Energy Markets

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Exercise Session 1: Day-Ahead electricity markets - Basics [SOLUTION]

The aim of this exercise session is to appraise and better understand the basic structure of electricity markets, and most particularly its day-ahead mechanism.

Problem 1: General description of a day-ahead market and the example of the Nord Pool

This Problem is based on the Nord Pool website, and more particularly its sets of webpages titled "The power market". The most recent status report for Nord Pool is available at: Nord Pool Annual Review 2020. Some hints and answers are also on the wikipedia page for the Nord Pool.

1.1 What is the common name of the day-ahead market in Nord Pool?
The common name of the day-ahead market in Nord Pool is Elspot.

1.2 How many participants are they in the day-ahead market? And how many power producers in the whole area covered by the Nord Pool? Can you explain why all power producers do not trade through the Nord Pool, and how they then proceed?
The power market has many actors involved, such as system operators, producers, distributors, traders, brokers, clearing companies, financial analysts etc. There are approximately 14 million end-users, more than 370 companies responsible for power production, around 500 distribution companies and around 370 companies supplying the Nordic and Baltic end-users of power. All power producers do not trade through the Nord Pool, as financial market or direct contract between producers and big consumers also exist. These products are traded through Nasdaq Commodities and are used for price hedging and risk management.

1.3 What is the overall volume (on average) of energy generated over the Nordic and Baltic countries?
The annual average generation in the Nordic and Baltic countries is around 420 TWh in total.

1.4 What was the average systems price in the Nordic area in 2020? The average system price was of 10.95 €.

1.5 What was the overall amount of energy exchanged through the Nord Pool (Nordic and Baltic) day-ahead market in 2018? What about the UK?
The overall amount of energy exchanged through the Nord Pool (Nordic and Baltic) day-ahead market in 2018 was of 717.9 TWh.

The overall amount of energy exchanged through the Nord Pool (UK) day-ahead market in 2018 was of 177.5 TWh.

1.6 What are the various types of power production technologies in the Nordic and Baltic countries? Rank them in terms of marginal production costs (in increasing order). What are the most important ones?
In Norway almost all power is generated by hydro power while Sweden and Finland have a mixture of hydro, nuclear and thermal power (steam driven). Denmark uses predominantly thermal power, but wind power is becoming increasingly important. In Estonia and Lithuania there is mostly thermal driven power. In dry years, Nordic countries become more dependent on the import of power from other countries: Russia, Estonia, Netherlands, Poland and Germany. In terms of marginal production cost, the ranking in an increasing order is the following: renewables(wind

and solar), hydro power, combined heat and power, nuclear, condensing coal, condensing oil and gas turbines.

Each of the power production technologies serves a role in the power supply for the Nordic countries. Renewables help towards reducing carbon emissions and achieving sustainability. Hydro power is also a non polluting technology and serves as an energy reservoir for the Nordic countries. Moreover, nuclear, CHP and coal power production units serve as base and intermediate load units ensuring the security of supply. Finally, oil and gas power production units help with their ramping capabilities when needed or when there is a lack of supply from hydro power.

1.7 Who are the various participants in the day-ahead market? What is their role?

- A **producer** is responsible for power production.
- A **distributor** ensures that power reaches the end-user. Power is transmitted from the power plant through the central grid and the transmission net to the end-user.
- A **supplier** buys power either directly from a producer, or through Nord Pool Spot. In general, a supplier then resells it to small and medium-sized companies and households.
- A **trader** represents the entity which owns the power while the trading process is taking place. For example, the trader may buy power from a producer and sell it to a retailer, or the trader may choose to buy power from one retailer and sell it to another retailer. There are many routes from the producer to the end-user.

1.8 Who owns Nord Pool? (see webpage "About us")
Nord Pool is owned by Euronext (66%) and the Nordic Transmission System Operators and Litgrid (Lithuanian TSO) retain 34% ownership through a joint holding company.

1.9 What is the market time unit (i.e, a few minutes, a whole day, or...?), and what are the bidding areas?
The market time unit is based on an hourly resolution. The bidding areas are the following: Norway is divided in 5 bidding areas, Denmark in two bidding areas (DK east and DK West), Finland, Estonia, Lithuania, Latvia and Sweden that is divided in 4 bidding areas. There is a total of 15 bidding areas.

1.10 What are the assumptions for the definition of bidding areas?
The different bidding areas help indicate constraints in the transmission systems, and ensure that regional market conditions are reflected in the price. Due to bottlenecks in the transmission system, the bidding areas may get different prices called area prices. When there are constraints in transmission capacity between two bidding areas, the power will always go from the low- price area to the high-price area. This principle is right for society: the commodity ought to move towards the high-price where the demand for power is the highest.

This system also secures that no market members are assigned privileges on any bottleneck, which is an important feature of a liberal market. Nord Pool Spot calculates a price for each bidding area for each hour of the following day.

Problem 2: General description of a day-ahead market and the example of the Nord Pool

For this and some of the following Problems, we set up our own day-ahead electricity market, with characteristics similar to that of the Nord Pool and analysed in Problem 1.

The market has 5 players on the supply side. For a given time unit (say, between 2pm and 3pm the following day), the market operator has received a set of single-hourly supply offers (i.e., blocks of energy for a single market time unit) from these 5 participants. These offers are defined as:

Supplier Name	Supplier id.	Quantity [MWh]	Price [€/MWh]
Flexigas	G_1	15	75
Nuke22	G_2	100	15
ShinyPower	G_3	32	0
RoskildeCHP	G_4	25	42
BlueWater	G_5	70	10

2.1 What do we call the "supply curve" in the day-ahead market?
The supply curve is also called the bidding curve or the aggregated supply curve. It gathers all the offers on the supply side.

2.2 How is it defined based on a set of offers?
It is the curve that shows all the supply offers aggregated for each delivery hour. The orders are ranked based on an ascending order of price together with the associated amount of energy that will be produced.

2.3 Draw (paper, or plot based on Matlab/R/Excel/etc.) the supply curve for this market time unit.

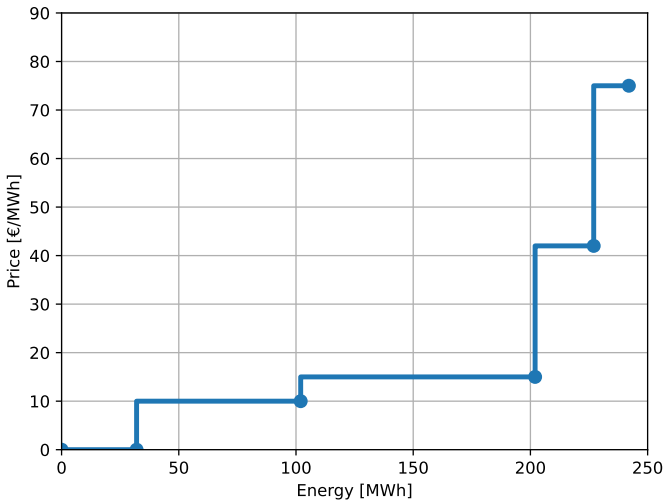

Figure 1: Supply Curve

2.4 What is the total amount of energy offered through the market?
The total amount of energy offered is 15 + 100 + 32 + 25 + 70 = 242MWh.

2.5 By the way... Can they be other types of offers than single-hourly offers?
There also time dependent bids, for instance a producer can offer a bid that is valid for several hours (e.g., regular block orders).

Problem 3: Consideration and ordering of demand offers in a pool

We continue here based on the previous Problem and our day-ahead electricity market setup.

The market has 7 players on the demand side. For the same time unit as in Problem 2 (say, between 2pm and 3pm the following day) the market operator has received a set of single-hourly consumption offers defined as:

3.1 What do we call the "demand curve" in the day-ahead market?
The demand curve is based on the same principle than the supply curve besides that it is taken

Demand Name	Demand id.	Quantity [MWh]	Price [€/MWh]
WeLovePower	D_1	35	65
CleanChange	D_2	23	78
JyskeEl	D_3	12	10
ElRetail	D_4	38	46
QualiWatt	D_5	43	63
IntelliWatt	D_6	16	32
El-Forbundet	D_7	57	50

from the "buying side" perspective. Meaning that consumers "bid" their willingness to pay (buy) for the energy. These offers are ranked from the most expensive to the cheapest.

3.2 How is it defined based on a set of offers?
The most "expensive" offers (the players willing to pay the most) are placed at the beginning and all offers are aggregated together as a decreasing demand curve (highest willingness to pay to the lowest willingness to pay for one unit of energy. Demand flexibility is reflected through the demand curve). Players willing to pay the most are the ones that have a prioritized access to the energy that will be available

3.3 Draw (paper, or plot based on Matlab/R/Excel/etc.) the demand curve for this market time unit.

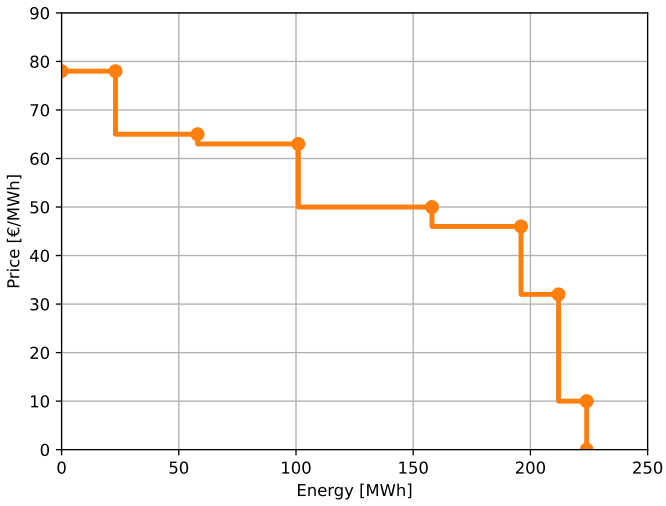

Figure 2: Demand Curve

3.4 What is the total amount of energy asked for through the market? Compare it to the total amount of energy supply offers. Is there a problem there?
The total energy asked for through the market is: 35 + 23 + 12 + 38 + 43 + 16 + 57 = 224 MWh. There does not seem to be a problem since supply is greater than the demand. A market equilibrium can be found which is at the crossing-point between supply and demand curves. There are enough producers willing to produce energy that has been asked for. However both curves have to cross in order to find this market equilibrium.

Problem 4: Equilibrium and market-clearing

We continue here based on Problems 2 and 3, and our day-ahead electricity market setup.

4.1 Have your supply and demand curve on the same drawing/plot.

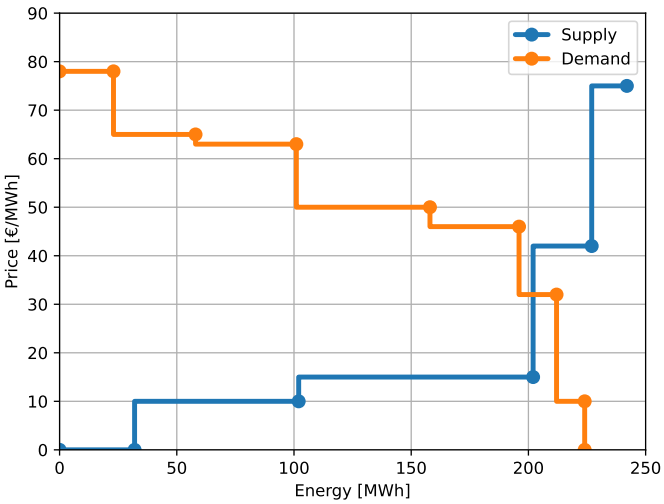

Figure 3: Demand vs Supply Curve

4.2 Identify the "equilibrium point". What does it mean in the present case?
The equilibrium point is the crossing point between both curves. In the present case, it means that there are enough producers willing to produce a given amount of energy for which consumers are willing to pay for.

4.3 What is the equilibrium price and quantity?
The equilibrium is at a quantity of 202 MWh and a price of 32 €/MWh.

4.4 Who will be effectively supplying power (and how much)? And, who will be effectively consuming (and how much)? Why does that make natural sense?
Producers G_3, G_5 and G_2 will be supplying power at their maximum offers, 32, 70 and 100 MWh respectively. Regarding the demand side, it is not so obvious at first, since the crossing point does not exactly match a producer's offer. Indeed it crosses the supply curve at a "step" (between two different price offers for a given quantity). Consumers D_2, D_1, D_5, D_7, D_4 and D_6 will be consuming 23, 35, 43, 57, 38, and 6 MWh respectively. As it can be noticed, consumer D6 only partially satisfies his demand.

The producers are willing to supply up to 202 MWh at a price of 15€/MWh. However, if the supply has to be increased by 1 unit (+1 MWh to be supplied), the next power producer has to be activated in order to produce this additional unit. This power producer is willing to produce at a price of 42€/MWh. The last consumer's demand can only be partially satisfied as he gets only 6 MWh of energy, which would both match his willingness to pay as well as the supply offers of the producers. If the last consumer's demand has to be met/satisfied fully, a higher price is required for the last unit to be generated. The last consumer is not willing to pay for this additional 1 MWh and the producer is not willing to produce at a lower price than the one he bid in the market.

4.5 Calculate social welfare.
Producers surplus: Sum over the producers of the difference between market price and bidding price multiplied by the produced quantity.
Total = 4264 €

Consumers surplus: Sum over the consumers of the difference between the market price and bidding price multiplied by the quantity bought.
Total = 5104 €

Social welfare (Sum of the consumers and producers surplus) = 4264 + 5104 = 9368 €