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

The Global Forum Electricity Ancillary Services and Balancing | Berlin, 23.11.2017

SmartNet project: TSO-DSO interaction architectures to enable DER participation in ancillary services markets

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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

- SmartNet project motivations
- Outline of SmartNet
- The simulation platform
- Five coordination schemes and their CBA
- Market architecture design
- Aggregation process
- 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 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 e
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

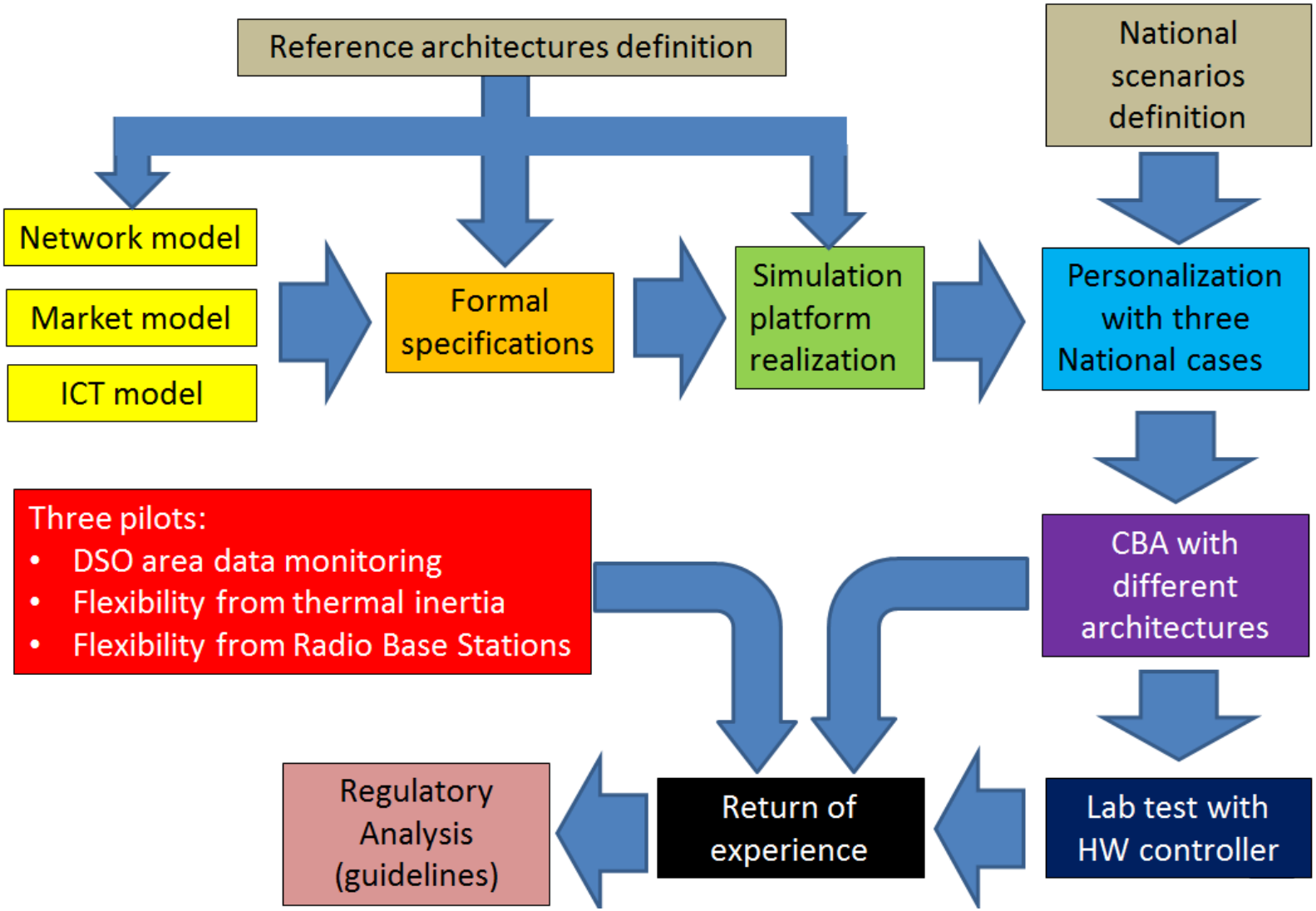
http://SmartNet-Project.eu

- **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

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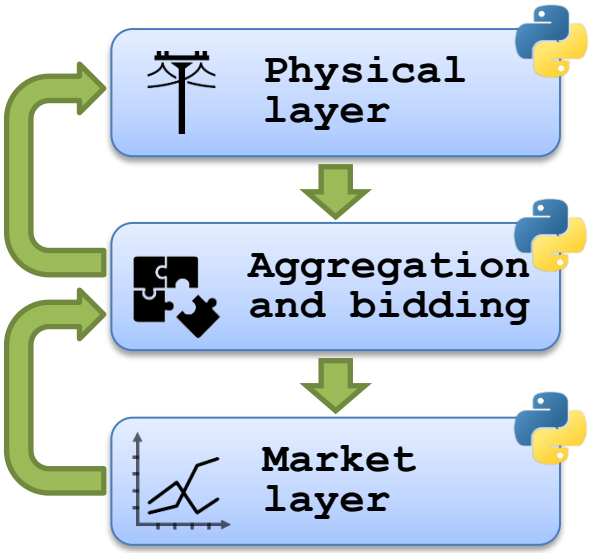
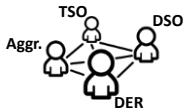
Development of simulation software



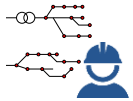
Definition of the reference scenario



Analysis of TSO-DSO coordination schemes

Definition of flexible devices profiles

Country-specific aspects and regulation



Network planning and operation

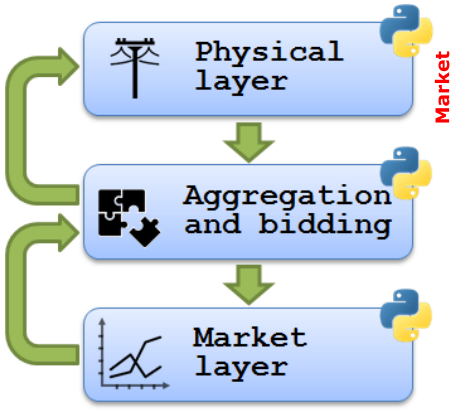
ICT specification and planning

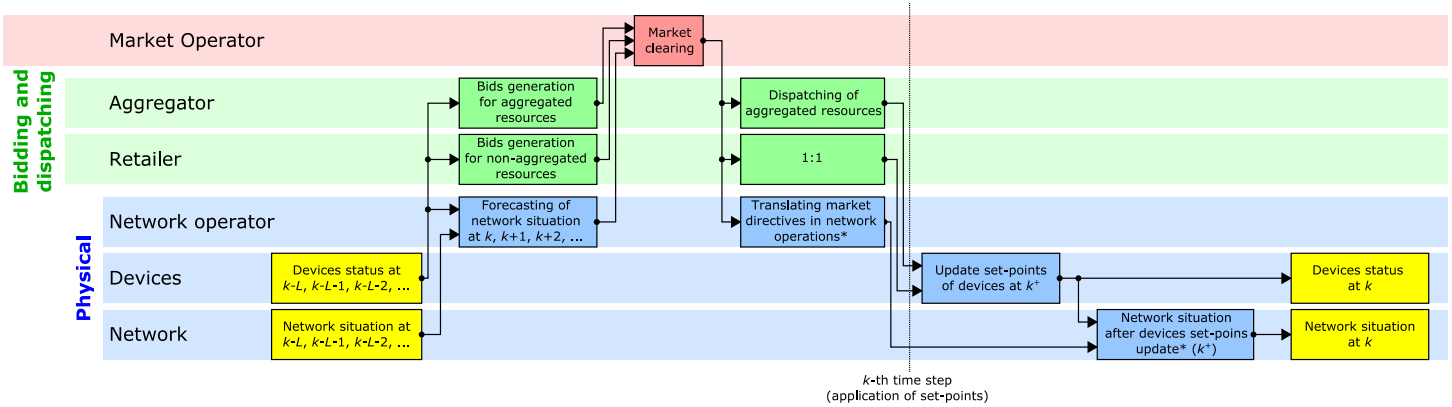
Simulation

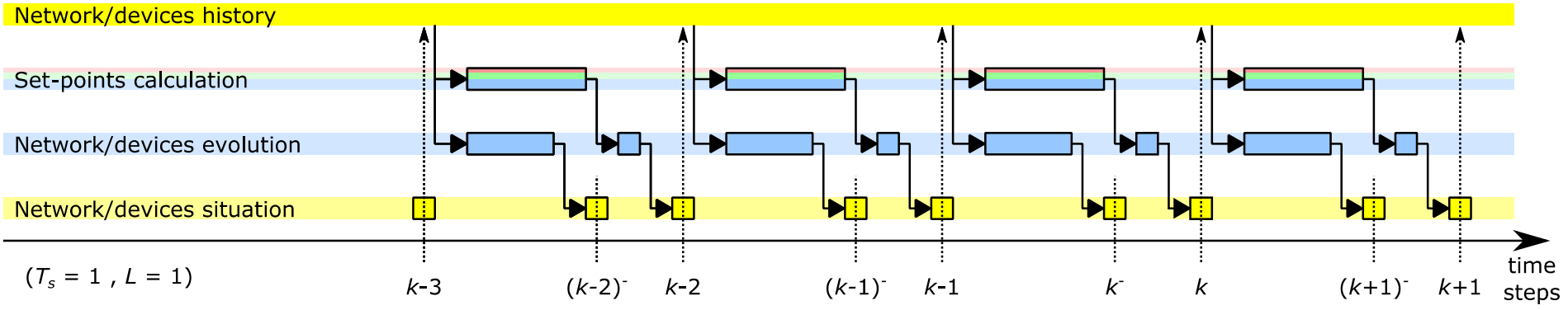
Cost Benefit Analysis

Lab implementation of the simulation environment

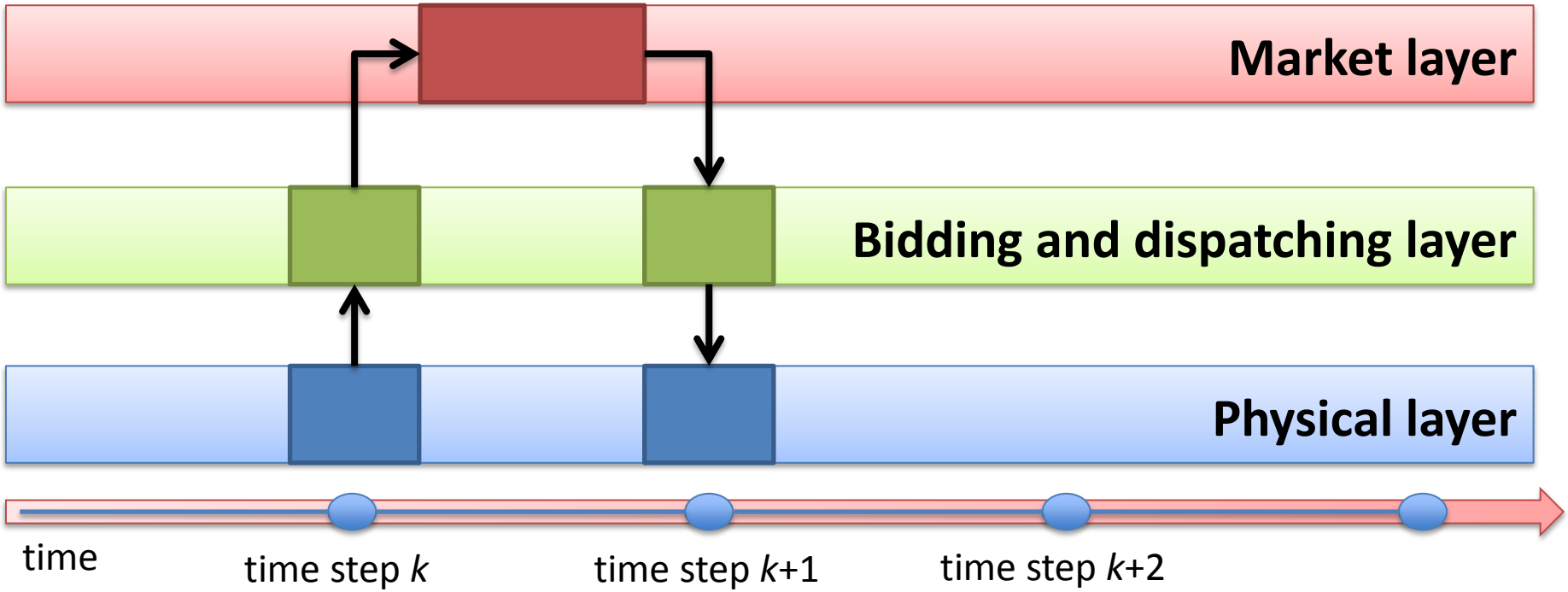
Interaction between the three layers



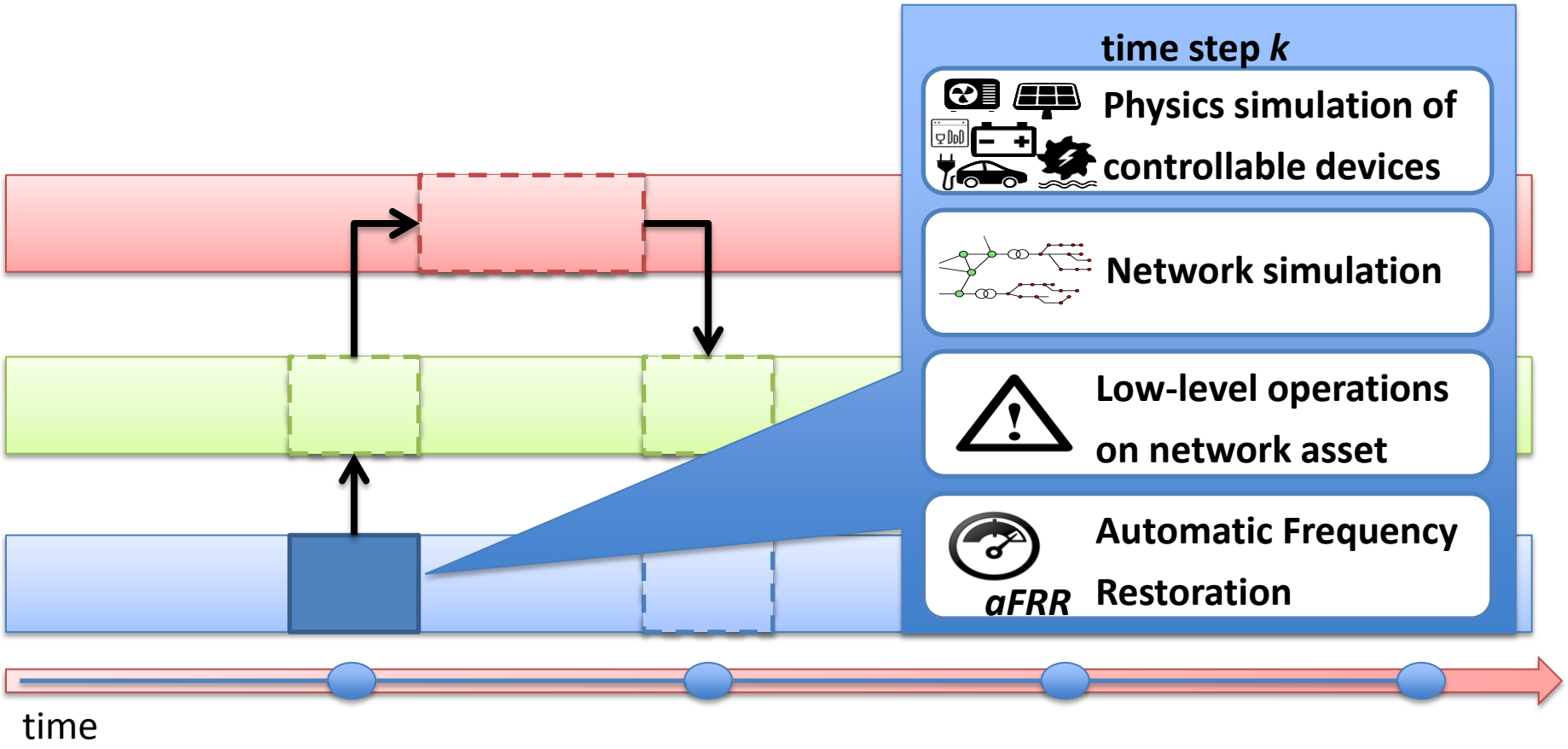




How the simulator works
Simulation based on three layers

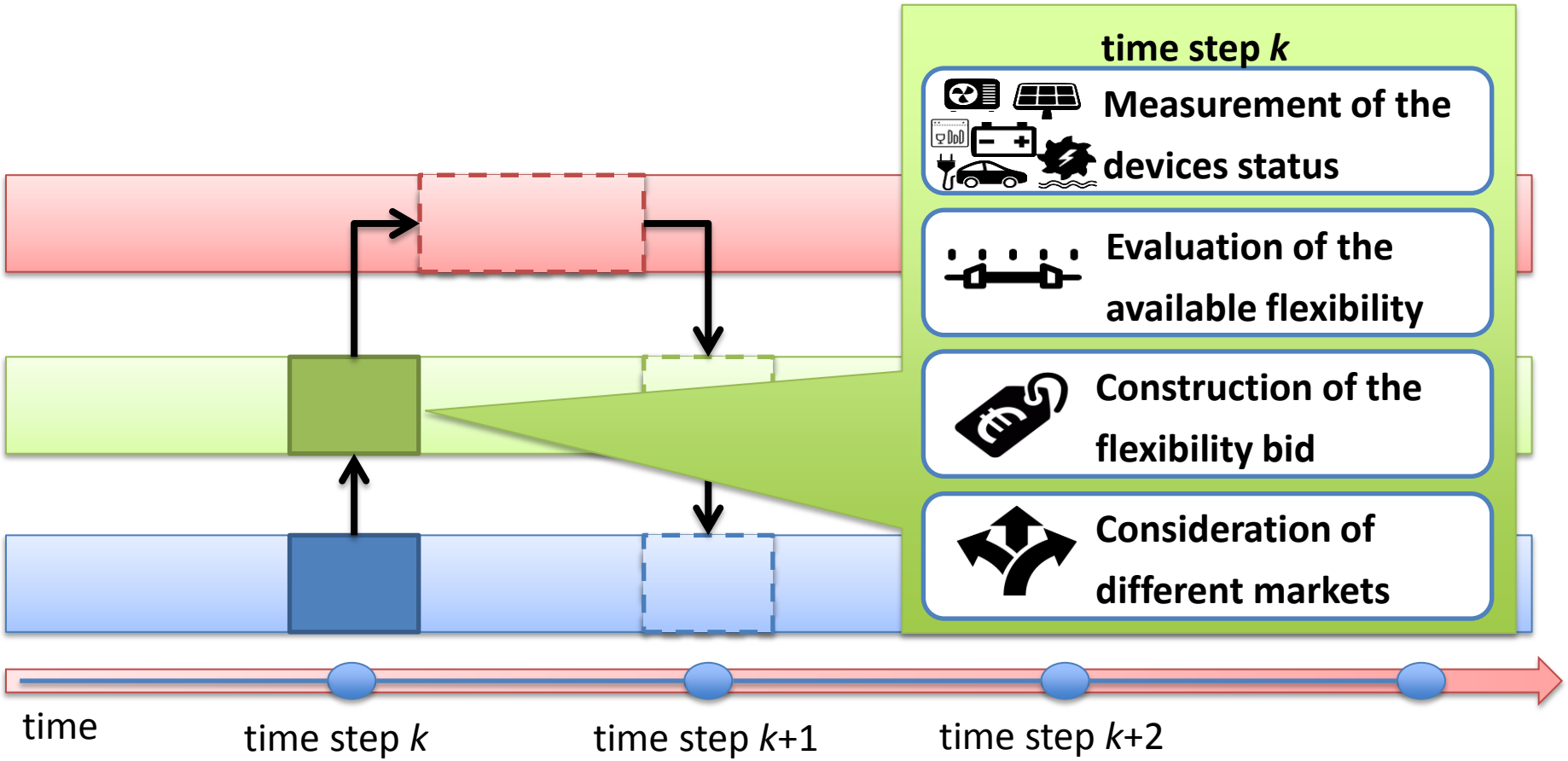


How the simulator works

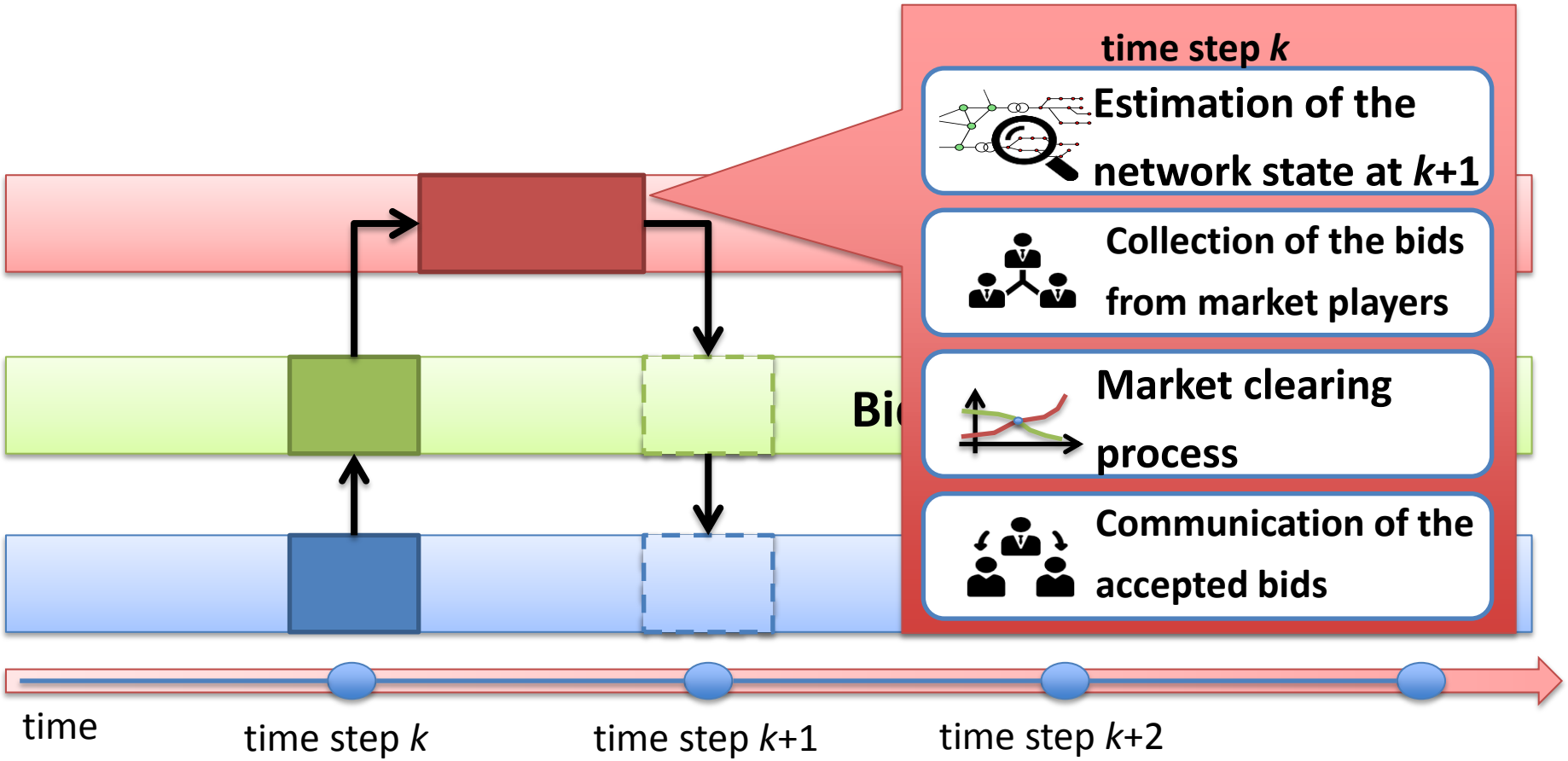


How the simulator works

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

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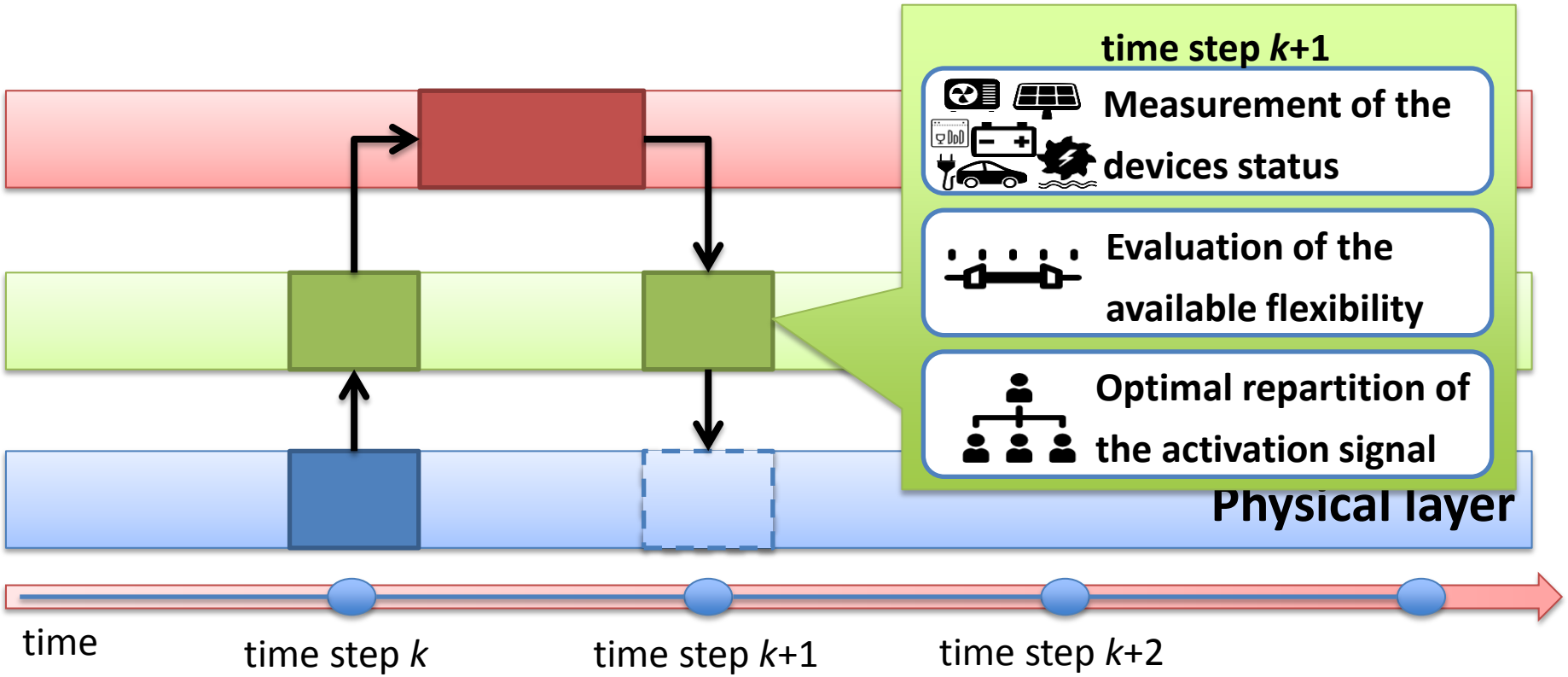

How the simulator works
How the physical layer is simulated

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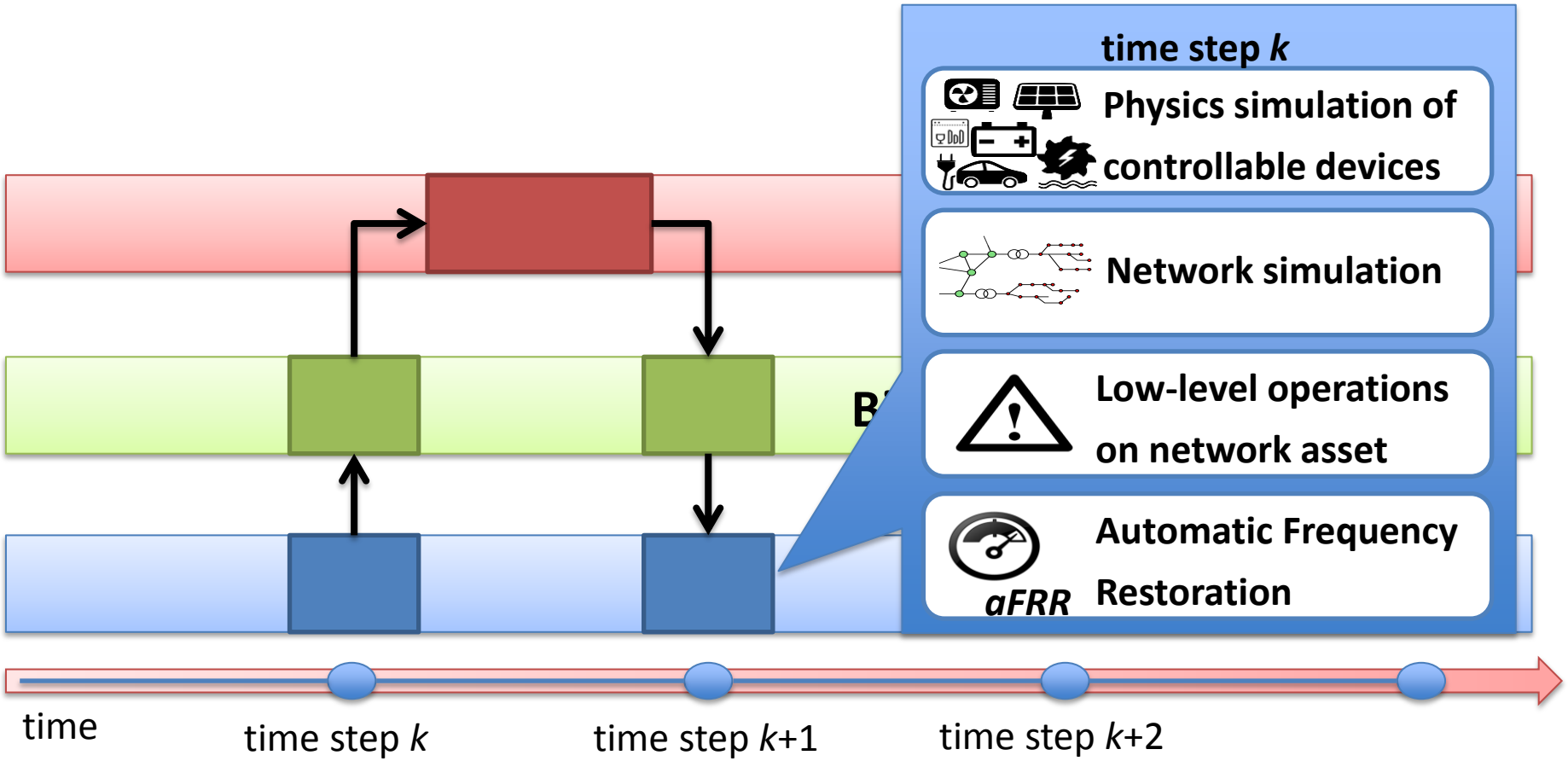

TSO-DSO coordination schemes

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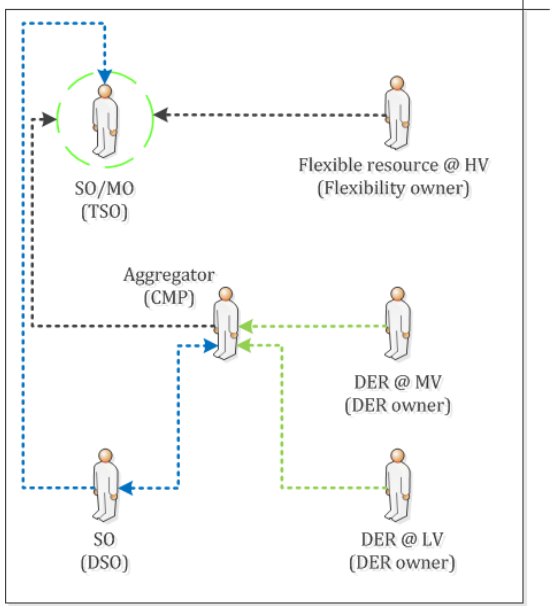
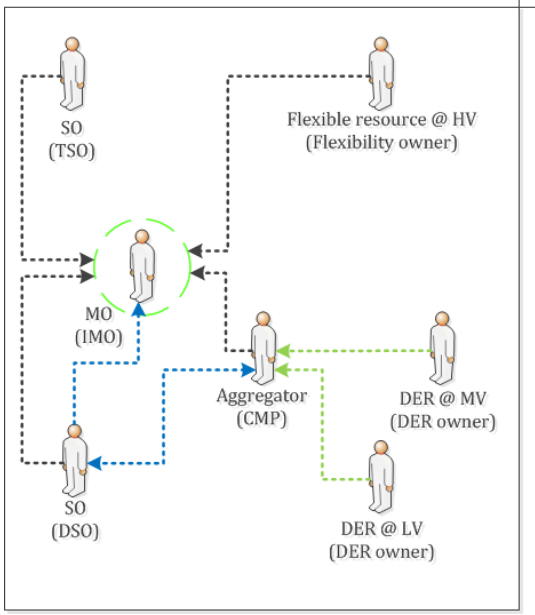
5 possible coordination schemes TSOs & DSOs for AS by distributed flexibility resources

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

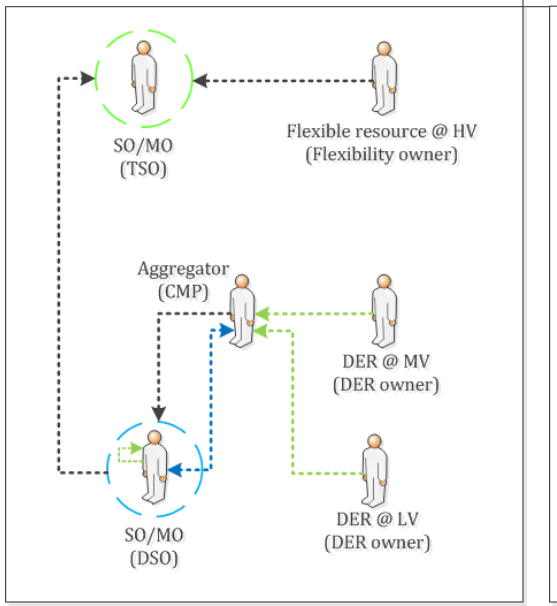
Centralized AS market model



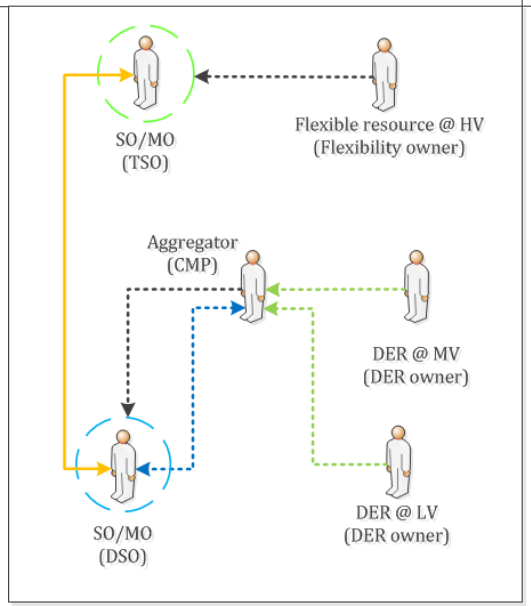
Integrated flexibility market model



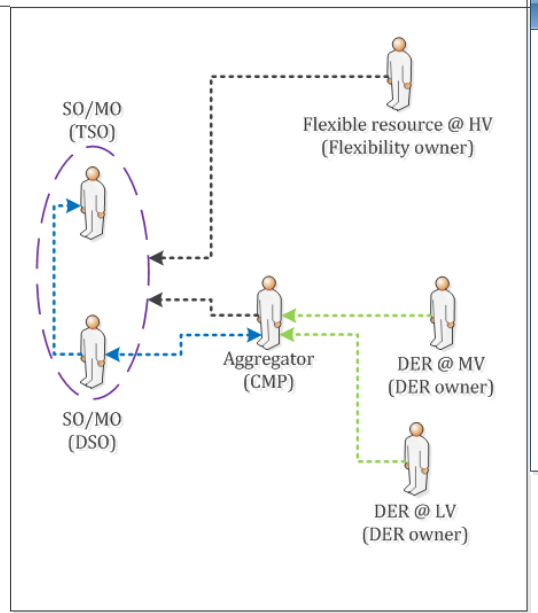
Local AS market model

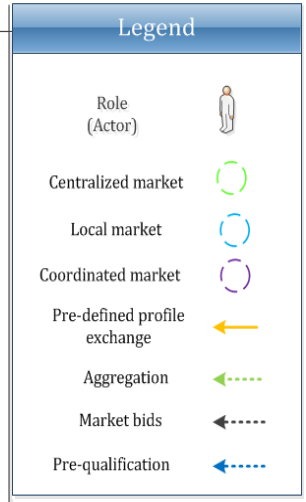


Shared balancing responsibility model



Common TSO-DSO AS market model





CBA among TSO-DSO coordination schemes

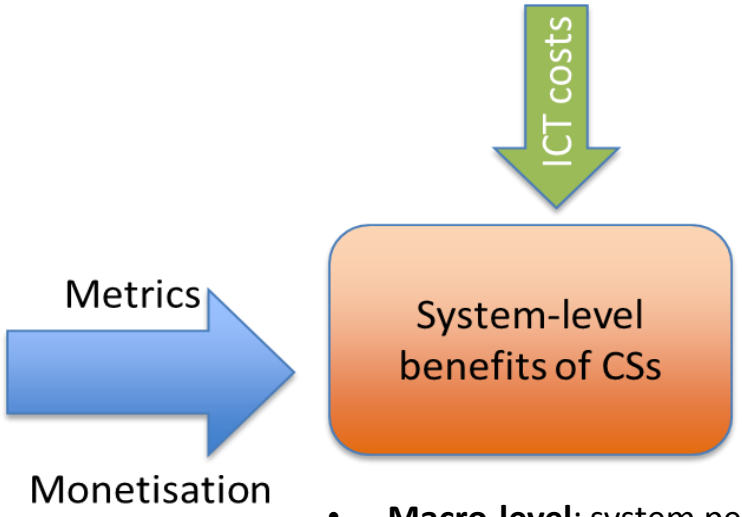
- Literature review:
  - EPRI/JRC
  - REALISEGRID
  - e-Highway2050

- 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.



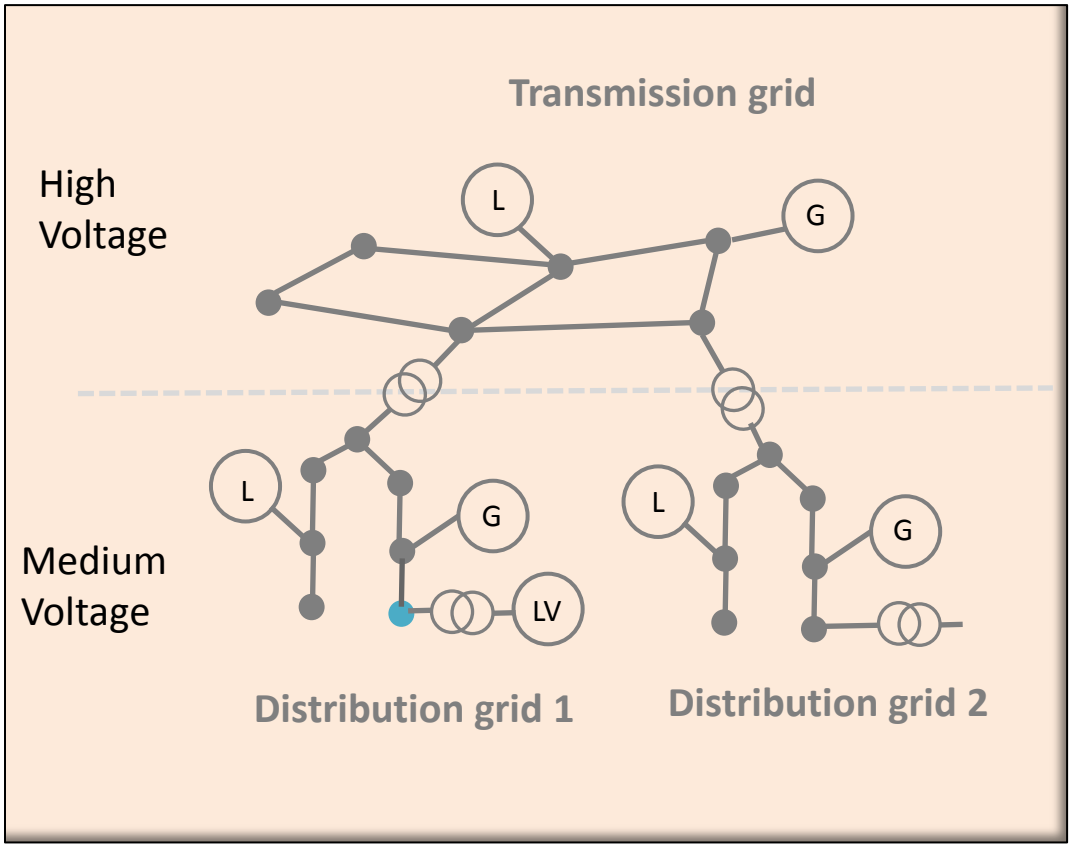
- **Macro-level**: system perspective
- **Micro-level**: actors' business case

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)

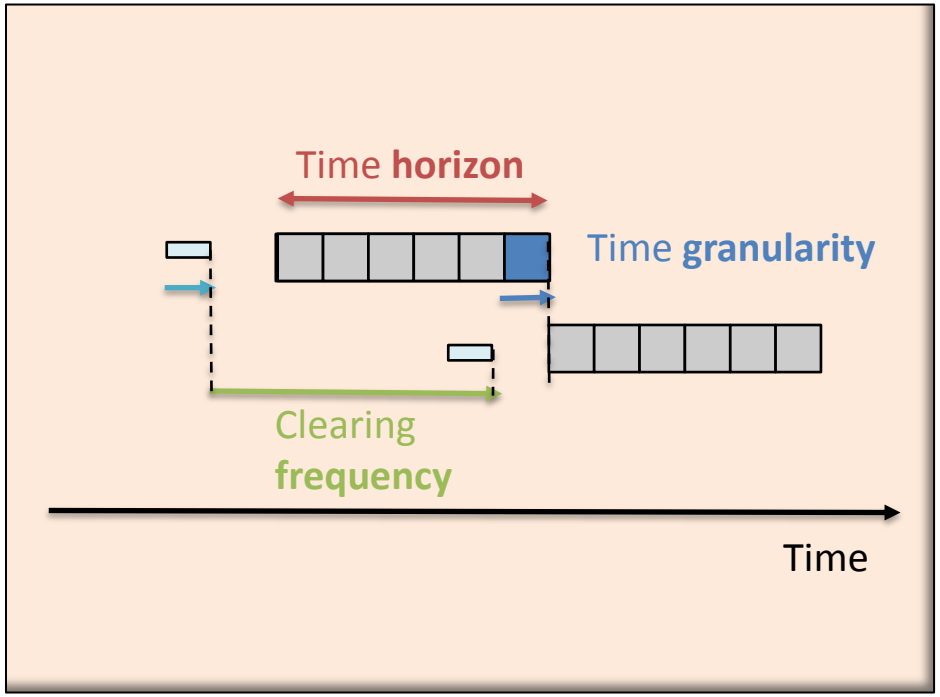
➔ Requirement for **transmission** and **distribution grid** models in the **market clearing algorithm**



Market clearing frequency, time step and horizon

- **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.



Network Dimension

Network layout and constraints

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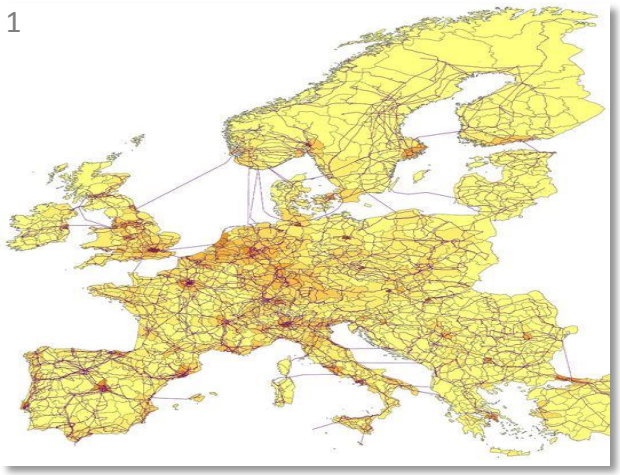
Transmission grid



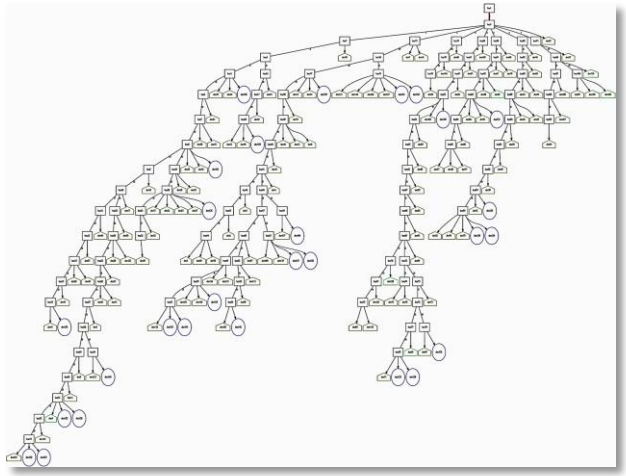
+ Accuracy

+ Numerical Complexity

Copper plate — LP — AC (NLP)

+

MV distribution grid



+ Accuracy

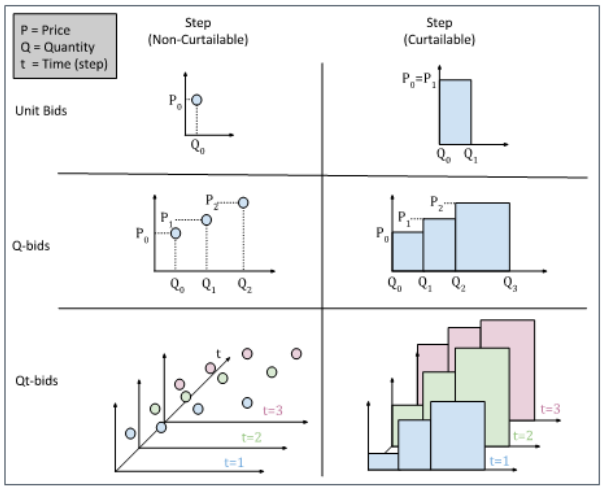
+ Numerical Complexity

Copper plate — LP — SOCP — AC (NLP)

SOCP Problem (Convex)

Bidding Dimension

Market products



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)

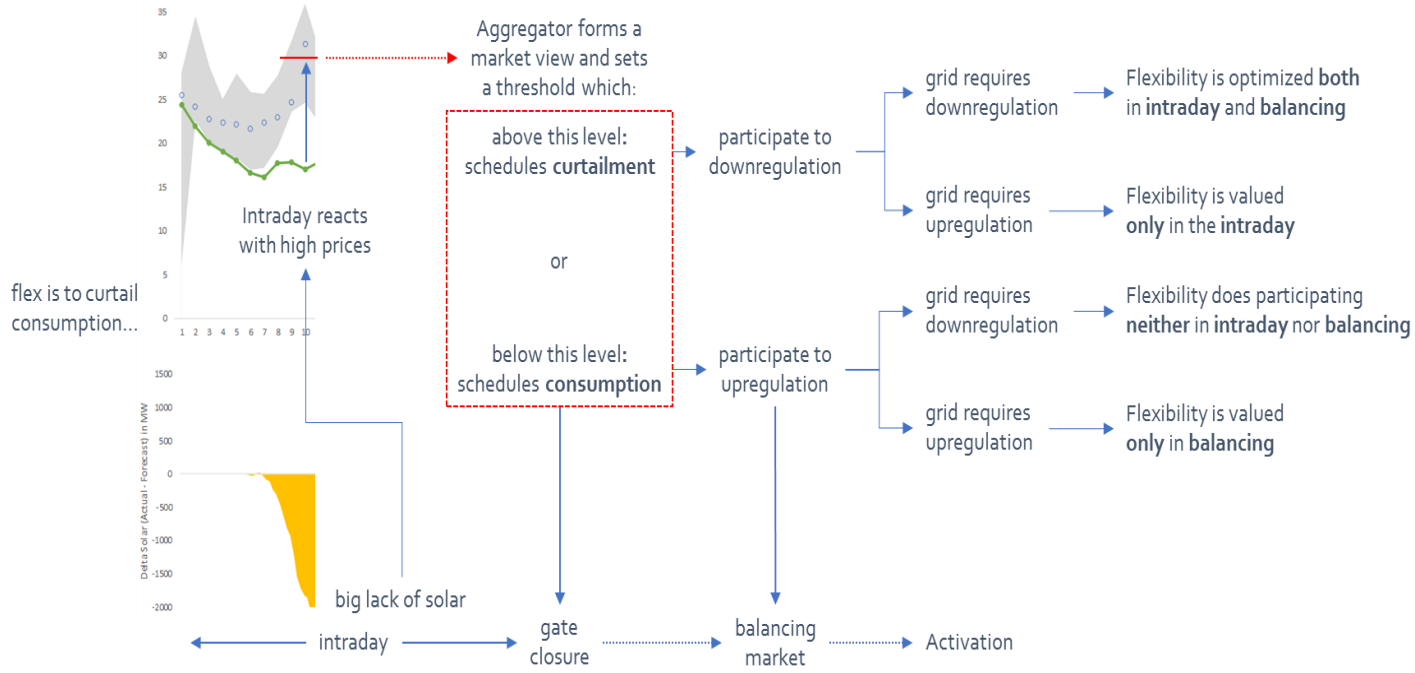
- **Implication**: → Series factory lines
- **Exclusive Choice**: → Parallel factory lines
- **Deferability**: → Wet appliances

- **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)

➔ MISOCP Optimisation problem

Bidding Dimension

Arbitrage between markets



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	• 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

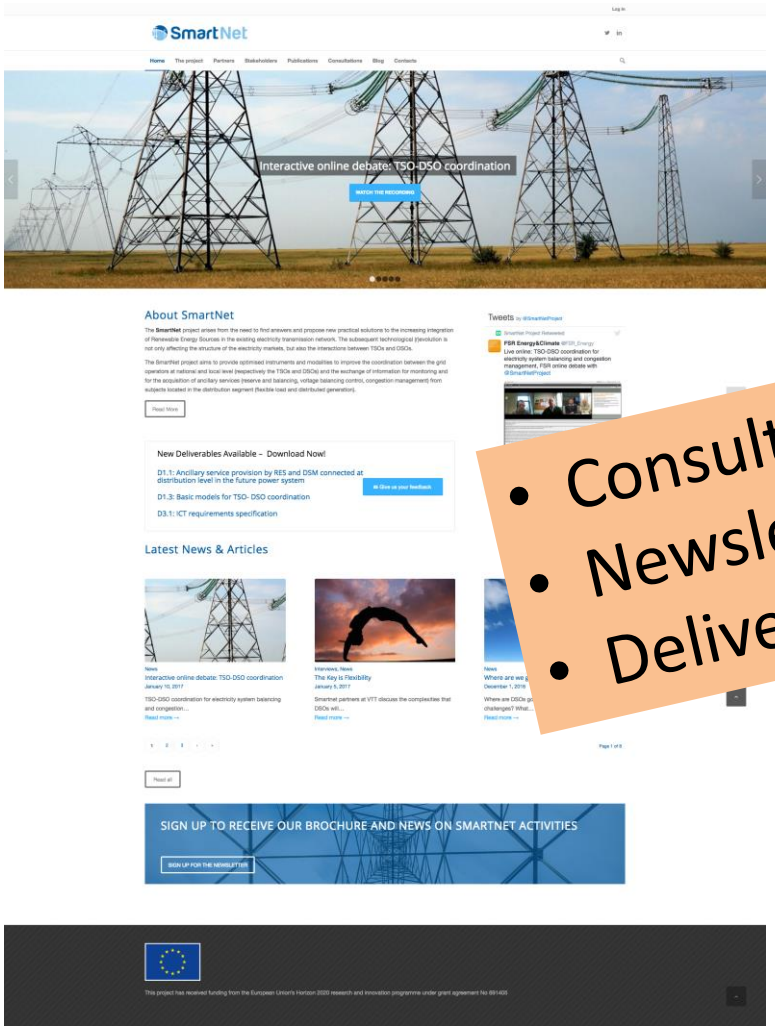
HYBRID: uses a single, or a limited number of virtual devices in order to represent the entire population of aggregated devices. Such practice reduces the number of individual devices and avoids exhaustive bid parametrization. Should the number of clusters equal the number of individual devices, the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

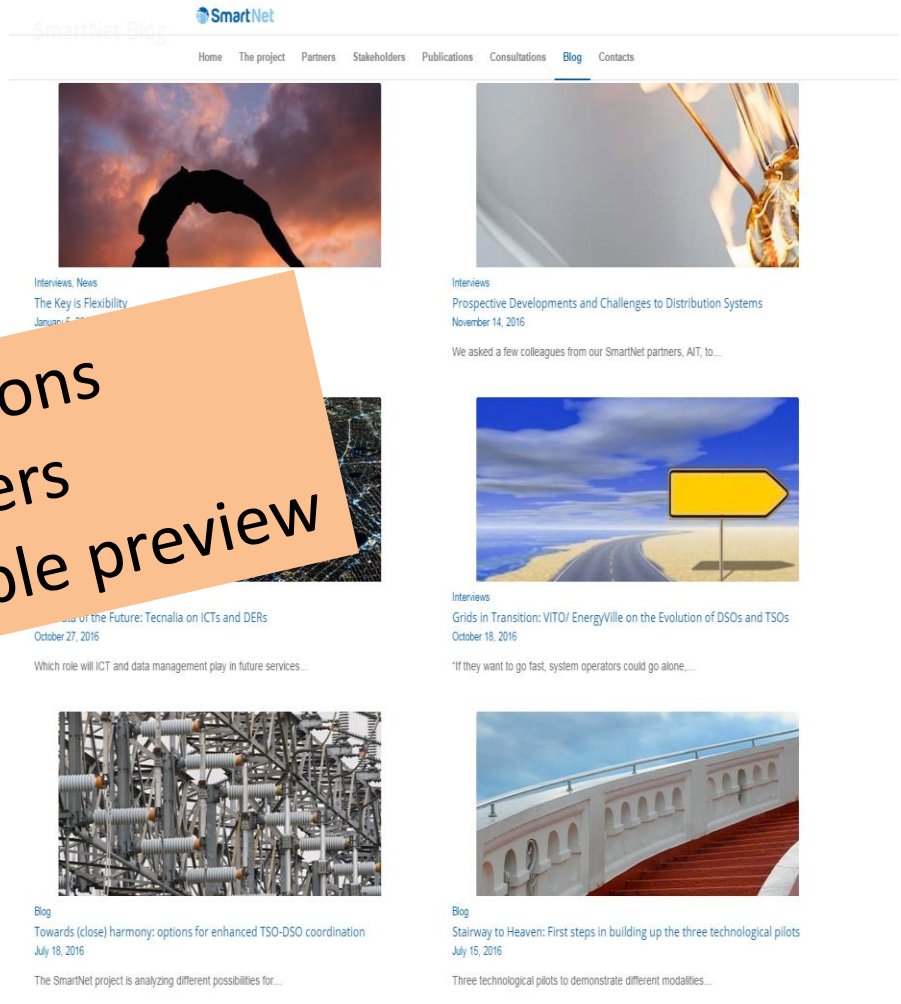
Some regulatory (preliminary) remarks

- 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 to 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-project webpage

http://SmartNet-Project.eu





- Consultations
- Newsletters
- Deliverable preview

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Thank You

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