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A new paradigm for Italy's electricity market price-fixation mechanism, the new way to overcome shocks and crises.

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1) INTRODUCTION

In an era marked by rapid changes in every aspect of our lives, caused by constant shocks from both internal and external factors ex. geo-political conflicts, increased financial instability, constant increase of liabilities and environmental challenges, the fear of not being able to cover our basic needs is more real than ever: This inquiry delves into the realm of electricity, specifically focusing price-fixation mechanisms, how they work and how they compare worldwide, with the aim of finding the one most suitable with the current world paradigm, all using Italy as its main study-subject and the well-being[1] of its customers and generators as the main metrics.

This will be done through a quantitative method that aims to replicate mathematically, with a certain accuracy, the existing systems at which both demand and supply changes are applied, first system by system then between them, in order to compare their behavior in response to systemic shocks and find the most resilient long term.

Through this analysis in the conclusions the following questions will be answered:

1. Is the European principle of minimizing the price for the consumer through free market still the best system?
2. What about a regulated one, the tariff system?
3. What are the pro and cons of the two, a mix is a viable strategy?

2) THE TWO ENERGY PRICE SYSTEMS

To start this inquiry is imperative to first understand how the energy market is organized: In this chapter, the focus will be on how the systems work. The one proposed are mainly two, the EU free market, the Jordan tariff system.

[1] With the concept of well-being is intended the stability of prices for consumers and a fair revenue for generators

2.1) EU ENERGY INFRASTRUCTURE DESIGN

The EU energy market is composed in mainly 4 players:

1. Generators: Mainly composed of energy companies that owns power plants ex. Coal PP, Wind and solar farms, Hydro ecc…They sell the produced energy to the market.
2. Transmission systems operators also known as TSOs: These are national entities that manage the power grid transmission. They are particularly important for this inquiry as they are the main source of data, in fact, they asset demand and constantly communicate with generators organizing supply through the day-ahead market, as well as managing flows not only internally but externally through the market-coupling, both terms are explained in the subchapter 2.1.2.
3. Distribution system operators or DSOs: They are responsible for delivering the product to consumers.
4. Suppliers: The intermediary responsible for selling the electricity to the customer.

For this paper the focus is on the interaction between generators and customers through the TSOs. The DSOs and the suppliers are left out as they influence the market in a marginal way.

2.1.1) TRASMISSION SYSTEM OPERATORS

Transmission system operators are key players in the market, managing it. They are organized through an entity called ENTSO-e or European network of transmission system operators, from a hierarchical standpoint is possible to organize the chain as follows: ENTSO-e, TSOs, DSOs and suppliers. Being the “market organizer” at the top of the chain, its database[2], works as the main data source for the models.

[2] https://transparency.entsoe.eu

2.1.2) HOW FREE MARKET PRICE FIXATION WORKS

The Eu price fixation mechanism follows the free-market concept, this is done through a bid system based on competition:

The process starts with TSOs announcing to generators the expected demand for each hour of the next day, then generators place a bid containing quantity of electricity and the price at which they are able to sell it, being that the free-market is competitive, that price is expected to be equal to the marginal cost of the power plant, that is the sum of operative expenses(OpEx), fuel and co2 emissions, then the bids are placed in order from the lowest price to the highest and matched with the expected demand using a discriminatory function: to make an example if there are three bids: Q=30MW P1=5, Q=20MW P2=10 and Q=40MW P=30 and the expected demand for that hour is 40MW then the last bid is cut and the last one accepted is the second, this process is called merit order. Then the generators a paid not with the inputted bid, but all with the last one accepted, in the previous example, the first bidder is paid 10 even if he had bid 5.

The other main process that influences this bid system is the market-coupling or cross-border demand allocation: basically and algorithm operated by ENTSO-e called MARI is used to move demand across the countries borders with the aim of minimizing the total price paid by consumers: for example if Italy's price is 10 euro per MW and France price is 20 euro per MW, the algorithm could find an optimization, and moving demand from France to Italy is able to change the prices from PIta=10 to 12 and PFra=20 to 15 thus minimizing the prices of the system.

ENTSO-e also takes into consideration local constraints, legislation, and several other factors.

2.2) TARIFF SYSTEM: JORDAN

The tariff system idea is to stabilize the prices almost completely and remunerate generators for the risk, where the government plans both demand and supply, in the case of Jordan the customer pays based on consumption: For example, two tariffs could be T1=0-10MW P=10 euro and T2=11-20MW 20 euro so if a customer consumes 15MW pays 10 euros.

The tariff prices are calculated using a weighted average of the total cost of generators and priced accordingly, they change based on fuel price. The total cost includes fuel cost, operative expenses (OpEx) and capital expenses (CapEx), CapEx is added to remunerate generators for the risk.

For simplicity reasons in this paper is assumed that there is only one tariff.

3) THE TWO SYSTEM TO THE TEST

In this chapter will be first explained the basic premises of the mathematical models produced to conduct this inquiry and then, into the multiple subchapters will be explained the results of each scenario analysis alone then, as more models are explained, comparatively. At the end of this paper, all the data produced by the models will be summarized in a table.

3.1) EU SYSTEM REPLICA

The EU model replica has been built to mimic the system used in EU, its functioning and premises are explained in the following subchapter, this model is the only one of the three that has been benchmarked with actual data.

3.1.1) HOW THE MODEL WORKS

The European market is based on a free market system, it's most basic explanation is: It takes all the bidders(generators) and selects, through a merit order, the lowest ones that cumulatively match the demand, in the day-ahead market [3] ,and simultaneously minimizes the overall cost for the customers giving the transmission limit, generation limit and local restraints, this is done by moving the demand in

[3] https://transparency.entsoe.eu/transmission-domain/r2/dayAheadPrices/show

real time through cross-border demand allocation, in a process is operated by the MARI[4] algorithm.

To replicate this complex mechanism is used a model that is based on supply/demand balance, marginal cost, and merit order. At high levels the steps done are the following:

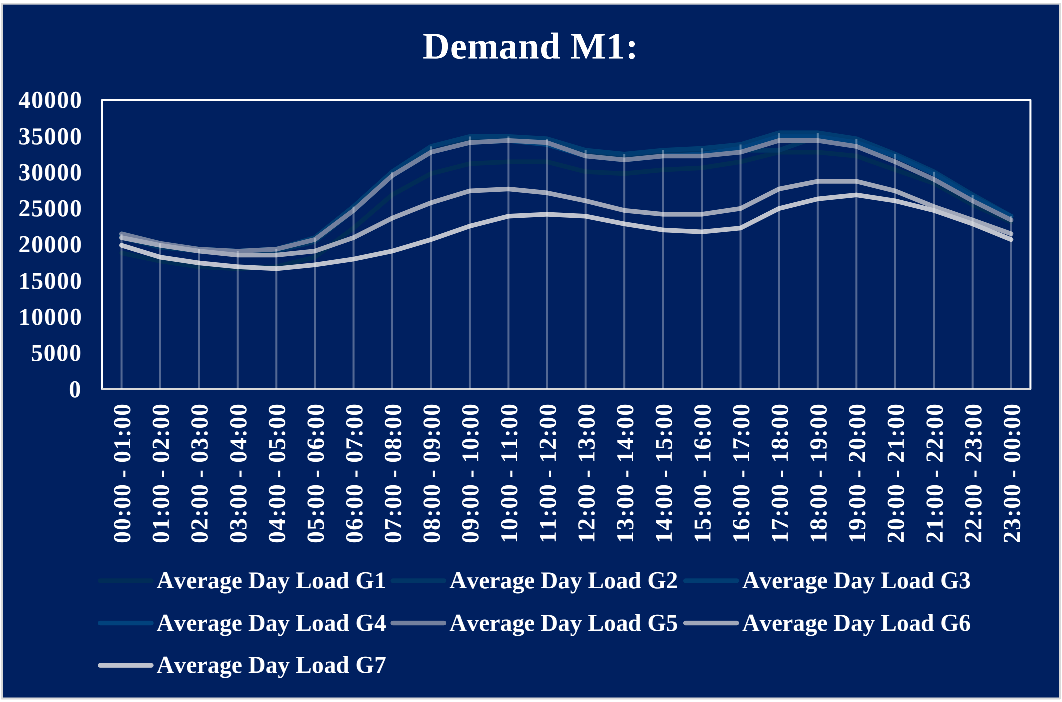
Simplifications:

1) Aggregation of each generation supply type: solar, wind, nuclear, hydro, gas, coal, oil, bio in 2 variants per type divided by older and newer power plants.
2) Allocation for each generation type a typical marginal cost, computed through the weighted average by generation type of opex, fuel cost, c02 emissions per ton of fuel and efficiency, based on 2017 data.
3) The cross-border balancing system has not been implemented as it would require a scale model of the other EU energy markets and a replica of the MARI algorithm, overall given the aim of the study, is not required.
4) The elasticity of the demand has not been computed as it is low and would not provide significant improvement to the model.
5) Transmission costs are not considered.

Input data:

1. The demand hourly function. It comes from ENTSO-E historical data based on 2017[5] and aggregated by weeks of a year and expressed as percentages. Follows a table that contains the data regarding the first month, it has been aggregated this way because the difference between days of the week is significative while the difference between the weeks of the month is not, as shown on the following *Graph 1*, on day 6 and 7 (the weekend) the demand is significantly lower:

[4] https://www.entsoe.eu/network_codes/eb/mari/
[5] https://transparency.entsoe.eu



Graph 1

2. Average solar and wind generation per hour per month, expressed as percentage of installed capacity, it's not possible to show it as the table is too big, these generations are computed hourly.
3. The commodities price ex. Coal, C02, Oil, gas per month, shown on the following.

Time	Gas	Coal	Oil	CO2
Currency	EUR	EUR	EUR	EUR
01/01/2017	13,61 €	13,66 €	28,58 €	11,71 €
01/02/2017	13,51 €	13,15 €	28,90 €	11,28 €
01/03/2017	11,41 €	12,23 €	27,06 €	10,49 €
01/04/2017	11,57 €	12,10 €	27,59 €	10,38 €
01/05/2017	11,58 €	11,14 €	26,49 €	9,55 €
01/06/2017	11,42 €	11,52 €	24,42 €	9,88 €
01/07/2017	11,28 €	12,18 €	25,36 €	10,45 €
01/08/2017	11,47 €	11,87 €	26,75 €	10,18 €
01/09/2017	11,80 €	12,40 €	28,72 €	10,63 €
01/10/2017	11,92 €	13,08 €	30,01 €	11,22 €
01/11/2017	12,46 €	13,52 €	32,58 €	11,60 €
01/12/2017	12,78 €	12,99 €	33,44 €	11,14 €

Table 1

4. Installed capacity by generation type:

Generators	Installed capacity 2017 in MW
Biomass	1652,71
Solar	19181,81
Wind	8963,35
Hydro 1	1655,40
Hydro 2	10220,91
Hydro 3	4057,61
Pumped storage 1	1928,95
Pumped storage 2	4048,90
Other 1	44,40
Other 2	902,00
Coal 1	3893,00
Coal 2	6021,00
Gas 1	1766,30
Gas 2	45954,68
Oil 1	3289,08
Oil 2	2358,48

Table 2

5. Marginal cost by generation type per month, on the table the marginal costs of biomass, solar and wing MC are set to 1,2,3 respectively to simplify the merit order process, as anyway the total supply of these three is not enough to cover the hourly demand, not even once in the full year, the same is true for pumped storage and hydro.
6. Percentage of average load per aggregated generation unit (load factor) this percentage is multiplied to the installed capacity to find the total contribution of the generator in the supply function (this shown here is the first month), the X shown next to solar, and wind is a placeholder as the total generation comes from the actual historical hourly averages.

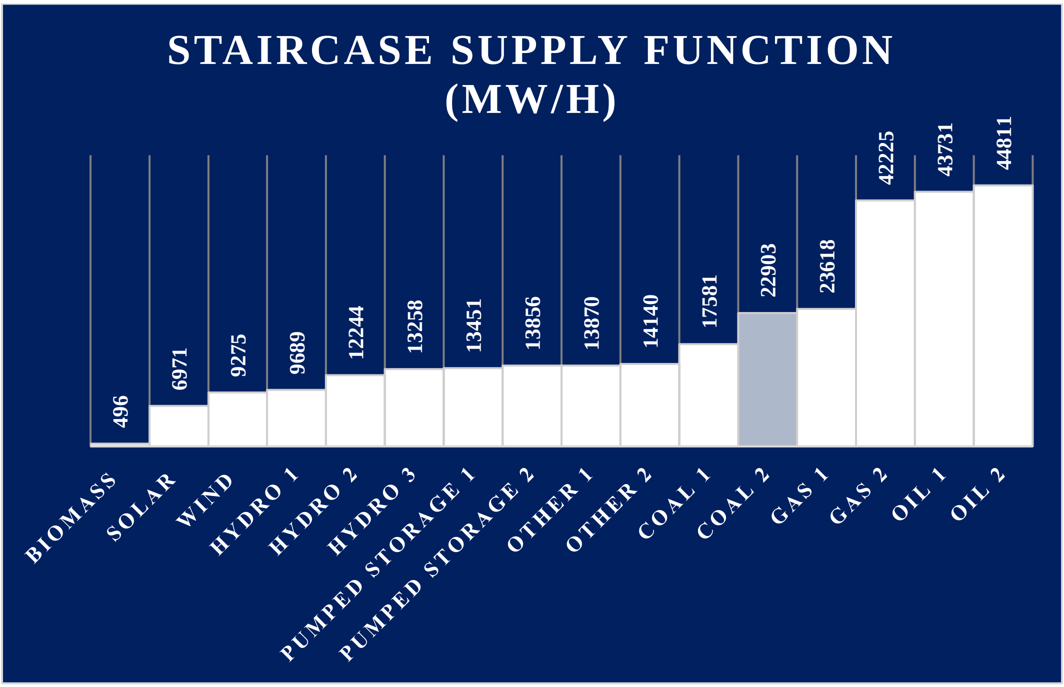
Both points are aggregated in the following *table 3*:

Marginal cost	Technology	Load factor
1,00	Biomass	0,30
2,00	solar	X
3,00	wind	X
10,39	Hydro 1	0,25
10,39	Hydro 2	0,25
10,39	Hydro 3	0,25
10,39	Pumped storage 1	0,10
10,39	Pumped storage 2	0,10
37,89	Other 1	0,30
37,89	Other 2	0,30
66,70	Coal 1	0,88
66,70	Coal 2	0,88
84,95	Gas 1	0,40
84,95	Gas 2	0,40
150,22	Oil 1	0,46
150,22	Oil 2	0,46

Table 3

Output:

1. The model calculates the cumulative staircase supply function with its relative marginal cost, total supply, it's aggregated by weeks for a year.

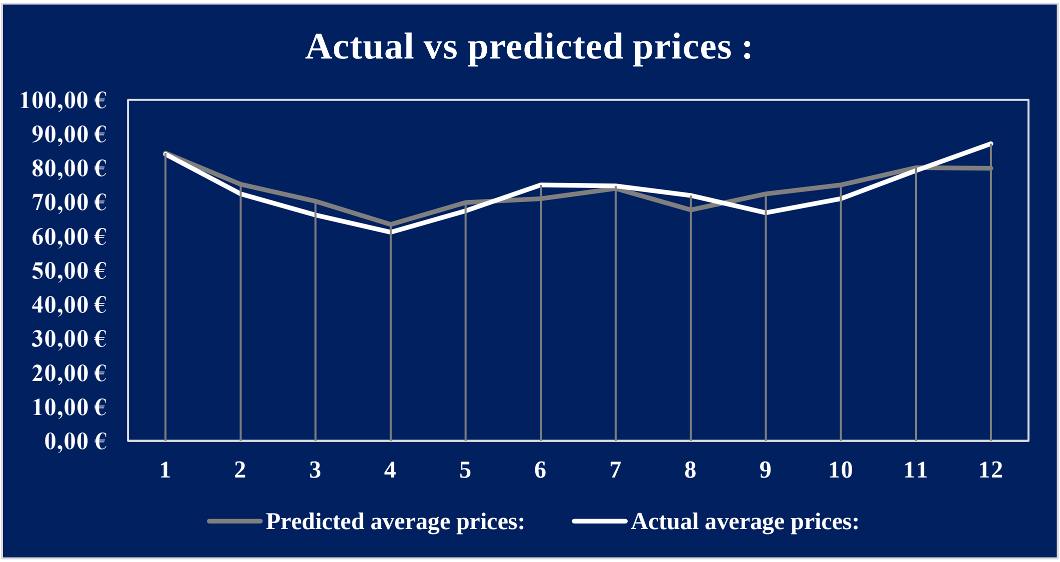


Graph 2

2. The model calculates the hourly demand for a year using total demand (so we take one series from the *graph 1*)
3. The cross of supply and demand represent the market price (that equals to the highest accepted generator bid), it is computed hourly for a year and converted in an annual average price. To make an example if we take in consideration HH6 of month 1 on Monday, the hourly demand is around 22291MW, so the last generator needed to be activated to cover demand is Coal 2, as shown on *graph 2,* with a marginal price of 66,70 euro/MW, as shown on *table 3*, that is the price that the consumer pays for 1MW of energy at that specific time.

3.1.2) NORMAL REGIME AND MODEL BENCHMARK

First of all, to validate the results of the following paper, the model has been benchmarked with the real average annual price of 2017, the comparison has been made on the twelve months through a statistical analysis against the prediction of the model. The model reached a R squared equal to 0,7304 which means that approximately 73.04% of the variance in the annual price can be explained by the model's predictions, moreover the resulted RMSE is 3,76 an has a root mean squared error of 14,12. This model is not precise enough for trading or really precise predictions but it's more than enough for explaining the underlining mechanism, assumptions and results of this inquiry, moreover to farther augment the precision all the results has been taken as a weighted average of the months of the year, at the end the model and the real prices, in a normal regime, differs only by 0,88%, This suggests that the model aligns reasonably well with actual data. This way of calculating the prices isn't only used to legitimize this model but also the other two that will be discussed in the following chapters, given the fact that it's impossible to compare them with actual data, and it's only possible to give an educated guess about them. Follows the *graph 3* and *table 4* with the model output vs real and the statistical analysis in *table 5*.



Graph 3

Follows the table containing the predictions and the actual average prices:

Months	Predicted average prices:	Actual average prices:	Diff %
M1	84,41 €	84,09 €	0,38%
M2	75,25 €	72,46 €	3,78%
M3	70,26 €	66,20 €	5,95%
M4	63,47 €	61,18 €	3,67%
M5	69,93 €	67,48 €	3,57%
M6	71,05 €	75,03 €	-5,45%
M7	73,97 €	74,81 €	-1,12%
M8	67,72 €	71,96 €	-6,06%
M9	72,41 €	66,91 €	7,90%
M10	75,06 €	71,06 €	5,49%
M11	80,14 €	79,30 €	1,06%
M12	79,91 €	87,14 €	-8,67%
		Average % difference:	0,88%

Table 4

Follows a table containing the statistical analysis conducted:

Y Real	Y Predicted	u	I(u)I	(u)^2	RSS/TSS
84,0865	84,4065	0,3200	0,3200	0,1024	119,9626
72,4560	75,2505	2,7945	2,7945	7,8094	0,4593
66,1989	70,2569	4,0580	4,0580	16,4677	48,0925
61,1846	63,4703	2,2856	2,2856	5,2241	142,7814
67,4760	69,9308	2,4548	2,4548	6,0259	32,0099
75,0293	71,0520	-3,9773	3,9773	15,8187	3,5930
74,8087	73,9742	-0,8345	0,8345	0,6964	2,8054
71,9555	67,7235	-4,2320	4,2320	17,9102	1,3882
66,9101	72,4104	5,5003	5,5003	30,2535	38,7341
71,0564	75,0640	4,0076	4,0076	16,0611	4,3155
79,3007	80,1426	0,8419	0,8419	0,7088	38,0307
87,1424	79,9081	-7,2343	7,2343	52,3350	196,2424
877,6051	883,5898	5,9847	38,5409	169,4131	628,4150

Yreal Mean	Ypred. Mean	Mean abs. Err.	Mean err. sqrd.	RMSE	R^2
73,1338	**73,6325**	**3,2117**	**14,1178**	**3,7574**	**0,7304**

Table 5

Moving on, with the analysis of the model on the “normal regime scenario”, the predicted price by the model is 73,63 euro/MW that put against the actual price of 73,13 euro/MW gives us the 0,88% difference.

3.2) ANALYSIS OF THE SHOCKS IN A FREE-MARKET

In this subchapter various scenarios are explored in order to better understand mathematically and intuitionally the behavior of the free-market system: into the produced model will be imputed four scenarios: Demand decrease, demand increase, commodities decrease, and commodities increase. Each one of those scenarios is named after a real shock, basically covid and Ukraine. Covid is used to explain three scenarios:

- Demand decrease: As in Italy suffered one of the most drastic demand reductions of the world,
- Demand increase: As “relatively speaking” when the quarantine ended and the demand went back to normal, from the low point can be considered a shock,

- Commodities decrease: It’s also used covid as with the drastic reduction of electricity demand, the demand of commodities dropped also, reducing the price.

Ukraine in one:

- Commodities increase: The most recent example of positive commodities shock is the Ukraine crisis; being EU is not able to import Russian oil the market faced a decrease in commodities supply and therefore the price skyrocketed.

This format of “scenario analysis” will be used not only on this model but also on the other two, for simplicity the variation has been set to ±30% both for demand and commodities to compare them.

Finally, as another mean of simplifying the study the cross-scenarios (ex. 30% of demand increase and 30% of commodities increase) is not being considered in this paper, even if the model allows it.

3.2.1) DEMAND SHOCK: COVID-19

For the first scenario, is taken into account a drastic drop in demand, as happened during the covid-19 crisis. From a historical standpoint this period was characterized by a dramatic reduction in electricity demand in Italy. The average decrease in March–June 2020 was 18% less than the same period in 2019, with daily peaks of −60% (Haxhimusa and Liebensteiner, s.d.)[6]. To simplify calculations and behavioral comparisons the reduction of demand is set to 30% as middle ground and the reduction of commodities price is not considered as it will be analyzed later. When this scenario is inputted into the model, the demand reduction brings down the price to 58,15 euro/MW from the normal equilibrium of 73,63 euro/MW. A reduction of around -23,6% of the price.

[6]https://www.sciencedirect.com/science/article/pii/S0301421521005656#:~:text=This%20crisis%20period%20was%20characterized,daily%20peaks%20of%20%E2%88%9260%25.

3.2.2) DEMAND SHOCK: POST COVID-19

In the second scenario a positive demand shock is set into the model, while maintaining equal other variables. This shock that can be “relatively” found in the end of the demand depression caused by covid-19, as said before, when the demand returned to normal. For this reason and for comparison simplicity the demand increase is set to +30%: The price after the increase (from the normal regime) is 85,46 euro/MW, compared to the normal regime of 73,63 euro/MW the percentage increase is about 15%. Compared to the demand decrease the increase of price is almost double, thanks to the reservoir of installed capacity held by fossil fuel generators.

3.2.3) COMMODITIES SHOCK: COVID-19

As third scenario into the model is inputted a reduction of the price of the commodities, again historically this event can be seen during the covid-19 crisis, as the reduction of demand struck the fossil generators, fuel consumption greatly decreased provoking a decrease of the fuel cost itself. For simplicity the decrease in price is set to -30%: In this scenario the output price is 52,78 euro/MW, the percentage reduction against normal regime is around -33%, this drastic drop is explained by the partial removal from the merit order of the costliest generation methods: fossil fuels (that still hold most of the baseload of the Italian energy market).

3.2.4) COMMODITIES SHOCK: UKRAINE CRISIS

As the last scenario, as the title suggest we take the Ukraine crisis as a way of providing an explanation to a positive shock in commodities: the increased price of those (as explained as broadly as possible) is caused by the block of import of oil from Russia, as alternative routes were created the transportation cost and scarcity of the resource has driven the price up. As simplicity, again, the price of all commodities has been increased by 30% resulting in an output increase of 25% with a price of 94,49 euro/MW.

3.2.5) FREE-MARKET SYSTEM BEHAVIOUR

As another benchmark has been inputted into the model both a reduction of demand and a reduction of commodities price, the result accurately describes the real-life scenarios seen into the covid-19 crisis: the price fluctuation matches the actual data.

As shown by the variations, the free-market system is highly volatile given systemic shocks, more with negative inputs that with positive ones. To analyze the behavior of the system are used as a metric the point of view of the two main sides of the market: Customer side and the generators side.

Starting with the customers:

The system is designed to provide the minimal possible price in a normal regime, for this reason it's very effective in that regard, thanks to the free-market, being the marginal price of the generators the price paid the customer is always satisfied with low price in absence of shocks, on the other hand the situation changes drastically in front of positive shocks, in fact the prices can changes greatly, making the upward volatility the biggest threat and weakness of the system, lastly in front of negative variations the customer is greatly favored with a considerable reduction in price.

Generators side:

Given the duality of the relationship, it's not a surprise that while the situation of customers is favored, the one of the generators it's not: Starting with the normal regime, the generators through the free-market mechanism are forced to bid their marginal cost to play in the market. Remembering how the merit order works, (the highest bid accepted is the price/MW that the other generators, independent of their marginal cost, are going to receive), the renewable energy generators (with low MC) are mostly receiving a price way higher, given that most of the time the last accepted bid is a fossil fuel one (high MC), This means that in normal regime the fossil fuel generators have paper-thing margins to operate with while renewables have higher ones, moreover, this mechanism heavily affects innovation, forcing fossils to try and innovate to remain in the market while the renewables have not the need. Moving into the variation of commodities price the generators are little to no affected as the price for the fuel is discharged to the customers, so generators aren't exposed to risks. This reasoning changes when the change in demand is analyzed: As it increases, in extreme scenarios the generators are forced to run their facilities harder as investment in a free-market blocks newcomers, in more normal ones generally the highest accepted bidder (most of the times) is the oil, making the prices rise considerably in favor of generators that expands their profit margins. When the demand decreases the opposite effect occurs, fossil generator has less possibility to sell in the market, in long term this could lead fossil generators to exit the market.

In conclusion:

For the reasons seen above, the free-market system has a high volatility, making it not well suited in protecting both generators and customers against shocks, moreover it presents itself as heavily centered around customers.

3.3) TARIFF SYSTEM

The tariff system model replica has been built to mimic the system used in Jordan and Emirates, substantially in this section it's tried to calculate, given the Italian infrastructure, what could be the price of electricity in Italy if it tomorrow the government would intervene and switch into a tariff system; its functioning and premises are explained in the following subchapter.

3.3.1) HOW THE MODEL WORKS

As recap: The tariff system is based on a heavily state regulated market that select the price based on a weighted mean of the Total costs and capacity (for weight), the total cost is part computed with the components of the free market system: opex, fuel cost and co2 cost, at which is added capex to obtain total cost. The total cost is weighted by capacity to obtain the fixed tariff at which is extracted part of the fuel cost in order to obtain a variable part, as to show one of the possible formulas:

$$\text{Tariff price} = \sum \frac{(Total\ cost * Installed\ capacity)}{Total\ installed\ cappacity} + (R * fuel\ price)$$

Where R is the percentage of fuel price variation risk left to the customer, and the first part represents the fixed part and the second the variable one.

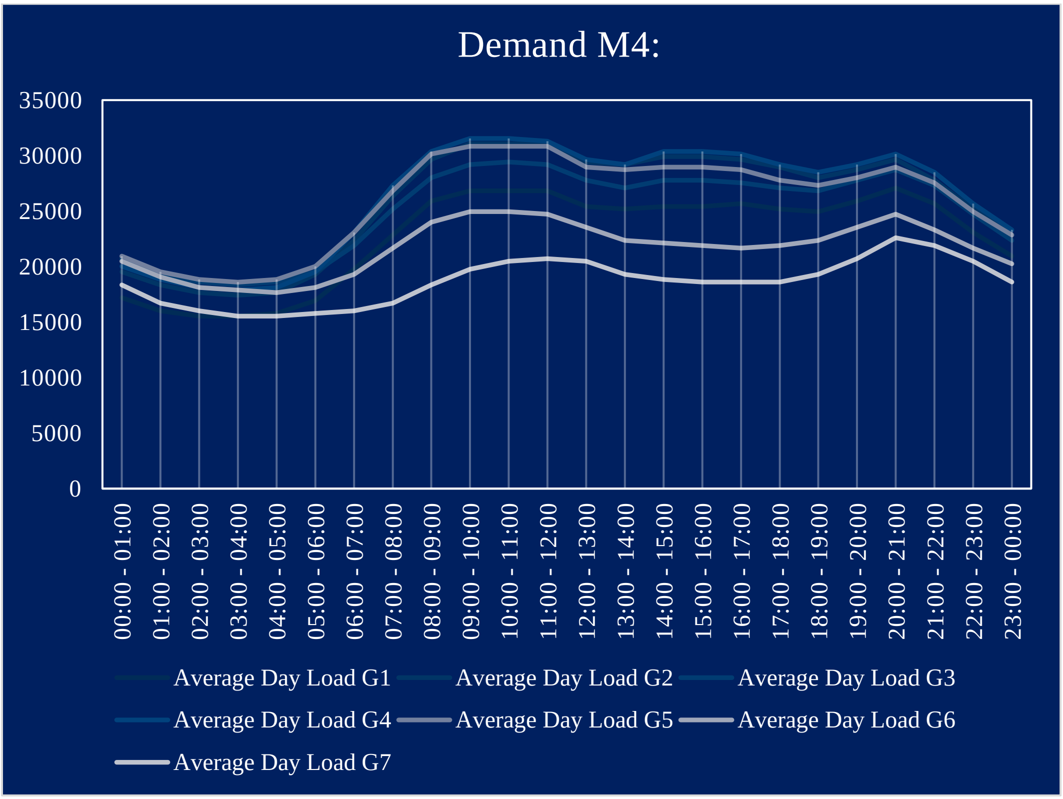
To replicate this mechanism, it has been created a new model that is partially based on the same data as the free-market one, plus the Capex, as in the previous paragraph, at high level the steps done are the following:

Simplifications:

1) Aggregation of each generation supply type: solar, wind, nuclear, hydro, gas, coal, oil, bio in 2 variants per type divided by older and newer power plants.
2) Allocation for each generation type a typical Total cost, computed through the sum, by generation type, of opex, fuel cost, c02 emissions per ton of fuel, efficiency, and Capex. based on 2017 data.
3) The cross-border balancing system has not been implemented as it would require a full-scale integration system like the EU. For the aim of this paper is not necessary to reach that level of precision.
4) The elasticity of the demand has not been computed as the offer and price is pseudo-fixed and it's low on itself.

Input data:

1. The demand hourly function. It comes from ENTSO-E historical data based on 2017 and aggregated by weeks of a year and expressed as percentages, this time month 4 is showed in *graph 4*.



Graph 4

2. Average solar and wind generation per hour per month, not shown for the reasons stated in the other model.
3. The commodities price ex. Coal, C02, Oil, gas per month:

Time	Gas	Coal	Oil	CO2
Currency	EUR	EUR	EUR	EUR
01/01/2017	13,61 €	13,66 €	28,58 €	11,71 €
01/02/2017	13,51 €	13,15 €	28,90 €	11,28 €
01/03/2017	11,41 €	12,23 €	27,06 €	10,49 €
01/04/2017	11,57 €	12,10 €	27,59 €	10,38 €
01/05/2017	11,58 €	11,14 €	26,49 €	9,55 €
01/06/2017	11,42 €	11,52 €	24,42 €	9,88 €
01/07/2017	11,28 €	12,18 €	25,36 €	10,45 €
01/08/2017	11,47 €	11,87 €	26,75 €	10,18 €
01/09/2017	11,80 €	12,40 €	28,72 €	10,63 €
01/10/2017	11,92 €	13,08 €	30,01 €	11,22 €
01/11/2017	12,46 €	13,52 €	32,58 €	11,60 €
01/12/2017	12,78 €	12,99 €	33,44 €	11,14 €

Table 1

4. Installed capacity by generation type:

Generators	Installed capacity 2017 in MW
Biomass	1652,71
Solar	19181,81
Wind	8963,35
Hydro 1	1655,40
Hydro 2	10220,91
Hydro 3	4057,61
Pumped storage 1	1928,95
Pumped storage 2	4048,90
Other 1	44,40
Other 2	902,00
Coal 1	3893,00
Coal 2	6021,00
Gas 1	1766,30
Gas 2	45954,68
Oil 1	3289,08
Oil 2	2358,48

Table 2

5. Total cost by generation type per month.
6. Percentage of average load per aggregated generation unit (load factor).

Total cost	Technology	Load factor
60,75	Biomass	0,50
70,74	solar	X
76,26	Pumped storage 1	0,35
76,26	Pumped storage 2	0,35
83,51	Gas 1	0,45
83,51	Gas 2	0,45
88,89	Other 1	0,35
88,89	Other 2	0,35
92,82	wind	X
110,52	Coal 1	0,85
110,52	Coal 2	0,85
132,91	Hydro 1	0,40
132,91	Hydro 2	0,40
132,91	Hydro 3	0,40
193,15	Oil 1	0,46
193,15	Oil 2	0,46

Table 3

Output:

1) The model calculates the Capacity usage based on demand.
2) The model calculates the demand using total demand.
3) The weighted average of the total costs respect to the individual installed capacity without a part of the fuel price plus the remaining part of the fuel price gives us the Tariff price.

3.3.1) NORMAL REGIME

As done before, the first step would be to benchmark the model, but on the question on "what would happen to the price of electricity if Italy switched to a tariff system?" there is no literature, for this reason, and for the impossibility to benchmark the model, the numerical results are not meant to be precise but are meant to be used a way to understand the behavior and the differences of the various systems. Looking at the normal regime, the tariff model outputs a price of 105,46 euro/MW, this price represents a close guess of the price that Italy would have if the government introduced a state-regulated energy market system. As first comparison this price can be compared to the free-market one of 73,63 euro/MW, the percentage of difference between the two is about 36%. This number is mainly affected by Opex, capex and fuel. The first one affected by efficiency of maintenance, the second one by efficiency of capital and the third one by the price of the fuel: it's not a surprise that Italy is not well-placed in all of three of these factors, and as a result the normal regime price of the tariff system is much higher than it's free-market counterpart. Finally, this it's the reason why, for example, Emirates use this system while maintaining an average price much lower than the one of Italy.

Follow *Table 6*, showing processed data for the computation:

Generators	Installed capacity:	Average total cost:	
Biomass	495,81	60,66	
Solar	2709,90	70,57	
Pumped storage 1	192,90	76,26	
Pumped storage 2	404,89	76,26	
Other 1	13,32	85,19	
Other 2	270,60	85,19	
Wind	1251,91	89,39	Price:
Gas 1	715,16	89,70	105,46 €
Gas 2	18606,58	92,88	
Coal 1	3440,91	112,30	
Coal 2	5321,79	112,30	
Hydro 1	413,85	132,91	
Hydro 2	2555,23	132,91	
Hydro 3	1014,40	132,91	
Oil 1	1506,28	196,78	
Oil 2	1080,09	196,78	

Table 6

3.4) ANALYSIS OF SYSTEMIC SHOCKS IN TARIFF SYSTEM

In this subchapter, as done before, various scenarios are explored in order to better understand mathematically and intuitionally the behavior of the state-driven market system: into the produced model will be imputed four scenarios: Demand decrease, demand increase, commodities decrease, and commodities increase. At the end of this section a conclusion will summarize the findings of this investigation.

3.4.1) DEMAND INCREASE/DEMAND DECREASE

Into the model has been imputed an increase and a decrease of the demand respectively of +30% and -30%, the given output in both scenarios is: 105,46 euro/MW, it has not changed from the normal regime. As shown, this system totally shields the consumers from demand shocks.

3.4.2) COMMODITIES SHOCK: COVID-19

In this scenario has been imputed a decrease of the price of the commodities of -30%, while the risk left costumers is set 20%, with these inputs the price drops to 98,95 euro/MW, with a total reduction respect of normal regime of about -6,38%.

3.4.3) COMMODITIES SHOCK: POST COVID-19

In this scenario has been imputed an increase of the price of the commodities of +30% while in the tariff system formula has been inserted 20% as the delta of the fluctuation of fuel prices left to customers. In this scenario the price of the electricity is 107,09 euro/MW that in comparison with the normal regime is only 1,72% more.

3.4.1) TARIFF SYSTEM BEHAVIOUR

To analyze the behavior of the system all the various shocks have been imputed as a process identical for the analysis of the previous system with a change in demand/commodity price of +30% and -30%: Is not a surprise that the price of electricity in the market remains the same in the demand shocks as the customer is fully shielded by the supply contract issued by the government that regulates the price beforehand, in reality these contracts last for up to 20yrs. Important to note that the price of 105,46 euro/MW is significantly higher from the free-market system, by around 36 %. Some consideration could be done as part (80%) the risk of fuel-price changes and all demand fluctuations are transferred to the generators, in fact: In the scenario of increase in price of the commodities and the increase of the demand the generators see their profit margins decrease, but given the high price per MW given by the inclusion of the capex in the price-fixation mechanism, this is not a threat for them (except in extreme shocks) while the customer is almost fully shielded with the drawback of having to pay a significantly higher bill in comparison to the free-market system, the opposite scenarios when demand and commodities decrease their profit margins increases. Important to note that in the scenario of commodity decrease generators give up 20% of fuel profit margin to customer while in the demand decrease, they hold all the benefits. Overall, this system present itself as the opposite of the other one, having an extremely low volatility and presenting itself as heavily generator centric.

4) COULD A HYBRID SYSTEM EXIST?

As the third chapter is proposed a new price-fixation mechanism, one that tries to restrain the pros of the two seen before while reducing the impact of the cons, as to create a system that is not either customer oriented or generator oriented but rather a mix of the two. So, the objective is: Maintaining the affordable prices of the free-market system, while reducing the volatility like the tariff system does while both shielding generators and customers from systemic shocks, as to level the playing field for both.

4.1) THE HYBRID SYSTEM MODEL

The hybrid system model has been built to try to predict the behavior of this hypothetical system, as done before in the following subchapter will be explained how it works, how can it behave in a normal setting and finally it's reaction to shocks. In the conclusion chapter a comparison between all of them will be presented to better explain the thesis questions.

4.1.1) HOW IT WORKS

As recap: The Hybrid system is based on a mix of the heavily state-regulated market system and a free-market system, the main idea behind the model is to take from the two model their qualities, leaving behind the weaknesses: this will be done dividing the generators in two groups: fuel based and non-fuel based or renewables and non-renewables (nuclear and bio still are included in the second category as the fuel price is stable and they don 'provide much capacity, giving that nuclear generation is not present in Italy) the first group follows the tariff system price fixation and the second the free-market system, the final price would be the sum of this two prices by the following formula each hour and then will be averaged annually (this formula is made to explain the model and doesn't represents the actual calculations):

Hybrid price = Free-market price (variable) + Tariff system price (constant)

By this system the renewables would constantly be in competition with each other, providing the best price at every given time while promoting innovation with the aim to undercut competition, and in reverse the fossil fuels would not be in competition and there would be little incentive to enter the market while slowing down innovation.

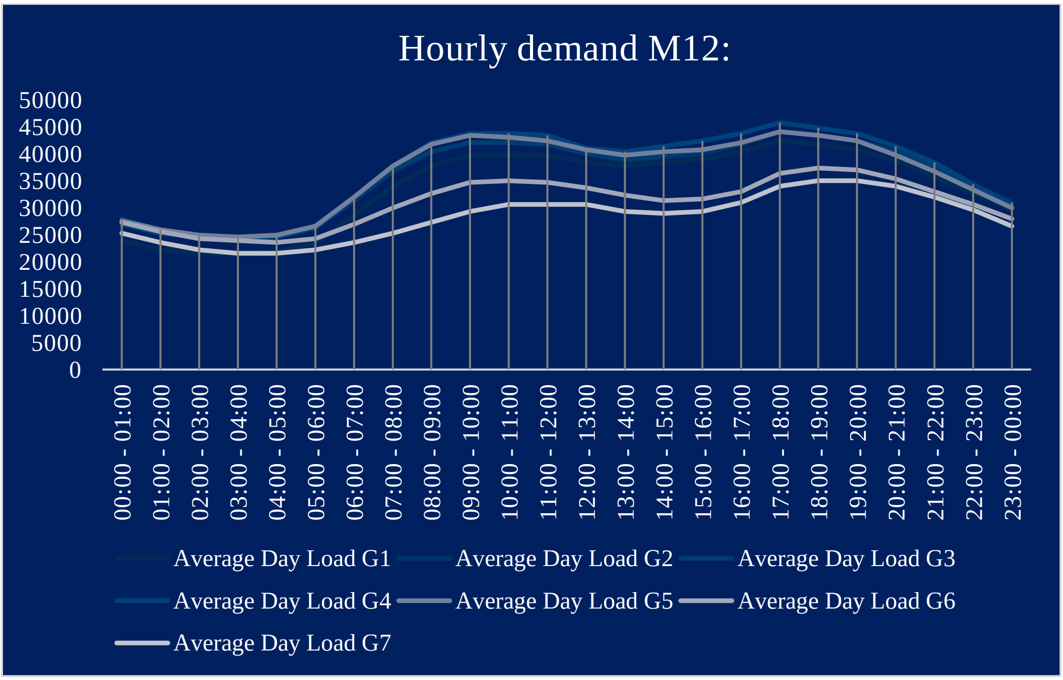
To replicate it is used a model that is based on a hybrid of the two models shown before, at high level the steps done are the following:

Simplifications/premises:

1. Aggregation of each generation supply type: solar, wind, nuclear, hydro, gas, coal, oil, bio in 2 variants per type divided by older and newer power plants.
2. Allocation for fossil fuels energy generation type a typical Total cost, computed through the weighted average by generation type of opex, fuel cost, c02 emissions per ton of fuel, efficiency, Capex, and profit; For renewables opex as they input price equal to marginal cost.
3. The cross-border balancing system has not been implemented as a sum of the reasons in tariff and free-market model.
4. The elasticity of the demand has not been computed for the same reason.

Input data:

1. The demand hourly function comes from ENTSO-E historical data based on 2017 and aggregated by weeks for a year expressed as percentage, this time month 12 is showed in *graph 5*:



Graph 5

2. Solar and wind generation per hour per month, not shown for the same reasons as before.

3. The commodities price ex. Coal, C02, oil, gas per month:

Time	Gas	Coal	Oil	CO2
Currency	EUR	EUR	EUR	EUR
01/01/2017	13,61 €	13,66 €	28,58 €	11,71 €
01/02/2017	13,51 €	13,15 €	28,90 €	11,28 €
01/03/2017	11,41 €	12,23 €	27,06 €	10,49 €
01/04/2017	11,57 €	12,10 €	27,59 €	10,38 €
01/05/2017	11,58 €	11,14 €	26,49 €	9,55 €
01/06/2017	11,42 €	11,52 €	24,42 €	9,88 €
01/07/2017	11,28 €	12,18 €	25,36 €	10,45 €
01/08/2017	11,47 €	11,87 €	26,75 €	10,18 €
01/09/2017	11,80 €	12,40 €	28,72 €	10,63 €
01/10/2017	11,92 €	13,08 €	30,01 €	11,22 €
01/11/2017	12,46 €	13,52 €	32,58 €	11,60 €
01/12/2017	12,78 €	12,99 €	33,44 €	11,14 €

Table 1

4. Installed capacity by generation type:

Generators	Installed capacity 2017 in MW
Biomass	1652,71
Solar	19181,81
Wind	8963,35
Hydro 1	1655,40
Hydro 2	10220,91
Hydro 3	4057,61
Pumped storage 1	1928,95
Pumped storage 2	4048,90
Other 1	44,40
Other 2	902,00
Coal 1	3893,00
Coal 2	6021,00
Gas 1	1766,30
Gas 2	45954,68
Oil 1	3289,08
Oil 2	2358,48

Table 2

5. Total cost for fuel generators and Marginal cost for non-fuel generators.
6. Percentage of load per aggregated generation unit aka load factor.

Output:

1. The model calculates the Tariff price (same tariff model discussed before with no renewables) according to covered demand, as shown in the following *table 7*:

Generators	Installed capacity	Average total cost:	
Other 1	13,32	85,19	
Other 2	270,60	85,19	
Gas 1	715,16	89,70	
Gas 2	18606,58	89,70	Price:
Coal 1	3440,91	112,30	105,00 €
Coal 2	5321,79	112,30	
Oil 1	1506,28	196,78	
Oil 2	1080,09	196,78	

Table 7

2. The model calculates hourly the free-market price (same free-market model discussed before with no fuel generation) according to covered demand.

The computation of the free-market part is done with this system, so avoiding the merit order, because the marginal cost of the hydro would dominate the bid system every hour of the day, so the MC for every hour would be around 40 euro/MW.

3. The weighted mean of the two in respect to demand allocated represent the consumer price for each hour for a year, then is converted annually:

	M1	M2	M3	M4	M5	M6	Prices:
Tot Demand:	640870	616916	648812	569828	604563	634169	MC:
Demand MC:	214762	317174	328854	340282	235490	239316	Tariff:
Demand Tariff:	426109	299742	319958	229546	369073	394854	Hybrid:
	M7	M8	M9	M10	M11	M12	40,00 €
	715900	616849	640449	626500	613508	627536	105,00 €
	261660	362679	323677	308018	256494	238906	75,52 €
	454240	254171	316772	318483	357015	388630	

	M1	M2	M3	M4	M5	M6	
Costo MC:	8590463	12686972	13154177	13611285	9419593	9572621	Total:
Costo Tariff:	44741399	31472909	33595590	24102301	38752656	41459627	137092463
	M7	M8	M9	M10	M11	M12	433502001
	10466419	14507151	12947071	12320712	10259750	9556249	**570594464**
	47695194	26687911	33261067	33440671	37486527	40806149	

Table 8

Where Tot demand is the total monthly demand, MC dem. represent the demand covered by the free-market system (based on generation) and the Tariff dem. the part covered by the tariff system (tor demand- demand MC).

Where MC cost is the product of the MC dem and the MC price, Tariff cost is the product of Tariff price and Tariff dem.

Then is computed the total cost of the MC and Tariff, and finally the price with this formula:

$$\text{Hybrid price} = \frac{Total\ MC\ cost + Total\ Tariff\ cost}{Total\ demand} = \frac{Total\ cost}{Total\ demand} = \sum \frac{(Price\ Mc * Dem.MC) + (Price\ Tariff * Dem.Tariff)}{Total\ Demand}$$

4.1.2) NORMAL REGIME

The first output of the hybrid system in the normal regime is 75,52 euro/MW, first thing, its easily compared with the other two models: The hybrid is 2,57% more expensive than the free market (73,63 euro/MW) one but 33,34% cheaper than the tariff system (105,46 euro/MW); so, the price for MW is between the other systems but really close to the free market.

As before, it’s really difficult to benchmark the model, viewing the model as a mix of the other two, though, is possible to validate the free-market part using the statistical analysis conducted before, in regards to the tariff part it’s hard to conduct a comparison and as before the prices outputted by the model are not meant to be precise but to give an idea of the mechanism of this proposed system.

The price is greater than the free-market system as the tariff part (that satisfy approximately 2/3 of the demand) brings up the price, but significantly lower as the free-market system part (dominated by the marginal cost of hydro[7]) brings down the price, and it brings it lower even more than the pure free-market one as at least 4 or 5 hours a day the MC inputted into the market is the one of fossil fuels. The principle is to stabilize the volatility using fossil generation as a shield while

[7] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2012/RE_Technologies_Cost_Analysis-HYDROPOWER.pdf

protecting them through capex and bringing down the price using the free-market system.

4.2) TO THE TEST

In this subchapter various scenarios are explored in order to better understand mathematically and intuitionally the behavior of the hybrid-market system: into the produced model will be imputed four scenarios: Demand decrease, demand increase, commodities decrease, and commodities increase. At the end of this section a conclusion is places to resume the findings of this quantitative method.

4.2.1) DEMAND SHOCK: COVID-19

As done for the other models has been imputed a reduction in demand by -30%, this reduction would not affect the price, as the tariff part of the formula is not affected by demand.

4.2.2) DEMAND SHOCK: POST COVID-19

As with the same logic, when demand increases by 30% the price stays the same as the tariff part doesn't change, all the costs are transferred to the generators.

4.2.3) SUPPLY SHOCK: COVID-19

Tackling the decrease in commodities price by -30% the price reacts by decreasing to 62,25 euro/MW so a reduction of about 19,32%.

4.2.4) SUPPLY SHOCK: UKRAINE CRISIS

In the last scenario an increase of commodities price has been imputed by 30%: the price is 86,30 euro/MW, so an increase of 13,34%.

4.2.5) HYBRID SYSTEM BEHAVIOUR

As shown by the scenario analysis, the new system reacts as expected, the system is resilient against price volatility:

Starting with demand variations, in case of decreased demand the price would not be affected for the customers, while the fossil generators would see their margin expanded thanks to the major role of the renewables in covering relatively more of the demand (as they have priority in demand satisfaction), on the opposite scenario, when the demand increases, the prices for customers remains the same but this time the fossil fuel generators are contractually forced to provide the required energy to cover demand, as they see a profit margin thinning, on the other hand still they should not have too big troubles as the tariff system is inclusive of the Capex and they are shielded from this shock.

Moving to the price of commodities variations in case of a negative one, a similar mechanism occurs as with pure tariff system: the generators allow the customer to take 20% of the benefit of this cost reduction while maintaining 80%, for the opposite scenario, generators see an increment of their costs while being able to discharge 20% in the customers.

In conclusion, this proposed system works as a middle ground of the previous two with great success: Both generators and customers are shielded from shocks and the price volatility effects have been mitigated. The only player left with less of what they had before is the renewables generators as they see their current high profits cut down considerably.

5) CONCLUSIONS

In conclusions, this inquiry has the aim to answer the following question: Is the European principle of minimizing the price for the consumer through free market still the best system? What about other existing ones?

To answer this, in first instance it's broadly explained how the systems works and in which ideologies they are based on. The systems taken into consideration are taken ideologically and practically as far apart as possible, for this reason have been chosen the Eu free-market system and the Jordan state-regulated tariff system.

In second instance, to focus on the mechanisms of the systems and excluding other variables, two mathematical replicas are used with the aim of analyzing the behavior of those price-fixation mechanisms, in reaction to both demand and supply systemic shocks.

Once the two models got analyzed, a criticality emerged from both: Both are imbalanced towards either costumers (Free market) or generators (Tariff), while having complementary weaknesses and strengths[8].

For this reason, a third price-fixation mechanism has been proposed and model has been created, a mix of the two analyzed, with the aim of taking all the strengths while containing the weaknesses, this system is called hybrid.

Following with the behavioral study of this systems it has been found that does exactly what it has been thought for, being more stable in volatility, having an acceptable normal regime and without favoring either costumer or generators.

The data [9]produced form all the models is summarized in the following *table 9* and *table 10*, the first containing the price outputted from the models and the second their relative variations:

System:	Normal:	Dem down:	Dem up:	Comm down:	Comm up:
Free:	73,63 €	58,15 €	85,46 €	52,78 €	94,49 €
Tariff:	105,46 €	105,46 €	105,46 €	98,95 €	107,09 €
Hybrid:	75,52 €	75,52 €	75,52 €	62,25 €	86,30 €

Table 9

System:	Dem down:	Dem up:	Comm down:	Comm up:
Free:	-23,60%	14,90%	-33,29%	24,94%
Tariff:	0,00%	0,00%	-6,37%	1,53%
Hybrid:	0,00%	0,00%	-19,32%	13,34%

Table 10

As the table shows the hybrid system is resilient to both demand and supply shocks. While maintaining the energy price volatility in check (*table 10*).

[8] As an example, the biggest weakness of the Tariff system is the normal regime price, which is the biggest strength of the normal regime, and the biggest weakness of the free market is price volatility while that is practically removed in the tariff system.
[9] The shocks inputted are for all scenarios +30% for increases and -30% for decreases.

5.1) IS THE EUROPEAN PRINCIPLE OF MINIMIZING THE PRICE FOR THE CONSUMER THROUGH FREE MARKET STILL THE BEST SYSTEM?

The system works well in some specific market conditions:

1. Stable commodities price
2. Availability of baseload and different generation source
3. The goal is a short/medium term goal to minimize the overall cost for the final customer.

What was seen during these crises is the inability to absorb shocks and the inability to guarantee the investors (generators) a long-term stable payback of the investment damaging both customers and generators. Being based on marginal cost the system is by definition oriented to previously existing generation source and as a result only with subsidies the renewable were able to start up their existence.

With the aim of long-term stability, the European system seems sub-optimal.

5.2) WHAT ABOUT A REGULATED ONE, THE TARIFF SYSTEM?

This can create an oligopoly where the market conditions are fixed for 15/20 years (average PPA duration) and can create a distortion, without providing the final customer with the benefit of new technology, progress, and a most importantly a fair price.

5.3) A MIX IS A VIABLE STRATEGY?

We demonstrated in this inquiry that a mix system can benefit final customer and investors, each of them will sacrifice a bit, but in the long term there will a stable system capable of absorbing shocks without transferring them to any of the participant of the market.

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