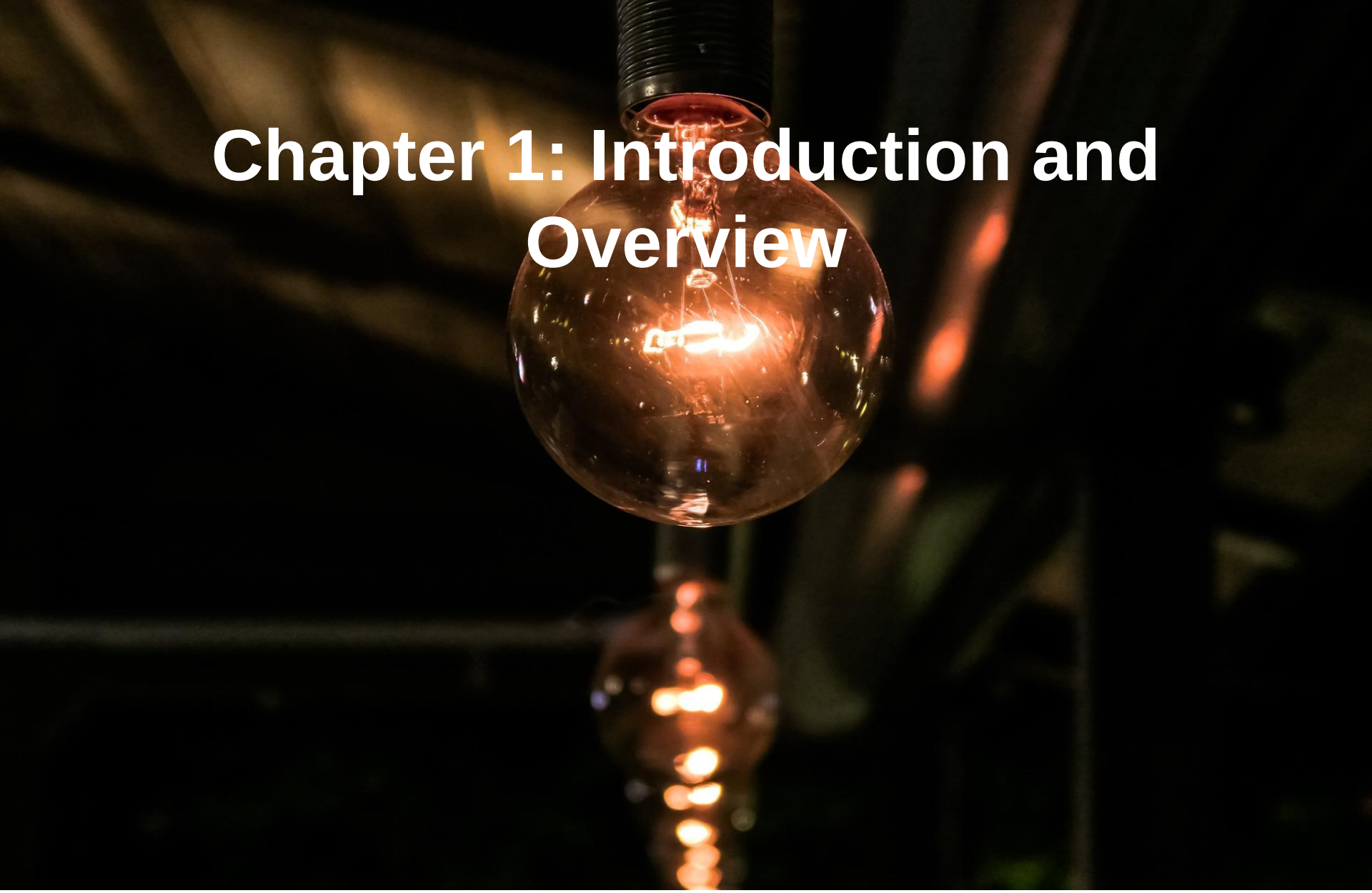
I-SEM Training
Imbalance Pricing

September 2017

Chapter 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.

Introduction and Overview

- The I-SEM ETA Markets Decision Paper went into further detail on what the price intended to represent and achieve:
  - Imbalance prices should be based on the actions taken by the TSO to balance the system;
  - The approach should be capable of delivering prices shortly after the trading period;
  - Any arrangements should not be overly influenced by any TSO subjectivity in determining which actions, or parts of actions, are classified as non-energy and thus excluded from the calculation of imbalance prices; and
  - The basis of the price calculation should be transparent.
- In addition to this, the SEMC has decided that an approach of Flagging and Tagging (similar to that in the BETTA market in GB) should be implemented in the I-SEM:
  - It was considered more strongly aligned with the intention of the HLD as it explicitly identifies the nature of each action taken, and the marginal energy action taken to meet the NIV;
  - It was also considered that these measures can build upon the GB experience, while accounting for differences due to the I-SEM.

Introduction and Overview

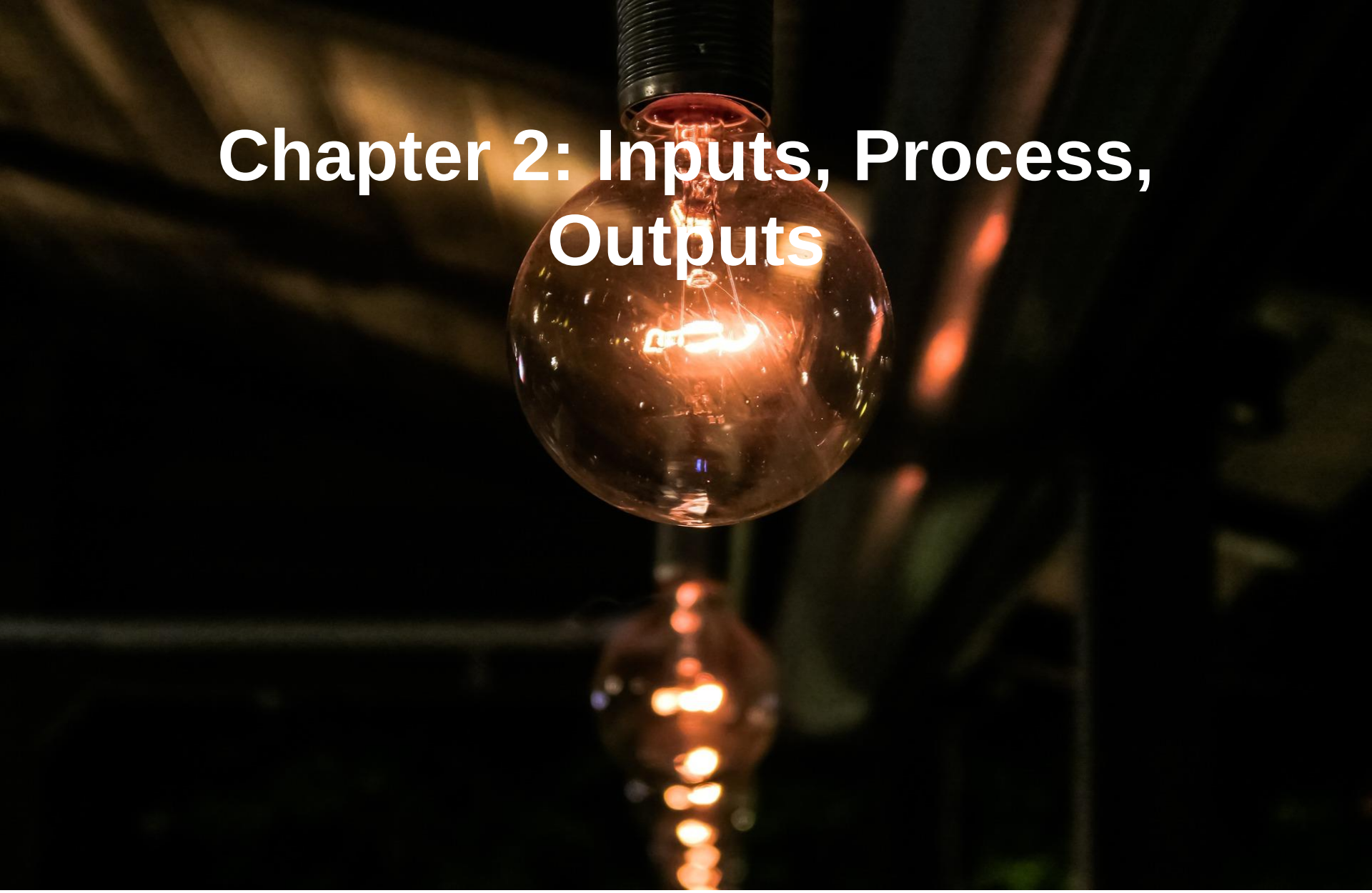
- In order to ensure the greatest level of objectivity that can be achieved, three elements were outlined in the decision:
  - First, the process for the classification of actions taken by the TSOs needs to be clearly documented, thus avoiding ambiguity;
  - Second, the processes put in place by the TSOs to tag out non-energy actions from the calculation of imbalance prices must be published, and the TSO performance audited and reported on annually;
  - Third, the SEMC considers that the implementation of Flagging and Tagging in TSO systems should focus on solutions that are automated to the greatest extent practical.
- The approach to marginal pricing and pay-as-bid settlement was also clarified:
  - Actions which are “in merit” (i.e. have an offer or bid price which would result in a less favourable settlement outcome than at the Imbalance Settlement Price) should be settled at the Imbalance Settlement Price;
  - Otherwise they should be settled based on their offer or bid price.
- This is an important feature, as it means units can submit prices based on their marginal costs rather than based on their expectation of the Imbalance Settlement Price, as they are guaranteed to receive the better price.

Introduction and Overview

- In summary, the Imbalance Pricing rules and functionality has been developed in-keeping with these decisions to have the following characteristics:
- Efficient:
  - Marginal energy action taken to meet the Net Imbalance Volume;
  - Based on actual dispatch / actions taken;
  - Mitigates imbalance price pollution by non-energy actions;
  - Mitigates spurious outcomes and/or excessive volatility; and
  - Can produce prices within one hour of real time.
- Robust & Adaptable:
  - Builds on GB experience;
  - Adapted for non-energy requirements of I-SEM;
  - Not susceptible to over-tagging; and
  - Capable of operating under changing market dynamics.
- Objective & Transparent:
  - Clearly documented process published;
  - Automated to the greatest extent practical; and
  - Not be overly influenced by any TSO subjectivity.

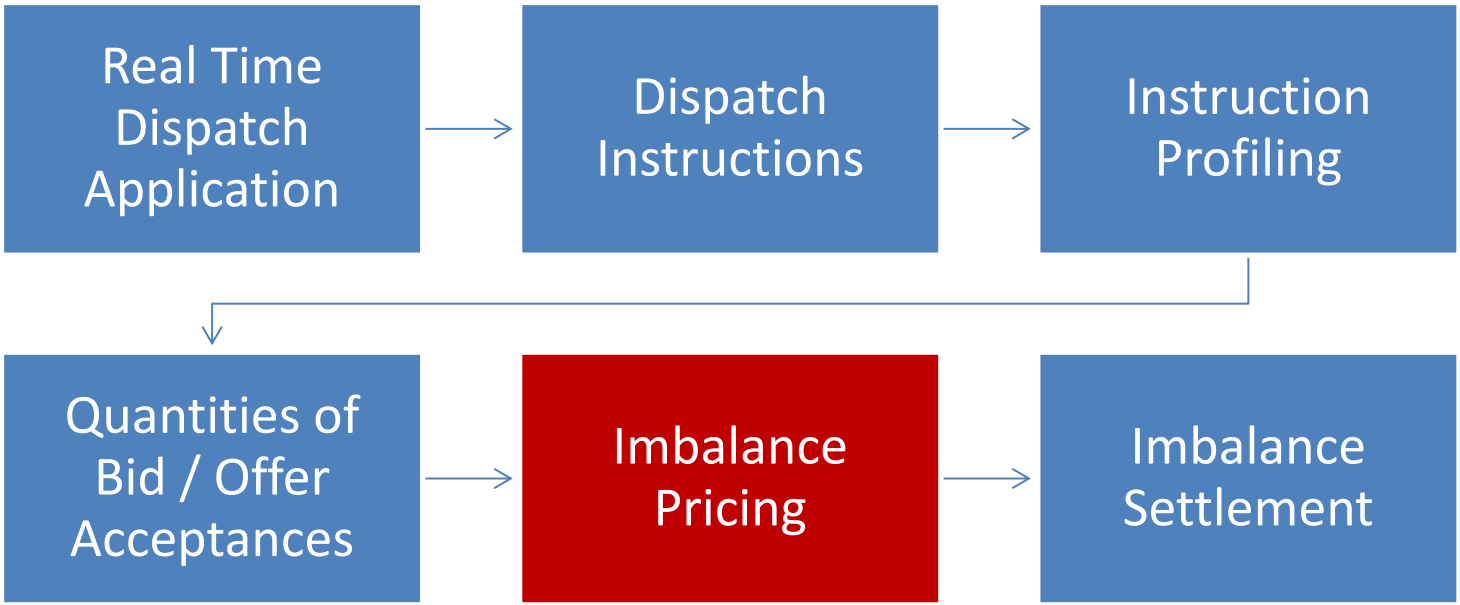
Introduction and Overview

- In the I-SEM CRM Detailed Design Decision Paper 1 it was also decided that the Imbalance Price would be one of the reference prices for the Capacity Market performance incentives (Difference Charges), in particular the reference price for delivery shortfall;
- As part of that it was decided to introduce an Administered Scarcity Pricing function into the Imbalance Price to enhance these incentives:
  - This price sets the Price Floor at times of system stress (for example, reserve shortfall or load-shedding) to a much higher price than would normally be expected in the balancing market, but which should be reflective of the cost of scarcity in such times;
  - This creates higher incentives on:
    - Generator Units to be available in the Balancing Market at these times due to expectation of being paid this higher price;
    - Capacity Market Units to ensure there is no shortfall in capacity provision in the energy markets at these times due to expectation of being charged this higher price;
    - Supplier Units to reduce their consumption, or to ensure that they have contracted for all of their consumption through their ex-ante market trades, at these times due to exposure to a higher price.



Chapter 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 and once at 30-min resolution.

- 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.

Transparency

- A major focus in the detailed design of the Imbalance Pricing functionality was transparency;
- Transparency relates primarily to the timely availability of data and information required to understand and replicate the process and its outcomes, which needs to consider the following three timescales:
  - Ex-ante transparency:
    - Information based current scheduling and trading that facilitates forecasting of PIMB.
  - Real-time transparency:
    - Information based on actual values feeding into the PIMB provided close to real time.
  - Ex-post transparency:
    - Information provided ex-post to facilitate shadow settlement, queries, etc.

Ex-ante transparency

- Ex-ante transparency includes the following considerations:
  - Rules governing the price calculation:
    - These need to be unambiguous in how they are applied to enable shadow calculations.
  - Processes feeding the price calculation:
    - These are not as detailed as rules, but provide clarity on the steps involved in the process to facilitate modelling and forecasting.
  - Data feeding into the price calculation:
    - This includes parameters and indications of the state of the system in advance inform ex-ante trading decisions.

Real-time transparency

- Real-time transparency primarily relates to the timely availability of suitable data, including:
  - Providing as close as possible to real-time all required inputs to shadow calculate PIMB based on rules;
  - Providing as close as possible to real-time all reports necessary from input calculations to support forecasting and shadow calculations.

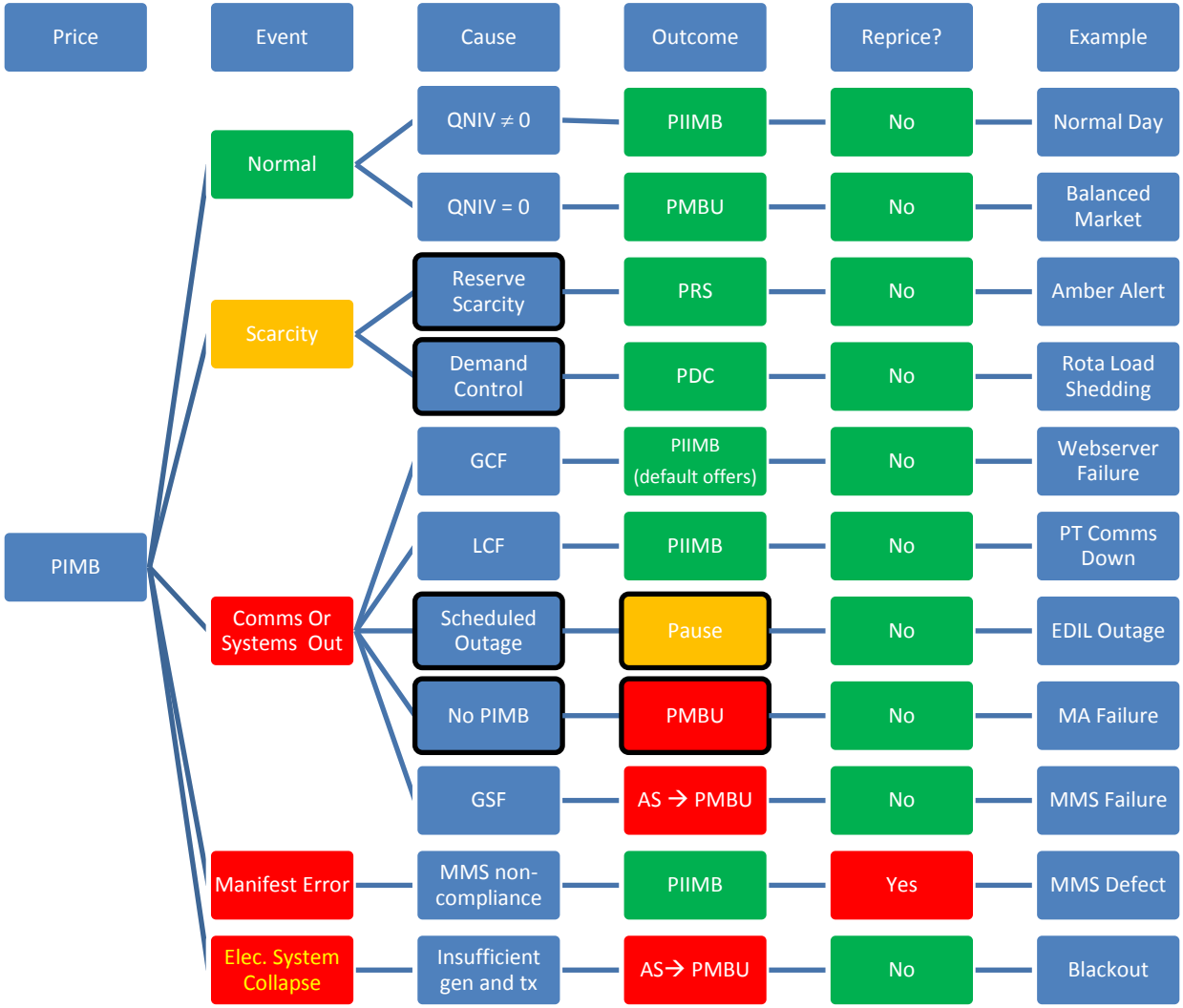
Ex-post transparency

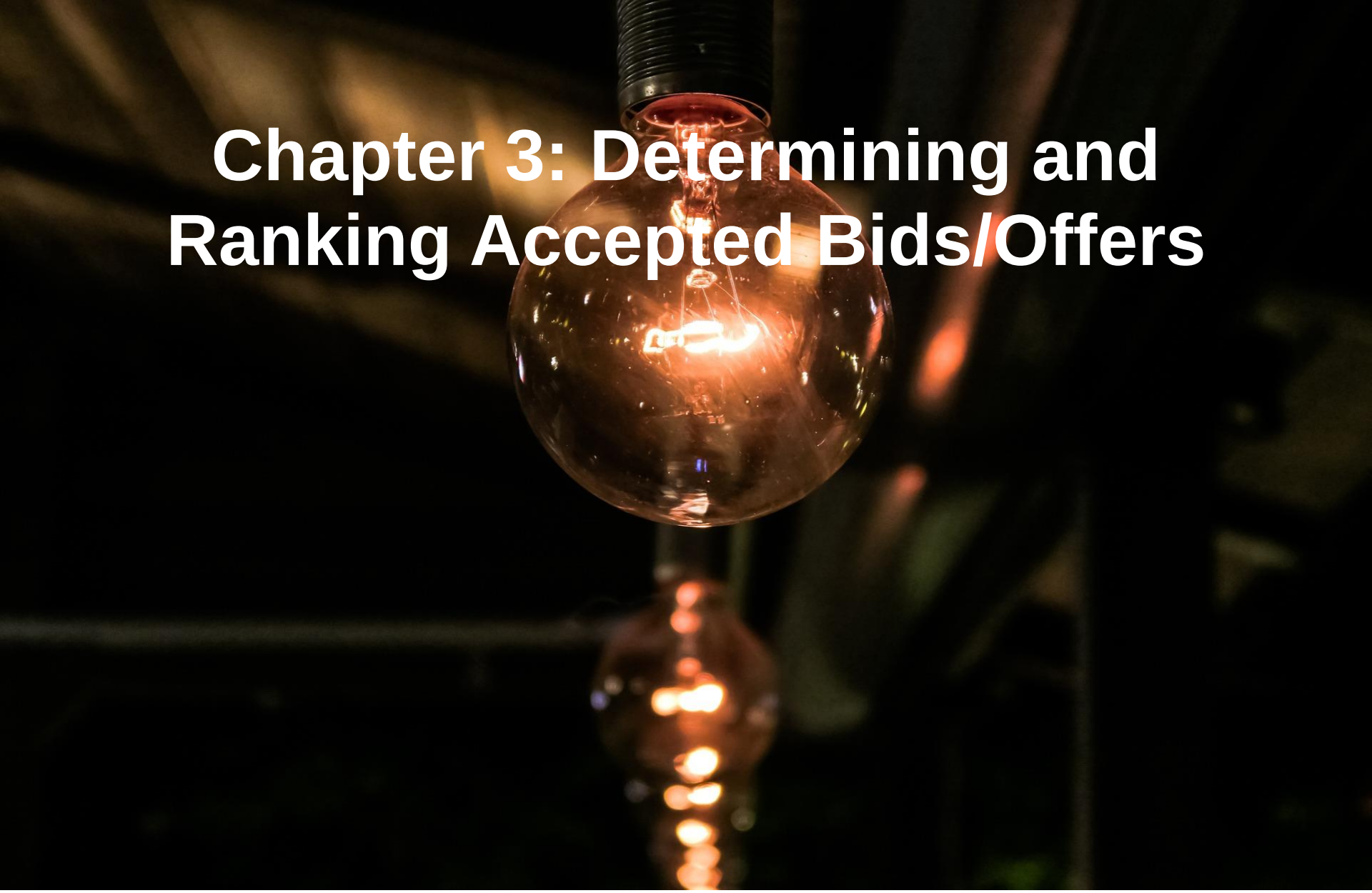
- Ex-post transparency also primarily relates to the timely availability of suitable data, including:
  - Providing more accurate data used in settlement to facilitate shadow calculations based on rules;
  - Providing a more complete set of data not available in real-time for commercial / market power reasons.

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





Chapter 3: Determining and Ranking Accepted Bids/Offers

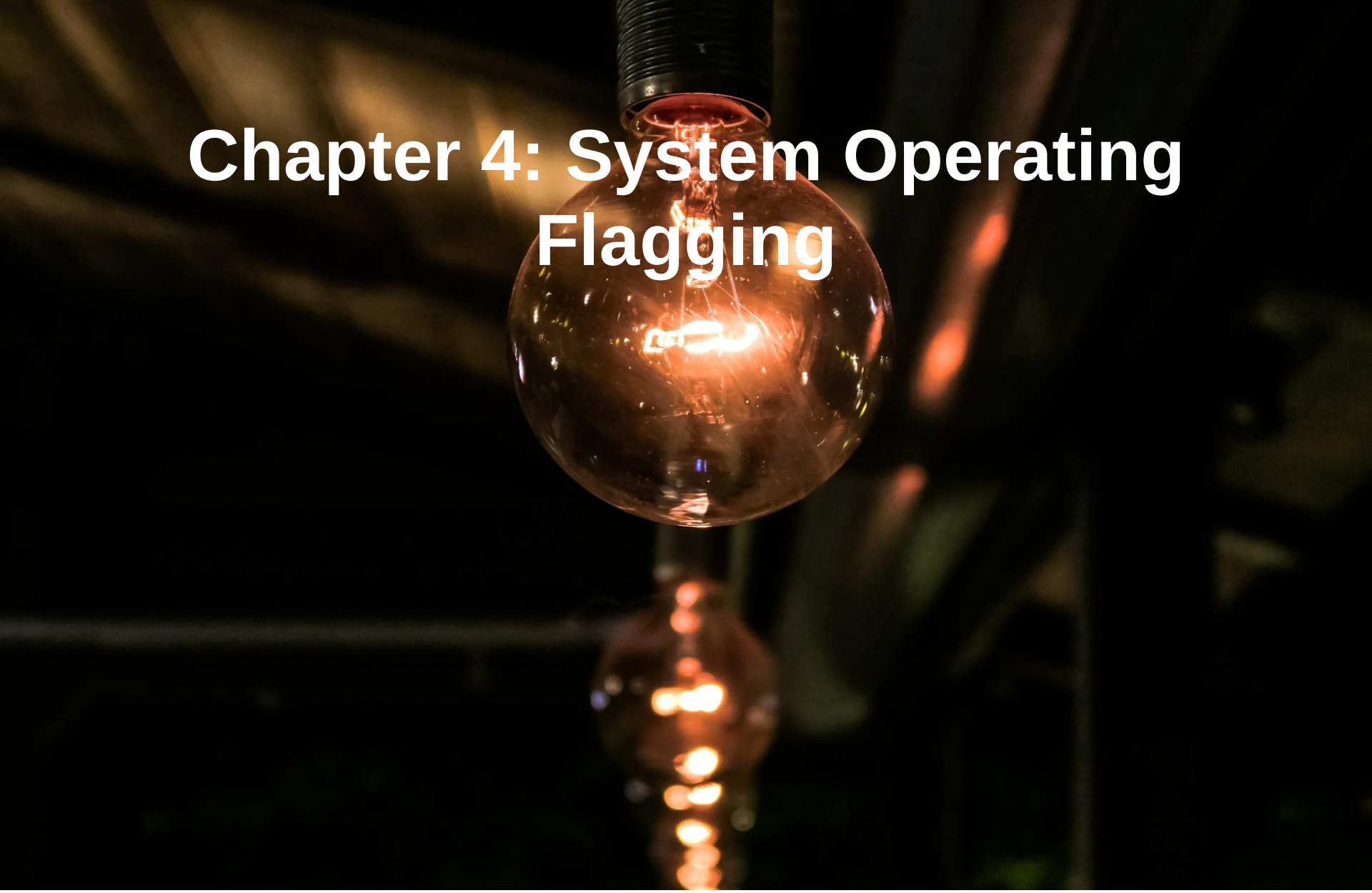
De Minimis Acceptance Threshold and Ranked Sets

- 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.

Chapter 4: System Operating Flagging



System Operator Flagging

- The System Operator Flagging process identifies Bid Offer Acceptances taken for system reasons, such as binding network or operational constraint, as opposed to energy balancing reasons;
- This is done to minimise the extent of non-energy actions influencing or setting the price for energy balancing actions and imbalances;
- Although non-energy actions are taken on a least-cost basis, they are taken for reasons other than the economics of ensuring energy demand and supply are balanced at least-cost, and may only have a subset of units available for such actions which may not reflect those units that are least-cost from an overall market perspective:
  - Therefore their cost must be removed from the price setting to ensure that the actual cost of keeping the system energy- balanced feeds into the final Imbalance Settlement Price, to ensure that the price signals reflect the correct costs to create the correct incentives for behaviour in the energy trading markets.
- The SO Flagging process consists of testing, for every constraint in the Indicative Operations Schedule outlined in the Operational Constraints Update and System Operator and Non-Marginal Flagging Methodology:
  - Whether an operational constraint is binding; and
  - Whether the Generator Unit is bound by this constraint.

System Operator Flagging

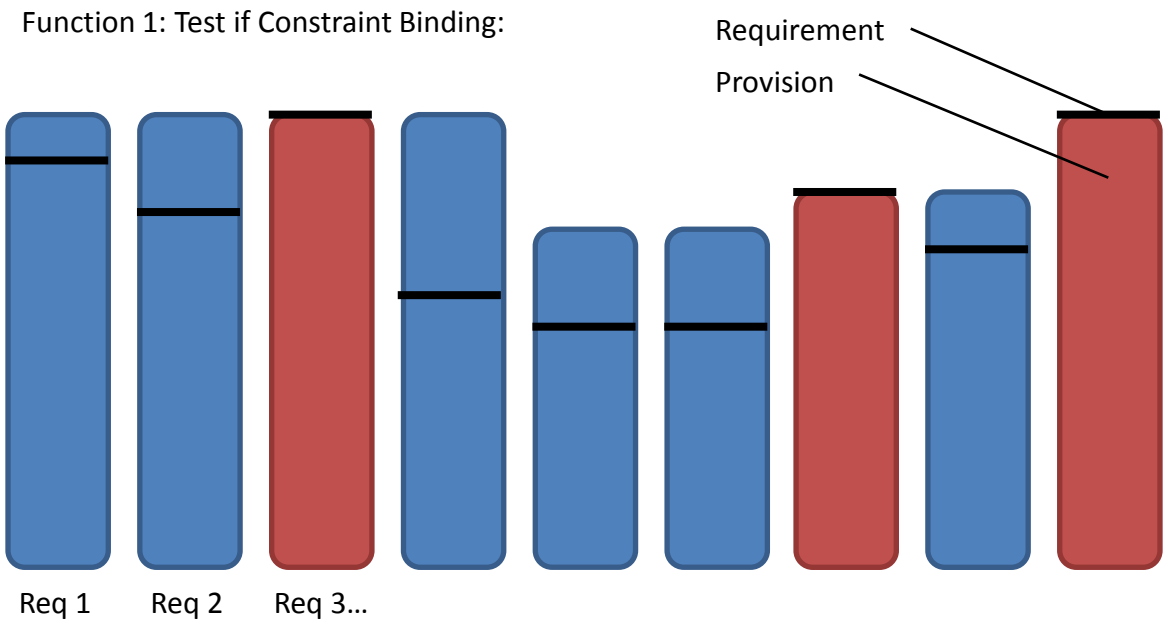
- A balance needs to be found between instances of system actions influencing the imbalance price vs the risk of over-flagging:
  - The Imbalance price can be influenced by non-energy actions if flagging does not accurately identify them;
  - Over-flagging occurs where all actions taken are flagged as non-energy and there are no actions to set the imbalance price.
- Efficient price exists between these two extremes;
- An automated approach to determining flags has been developed:
  - It utilises the Real Time Dispatch tool which drive the dispatch actions the SOs take and contain the most accurate and up to date system and unit information available.

System Operator Flagging

- Because of this the SO Flagging approach:
  - Is based on actual dispatch / actions taken;
  - Reduces the risk of system actions influencing the imbalance price by considering all operational constraints in the scheduling system;
  - Reduces the risk of over-tagging based on considering the data outputs of an optimised schedule, which by the nature of optimisations would tend to have at least one unconstrained unit;
  - Reduces operational errors and SO subjectivity in pricing as it is a systemised ruleset applied to the outcomes of a highly accurate scheduling process;
  - Is transparent and auditable; and
  - Can produce prices within one hour of real time.

System Operator Flagging

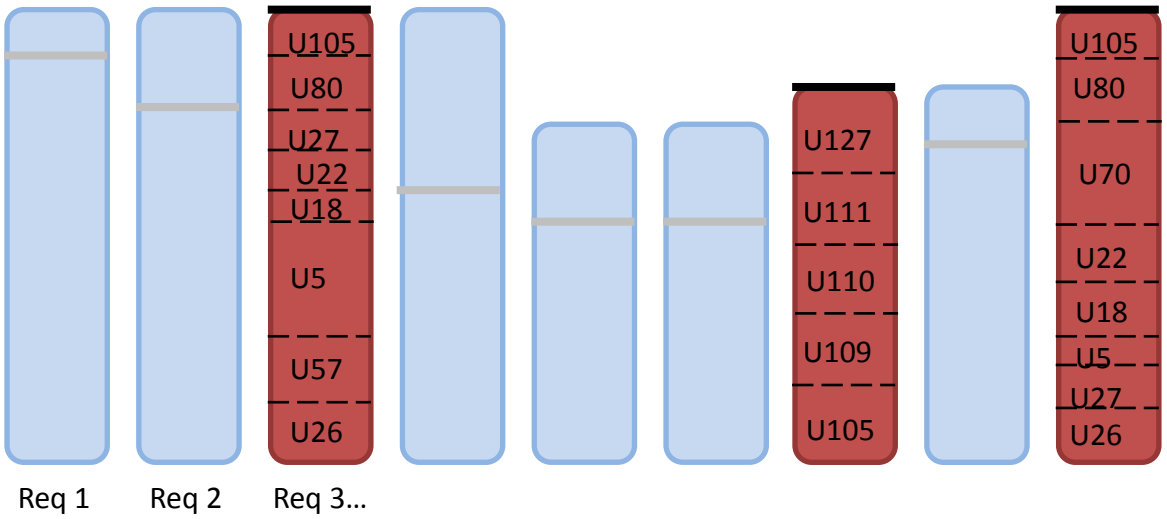
These slides visualise the concept of the functions being carried out by the SO Flagging approach:



System Operator Flagging

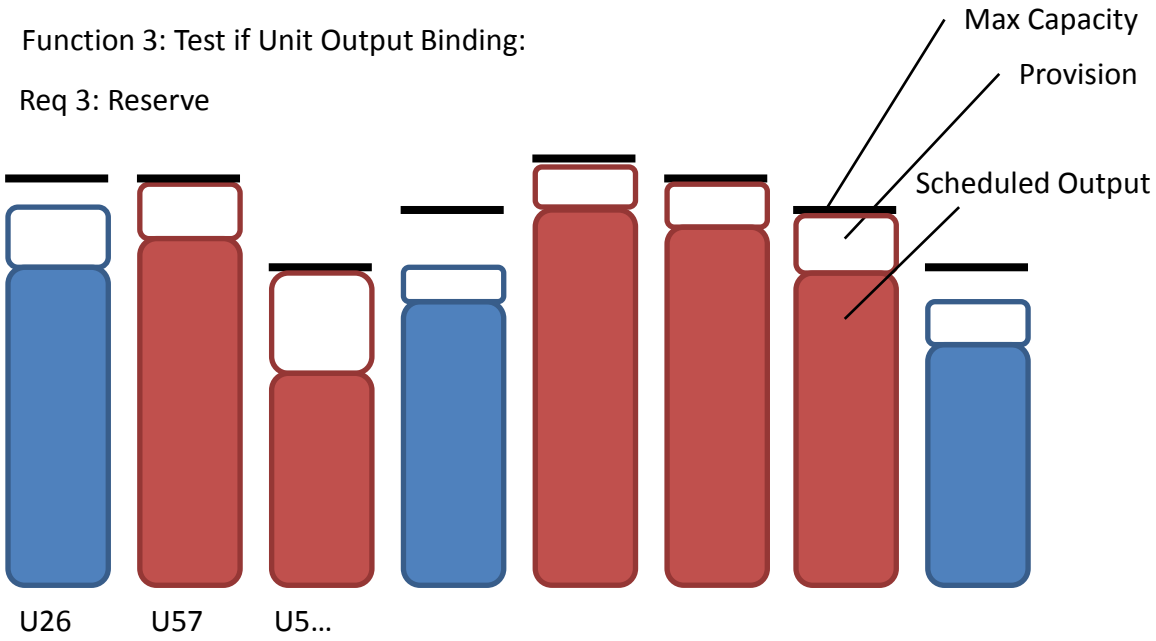
These slides visualise the concept of the functions being carried out by the SO Flagging approach:

Function 2: Identify Units Contributing to Binding Constraint:



System Operator Flagging

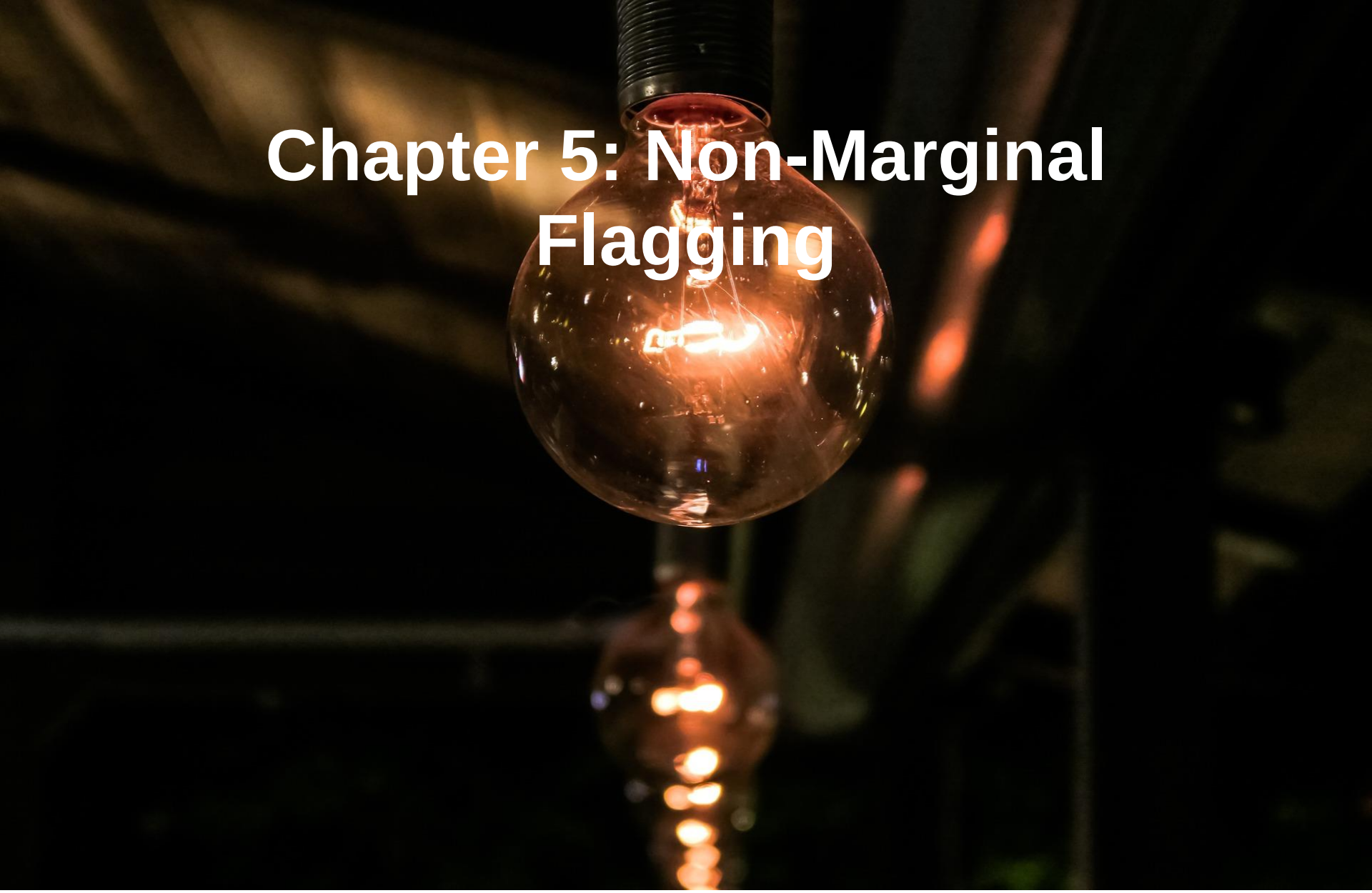
These slides visualise the concept of the functions being carried out by the SO Flagging approach:



System Operator Flagging

- Since SO Flags are used to identify that a unit is non-energy for the purposes of the Imbalance Pricing process, it is also used in a Market Power Mitigation functionality:
  - RA decision that non-energy actions should be settled on Complex Bid Offer Data which has bidding controls applied which should ensure that they are cost-based;
  - Therefore units which are SO-Flagged in any Imbalance Pricing Period in the Imbalance Settlement Period will be settled using their Complex Bid Offer Data to calculate their Bid Offer Acceptance Quantities and Prices;
  - Note that it only applies to the settlement process: the unit's Simple Bid Offer Data may still be used in the pricing process if the other requirements for its use are met.
- The SO Flagging methodology is also used to determined System Service Flags (FSS) for Capacity Market Settlement:
  - Provision of Replacement Reserves counts towards meeting capacity market obligations;
  - If unit is bound by the Replacement Reserve operational constraint, its FSS = 0.

Chapter 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

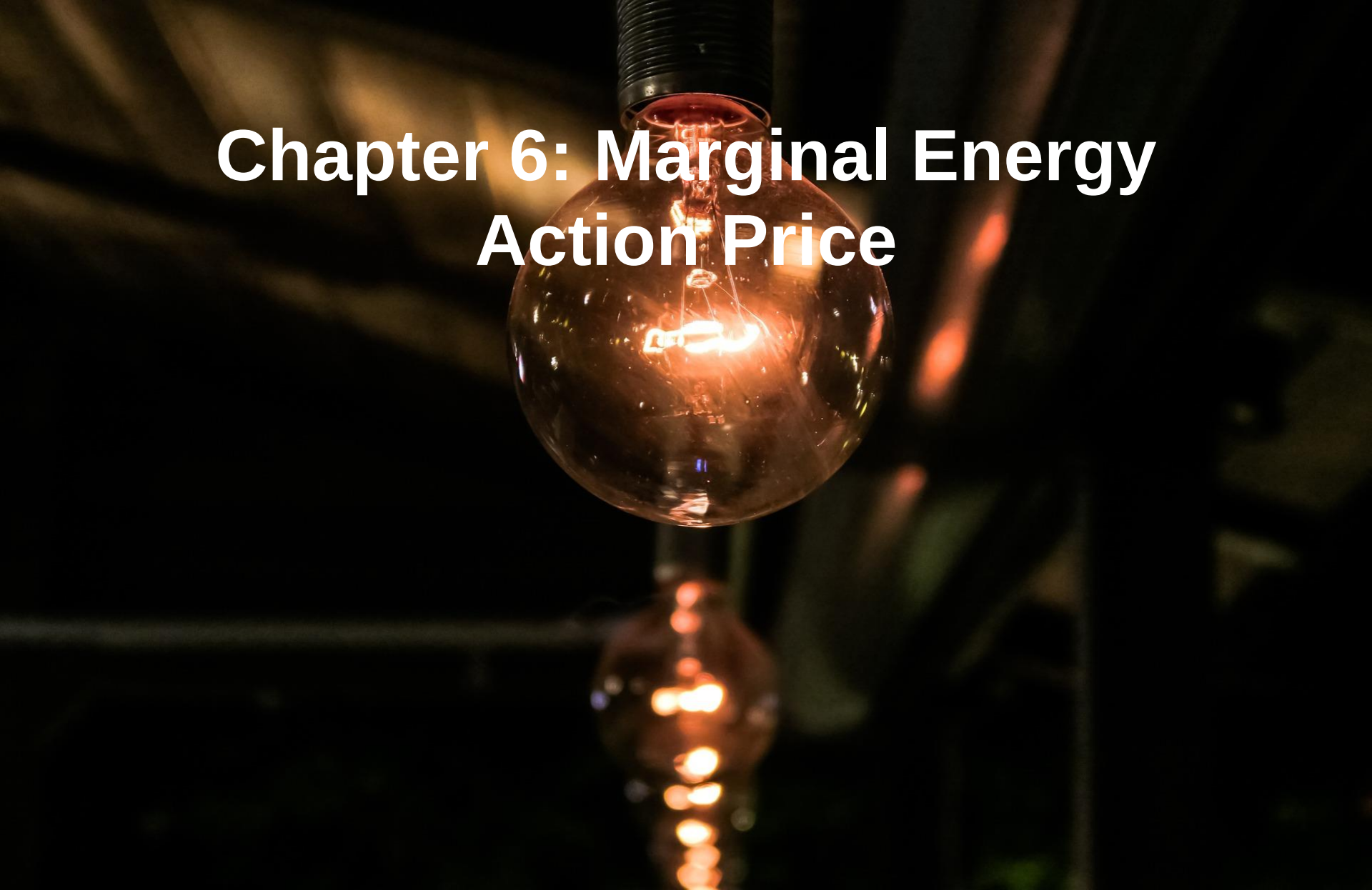
- A Plain-English explanation of these tests is as follows:
  - For each unit:
    - If the unit's scheduled output is at its Minimum Stable Generation; or
    - If the unit's scheduled output is at its Maximum Generation; or
    - The unit's scheduled output is at a level which represents the maximum 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.



Chapter 6: Marginal Energy Action Price

PMEA and PRBO

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

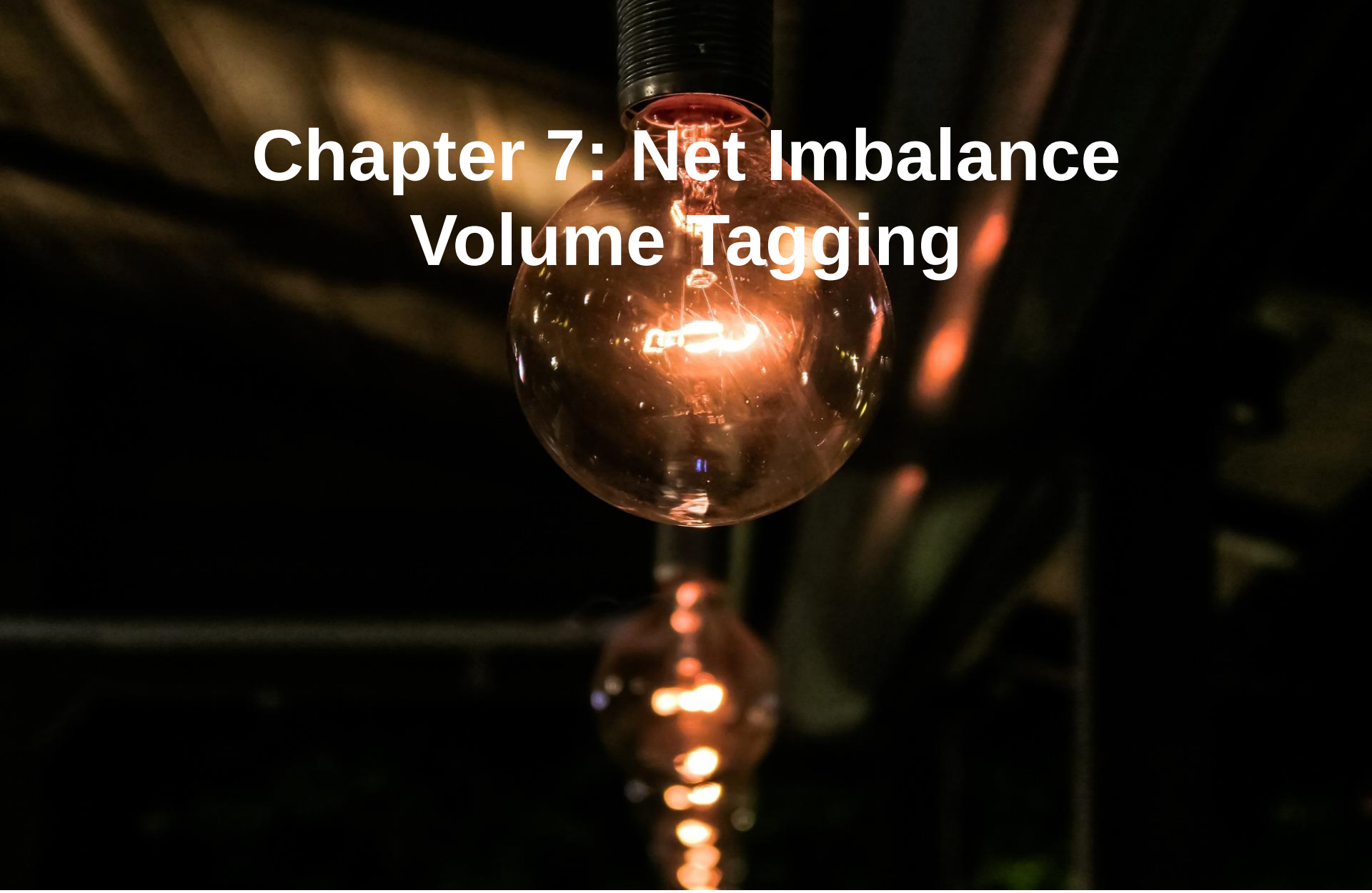
- The Marginal Energy Action Price (PMEA) is the most expensive unflagged action in the ranked set:
  - When QNIV is positive more incs have been taken and the higher the price of the inc the more expensive it is (i.e. the more has to be paid to a unit to increase generation) – PMEA is the highest priced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

- All actions which have less economic prices than the Marginal Energy Action Price (PMEA) have their prices replaced by PMEA for the remainder of the process:
  - This ensures that the prices of all actions which were not in merit for setting the marginal price are not considered further in the process;
  - With this, the price cannot be set less economic than PMEA in the NIV and PAR Tagging processes, but can be set by another economic action which was in-merit in the ranked set if it is found to be relevant through NIV or PAR Tagging;
    - This means that the price cannot be set higher than PMEA with when the system is short (QNIV is positive), but the price can be set lower than PMEA;
    - This means that the price cannot be set lower than PMEA when the system is long (QNIV is negative), but the price can be set higher than PMEA.

PMEA and PRBO

- Through the Marginal Energy Action Price and Replacement Price process, it is possible for an action which was in the opposite direction to the NIV to set the Imbalance Price if it was the marginal action:
  - If the QNIV was positive but all Accepted Offers were flagged, the process will select the highest priced Accepted Bid to be the Marginal Energy Action Price;
  - While not intuitive this could be the marginal action, for example:
    - If there was a need for additional generation and the only way to meet it was to turn on a unit, the Minimum Stable Generation of that unit may be too much energy for the additional required, so that unit would be switched on to its MSG and another unit would be turned down to maintain the balance – the unit which was turned down is the marginal action in this scenario.
  - Through setting the Replacement Bid Offer Price of the Accepted Offers with higher prices, PMEA can now set the Imbalance Price even after NIV Tagging determines that an Accepted Offer should set the price.



Chapter 7: Net Imbalance Volume Tagging

Net Imbalance Volume Tagging

- The purpose of NIV Tagging after applying the Replacement Bid Offer Price is to ensure that there are now sufficient untagged actions to meet the Net Imbalance Volume Quantity, which can then be used as part of the PAR Tagging process to set the final Imbalance Price;
- The NIV Tagging process has similar functionality to the Classification step in the BETTA Market pricing approach, where it has steps which allow for actions which were previously flagged to be tagged and removed from setting the price for not being in-merit, or not being tagged and allowed to be included in setting the price due to being in-merit, depending on various circumstances;
- This is important as it is establishing a list of actions whose total volume equals the energy balancing requirement (QNIV) which are finally considered in-merit (despite any initial energy or non-energy classification) for the purposes of setting a final Imbalance Price. This ensures the final price is set by in-merit actions taken to meet the energy balancing requirement, which is important to enact the decision that the price has to be based on the costs incurred in keeping the system energy balanced.

Net Imbalance Volume Tagging

- This is done in a number of steps:
  - Initial NIV Tagging, where it is assumed that all actions in the opposite direction to the NIV are Initial NIV Tagged, and then all actions in the same direction as the NIV which have been SO or NM Flagged are Initial NIV Tagged;
  - Considering the Initial NIV Tagging, calculate the Residual Tagged Quantity, which is the volume of additional actions which need to be tagged or untagged in order to have a number of untagged actions equal to QNIV;
  - Apply the Residual Tagged Quantity on the tagged and untagged actions in the ranked set in different ways depending on the sign of QNIV (if system imbalance is long or short), and depending on the sign of QRTAG (if more action need to be tagged, or if some actions need to be untagged, in all cases either tagging or untagged a volume of actions in the ranked set equal to the volume of the Residual Tagged Quantity;
  - The result is a value of Net Imbalance Volume Tag (TNIV) for each action in the ranked set which determines whether or not that action can be included in setting the final Imbalance Price.

Net Imbalance Volume Tagging

- When tagging additional actions, it is done in order of the actions least “in-merit” to most “in-merit”, i.e. the most “expensive” actions get tagged first:
  - If QNIV is positive, then the highest priced Incs get tagged first until the volume of additional actions tagged equals QRTAG;
  - If QNIV is negative, then the lowest priced Decs get tagged first until the volume of additional actions tagged equals QRTAG;
- When untagging actions, in the general this is done in order of the most “in-merit” to the least “in-merit”, i.e. the least “expensive” actions get untagged first:
  - If QNIV is positive, then the lowest priced Incs get untagged first until the volume of the actions untagged equals QRTAG;
  - If QNIV is negative, then the highest priced Decs get untagged first until the volume of the actions untagged equals QRTAG.

Net Imbalance Volume Tagging

- The benefits of this approach include the following:
  - It identifies a set of balancing energy actions to meet the Net Imbalance Volume in all cases;
  - Actions which are accurately identified as non-energy will be tagged out first before starting to tag previously unflagged actions, which ensures that energy actions are not unnecessarily NIV Tagged (and thus prevented from setting the final Imbalance Price, potentially arbitrarily removing the marginal energy action) when it is possible to accurately exclude non-energy actions on the basis of their flags;
  - It will also ensure that, where necessary to further tag actions to meet the NIV, expensive non-energy actions that were not positively identified by SO Flagging are removed from setting the Imbalance Price by being NIV Tagged:
    - While we are confident that the SO flagging process will result in a more accurate identification of non-energy actions, this approach caters for cases where resultant unflagged actions exceed the NIV and ensures a robust price formation in all circumstances.
  - It ensures that the least expensive unflagged actions used to meet the NIV set the price, particularly for a non-marginal value for QPAR.

Net Imbalance Volume Tagging

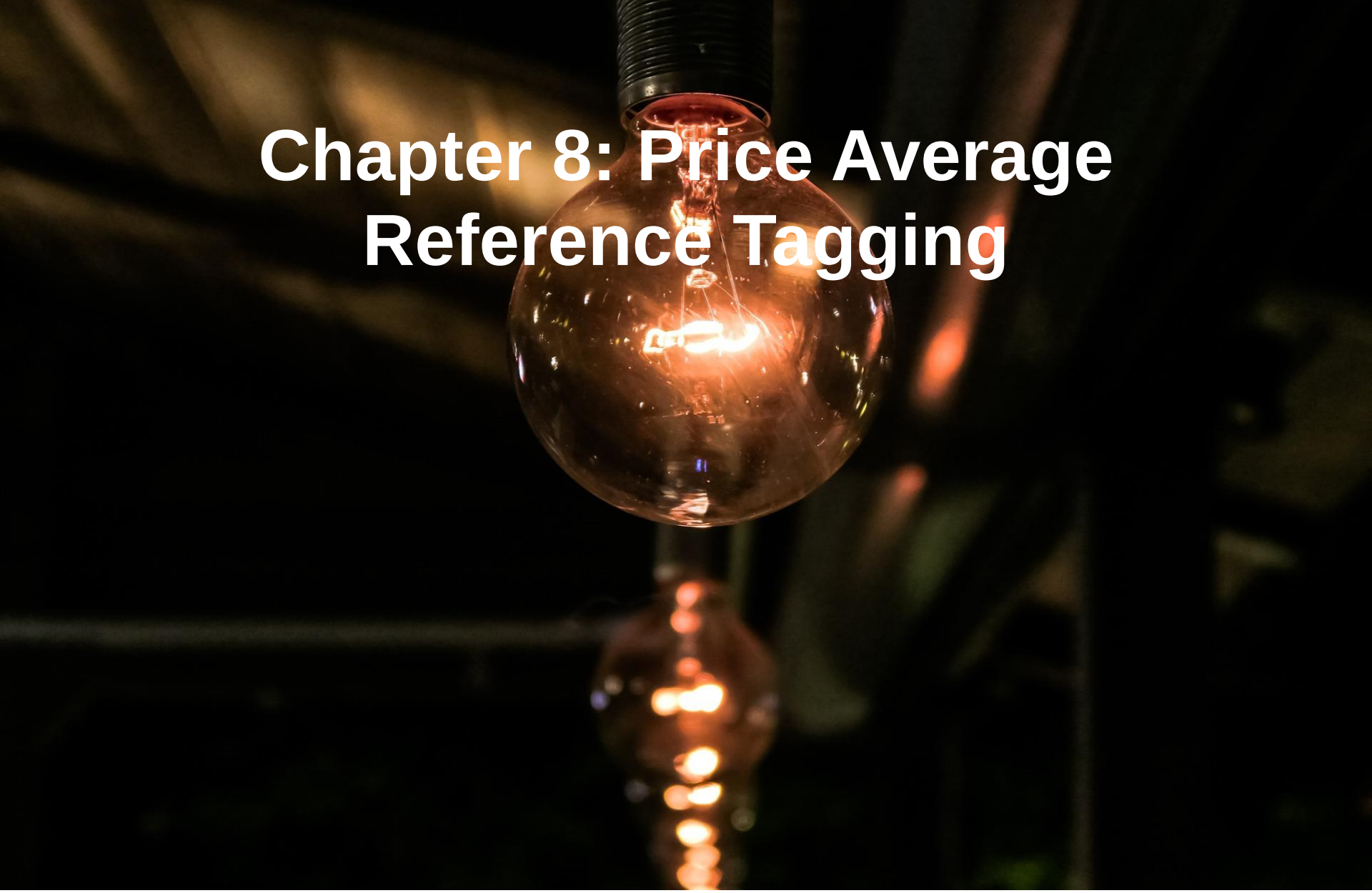
- Outcomes of this NIV Tagging approach include the following:
  - If there are insufficient flagged balancing actions to tag in order to meet the NIV, the most expensive remaining actions are then tagged until the NIV is met through untagged actions:
    - Since there are some non-energy actions which were not identified through the SO Flagging approach, this approach assumes that the most expensive actions were the ones that were taken for non-energy reasons.
  - If there are too many Actions which were flagged but then not tagged (the action is said to be "untagged" or "unflagged") are now able to influence the imbalance price again after not being able to set the Marginal Energy Action Price:
    - Because of the Replacement Bid Offer Price process, only those actions which are more "in-merit" than PMEA will be able to have their own price influence the final Imbalance Price, either entirely for a small, very marginal value for QPAR, or being one of the actions considered in the average for a larger non-marginal value for QPAR.
  - This is particularly important when using a non-marginal QPAR value to set the final price:
    - It allows actions which are in merit (i.e. have more economic prices than PMEA) and meeting the Net Imbalance Volume to be included in the average when calculating the price;
    - When QNIV is positive, can result in PMEA or a lower price;
    - When QNIV is negative, can result in PMEA or a higher price.

Net Imbalance Volume Tagging

- Untagged actions can still contain the price of actions in the direction opposite to NIV for purposes of PAR Tagging if that was the marginal price, due to the Replacement Bid Offer Price mechanism;
- An action which was initially identified as being non-energy, but which is “in-merit” when considered against the Marginal Energy Action Price, can be included in setting the final imbalance price;
- If tagging additional actions it could have the effect of removing PMEA from the prices considered in the final Imbalance Price calculation, with the less expensive, more “in-merit” prices being used in the PAR Tagging and final imbalance price calculations;
- With this functionality it is also possible to ensure that Untagged actions contain only actions in direction of NIV
    - This has the potential to result in a reduced volume over which to calculate average prices for non-marginal values of QPAR, but the volume over which this can be calculated is the Net Imbalance Volume so only actions with volumes meeting the energy balancing requirement can be included in setting the average price.

Net Imbalance Volume Tagging

- Since NIV Tags are used to identify actions which are non-energy for the purposes of the Imbalance Pricing process, it is also used in a Market Power Mitigation functionality in addition to the SO Flags:
  - Units which are NIV Tagged in any Imbalance Pricing Period in the Imbalance Settlement Period will be settled using their Complex Bid Offer Data to calculate their Bid Offer Acceptance Quantities and Prices;
  - Again this only applies to the settlement process: the unit's Simple Bid Offer Data may still be used in the pricing process if the other requirements for its use are met.



Chapter 8: Price Average Reference Tagging

Price Average Reference Tagging

- The last tagging process is Price Average Reference (PAR) Tagging;
- The purpose of PAR Tagging is to determine what actions which are not NIV Tagged, and what volume of those actions, are considered in the final calculation of the Imbalance Price;
- The Imbalance Price is calculated based on the volume-weighted average over a defined volume of the most expensive actions remaining, the defined volume being the Price Average Reference Quantity (QPAR);
- The size of the QPAR value determines how marginal the price is:
  - A smaller value for QPAR means the price is closer to a marginal price;
  - A larger value for QPAR means the price is closer to an average price.

Price Average Reference Tagging

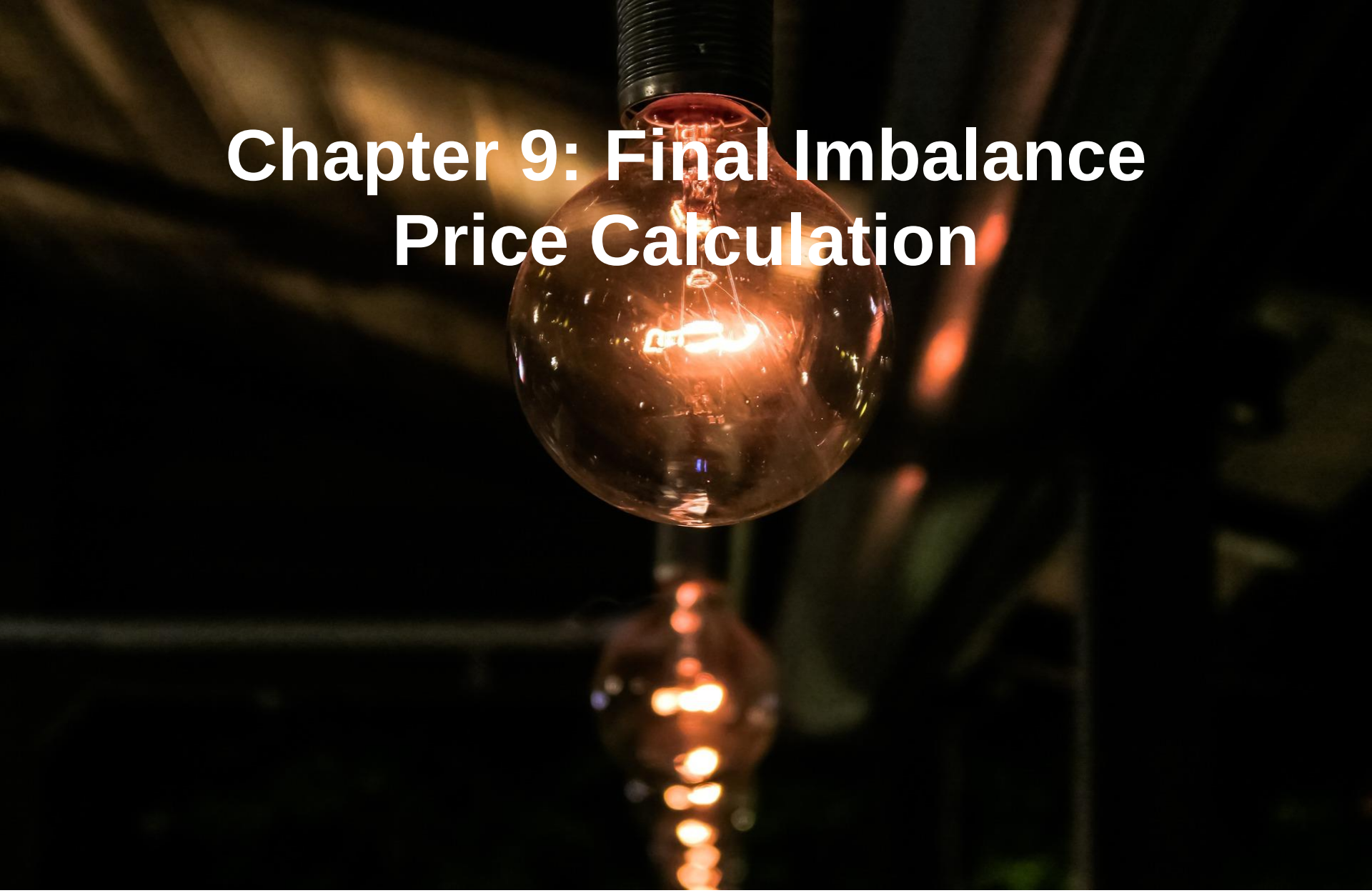
- The market design decisions set out the following in relation to PAR:
  - I-SEM High Level Design:
    - There should be a single marginal imbalance price.
  - I-SEM Energy Trading Arrangements Markets Detailed Design:
    - Preference for marginal imbalance price;
    - A suite of pricing parameters can be considered together to mitigate the concerns of participants (e.g. Continuous Acceptance Duration Limit or CADL, De Minimis Acceptance Threshold or DMAT, and QPAR);
    - Some averaging may be permitted if evidence-based and time limited; and
    - If any averaging measure is introduced, it should not unduly dampen the Imbalance Price or blunt incentives to balance.
- For I-SEM go-live, the RAs have decided on a value of 10MWh for QPAR for an Imbalance Pricing Period. This is equivalent to 60MWh for an Imbalance Settlement Period:
  - The RAs expect that the first review of parameters post go-live will prioritise reducing the value of QPAR to a marginal level if experience of live market operation shows no compelling evidence that this cannot be done.

Price Average Reference Tagging

- PAR Tagging is applied such that the price can be equal to the most marginal price after NIV Tagging, or can be less marginal than the most marginal price after NIV Tagging. Which is the most marginal price is different for when the system position is short or long (i.e. if QNIV is positive or negative):
  - If QNIV is positive, the marginal price is the highest priced offer which is not NIV tagged. Therefore the price after PAR Tagging can be equal to the marginal price or lower;
  - If QNIV is negative , the marginal price is the lowest priced bid which is not NIV tagged. Therefore the price after PAR Tagging can be equal to the marginal price or higher.
- One of the main reasons for PAR Tagging which is weighted towards an average price approach rather than a marginal price approach is to mitigate volatility in the Imbalance Price. It is part of a suite of tools which can be used to mitigate volatility, including:
  - De Minimis Tagging;
  - Calculating the half-hour Imbalance Settlement Price as a simple average of the six five-minute Imbalance Prices; and
  - When tagging additional actions in NIV Tagging, taking the most expensive actions first after taking flagged actions;
  - When untagging actions in NIV Tagging, taking the least expensive actions first.

Price Average Reference Tagging

- Note that the approach of settling an action at the most beneficial of the Imbalance Settlement Price and the Bid Offer Price applies in all cases, regardless of whether the action was “energy” or “non-energy”, if it was the “marginal” action or not, if it was “in-merit” or not, etc.:
  - For example, say a unit set PMEA, and that this would have been the final Imbalance Settlement Price, except that a non-marginal QPAR is implemented meaning the price was reduced by PAR averaging;
  - In the words of the High Level Design, the decision that “energy” actions should be pay-as-clear getting the Imbalance Settlement Price, and “non-energy” actions should be pay-as-bid getting their could seem like it is saying that the unit which set PMEA should now only be paid the average Imbalance Settlement Price, which is lower than its Bid Offer Price;
  - However with the clarification in the detailed design, the implementation approach in the settlement rules is applied solely on the basis of whether the Bid Offer Price used in settlement is higher (in the case of Inc actions) or lower (in the case of Dec actions) than the Imbalance Settlement Price.



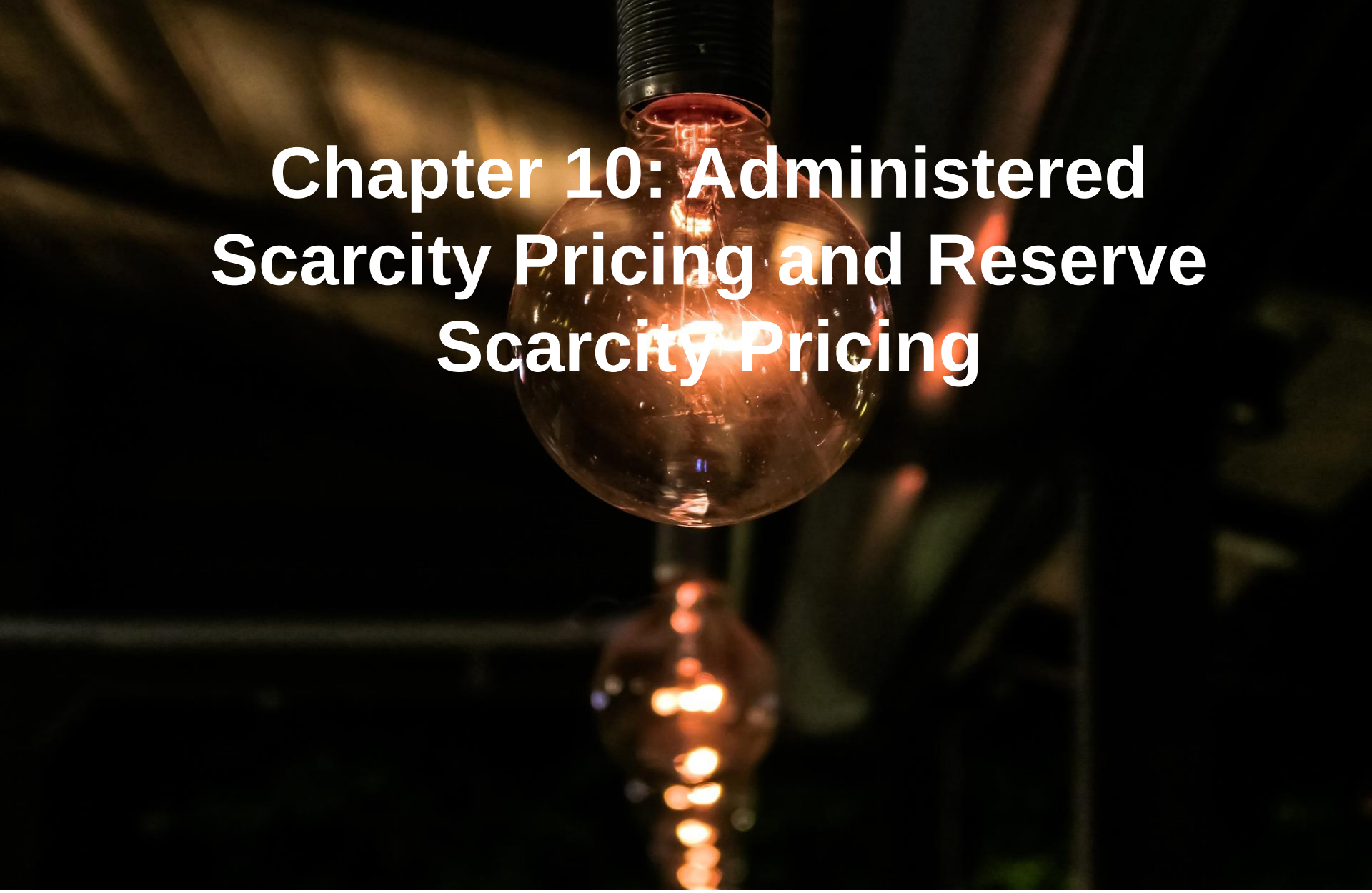
Chapter 9: Final Imbalance Price Calculation

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 final Imbalance Price calculation is carried out in three steps:
  - The Initial Imbalance Price ($PIIMB_{\phi}$) is calculated as a quantity-weighted average of the price of all actions which are not NIV or PAR tagged;
  - The Imbalance Price ($PIMB_{\phi}$) for Imbalance Pricing Period ensures that if the Administered Scarcity Price (PAS_{ϕ}) is higher, it sets the Imbalance Price;
  - Imbalance Settlement Price for Imbalance Settlement Period is the simple average of all Imbalance Prices for Imbalance Pricing Periods within the Imbalance Settlement Period.
- In the calculation of $PIMB_{\phi}$, if the result is greater than the Price Cap (PCAP) then $PIMB_{\phi}$ is made equal to PCAP, and if the result is greater than the Price Floor (PFLOOR) then $PIMB_{\phi}$ is made equal to PFLOOR:
  - The RA policy parameters decision stated that the values for these parameters for I-SEM go-live will be PCAP = 10,000 €/MWh, PFLOOR = -1,000 €/MWh.
- Since the Imbalance Settlement Price is an of the six Imbalance Pricing Period (five minutes), this means that if a high priced action was accepted for a short period of time, it does not set the price for the whole half-hour.



Chapter 10: Administered Scarcity Pricing and Reserve Scarcity Pricing

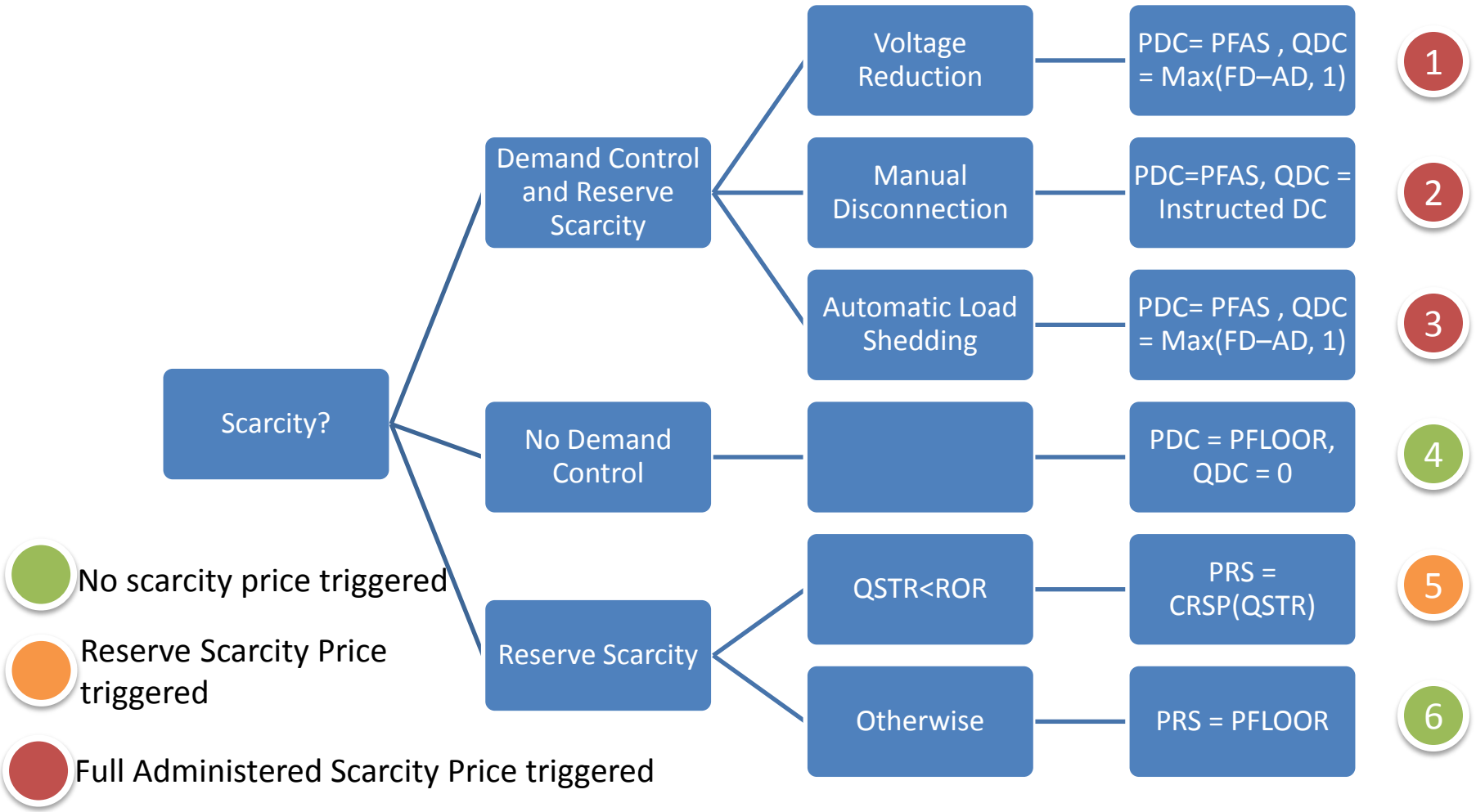
ASP and RSP

- The purpose of the Administered and Reserve Scarcity Pricing functionality is to ensure that the price reflects the cost and value of power in times of scarcity, in case the market prices and normal pricing process may not reflect this;
- It was introduced in particular to enhance the Capacity Market performance incentives:
  - This price sets the Price Floor at times of system stress (for example, reserve shortfall or load-shedding) to a much higher price than would normally be expected in the balancing market, but which should be reflective of the cost of scarcity in such times.
- There are two main considerations for this functionality:
  - How the functionality is triggered; and
  - How the price is derived when it is triggered.

ASP and RSP

- The times that the functionality is triggered is related to stress on the system, in particular:
  - When load shedding occurs; or
  - Where shortfall in short term reserves occurs.
- The main input for determining the price at times that the functionality is triggered is an RA determined Reserve Scarcity Curve, which reflects what the price should be at different levels of reserve scarcity;
- Reserve scarcity is where the volume of short term reserves actually being provided is less than the volume required for them;
- The following slide summarises the instances where the functionality is triggered, and the resulting administered pricing outcome.

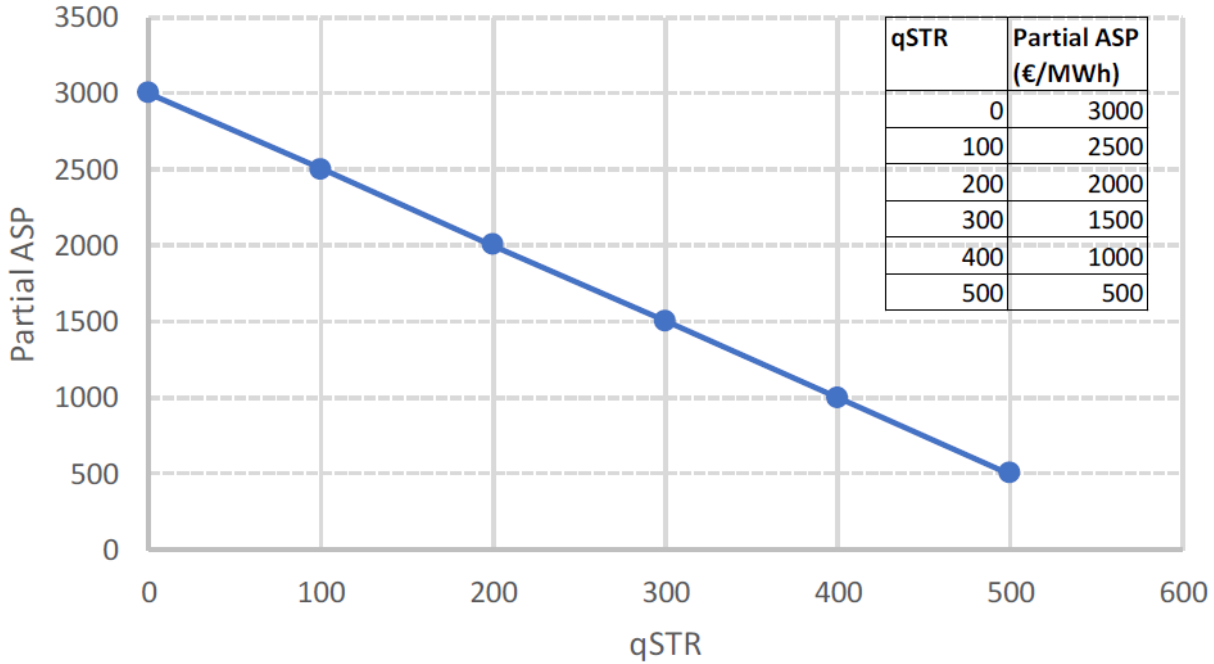
ASP and RSP


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

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

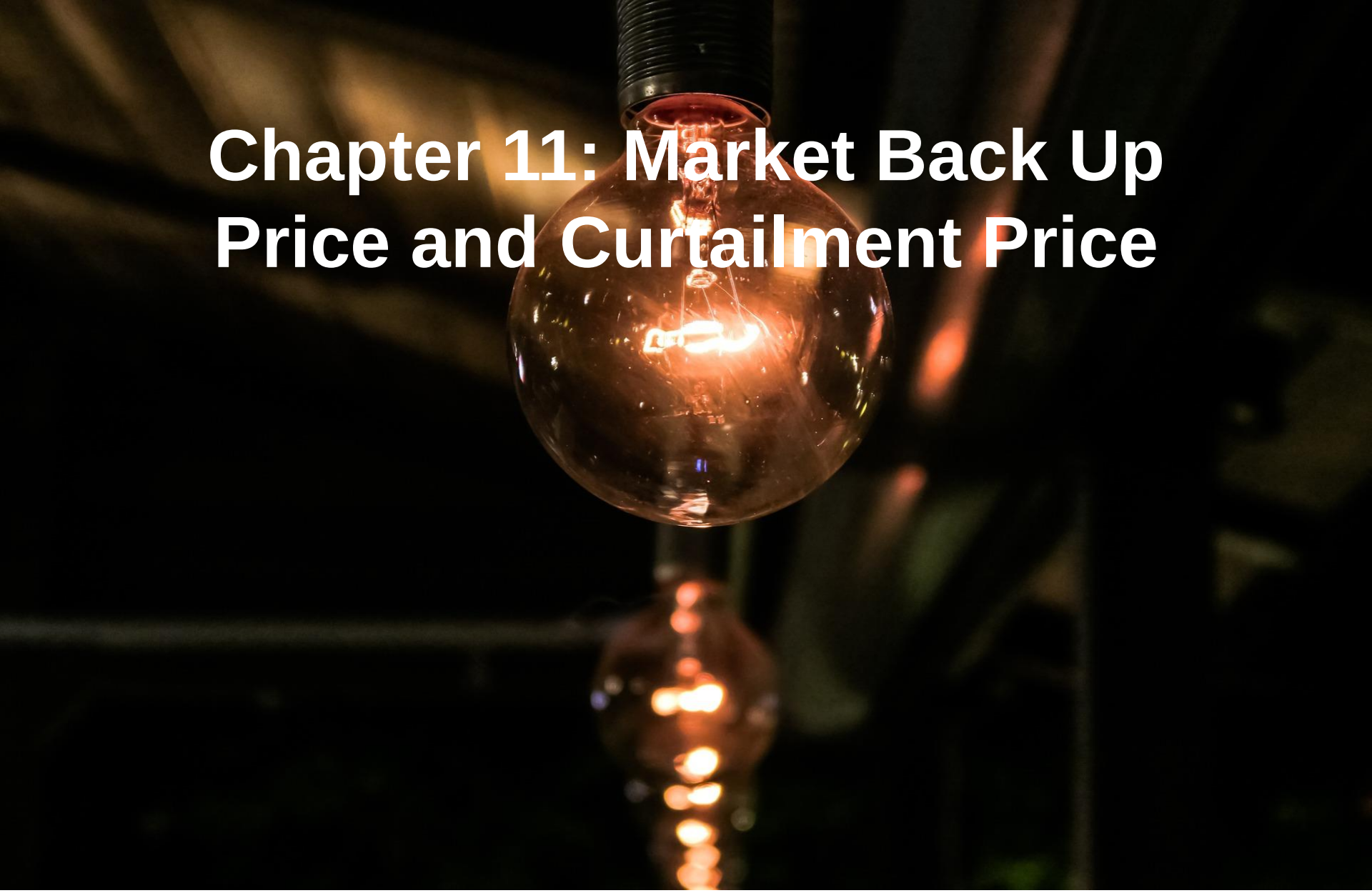
- The Full Administered Scarcity Price (PFAS) can be triggered for Demand Control triggered in either Ireland or Northern Ireland jurisdictions;
- However to ensure that it is only triggered for system-wide events rather than local jurisdiction events, there is a “double-lock”, where this approach only 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 (when reserve scarcity is present):
  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.



Chapter 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.

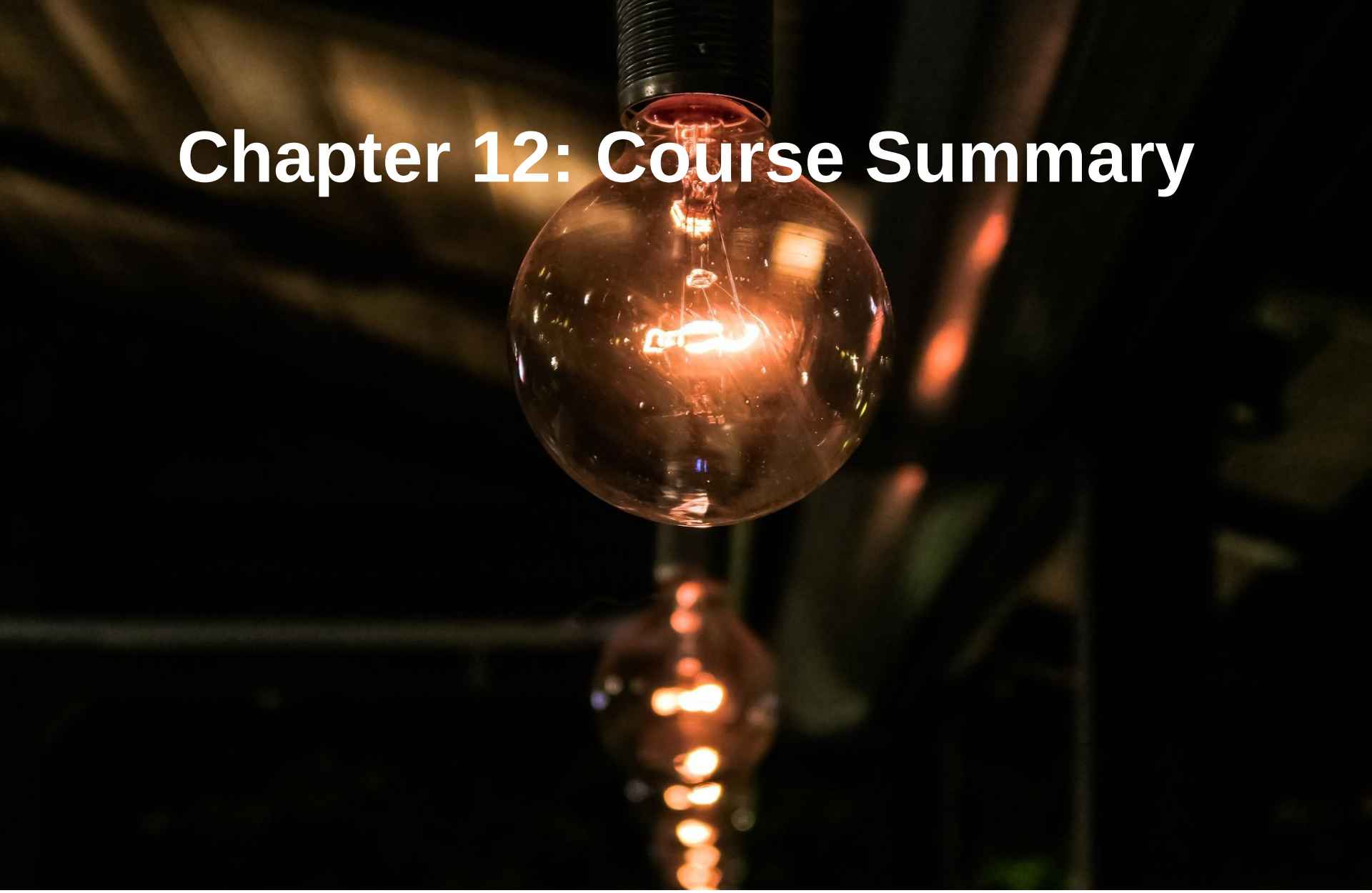
- For each Imbalance Settlement Period, γ, the Market Operator shall calculate the Market Back Up Price (PMBUγ) as the quantity-weighted average price of the prices associated with each Day-ahead Trade Quantity (qTDAxuh, qTDAxvh) and Intraday Trade Quantity (qTIDxuh, qTIDxvh) for all Generator Units,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

Chapter 12: Course Summary



Review of 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