



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

Arona (IT) | May 16<sup>th</sup>, 2019

## Final simulations and Cost Benefit Analysis results

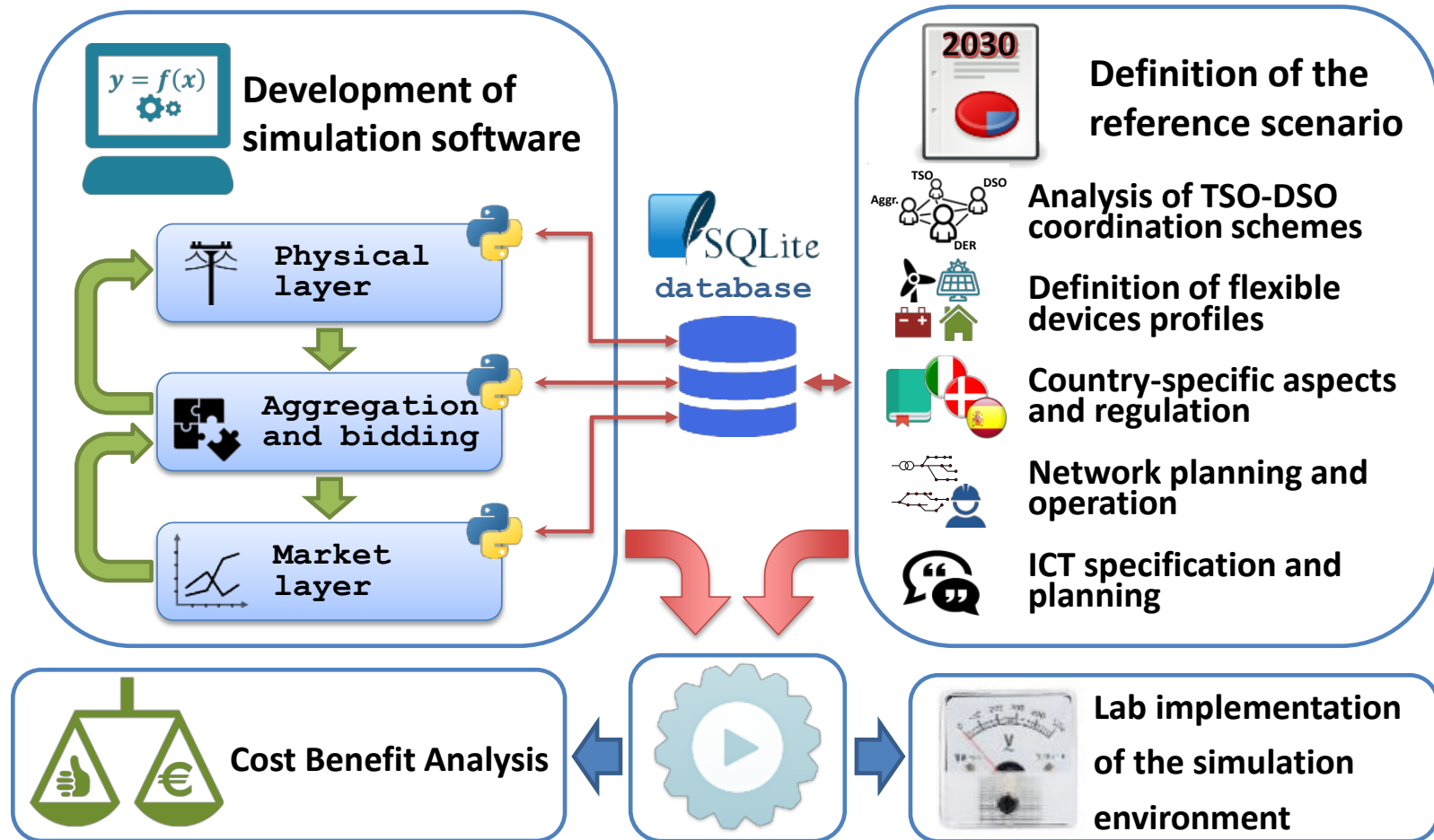
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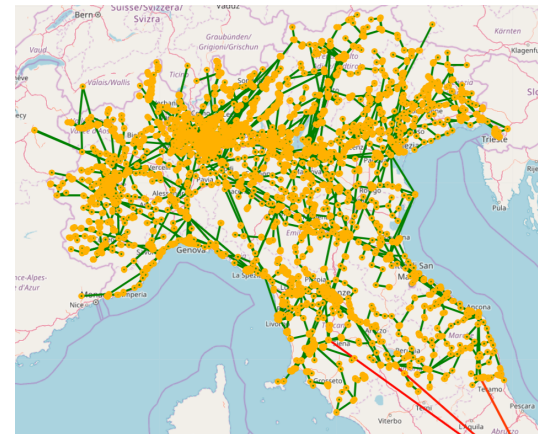
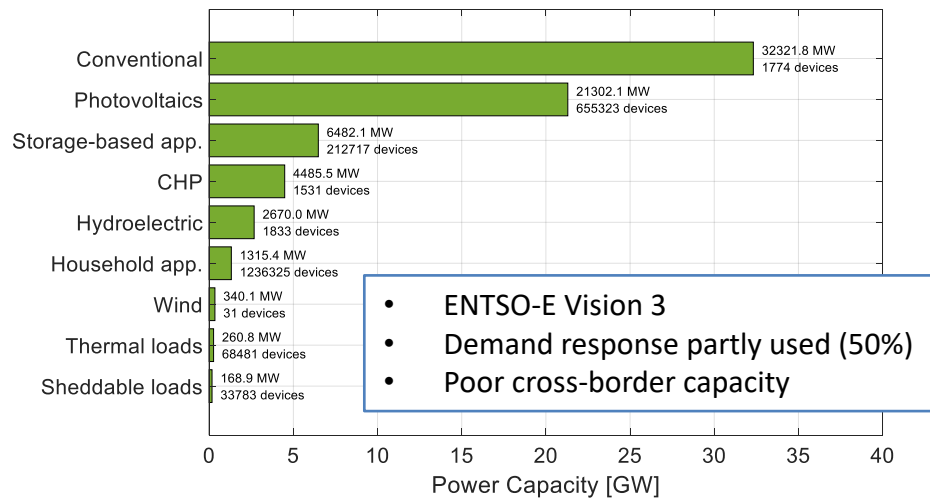
This project has received funding from the European Union's Horizon 2020  
research and innovation programme under grant agreement No 691405

# Structure of the Analysis

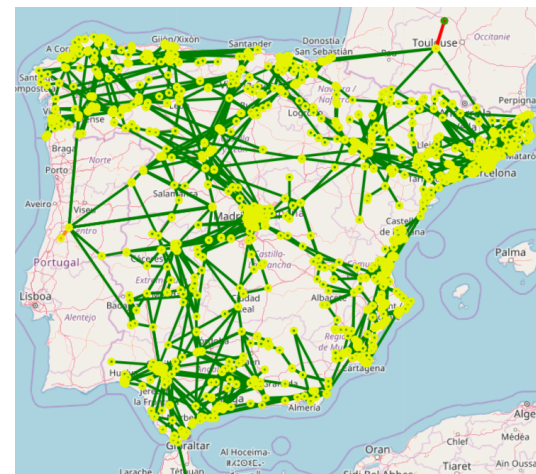
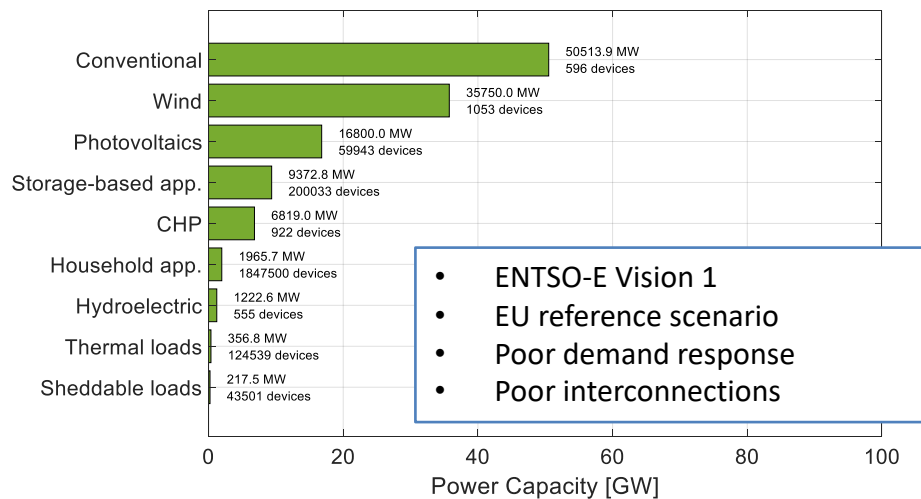
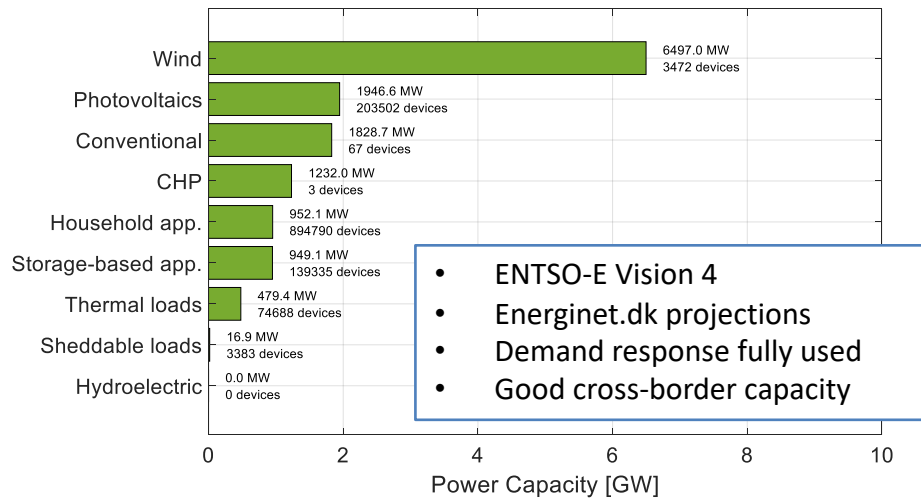


# Simulation scenarios

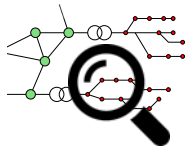
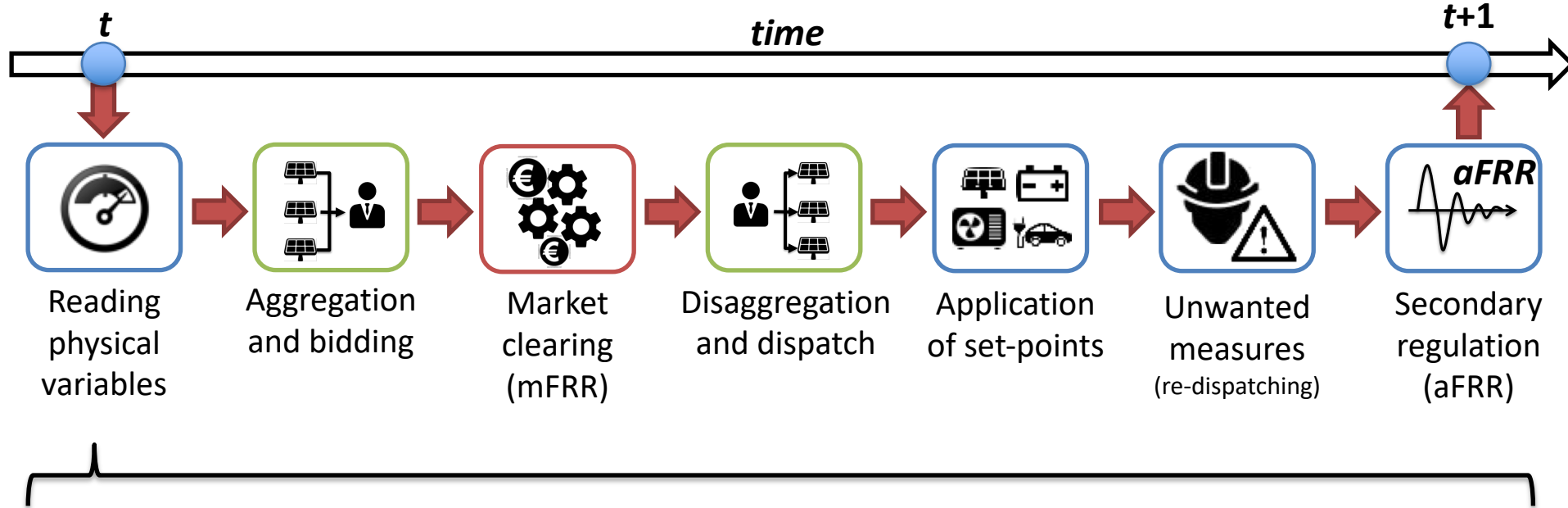
- SmartNet considers three countries in 2030 scenarios
  -  Northern Italy
  -  Continental Denmark
  -  Spain
- Resources expected for 2030 are connected to the system, considering also
  - Network upgrade
  - Correlation between weather variables and power
  - Pre-processed day-ahead and intra-day markets



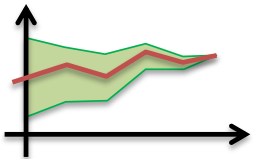
# Simulation scenarios



# Structure of the Simulator



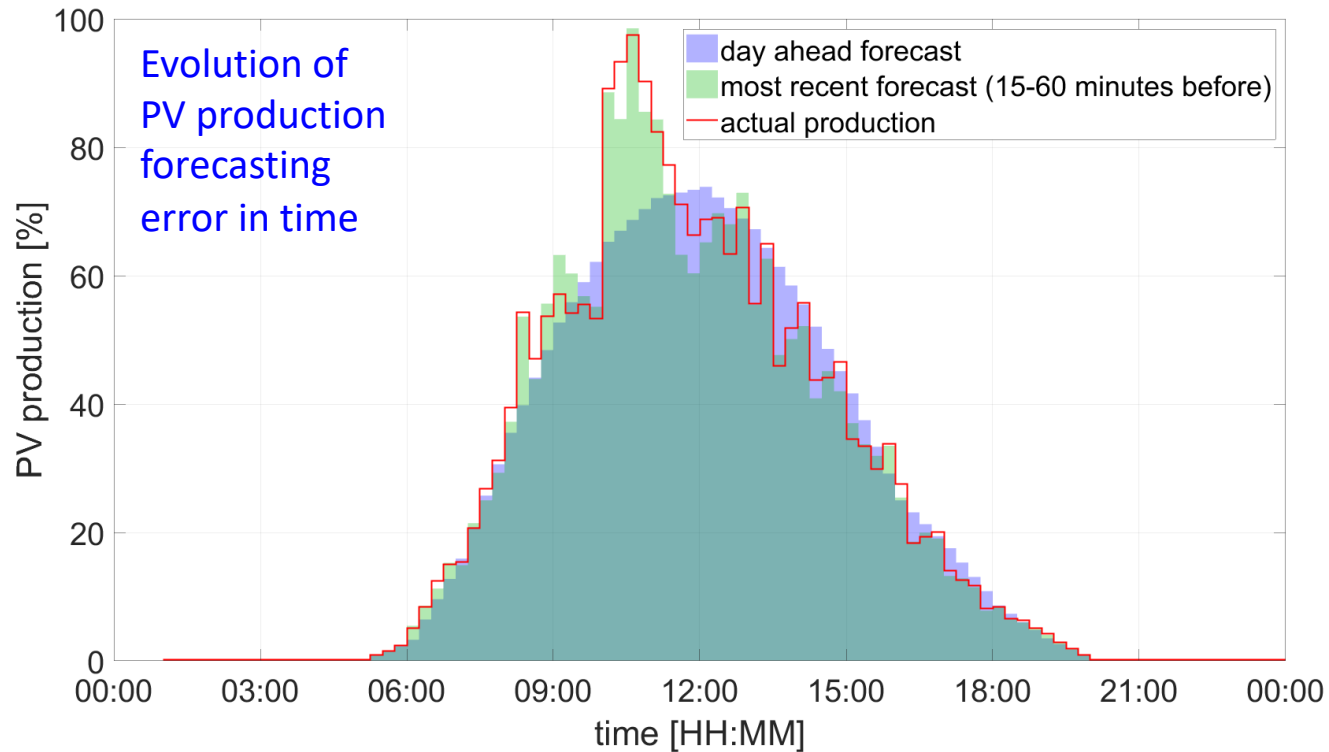
Power flexibility variables of resources and network state are monitored



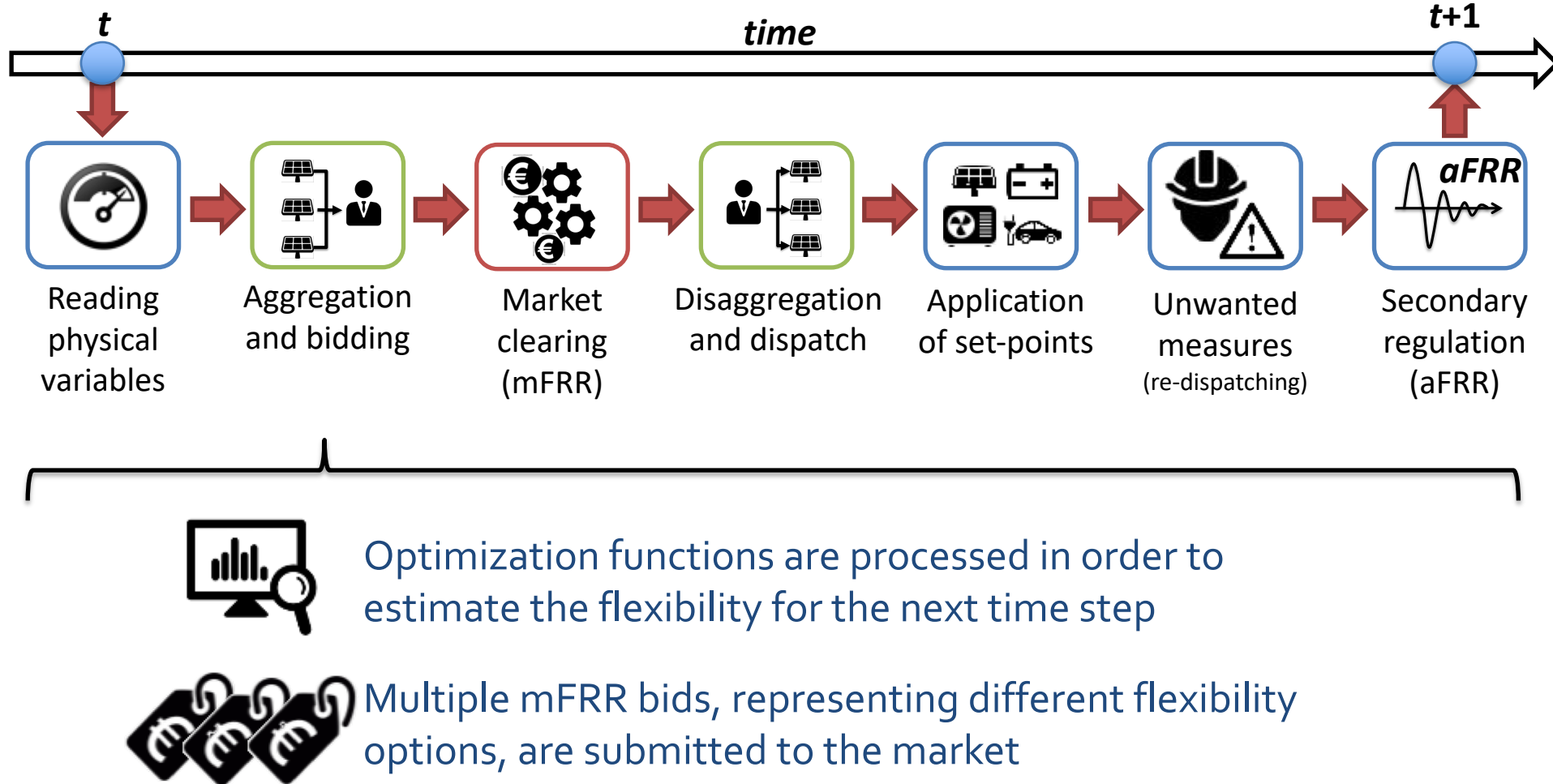
The forecast error related to the next time instant is updated

# Structure of the Simulator

## Reading physical variables

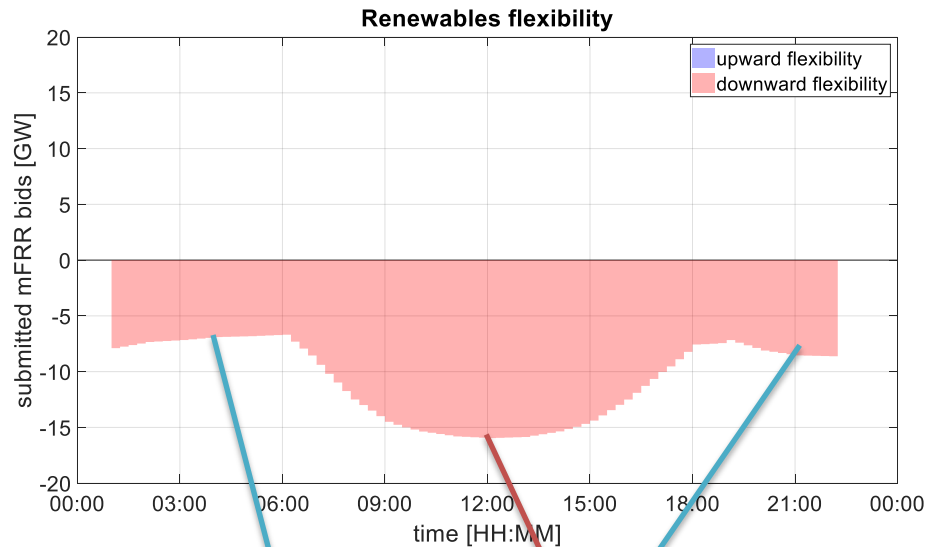


# Structure of the Simulator



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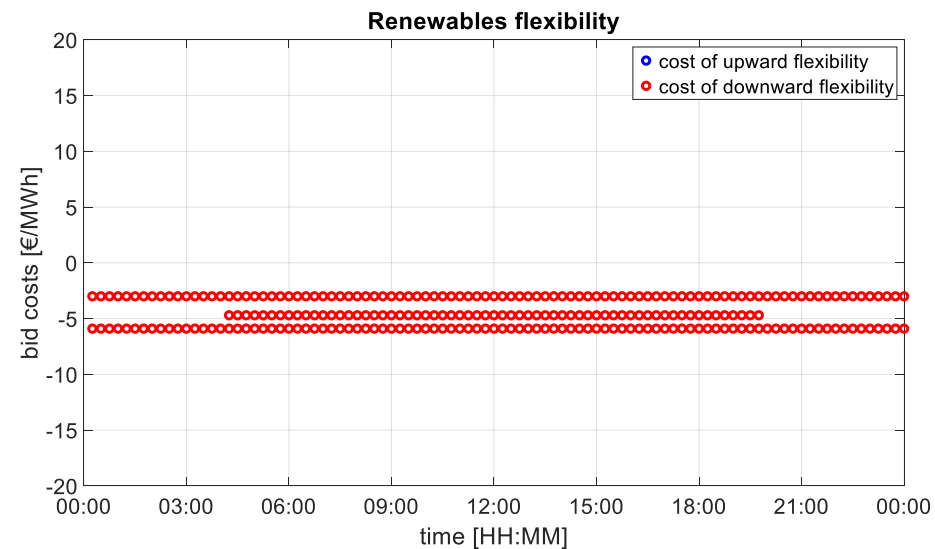
## Aggregation and bidding (renewables)



Flexibility of solar power plants  
(mostly at distribution level)

Flexibility of wind power plants  
(mostly at transmission level)

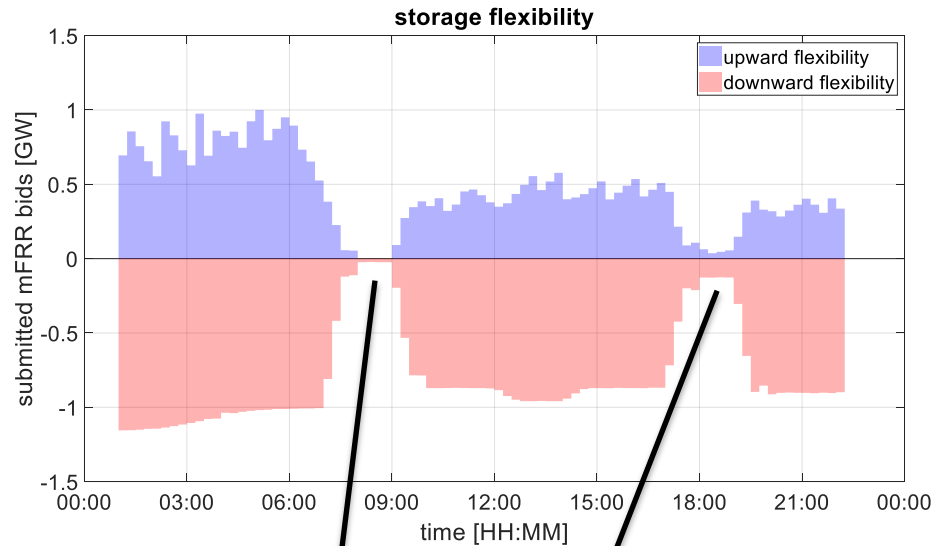
Renewables are assumed to offer only  
downward flexibility at high cost





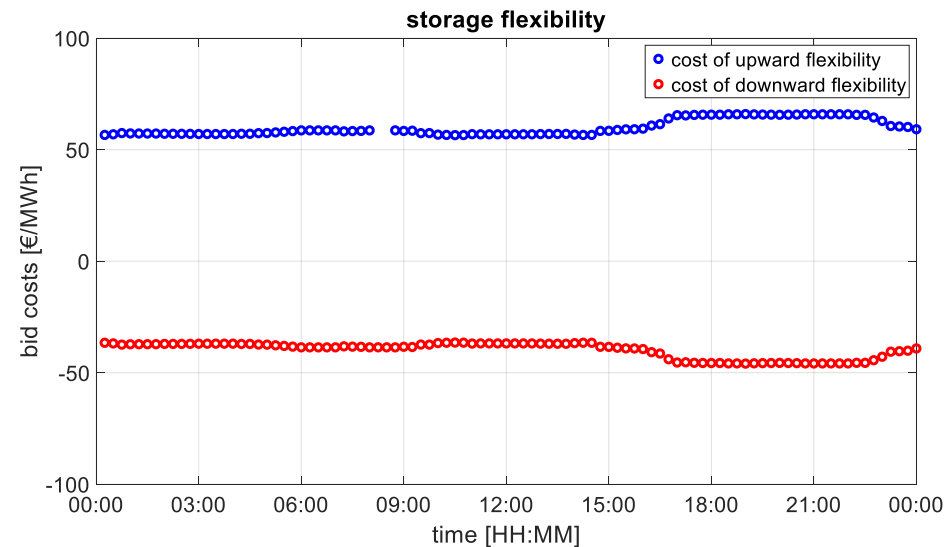
# Structure of the Simulator

## Aggregation and bidding (storage)

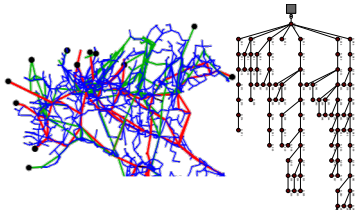
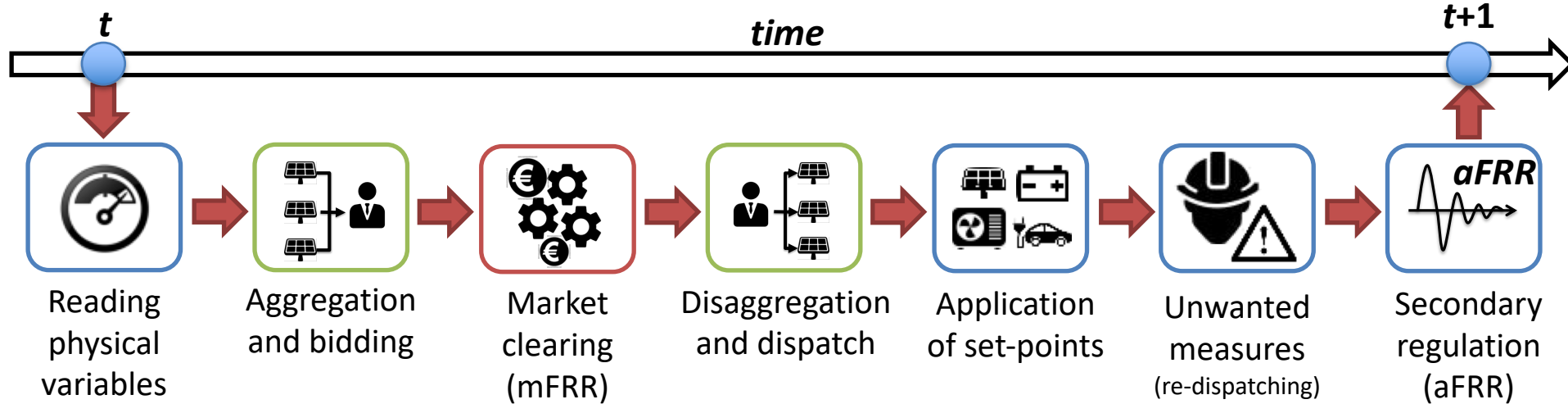


Most of Electric Vehicles are on the road (poor flexibility)

Bidding price depends on the actual cost of energy (resulting from day-ahead market)



# Structure of the Simulator



Transmission and distribution network models are integrated within the market clearing routine

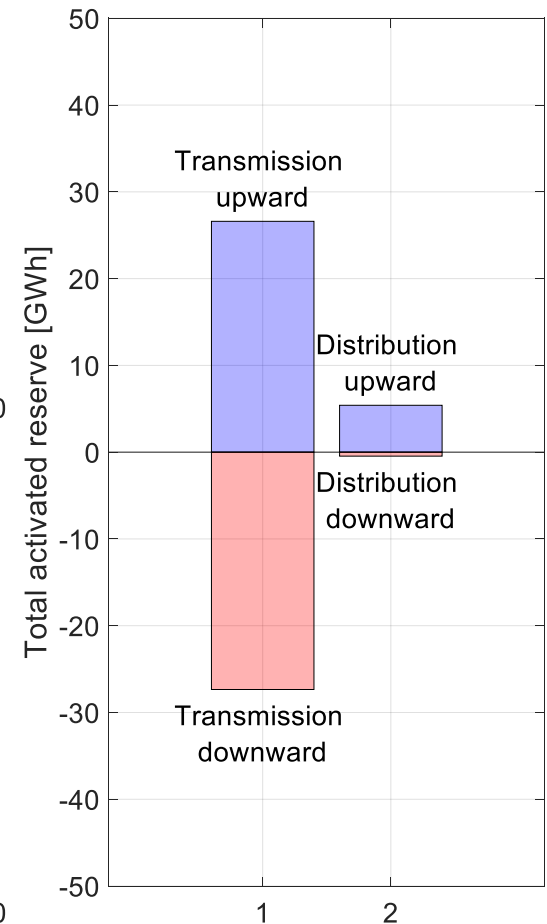
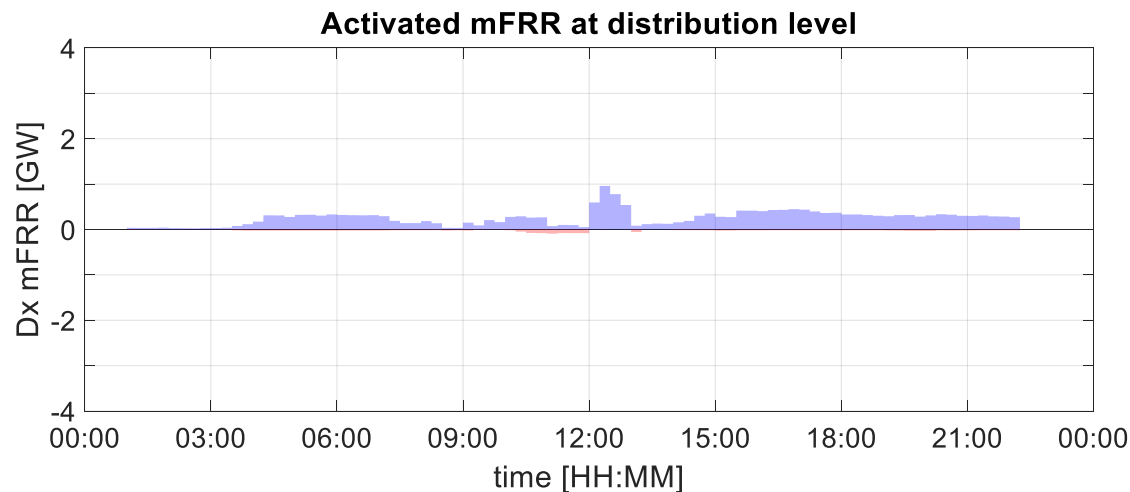
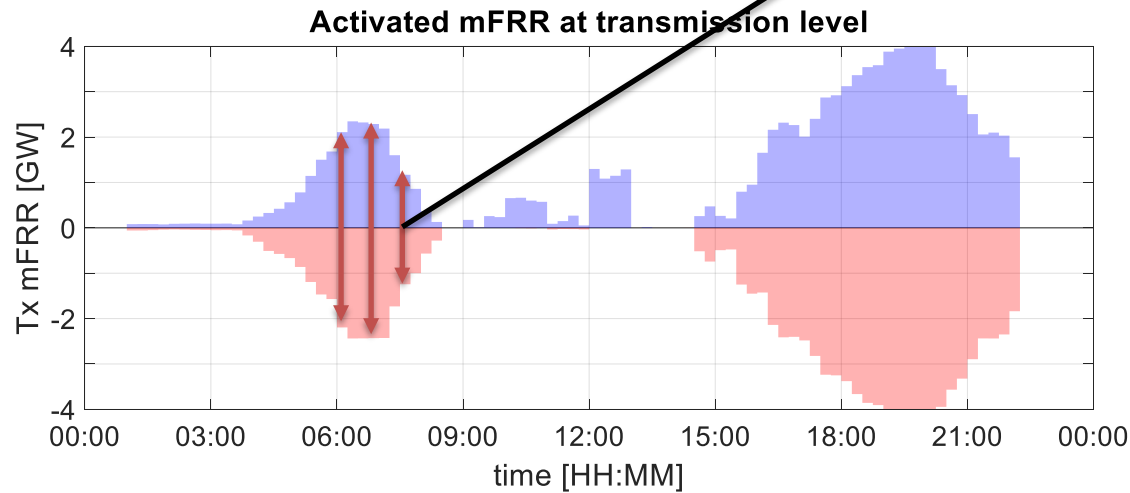


Bids are processed on the basis of the forecasted imbalance and network congestions

# Structure of the Simulator

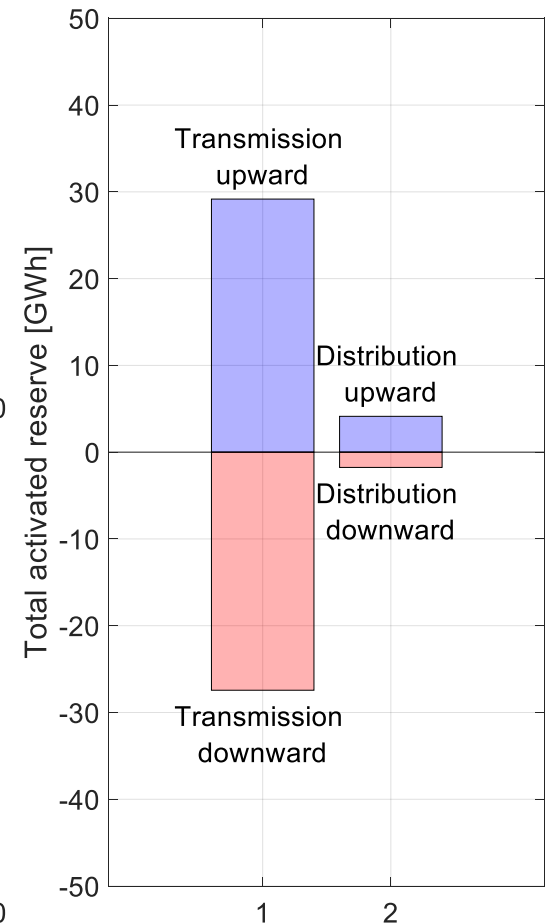
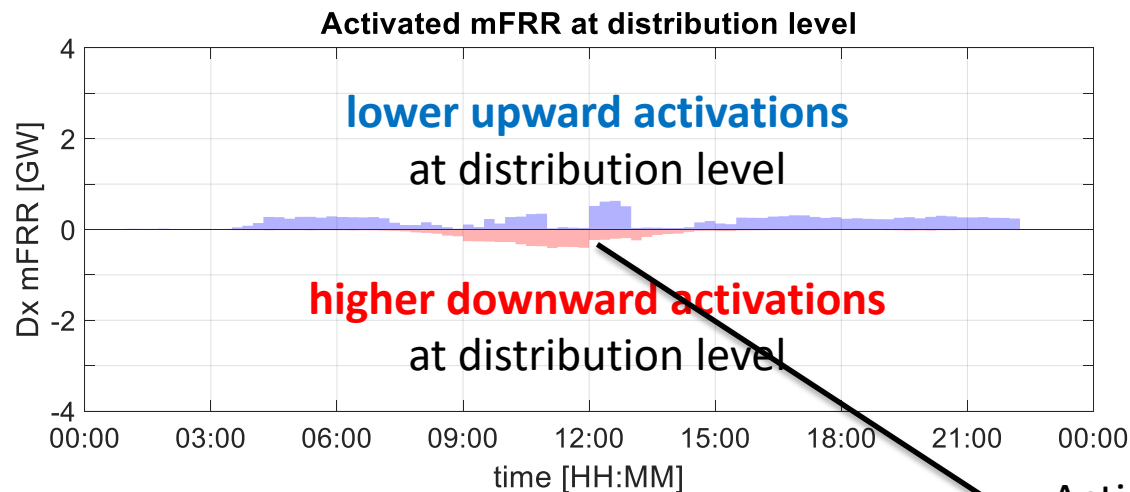
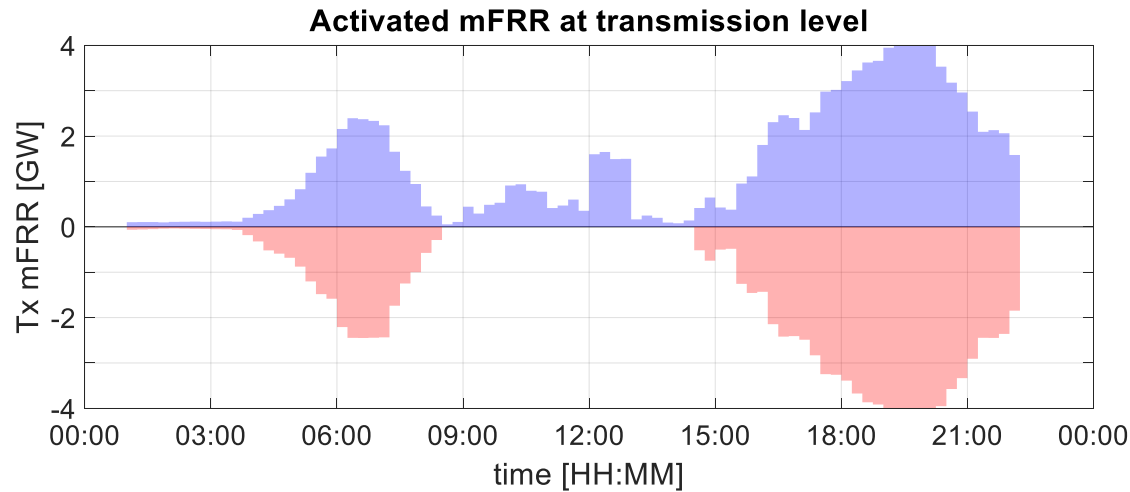
## Market clearing (CS A)

Simultaneous activation of both upward and downward regulation: presence of congestions



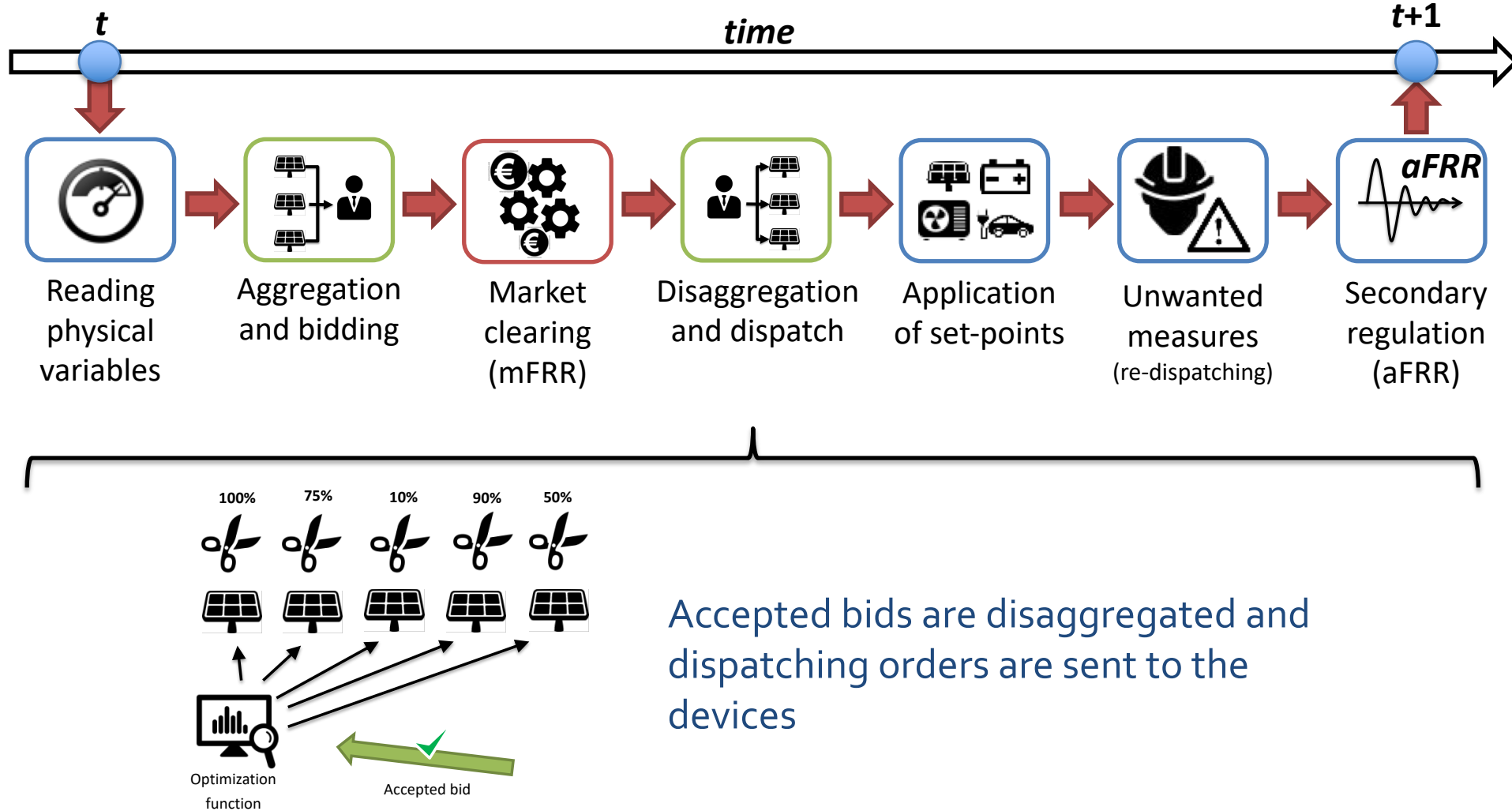
# Structure of the Simulator

## Market clearing (CS D)



Activations for distribution network congestions

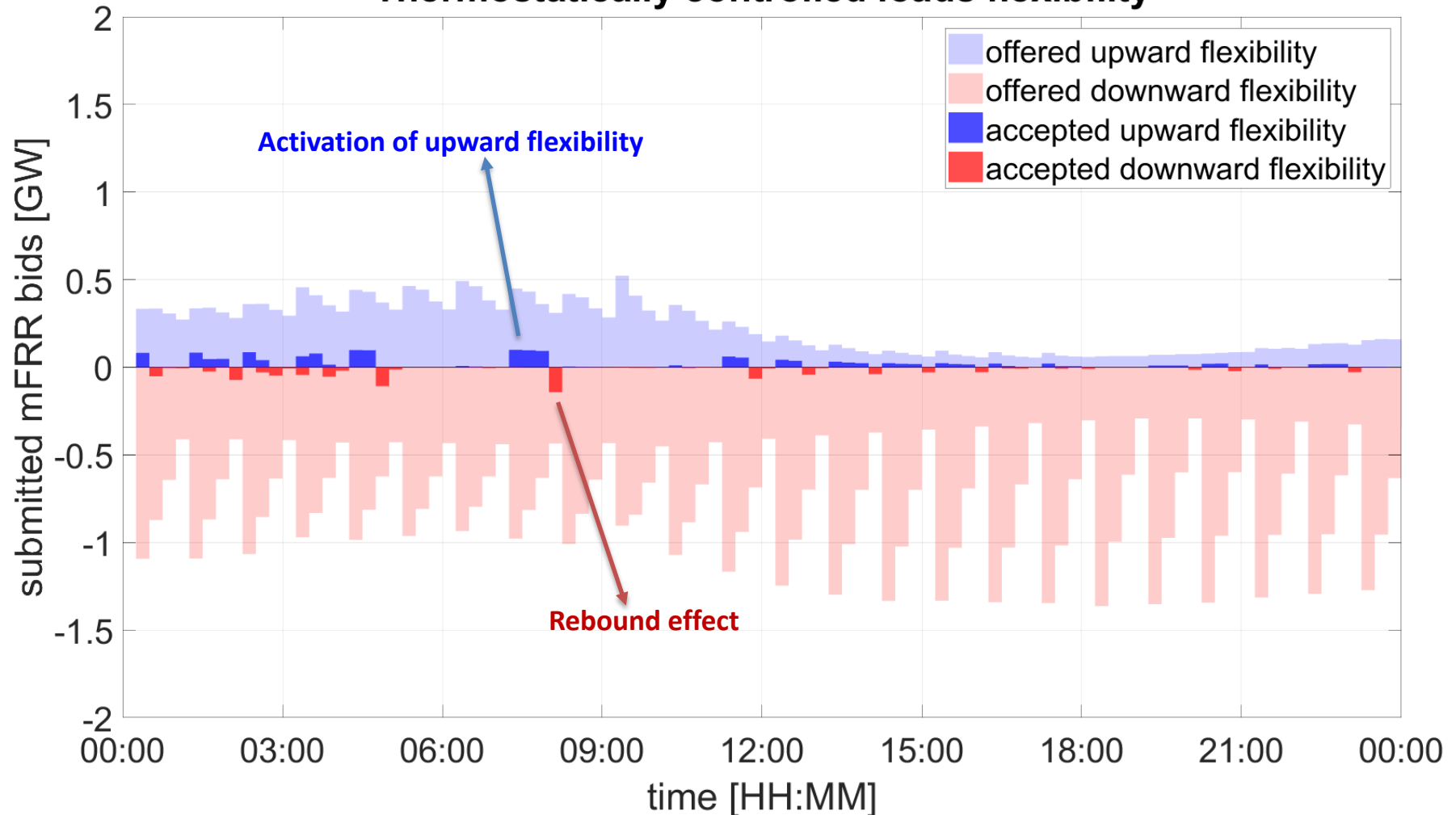
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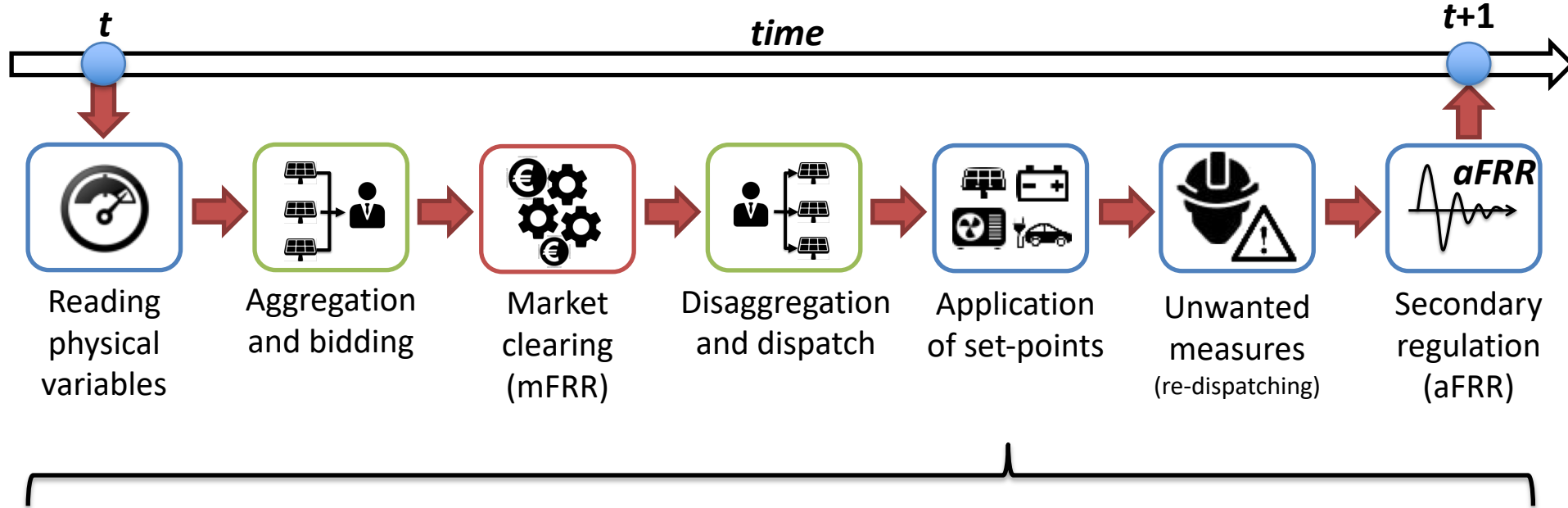
# Structure of the Simulator

## Disaggregation and dispatch (Thermostatic Controllable Loads)

### Thermostatically controlled loads flexibility



# Structure of the Simulator



Dispatching order: 80 MW

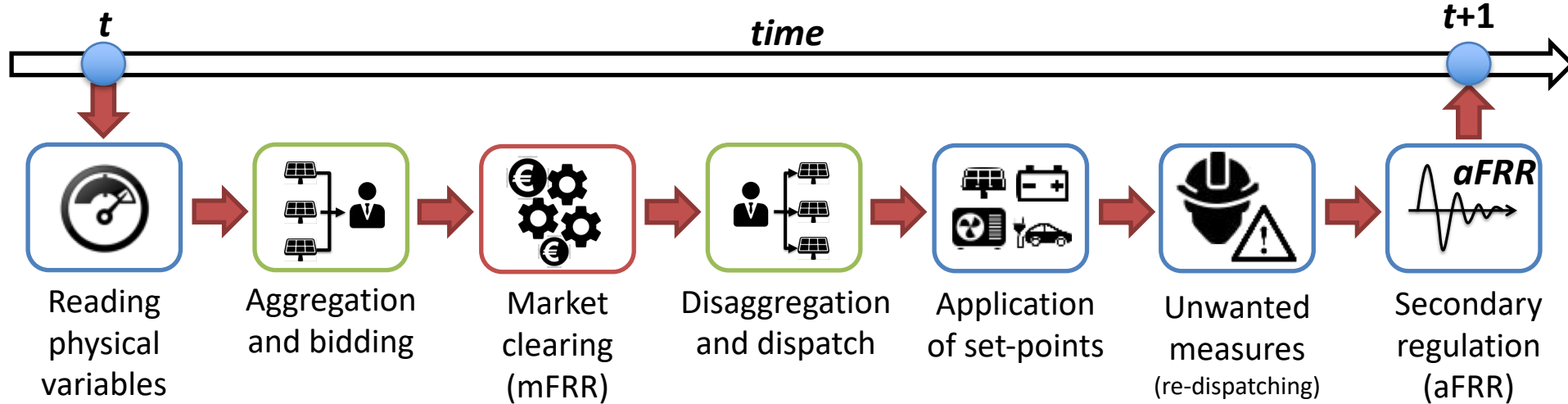
Available wind: 75 MW ⚠



Devices variables are updated and, in some cases, mFRR set-points are modified

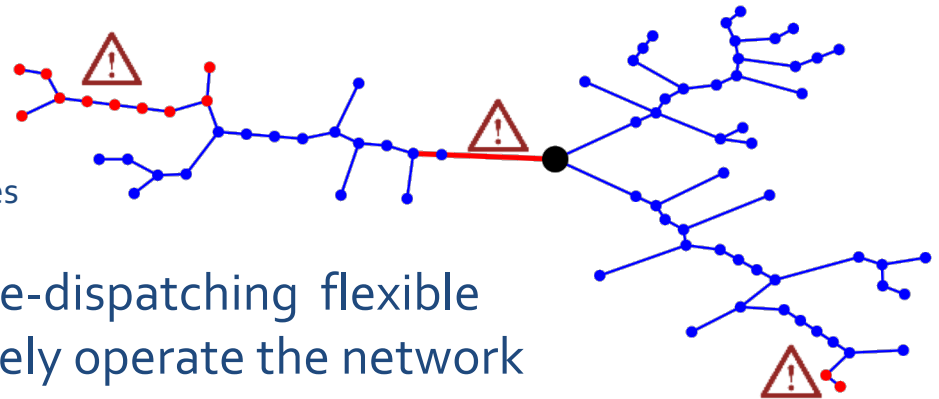
Forecasting/monitoring errors could make some dispatching orders inapplicable.

# Structure of the Simulator



Markets may fail in predicting network congestions

- distribution is not monitored in CS.A
- forecasting error impact on network variables



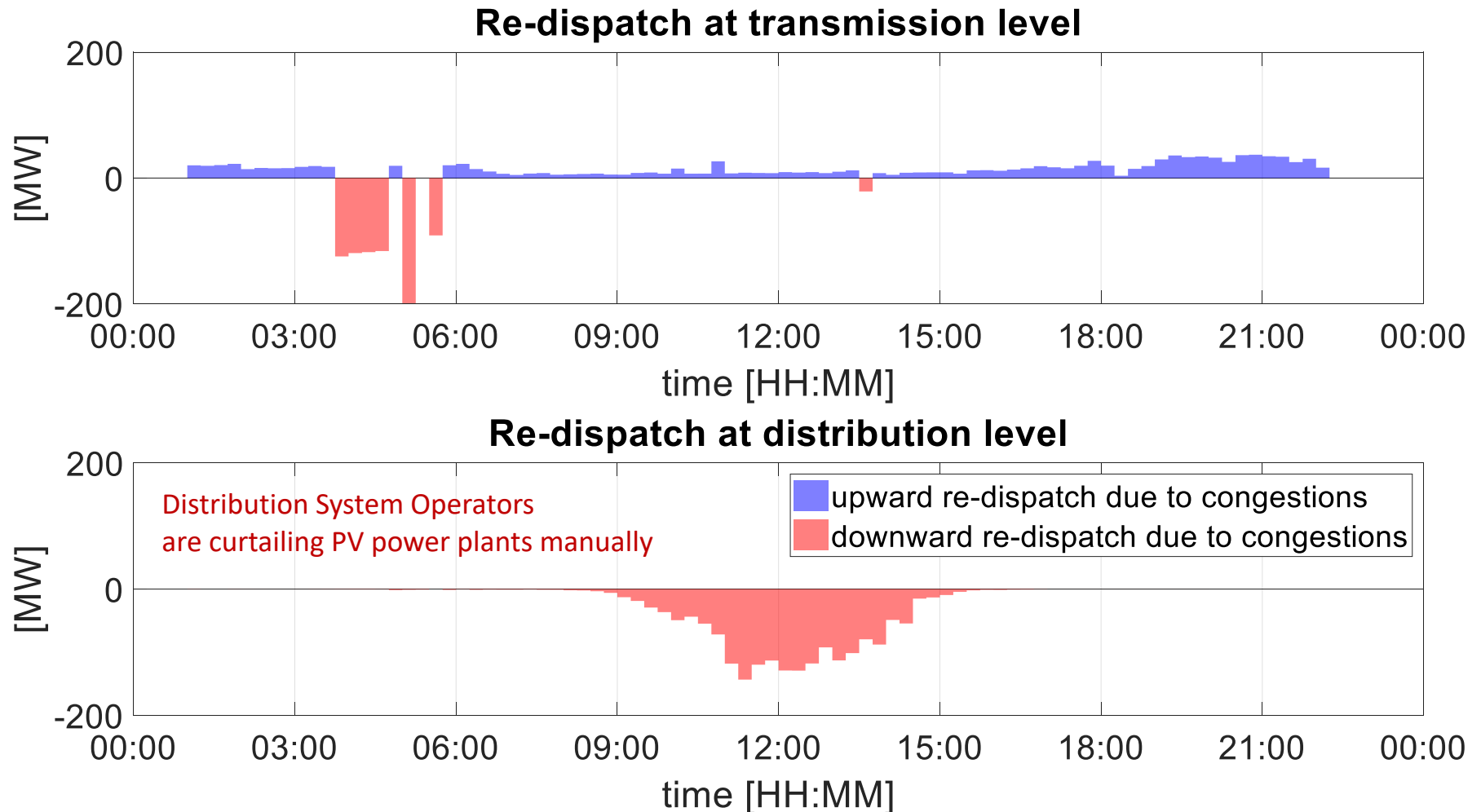
Network operators are re-dispatching flexible resources in order to safely operate the network





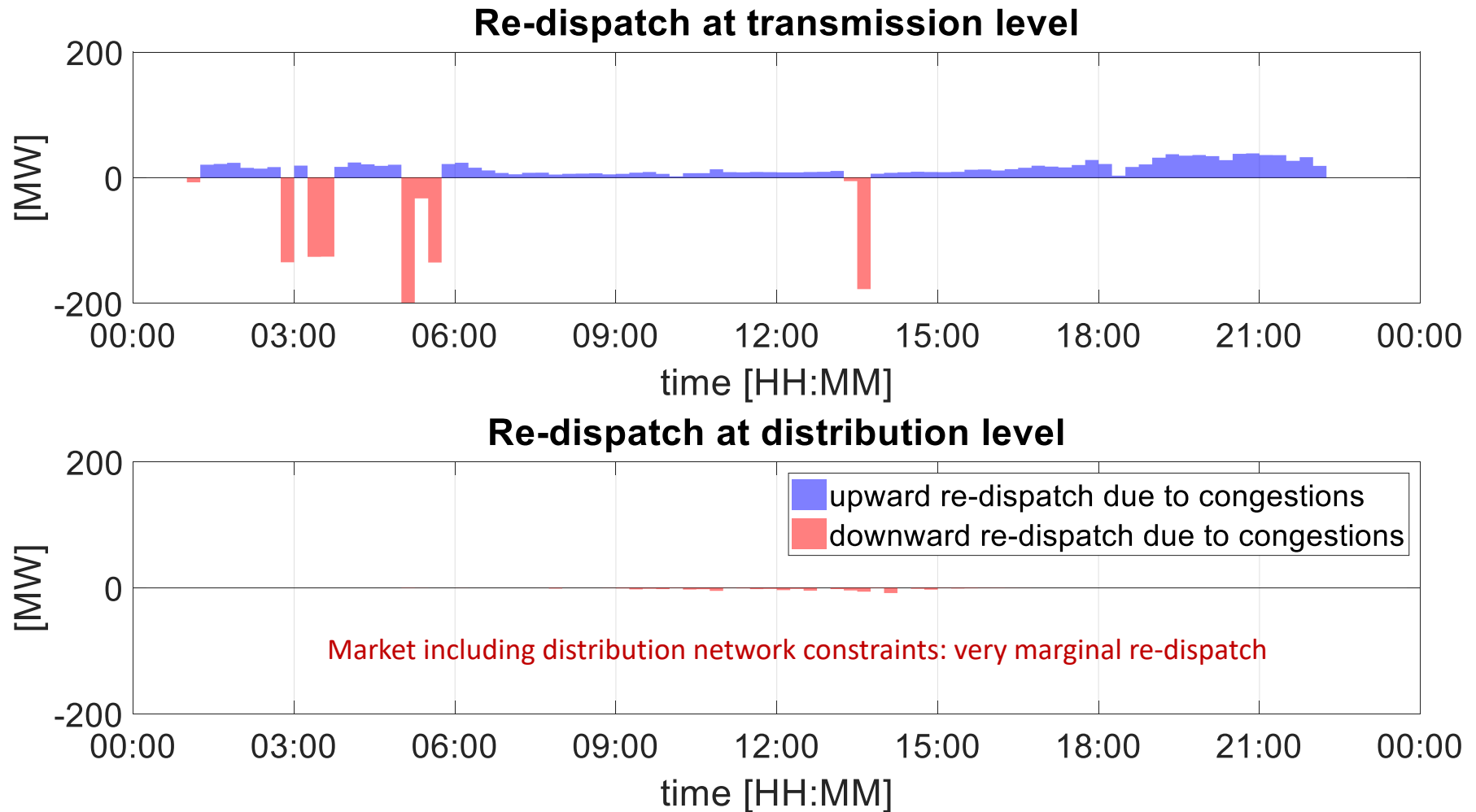
# Structure of the Simulator

## Unwanted measures (CS A)

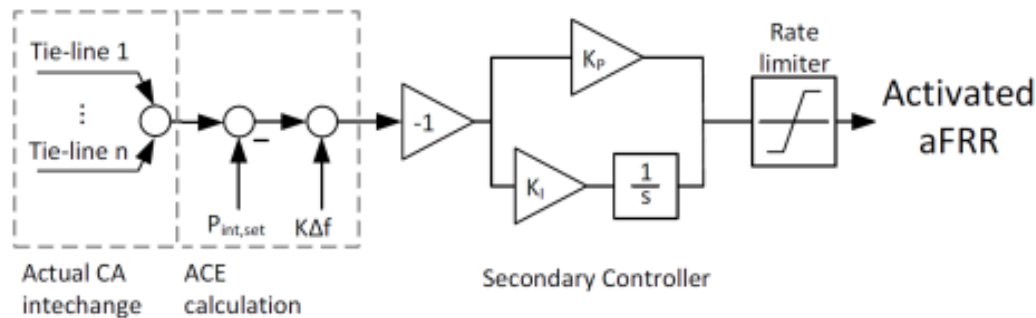
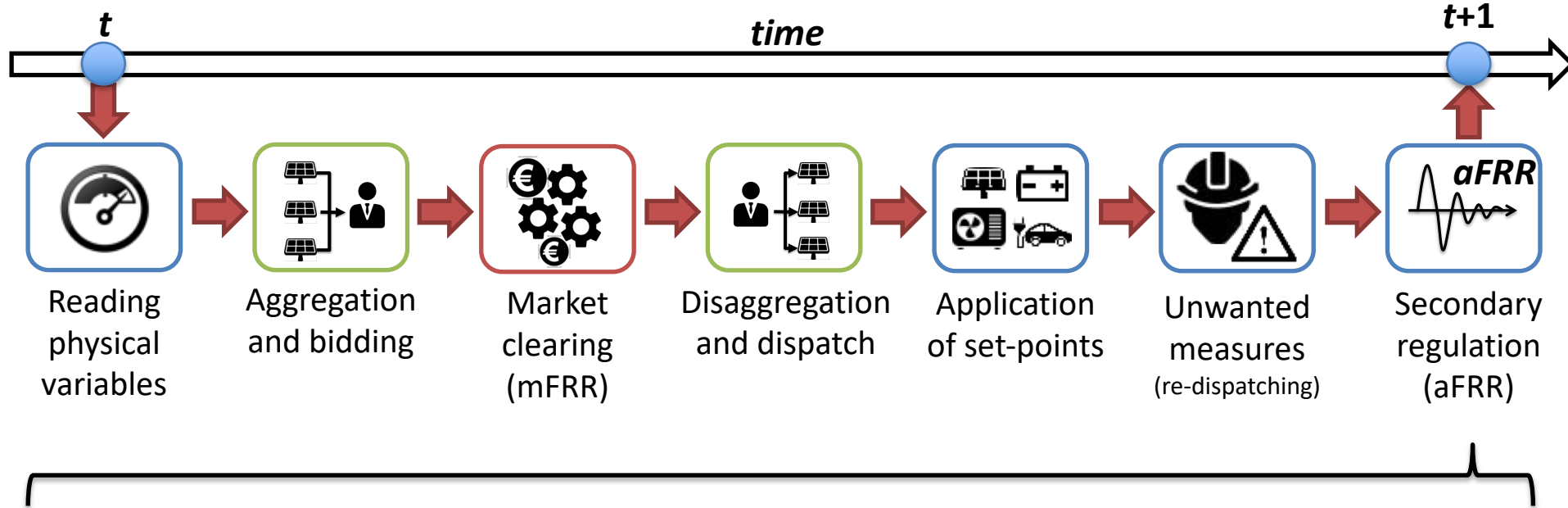


# Structure of the Simulator

## Unwanted measures (CS D)



# Structure of the Simulator

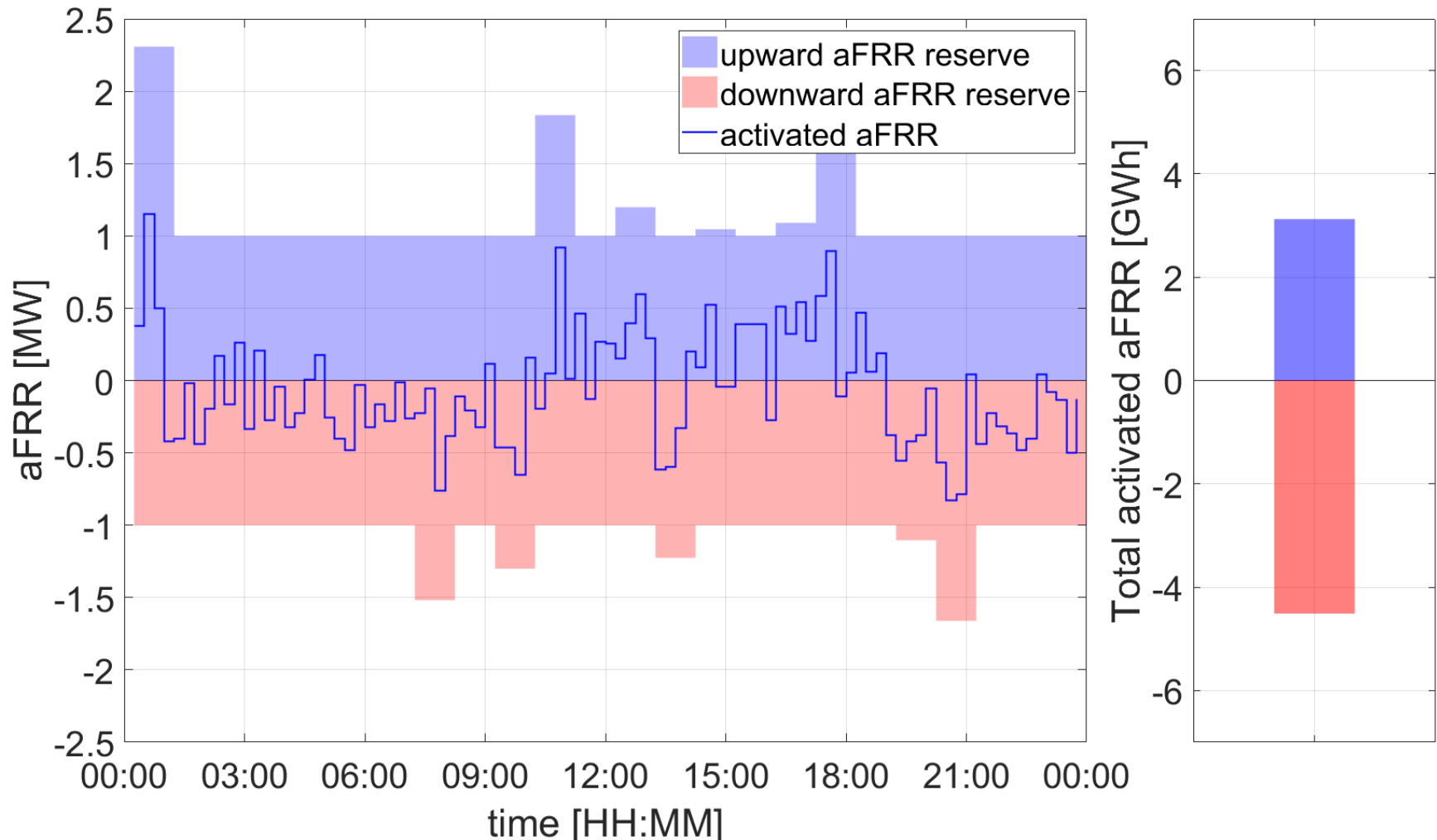


The imbalance occurred between  $t$  and  $t+1$  (residual imbalance) is managed by aFRR

Merit-order selected resources are participating to aFRR regulation

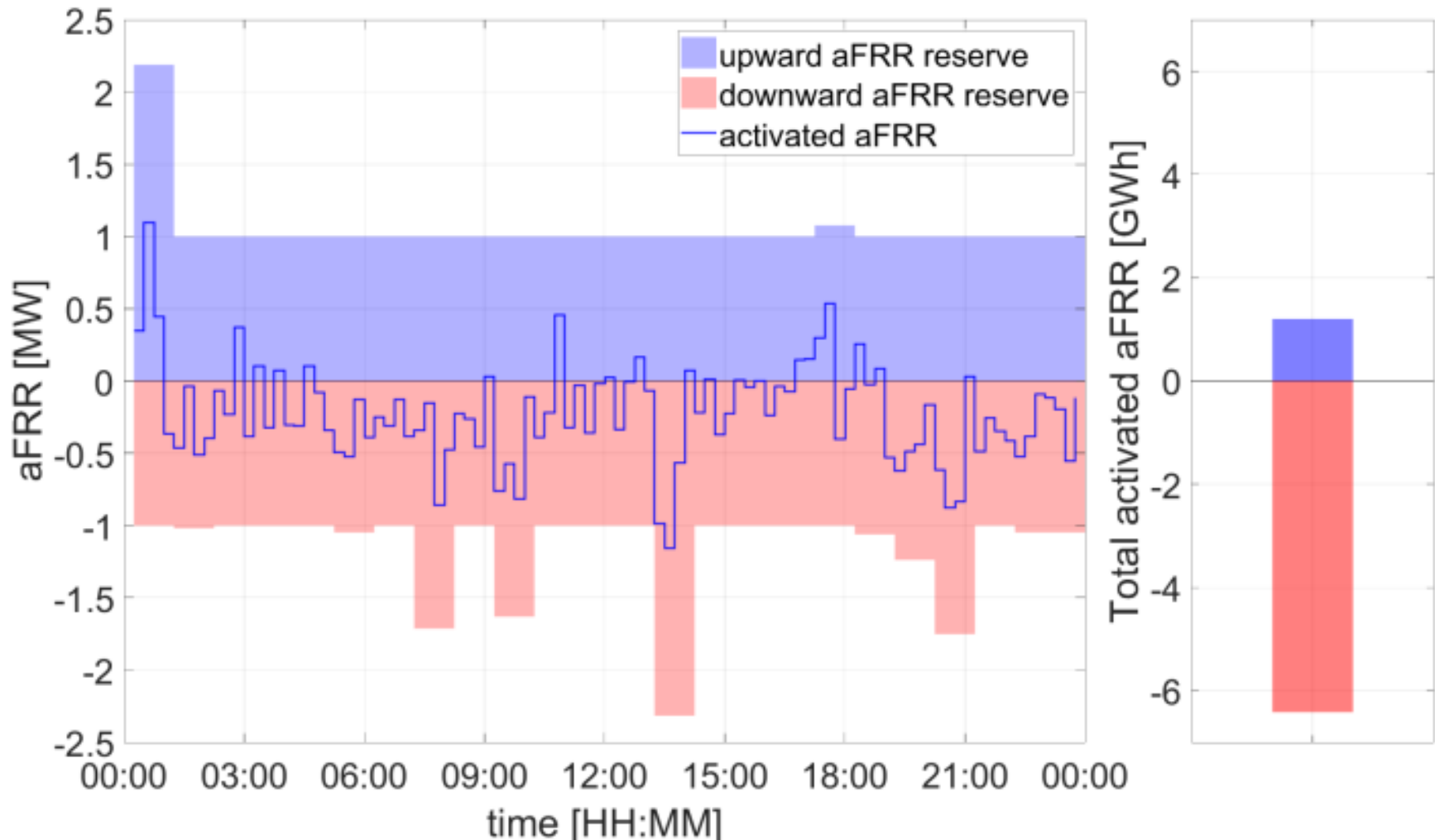
# Structure of the Simulator

## Automatic Frequency Restoration Reserve (CS A)

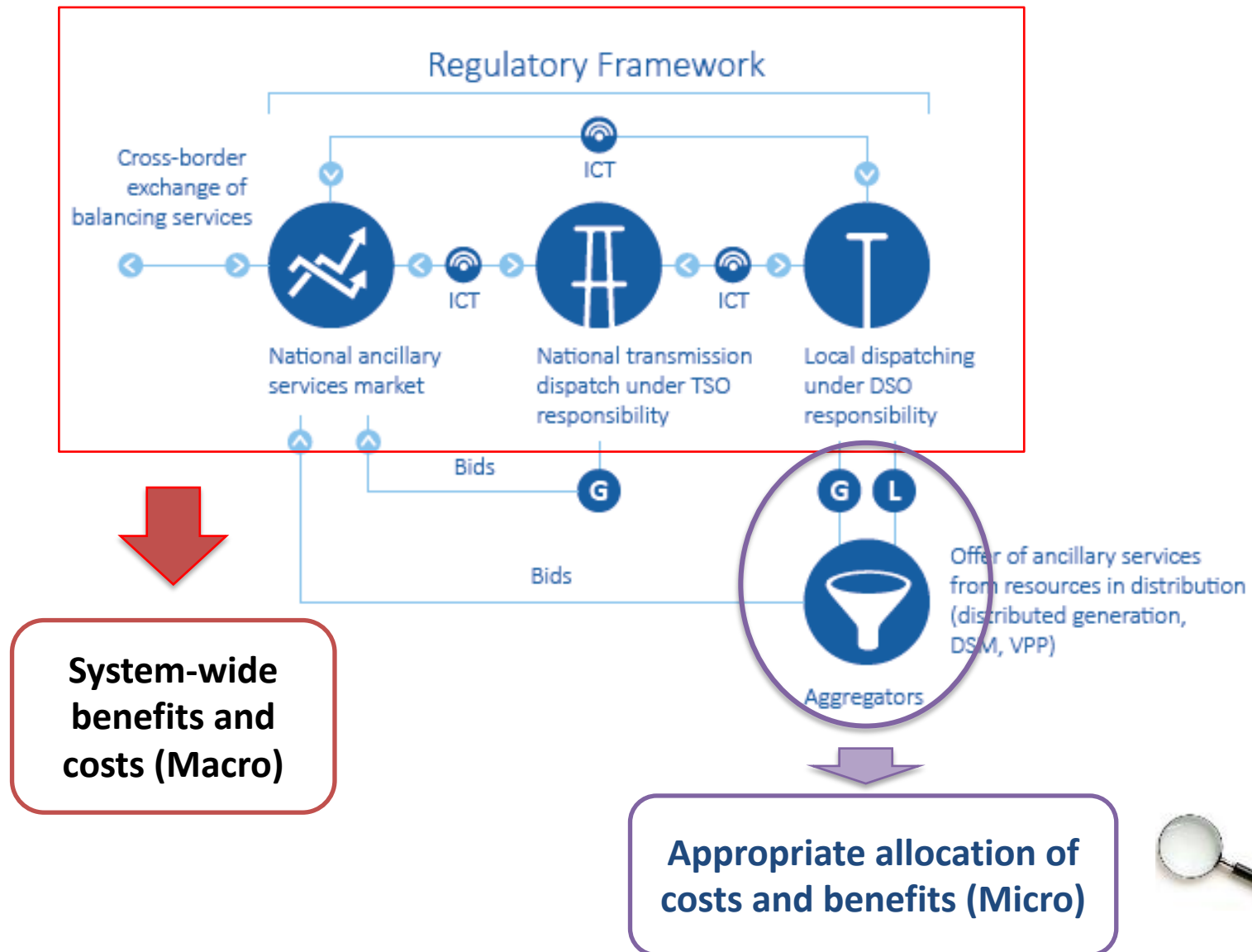


# Structure of the Simulator

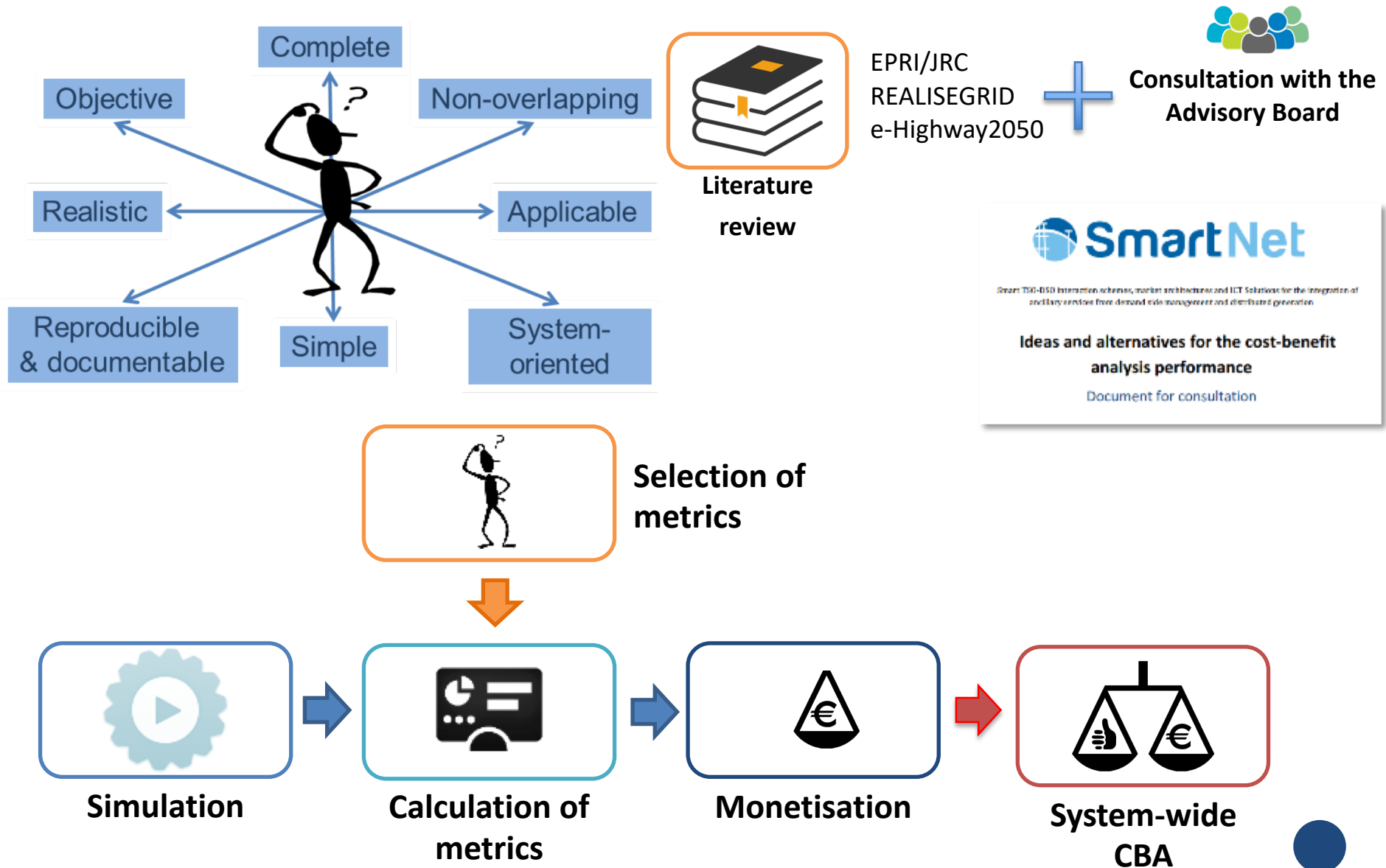
## Automatic Frequency Restoration Reserve (CS D)



# Relationship between main system actors



# Structure of the Macro Level Analysis



## Economic indicators

### Total mFRR cost

Cost of the market defined in SmartNet.  
Nodal pricing & pay-as-clear

### Total aFRR cost

Cost of re-balancing the system after mFRR.  
System-wide merit order based on bids to mFRR

### Cost of re-dispatching

Unexpected congestions solved with curtailment of  
load/generation, etc.

### Total ICT cost

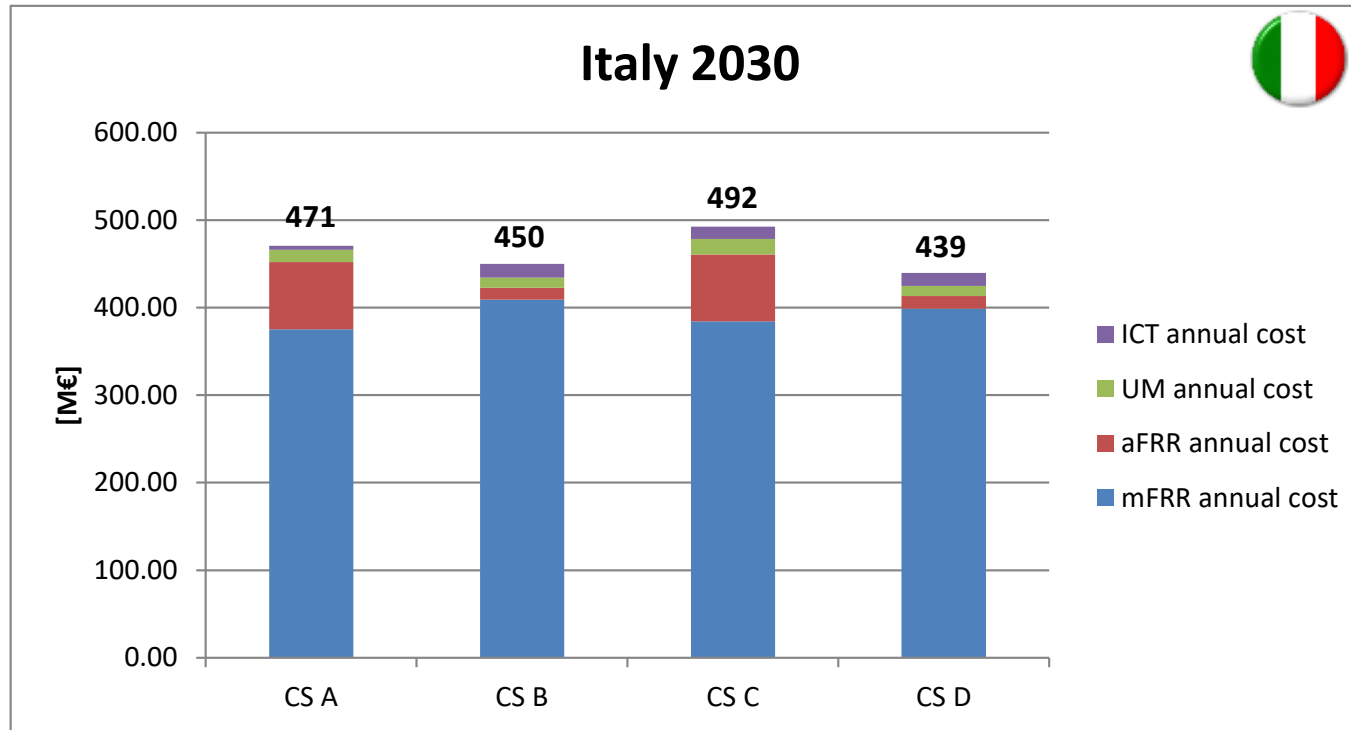
Information Technology costs based on development effort  
for aggregation and market clearing routines.  
Communication costs assumed to be comparable in all CSs  
CS A assumed to be in place by 2030 → additional costs for  
the rest of CSs

## Additional indicators

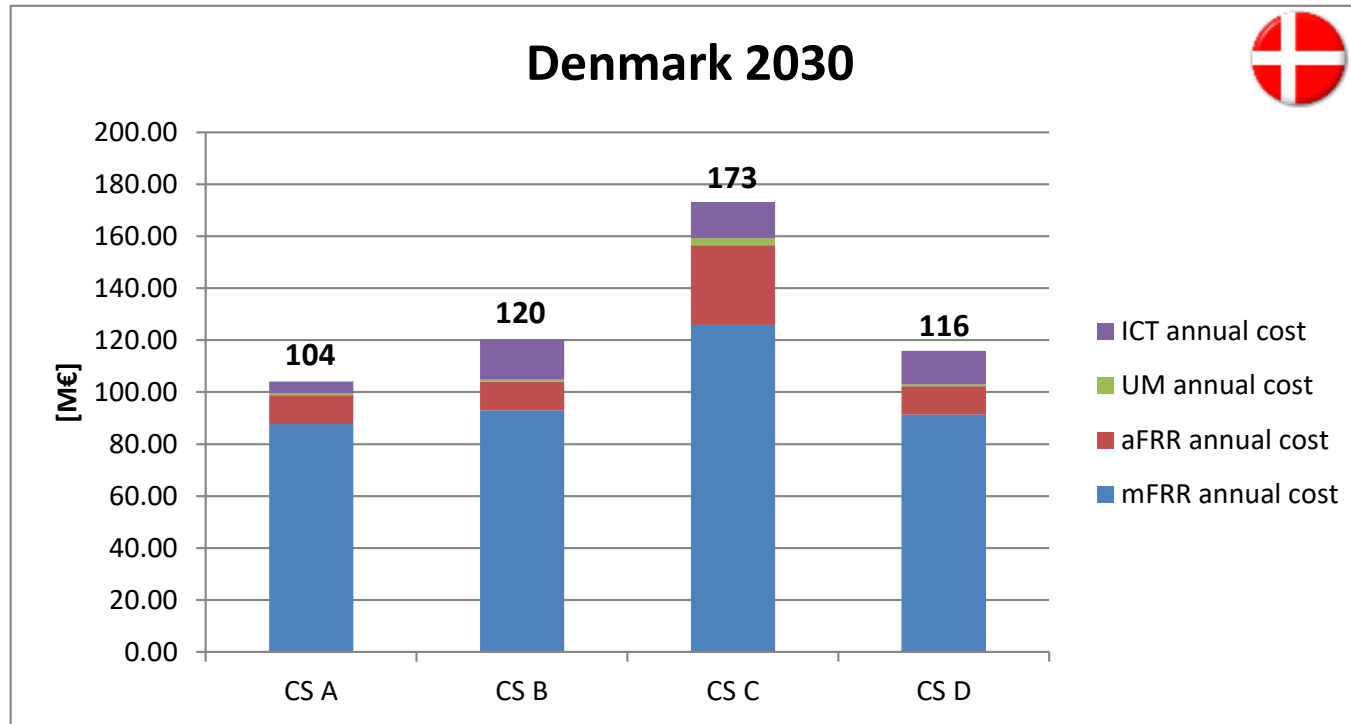
### CO<sub>2</sub> emissions

Standard emission rates per generation technology. Cost  
included in bids

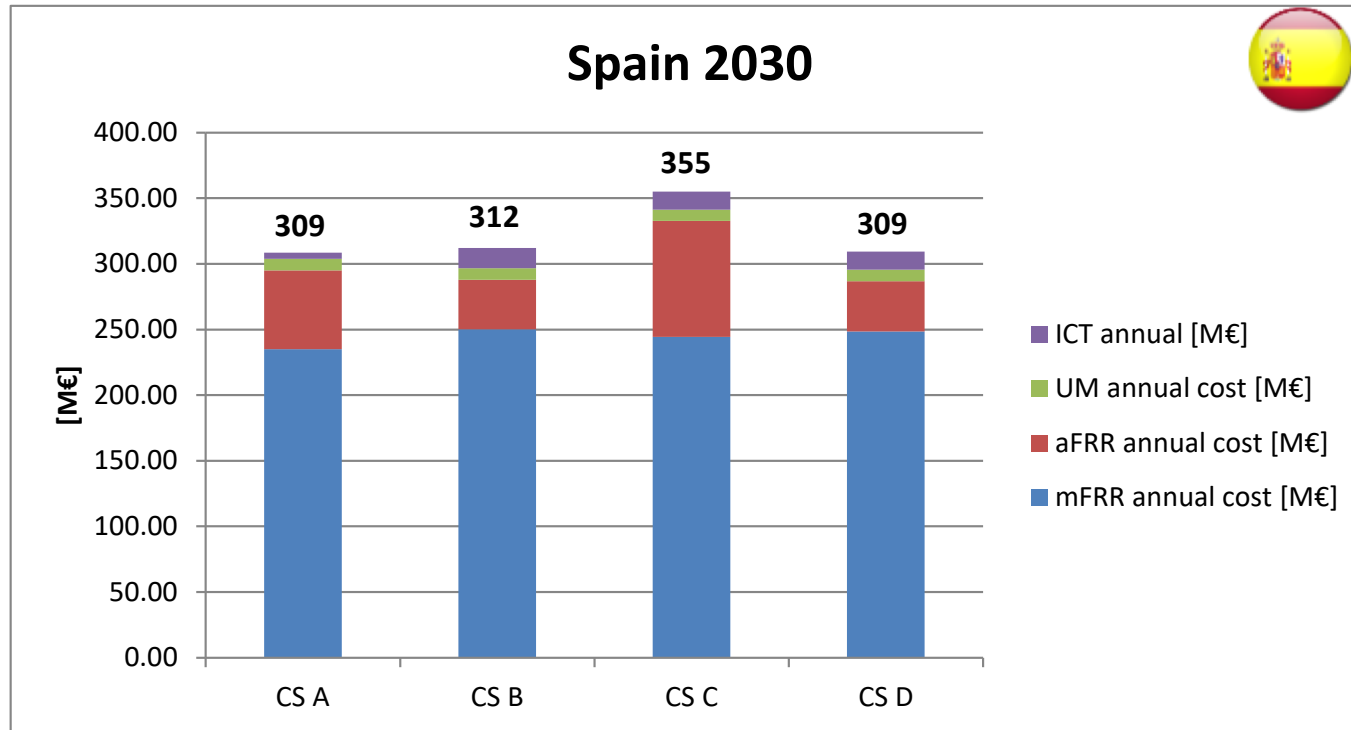




- The main component of the CBA is the mFRR cost. This cost is very similar in all CSs.
- UM and ICT costs are a small part of total costs.
- The main difference between CSs is determined by the aFRR cost.
- In the scenarios considered, the most efficient CSs are the CS B and CS D, although the total costs obtained for all CSs are very similar.

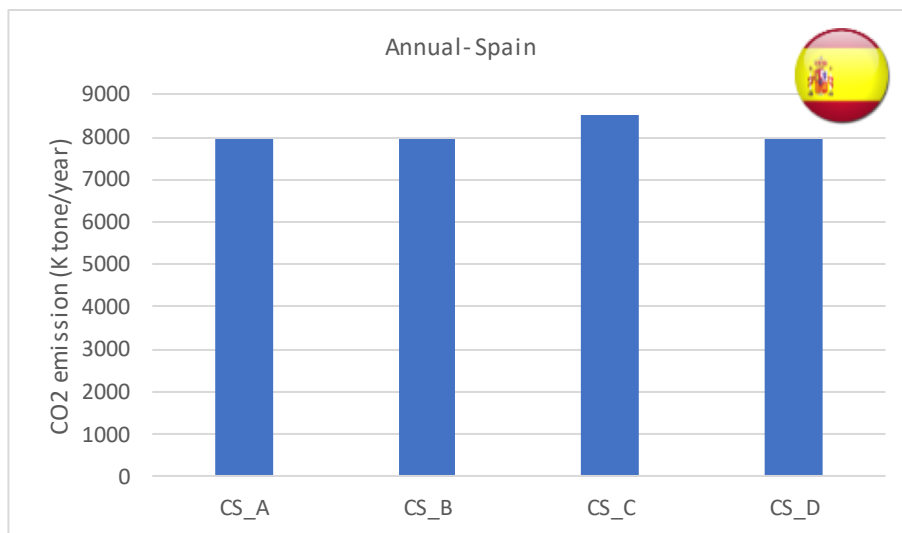
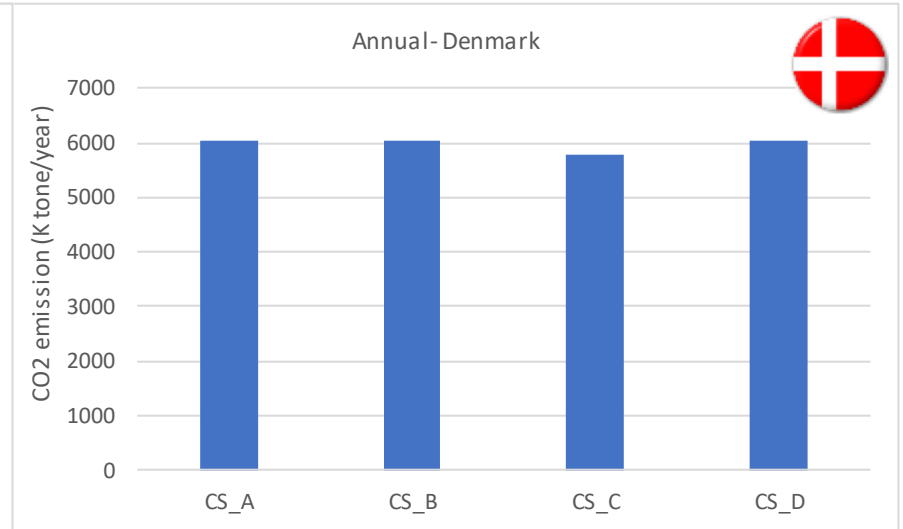
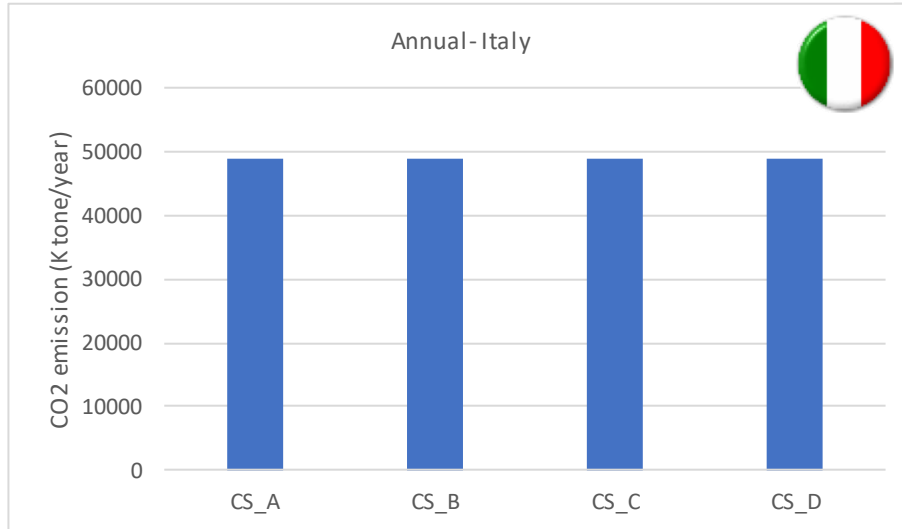


- The main component of the CBA is the mFRR cost.
- UM are almost negligible and ICT costs are a small part of total costs.
- The results for CS A, CS B and CS D are very similar. The main difference is caused by the ICT costs.
- In the scenarios considered, the most efficient CSs are either the evolutionary one (CS A) or the revolutionary one (CS D).



- The main component of the CBA is the mFRR cost. This cost is practically equal in all CSs.
- UM and ICT costs are a small part of total costs.
- The main difference between CSs is determined by the aFRR cost.
- However CS A, having higher aFRR costs, performs similar as ICT costs are lower.
- In the scenarios considered, the least efficient CS is CS C.

# Non-economic results: CO<sub>2</sub> emissions



- Italy is characterized by large CO<sub>2</sub> emissions if compared to other countries
  - DK has small demand and mostly renewable energy mixes
  - Spain energy mix is predominantly CO<sub>2</sub> free (nuclear and large portions of renewables)
- All CSs features similar CO<sub>2</sub> emissions:
  - mFRR activations are small if compared to the total energy demand
  - Sub-optimal mFRR activations (CS C) drive to more visible impacts on CO<sub>2</sub>. In Denmark, especially, CS C is resulting more efficient

- Effectiveness of TSO-DSO coordination schemes depends on level of services requested by the DSO
  - In case of **few congestions at distribution level** (forecasting errors are comparable to the possibility of having congestions in distribution grid), CS A has higher economic performance with respect to CS B and CS D
  - **When distribution congestions are significant (and predictable)**, the adoption of CS B or CS D results to be beneficial
- The implementation of two-steps markets is generally less efficient than optimizing in a single step (capable of considering both TSO and DSO needs – CS D)

**CS B  $\approx$  CS D**      Local market in CS B activates local mFRR for distribution congestion management. The results are pretty similar to the ones returned by CS D, even if slightly more costly in the simulated scenarios.

**CS C  $>$  CS x**      Local market in CS C, in addition to congestions, balances distribution grids. Scarcity and illiquidity of resources makes this scheme the least efficient one

**CS C  $<$  CS x**  
**CS B  $<$  CS x**      However, in rare circumstances (i.e. severe congestions at transmission level) the selection of two-steps markets architectures can be more beneficial than other schemes, as market separation potentially prevent the spreading of high nodal prices among distribution and transmission systems

- **Aggregators will bear a large portion of ICT costs:** communications with DERs, aggregation software, updates in aggregation algorithms to make competitive offers.
  - Potential issue with the **last kilometer DER communications**: it may be possible that DER communication/activation costs turn out to be too large for a profitable aggregation business (applicable to all CSs).
- **ICT costs in different CSs are almost the same and much lower than operational costs:**
  - Not the key element to select the best coordination scheme
  - Depending on the country, the cost of upgrading ICT systems may be greater than the energy benefits gained by adopting one complex coordination scheme rather than CS A

Italy



*significant congestions at distribution level*

Upgrading from CS A to CS B/D is convenient and not jeopardized by ICT costs

Spain



*average congestions at distribution level*

ICT costs is comparable to the benefits brought by adopting CS B/D rather than maintaining CS A

Denmark



*no relevant congestions if compared to forecasting error*

The implementation of CSs which includes DSO services failed



Thank You

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# SmartNet



[SmartNet-Project.eu](http://SmartNet-Project.eu)

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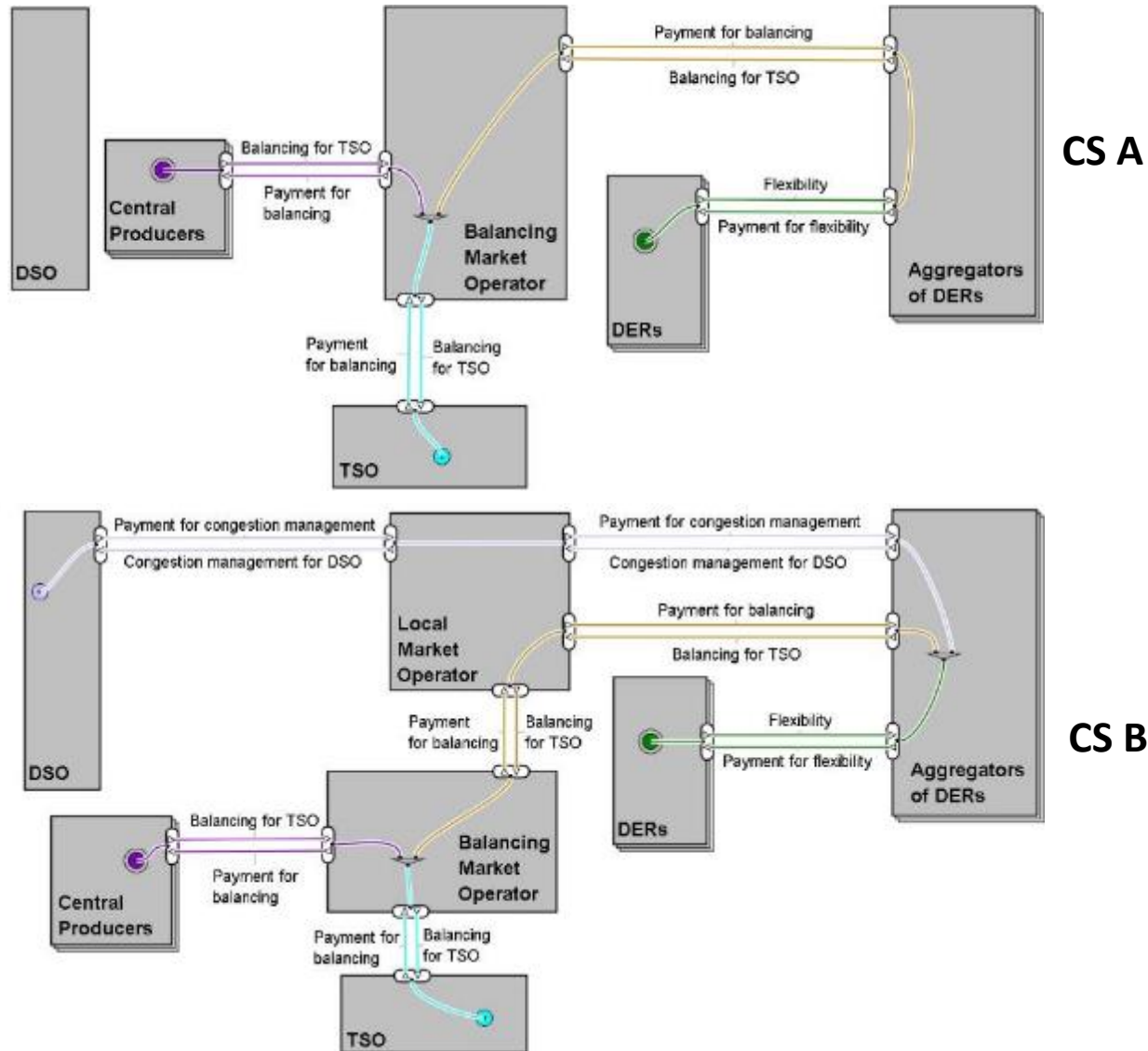
# Structure of Micro Level Analysis

## System-wide CBA



## Micro-level CBA

- Identification of the value chain
- Allocation of cost and benefits for each stakeholder
- Sensitivity analysis



# Structure of Micro Level Analysis

