SmartNet

Smart TSO-DSO interaction schemes, market architectures and ICT Solutions for the integration of ancillary services from demand side management and distributed generation

**Meeting with TEPCO and Mitsubishi Institute| 28.09.2018**

# The SmartNet Project

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691405

# Agenda

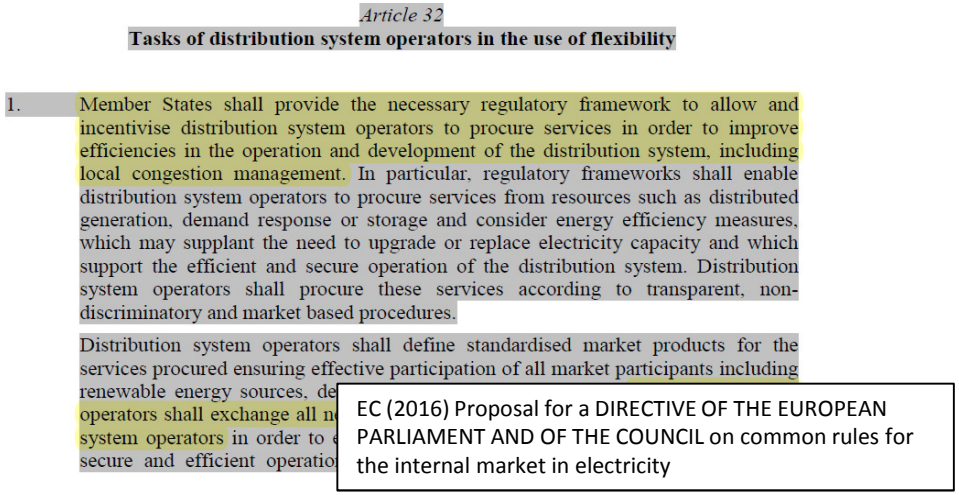
- The SmartNet project (motivations, set-up, consortium, activities flow)
- Five TSO-DSO coordination schemes
- Proposed AS market design
- The simulation platform
- Balancing market and aFRR
- ICT requirements (including some considerations from eBADGE project)
- Results for the Italian simulation scenario
- Layout of three project pilots
- Regulatory Analysis: work structure

# Motivations

- Increased reserve needs due to explosion of variable RES
- Opportunities from new DER in distribution?
- Five key questions:

| | |
|---|---|
| Which ancillary services could be provided from entities located in distribution networks | How the architectures of dispatching services markets should be consequently revised |
| Which optimized modalities for managing the network at the TSO-DSO interface | What ICT on distribution-trans-mission border to guarantee observability and control |
| Which implications on the on-going market coupling process | |

*"Some actions can have a negative cross-network effect. For instance, TSO use of distributed resources for balancing purposes has the potential to exacerbate DSO constraints. Equally, whilst DSO use of innovative solutions, such as active network management, can deliver benefits to customers, if not managed properly they may in some cases counteract actions taken by the TSO"* (CEER Position Paper on the Future DSO and TSO Relationship – Ref. C16-DS-26-04 – 21.09.2016)



*Article 32*

**Tasks of distribution system operators in the use of flexibility**

1. Member States shall provide the necessary regulatory framework to allow and incentivise distribution system operators to procure services in order to improve efficiencies in the operation and development of the distribution system, including local congestion management. In particular, regulatory frameworks shall enable distribution system operators to procure services from resources such as distributed generation, demand response or storage and consider energy efficiency measures, which may supplant the need to upgrade or replace electricity capacity and which support the efficient and secure operation of the distribution system. Distribution system operators shall procure these services according to transparent, non-discriminatory and market based procedures.

Distribution system operators shall define standardised market products for the services procured ensuring effective participation of all market participants including renewable energy sources, de
operators shall exchange all n
system operators in order to
secure and efficient operatio

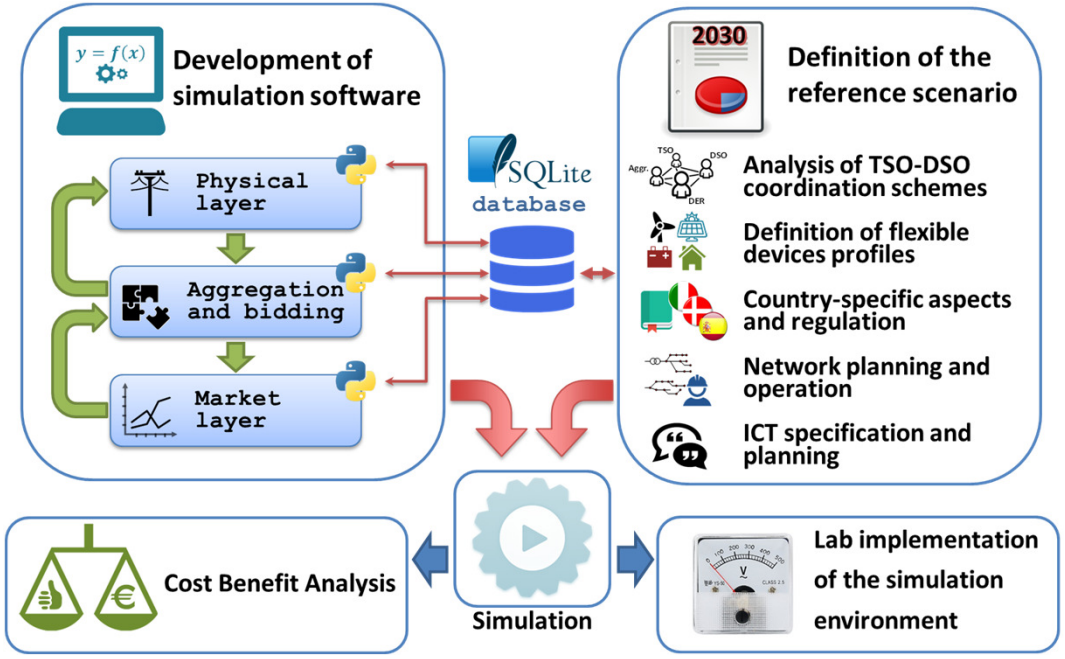
EC (2016) Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on common rules for the internal market in electricity

Winter package assigns a role to DSOs for local congestion management, but not for balancing

# The SmartNet project http://SmartNet-Project.eu

Project video: https://vimeo.com/220969294/73d98edde6

- **architectures for optimized interaction between TSOs and DSOs** in managing the purchase of ancillary services from subjects located in distribution.
- **three national cases** (Italy, Denmark, Spain);
- *ad hoc* **simulation platform** (physical network, market and ICT)
- **CBA** to assess which TSO-DSO coordination scheme is optimal for the three countries.
- use of **full replica lab** to test performance of real controller devices.
- **three physical pilots** to demonstrate capability to monitor and control distribution by TSO and flexibility services that can be offered by distribution (thermal inertia of indoor swimming pools, distributed storage of radio-base stations).



# The SmartNet project

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AIT Austrian Institute of Technology
DTU Technical University of Denmark
edyna
endesa
ENERGINET.DK
European University Institute
EURISCO Research & Development
KU LEUVEN
NOVASOL
N-SIDE
RSE
SELTA
SIEMENS
SINTEF
University of Strathclyde Glasgow
tecnalia Inspiring Business
Terna Rete Italia Terna Group
vito vision on technology
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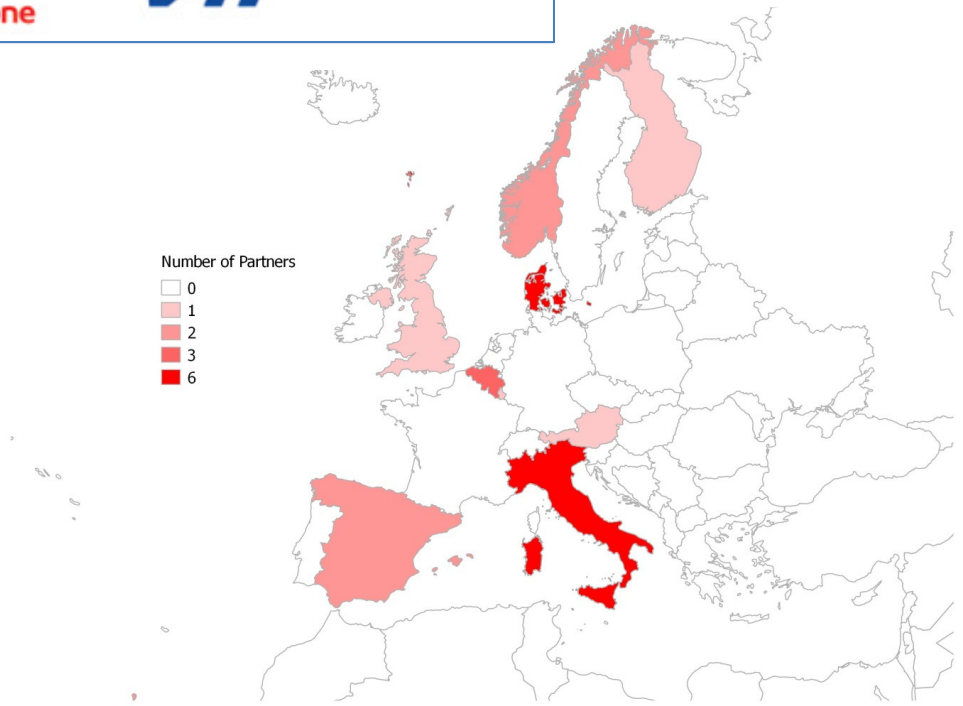
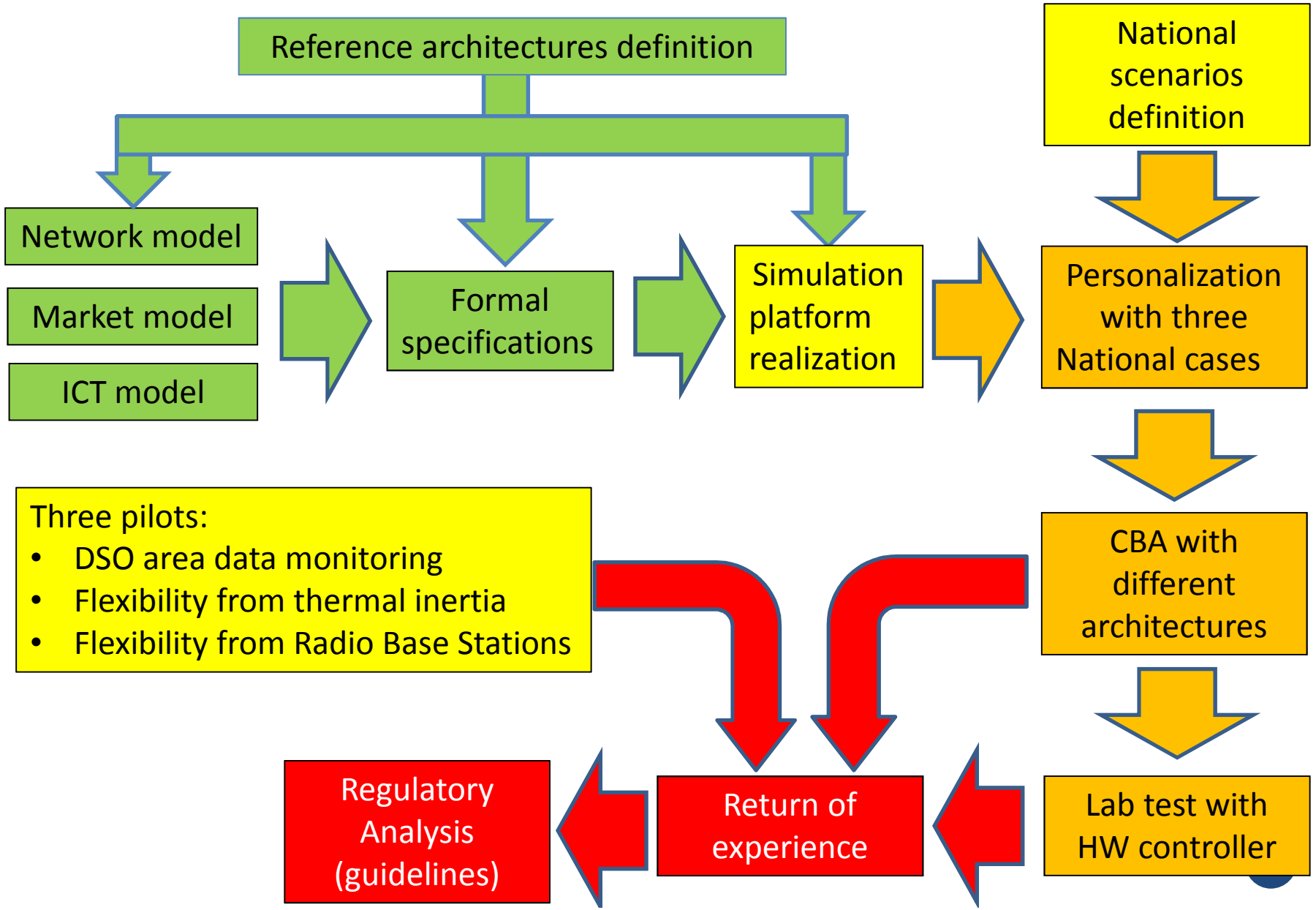


# Year 1 – Year 2 – Year 3



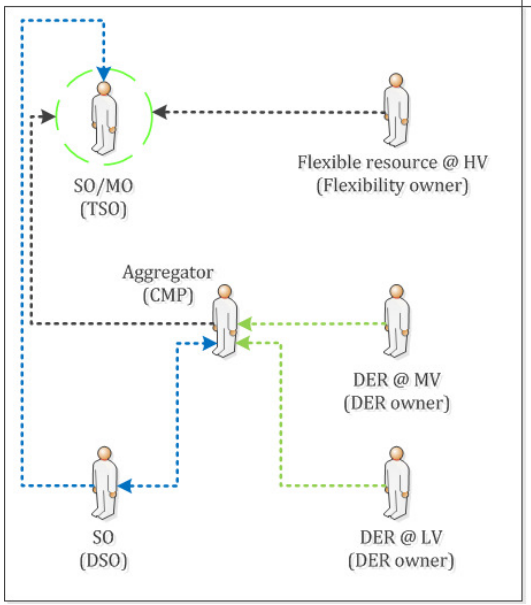
# TSO-DSO coordination schemes

SmartNet

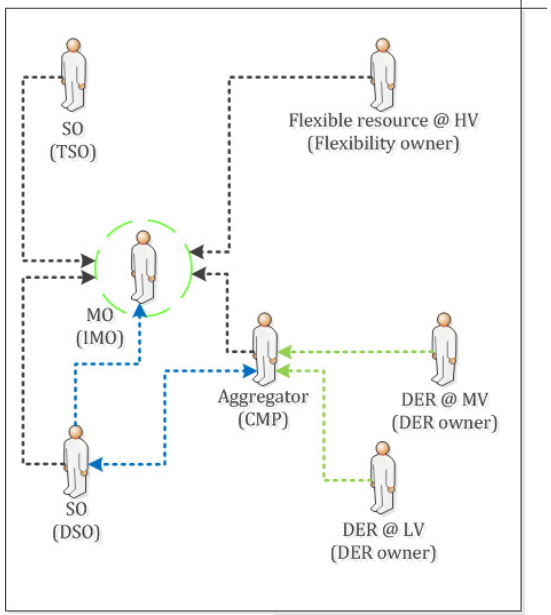
## 5 possible coordination schemes TSOs & DSOs for AS by distributed flexibility resources

A. Centralized AS market model
B. Local AS market model
C. Shared balancing responsibility model
D. Common TSO-DSO AS market model
E. Integrated flexibility market model

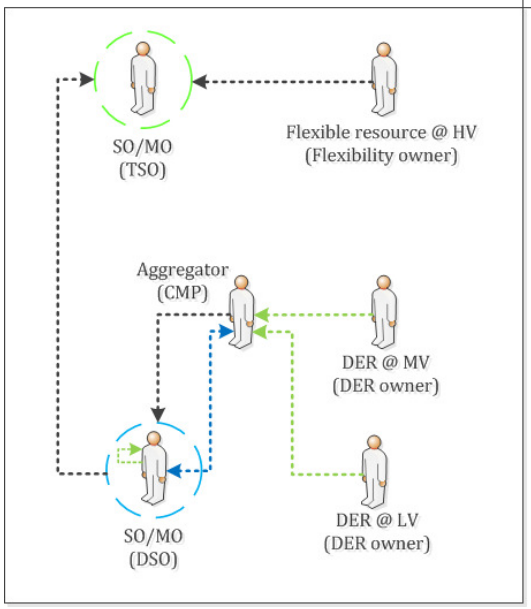
Centralized AS market model



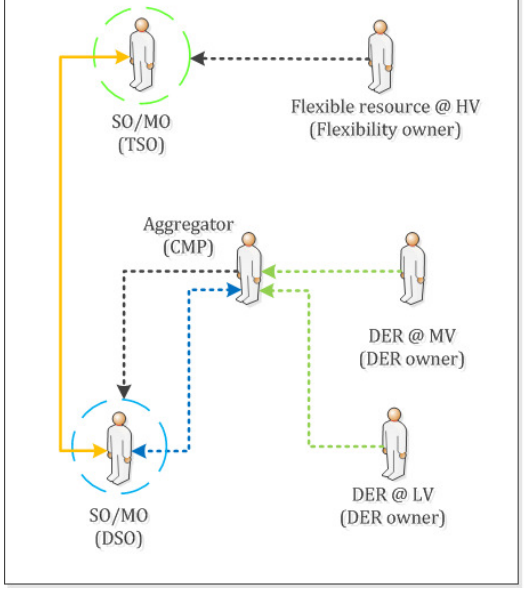

Integrated flexibility market model



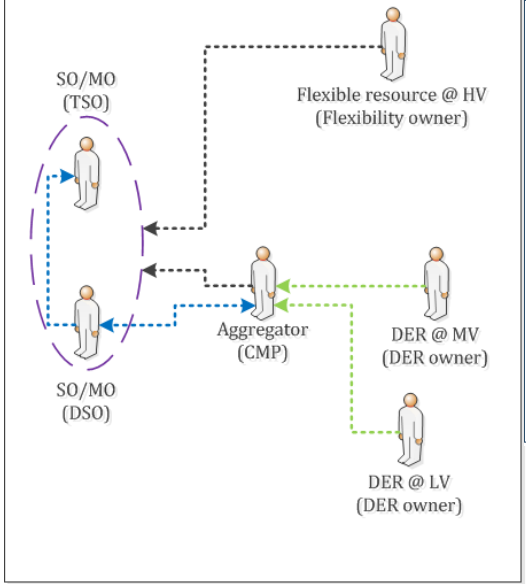

Local AS market model

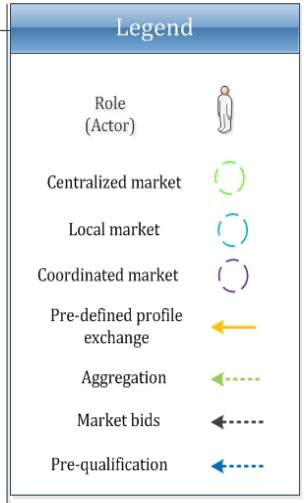



Shared balancing responsibility model



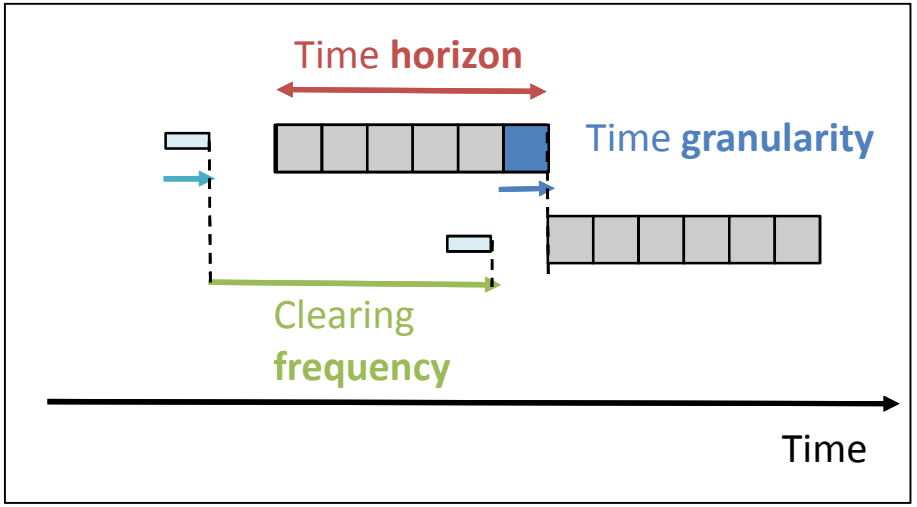

Common TSO-DSO AS market model

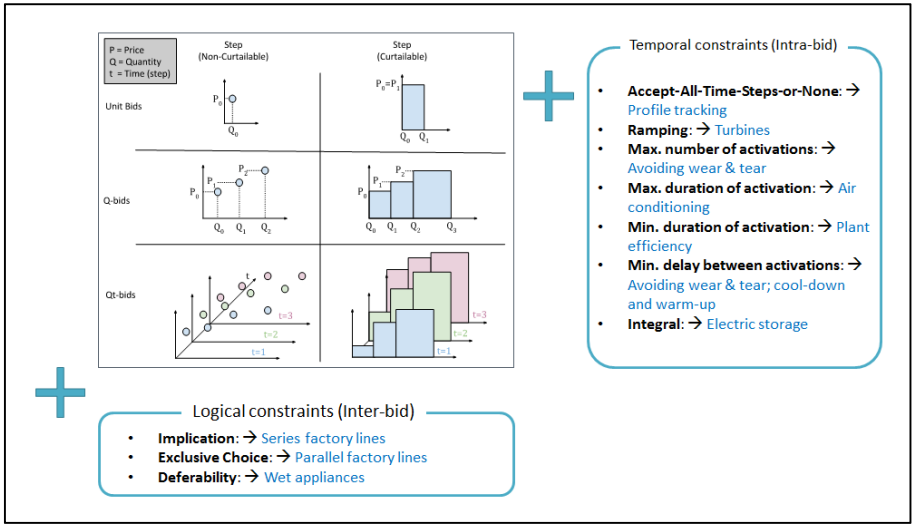


# Proposed Market Design

- **Considered services:** **balancing** and **congestion** management at transmission (HV) and distribution level (MV), including voltage constraint at MV
- **Rolling optimisation concept:** Results for the **first** time step are a **firm** decision. Results for the **next** time steps are **advisory** decisions.
- **Network representation:** DC approximation for HV, SOCP for MV
- **Market products:** implementation of typical constraints of flexibility providers (extension to **multi-period bids** with **temporal** and **logical** constraints
- **Representation of arbitrage opportunity between cascading markets:** day-ahead, intraday, AS market



# The SmartNet simulation platform

**The physical layer** simulates T&D and devices operation, including voltage regulation, reactive compensation, aFRR and network protections.

**The bidding layer** aggregates flexibility offers of a huge number of resources (electric storage, electric vehicles, distributed generation, demand response) into balancing market bids and transforms market clearing into activations.

**The market layer** carries out system balancing and congestion management while including voltage constraints.
Some innovative features are:

- **rolling optimisation** concept
- **network representation:** DC approximation for HV networks, SOCP for MV networks
- **market products:** typical **multi-period** and **logical** constraints of flexibility providers
- **arbitrage opportunities between cascading markets** (day-ahead, intraday, AS market).

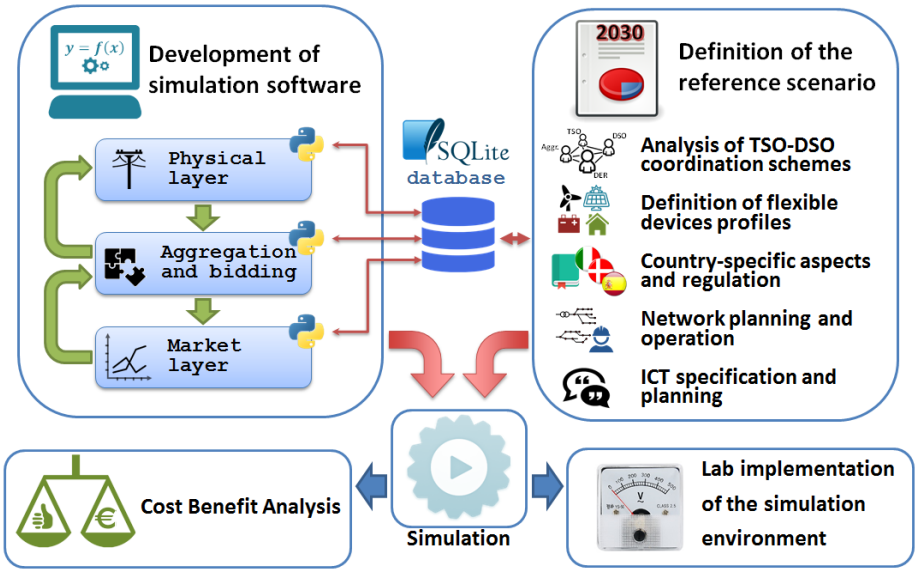
**Cost benefit analysis** compares the 5 coordination schemes over 3 national scenarios on the basis of:

- **total AS market cost**
- **aFRR cost** due to congestion not "seen" by AS market, forecasting errors, transmission losses (neglected by AS market).
- **unwanted measures** New
- **ICT deployment costs**

Sensitivity factors:

- **emission savings**

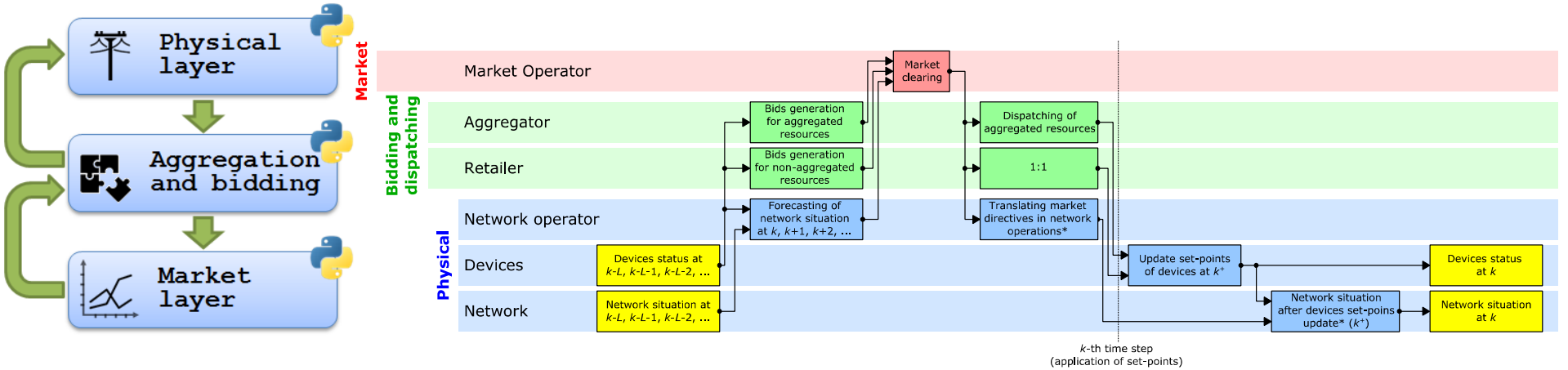
Further "micro" **cash flows analysis**.

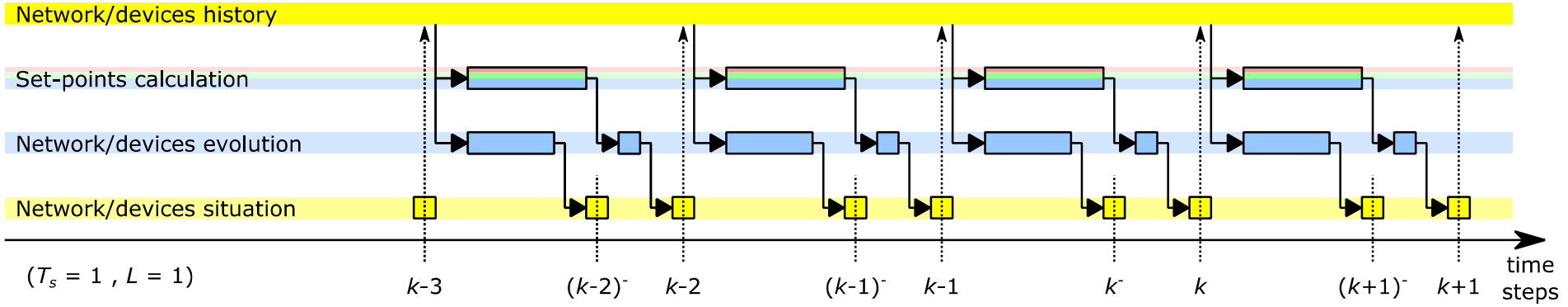



**Simulation scenarios at 2030** for Italy, Denmark and Spain. Very large datasets (Italian scenario: 655,323 photovoltaic panels, 31 wind farms, 20 large CHP plants, 1,833 run-of-river hydropower plants, 308 conventional fuel-based generators, 13 pumped hydro stations, 212,704 electrical cars, 1,489,193 residential wet appliances, 68,481 residential heat pumps, 33,783 dimmable street-lights, as well as non-controllable loads in all distribution grids and some transmission nodes.

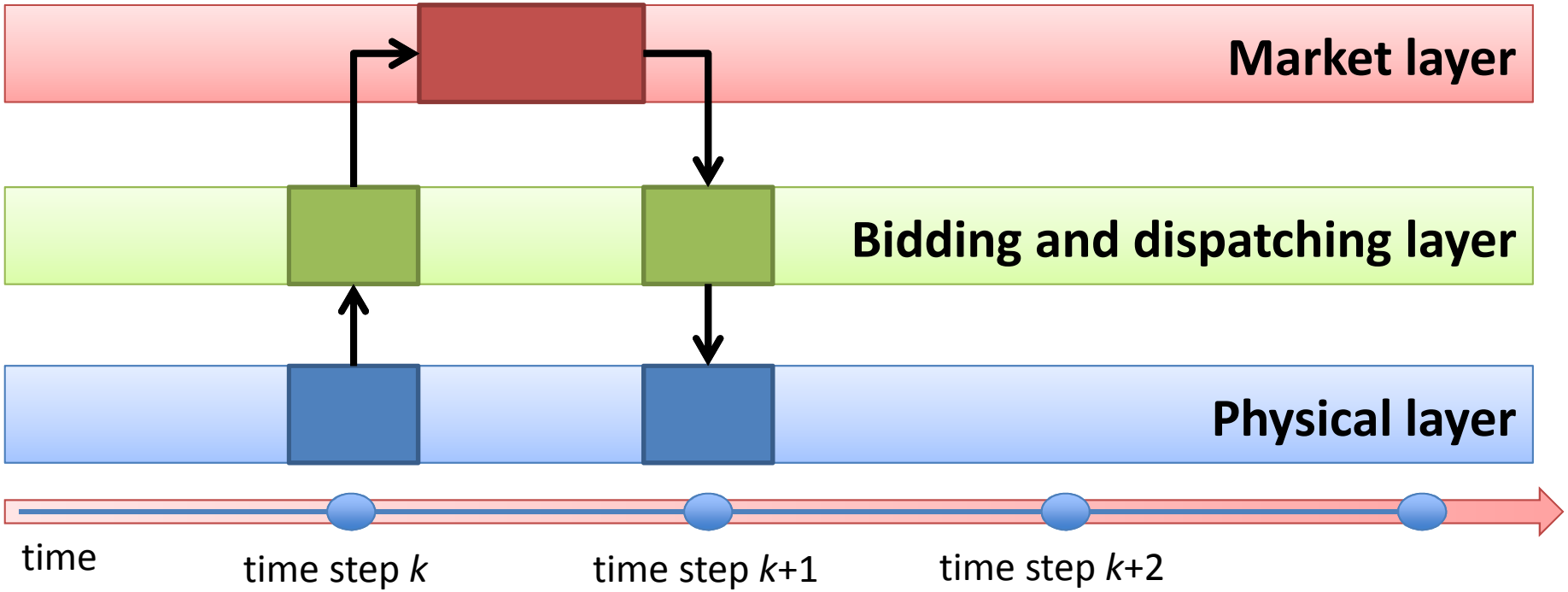
**Hardware-in-the-loop simulations** to test in real-time-simulated scenarios the performances of real equipment (controllers for flexible devices, SCADAs, etc.) and the effects of non-ideal information transmission channels.

# Interaction between the three layers

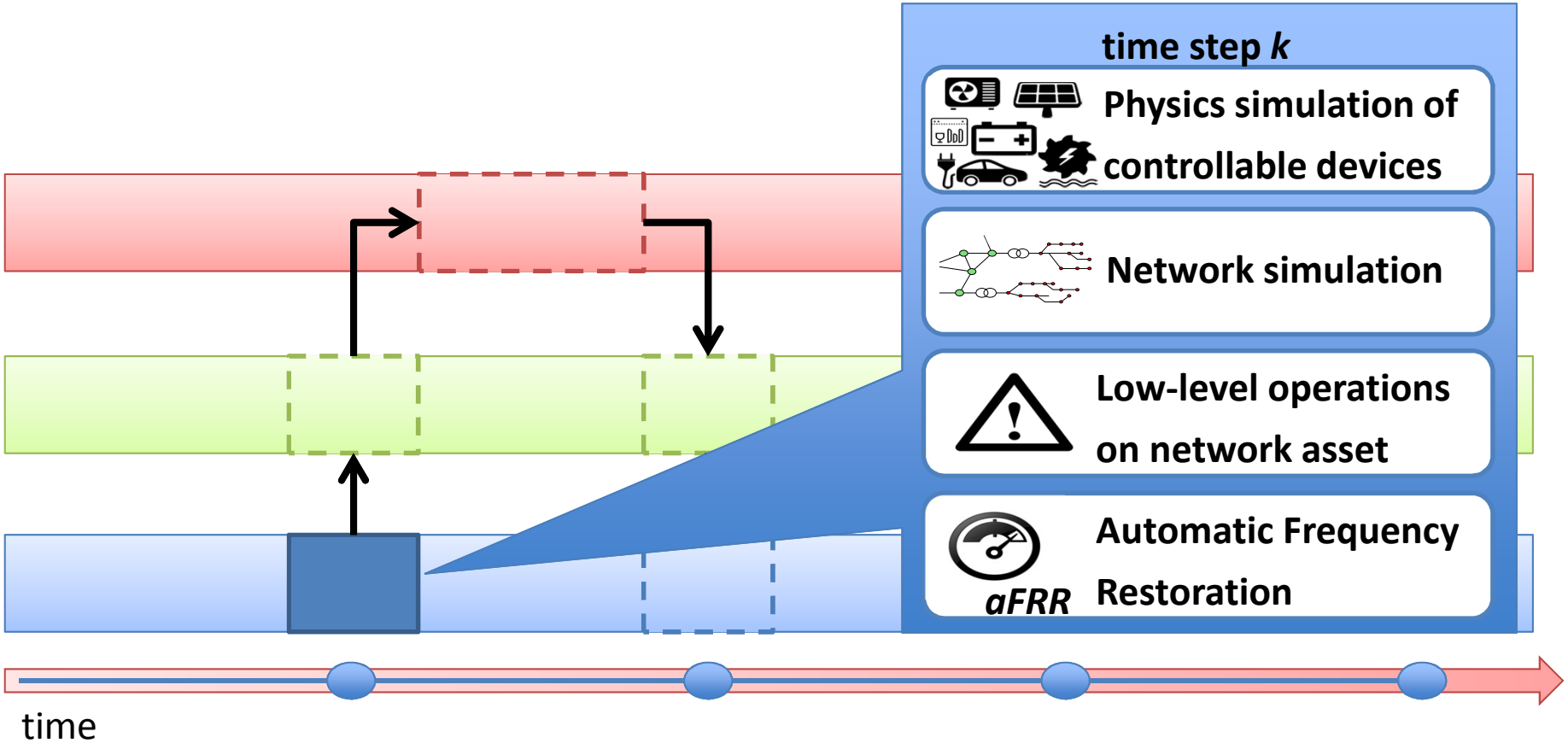


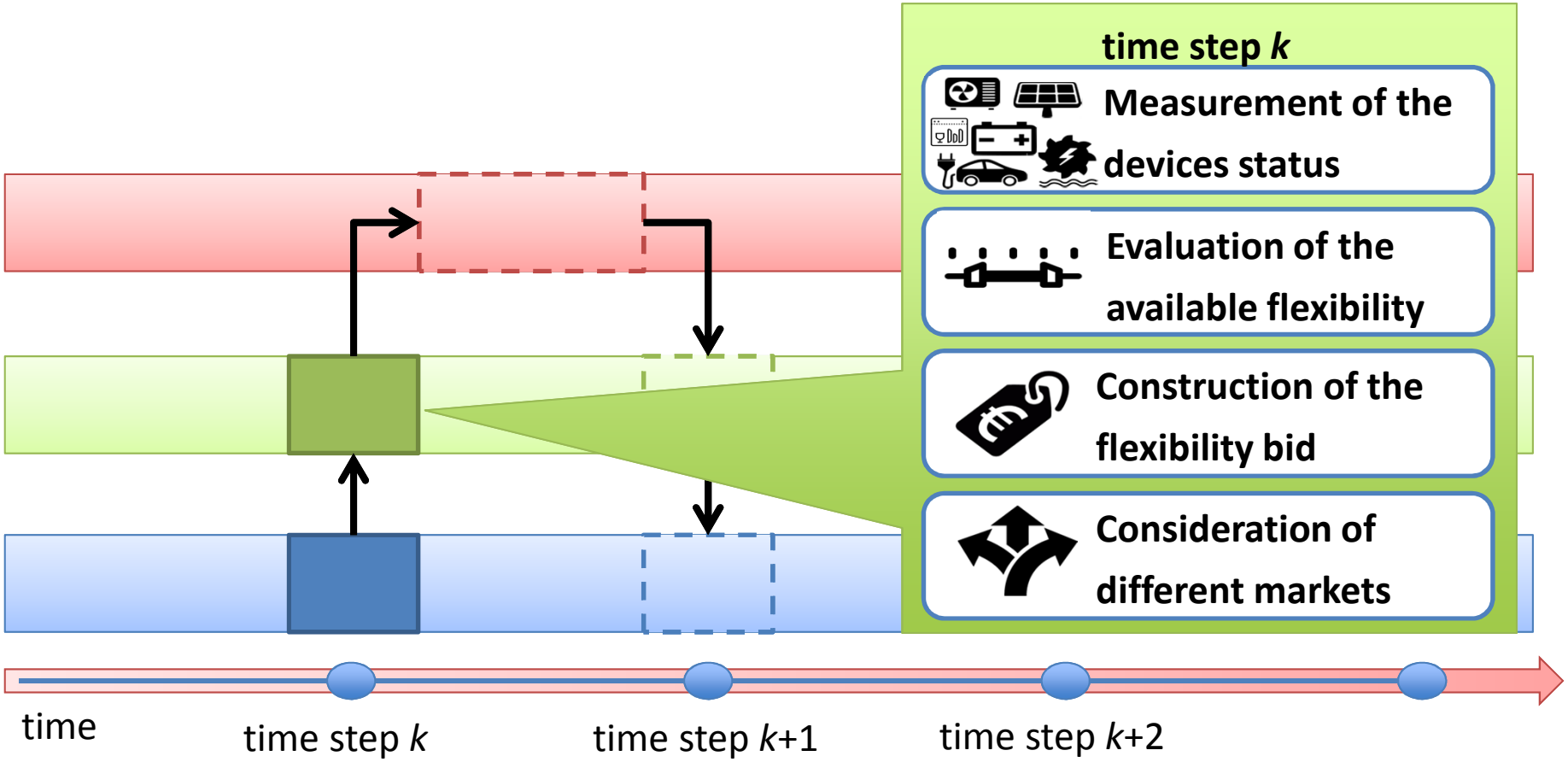
# How the simulator works
## Simulation based on three layers



# How the simulator works

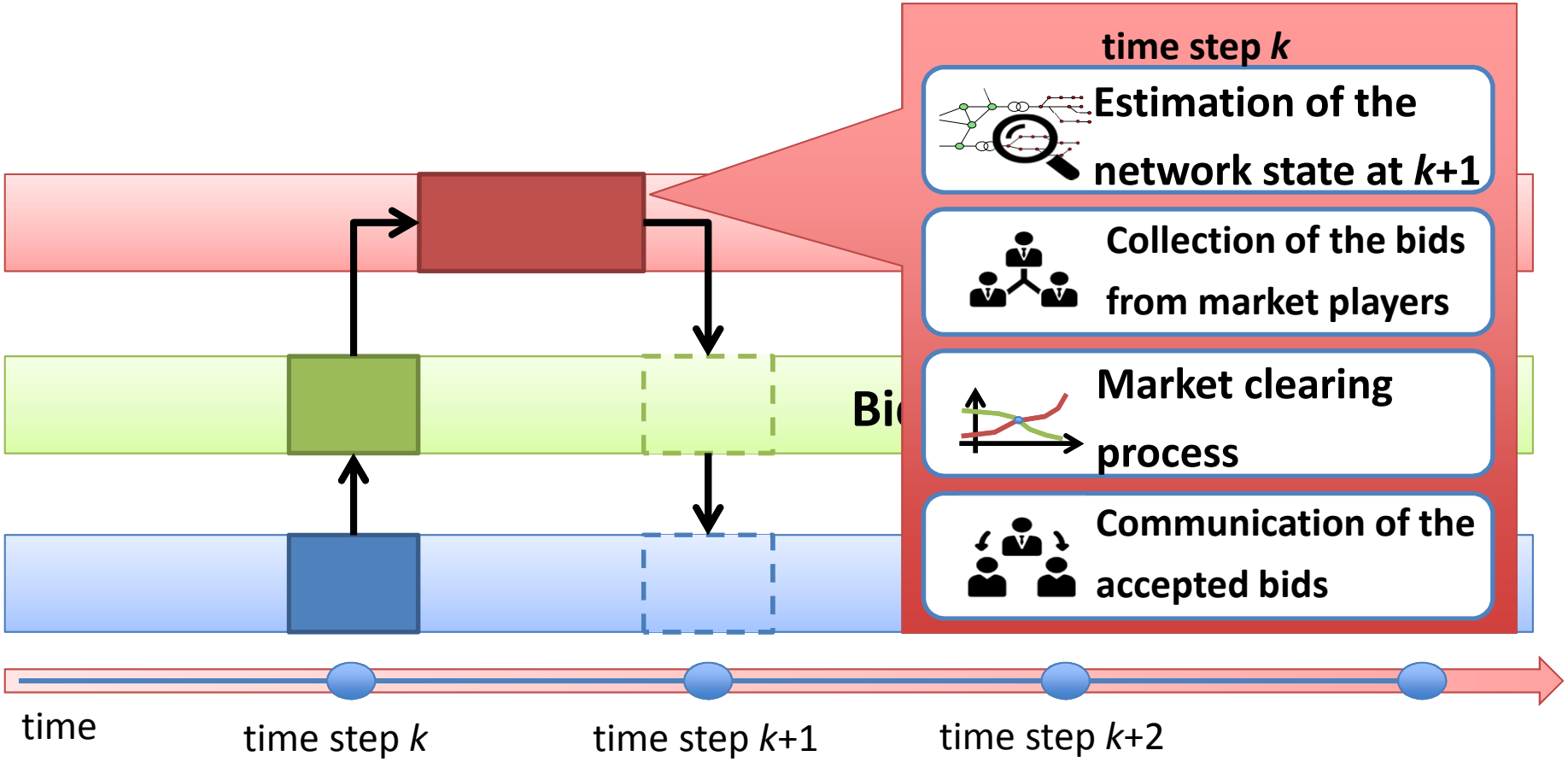


# How the simulator works
## How the bidding process is simulated

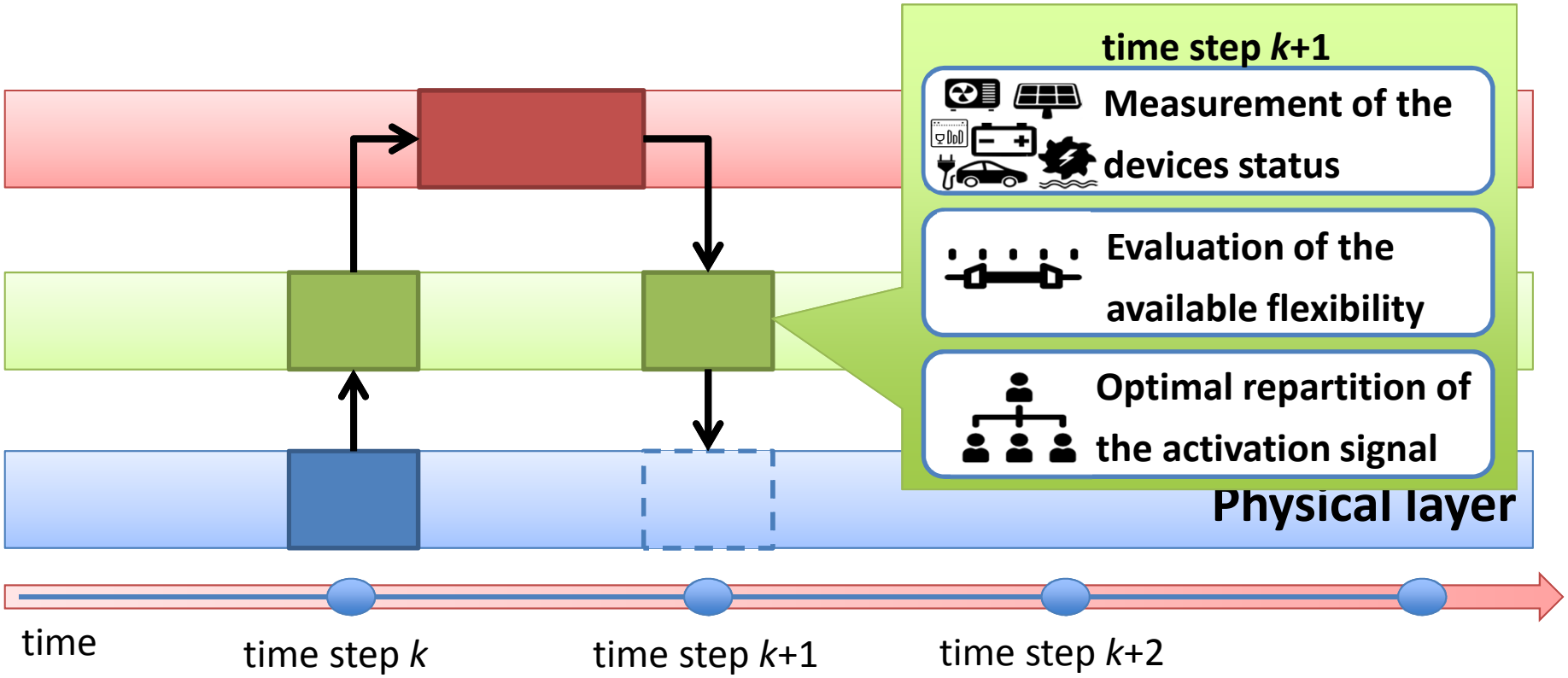


# How the simulator works

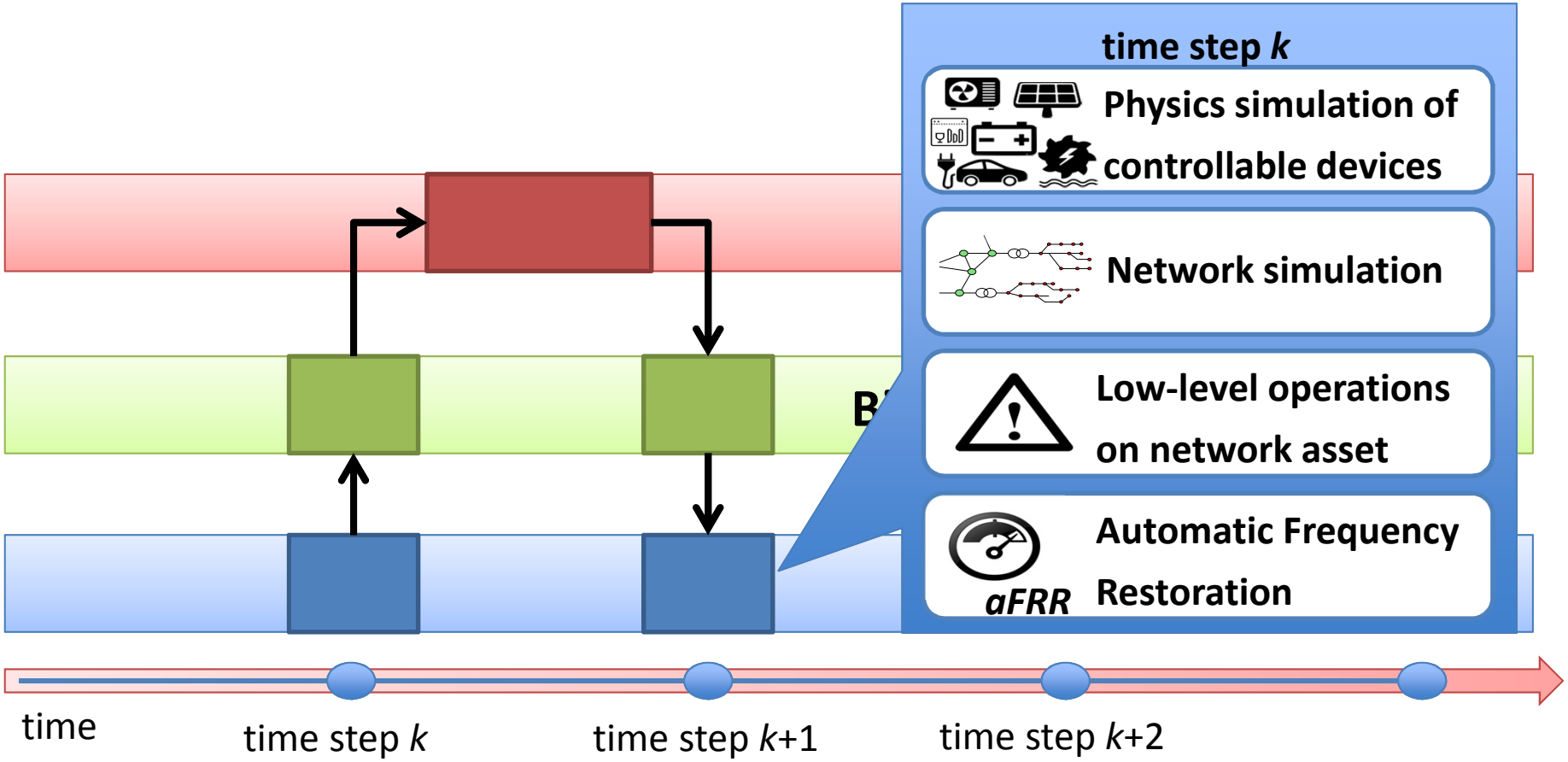
## How the market process is simulated



# How the simulator works
## How the dispatching process is simulated



# How the simulator works
## How the physical layer is simulated



# Balancing market and aFRR (1/2)

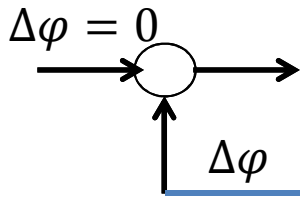
Tertiary market mFRR
(balancing + congestion management)

Residual congestion /
Unavailability of activated flexibility

Unwanted measures
(re-dispatching due to unpredicted
congestions and/or unavailability of resources)

Residual imbalance

aFRR in physical layer
(system balancing: by
controlling flows with
neighbouring countries)




**CBA**

Cost mFRR

Cost Unwanted Measures **New**

**Two kinds:**

- **Congestion not detected by tertiary market**
- **Forecast errors of aggregators (penalized)**

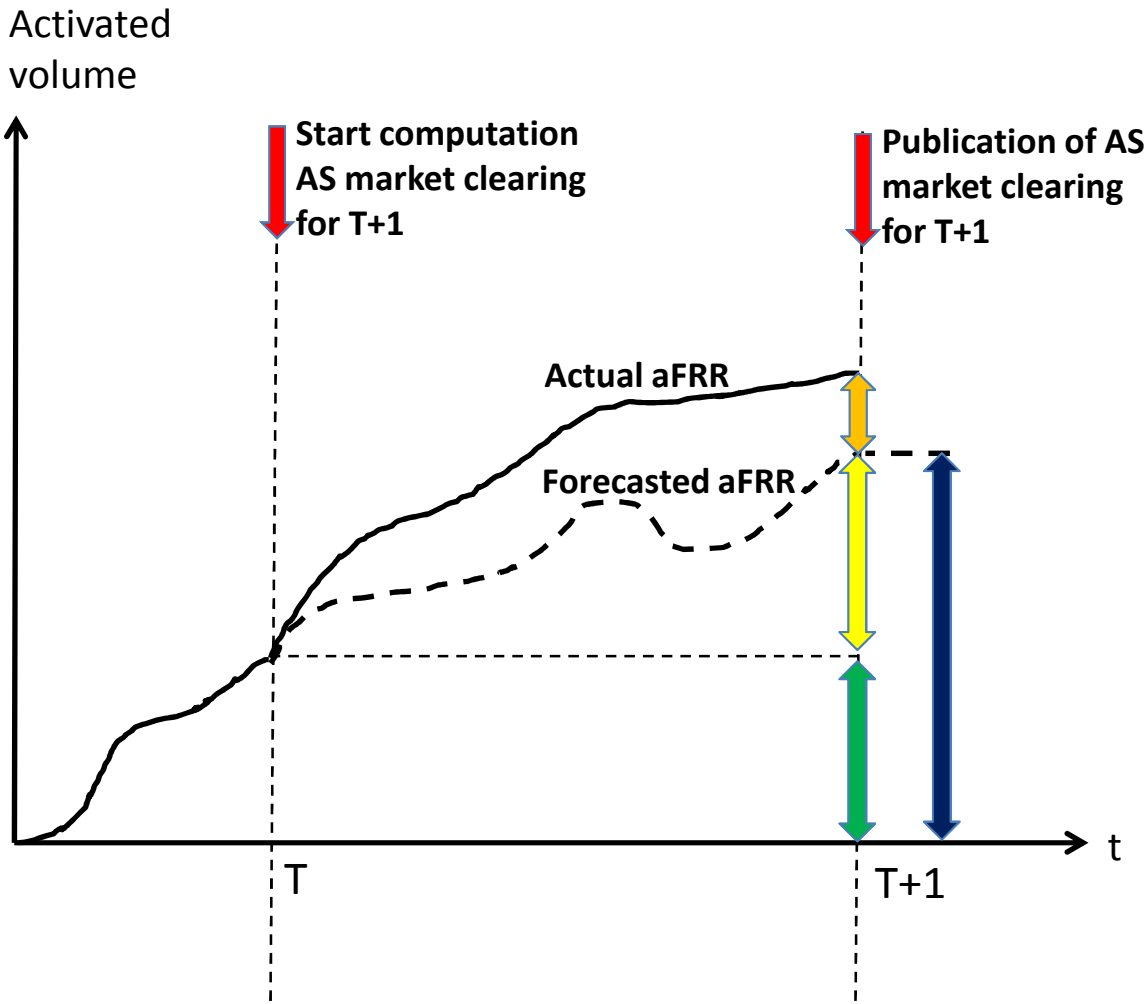
Cost aFRR, higher than mFRR:

$P_{mFRR\_BID} * k$

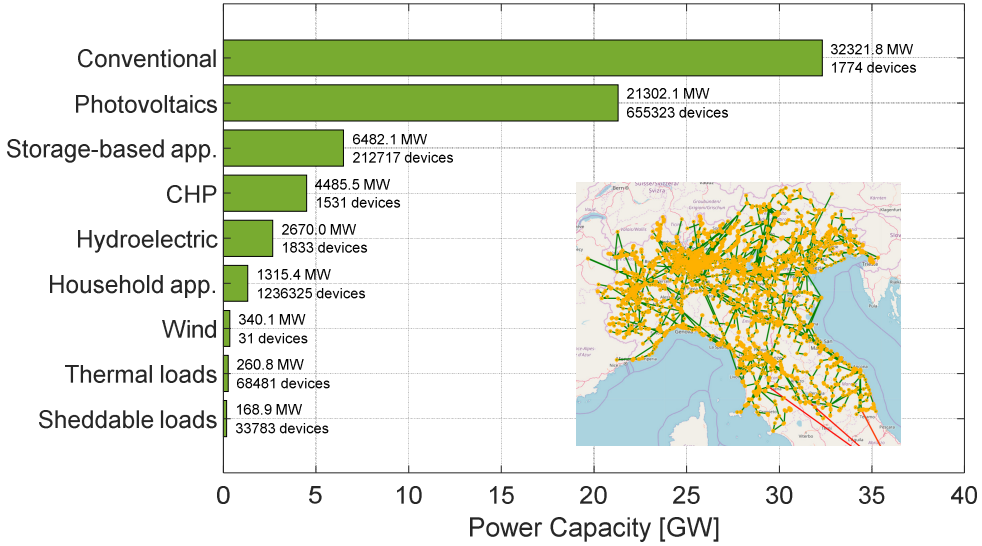
**$k < 1$ if $P_{mFRR\_BID} < 0$**
**$k > 1$ if $P_{mFRR\_BID} > 0$**

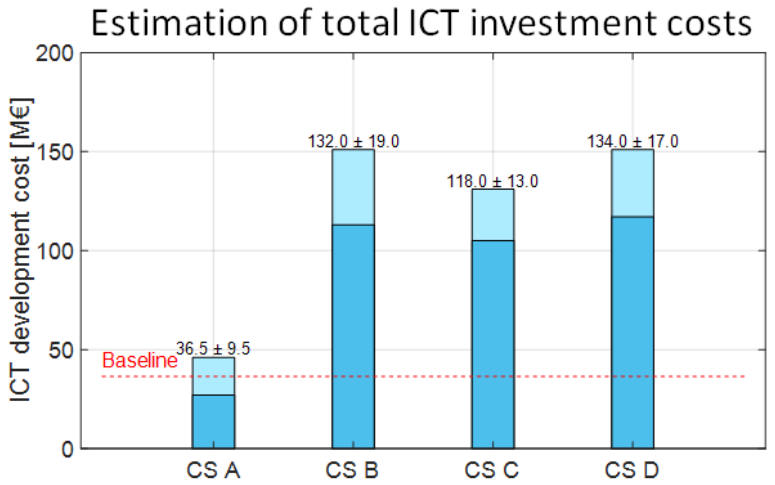
# Balancing market and aFRR (2/2)

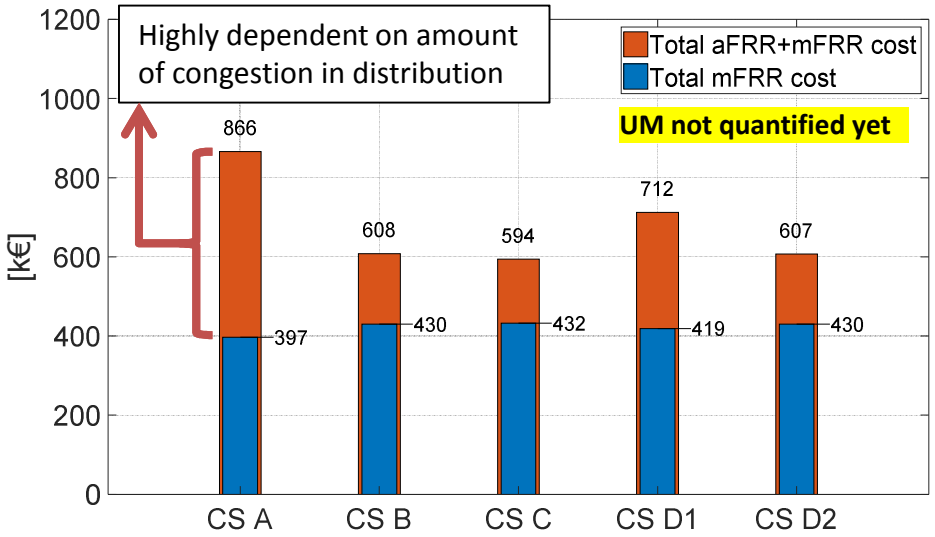
- aFRR volume already activated before T and not yet released
- Forecasted further aFRR volume activated to compensated imbalance between T and T+1
- Actual aFRR volume activated between T and T+1 (different from forecast due to forecast errors and CS imperfections in representing the system
- Volume of tertiary reserve activated by the AS market at T+1

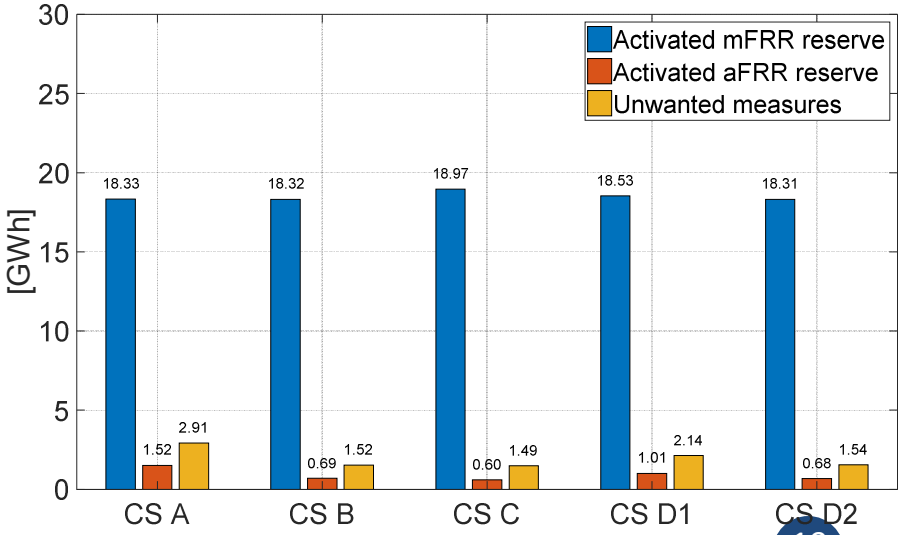


# Results for the Italian simulation scenario

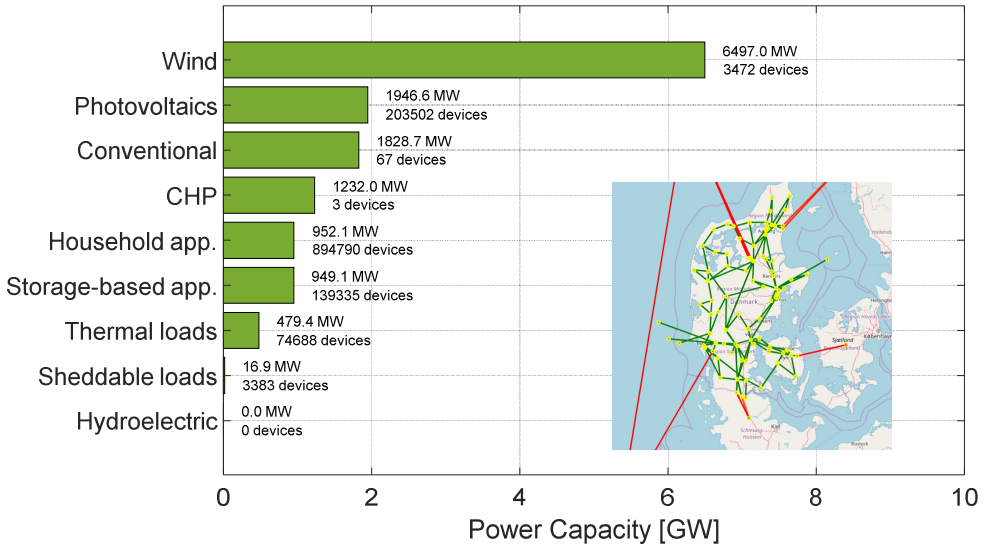


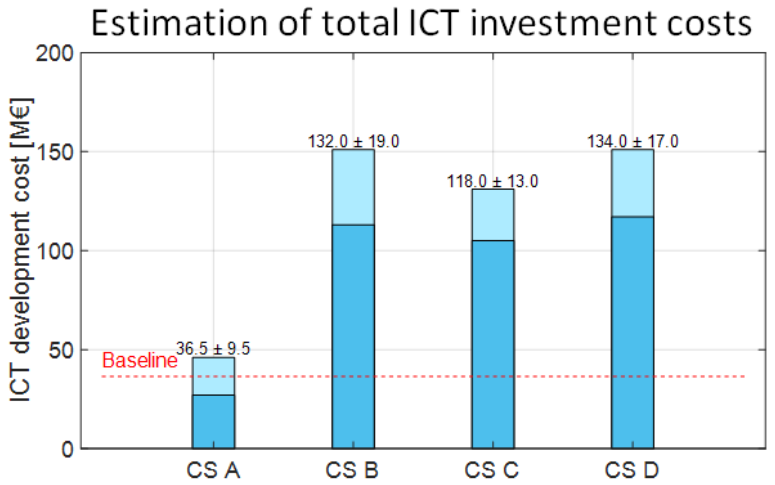



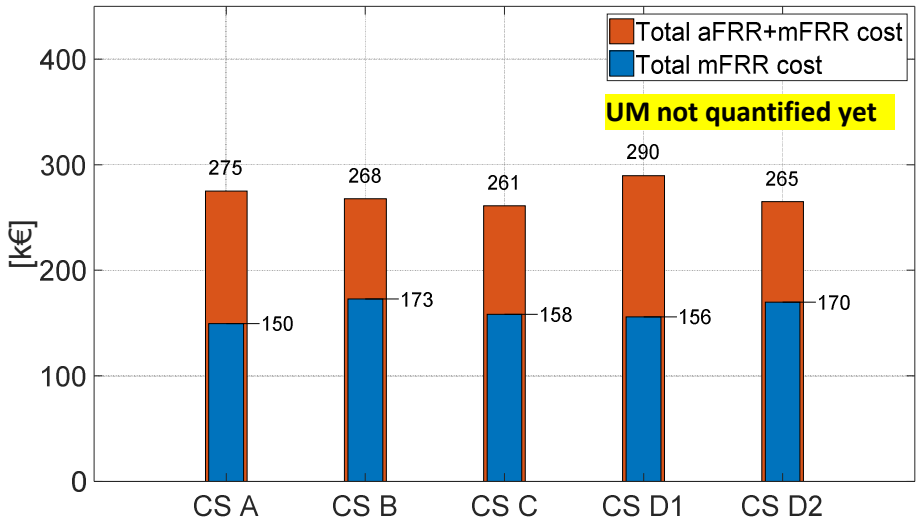



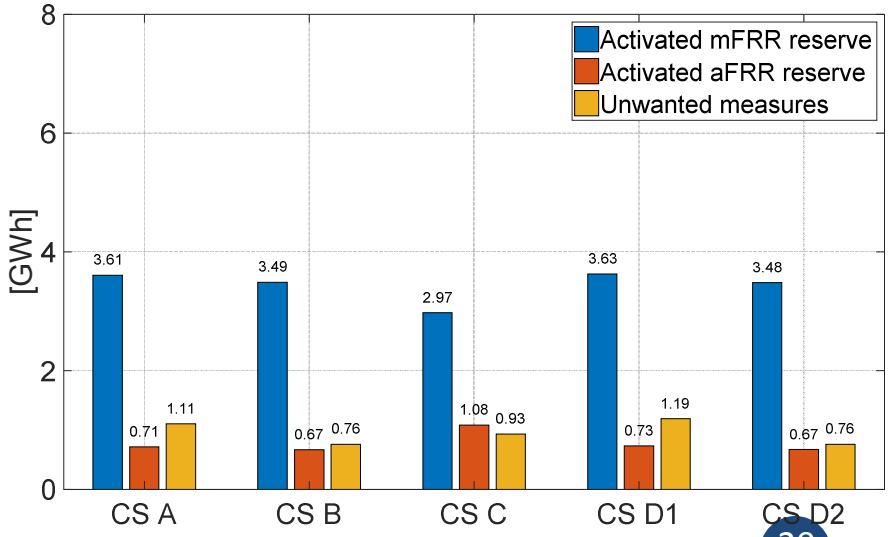



# Results for the Danish simulation scenario

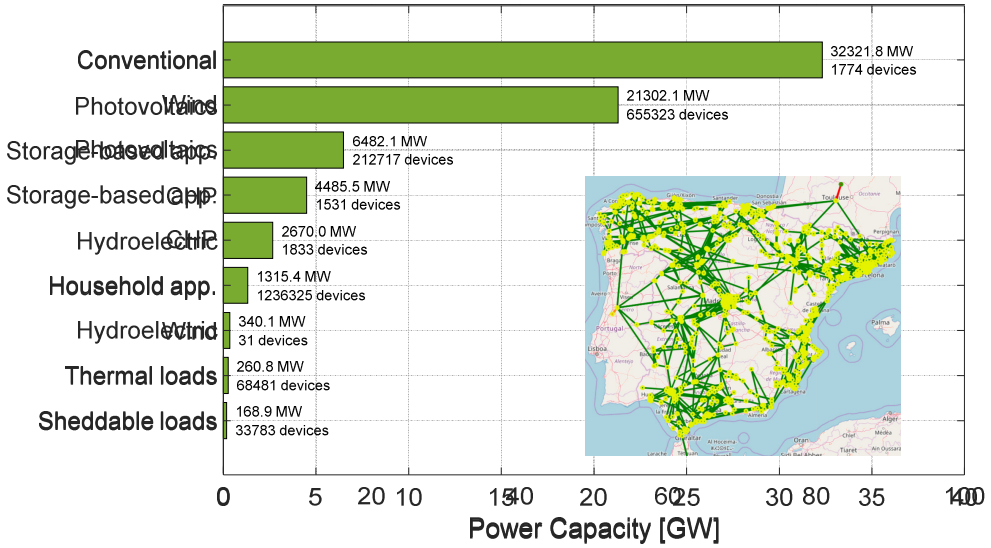


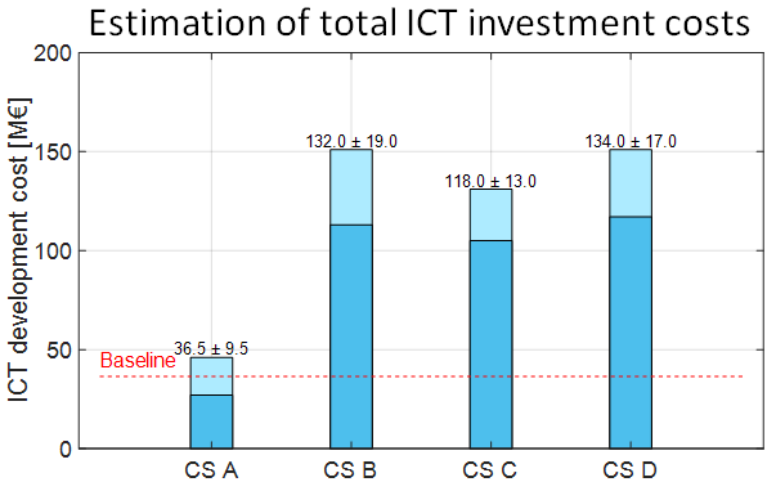



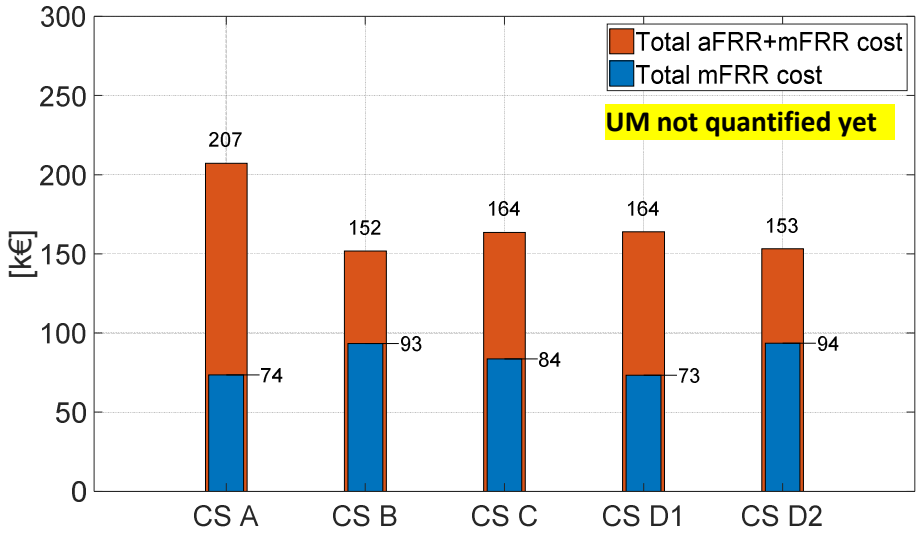



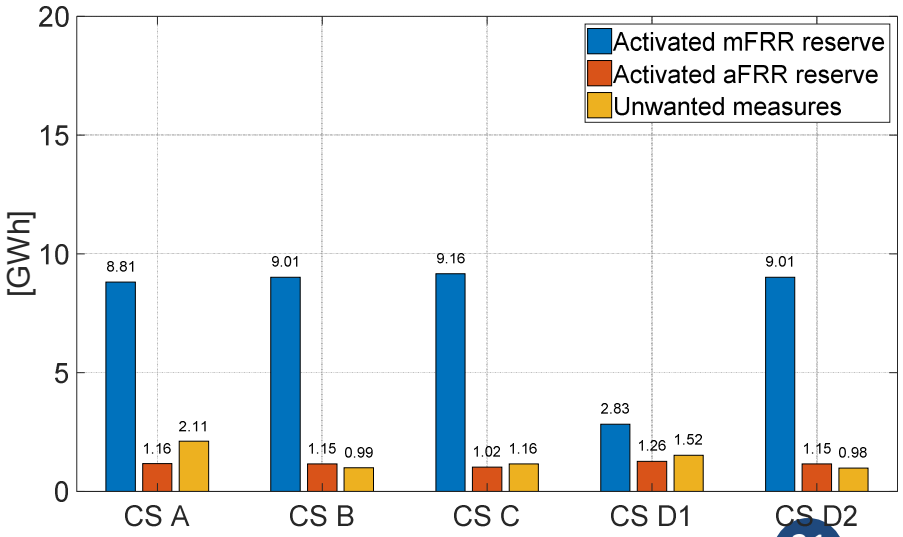



# Results for the Spanish simulation scenario

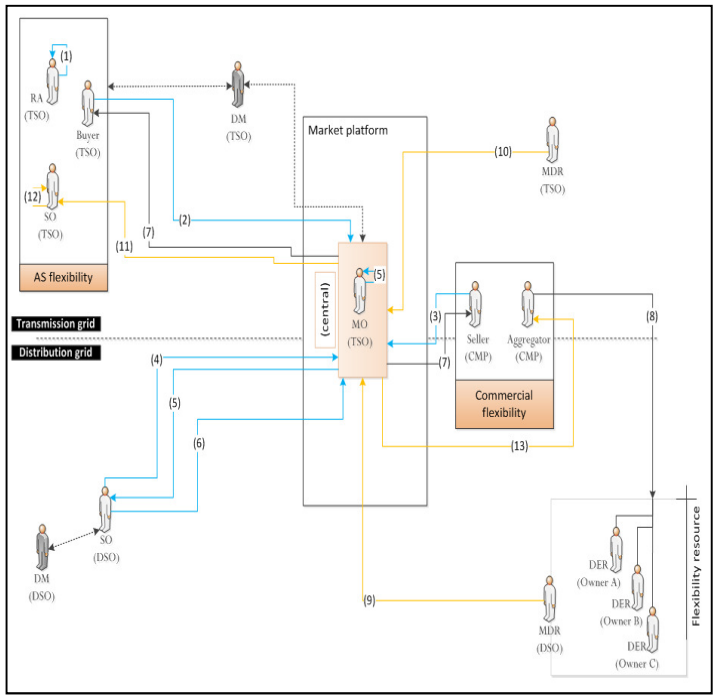


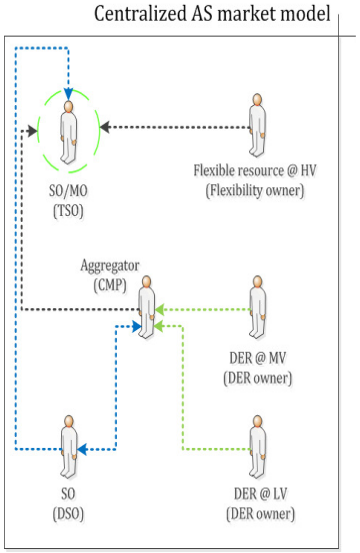



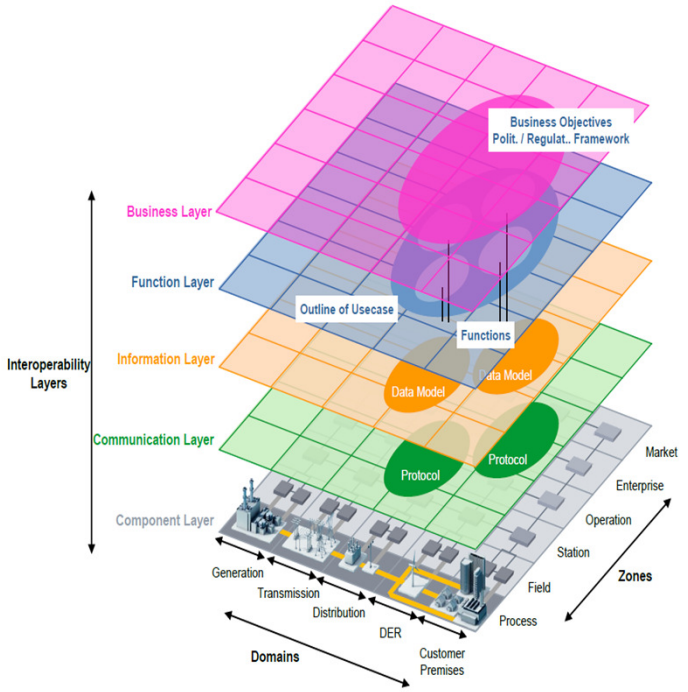
# Analysis of information flows for each CS



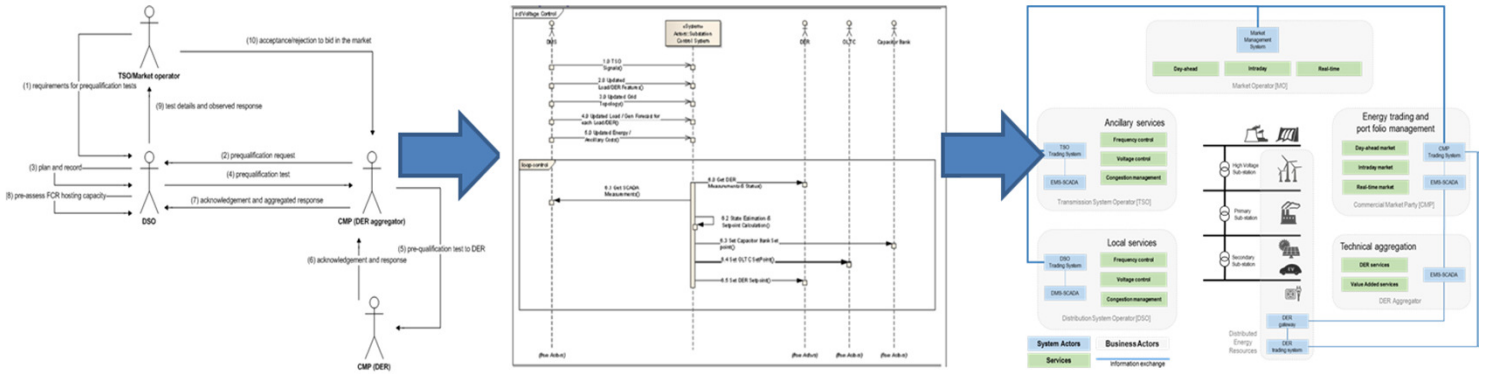




| | Steps (#) | Origin | Action | Recipient |
|---|---|---|---|---|
| Procurement | 1 | RA (TSO) | Determines volumes to be procured | |
| | 2 | Buyer (TSO) | Communicates volumes to | MO (TSO) |
| | 3 | Seller (CMP) | Sends aggregated bids (from transmission and distribution) to | MO (TSO) |
| | 4 | SO (DSO) (*) | Communicates distribution grid constraints to | MO (TSO) |
| | 5 | MO (TSO) | Clears market and communicates results to | SO (DSO) |
| | 6 | SO (DSO) (**) | Checks if local constraints allow for activation requested by TSO and blocks if needed – communication to MO and step 5 will be repeated | MO (TSO) |
| Activation | 7 | MO/FD (TSO) | Communicates results to (activation is simultaneous if no capacity is procured) | Buyer (TSO)<br>Seller (CMP) |
| | 8 | Aggregator/FD (CMP) | Activates units based on the selected bids | DER |
| Settlement | 9 | MDR (DSO) | Communicates measurements to | MO (TSO) |
| | 10 | MDR (TSO) | Communicates measurements to | MO (TSO) |
| | 11 | MO (TSO) | Communicates measurements to | SO (TSO) |
| | 12 | SO (TSO) | Corrects perimeter of BRPs affected by activation | |
| | 13 | MO (TSO) | Performs financial settlement of flexibility activation for resources connected at distribution and transmission grid | Aggregator (CMP) |

# ICT requirements: a SGAM analysis framework




- **Use Case Analysis:** to create an initial use case description.
- **Business Layer Design**: business processes, services, and organizations linked to the use case
- **Function Layer Design:** functions, derived from the initial use case description.
- **Component Layer Design:** components needed for use cases, assigned to domain and zone. Subsequently, to a corresponding hardware.
- **Information Layer Design:** information exchanged between functions, services, and components identified, by analysing the data exchanged between actors
- **Communication Layer Design:** suitable communication protocols and ICT techniques




Business and function layers

Information layer

Communication and component layers

# ICT needs and challenges for RT-markets coupling

The ENTSO-E NCEB provides for a phased approach to foster cooperation amongst TSOs in various areas of Balancing. The key concept of **Coordinated Balancing Areas**. As time passes, the level of cooperation within a Coordinated Balancing Area and between neighboring ones will increase; neighboring Coordinated Balancing Areas will merge; and finally all Coordinated Balancing Area s will merge to reach the **final target of a single pan-European Common Merit Order list**.

The e-BADGE project identified a few requirements of ICT technology suited for RT-coupling:

- **integrated among all the actors** participating in the trans-national market (TSOs, DSOs, market operators, aggregators, retailers, final users), each with his role ➔ **interoperability** is key, the HW stretching from large central servers up to smart meters of residential users.
- Able to ensure **computability** in a limited amount of time. This may put strong limitations both to algorithms and to the SW/HW requirements
- Conceived in a **modular** way that ensures **scalability** with a ever-increasing huge number of connected players, asynchronous distributed transactions, etc (relatively low performance requirements but with high distributed data storage capability)
- Able to **reconfigure** themselves fast to respond to requests in real time
- Algorithms **robust** whatever are the market conditions; **reliability** of components, also by means of components redundancy
- **Secure** and protected against cyber-attacks (use of dedicated network, firewalls allowing only communications between enabled subjects).

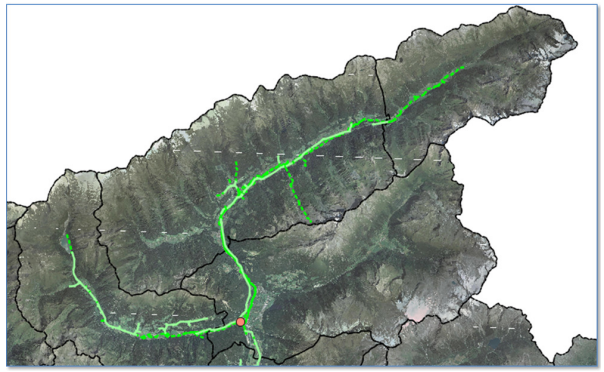
BADGE

# The Italian Pilot A

**Observability (20s)** at primary substation

**Voltage regulation (4 s)** with generators in HV and MV sections

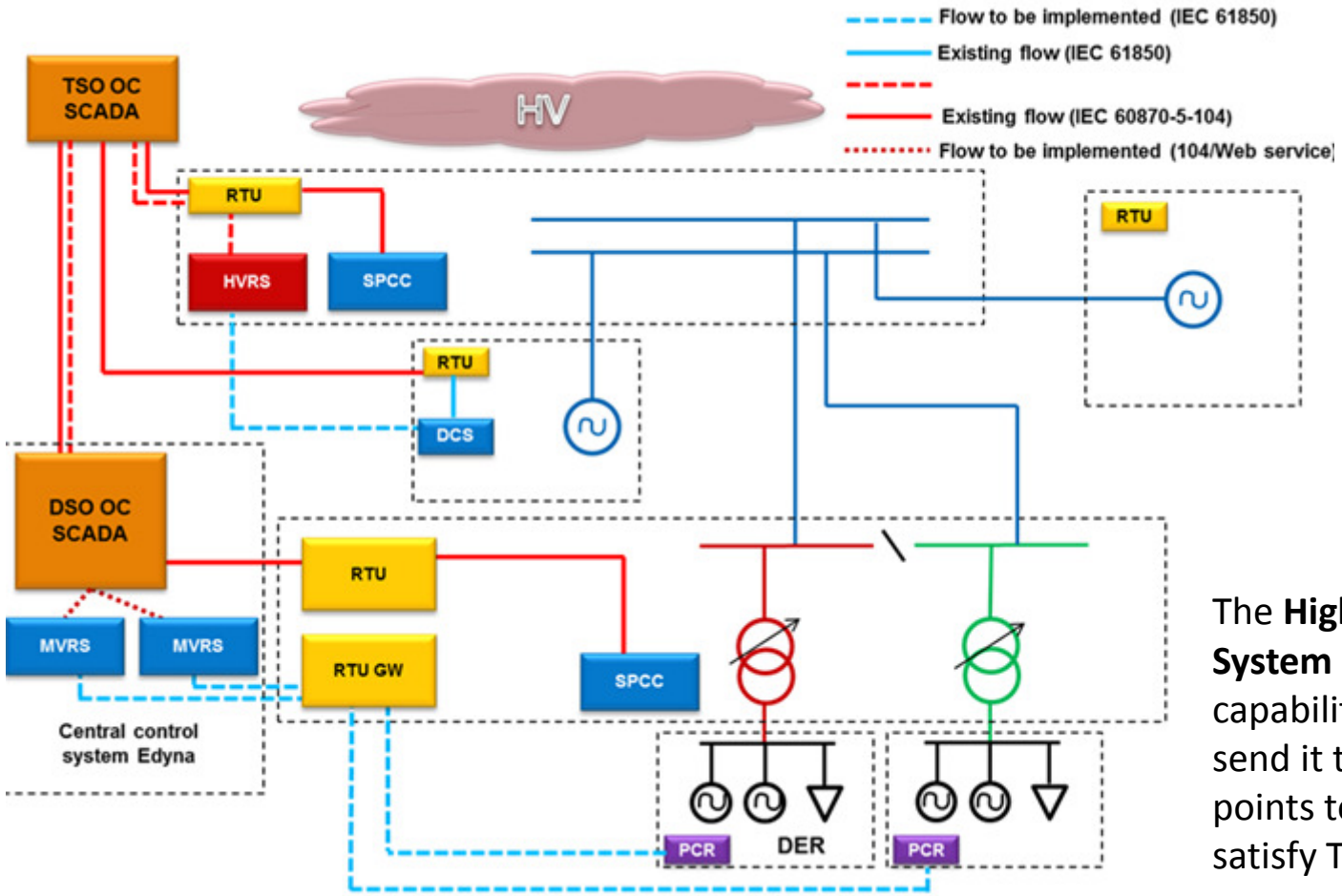
**Power-frequency regulation & balancing (4s)** with MV generators



- The pilot is located in Ahrntal, characterized by
  - a long “antenna” distribution network with little load
  - many hydroelectric plants connected to different voltage levels
  - the significant number of installations at MV and LV grid leads often to reverse flow (summer peak > 30MW)
- **HV part of the pilot**: two hydroelectric plants Molini and Lappago (20MW each) both connected to the same HV substation (Molini di Tures)
- **MV part of the project**: the project involves the MV grid powered by the primary substation “Molini di Tures” of DSO; 23 connected producers, with an installed power of 29 MW (27.7 run-of-river hydro power, 1.5 biomass, 0.2 PV), and 5 local DSOs characterized by a small number of customers fed by one or more hydro power plants.

# Pilot A: monitoring and control

**It implements an «intelligent» version of CS_A by additionally estimating the virtual capability at the TSO/DSO interconnection point**

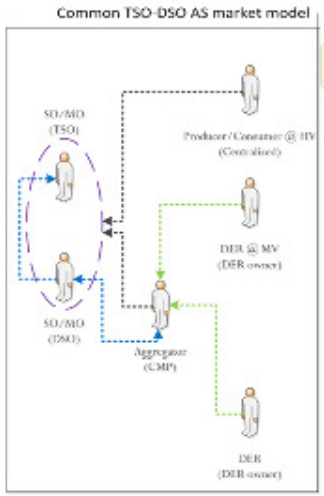



**The Medium Voltage Regulation System (MVRS)** aggregates active and reactive power, differentiated according to the type of energy source, calculates the virtual capability at the TSO/DSO interconnection point in order to define the active and reactive availability of the MV resources and sends set point variations in order to actuate TSO command

The **Plant Central Regulators (PCR)** represents the most peripheral device in the communication chain between the TSO and the plant. It makes available the functions of reactive power modulation and active power modulation.

The **High Voltage Regulation System (HVRS)** calculates reactive capability of the generators and send it to the TSO; then sends set points to generators in order to satisfy TSO command (reactive power or voltage set point)

# Pilot B: Ancillary services from indoor swimming pools




Receive Grid Load

Market Management System

Day-ahead | Intraday | Real-time

MO

Receive bids

Activate bids

Calculate residual capacity

Clear market

Energy Trading

Day-ahead market

Intraday market

Real-time market

CMP

CMP Trading System

EMS-SCADA

Ancillary services

TSO Trading System

Frequency control

Congestion management

Voltage control

EMS-SCADA

TSO

High Voltage Substation

Primary Substation

Secondary Substation

Send price signal incl. forecast

Technical aggregation

DER services

Value-added services

EMS-SCADA

DER aggregator

Ancillary services

DSO Trading System

Local Frequency control

DMS-SCADA

Local Voltage control

Congestion management

DSO

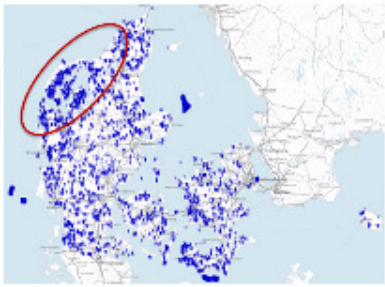
DER gateway

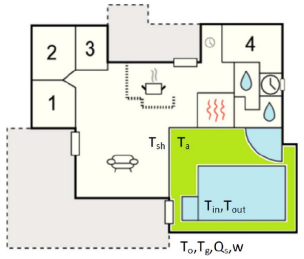
DER trading system

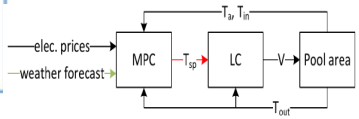
DER

Measurements

Setpoint





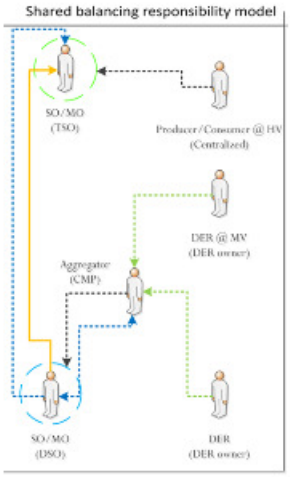




**Congestion management**
to better integrate PV, EV and HP

**Price-based control**
of thermal controllers of swimming pools in summer houses

**Balancing**
of wind power with decreasing contribution of thermal units

# Pilot C: Ancillary services from radio-base stations




REGULATED MARKET

NON-REGULATED MARKET

TSO

Balancing

Scheduled profile

Simulated

Smart Houses

EVs (V2G)

PV/ Wind plants

ESCOs

Other flexibility aggregators

DSO

DSO Flexibility manager

Monitoring (metering data)

Congestion management

Demand response

Aggregator

DR optimisation

Vodafone Network

endesa

Point of delivery connection

Narrowband IoT technology

Vodafone

20 base stations

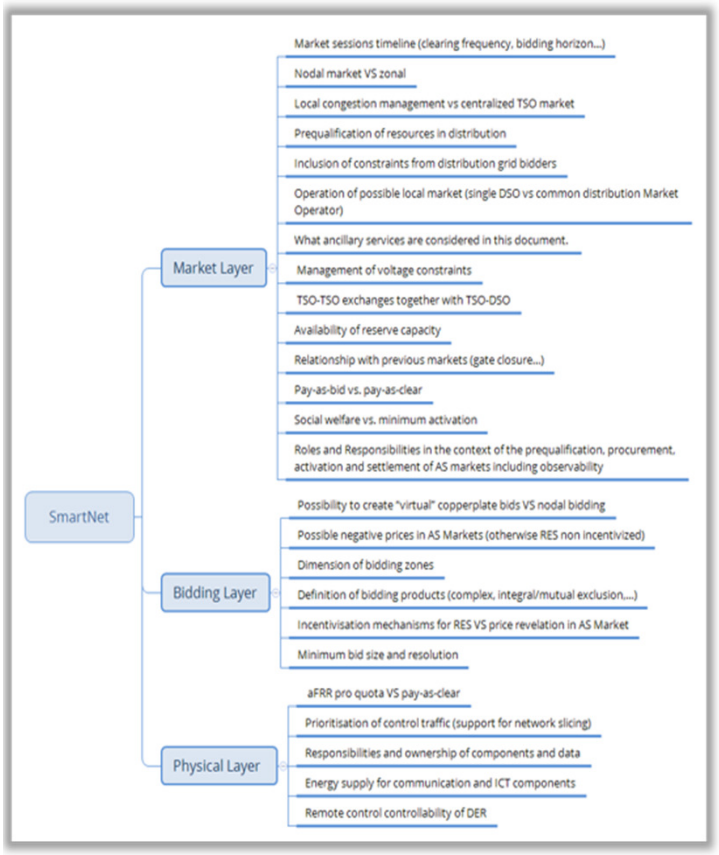
MID-approved Sub-meters

**Congestion management** at DSO level

**Demand Response Aggregation** by using storage flexibility (BS and EV)

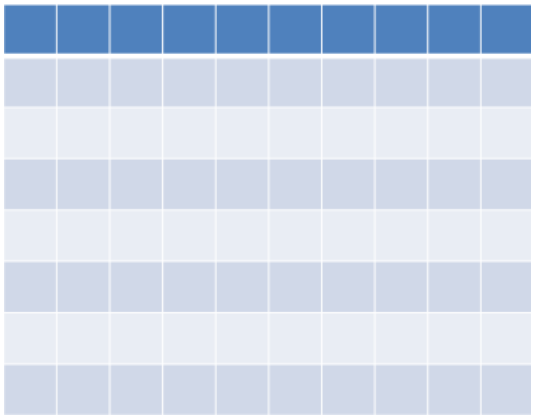
**Power-frequency regulation / balancing** by respecting the exchange program at the TSO-DSO interconnection

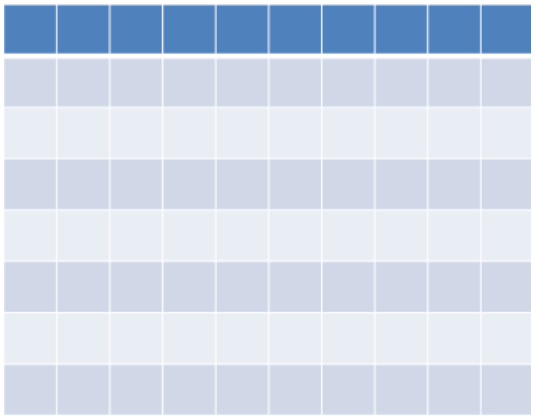
# Regulatory Analysis: work structure




**40+ regulatory documents and position papers (EU, I, DK, ES)**

**lessons learned from project activities**





Deliverable D6.2

Deliverable D6.1

Regulatory guidelines (deliverable D6.3)

# Some preliminary regulatory reflections

- If the contribution from entities in distribution will grow, DSOs should **implement real time network monitoring** and TSOs could need to **share with DSOs part of responsibility** for the provision of AS.
- Whatever coordination scheme is implemented, it is important that that actions taken by the **TSO and DSO don't cause counteracting effects** (e.g. between local congestion management and balancing) – see CEER Position Paper on Future DSO-TSO Relationship
- between the different AS markets, "**common marketplace**" (see ENTSO-E working paper on Distributed Flexibility and the value of TSO/DSO cooperation) is preferable in order to avoid duplicating bids and avoiding double activations.
- before implementing a separate market for a given AS, it should be attentively considered if it can be **sufficiently liquid** (e.g. local congestion management in distribution).
- restructuring national AS markets should take into account possibility of a **seamless integration with preceding energy markets** (DAM, ID) so as to avoid providing gaming opportunities (e.g. between non-nodal energy markets and nodal AS market)
- new AS architectures should **integrate with on-going transnational integration process** (ENTSO-E platforms): sharing reserve between Countries is a key for allowing further RES integration.
- a **balance** has to be sought for between local optimality (e.g. for a given Country) and the implementation of a harmonized pan-European design.
- **smaller DSOs have to integrate their efforts** in order to be fit for the new responsibilities.
- **real-time market architectures** must take into account the characteristics/constraints of the potential flexibility providers connected to distribution grids
- **aggregators** must be able to provide a simplified interface towards the market, hiding details of flexibility providers, and deliver efficient price signals to incentivize participation from distribution.
- **viable business models** must be available for all market participants, including DERs, aggregators and other customers.
- **network planning** will also have to facilitate better utilization of RES exploiting flexibility.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# Thank You


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