

ETA Workshop 2.3

Imbalance Settlement

Extra content added after ETA Workshop 2.2

Imbalance Settlement

- Imbalance Settlement must ensure that participants pay and get paid the correct amounts for electricity volumes that they consume and produce
- Balance Responsibility in I-SEM
 - Generator and Supplier units are subject to imbalance settlement
- Imbalance Settlement = (Total Metered Energy – Total Contracted Energy) * Imbalance Price
- Single marginal Imbalance Price
- Building Blocks – proposed settlement for non-energy actions
 - A unit that is ‘constrained down’ due to a dispatch instruction pays back the lower of its decremental offer price or the imbalance price
 - A unit that is ‘constrained up’ due to a dispatch instruction receives the higher of its incremental offer price or the imbalance price
- The amount a generator gets paid is then not affected by TSO classifications
- A generator is never financially worse off for having solved a constraint

Notation and Definitions for Cash Flow Algebra

Notation	Definition
C	Cashflow
P_{CON}	Ex-ante contracted price
Q_{CON}	Ex-ante contracted quantity
P_{IMB}	Energy imbalance price
Q_{DQ}	Dispatch quantity
P_{BO}	Balancing order price
Q_{FAQ}	Firm access quantity
Q_{FPN}	Final Physical Notification quantity
Q_{BOA}	Bid/Offer Acceptance quantity

Settlement – Up Regulation

Physical Notification = Ex-ante Contract

$$\begin{aligned} C &= P_{\text{CON}} \cdot Q_{\text{CON}} \\ &+ P_{\text{IMB}} \cdot (Q_{\text{DQ}} - Q_{\text{CON}}) \\ &+ \max(P_{\text{BO}} - P_{\text{IMB}}, 0) \cdot \max(Q_{\text{DQ}} - Q_{\text{CON}}, 0) \end{aligned}$$

□ Unit Dispatched up for Energy

□ Cashflow = Revenue from ex-ante trades
+ Imbalance Price * Dispatch Up Volume (Energy)

□ Unit Dispatched up for Non-Energy

Cashflow = Revenue from ex-ante trades
+ Imbalance Price * Dispatch Up Volume (Non-Energy)
+ Premium of Inc Price over Imbalance Price * Dispatch
Volume Up (Non-Energy)

Settlement – Down Regulation

Physical Notification = Ex-ante Contract

$$\begin{aligned}
 \square C &= P_{CON} \cdot Q_{CON} \\
 \square &+ P_{IMB} \cdot (Q_{DQ} - Q_{CON}) \\
 \square &+ \min(P_{BO} - P_{IMB}, 0) \cdot \min(Q_{DQ} - \min(Q_{FAQ}, Q_{CON}), 0)
 \end{aligned}$$

Unit Dispatched down for Energy

- Cashflow = Revenue from ex-ante trades
 - Imbalance Price * Dispatch Down Volume (Energy)

Unit Dispatched down for Non-Energy

- Cashflow = Revenue from ex-ante trades
 - Imbalance Price * Dispatch Down Volume (Non-Energy)
 - + Discount of Dec Price under Imbalance Price * Firm Dispatch Down Volume (Non-Energy)

Settlement – Up Regulation

Physical Notification \neq Ex-ante Contract

$$\begin{aligned}
 \square C &= P_{\text{CON}} \cdot Q_{\text{CON}} \\
 &\quad + P_{\text{IMB}} \cdot (Q_{\text{DQ}} - Q_{\text{CON}}) \\
 &\quad + \max(P_{\text{BO}} - P_{\text{IMB}}, 0) \cdot \max(Q_{\text{DQ}} - Q_{\text{FPN}}, 0)
 \end{aligned}$$

Unit Dispatched up for Energy

$$\begin{aligned}
 \square \text{Cashflow} &= \text{Revenue from ex-ante trades} \\
 &\quad + \text{Imbalance Price} * (\text{Dispatch Quantity over Ex-ante Quantity})
 \end{aligned}$$

Unit Dispatched up for Non-Energy

$$\begin{aligned}
 \text{Cashflow} &= \text{Revenue from ex-ante trades} \\
 &\quad + \text{Imbalance Price} * (\text{Dispatch Quantity over Ex-ante Quantity}) \\
 &\quad + \text{Premium of Inc Price over Imbalance Price} * \\
 &\quad (\text{Dispatch Quantity over FPN})
 \end{aligned}$$

Settlement – Down Regulation

Physical Notification \neq Ex-ante Contract

$$\begin{aligned}
 C = & P_{CON} \cdot Q_{CON} \\
 & + P_{IMB} \cdot (Q_{DQ} - Q_{CON}) \\
 & + \min(P_{BO} - P_{IMB}, 0) \cdot \min(Q_{DQ} - \min(Q_{FAQ}, Q_{FPN}, \\
 & Q_{CON}), 0)
 \end{aligned}$$

Unit Dispatched down for Energy

Cashflow = Revenue from ex-ante trades
 - Imbalance Price * (Dispatch Quantity under Ex-ante Quantity)

Unit Dispatched down for Non-Energy

Cashflow = Revenue from ex-ante trades
 - Imbalance Price * (Dispatch Quantity under Ex-ante Quantity)
 + Discount of Dec Price under Imbalance Price *
 lesser **firm** volume of (Dispatch Quantity under FPN) and
 (Dispatch Quantity under Ex-ante Quantity)

Numerical Example (1)

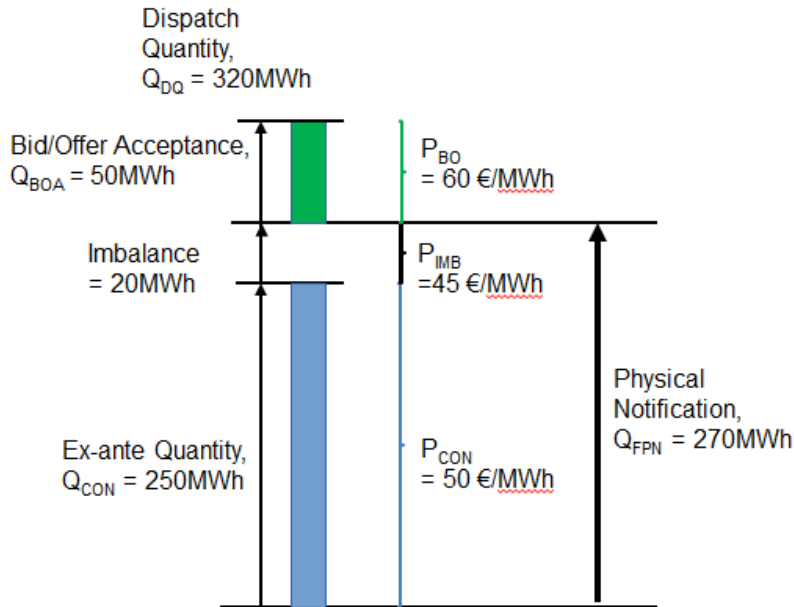
- Unit sells 250MWh in the ex-ante markets @ 50 €/MWh
- Submits FPN of 270MWh and Inc Offer to BM of 50MWh @ 60 €/MWh
- TSO activates this Inc Offer for non-energy action by dispatching unit at 320MWh
- The Imbalance price clears @ 45 €/MWh

Unit Dispatched up for Non-Energy

$$\begin{aligned} \text{Cashflow} = & \text{Revenue from ex-ante trades} \\ & + \text{Imbalance Price} * (\text{Dispatch Quantity over Ex-ante Quantity}) \\ & + \text{Premium of Inc Price over Imbalance Price} * \\ & (\text{Dispatch Quantity over FPN}) \end{aligned}$$

Direct from Algebra:

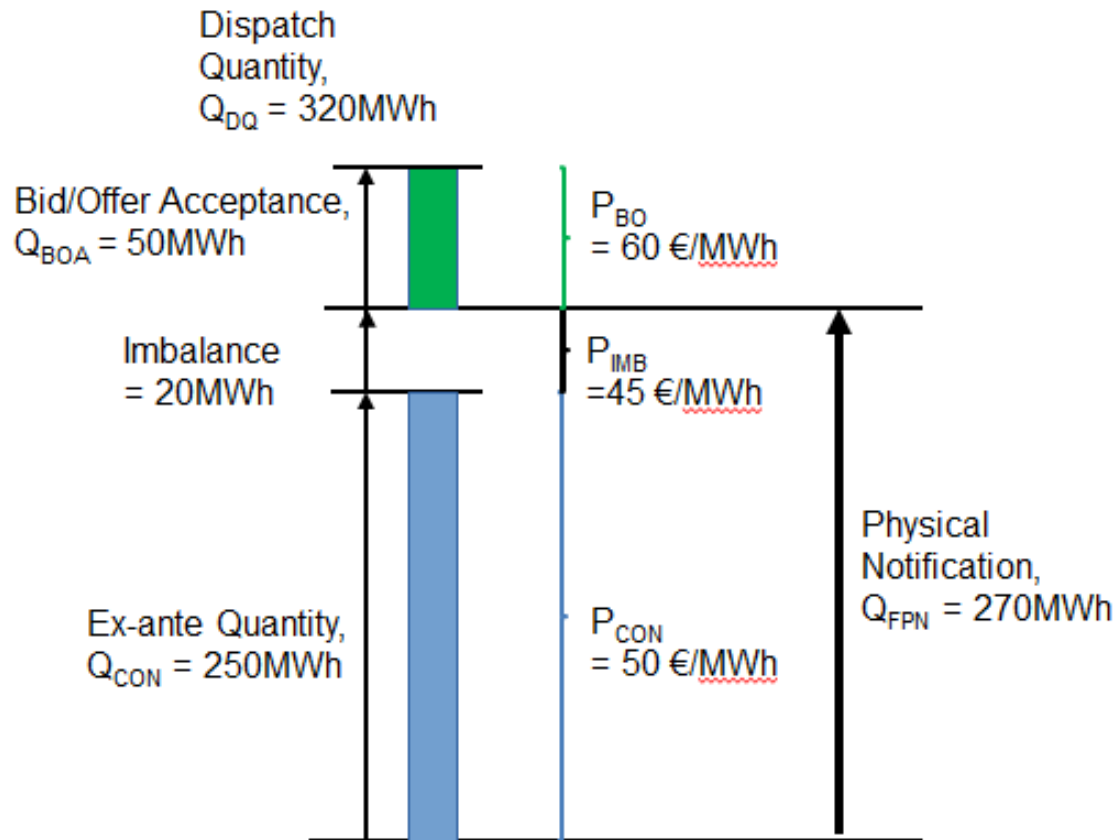
$$\begin{aligned} & 1) \text{ 250MWh @ } 50 \text{ €/MWh} \\ & 2) \text{ 70MWh @ } 45 \text{ €/MWh} \\ & 3) \text{ 50 MWh @ } 15 \text{ €/MWh} \\ & = 12,500 + 3,150 + 750 = \text{€16,400} \end{aligned}$$



Alternative Breakdown:

$$\begin{aligned} & 1) \text{ 250MWh @ } 50 \text{ €/MWh (Ex-ante trades)} \\ & 2) \text{ 20MWh @ } 45 \text{ €/MWh (Imbalance)} \\ & 3) \text{ 50 MWh @ } 60 \text{ €/MWh (Activated Inc)} \\ & = 12,500 + 900 + 3,000 = \text{€16,400} \end{aligned}$$

Numerical Example (1)



Numerical Example (2)

- Unit sells 250MWh in the ex-ante markets @ 50 €/MWh (FAQ = 600MW)
- Submits FPN of 270MWh and Dec Bid to BM of 100MWh @ 45 €/MWh
- TSO activates this Dec Bid for non-energy action by dispatching unit at 170MWh
- The Imbalance price clears @ 70 €/MWh

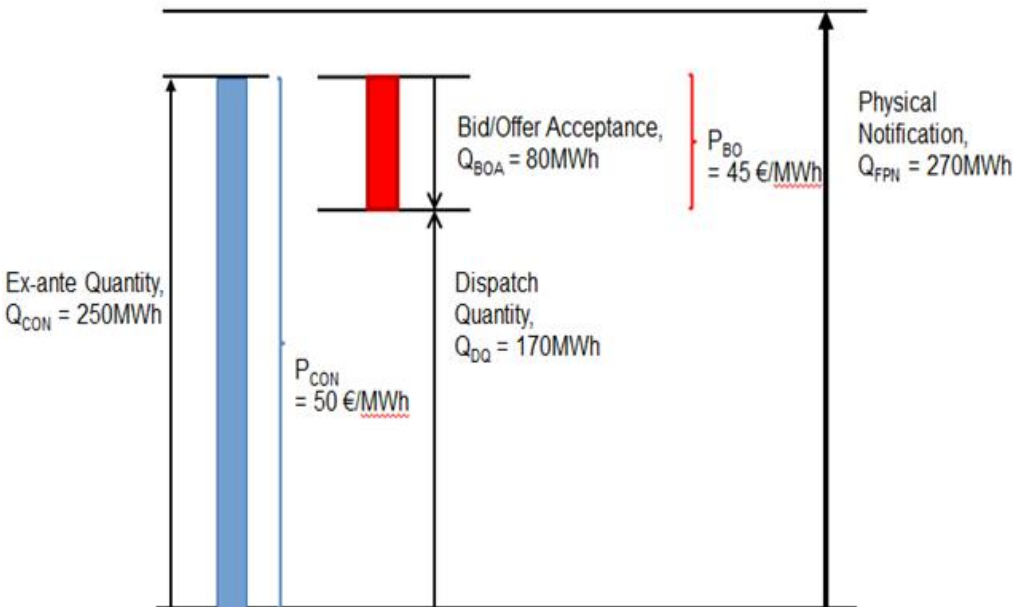
Unit Dispatched down for Non-Energy

Cashflow = Revenue from ex-ante trades

- Imbalance Price * (Dispatch Quantity under Ex-ante Quantity)
- + Discount of Dec Price under Imbalance Price * lesser **firm** volume of (Dispatch Quantity under FPN) and (Dispatch Quantity under Ex-ante Quantity)

Direct from Algebra:

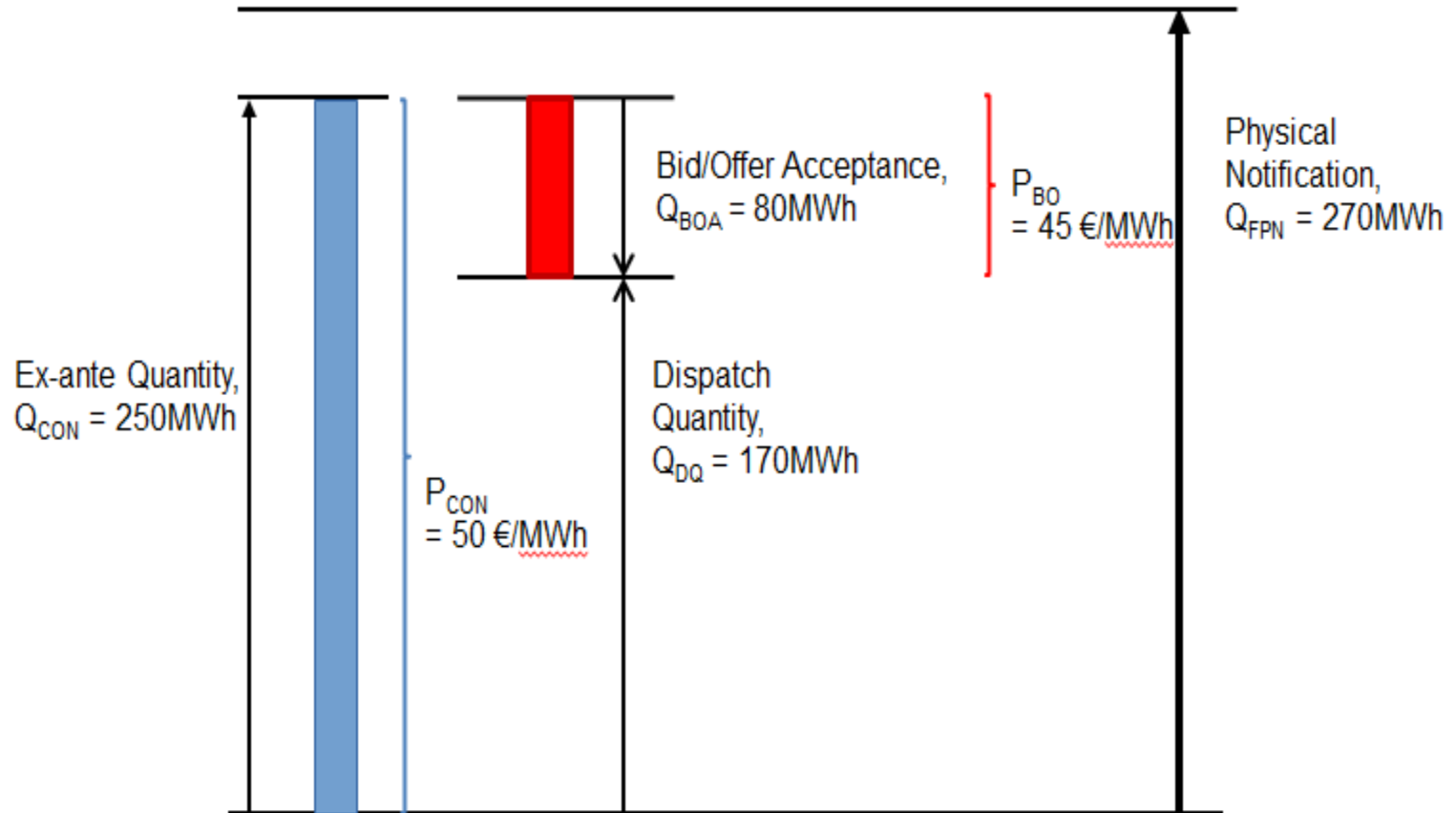
- 1) 250MWh @ 50 €/MWh
 - 2) minus 80MWh @ 70 €/MWh
 - 3) 80 MWh @ 25 €/MWh
- = 12,500 - 5,600 + 2,000 = €8,900



Alternative Breakdown:

- 1) 250MWh @ 50 €/MWh (Ex-ante trades)
 - 2) minus 80MWh @ 45 €/MWh (Activated Dec)
- = 12,500 - 3,600 = €8,900

Numerical Example (2)



Numerical Example (3)

- Unit sells 250MWh in the ex-ante markets @ 50 €/MWh (FAQ = 600MW)
- Submits FPN of 230MWh and Dec Bid to BM of 100MWh @ 30 €/MWh
- TSO activates this Dec Bid for non-energy action by dispatching unit at 130MWh
- The Imbalance price clears @ 40 €/MWh

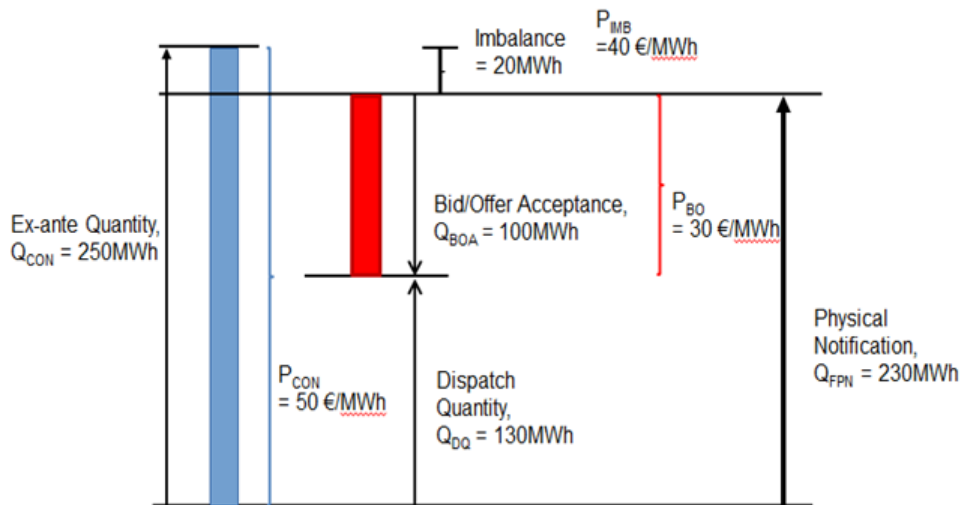
Unit Dispatched down for Non-Energy

Cashflow = Revenue from ex-ante trades

- Imbalance Price * (Dispatch Quantity under Ex-ante Quantity)
- + Discount of Dec Price under Imbalance Price * lesser **firm** volume of (Dispatch Quantity under FPN) and (Dispatch Quantity under Ex-ante Quantity)

Direct from Algebra:

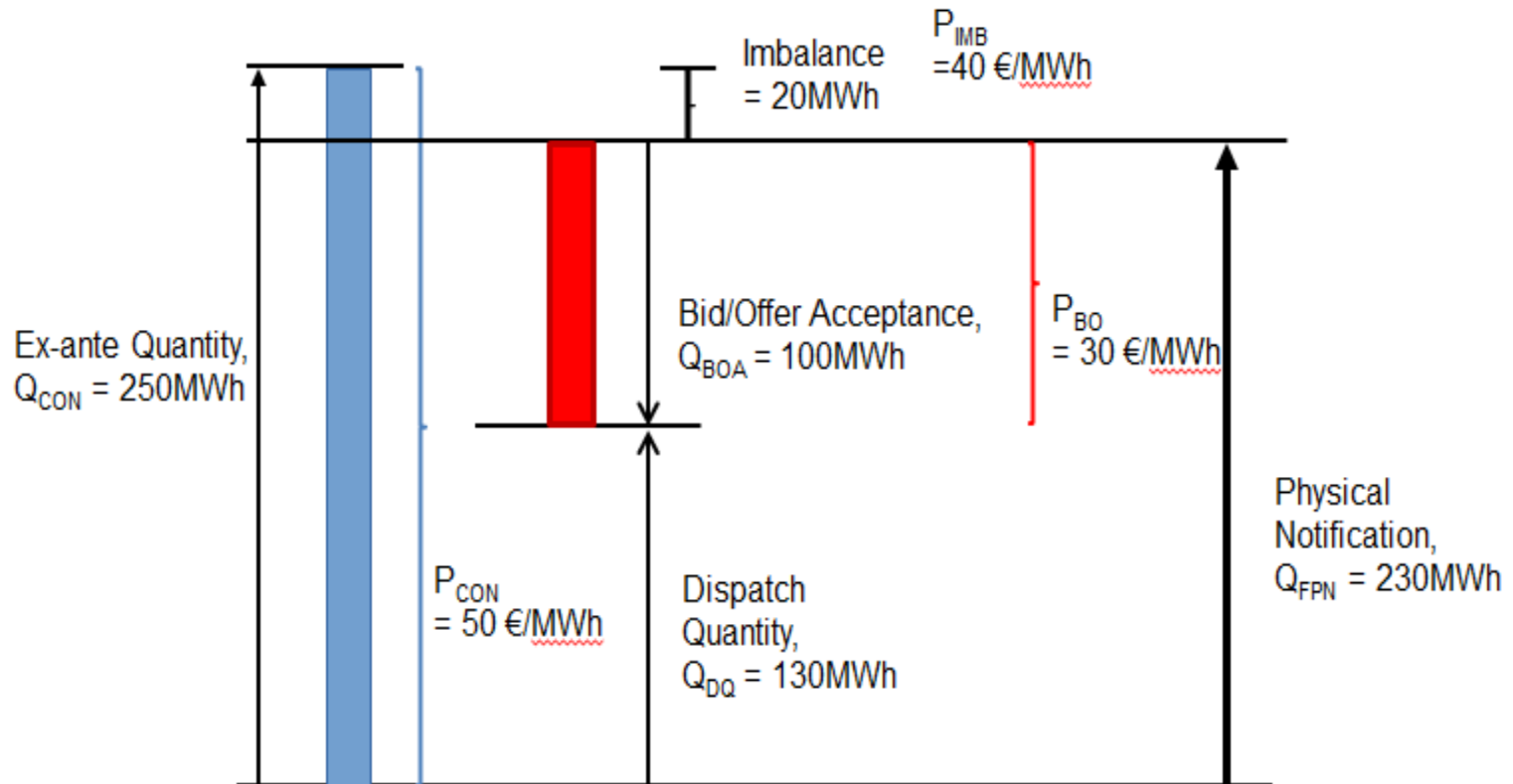
- 1) 250MWh @ 50 €/MWh
 - 2) minus 120MWh @ 40 €/MWh
 - 3) 100 MWh @ 10 €/MWh
- = 12,500 – 4,800 + 1,000 = €8,700



Alternative Breakdown:

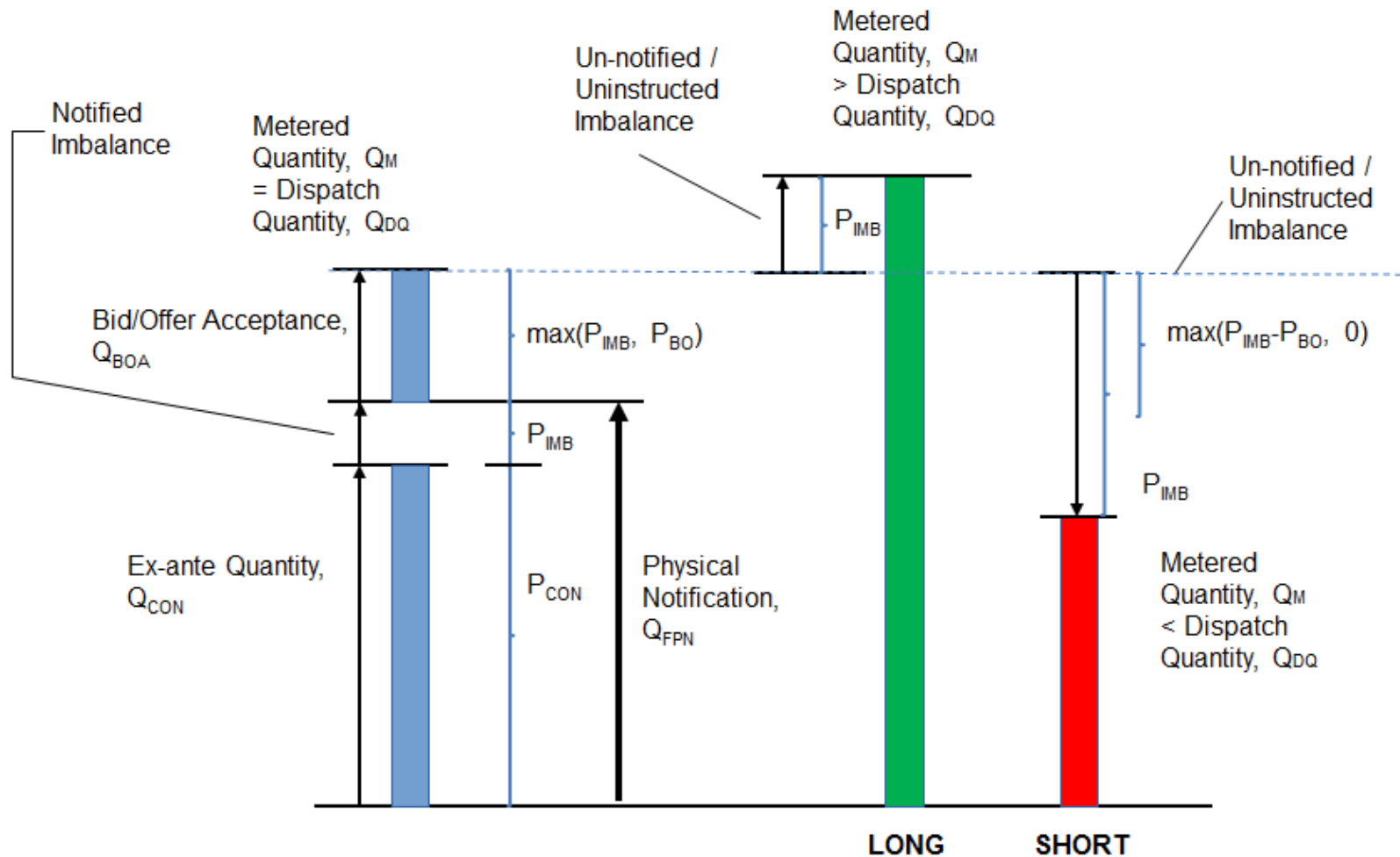
- 1) 250MWh @ 50 €/MWh (Ex-ante trades)
 - 2) minus 100MWh @ 30 €/MWh (Activated Dec)
 - 3) minus 20MWh @ 40 €/MWh (Imbalance)
- = 12,500 – 3,000 – 800 = €8,700

Numerical Example (3)



Dispatch Quantity vs Metered Generation

- Un-notified / Uninstructed Imbalances
- Non-Delivery Rule



Imbalance Settlement Discussion



Extra Slides and Examples

(subsequent to ETA RLG 2.2)

FAQ Example

- Unit sells 250MWh in the ex-ante markets @ 50 €/MWh
- Unit has Firm Access Quantity of 210MWh
- Submits FPN of 230MWh and Dec Bid to BM of 100MWh @ 30 €/MWh
- TSO activates this Dec Bid for non-energy action by dispatching unit at 130MWh
- The Imbalance Price clears @ 40 €/MWh

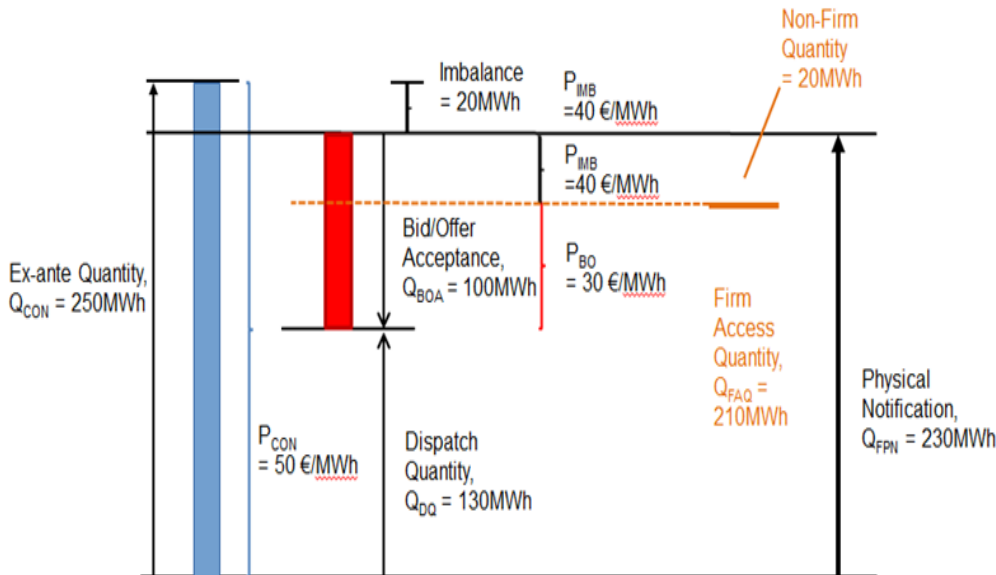
Unit Dispatched down for Non-Energy

Cashflow = Revenue from ex-ante trades

- Imbalance Price * (Dispatch Quantity under Ex-ante Quantity
- + Discount of Dec Price under Imbalance Price *
- lesser **firm** volume of (Dispatch Quantity under FPN) and
- (Dispatch Quantity under Ex-ante Quantity)

Direct from Algebra:

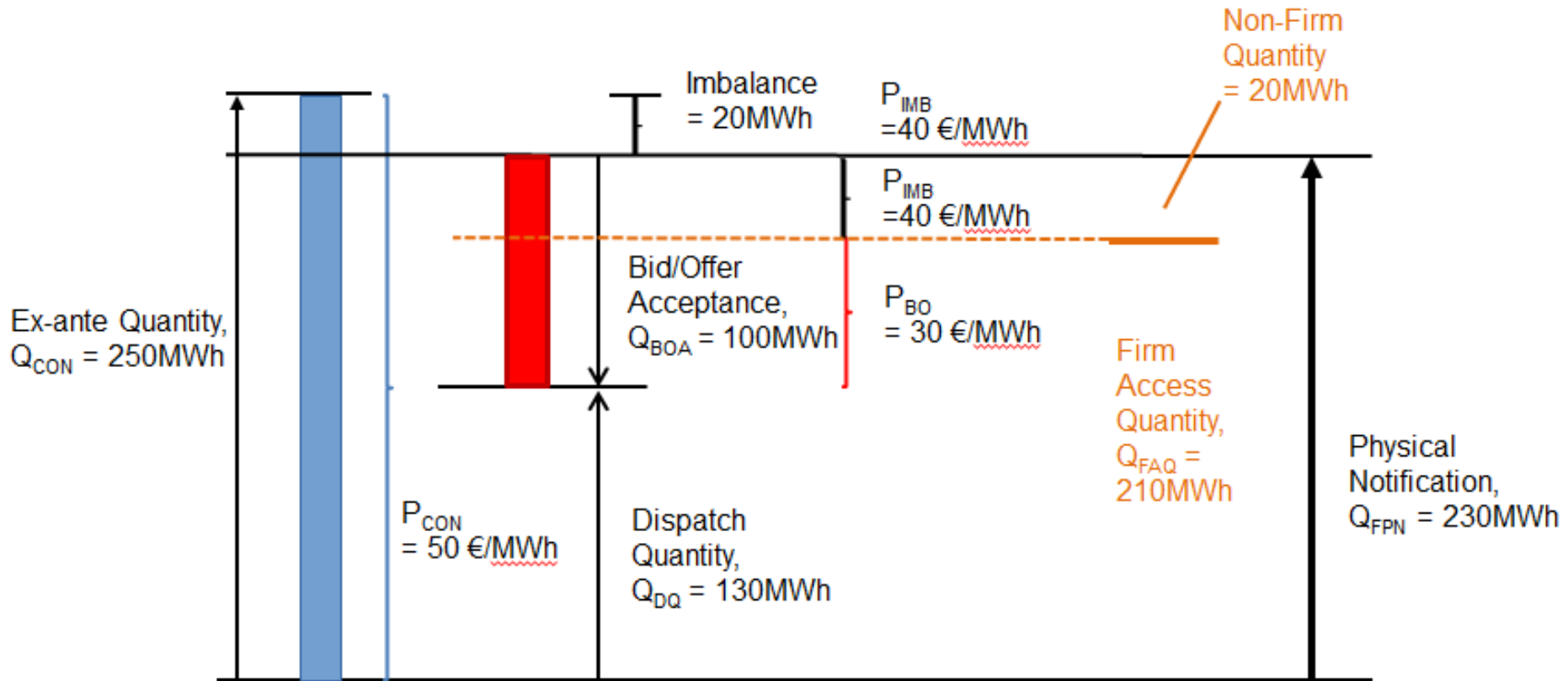
- 1) 250MWh @ 50 €/MWh
 - 2) minus 120MWh @ 40 €/MWh
 - 3) 80 MWh @ 10 €/MWh
- = 12,500 - 4,800 + 800 = €8,500



Alternative Breakdown:

- 1) 250MWh @ 50 €/MWh (Ex-ante trades)
 - 2) minus 20MWh @ 40 €/MWh (Imbalance)
 - 3) minus 20MWh @ 40 €/MWh (Activated Dec above FAQ)
 - 4) minus 80MWh @ 30 €/MWh (Activated Dec within FAQ)
- = 12,500 - 800 - 800 - 2,400 = €8,500

FAQ Example



From the Supplier's perspective

- Purchase quantities are negative
- An Incremental Offer is a proposal to reduce demand
- The price of a supplier's Incremental Offer represents the price at which the supplier will reduce demand
- A Decremental Bid is a proposal to increase demand
- The price of a supplier's Decremental Bid represents the price at which the supplier will increase demand

Supplier (with no dispatchable demand)
Physical Notification **probably not required**

$$C = P_{\text{CON}} \cdot Q_{\text{CON}} + P_{\text{IMB}} \cdot (Q_{\text{M}} - Q_{\text{CON}})$$

where cashflow is to the supplier, i.e. negative

Supplier with Metered Demand greater than Ex-ante Purchases

Cashflow = - Payment for ex-ante purchases
- Imbalance Price * (Metered Quantity under Ex-Ante Quantity)
{where both are negative}

Supplier with Metered Demand less than Ex-ante Purchases

Cashflow = - Payment for ex-ante purchases
+ Imbalance Price * (Metered Quantity over Ex-Ante Quantity)
{where both are negative}

Supplier Example (1)

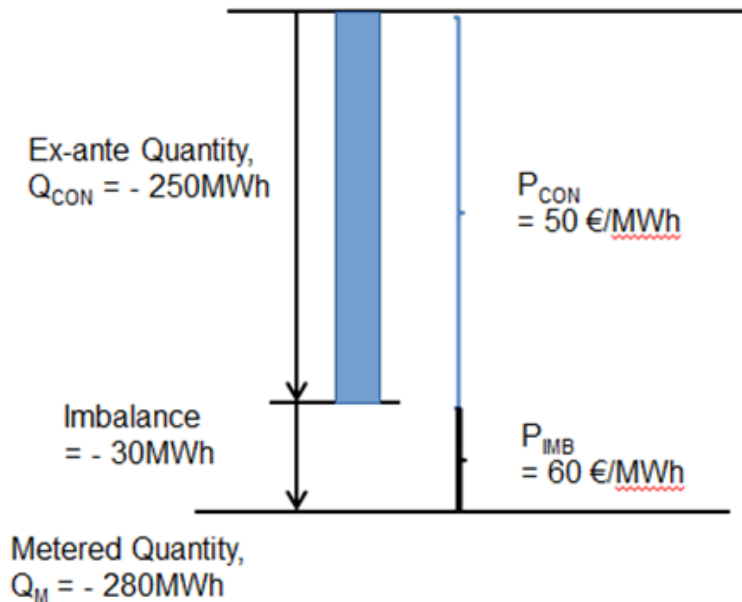
- Supplier buys 250MWh in the ex-ante markets @ 50 €/MWh
- Supplier's Metered Quantity is -280MWh
- The Imbalance Price clears @ 60 €/MWh

Supplier with Metered Demand greater than Ex-ante Purchases

Cashflow = - Payment for ex-ante purchases
 - Imbalance Price * (Metered Quantity
 under Ex-ante Quantity)

Direct from Algebra:

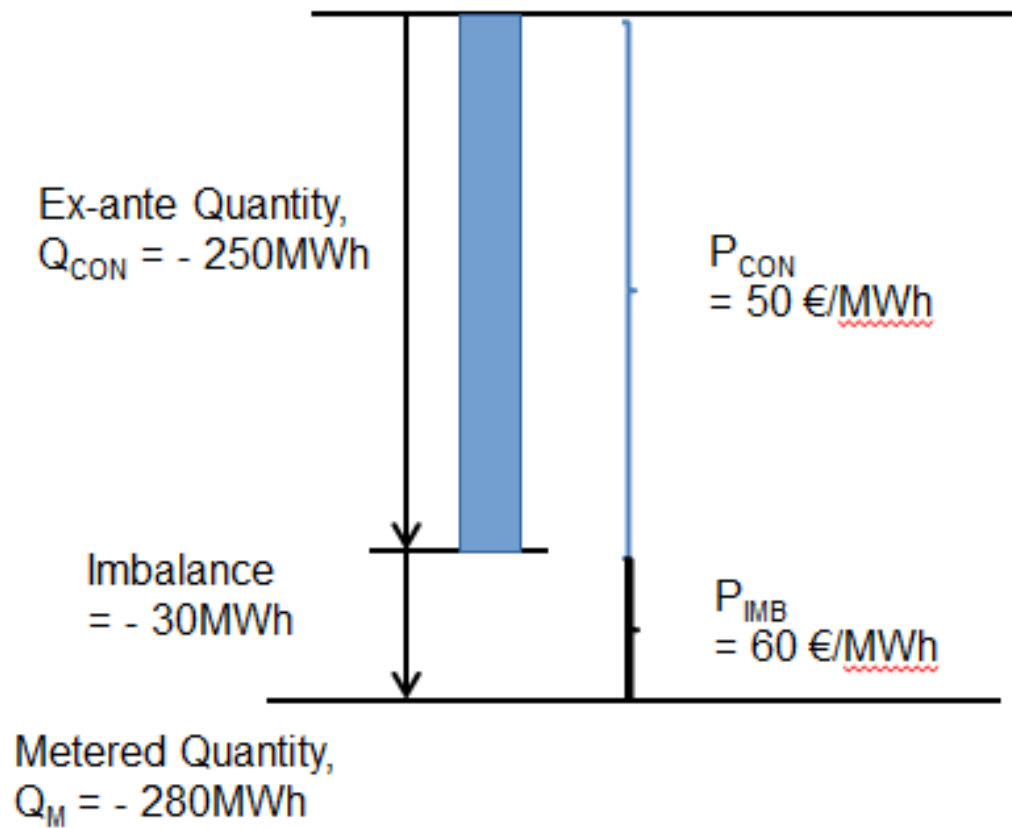
$$\begin{aligned}
 &1) - 250\text{MWh @ } 50 \text{ €/MWh} \\
 &2) + ((-280) - (-250))\text{MWh @ } 60 \text{ €/MWh} \\
 &= -12,500 - 1,800 = - \text{€}14,300
 \end{aligned}$$



Alternative Breakdown:

$$\begin{aligned}
 &1) - 250\text{MWh @ } 50 \text{ €/MWh (Ex-ante purchases)} \\
 &2) - 30\text{MWh @ } 60 \text{ €/MWh (Imbalance)} \\
 &= -12,500 - 1,800 = - \text{€}14,300
 \end{aligned}$$

Supplier Example (1)



Supplier Example (2)

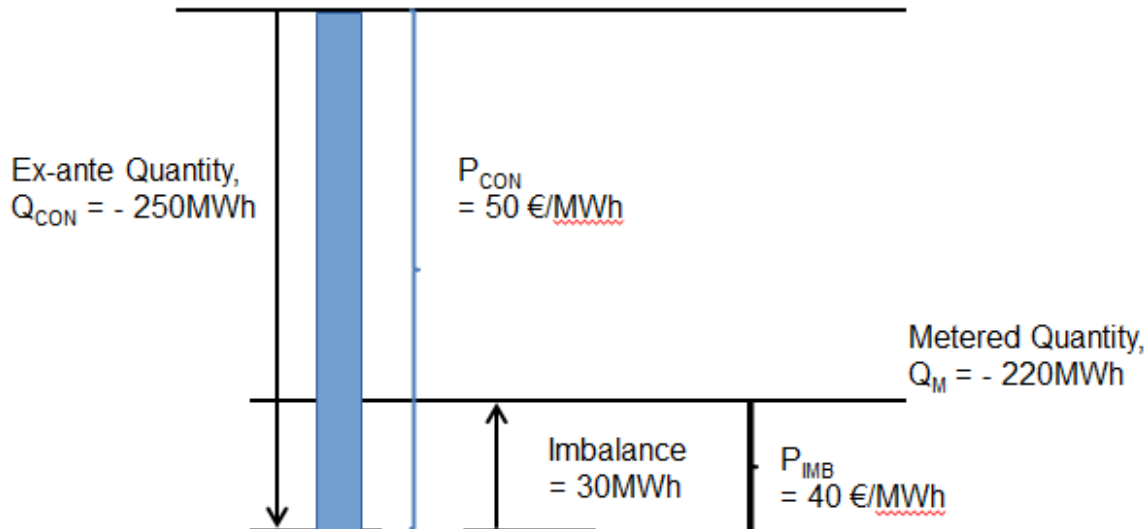
- Supplier buys 250MWh in the ex-ante markets @ 50 €/MWh
- Supplier's Metered Quantity is -220MWh
- The Imbalance Price clears @ 40 €/MWh

Supplier with Metered Demand less than Ex-ante Purchases

$$\text{Cashflow} = - \text{Payment for ex-ante purchases} \\ + \text{Imbalance Price} * (\text{Metered Quantity} \\ \text{over Ex-ante Quantity})$$

Direct from Algebra:

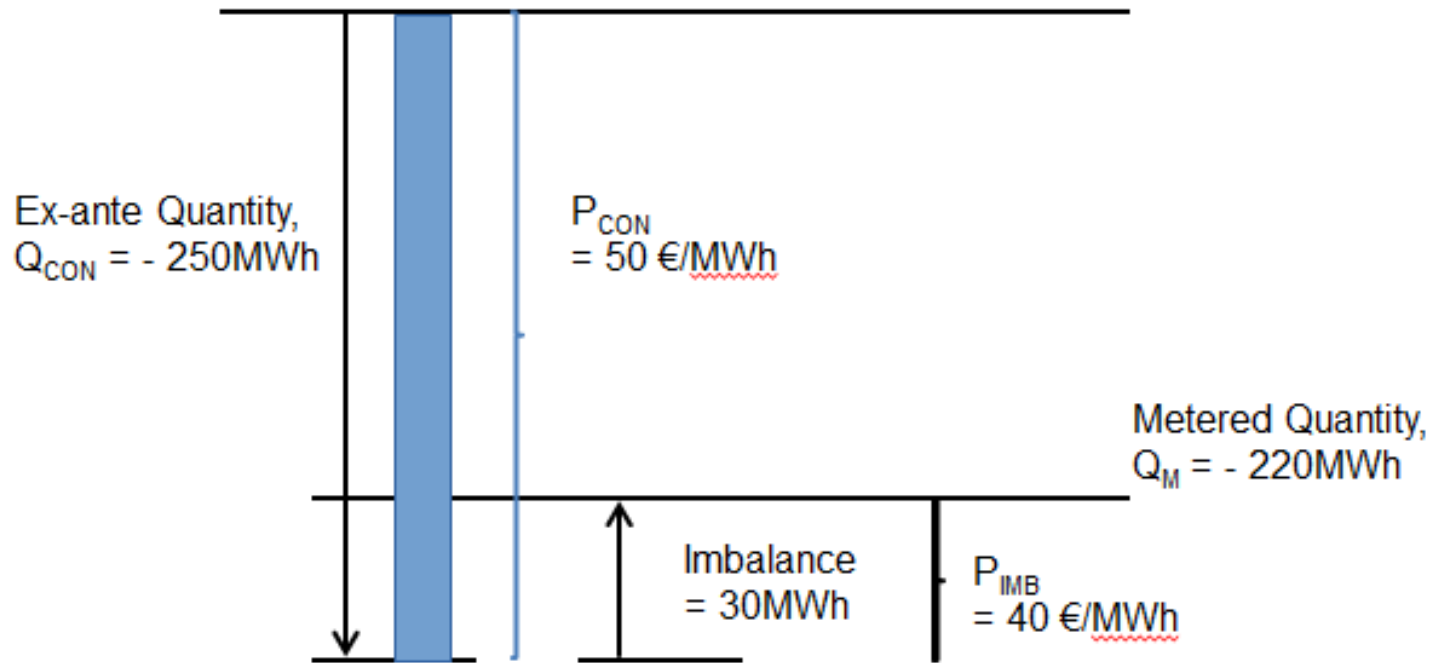
$$\begin{aligned} 1) & - 250\text{MWh} @ 50 \text{ €/MWh} \\ 2) & + ((-220) - (-250))\text{MWh} @ 40 \text{ €/MWh} \\ & = -12,500 + 1,200 = - \text{€}11,300 \end{aligned}$$



Alternative Breakdown:

$$\begin{aligned} 1) & - 250\text{MWh} @ 50 \text{ €/MWh} \\ & \quad \quad \quad \text{(Ex-ante trades)} \\ 2) & + 30\text{MWh} @ 40 \text{ €/MWh} \\ & \quad \quad \quad \text{(Imbalance)} \\ & = -12,500 + 1,200 = - \text{€}11,300 \end{aligned}$$

Supplier Example (2)



Supplier – Dispatchable Demand with Accepted Dec Physical Notification **required**

$$C = P_{CON} \cdot Q_{CON} + P_{IMB} \cdot (Q_{DQ} - Q_{CON}) + \min(P_{BO} - P_{IMB}, 0) \cdot \min(Q_{DQ} - \min(Q_{FPN}, Q_{CON}), 0)$$

Demand Dispatched Down for Energy (i.e. Increased Demand)

Cashflow = - Payment for ex-ante purchases
- Imbalance Price * Dispatch Down Volume

Demand Dispatched Down for Non-Energy (i.e. Increased Demand)

Cashflow = - Payment for ex-ante purchases
- Imbalance Price * Dispatch Down Volume
+ Discount of Dec Price under Imbalance Price *
lesser volume of (Dispatch Quantity under FPN) and
(Dispatch Quantity under Ex-ante Quantity)

Supplier (with dispatchable demand) Example (1)

- Supplier buys 100MWh in the ex-ante markets @ 50 €/MWh
- Submits FPN of -100MWh and Dec Bid to BM of -10MWh @ - 100 €/MWh
- TSO activates this Dec Bid for non-energy action by changing the dispatchable demand to -110MWh
- The Imbalance Price clears @ 60 €/MWh

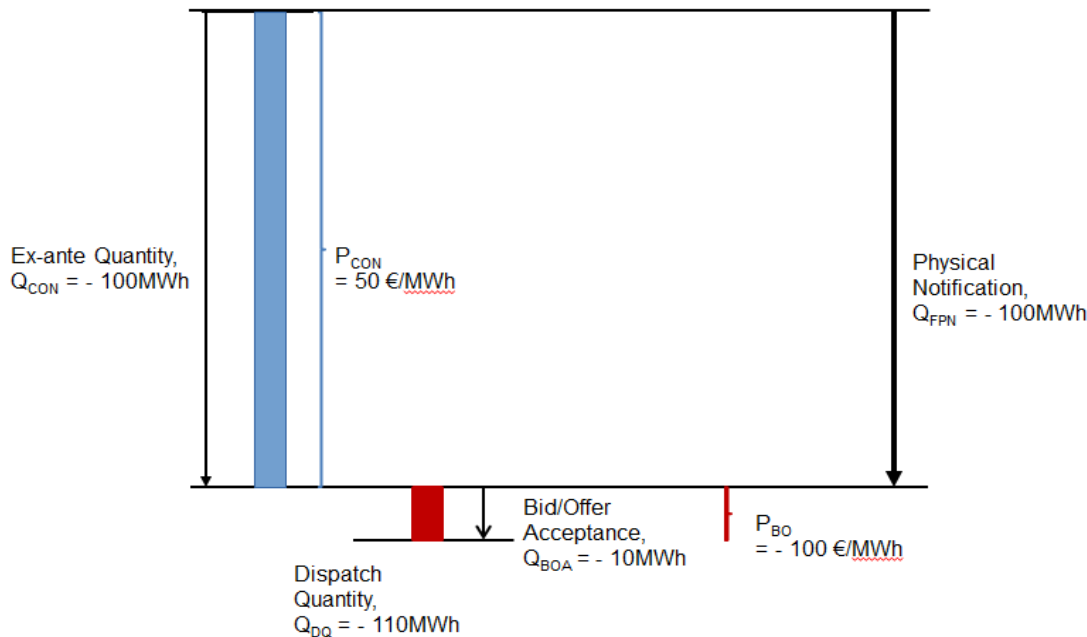
Demand Dispatched Down for Non-Energy (i.e. Increased Demand)

Cashflow = - Payment for ex-ante purchases
 - Imbalance Price * Dispatch Down Volume
 + Discount of Dec Price under Imbalance Price *
 lesser volume of (Dispatch Quantity under FPN)
 and (Dispatch Quantity under Ex-ante Quantity)

Direct from Algebra:

- 1) - 100MWh @ 50 €/MWh
- 2) + ((-110) - (-100))MWh @ 60 €/MWh
- 3) + ((-110) - (-100))MWh @ - 160 €/MWh

$$= - 5000 - 600 + 1,600 = - \text{€}4000$$

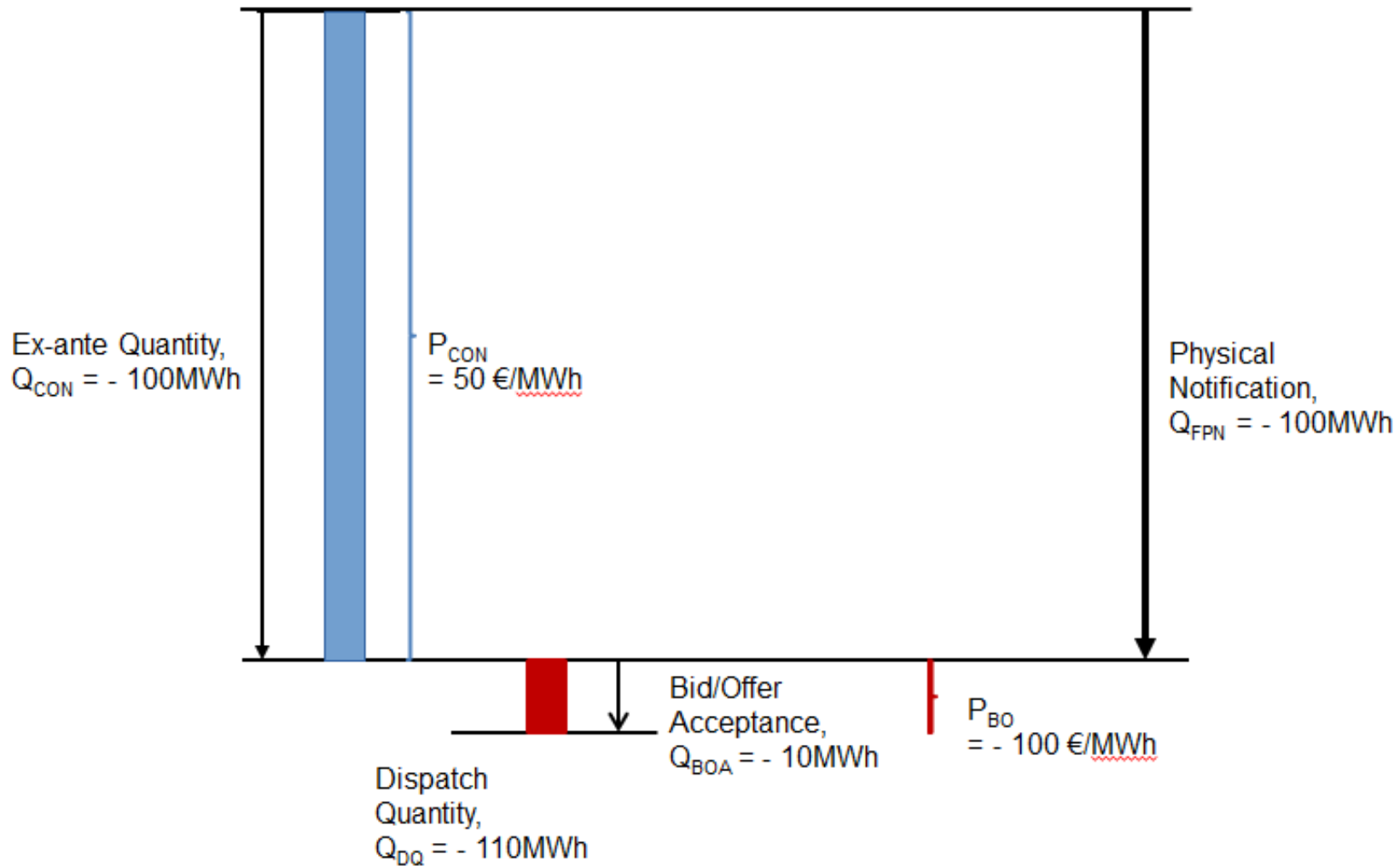


Alternative Breakdown:

- 1) - 100MWh @ 50 €/MWh
(Ex-ante trades)
- 2) - 10MWh @ -100 €/MWh
(Activated Dec)

$$= - 5000 + 1,000 = - \text{€}4,000$$

Supplier (with dispatchable demand) Example (1)



Supplier – Dispatchable Demand with Accepted Inc Physical Notification **required**

$$C = P_{CON} \cdot Q_{CON} + P_{IMB} \cdot (Q_{DQ} - Q_{CON}) + \max(P_{BO} - P_{IMB}, 0) \cdot \max(Q_{DQ} - \max(Q_{FPN}, Q_{CON}), 0)$$

Demand Dispatched Up for Energy (i.e. Reduced Demand)

$$\text{Cashflow} = - \text{Payment for ex-ante purchases} + \text{Imbalance Price} * \text{Dispatch Up Volume}$$

Demand Dispatched Up for Non-Energy (i.e. Reduced Demand)

$$\text{Cashflow} = - \text{Payment for ex-ante purchases} + \text{Imbalance Price} * \text{Dispatch Up Volume} + \text{Premium of Inc Price over Imbalance Price} * \text{lesser volume of (Dispatch Quantity over FPN) and (Dispatch Quantity over Ex-ante Quantity)}$$

Supplier (with dispatchable demand) Example (2)

- Supplier buys 100MWh in the ex-ante markets @ 50 €/MWh
- Submits FPN of -100MWh and Inc Offer to BM of 10MWh @ 200 €/MWh
- TSO activates this Inc Offer for non-energy action by changing the dispatchable demand to -90MWh
- The Imbalance Price clears @ 60 €/MWh

Demand Dispatched Up for Non-Energy (i.e. Reduced Demand)

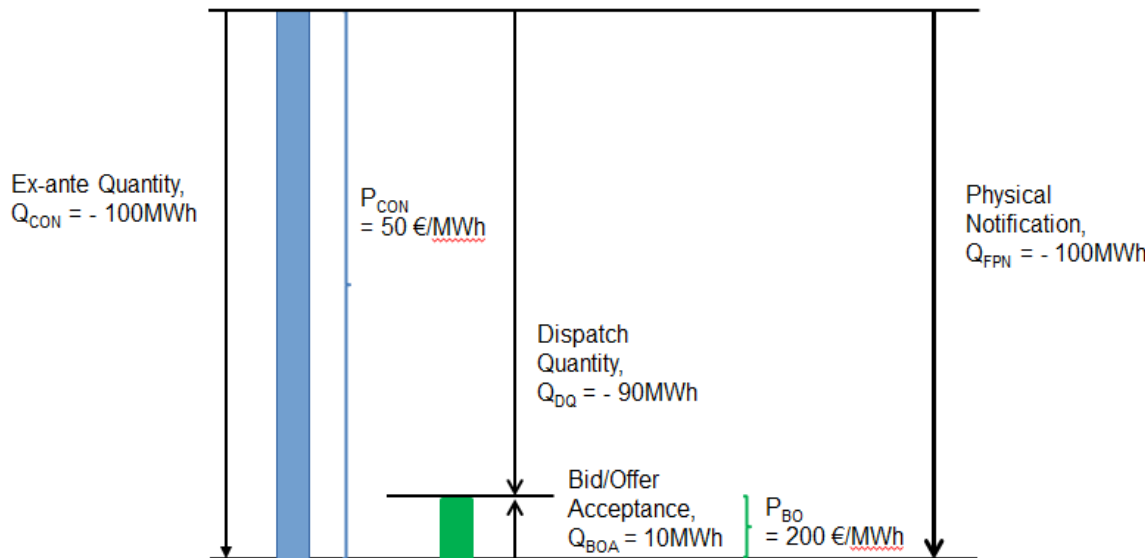
Cashflow = - Payment for ex-ante purchases
 + Imbalance Price * Dispatch Up Volume
 + Premium of Inc Price over Imbalance Price *
 lesser volume of (Dispatch Quantity over FPN)
 and (Dispatch Quantity over Ex-ante Quantity)

Direct from Algebra:

- 1) - 100MWh @ 50 €/MWh
 - 2) + ((-90) - (-100))MWh @ 60 €/MWh
 - 3) + ((-90) - (-100))MWh @ 140 €/MWh
- = - 5000 + 600 + 1,400 = - €3,000

Alternative Breakdown:

- 1) - 100MWh @ 50 €/MWh
 (Ex-ante trades)
 - 2) + 10MWh @ 200 €/MWh
 (Activated Inc)
- = - 5000 + 2,000 = - €3,000



Supplier (with dispatchable demand) Example (2)

