# The Energy Game – Tutorial

The tutorial against the computer is progressive and only intends to give you a first idea of the complete game. We advise you not to look for the best strategy or to try to understand everything from the start. Often, we will invite you to let aside the analysis of some curves or some information for later. Please, trust us, we will come back to this later, at a point where required fundamental notions will have become clear enough to make things easier to grasp. And do not pay attention to the score! (the right way to learn how to play is to make many trials and mistakes in the tutorial, even when you know they are mistakes…)

You are responsible for managing an electricity producer selling its energy on a wholesale market to electricity retailers. In this tutorial, you are active on only one market and you have only one (robot) competitor.

The timeline of the general game is separated into "years". At beginning of the year, you first have to choose what plants to build. Then, every "day", you will make offers to sell your electricity for the coming day, on a wholesale market. Each year consists of only two "days" (we call these days, rounds), one in peak period and the other in off-peak period. Finally, once sales are determined, you have to decide what plants to use to produce what you have sold.
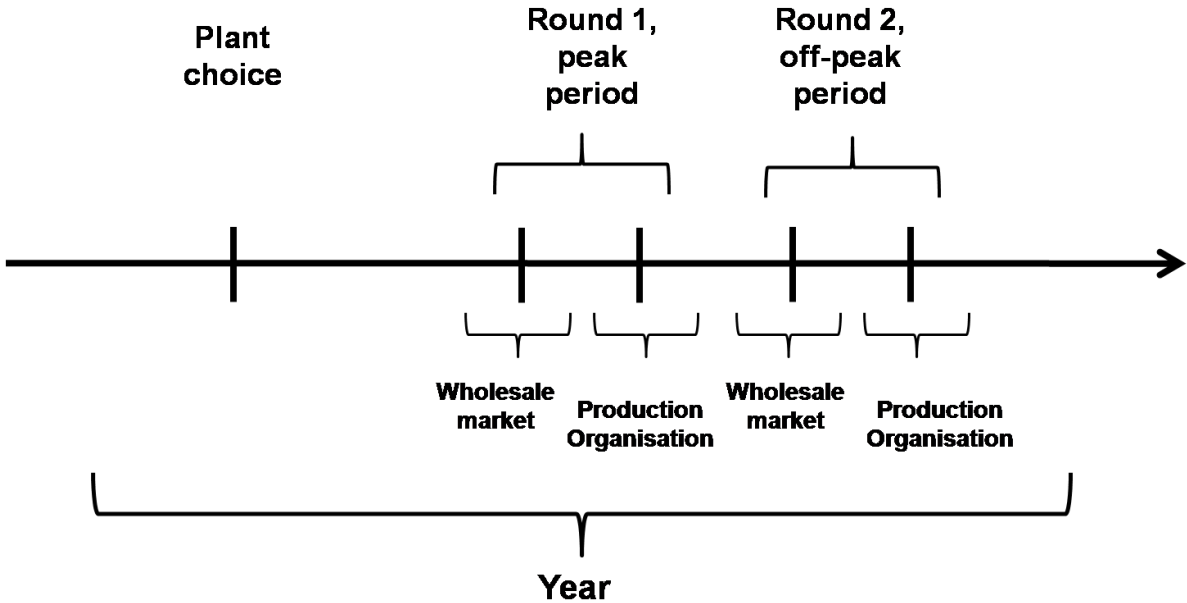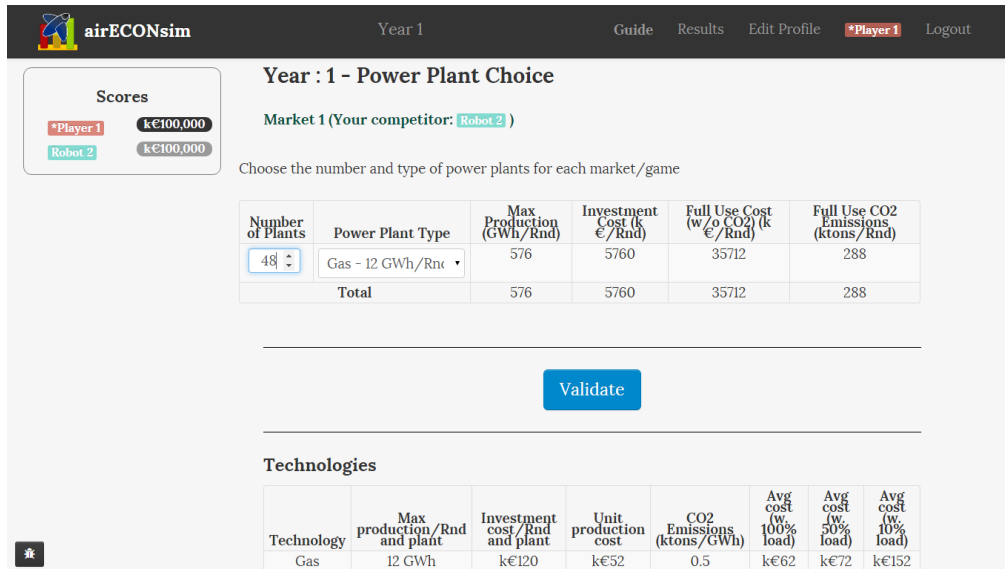
First Year

Power Plant Choices

At the start of each year, the first screen invites you to choose what power plants to install for the coming year (to make things simple, at the start, you will be able to change all of your fleet every year).

For the moment, you cannot choose the type of power plant and can only use gas thermal plants.

As you can see on the technology table at the bottom of the "plant choice" page, in order to have one gas plant, you will have to pay 120 k€ each round, even if you don't use the plant to produce (these are investment and maintenance costs). Then, every GWh produced will cost you an additional 52 k€. Each plant can produce up to 12 GWh each round (and you cannot store electricity).

Technology	Max production/Rnd and plant	Investment cost/Rnd and plant	Unit production cost	CO2 Emissions (ktons/GWh)	Avg cost (w. 100% load)	Avg cost (w. 50% load)	Avg cost (w. 10% load)
Gas	12 GWh	k€ 120	k€ 52	0.5	k€ 62	k€ 72	k€ 152

Also, note that in order to be active on a market, you will have to bear a fixed activity cost equal to 2000k€ every round.

This year, **choose 48 gas plants** (trust us. For now, just go through the game to understand its structure).

➔ You will then be able to produce up to 48*12=576 GWh each round for a unit production cost of 52 k€.

➔ Once you have built the 48 plants, whatever your production, you will bear the same investment costs, equal to 5760k€ (i.e. 48*120 k€) + 2000 k€ of activity cost by round. During the rest of the year, these investment and activity costs will be considered as fixed costs.

You can see that your robot-competitor has built 40 gas plants and will thus be able to produce up to 480 GWh each round.

Then, proceed to the next page.

Wholesale market: electricity sales

Once plants are built, players can make offers on the wholesale market to sell their energy. The wholesale market is a centralized market on which producers like you will be able to sell energy to retailers and large industrial consumers.

Designing strategic offers on the wholesale market is complex and you will only control this in the 3rd and 4th games (in the 2nd game, the computer will choose offers for you).

However, we want you to understand now how this works, so in the tutorial you will be able to submit offers. Just do not try to find the best offer for now.
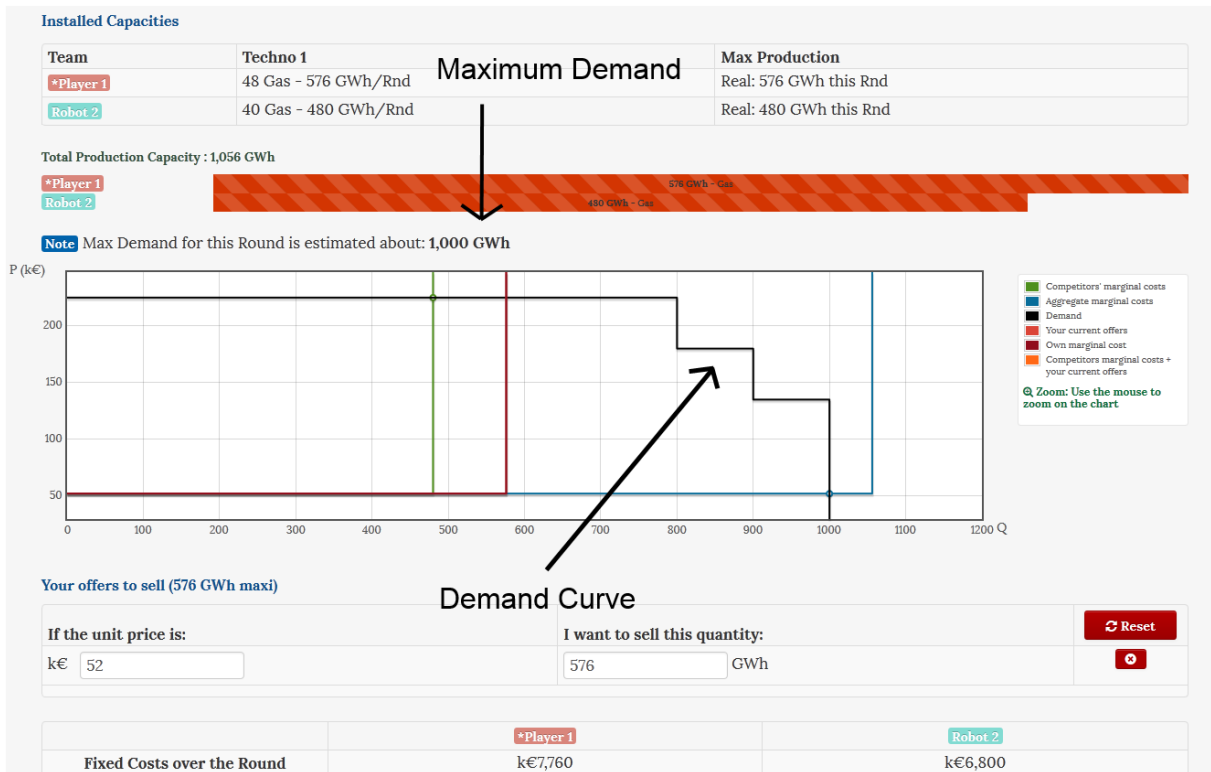
So, how are energy sales determined on the wholesale market?

All producers submit (p,q) price-quantity offers to the market operator. A (p,q) price-quantity offer means that for any **unit** price above p, you are willing to sell a **total** quantity q (this will be very important: q is the **total** quantity that you are willing to sell if the equilibrium **unit** price exceeds p).

At the same time, energy buyers ("inside the game") do the same and submit offers to buy energy on the market. You will not see details about these buying offers, you will just see the total demand curve.
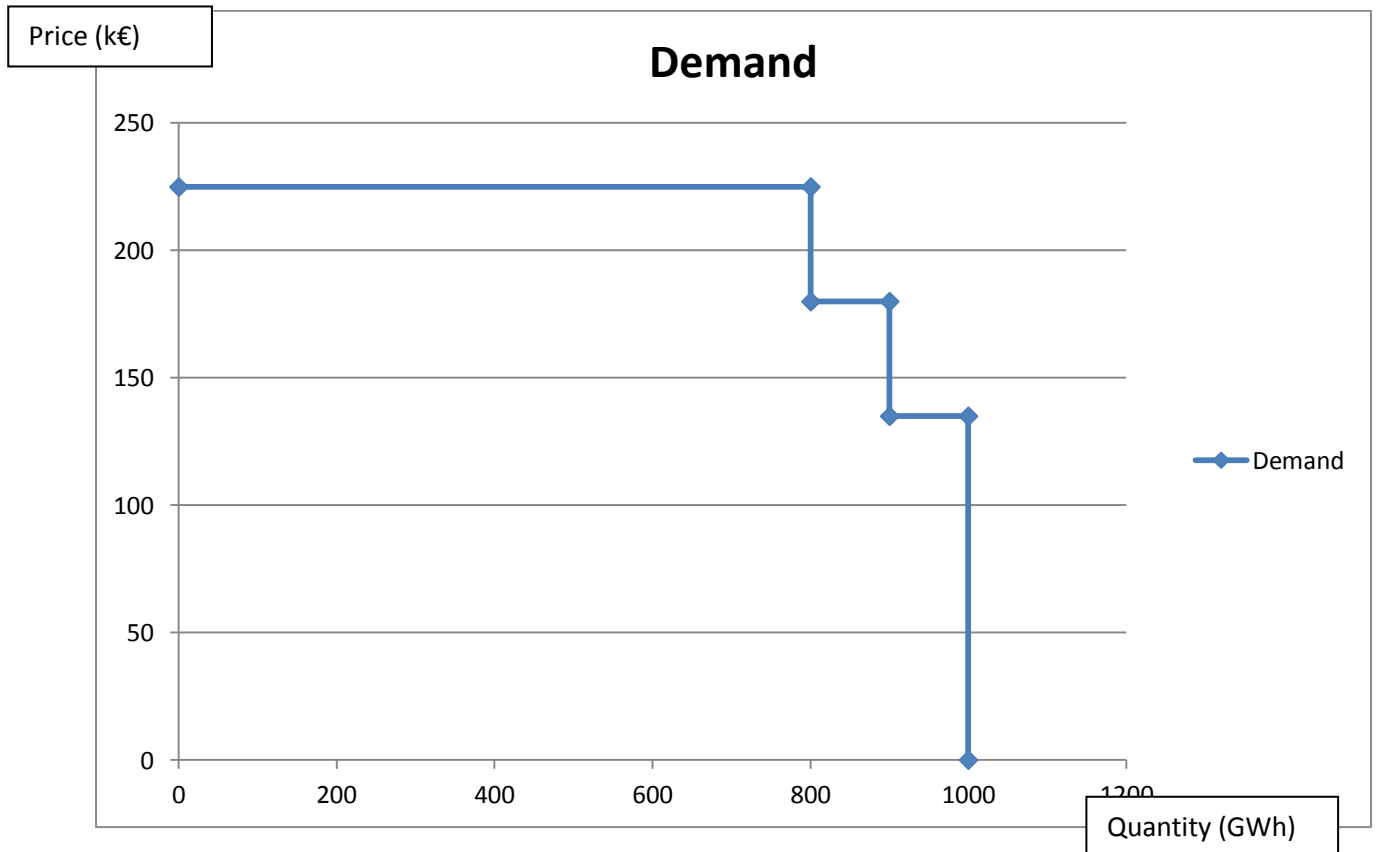
Equilibrium price and sales are determined by finding the highest price such that demand exceeds price (a few examples are given below, just after the description of demand).

Consequently, all firms on a market will sell their energy at the same price, which is centrally computed by the market operator as a function of all submitted offers.

Installed Capacities

Team	Techno 1	Max Production
*Player 1	48 Gas – 576 GWh/Rnd	Real: 576 GWh this Rnd
Robot 2	40 Gas – 480 GWh/Rnd	Real: 480 GWh this Rnd

Maximum Demand

Total Production Capacity : 1,056 GWh

*Player 1 — 576 GWh - Gas
Robot 2 — 480 GWh - Gas

Note Max Demand for this Round is estimated about: **1,000 GWh**

Legend:
- Competitors' marginal costs
- Aggregate marginal costs
- Demand
- Your current offers
- Own marginal cost
- Competitors marginal costs + your current offers

🔍 **Zoom:** Use the mouse to zoom on the chart

Demand Curve

Your offers to sell (576 GWh maxi)

If the unit price is:	I want to sell this quantity:	↻ Reset
k€ 52	576 GWh	✖

	*Player 1	Robot 2
Fixed Costs over the Round	k€7,760	k€6,800

Maximum demand is displayed on your screen. For this round, it is 1000GWh.

Demand is very little sensitive to price (economists say: "price-elasticity of demand is very low"). See the graph below giving you demand at the start of the tutorial for peak periods.


Demand

5

Examples of how sales and price are computed in a more general case

Equilibrium price and sales are determined by finding the highest price such that demand exceeds price.

To find that price, you can draw the total offer curve on the same graph as the demand curve: It can be built by computing, for every price, the sum of the quantities that are offered by all the firms on the market. The wholesale price and sales are found at the intersection of this curve with the demand curve.

- Consider that player 1 offers to sell 530 GWh at 52k€ and player 2 offers 480 GWh at 70k€. The game first builds the total offer curve, by adding, for every price, the quantity offered by all the players. Here, below 52k€, this quantity is 0 GWh. Between 52k€ and 70k€, it is 530 GWh (only player 1 wants to sell). Above 70k€, it is 530+480=1010 Gwh.
  Demand and offer curves cross at price 70k€ and quantity 1000 Gwh -> equilibrium price will be 70k€, player 1 will sell 530 GWh (offers below the equilibrium price are given a priority) and player 2 will sell the residual demand at 70k€, i.e. 1000-530=470 GWh.
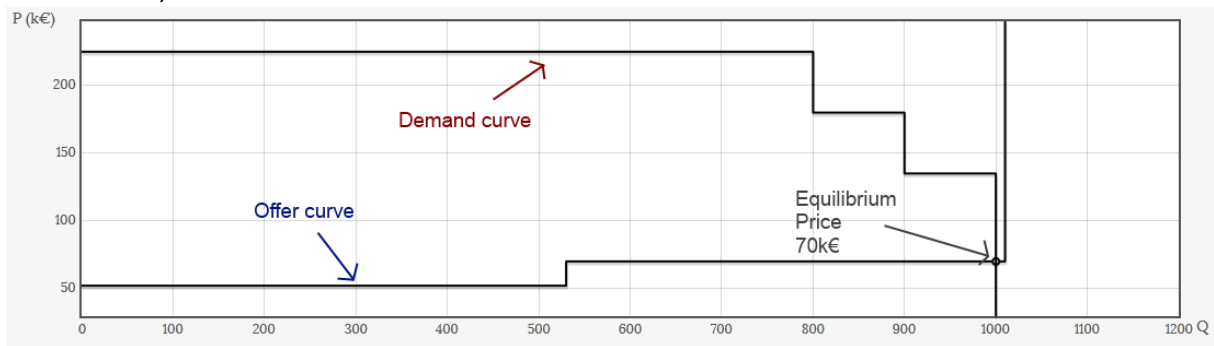
- If player 1 offers to sell 30 more GWh, that is 560 GWh, at 52k€ and player 2 offers 480 GWh at 70k€, equilibrium price will be 70k€, player 1 will sell 560GWh, and player 2, 440 GWh (because player 1 is willing to sell 560 GWh for a lower price than 70k€, so he has a priority right to sell all its 560 GWh).
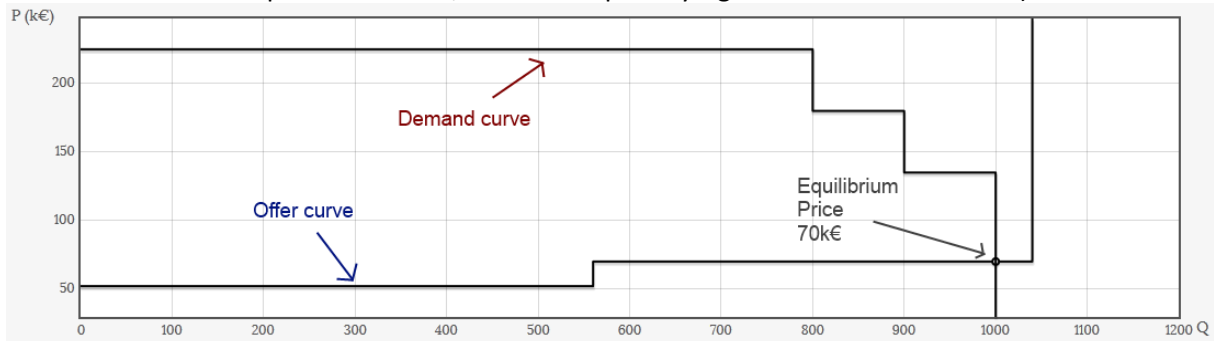
- If player 1 offers to sell 530 GWh at 52k€ and player 2 offers 370GWh at 70k€, equilibrium price will be 180k€ (the "higher" point of the curves' intersection), player 1 will sell 530 GWh, and player 2, 370 GWh.
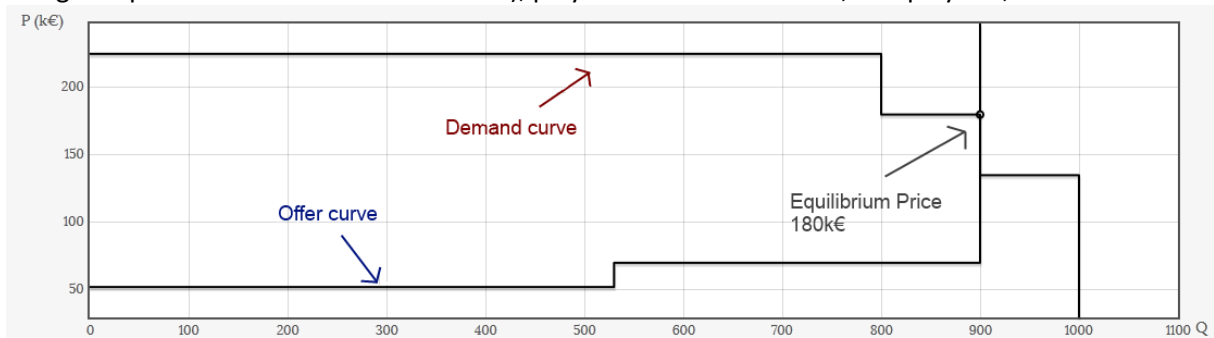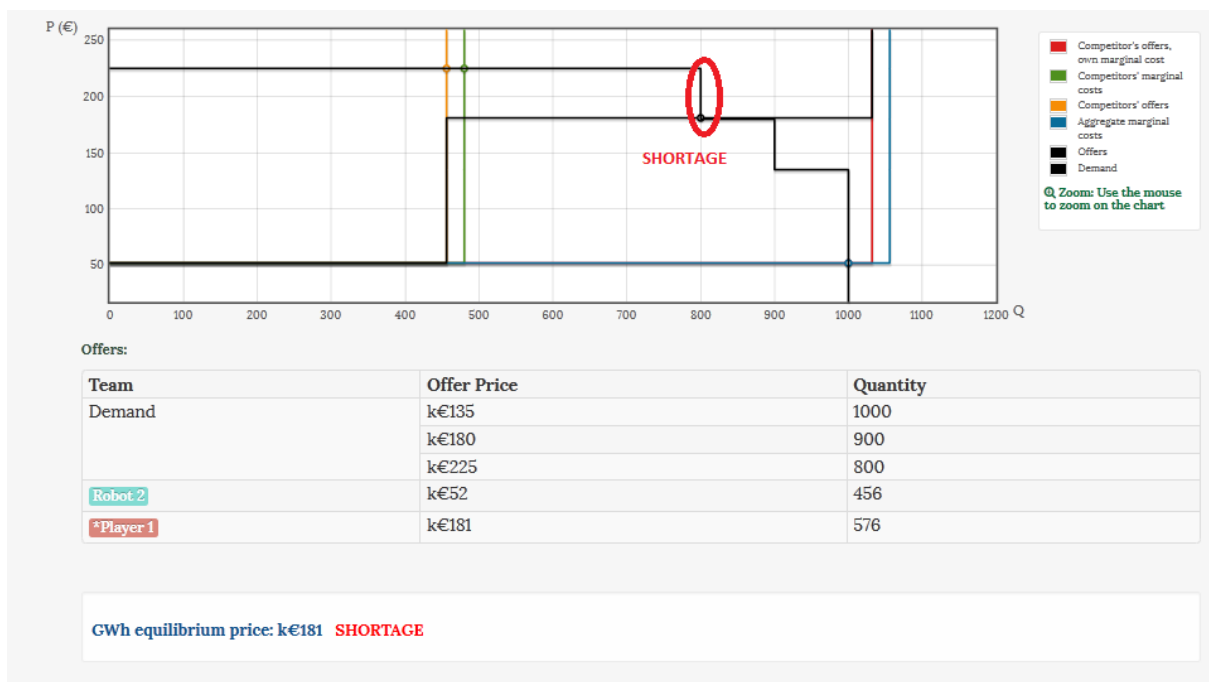
Shortages

If total energy sold on the market is too low (80% or less of maximum demand, here 800 GWh or less), a shortage occurs. This shortage has serious consequences for your customers and for society, and triggers political responses that are eventually harmful for every firm of your industry: You will have a shortage penalty equal to k€70000.

(Remark : In the real world, prices can go at least 10 times higher than 225k€ when supply is too low, but we need a low enough threshold in order to keep the game balanced)

Be careful, if the intersection takes place at price €181, for a quantity equal to 80% of the maximum, then a shortage does happen (just consider these limit cases as simplifications meant to make the game less complex).

Offers:

Team	Offer Price	Quantity
Demand	k€135	1000
	k€180	900
	k€225	800
Robot 2	k€52	456
*Player 1	k€181	576

GWh equilibrium price: k€181   SHORTAGE

Graphs on the wholesale market offers page

Graphs are here to help you, but in the start, they can be quite difficult to understand. **During the first part of the game**, "with perfect competition", **the game will select offers on the wholesale market for you**, setting them as equal to your short-run marginal costs (i.e. production costs, more on this later). So, for now, only the green, red and blue curves are useful (we will talk about the other ones later).
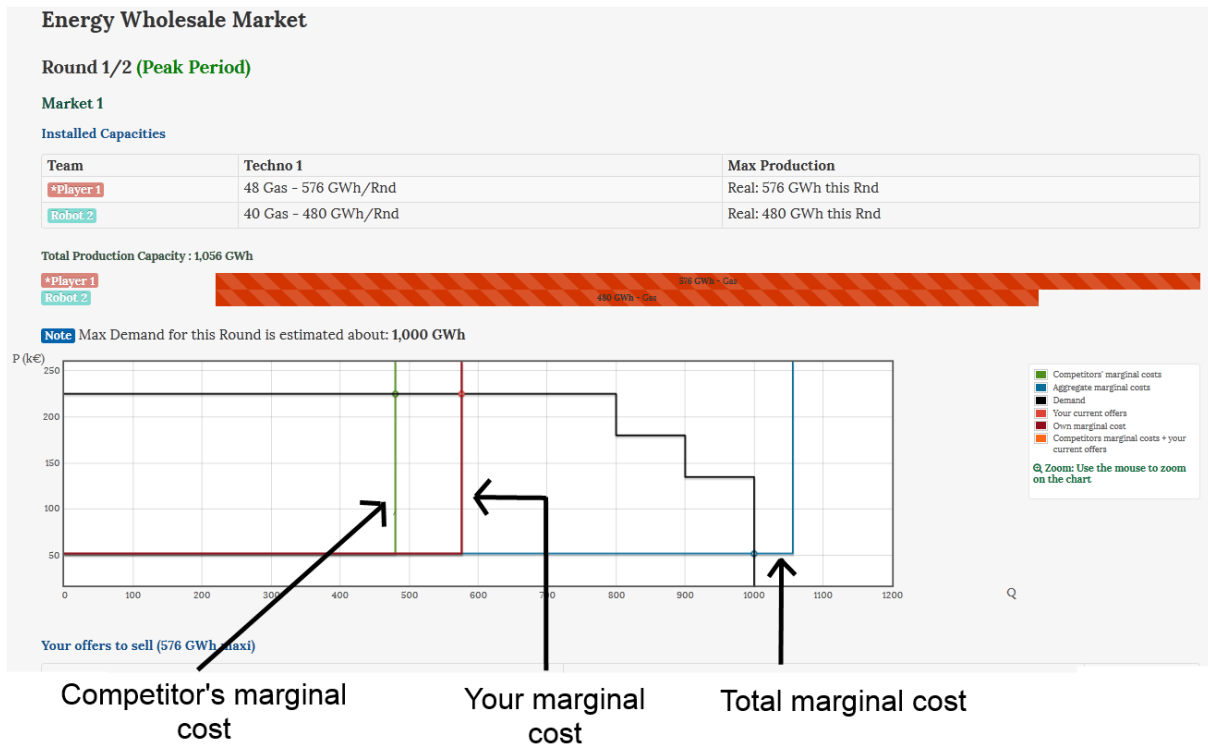
Competitor's marginal cost — Your marginal cost — Total marginal cost

The first, green, curve displays your competitor's short-run production **marginal** costs (i.e. the **additional** cost incurred by your competitor if it produces an **extra** GWh, **once plants have been built and investment cost has become fixed**). For now, there is only one technology, so this is just the production cost of an extra GWh with a gas thermal plant, as long as maximal production capacity has not been reached. Here, Robot 2, can produce up to 480 GWh, so the green curve is just horizontal, at k€52, as long as Q is lower than 480 GWh.

The second, red, curve displays your marginal costs. Here, you can produce up to 576 GWh for a unit production cost of k€52, so the red curve is just horizontal, at k€52, as long as Q is below 576 GWh.

The third, blue, curve is built by «adding **along the quantity axis**» your marginal cost **curve** with that of your competitor ("adding the green and red curves along the quantity axis"). Here it is horizontal, at k€52, as long as Q is lower than 480+576=1056 GWh.

Enter an offer

At this point of the tutorial, your competitor always offers to sell 456 GWh for a price of 52k€.

Enter a first decision,

- **576 GWh and a price of 52k€**

then by using the "back to previous decision" button, compare to the following choices, after guessing the resulting prices and sales (here, drawing a small graph may be useful):

- **576 GWh and a price of 51k€ (is it a better choice than with 52k€?)**
- **576 GWh and a price of 70k€**
- **540 GWh and a price of 70k€**

For now, only one offer can be made. Later in the tutorial, and in the end of the real game, you will be able to make several simultaneous offers.
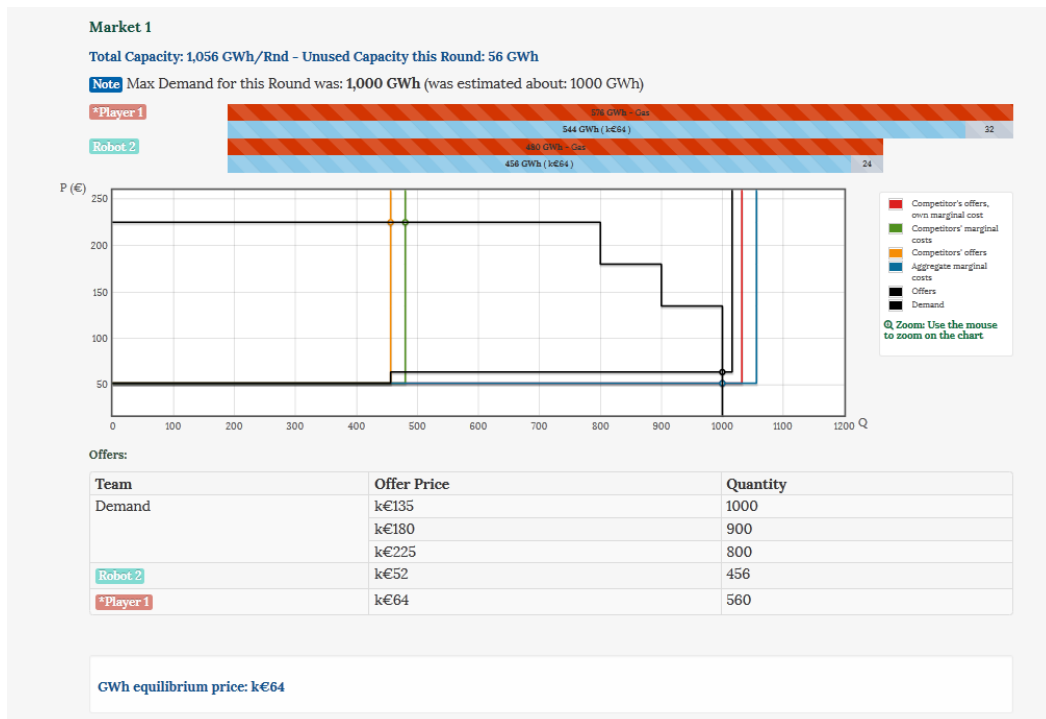
Demand

Demand
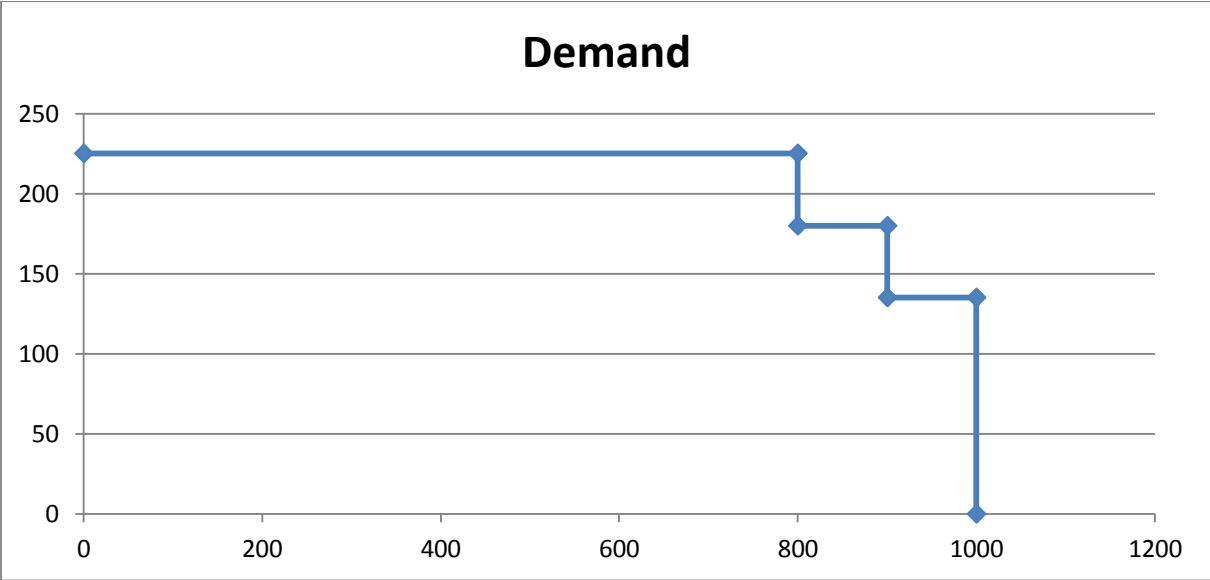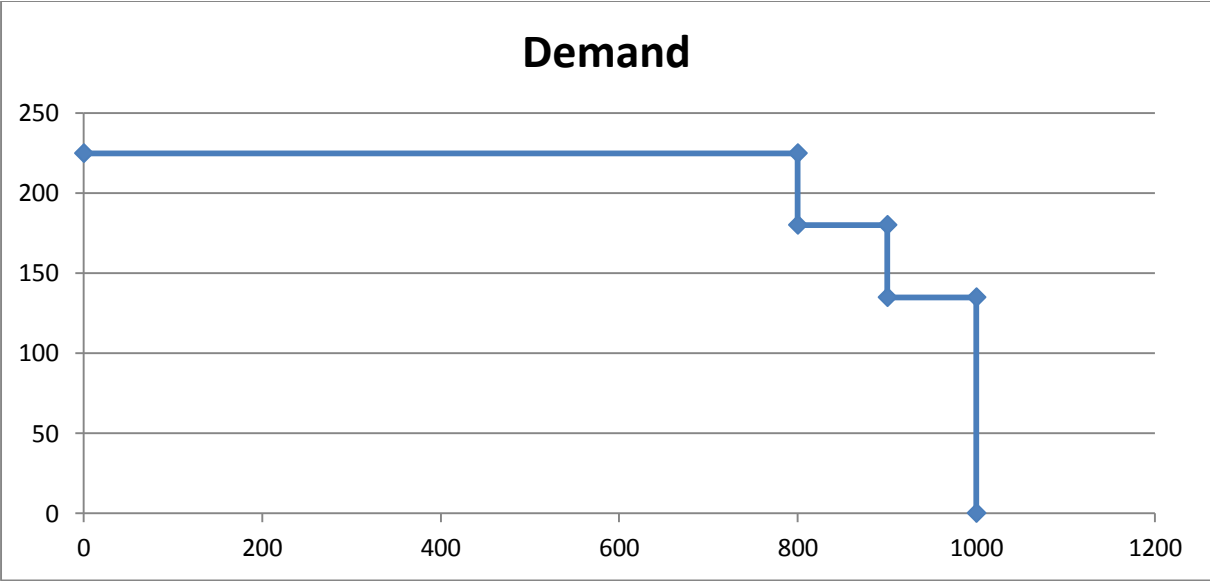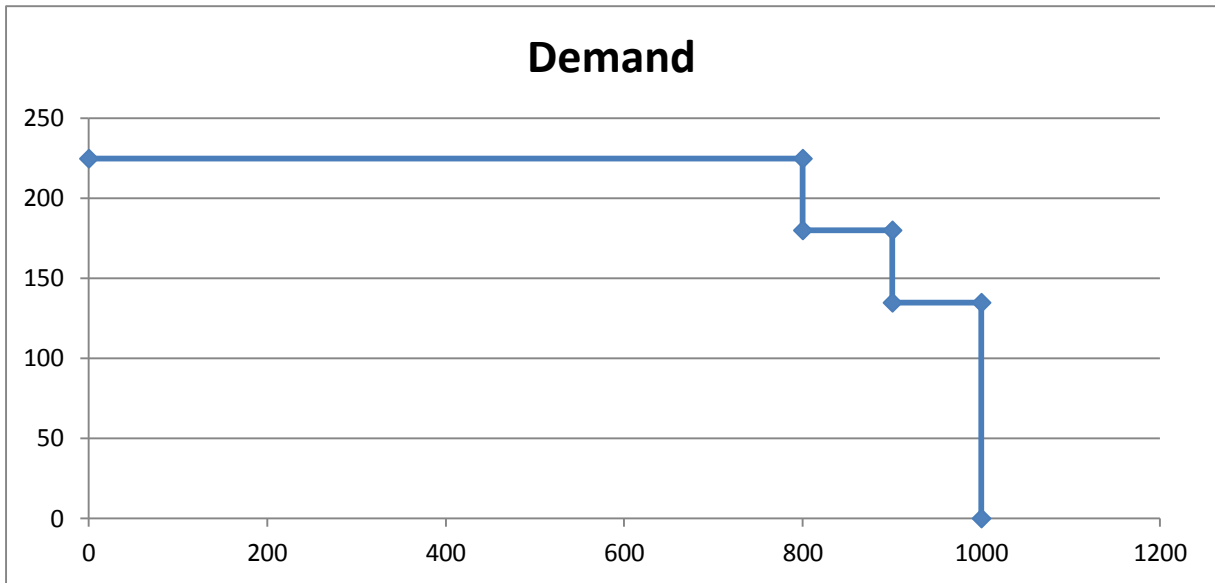
Results page

On, the results page, you will also find three other curves :

- The black curve represents the total offers that were made (just built by adding the players' offers: this is the curve that determines the equilibrium price).

- The orange curve depicts your competitor's offers.
- (the red curve is much less important. I would recommend you not to pay attention to it at this time: For your information, it is built by « adding along the quantity axis» the offer curve of your competitor and your marginal cost curve).

During the first game "with perfect competition", after this tutorial, the orange and red curves will be merged with the green and blue-black curves.

Check the round's results and proceed to the second round.
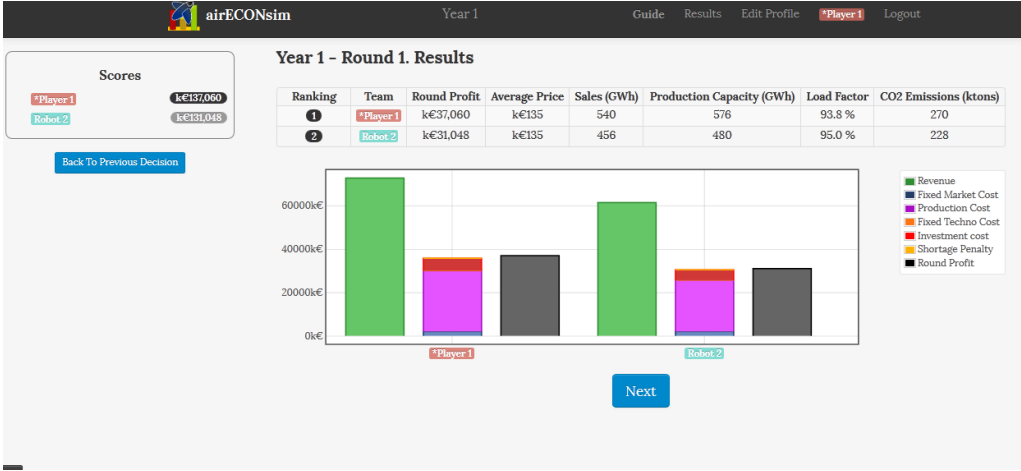
2nd round of Year 1

The second round of each year is in off-peak period. Demand is only half of peak-period demand, here 500 GWh at the maximum.

Do not spend too much time on this round. Demand is low and your competitor is nearly in a position to supply the whole demand by himself, and submits competitive offers (it always offers 480 GWh for a price of 52k€): in such cases, there is little you can do except cutting your losses (and you cannot beat the robot).

IN THIS GAME, YOUR GOAL IS TO MAXIMIZE YOUR PROFIT, NOT TO BEAT THE ROBOT!

2nd Year

1) You can now use gas thermal plants and nuclear plants

Disclaimer **:** costs presented here rely on assumptions about the risks of nuclear power and about the costs of radioactive waste management. Some will find this assumption too weak or too strong. We do not intend to get into this complicated debate, just accept these figures for what they are: an element of the game based on a scenario that we do not present as being more realistic than another, as there are huge uncertainties … And consequently, do not conclude anything about the potential interest or danger of nuclear power from your experience in this game).
Also, most of the time, we have calibrated the models so that orders of magnitudes for costs and prices would be respected. Sometimes, we had to adapt data a little for playability reasons. We will mention this, when this is the case (mainly for fuel plant costs, and for the demand curve)

Choose 29 gas thermal plants and 9 nuclear plants.

2) You can now make 2 offers on the wholesale market.
   In peak period, the robot always submits the same two offers: 182 GWh for a unit price of k€22 by GWh, or 456 GWh if price reaches k€52 by GWh.

Installed Capacities

Team	Techno 1	Techno 2	Max Production
*Player 1	9 Nuclear - 216 GWh/Rnd	29 Gas - 348 GWh/Rnd	Real: 564 GWh this Rnd
Robot 2	8 Nuclear - 192 GWh/Rnd	24 Gas - 288 GWh/Rnd	Real: 480 GWh this Rnd

Total Production Capacity : 1,044 GWh

Note Max Demand for this Round is estimated about: **1,000 GWh**

Your offers to sell (564 GWh maxi)

If the unit price is:		I want to sell this quantity:		♻ Reset
k€ 22		216	GWh	✖
k€ 52		564	GWh	✖
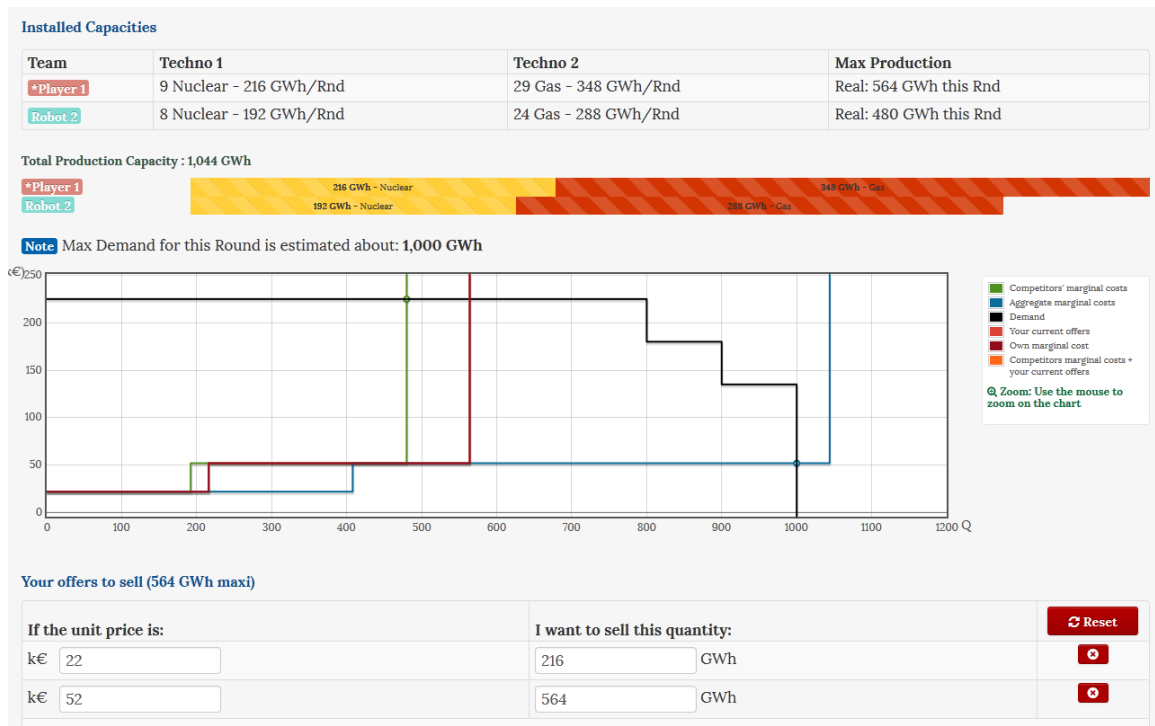
Reminder I: The first, green, curve displays your competitor's short-run production **marginal** costs (i.e. the **additional** cost that your competitor will have to pay if it produces an **extra** GWh, **once plants have been built and investment cost has become fixed**). Here, there are 2 technologies, and your competitor can produce up to 192 GWh with nuclear plants, at a unit production cost of k€22, and up to 288 GWh with gas thermal plants, at a unit production cost of k€ 52. So the green curve has two steps:

- As long as production required is lower than 192 GWh, the cheapest way to produce it, is to use nuclear plants with production marginal cost of k€22 (indeed, at this stage investment costs are fixed, and the only costs that you still control are production costs)-> the green curve is flat, at k€22 below 192 GWh.
- If production required is higher than 192 GWh, then the cheapest way to produce it, is to fully use nuclear plants to produce 192 GWh and to complete production with gas plants. Each GWh required above 192 GWh generates an extra cost equal to the production marginal cost of gas plants, i.e. k€52 -> the green curve is flat, at k€52 between 192 GWh and the maximum production, 192+288=480 GWh.

The red curve displays your production marginal costs: You can produce the first 216 GWh at unit cost k€22. If you want to produce between 216 GWh and 564 GWh, you must complete by producing with gas thermal plants, which costs k€52 by GWh.

Reminder II: A (p,q) price-quantity offer means that for any UNIT price above p, you are willing to sell a TOTAL quantity q

Example

As an example, here is what happens if you submit an offer of 70 GWh for a unit price of k€32 by GWh, and a second of 475 GWh for k€85 by GWh (which means that for a unit price of k€85, you are willing to sell a TOTAL of 475 GWh, not 475+70 !). Recall that the robot submits two offers: 182 GWh for a unit price of k€22 by GWh, or 456 GWh if price reaches k€52 by GWh.

To find the price and sales, the market operator starts by computing the offer curve:

- There are no offers to sell below k€22.
- At k€22, the robot offers to sell up to 182 GWh.
- There are no offers to sell for prices between k€22 and k€32: For these prices, total offer remains equal to 182 GWh.
- At k€32, you offer to sell up to 70 GWh. Total offer is 182 GWh (for the robot)+70 GWh (for you), that is 252 GWh.
- There are no offers to sell for prices between k€32 and k€52: For these prices, total offer remains equal to 252 GWh.
- At k€52, the robot offers to sell up to 456 GWh, instead of the 182 GWh that it offers for lower prices. At this price, you are still willing to sell 70GWh. So, total offer is 456 GWh (for the robot)+70 GWh (for you), that is 526 GWh.
- There are no offers to sell for prices between k€52 and k€85: For these prices, total offer remains equal to 526 GWh.
- At k€85, you offer to sell up to 475 GWh, instead of the 70 GWh that you offer for lower prices. At this price, the robot is still willing to sell 456 GWh. So, total offer is 456 GWh (for the robot)+475 GWh (for you), that is 931 GWh.

Price and sales can then be found by looking at the intersection of demand and offer curves. Equilibrium price is k€ 135. At this price, demand is between 900 GWh and 1000GWh, and offers equal 931GWh. So here, you sell 475 GWh, the robot sells 456 GWh and demand is rationed.
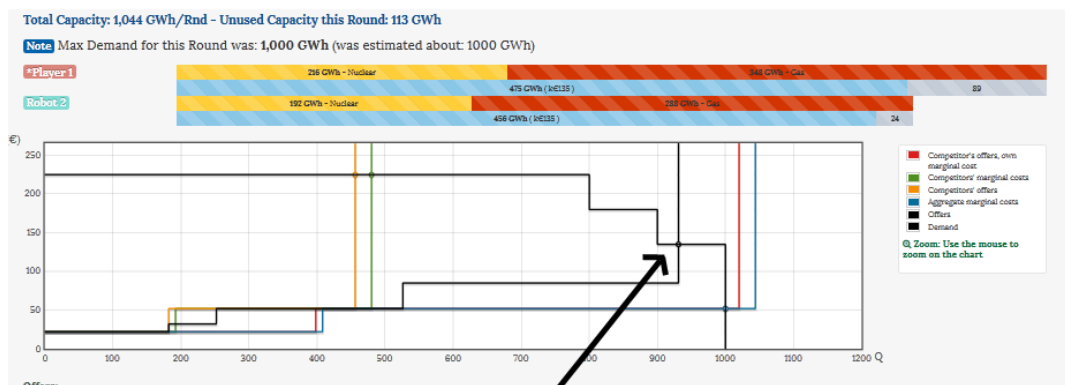
Intersection of offer
and demand curves

Note that if you know for sure what your competitor will offer and if there is no uncertainty about demand, multiplying your offers is not really useful.
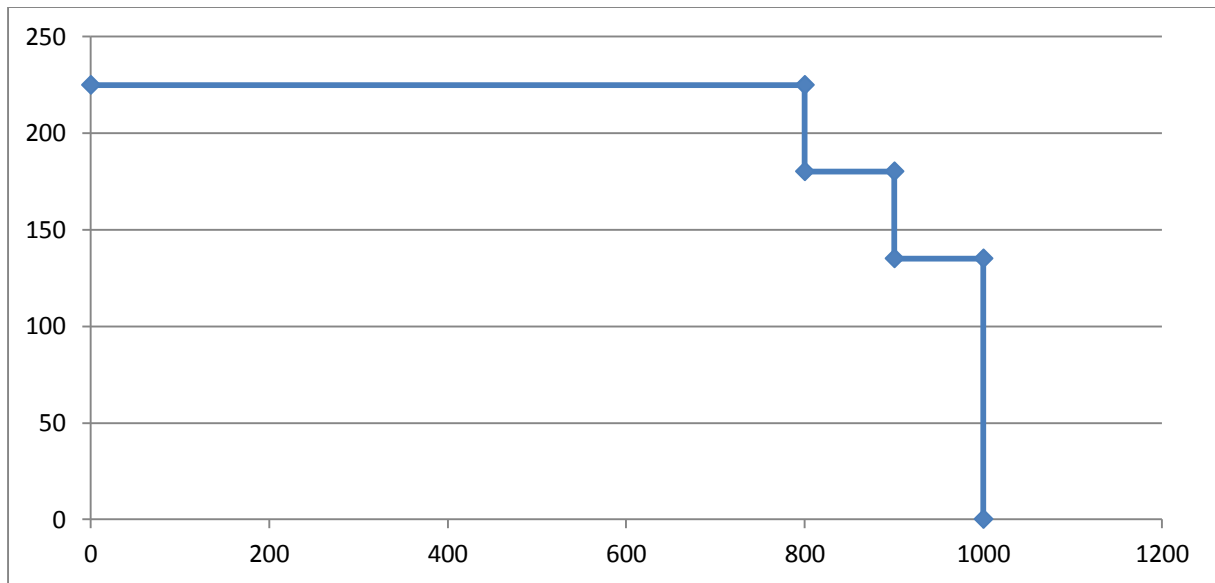
Production organization

As there are two technologies, once sales results are known, you will be directed to a new screen where you will be invited to explain what plants you want to use to produce the electricity that you have just sold. The game suggests an organization, but you are completely free to change it (but try to understand what is the logic behind the suggestion).

Market 1

Production needed: 475 GWh

Power Plant Type	Production Unit Cost (k€)	Production Unit CO2 Emissions (ktons)	Production (GWh)	Max Production (GWh)	Production Cost (k€)	CO2 Emissions (ktons)
Nuclear	22.0	0.0	216	216	4752	0.0
Gas	52.0	0.5	259	348	13468	129.5
Total			475	564	18220	129.5

*Player 1 — 216 GWh - Nuclear — 475 GWh (k€135) — 348 GWh - Gas — 89

Robot 2 — 192 GWh - Nuclear — 456 GWh (k€135) — 283 GWh - Gas — 24

	*Player 1	Robot 2
Revenue over the Round (excluding CO2 and exceptional)	k€64,125	k€61,560
Fixed Costs over the Round (excluding CO2 and exceptional)	k€11,528	k€10,256
CO2 emissions over the year, so far (ktons)	0	0

Validate

3rd year

This year, you can use 2 new technologies, coal and fuel thermal plants. Also, from this year on, you can make as many offers as you want on the wholesale market.

Another new feature, peak and off-peak demands are now getting a bit uncertain.

On the offers page, an estimation of maximum demand appears here, « Max Demand for this Round is estimated about» (on average, demand stays the same as before, but real maximum demand is now a Gaussian variable with a variation coefficient equal to 15%: Which basically means that there is about one chance out of 3 that real maximum demand will be at a distance of more than 15% from its average value: In peak period for example, there is one chance out of 3 that maximum demand is

more than 150GWh away from 1000. Hence there is about one chance out of 6 that maximum demand is above 1150 GWH and about one chance out of 6 that maximum demand is below 850GWh). Prices at which demand drops are now also uncertain.

Note that the "main part" of the uncertainty is disclosed before the offers stage, but a slight part remains until after offers are made. It explains why values on the offers page (demand estimations) are slightly different from values on the results pages (real demand). Here, for example, real maximum demand is 952GWh while it was estimated about 954GWh.
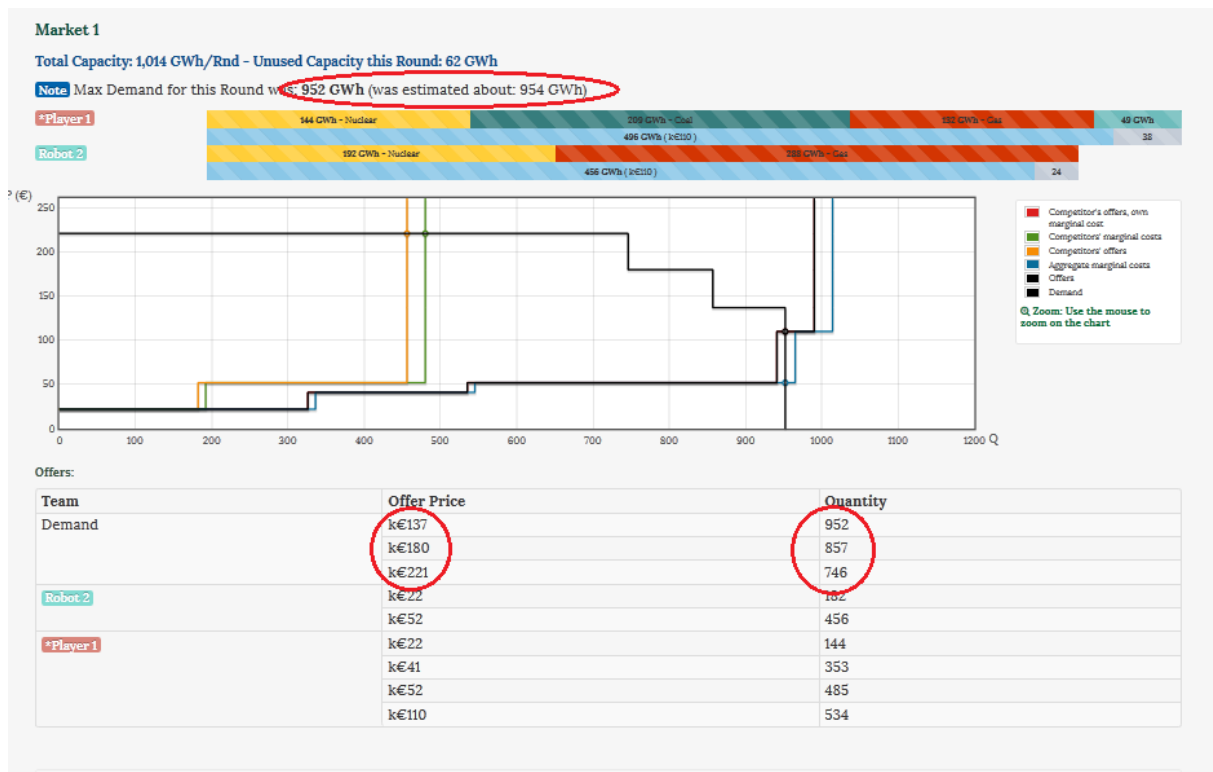
4th year

This year, two new technologies appear: Wind Farms and Hydro (limited to 6 dams by player).

Technology	Max production/Rnd and plant	Investment cost/Rnd and plant	Unit production cost	CO2 Emissions (ktons/GWh)	Avg cost (w. 100% load)	Avg cost (w. 50% load)	Avg cost (w. 10% load)
Nuclear (1 reactor)	24 GWh	k€ 672	k€ 22	0	k€ 50	k€ 78	k€ 302
Gas	12 GWh	k€ 120	k€ 52	0.5	k€ 62	k€ 72	k€ 152
Coal	19 GWh	k€ 266	k€ 41	1	k€ 55	k€ 69	k€ 181
Oil	7 GWh	k€ 14	k€ 110	1	k€ 112	k€ 114	k€ 130
Wind Farm	4 GWh	k€ 224	k€ -10	0	k€ 46	k€ 102	k€ 550
Hydro	8 GWh	k€ 160	k€ 2	0	k€ 22	k€ 42	k€ 202

Wind Farms are subsidized: production costs take this subsidy into account, which explains why they are negative. Once you have invested in wind farms, every GWh produced yields 10k€ (of course you cannot produce more than what you have sold).

Wind is an intermittent source of energy: Sometimes wind blows, sometimes it does not. In the game, to make things simple, the max production that you choose when you enter your decisions is the targeted production capacity and the real capacity will be a uniform random draw between 60% and 140% of that value (things are a little more complicated in the real world, since sometimes wind farms cannot produce any energy at all. But this would make the game too complex, without adding much to it). The real production capacity level will be known before offers are submitted on the wholesale market, and will thus have an impact on offers.

Of course, every player would ideally prefer to locate its wind farms in places where wind is the strongest (and steadiest). This is what you do when you choose the first wind technology "Wind Farm". The consequence is that all players choosing this first technology will have their wind farms located at the same area: The random shocks are perfectly correlated between all the wind farms of this type on a market during a particular round. If you can produce 12% more than the targeted production capacity with your wind farms, so will your competitor.

Hydro energy is storable. For every dam you build, you will "receive" 2*8=16GWh at the start of the year, that you can use when you want: you can either share between the round or use it all during of the rounds if you prefer.

Later in the game, scenario events will regularly change the background of the game (flexibility constraints, solar panels, evolving costs, co_2 emissions, secondary spot for wind farms …).

You have two years left in the tutorial to try bold decisions. Then, you will be ready to play against other humans.

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