I-SEM Training
Instructor Led Training
Part 1: TSO Scheduling
Part 2: Imbalance Pricing

Version 1

Duration and Timing

The training session will run from 9AM to 3PM with the following breaks:

Break	10.30 to 11.00
Lunch	12.30 to 13.15
Break	14.00 to 14.15

Training Guidelines

Please ensure that you allow yourself enough time to arrive at the training room both at the start of the day and after each break so that the training can finish on time.

Please limit use of mobile phones throughout the day so as not to distract other trainees and ensure that mobile phones are kept on silent mode throughout the day.

Please ensure you have left the training room before answering a phone call.

The instructor will stop at various points throughout this presentation to deal with any questions that arise.

Please feel free to ask questions during the training session or alternatively please contact the Query Management Team through the mailbox: I-SEMproject@sem-o.com.

Agenda

Part 1: TSO Scheduling
Learning Objectives
Topic 1: Overview
Topic 2: Obligations
Topic 3: The Scheduling and Dispatch Process
Topic 4: Example
Topic 5: Other Outputs
Topic 6: Further Information

Agenda

Part 2: Imbalance Pricing
Learning Objectives
Topic 1: Introduction and Overview
Topic 2: Inputs, Process, Outputs
Topic 3: Determining and Ranking Bid Offer Acceptances
Topic 4: System Operator Flagging
Topic 5: Non-Marginal Flagging
Topic 6: Marginal Energy Action Price
Topic 7: Net Imbalance Volume Tagging
Topic 8: Price Average Reference Tagging
Topic 9: Final Imbalance Price Calculation
Topic 10: Administered Scarcity Pricing
Topic 11: Market Back Up Price & Curtailment Price
Topic 12: Course Summary

Part 1: TSO Scheduling

TSO Scheduling Agenda

Training Topic
Learning Objectives
Topic 1: Overview
Topic 2: Obligations
Topic 3: The Scheduling and Dispatch Process
Topic 4: Example
Topic 5: Other Outputs
Topic 6: Further Information

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Learning Objectives

- By the end of this training session you should:
  - Appreciate the objectives of the scheduling and dispatch process;
  - Understand the main activities within the scheduling and dispatch process; and
  - Be aware of the outputs of the scheduling and dispatch process and where to find more information.

Topic 1: Overview

Scheduling and Dispatch Overview

- Scheduling and Dispatch is the process by which the TSOs (SONI and EirGrid) manage the close to real-time planning and the real-time operation of units on the power system.
- This is a continuous, ‘24/7’ process coordinated by the respective control centres in Belfast and Dublin using common operational systems and processes.

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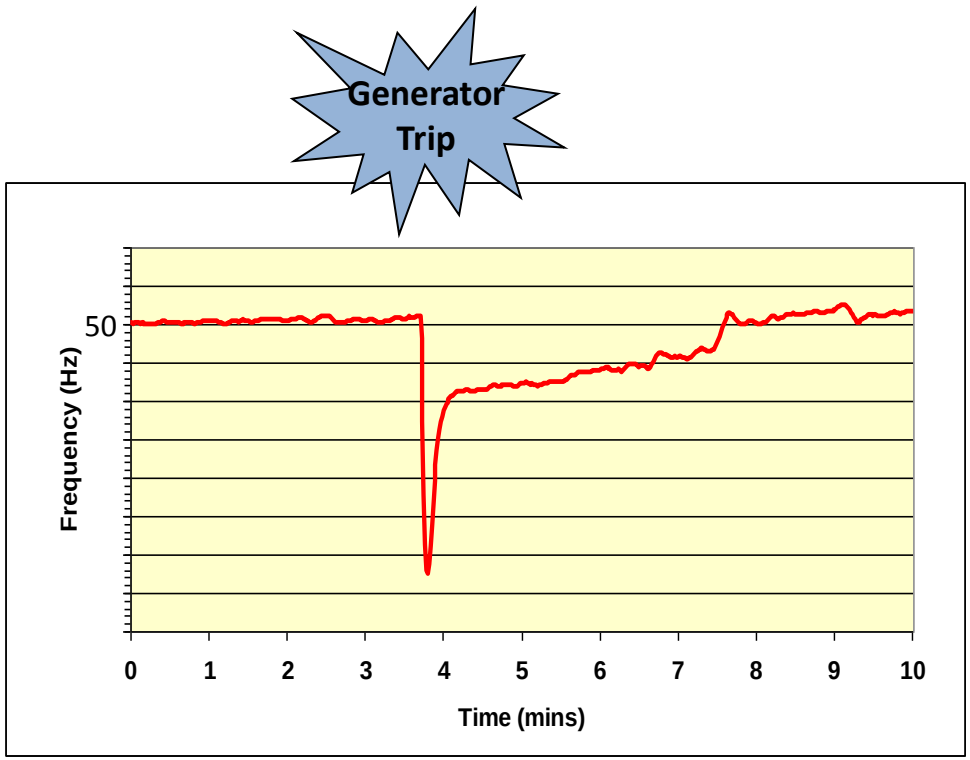
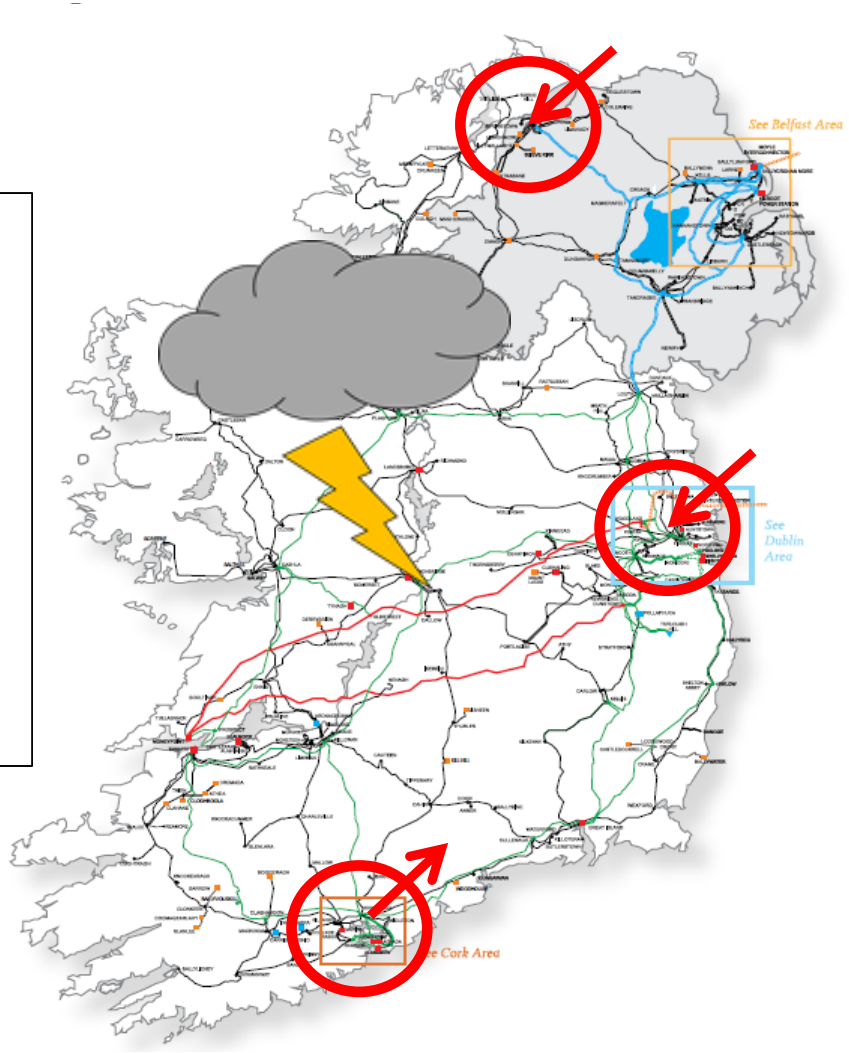
To Maintain Power System Security





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To Maximise Priority Dispatch Generation

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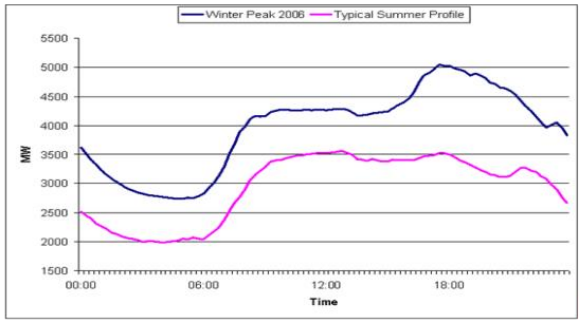
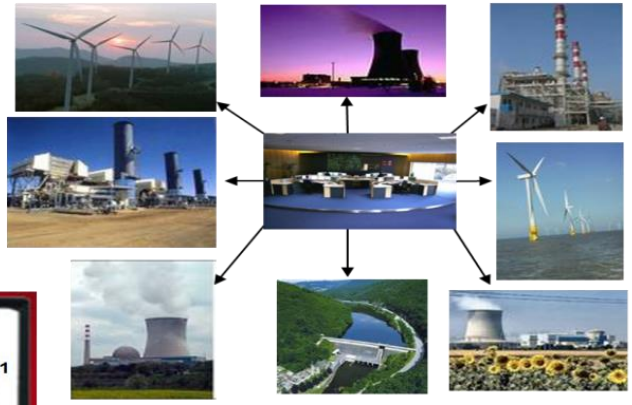
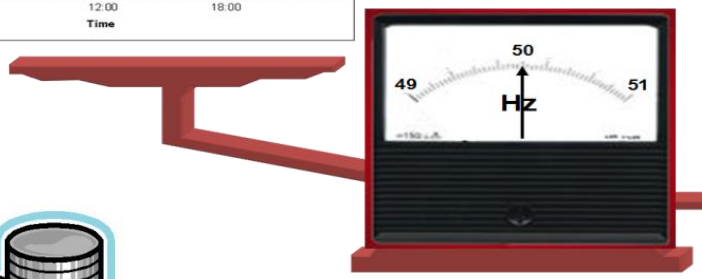
To Facilitate Efficient Operation of the Market

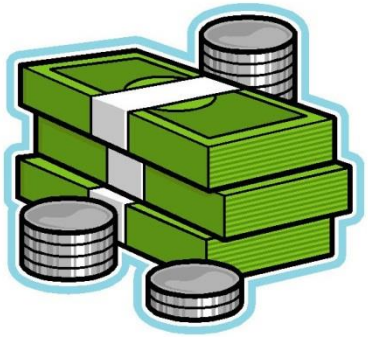
Load changes through the day …



…Generation output must match this







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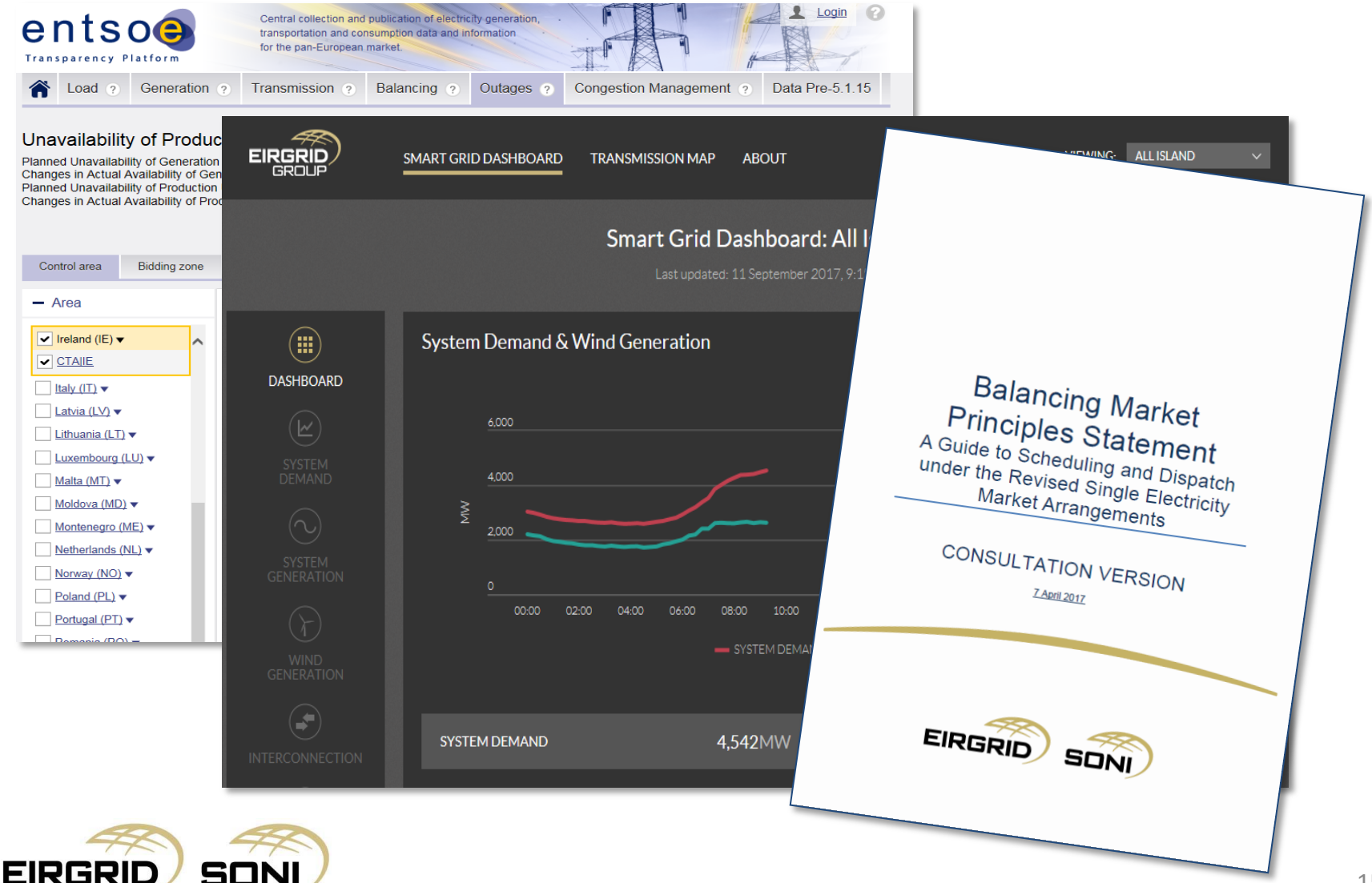
And To Do This In A Transparent Manner



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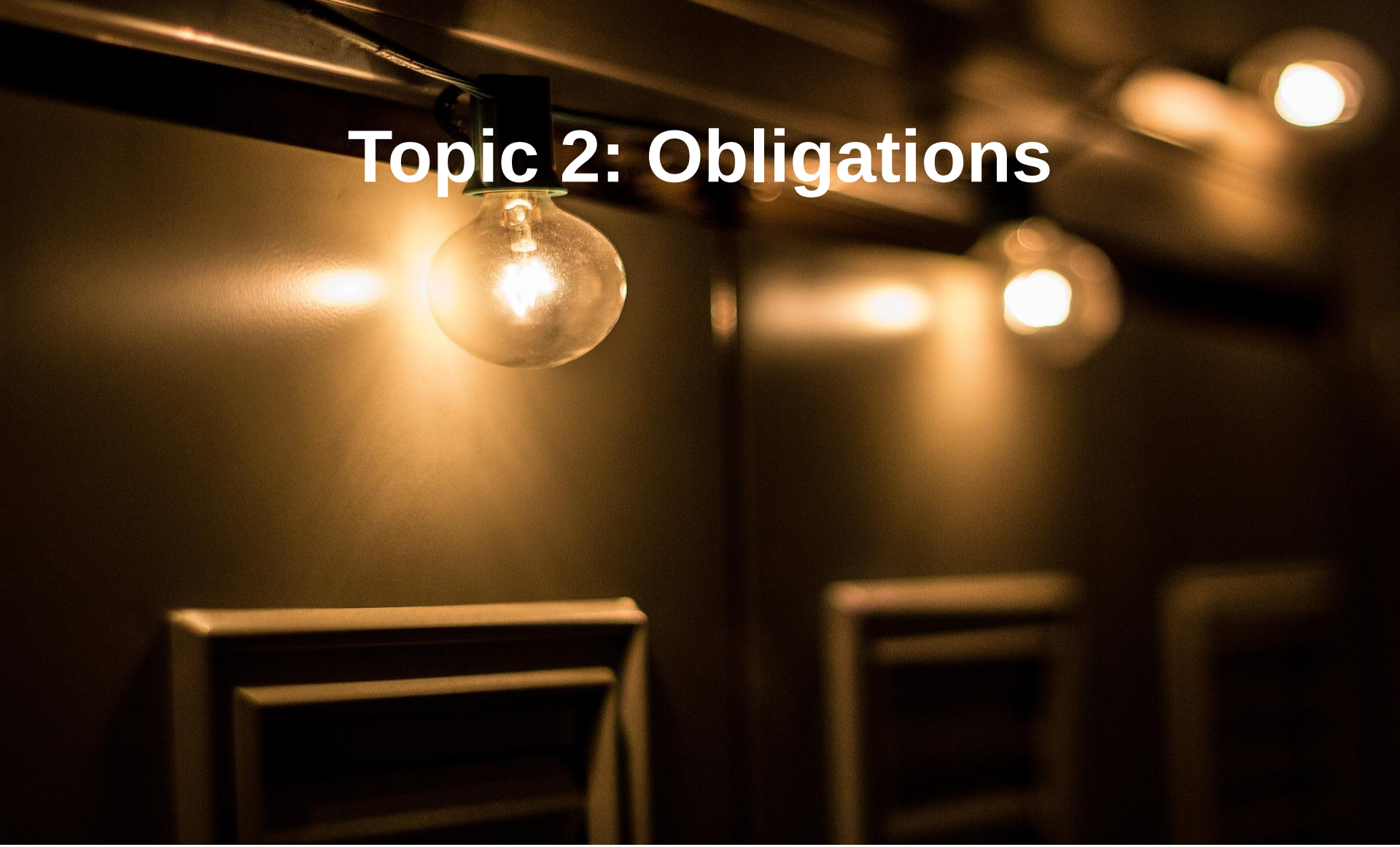
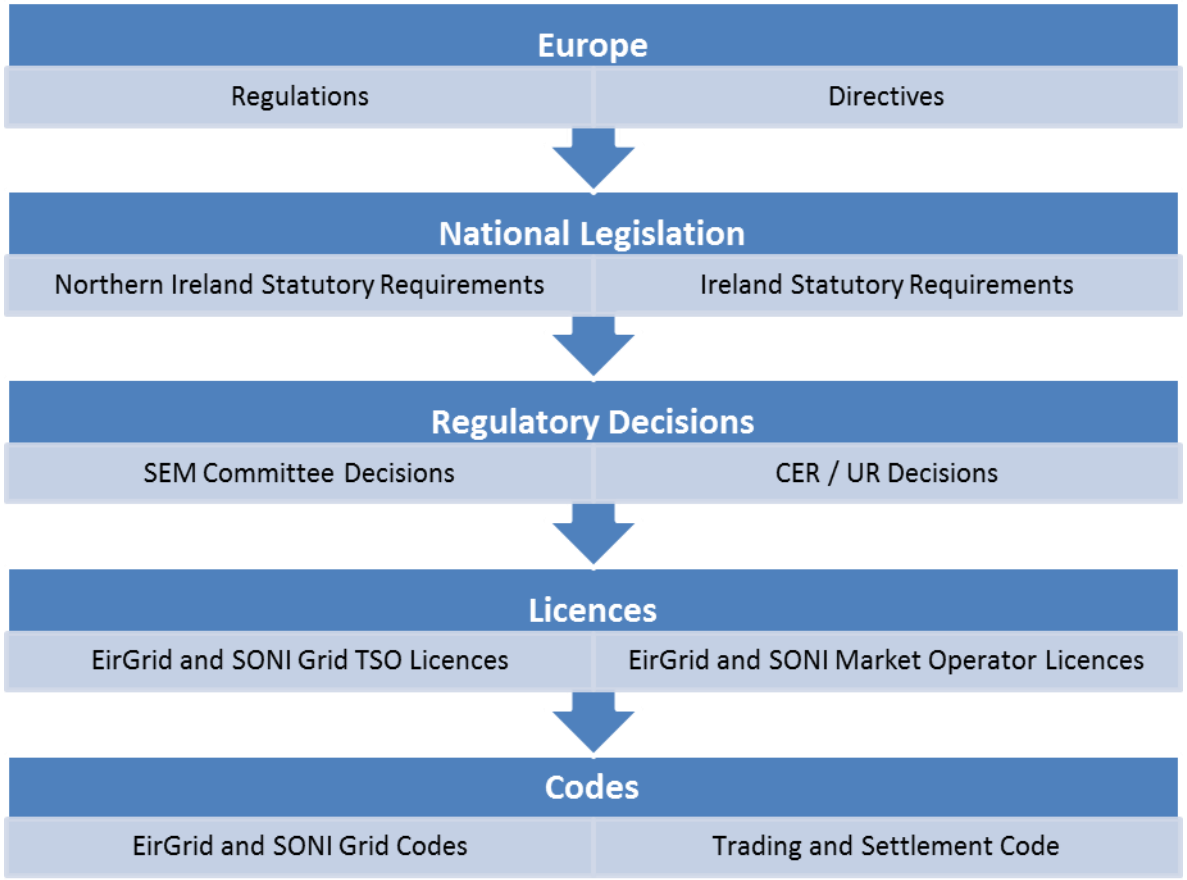
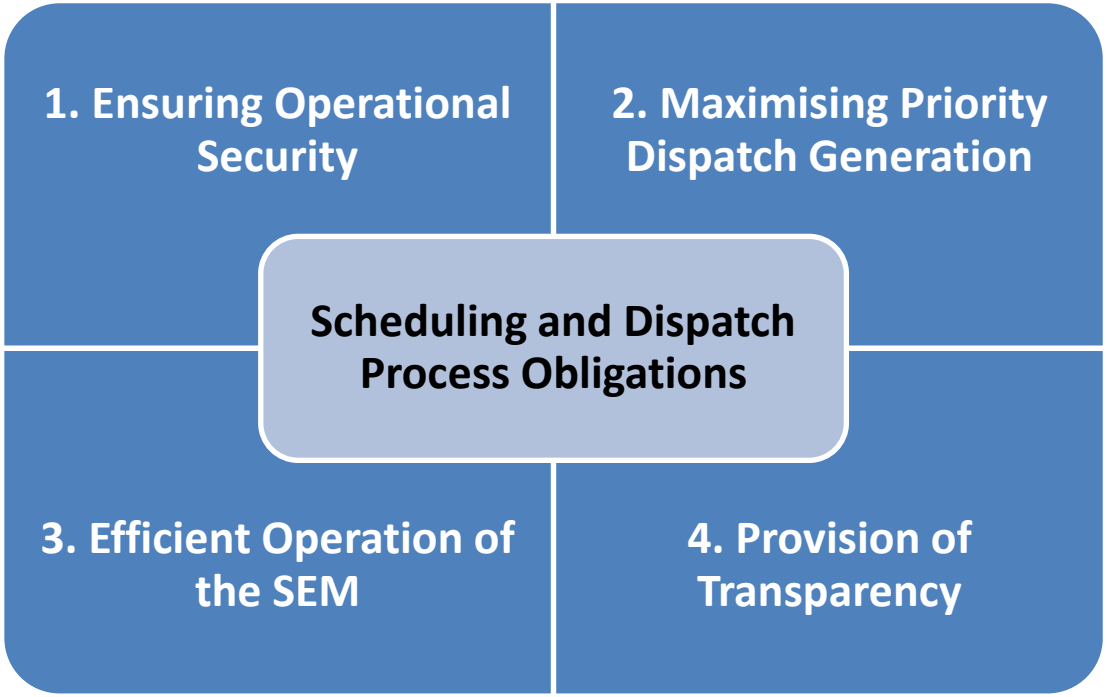


Topic 2: Obligations

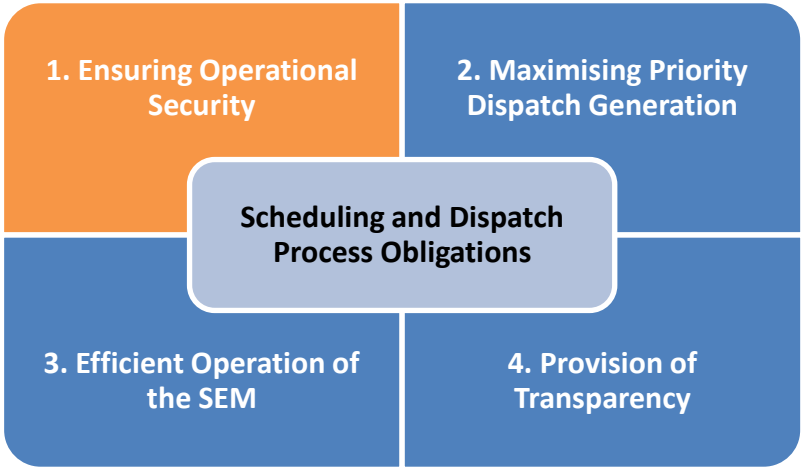
Obligations



Obligations



Obligations



To prepare Indicative Operations Schedules…..and issue Dispatch Instructions….to match continuously unit output to demand whilst maintaining the integrity of the transmission system….security and quality of supply.

EirGrid and SONI Grid Codes

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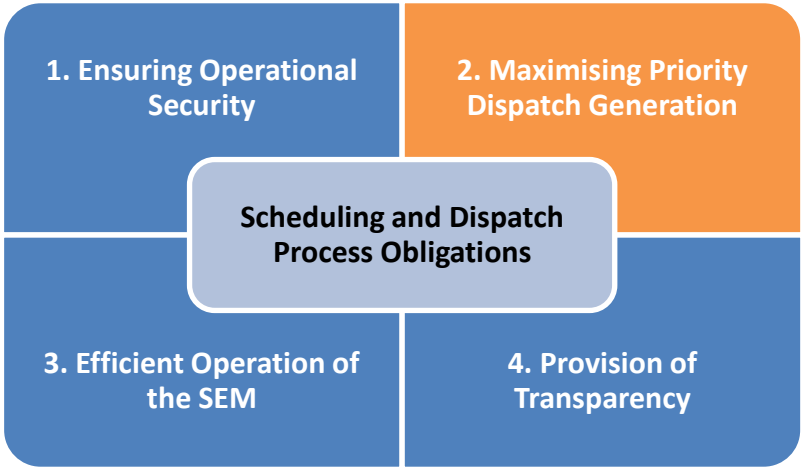
Obligations



Adhere to an 'absolute' interpretation of priority dispatch whereby economic factors are only taken account of in exceptional situations.

SEM Committee Decision SEM-11-062

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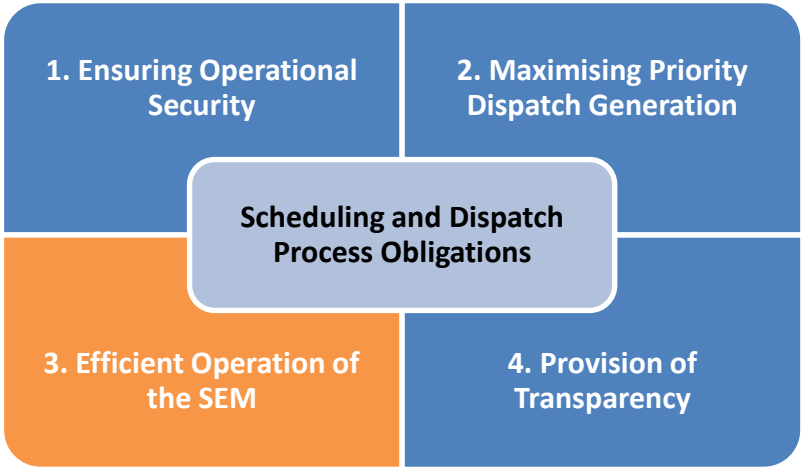
Obligations

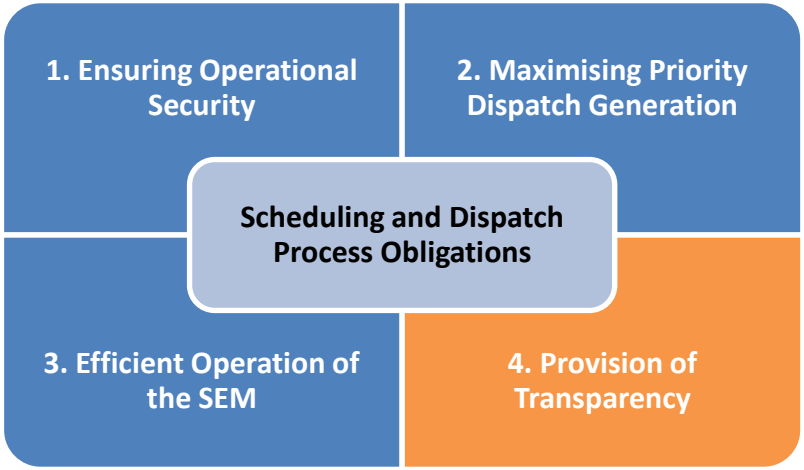


- minimising the cost of diverging from physical notifications;
- as far as practical, enabling the Ex-Ante Market to resolve energy imbalances; and
- as far as practical, minimising the cost of non-energy actions.

EirGrid and SONI Transmission Licences

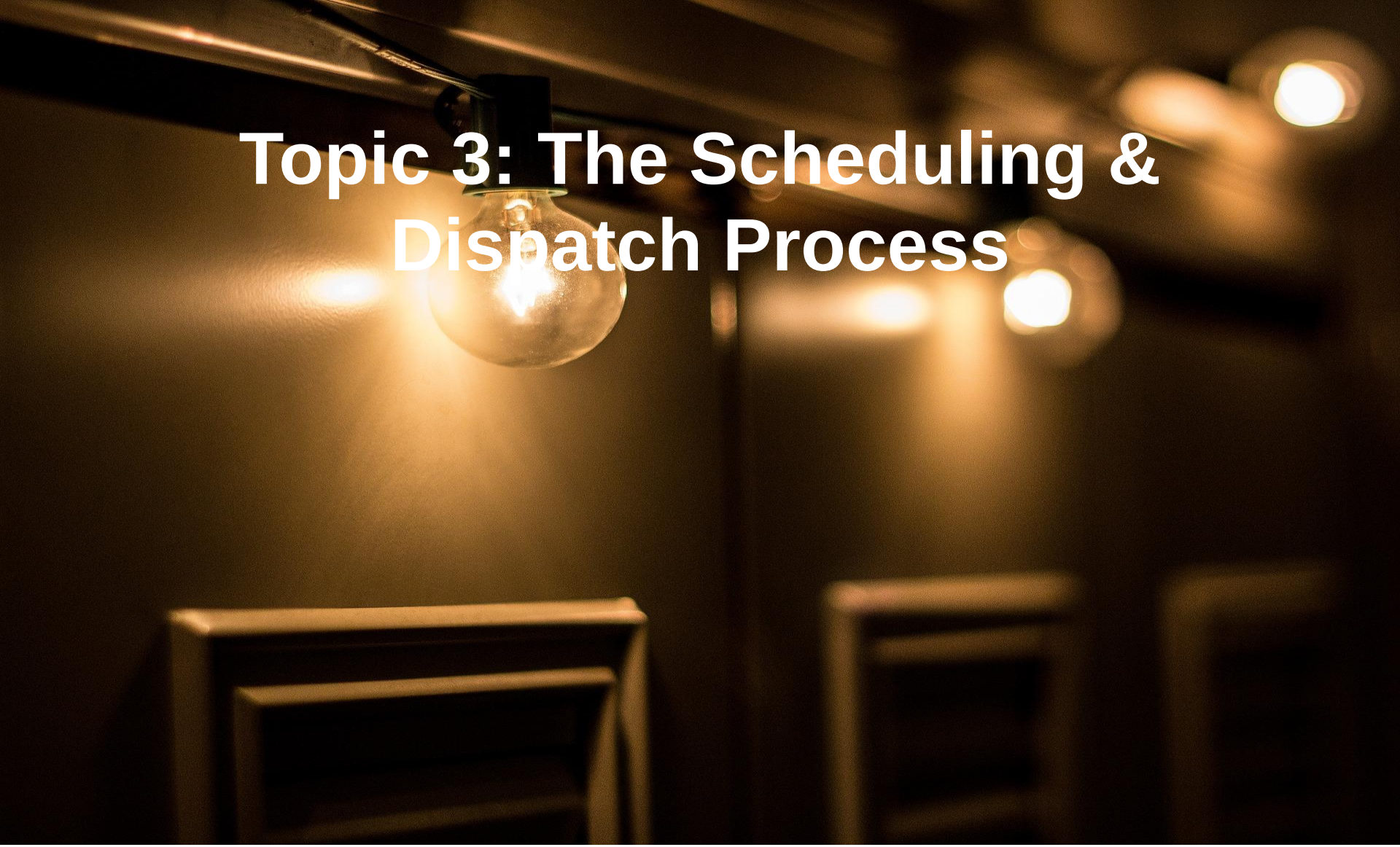
EIRGRID SONI

Obligations



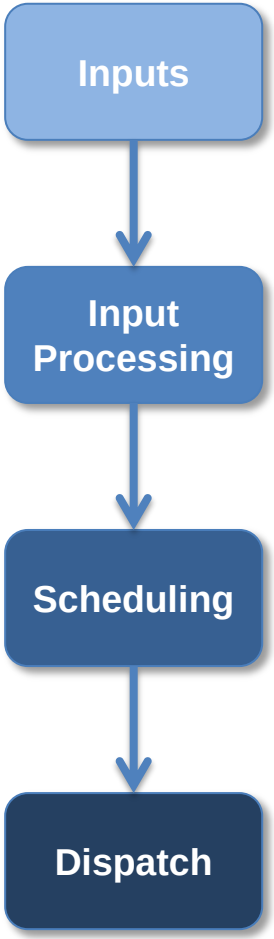
- to prepare a Balancing Market Principles Statement as an accurate and up-to-date description of our scheduling and dispatch process.

EirGrid and SONI Transmission Licences

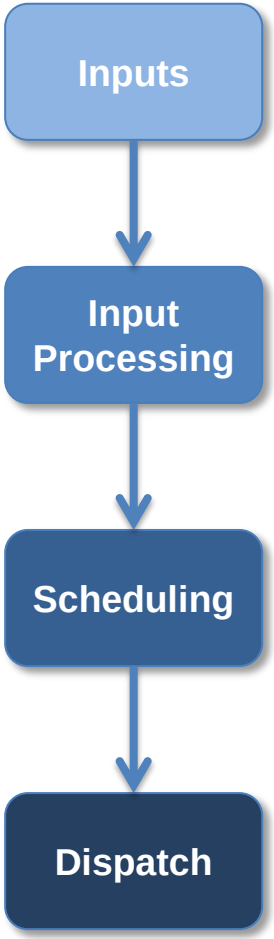


Topic 3: The Scheduling & Dispatch Process

Scheduling & Dispatch Process



Scheduling & Dispatch Process



The following slides provide an overview of the scheduling and dispatch process as expected to operate under the revised SEM arrangements. It should be noted that our processes and tools are changing significantly to facilitate these new arrangements and they remain under development at this time. This processes is therefore subject to change.

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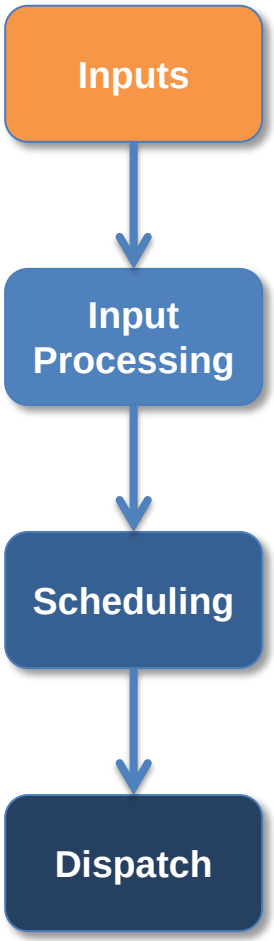
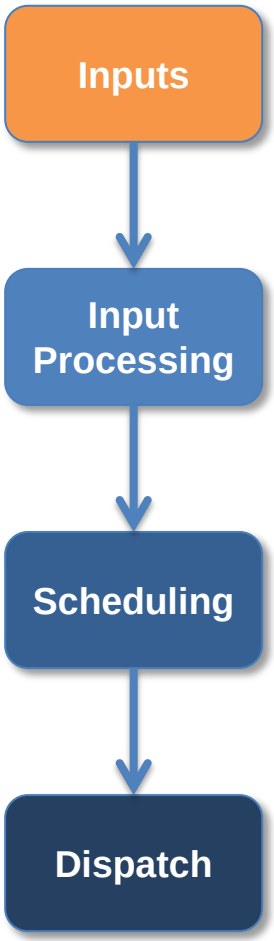
Scheduling & Dispatch Process



EIRGRID SONI

Scheduling & Dispatch Process



Policy Objectives

- Priority Dispatch categorisation
- Scheduling and Dispatch Policy Parameters

Participants / System Service Providers

- Technical Data - energy market and System Services
- Commercial Data - energy market and System Services
- Physical Notifications
- Availability / System Service Capability Declarations
- Unit Under Test

Ex Ante Markets

- Interconnector Schedules

System Operators

- Demand and Renewables Forecasts
- System Constraints
- System Service Requirements
- Interconnector Technical Data
- Prices and Volumes for Cross-Zonal Actions
- Real-Time System Conditions

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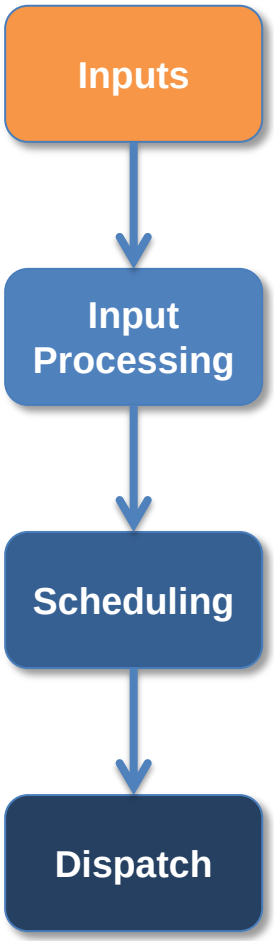
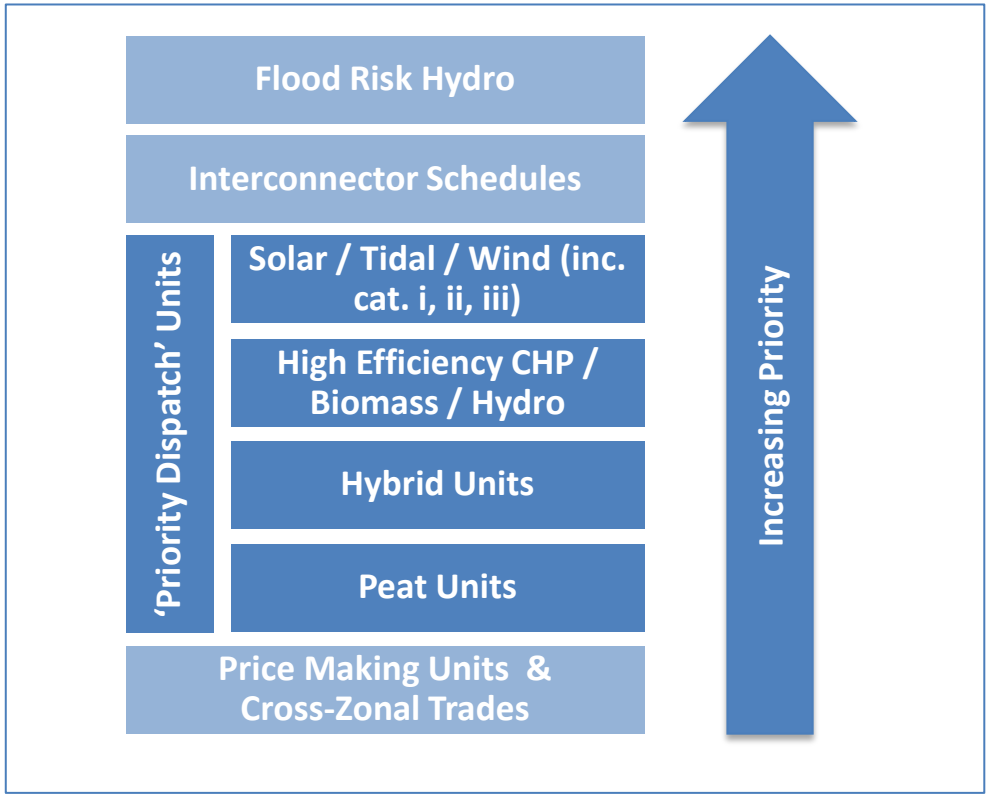
Scheduling & Dispatch Process



Policy - Priority Dispatch Hierarchy:



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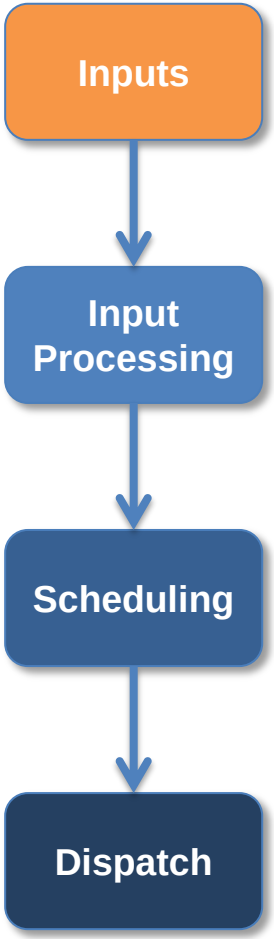
Scheduling & Dispatch Process



Policy - Scheduling and Dispatch Policy Parameters:

- The Long Notice Adjustment Factors (LNAF) relative to unit Notification Times;
- The System Imbalance Flattening Factors (SIFF) relative to the System Shortfall Imbalance Index (SSII); and
- The Daily Time for fixing the SSII/SIFF for a Trading Day.

- Per SEM-17-046 of 7 July 2017, the SEM Committee has decided that, at go-live of the revised SEM arrangements, LNAF and SIFF will be zero and that the time to set SSII/SIFF will be determined at a later date. This decision also requires us to re-evaluate the determination of these factors in time for application from 1 January 2020.

- As these parameters will be set to zero at this time, they will have no impact on the scheduling and dispatch process.

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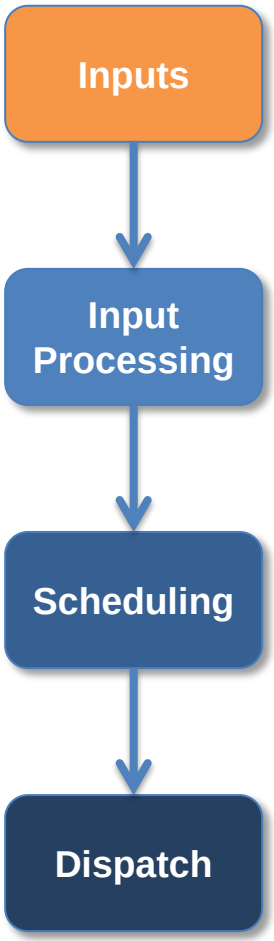
Scheduling & Dispatch Process



TSO - Constraints:

Reserve (Frequency Limits)	Thermal	Voltage	Dynamic Stability
• All Island OR Requirement	• North-South Tie-Line Limit	• Coolkeeragh Must Run	• Inertia
• NI / IRL Min OR Requirement	• Ballylumford Export Limit	• Kilroot Must Run	• RoCoF*
• NI / IRL RR (OCGT) Limitation	• Various Dublin Must Run	• Various Dublin Must Run	• SNSP*
• NI / IRL Negative Reserve	• Cork Export limit	• South West Must Run	• NI 3 Units Must Run
• Ramping		• Moneypoint Must Run	• IRL 5 Units Must Run

*RoCoF: Rate of Change of Frequency
*SNSP: System Non-Synchronous Penetration

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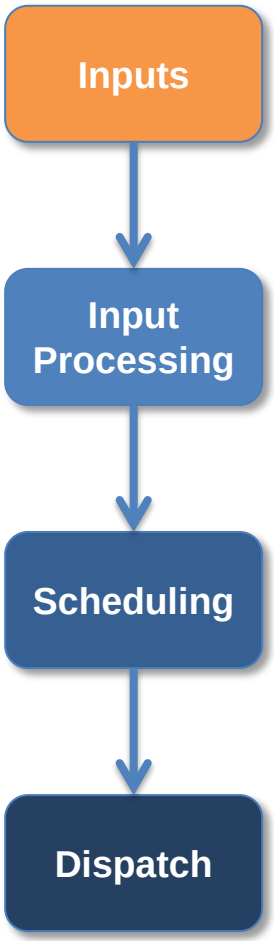
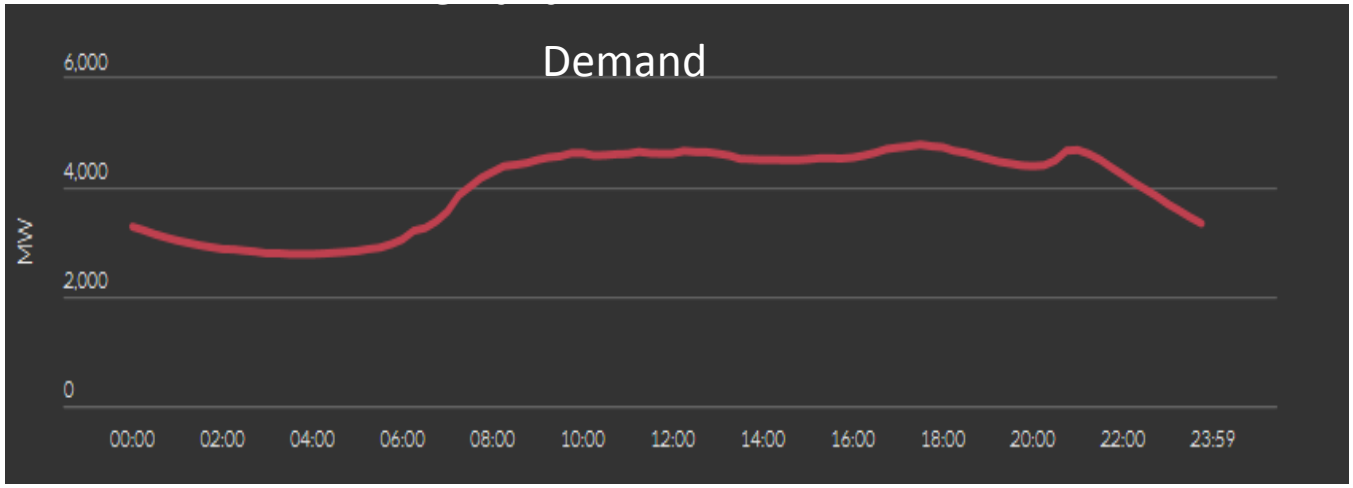
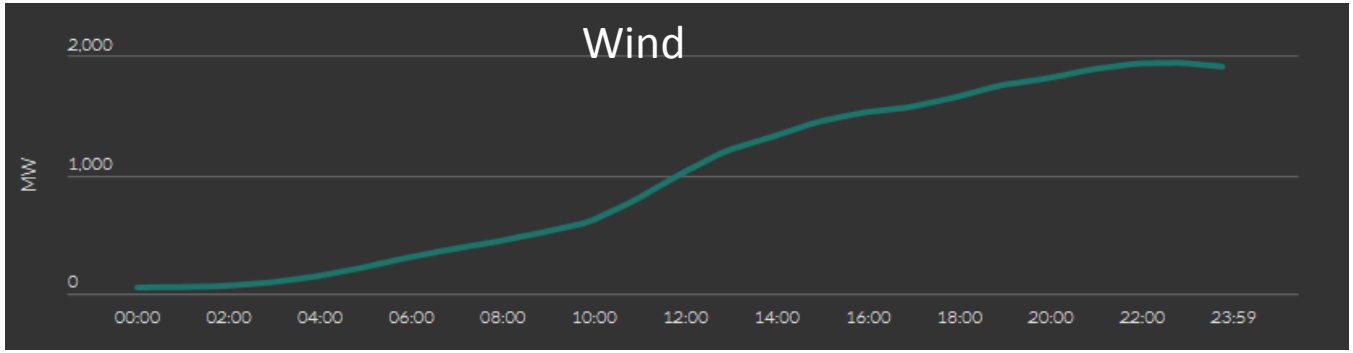
Scheduling & Dispatch Process



TSO - Forecasts:





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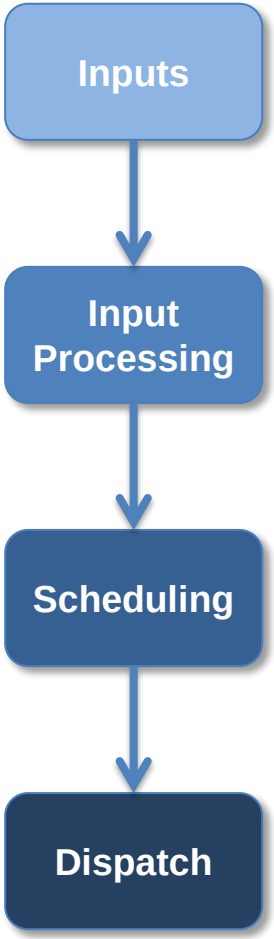
Scheduling & Dispatch Process



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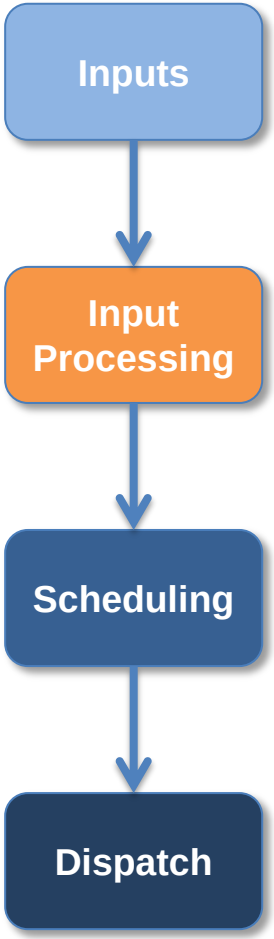

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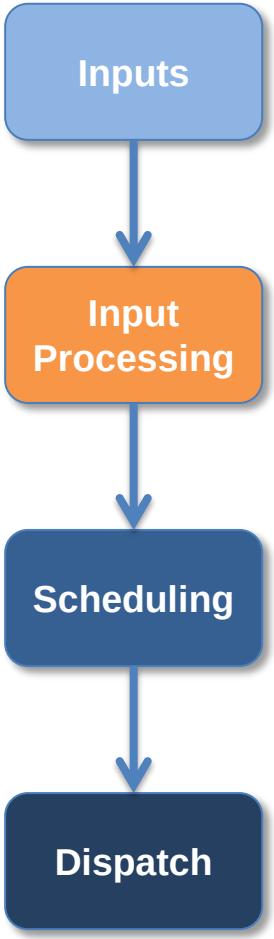
Scheduling & Dispatch Process



Selection of Appropriate Commercial Offer Data:

Scheduling Run Type	Source of Commercial Data		
	Primary	Back-Up 1	Back-Up 2
LTS – Long-Term Schedule	Complex	Default	N/A
RTC – Real-Time Commitment	Complex	Default	N/A
RTD – Real-Time Dispatch	Simple	Complex*	Default*

*Note: only inc/dec component of complex or default commercial offer data is used

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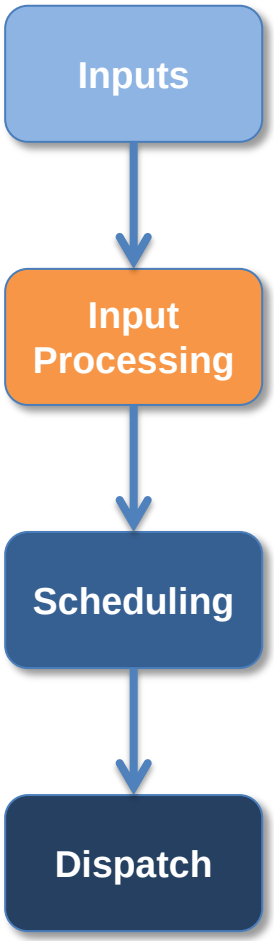
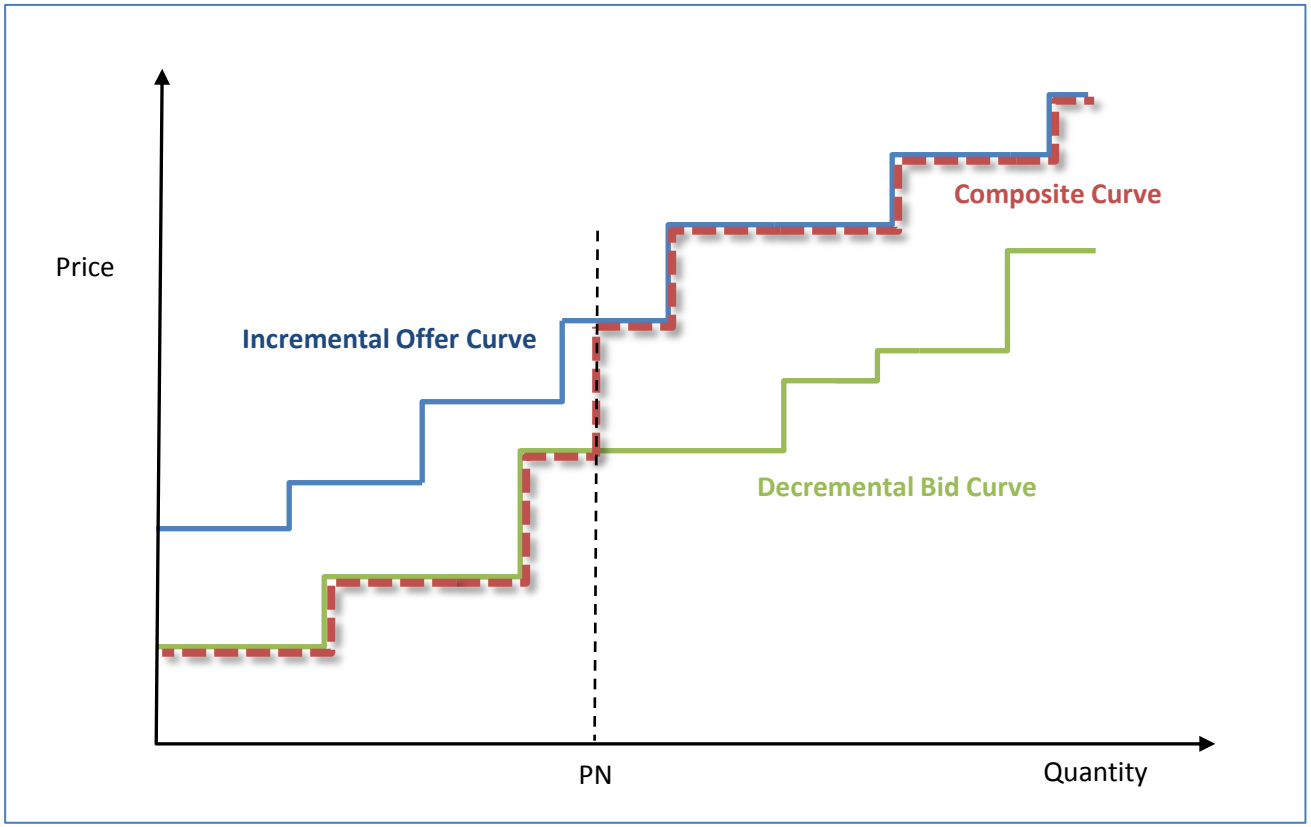
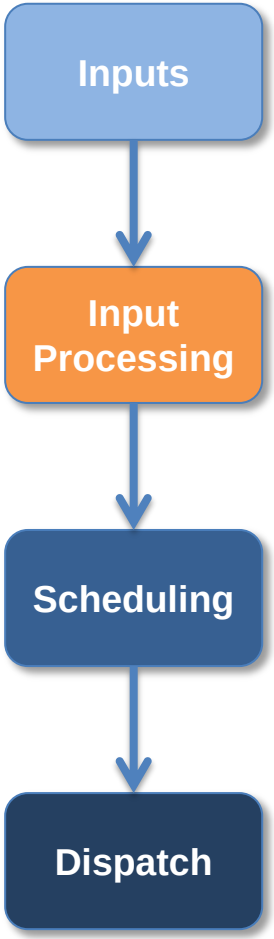
Scheduling & Dispatch Process



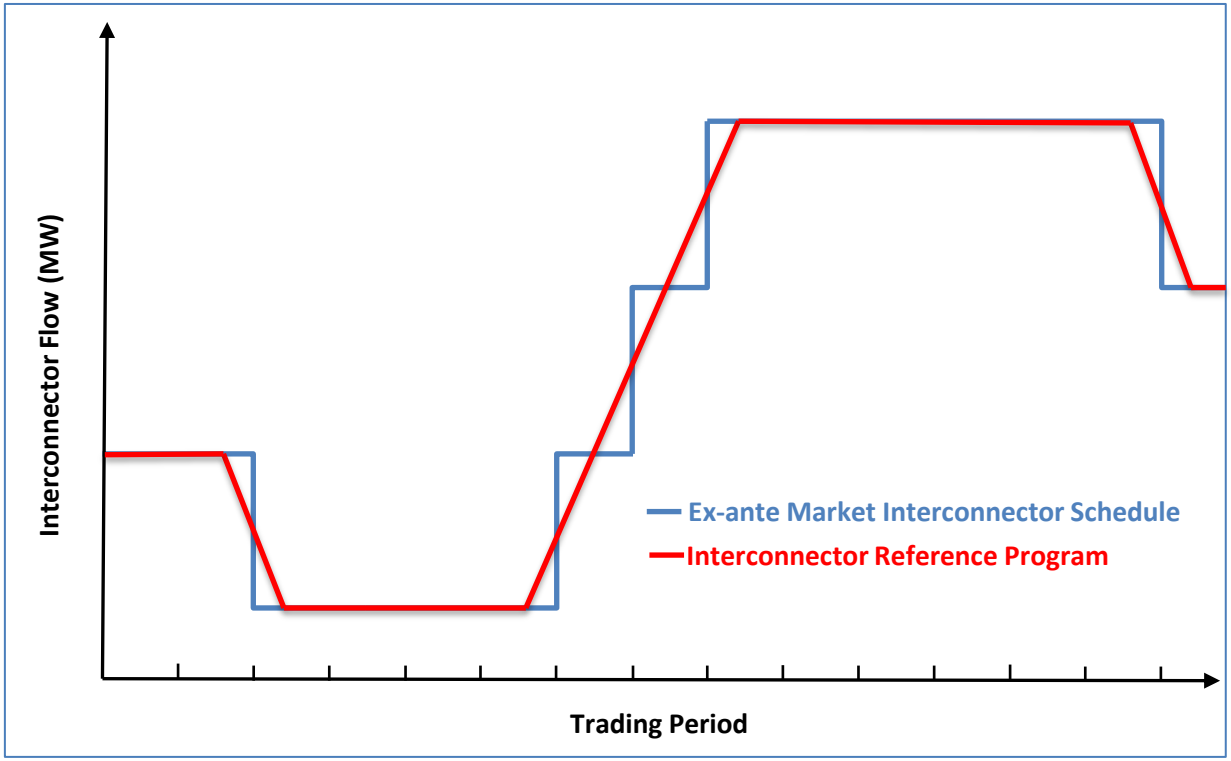
Production of Composite Cost Curves:



Scheduling & Dispatch Process



Production of Interconnector Reference Programme:



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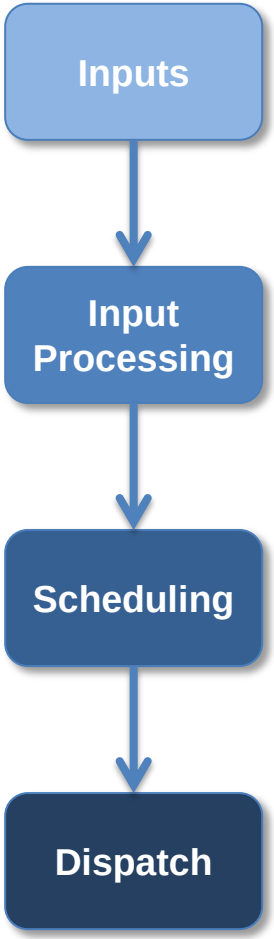
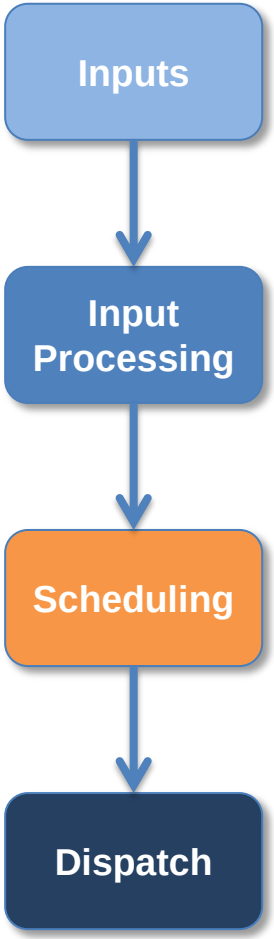
Scheduling & Dispatch Process



Scheduling & Dispatch Process



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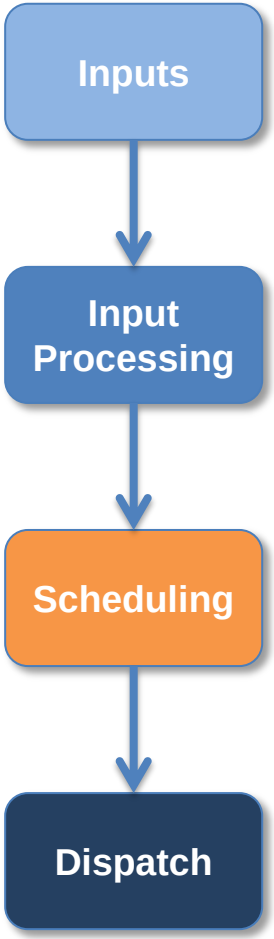
Scheduling & Dispatch Process



- Scheduling is the process of planning the dispatch instructions to be issued.
- Given the time it takes for units to respond (start-up, shut-down and change output) can range from seconds to many hours, our scheduling process operates over a range of timescales:
  - **Real-Time Dispatch (RTD)** – for the next hour
  - **Real-Time Commitment (RTC)** – for the next four hours
  - **Long-Term Schedule (LTS)** – for the next day

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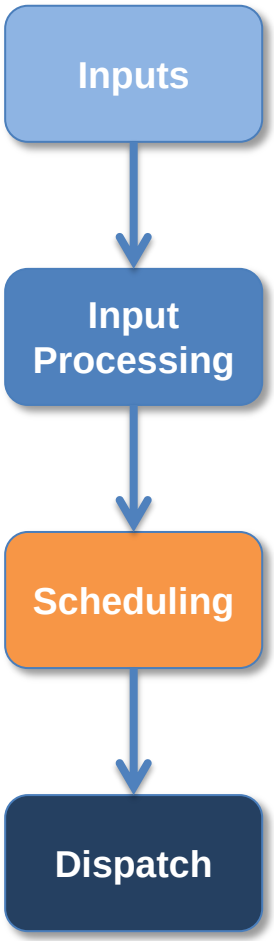
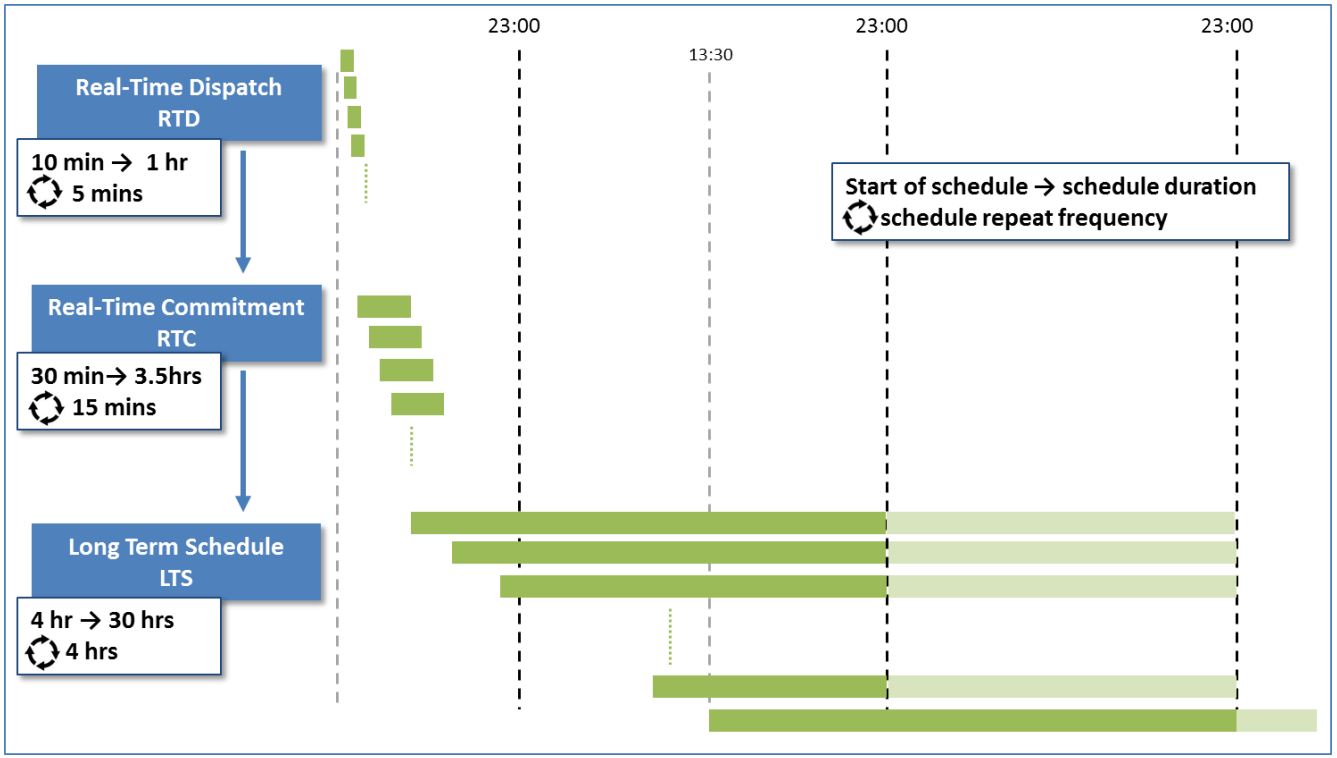
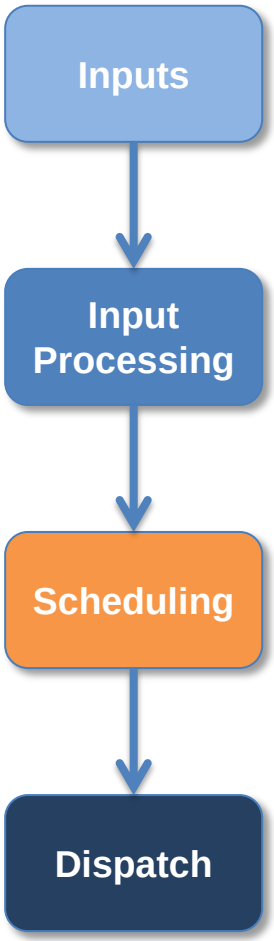
Scheduling & Dispatch Process



Indicative Scheduling Run Sequence:



Scheduling & Dispatch Process



Output of each scheduling run is an Indicative Operational Schedule:

RTD	14:25	14:30	14:35	14:40	14:45	14:50	14:55	15:00	15:05	15:10	15:15	15:20
Unit_1	29	29	29	29	29	29	29	29	29	29	29	29
Unit_2	0	5	3	13	16	16	15	10	0	0	0	1
Unit_3	260	260	260	260	260	260	260	260	260	260	260	260
Unit_4	0	0	0	0	0	0	0	0	0	0	0	0

RTC	15:30	15:45	16:00	16:15	16:30	16:45	17:00	17:15	17:30	17:45	18:00	18:15	18:30	18:45
Unit_1	0	0	0	0	0	0	0	29	29	29	29	29	29	29
Unit_2	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Unit_3	260	260	260	260	260	260	260	260	260	260	260	260	260	260

LTS	18:00	18:30	19:00	19:30	20:00	20:30	21:00	21:30	22:00	22:30	23:00	23:30	00:00	00:30	01:00	01:30	02:00
Unit_1	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Unit_2	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Unit_3	260	260	260	260	260	267	260	260	350	260	260	260	260	260	260	260	260
Unit_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit_5	113	113	113	113	113	113	113	113	113	118	113	113	120	113	136	124	113
Unit_6	113	113	113	113	113	113	123	139	232	113	137	113	113	113	113	113	113
Unit_7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit_8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit_9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit_10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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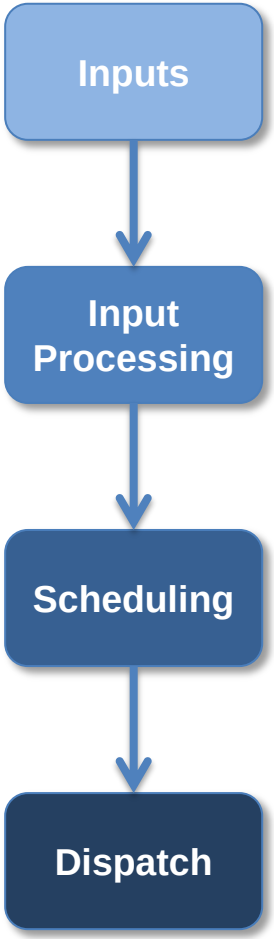
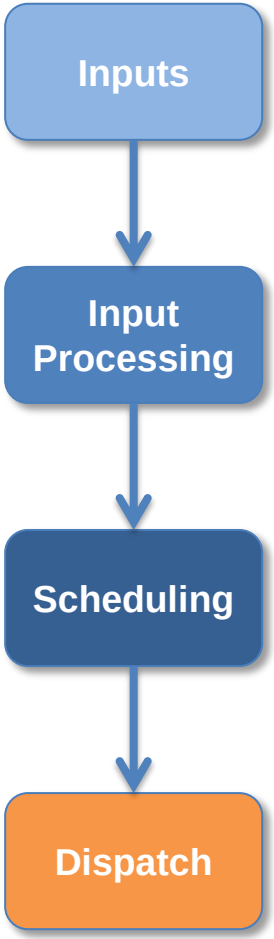
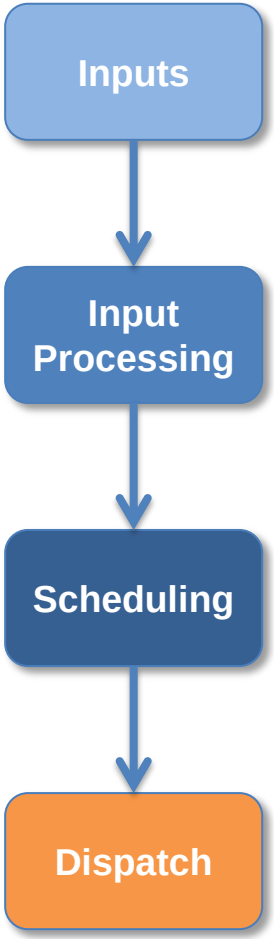
Scheduling & Dispatch Process



Scheduling & Dispatch Process



Scheduling & Dispatch Process



The following dispatch instructions / control actions are taken based on the Indicative Operational Schedules:

- **Commit** – connect (synchronise) to the power system;
- **De-commit** – disconnect (de-synchronise) from the power system;
- **MW Level** – the active power MW level to which the unit should operate;
- **Active Power Control** of wind / solar unit– MW active power control set-points;
- **Cross-Zonal Action** – implementation of a change to an Interconnector Reference Programme to implement a Cross-Zonal Action.

In addition there are also instructions to provide System Services, change operating modes, change fuels, maximise output and implement emergency actions.

Units should only respond to the dispatch instructions issued by the TSOs*

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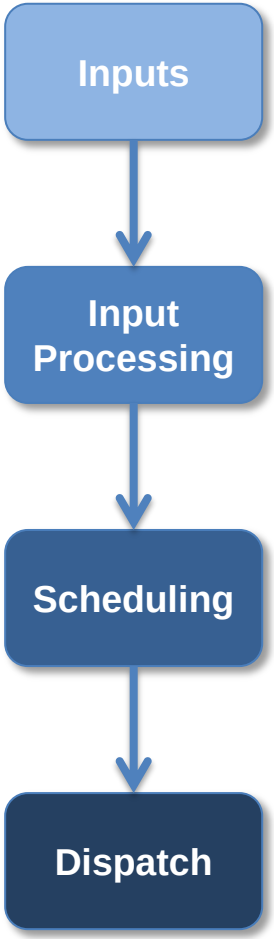
* Other than automated control actions such as frequency response

Scheduling & Dispatch Process



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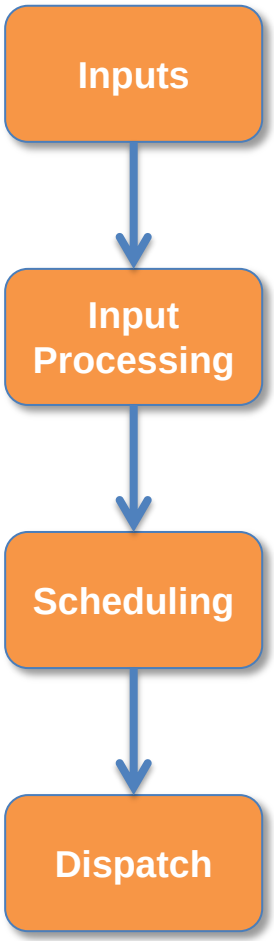
Scheduling & Dispatch Process



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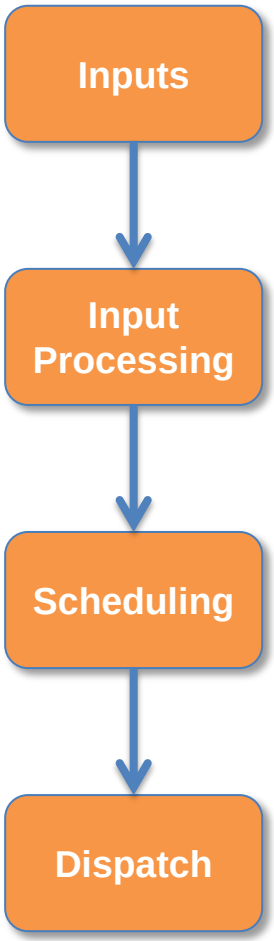
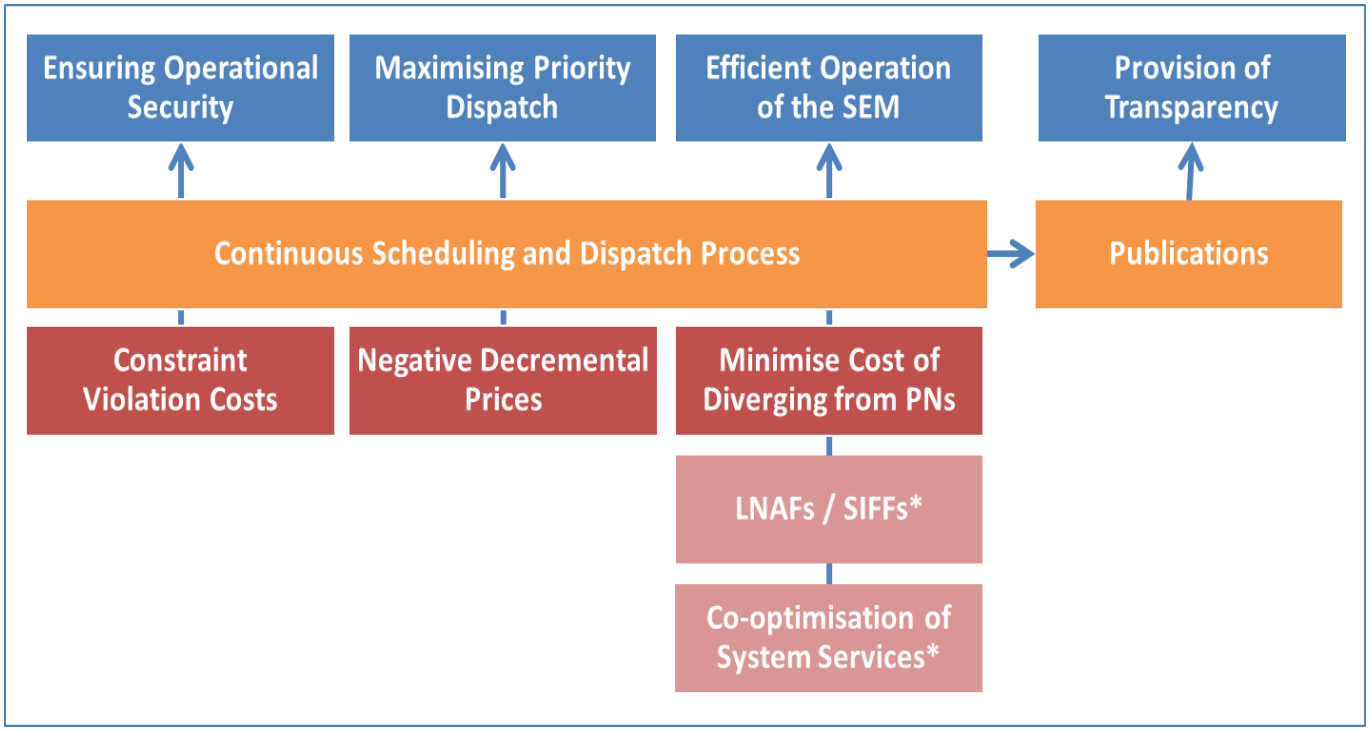
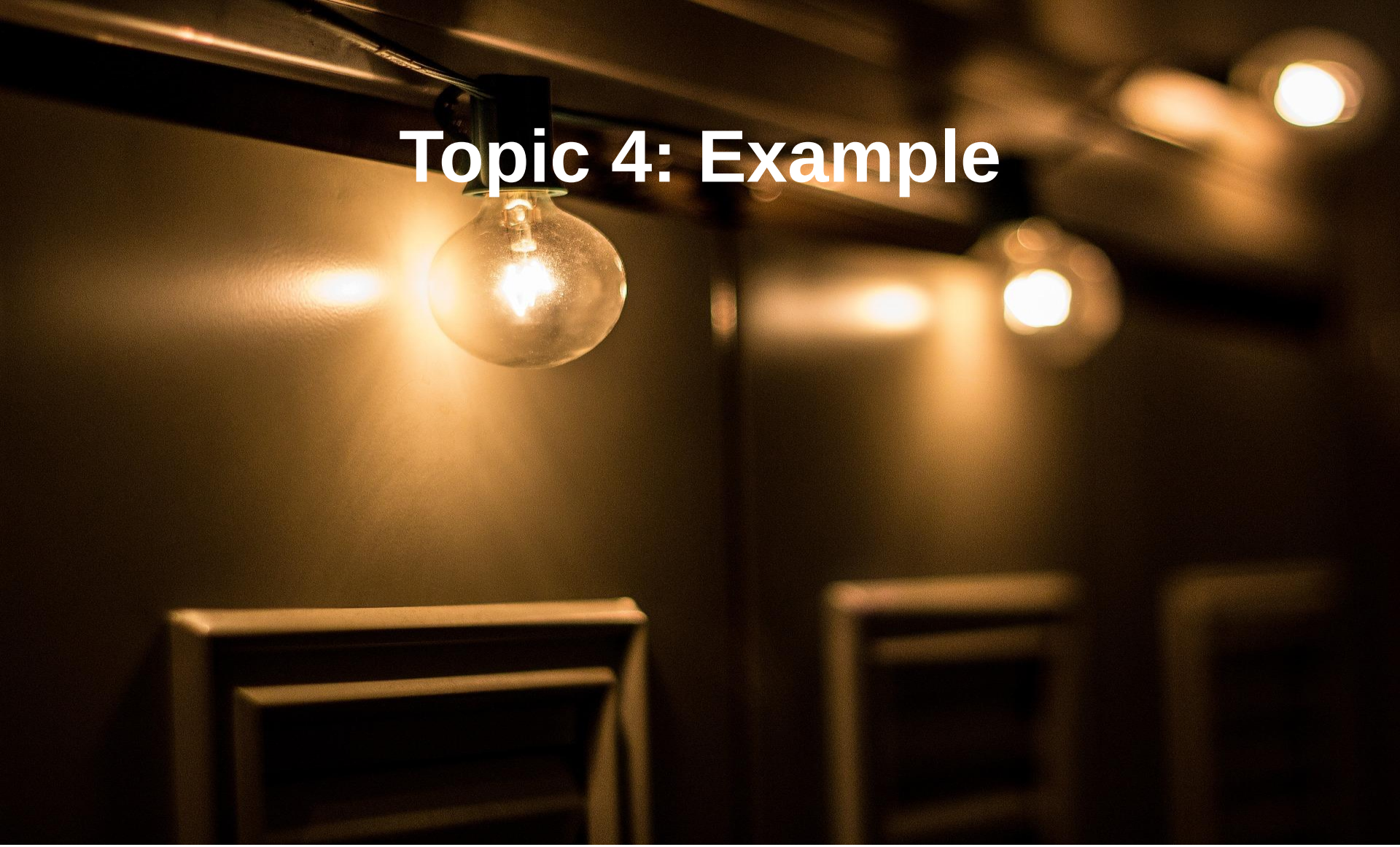
Scheduling & Dispatch Process





(*not being implemented at go-live of the revised SEM arrangements)



Topic 4: Example

Example

The following slides provide an illustration of the process from receiving PNs from Participants, the resulting production of an Indicative Operations Schedule to the issue of Dispatch Instructions.

Example

PNs	Availability Max / Min	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
Unit A	400 / 200	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Unit B	400 / 200	300	350	400	400	400	400	400	400	400	400	400	400	300	200
Unit C	400 / 200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit D	300 / 100	100	200	250	250	300	250	200	200	200	250	300	300	250	200
Unit E	300 / 100	100	200	200	200	200	200	200	200	200	250	300	200	100	100
Unit F	100 / 20	0	0	0	0	0	0	0	0	0	100	100	50	0	0
Unit G	100 / 20	0	0	0	0	0	0	0	0	0	0	50	0	0	0
Unit H	50 / 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total PN		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900
Demand		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900

Snapshot of PNs submitted as of 16:00 on D-1 for 08:00 to 21:00 on D.

For illustration purposes this data is presented at hourly resolution.

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Example

PNs	Availability Max / Min	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
Unit A	400 / 200	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Unit B	400 / 200	300	350	400	400	400	400	400	400	400	400	400	400	300	200
Unit C	400 / 200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit D	300 / 100	100	200	250	250	300	250	200	200	200	250	300	300	250	200
Unit E	300 / 100	100	200	200	200	200	200	200	200	200	250	300	200	100	100
Unit F	100 / 20	0	0	0	0	0	0	0	0	0	100	100	50	0	0
Unit G	100 / 20	0	0	0	0	0	0	0	0	0	0	50	0	0	0
Unit H	50 / 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total PN		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900
Demand		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900

Schedule	Availability Max / Min	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
Unit A	400 / 200	370	370	370	370	370	370	370	370	370	370	370	370	370	370
Unit B	400 / 200	330	350	370	370	370	370	37							
Unit C	400 / 200	0	200	200	200	200	200	20							
Unit D	300 / 100	100	130	210	210	260	210	16							
Unit E	300 / 100	100	100	100	100	100	100	10							
Unit F	100 / 20	0	0	0	0	0	0	0							
Unit G	100 / 20	0	0	0	0	0	0	0							
Unit H	50 / 10	0	0	0	0	0	0	0							
Total Sch		900	1150	1250	1250	1300	1250	12							
Demand		900	1150	1250	1250	1300	1250	12							

Dec
Inc

The resulting Long Term Schedule (LTS) produced at 16:00 on D-1.

Red values represent decrements from the PN, green values represent increments from the PN.

Again, for illustration purposes this is presented in hourly resolution.

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Example

PNs	Availability Max / Min	08:00	09:00	10:00	11:00								20:00	21:00
Unit A	400 / 200	400	400	400	400								400	400
Unit B	400 / 200	300	350	400	400								300	200
Unit C	400 / 200	0	0	0	0								0	0
Unit D	300 / 100	100	200	250	250								250	200
Unit E	300 / 100	100	200	200	200								100	100
Unit F	100 / 20	0	0	0	0								0	0
Unit G	100 / 20	0	0	0	0								0	0
Unit H	50 / 10	0	0	0	0								0	0
Total PN		900	1150	1250	1250							1350	1050	900
Demand		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900

Unit C is scheduled at minimum load from 09:00 to 20:00.

This is driven by a 'must run' voltage requirement but the unit will also contribute to inertia and reserve requirements.

Unit C also provides energy.

Schedule	Availability Max / Min	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
Unit A	400 / 200	370	370	370	370	370	370	370	370	370	370	370	370	370	370
Unit B	400 / 200	330	350	370	370	370	370	370	370	370	370	370	370	280	230
Unit C	400 / 200	0	200	200	200	200	200	200	200	200	200	250	200	200	0
Unit D	300 / 100	100	130	210	210	260	210	100	100	100	250	270	270	100	200
Unit E	300 / 100	100	100	100	100	100	100	100	100	100	190	270	120	100	100
Unit F	100 / 20	0	0	0	0	0	0	0	0	0	20	20	20	0	0
Unit G	100 / 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit H	50 / 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Sch		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900
Demand		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900

Dec
Inc

EIRGRID SONI

Example

PNs	Availability Max / Min	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
Unit A	400 / 200	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Unit B	400 / 200	300	350									400	400	300	200
Unit C	400 / 200	0	0									0	0	0	0
Unit D	300 / 100	100	200									300	300	250	200
Unit E	300 / 100	100	200									300	200	100	100
Unit F	100 / 20	0	0									100	50	0	0
Unit G	100 / 20	0	0									50	0	0	0
Unit H	50 / 10	0	0									0	0	0	0
Total PN		900	1150									1550	1350	1050	900
Demand		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900

Units A, B, D and E are decremented below their maximum availability to provide reserve headroom.

As a result they produce less energy.

Schedule	Availability Max / Min	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
Unit A	400 / 200	370	370	370	370	370	370	370	370	370	370	370	370	370	370
Unit B	400 / 200	330	350	370	370	370	370	370	370	370	370	370	370	280	230
Unit C	400 / 200	0	200	200	200	200	200	200	200	200	200	250	200	200	0
Unit D	300 / 100	100	130	210	210	260	210	160	160	160	250	270	270	100	200
Unit E	300 / 100	100	100	100	100	100	100	100	100	100	190	270	120	100	100
Unit F	100 / 20	0	0	0	0	0	0	0	0	0	20	20	20	0	0
Unit G	100 / 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit H	50 / 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Sch		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900
Demand		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900

Dec
Inc

EIRGRID SONI

Example

Additional adjustments are made to units B, D, E, F and G to balance generation and demand.

Unit G is not scheduled to run.

PNs	Availability Max / Min	08:00	09:00	10:00	11:00	12:00									21:00
Unit A	400 / 200	400	400	400	400	400									400
Unit B	400 / 200	300	350	400	400	400									200
Unit C	400 / 200	0	0	0	0	0								0	0
Unit D	300 / 100	100	200	250	250	300	250	200	200	200	250	300	300	250	200
Unit E	300 / 100	100	200	200	200	200	200	200	200	200	250	300	200	100	100
Unit F	100 / 20	0	0	0	0	0	0	0	0	0	100	100	50	0	0
Unit G	100 / 20	0	0	0	0	0	0	0	0	0	0	50	0	0	0
Unit H	50 / 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total PN		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900
Demand		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900

Schedule	Availability Max / Min	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
Unit A	400 / 200	370	370	370	370	370	370	370	370	370	370	370	370	370	370
Unit B	400 / 200	330	350	370	370	370	370	370	370	370	370	370	370	280	230
Unit C	400 / 200	0	200	200	200	200	200	200	200	200	200	250	200	200	0
Unit D	300 / 100	100	130	210	210	260	210	160	160	160	250	270	270	100	200
Unit E	300 / 100	100	100	100	100	100	100	100	100	100	190	270	120	100	100
Unit F	100 / 20	0	0	0	0	0	0	0	0	0	20	[illegible]	20	0	0
Unit G	100 / 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit H	50 / 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Sch		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900
Demand		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900

Dec
Inc

EIRGRID SONI

Example

Schedule	Availability Max / Min	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
Unit A	400 / 200	370	370	370	370	370	370	370	370	370	370	370	370	370	370
Unit B	400 / 200	330	350	370	370	370	370	370	370	370	370	370	370	280	230
Unit C	400 / 200	0	200	200	200	200	200	200	200	200	200	250	200	200	0
Unit D	300 / 100	100	150	210	210	260	210	160	160	160	250	270	270	100	200
Unit E	300 / 100	100	100	100	100	100	100	100	100	100	190	270	120	100	100
Unit F	100 / 20	0	0	0	0	0	0	0	0	0	20	20	20	0	0
Unit G	100 / 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit H	50 / 10	0	0									0	0	0	0
Total Sch		900	1150									1550	1350	1050	900
Demand		900	1150									1550	1350	1050	900

This is a Long-Term Schedule produced at 16:00 on D-1.

Its primary purpose is to indicate unit commitment / de-commitment decisions:

- Unit C must be on by 09:00 on D
- Unit G is not committed.

There will be subsequent LTS runs that re-evaluate these decisions before action needs to be taken.

Dec
Inc

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Example

Schedule	Availability Max / Min	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
Unit A	400 / 200	370	370	370	370	370	370	370	370	370	370	370	370	370	370
Unit B	400 / 200	330	350	370	370	370	370	370	370	370	370	370	370	280	230
Unit C	400 / 200	0	200	200	200	200	200	200	200	200	200	250	200	200	0
Unit D	300 / 100	100	150	210	210	260	210	160	160	160	250	270	270	100	200
Unit E	300 / 100	100	100	100	100	100	100	100	100	100	190	270	120	100	100
Unit F	100 / 20	0	0	0	0	0	0	0	0	0	20	20	20	0	0
Unit G	100 / 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unit H	50 / 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Sch		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900
Demand		900	1150	1250	1250	1300	1250	1200	1200	1200	1400	1550	1350	1050	900

Unit C has a 6 hour notification time (the time from a commitment instruction being issued to the unit being on at minimum generation).

The instruction to commit unit C must be issued by 03:00.

Unit G does not receive a de-commit instruction as the last de-commit instruction remains valid.

Dec
Inc

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Example

Schedule	Availability Max / Min	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00
Unit A	400 / 200	370	370	370	370	370	370	370	370	370	370	370	370	370	370
Unit B	400 / 200	330	350	370	370	370	370	370	370	370	370	370	370	280	230
Unit C	400 / 200	0	200	200	200	200	200	200	200	200	200	250	200	200	0
Unit D	300 / 100	100	130	210	210	260	210	160	160	160	250	270	270	100	200
Unit E	300 / 100	100	100	100	100	100	100	100	100	100	190	270	120	100	100
Unit F	100 / 20	0	0	0	0	0	0	0	0	0	20	20	20	0	0
Unit G	100 / 20	0	0									0	0	0	0
Unit H	50 / 10	0	0									0	0	0	0
Total Sch		900	1150									1550	1350	1050	900
Demand		900	1150									1550	1350	1050	900

All other incremental and decremental dispatch decisions are made based on Real-Time Dispatch (RTD) advice and real-time system conditions, e.g.:

The RTD run at 09:45 advises that unit B should be dispatched from 350 to 370 at 09:55.

However taking into account actual system conditions (demand is higher than forecast and system frequency is below target), unit B is dispatched to 380 MW at 09:50.

Dec
Inc

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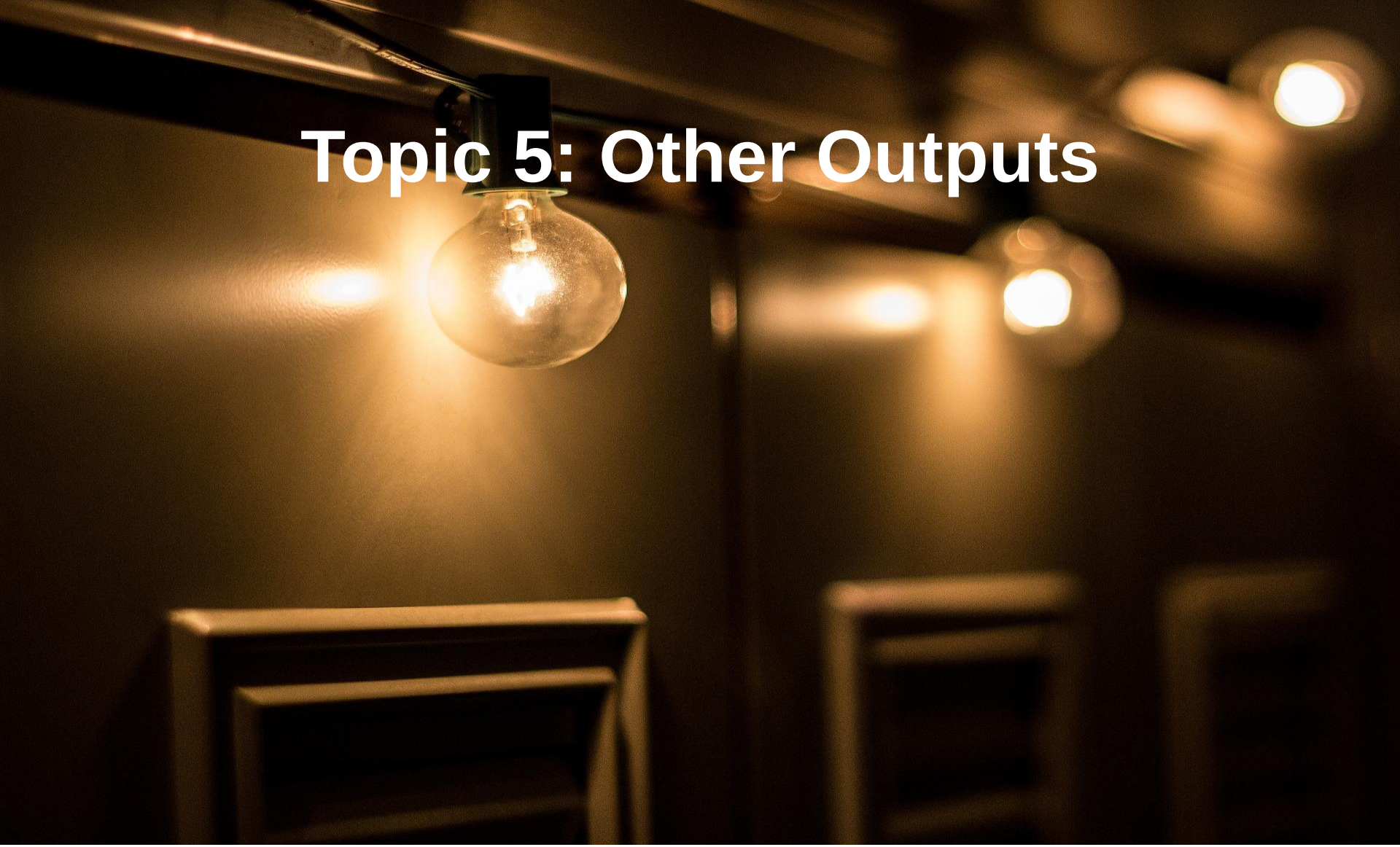

Topic 5: Other Outputs

Other Outputs

The dispatch instructions issued and actions that we take result in the delivery of balancing energy and System Services. Data from the scheduling and dispatch process feeds the respective settlement systems so that Participants and System Service providers are settled appropriately. There are also charges related to the performance of units such as Other System Charges and Generator Performance Incentives (GPIs) and outputs of the process that relate to Capacity Market settlement.

Scheduling and Dispatch Process Data Item	Imbalance Pricing	Balancing / Capacity Market Settlement	System Services Settlement	Other System Charges & GPIs
Dispatch instructions	Y	Y	Y	Y
Cross-Zonal Actions	Y	Y	Y	
Real-Time Availabilities	Y	Y	Y	Y
System Operator Flags	Y	Y		
Non-Marginal Flags	Y			
Short Term Reserve Quantity	Y			
Short Term Reserve Requirement	Y			
Quantity of Demand Control	Y			
System Services Flag		Y		
Operational metering (SCADA)			Y	Y

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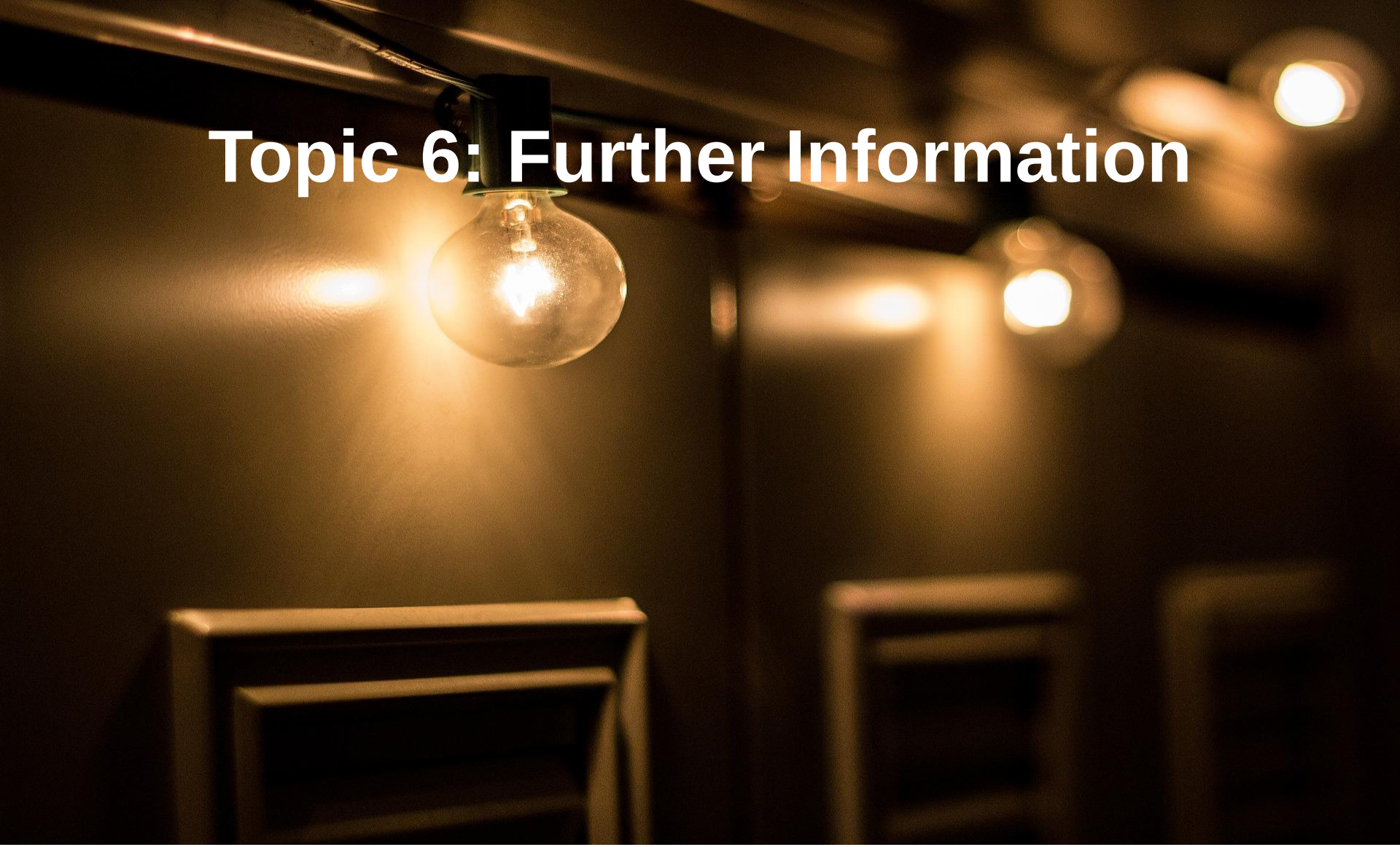
Topic 6: Further Information



Further Information

We expect to publish the Balancing Market Principles Statement in October 2017 (subject to SEM Committee approval).

The consultation version is available on the I-SEM publications page of the SEM-O website www.sem-o.com.

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Review of Learning Objectives

As a result of this training module you should now:

Appreciate the objectives of the scheduling and dispatch process; ✓

Understand the main activities within the scheduling and dispatch process ✓

Be aware of the outputs of the scheduling and dispatch process and where to find more information ✓

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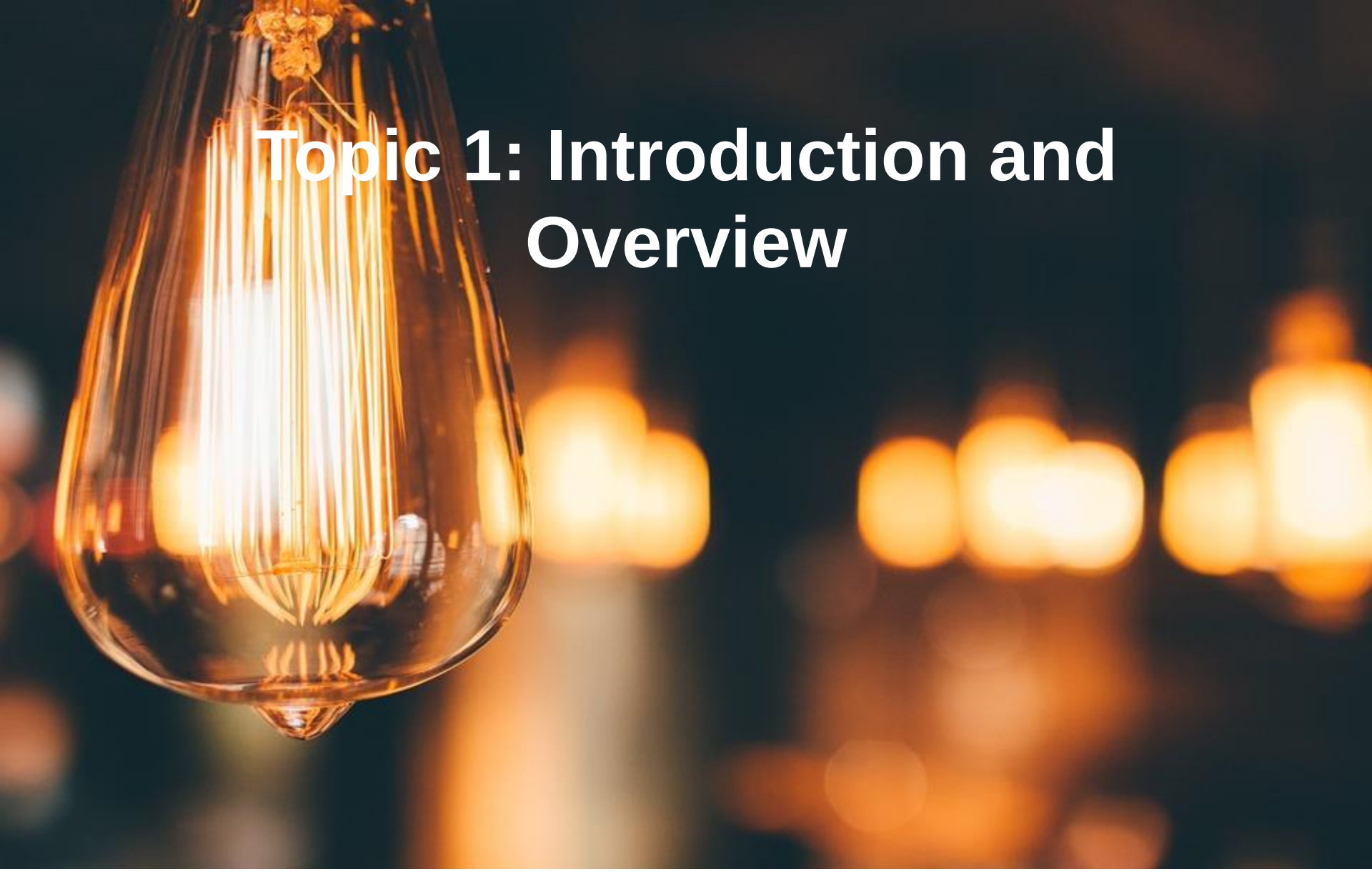
Part 2: Imbalance Pricing

Imbalance Pricing Agenda

Training Topic
Learning Objectives
Topic 1: Introduction and Overview
Topic 2: Inputs, Process, Outputs
Topic 3: Determining and Ranking Bid Offer Acceptances
Topic 4: System Operator Flagging
Topic 5: Non-Marginal Flagging
Topic 6: Marginal Energy Action Price
Topic 7: Net Imbalance Volume Tagging
Topic 8: Price Average Reference Tagging
Topic 9: Final Imbalance Price Calculation
Topic 10: Administered Scarcity Pricing
Topic 11: Market Back Up Price & Curtailment Price
Topic 12: Course Summary

Learning Objectives

- After completing self learning and instructor-led training for this course you should understand:
  - the inputs, process and outputs of the Imbalance Pricing process
  - the application of the flagging and tagging methodologies
  - the application of Administered Scarcity Pricing
  - the calculation of the Imbalance price and the Imbalance Settlement Price



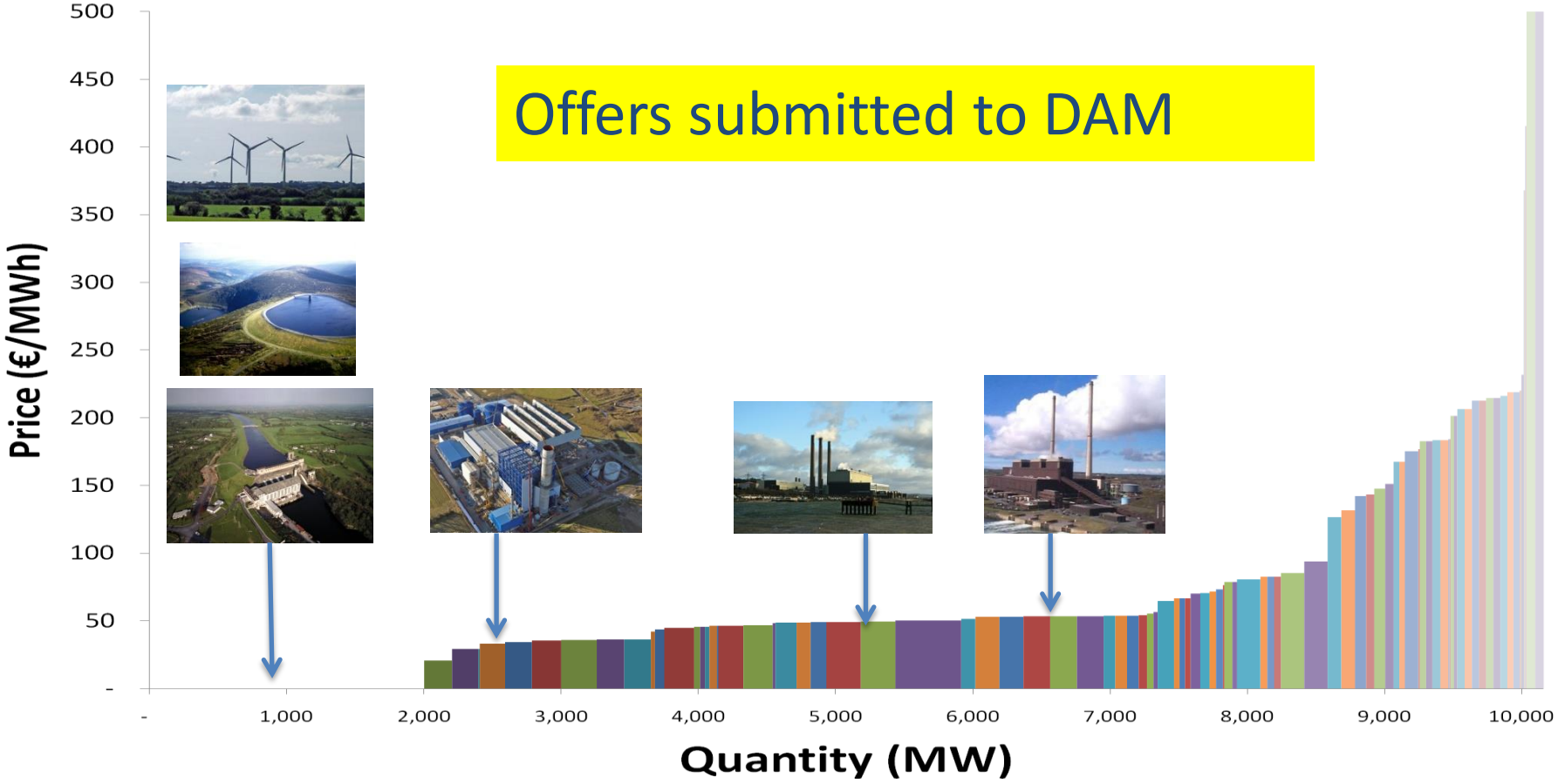
Topic 1: Introduction and Overview

Introduction and Overview

- The Imbalance Settlement Price is the primary price used for settlement in the Balancing Market, and therefore it is an important signal for the whole market;

- It is the primary signal which “Balance Responsibility” is implemented:
  - Participants are financially responsible for differences between their trade volumes and actual consumption or generation;
  - The Imbalance Settlement Price is the price applied to this difference.
- The I-SEM High Level Design detailed that:
  - There should be a single Imbalance Settlement Price for imbalances in all directions, and all Energy Balancing actions;
  - The price should be marginal, based on the cost of generating one more or one fewer MWh to provide balancing energy;
  - Non-Energy Balancing actions should be settled pay-as-bid.

Day in the Life 1a: D-1 10:00



Day in the Life 1a: D-1 11:00

Day Ahead Market (17:00 – 18:00 D)

Price = 50€/MWh

ON

ON

ON

ON

OFF

ON

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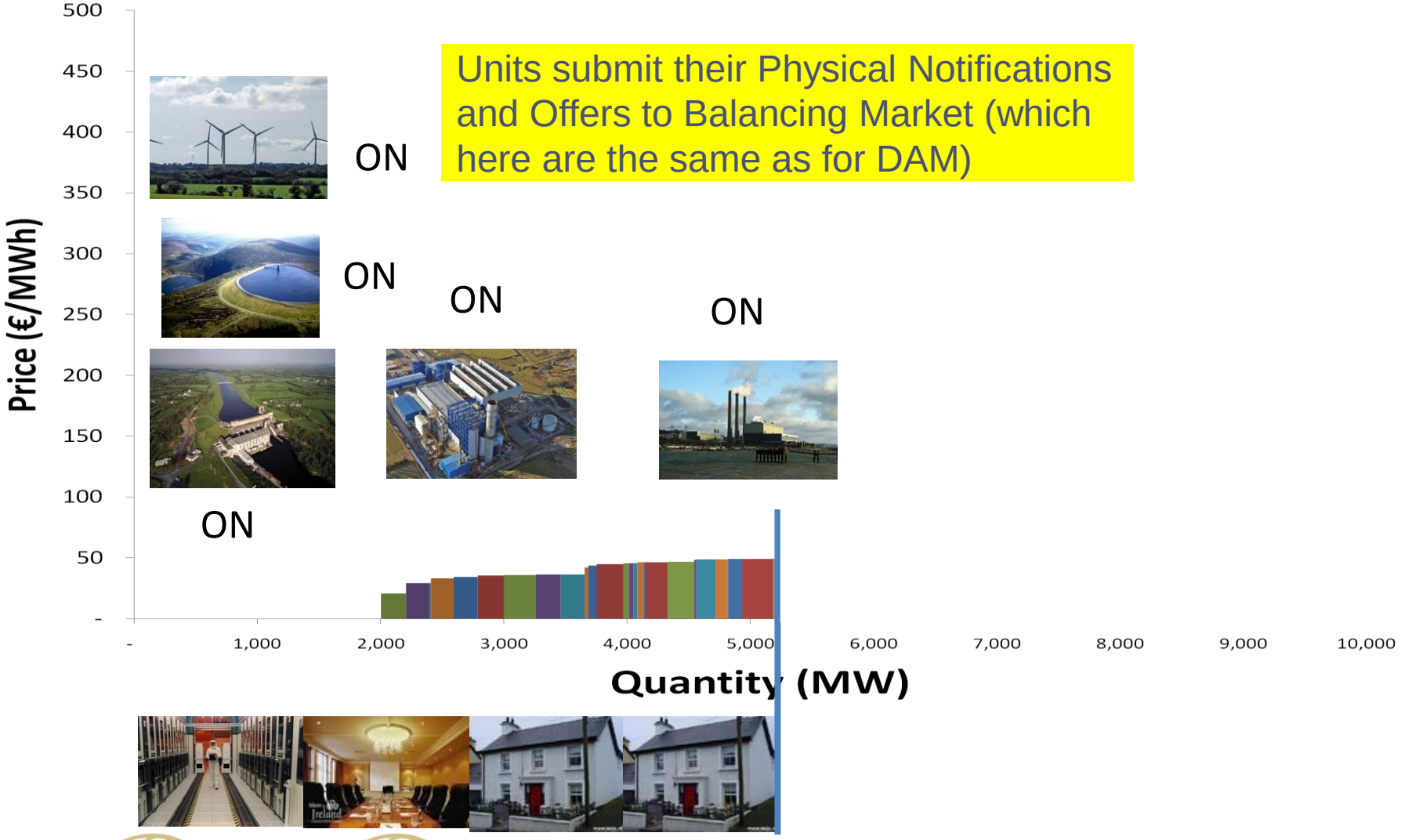
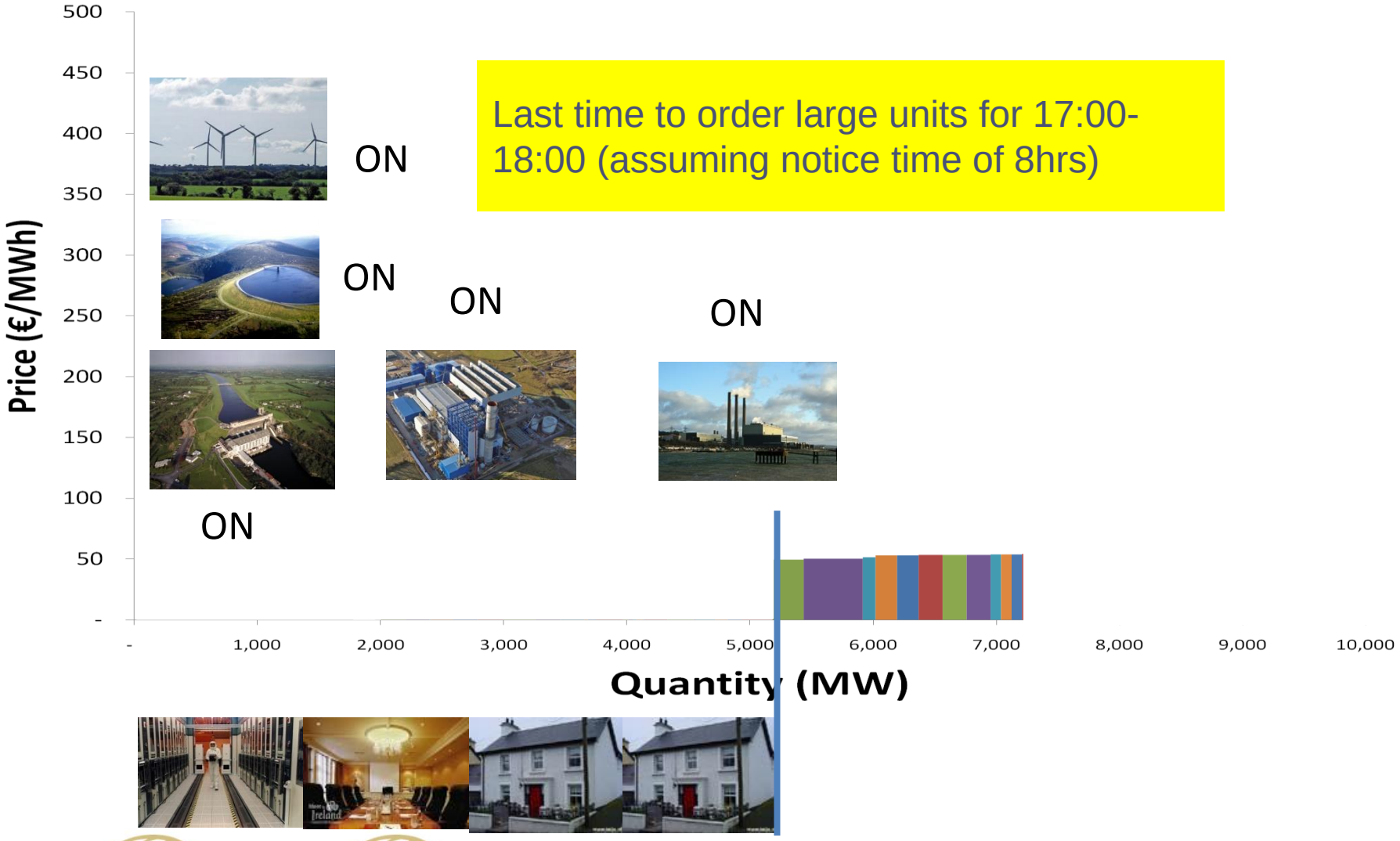
Single Electricity Market Operator

Day in the Life 1a: D-1 13:30



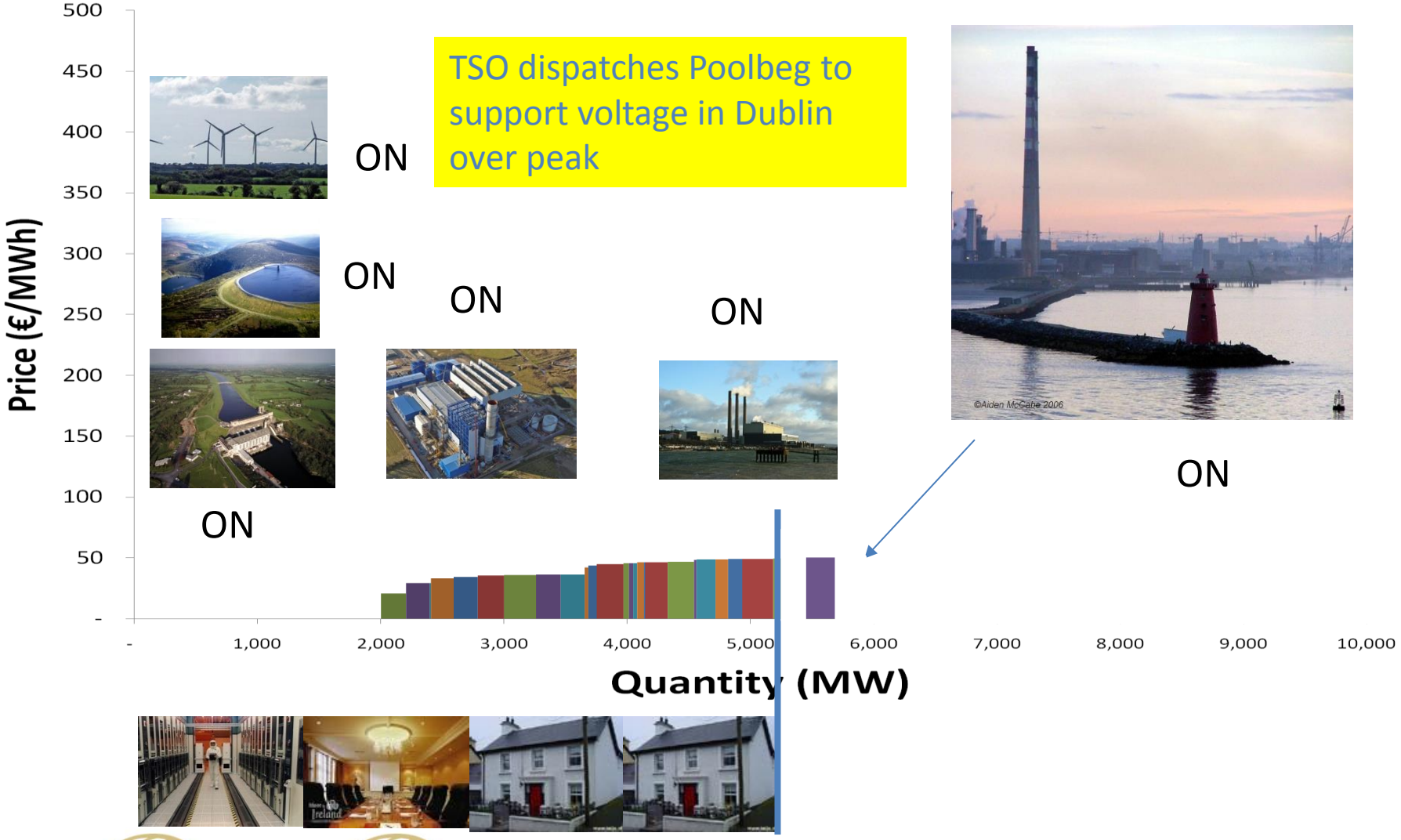
Units submit their Physical Notifications and Offers to Balancing Market (which here are the same as for DAM)

Day in the Life 1a: 09:00

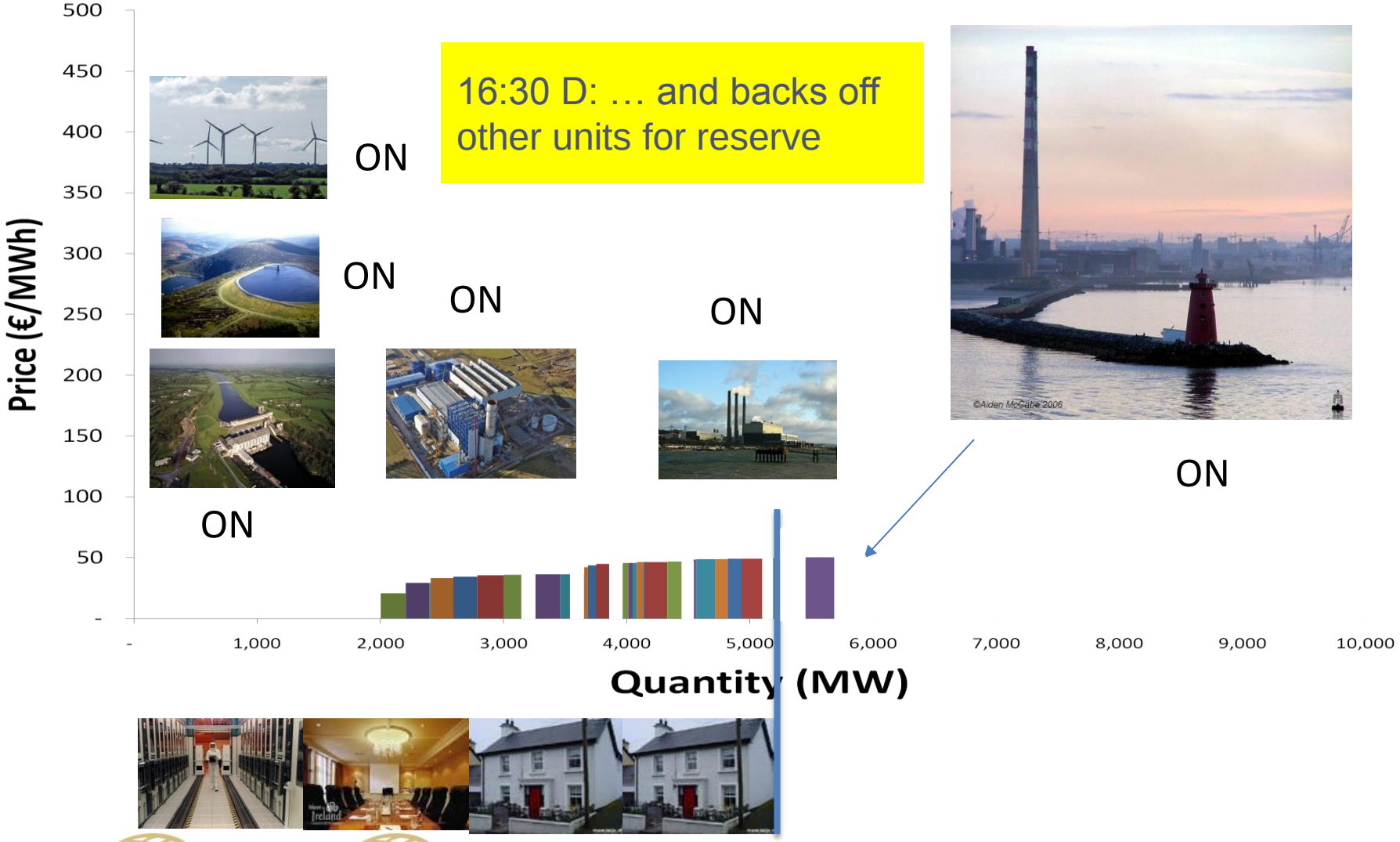


Last time to order large units for 17:00-18:00 (assuming notice time of 8hrs)

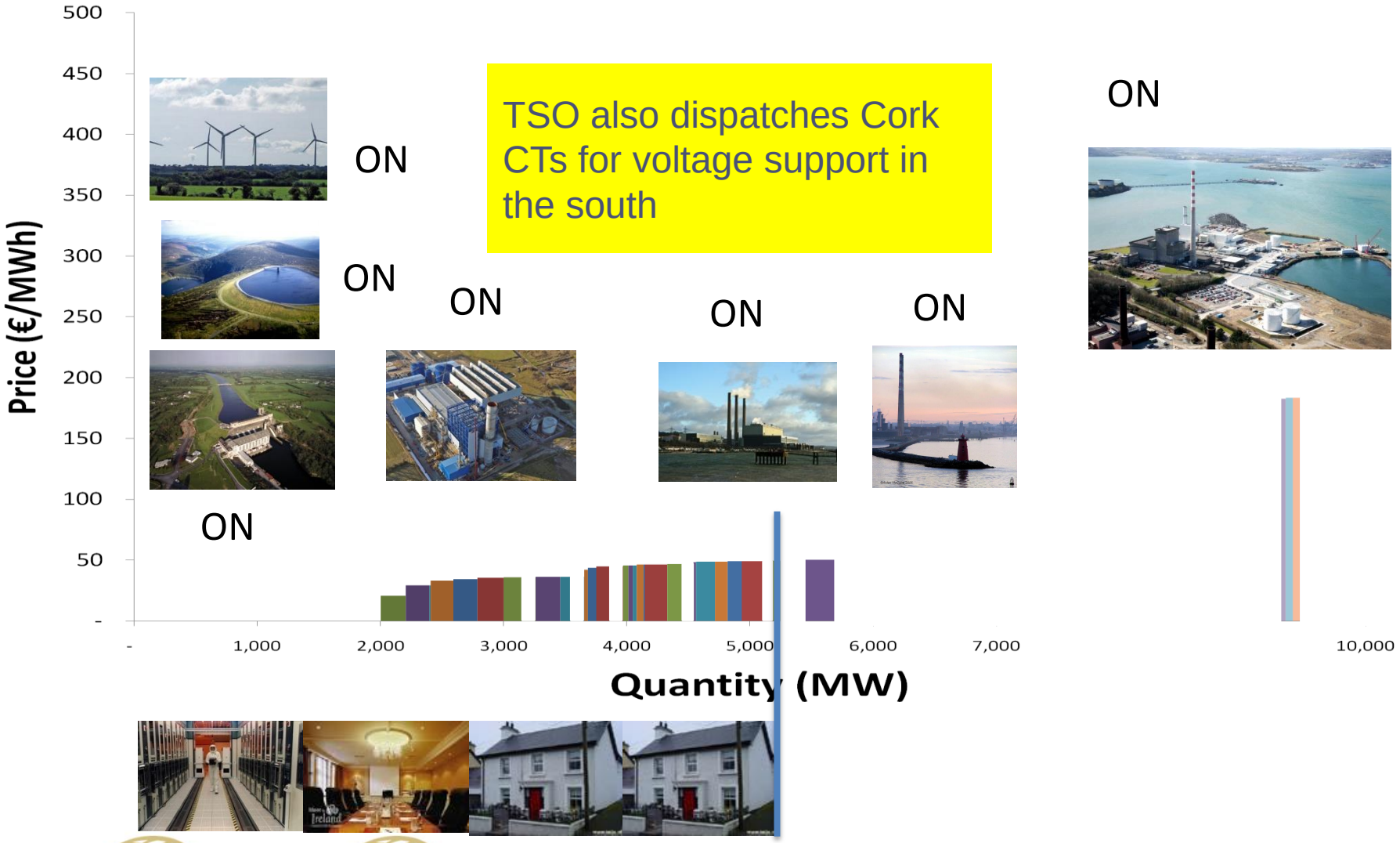
Day in the Life 1a: 09:00



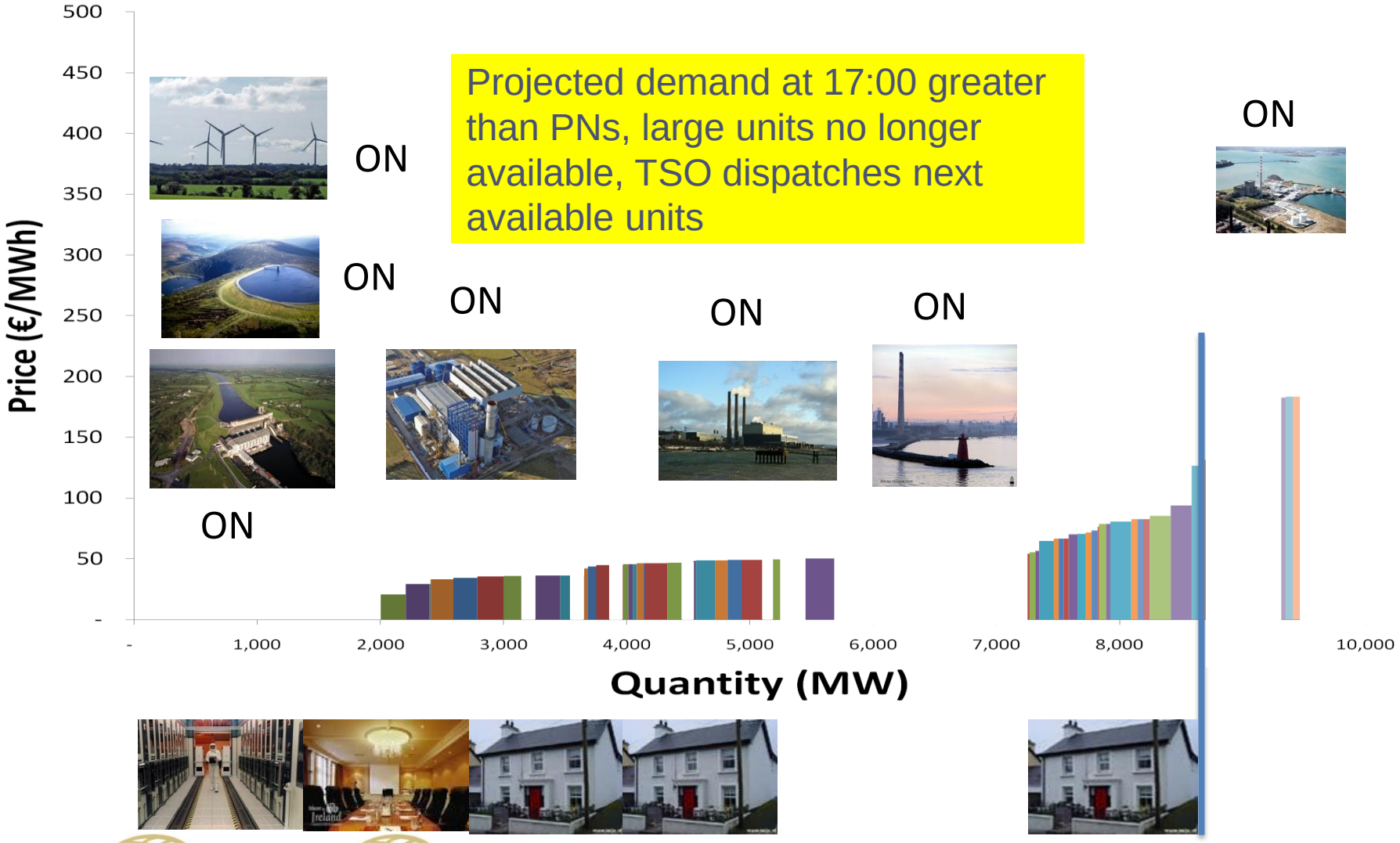
Day in the Life 1a: 16:30



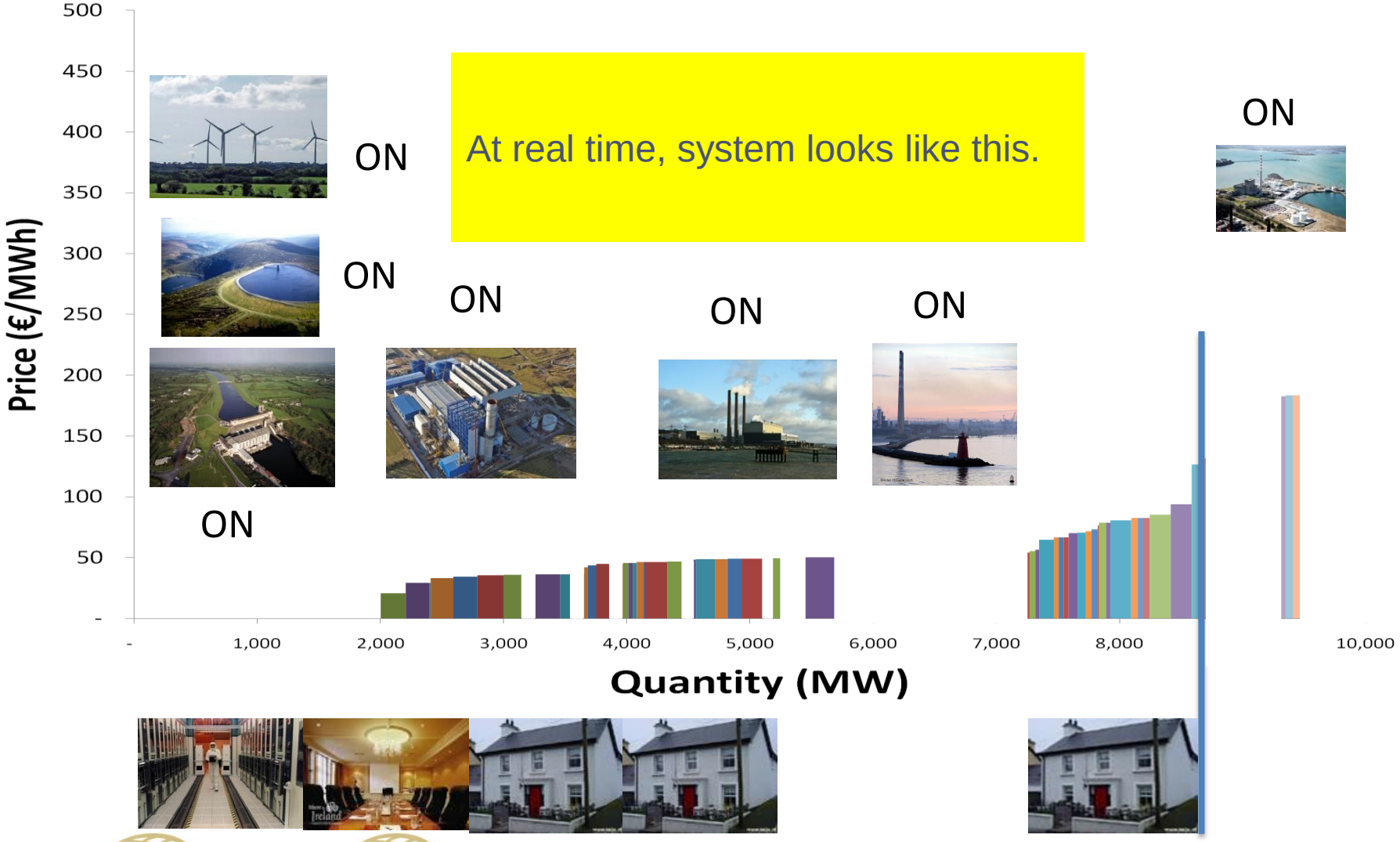
Day in the Life 1a: 16:30



Day in the Life 1a: 16:45



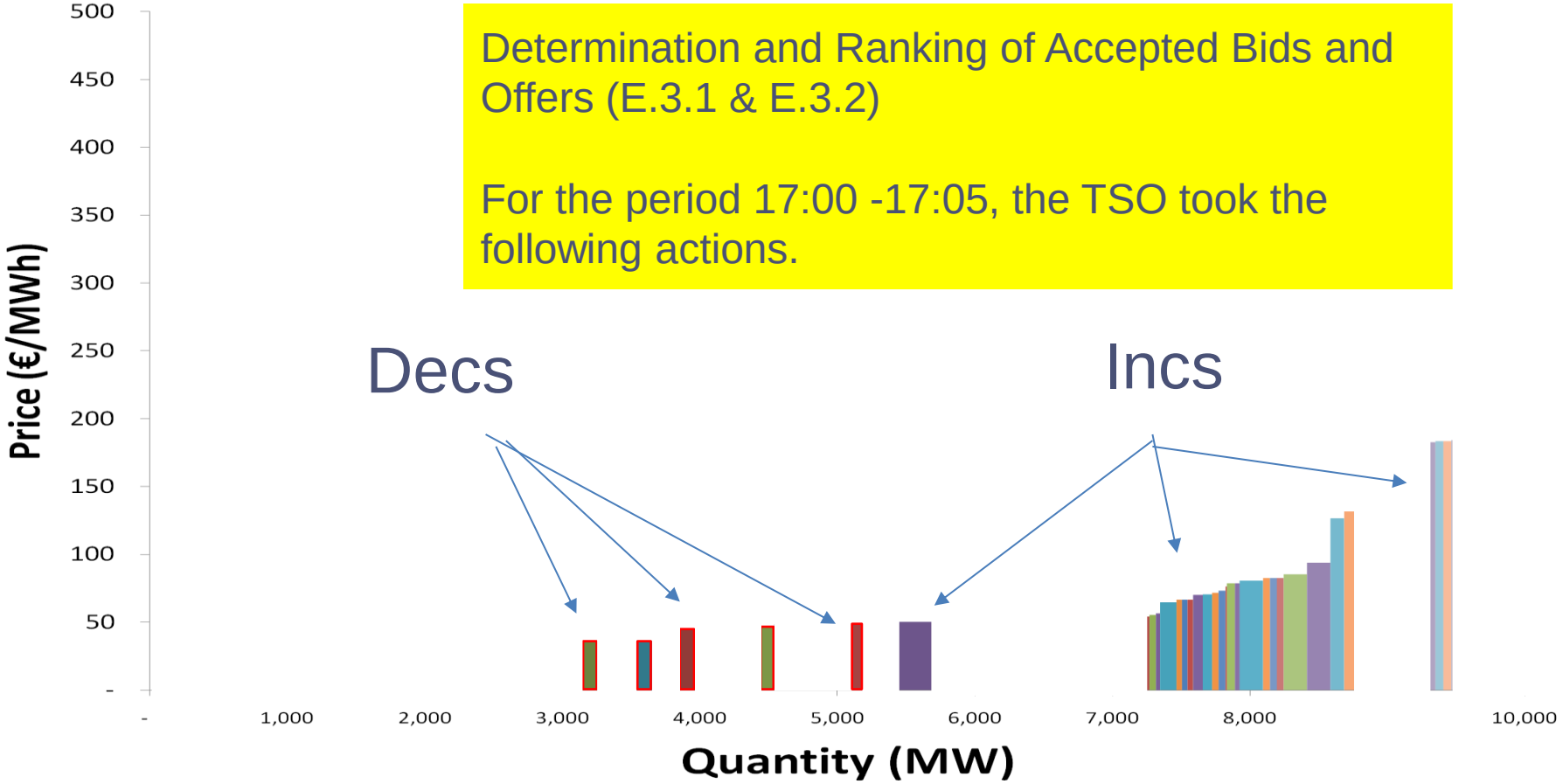
Day in the Life 1a: 17:00 (Real time)



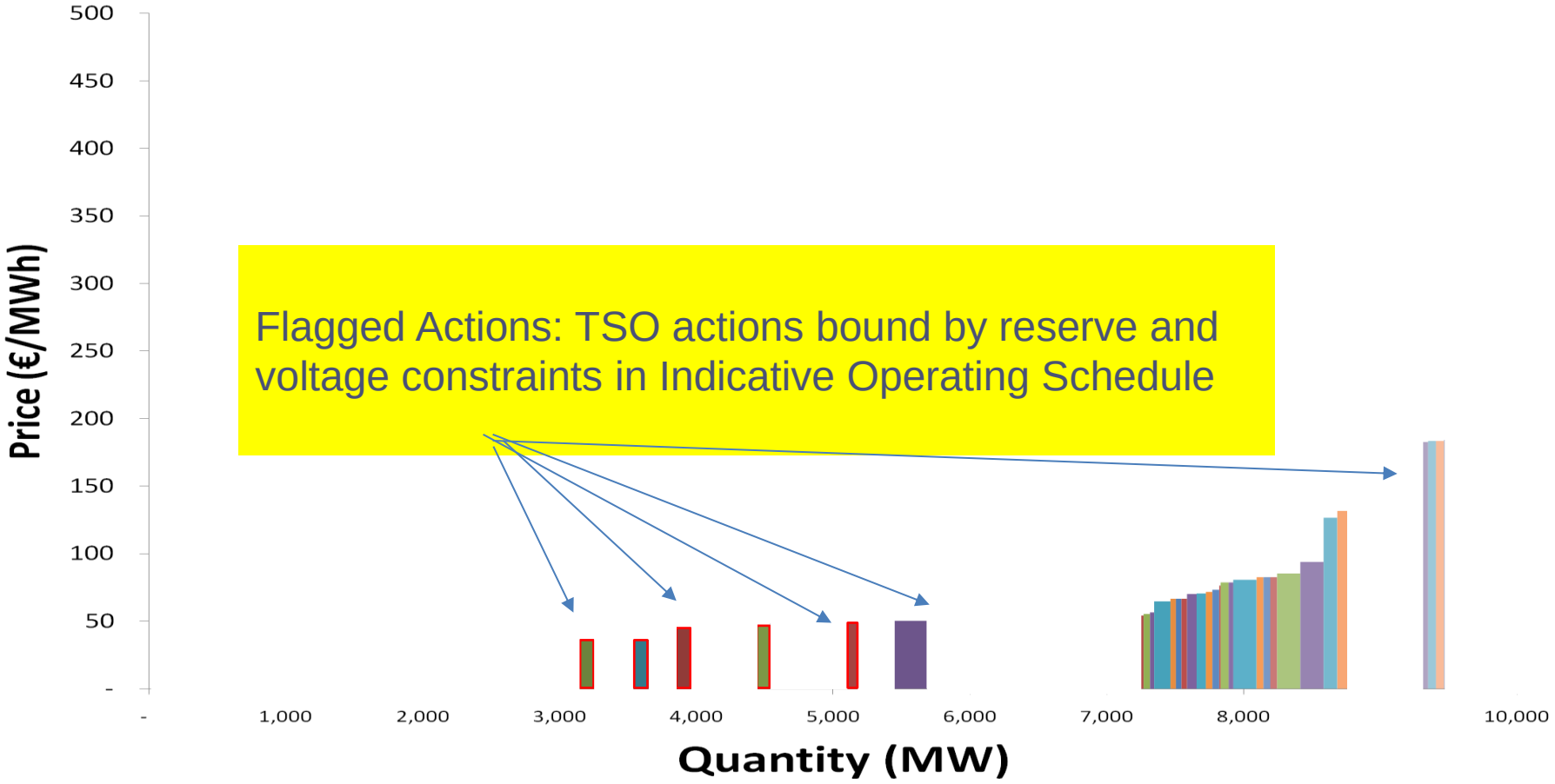
Day in the Life 1a: 17:25 (Imbalance Pricing)

Determination and Ranking of Accepted Bids and Offers (E.3.1 & E.3.2)

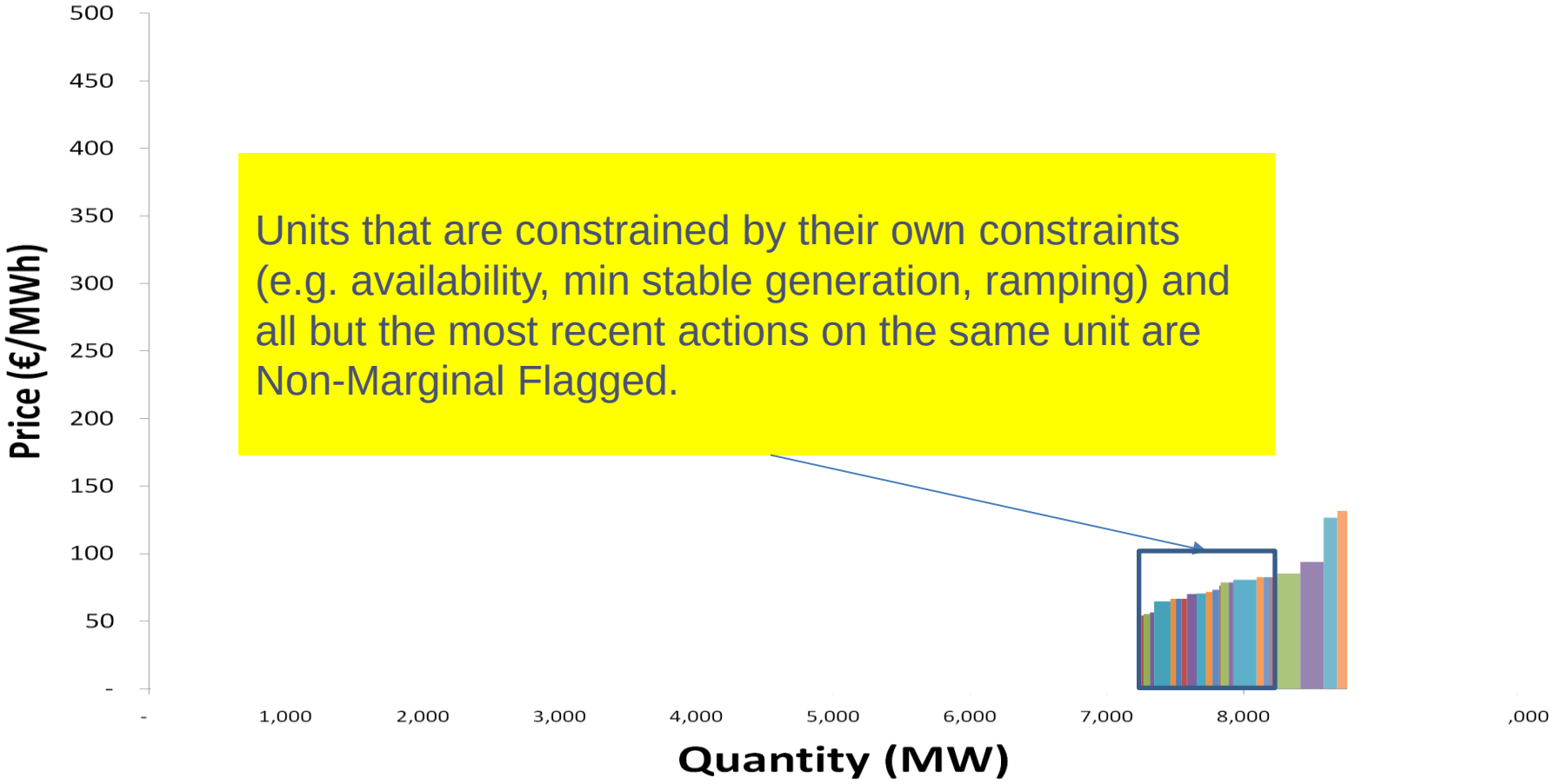
For the period 17:00 -17:05, the TSO took the following actions.



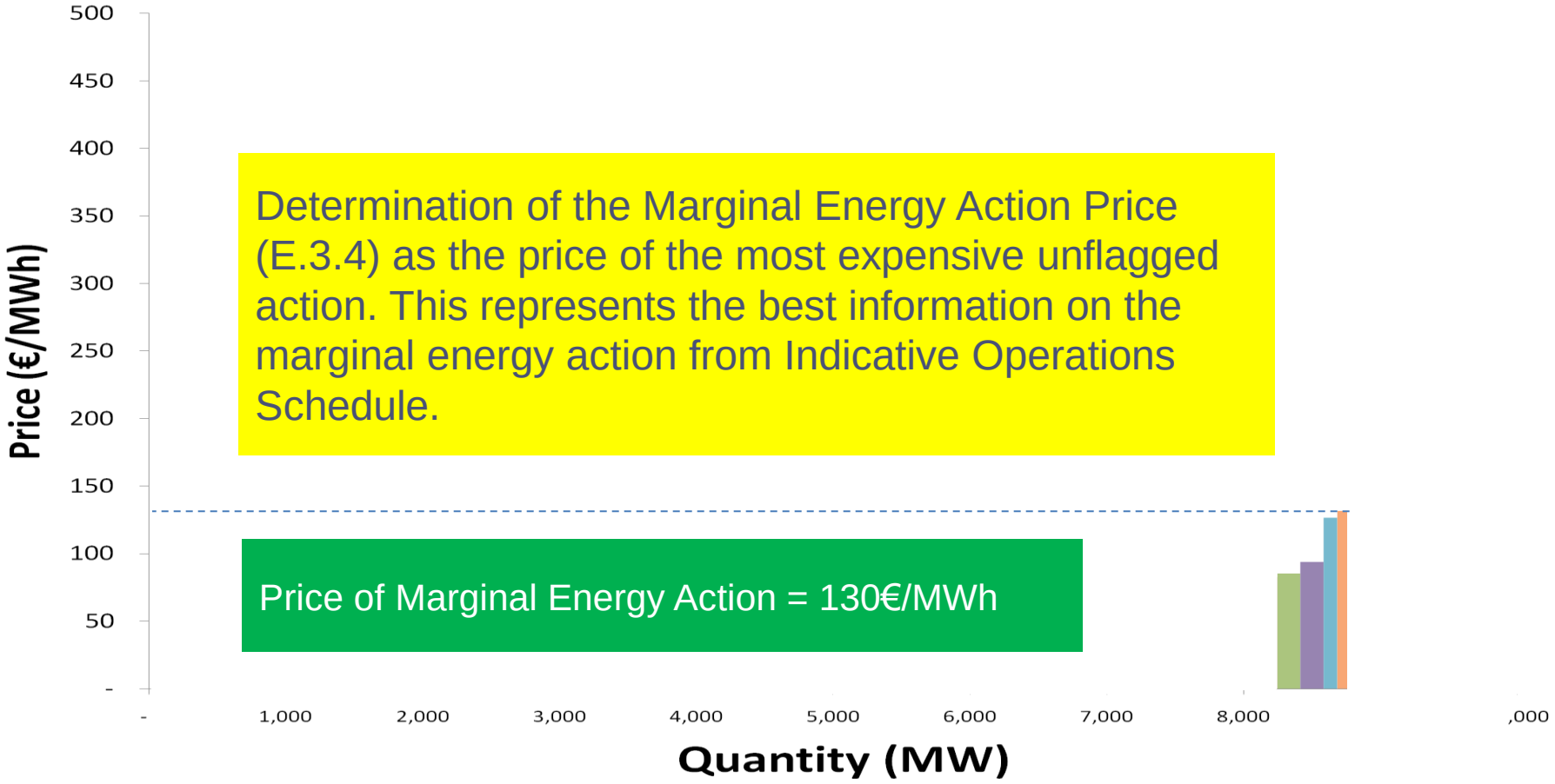
Day in the Life 1a: 17:25 (Imbalance Pricing)



Day in the Life 1a: 17:25 (Imbalance Pricing)



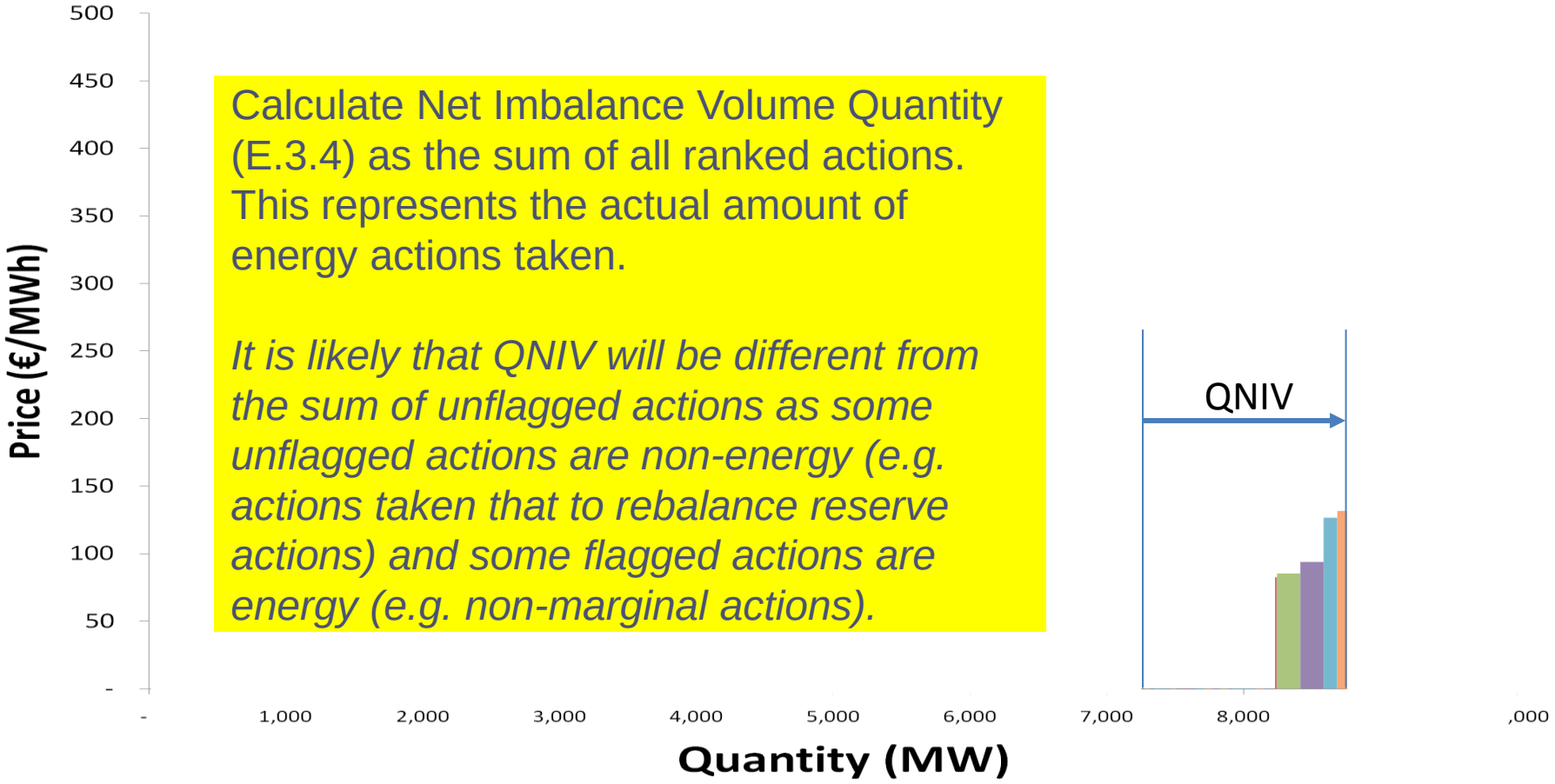
Day in the Life 1a: 17:25 (Imbalance Pricing)



Day in the Life 1a: 17:25 (Imbalance Pricing)

Calculate Net Imbalance Volume Quantity (E.3.4) as the sum of all ranked actions. This represents the actual amount of energy actions taken.

It is likely that QNIV will be different from the sum of unflagged actions as some unflagged actions are non-energy (e.g. actions taken that to rebalance reserve actions) and some flagged actions are energy (e.g. non-marginal actions).

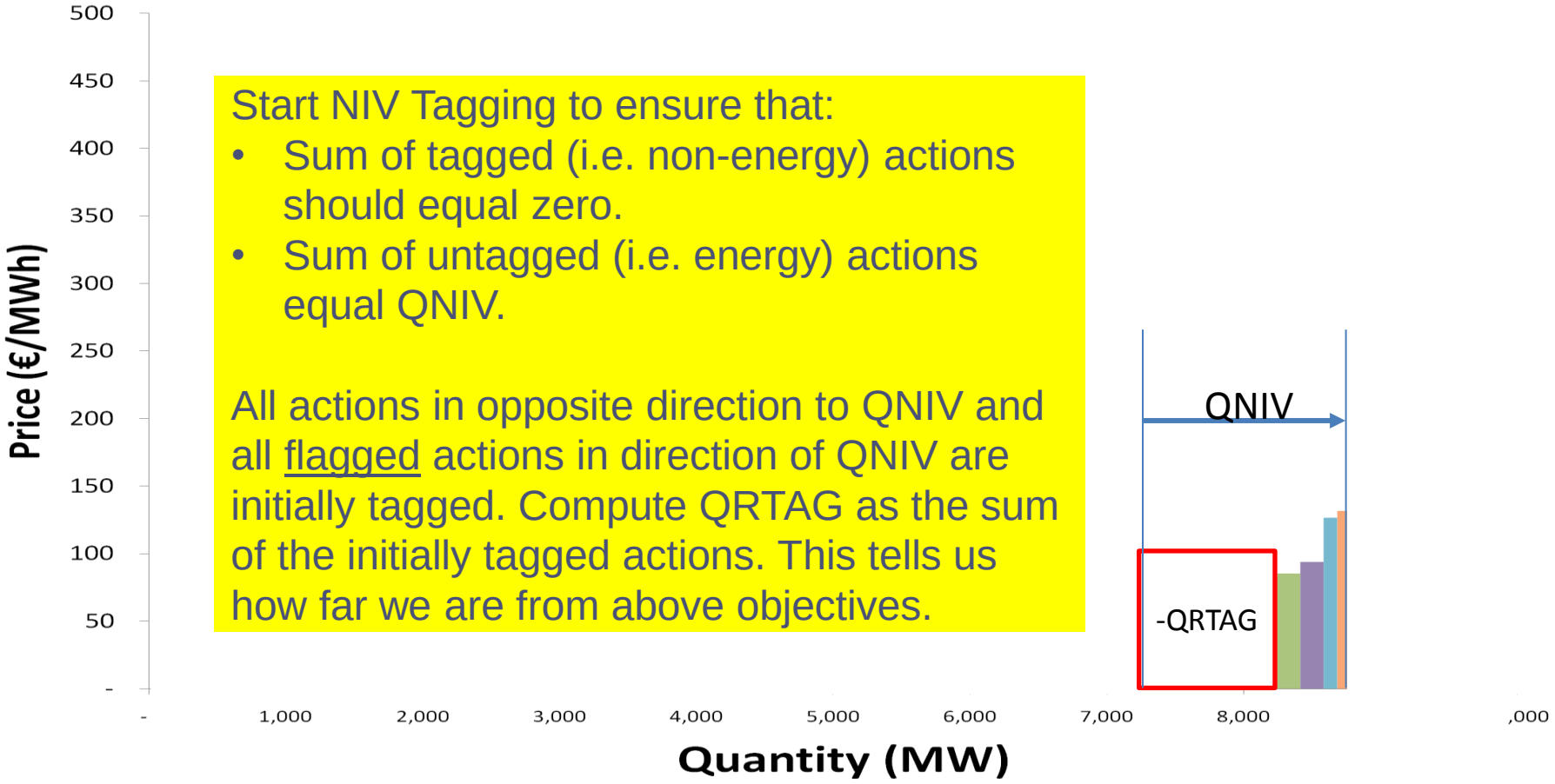


Day in the Life 1a: 17:25 (Imbalance Pricing)

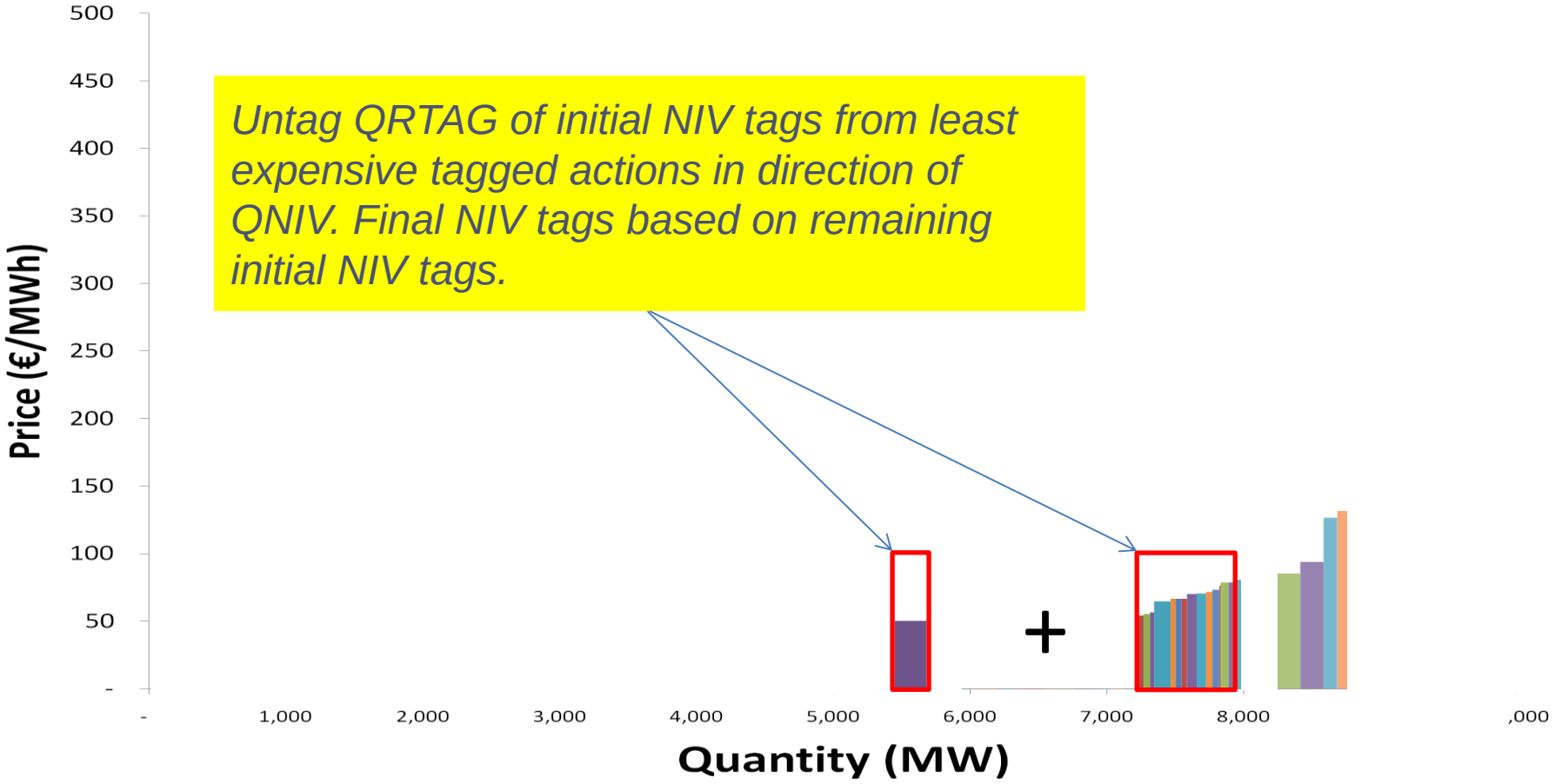
Start NIV Tagging to ensure that:

- Sum of tagged (i.e. non-energy) actions should equal zero.
- Sum of untagged (i.e. energy) actions equal QNIV.

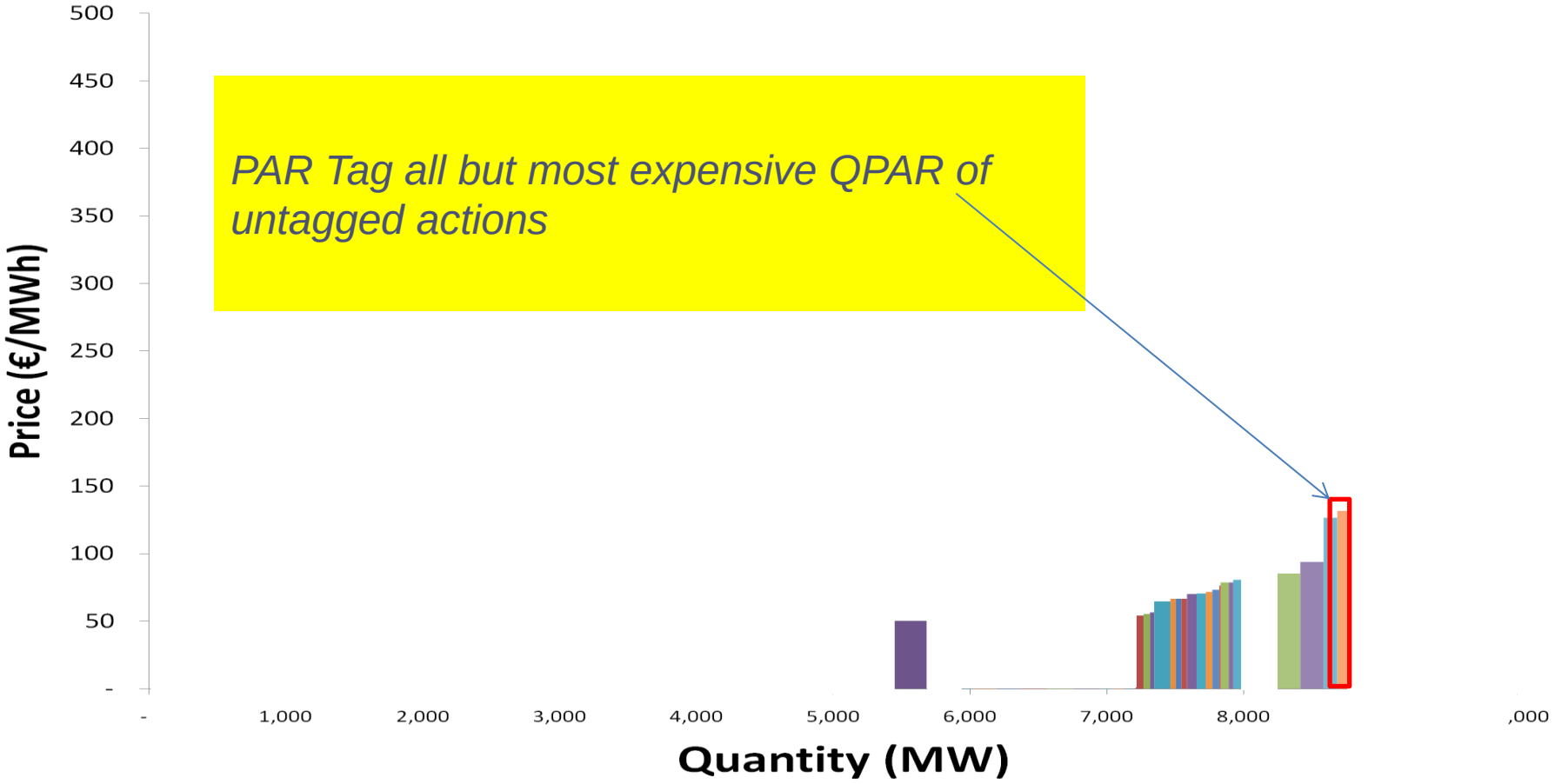
All actions in opposite direction to QNIV and all flagged actions in direction of QNIV are initially tagged. Compute QRTAG as the sum of the initially tagged actions. This tells us how far we are from above objectives.



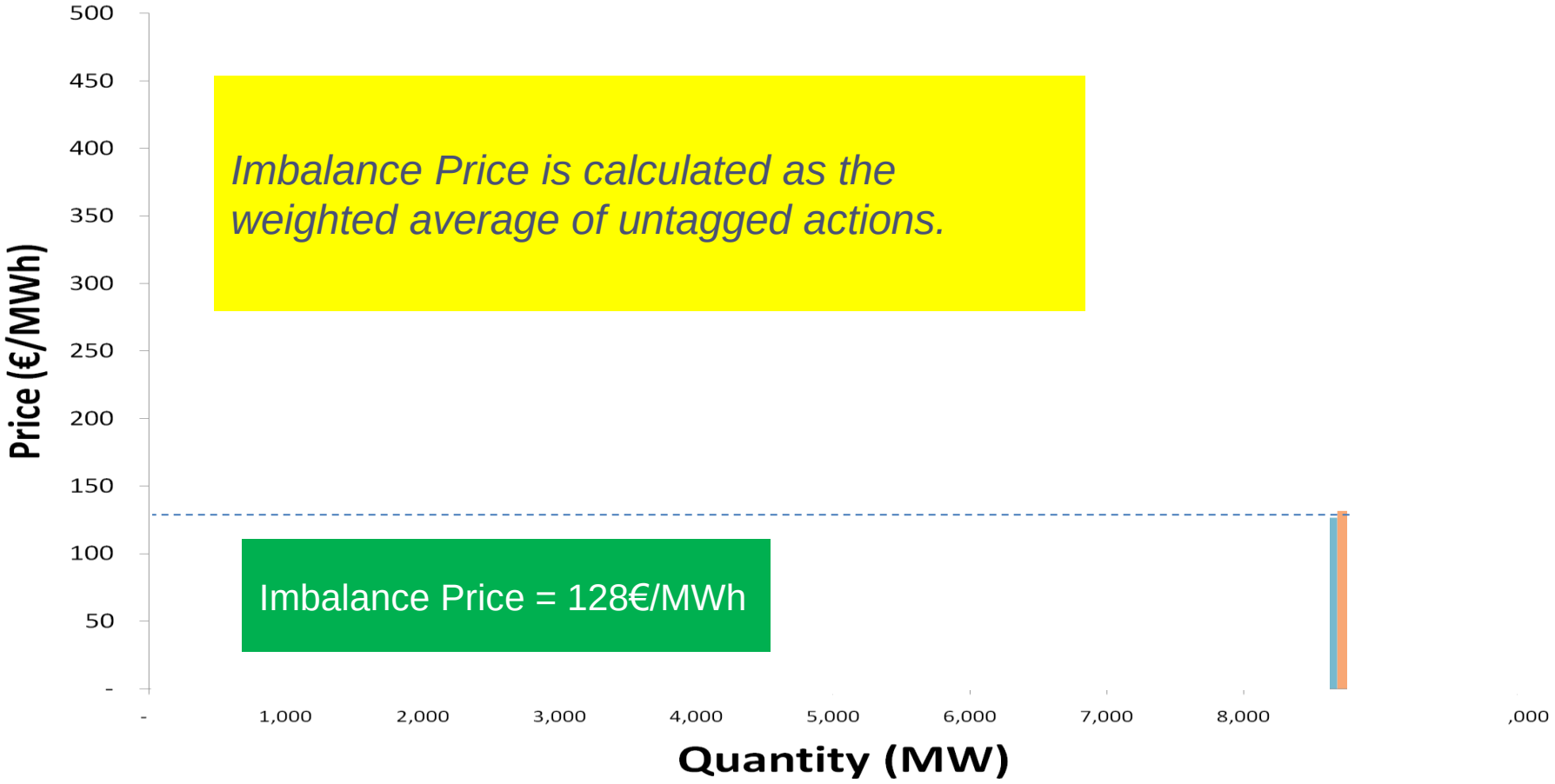
Day in the Life 1a: 17:25 (Imbalance Pricing)



Day in the Life 1a: 17:25 (Imbalance Pricing)

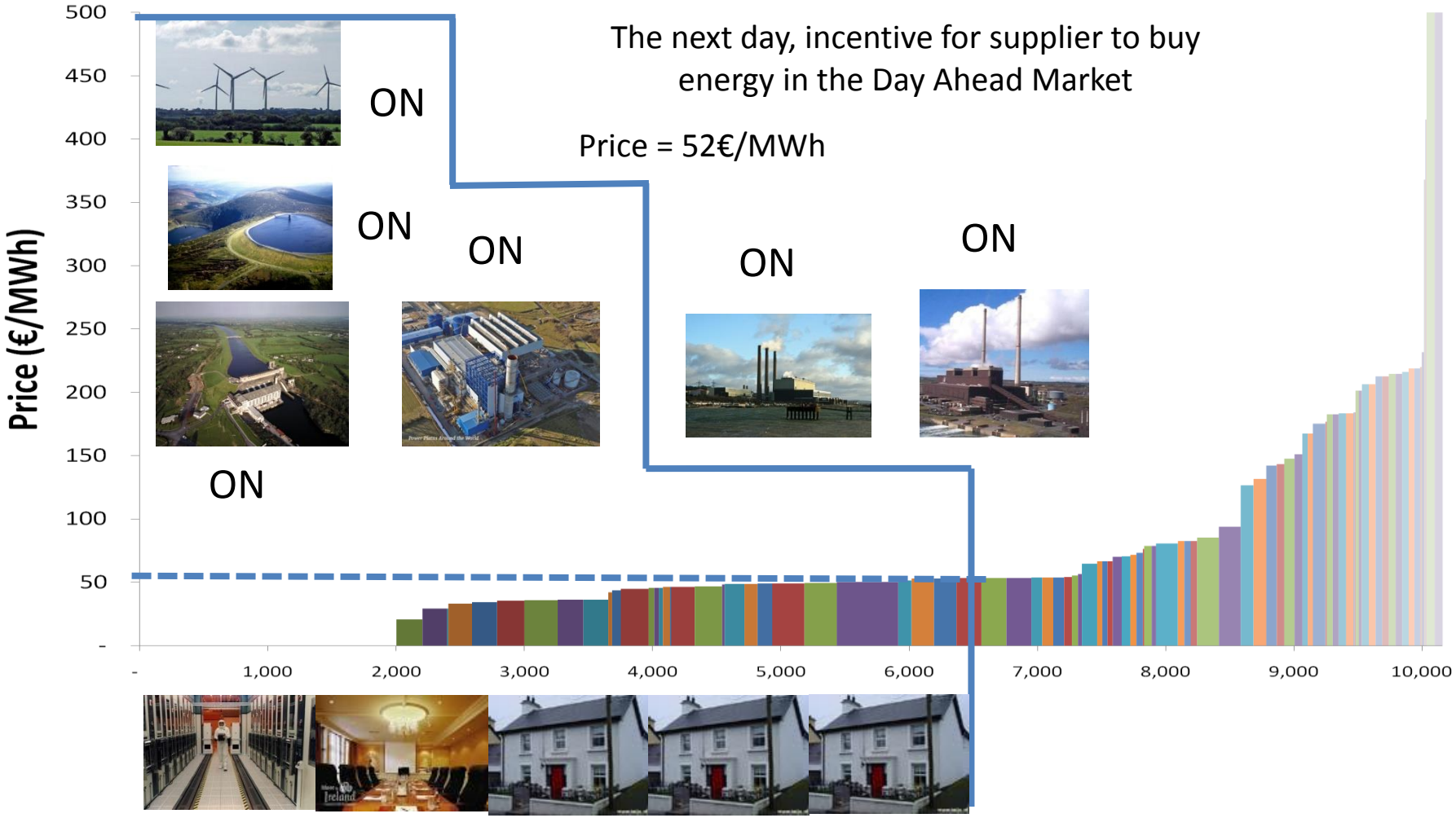


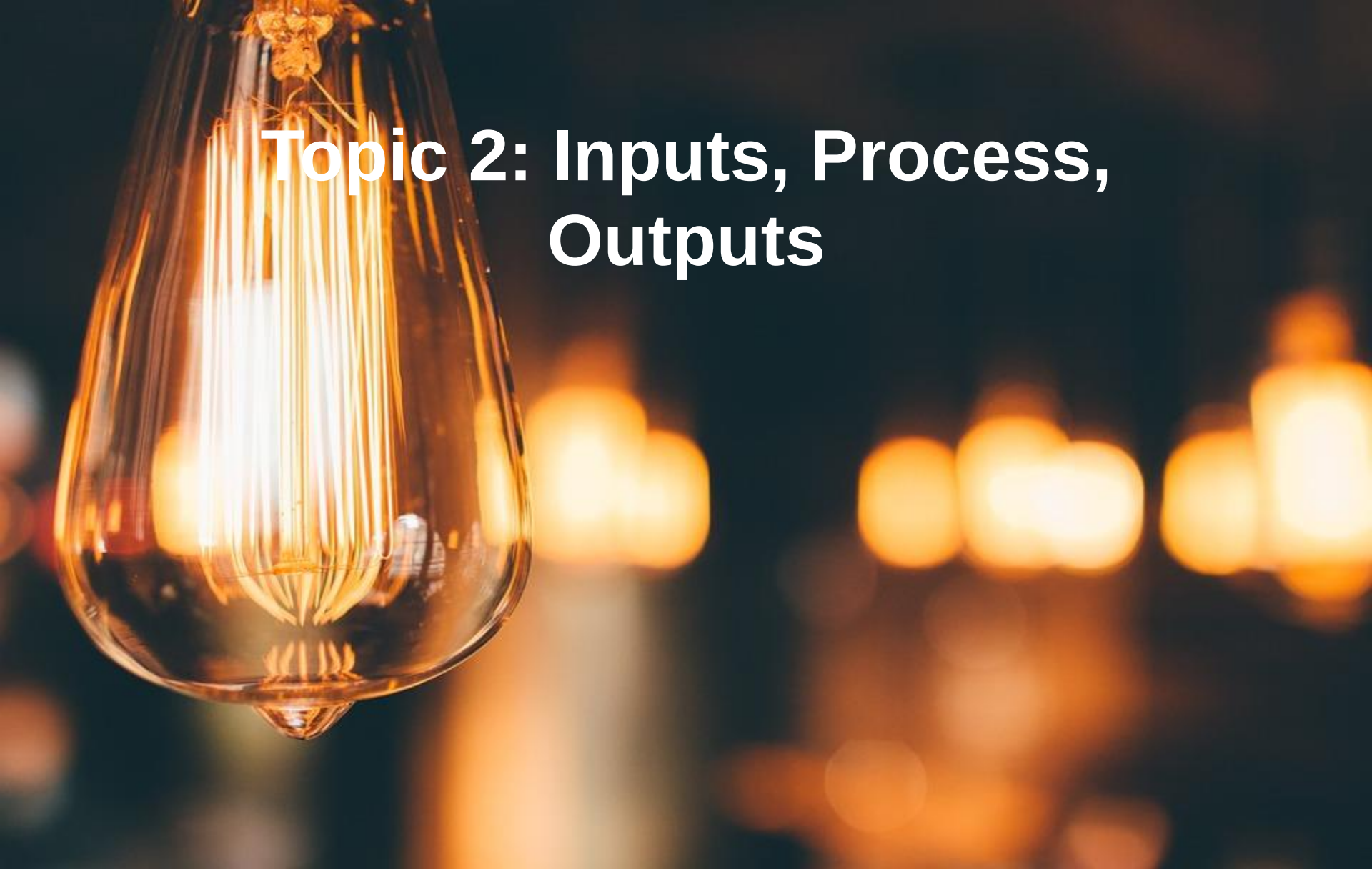
Day in the Life 1a: 17:25 (Imbalance Pricing)



EIRGRID semo Single Electricity Market Operator SONI

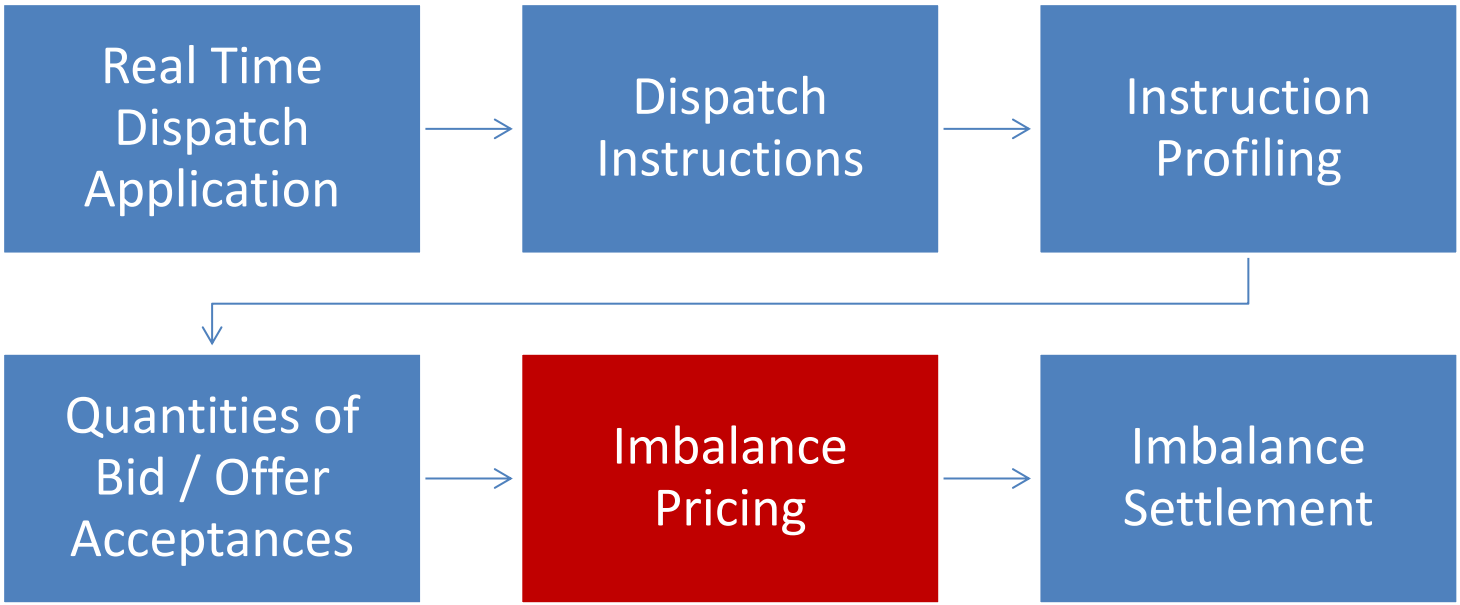
The Next Day


The next day, incentive for supplier to buy energy in the Day Ahead Market
Price = 52€/MWh
ON
ON
ON
ON
ON
ON
Price (€/MWh)
500
450
400
350
300
250
200
150
100
50
-
-
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000



Topic 2: Inputs, Process, Outputs

Imbalance Pricing Process



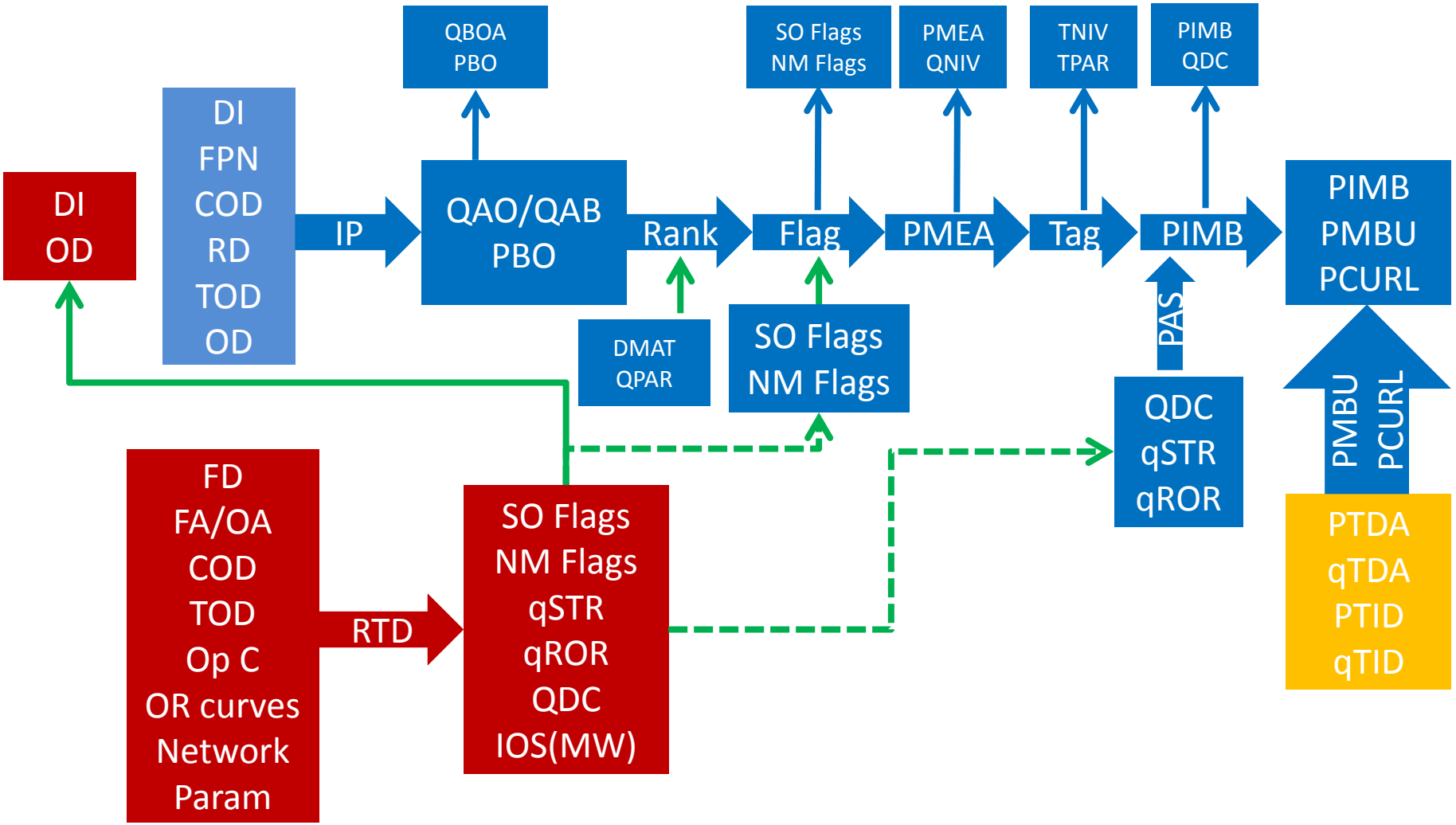
- The Imbalance Pricing process takes place immediately after the real time operation of the system between the calculation of instruction profiles and quantities of bid/offer acceptances and before imbalance settlement;

Process and Timings

- The Imbalance Pricing Period is five minutes:
  - This is in line with the resolution of the systems used to facilitate the objective application the Flagging & Tagging process;
  - A price for each five minute period is calculated, and the average of all five minute prices in a half hour is used as the price which applies in settlement;
  - This means that Bid Offer Acceptances, the primary input into the pricing process, are calculated twice by the Market Operator: once at five-minute resolution in line with.

- Imbalance Price Reports published publically ex-post close to real-time:
  - Imbalance Pricing Period and Imbalance Settlement Period granularity prices published asap after completion of each pricing calculation run, no later than 30 minutes after Imbalance Settlement Period;
  - Includes all supporting data: important interim price calculations, QNIV, all QBOA and PBO, Flags and Tags.

Imbalance Pricing – Inputs, Process, Outputs



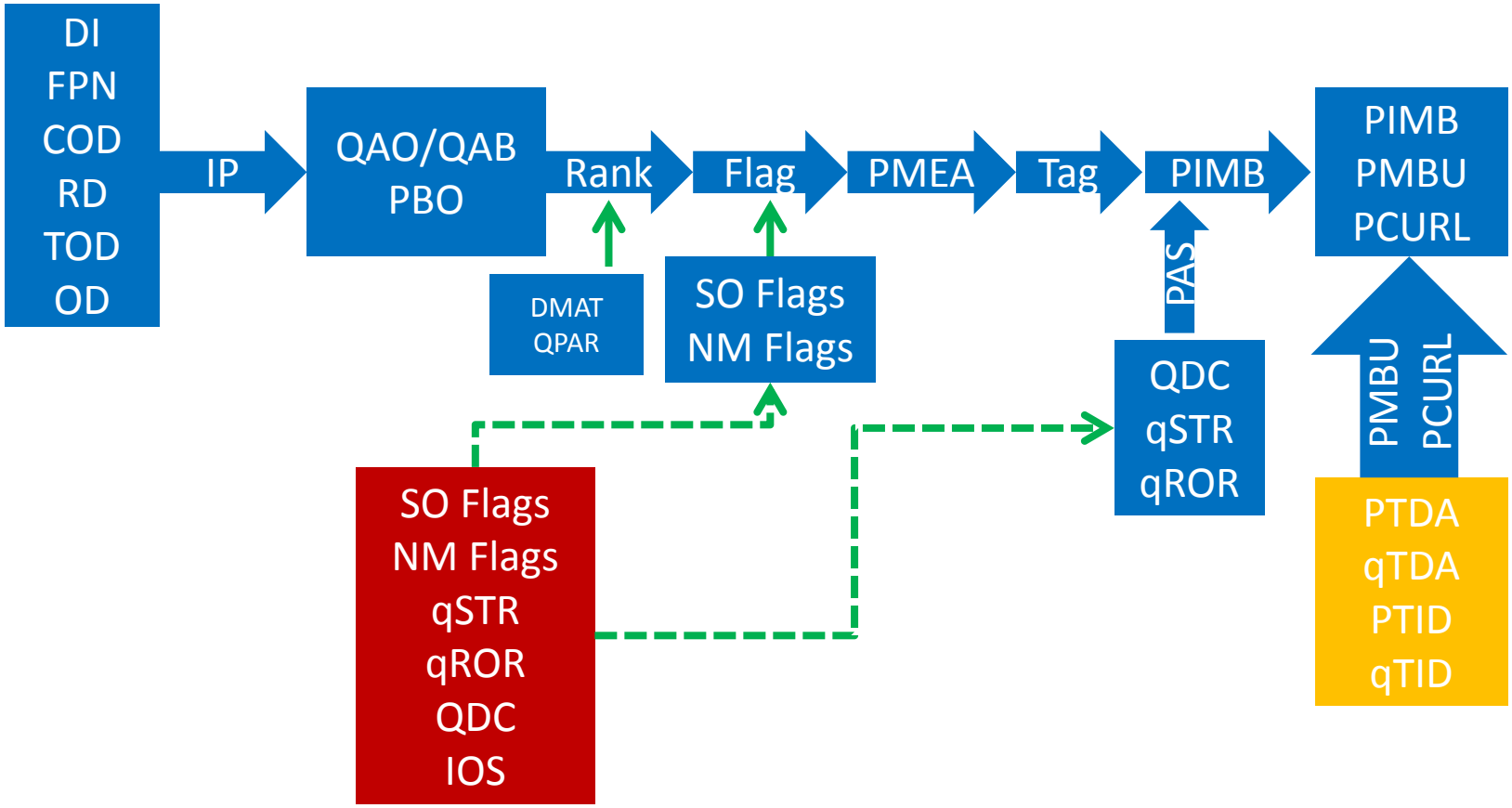
Inputs and Data Sources

- The primary input into the Imbalance Pricing process are the Dispatch Instructions from the TSO to keep the system balanced;
- Outputs from that go into the Instruction Profiling and Bid Offer Acceptance Quantity calculation process:
  - The difference being that the resulting quantities are for five minute periods, rather than for half-hour periods;
  - Further detail on this is provided as part of Imbalance Settlement Training.
- Cross-Border Balancing Actions are included in the ranked set like any other balancing action:
  - SO-SO cross-border balancing trades have a quantity and a price, which are taken to be the Accepted Offer or Accepted Bid Quantity and Bid Offer Price for pricing and settlement;
  - Quantities are calculated per 5-minute Imbalance Pricing Period for the pricing process and per half-hour Imbalance Settlement Period for the settlement process;
  - Flagging of cross-border balancing actions based on interconnector ramp constraints, etc.

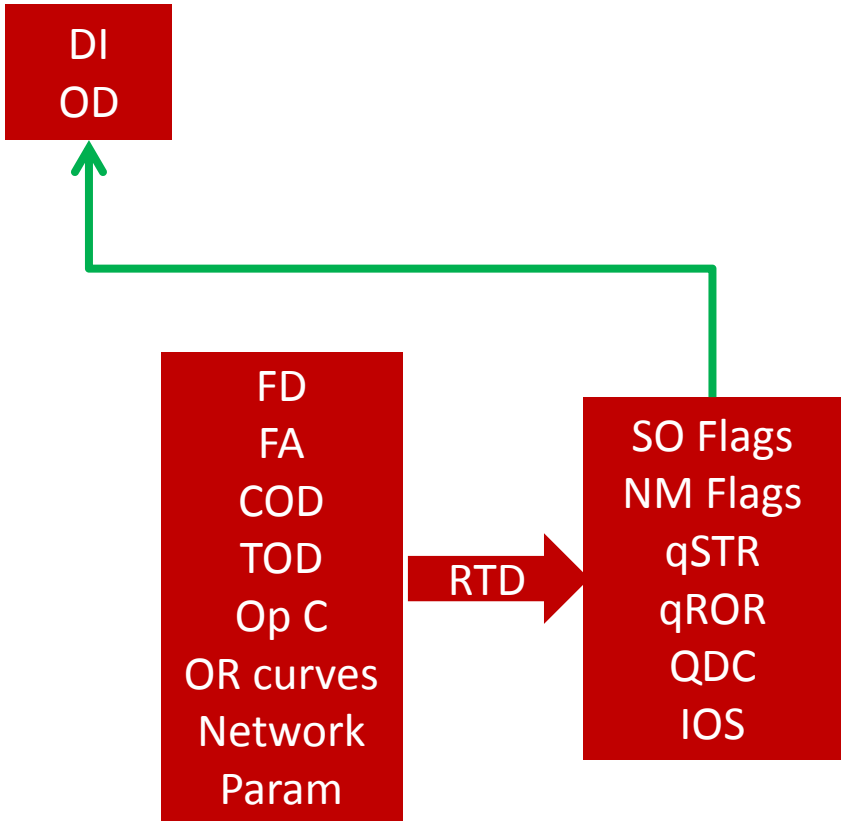
Inputs and Data Sources

- Actions on Priority Dispatch units are also included in the ranked set:
  - Required to ensure that the Net Imbalance Volume is correctly calculated;
  - SO Flags for curtailment, constraints, SNSP etc. used to ensure the unit does not set the price.
- Emergency actions are treated on same basis as other actions:
  - Demand control is calculated to be an energy action;
  - Its volume is calculated based on Four Day Load Forecast Quantity and Instantaneous Actual Demand Quantity;
  - Its price is based on the Full Administered Scarcity Price;
  - The Administered Scarcity Price is applied separately at end of process also, but this approach allows for the NIV to be correctly calculated and for ease in implementing different approaches to Administered Scarcity Pricing if desired in the future operation of the market.

Ex Ante Transparency – Rules Trading & Settlement Code

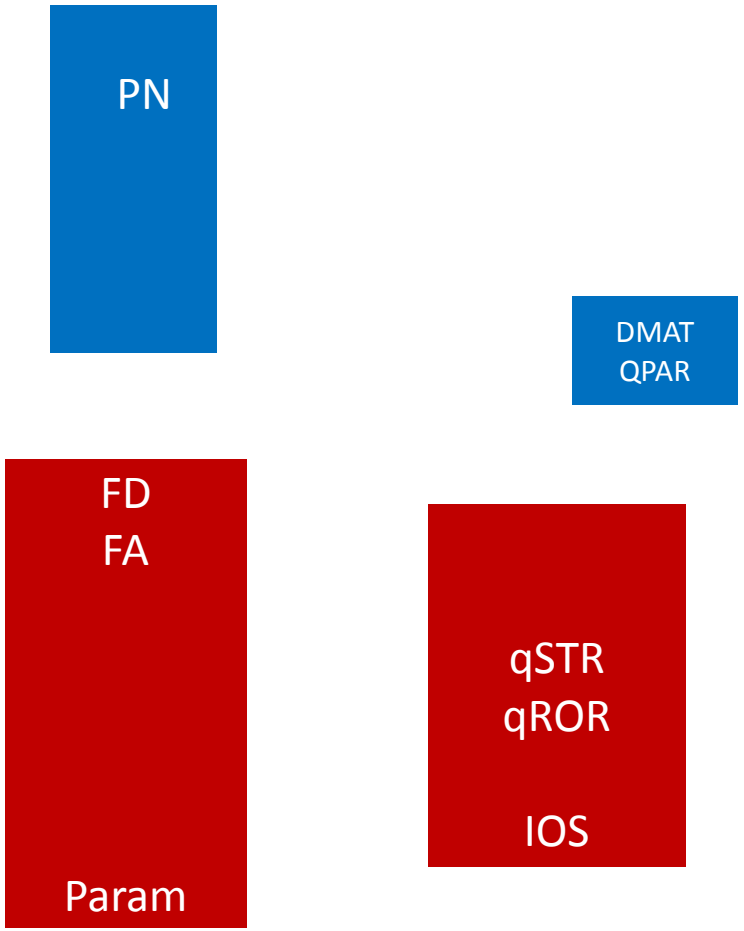


Ex Ante Transparency – Processes BMPS & F&T Processes



- Flagging takes place at end of scheduling run, not at beginning of pricing.
- Flagging is a System Operator responsibility in Code, followed by transaction to pass flags to Market Operator.
- The Market Operator then maps flags to Bid Offer Acceptances.
- The scheduling, dispatch and flagging process will be covered by the BMPS.
- Specific requirement for System Operator to publish detailed flagging methodologies to be applied in Appendix N.

Ex Ante Transparency – Data Reports



Parameters published in advance include:

- DMAT and QPAR.

TSC Reports published in advance include:

- Hourly forecast imbalance reports covering rest of day based on:
  - Forecast Demand;
  - Forecast Wind Availability;
  - Sum of PNs;
  - Net I/C schedules.
- Aggregated FPNs;
- qSTR and qROR

BMPS Reports include:

- Publication of IOS (MW) scheduling runs.

Real-Time Transparency Data

Above published following each Imbalance Pricing Period

QBOA PBO	SO Flags NM Flags	PMEA QNIV	TNIV TPAR	PIMB QDC

Ex-post Transparency

DI
FPN
COD
RD
TOD
OD

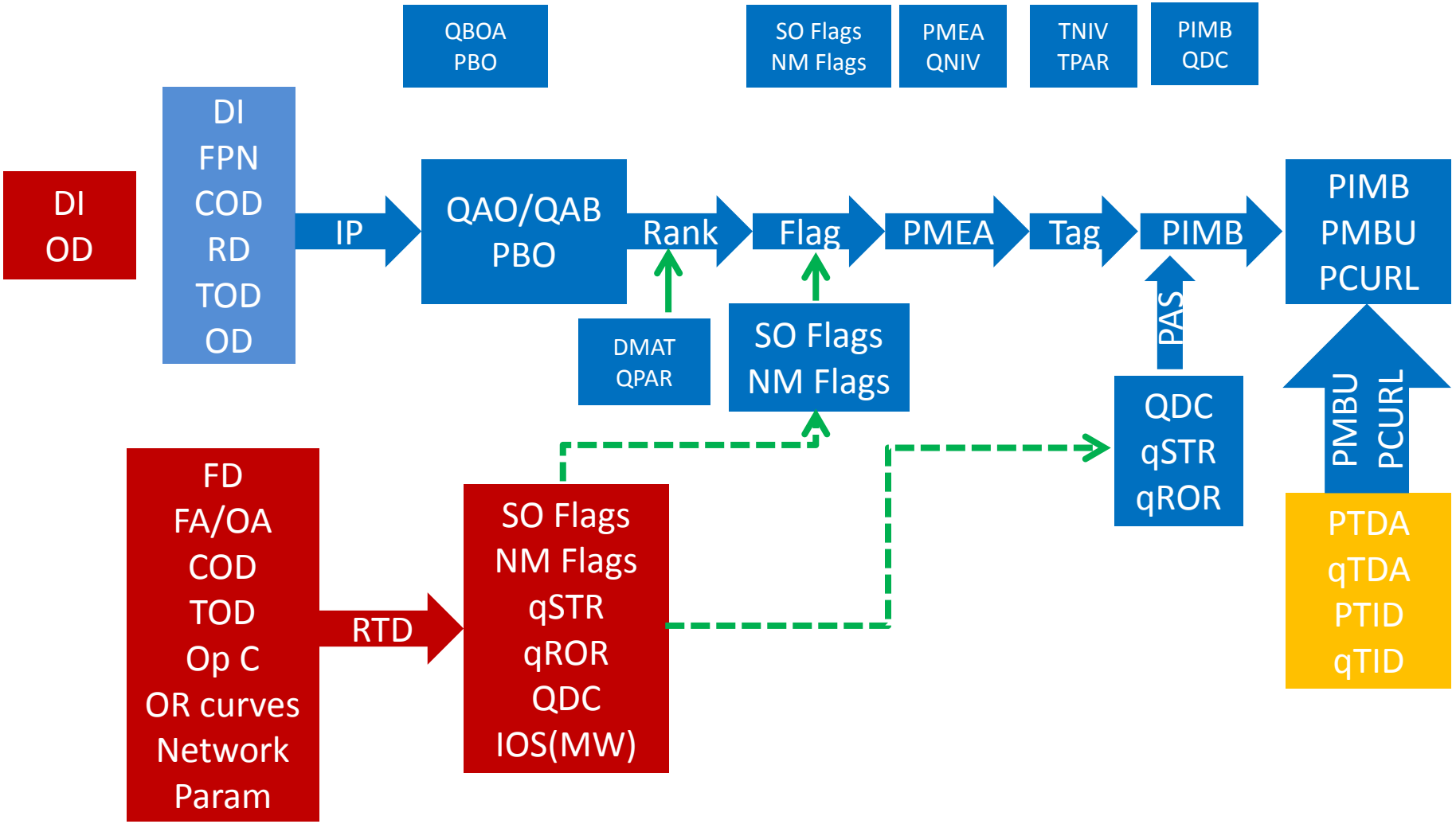
QAO/QAB
PBO

Most information used in market is made available D+1

FD
FA/OA
COD
TOD
Op C
OR curves
Network
Param

PTDA
qTDA
PTID
qTID

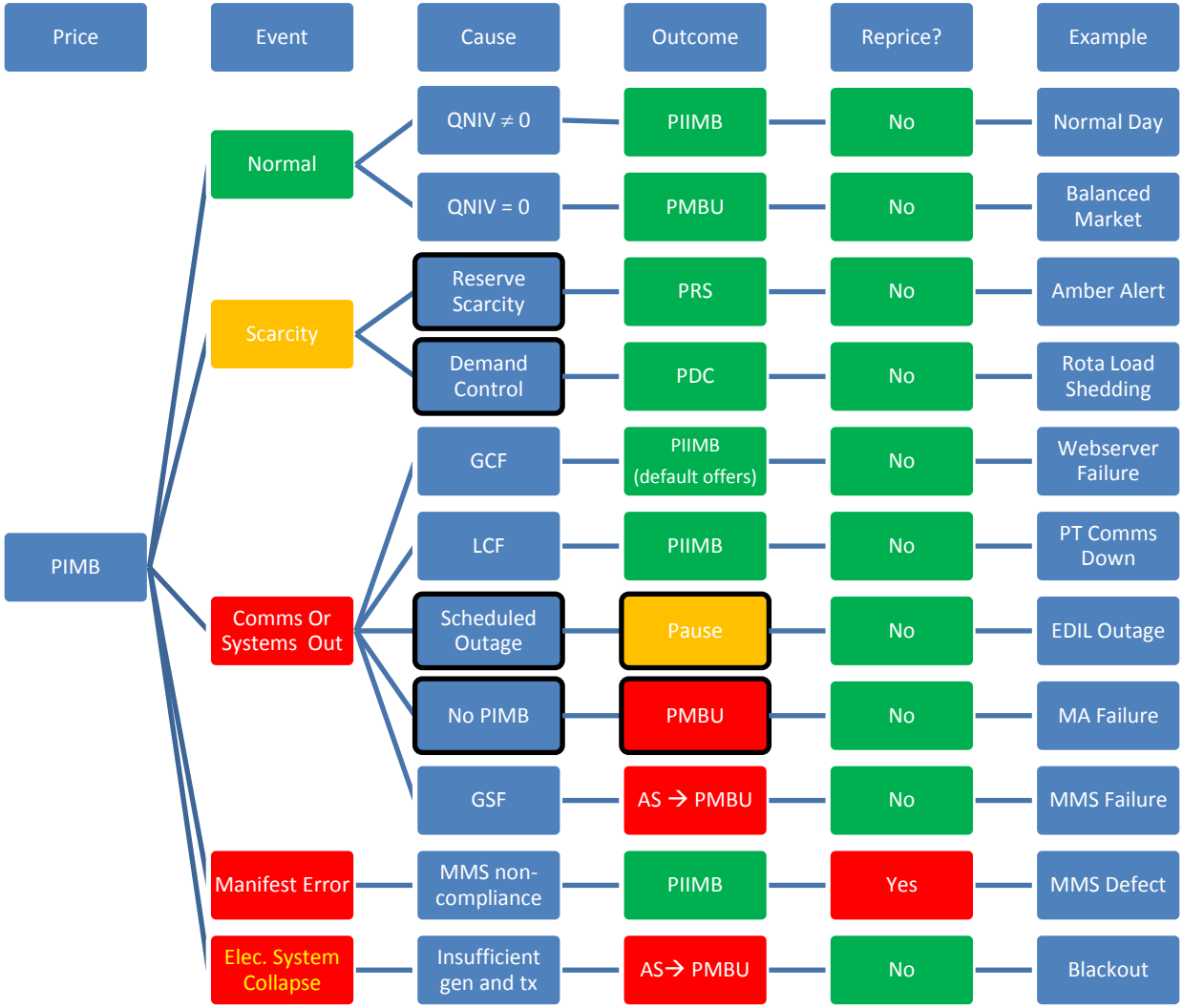
Transparency



Exception handling

- Exception handling in the Imbalance Pricing Process:
  - Repricing only occurs for manifest errors in the pricing calculator:
    - In all other situations alternative options exist, for example using a backup price or pausing the calculation and publication of the price for a short period of time.
  - In order to result in a recalculation of the price, the manifest error must be queried within five Working Days;
  - The following slide shows the pricing outcomes in a number of events.

Chapter E - Imbalance Pricing - Exception Handling Map



Topic 3: Determining and Ranking Accepted Bids/Offers

De Minimis Acceptance Threshold and Ranked Sets

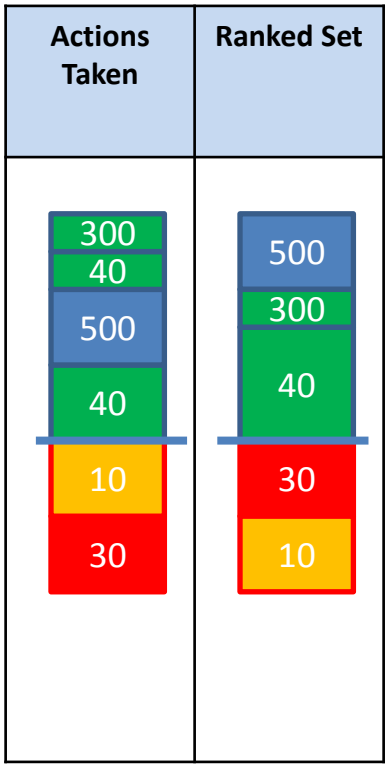
- Ranked sets are the start point of the Imbalance Pricing process:
  - The inputs of Accepted Offer and Accepted Bid Quantities and Bid Offer Prices are used to derive a single ranked set where they are sorted in order of price.

- All actions with volumes smaller than the De Minimis Acceptance Threshold (DMAT) are excluded from the ranked set and are not included in the process any further;

- Actions ranked in order of economic merit, based on their expense to the system:
  - First, all Accepted Bids (decs) are ranked in order of increasing price from lowest first to highest;
  - Then all Accepted Offers (incs) are ranked in order of price from lowest first to highest;
  - All actions assigned a rank number, k, starting at 1 from the lowest priced dec action and ending at the highest priced inc action.

De Minimis Acceptance Threshold and Ranked Sets

- As part of ranking process, the variable M is used to describe the number of Accepted Bids, and the variable N is used to describe the number of Accepted Offers;
- All Accepted Bids ($QAB_{uoi\phi}$, $PBO_{uoi\phi}$) are assigned a rank (k) in order of Bid Offer Price ($PBO_{uoi\phi}$), lowest priced first, from k = 1 to M;
- All Accepted Offers ($QAO_{uoi\phi}$, $PBO_{uoi\phi}$) are assigned a rank (k) in order of Bid Offer Price ($PBO_{uoi\phi}$), lowest priced first, from M+1 to N;
- For the remainder of the process, ($QAB_{uoi\phi}$, $PBO_{uoi\phi}$) is then read as ($QAB_{uk\phi}$, $PBO_{uk\phi}$), and ($QAO_{uoi\phi}$, $PBO_{uoi\phi}$) is then read as ($QAO_{uk\phi}$, $PBO_{uk\phi}$).



Topic 4: System Operating Flagging

System Operator Flagging

- The following table shows a number of non-energy requirements for operational security;
- There are also non-energy requirements not due to operational security, including:
  - Priority Dispatch; and
  - Remedial Actions from CACM capacity calculation.

Operational Security Limits from NCOS	All-island Security Limits	Type of constraint service
Frequency	Reserve • Frequency Containment (e.g. POR min, SOR, min) • Frequency Restoration (TOR1, TOR2) • Replacement Reserve (RR) • Negative reserve • Control Area Limit (NI min, ROI min) • Static reserve limit	System wide
Short-circuit current	Short circuit current (Safety ratings usually addressed by Tx sectionalising)	Local max gen Local min gen
Thermal	Power flow (MVA ratings) • General 110% on lines • Specific overload ratings on transformers & cables	Local max gen Local min gen
Voltage	Voltage	Local min gen
Dynamic Stability •Frequency Stability (after system disturbance) •Voltage Stability (after system disturbance) •Rotor Angle Stability (“fault ride through”)	Area stability (e.g. Min 3 units NI, 5 ROI) (e.g. Rule Based Area Constraint: ROI Demand >4450MW Wind % max SNSP % max Inertia min (fault ride through address by Grid Code testing)	Local min gen System wide System wide System wide
	Hydro station op constraints	

System Operator Flagging

- There are two tests carried out for every non-energy requirement (although some only require the first, and if it is true then all units contributing to the constraint are flagged):
  1. Identify binding non-energy requirements (i.e. supply of requirement = requirement);
  2. Determine whether unit's scheduled output level is due to this binding non-energy requirement.
- First there is a constraint test:
  - Test if the constraint is binding or breached (e.g. has a non-zero shadow price);
  - If this test is passed, the unit tests are followed for all units contributing to the constraint, otherwise no unit can be flagged for this particular constraint in this period.
- Then there are unit tests, for example:
  - For reserve constraints test if the unit's reserve provision is equal to their capability;
  - For wind units test if the unit is constraint or curtailed;
  - For minimum unit constraints test if the unit is at its Minimum Stable Generation.

System Operator Flagging

- This is carried out for every constraint in the Indicative Operations Schedule outlined in the Operational Constraints Update and System Operator and Non-Marginal Flagging Methodology:
  - This is intended to enable the imbalance pricing to reflect the changing system conditions but be clear and unambiguous regarding the application of the rule.
- If both of these tests are passed for a unit for any constraint, then the unit is SO Flagged:
  - “Flagged” means the value for FSO is zero;
- Unit level SO Flags are determined by the System Operator at the end of the Indicative Operations Schedule process:
  - These are then sent to the MO who maps the unit level flags to the bids and offers of the unit.

System Operator Flagging

- There are a number of individual types of constraints which have an individual approach to being tested because of differences in how they are modelled in the scheduling software:
  - Total Operating Reserve;
  - Minimum Operating Reserve;
  - Replacement Reserve;
  - Negative Reserve;
  - Inertia;
  - System Non-Synchronous Penetration (SNSP);
  - Rate of Change of Frequency (ROCOF);
  - Dynamic and Voltage Stability;
  - Generator Unit Limits;
- Details on how these are modelled are outlined in System Operator and Non-Marginal Flagging Methodology, the following slides highlight a few of these.

System Operator Flagging

Operating Reserves (e.g. POR, SOR, TOR1, TOR2)

Test A: For period ϕ and Operating Reserve, ζ, check if the following is true:

$$\sum_{u*} qSSIOS_{u\xi\varphi} = \kappa_{\xi} \times Max\ qIOS_{u\varphi}$$

Test B: For unit u, who contributes to Operating Reserve, ζ, check if either of the following are true:

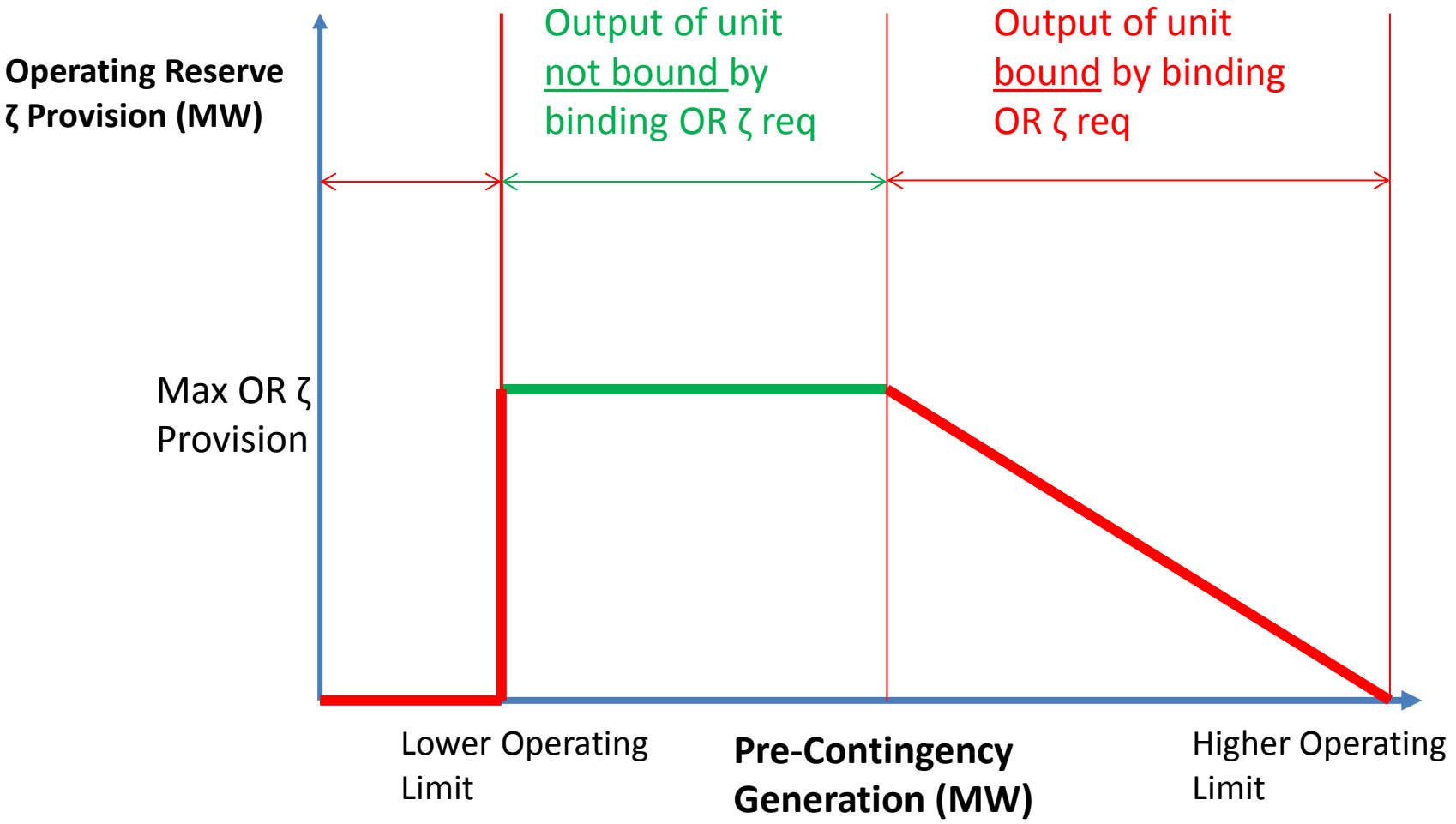
$$qIOS_{u\varphi} + qSSIOS_{u\xi\varphi} = qHOL_{u\varphi}$$
$$qIOS_{u\varphi} = qLOL_{u\varphi}$$

Where $qSSIOS_{u\zeta\phi}$ is the Operating Reserve provision of unit u; κ_{ζ} is the percentage of the largest infeed required for the Operating Reserve; Σ_{u*} is the sum over all units contributing to the Operating Reserve ζ which are not the Largest In-Feed; $qIOS_{u\phi}$ is the Indicative Operations Schedule Quantity being the active power level to which the unit is scheduled; $Max_u\ qIOS_{u\phi}$ is the Largest In-Feed; $qHOL_{u\phi}$ is the Higher Operating Limit in the schedule of unit u in period ϕ; and $qLOL_{u\phi}$ is the Lower operating Limit of unit u in period ϕ.

If Test A and Test B are true, unit u is SO flagged.

The unit which was the Largest In-Feed is also SO Flagged as this unit is bound by the Operating Reserve.

System Operator Flagging



System Operator Flagging

Dynamic and Voltage Stability (particularly minimum number of units in Ireland and Northern Ireland jurisdictions, functions of unit commitment status) and Inertia

Test A: For period ϕ and operational constraint, ζ, check if the following is true:

$$\sum_{u*} qCIOS_{u\xi\varphi} = qRCIOS_{\xi\varphi}$$

Test B: For unit u, who contributes to operational constraint, ζ, check if the following is true:

$$qIOS_{u\varphi} = qLOL_{u\varphi}$$

Where $qCIOS_{u\zeta\phi}$ is the is the quantity of provision of unit u to operational constraint ζ which differs according to context, for example for minimum number of units it would be a binary with a value of 1 if the unit was committed on and value of 0 if the unit was committed off; $qRCIOS_{\zeta\phi}$ is the quantity of provision required for operational constraint ζ which differs according to context, for example for minimum number of units it would be a the number of units required in an area; Σ_{u*} is the sum over all units contributing to the operational constraint ζ; $qIOS_{u\phi}$ is the Indicative Operations Schedule Quantity being the active power level to which the unit is scheduled; and $qLOL_{u\phi}$ is the Lower operating Limit of unit u in period ϕ.

If Test A and Test B are true, unit u is SO flagged.

The unit which was the Largest In-Feed is also SO Flagged as this unit is bound by the Operating Reserve.

System Operator Flagging

System Stability	NB	N:>=	3 Units at all times	C30, B31, B32, B10, BPS4, BPS5, BPS6, K1, K2	There must be at least 3 high-inertia machines on-load at all times in Northern Ireland. Required for dynamic stability.

- Market Operator shall determine whether **each Generator Unit is bound by one or more of the Operational Constraints** set out in the Operational Constraints Update …
- … If number of relevant units on in NI is three, this constraint is binding …
- … If any of three relevant units operating at or below minimum stable generation, they are bound by this constraint.

System Operator Flagging

- The **Market Operator** shall flag actions taken for non-energy reasons by setting the value of the **SO Flag** ($\mathbf{FSO_{uk\phi}}$) to a value of zero in line with the detailed methodology for the application of **SO Flags** set out in Appendix B as follows:
  - For all **k**, $\mathbf{FSO_{uk\phi}} = \Pi\ \mathbf{FCON_{u\xi\phi}}$, where Π is the product across all constraints **ξ**;

Topic 5: Non-Marginal Flagging

Non-Marginal Flagging

- Non Marginal Flags (FNMs) are determined by testing if a unit is against its physical output limits;
- Similar to SO Flags, Unit level NM Flags are determined by the System Operator at the end of the Indicative Operations Schedule process:
  - These are then sent to the MO who maps the unit level flags to the bids and offers of the unit.
- The Market Operator also applies FNMs to all but the latest action for the unit:
  - The marginal energy action represents the last action taken by the System Operator to balance the system. Therefore, earlier actions on units cannot be the marginal energy action.

Non-Marginal Flagging

- A Plain-English explanation of these tests is as follows:
  - For each unit:
    - If the unit's scheduled output is at its Minimum Stable Generation; or
    - If the unit's scheduled output is at its Maximum Generation; or
    - The unit's scheduled output is at a level which represents the maximum change possible when ramping from the scheduled output in the previous period;
  - Then the unit is NM Flagged.

- "Flagged" means the value for FNM is zero;

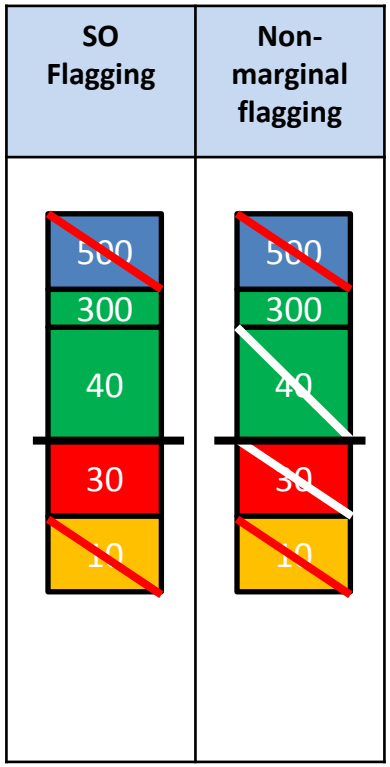
- If the unit is flagged, then all of its Bid Offer Acceptances are flagged. If the unit is not flagged, then all but the latest of the Bid Offer Acceptances are flagged.

Non-Marginal Flagging

- The marginal action is action that satisfies the rule:
  - Cost of Next Action = Cost of Action Taken (Assuming the Net Imbalance Volume does not occur at a breakpoint, which is extremely unlikely);
  - Actions at system or unit limits are not the marginal action.
- Example:
  - Net Imbalance Volume of 80MWh,
  - Unit A inc'd to Min Stable Gen of 100MWh @ 100 €/MWh,
  - Unit B dec'd from Max Availability by 20MWh @ 60 €/MWh
  - If NIV went up or down, Unit B would move.
  - Unit B satisfies the rule cost of next action = cost of action taken
- **Rules: Flag all actions at unit limits i.e. Min Stable Generation, Max Availability or Ramping Limits.**
- Non-Marginal Flagging Rules intend to capture all instances where the cost of the action taken ≠ cost of the next action, based on unit constraints:
  - A unit with a scheduled output at its Minimum Stable Generation, Maximum Generation, or at a certain level due to being constrained by its ramp rates Non-Marginal Flagged;
  - This is captured through rules which test the unit's Lower and Higher Operating Limit Quantities in the schedule. HOL and LOL are the minimum or maximum level of scheduled output possible for the unit considering its output position in previous periods and the unit limits, including its ramp rates;

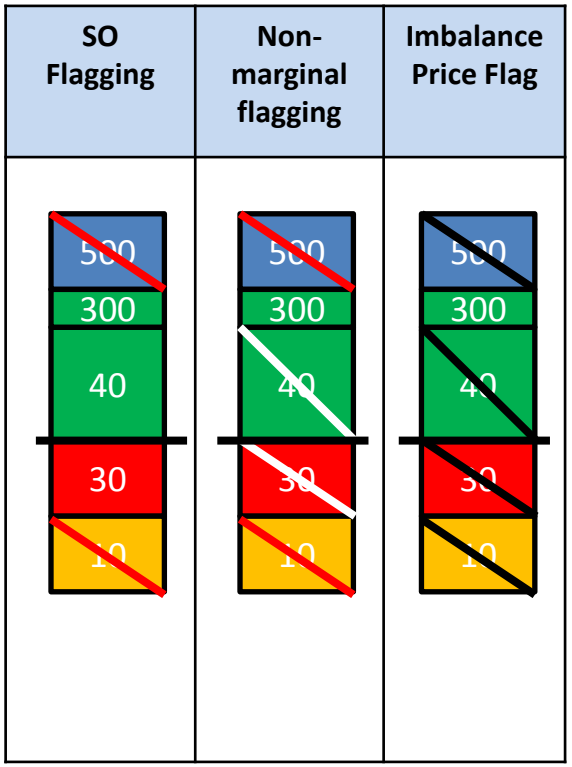
Non-Marginal Flagging

- The **Market Operator** shall flag actions taken that are non-marginal by setting the value of the **Non-marginal Flag ($FNM_{uk\phi}$)** to a value of zero in line with the detailed methodology for the application of Non-marginal Flags set out in Appendix B;



Imbalance Price Flag

- The **Market Operator** shall calculate the **Imbalance Price Flag ($FIP_{uk\phi}$)** as follows:
- $FIP_{uk\phi} = FSO_{uk\phi} \times FNM_{uk\phi}$;
- This is a combination of the two flag types where they are multiplied so that if the unit is flagged by either SO or NM approaches, they will be considered "flagged" in the calculation steps to follow;
- FIP = 1 if unit is unflagged, FIP = 0 if unit is flagged;
- If an action's FIP is zero, then it is not the marginal energy action taken. It may still be included in the price calculation if it is not tagged in the NIV or PAR tagging sections.



Topic 6: Marginal Energy Action Price

PMEA and PRBO

- A key component of the Imbalance Pricing process is to determine the Marginal Energy Action Price;

- A key input to this is the calculation of the Net Imbalance Volume Quantity (QNIV):
  - This key market metric has large influence on the Imbalance Price;
  - Represents the imbalances being resolved through the balancing market.

- QNIV is calculated based on the volumes of actions taken in the balancing market:
  - Sum of all Accepted Offer and Accepted Bid Quantities in the Ranked Set (i.e. excludes orders with volumes below DMAT);
  - If QNIV is negative, there was too much generation vs demand and the TSO had to take more negative “dec” actions to reduce generation than positive “inc” actions to increase generation. In this case the market is said to be “long”;
  - If QNIV is positive, there was too little generation vs demand and the TSO had to take more positive “inc” actions to increase generation than positive “dec” actions to reduce generation. In this case the market is said to be “short”.

PMEA and PRBO

- The Marginal Energy Action Price (PMEA) is the most expensive unflagged action in the ranked set:
  - When QNIV is positive more incs have been taken and the higher the price of the inc the more expensive it is (i.e. the more has to be paid to a unit to increase generation) – PMEA is the highest priced unflagged action;
  - When QNIV is negative more decs have been taken and the lower the price of the dec the more expensive it is (i.e. the less is paid by the unit, or the more is paid to the unit, to reduce generation) – PMEA is the lowest priced unflagged action.

- This enacts the decision that the marginal price is the price of the next MWh up or down which would be used, on the basis that the last MWh used, if it was not at a breakpoint (which it wouldn't be, based on it not having a Non-Marginal Flag) or constrained by system reasons (which it wouldn't be, based on it not having a System Operator Flag) would be the next MWh used;

- The component of the process which follows, NIV Tagging, enacts the decision that it is the price of the action required to meet the NIV:
  - This allows actions with prices which are in-merit but less marginal than that found through PMEA to set the Imbalance Price, but the Replacement Price process ensures that no action with a price which is not in-merit considering PMEA could set the price.

PMEA and PRBO

- The **Market Operator** shall calculate the **Net Imbalance Volume Quantity ($QNIV_{\phi}$)** as follows:

  $QNIV_{\phi} = \sum QAO_{uk\phi} + \sum QAB_{uk\phi}$;

- The **Market Operator** shall calculate the **Price** of the **Marginal Energy Action Price** ($PMEA_{uk\phi}$) as follows:

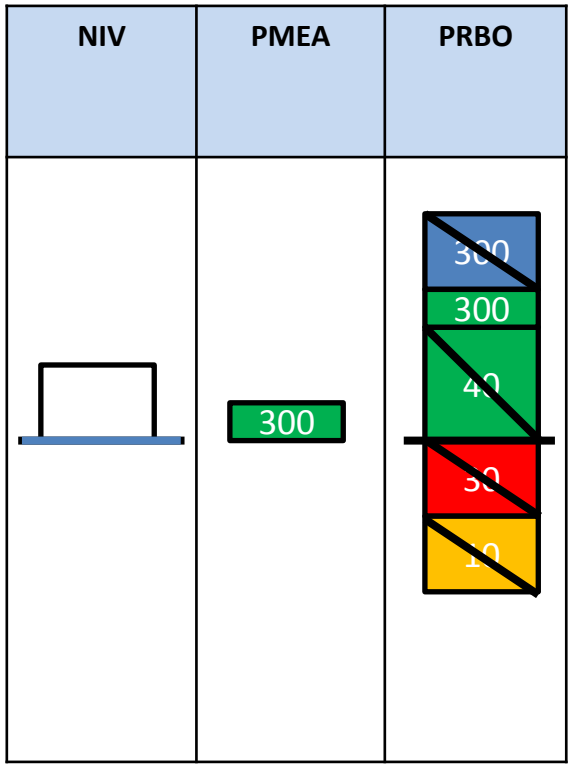
  If $NIV_{\phi} > 0$, $PMEA_{uk\phi} = \text{Max}(PBO_{uk\phi})$ where $FIP_{uk\phi} = 1$

  If $NIV_{\phi} < 0$, $PMEA_{uk\phi} = \text{Min}(PBO_{uk\phi})$ where $FIP_{uk\phi} = 1$

- The **Balancing Market Operator** shall calculate **Replaced Bid Offer Prices** ($PRBO_{uk\phi}$) as follows:

  If $NIV_{\phi} > 0$, $PRBO_{uk\phi} = \text{Min}(PBO_{uk\phi}, PMEA_{uk\phi})$;

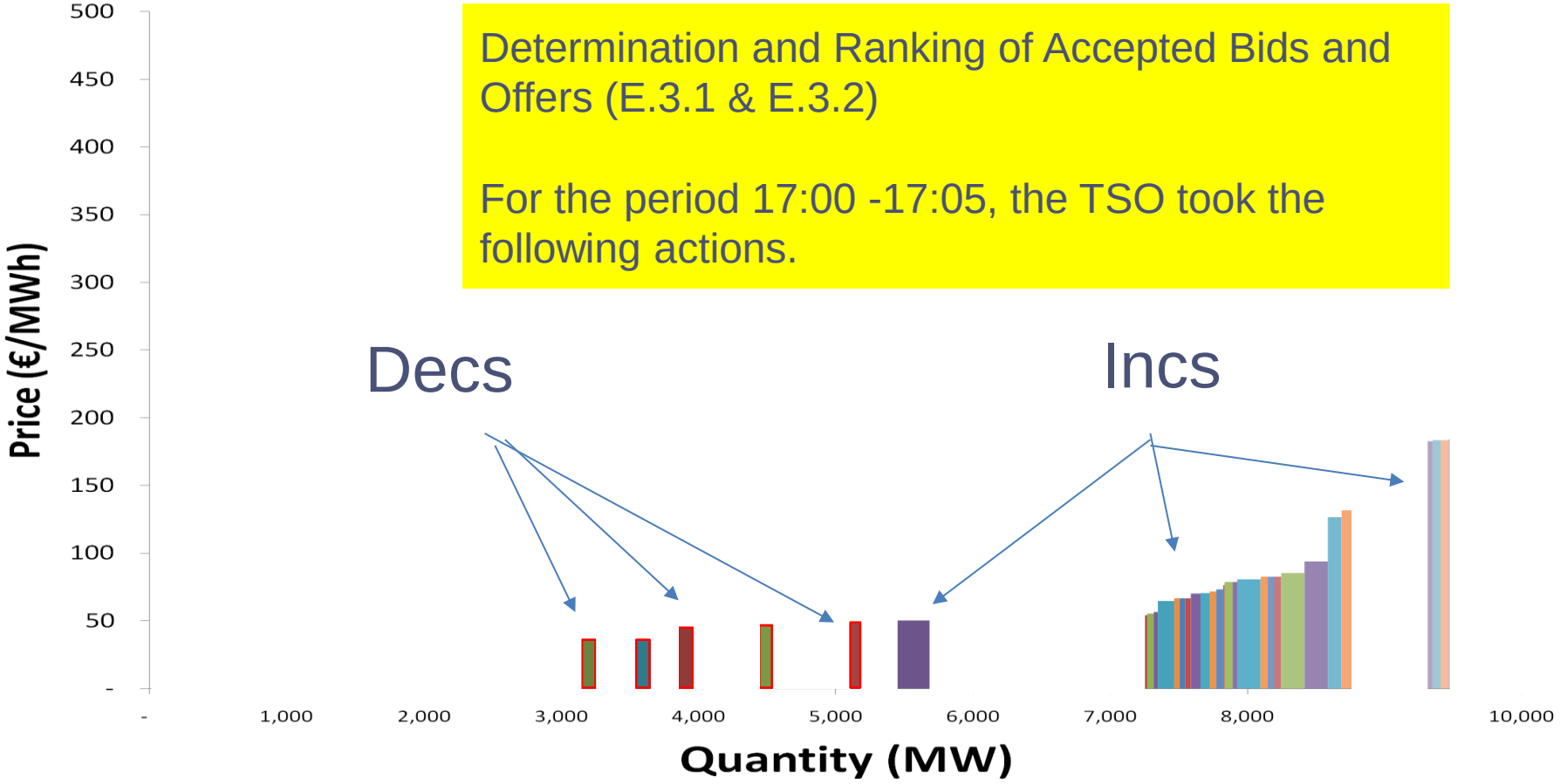
  If $NIV_{\phi} < 0$, $PRBO_{uk\phi} = \text{Max}(PBO_{uk\phi}, PMEA_{uk\phi})$;



Day in the Life 1a: 17:25 (Imbalance Pricing)

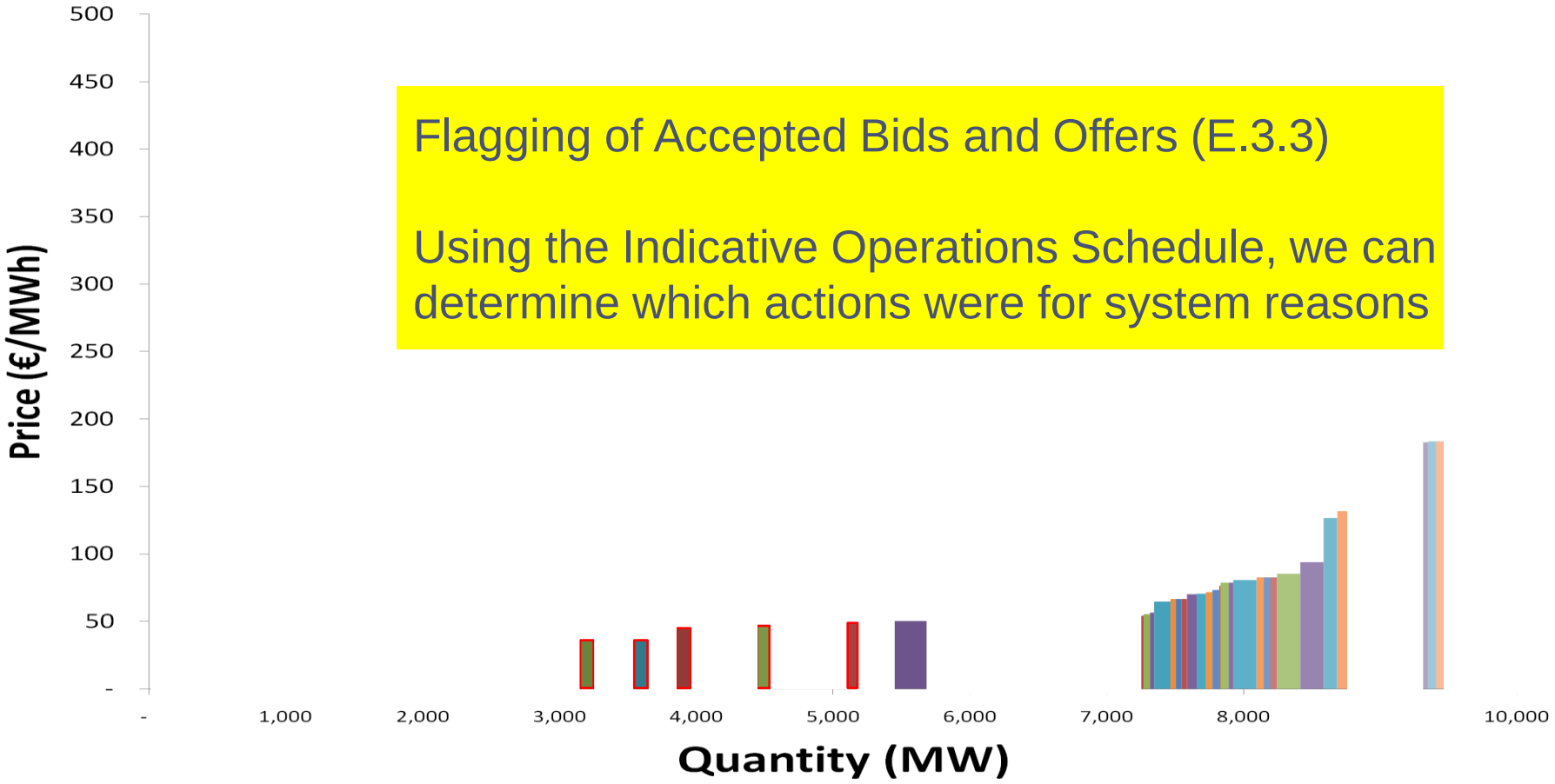
Determination and Ranking of Accepted Bids and Offers (E.3.1 & E.3.2)

For the period 17:00 -17:05, the TSO took the following actions.



Rank k 1 2 3 4 5 6 7 to 27 28-31

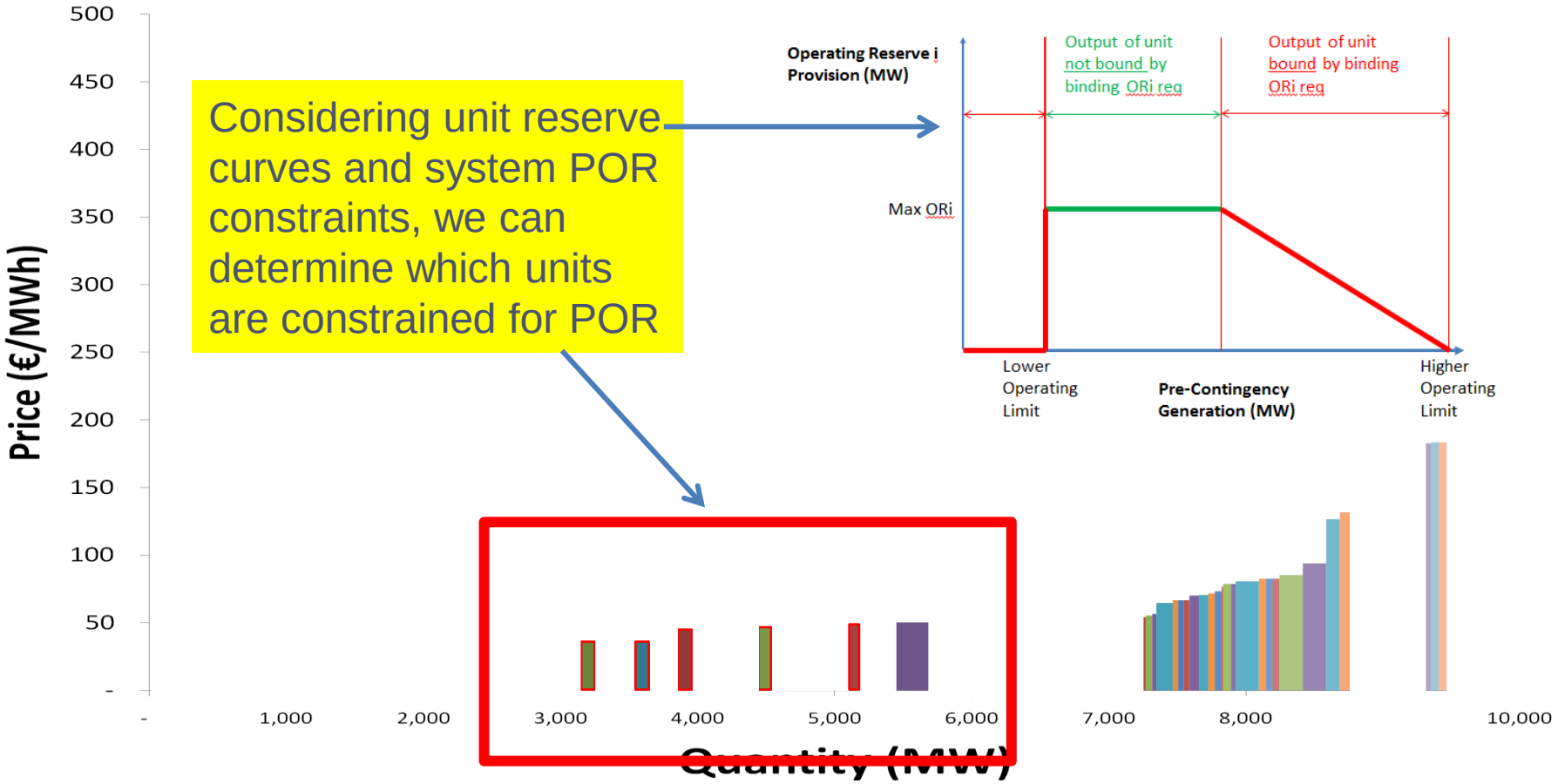
Day in the Life 1a: 17:25 (Imbalance Pricing)



Flagging of Accepted Bids and Offers (E.3.3)

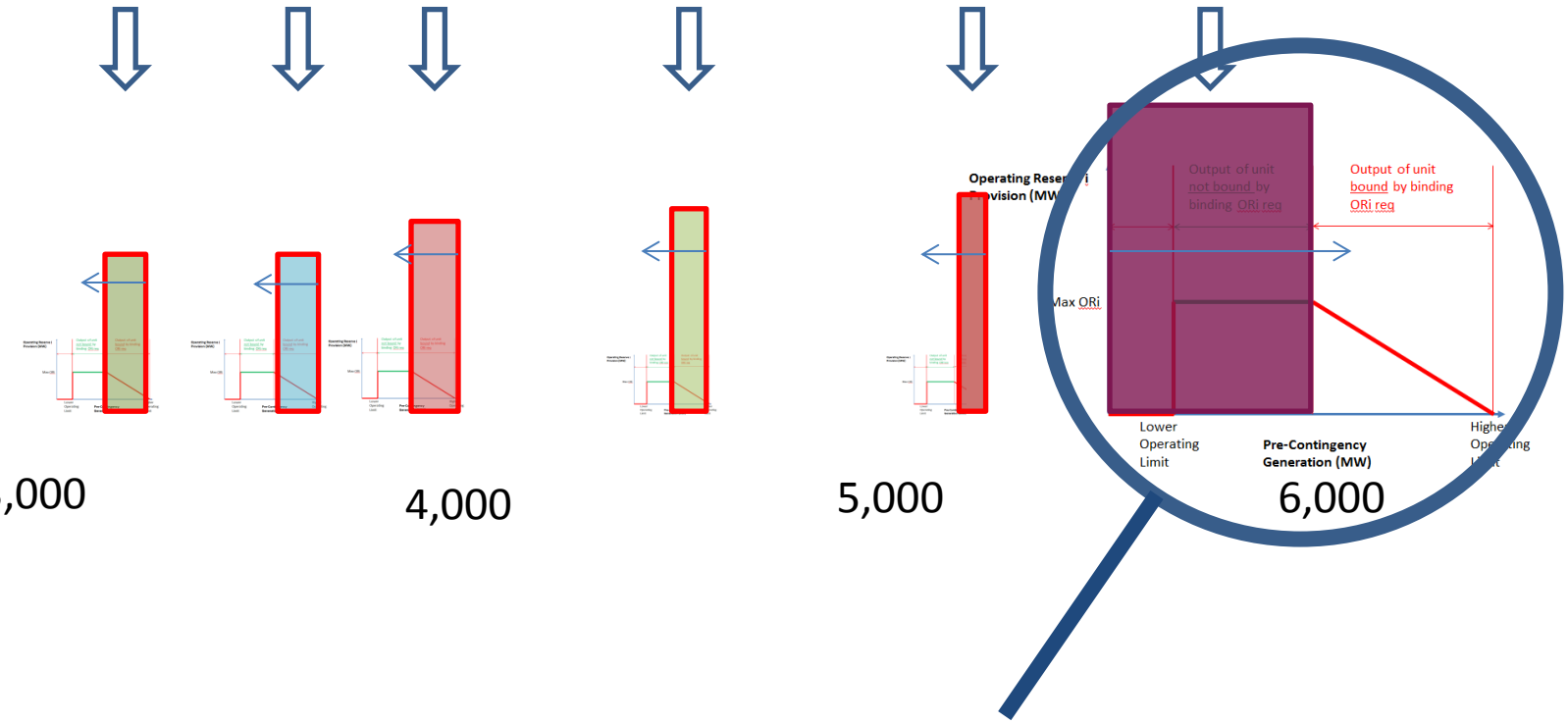
Using the Indicative Operations Schedule, we can determine which actions were for system reasons

Day in the Life 1a: 17:25 (Imbalance Pricing)



Day in the Life 1a: 17:25 (Imbalance Pricing)

Units constrained for POR
System Operator Flagged



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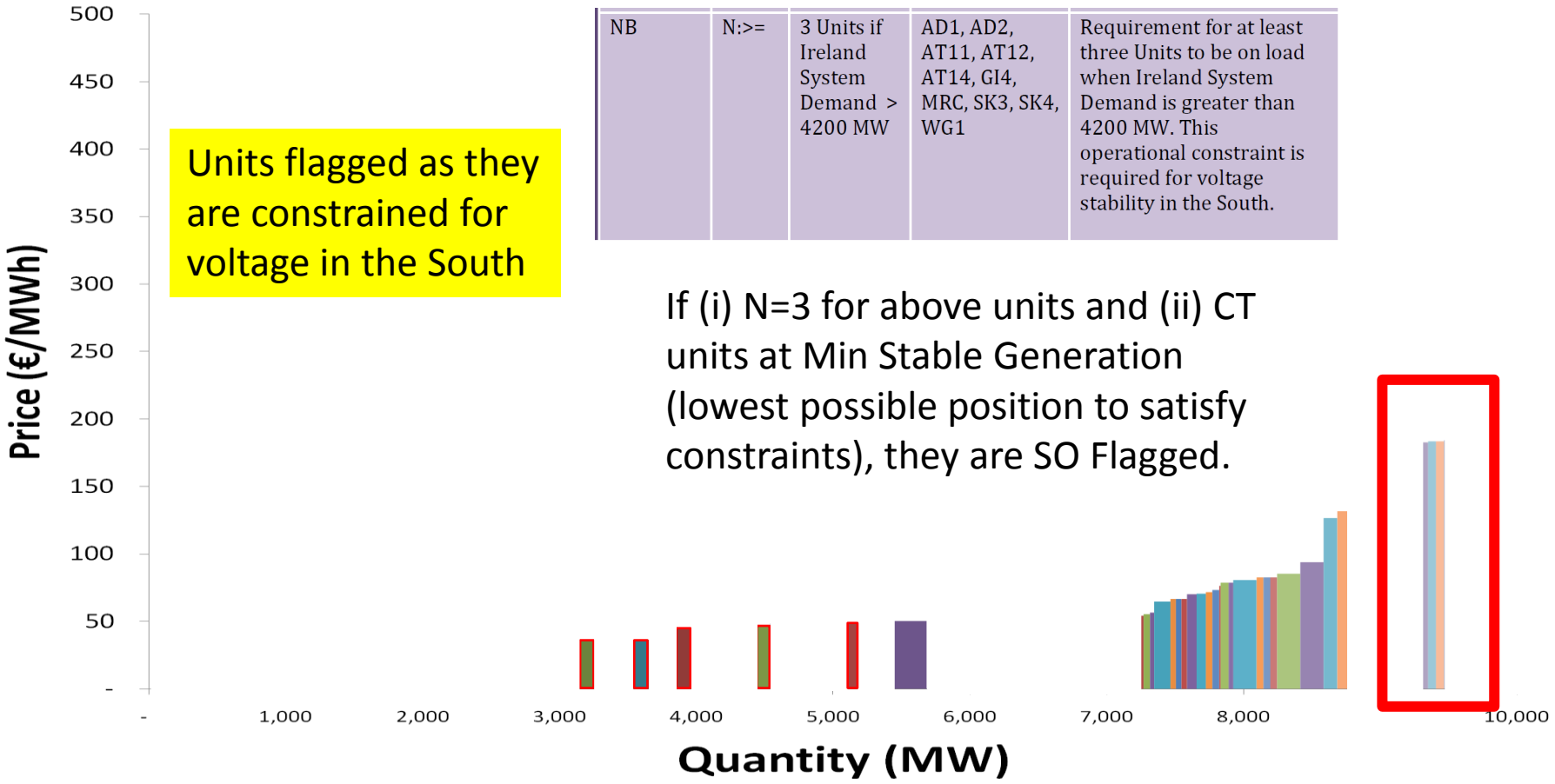
Day in the Life 1a: 17:25 (Imbalance Pricing)

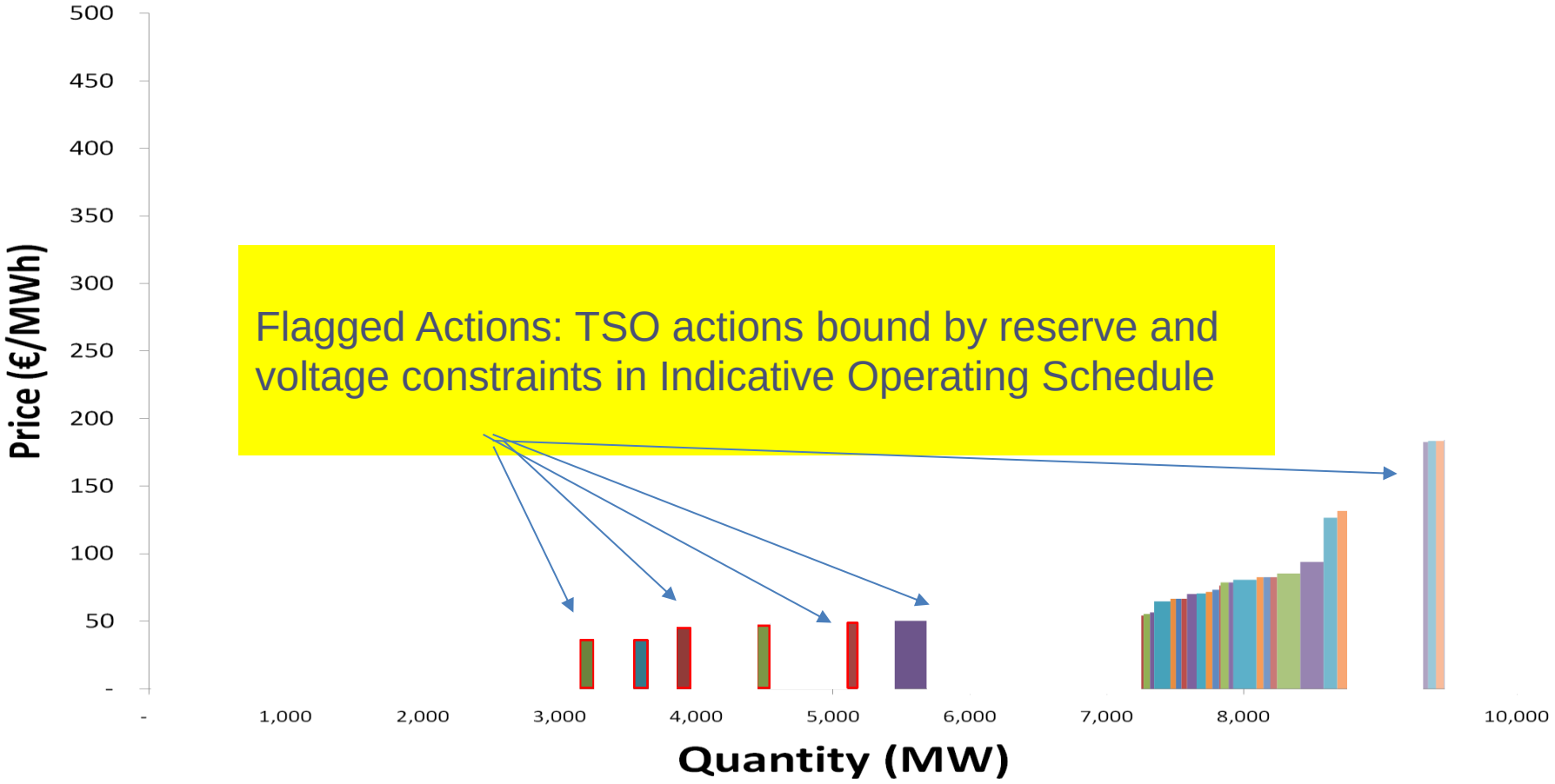
Units flagged as they are constrained for voltage in the South

NB	N:>=	3 Units if Ireland System Demand > 4200 MW	AD1, AD2, AT11, AT12, AT14, GI4, MRC, SK3, SK4, WG1	Requirement for at least three Units to be on load when Ireland System Demand is greater than 4200 MW. This operational constraint is required for voltage stability in the South.

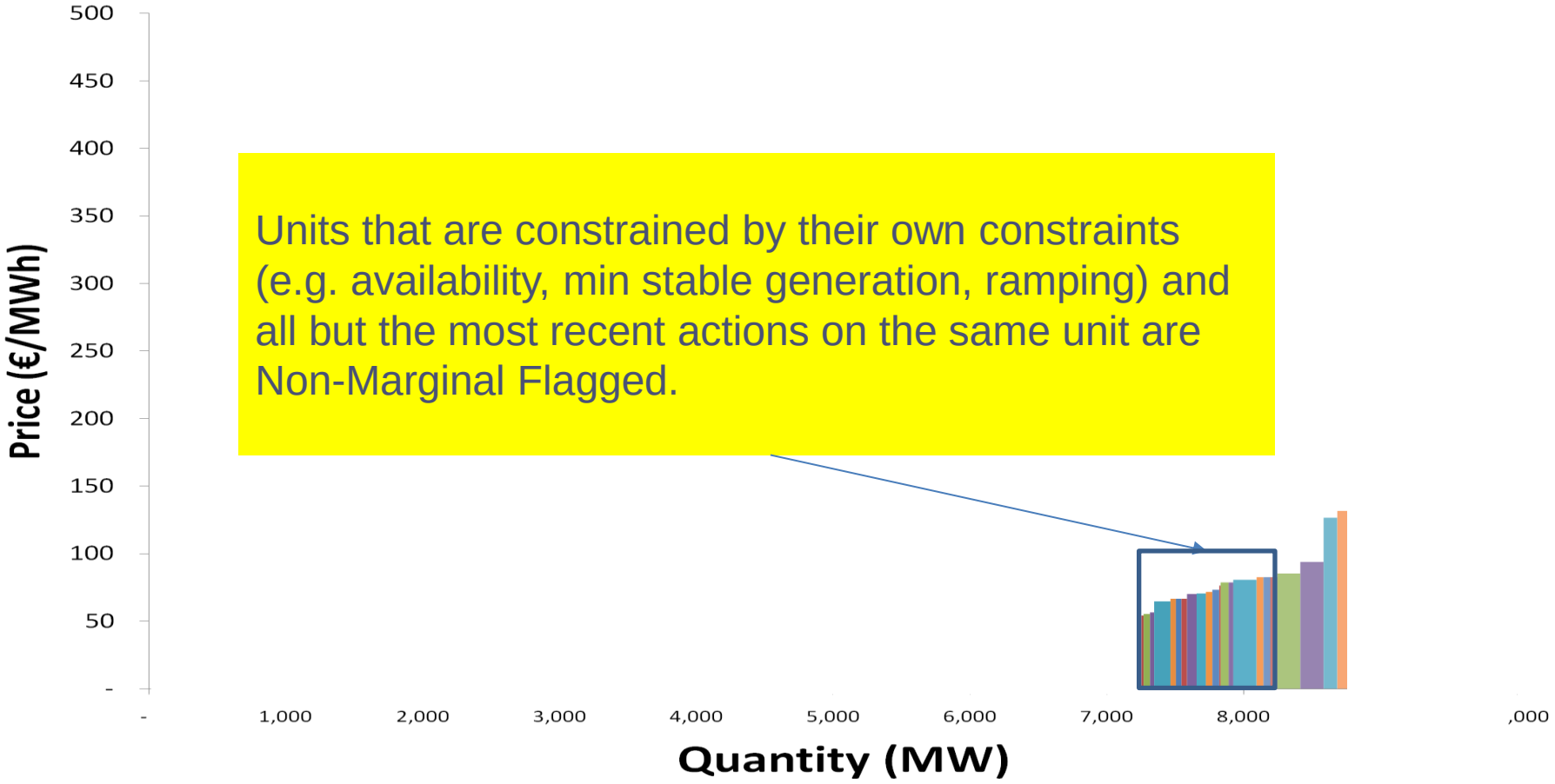
If (i) N=3 for above units and (ii) CT units at Min Stable Generation (lowest possible position to satisfy constraints), they are SO Flagged.



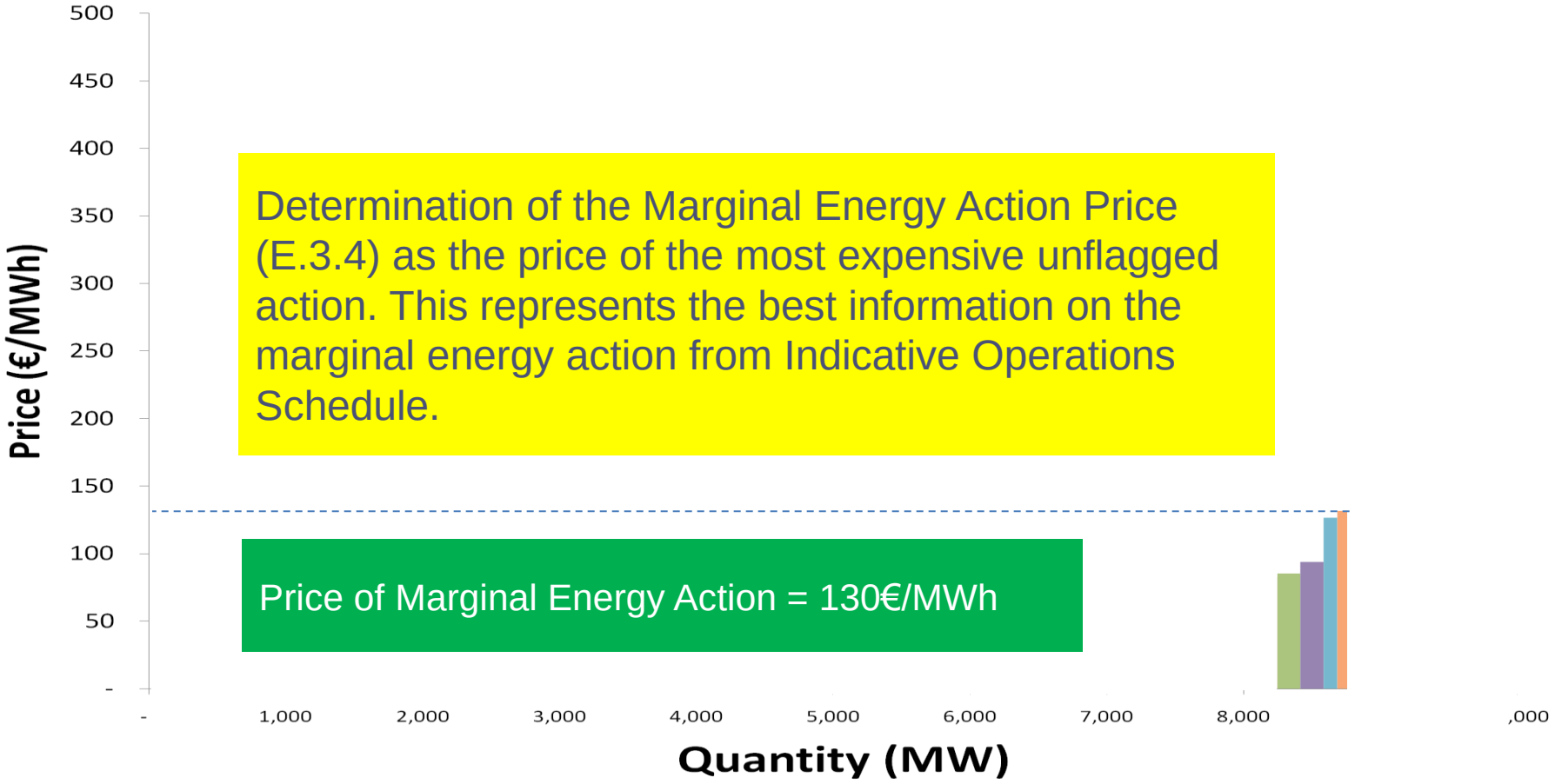
Day in the Life 1a: 17:25 (Imbalance Pricing)



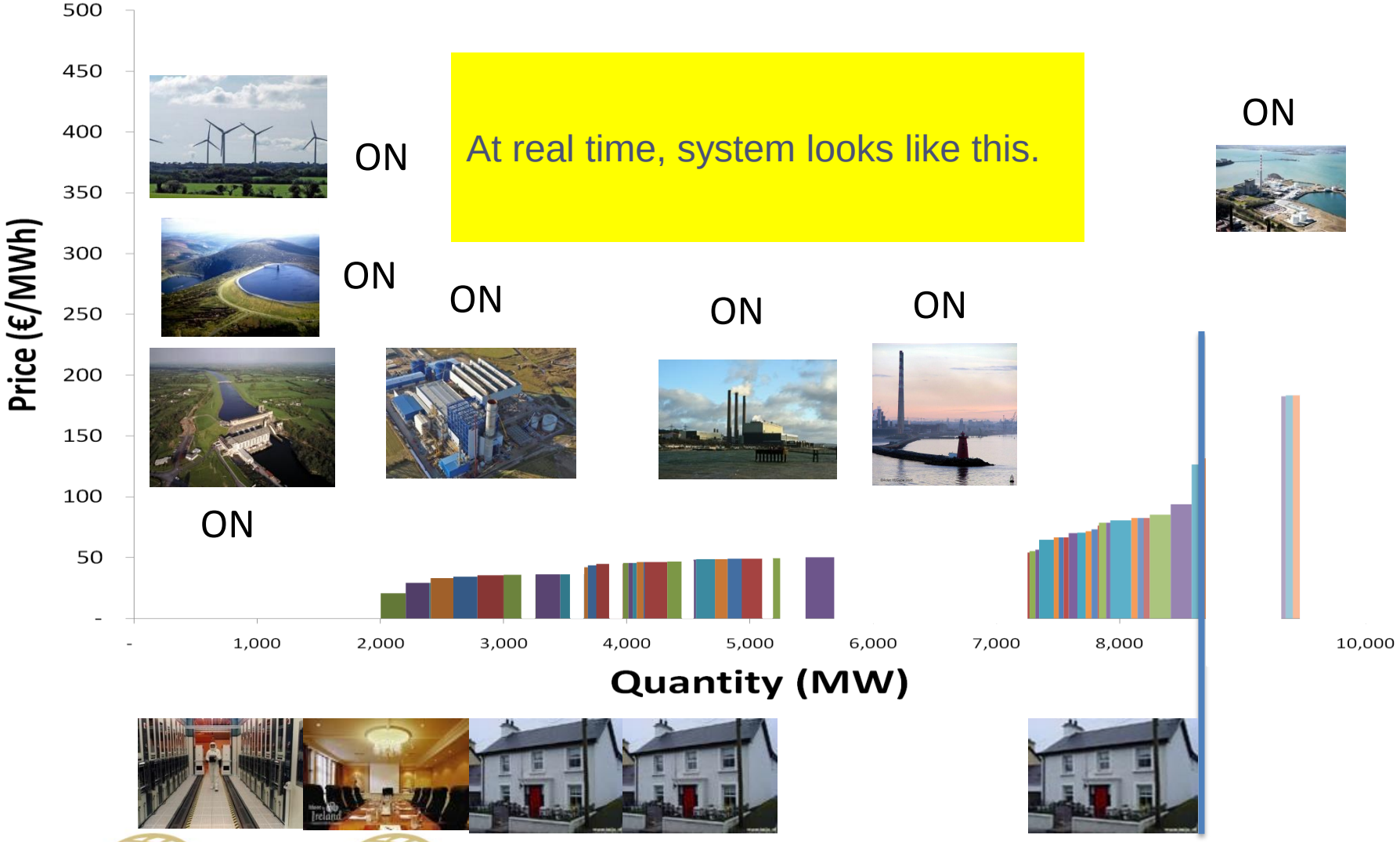
Day in the Life 1a: 17:25 (Imbalance Pricing)



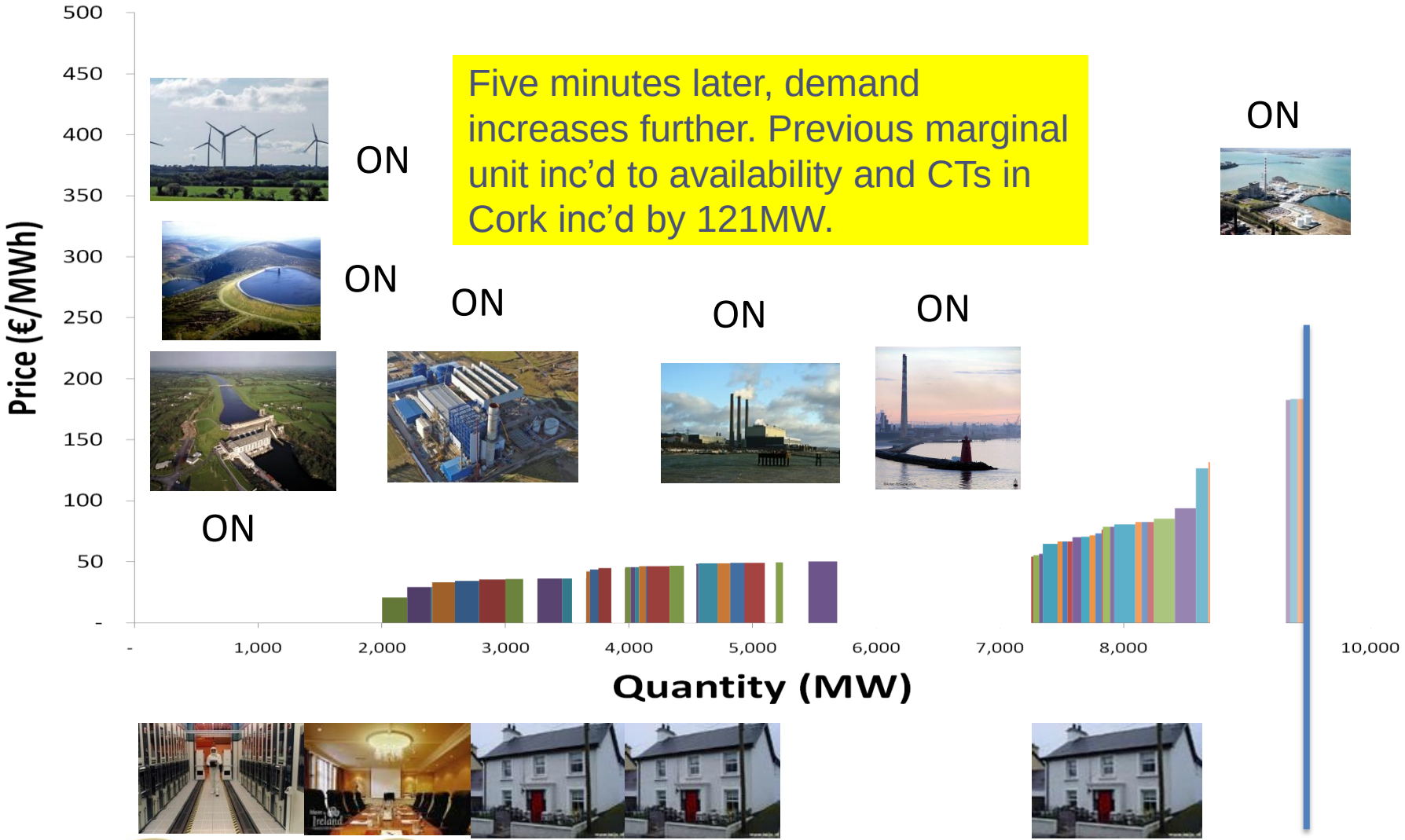
Day in the Life 1a: 17:25 (Imbalance Pricing)



Day in the Life 1b: 17:00 (Real time)



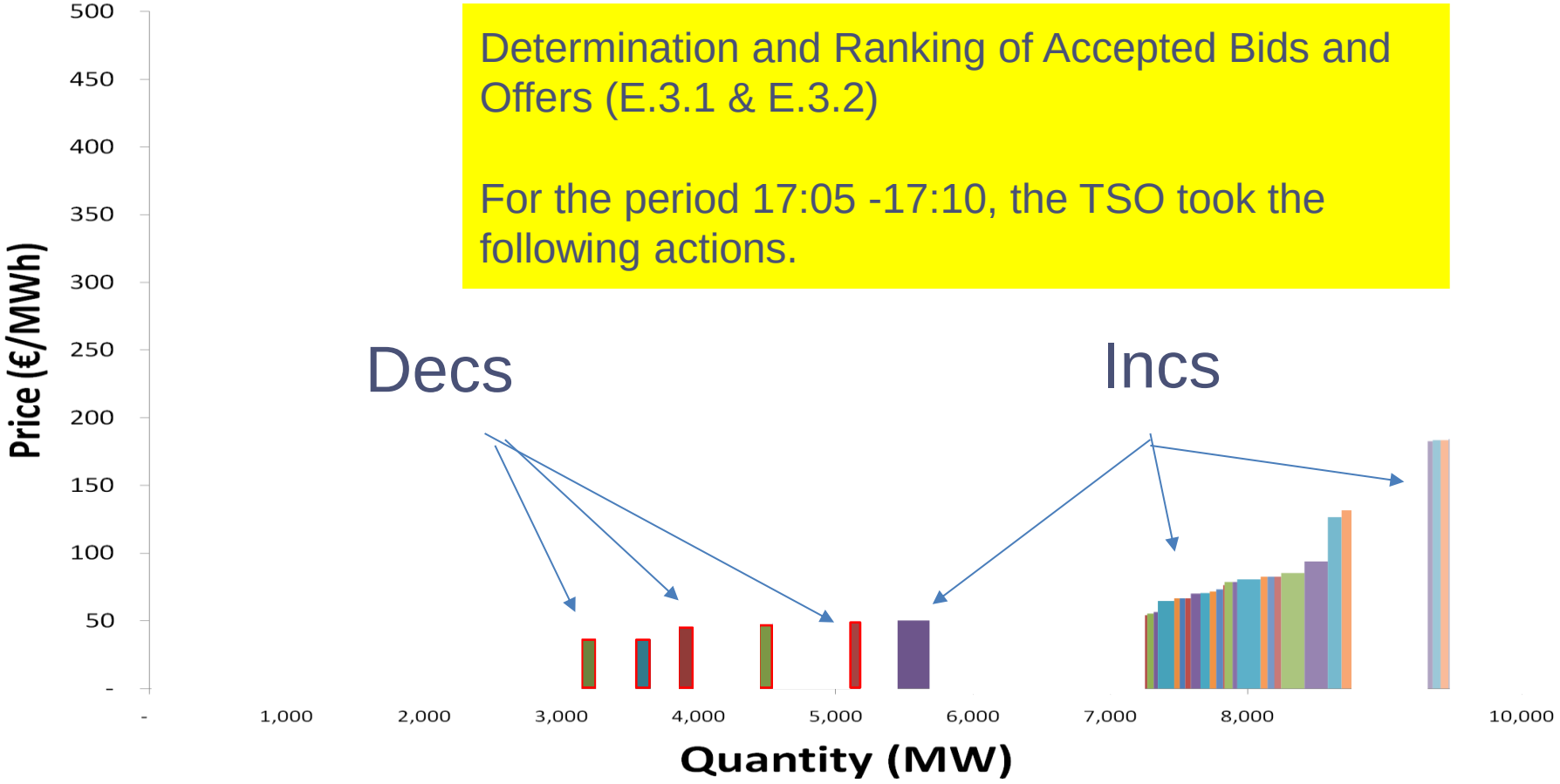
Day in the Life 1b: 17:05 (Real time)



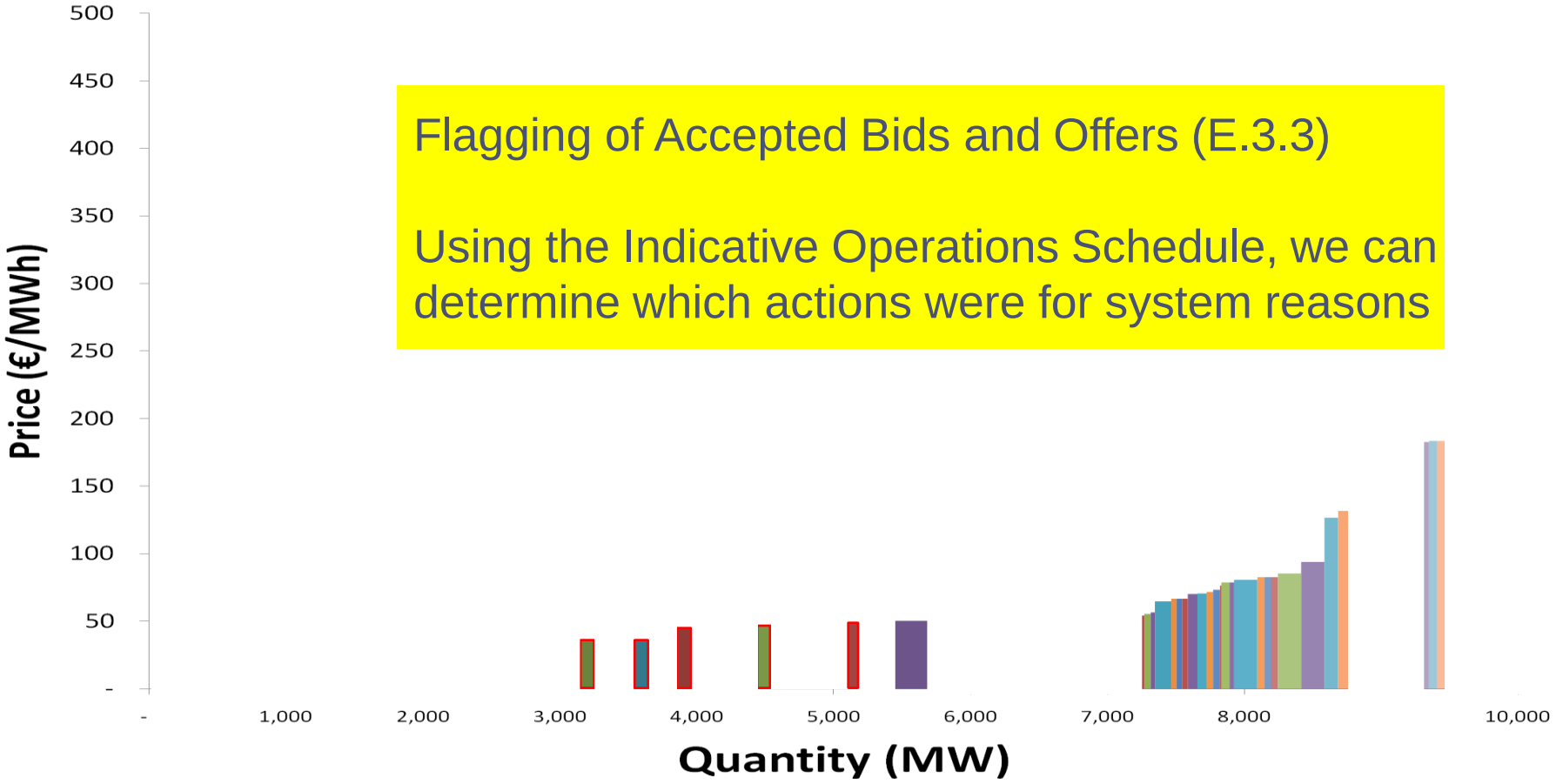
Day in the Life 1b: 17:30 (Imbalance Pricing)

Determination and Ranking of Accepted Bids and Offers (E.3.1 & E.3.2)

For the period 17:05 -17:10, the TSO took the following actions.



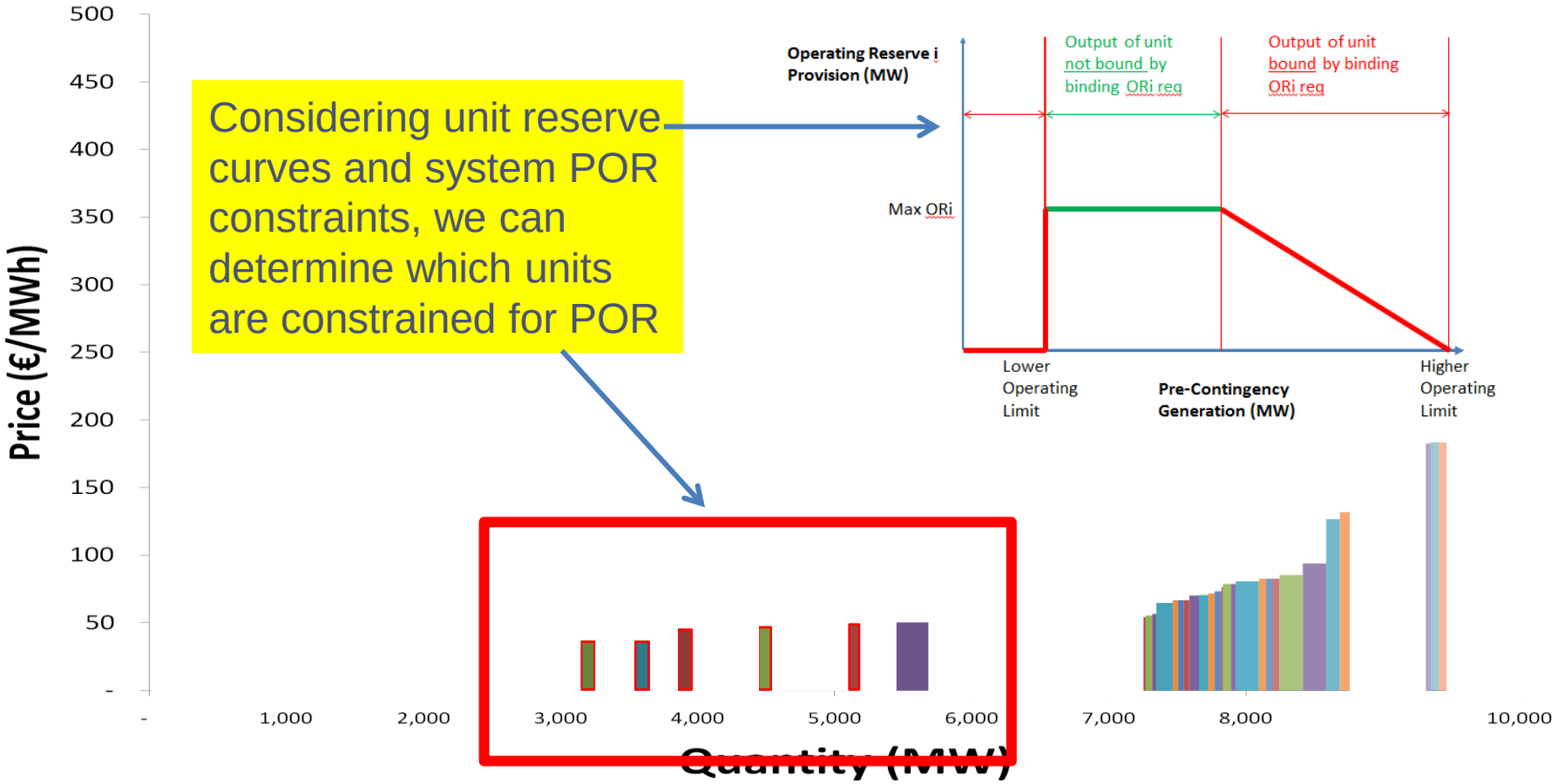
Day in the Life 1b: 17:30 (Imbalance Pricing)



Flagging of Accepted Bids and Offers (E.3.3)

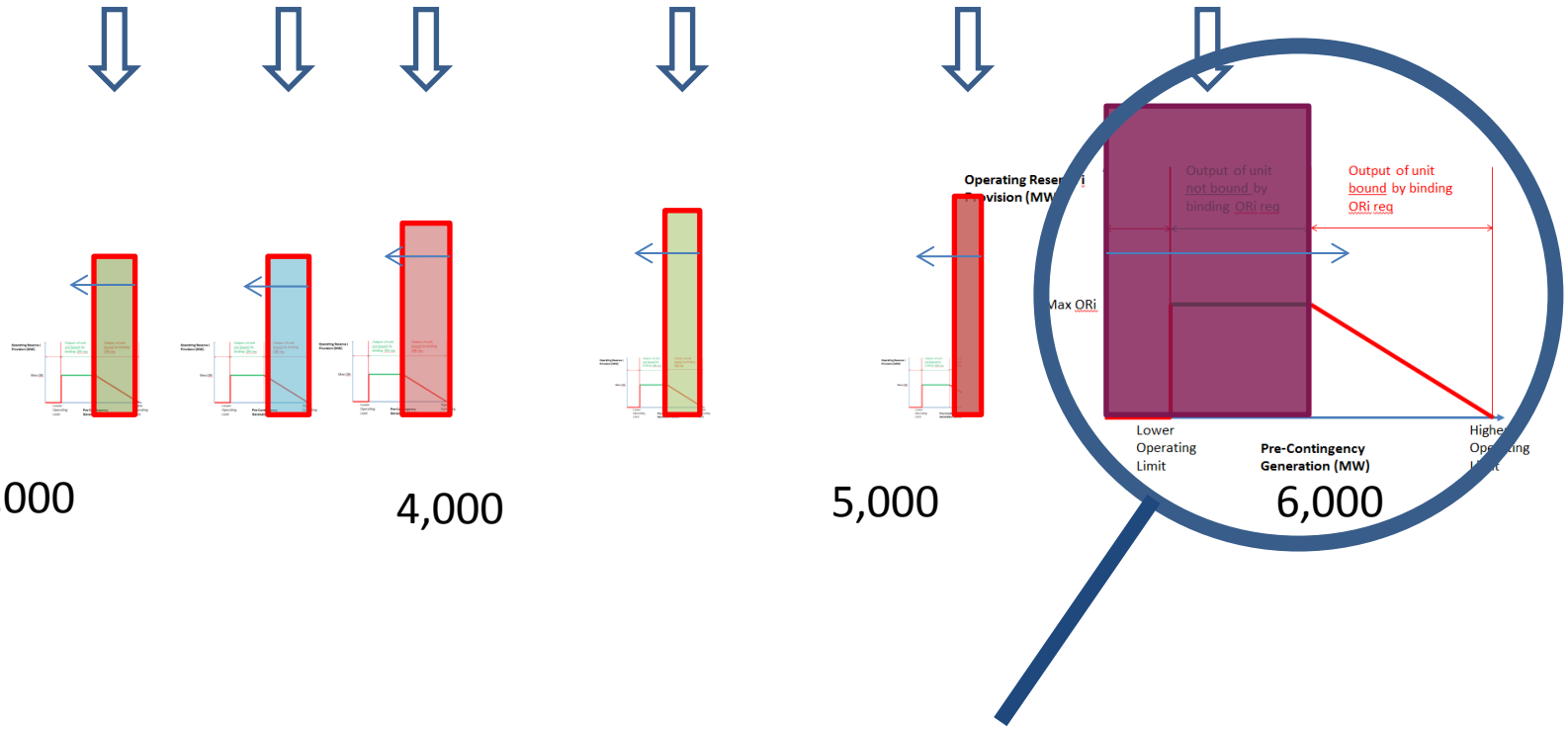
Using the Indicative Operations Schedule, we can determine which actions were for system reasons

Day in the Life 1b: 17:30 (Imbalance Pricing)



Day in the Life 1b: 17:30 (Imbalance Pricing)

Units constrained for POR
System Operator Flagged



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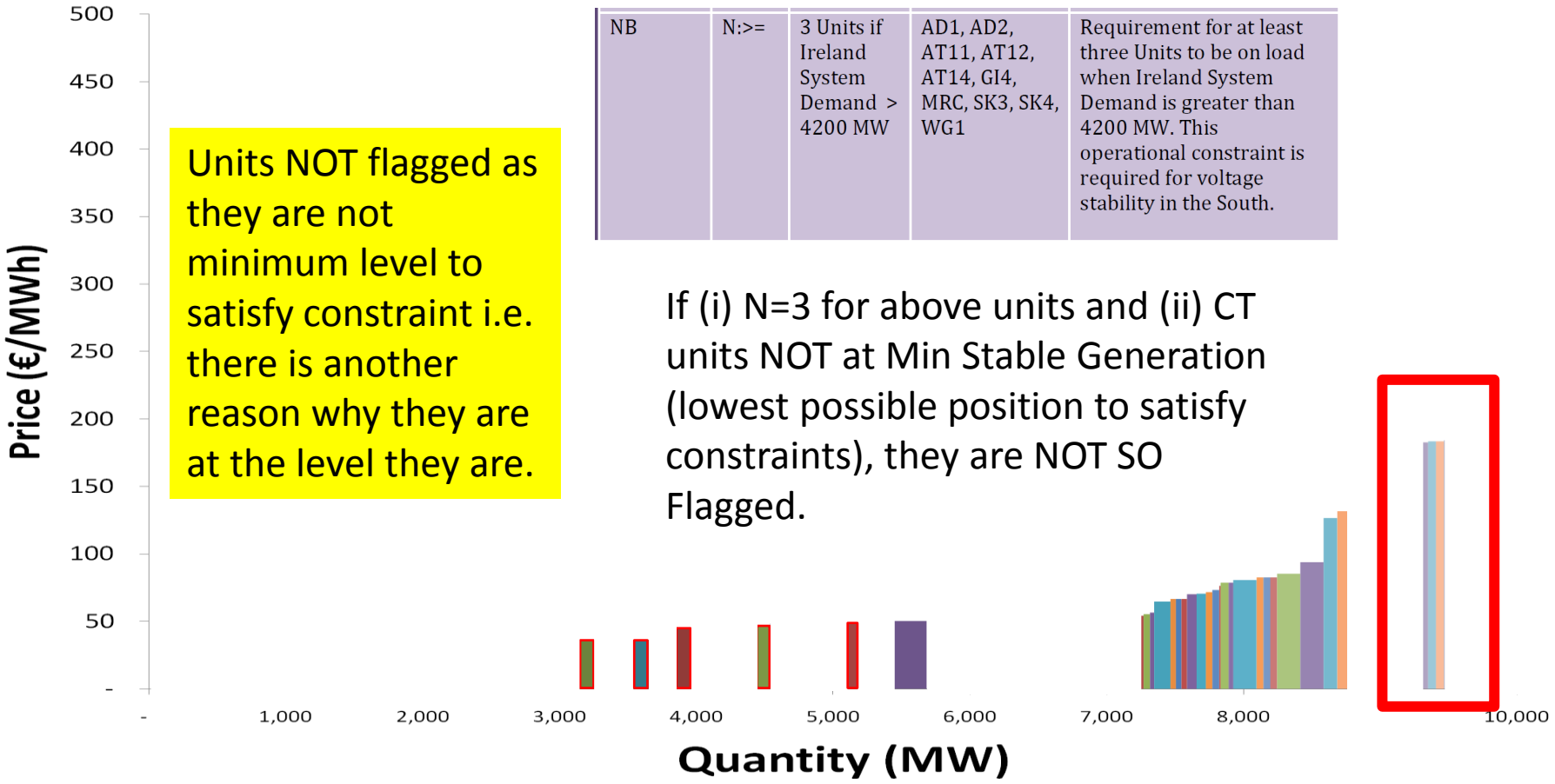
Day in the Life 1b: 17:30 (Imbalance Pricing)

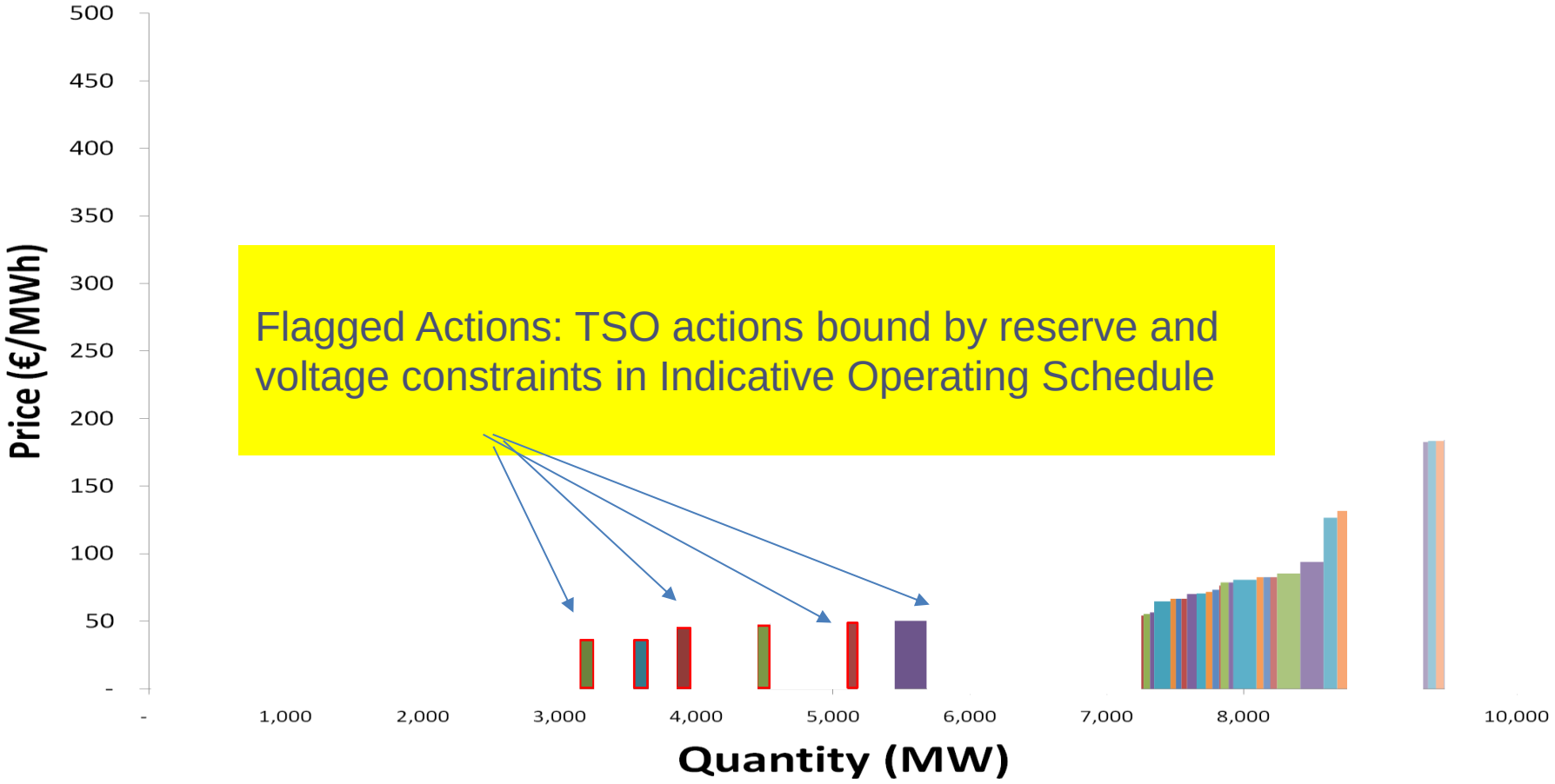
NB	N:>=	3 Units if Ireland System Demand > 4200 MW	AD1, AD2, AT11, AT12, AT14, GI4, MRC, SK3, SK4, WG1	Requirement for at least three Units to be on load when Ireland System Demand is greater than 4200 MW. This operational constraint is required for voltage stability in the South.

Units NOT flagged as they are not minimum level to satisfy constraint i.e. there is another reason why they are at the level they are.

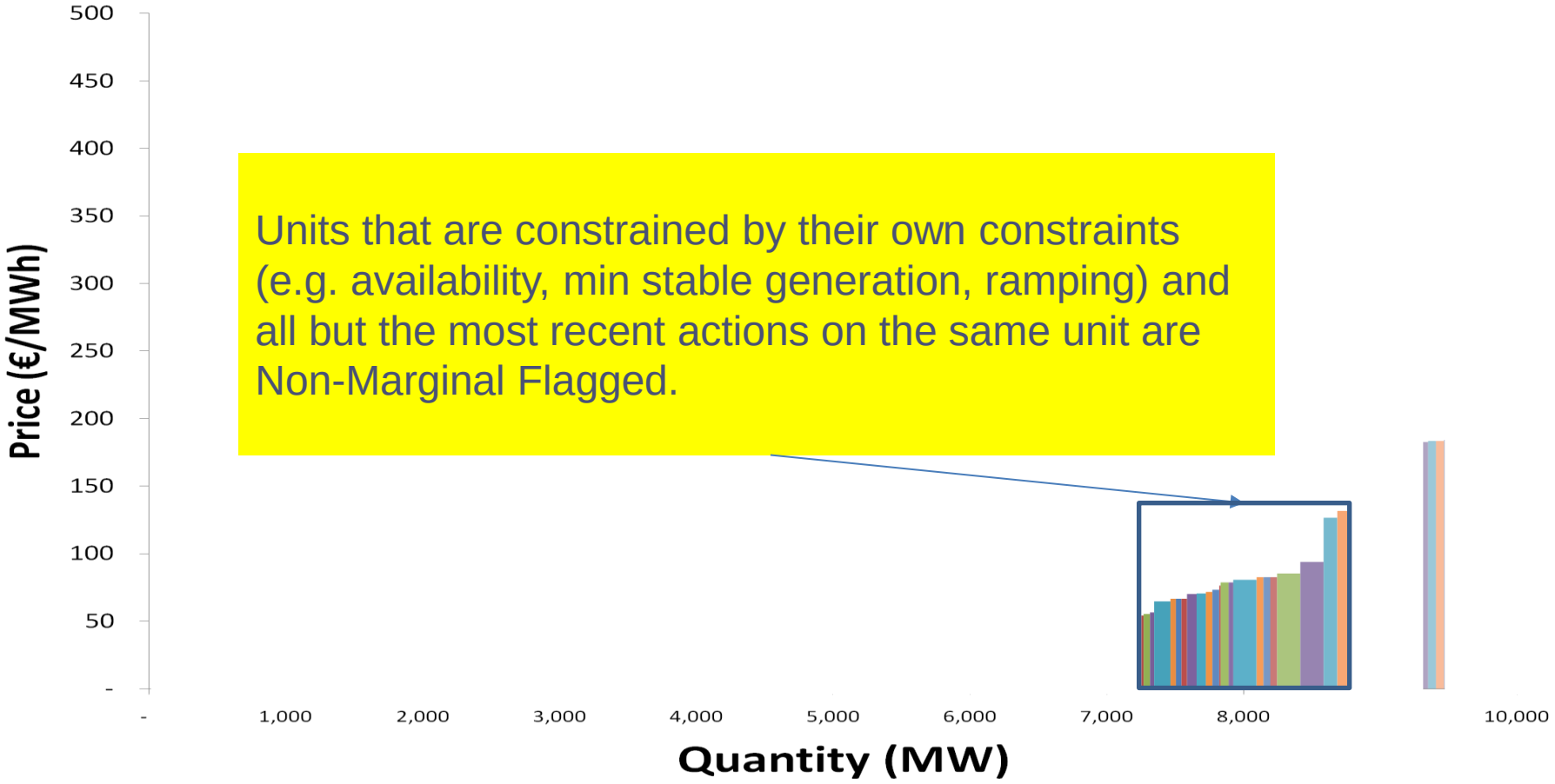
If (i) N=3 for above units and (ii) CT units NOT at Min Stable Generation (lowest possible position to satisfy constraints), they are NOT SO Flagged.



Day in the Life 1b: 17:30 (Imbalance Pricing)

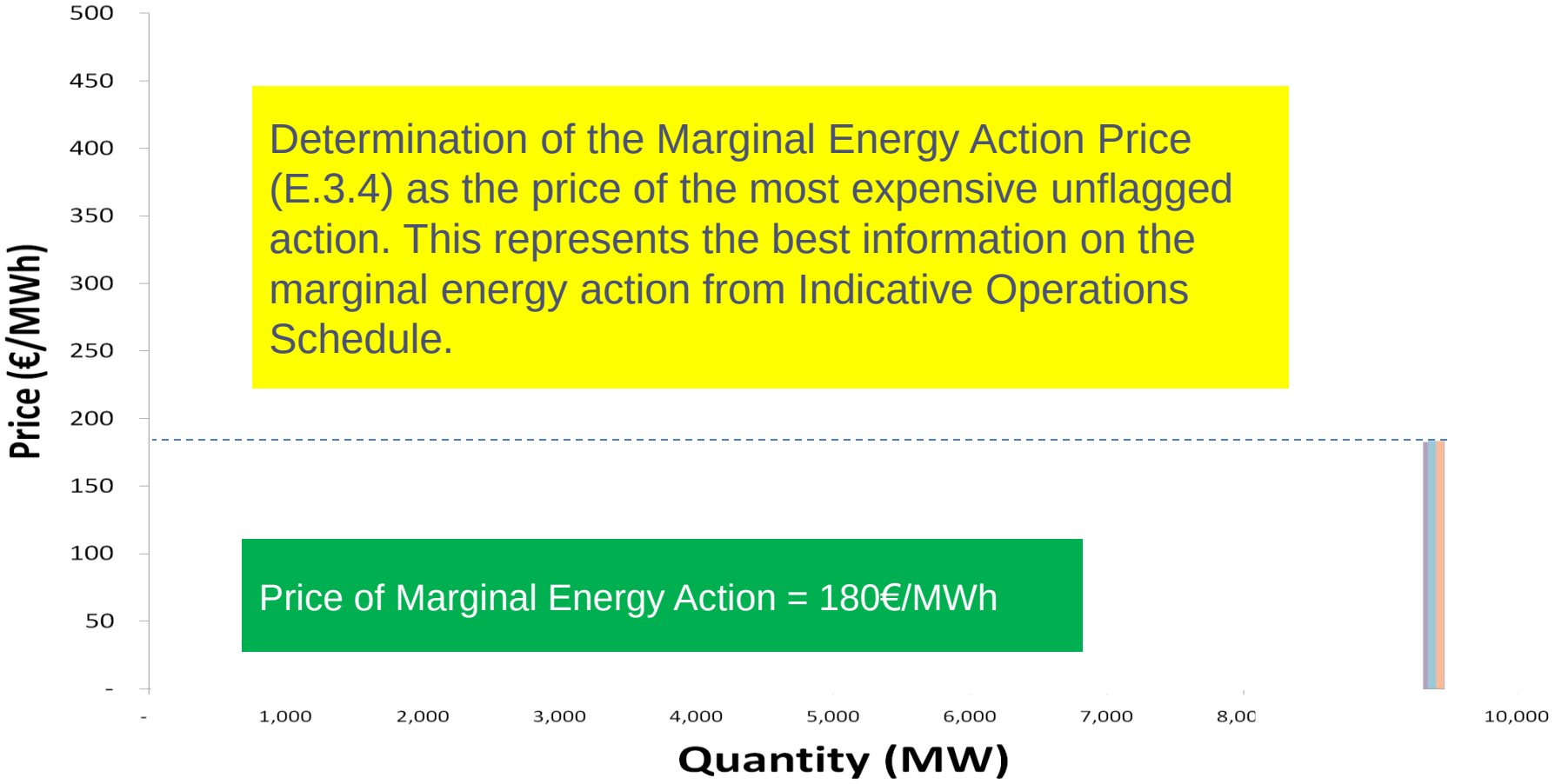


Day in the Life 1b: 17:30 (Imbalance Pricing)



Units that are constrained by their own constraints (e.g. availability, min stable generation, ramping) and all but the most recent actions on the same unit are Non-Marginal Flagged.

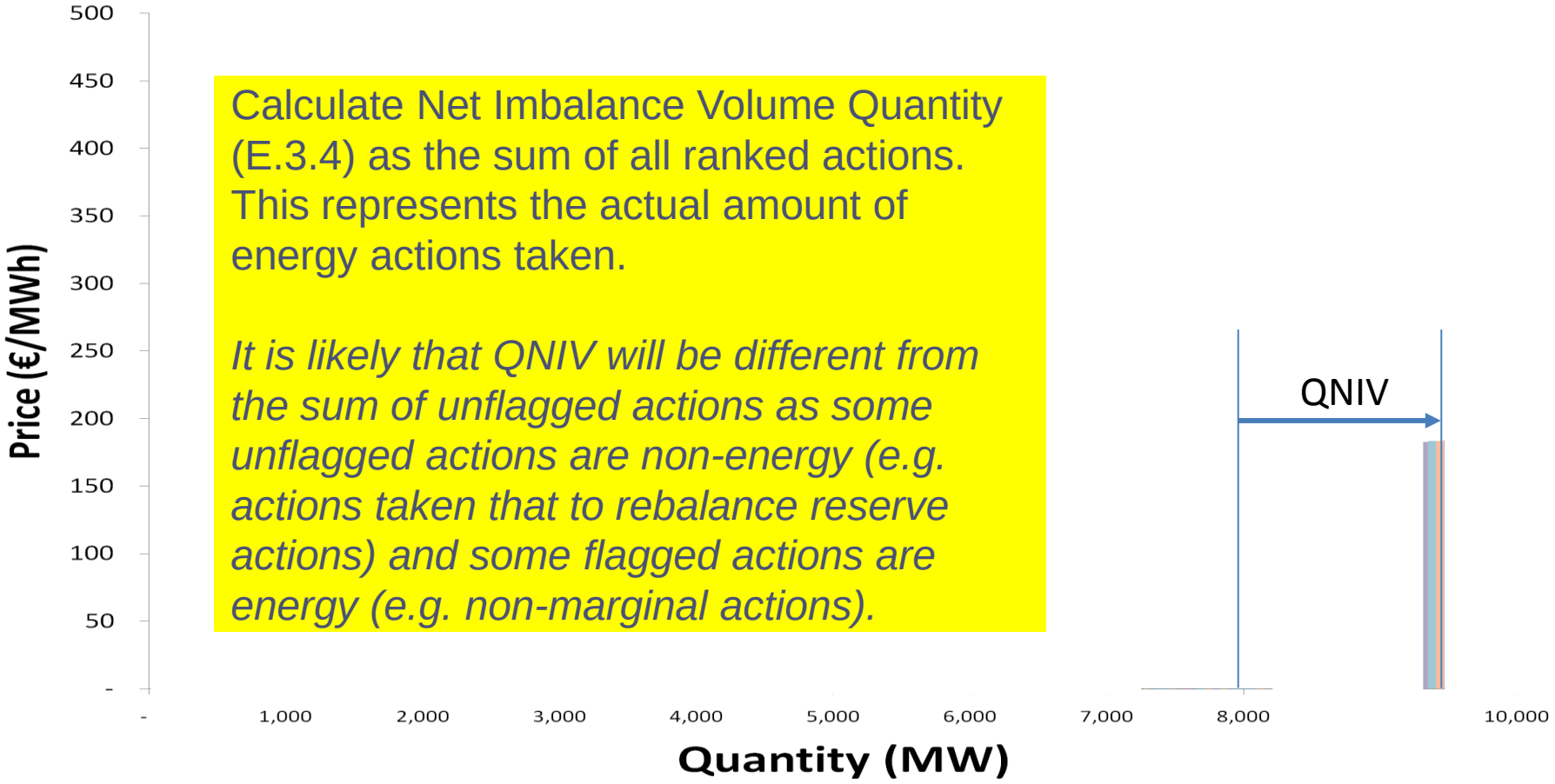
Day in the Life 1b: 17:30 (Imbalance Pricing)



Day in the Life 1b: 17:30 (Imbalance Pricing)

Calculate Net Imbalance Volume Quantity (E.3.4) as the sum of all ranked actions. This represents the actual amount of energy actions taken.

It is likely that QNIV will be different from the sum of unflagged actions as some unflagged actions are non-energy (e.g. actions taken that to rebalance reserve actions) and some flagged actions are energy (e.g. non-marginal actions).

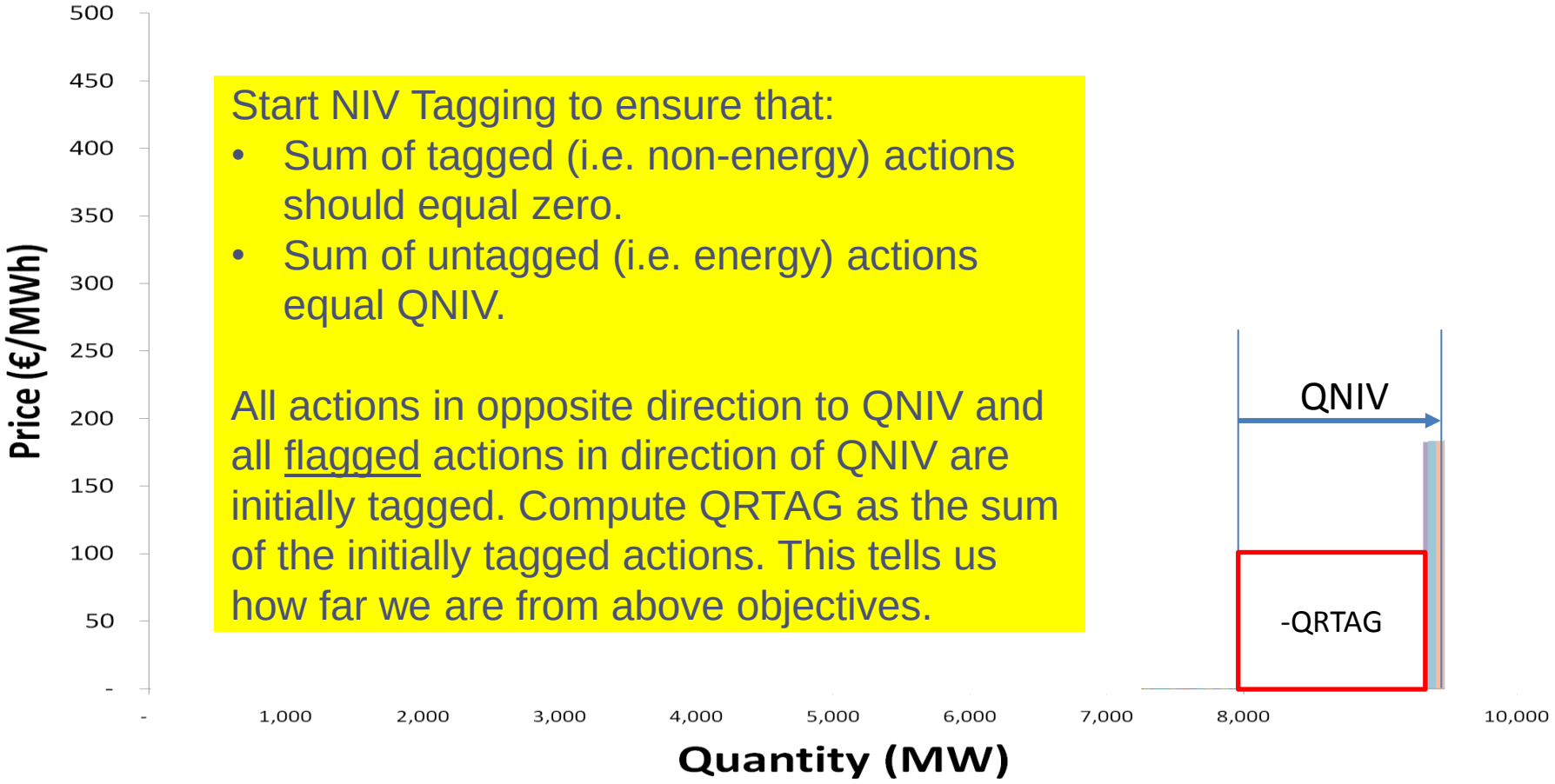


Day in the Life 1b: 17:30 (Imbalance Pricing)

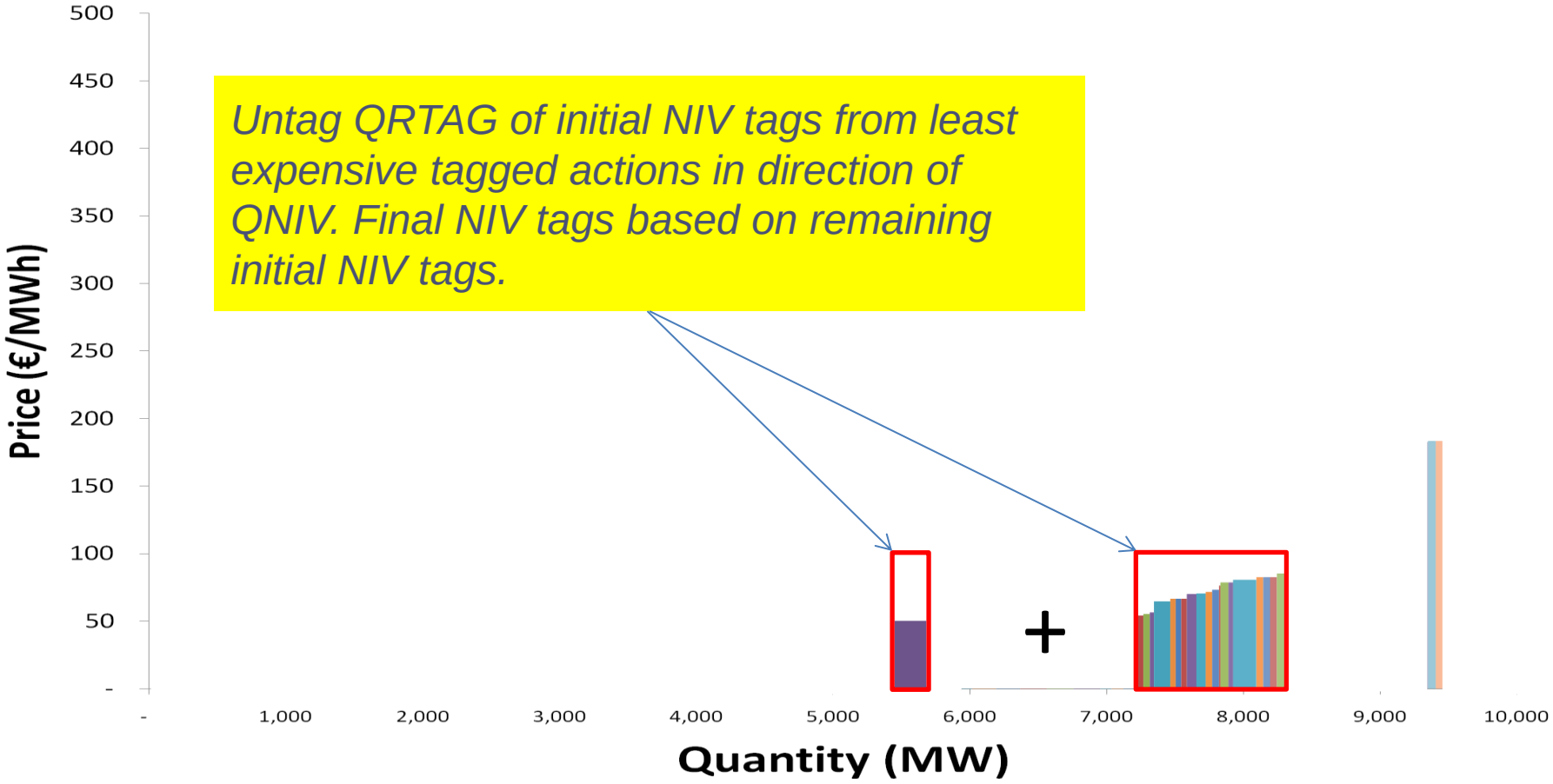
Start NIV Tagging to ensure that:

- Sum of tagged (i.e. non-energy) actions should equal zero.
- Sum of untagged (i.e. energy) actions equal QNIV.

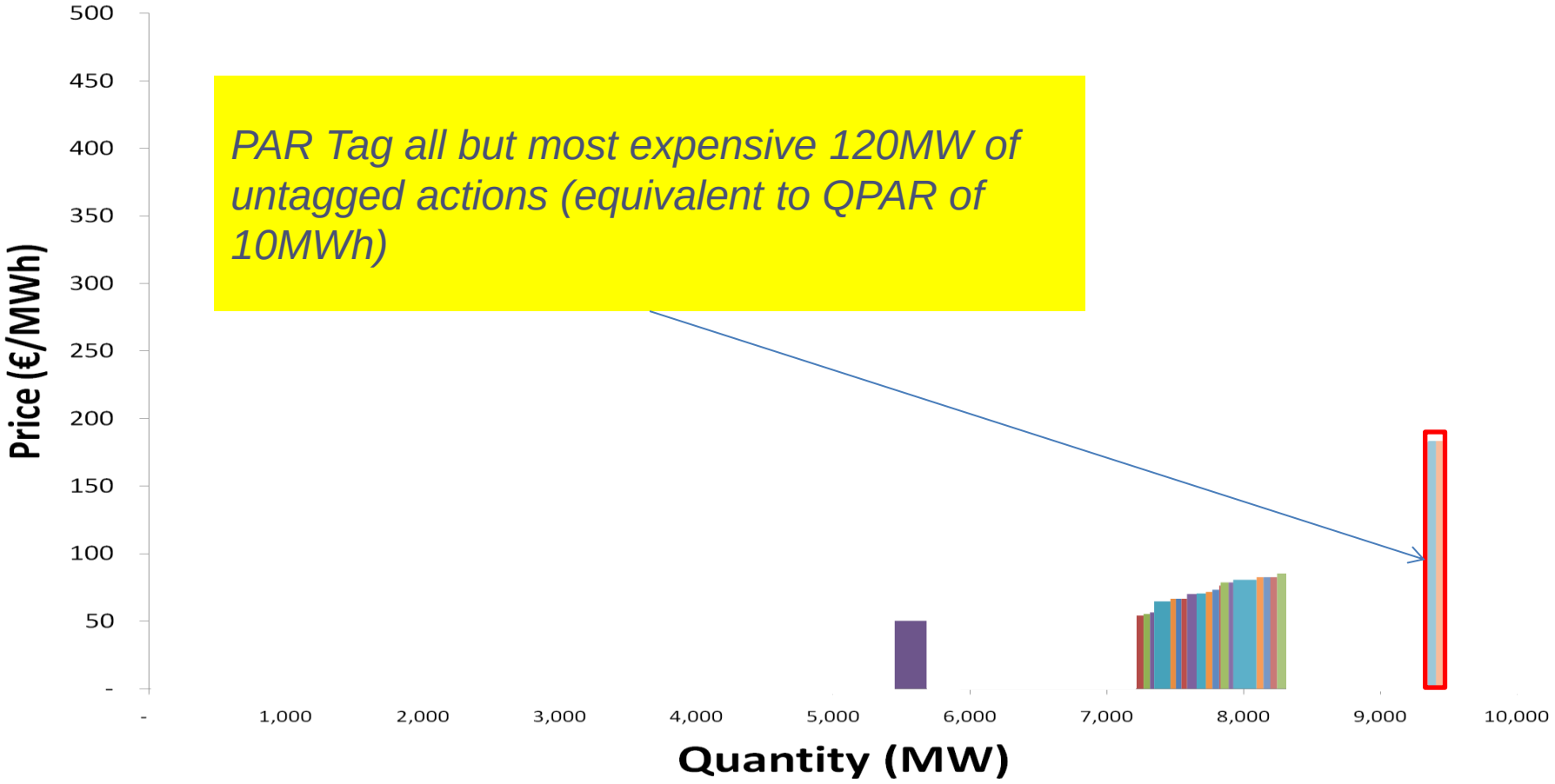
All actions in opposite direction to QNIV and all flagged actions in direction of QNIV are initially tagged. Compute QRTAG as the sum of the initially tagged actions. This tells us how far we are from above objectives.



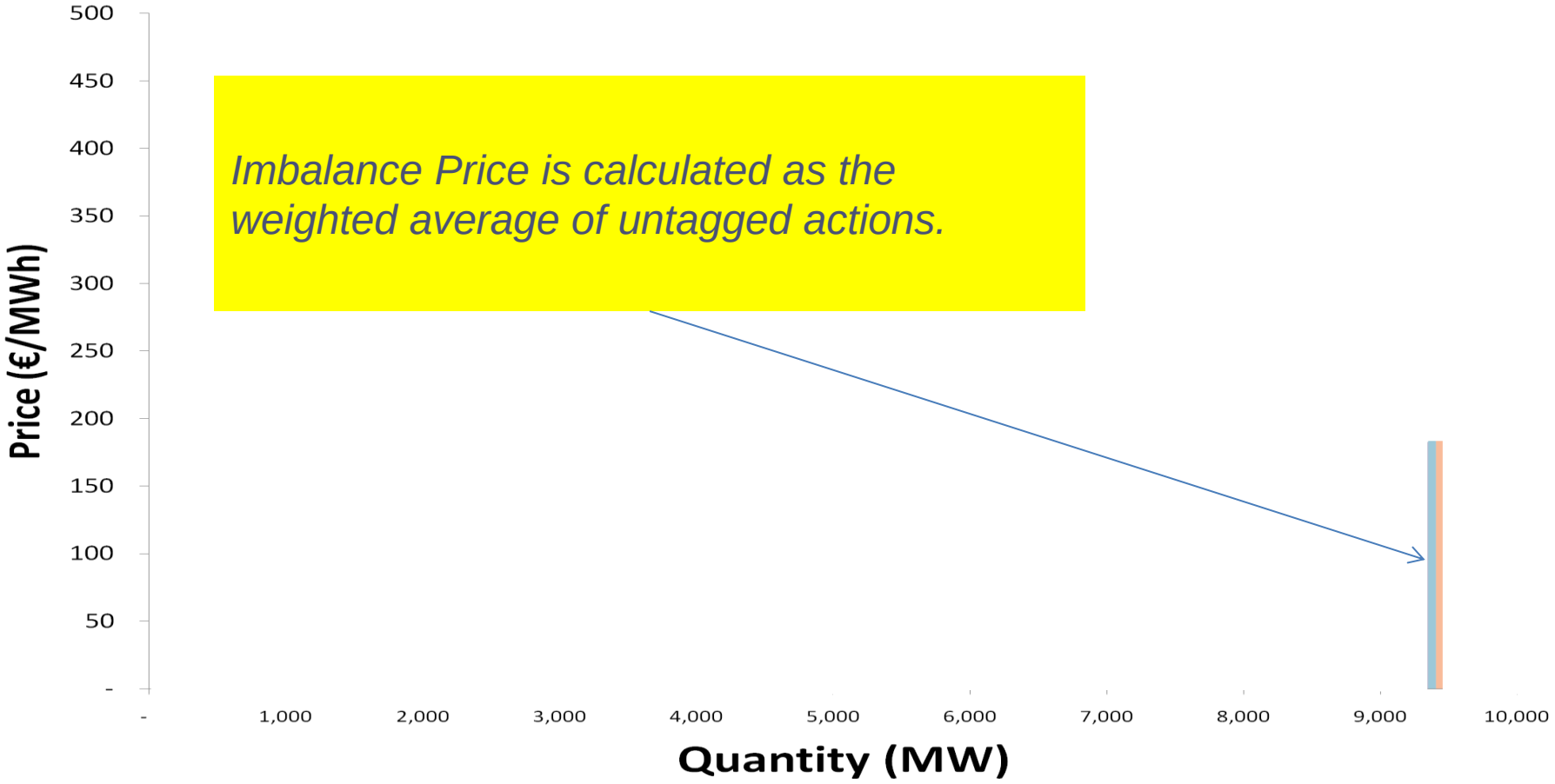
Day in the Life 1b: 17:30 (Imbalance Pricing)



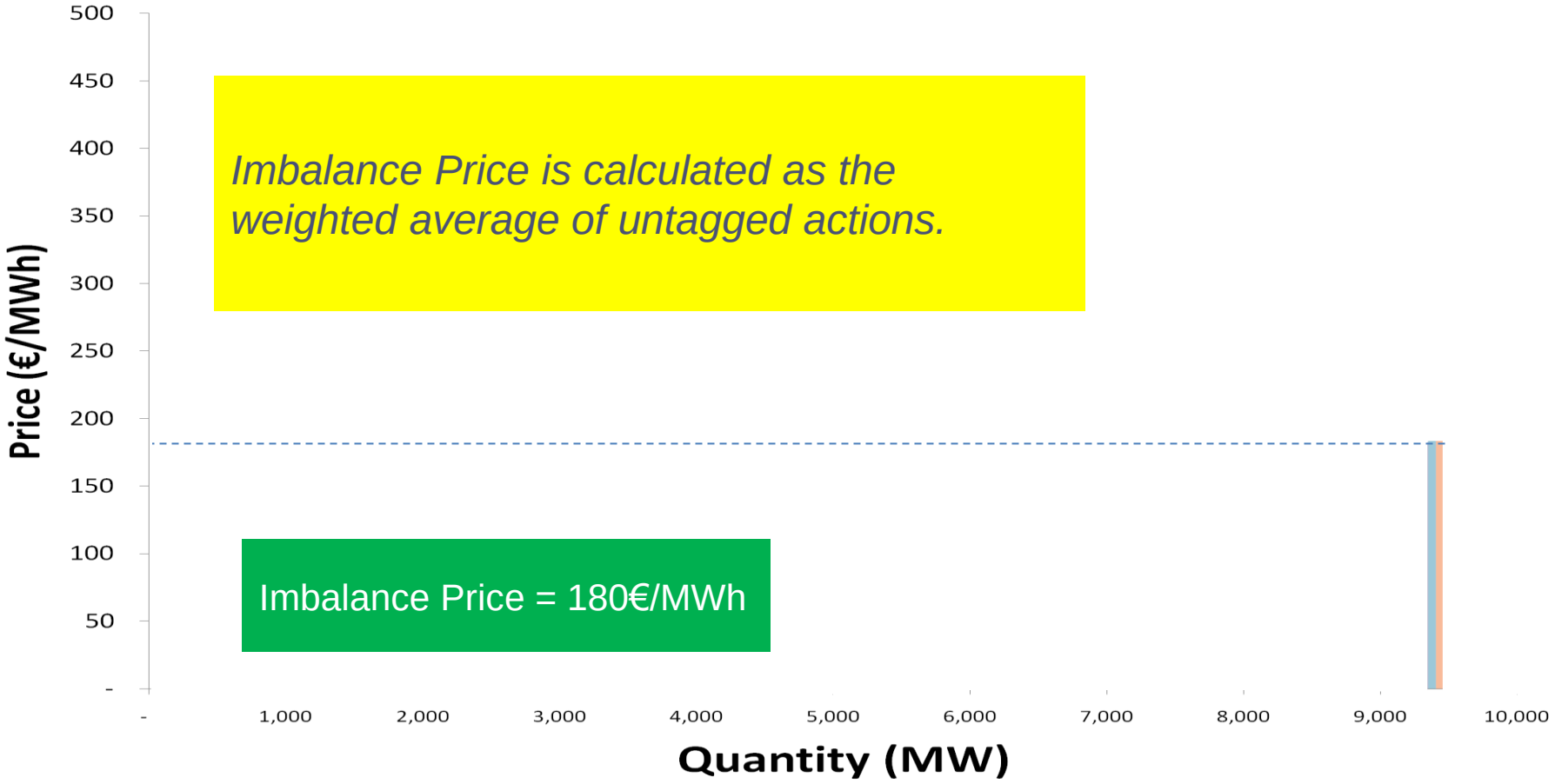
Day in the Life 1b: 17:30 (Imbalance Pricing)



Day in the Life 1b: 17:30 (Imbalance Pricing)



Day in the Life 1b: 17:30 (Imbalance Pricing)



Topic 7: Net Imbalance Volume Tagging

Net Imbalance Volume Tagging

- The form of the equations for NIV tagging in Appendix N are generalised to work in all cases, but may not be possible to easily see what it is they are doing or how they solve;

- The following is an explanation of what the equations are trying to do in words, it is not in very Plain-English but it gives rules of thumb which can be applied when trying to understand the equation;

- When discussing the “bottom”, “middle” and “top”, this is the position in the Ranked Set, where the “bottom” is the lowest priced Accepted Bid, the “middle” is where the final Accepted Bid in the ranked set and the first Accepted Offer in the ranked set meet, and the “top” is the highest priced Accepted Offer.

Net Imbalance Volume Tagging

- The Net Imbalance Volume Quantity (QNIV) is the sum of all actions in the ranked set;
- All actions in the opposite direction to the NIV, and all actions in the same direction as the NIV which were Non-Marginal and/or System Operator Flagged, are Initially NIV Tagged;
- The Residual Tagged Quantity (QRTAG) is the negative of the sum of all Initially NIV Tagged actions in the ranked set. The negative is taken to make the relationship between QRTAG and QNIV more clear;
- If QRTAG and QNIV are the same sign, then there has been undertagging and some additional orders which were initially untagged need to be tagged to reach the NIV;
- If QRTAG and QNIV are different signs, then there has been overtagging and some orders which were initially tagged need to be untagged to reach the NIV;
- If QNIV is positive, the solution would be looking to tag or untag offers;
- If QNIV is negative, the solution would be looking to tag or untag bids.

Net Imbalance Volume Tagging

- If looking at offers, untag from the middle up to the top, tag from the top down to the middle:
  - For untagging (QNIV positive, QRTAG negative):
    - From the middle up, find the transitional tagged offer, b, where the sum of all prior tagged offers and part of this offer (the proportion of which is β) equal QRTAG if it was positive, considering actions whose TINIV = 0;
    - Tag according to flags (set TNIV = TINIV) for all bids and all offers from after the transitional offer up to the top, untag (TNIV = 1) all offers from the middle up to the transitional offer, and partially untag (TNIV = β) the transitional offer.
  - For tagging (QNIV positive, QRTAG positive):
    - From the top down, find the transitional untagged offer, b, where the sum of all prior untagged offers and part of this offer (the proportion of which is β) equal QRTAG if it was positive, considering actions whose TINIV = 1;
    - Tag according to flags (set TNIV = TINIV) for all bids and offers from the bottom up until the transitional offer, tag (TNIV = 0) all offers from after the transitional offer up to the top, and partially tag (TNIV = 1 – β) the transitional offer.

Net Imbalance Volume Tagging

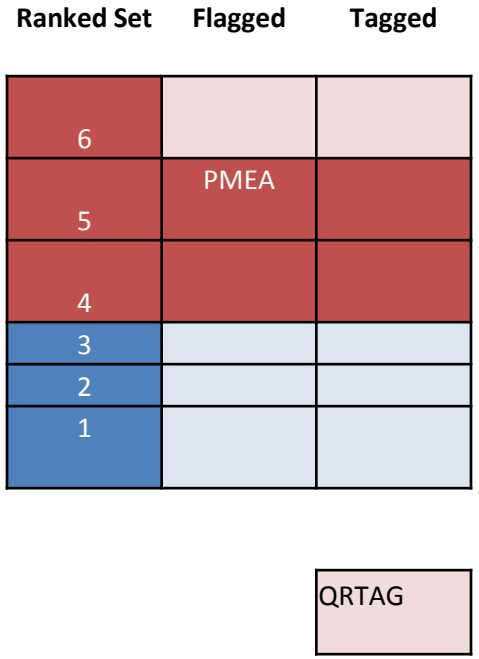
- If looking at bids, untag from the middle down to the bottom, tag from the bottom up to the middle:
  - For untagging (QNIV negative, QRTAG positive):
    - From the middle down, find the transitional tagged bid, b, where the sum of all prior tagged bids and part of this bid (the proportion of which is β) equal QRTAG if it was negative, considering actions whose TINIV = 0;
    - Tag according to flags (set TNIV = TINIV) for all offers and all bids from after the transitional bid down to the bottom, untag (TNIV = 1) all bids from the middle down to the transitional bid, and partially untag (TNIV = β) the transitional bid.
  - For tagging (QNIV negative, QRTAG negative):
    - From the bottom up, find the transitional untagged bid, b, where the sum of all prior untagged bids and part of this bid (the proportion of which is β) equal QRTAG if it was negative, considering actions whose TINIV = 1;
    - Tag according to flags (set TNIV = TINIV) for all offers and bids from the top down until the transitional bid, tag (TNIV = 0) all bids from after the transitional offer down to the bottom, and partially tag (TNIV = 1 – β) the transitional bid.

Net Imbalance Volume Tagging – Example 1

- If **$QNIV_{\phi}$** > 0 and **$QRTAG_{\phi}$** > 0:
  - Set **$TINIV_{uk\phi}$** = 0 for all **k** = 1 to M;

- **Values**
  - **$PMEA_{\phi}$ = P5**
  - **$QAO_{u5\phi}$ = 100**
  - **$\sum QAO_{uk\phi}$ x $TINIV_{uk\phi}$ = 200**
  - **$QRTAG_{\phi}$ = 100**

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged



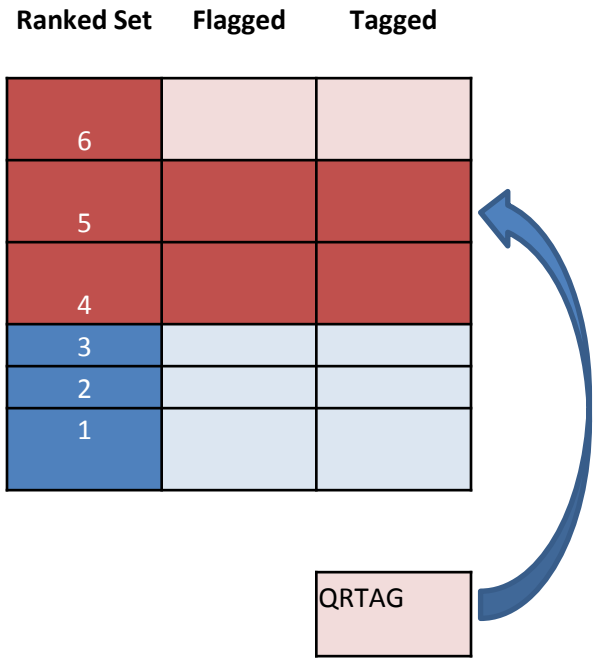
QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero

Net Imbalance Volume Tagging – Example 1

- If $\mathbf{QNIV_{\phi}} > 0$ and $\mathbf{QRTAG_{\phi}} > 0$:
  - Set $\mathbf{TINIV_{uk\phi}} = 0$ for all $\mathbf{k} = 1$ to M;
  - Find **b** and **β**, $\mathbf{QRTAG_{\phi}} = \sum_{k>b}\mathbf{QAO_{uk\phi}} \times \mathbf{TINIV_{uk\phi}} + \mathbf{\beta_{k=b}} \times \mathbf{QAO_{uk\phi}} \times \mathbf{TINIV_{uk\phi}}$;

- **Values**
  - $\mathbf{PMEA_{\phi}} = \mathbf{P5}$
  - $\mathbf{QAO_{u5\phi}} = \mathbf{100}$
  - $\sum\mathbf{QAO_{uk\phi}} \times \mathbf{TINIV_{uk\phi}} = \mathbf{200}$
  - $\mathbf{QRTAG_{\phi}} = \mathbf{100}$
  - $\mathbf{b} = \mathbf{5}, \mathbf{\beta} = \mathbf{1}$

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged

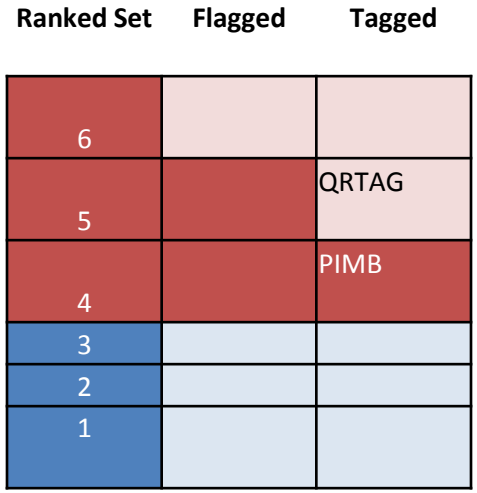


QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero

Net Imbalance Volume Tagging – Example 1

- If $\mathbf{QNIV_{\phi}} > 0$ and $\mathbf{QRTAG_{\phi}} > 0$:
  - Set $\mathbf{TNIV_{uk\phi}} = 0$ for all $\mathbf{k} = \mathbf{b} + 1$ to N, $\mathbf{TNIV_{uk\phi}} = 1 - \boldsymbol{\beta}$ for $\mathbf{k} = \mathbf{b}$;
- **Values**
  - $\mathbf{PMEA_{\phi}} = \mathbf{P5}$
  - $\mathbf{QAO_{u5\phi}} = \mathbf{100}$
  - $\mathbf{\sum QAO_{uk\phi} \times TINIV_{uk\phi}} = \mathbf{200}$
  - $\mathbf{QRTAG_{\phi}} = \mathbf{100}$
  - $\mathbf{b} = \mathbf{5}, \boldsymbol{\beta} = \mathbf{1}$
  - $\mathbf{PIMB_{\phi}} = \mathbf{P4}$

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged



QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero

Net Imbalance Volume Tagging – Example 2

- If **$QNIV_{\phi}$** > 0 and **$QRTAG_{\phi}$** < 0:
  - Set **$TINIV_{uk\phi}$** = 0 for all **k** = 1 to M;

- **Values**
  - **$PMEA_{\phi}$ = P3**
  - **$QAO_{u5\phi}$ = 100**
  - **$\sum QAO_{uk\phi}$ x $TINIV_{uk\phi}$ = 0**
  - **$QRTAG_{\phi}$ = -100**

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged

Ranked Set	Flagged	Tagged
6	PMEA	PMEA
5	PMEA	PMEA
4	PMEA	PMEA
3	PMEA	PMEA
2		
1		

QRTAG

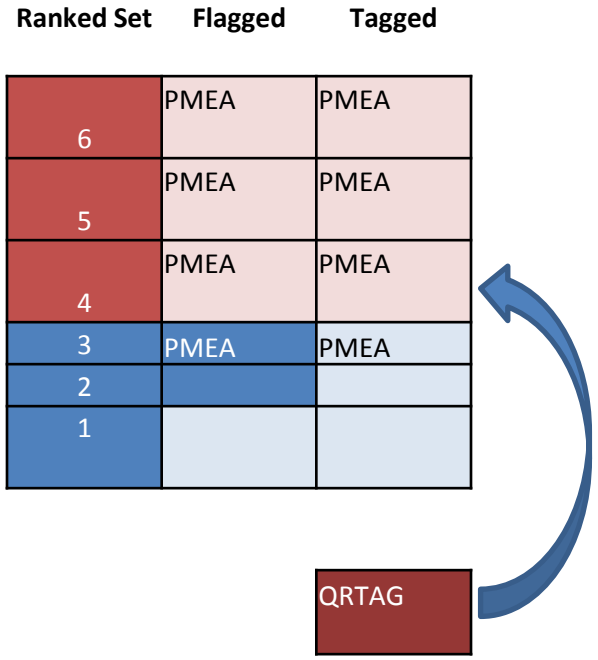
QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero

Net Imbalance Volume Tagging – Example 2

- If $\mathbf{QNIV_{\phi}} > 0$ and $\mathbf{QRTAG_{\phi}} < 0$:
  - Set $\mathbf{TINIV_{uk\phi}} = 0$ for all $\mathbf{k} = 1$ to M;
  - Find **b** and **β**, $-\mathbf{QRTAG_{\phi}} = \sum_{k<b}\mathbf{QAO_{uk\phi}} \times (1 - \mathbf{TINIV_{uk\phi}}) + \boldsymbol{\beta}_{\mathbf{k=b}} \times \mathbf{QAO_{uk\phi}} \times (1 - \mathbf{TINIV_{uk\phi}})$;

- **Values**
  - $\mathbf{PMEA_{\phi}} = \mathbf{P3}$
  - $\mathbf{QAO_{u5\phi}} = \mathbf{100}$
  - $\sum\mathbf{QAO_{uk\phi}} \times \mathbf{TINIV_{uk\phi}} = \mathbf{0}$
  - $\mathbf{QRTAG_{\phi}} = \mathbf{-100}$
  - $\mathbf{b} = \mathbf{4}, \boldsymbol{\beta} = \mathbf{1}$

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged



QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero

Net Imbalance Volume Tagging – Example 2

- If $\mathbf{QNIV_{\phi}} > 0$ and $\mathbf{QRTAG_{\phi}} < 0$:
  - Set $\mathbf{TNIV_{uk\phi}} = 1$ for all $\mathbf{k} = M + 1$ to $\mathbf{b} - 1$, $\mathbf{TNIV_{uk\phi}} = \boldsymbol{\beta}$ for $\mathbf{k} = \mathbf{b}$;
- **Values**
  - $\mathbf{PMEA_{\phi}} = \mathbf{P3}$
  - $\mathbf{QAO_{u5\phi}} = \mathbf{100}$
  - $\sum \mathbf{QAO_{uk\phi}} \times \mathbf{TINIV_{uk\phi}} = \mathbf{0}$
  - $\mathbf{QRTAG_{\phi}} = \mathbf{-100}$
  - $\mathbf{b} = \mathbf{4}, \boldsymbol{\beta} = \mathbf{1}$
  - $\mathbf{PIMB_{\phi}} = \mathbf{P4 = PMEA}$

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged

Ranked Set	Flagged	Tagged
6	PMEA	PMEA
5	PMEA	PMEA
4	PMEA	PIMB ORTAG
3	PMEA	PMEA
2		
1		

QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero

Net Imbalance Volume Tagging – Example 3

- If $\mathbf{QNIV_{\phi}} < 0$ and $\mathbf{QRTAG_{\phi}} > 0$:
  - Set $\mathbf{TINIV_{uk\phi}} = 0$ for all **k** = M + 1 to N;

- **Values**
  - $\mathbf{PMEA_{\phi}} = \mathbf{P4}$
  - $\mathbf{QAO_{u5\phi}} = \mathbf{50}$
  - $\mathbf{\sum QAO_{uk\phi} \times TINIV_{uk\phi}} = \mathbf{100}$
  - $\mathbf{QRTAG_{\phi}} = \mathbf{100}$

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged

Ranked Set	Flagged	NIV Tagged
6		
5		
4	PMEA	PMEA
3	PMEA	PMEA
2	PMEA	PMEA
1	PMEA	PMEA

QRTAG

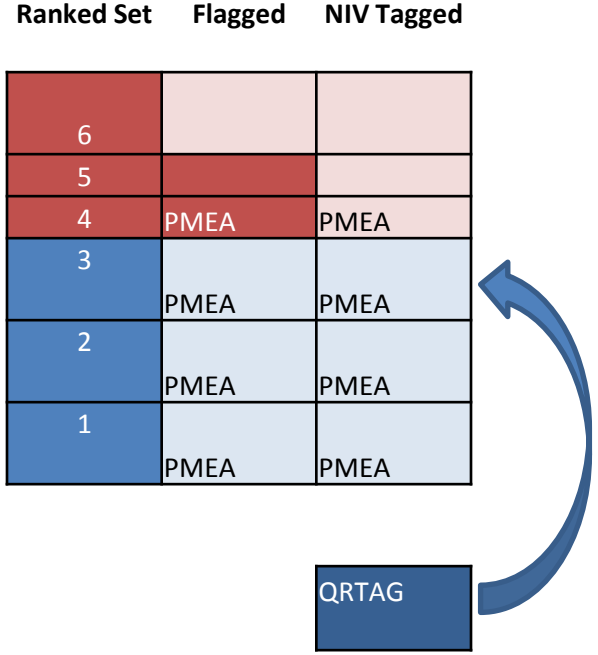
QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero

Net Imbalance Volume Tagging – Example 3

- If $\mathbf{QNIV_{\phi}} < 0$ and $\mathbf{QRTAG_{\phi}} > 0$:
  - Set $\mathbf{TINIV_{uk\phi}} = 0$ for all $\mathbf{k} = M + 1$ to N;
  - Find **b** and **β**, $-QRTAG_{\phi} = \sum_{k>b} \mathbf{QAB_{uk\phi}} \times (1 - \mathbf{TNIV_{uk\phi}}) + \beta_{k=b} \times \mathbf{QAB_{uk\phi}} \times (1 - \mathbf{TNIV_{uk\phi}})$;

- **Values**
  - $\mathbf{PMEA_{\phi}} = \mathbf{P4}$
  - $\mathbf{QAO_{u5\phi}} = \mathbf{50}$
  - $\sum \mathbf{QAO_{uk\phi}} \times \mathbf{TINIV_{uk\phi}} = \mathbf{100}$
  - $\mathbf{QRTAG_{\phi}} = \mathbf{100}$
  - $\mathbf{b} = \mathbf{3}, \boldsymbol{\beta} = \mathbf{1}$

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged



QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero.

Net Imbalance Volume Tagging – Example 3

- If $\mathbf{QNIV_{\phi}} < 0$ and $\mathbf{QRTAG_{\phi}} > 0$:
  - Set $\mathbf{TNIV_{uk\phi}} = 1$ for all $\mathbf{k} = \mathbf{b} + 1$ to M, $\mathbf{TNIV_{uk\phi}} = \boldsymbol{\beta}$ for $\mathbf{k} = \mathbf{b}$;
- **Values**
  - $\mathbf{PMEA_{\phi}} = \mathbf{P4}$
  - $\mathbf{QAO_{u5\phi}} = \mathbf{50}$
  - $\mathbf{\sum QAO_{uk\phi} \times TINIV_{uk\phi}} = \mathbf{100}$
  - $\mathbf{QRTAG_{\phi}} = \mathbf{100}$
  - $\mathbf{b = 3, \beta = 1}$
  - $\mathbf{PIMB_{\phi}} = \mathbf{P3 = PMEA}$

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged

Ranked Set	Flagged	NIV Tagged
6		
5		
4	PMEA	PMEA
3	PMEA	QRTAG PIMB
2	PMEA	PMEA
1	PMEA	PMEA

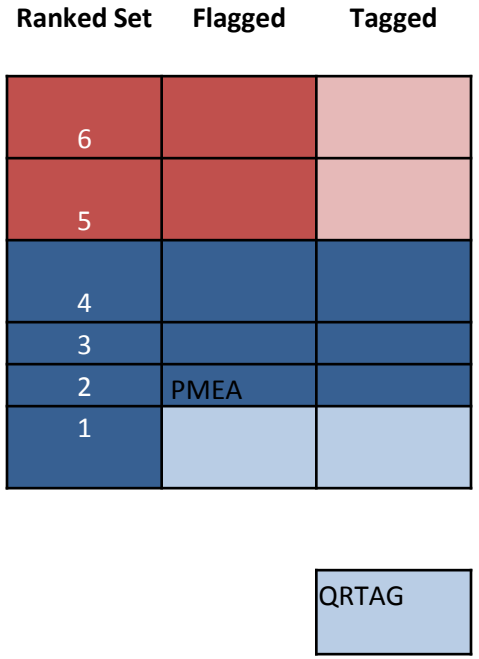
QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero

Net Imbalance Volume Tagging – Example 4

- If **$QNIV_{\phi}$ < 0** and **$QRTAG_{\phi}$** < 0:
  - Set **$TINIV_{uk\phi}$** = 0 for all **k** = M + 1 to N;

- **Values**
  - **$PMEA_{\phi}$ = P2**
  - **$QAO_{u5\phi}$ = 100**
  - **$\sum QAB_{uk\phi}$ x $TINIV_{uk\phi}$ = -200**
  - **$QRTAG_{\phi}$ = -100**

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged



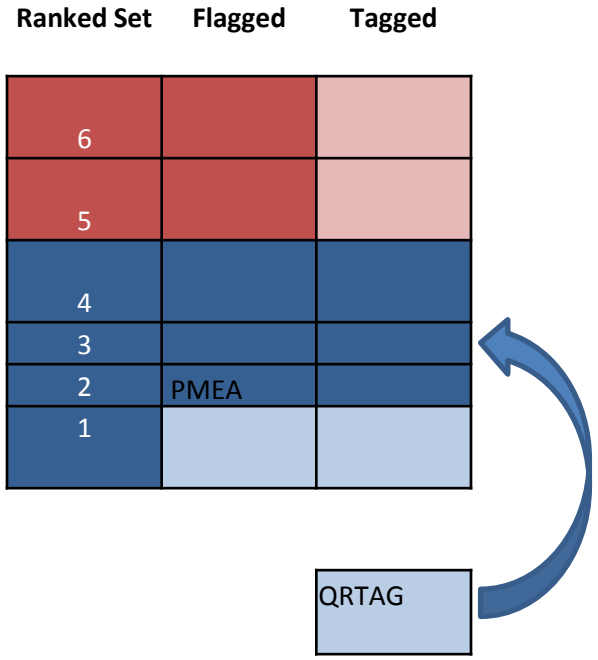
QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero

Net Imbalance Volume Tagging – Example 4

- If $\mathbf{QNIV_{\phi}} < 0$ and $\mathbf{QRTAG_{\phi}} < 0$:
  - Set $\mathbf{TINIV_{uk\phi}} = 0$ for all $\mathbf{k} = M + 1$ to N;
  - Find **b** and **β**, $\mathbf{QRTAG_{\phi}} = \sum_{k<b} \mathbf{QAO_{uk\phi}} \times \mathbf{TINIV_{uk\phi}} + \mathbf{\beta_{k=b}} \times \mathbf{QAO_{uk\phi}} \times \mathbf{TINIV_{uk\phi}}$;

- **Values**
  - $\mathbf{PMEA_{\phi}} = \mathbf{P2}$
  - $\mathbf{QAO_{u5\phi}} = \mathbf{100}$
  - $\sum \mathbf{QAB_{uk\phi}} \times \mathbf{TINIV_{uk\phi}} = \mathbf{-200}$
  - $\mathbf{QRTAG_{\phi}} = \mathbf{-100}$
  - $\mathbf{b} = \mathbf{3}$, $\mathbf{\beta} = \mathbf{1}$

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged

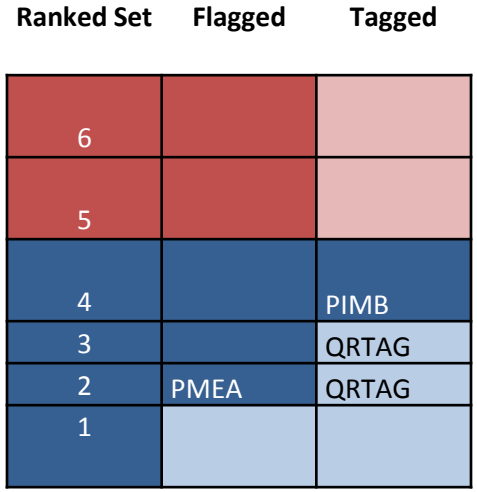


QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero

Net Imbalance Volume Tagging – Example 4

- If $\mathbf{QNIV_{\phi}} < 0$ and $\mathbf{QRTAG_{\phi}} < 0$:
  - Set $\mathbf{TINIV_{uk\phi}} = 0$ for all $\mathbf{k}$ = M + 1 to N;
  - Find $\mathbf{b}$ and $\boldsymbol{\beta}$, $\mathbf{QRTAG_{\phi}} = \sum_{k<b}\mathbf{QAO_{uk\phi}} \times \mathbf{TINIV_{uk\phi}} + \boldsymbol{\beta}_{\mathbf{k=b}} \times \mathbf{QAO_{uk\phi}} \times \mathbf{TINIV_{uk\phi}}$;
  - Set $\mathbf{TNIV_{uk\phi}} = 0$ for all $\mathbf{k}$ = 1 to $\mathbf{b}$ -1 , $\mathbf{TNIV_{uk\phi}} = 1 - \boldsymbol{\beta}$ for $\mathbf{k} = \mathbf{b}$;
- **Values**
  - $\mathbf{PMEA_{\phi}} = \mathbf{P2}$
  - $\mathbf{QAO_{u5\phi}} = \mathbf{100}$
  - $\sum\mathbf{QAB_{uk\phi}} \times \mathbf{TINIV_{uk\phi}} = \mathbf{-200}$
  - $\mathbf{QRTAG_{\phi}} = \mathbf{-100}$
  - $\mathbf{b} = \mathbf{3}, \boldsymbol{\beta} = \mathbf{1}$
  - **PIMB = P4**

Dark Red = +ve Unflagged / Untagged
Light Red = +ve Flagged / Tagged
Dark Blue = -ve Unflagged / Untagged
Light Blue = -ve Flagged / Tagged



QRTAG is the sum of the initial tagged bids & offers. Indicates how much tagging is required to bring sum of tagged bids & offers to zero

Net Imbalance Volume Tagging – Summary

QNIV	QRTAG	Description	Action	Where
Positive	Positive	Overtagged Offers	Untag Offers	Middle Up
Positive	Negative	Undertagged Offers	Tag Offers	Top Down
Negative	Positive	Undertagged Bids	Tag Bids	Bottom Up
Negative	Negative	Overtagged Bids	Untag Bids	Middle Down

Topic 8: Price Average Reference Tagging

Price Average Reference Tagging

- The form of the equations for PAR Tagging in Appendix N are generalised to work in all cases, but may not be possible to easily see what it is they are doing or how they solve;

- The following is an explanation of what the equations are trying to do in words, it is not in very Plain-English but it gives rules of thumb which can be applied when trying to understand the equation;

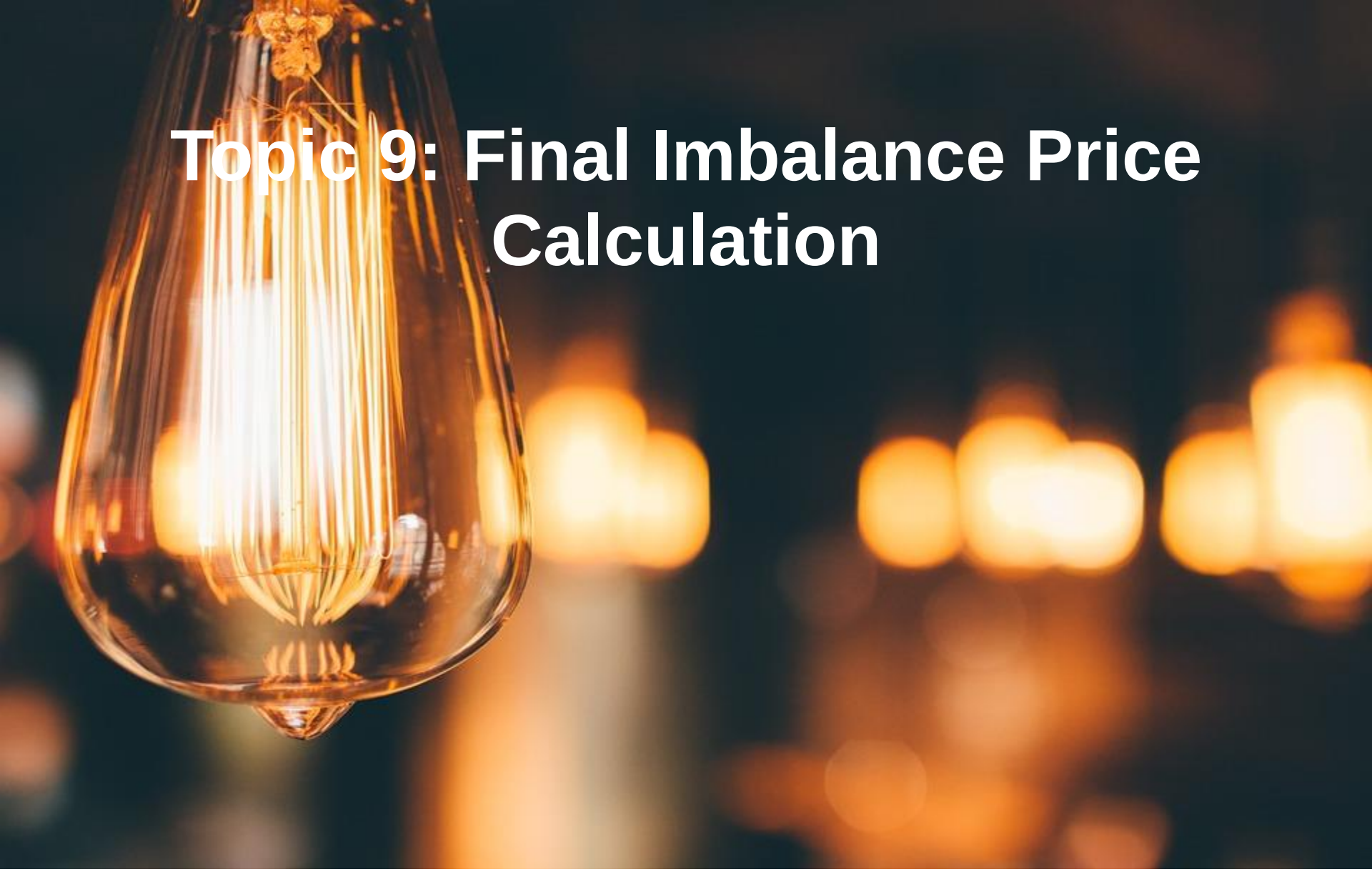
- When discussing the “bottom”, “middle” and “top”, this is the position in the Ranked Set, where the “bottom” is the lowest priced Accepted Bid, the “middle” is where the final Accepted Bid in the ranked set and the first Accepted Offer in the ranked set meet, and the “top” is the highest priced Accepted Offer.

Price Average Reference Tagging

- TPAR applied to (QAO x TNIV) and (QAB x TNIV) rather than QAO and QAB. This ensures that TPAR applies to untagged volumes as opposed to volumes already tagged during NIV Tagging stage. Therefore the average price considers a volume of untagged actions.

Price Average Reference Tagging

- Determine Price Average Reference Tag (TPAR) for each unit for each order:
  - If the absolute value of QNIV is less than QPAR, then set TPAR equal to 1 for all actions;
  - If QNIV is positive, looking to PAR tag offers. If QNIV is negative, looking to PAR tag bids;
    - If looking at offers, tag from the middle up to the top:
      - From the top down, find the transitional offer which is not NIV tagged, b, where the sum of all prior offers which are not NIV tagged and part of this offer (the proportion of which is β) equal QPAR if it was positive;
      - Tag (TPAR = 0) all offers from the middle up until the transitional offer, set TPAR = 1 for all bids and all offers from after the transitional offer up to the top, and partially tag (TPAR = β) the transitional offer.
    - If looking at bids, tag from the middle down to the bottom:
      - From the bottom up, find the transitional bid which is not NIV tagged, b, where the sum of all prior bids which are not NIV tagged and part of this bid (the proportion of which is β) equal QPAR if it was negative;
      - Tag (TPAR = 0) all bids from the middle down until the transitional bid, set TPAR = 1 for all offers and all bids from after the transitional bid down to the bottom , and partially tag (TPAR = β) the transitional bid.



Topic 9: Final Imbalance Price Calculation

Final Imbalance Price Calculation

- Following determination of the PAR Tag for each action, a combination of NIV Tag and PAR Tag are created to identify which actions should be included in calculating the final price:
  - The Imbalance Price Tag (TIP) for each action is calculated by multiplying TNIV and TPAR, so that if either are zero, the action is excluded from the calculation;
  - The final calculation considers a quantity-weighted average of the price of all actions which are not NIV or PAR tagged.

Final Imbalance Price Calculation

- The Initial Imbalance Price is calculated as a quantity-weighted average of the price of all actions which are not NIV or PAR tagged:

$$\mathrm{PIIMB}_{\varphi} = \frac{\sum_{k}\left(\mathrm{PRBO}_{uk\varphi} \times \mathrm{QAO}_{uk\varphi} \times \mathrm{TIP}_{uk\varphi} - \mathrm{PRBO}_{uk\varphi} \times \mathrm{QAB}_{uk\varphi} \times \mathrm{TIP}_{uk\varphi}\right)}{\sum_{k}\left(\mathrm{QAO}_{uk\varphi} \times \mathrm{TIP}_{uk\varphi} - \mathrm{QAB}_{uk\varphi} \times \mathrm{TIP}_{uk\varphi}\right)}$$

- The Imbalance Price for Imbalance Pricing Period ensures that if the Administered Scarcity Price is higher, it sets the Imbalance Price:

$$PIMB_{\varphi} = Max\left(PIIMB_{\varphi}, PAS_{\varphi}\right)$$

- Imbalance Settlement Price for Imbalance Settlement Period is the simple average of all Imbalance Prices for Imbalance Pricing Periods within the Imbalance Settlement Period:

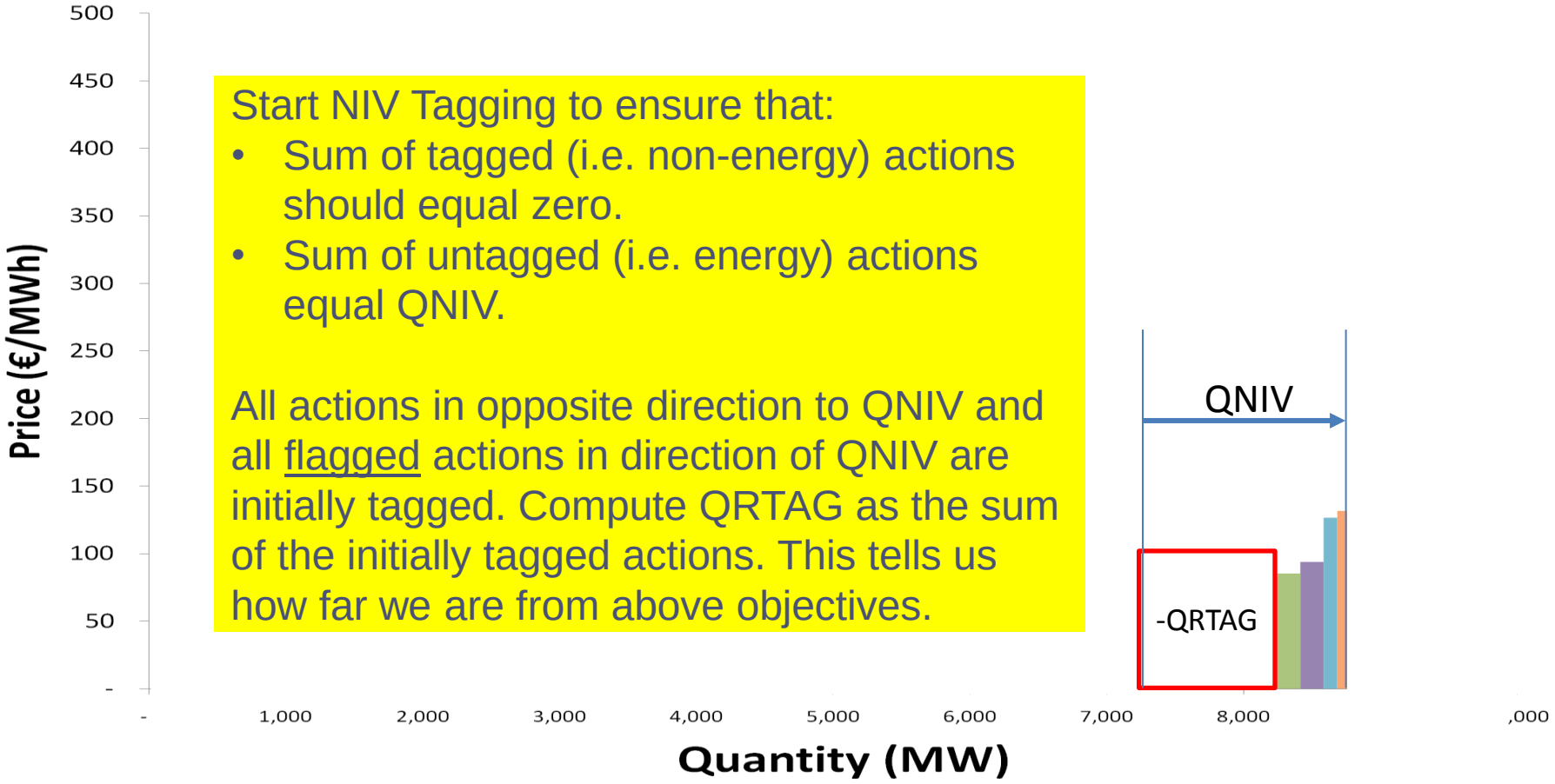
$$PIMB_{\gamma} = \sum_{\varphi \in \gamma} PIMB_{\varphi} \times \frac{DIPP}{DISP}$$

Day in the Life 1a: 17:25 (Imbalance Pricing)

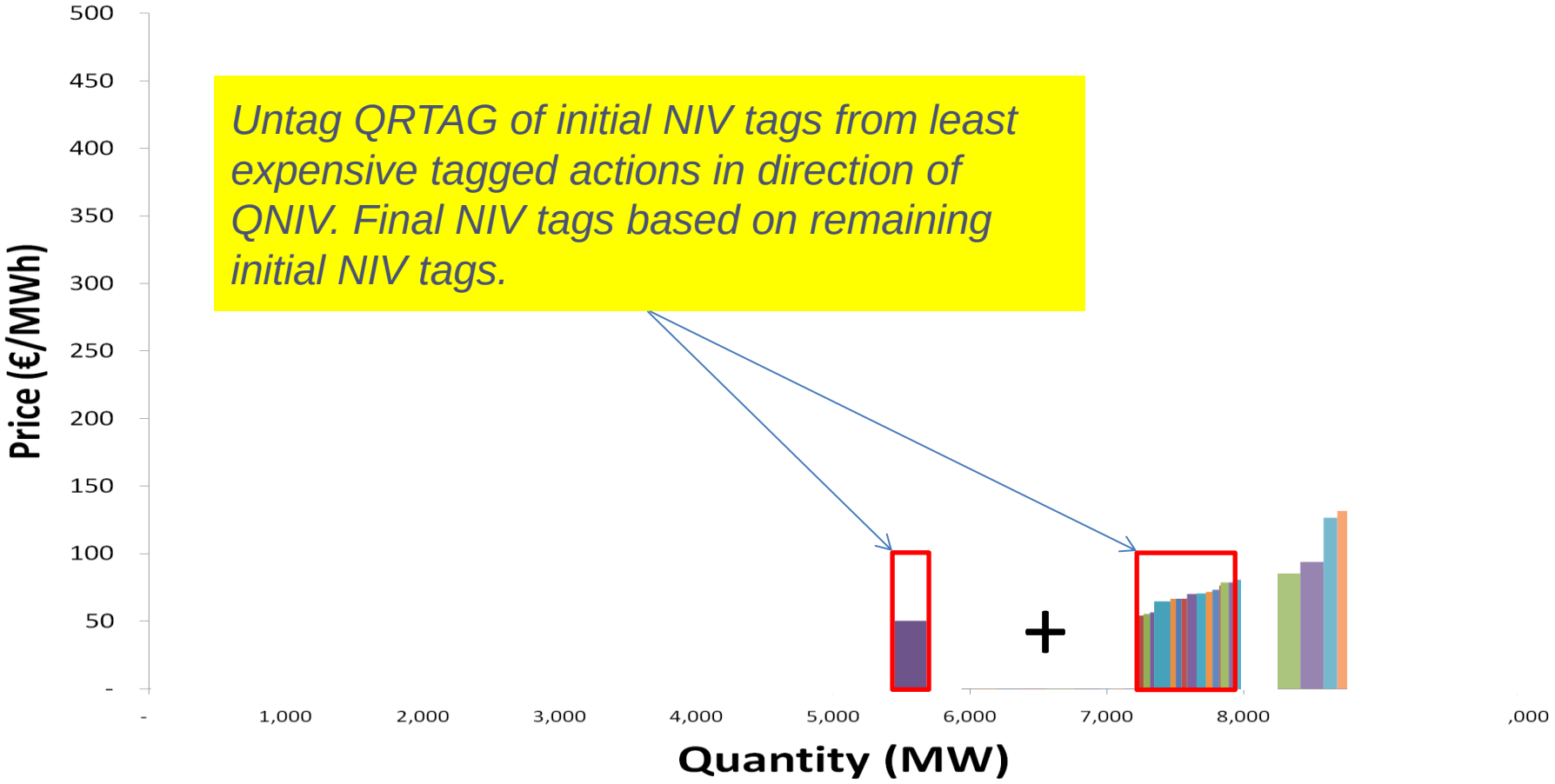
Start NIV Tagging to ensure that:

- Sum of tagged (i.e. non-energy) actions should equal zero.
- Sum of untagged (i.e. energy) actions equal QNIV.

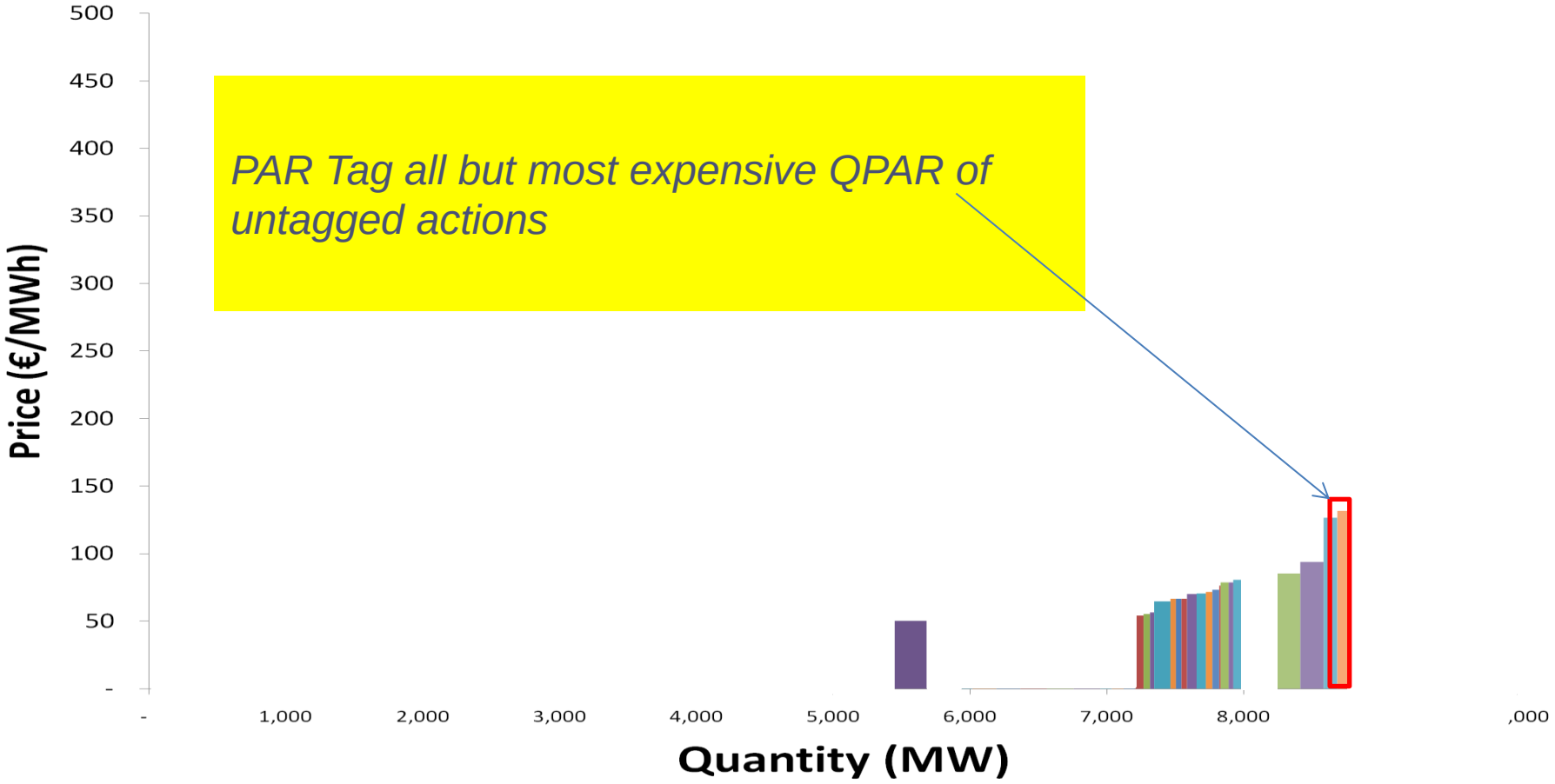
All actions in opposite direction to QNIV and all flagged actions in direction of QNIV are initially tagged. Compute QRTAG as the sum of the initially tagged actions. This tells us how far we are from above objectives.



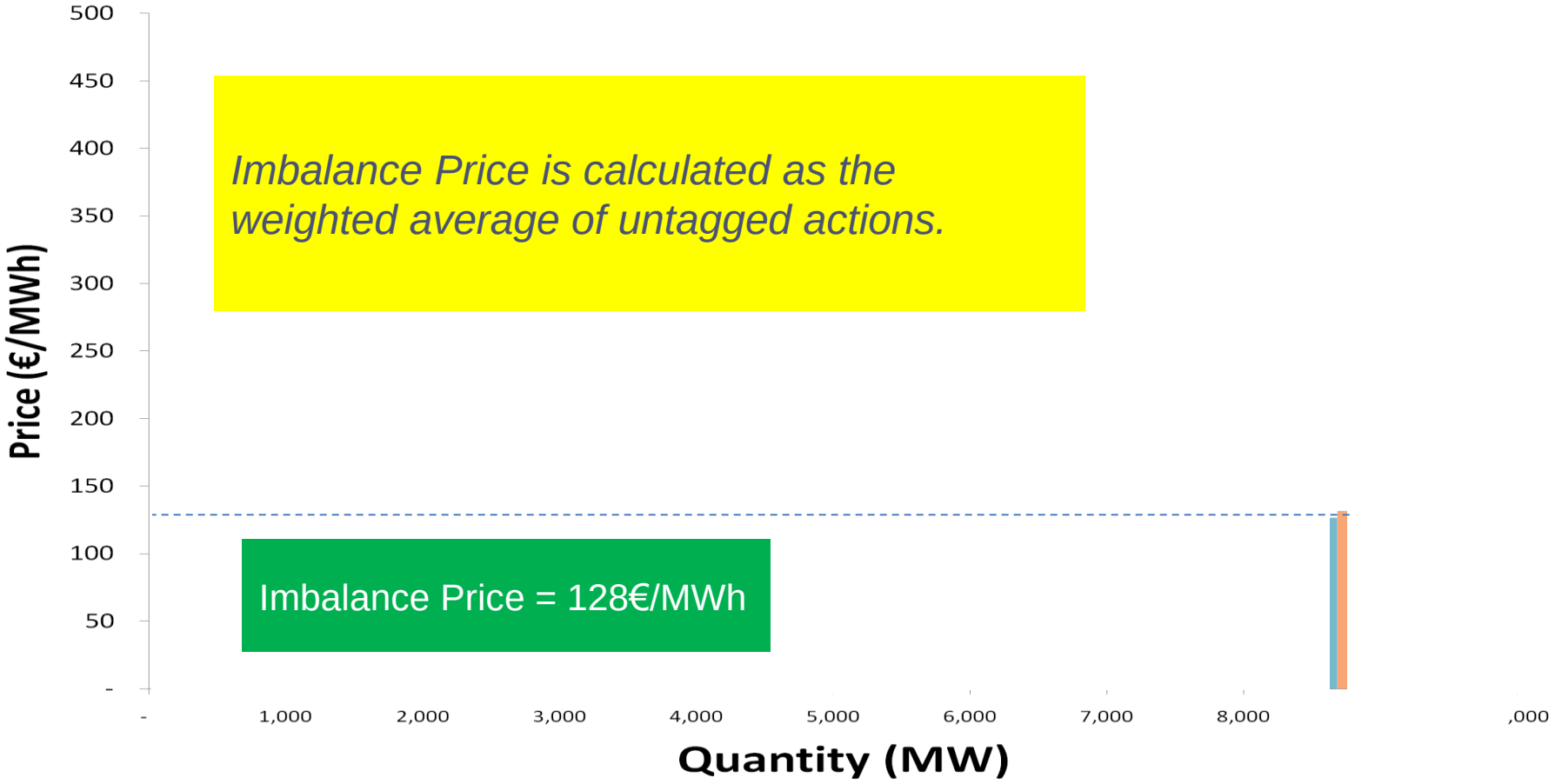
Day in the Life 1a: 17:25 (Imbalance Pricing)



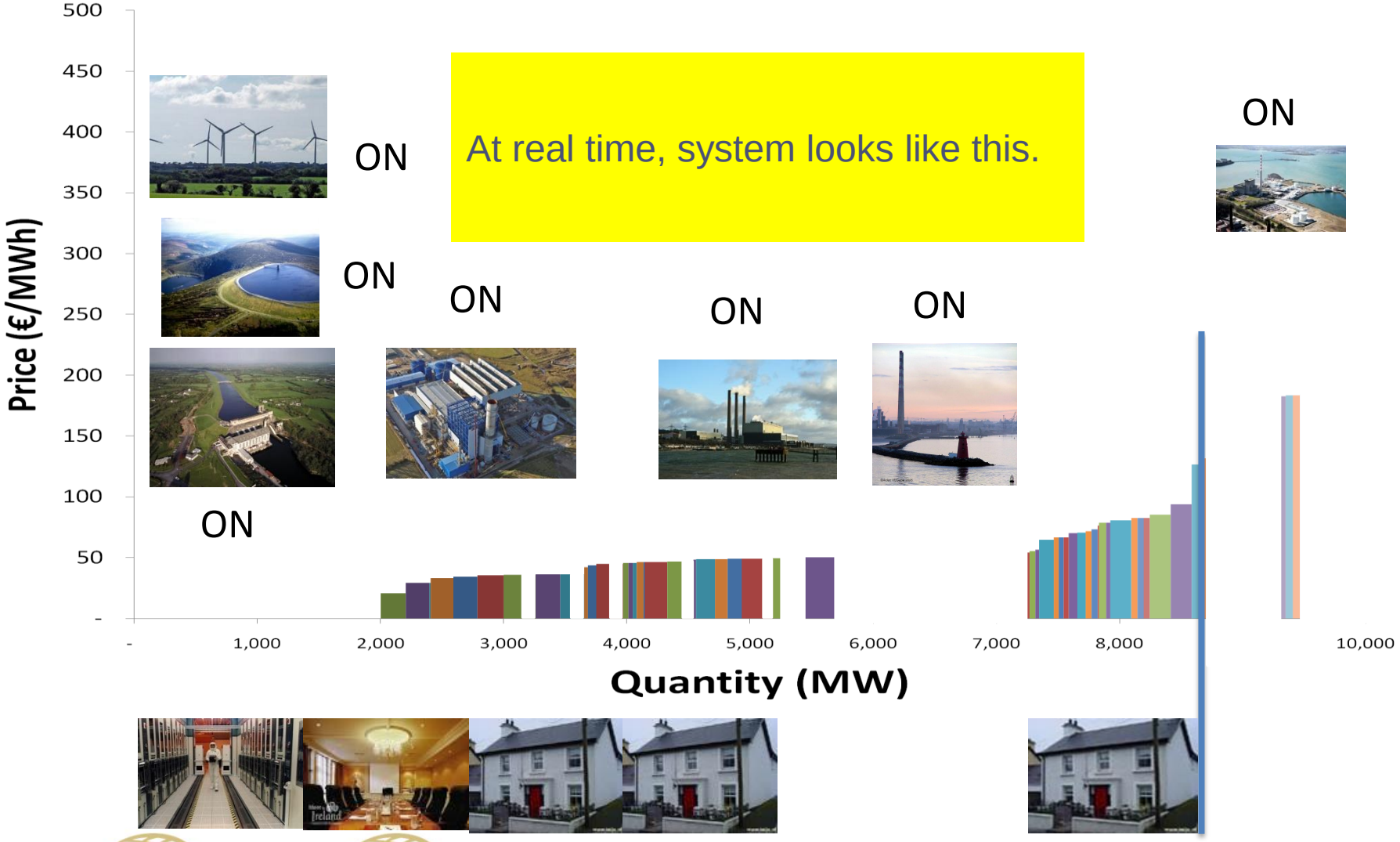
Day in the Life 1a: 17:25 (Imbalance Pricing)



Day in the Life 1a: 17:25 (Imbalance Pricing)



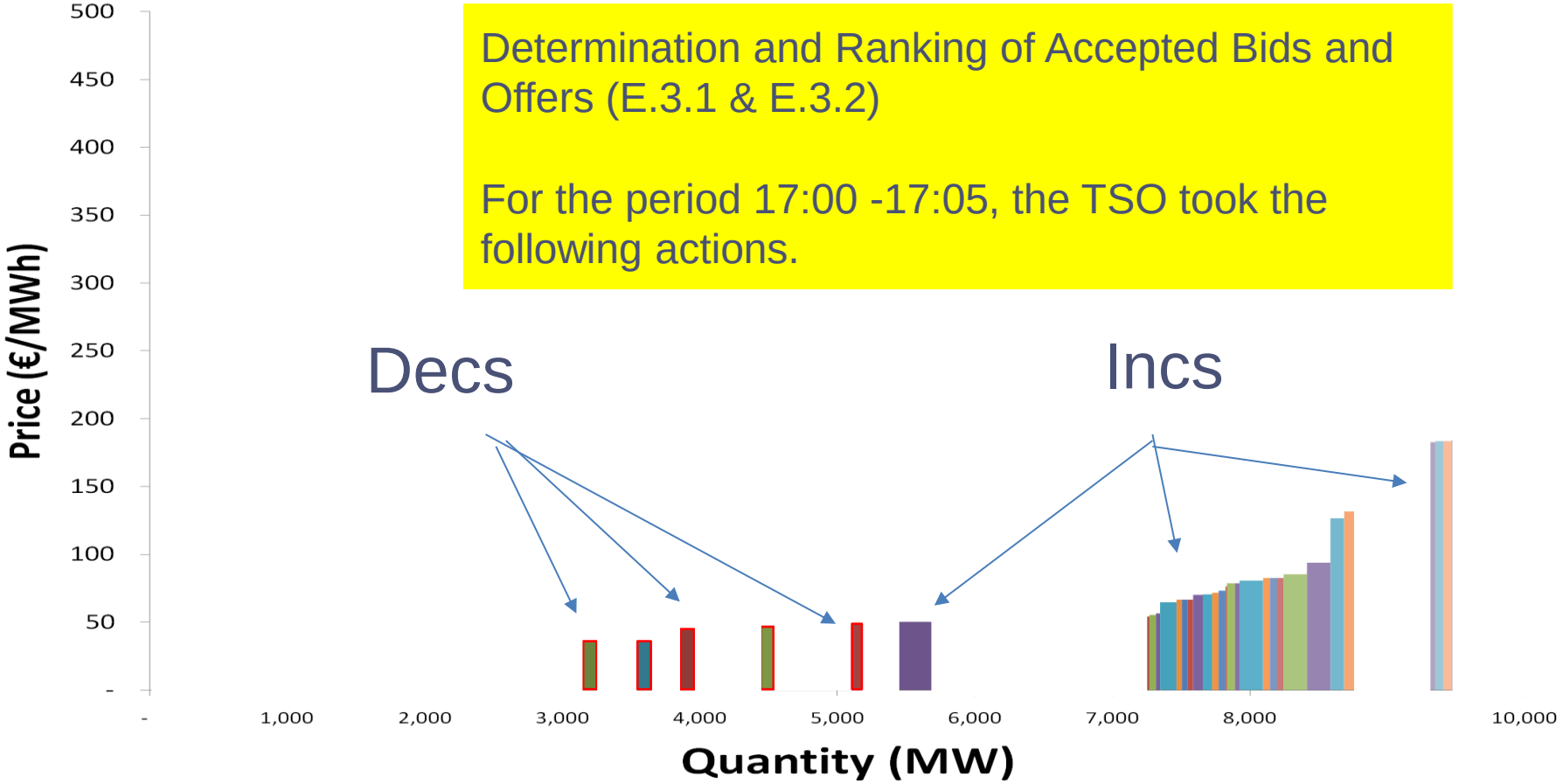
Day in the Life 1c: 17:00 (Real time)



Day in the Life 1c: 17:25 (Imbalance Pricing)

Determination and Ranking of Accepted Bids and Offers (E.3.1 & E.3.2)

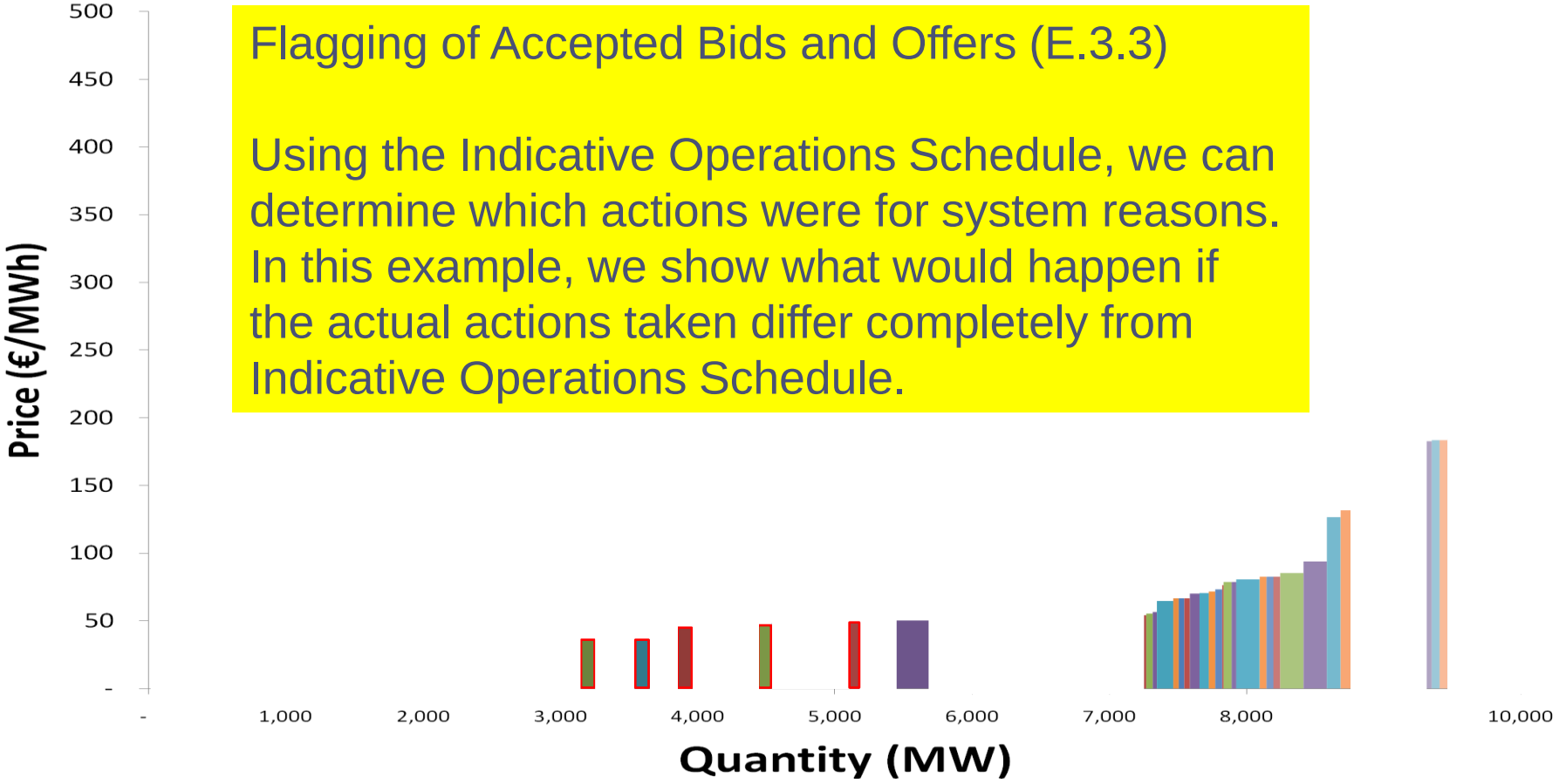
For the period 17:00 -17:05, the TSO took the following actions.



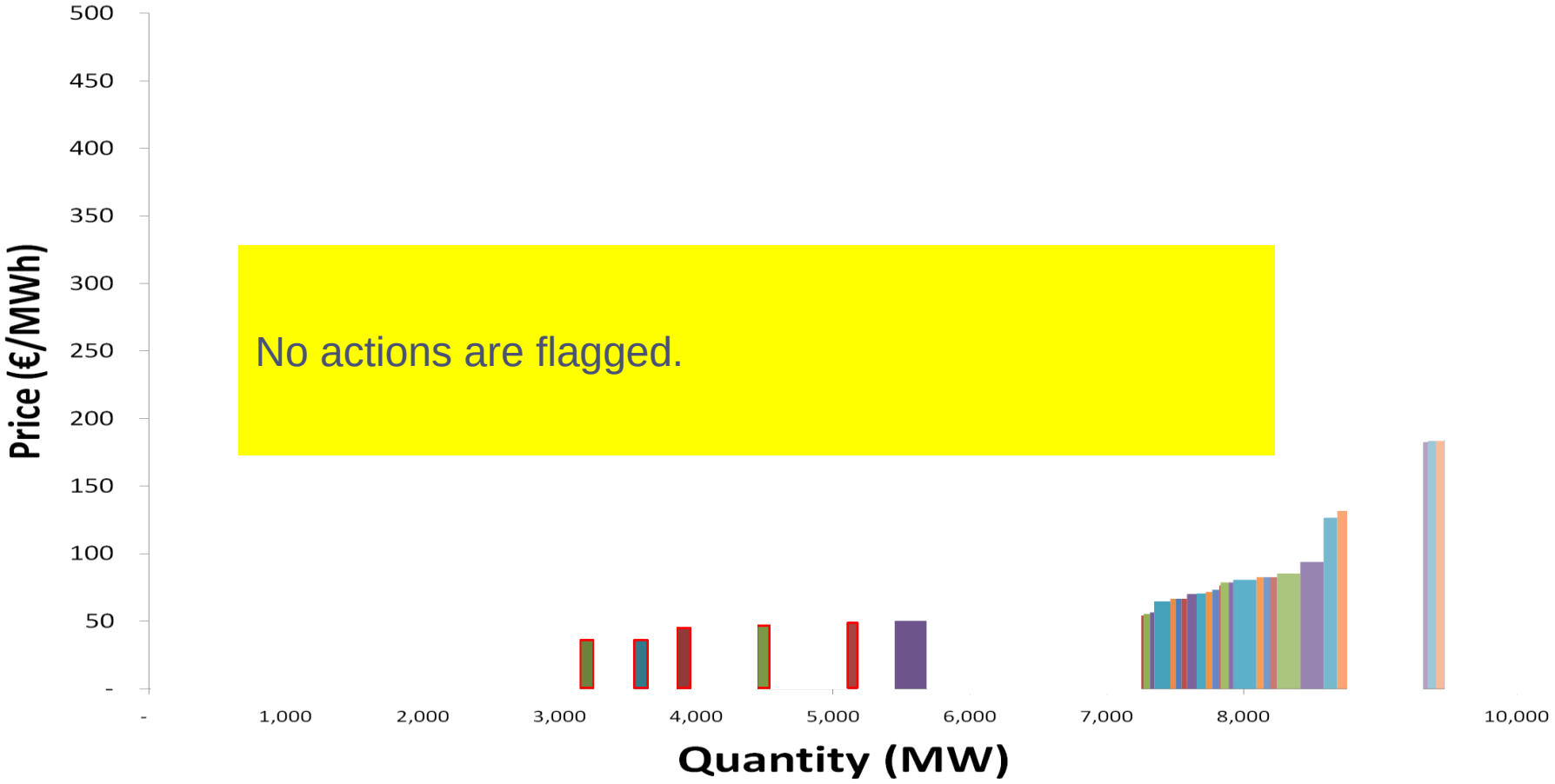
Day in the Life 1c: 17:25 (Imbalance Pricing)

Flagging of Accepted Bids and Offers (E.3.3)

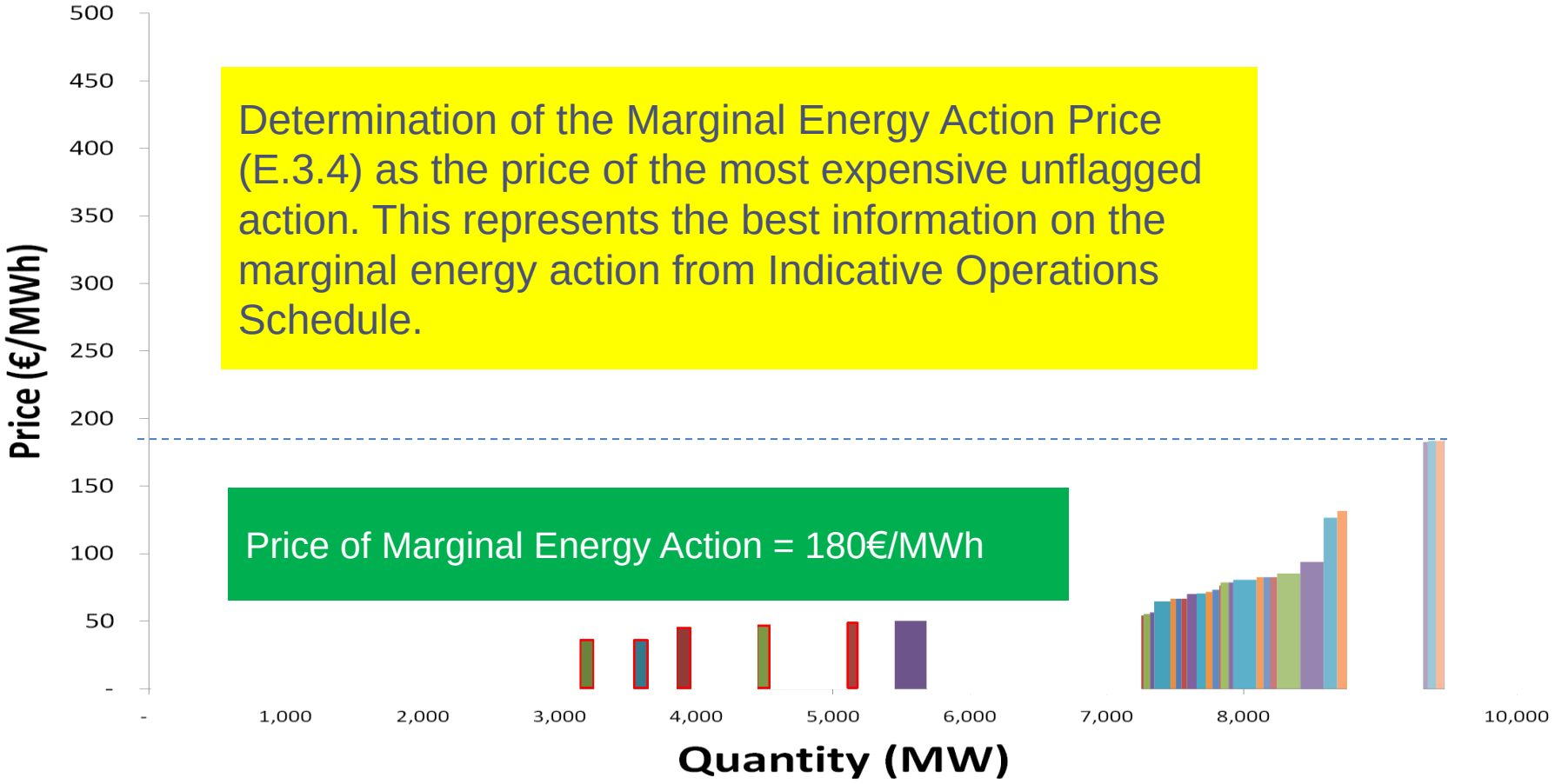
Using the Indicative Operations Schedule, we can determine which actions were for system reasons. In this example, we show what would happen if the actual actions taken differ completely from Indicative Operations Schedule.



Day in the Life 1c: 17:25 (Imbalance Pricing)



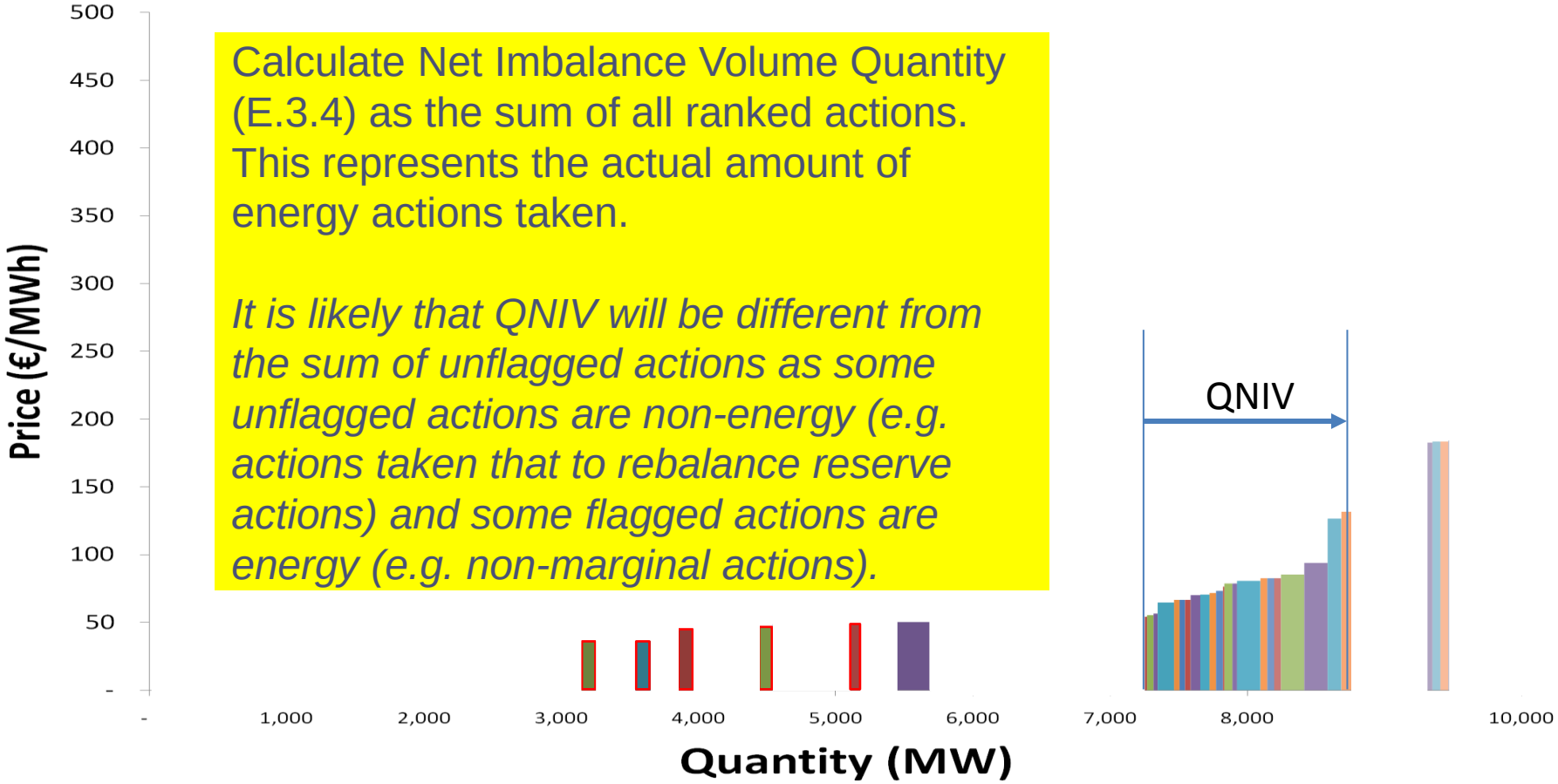
Day in the Life 1c: 17:25 (Imbalance Pricing)



Day in the Life 1c: 17:25 (Imbalance Pricing)

Calculate Net Imbalance Volume Quantity (E.3.4) as the sum of all ranked actions. This represents the actual amount of energy actions taken.

It is likely that QNIV will be different from the sum of unflagged actions as some unflagged actions are non-energy (e.g. actions taken that to rebalance reserve actions) and some flagged actions are energy (e.g. non-marginal actions).

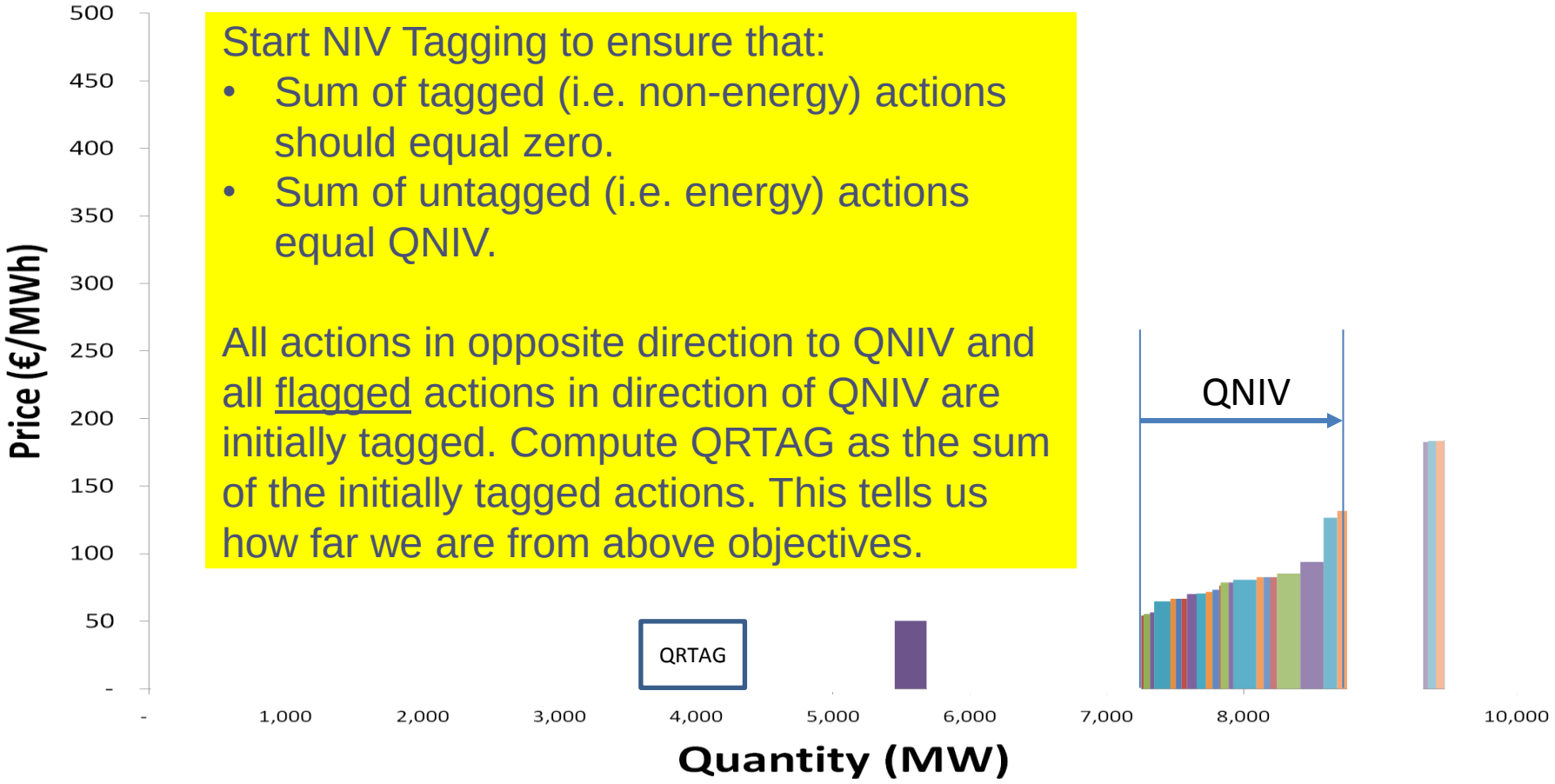


Day in the Life 1c: 17:25 (Imbalance Pricing)

Start NIV Tagging to ensure that:

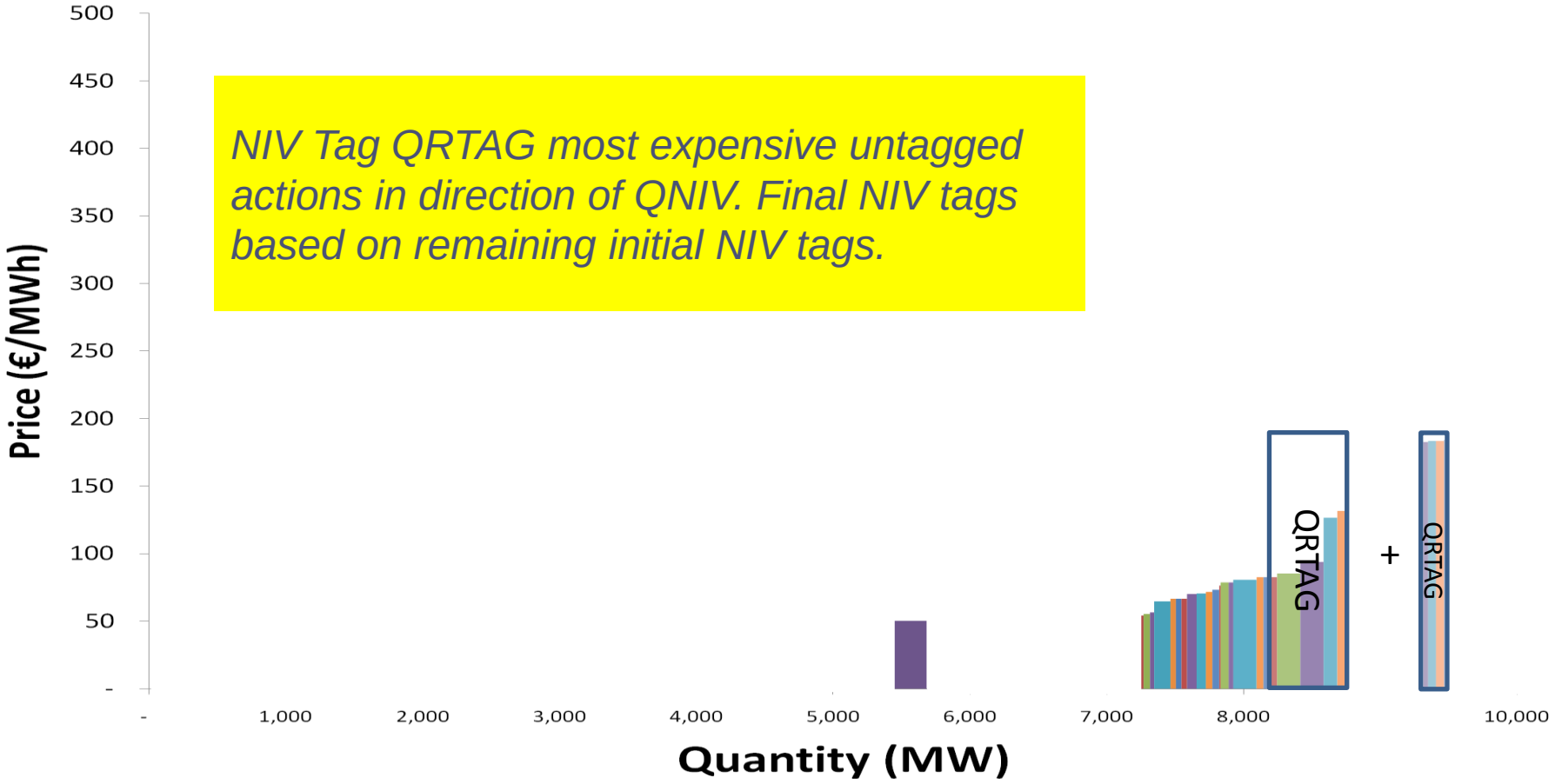
- Sum of tagged (i.e. non-energy) actions should equal zero.
- Sum of untagged (i.e. energy) actions equal QNIV.

All actions in opposite direction to QNIV and all flagged actions in direction of QNIV are initially tagged. Compute QRTAG as the sum of the initially tagged actions. This tells us how far we are from above objectives.

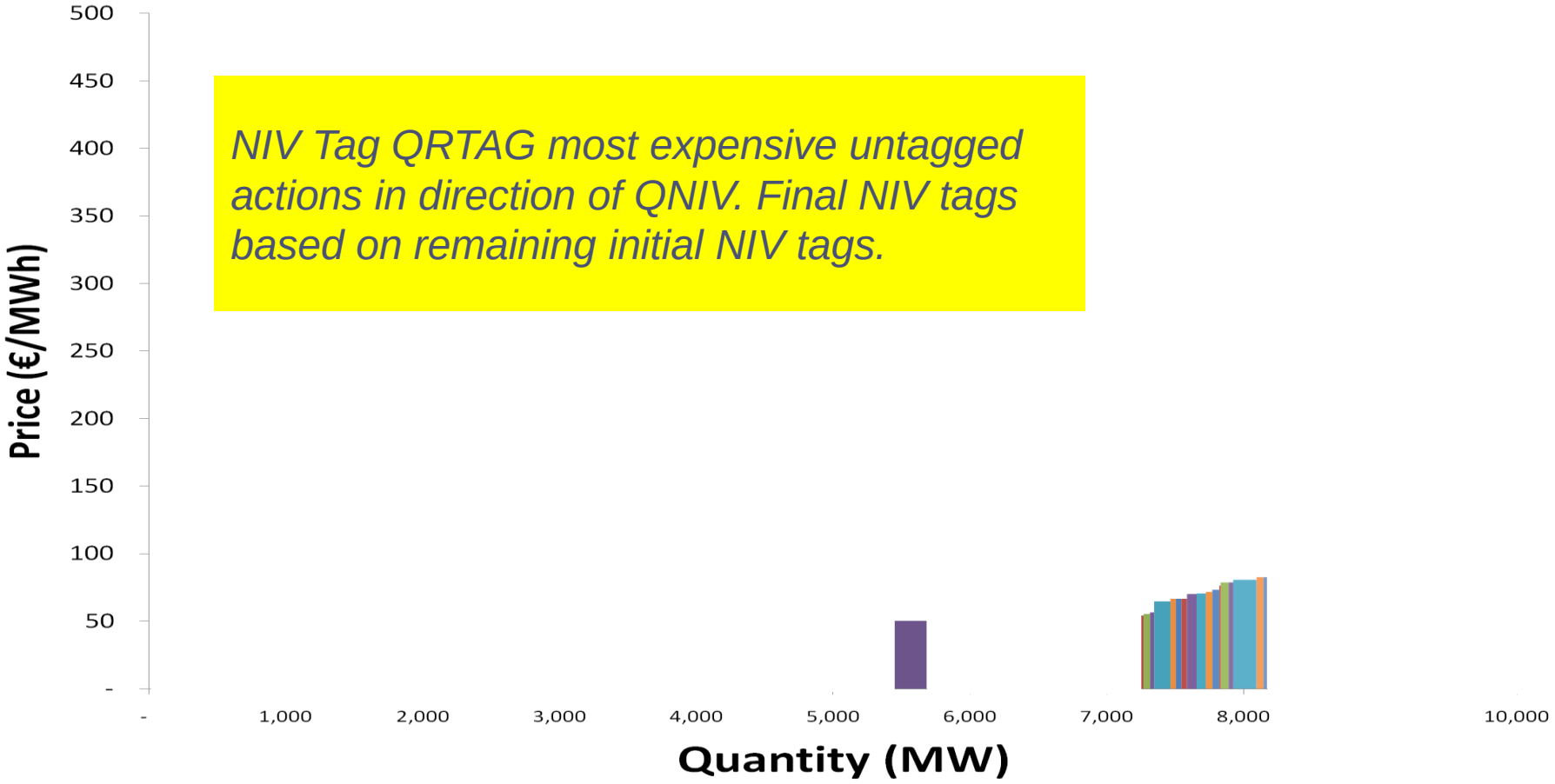


Day in the Life 1c: 17:25 (Imbalance Pricing)

NIV Tag QRTAG most expensive untagged actions in direction of QNIV. Final NIV tags based on remaining initial NIV tags.

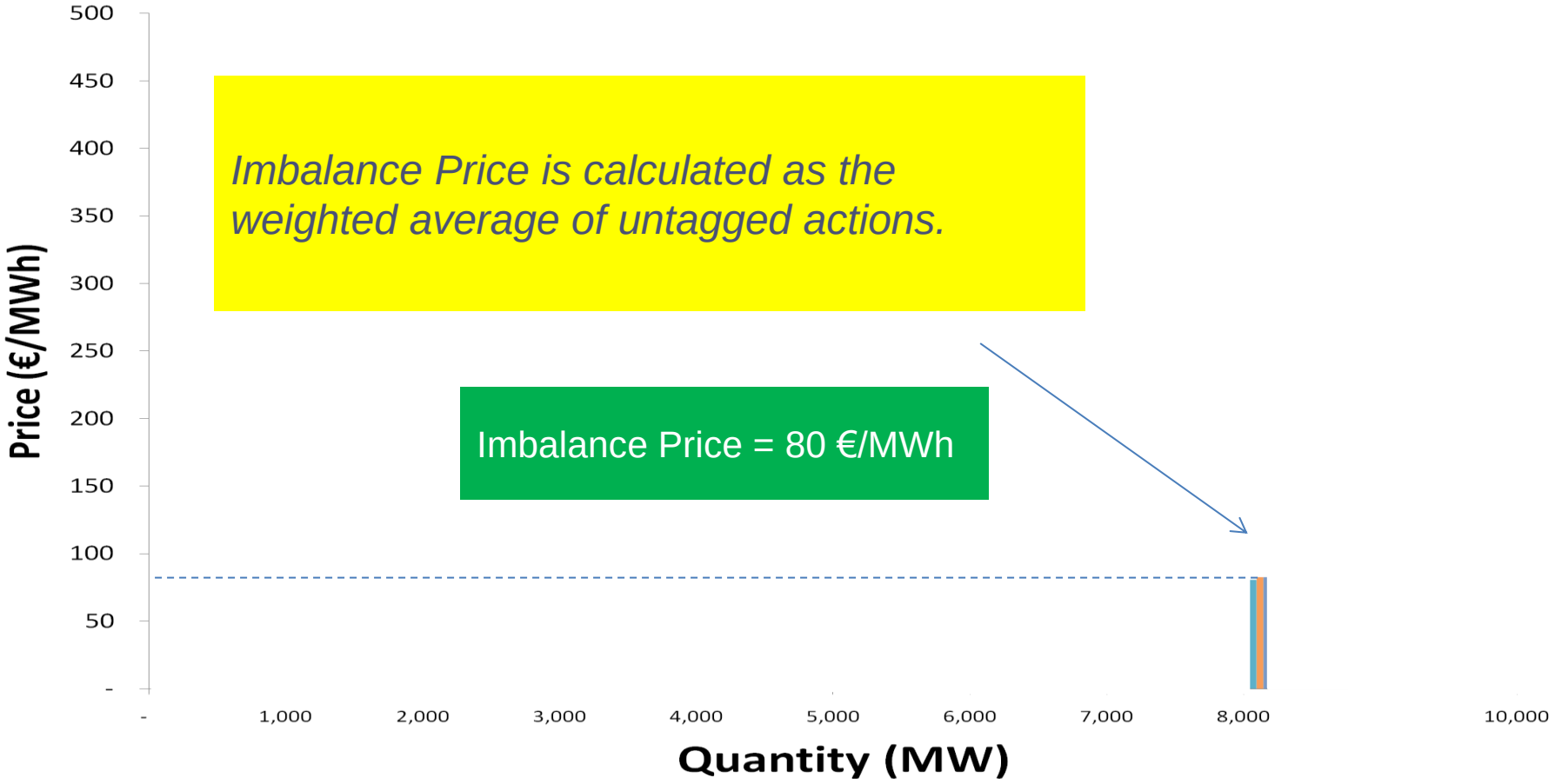


Day in the Life 1c: 17:25 (Imbalance Pricing)

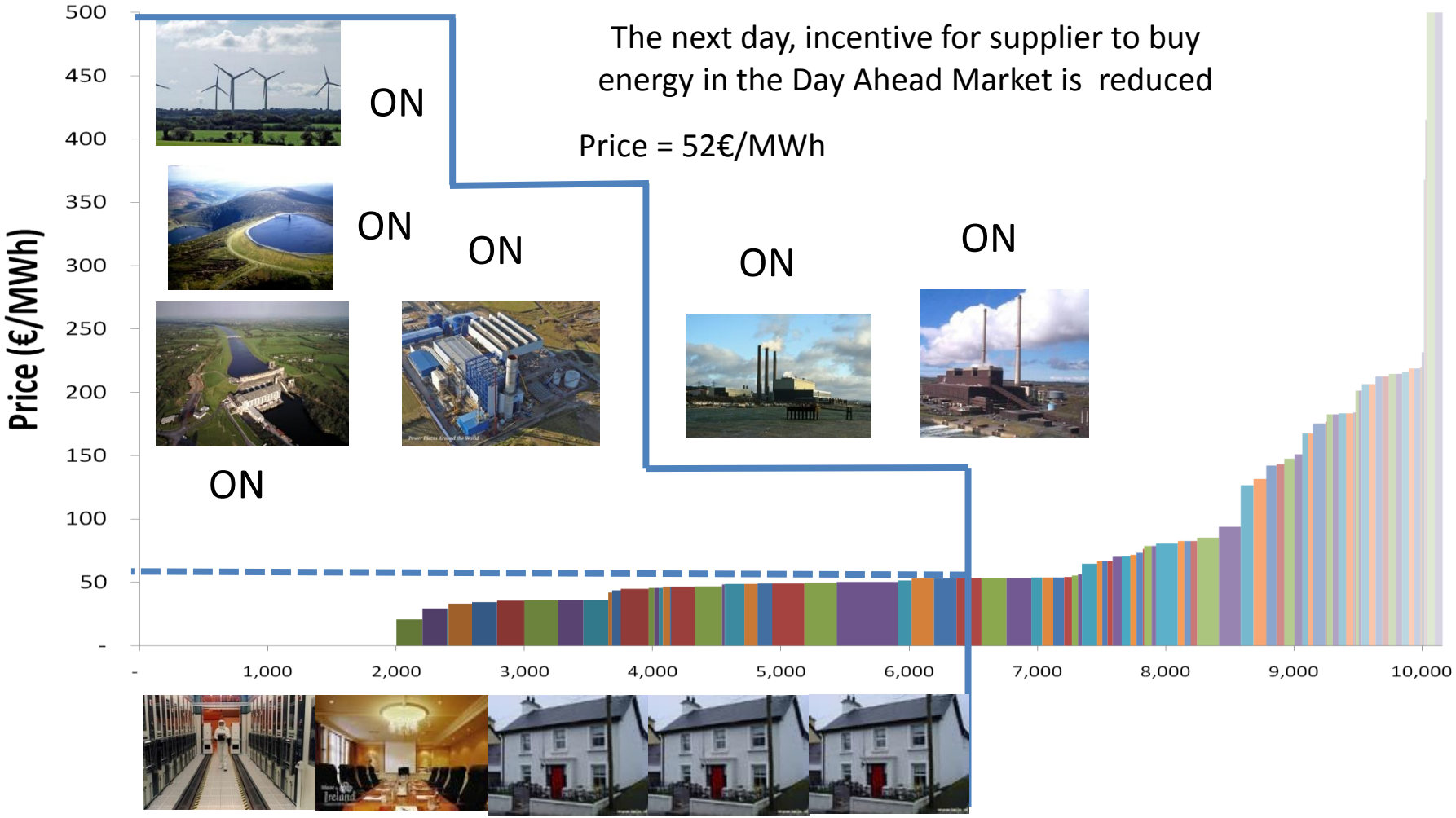


NIV Tag QRTAG most expensive untagged actions in direction of QNIV. Final NIV tags based on remaining initial NIV tags.

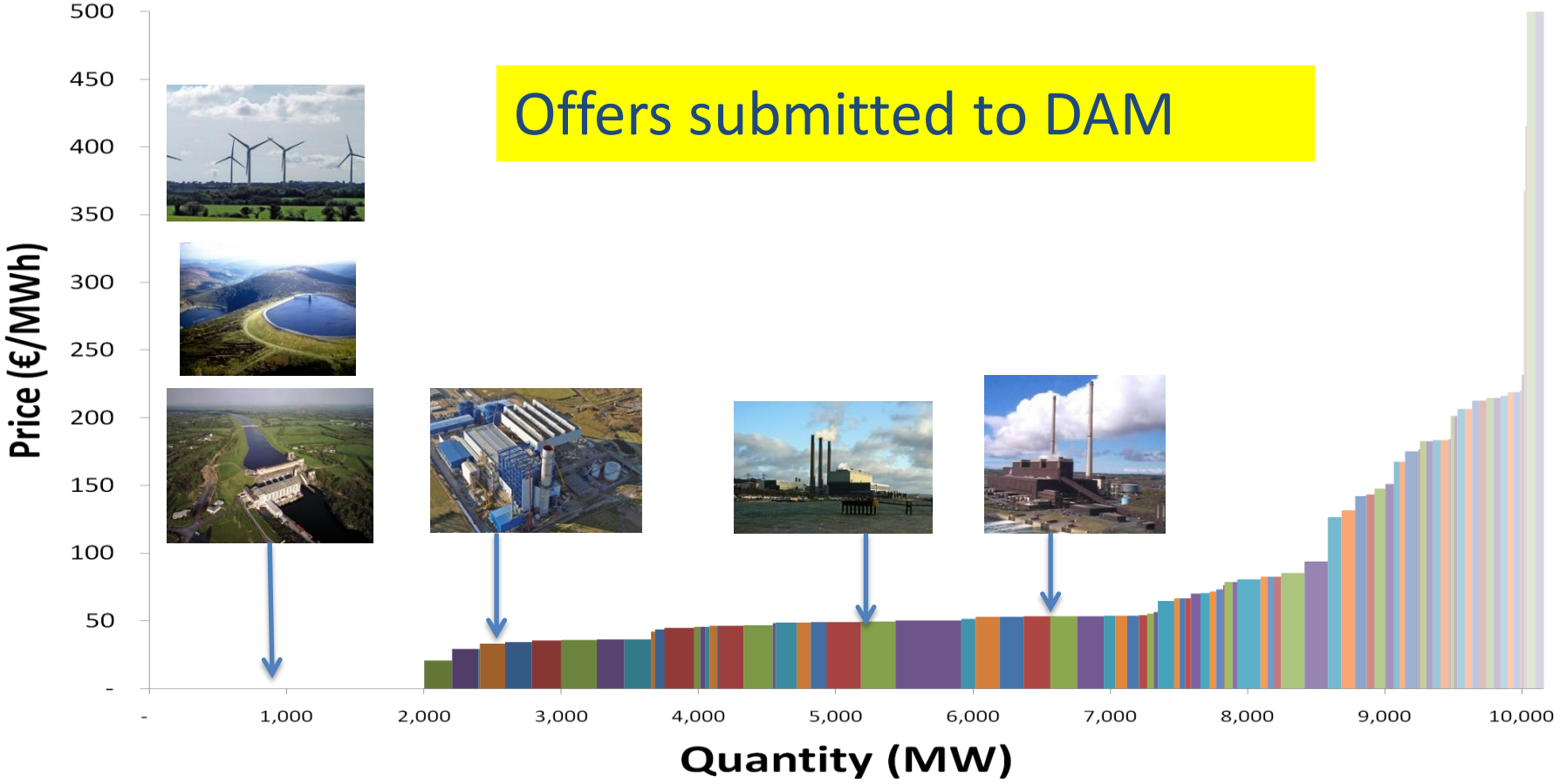
Day in the Life 1c: 17:25 (Imbalance Pricing)



The Next Day


The next day, incentive for supplier to buy energy in the Day Ahead Market is reduced
Price = 52€/MWh
ON
ON
ON
ON
ON
ON
Price (€/MWh)
500
450
400
350
300
250
200
150
100
50
-
-
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000

Day in the Life 2: D-1 10:00



Day in the Life 2: D-1 11:00

Day Ahead Market (17:00 – 18:00 D)

Price = 52€/MWh


ON


ON


ON


ON

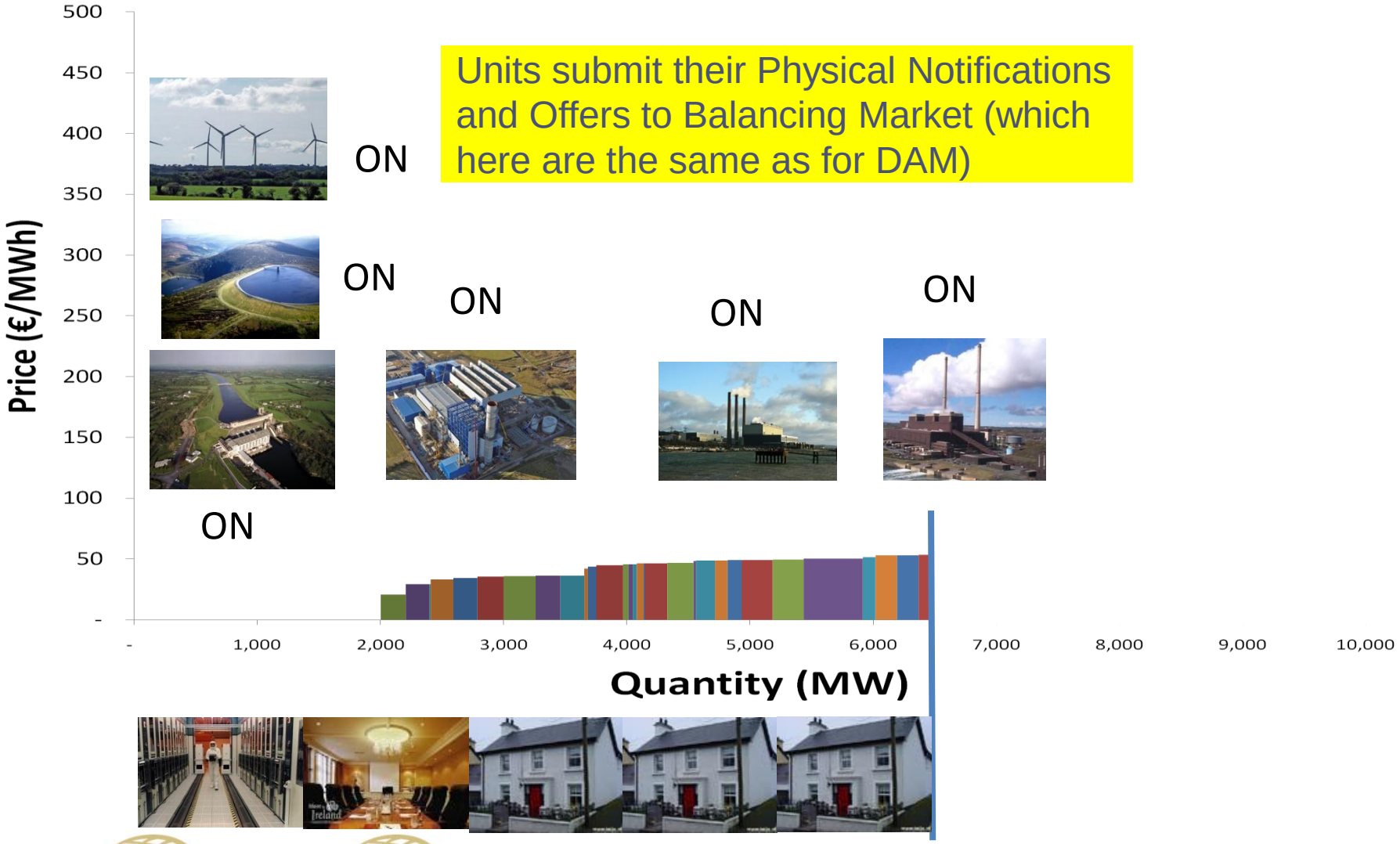

ON



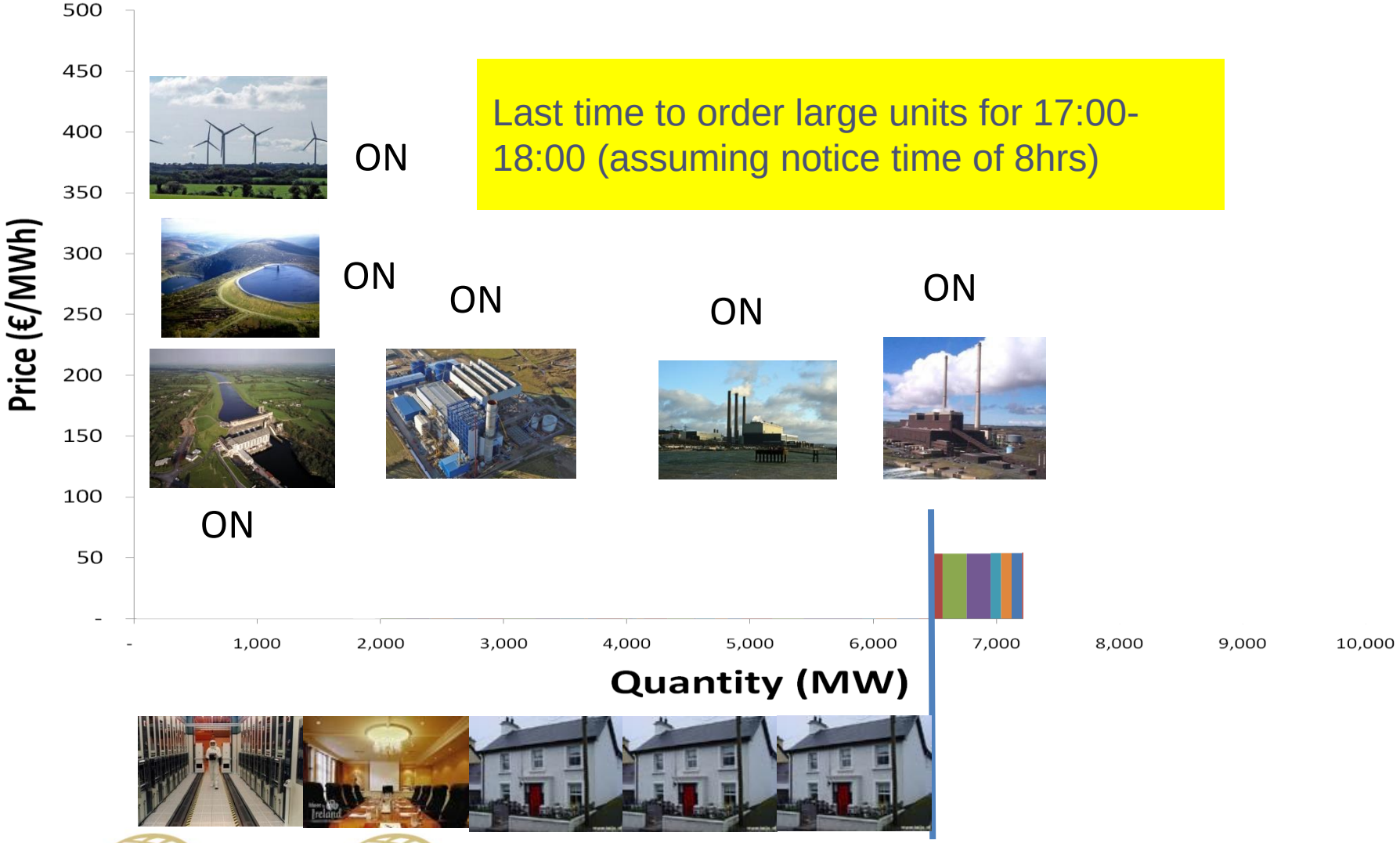


EIRGRID semo SONI
Single Electricity Market Operator

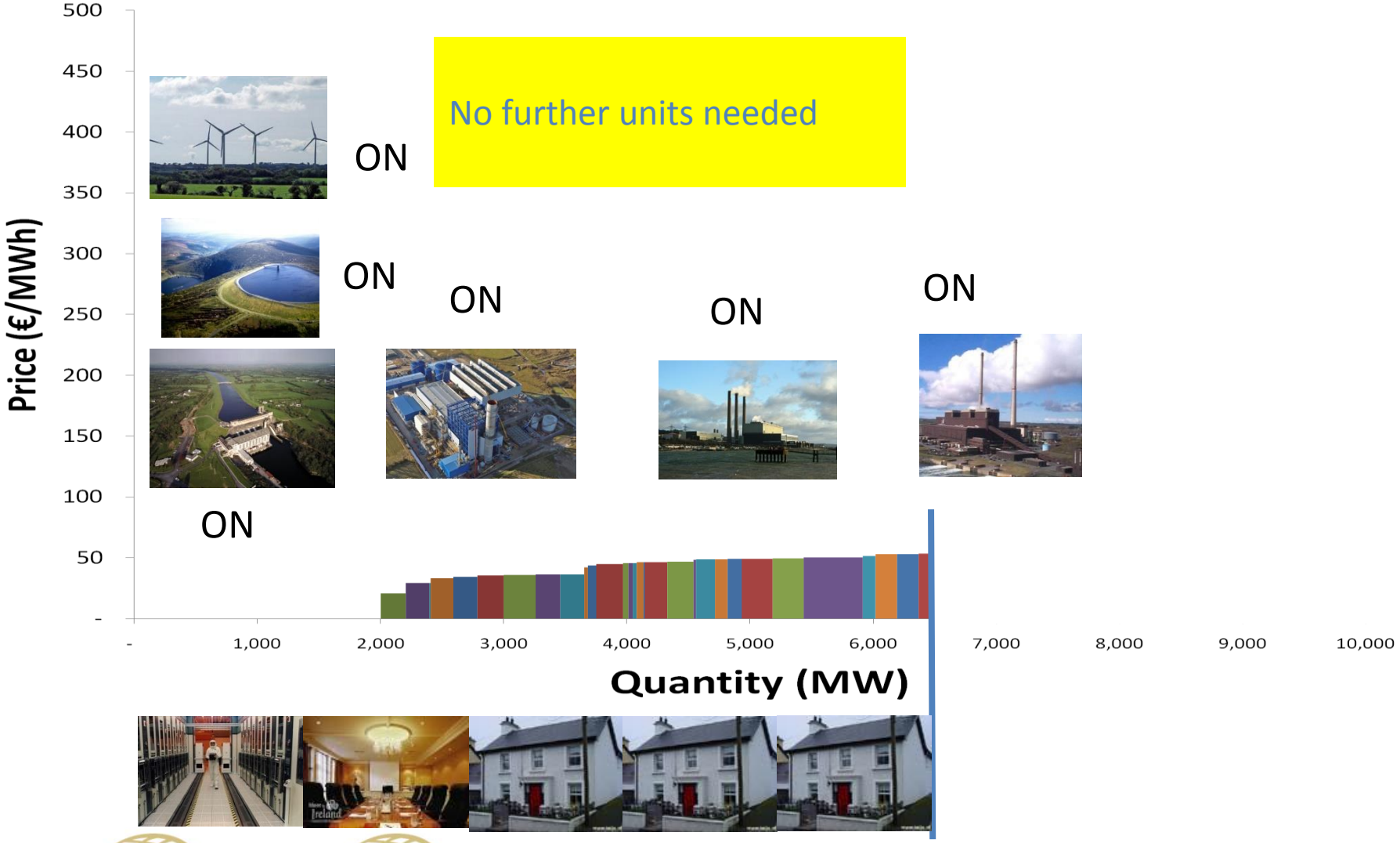
Day in the Life 2: D-1 13:30



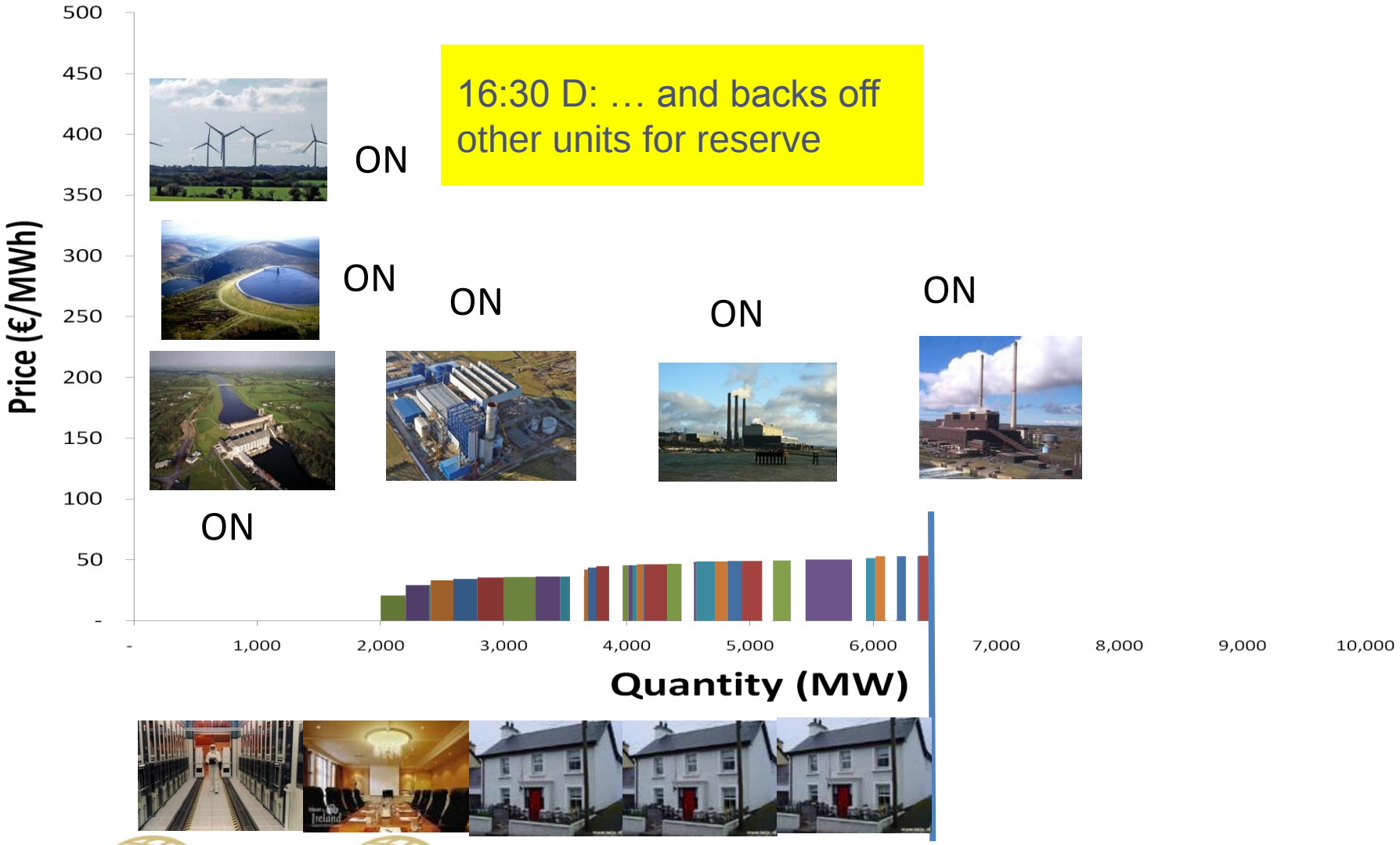
Day in the Life 2: 09:00



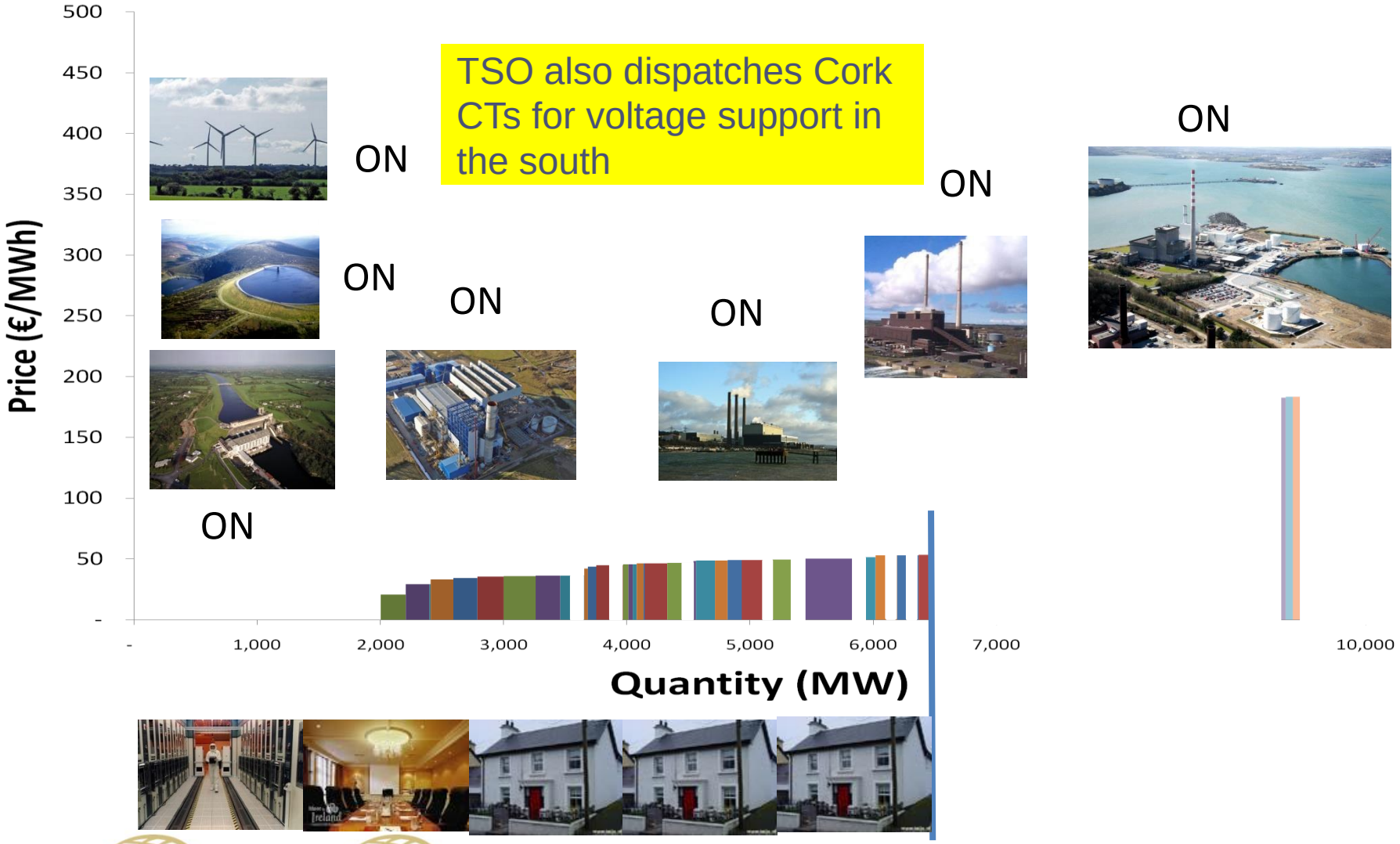
Day in the Life 2: 09:00



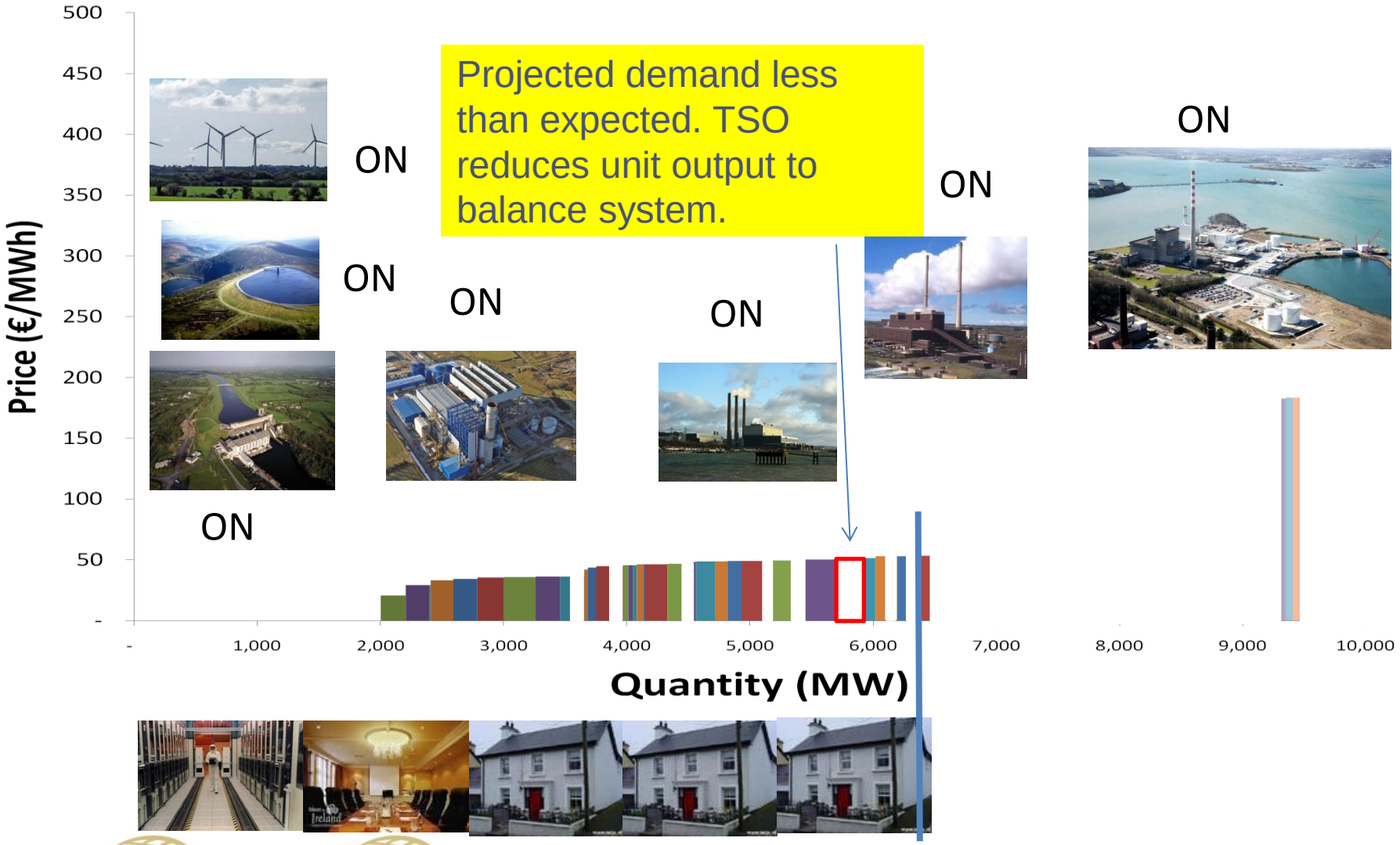
Day in the Life 2: 16:30



Day in the Life 2: 16:30



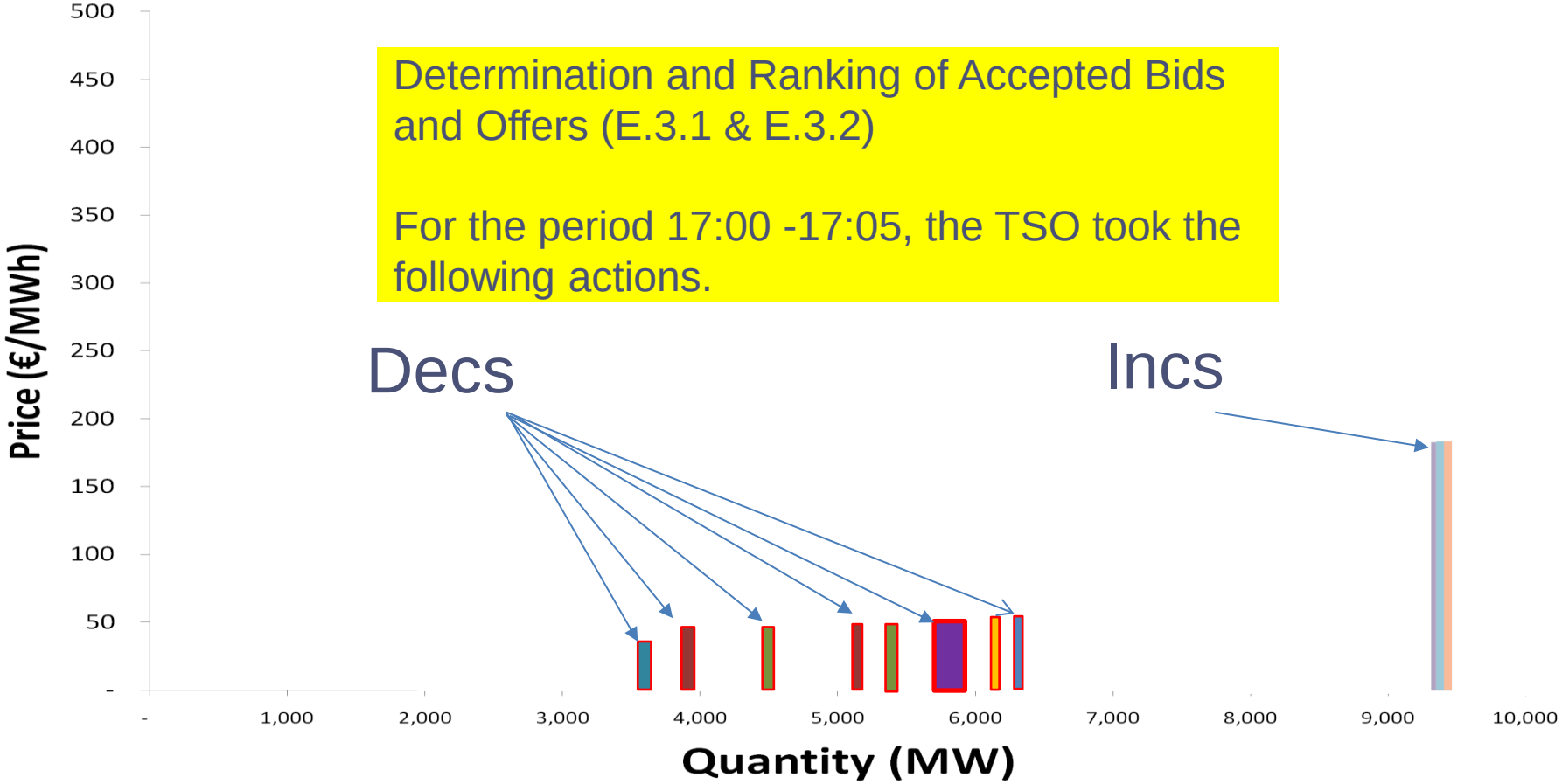
Day in the Life 2: 16:50



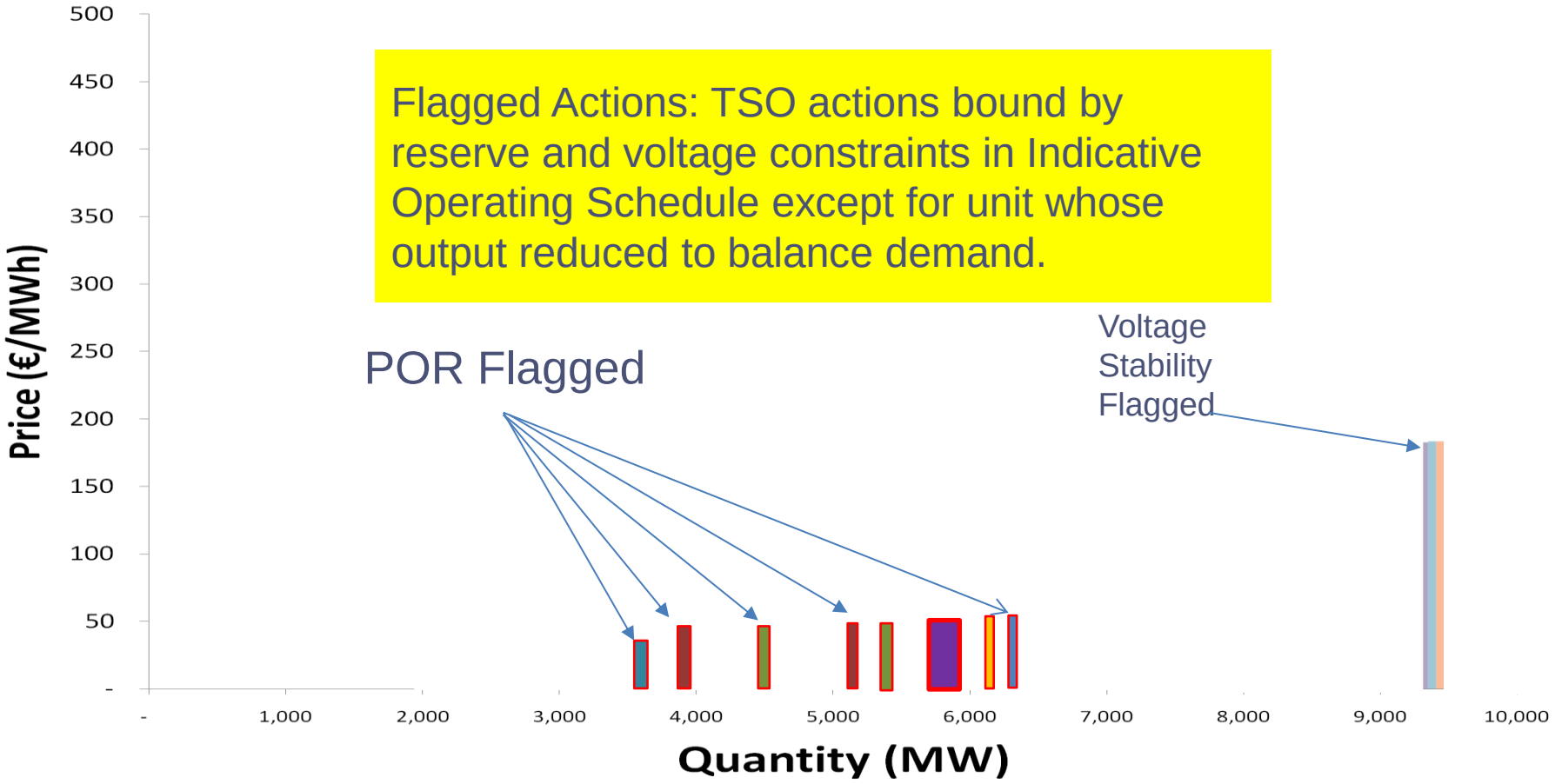
Day in the Life 2: 17:25

Determination and Ranking of Accepted Bids and Offers (E.3.1 & E.3.2)

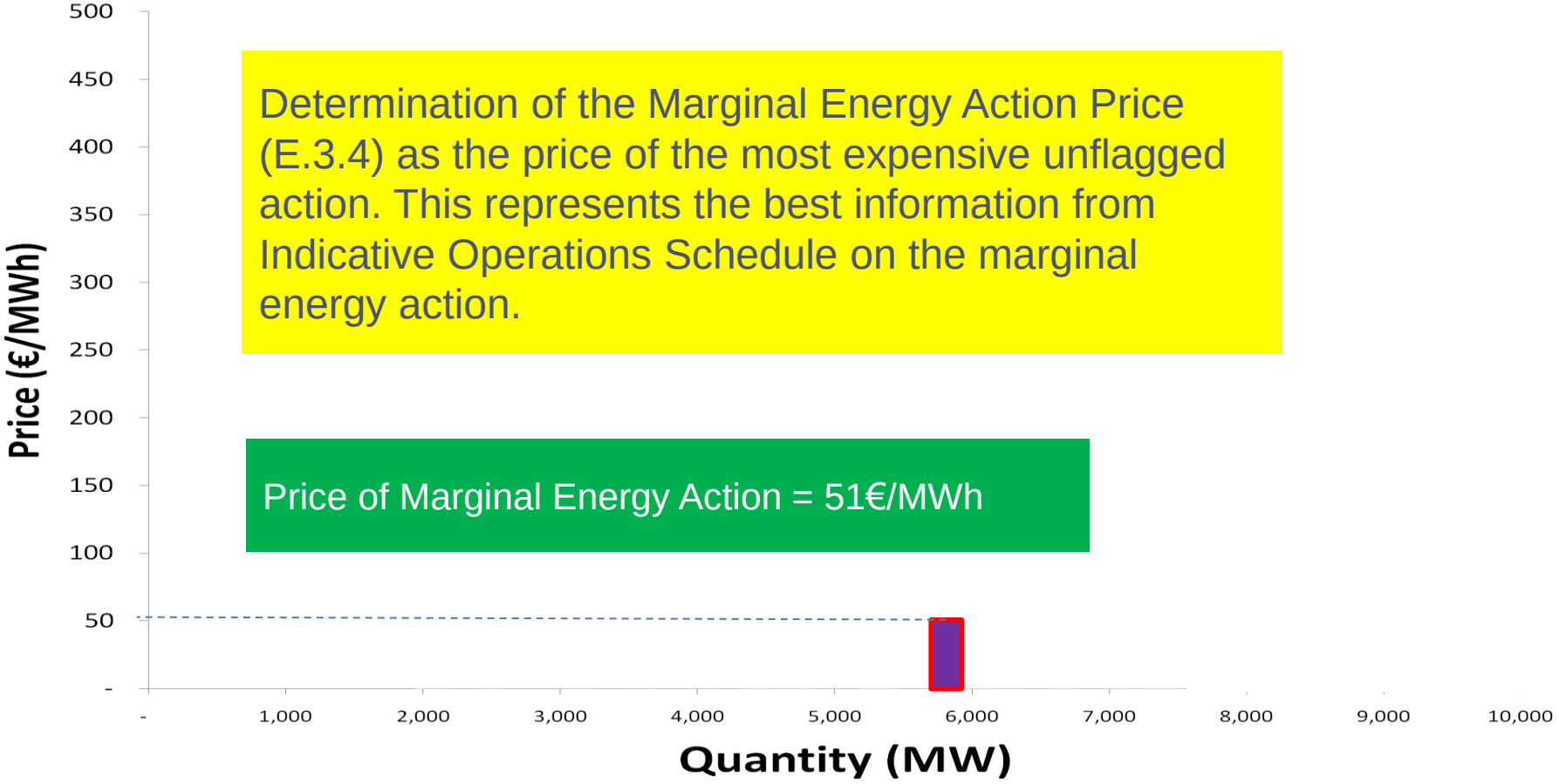
For the period 17:00 -17:05, the TSO took the following actions.



Day in the Life 2: 17:25



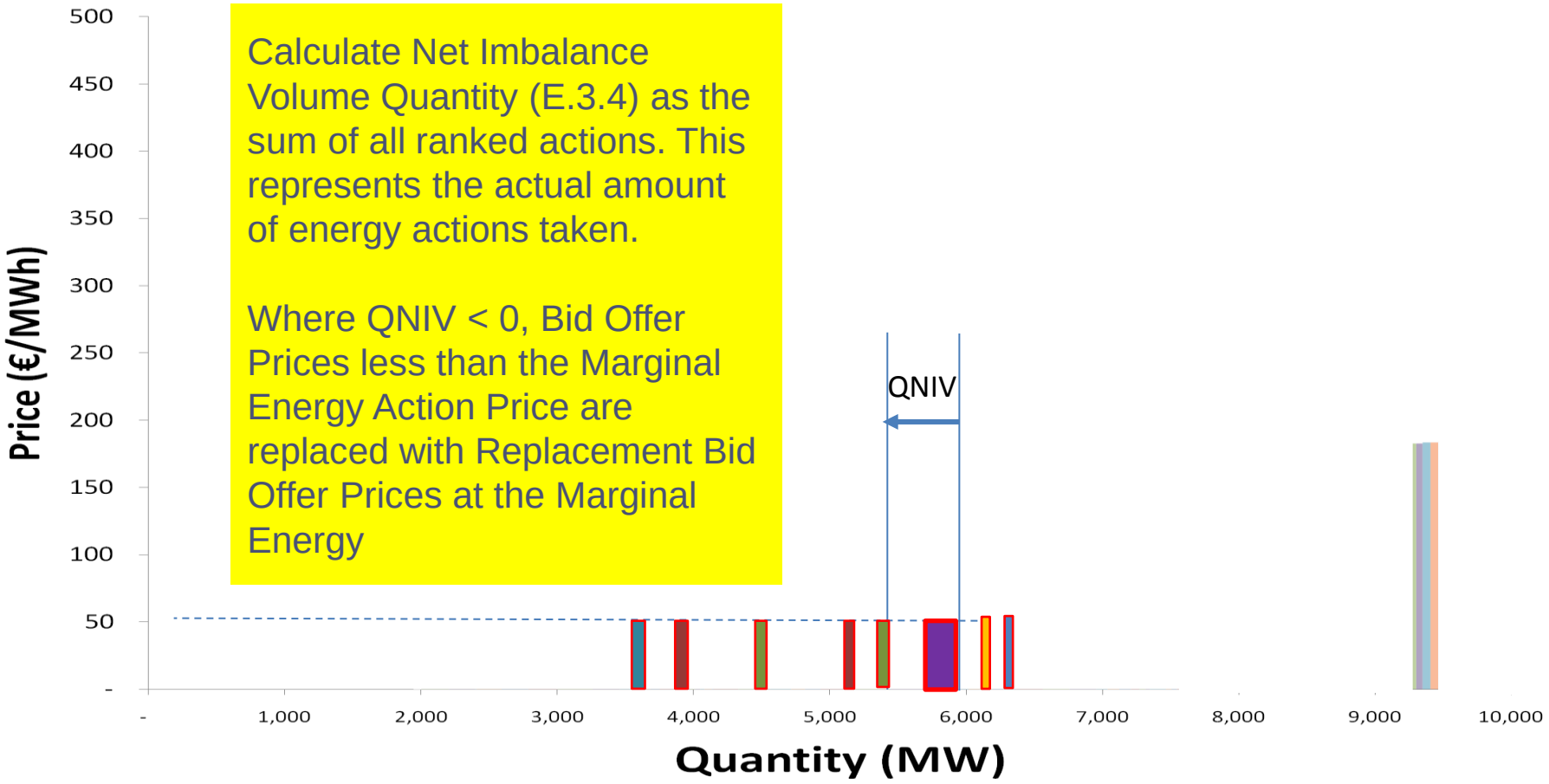
Day in the Life 2: 17:25



Determination of the Marginal Energy Action Price (E.3.4) as the price of the most expensive unflagged action. This represents the best information from Indicative Operations Schedule on the marginal energy action.

Price of Marginal Energy Action = 51€/MWh

Day in the Life 2: 17:25

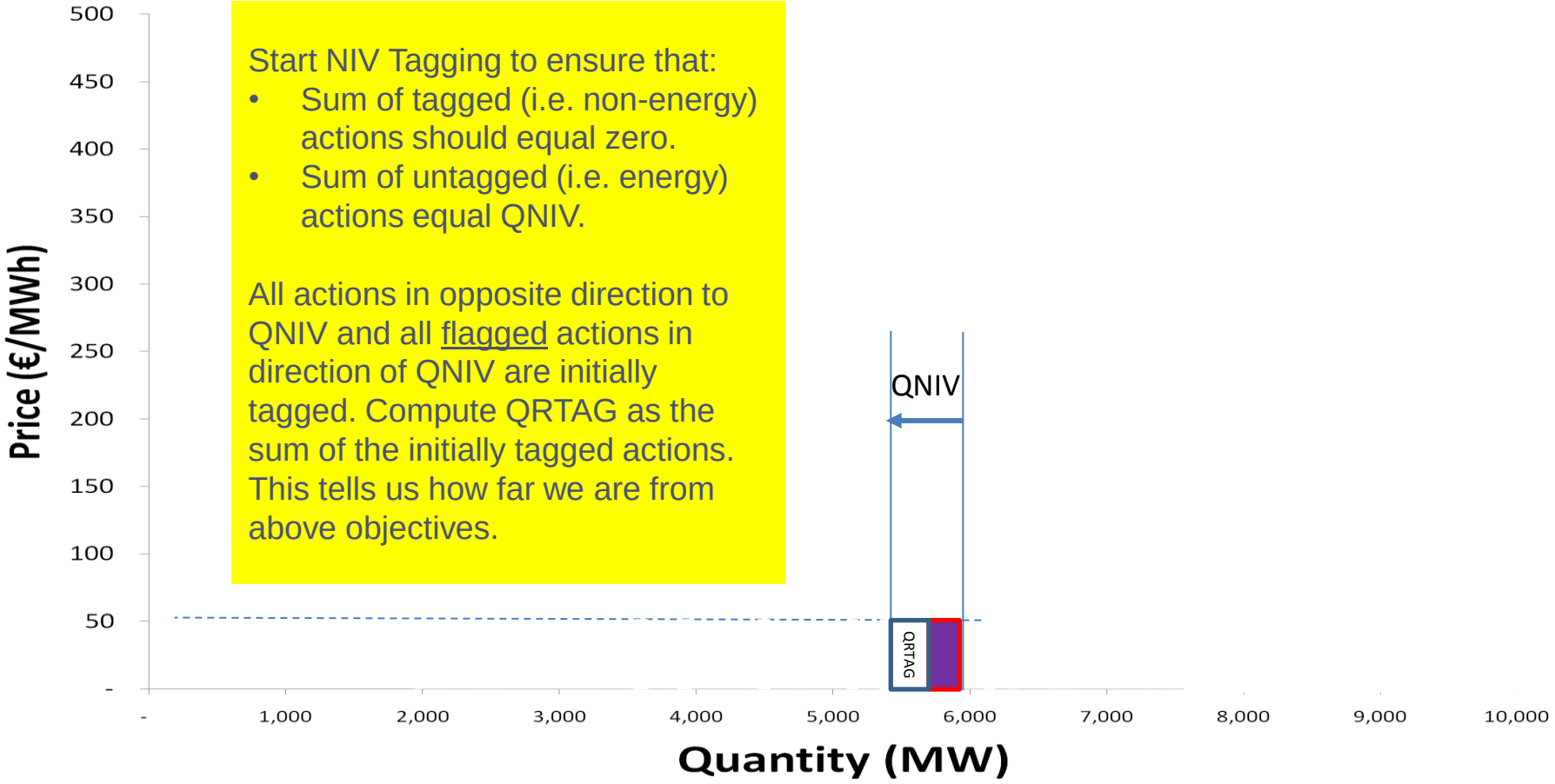


Day in the Life 2: 17:25

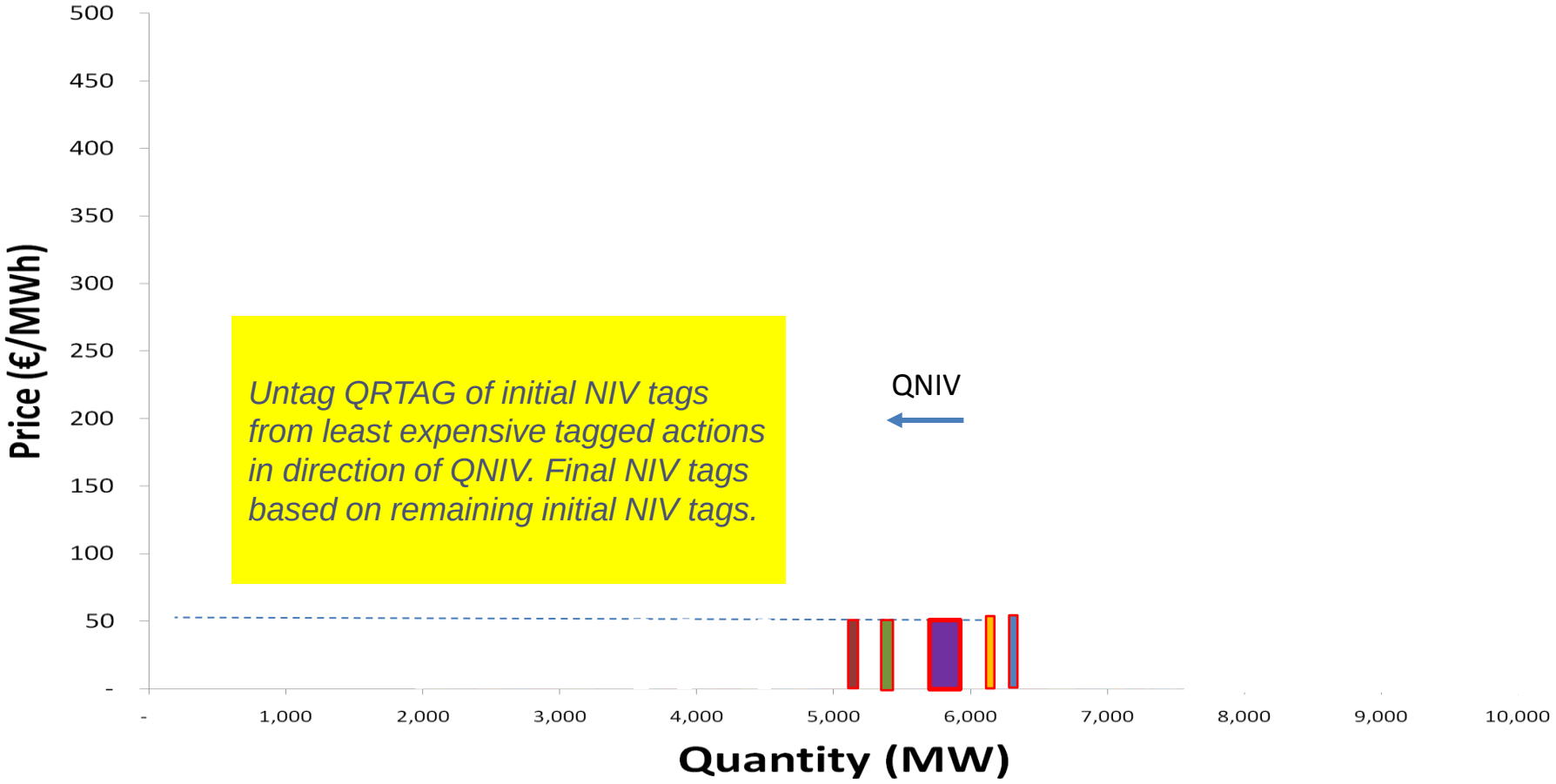
Start NIV Tagging to ensure that:

- Sum of tagged (i.e. non-energy) actions should equal zero.
- Sum of untagged (i.e. energy) actions equal QNIV.

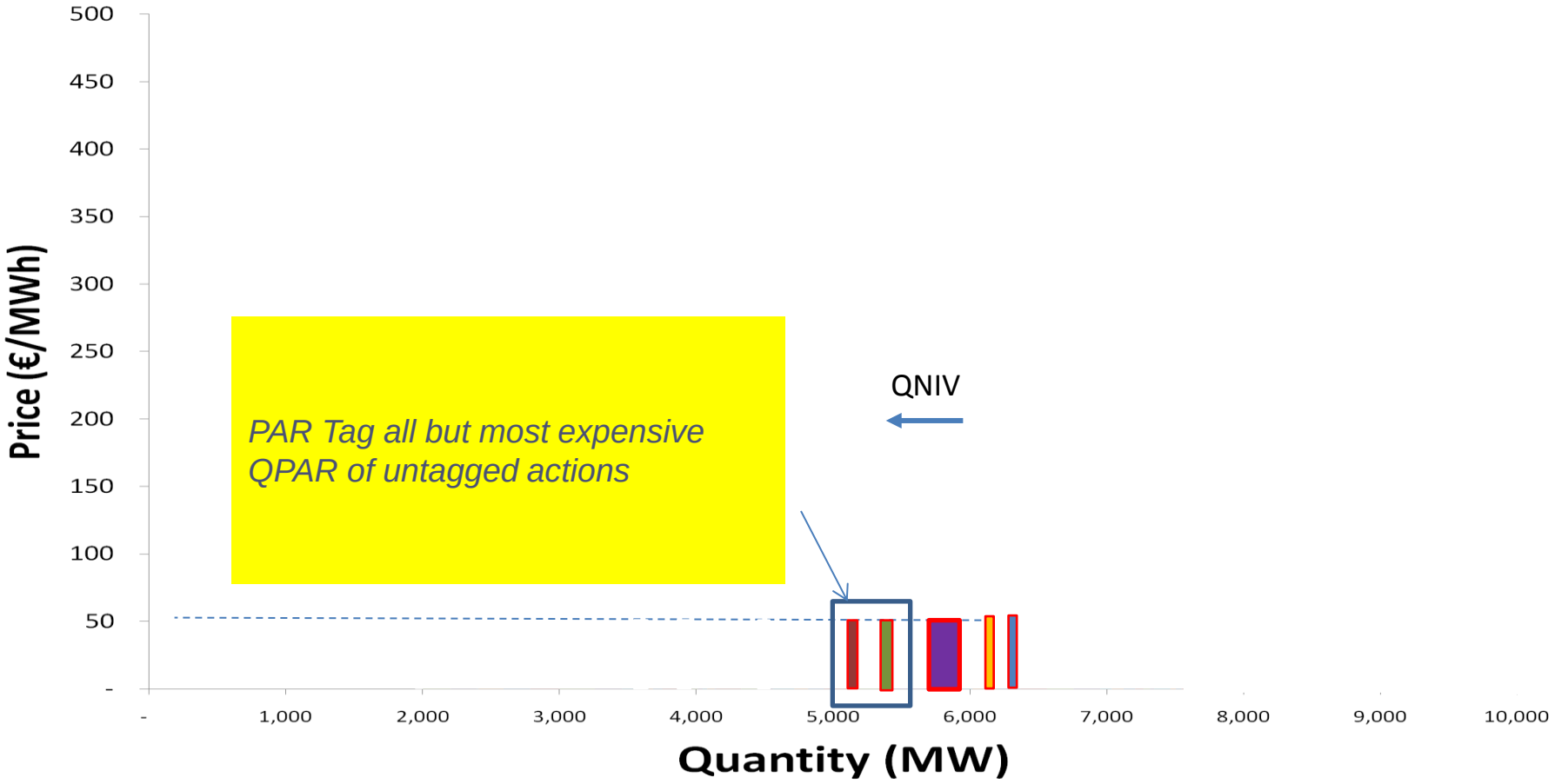
All actions in opposite direction to QNIV and all flagged actions in direction of QNIV are initially tagged. Compute QRTAG as the sum of the initially tagged actions. This tells us how far we are from above objectives.



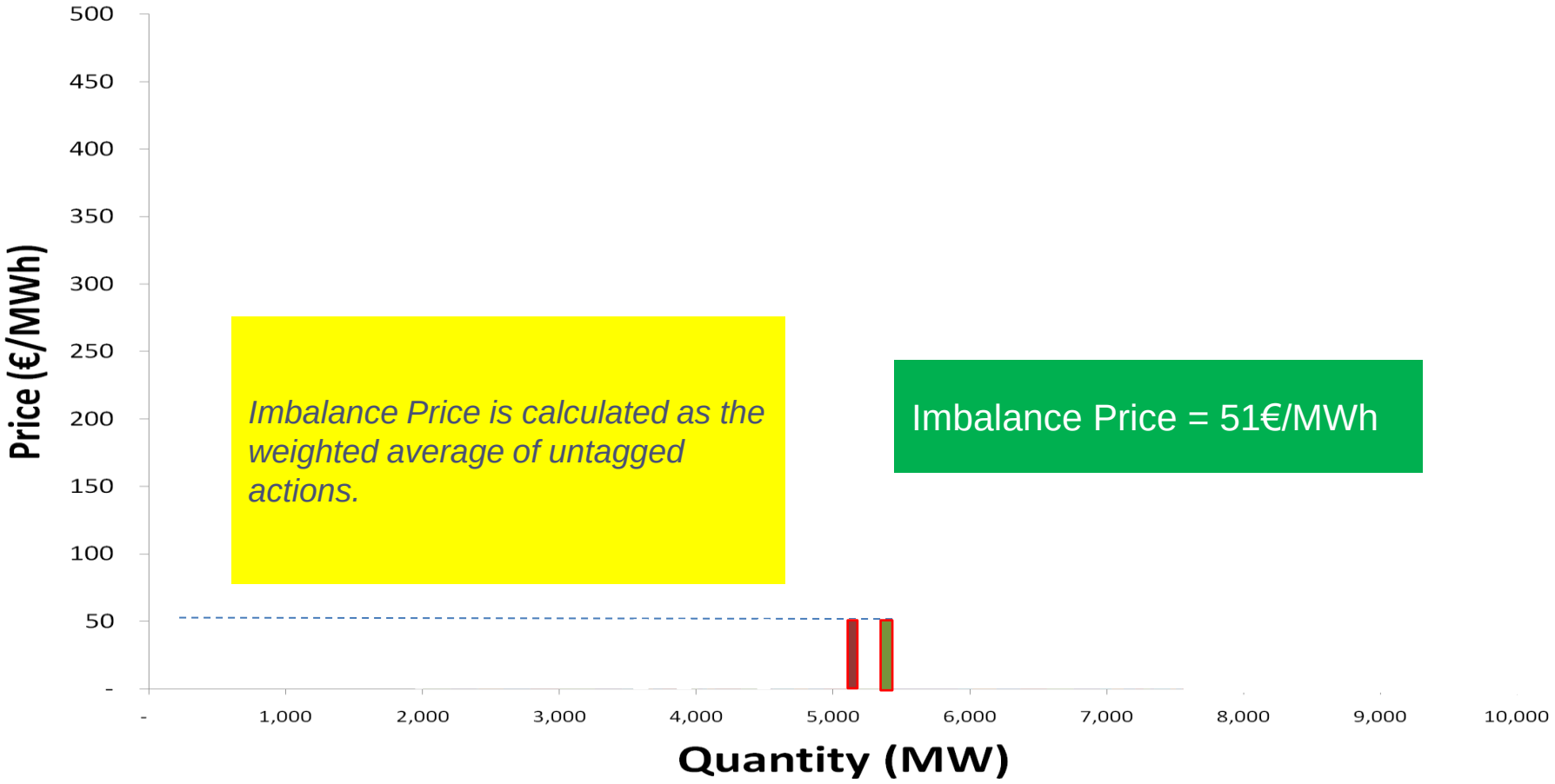
Day in the Life 2: 17:25



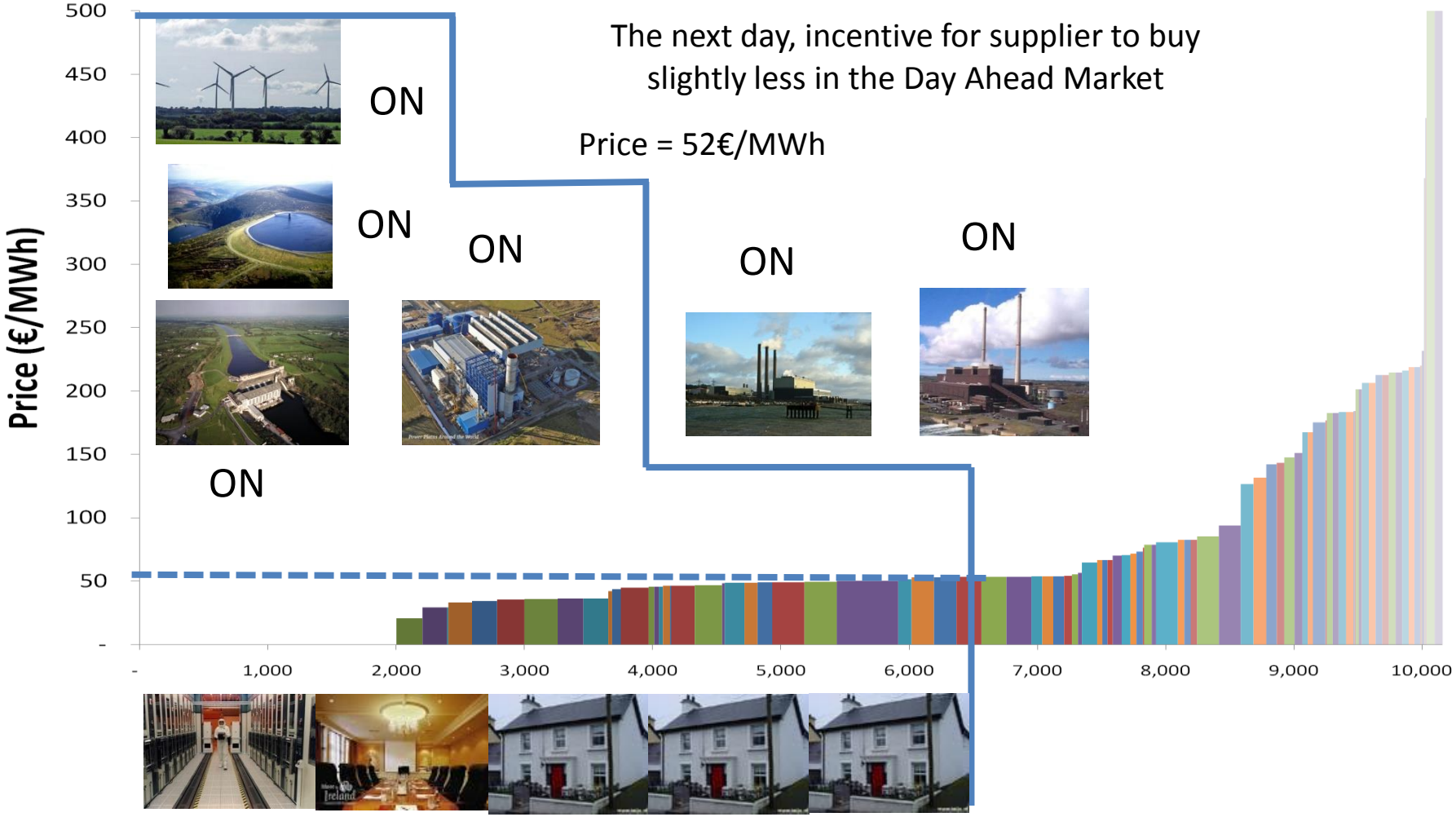
Day in the Life 2: 17:25



Day in the Life 2: 17:25

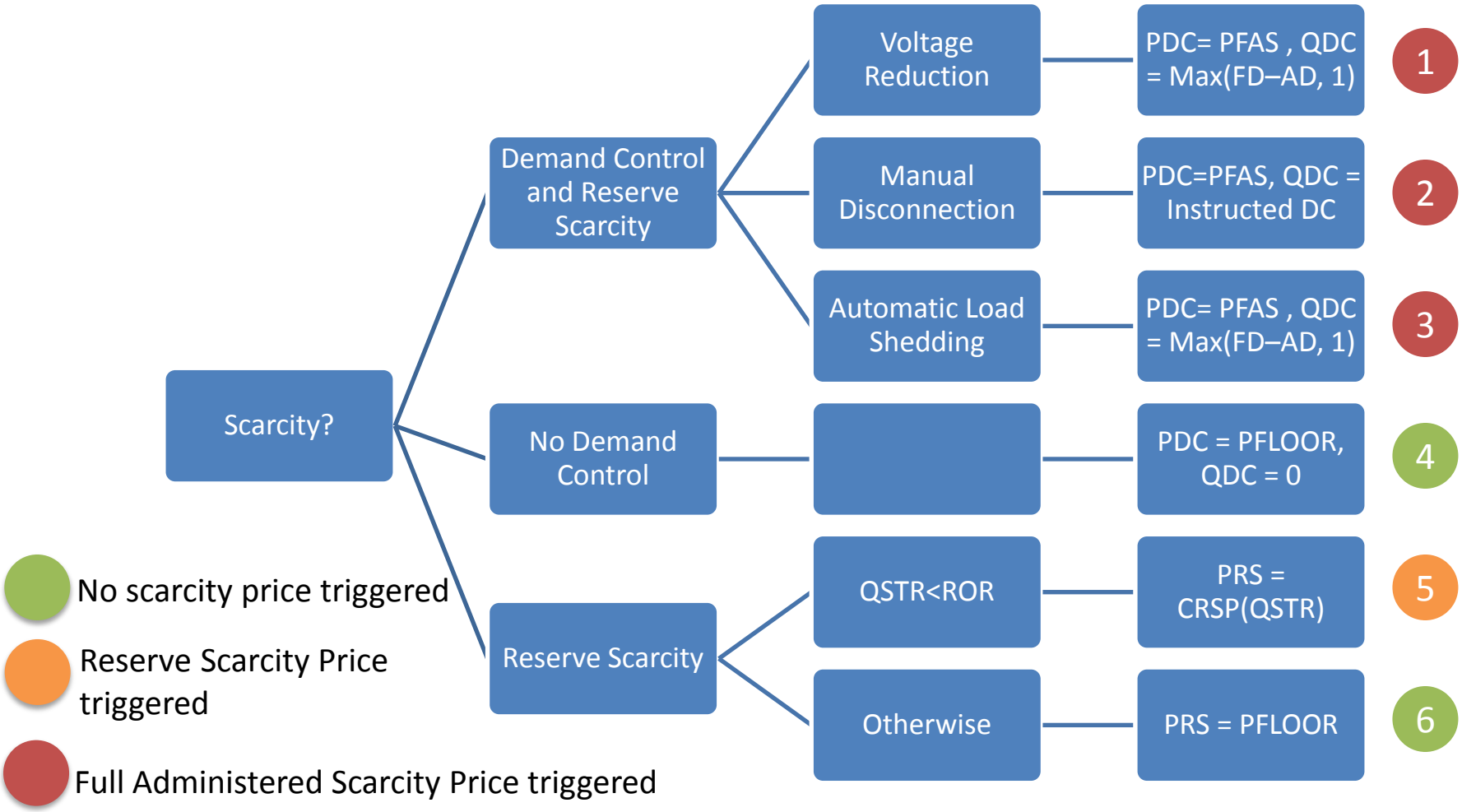


The Next Day


The next day, incentive for supplier to buy slightly less in the Day Ahead Market
Price = 52€/MWh
ON
ON
ON
ON
ON
ON
Price (€/MWh)
500
450
400
350
300
250
200
150
100
50
-
-
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000

Topic 10: Administered Scarcity Pricing

ASP and RSP


Scarcity?
Demand Control and Reserve Scarcity
No Demand Control
Reserve Scarcity
Voltage Reduction
Manual Disconnection
Automatic Load Shedding
QSTR<ROR
Otherwise
PDC= PFAS , QDC = Max(FD–AD, 1)
PDC=PFAS, QDC = Instructed DC
PDC= PFAS , QDC = Max(FD–AD, 1)
PDC = PFLOOR, QDC = 0
PRS = CRSP(QSTR)
PRS = PFLOOR
1
2
3
4
5
6
No scarcity price triggered
Reserve Scarcity Price triggered
Full Administered Scarcity Price triggered

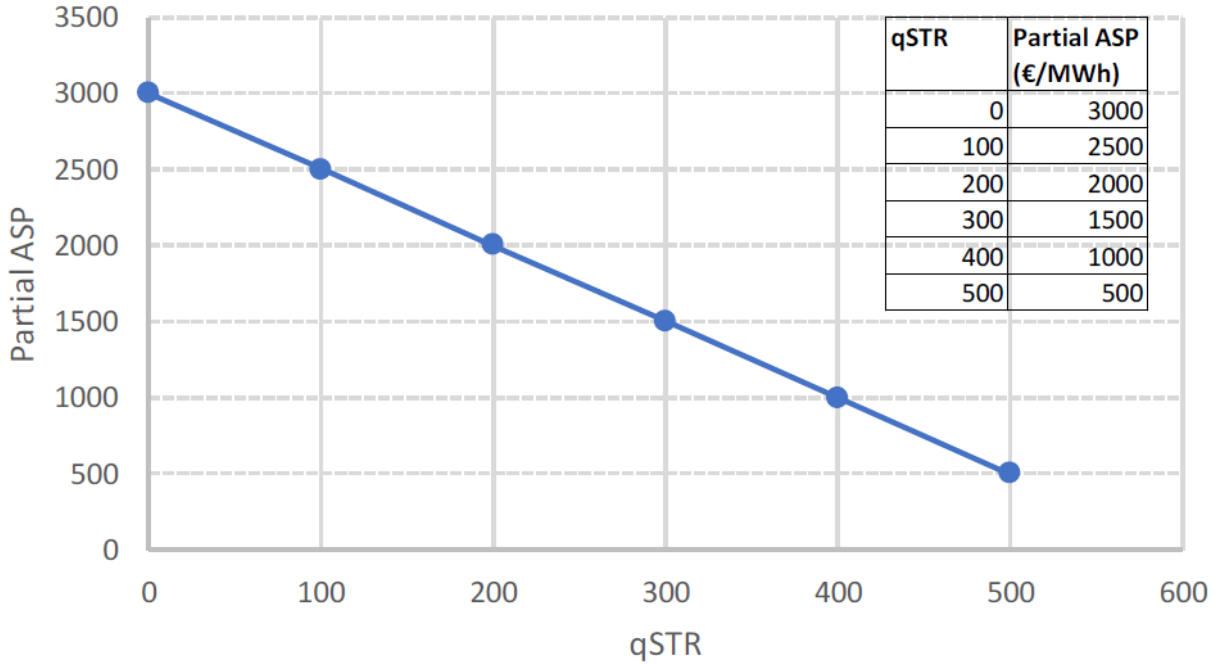
ASP and RSP

- The Reserve Scarcity Price Curve is one of the primary inputs to the function, consisting of parameters from the RAs which determine the prices, and the quantities of reserve shortfall at which these prices occur;
- The other two main inputs are the system operations data which determine whether reserve scarcity occurred, as the ASP function only applies when the available Short Term Reserve (qSTR) is less than the operating reserve requirement (qORR). Therefore, if the operating reserve requirement is only 450MW, and the available Short Term Reserve falls to 490MW, the ASP function above does not apply;
- Short Term Reserve Quantity ($qSTR_{\phi}$) based on available operating reserves and reserves capable of replacing operating reserves within one hour in the most recent Indicative Operations Schedule;
- Systems State Alerts are likely to accompany Reserve Scarcity and Demand Control but they are not a precondition;
- The following slides show a generalised form of the reserve Scarcity Price Curve to explain some of its characteristics, followed by the actual curve determined by the RAs for I-SEM go-live.

ASP and RSP

RAs have decided what the curve will look like for I-SEM go-live (from RA CRM Parameters Decision):

5



qSTR	Partial ASP (€/MWh)
0	3000
100	2500
200	2000
300	1500
400	1000
500	500

ASP and RSP

- The Full Administered Scarcity Price (PFAS) can be triggered for Demand Control triggered in either Ireland or Northern Ireland jurisdictions;

- However to ensure that it is only triggered for system-wide events rather than local jurisdiction events, there is a “double-lock”, where this approach only applies when there is both Demand Control / a frequency event in either jurisdiction, AND a system-wide reserve scarcity event;
- When both of these occur, the Demand Control Price (PDC) is set equal to the PFAS, and a Demand Control Quantity (QDC) is calculated for inclusion in the Ranked Set;

- The following slides show which events can result in Demand Control, and how their volume and prices are determined and used.

ASP and RSP

- Any of the following events can trigger the demand control:

  Voltage Reduction:

  - Customer Voltage Reduction in Northern Ireland,
    - in accordance with section OC4.4.5 of the Northern Ireland Grid Code,
  - Emergency or Exceptional Voltage Control in Ireland,
    - in accordance with OC4.4.6 of the Ireland Grid Code,

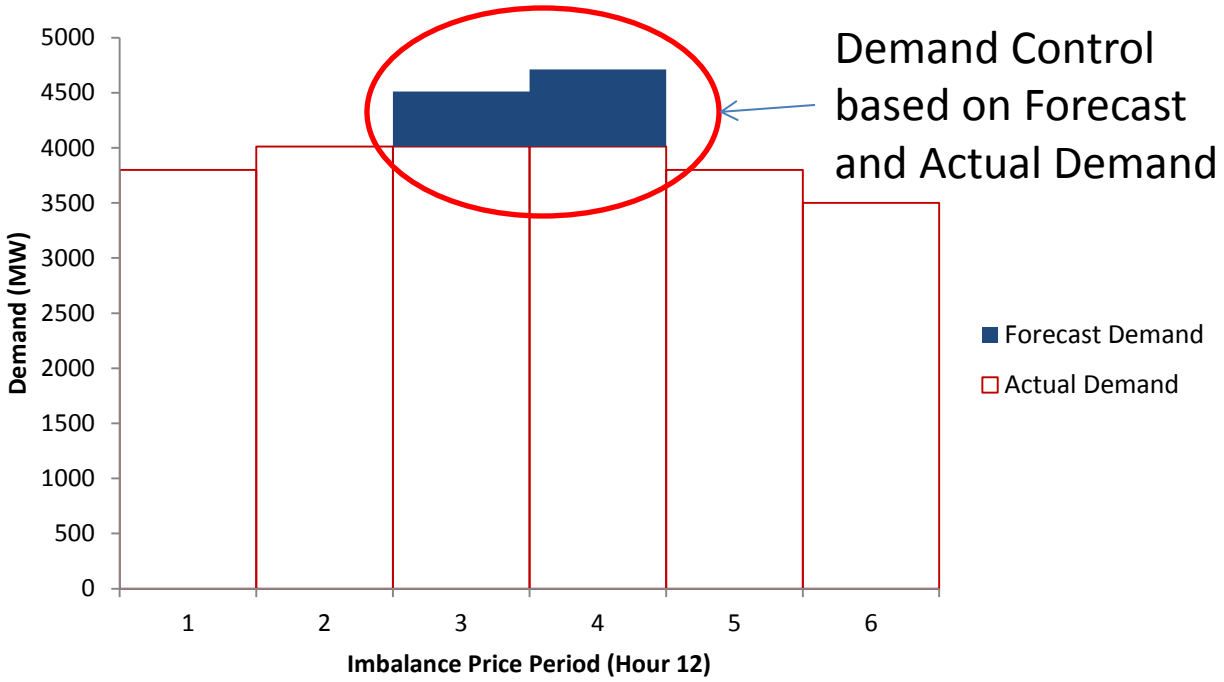
- Automatic Load Shedding:
  - Automatic Load Shedding in Northern Ireland,
    - in accordance with section OC4.4.8 of the Northern Ireland Grid Code,
  - Automatic Low Frequency Demand Disconnection in Ireland,
    - in accordance with section OC5.5 of the Ireland Grid Code,

- Planned or Emergency Manual Disconnection:
  - Planned or Emergency Manual Disconnection in Northern Ireland,
    - in accordance with section OC4.4.6 of the Northern Ireland Grid Code,
  - Demand Control on the instructions of the TSO in Ireland,
    - in accordance with section OC5.4 of the Ireland Grid Code.

ASP and RSP

1 3

Customer Voltage Reduction and Automatic Load Shedding



ASP and RSP

2

Planned/Emergency Manual Disconnection:

- These are reductions in demand taken in fixed MW blocks;
- Demand Control Quantities based on instructions sent to DSO.

Where there is no Demand Control:

PDC = PFLOOR

Where there is no Reserve Scarcity:

PRS = PFLOOR

4 6

ASP and RSP

- **Determination of Demand Control Bid Offer Acceptances**
  - $QAO_{uoi\phi} = QDC_{\phi}$;
  - $PBO_{uoi\phi} = PFAS$;
  - Treats Demand Control action in a similar manner to any other energy action;
  - Ensures that Demand Control reflected in the NIV, so that NIV Tagging is carried out correctly reflecting this action.

- **Inclusion of Administered Scarcity Price in determining Imbalance Price:**

$$PAS_{\varphi} = Max\left(PDC_{\varphi}, PRS_{\varphi}\right)$$

$$PIMB_{\varphi} = Max\left(PIIMB_{\varphi}, PAS_{\varphi}\right)$$

  - If Demand Control occurs, $PIMB_{\phi}$ >= PFAS.

Topic 11: Market Back Up Price and Curtailment Price

Market Back-Up Price

- Only used when:
  - QNIV=0 (very unlikely)
  - Failure of pricing system (unlikely)
  - Administered Settlement (unlikely)

- Due to design of the I-SEM pricing, the use of the Market Back Up Price will not arise due to overtagging.

- For each Imbalance Settlement Period, γ, the Market Operator shall calculate the Market Back Up Price (PMBUγ) as the quantity-weighted average price of the prices associated with each Day-ahead Trade Quantity (qTDAxuh, qTDAxvh) and Intraday Trade Quantity (qTIDxuh, qTIDxvh) for all Generator Units, u, and Supplier Units, v, in the Imbalance Settlement Period, γ.

Curtailment Price

- For use in Settlement where a curtailment (CURL) instruction has been issued.

- For each Imbalance Settlement Period, γ, the Market Operator shall calculate the Curtailment Price (PCURLuγ) for each Generator Unit, u, as the quantity-weighted average price of the prices associated with each Intraday Trade Quantity (qTIDxuh) and Day-Ahead Trade Quantity (qTDAxuh) for the Generator Unit, u, in the Imbalance Settlement Period, γ.

Topic 12: Course Summary

Review of Learning Objectives

After completing self learning and instructor-led training for this course you should have a clear understanding of :

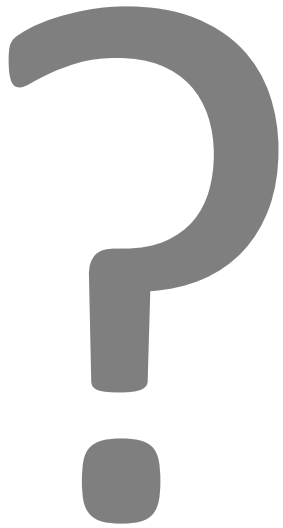
the inputs, process and outputs of the Imbalance Pricing process ✓

the application of the flagging and tagging methodologies ✓

the application of Administered Scarcity Pricing ✓

the calculation of the Imbalance price and the Imbalance Settlement Price ✓

Questions



Thank You!

Thank you for your time and engagement during this session.

Please take the time to share your feedback with us by completing the short feedback survey before you leave.