

# 31761 - Renewables in Electricity Markets

## 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. The session relies on Modules 1 and 2 of the course.

### **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 Report 2018](#). Some hints and answers are also in the lecture slides, and 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 there 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 system price in the Nordic area in 2018?

The average system price was of 43.99 €

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 396 TWh.

The overall amount of energy exchanged through the Nord Pool (UK) day-ahead market in 2018 was of 120 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: Consideration and ordering of supply offers in a 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. An example of such a day-ahead electricity market was given in Lecture 2.

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 <sub>1</sub>	15	75
Nuke22	G <sub>2</sub>	100	15
ShinyPower	G <sub>3</sub>	32	0
RoskildeCHP	G <sub>4</sub>	25	42
BlueWater	G <sub>5</sub>	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.

→ See Figure 1

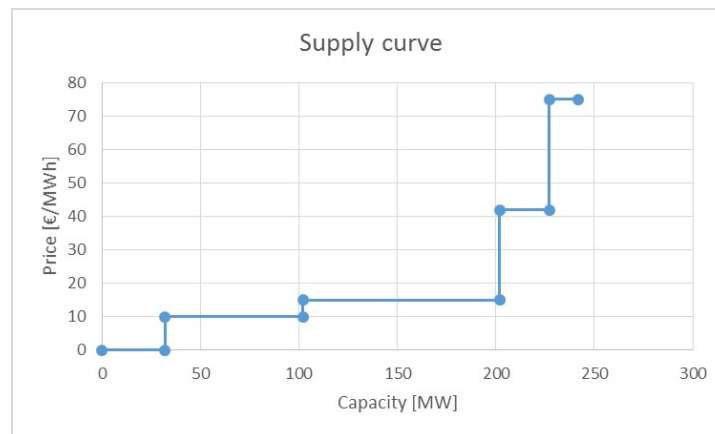


Figure 1: Supply curve

2.4 What is the total amount of energy offered through the market?

The total amount of energy offered is  $15 + 100 + 32 + 25 + 70 = 242$ MWh.

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:

Demand name	Demand id.	Quantity [MWh]	Price [€/MWh]
WeLovePower	D <sub>1</sub>	35	65
CleanCharge	D <sub>2</sub>	23	78
JyskeEl	D <sub>3</sub>	12	10
ElRetail	D <sub>4</sub>	38	46
QualiWatt	D <sub>5</sub>	43	63
IntelliWatt	D <sub>6</sub>	16	32
El-Forbundet	D <sub>7</sub>	57	50

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 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.

→ See Figure 2

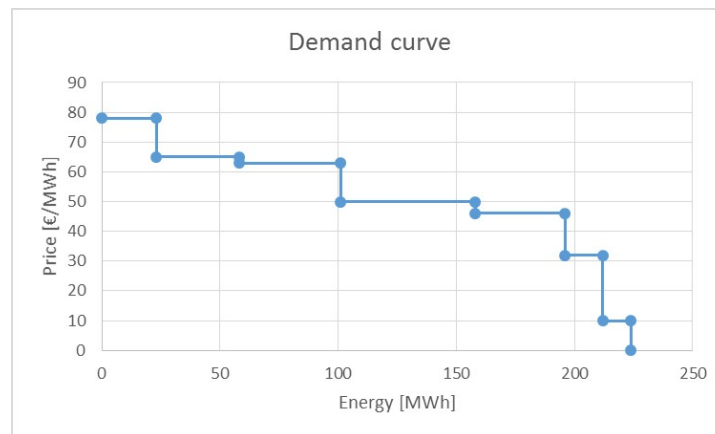


Figure 2: Demand curve

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.

→ See Figure 3

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.

