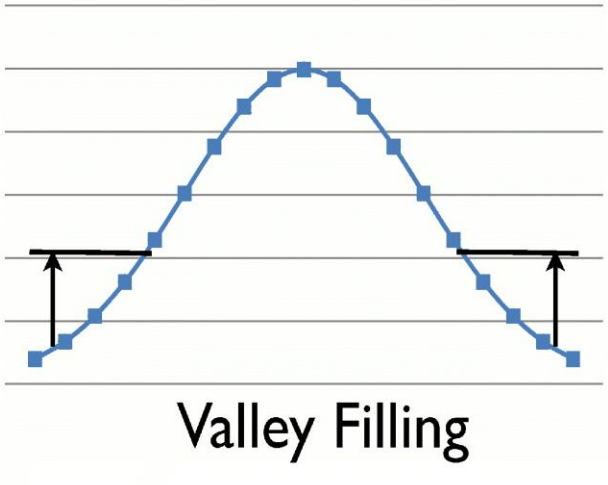
- Changes in the electricity consumption caused by changing prices of electricity or by incentives payed to the consumers.



Peak Clipping

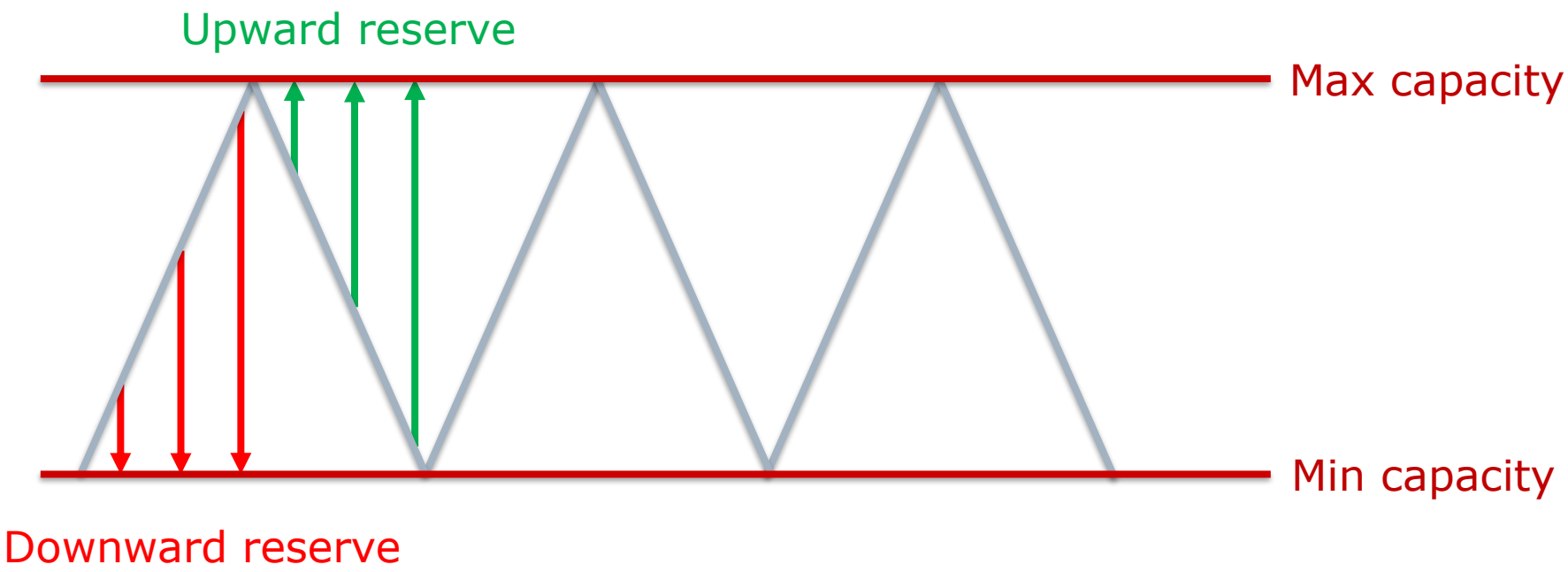


Load Shifting



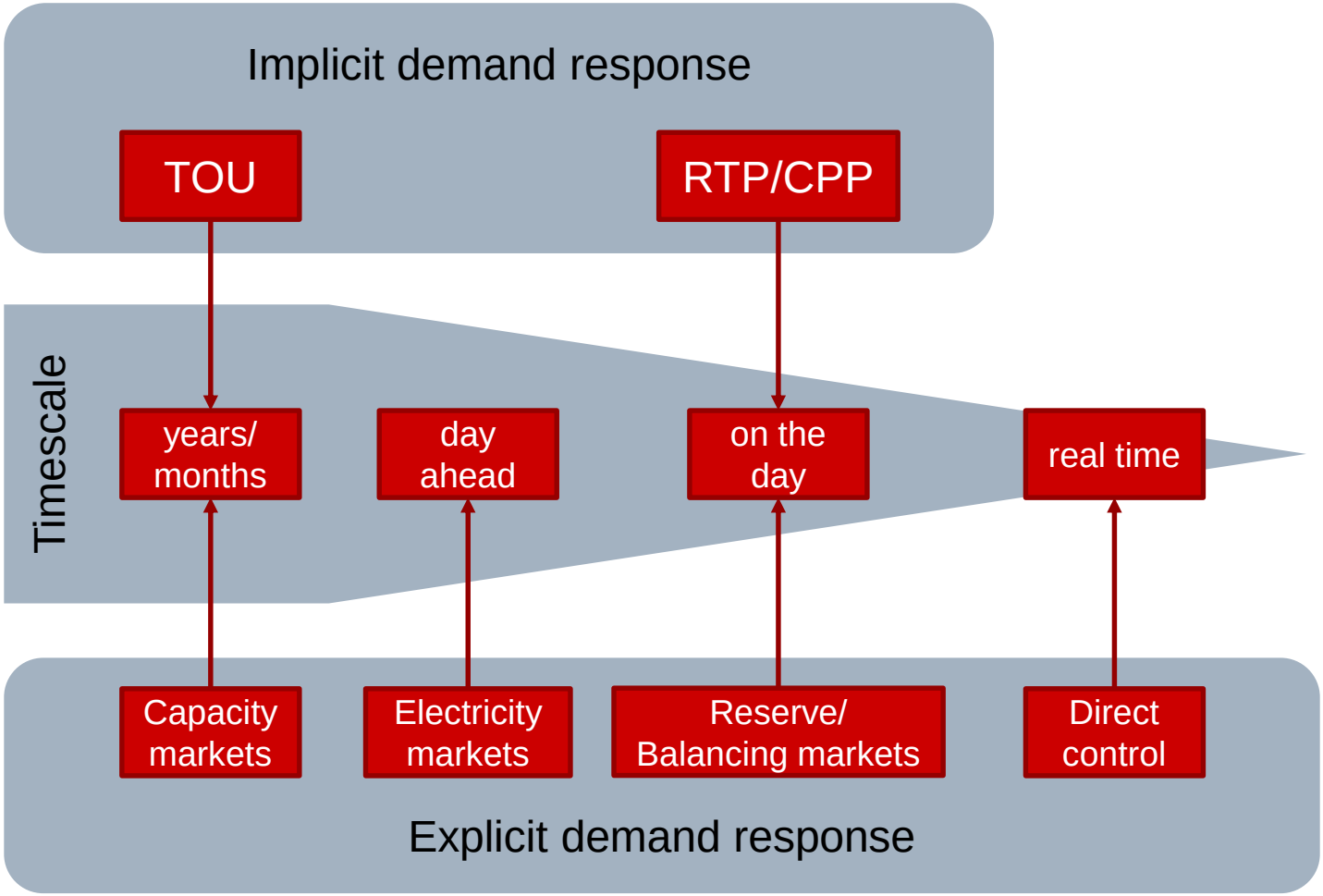
Valley Filling

Principle of Demand Response



Length of arrows correspond to the reserve duration ability

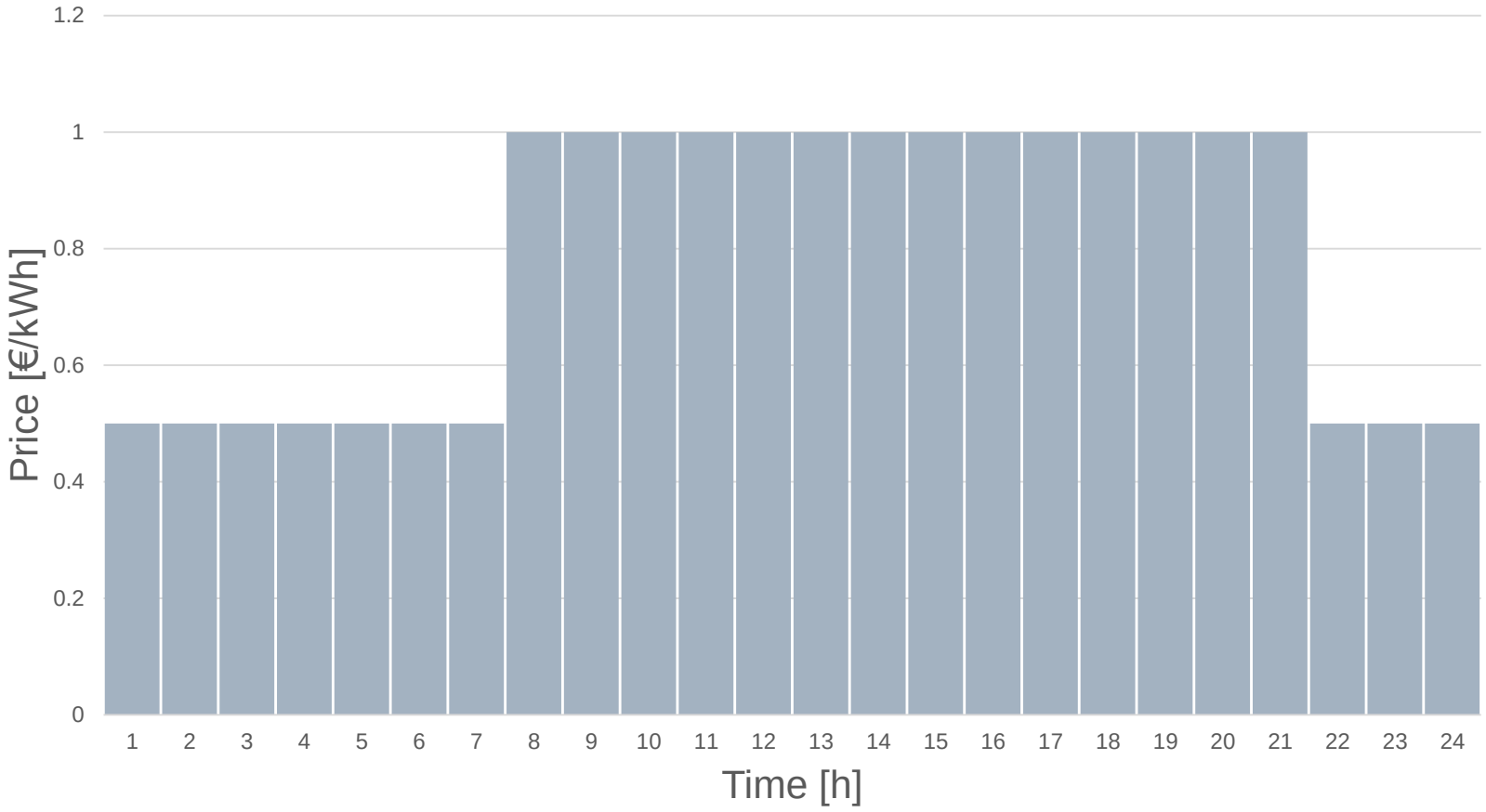
Demand Response



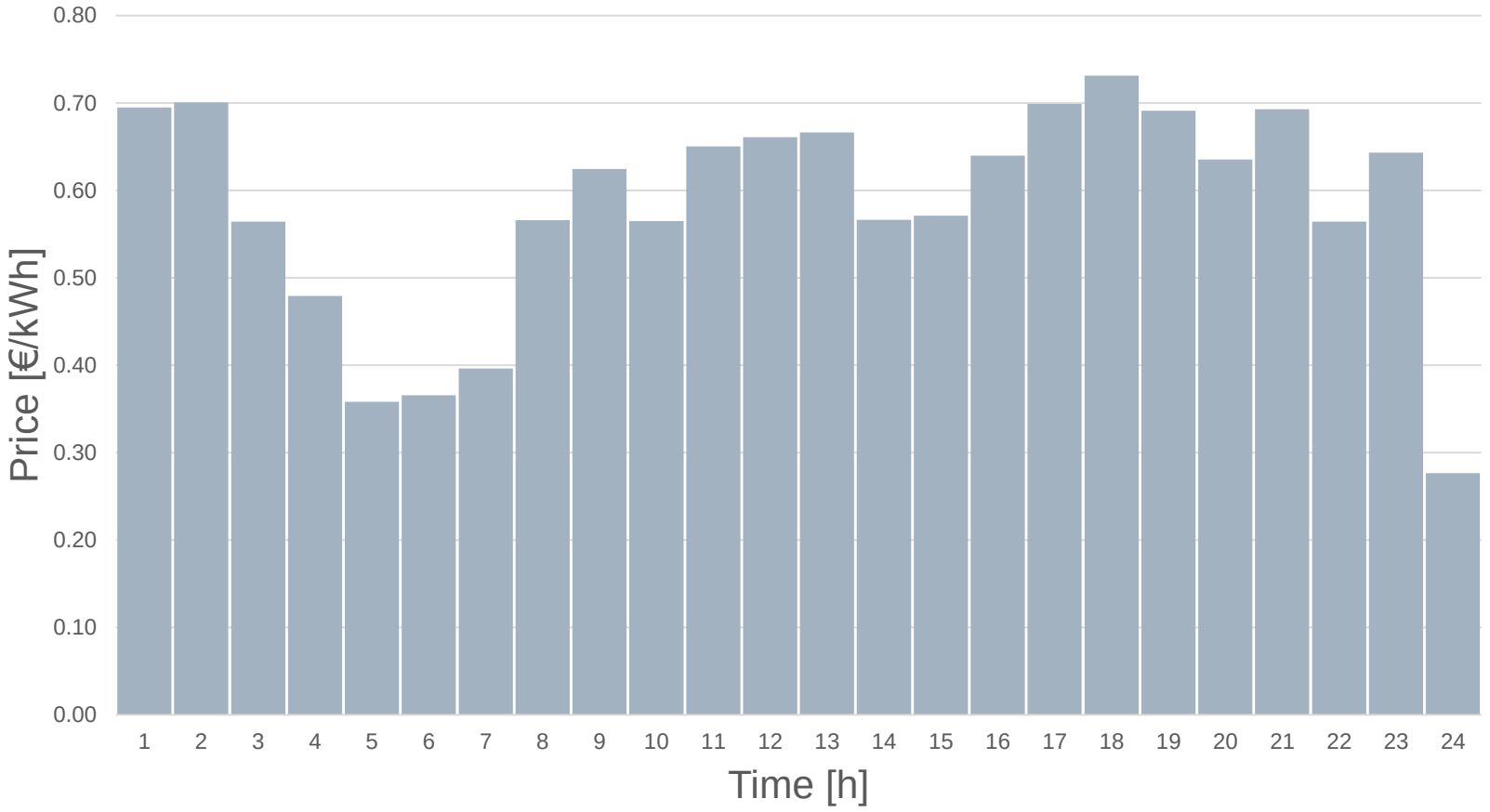
Implicit Demand Response

- Supplier **sets the prices** with the idea that the rational consumers will lower their electricity consumption when the price is higher, and increase it when the price is lower
- Consumers schedule their consumption accordingly

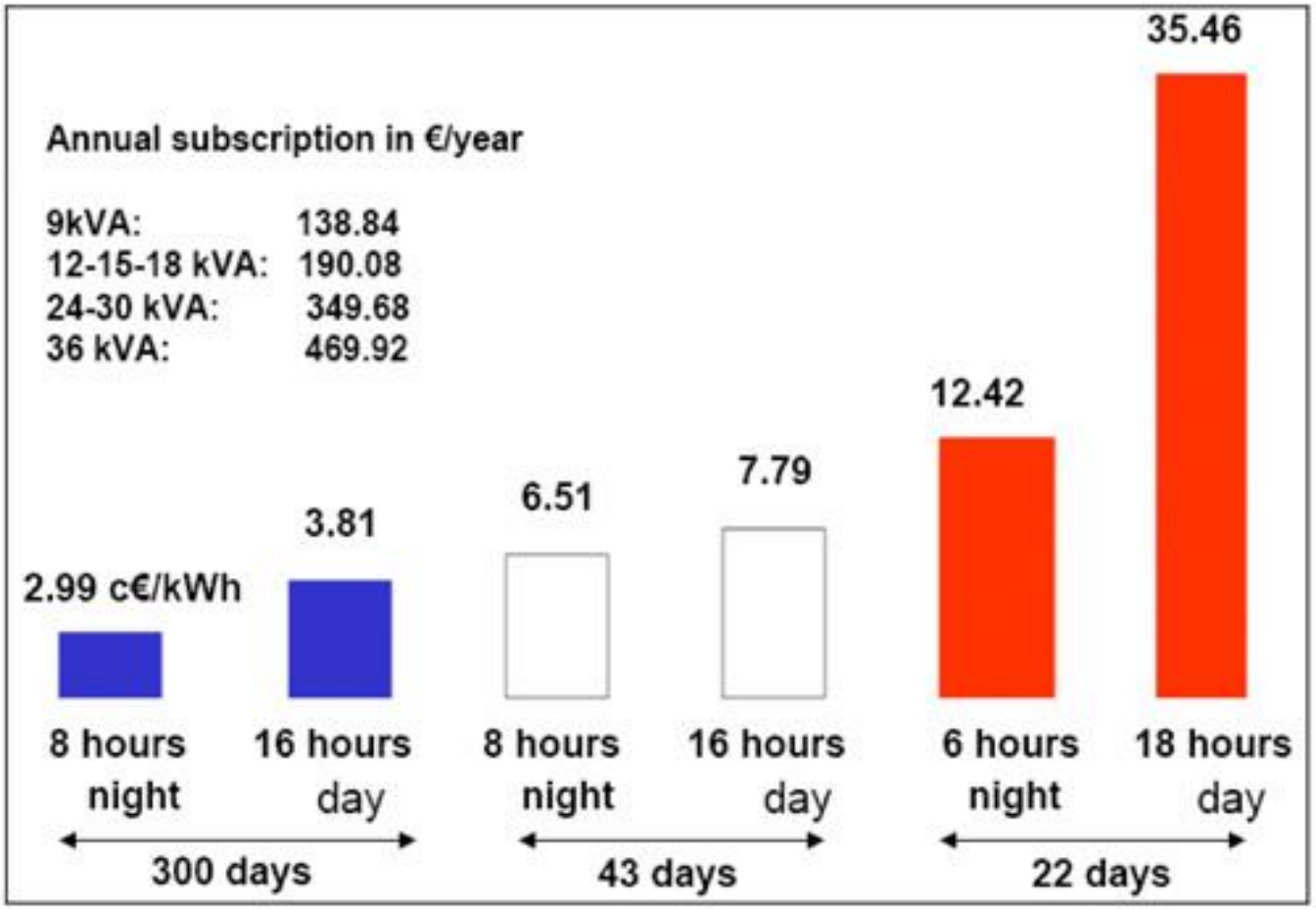
Time-Of-Use (TOU)



Real Time Pricing (RTP)



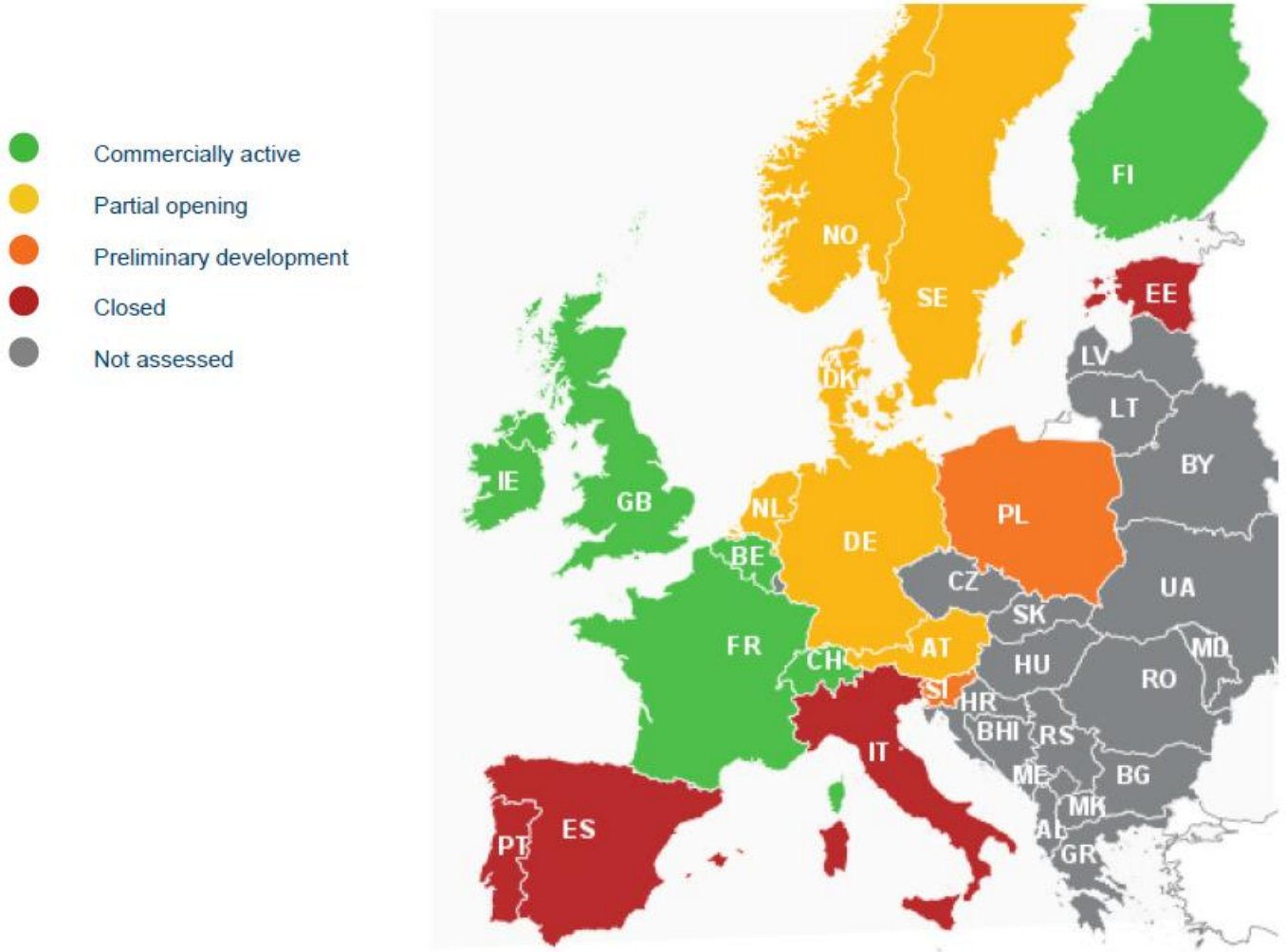
Critical Peak Pricing (CPP)



Explicit Demand Response

- An Aggregator or a System Operator has **direct control** over the consumers' appliances
- The on/off time of the appliances is scheduled in advance, sometimes without noticing the consumers, but taking into account their needs
- The consumers participating in this type of demand response are payed incentives or their electricity bill is discounted

Explicit Demand Response



https://www.smarten.eu/wp-content/uploads/2017/04/SEDC-Explicit-Demand-Response-in-Europe-Mapping-the-Markets-2017.pdf

Demand Response

PARTICIPANTS

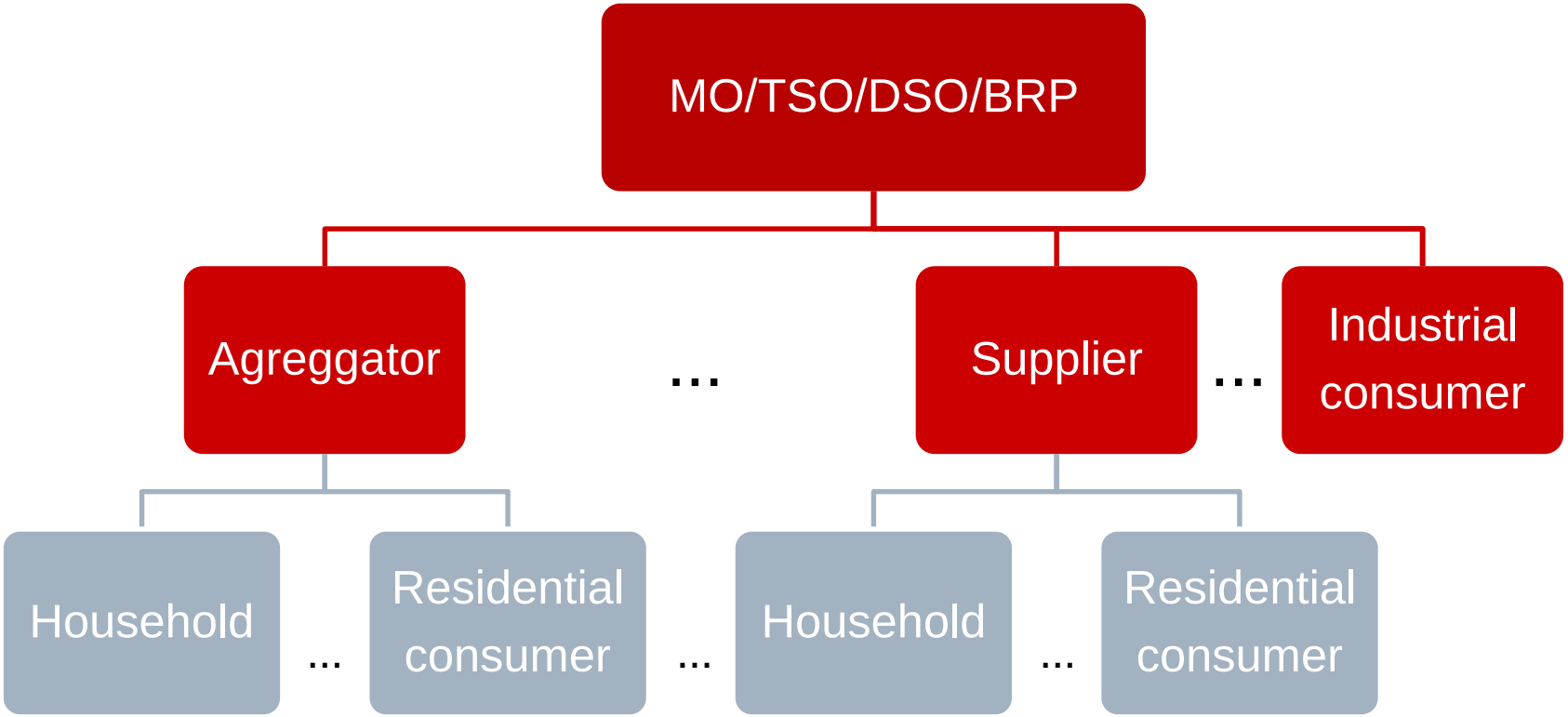
Why would anyone participate?

- Financial profit
- Benefits for the environment
- Ensuring the grid stability

Participants

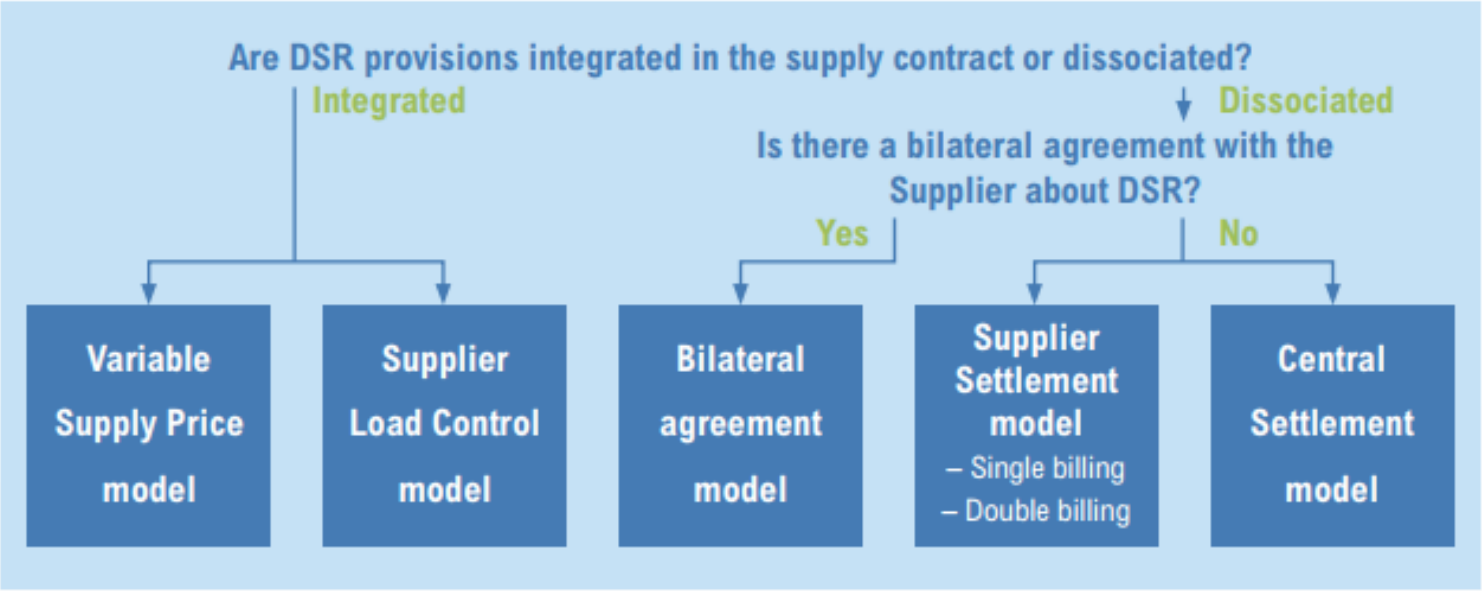
- Users: those who benefit from DR programmes
- Enablers: those who mediate between DR service users and providers
- Providers: those who have controllable devices and can change their load

Roles


MO/TSO/DSO/BRP
Agreggator
...
Supplier
...
Industrial consumer
Household
...
Residential consumer
...
Household
...
Residential consumer

Demand Response Enablers

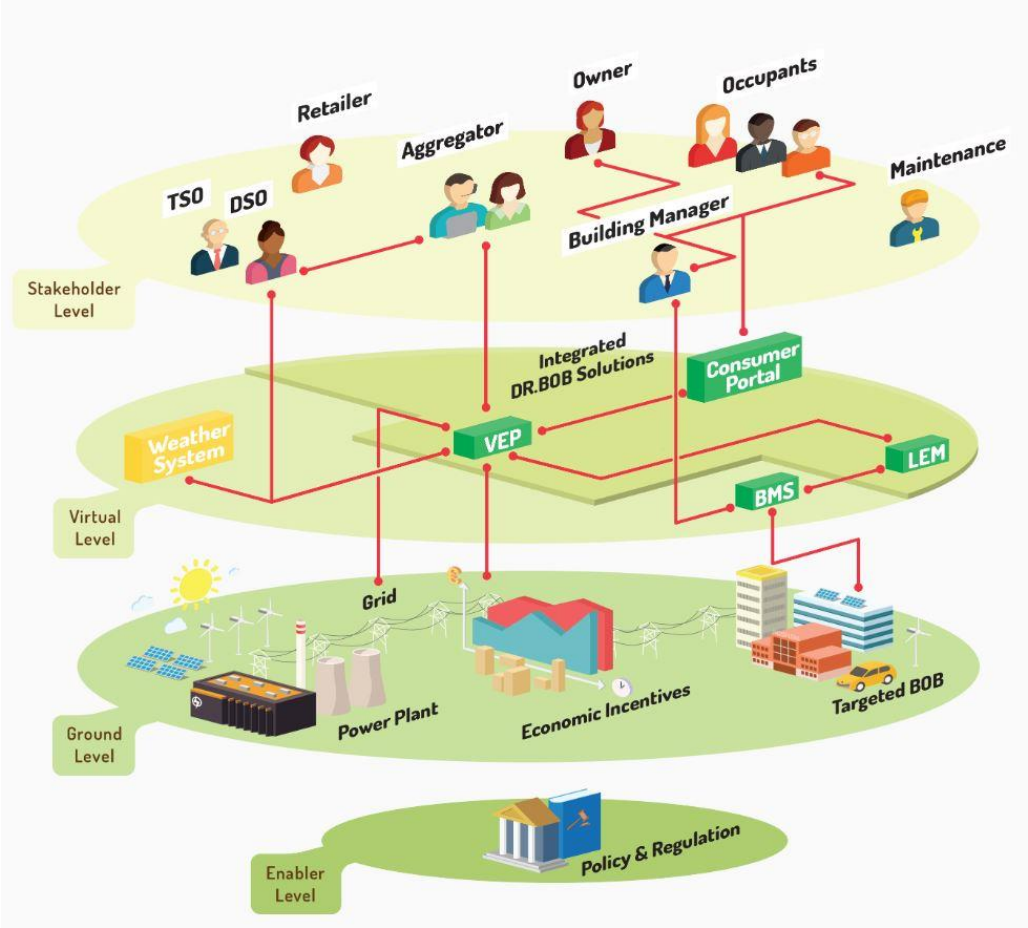
- Supplier
- Aggregator
- System Operator (Distribution or Transmission)



Aggregator

- ‘aggregator’ means a demand service provider that combines multiple short-duration consumer loads for sale or auction in organised energy markets

Directive 2012/27/EU



http://www.buildup.eu/en/explore/links/dr-bob-demand-response-block-buildings-project

Demand Response

USERS

Demand Response Users

- Depending on the DR programme applications, users are:
  - The power system
  - The grid
  - The end-users

System applications

- Independent of the providers' location in the grid:
  - Arbitrage
  - Adequacy
  - System or balance group balancing
  - Footroom
  - Flexiramp
  - Virtual inertia

Grid applications

- Depending on the providers' location in the grid, they can offer services to the network operator:
  - Congestion management
  - Postponing the investments
  - Voltage and reactive power management
  - Loss management

End user applications

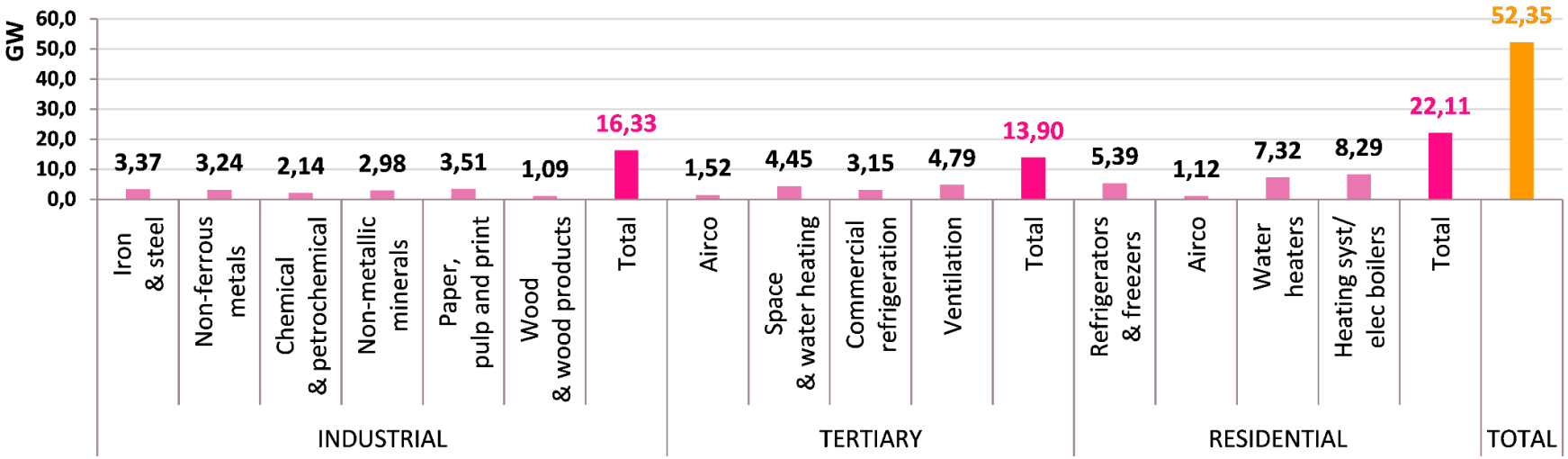
- Using own resources to reduce the operating costs or to improve working conditions:
  - Peak power clipping (for new or existing users)
  - Retail arbitrage (price-based or network tariff based)
  - Load following for the RES

Demand Response

PROVIDERS

Who can provide?

- Residential consumers (households)
- Commercial consumers
- Industrial consumers

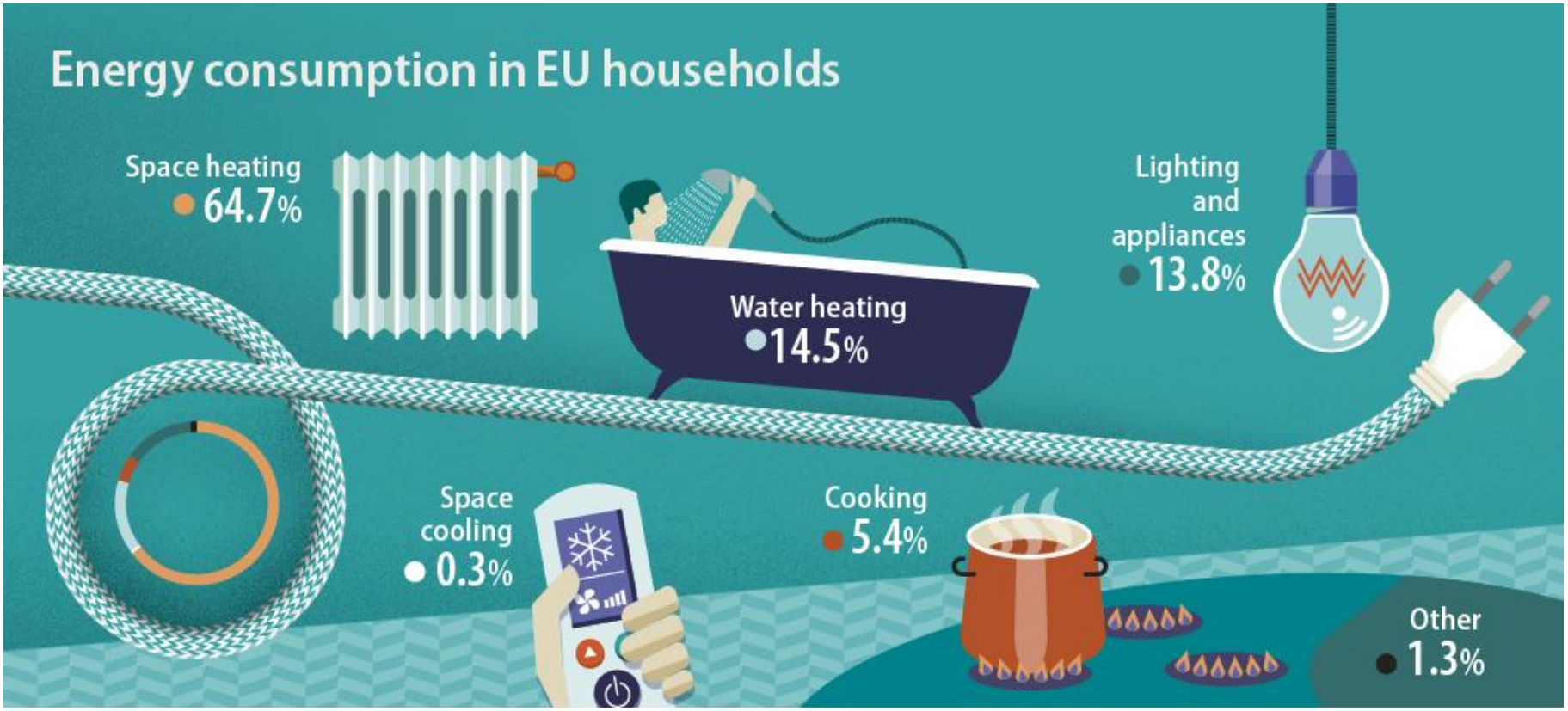


http://energy.sia-partners.com/demand-response-study-its-potential-europe

Processes with DR Potential

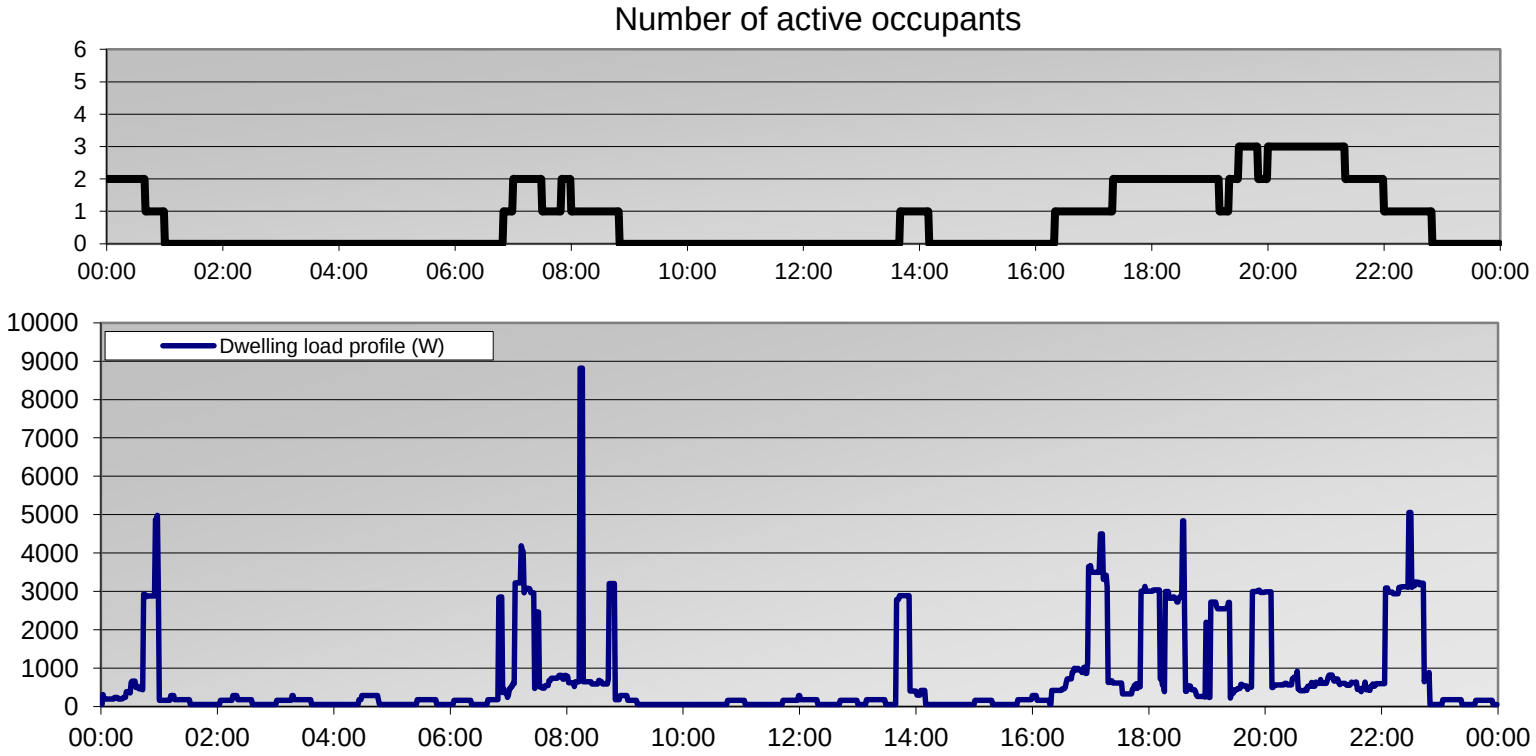
- Systems and structures with possibility of thermal storage
- Behind the meter battery storage systems
- Industry with the possibility of storing intermediate goods
- All other devices if the user is willing to shut them on or off when asked to

Energy consumption in households



Active occupancy

- Presence of people that are actively using the appliances in the building



https://dspace.lboro.ac.uk/dspace-jspui/handle/2134/3112

Household Appliances

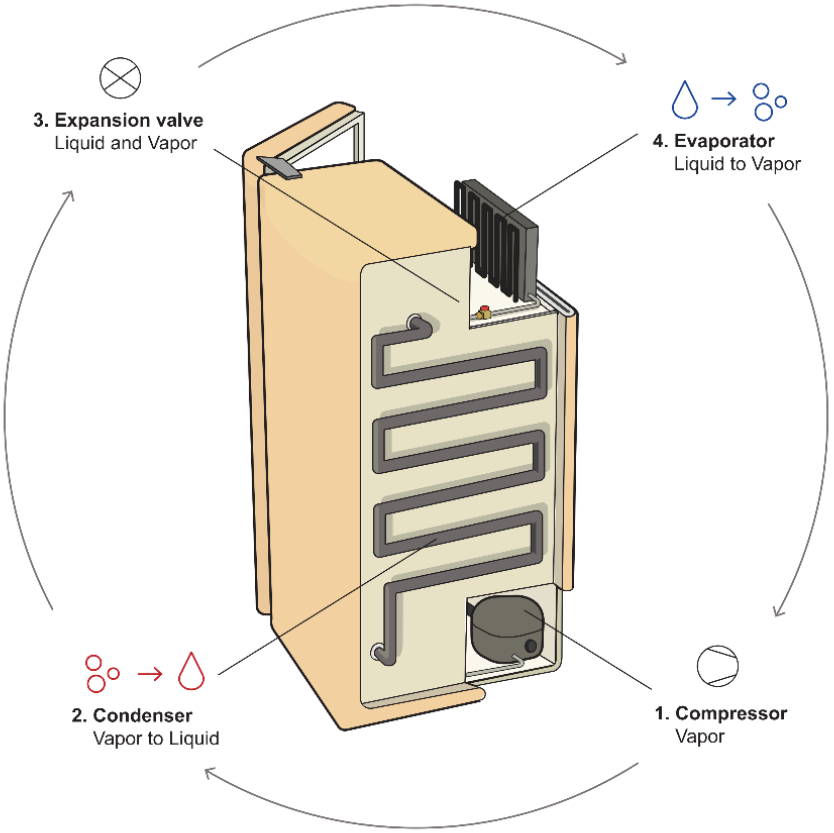
- Refrigerators and freezers
- Water heaters
- Space heaters
- Air conditioning devices

} Thermal storage

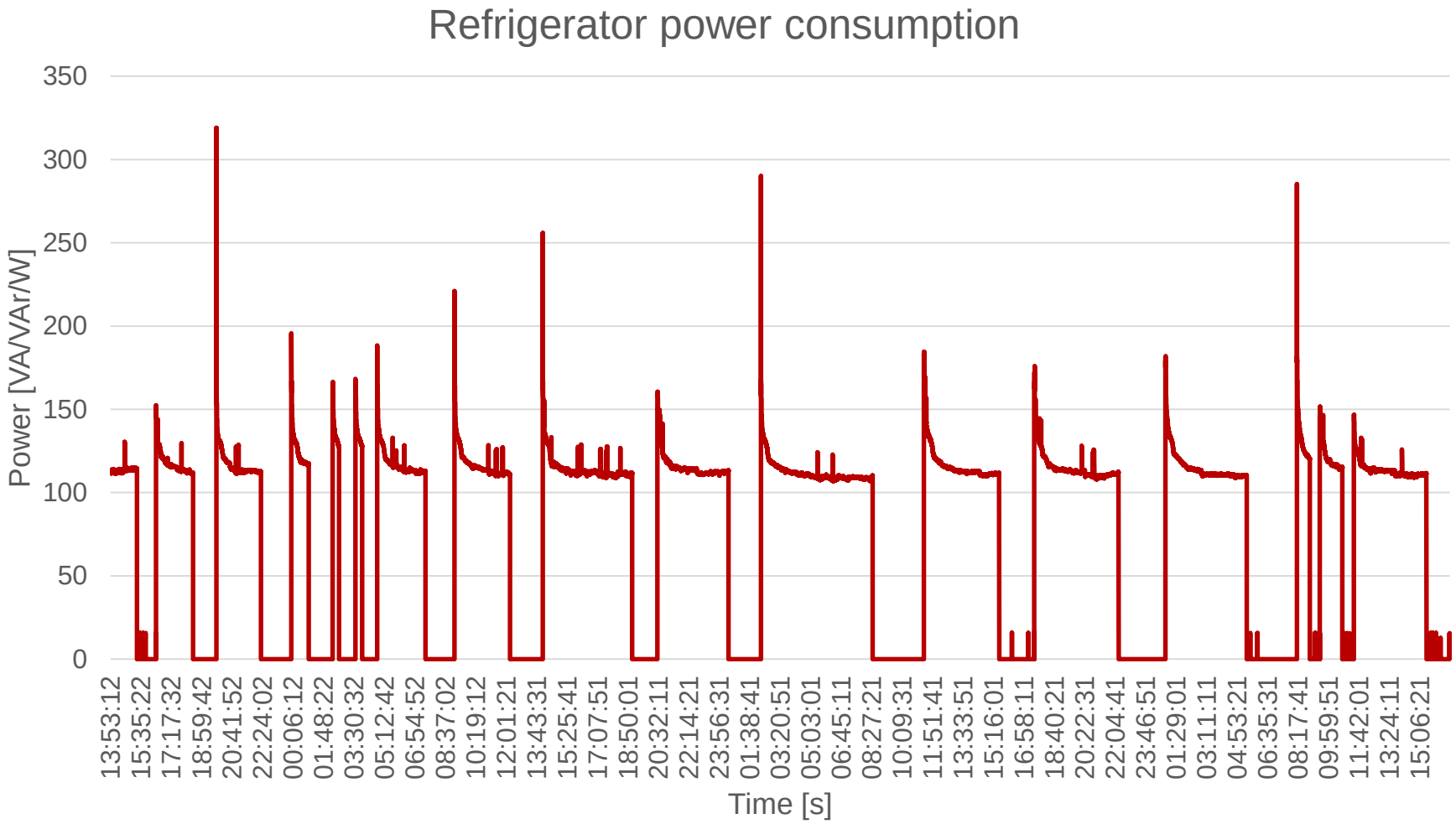
- Washing machines and clothes dryers
- Dishwashers
- Battery storage
- Electric vehicles = portable battery storage

Thermal storage

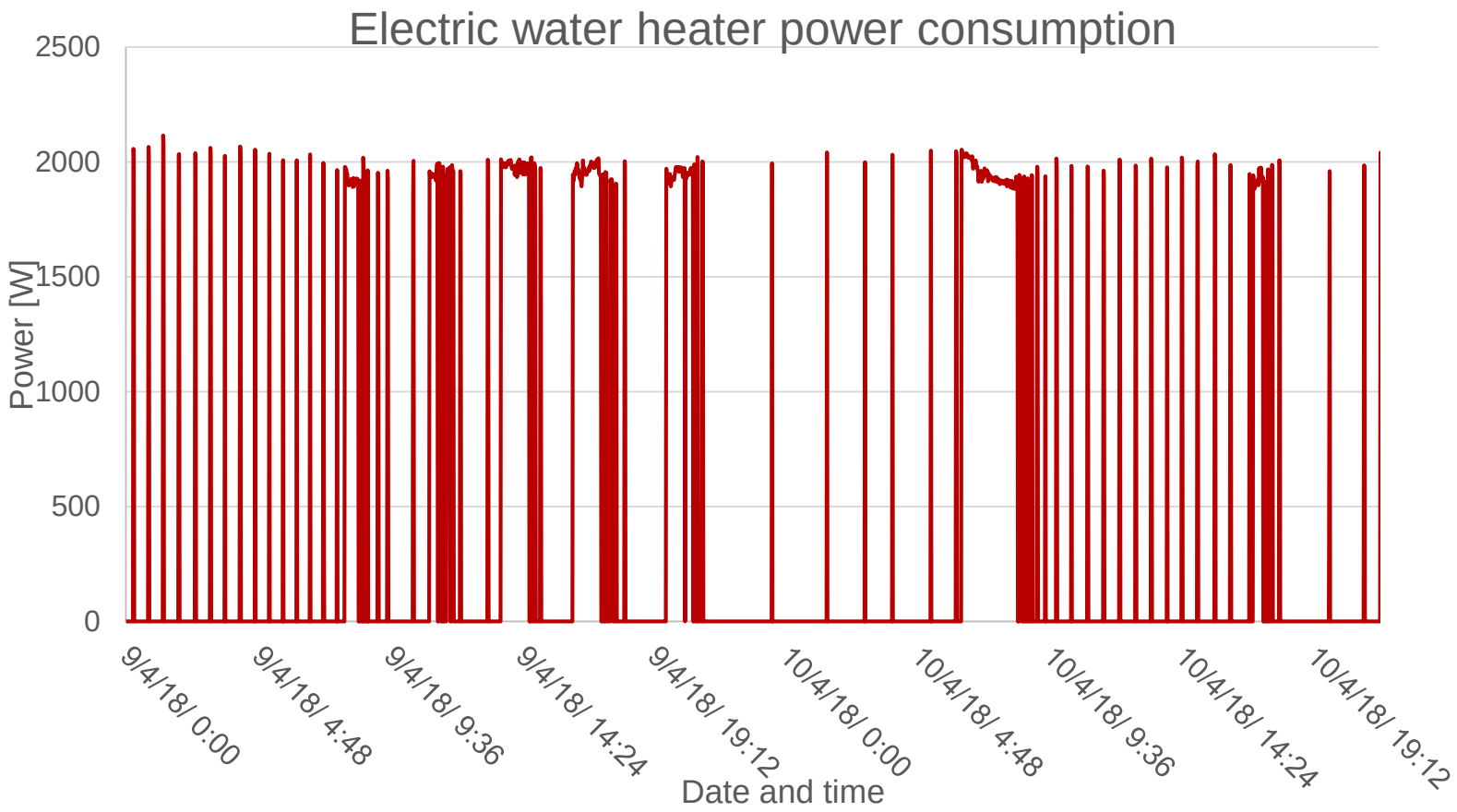
- Reversed Carnot cycle
- Thermal inertia of air, water, stored goods or building materials
- Load shifting increases the total consumed energy



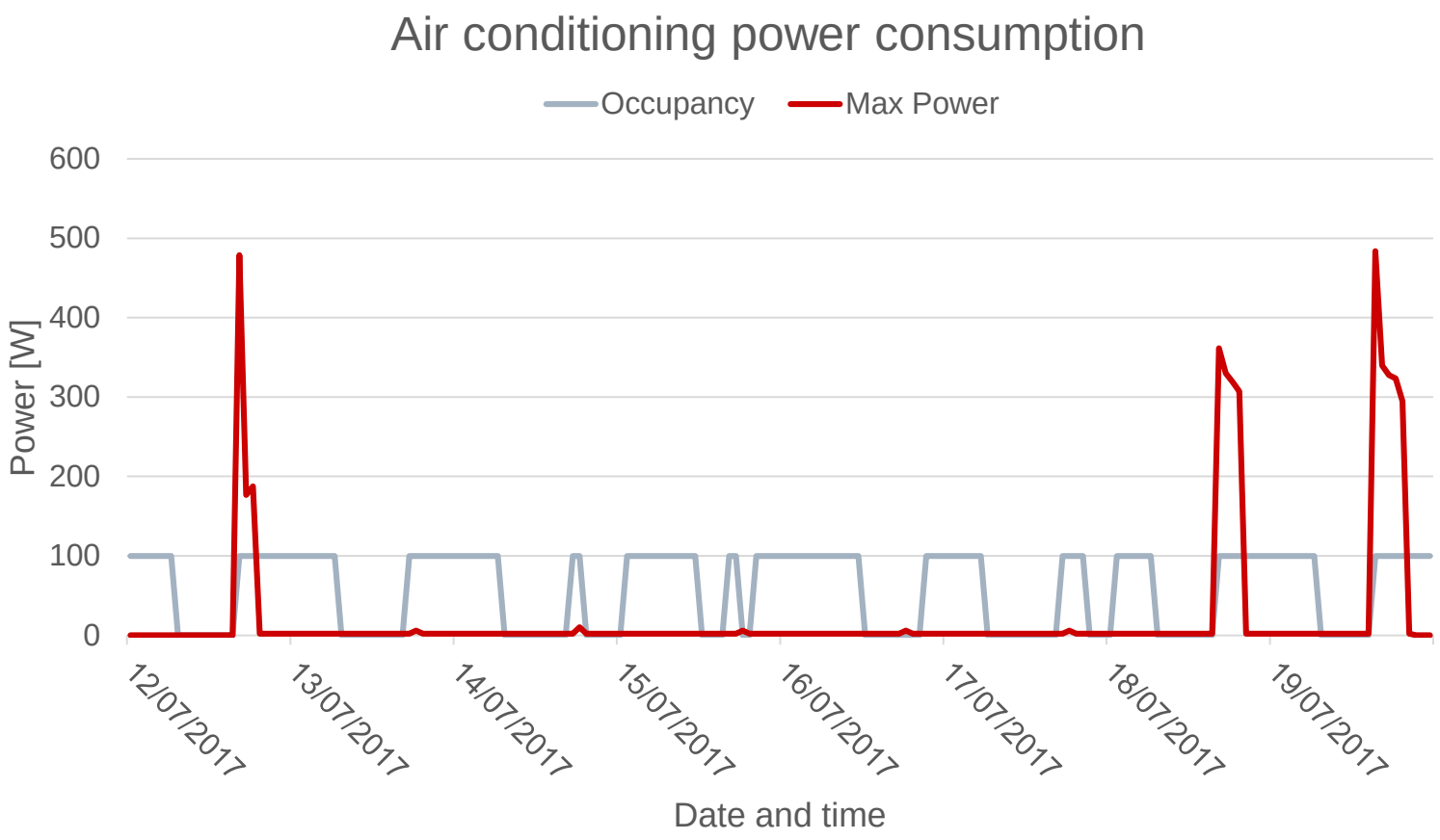
Refrigerators and Freezers



Electric Water Heater

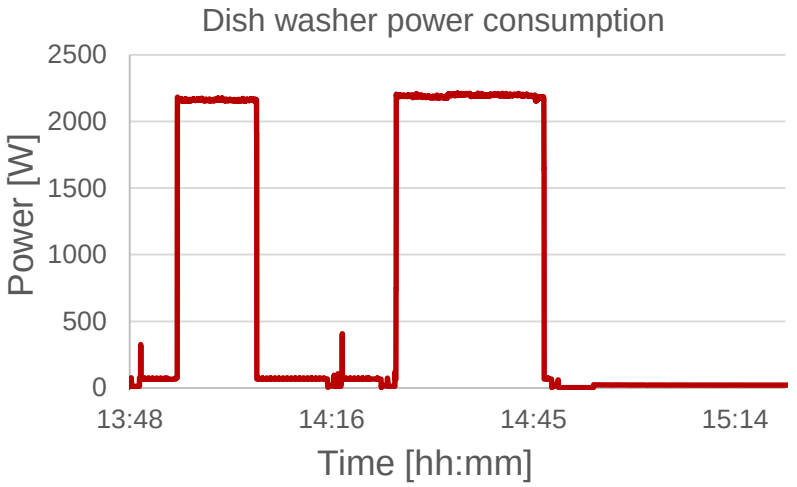


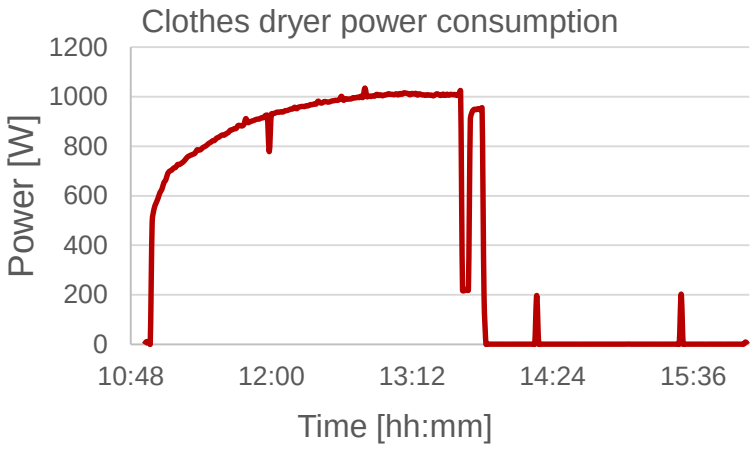
Air Conditioning

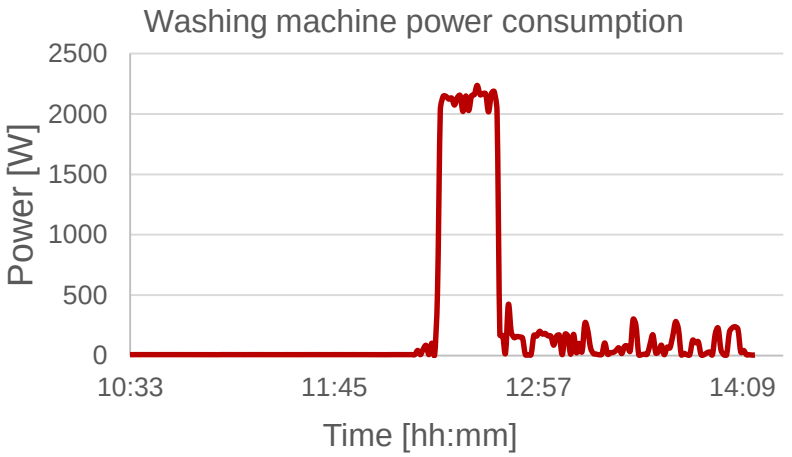


Controllable appliances

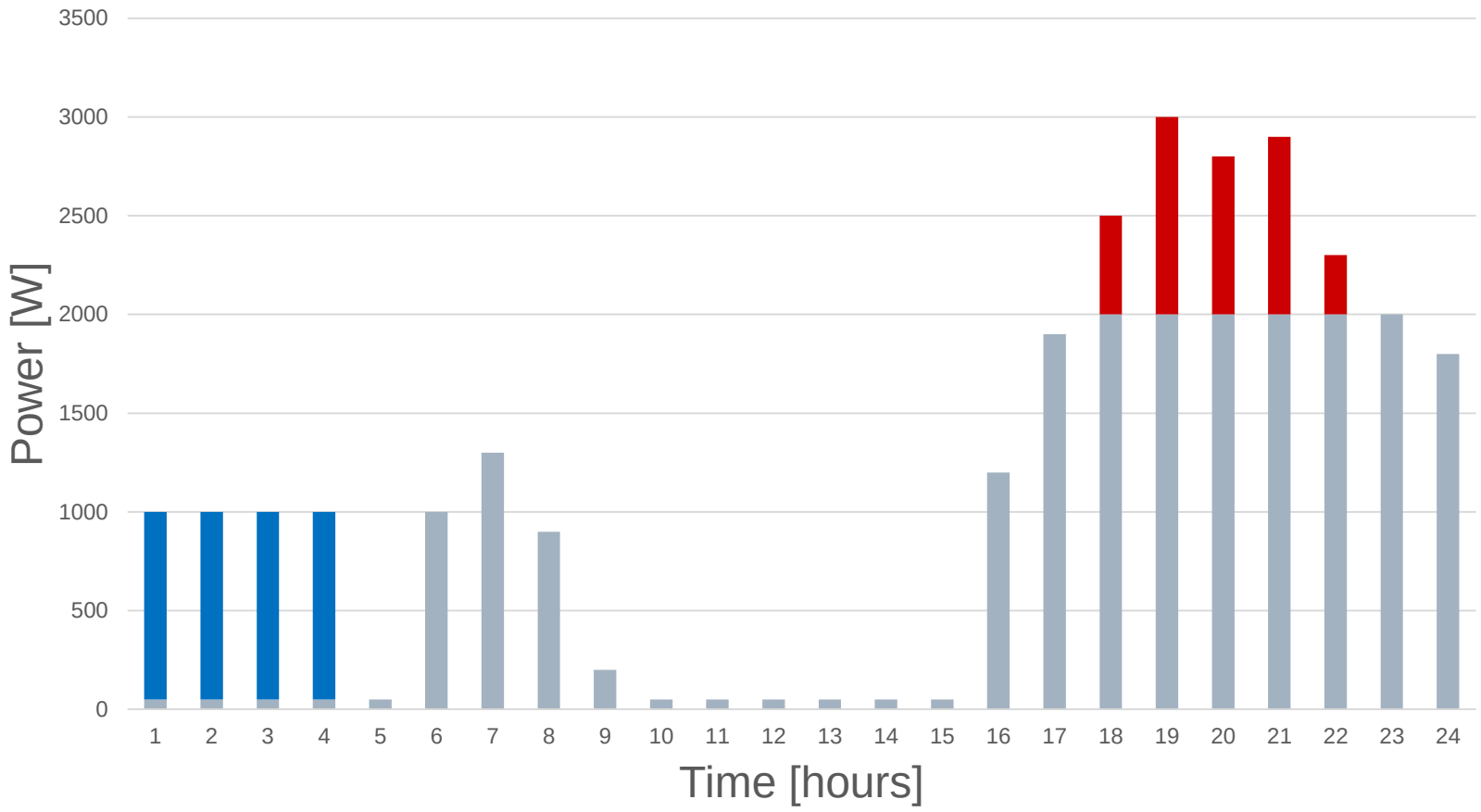
- Load shedding does not cause increase of consumed energy
- Can be scheduled in advance







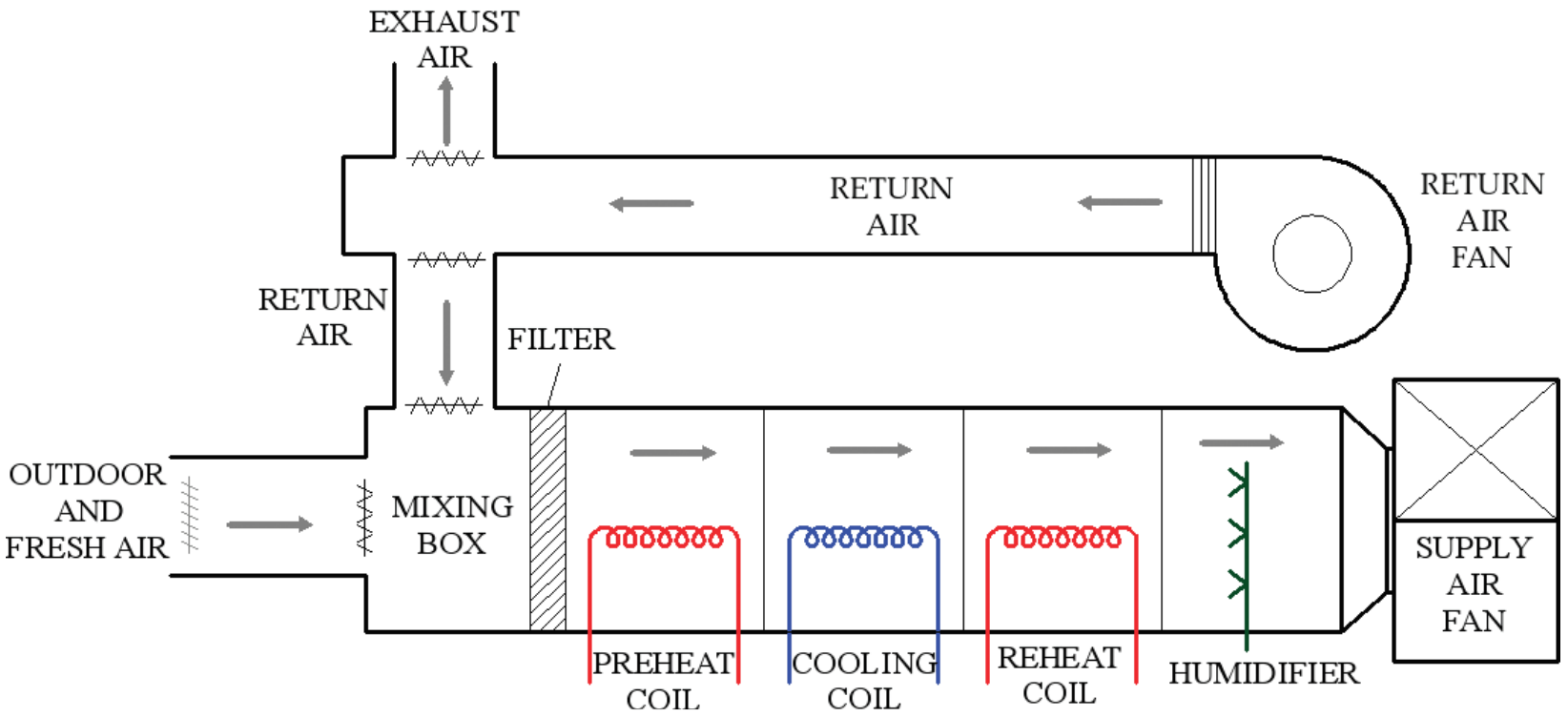
Household with Battery Storage



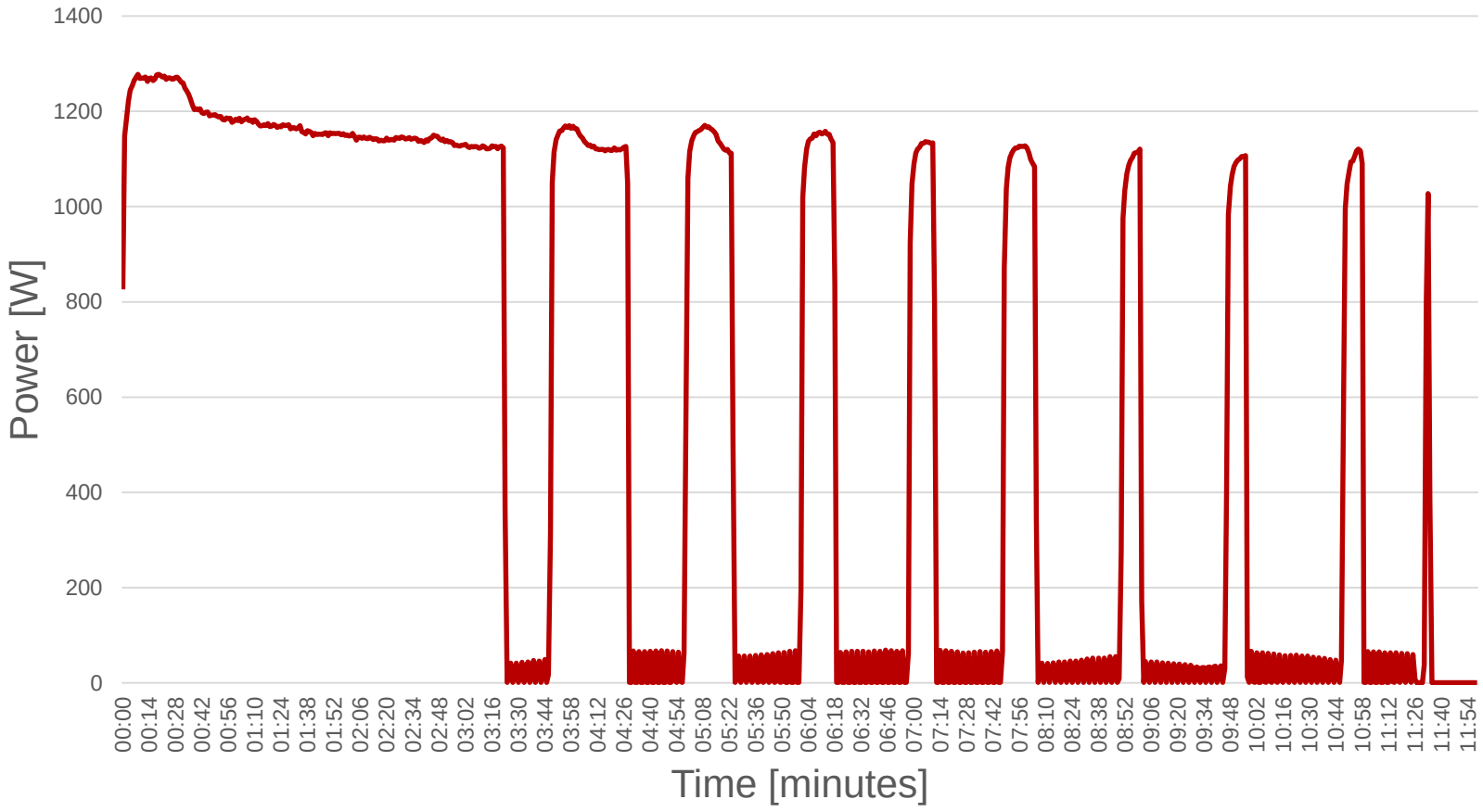
Commercial Buildings

- HVAC systems
- Cold storages
- Electric vehicle charging stations

HVAC


EXHAUST AIR
RETURN AIR
RETURN AIR FAN
RETURN AIR
FILTER
OUTDOOR AND FRESH AIR
MIXING BOX
SUPPLY AIR FAN
PREHEAT COIL
COOLING COIL
REHEAT COIL
HUMIDIFIER

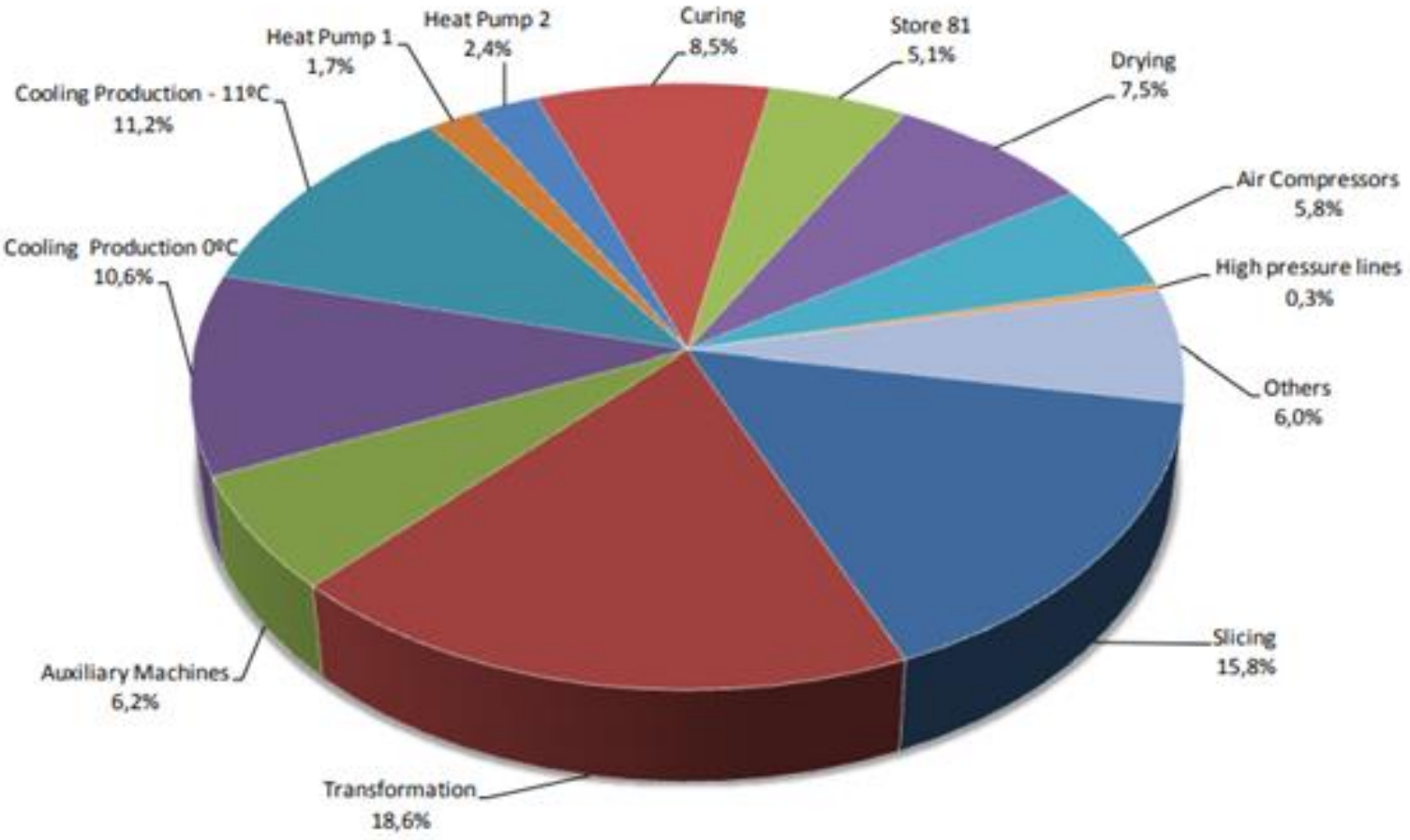
HVAC Electricity Consumption



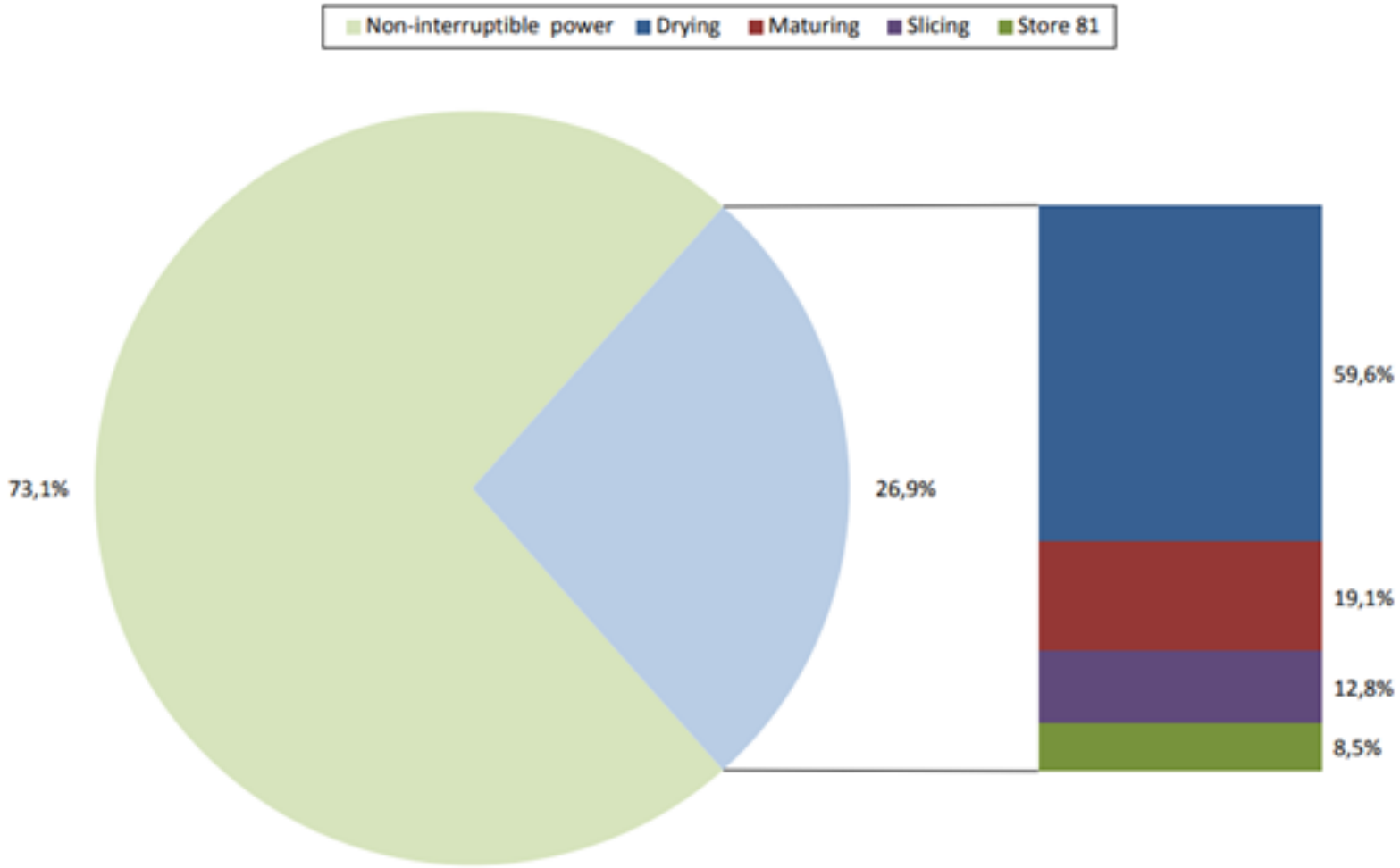
Industry

- Paper industry
- Food industry
- Water supply and waste water treatment plants
- Cement mills
- Petrochemical industry
- Metal, iron and steel
- Wood

Energy Consumption in Meat Industry



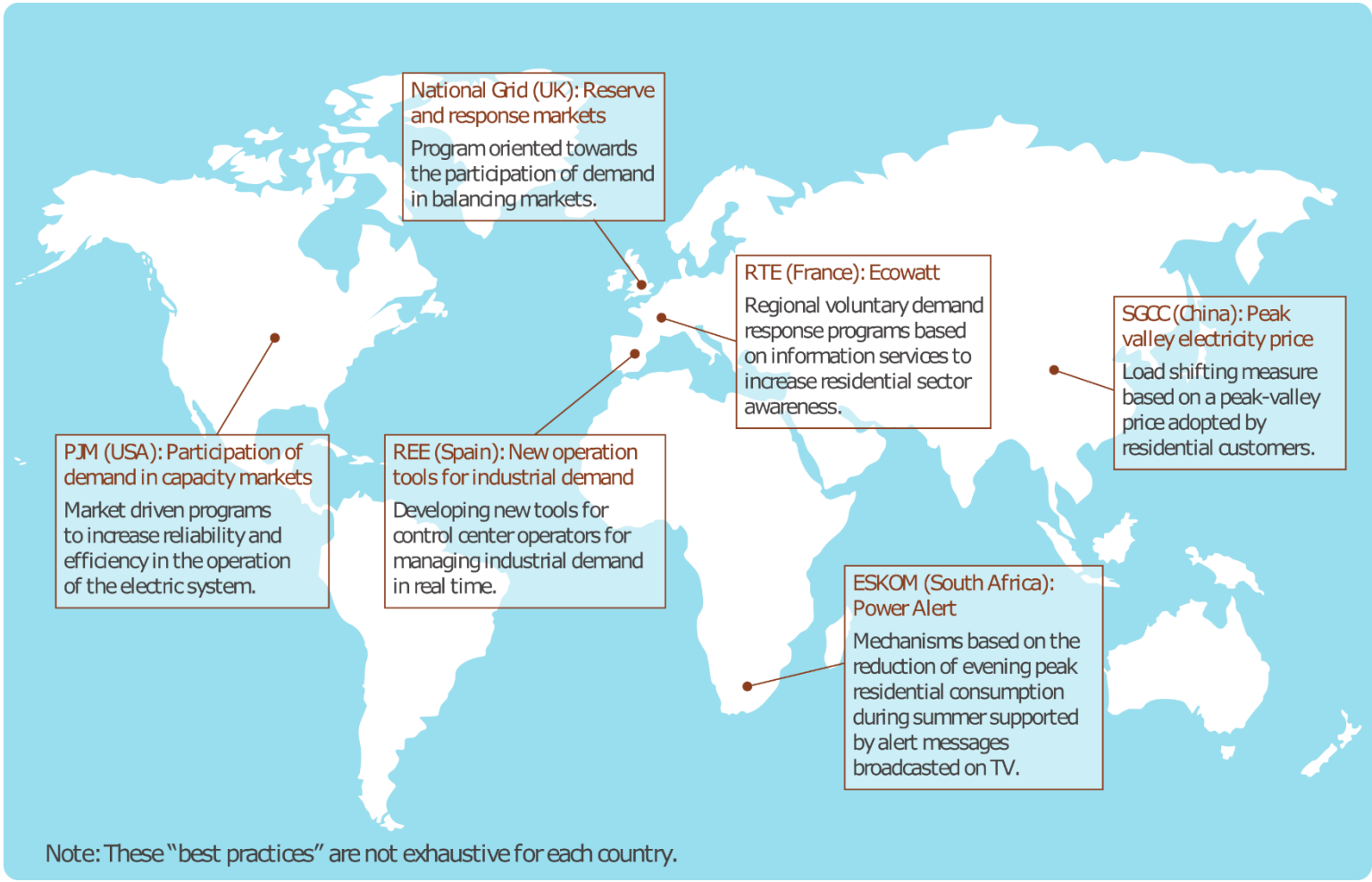
Meat Industry DR Events



Real World Demand Response

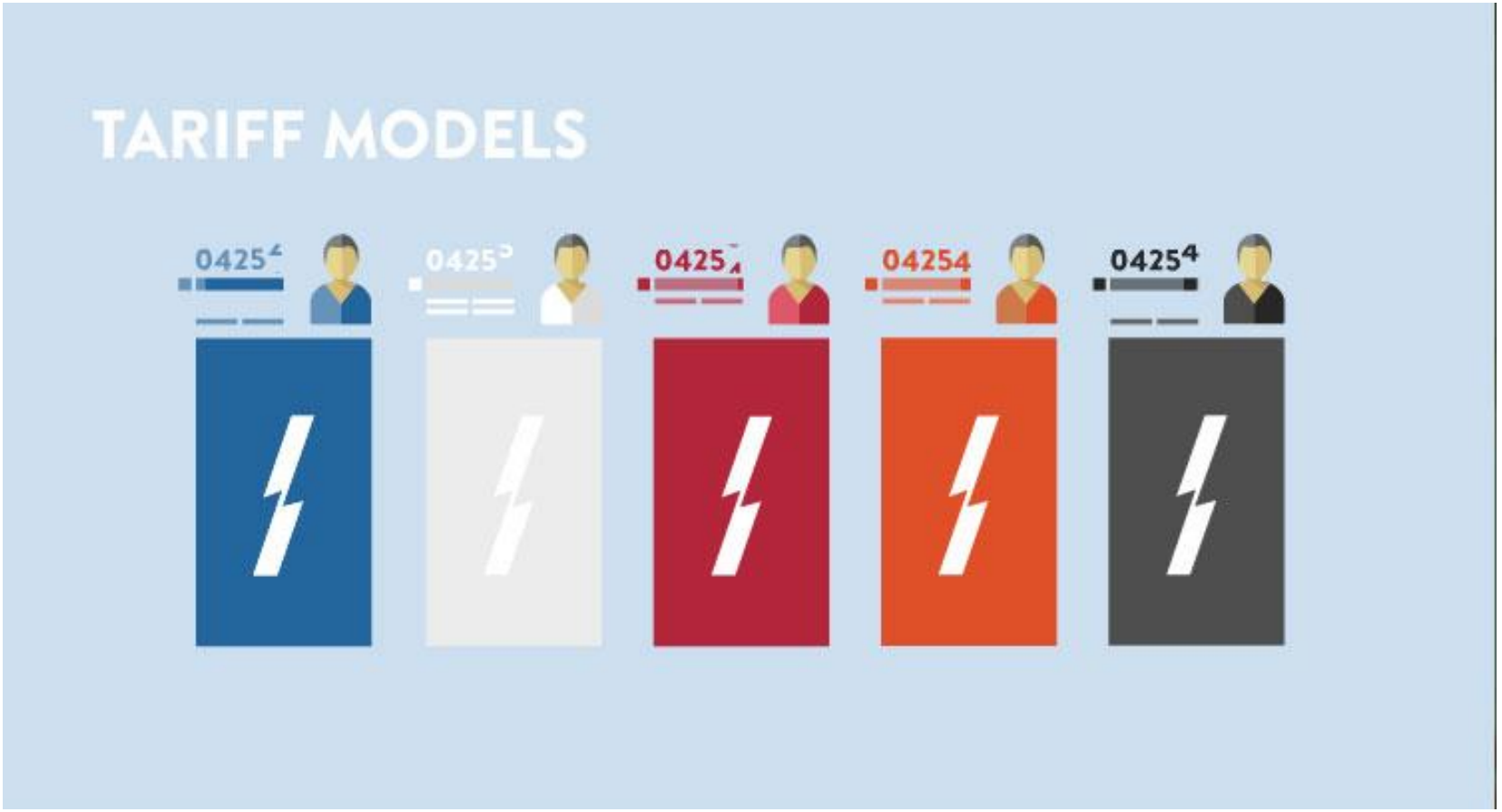
EXAMPLES

Best practices



https://www.ree.es/sites/default/files/go15_web.pdf

What do we have in Croatia



Electricity bill

Informativni izračun - kućanstvo

Tarifni model:

plavi

☐ samo korištenje mreže

Broj mjeseci

1 | 3 | 6 | 9 | 12

Potrošnja (kWh):

100

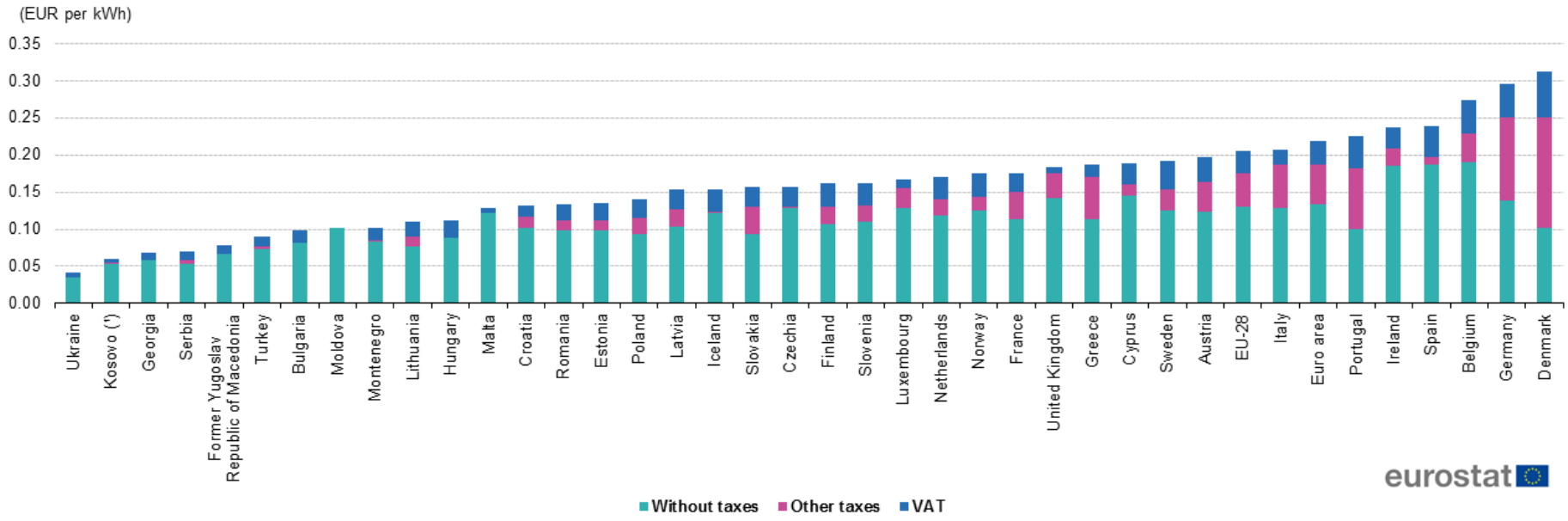
100 — 50000

Izračun

Stavka	Količina [kwh]	Cijena [Kn]	Iznos [Kn]
energija	100	0.4600	46.00
prijenos	100	0.0900	9.00
distribucija	100	0.2200	22.00
			77.00
opskrba	1 mj.		7.40
mjerno mjesto	1 mj.	10.00	10.00
oie	100	0.1050	10.50
osnovica za PDV			104.90
PDV (13 %)			13.64
Ukupno			**118.54**

http://mojracun.hep.hr/kalkulator/

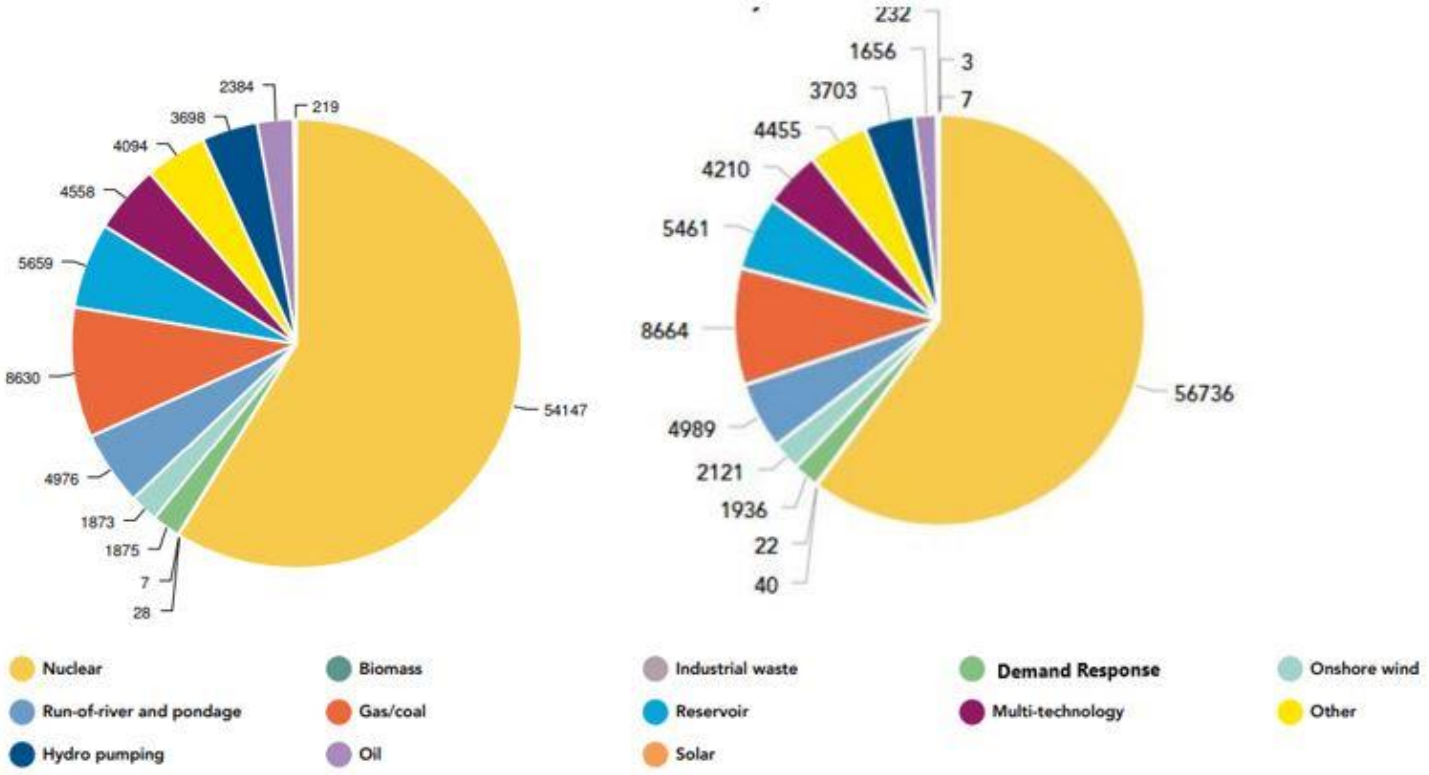
Electricity prices for households



France

- DR in the capacity mechanism
- DR in the energy markets
- DR for the balance group balancing
- DR for the system balancing
- DR specific auctions

France – capacity mechanism



France - the energy markets

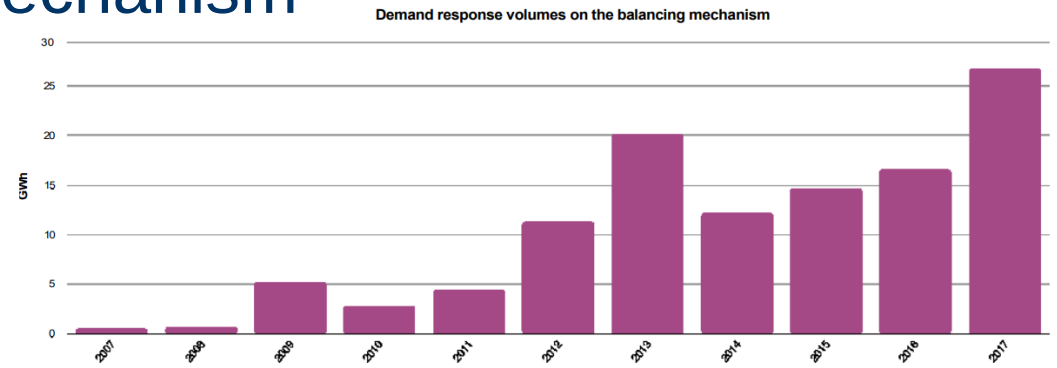
- Dynamic pricing signals:
  - Basic option (flat pricing)
  - Off-peak option (TOU pricing)
  - Tempo option (CPP pricing)
- NEBEF mechanism
  - The Block Exchange Notification of Demand Response mechanism
  - Explicit via the agreggators

France - balance group balancing

- Balance Responsible Entities (BRE)
- Two ways to participate:
  - Self balancing – participants are remunerated by the BRE
  - BRE block exchange – trading the balance blocks with the other BREs through the Block Exchange Service (PEB)

France - system balancing

- Defined by the French TSO (RTE):
  - Frequency and voltage ancillary services (primary and automatic secondary reserve for voltage and frequency)
  - Active reserves (manual secondary and tertiary reserve)
  - Balancing mechanism



France – DR specific auctions

- Used to additionally incentivise DR participation in different mechanisms and markets:
  - Capacity auctions for DR providers
  - Load shedding auctions

California

- Programmes for all types of consumers (residential, commercial, industrial, agricultural)
- Offered by utilities or aggregators
- Consumers notified by the phone, e-mail, text message
- Price signals, incentives, bill credits

https://www.cpuc.ca.gov/General.aspx?id=5925

California - CAISO

- Proxy Demand Response (PDR)
  - Independent providers
  - Energy and ancillary services markets
  - Load curtailment
- PDR – Load Shift Resource (PDR-LSR)
  - Providers can bit increase of the consumption

California – CAISO

- Reliability Demand Response Resource (RDRR)
  - Emergency load curtailment
  - Resource adequacy requirement by CPUC
- Participating Load
  - Includes pumped hydro storage
- Day ahead and real time markets

Lecture

OUTTAKES

Important to know

- What is the DR and what types exist
- What is an aggregator and why is it needed
- Why is the DR useful to the system, the grid and the end users
- What is the similarity between DR and ES

Further reading

- https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans
- https://ec.europa.eu/energy/en/topics/markets-and-consumers/market-legislation/electricity-market-design
- https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/demand-response-status-eu-member-states
- https://ec.europa.eu/energy/en/studies/impact-assessment-study-downstream-flexibility-price-flexibility-demand-response-smart
- https://www.rte-france.com/sites/default/files/rte_elec_report_2017.pdf
- http://www.caiso.com/participate/Pages/Load/Default.aspx