

# Energy Markets

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## Exercise session 4: Ancillary service markets

The aim of this exercise session is to appraise and better understand the basic structure of electricity markets, and most particularly its ancillary service markets and mechanisms.

### Problem 1: Participation in the primary reserve market

This problem focuses on the primary reserve market. The table below gathers the technical data needed to solve the problem.

Supplier Name	Supplier id.	Up. Quant. [MW]	Up. Price [€/MW]	Down. Quant. [MW]	Down. Price [€/MW]	Time response [s]
Flexigas	$G_1$	15	80	15	92	22
Nuke22	$G_2$	10	35	10	35	40
RoskildeCHP	$G_3$	5	50	15	62	20
BlueWater	$G_4$	7	13	5	12	15
Darkcoal	$G_5$	8	64	5	41	35

1.1 What is the common name of the payment for generators' availability to participate in the provision of ancillary services?

Generator's availability to participate in the provision of ancillary services is called **capacity payment**.

1.2 What is the common term used for some ancillary services to define that an energy payment is Generator's availability to participate in the provision of ancillary services is called capacity payment. not considered for that service? **The term used for some ancillary services to define that an energy payment is not considered for that service is energy neutral.**

1.3 Identify the suppliers that meet the technical requirements for providing primary reserves. **The suppliers that meet the technical requirements (Time response 30 seconds) for providing primary reserves are FlexiGas, RoskildeCHP and Bluewater.**

1.4 What is the total amount of capacity able to participate in the primary reserve market (i.e., which of the participants actually qualify)? **The total amount of power for up regulation is 27 MW. The total amount of power for down regulation is 30 MW.**

1.5 Determine the revenues for all participants in this market, considering that the up and down requirements established by the TSO is 25 MW.

**Calculation of revenues for upward regulation. The market price is 80 €/MW.**

- $G_1$ :  $13 \text{ MW} \cdot 80 \text{ €/MW} = 1040 \text{ €}$
- $G_3$ :  $5 \text{ MW} \cdot 80 \text{ €/MW} = 400 \text{ €}$
- $G_4$ :  $7 \text{ MW} \cdot 80 \text{ €/MW} = 560 \text{ €}$

**Calculation of revenues for downward regulation. The market price is 92 €/MW.**

- $G_1$ :  $10 \text{ MW} \cdot 92 \text{ €/MW} = 920 \text{ €}$
- $G_3$ :  $10 \text{ MW} \cdot 92 \text{ €/MW} = 920 \text{ €}$

- $G_4: 5 \text{ MW} \cdot 92 \text{ €/MW} = 460 \text{ €}$

1.6 Assuming now that all suppliers in the Table above are able to participate in the primary reserve market, re-determine the revenues of all participants for the same up and down requirements established by the TSO.

Calculation of revenues for upward regulation. The market price is 64 €/MW.

- $G_2: 10 \text{ MW} \cdot 64 \text{ €/MW} = 640 \text{ €}$
- $G_3: 5 \text{ MW} \cdot 64 \text{ €/MW} = 320 \text{ €}$
- $G_4: 7 \text{ MW} \cdot 64 \text{ €/MW} = 448 \text{ €}$
- $G_5: 3 \text{ MW} \cdot 64 \text{ €/MW} = 192 \text{ €}$

Calculation of revenues for downward regulation. The market price is 62 €/MW.

- $G_2: 10 \text{ MW} \cdot 62 \text{ €/MW} = 620 \text{ €}$
- $G_3: 5 \text{ MW} \cdot 62 \text{ €/MW} = 310 \text{ €}$
- $G_4: 5 \text{ MW} \cdot 62 \text{ €/MW} = 310 \text{ €}$
- $G_5: 5 \text{ MW} \cdot 62 \text{ €/MW} = 310 \text{ €}$

## Problem 2: Revenues from the secondary reserve market

For the secondary reserve market, the remuneration mechanism is based on bilateral contracts between the TSO and suppliers, for their availability, plus a premium for energy provision.

Let us assume that the supplier “FlexiGas” is qualified to provide secondary reserve services. The agreement with the TSO establishes that it may provide 20 MW (in both up and down directions) at 60 €/MW. In addition, the spot market was cleared at 143 €/MWh. The balancing price may vary in the following questions.

2.1 Determine the revenue of “FlexiGas” in case it is asked to provide an upward regulation service (energy fully delivered), with balancing price of 179 €/MWh.

$$\text{FlexiGas: } 20 \text{ MW} \cdot 60 \text{ €/MW} + 20 \text{ MWh} \cdot (143 \text{ €/MWh} + 119 \text{ €/MWh}) = 6440 \text{ €}$$

(The price per energy unit is of  $(143+119) \text{ €/MWh}$  since the difference between spot and balancing price  $(\lambda^B - \lambda^S)$  is of less than 119 €/MWh)

2.2 Re-determine that revenue if there is a need for down regulation instead (also with energy fully provided), with a balancing price of 12 €/MWh.

$$\text{FlexiGas: } 20 \text{ MW} \cdot 60 \text{ €/MW} - 20 \text{ MWh} \cdot 12 \text{ €/MWh} = 960 \text{ €}$$

(The price per energy unit is directly the balancing price (12 €/MWh) since the difference between spot and balancing price  $(\lambda^S - \lambda^B)$  is greater than 119 €/MWh)

2.3 Re-determine 2.1. and 2.2 assuming that the balancing market price is 299 €/MWh in the upward regulation case, and 107 €/MWh in the downward regulation case.

Upward regulation case:

$$\text{FlexiGas: } 20 \text{ MW} \cdot 60 \text{ €/MW} + 20 \text{ MWh} \cdot 299 \text{ €/MWh} = 7180 \text{ €}$$

(The price per energy unit is directly the balancing price (299 €/MWh) since the difference between spot and balancing price  $(\lambda^B - \lambda^S)$  is greater than 119 €/MWh)

Downward regulation case:

$$\text{FlexiGas: } 20 \text{ MW} \cdot 60 \text{ DKK/MW} - 20 \text{ MWh} \cdot (143 \text{ DKK/MWh} - 119 \text{ DKK/MWh}) = 720 \text{ DKK}$$

(The price per energy unit is of  $(143-119) \text{ DKK/MWh}$  since the difference between spot and balancing price  $(\lambda^S - \lambda^B)$  is of less than 119 DKK/MWh)

### Problem 3: Tertiary reserve market: clearing and revenues

Remember that the market mechanism for payment of suppliers of tertiary reserves comprises both a capacity payment based on uniform pricing and energy payment based on the balancing price. The Table below gathers the capacity offers of the various participants in the tertiary reserve market. Energy payments are obtained a posteriori when these participants are activated eventually.

Supplier Name	Supplier id.	Up. Quant. [MW]	Up. Price [€/MW]	Down. Quant. [MW]	Down. Price [€/MW]
Flexigas	$G_1$	25	36	20	48
Nuke22	$G_2$	20	18	10	42
RoskildeCHP	$G_3$	15	42	20	36
BlueWater	$G_4$	17	30	25	18
Darkcoal	$G_5$	18	24	15	30

3.1 Draw the supply curves and identify the suppliers that are scheduled to provide the service, considering that the service requirement for up and down regulation is of 50 MW.

The supply curves are illustrated in Figure 1 and Figure 2.

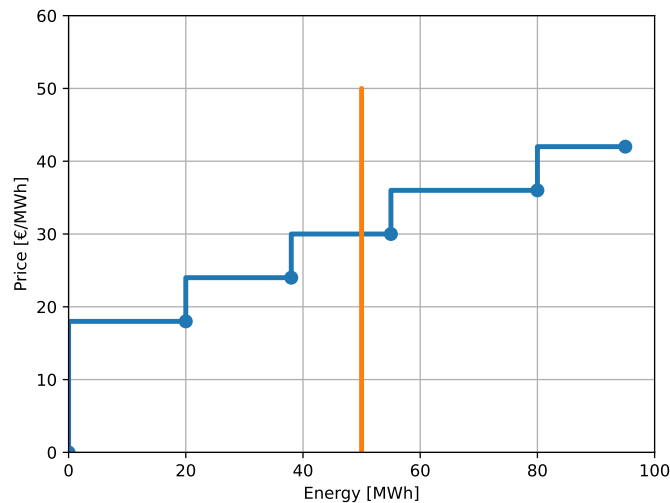


Figure 1: Supply and demand curve for up regulation

For up regulation the suppliers that are scheduled are  $G_2$ ,  $G_5$  and  $G_4$ . The market price is 30 €/MW.

- Nuke22 - 20 MW
- Darkcoal - 18 MW
- Bluewater - 12 MW

For down regulation the suppliers that are scheduled are  $G_4$ ,  $G_5$  and  $G_3$ . The market price is 36 €/MW

- Bluewater - 12 MW
- Darkcoal - 18 MW
- RoskildeCHP - 10 MW

3.2 Determine the revenue for each supplier for up regulation (service fully provided) considering upward regulating price of 24 €/MWh.

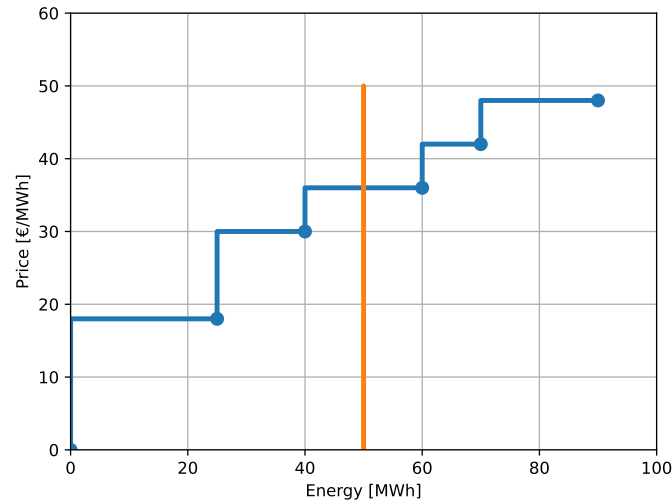


Figure 2: Supply and demand curve for down regulation

- $G_2: 20 \text{ MW} \cdot 30 \text{ €/MW} + 20 \text{ MWh} \cdot 24 \text{ €/MWh} = 1080 \text{ €}$
- $G_5: 18 \text{ MW} \cdot 30 \text{ €/MW} + 18 \text{ MWh} \cdot 24 \text{ €/MWh} = 972 \text{ €}$
- $G_4: 12 \text{ MW} \cdot 30 \text{ €/MW} + 12 \text{ MWh} \cdot 24 \text{ €/MWh} = 648 \text{ €}$

3.3 Determine the revenue for each supplier for down regulation (service fully provided) considering downward regulating price of 21 €/MWh. (tip: considers negative energy deviation as a positive value)

- $G_4: 25 \text{ MW} \cdot 36 \text{ €/MW} - 25 \text{ MWh} \cdot 21 \text{ €/MWh} = 375 \text{ €}$
- $G_5: 15 \text{ MW} \cdot 36 \text{ €/MW} - 15 \text{ MWh} \cdot 21 \text{ €/MWh} = 225 \text{ €}$
- $G_3: 10 \text{ MW} \cdot 36 \text{ €/MW} - 10 \text{ MWh} \cdot 21 \text{ €/MWh} = 150 \text{ €}$

3.4 Calculate the revenues for 3.2. and 3.3 considering that only half of the service requirement was used in the system.

Revenue for 3.2

- $G_2: 20 \text{ MW} \cdot 30 \text{ €/MW} + 20 \text{ MWh} \cdot 24 \text{ €/MWh} = 1080 \text{ €}$
- $G_5: 18 \text{ MW} \cdot 30 \text{ €/MW} + 5 \text{ MWh} \cdot 24 \text{ €/MWh} = 660 \text{ €}$
- $G_4: 12 \text{ MW} \cdot 30 \text{ €/MW} + 0 \text{ MWh} \cdot 24 \text{ €/MWh} = 360 \text{ €}$

Revenue for 3.3

- $G_4: 25 \text{ MW} \cdot 36 \text{ €/MW} - 25 \text{ MWh} \cdot 21 \text{ €/MWh} = 375 \text{ €}$
- $G_5: 15 \text{ MW} \cdot 36 \text{ €/MW} - 0 \text{ MWh} \cdot 21 \text{ €/MWh} = 540 \text{ €}$
- $G_3: 10 \text{ MW} \cdot 36 \text{ €/MW} - 0 \text{ MWh} \cdot 21 \text{ €/MWh} = 360 \text{ €}$