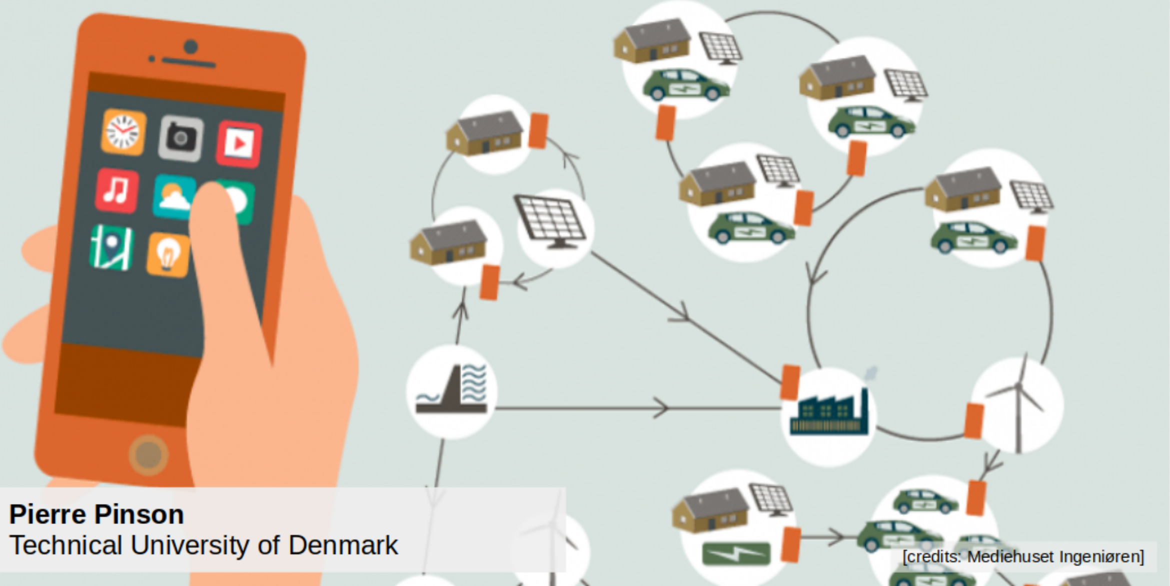
Module 3 – Intra-day and Balancing Markets

3.4 Balancing market operation and clearing



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Setting the scene

- **From the (previously cleared) day-ahead market:**
    - Balance of generation and consumption at quantity: P^S
    - Day ahead price: λ^S
    - Generators' schedules: $\hat{y}_j^G, \; j = 1, \ldots, N_G$
    - Demands' schedules: $\hat{y}_i^D, \; i = 1, \ldots, N_D$
- **Then reaching the balancing market:**
    - Imbalance to be handled: ΔP
    - Assume N_B balancing generators, able to move both up ($\uparrow$) and down ($\downarrow$)...
- **Their offers:**
    - *Upward* regulation: $P_j^{\uparrow}$, at price $\lambda_j^{\uparrow}, \; j = 1, \ldots, N_B$
    - *Downward* regulation: $P_j^{\downarrow}$, at price $\lambda_j^{\downarrow}, \; j = 1, \ldots, N_B$
- **One necessarily has:**
    - $\lambda_j^{\uparrow} > \lambda^S, \; j = 1, \ldots, N_B$
    - $\lambda_j^{\downarrow} < \lambda^S,, \; j = 1, \ldots, N_B$

Day-ahead market clearing results

- After market clearing (from Module 2), the supply and demand schedules are:

Supply id.	Schedule (MWh)	Demand id.	Schedule (MWh)
G_1	120	D_1	250
G_2	50	D_2	300
G_3	200	D_3	120
G_4	400	D_4	80
G_5	60	D_5	40
G_6	50	D_6	70
G_7	60	D_7	60
G_8	55	D_8	45
G_9-G_{15}	0	D_9	30
		D_{10}-D_{12}	0

- The system price is of 37.5 €/MWh, corresponding to the price offer of G_8

Example list of balancing offers

- *Deadline for offers*: 30th of January, 10:15 - *Delivery period*: 30th of January, 11:00-12:00
- Balancing offers include:

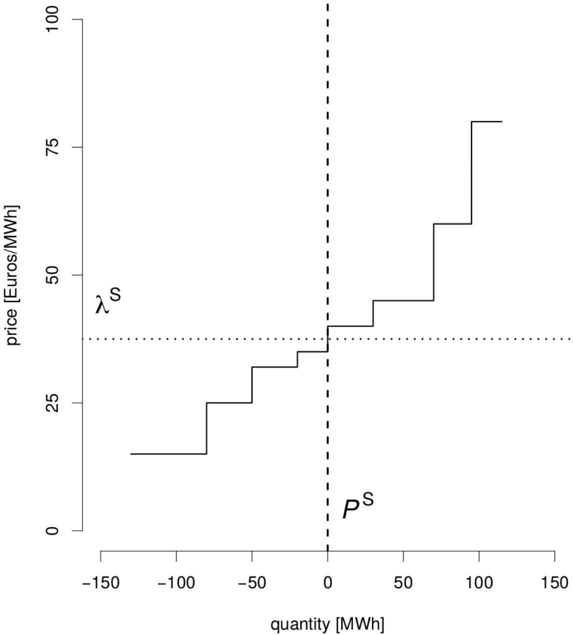
Company	id	$P_j^{\uparrow}$ (MWh)	$\lambda_j^{\uparrow}$ (€/MWh)	$P_j^{\downarrow}$ (MWh)	$\lambda_j^{\downarrow}$ (€/MWh)
BlueHydro*	B_1 (/G_3)	30	40	20	35
LastMinute	B_2	40	45	30	25
FlexiFast	B_3	25	60	30	32
DirtyPower*	B_4 (/G_8)	20	80	50	15

**already scheduled after day-ahead market clearing*

- Here, only generators offer balancing - Demand could actually also contribute...

Graphically as a supply curve...

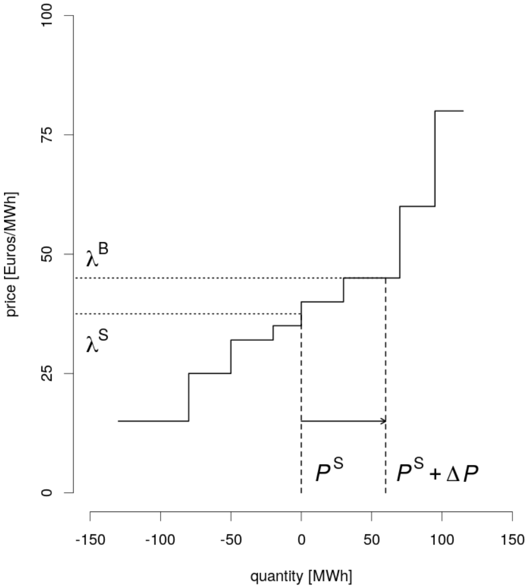
- This is the same type of supply curves than for day-ahead auctions, except that:
  - offers are for *adjustment* from the day-ahead quantity P^S (both upward and downward)
  - demand is here seen as inelastic (so, no demand curve - or seen as a vertical straight line)



Intuitively, two possible situations

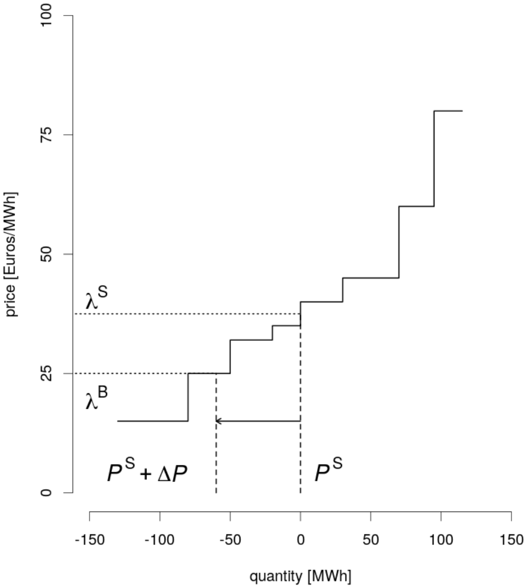
$\Delta P > 0$

(we need extra energy in the system)



$\Delta P < 0$

(we have too much energy in the system)



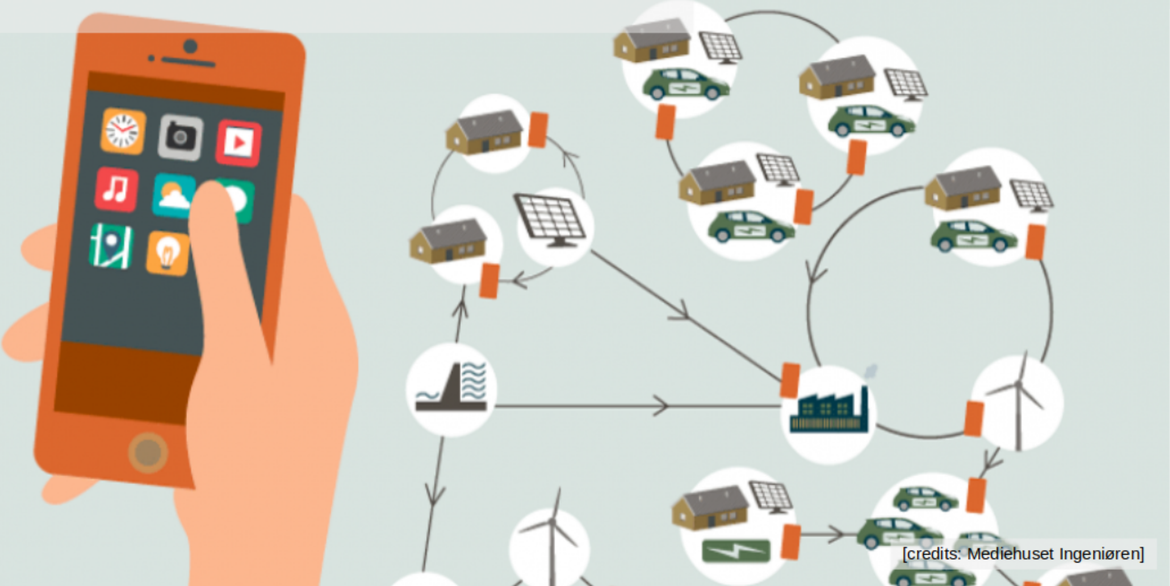
Writing the balancing auction as an LP

- Similarly to the day-market clearing, the auction can be solved through a Linear Program (LP):

$$
\begin{aligned}
\min_{\{y_j^{\uparrow}\},\{y_j^{\downarrow}\}} \quad & \sum_j \lambda_j^{\uparrow} y_j^{\uparrow} - \lambda_j^{\downarrow} y_j^{\downarrow} \\
\text{subject to} \quad & \sum_j y_j^{\uparrow} - y_j^{\downarrow} = \Delta P \ : \ \lambda^B \\
& 0 \leq y_i^{\uparrow} \leq P_i^{\uparrow}, \ j = 1, \ldots, N_B \\
& 0 \leq y_j^{\downarrow} \leq P_j^{\downarrow}, \ j = 1, \ldots, N_B
\end{aligned}
$$

- The balancing price λ^B can then be obtained by solving the dual LP
- It corresponds to the lagrange multiplier for the updated balance equation

Use the self-assessment quizz to check your understanding!



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