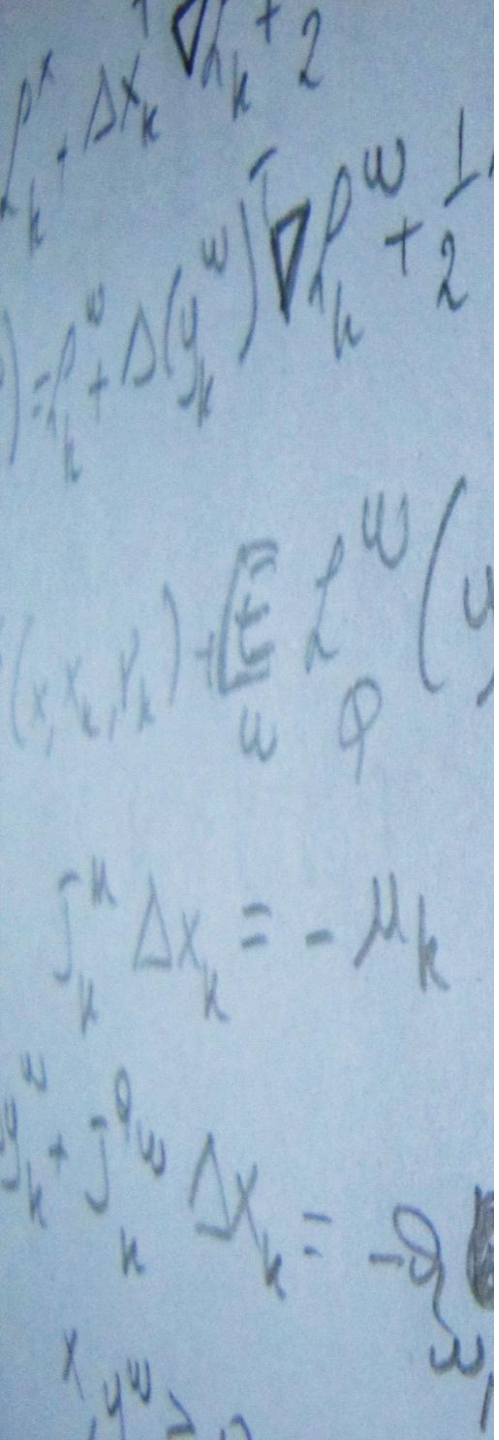

WG1-WG3: New problems in energy optimization: the industrial perspective.
Edinburgh 27th January 2016

New challenges in electricity and balancing market, the Market Operator and TSO perspective

Fabrizio Lacalandra:
Nomisma Energia-QuanTek

Outline

- ***Who we are and what we do***

- *The past, present and future (?) of the Electricity Market(s)*

- *Some challenges and some proposal/provocations*

- *The past, present and future (?) of the Balancing Market(s)*

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QuanTek – *Who we are and what we do*

Who we are:

QuanTek was born in 2009 by a group of **consultant** and **applied mathematicians** some of them working in the academies together with a **software development** unit.

Since 2011 ***NE Nomisma Energia*** is our majority partner. ***NE*** is a leading consulting company in the energy sector in Italy.

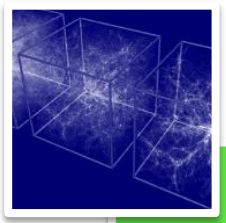
What we do:

QuanTek performs **analytics consulting** and develops **analytic software solution** in the **energy sector.**

Examples of quantitative solutions

Forecast and data mining

- Data mining and analysis of a set of market bids
- Competitors bids forecast in various market
- Forecast prices, network flows
- Forecast production for renewables
- Forecasting plants faults
- **Many others**



Simulation

- Simulating the operation of a market (electric or gas)
- Simulating the impact of a regulatory market change
- Simulating a long term evolution of an energetic system
- **Many others**

Optimization

- Optimize the production of (a portfolio of) hydro-thermal power plants in electricity markets
- Optimize a gas and power portfolio (forecast/optimization)
- Optimize a gas and power portfolio with derivatives instruments
- Optimize power plants maintenance strategy
- Optimize the use of gas storage resources
- **Many others**

QuanTek **Mission**:

- **Design**, **develop** and **implement** decision support systems based on quantitative approaches;
- Aiming at improving the **efficiency** and **performances** of various processes.

QuanTek **Vision**:

- Fill the gap between research and industry: mathematical methodologies improve at a fast pace;
- Realize **software solutions** based on a fast and flexible **proprietary software technology**;
- Proactive and reactive research;
- Develop a portfolio of flexible **App** that can be rapidly customized;
- Services covering the **whole lifecycle**.

QuanTek **Main market**:

- Energy companies (and utilities);
- Electricity producers/traders;
- Gas shippers/traders;
- Renewable energy producers;
- Transmission System Operator (TSO) and Market Operator (MO);
- Energy authorities;
- Other entities.

QuanTek – *Present partners and main on going projects*

QuanTek is working on the re design of the optimization models and algorithms for **Enel Generation Energy Management** short term together with **KPMG**

QuanTek is working on the analysis and development of the **data mining algorithms** for the **Regulation on Market Integrity and Transparency** (**REMIT**) for the Italian Energy Market Operator, **GME**

QuanTek is working on the simulation/optimization for the energetic system of Malta Island, within the EU project "***An energy roadmap - towards achieving decarbonization for the maltese islands***", COHESION POLICY 2007-2013

QuanTek is developing the **next generation** of predictive and optimization App for renewables sources in collaboration with BaxEnergy, producers of the Energy Studio Pro

QuanTek collaborates with **CNR** (Italian Research Council) IASI for the analysis, selection and development of the **best mathematical approaches**

QuanTek is a **partner** of the **GuRoBi Inc**, developer of the homonymous optimization solver

QuanTek uses Julia/JuMP, a modern software developing technology specifically oriented to **scientific computing**, notably optimization. QuanTek extended the JuMP optimization layer into a proprietary framework called **EasyOpt**

QuanTek - *pre competitive academic research*

- Fabio **D'Andreagiovanni**, G. **Felici, F. Lacalandra** **Revisiting the use of Robust Optimization for optimal energy offering under price uncertainty,** Dec 2015 submitted to IEEE Transactions on Power Systems.
- Fabio **D'Andreagiovanni**, G. **Felici, F. Lacalandra**. **A revised Robust Optimization approach for the Price-uncertain Power Offering Problem**. In AIRO Conference 2015, Pisa
- M. Tahanan, W. van Ackooij, A. Frangioni, **F. Lacalandra**. **Large-scale Unit Commitment under uncertainty: a literature survey,** invited survey 4OR, January 2015.
- S. Bruno, M. Di Lullo, **G. Felici**, **F. Lacalandra**, M. La Scala **Tight Unit Commitment models with Optimal Transmission Switching: Connecting the dots with Perturbed Objective Function**, COMPENG 2014 Conference, Barcellona
- **G. Felici**, A. Naimo, "**Committing electrical power units taking into account wind sources**", Procedia Social and Behavioral Sciences , Elsevier, (2013), vol.1
- A. Frangioni, **C. Gentile**, **F. Lacalandra**, A. Naimo "**Unit Commitment Models with Power Variables"**, IASI-CNR, R. 11-26, 2011
- A. Frangioni, **C. Gentile**, **F. Lacalandra** "**Sequential Lagrangian-MILP Approaches for Unit Commitment Problems**" International Journal of Electrical Power and Energy Systems 33, p. 585 - 593, 2011
- A. Frangioni, **C. Gentile, F. Lacalandra** "**Tighter Approximated MILP Formulations for Unit Commitment Problems**" IEEE Transactions on Power Systems, 24(1), p. 105 - 113, 2009
- A. Frangioni, **C. Gentile**, **F. Lacalandra** "**Solving Unit Commitment Problems with General Ramp Contraints**" International Journal of Electrical Power and Energy Systems 30, p. 316 - 326, 2008
- A. Borghetti, A. Frangioni, **F. Lacalandra** and C.A. Nucci "**Lagrangian Heuristics Based on Disaggregated Bundle Methods for Hydrothermal Unit Commitment**" IEEE Transactions on Power Systems, 18(1), p. 313 - 323, 2003
- A. Frangioni, **C. Gentile**, **F. Lacalandra** "**New Lagrangian Heuristics for Ramp-Constrained Unit Commitment Problems**" Proceedings of the 19th Mini-EURO Conference in Operational Research Models and Methods in the Energy Sector (ORMMES 2006), Coimbra, 6-8 September 2006
- A. Borghetti, A. Frangioni, **F. Lacalandra**, C.A. Nucci, P. Pelacchi "**Using of a Cost-based Unit Commitment Algorithm to Assist Bidding Strategy Decisions**" Proceedings IEEE 2003 Powerteck Bologna Conference, A. Borghetti, C.A. Nucci and M. Paolone editors, Paper n. 547, 2003
- A. Borghetti, A. Frangioni, **F. Lacalandra**, A. Lodi, S. Martello, C.A. Nucci, A. Trebbi "**Lagrangian Relaxation and Tabu Search Approaches for the Unit Commitment Problem**" Proceedings IEEE 2001 Powerteck Porto Conference, J.T. Saraiva and M.A. Matos editors, Vol. 3, Paper n. PSO5-397, 2001
- **G. Felici**, G. Rinaldi, A. Sforza, K. Truemper, "**A Logic Programming based Approach for on-line Traffic Control"**, *Transportation Research part C*, 14, (2006), 175-189
- M. Bielli, **G. Felici**, M. Mecoli and A. Pacifici, "**Equilibrium in Competing Supply-Demand Flow Problems"**, *System Science*, Vo.. 33, N. 1, pp. 7-17, 2007
- **G. Felici**, M.G. Mecoli, "**Resource Assignment with Preference Conditions"**, European Journal on Operational Research, Vol. 180-2 (2007), 519-531.
- **G. Felici**, B. Simeone, V. Spinelli. " **Classification Techniques and Error Control in Logic Mining"**, Annals of Information Systems, Volume 8, pp. 99 - 119 (2009). ISBN: 978-1-4419-1279-4.

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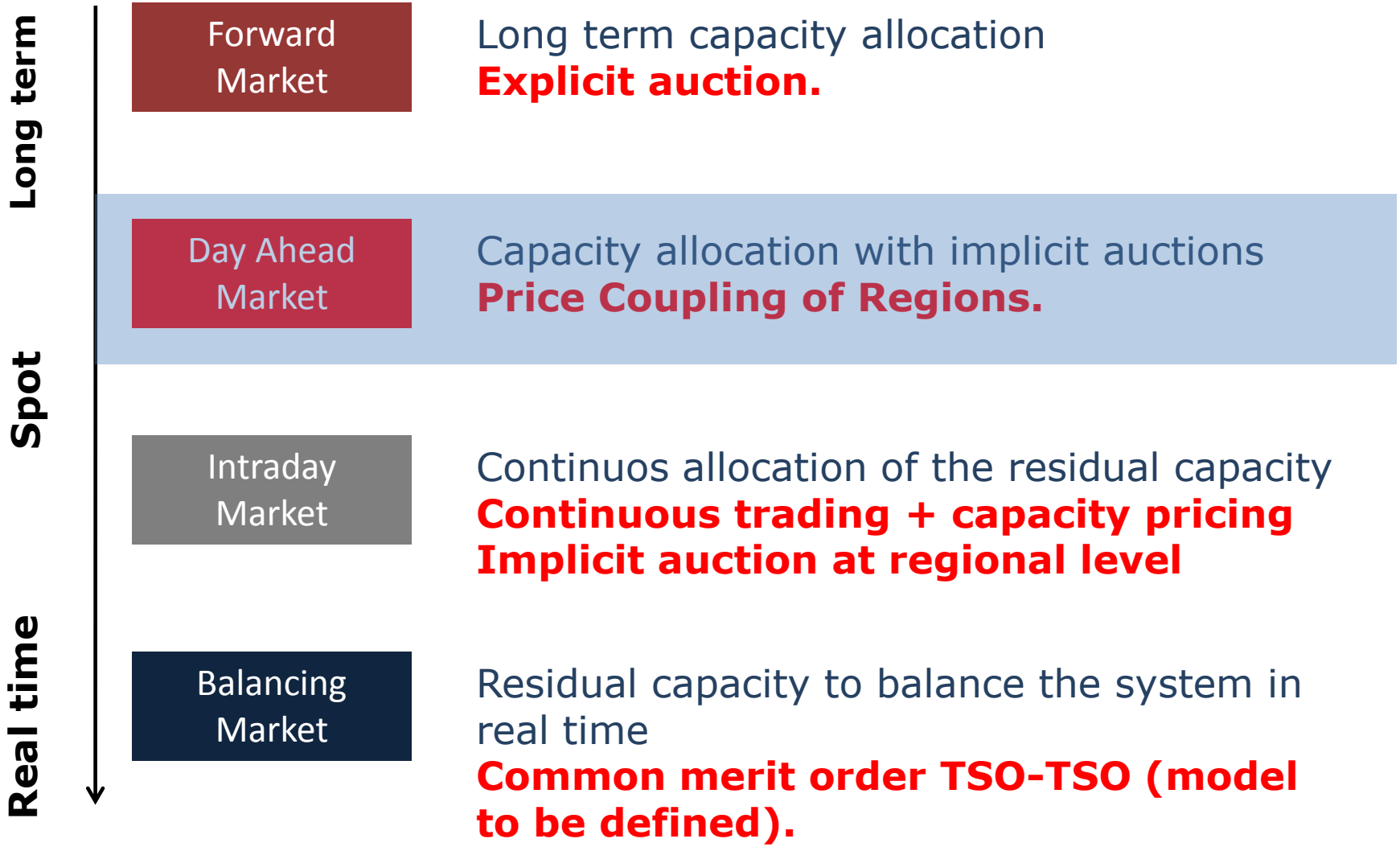
The electricity target model

The electricity target model



Network codes

- Connections
  - Requirements for generators, RfG
  - Demand Connection Code, DCC
  - High Voltage Direct Current, HVDC

- Of Sytem Operator
  - Operational security, OS
  - Operational planning and scheduling, OPS,
  - Load- Frequency Control and Reserve, LFC&R
  - Emergency and Restoration, E&R

- Of markets
  - Forward Capacity Allocation, FCA
  - Capacity Allocation and Congestion Management, **CACM**
  - Balancing, **BAL**

Work in progress…

Network codes

- Connections
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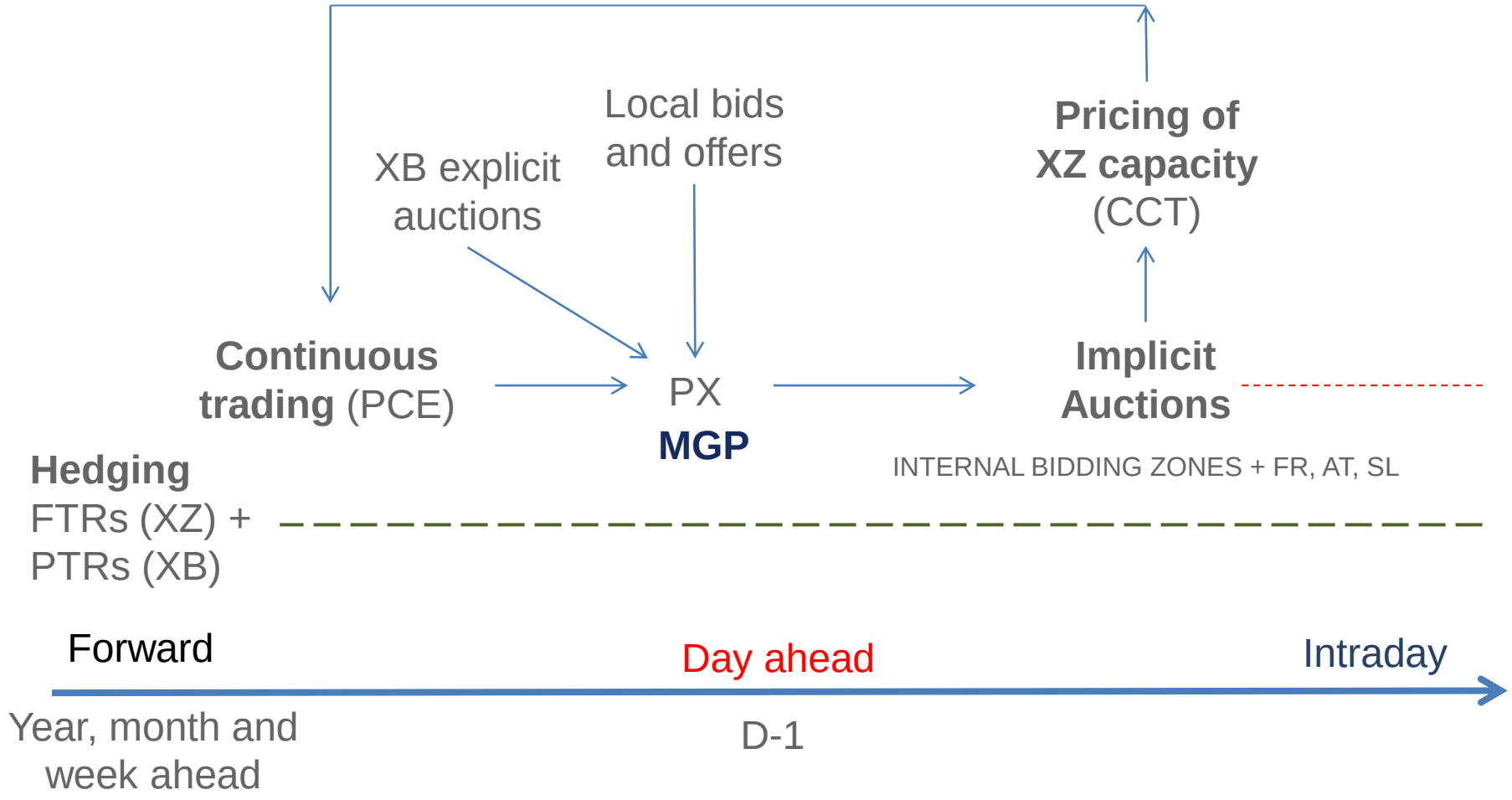
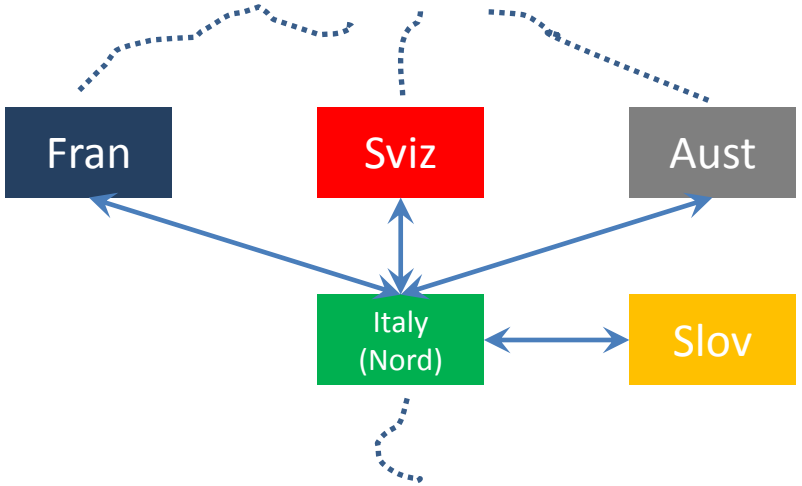
Work in progress…

Example of regional energy marked design (FWD to Day Ahead): Italy



The past: Basically **explicit** cross border transmission capacity allocation and individual regional markets products/rules **with different** clearing models, e.g.



Inefficient allocation of the transmission Capacity, energy flows accordingly with the contracts

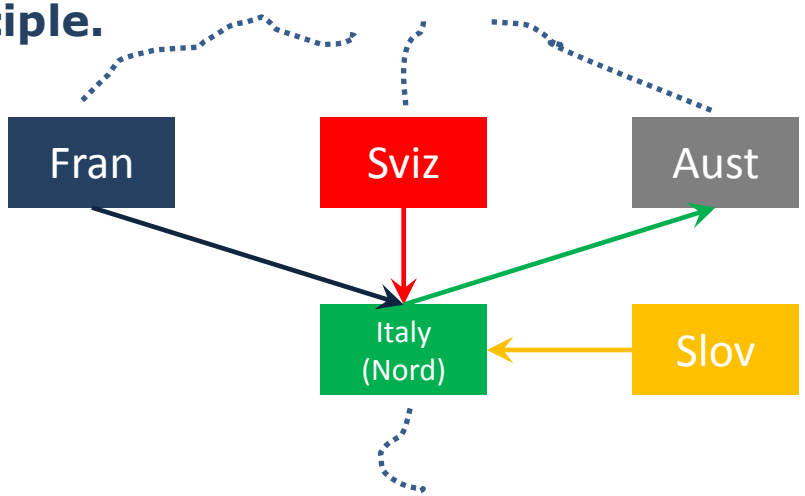
Pros:

- Single market algorithm **clears** its **own** model;
- Single authority **can** propose/define/introduce **new** products.

Cons:

- **Inefficient** allocation of transmission capacity.

The present: Basically **implicit** cross border transmission capacity allocation and individual regional markets products/rules in **one single** clearing model. Process is on a "**voluntary**" basin, considering the **subsidiary principle.**



Efficient allocation of the transmission Capacity, energy flows accordingly with the Offers..but lots of **unscheduled** flows too

Pros:

- **Efficient** allocation of transmission capacity.

Cons:

- Single market algorithm **must** clear all models **simultaneously, with all that this means;**
- Single authority **cannot** (?) autonomously propose/define new products.

List of individual products/rules of single regional markets

- hourly step and interpolated orders
- regular **block orders**
- Profile **block orders**
- Linked **block orders**
- Exclusive **block orders**
- Flexible block orders
- Curtailable block orders
- **MIC orders**
- Load gradients
- Scheduled stops
- **PUN orders**
- Merit orders
- Flow based intuitive

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Some challenges and some proposal/provocations, 1

The present energy market model (MRC/PCR) gave birth to the need of a central maximum welfare "hybrid" optimization model and algorithm. First **Cosmos,** then its evolution, named **Euphemia,** algorithm by the N-SIDE company.
Considering all the regional products, Euphemia was called to integrate all of them creating a **large scale non convex quadratic** optimization problem. AFAIK, it is solved with MIP technology (Cplex) and several primal heuristics.

(Some) challenges:

Time to find feasible solution(s)

- The algorithm is allowed to run for 10 minutes

Capability of proving optimality

- The algorithm should prove optimality in its allowed time ? And what if not ?

Possible simmetries in the (optimal) solution(s) ?

- What if we have multiple simmetrical solutions ?

What if e.g. Italy wants to implement Block Orders or MIC products?

- The present orientation is to «limit» futher extensions of the current products not to complicate the situation…*a first in, best served* principle, is that acceptable?

"…PJM, for instance, allows its MIP optimizer to run within a certain period of time or until the optimality gap is below some maximal threshold, and uses whatever intermediate integer feasible solution the solver has found. An obvious issue raised in using MIP to solve the commitment is, therefore, how robust the solution is in terms of economic efficiency and fairness to market participants…"

S. Oren et al, **Three-part auctions versus self-commitment in day-ahead electricity markets, 2010**

Lots of work!!

For each of the challenge a solution has to be found. One can take different **avenues**, basically:

1. **Working** on the model/algorithm itself (but allowing for future extensions of the products…);
2. **Simplify** the model and "**harmonize**" the future products at the Multi-Regional level, i.e. all the regional market have the same sub set of – simplified - products.

Avenue 1: Focus: Working on the model/algorithm: The UC story

Unit Commitment is the **archetypal** optimization problem in the energy sector;

- From formulations and algorithms of the '90, we improved several order of magnitude;
- Present commercial MIP solvers (Cplex/Gurobi/Xpress) are billions of time faster than 20 years ago.
- Moreover there are several AML that enable to try **different solvers** for a given problem (e.g. Julia/JuMP);
- The non convexity of the (envelope of the) constraints have been deeply explored and improved;
- Several possible decomposition/MIP approaches have been deeply explored and improved;

Proposal/Provocation: Organize a RODAEF-like challenge for the PCR

- Requires a **discosure** of real data and solutions;
- The partecipants should be **financed** (?). EU authorities (?)

For each of the challenge a solution has to be found. One can take different **avenues**, basically:

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2. **Simplify** the model and "**harmonize**" the future products at the Multi-Regional level, i.e. all the regional market have the same sub set of – simplified - products.

Avenue 2: Focus: Working on simplify the model: The US experience

US clearing models focus on the **dispatch;**
EU model is now focusing on **prices** coherent with the dispatch;
More generally simplify the products can lead to a simpler and solvable problem for the clearing.

Proposal/Provocation: Open a discussion with the regional Authorities to find a simplified model for the PCR;

- Requires a **change** in the regional products;
- Increases, for the producers, the "**responsibility**" of dealing with **uncertainty** in the outcomes, but they can better **exploit** the Intraday Markets.

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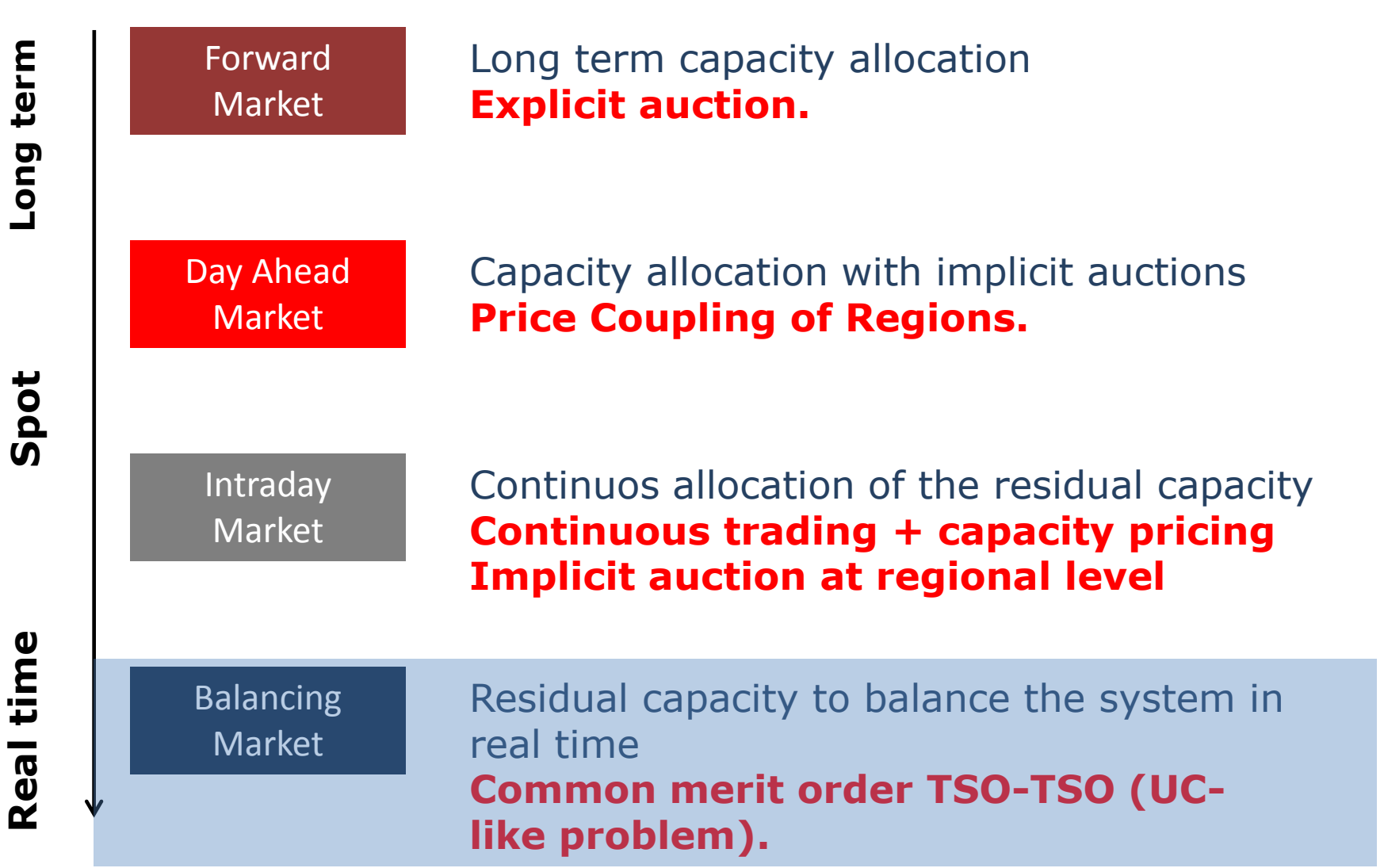
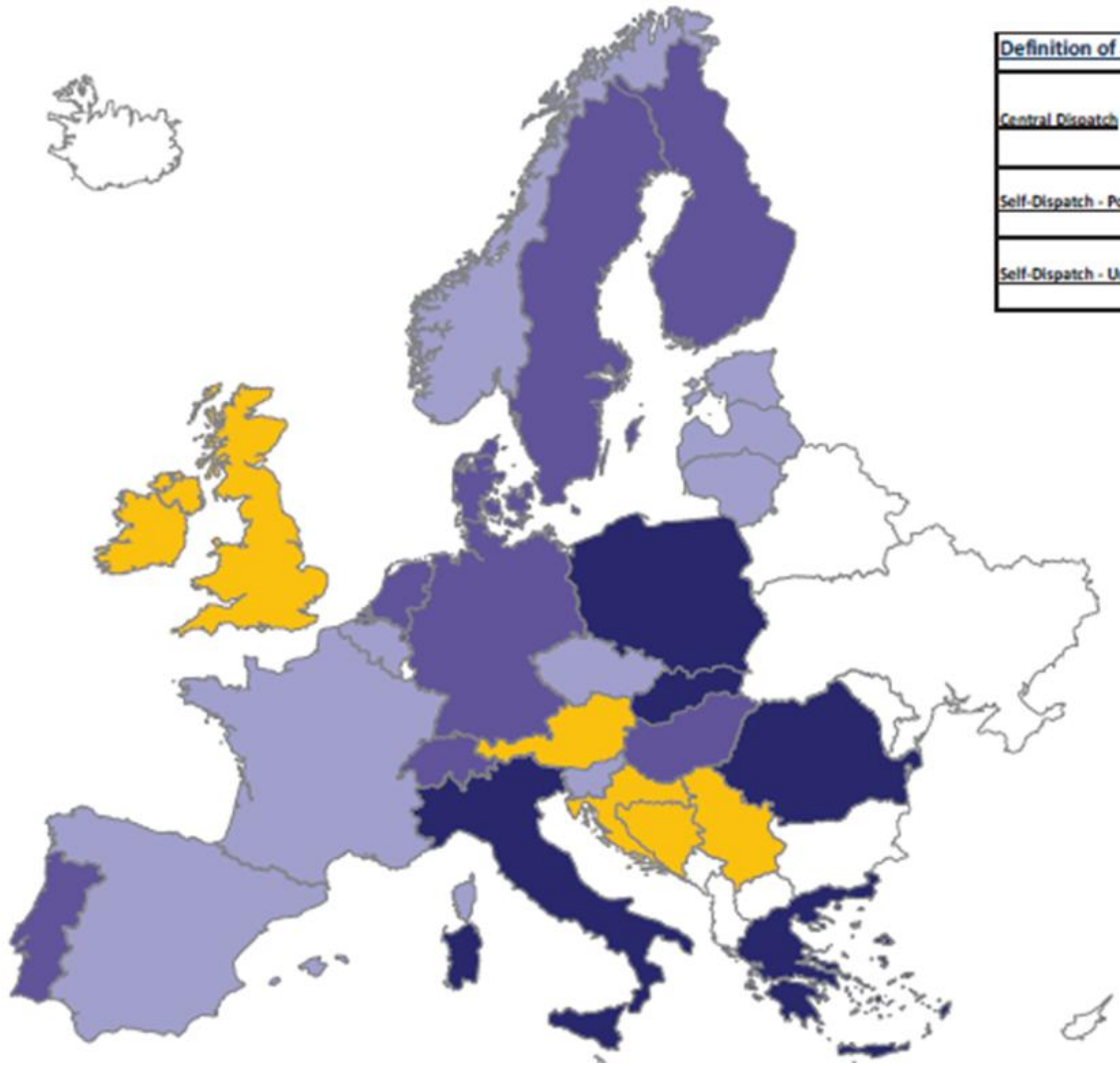
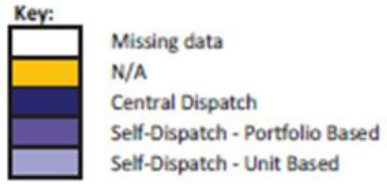
The electricity target model



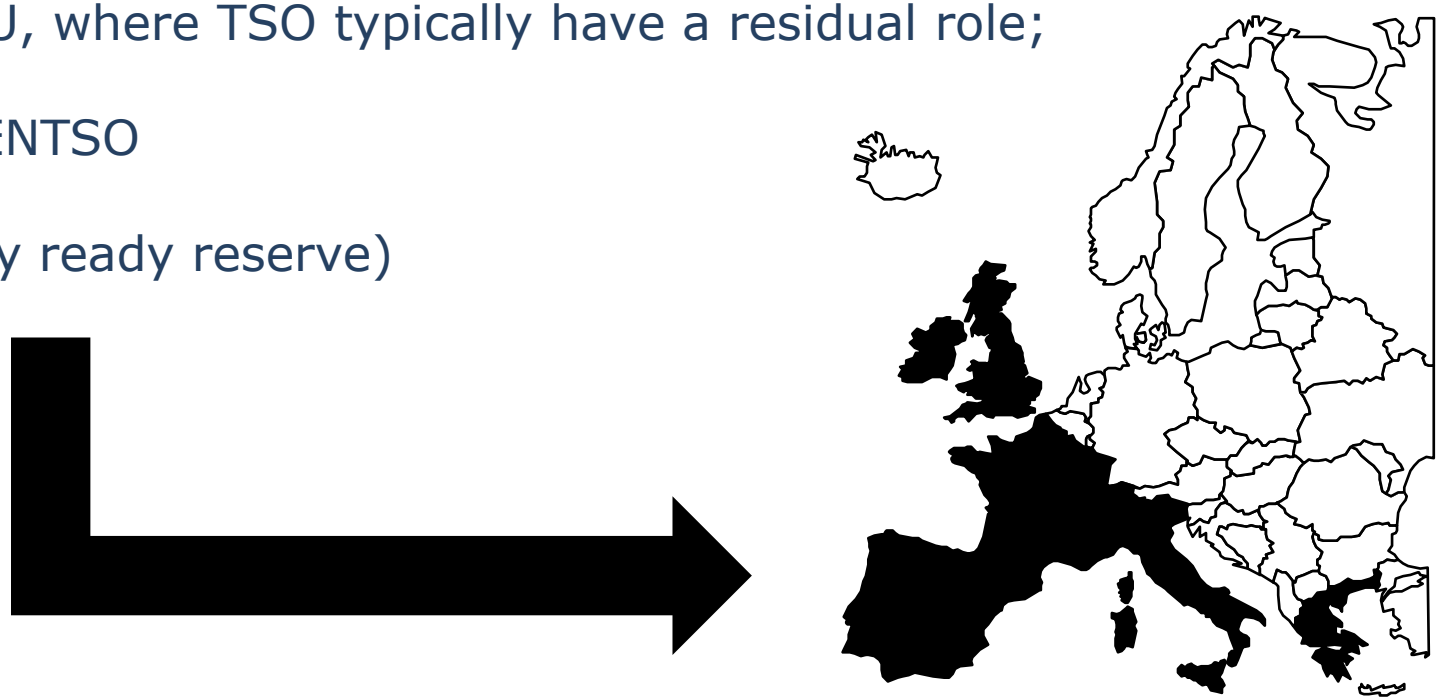
The past, present and future (?) of the Balancing Market(s): The EU situation



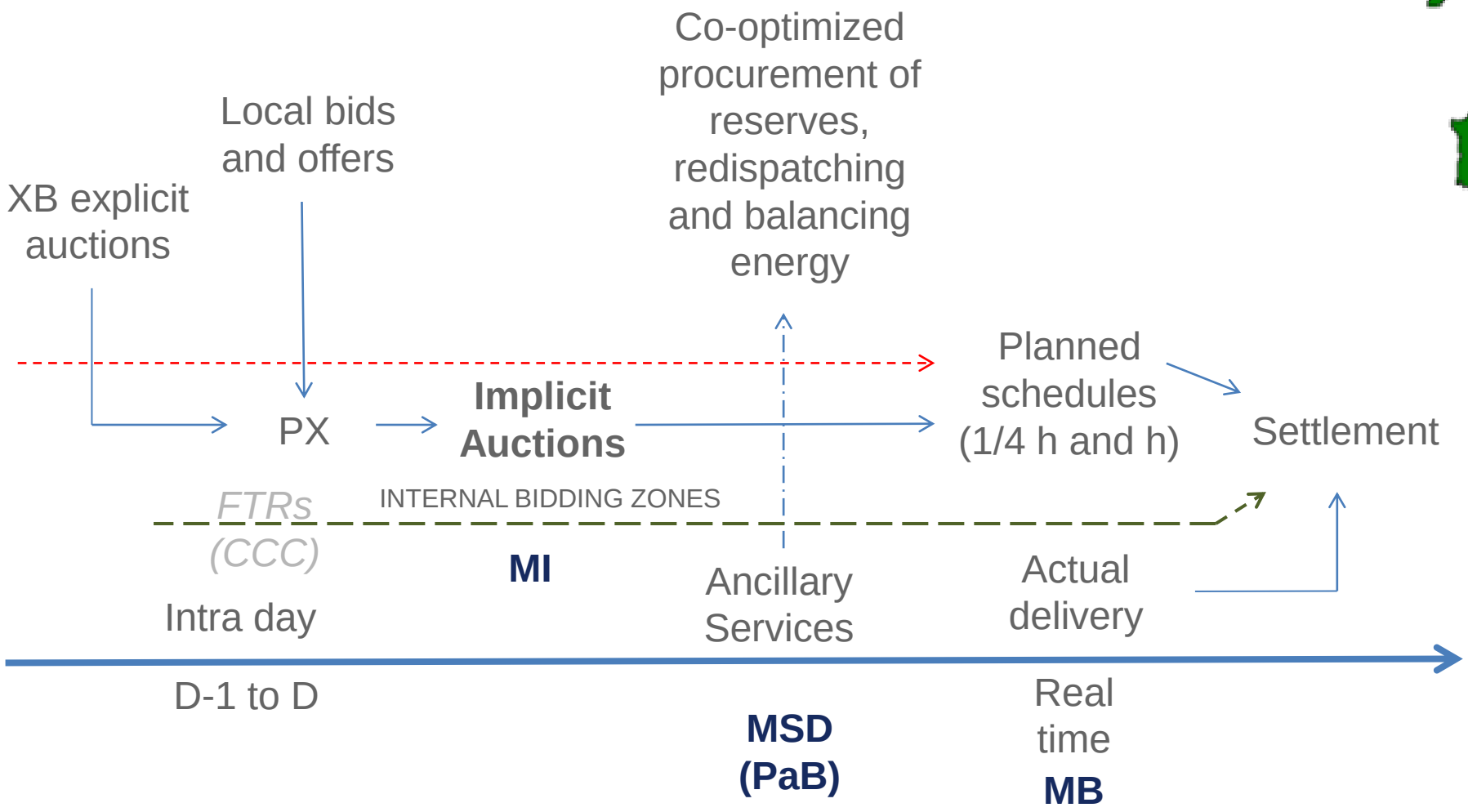
Definition of answer	
Central Dispatch	Central dispatch means a dispatch arrangement in a Relevant Area where the Transmission System Operator determines the commitment and output of a majority of generation or demand and issues dispatch instructions directly to them.
Self-Dispatch - Portfolio Based	A portfolio of units/generators (or other plant types) follow an aggregated schedule of actions to start/stop/increase output/decrease output in real time.
Self-Dispatch - Unit Based	Generators (or other plant types) following their own schedules of actions to start/stop/increase output/decrease output in real time.



- **Envelope** of (very) **different** approaches (maybe **worse** than MRC/PCR);
- E.g. Philosophy is Central Dispatch (Italy);
- Security-constrained Unit Commitment with co optimization of the services, is an exception in EU, where TSO typically have a residual role;
- Early implementation of the ENTSO
  - 9 pilots projects
  - IT: Project TERRE (tertiary ready reserve)



Example of intra day, ancillary services and balancing markets: Italy



Some challenges and some proposal/provocations, 1

- At the present time only a proposal/recommendations for the integration of the balancing market has been done;
- In the ***Annex II to Recommendation of the Agency for the Cooperation of Energy Regulators No 03/2015 of 20 July 2015 on the Network Code on Electricity Balancing***, from ENTSO-E there are some guidelines and some indications about the algorithms…namely:
- *No later than one year after the entry into force of this Regulation, all TSOs shall jointly develop the principles for balancing algorithms that are to be applied for the following functions:*
  1. *Imbalance Netting Process Function;*
  2. *Capacity Procurement Optimisation Function;*
  3. *Transfer of Balancing Capacity Function; and*
  4. *Activation Optimisation Function.*

(Some) challenges:

Shall we go for a centralized balancing market?

- This would mean being able to solve UC-like problems of very large size and several complexities

How can we manage the uncertainty from renewable sources

- New models from well established approaches (Robust opt ?)

Again, as in the PCR experience, shall the ENTSO-E/Autorities approve the algorithm ?

- What if the problem cannot be solved to optimality ?

Lots of work!!

Thank you

Fabrizio Lacalandra (General manager)

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