How Electricity Prices Form in the Turkish Market : An Excel based Supply Side Model

This paper describes an overview of an Excel based model to describe Electricity Price formation in The Turkish Power Market. The data on the Excel are not necessarily correct, some of them has been changed for public distribution. Use it for educational purposes only. Feel free to send your comments to barissanli2@gmail.com .

Excel Model : http://www.barissanli.com/calismalar/2014/TPM-v2.xlsx

Introduction

Turkish electricity market has been undergoing a transformation since 2001. This evolution was not that easy. There were times when government dominated the supply curve. Part of this domination owes debt to existing BOT-BO-ToOR (Build-Own-Transfer) projects.

But for the last two years, there is an elevated curiosity regarding how intermittent renewables react with the current mechanism. All this questions are well understood through complicated, state-of-the-art models. However as a policy maker or as an outside observer, sometimes you may need something simpler. The subject of this article is such a simple Excel based model that is free of VBA or macros.

Previous Studies

In 2010, one Energy expert asked me the question of "how much cross subsidization exists between different customer groups?". This question led me to work on two models, one for the supply side, one for the demand side. Both models were not the ultimate correct models but assumptions were safe enough to pave way for carrying out calculations.

During the modelling exercise, I was later informed that another group has been working on the same topic through customer statistics, payments etc. When I finished the work, I was told by the other group members that my calculations were very close to theirs.

In that study, the method used by me was an Excel based model. I later used it to calculate drought, wind, and carbon price effects. The results were published in 2011 and 2012. One of the results of that time was the effect of wind on prices. Years on, the effect of wind is much more visible in the price formation[1].

As time passed by, a more realistic model idea has occurred, that is fast, easy to use and understandable. So the model used for 2010 has been revised.

[1] http://www.barissanli.com/calismalar/2011/temmuz2011-TurkiyeElektrikArzEgrisininModellenmesi-bsanlimguler.pdf
http://www.barissanli.com/calismalar/2012/bsanli-TurkiyeElektrikProfilAnalizi.pdf

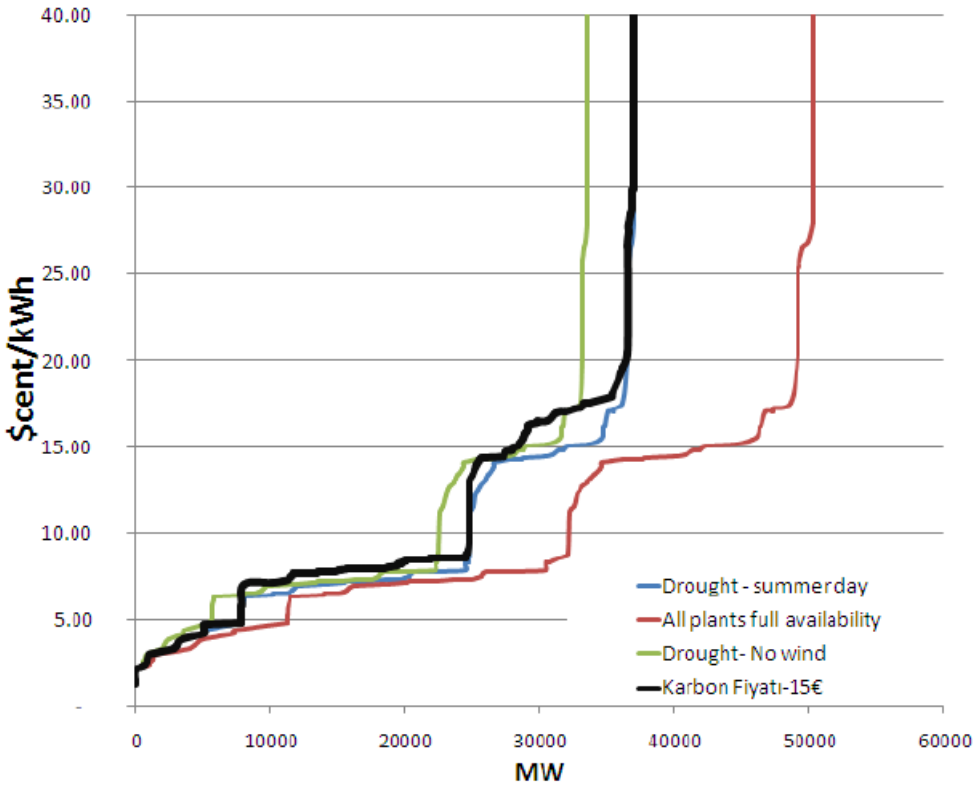


Figure 1 – The supply model in 2010 under several scenarios

Why not use the previous model?

Previous models were fine, but need some complicated data transfer code to get the Excel sheet working. Also I needed to show how prices "shift" when BO-BOT's were not available, wind is blowing and sun is shining. Actually there was a need for a more realistic model.

During our meetings with new energy experts in the Ministry. I found it hard to describe the shift of supply curve to the left and right with the current tools. They need to experiment themselves and find out how electricity dynamics work and how they interact with each other. This study is the fruit of these efforts.

In 2014, however I found out that most of the models I made are either lost, deleted. I decided to make them public, so someone can improve or benefit from the model, students can have a better understanding and if someone makes an improvement, he/she can share it with me.

The Basics – Turkish Power Prices 101

Model is an abstract understanding of the reality. Model is not the reality itself. As most of modelers know "All models are wrong, some are useful". The aim is to get a useful model.

Modelling of the supply side for the Turkish market is complicated, since not all the efficiencies for all the units are public/known, the data at that time was limited. So there has to be a way to make an acceptable abstraction to both reflect the reality behind price formation and achieve this with minimum available data.

In the Turkish electricity market, price formation curve has three distinct parts. These are

- **Renewables (as called YEK or YEKDEM for simplicity):** These are the renewables those register for FIT payment and the cost of these FIT payment volume is distributed to sellers.
- **Pre-2001 Contracts (BO/BOT/ToOR):** The contracts under this regime were tendered before 2001(before market reforms), and Ministry of Energy hence Treasury guaranteed them to buy their electricity through an agreed tariff system. Majority of them are natural gas plants, there is one exported coal plant and several dozens hydros. The thermal plants under this regime has an obligatory availability rate such as 90%, otherwise they are required to pay penalties.
- **Merit Order**: Since 2007, Turkish balancing market and then the day ahead market(DAM) is getting bids from IPP (Independent Power Producers) and state owned enterprises such as EÜAŞ and TETAŞ.

Combining all three parts in to an Excel model has been tricky and somehow labeling of these parts were the most difficult of them all.

At the end, the required model has to look like something below.

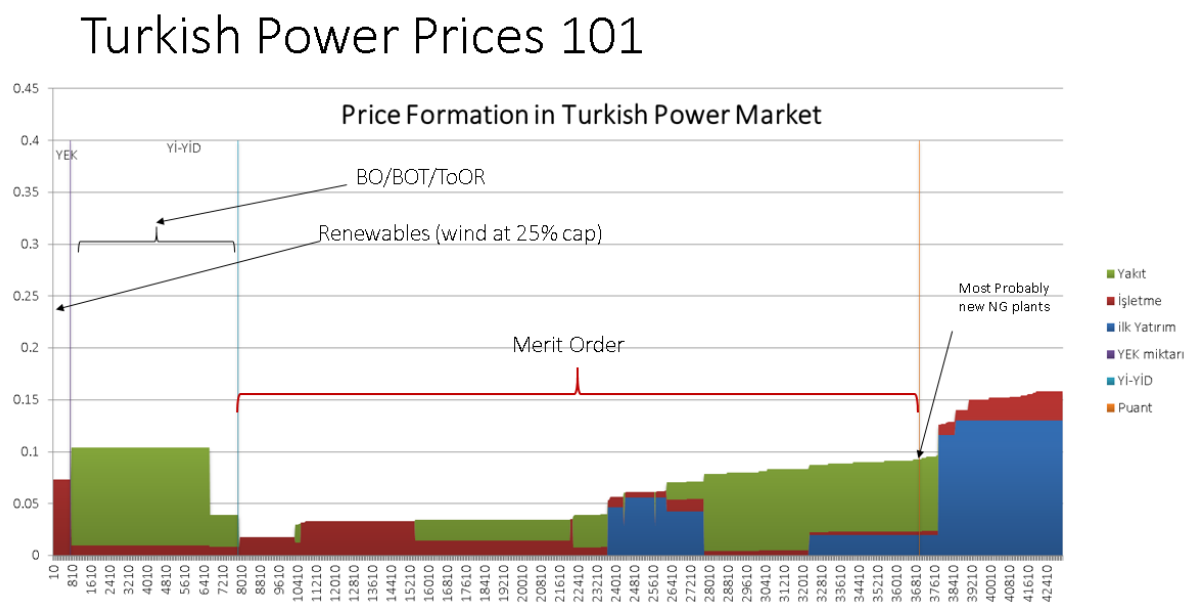


Figure 2: Turkish power prices and three parts form the price curve

Assumptions and Mechanisms

The abstraction needs further details to have a better reflection of the reality. First of all there are certain assumptions to be made:

- **Marginal Cost Formation:** Any power plant older than 12 years(in the model 7 years) has paid its debt. So its costs consist of operating and maintenance costs and fuel costs. There is the discussion of short term marginal costs and long term marginal costs. Correct model should work with short term marginal costs which excludes debt payment, however in our model it has been decided that long term marginal costs give better understanding for analysts-to-be.
- **Unit Assumption**: Instead of entering the data for each unit (which was not available publicly), the cumulative increased capacity for each year for each type is assumed as a single unit. For

example, Natural gas installed capacity in 2011 is 1302 MW. This 1302 MW is assumed as a single unit with age 2 (as of 2013)

- Thermal Plants: Thermal plants are divided into 5 categories
    - EÜAŞ lignite
    - EÜAŞ natural gas
    - BOT/BO natural gas
    - BO imported coal (Which is Isken)
    - Independent power plants
- Fuel Costs: Imported coal and domestic coal costs are gathered from newspaper articles as well as international sources. But there is one important distinction when it comes to natural gas prices for power plants. BOTAŞ has two prices, one for BO/BOT plants and another one for the rest. Prices differ, since state sells to the pre-2001 contract owners with a higher price.
- Investment Costs: For investment costs, the numbers are mainly taken from IEA's World Energy Outlook Technology database, however since independent power producers have shifted to Chinese market for their generating equipment, there are some slight adjustments. Also interest rates and other assumptions were given for educational purposes. The period for payback is limited to 7 years, although we are aware that there are lots of projects with over 10 years of payback time.

After making these assumptions (and all these assumptions are open for discussion), the focus has shifted to the mechanism for that model.

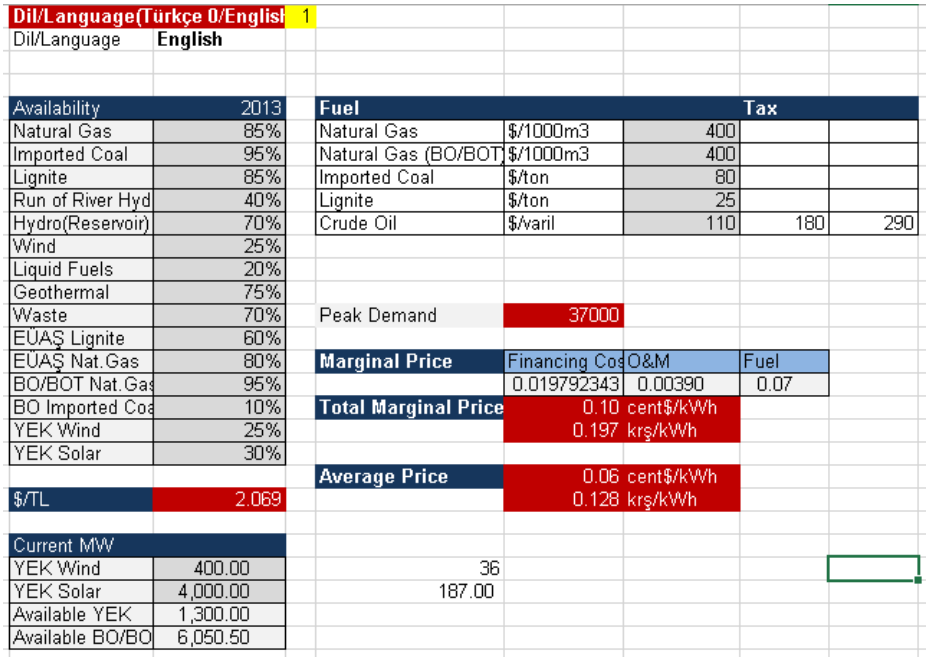
Basically, model needed a control panel, where availabilities, exchange rates and prices are entered, then the costs for the power plants are calculated.

The control panel has six type of inputs (Figure 3)

1. Choice of Language: Cell(D1) : The yellow cell defines the language of the graph and control panel. If it is 1, language is English, else if it is 0, language is Turkish
2. Availabilities: Cells(C6:C20): These are the availabilities for different types of power plants. By adjusting these availabilities, you can control the shape of the curve
3. Exchange Rate: Cell(C22): This is the exchange rate for USD to Turkish Lira. All calculations are made in USD then converted to TL.
4. Current MWs: Cells(C25 & C26): From these cells one can enter the MWs of wind and solar benefiting from FIT (Feed in tariffs). These values are later multiplied with availabilities to calculate adjacent cells. (C27)
5. Fuel Prices: Cells (G6:I10): These are the fuel prices in USD.
6. Peak Demand: Cell (F14): The peak demand that crosses the supply curve in orange can be set here.

Control panel also has some internal calculations. These are:

- Available YEK: Cell(27): That is the cell where available FIT wind and solar is calculated
- Marginal Price: Cells (F16:H17): The components of marginal price maker is given here
- Total Marginal Price: Cells (F18:F19): The summation of the cells above is given here and by using exchange rate, calculated in Turkish Liras.
- Average Price : Cells(F21:F22): In here the average price for the whole basket is calculated.



Dil/Language(Türkçe 0/English	1						
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Availability	2013	Fuel			Tax		
Natural Gas	85%	Natural Gas	$/1000m3	400			
Imported Coal	95%	Natural Gas (BO/BOT)	$/1000m3	400			
Lignite	85%	Imported Coal	$/ton	80			
Run of River Hyd	40%	Lignite	$/ton	25			
Hydro(Reservoir)	70%	Crude Oil	$/varil	110	180	290	
Wind	25%						
Liquid Fuels	20%						
Geothermal	75%						
Waste	70%	Peak Demand	37000				
EÜAŞ Lignite	60%						
EÜAŞ Nat.Gas	80%	Marginal Price	Financing Cos	O&M	Fuel		
BO/BOT Nat.Gas	95%		0.019792343	0.00390	0.07		
BO Imported Coa	10%	Total Marginal Price	0.10	cent$/kWh			
YEK Wind	25%		0.197	krş/kWh			
YEK Solar	30%						
		Average Price	0.06	cent$/kWh			
$/TL	2.069		0.128	krş/kWh			
Current MW							
YEK Wind	400.00	36					
YEK Solar	4,000.00	187.00					
Available YEK	1,300.00						
Available BO/BO	6,050.50						

Figure 3 - Control Panel of the Model

Sheets

There are six sheets in the Excel file. These are :

- **Info**: The information panel.
- **CP** : Control panel sheet as explained above.
- **Ana**: (Main Panel): This is the main assumptions in rows. It calculates the yearly increases, costs etc.
- **Dinamik_Ana(Dynamic Main):** In this panel, the rows in the Ana sheet are transposed into columns and then ranked
- **NihaiTablo(Final Table)**: The ranked entrants in the previous sheet is ordered here and graphic is formed
- **Dil (Language):** This is the language sheet.

The sheets gather up the information from the TEİAŞ data collected in the "ana" sheet, makes some calculations, orders them and graphs. The graph is then overlaid with other data such as Available YEK, Available BO/BOT and Peak Demands.

Some Simple Exercises

As the sheet's link is available in the first page, now it is time for some simple exercises.

Exercise 1: Assuming a total of 3000 MW's of wind, what is the price change as wind availability increases from 10% to 90%.

Solution 1: Let's assume all this wind is registered for the FIT. So :

- Enter C25 in CP sheet : 3000

YEK Wind	10%
YEK Solar	0%
$/TL	2.069
Current MW	
YEK Wind	3,000.00
YEK Solar	4,000.00

- Then enter C19 in CP "YEK Wind" Availability as **10%**
- See the price in F18&F19

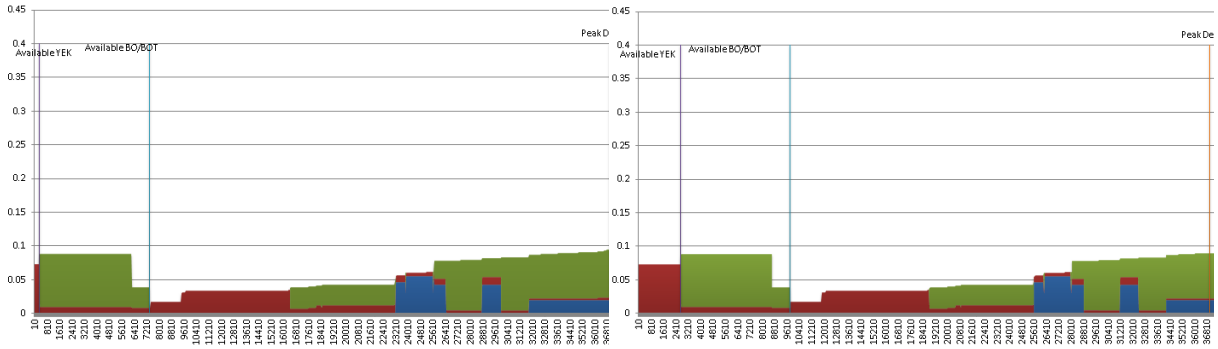
Total Marginal Price	0.10 cent$/kWh 0.197 krş/kWh
Average Price	0.06 cent$/kWh 0.126 krş/kWh

- Now repeat the **same for 90% availability**, and change the C19 as 90%.

Total Marginal Price	0.09 cent$/kWh 0.186 krş/kWh
Average Price	0.06 cent$/kWh 0.124 krş/kWh

For the given configuration prices drop slightly. From 0.10 cents to 0.09 cents. Remember to calibrate the model before using it.

The change in the supply curve graphs are more visible. The supply curve is shifted to the right. The YEK (Renewable FIT) volume on the very left has increased and pushed the supply curve "merit order" to the right.



10% wind availability 90% wind availability

Figure 4- Effect of different wind availabilities on the supply curve

Exercise 2: Let's assume there is 4000 MWs of solar in the system. How does the price change when the availability of solar goes from 0% (night) to 90% (mid day)?

Solution 2: Let's assume all this solar is registered for the FIT. So :

- Enter C26 in CP sheet : 4000

YEK Wind	25%
YEK Solar	0%
$/TL	2.069
Current MW	
YEK Wind	3,000.00
YEK Solar	4,000.00
Available YEK	300.00

- Then enter C20 in CP "YEK Solar" Availability **as 0%**

YEK Wind	25%
YEK Solar	0%

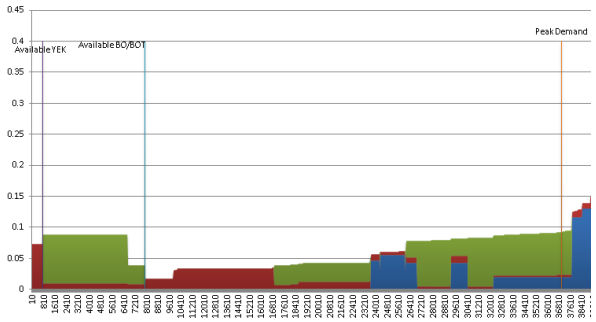
- See the price in F18&F19

Total Marginal Price	0.09 cent$/kWh
	0.191 krş/kWh

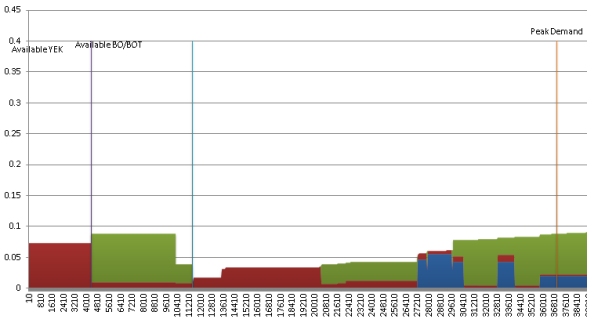
- Now repeat the same for 90% availability, and change the C20 **as 90%** and observe the price.

Total Marginal Price	0.09 cent$/kWh
	0.183 krş/kWh

It is interesting that, the availability of solar does not change prices a lot, this is during the demand of 37000 MWs. This is a setting for 2013 installed capacity and demand of 37000 MWs. However if the demand is much less price drops are much more observable and close to 16 krş/kWh.



Solar availability 0%

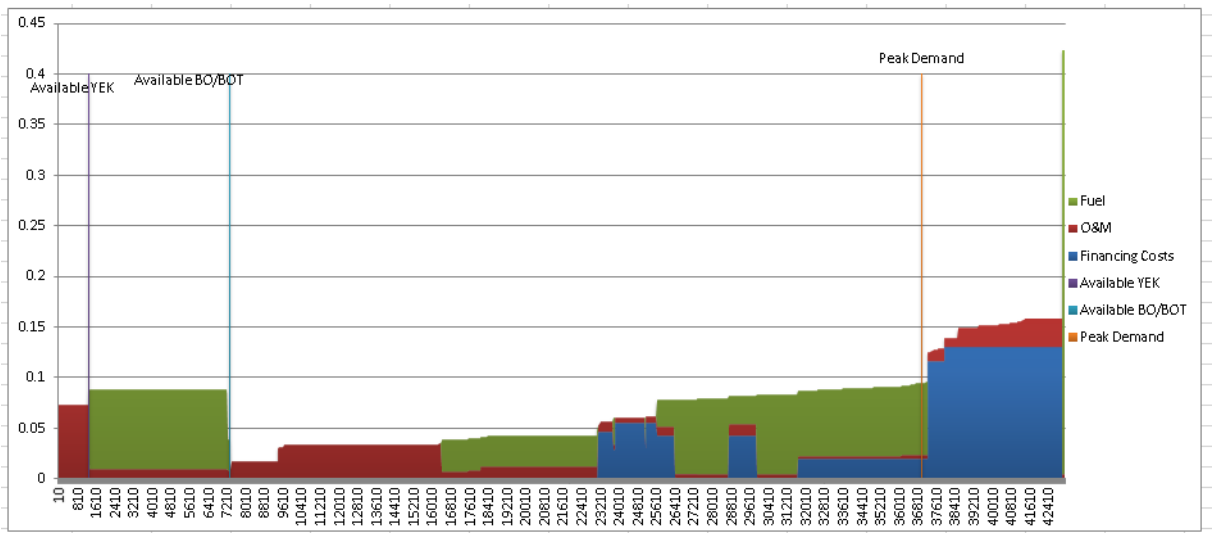


Solar availability 90%

Figure 5- Effect of different solar availabilities on the supply curve

Conclusion

Turkish power prices are not just a function of a merit order composed of bids entered into PMUM, Turkish market operator. There are two more components. One of them is well known renewable guarantees, the other is pre-2001 contracts of BO/BOT/ToOR.



The model and Excel file given is not the best/correct model for the real setting. Even the inputs entered need to be calibrated. But it shows how the supply curve can change with different availabilities and how this change affects prices.

Use this tool as an educational tool to explain the workings of Turkish power market. If you find it helpful or have any suggestions or corrections, happy to hear that.

Excel File : http://www.barissanli.com/calismalar/2014/TPM-v2.xlsx

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