



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

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Participation of Distributed Generation & Small Customers to Ancillary Services

Case study: the SmartNet project

Diana Moneta (RSE)



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Agenda

- Provision of ancillary services from distribution grids: interaction between TSO and DSO
- Schemes of interaction: the **SmartNet** Project
  - Market architecture design
  - Aggregation process
  - The simulation platform
  - The three technological pilots
  - Improved TSO-DSO data exchange through specific ICT architectures
- Some (preliminary) regulatory remarks

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 the distribution-transmission border to guarantee observability and control
Which implications on the on-going market coupling process	

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, demand response, and aggregators. Distribution system operators shall exchange all necessary information and coordinate with transmission system operators in order to ensure the optimal utilisation of resources, ensure the secure and efficient operation of the system and facilitate market development.

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

Example: Italy

Review of the AS and Balancing markets

Resources enabled to AS market (MSD)

Production		Consumption
Relevant (>10 MVA)	Not Relevant	
Programmable	Not Programmable	
✓	✗	✗

Act 300/17 (May 2017) reform of the AS market:

UVA (virtual aggregated unit)

P: production

C: consumption (loads)

N: nodal

M: mixed

Production (ESS included)		Mixed	Consumption
Relevant	Not Relevant		
Programmable	Not Programmable		
✓ (UVAN)	✓ (UVAN)	✓ (UVAP, UVAN)	✓ (UVAC)

The SmartNet project

<http://SmartNet-Project.eu>



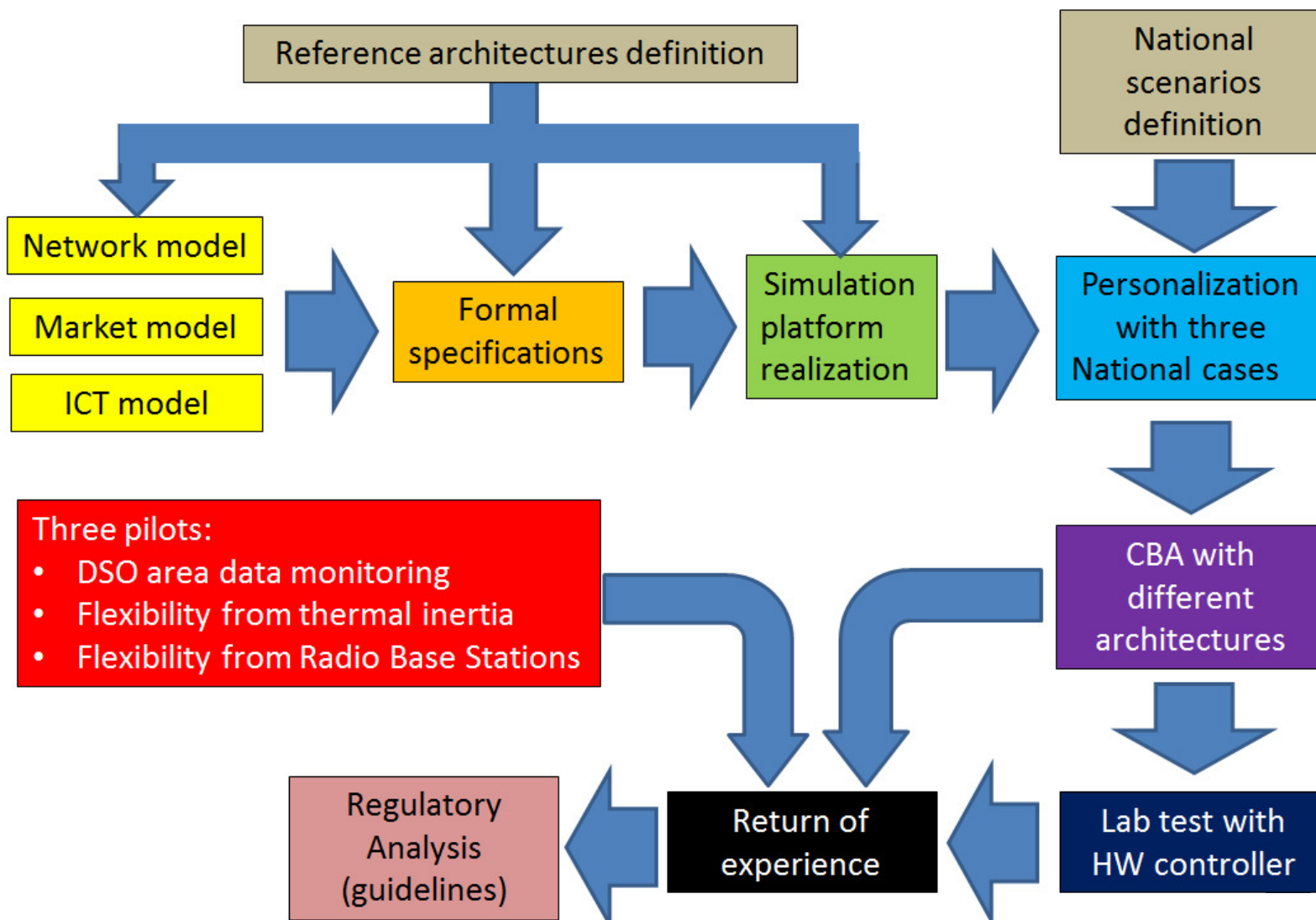
- **architectures for optimized interaction between TSOs and DSOs** in managing the purchase of ancillary services from subjects located in distribution.
- **three national cases** (Italy, Denmark, Spain);
- ***ad hoc* simulation platform** (physical network, market and ICT)
- **CBA** to assess which 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** are also developed to demonstrate capability to monitoring and control distribution by the TSO and flexibility services that can be offered by distribution (thermal inertia of indoor swimming pools, distributed storage of radio-base stations).



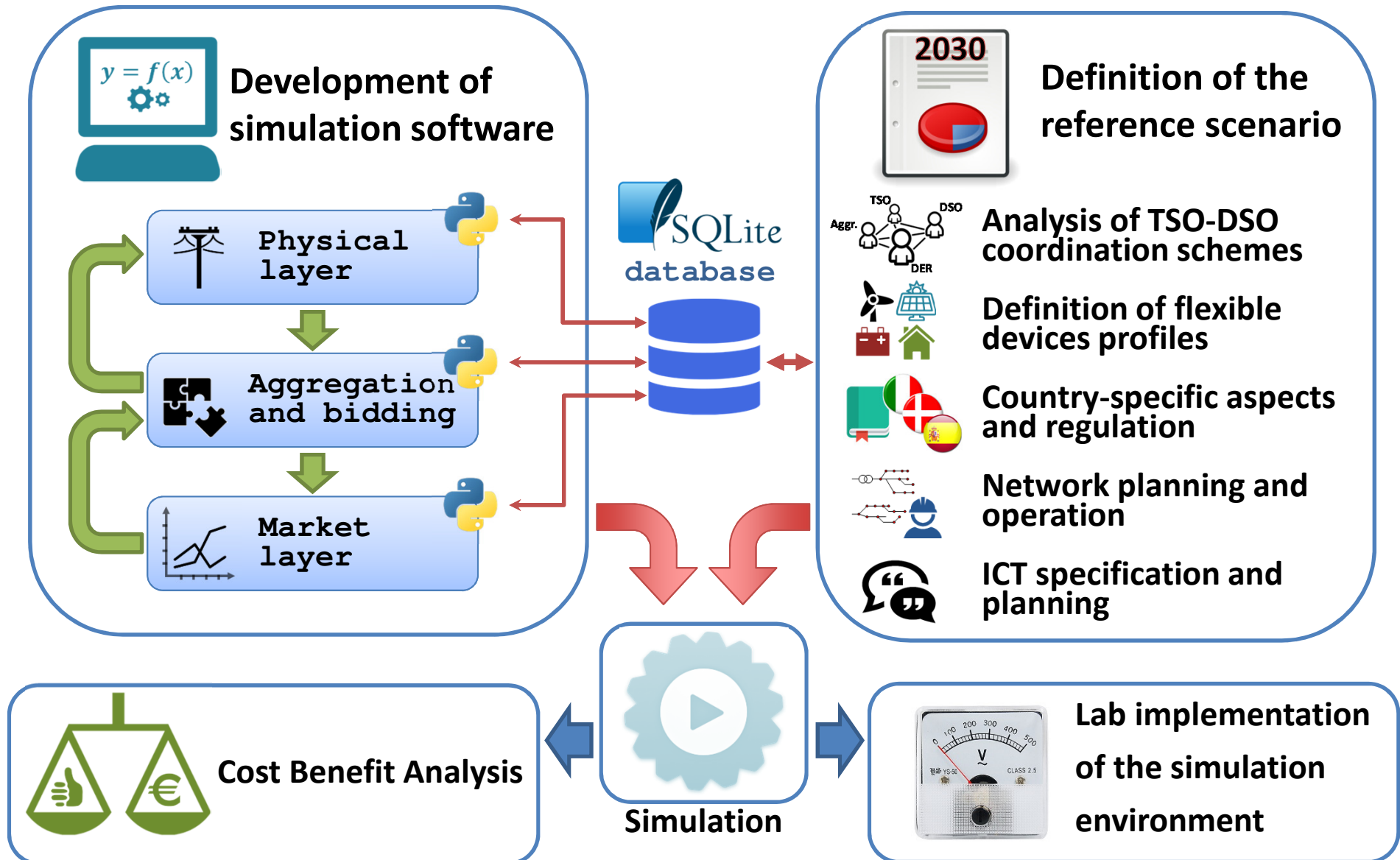
Project video:

<https://vimeo.com/220969294/73d98edde6>

Overall project layout

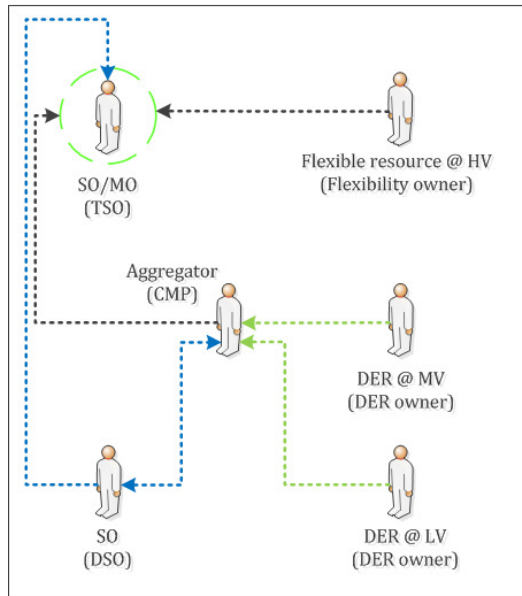


Comparison of the national cases in a simulation environment and laboratory testing



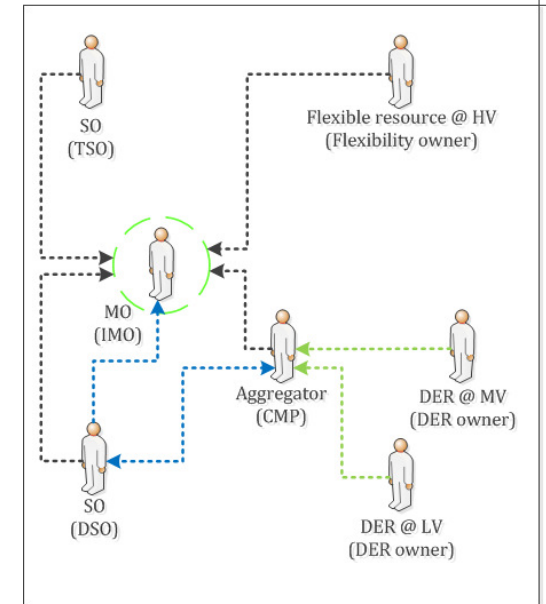
TSO-DSO coordination schemes

Centralized AS market model

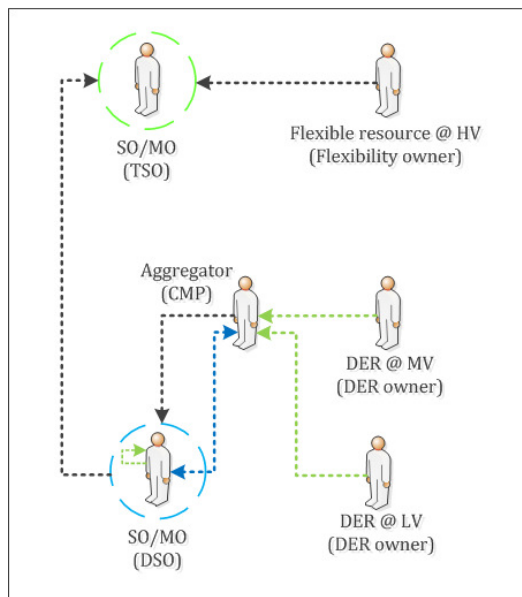


5 possible coordination schemes TSOs & DSOs for AS by distributed flexibility resources

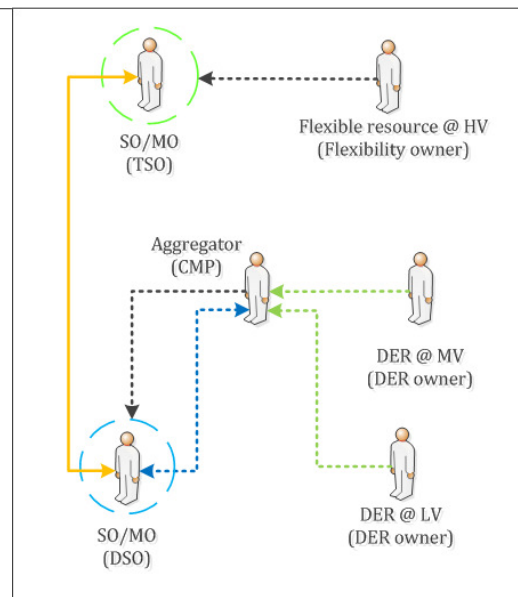
- Centralized AS market model
- Local AS market model
- Shared balancing responsibility model
- Common TSO-DSO AS market model
- Integrated flexibility market model



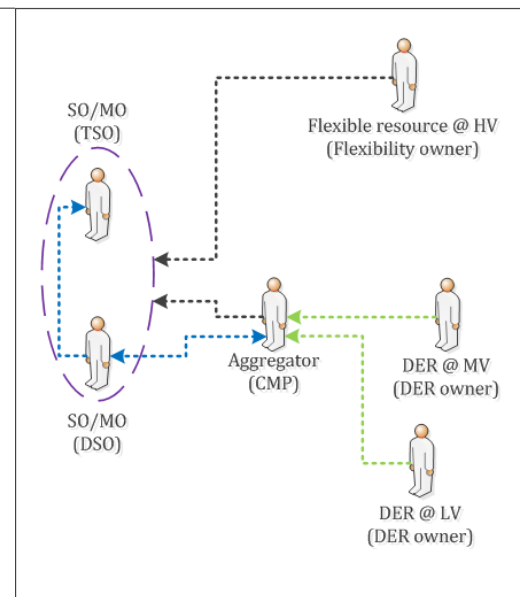
Local AS market model



Shared balancing responsibility model



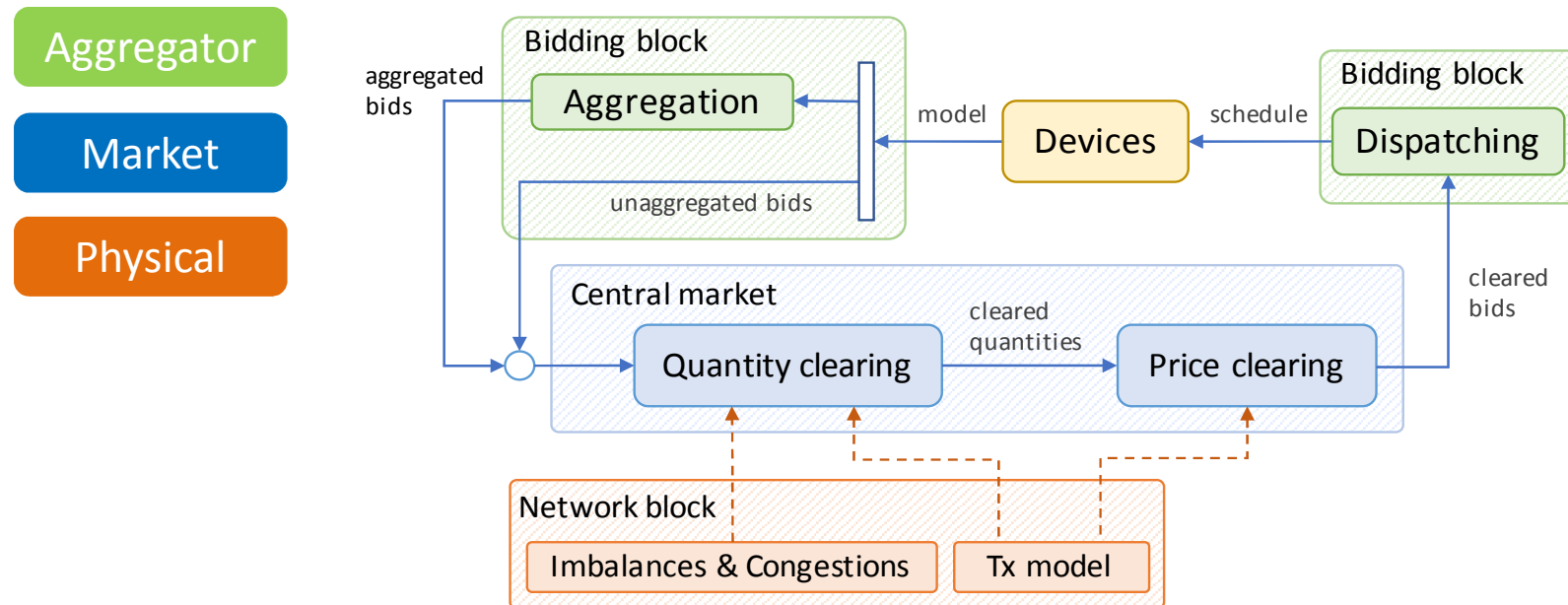
Common TSO-DSO AS market model



Legend

Role (Actor)	
Centralized market	
Local market	
Coordinated market	
Pre-defined profile exchange	
Aggregation	
Market bids	
Pre-qualification	

Centralized AS market model



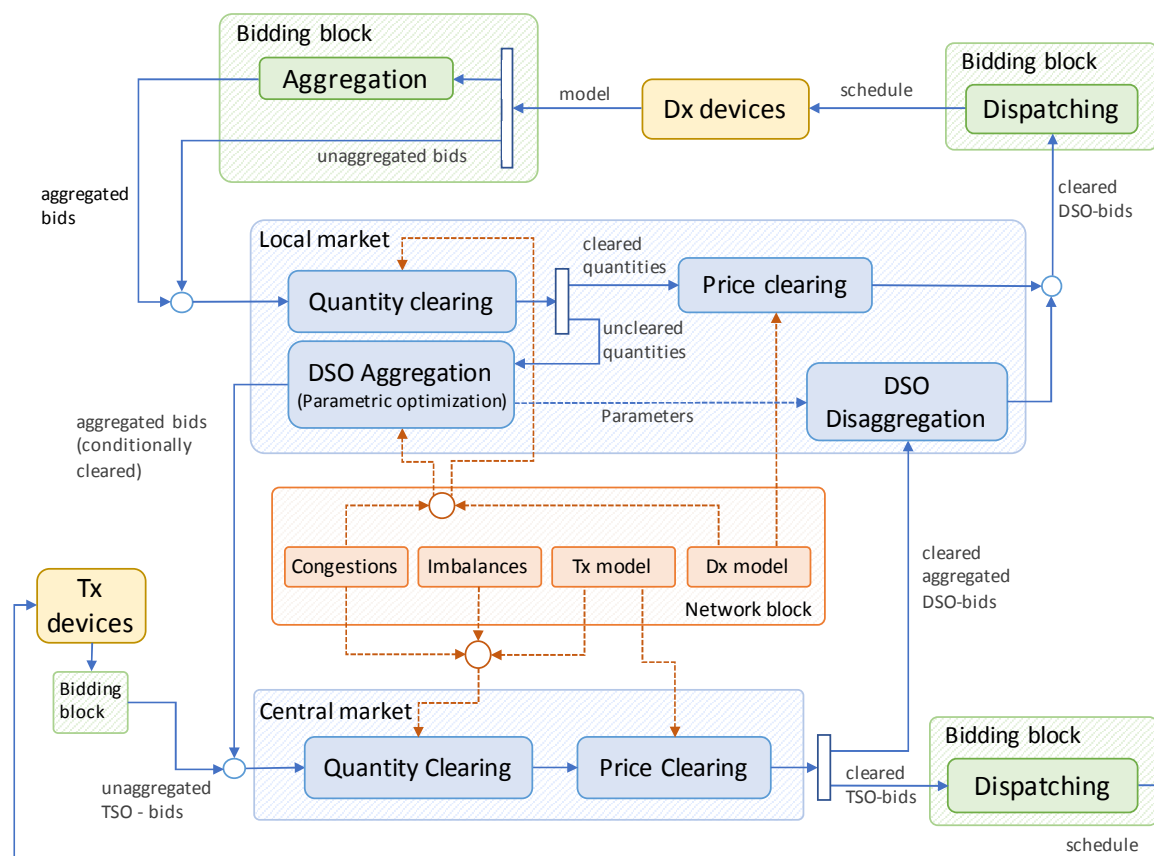
Benefits

- Aggregation could use resources from different DSO-areas.
- Few communication between system operators needed
- One central market can function at low operational costs

Attention points

- DSO grid constraints not included
- DSOs do not benefit from possible advantages of the use of flexibilities

Local AS market model



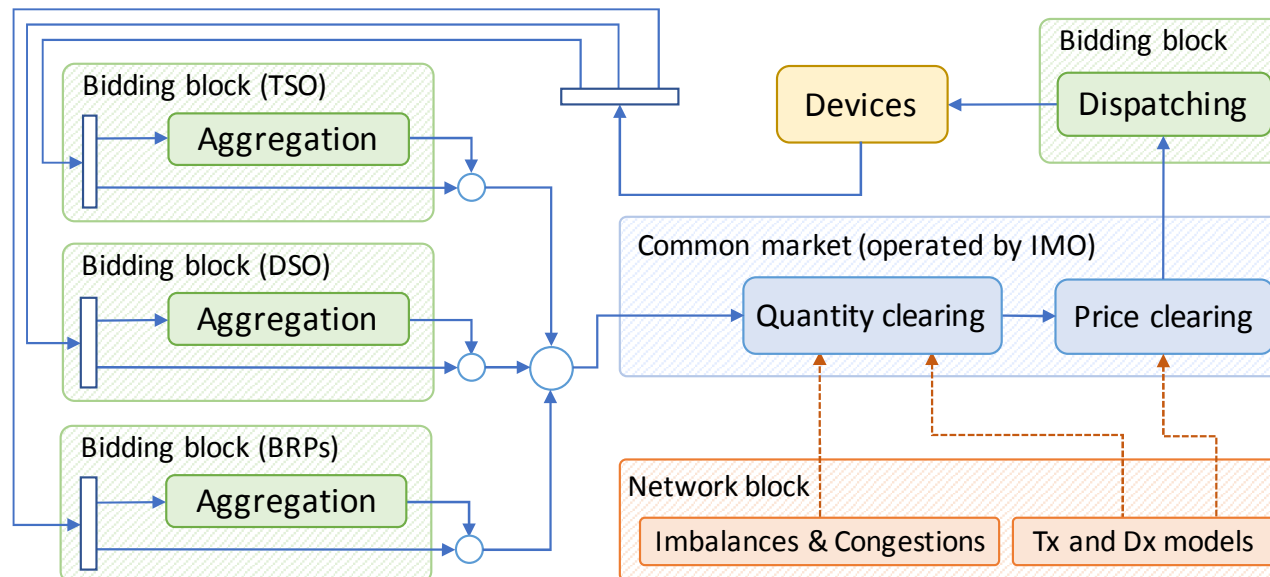
Benefits

- DSO grid constraints included
- Nodal detail of transmission network

Attention points

- Complex market architecture, which can result in higher costs
- Risk of non liquid markets

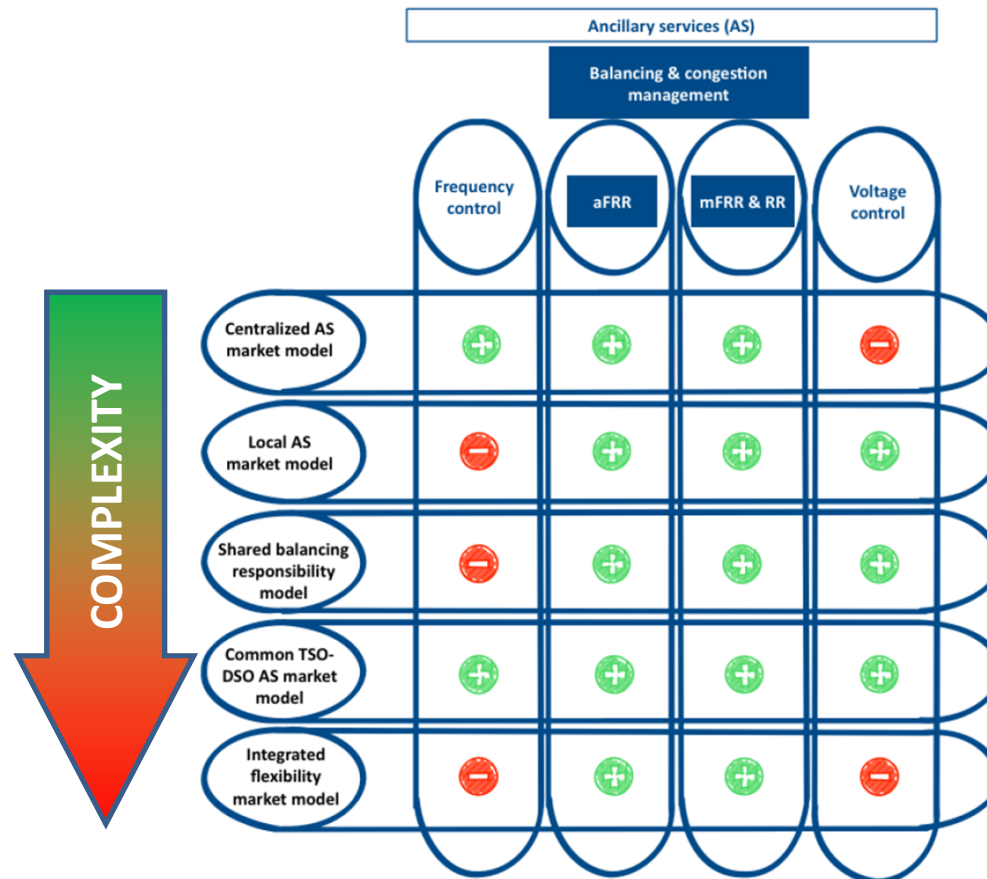
Integrated flexibility market



! Deliverable 2.3
! Deliverable 2.4

Benefits	Attention points
▪ All constraints included ▪ Most efficient solution in theory	▪ Very complex market ▪ Numerical unfeasibility

Application of coordination schemes

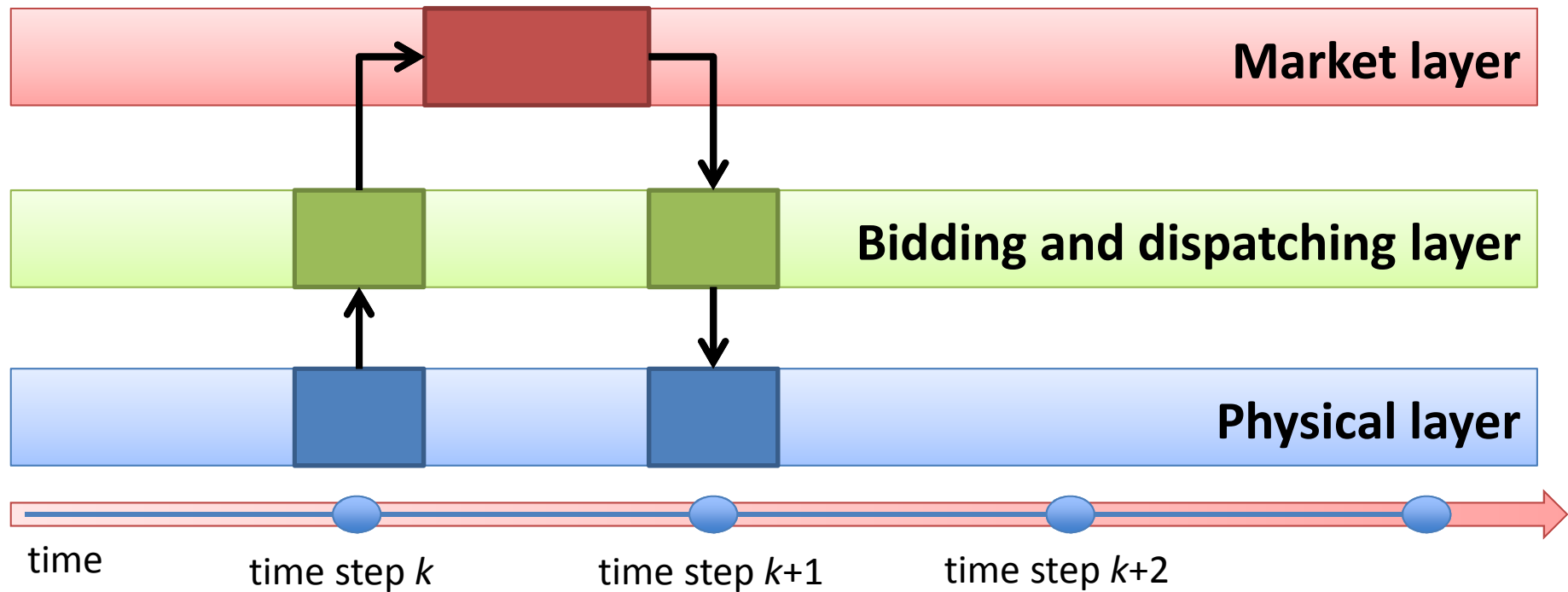


From these analyses it is already possible to draw a big picture of the *pro* and *cons* of each coordination scheme and their application on different services



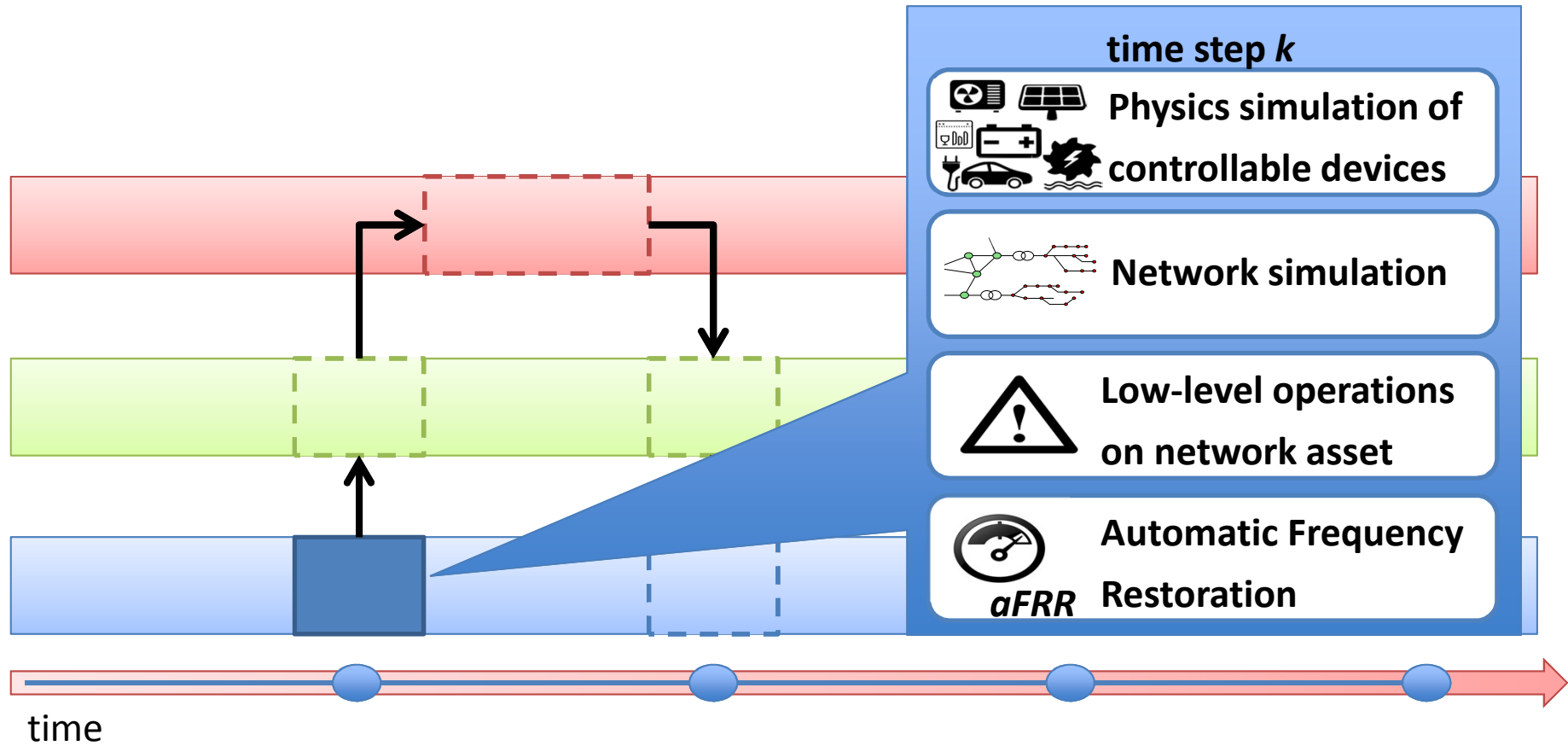
How the simulator works

Simulation based on three layers





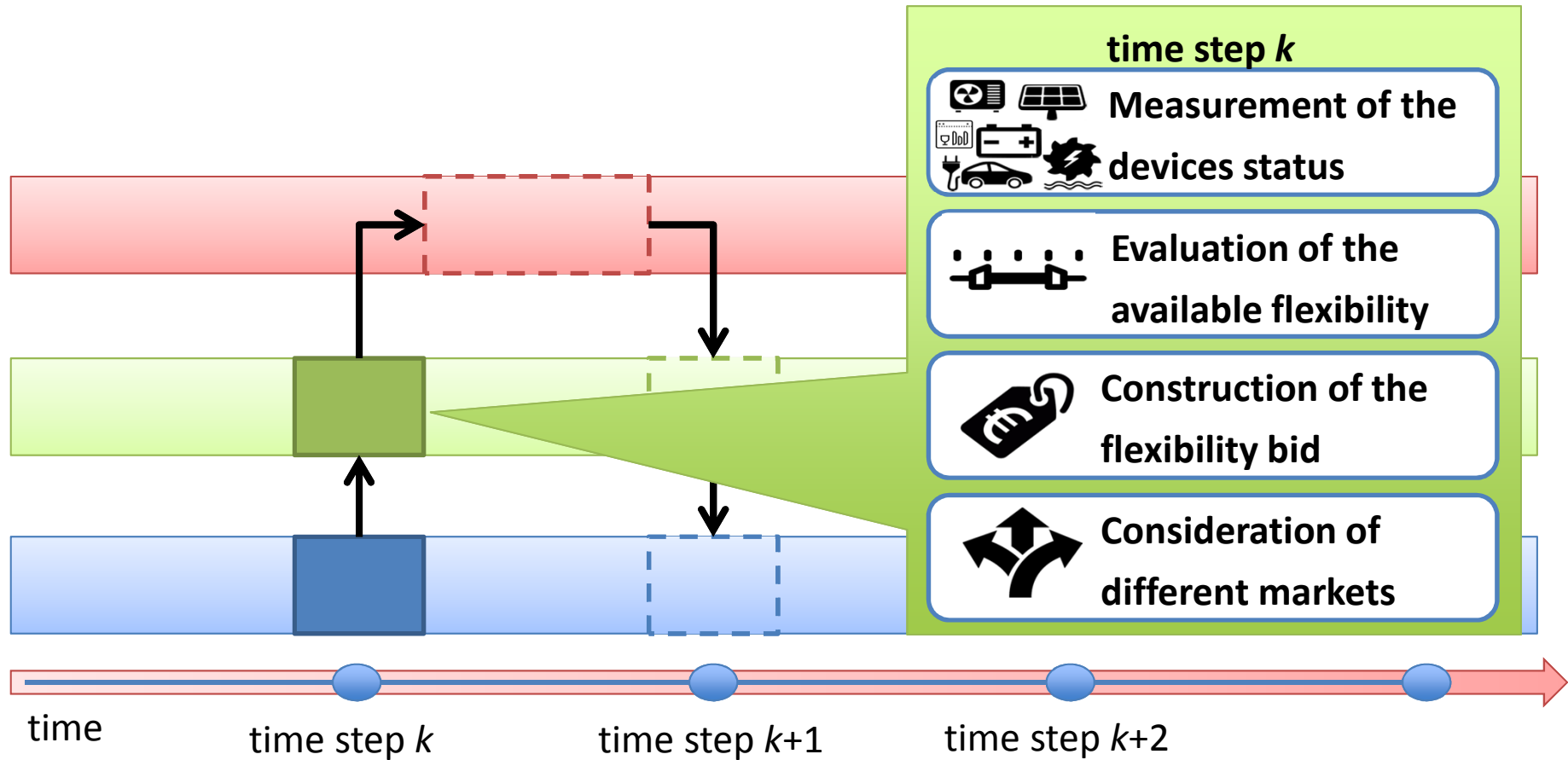
How the simulator works





How the simulator works

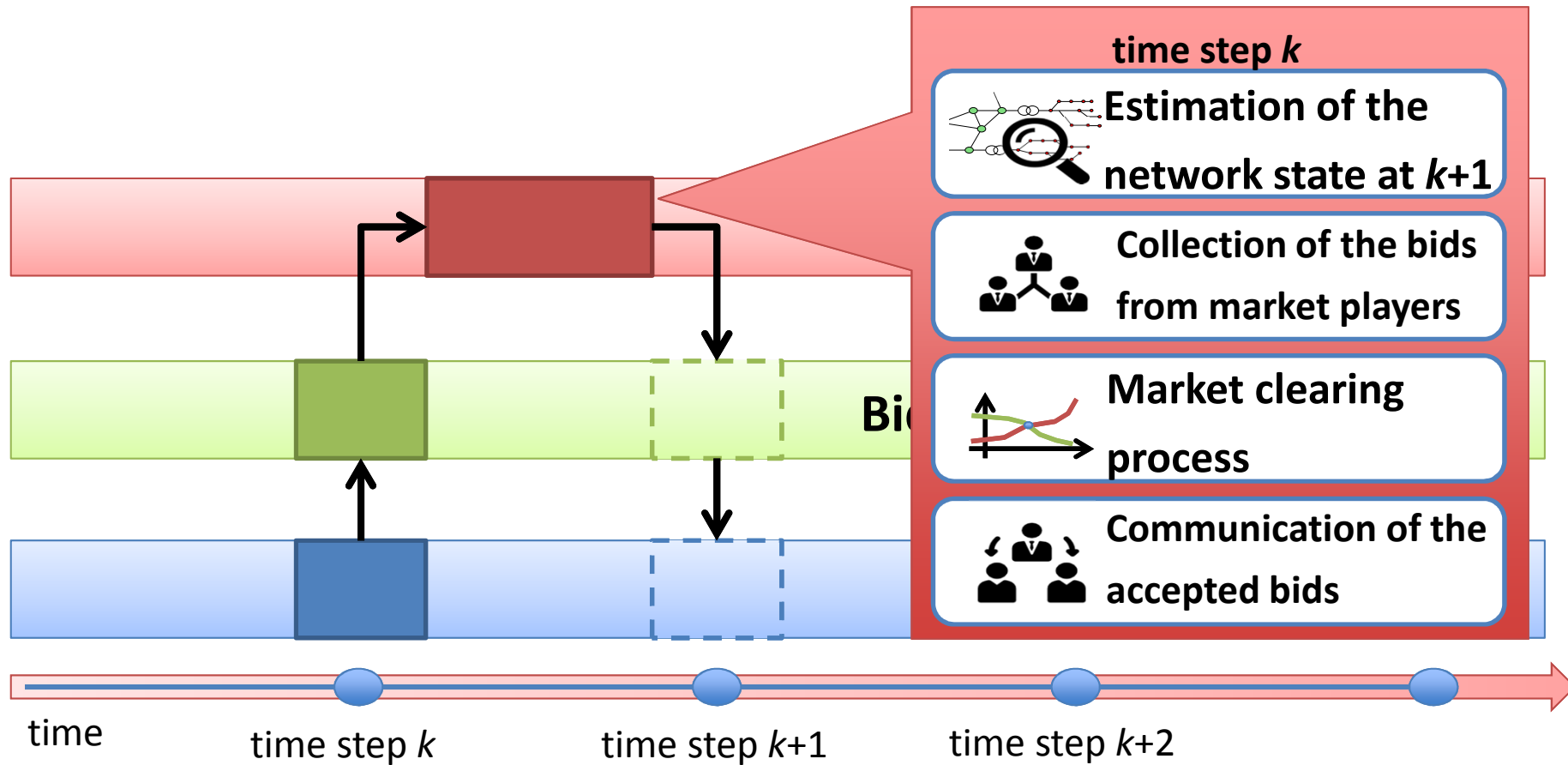
How the bidding process is simulated





How the simulator works

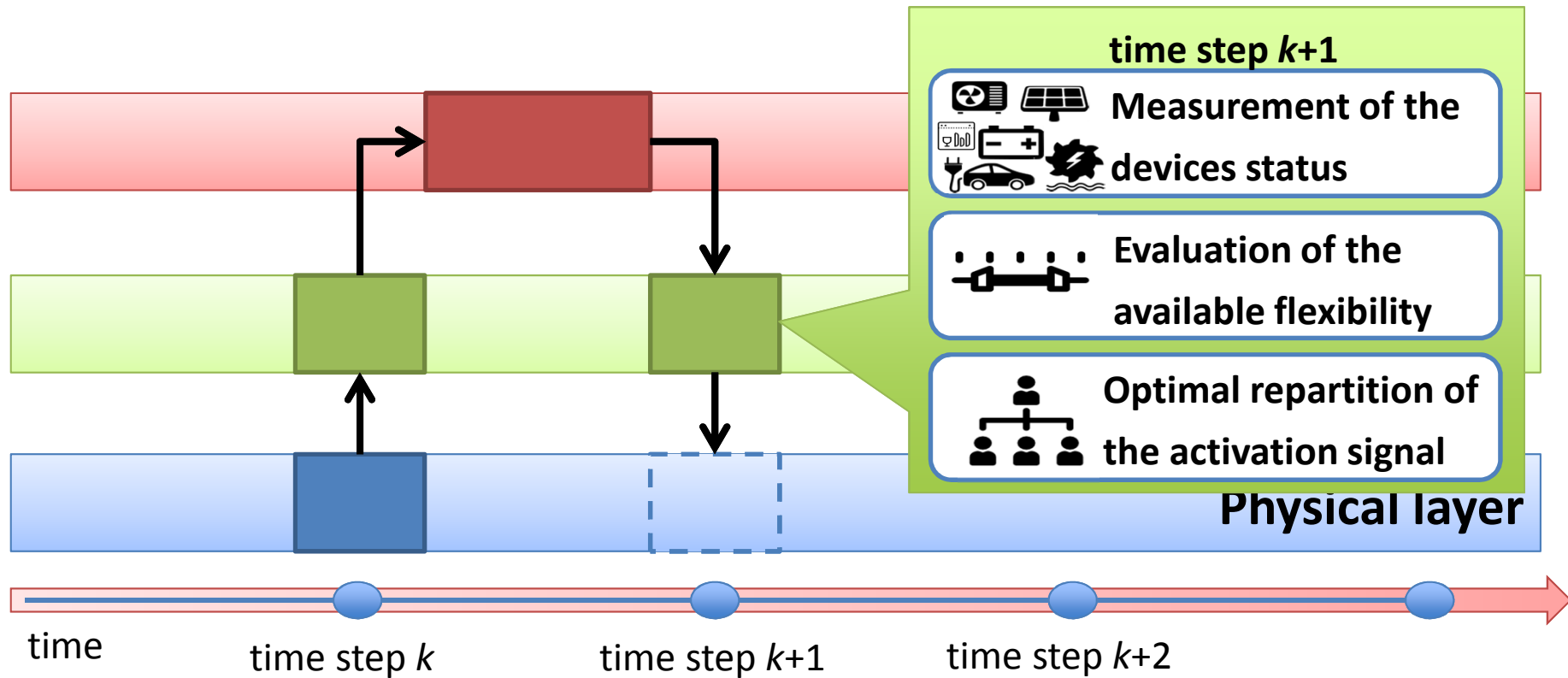
How the market process is simulated





How the simulator works

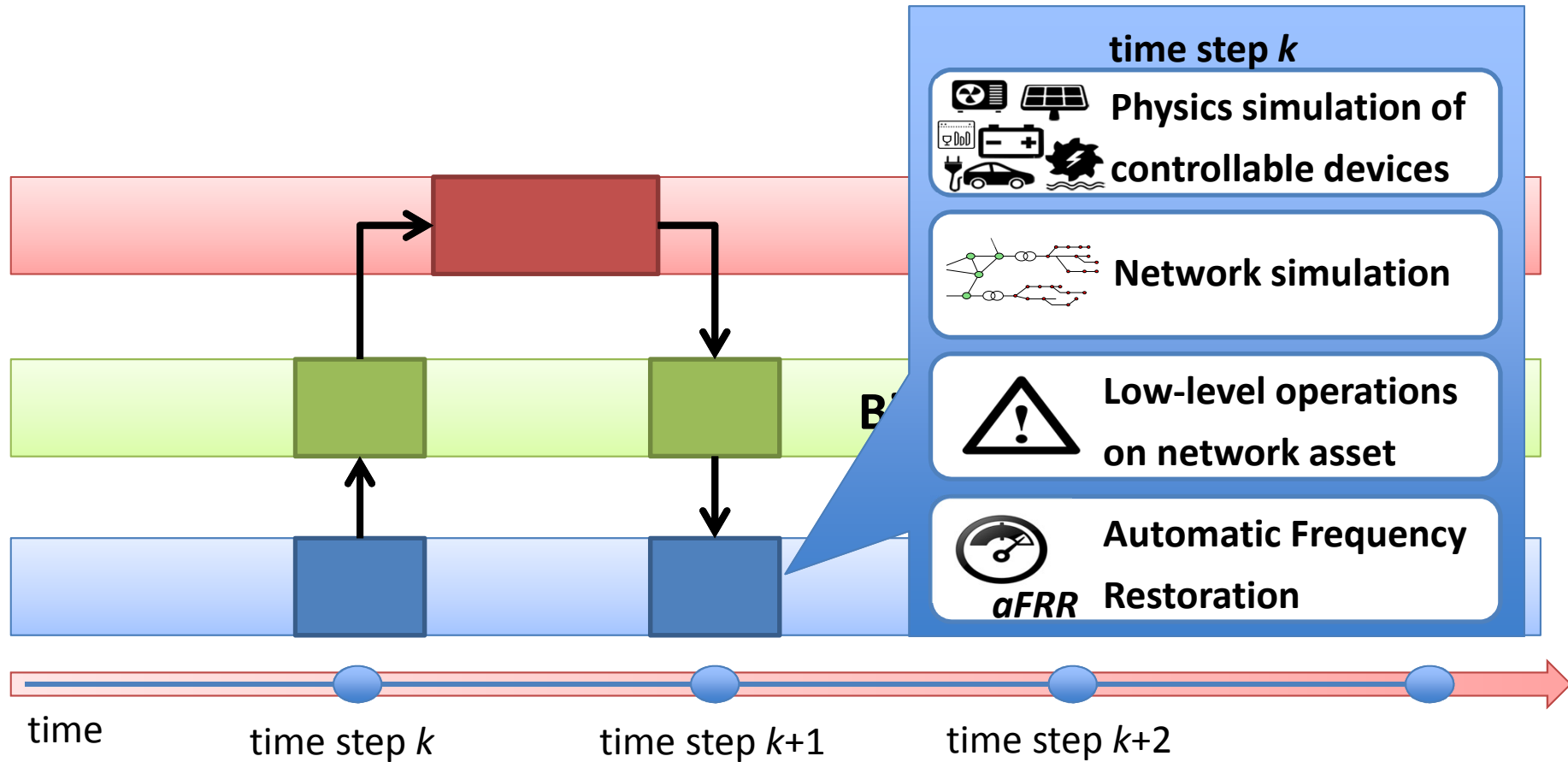
How the dispatching process is simulated

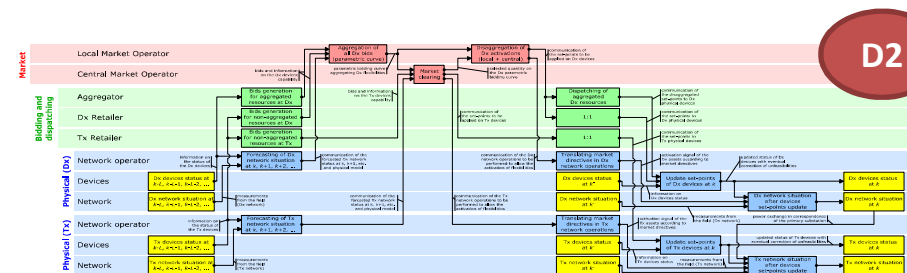




How the simulator works

How the physical layer is simulated



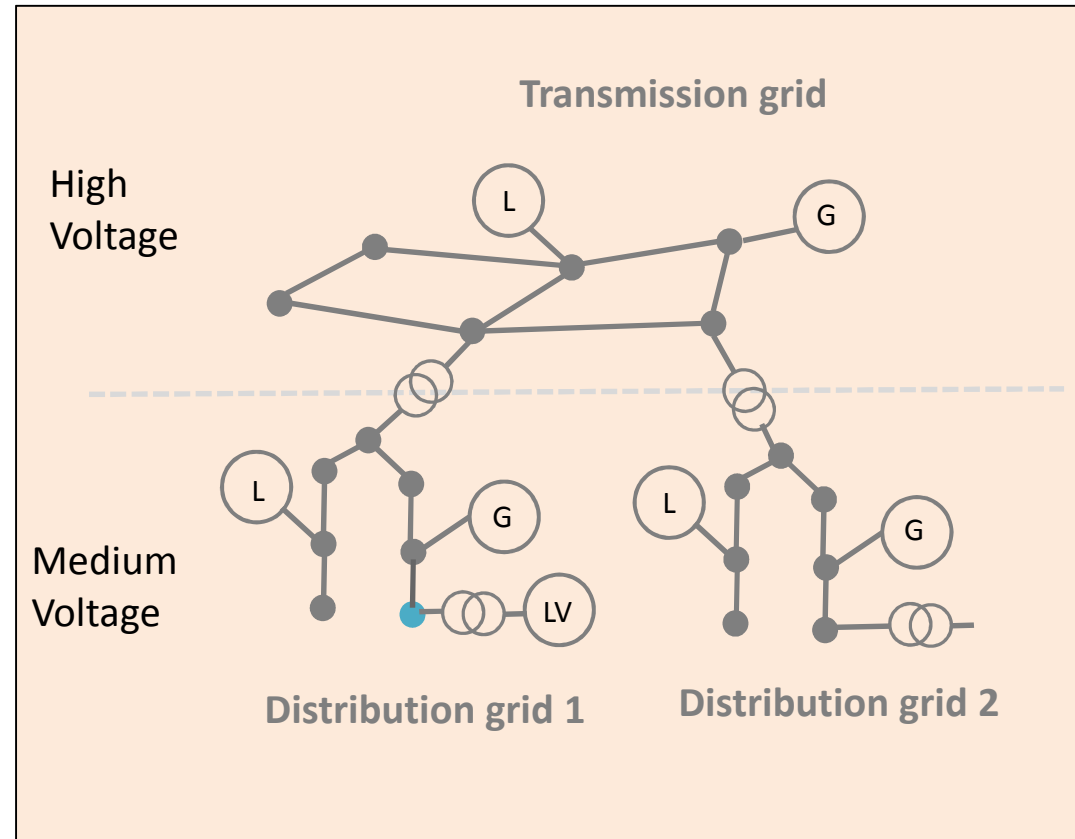


Objectives of proposed Market Design

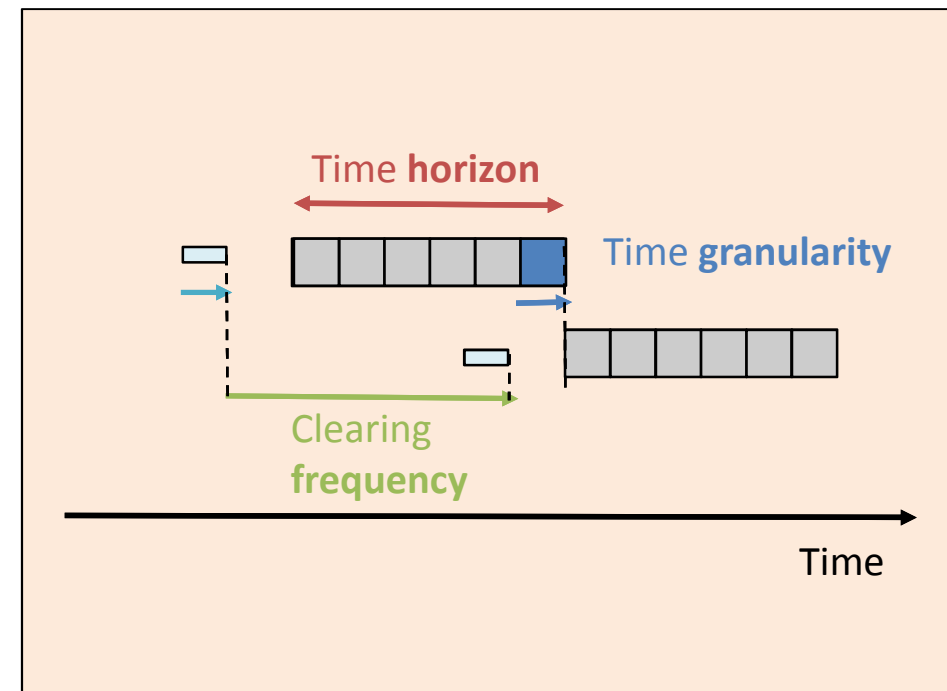
- **Balancing** services
- **Congestion** management
  - At the **transmission** grid level
  - At the **distribution** grid level (medium voltage)
- In addition, the goal is also to **avoid creating voltage problems** in the distribution grid (medium voltage)

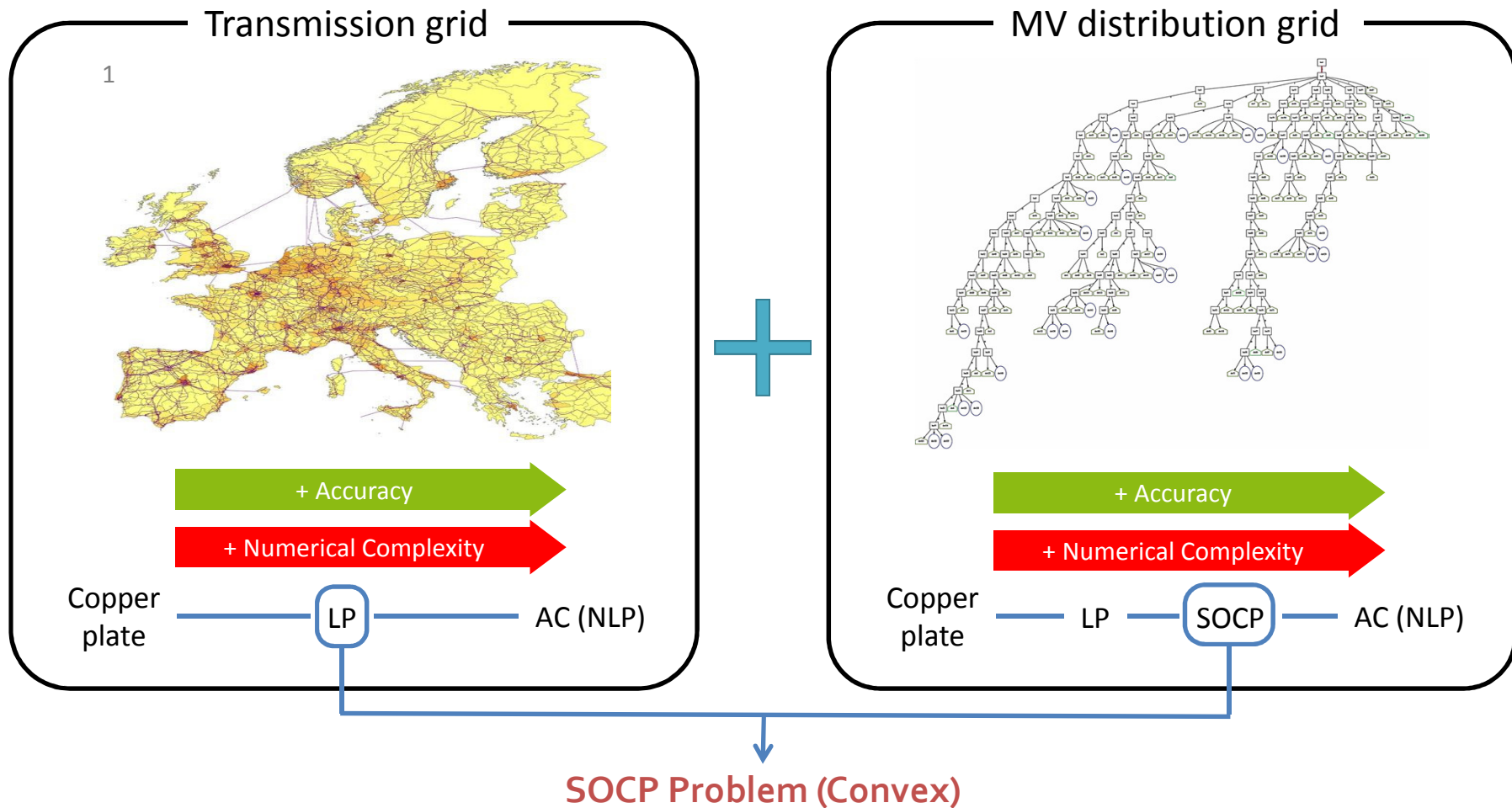


Requirement for **transmission** and **distribution grid** models in the **market clearing algorithm**



- **Time horizon** of the market (optimisation window, delivery period)
- **Time granularity** of the market horizon
- **Market clearing frequency**
  - The shorter, the better, but limited by optimization problem complexity (market clearing duration)
- **Rolling optimisation concept**
  - e.g. horizon = 30 min, frequency = 5 min, granularity = 5 min
  - Results for the **first** time step are a **firm** decision. It contains the actual activation of flexible assets and has to be followed by the aggregators/owners
  - Results for the **next** time steps are (mostly) **advisory** decisions. They will assist the aggregators and the TSO to anticipate the availability of flexibility in the upcoming time steps.



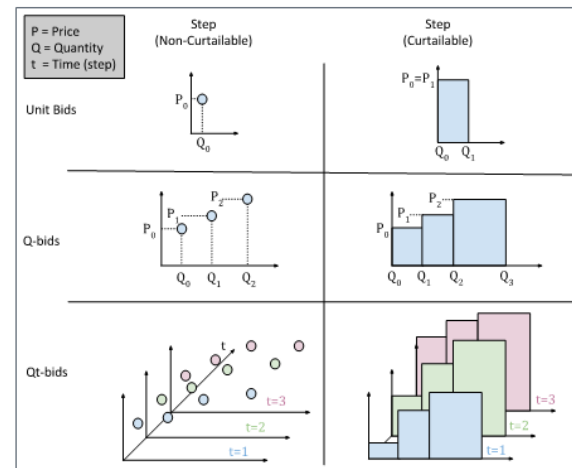


Second Order Cone Optimization: a linear function is optimized over the intersection between a n -dimensions plane and a 2nd order cone

Bidding Dimension

Market products

- **Bids** are energy offers/asks, defined by **quantity/price** pairs in their simplest form
- **Curtailable** or non-curtailable
- Extension to **multi-period bids** when time horizon is larger than the time granularity
- **Complex constraints**
  - **Temporal** constraints
  - **Logical** constraints
- **Binary variables** are needed to express some of these constraints (e.g. a simple non-curtailable bid requires a binary variable)



Temporal constraints (Intra-bid)

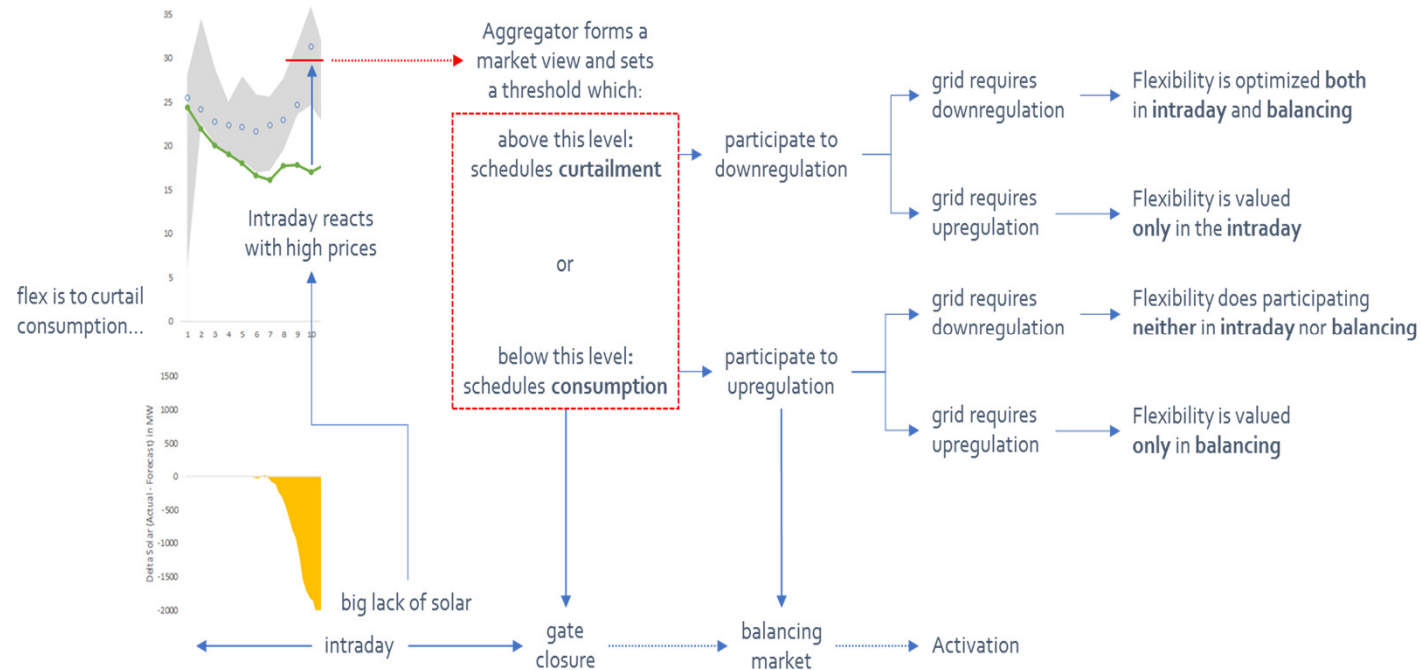
- **Accept-All-Time-Steps-or-None:** → [Profile tracking](#)
- **Ramping:** → [Turbines](#)
- **Max. number of activations:** → [Avoiding wear & tear](#)
- **Max. duration of activation:** → [Air conditioning](#)
- **Min. duration of activation:** → [Plant efficiency](#)
- **Min. delay between activations:** → [Avoiding wear & tear; cool-down and warm-up](#)
- **Integral:** → [Electric storage](#)

Logical constraints (Inter-bid)

- **Implication:** → [Series factory lines](#)
- **Exclusive Choice:** → [Parallel factory lines](#)
- **Deferability:** → [Wet appliances](#)

➔ MISOCP Optimisation problem

Mixed-integer Second Order Cone Optimization: discrete and continuous variables



Additionally...

- Aggregators are not always expected to immediately activate flexibility as soon as it is “in the money”: strategies consider multiple market layers and multiple periods.
- A risk-premium is a “market discomfort” bid-up price delaying flexibility activation in real-time balancing markets when more profitable opportunities exist in the next markets
- The rationale behind this strategy is based on the fact that forecast errors are often correlated.

$$RiskPremium = f(next\ market, current\ market\ price, etc)$$

The aggregation algorithms

The aggregator acts on behalf of the service providers on the electricity market:

- determining the price and the quantity of individual bids (per node),
- performing aggregation (before bidding on the market)
- Performing disaggregation (after getting market clearing results)

Models	Aggregation approach
Atomic Loads	• Traces
CHP	• Physical
TCL <i>Therm. Controlled Load</i>	• Physical • Hybrid
Storage	• Physical
Curtailable generation and sheddable loads	• Physical

TRACES: the aggregation is represented by all the possible combinations of feasible profiles of all the devices.

PHYSICAL (bottom-up): horizontal summation of power for the individual devices: the aggregator knows all of the parameters of each individual device and also its real time status. It becomes difficult to implement when many heterogeneous energy resources are included

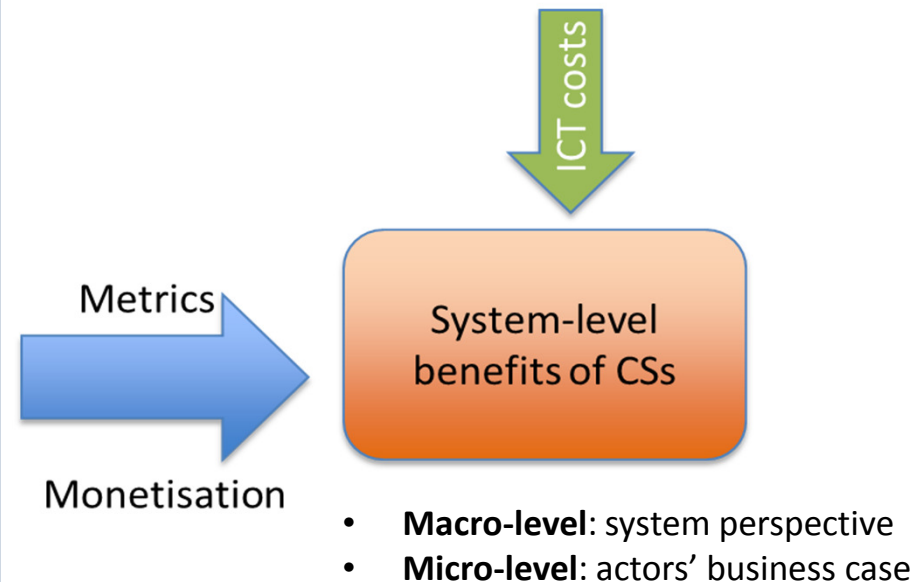
HYBRID: uses a single, or a limited number of virtual devices in order to represent the entire population of aggregated devices. Such practice reduces the number of individual devices and avoids exhaustive bid parametrization. Should the number of clusters equal the number of individual devices, the hybrid approach becomes the physical, bottom-up, approach.

- Literature review:
  - EPRI/JRC
  - REALISEGRID
  - e-Highway2050
- Proposed indicators:
  - **Enhanced provision of ancillary services:** total balancing cost (vs social welfare)
  - **Cost due to network limitations:** comparing costs taking network into account with Ideal situation (bus bar)
  - **Reduction of unwanted measures :** unexpected congestions solved with curtailment of load/generation, etc. Monetized at imbalance price or associated resource costs
  - **Reduced network losses**
  - **Emissions savings:** with standard emission rates for each generation technology and CO2 prices forecasted at studied horizon.

ICT costs include communication, market clearing software).... Steps :

1. Comparison of the coordination schemes in terms of functionalities and ICT
2. Convert each ICT system into a cost at target year

Main focus on issues that can differ between coordination schemes.

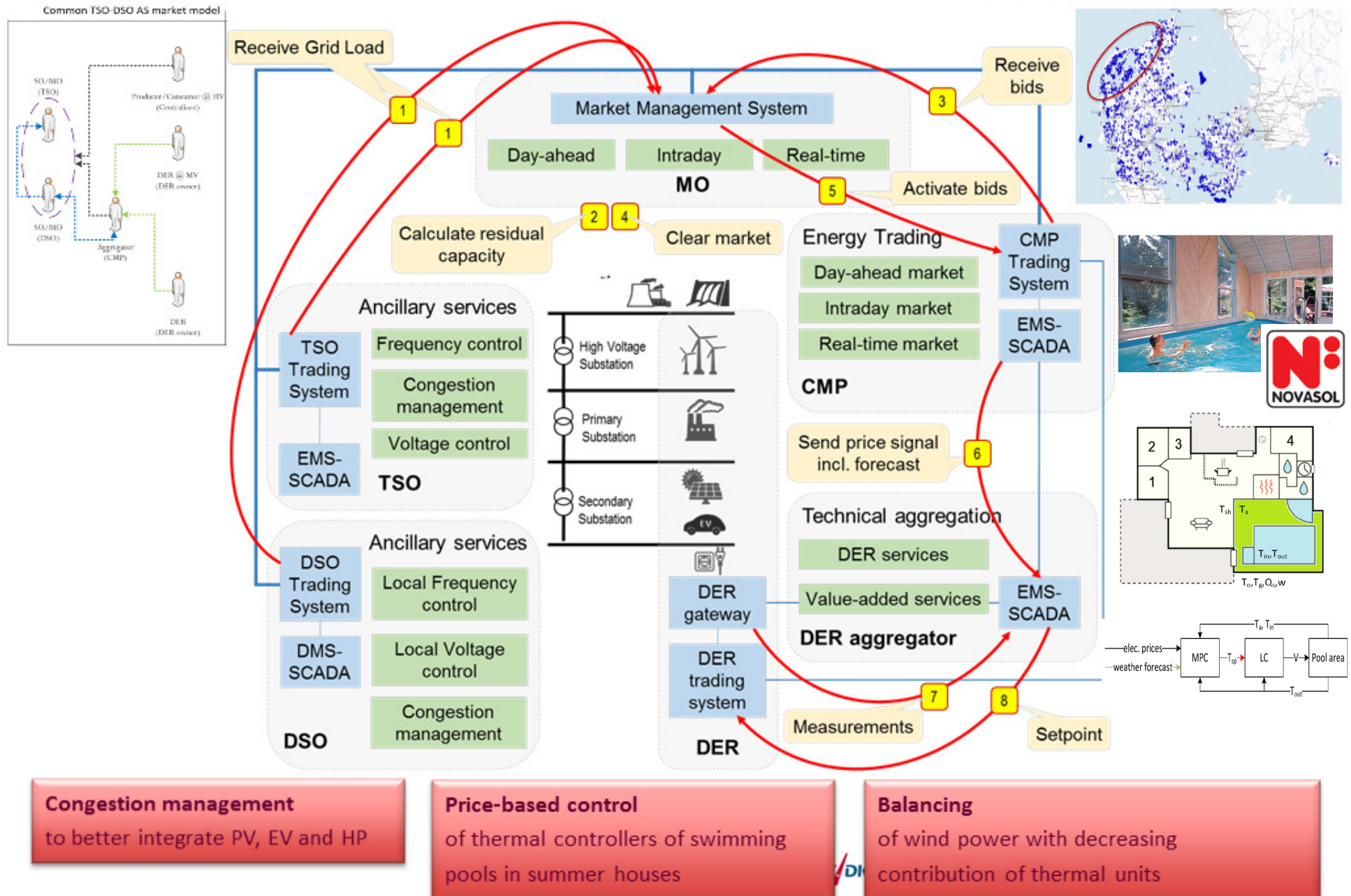




Voltage regulation
by generators connected at HV and MV levels

Power-frequency regulation / balancing
by generators connected at HV and MV
levels

Pilot B: Ancillary services from indoor swimming pools



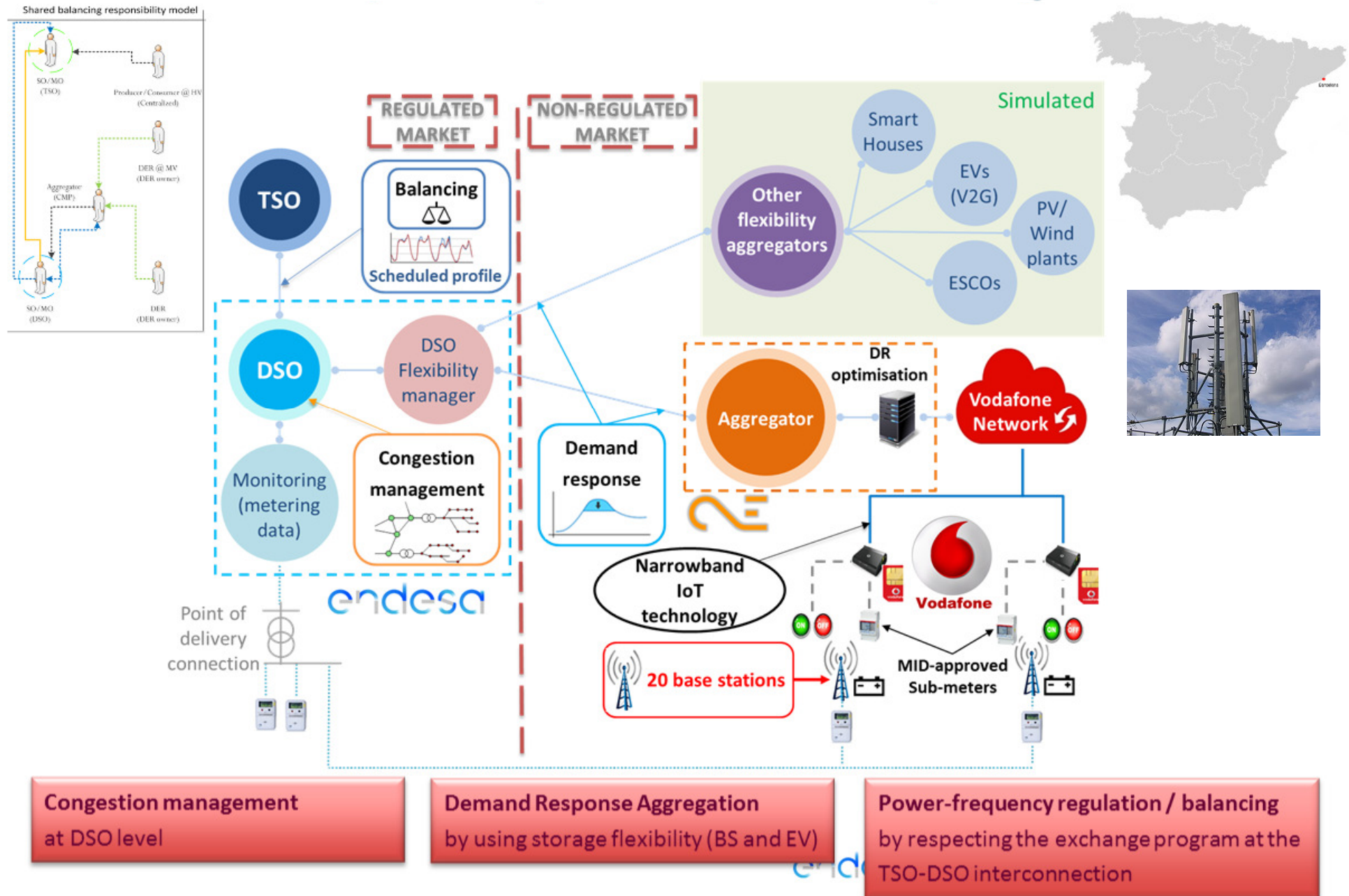
Congestion management
to better integrate PV, EV and HP

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

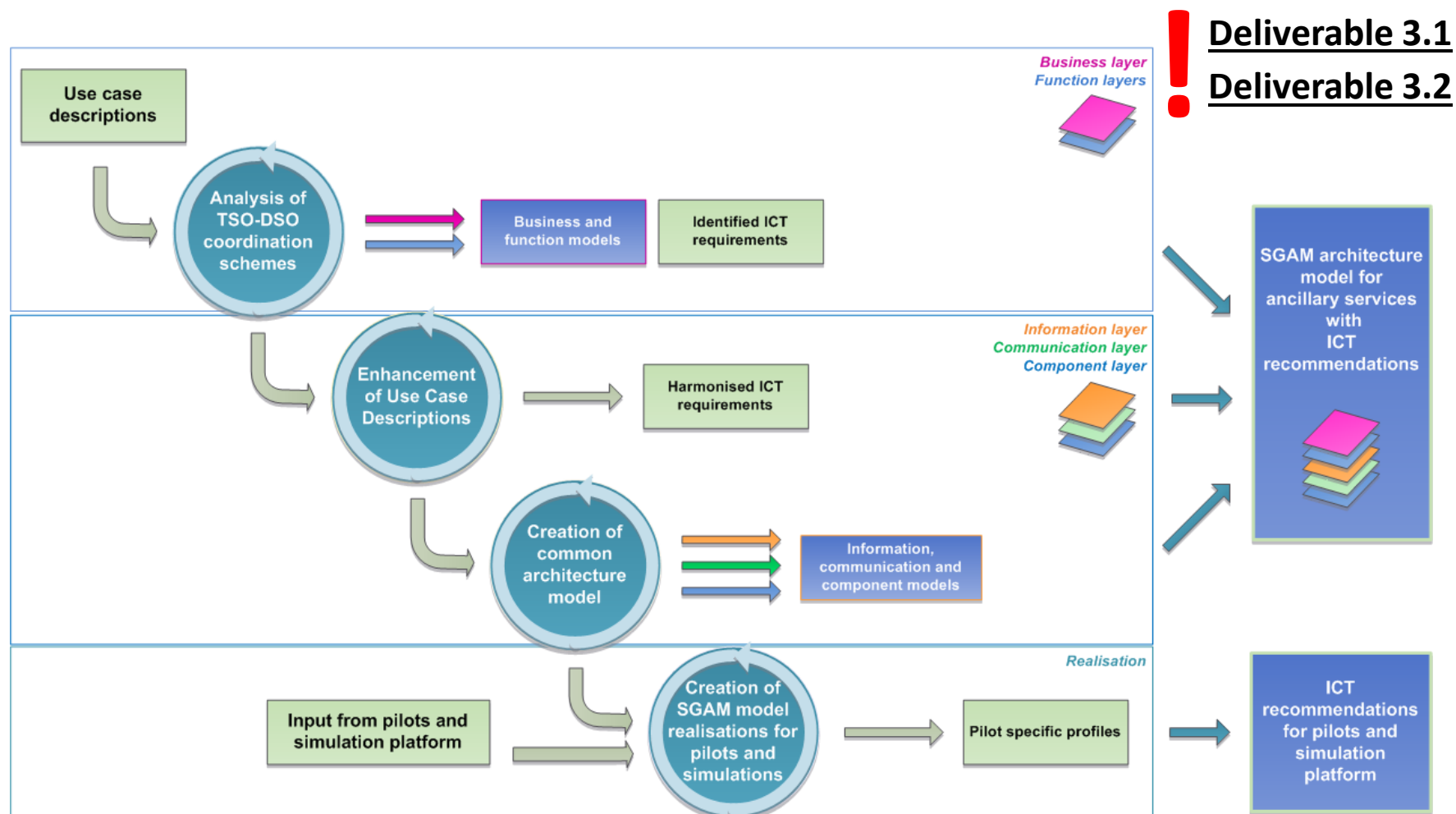
Balancing
of wind power with decreasing
contribution of thermal units



Pilot C: Ancillary services from radio-base stations

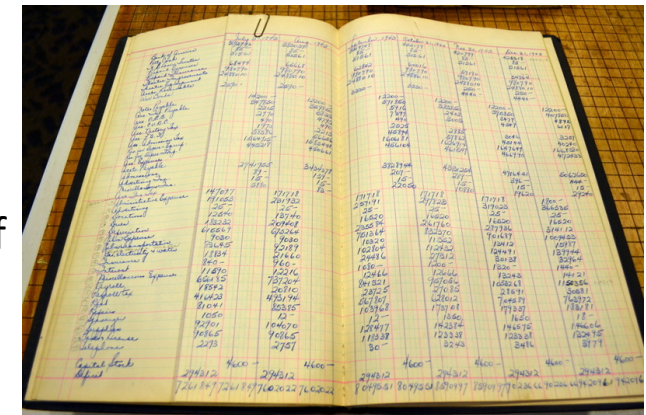


ICT Architecture Design Specification



ICT – blockchain?

- Blockchain: an electronically distributed *ledger* (asset transaction *database* that can be shared across a network of multiple sites/geographies/ institutions. Any changes to the ledger are reflected in all copies)
- The blockchain is, in essence, *an open system* where all participants can contribute to the validation process
- Blockchains remove the need for trusted *intermediaries*
- Pros (blockchain vs trusted intermediary): lower costs, faster transactions, automatic reconciliation, *new regulation*
- Blockchain can be adopted for the *decentralized variant of the Common TSO-DSO AS market* and especially for the *Integrated flexibility market model*
- Blockchain technology that is likely to be used in AS markets would be a *permission-based* system with *authorized participants only* (vs “Bitcoin” blockchain 1.0: ‘permissionless’ system)



Account	Debit	Credit	Balance
Capital stock		1000000	1000000
Reserves		250000	250000
Accounts receivable	50000		50000
Inventory	10000		10000
Prepaid expenses	5000		5000
Accounts payable		20000	20000
Accrued liabilities		10000	10000
Deferred revenue		15000	15000
Equity		1450000	1450000

Some regulatory (preliminary) remarks

- TSOs could need to **share with DSOs part of responsibility** for the provision of ancillary services if the contribution from entities in distribution will grow.
- a **balance** has to be sought for between local optimality 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 architecture** must take into account the characteristics 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



SmartNet



SmartNet-Project.eu

This presentation reflects only the author's view and the Innovation and Networks Executive Agency (INEA) is not responsible for any use that may be made of the information it contains.



Thank You

Gianluigi Migliavacca (coordinator)

Diana Moneta



Contact Information

Affiliation: RSE S.p.A.

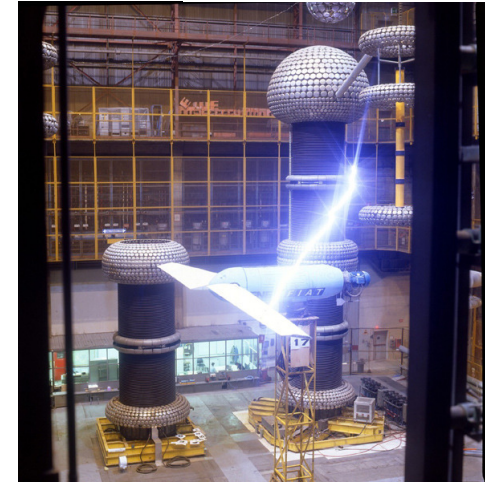
Email: {gianluigi.migliavacca; diana.moneta}@rse-web.it

Additional slides

RSE - Ricerca sul Sistema Energetico S.p.A.

RSE S.p.A. (formerly CESI RICERCA SpA, ERSE SpA) has been established at the end of 2005, with the mission to take over funded research activities of national and international interest focused on electricity and energy sector and it started operating on January 1st 2006.

RSE S.p.A. is currently owned by GSE, a publicly-owned company promoting and supporting renewable energy sources in Italy.



- ~320 researchers and technicians in 4 departments (60% with degree)
- research on all aspects of energy sectors: security, power supply, regulation...