POLITECNICO DI TORINO

Master degree in electrical engineering

Final project

ANALYSIS OF THE ITALIAN ELECTRICITY SECTOR

IMPACT OF RENEWABLE GENERATION AND DEMAND RESPONSE

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Summary

1. Introduction

The great diffusion of non-programmable renewable plants involves two aspects. One is the reduction of the traditional source from production offered at positive prices and not at null price like the renewable sources. The second one is a more complex electric system, in terms of voltage and frequency regulation. The reduction of the fuel power generation reduced the energy price, but because of the non-programmability of these sources the reserve margins have to be bigger and so more expensive. Indeed the different energy prices between the zones involve trades between them, but not always the electric system is able to withstand large quantities of exchanged power, making congestions which isolate the market area. One solution is obviously developing the national electric system, but it is a slow process and particularly expensive. Another possible solution is the demand response, which is starting to expand in the European countries.

The first part of this work describes the Italian electric system and the Italian energy market. The second part will be analyzes and comments the highest price differences between the surrounding main zones. The third part describes with different tools the statistics about the difference between the forecast of solar and wind energy and the real energy produced by the solar panels and by wind turbines. This difference impacts drastically on the MGP making especially on the offer curve, because it is based on the forecast. Indeed, one of the elements of the merit order is the type of generation and the renewable suppliers own the highest priority. If the total prediction of the renewable sources is overestimated some traditional producers, or in general producers with lower merit order, cannot enter inside the market, while could enter with more accurate forecast. Finally, the last part explains what demand response programs Italy is using to solve the problem about the necessity of bigger reserve margins. These programs, for the first time in Italy, authorized the demand to participate inside the ancillary service, but not inside the electricity market, and in particularly allowed the loads to contribute in the reserve programming and/or in the real time balancing.

The term Demand Response identifies all those behaviors that determine a change, compared to normal consumption models, in the load profile of end users, in response to price signals coming from the market or emergency signals ordered by the system operator, when the security or reliability of the network is compromised.

The final consumers that participate in Demand Response programs reduce their consumption through the payment of incentives, according to specific programs designed to reduce electricity consumption, in order to help the system to address the critical issues of the network, solve congestion and reduce zonal and infra-zonal from blackouts risk. These Demand Response programs represent a form of demand elasticity and allow the system to be relieved of unwanted or unforeseen critical conditions.

The programs are made by different variables like:

- The possibility of choosing to participate or be obliged to supply the service, using automatic devices in the second case.
- The duration of the answering times from the signal arrival, which could be second, minutes, hours or days.
- The kind of the signal, that could be a price signal, coming from the energy market, to advise the client when to use the loads, or emergency signal, coming from the system operator, usually used in congestion situations.
- The type of remuneration, which could be an incentive or a gain, and this case it is an annual fixed gain or depends of the interventions.

The principal aim of Demand Response is to decrease the demand peaks located in the most expensive periods, usually around hours 13:00 and 21:00. Moreover, the introduction of this program would bring other benefits, which are:

- Economic entries for end customers earned through the incentive or the gain for the service provided, in addition to the money saved in the bills.
- The decrease of the price in the energy market , and of the price volatility as well, through a increased production coming from the renewable sources with a null marginal price and, so, a reduction of the supply coming from fuel plants that offer at more expensive prices. This, also, preserves the environment because they are going to decrease the CO_2 emissions.
- The increase of the electric system efficiency, reducing the number of congestions so there is no need of the grid expansion, and increasing the reserve margins opening the ancillary market to the demand, given that only the ability points can provide this service.
- The improvement of the choice of the energy production sources based on better efficiency, until achieving the goal where the customers pay only the marginal costs.

The difficulties in the diffusion of the Demand Response programs are:

- The initial costs, for the system operator which has to design the program and develop the software and the buildings, but can recover these expenses from a part of the bills; and for the customers which have to buy intelligent devices to participate inside this service.
- The lack of dissemination of these programs between the customers, so they are not able to quantify the possible gain from this service. This aspect continues to favour the position of the producers wholesalers and dispatch users, because in this way they have less concurrency.
- The missing of variable energy prices, indeed the customers are used to pay a flat price that, usually, is far from the generation cost.
- The missing of a legislative part about this argument inside the energy market rules.

2. Italian electric system configuration

The Italian transmission network measures 40.000 km and is composed of the very high voltage grid (380-220 kV) and the high voltage grid (150-132 kV). To manage the network, and especially to avert congestions, it is divided into zones:

- Geographical, because of morphology features, their borders are virtual line that are more subject to the achieving of the exchange limits between them (North, Center-North, Center-South, South, Sicily, Sardinia)
- Virtual, where are placed the connections with the lines of connection with the neighboring countries.
- Limited production poles, they are zones with only supply units where the grid, for technical reasons, cannot absorb all the energy produced

The geographical and virtual zones are offering points. The offering points are the minimum elements of the grid under which are referred the hourly programs of injection and demand. An injection point is a production unit, while a demand point is one or more loads. For each supply point there is its dispatch user enrolled by Terna. The dispatch user has to control the exact execution of the hourly program; and manages the balance in real time, under the Terna's provisions. If there is an imbalance the dispatch user is responsible for the payments about it.

2.1. Zones in the Italian system

In the North of Italy the network is highly meshed, so if a line has an outage, there will be the redistribution of the power flows and all the grid points will be supplied. From the center to the South of Italy, the transmission network is extended on the two sides, right and left, with interconnections between them. The Sicily is connected with a sea wire at 380 kV in alternate current; and Sardinia is linked with connections in continuous current, called "SA.CO.I" (with three terminals: Sardinia, Corsica and Italy) and SA.PEI (Sardinia-Italian peninsula).

A section, like zone border, is defined "structurally critical" if the production inside a zone is bigger than the maximum power that is possible to exchange under security conditions. A section is, also, defined "operationally critical" if its power flow is above its limit. The exchange limits are the edge until it is possible to work in steady-state operation and in N-1 security condition.

The market tries to find the maximum benefit respecting the transmission limits. In a system with k zones the exchange between the zones *i* and *j* are as:

$$F_{ij} = \sum_{k=1}^{K} S_{ij}^{k} \cdot EN_k$$

where:

- F_{ij} is the energy exchanged between the two zones, that has to be less than its maximum $Max(F_{ij})$;
- S_{ij}^k is the energy contribution by the zone k on this specific exchange;
- EN_k is the difference among the sales and the purchases in zone k.

The general exchange G_α is expressed by the following formula:

$$G_\alpha = \sum_{k=1}^{N} A_\alpha^k \cdot EN_k$$

where A_α^k is the contribution of the zone k to the general exchange G_α, and is fixed by Terna. G_α has to be lower than the maximum exportation b_α.

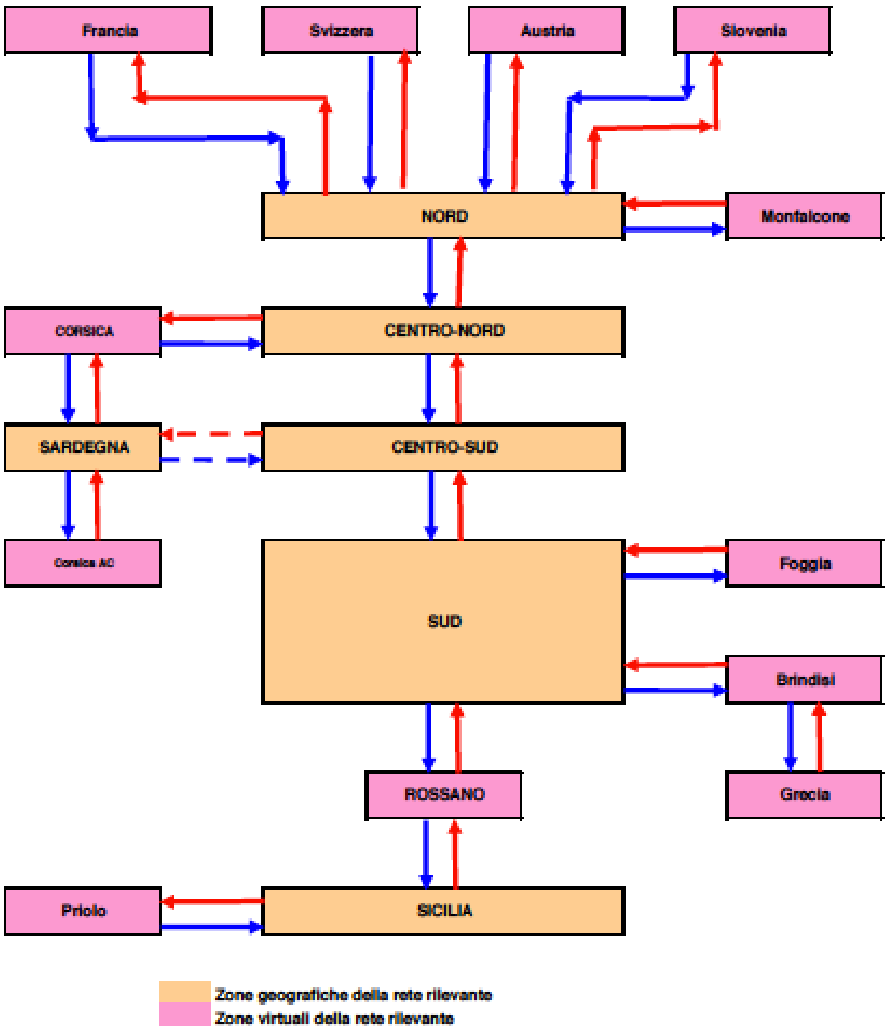


Figure 1 – Geographical and virtual zones in the Italian system

- **Monfalcone zone**, virtual zone with limited production pole linked with the North Zone;
- **North Zone**, connected with the virtual zones:
  - France
  - Switzerland
  - Austria
  - Slovenia
  - Monfalcone

  It is also connected with the geographical zone Center-North, with 380 kV lines:

  - La Spezia – Marginone
  - La Spezia – Acciaiolo
  - Bargi – Calenzano
  - Forlì – Fano
  - S.Martino in XX – Fano

  and 220 kV lines:

  - La Spezia – Avenza
  - S. Colombano – Avenza
  - Colunga – Casellina
  - Sarmato – Avenza

  On the Adriatic side, right-hand side, usually there are more congestions because in the Tyrrenian cost are located big thermoelectric producers. So the export limits of this zone are not the same as the import ones.

- **Center-North zone**, related with the North zone, with previous connections, and Center-South zone through the 380 kV lines:
  - Suvereto– Montalto
  - Suvereto – Valmontone
  - Pian della Speranza - Montalto
  - Rosara – Teramo
  - Villavalle – Villanova
  - Montalto – Villavalle

  and 220 kV lines:

  - Rosara – Montorio
  - Villavalle – Provvidenza (232)
  - Villavalle – Roma Nord
  - Villavalle – S.Lucia

A terminal of the “SA.CO.I” cable is present in this zone. Furthermore, in this zone the right side presents more exchanges, so there will be voltage falls in case of trip of the circuit breakers located in the pairs of 380 kV lines.

- **Center-South zone**, linked with the Center-North zone, through the previous connections, and the South zone through the 380 kV lines:
  - Benevento - Foggia
  - Villanova - Gissi
  - S. Sofia – Matera
  - Montecorvino – Laino 1
  - Montecorvino – Laino 2

  and the 220 kV line of Tusciano – Rotonda.

  The possible congestions in this zone could be made by the supply source tied at 380 kV grid, especially by the limited supply points of Foggia, Brindisi and Rossano. Indeed, if the central in Gissi is out of service there are some voltage falls.

- **South zone,** related with the Center-South zone, as explained, and with the Sicily and the limited production points of Foggia, Brindisi and Rossano.
- **Foggia zone**, virtual zone with limited production pole connected with the South zone. There are reduced unit productions if the following 380 kV lines arrive to the saturation:
  - Gissi Villanova-Gissi;
  - Larino Gissi;
  - Larino-Foggia.
- **Brindisi zone**, virtual zone with limited production pole interconnected with the South zone. When the following 380 kV connections are opened, the imports from Greece are limited, like the local production of energy:
  - Andria – Brindisi Sud;
  - Brindisi – Bari Ovest;
  - Bari Ovest – Foggia;
  - Foggia – Andria;
  - Laino – Matera;
  - Matera – S. Sofia;
  - Brindisi Sud – Matera
  - Taranto Nord – Matera;
  - Brindisi – Taranto Nord
- **Rossano zone**, virtual zone with limited production pole linked with the South zone, and Sicily through a 380 kV Sorgente - Rizziconi connection. The power outputs then the electric power stations tied at high voltage in this area are limited if the following lines do not work:
  - Montecorvino – S. Sofia
  - Rossano – Laino 1

- Rossano – Laino 2
- Laino – Montecorvino 1
- Laino – Montecorvino 2
- Calabria’s ring (Altomonte – Feroleto – Rizziconi – Simeri Crichi – Scandale – Rossano)

- **Sicily zone,** that includes the isles network and the link with the Rossano zone, mentioned before. The limits on this line take into account the operation of other automatic circuit breakers, to reestablish a correct functionally, in isolated mode too, if this connection is opened.
- **Priolo zone,** virtual zone with limited production pole linked with the Sicily zone that reduces the supply if the line at 220 kV Melilli – Misterbianco goes down.

- **Sardinia zone**, connected with a terminal to Italy and another to Corsica, so there are transactions with the French market, all in direct current at 200 kV. The nominal power of this wire is about 300 MW in both directions, but it must considered the power lost for conversion. The Sardinia zone is connected with Corsica also by a line in alternate current at 150 kV, between the stations of Santa Teresa di Gallura and Bonifacio.

2.2. Interconnections with other European markets

Italy is connected with other countries through 20 lines.

- 6 with France, three at 380 kV:
  - Villarodin – Venaus
  - Albertville – Rondissone 1
  - Albertville – Rondissone 2

  The Le Broc Carros – Camporosso at 220 kV, and the two connections between Sardinia and Corsica.

- 10 with Switzerland, where the links at 380 kV are:
  - Lavorgo – Musignano
  - Soazza – Bulgiago
  - Robbia – S. Fiorano
  - Robbia – Gorlago

  The ones at 220 kV:

  - Riddes – Avise
  - Riddes – Valpelline
  - Morel – Pallanzeno
  - Airolo – Ponte

    - Gorduno – Mese

  and the Villa di Tirano – Campocologno at 132 kV

- 1 with Austria, that is, the Lienz – Soverzene at 220 kV
- 2 with Slovenia:
    - Divaca – Redipuglia at 380 kV
    - Divaca – Padriciano at 220 kV
- 1 with Greece at 440 kV the Arachthos – Galatina in DC.

3. Electricity market organization in Italy

The Italian electricity market started in 1999 with the Bersani decree, that liberalized the production, the transmission and the distribution. Especially introduced Terna S.p.a that initially was only the owner of the transmission network, and after became the Transmission System Operator (TSO). This decree introduced also the GME (Gestore dei Mercati Energetici) that manages the electricity market guaranteeing the competition between the market operators.

The Italian market is composed of:

- Spot market (Mercato a Pronti)
- Forward market (Mercato Elettrico a Termine)
- Platform for the physical delivery of financial contracts concluded (CDE)

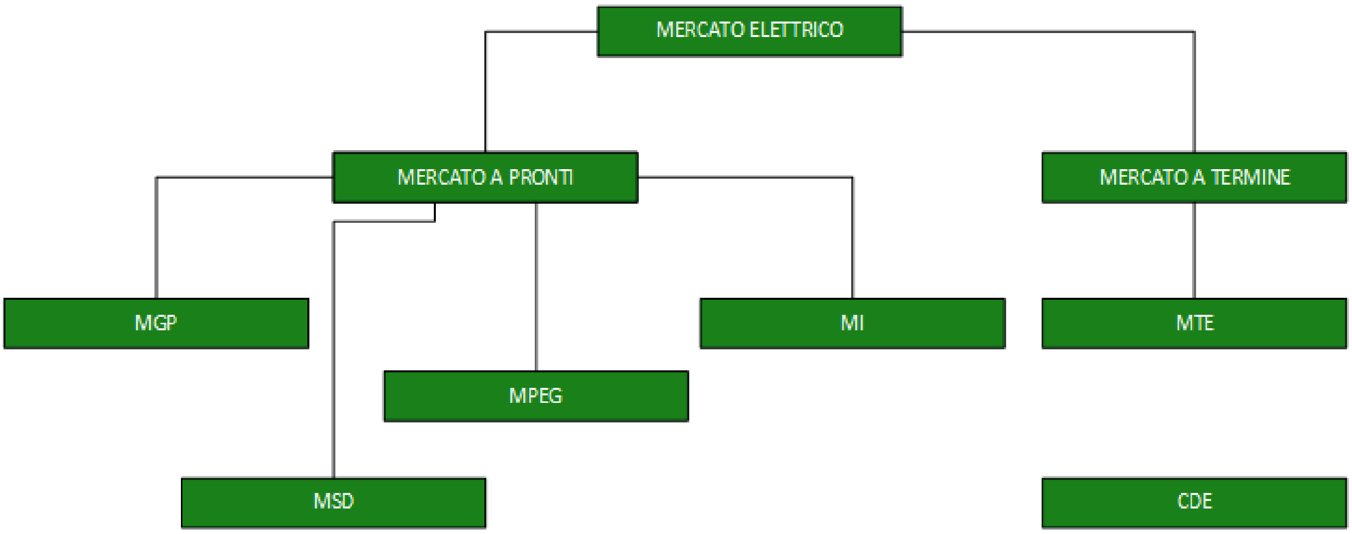


Figure 2 Electricity market structure

3.1. Market operators

All the operators, which comply with the requirements, are included the list of allowed operators in the market, where there are published the personal data of the operators, of the supply point where can be formulated offers, and bank details. Yearly, all the members have to pay an agreed remuneration to GME for its services; a fee to enter in the market about 7.500 €, paid just one time, and the yearly participation quote about 10.000€. In the spot market the variable fees are monthly and in function of the trade energy weight:

- under the 0.02 TWh it is exempted to pay them;

- between 0.02 TWh and 1 TWh are about 0.04 €/MWh for each transaction;
- between 1 TWh and 10 TWh are about 0.03 €/MWh for each transaction;
- with more than 10 TWh are 0.02 €/MWh.

While in the MTE the variable fee is about 0.01 €/MWh. The market regulator is the ARERA, regulatory authority for energy networks and environment.
Terna is the Italian Transmission System Operator (TSO), the society that owns and manages the National transmission grid. The production system, namely with renewable and non-renewable plants, convert the energy from other forms to electricity.
Another category is the eligible customers. Since 1 July 2007, all the customers are able to buy the electric energy, physically or not, by themselves, preferring between producers, distributor and wholesaler. The residential customers and the small companies, that are supplied in low voltage and do not earn ten millions per year, are subject to the enhanced protection service. This service provides that "Acquirente Unico", society for actions belonging to Gestore dei Servizi Energetici S.p.a, buys electrical energy at the cheapest price in the market on behalf of the users that have chosen not to buy in the free market. The distributors shall be empowered to deliver the electricity to all the clients that do not operate in the market.
The wholesaler is an operator that trades electrical energy focusing above the balance between costs and revenues usually, with future contracts.

3.2. Organization and structure of the spot market (MPE)

The MPE is divided in:

- Day ahead market (MGP-Mercato Giorno Prima)
- Adjustment market (MI-Mercato Infragiornaliero)
- Ancillary services market (MSD-Mercato del Servizio di Dispacciamento)
- Daily products market (MPEG)

In the first three markets the quantity and their corresponding unit prices are about electrical energy. The quantities can be only positive; and the prices in MGP and MI arenot mandatory. The price of the offers can be included between 0 €/MWh and 3000 €/MWh, where if takeover offer presents a 0€/MWh means that it has not price, so they have the maximum priority. An important offer element is the supply place; because the MPE's offers must be consistent with the entry or withdrawal potential of this network point. The operators present the offers by the compilation of the appropriate modules in the GME information system. If this system crushes and GME cannot publish the results, or receive the offers, GME establishes the emergency state informing Terna and the operators.

In each offer is specified:

- The code of the operator that makes the offer;

- The code of the market session;
- The code of the supply point;
- The period referred;
- If is predefined or balanced, in fact the second one has less priority than the first;
- If is a bid or a sold;
- The quantity of energy in MWh;
- The unit price respected to the quantity offered in €/MWh.

The GME judges if an offer is valid or not, explains the reasons. The operators are allowed to change, or retire, their offer until the deadline of the session.

3.2.1. Day-ahead market (MGP)

In the MGP the bids and the offers are chosen for trading electrical energy for the 24 periods of the day after the end of its deadline.

This market opens nine days before the periods considered and closes the day before. Until thirty minutes before closing, Terna sends to GME the hourly electrical demand for each geographic zone, and the eligible limits about hourly transit of energy between geographical and virtual zones.

A MGP sale offer, of an injection supply point, is considered adequate if the quantity of the electrical energy proposed is lower than the upward margin for that point in that period; after that, offers with the highest priority have already been accepted. A bid of a withdrawal supply point is deemed adequate if its quantity is less than the margin to fall, after the offers with higher priority for that point are approved, in that specific period.

An offer is not allowed to sell more energy with a unit price lower than the one expressed in the offer; so if one of them is accepted it is compulsory to inject in the network its quantity of energy, or less if the offer is accepted partially, in a relevant period specified in the offer. For a bid, it is not allowed to buy more energy with a unit price higher than the communicated one in the market, and an accepted bid implies the engagement to take from the network the quantity of energy, or less if the bid is accepted partially, in a set period specified in the offer.

The sale offers are arranged in increasing order, from the smallest to the highest; while the bids are ranked in descending order, where the owners with higher priority are the ones corresponding to offers with null price. If two offers have the same price, the discriminant factor is their arrival time, in favor of the older.

An offer can be:

- simple with only a pair of MWh-€/MWh;
- multiple with a maximum of four pairs MWh-€/MWh;

- predefined, they are simple or multiple offers, with a specific quantity and at specific time, that the GME is allowed to use when there is no other offer; and they have the weakest priority.

For each hour the GME, through the PCR algorithm, solves the market finding a price for each MWh negotiated, and guaranteeing that energy flows between different zones (national and foreigners) are conformed to the technical restrictions.
If more zones do not exceed the flow limits, they make a common demand curve and a common request curve, so, from the crossing of the curves will result the same price for these zones. The intersection between the curves reveals the total quantity exchanged inside that zone as well. But in case where the limits are exceeded the algorithm makes the market split dividing the country in two or more parts, and they are the zones. Each zone will have its price and probably it will be different from the other ones; indeed the zonal price is unique inside that zone. In the market splitting there are import zones, which have higher zonal prices, and export zones with cheaper zonal prices.

All the bids, in a geographical or virtual zone, with a price higher than the zonal price are accepted; while the sales are accepted if their prices are lower than that zonal price. The offers from bilateral contracts impact the quantity of exchanged energy, because they are added as bids without price and sale offer at 0 €/MWh.

Only for the geographical withdrawal supply points, the GME uses the Unique National Price (PUN) calculated as the average of the zonal prices weighted about zonal loads; so these points buy at this price. While, all the other supply points use the zonal price. The offers coming from bilateral offers impact the PUN as well.

In the specific case of market splitting all the consumers of a cheaper zone would make only bilateral contracts, if not they are going to pay more at PUN. So, to avoid the arbitrate the payment above bilateral contracts, in terms of transit rights, is the difference between the PUN and the zonal price.

At the end of the MGP GME sends the hourly results to Terna, and at 12:55 publishes the results.

3.2.2. Intra-Day market (MI)

It is the market where the result program of the MGP is corrected with additional trades. This market has seven sessions:

- The MI1 session starts, after the MGP closing, at 12:55 of the day before the delivery and ends at 15:00 of the same day. The outcomes are published at 15:30 the day before the delivery.
- The MI2 session starts at 12:55 of the day before the delivery and ends at 16:30 of the same day. The results are announced at 17:00 the day before the delivery.

- The MI3 session starts at 17:30 of the day before the delivery and ends at 23:45 of the same day. The achievements are issued at 00:15 the day of the delivery.
- The MI4 session starts at 17:30 of the day before the delivery and ends at 03:45 of the delivery day. The findings are posted at 04:15 the day of the delivery.
- The MI5 session starts at 17:30 of the day before the delivery and ends at 07:45 of the delivery day. The outcomes are announced at 08:15 the day of the delivery.
- The MI6 session starts at 17:30 of the day before the delivery and ends at 11:15 of the delivery day. The results are published at 11:45 the day of the delivery.
- The MI7 session starts at 17:30 of the day before the delivery and ends at 15:45 of the delivery day. The achievements are posted at 16:15 the day of the delivery.

Before the deadline of each MI, Terna informs GME about the energy quantity that it is possible to exchange between the geographical zones, national and abroad, until achieving the saturation of that part of the network; these data are referred to the before-market session, that could be a MGP's or a MI's one. Furthermore, Terna sends to GME the remaining hourly capacity of the energy that the input places are still able to export, from the before-market session.

A MI sale offer, of an injection supply point, is considered adequate if the quantity of the electric energy proposed is lower than the upward margin for that point in that period, after that offers with major priority are already been accepted. A bid of a withdrawal supply point is deemed adequate if its quantity is less than the margin to fall, after the offers with more priority for that point are been approved, in that specific period. Also in this market an offer without price owns the maximum priority.

An offer can be:

- simple with only a pair of MWh-€/MWh;
- multiple with a maximum of four pairs MWh-€/MWh;
- balanced, they are offer groups with at least one bid offer and one sale offer, at the some geographical zone and at the same period, with the same quantity and a void price. It is not utilized by the injection supply points when do not sell for a few hours but would be not convenient to switch some units off.

In each MI session the GME finds a market solution guaranteeing that all the technical restrictions are respected, like the power flows between different zones. The energy sold inside a session is equal to the amount of the bids accepted, considering the imports and exports with the foreign countries. If for some reasons it is not possible the coupling with other markets, GME has to inform the operators about it.

All the session bid offers greater than or equal the geographical price are accepted, while only the sale offers lower than or equal the geographical price are selected. It might happen that an offer is accepted partially, in this case the market manager communicates to the operators the exact quantity they have to buy or sale. Differently from the MGP, the geographical withdrawal supply point uses the zonal price, and not the PUN.

At the end of a session GME publishes the price and the energy quantity of the offers contracted for each geographical or virtual zone , and the demand and offer curve.

3.2.3. Dispatching services market (MSD)

This market deals with the contracts trade of the dispatch service, where Terna is the counterpart.

It is divided into Balancing Market (MB) and MSD ex-ante. In the first one, the offers are presented the delivery day only by the dispatch users, to balance in real time the quantity of injections and withdrawal in the network and performing the secondary control service. In MSD ex-ante, where are allowed only predefined offers, takes place exactly after the MI and its aims are to cancel possible residual congestions in the system and to guarantee the reserve margins. Both have six sessions.

GME is the bridge between the dispatch users and Terna. It informs about the offers above a specific point and period. Terna, after, answers to GME with the accepted offers.

Hourly, for each zone GME publishes the total quantity of the offers accepted, the hourly average price, the lowest purchase offer and the highest sale accepted. GME, also, informs the dispatch user of each certificate point about the input or output program.

Table 1 MPE timing activities related to day D

MPE ACTIVITY TIMESHEET ABOUT D DAY

DAY	D-1				D															
	MGP	MI1	MI2	MSD1	MB1	MI3	MSD2	MB2	MI4	MSD3	MB3	MI5	MSD4	MB4	MI6	MSD5	MB5	MI7	MSD6	MB6
Prior information	11.30	15.00	16.30	n.d.	n.d.	23.45*	n.d.	n.d.	3.45	n.d.	n.d.	7.45	n.d.	n.d.	11.15	n.d.	n.d	15.45	n.d.	n.d
Opening session	08.00**	12.55	12.55	12.55	°	17.30*	°	22.30*	17.30*	°	22.30*	17.30*	°	22.30*	17.30*	°	22.30*	17.30*	°	22.30*
Closing session	12.00	15.00	16.30	17.30	°	23.45*	°	3.00	3.45	°	7.00	7.45	°	11.00	11.15	°	15.00	15.45	°	19.00
Temporary Results	12.42	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Defined Results	12.55	15.30	17.00	21.45	#	0.15	2.15	#	4.15	6.15	#	8.15	10.15	#	11.45	14.15	#	16.15	18.15	#

3.2.4. Daily products market (MPEG)

In MPEG the operators trade daily products with energy delivery duty. Specifically the daily products of this market are exchanged through "the differential unit price" and "the full unit price". The first is the price that the buyers consider adequate to trade these products, and is expressed by a differential in relation to PUN. The "full unit price" is the price put on the offer and represents the unit value of the electric energy traded through these contracts.

GME, counterpart of this market, for each of these products can evaluate the Baseload profile, that is quoted each hour every day, and the Peak Load, quoted only in working days and from 09:00 to 20:00, when the demand is higher.

GME decides when and how long during these markets, and organizes a negotiation book for each product and for each profile, where the bids are ordered in descending order and the sale offer in increasing one.

An offer in MPEG contains the delivery profile of the product, the number of products that it has to be greater than or equal to one, the type of operation and the price. This for differential unit price products has to be inside the maximum and minimum limits presented before each session, while the price for full unit products is required been between 0 €/MWh and 3000 €/MWh. The offer without price are prohibits.

During the continuous trading inside a book the offers are combined automatically, indeed when a bid is considered successful, it shall be matching with some capacity of one or more sale offers with a price lower than or equal to the price inserted. While a sale offer is combined with one or more bid offers, inside the book, with greater price. It is impossible that the offer coming from the same operator matching.

At the end of each MPEG session GME publishes for each delivery profile of the products traded the lowest and highest price in that session, the reference price and the volume exchanged. Additionally, GME calculates the delivery net position for each operator about all the periods considered.

3.3. Organization and structure of the forward market (MTE)

The MTE market trades the forward contracts about the electrical energy with compulsory delivery. The counterpart of this market is GME, that is the account owner on the PCE that registers the delivery net position for each operator.

The contract could be ”Baseload”, with a delivery for all the hours every day, and “Peak Load, referring only to the hours between nine and twenty of the weekday. The period contracted can extend from a month, to three months, to one year. GME has established that the energy quantity, for each contract, results by the product of 1 MW with the number of the contract hours. The GME creates a trading book for each period for the two kinds of contracts, in this way it is easier to organize the MTE given the continuing bargaining.

An MTE offer has to express:

- the period and the type of the contract;
- the number of contracts, where one is the minimum;

- if it is a bid or a sale;
- the price, if it is not put by the user it will be amounting to the maximum price of the other kind of offer in the book, until the achieving of the full capacity.

In this market it is allowed to insert an offer without price limits, but only if, inside the same book, there is not already an offer of other kind with price limit. Additionally, the offer could be modified, but this changes its priority, in fact the oldness is the discriminant factor between more offers with the same price; while the offers without price limits have maximum priority. The sale offers are arranged in increasing order, from the smallest to the highest; while the bids are ranked by a descending order. Inside the book the offers are anonymous. The operators insert their offer by the information system of the MTE and it checks if it is punish, putting inside the book, or refusing explaining the reasons.

During the continuous trading inside a book, offers are combined automatically, indeed when a bid is considered successful, shall be matching with the same capacity of one or more sale offers with a price lower than or equal to the price inserted. Conversely, a sale offer is combined with one or more bid offers, inside the book, with a greater or equal price. It is impossible that the offer coming from the same operator matches. If an offer is traded partially, the remaining part is left on the book at the same price and for the same period, but it will be deleted if there is an offer without price limits.

The MTE admits bilateral contracts, deals achieved between the buyer and the seller outside the power market, but it is compulsory to communicate, through the energy platform called PCE, the quantity of the energy traded and the period to guarantee the absence of congestions.

At the end of the last trading session about the monthly contracts, the GME calculates the net delivery position for each operator, observing the hourly purchases and sales inside the MTE. This net delivery will be loaded on the PCE.

4. Zonal Price Differences

This part describes the maximum price differences between the main bordering zones of Italy in 2017. These differences are made, mainly, by the use of the non-programable renewable energies and by the demand. The first ones have zero as the marginal price, own the maximum priority in the dispatch and earn the highest price accepted inside the market. The renewable plants excluded the traditional ones that work with fuel; however, the photovoltaic plants, that are enough distributed in the whole Italy, can generate only between the sunrise and the sunset so, only in this period, they can decrease the price. The traditional generators are so limited in the peripheric day hours, and to recover the fuel costs they are obliged to introduce expensive offers, creating a great ramp when the renewable cannot produce energy and the demand grows. For all these aspects, in each case, are showed how many MWhs are introduced by the renewables and traditional plants.

The second element that influences the zonal price is the demand, that changes depending on the hour, where the night hours are less crowed than 13:00's ones resulting cheaper; by the day, if is weekday or holiday, in fact the demand belonging to a holiday is lower than in a weekday. Finally, the last aspect that affects the demand, is the season, because in some cases in the winter some heatings are electrical, while in the summer the use of conditioned air has a relevant part in the electric bill. For these reasons the MWh of the demand, are included between the parameters analyzed.

In the analysis of each zone are put the respective minimum price of the 2017, to compare how much the parameters are near or far from a "good production", which means that a large quantity of renewable energy could also satisfy the entire demand, at the expense of the thermal source.

4.1. North-Northcentral maximum price differences

In 2017 the maximum price differences between the North zone and the Northcentral zone were on 25th January at 9:00, where the first one was more expensive; and on 5th June at 22:00, where the North was cheaper.

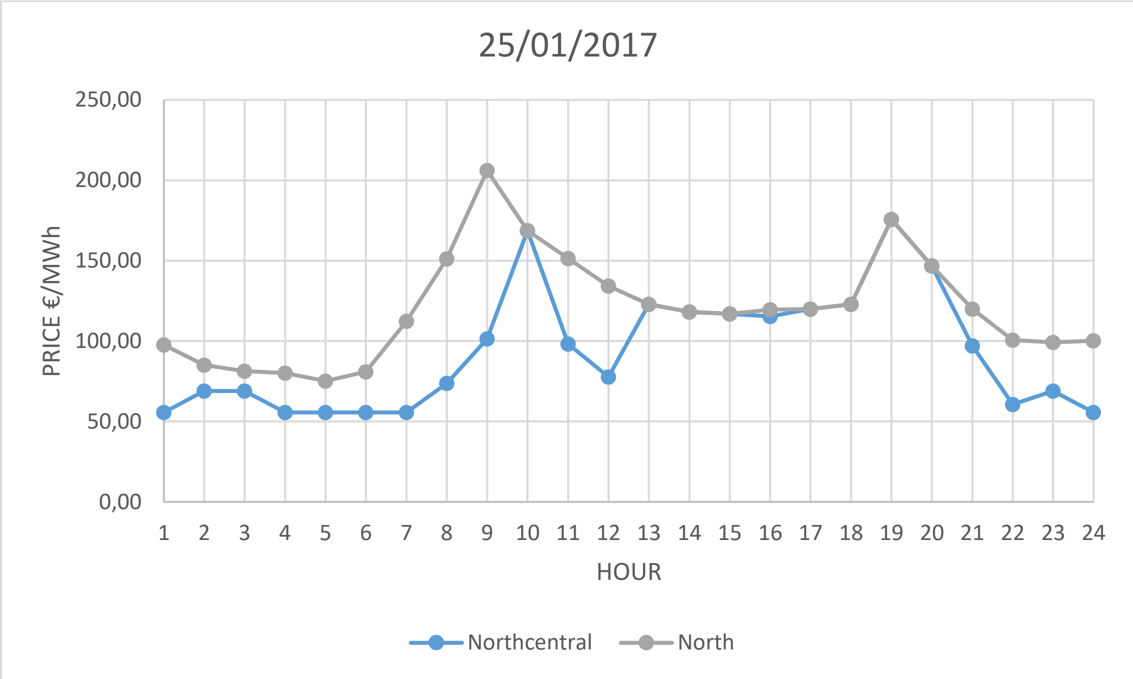


Figure 3 Price per hour of zone North and Northcentral on 25th January

On 25th January the North zone reached a price peak at 9:00 equal to 206.12 €/MWh, while the price for the Northcentral at this time is about 101.36 €/MWh, so 49% less. It was a Thursday, so in the middle of the week, where all the industries work and the area North is the one with the highest industrialization rate; for this reason the demand reaches 27315 MWh. Another factor to keep in consideration is the season, that is winter, so a lot of heaters were working consuming energy.

The North has an efficient net productive power divided according to the source:

- Hydro 16407 MW
- Photovoltaic 8703 MW
- Wind 119 MW
- Thermal 28555 MW

The generation of the North area, how is possible to see from Figure 4, at 09:00 almost satisfied the demand, but to achieve this target produced a lot energy, 18127 MWh, coming from the traditional source, that is, 63% of the overall energy of this source, and four times higher than the day with the lowest price (Figure 6). A bit contribution is supplied by renewable sources, especially by the hydro that injected 5135 MWh, using 31% of its capacity. At this time, far from the maximum radiation for this reason, are generated 75 MWh by the solar panels, that is, equal to only 1% of their availability. The last renewable source that contributes to decrease the zonal price is the wind with 15 MWh, 13% of the area wind ability.

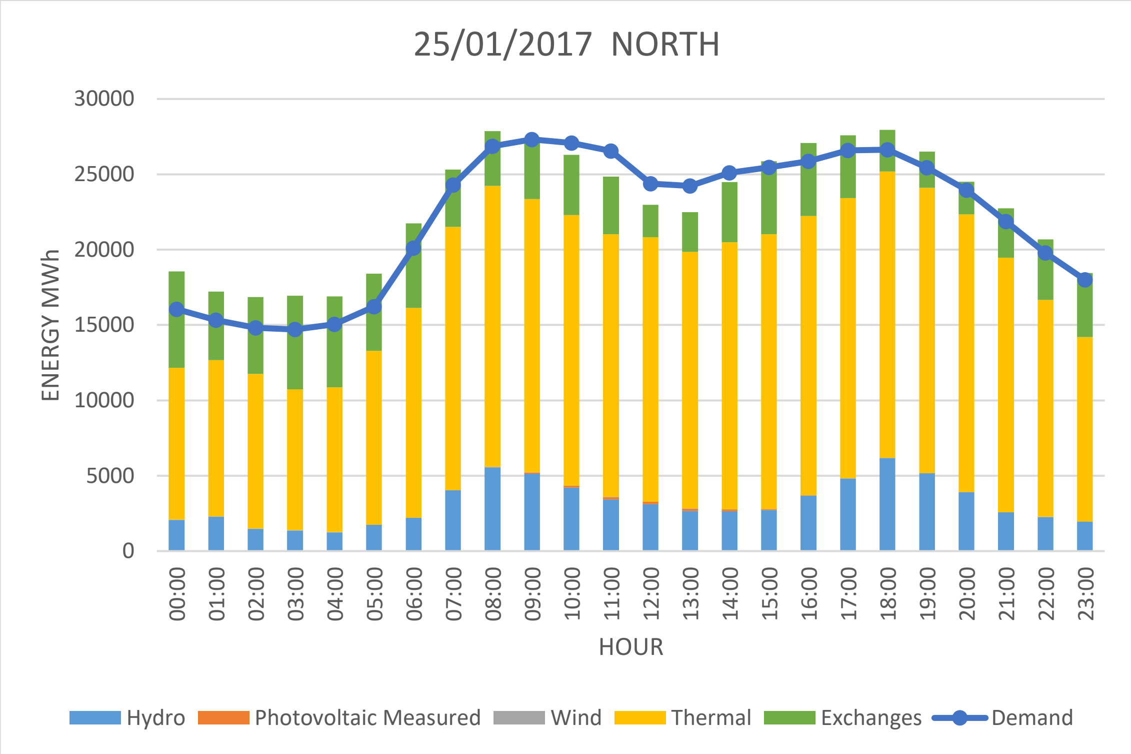


Figure 4 Demand and real energy produced by the sources per hour in the North area on 25th January

At 9:00 of the 25th January the Northcentral (NC) area presents a demand of 5356 MWh. This is a high value, in fact it is two times bigger than the day with the lowest price, Figure 7.

The Northcentral zone has an efficient net productive power divided according to the source:

- Hydro 1120 MW
- Photovoltaic 2333 MW
- Wind 145 MW
- Thermal 4300 MW

But in this period, there was a great contribution from the renewable sources (Figure 5), indeed the geothermal, with 676 MWh, and the hydro, with 579 MWh that is, 52% of the zonal availability, help to reduce the price. The photovoltaic generated 4 MWh, that is 0% of the overall energy and considering the hours is not good; while the wind with 54 MWh achieves 37% of its potential. The traditional source contributes with 1573 MWh, equal to 37% of the total energy that is possible to generate; so the price is quite modest.

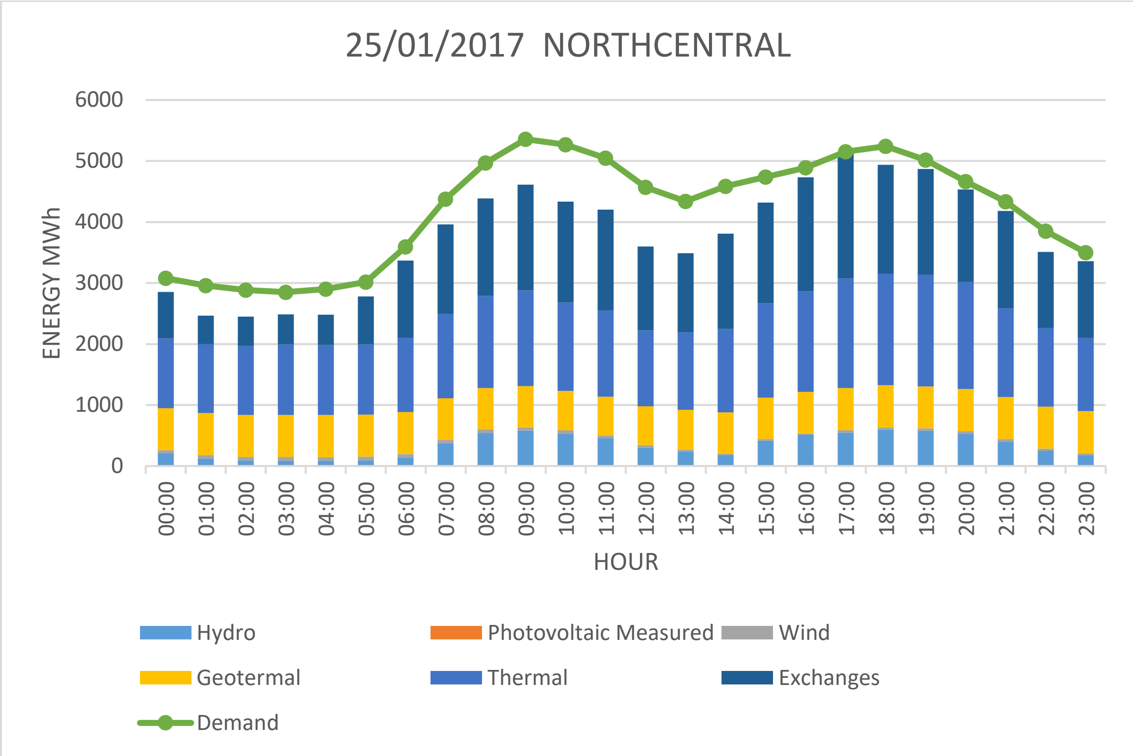


Figure 5 Demand and real energy produced by the sources per hour in the Northcentral area on 25th January

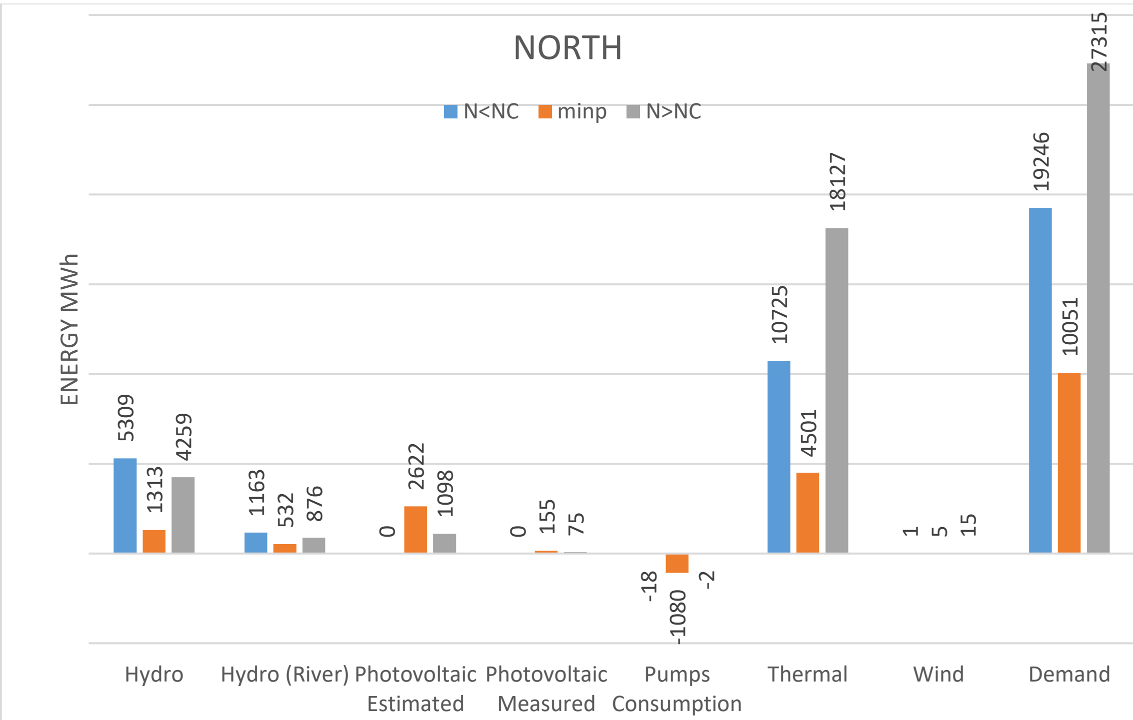


Figure 6 Comparison of the energy produced by the different sources in the North zone, in the 2017 lowest price hour (minp), on 25th January at 09:00 (N>NC) and on 5th June at 22:00 (N<NC)

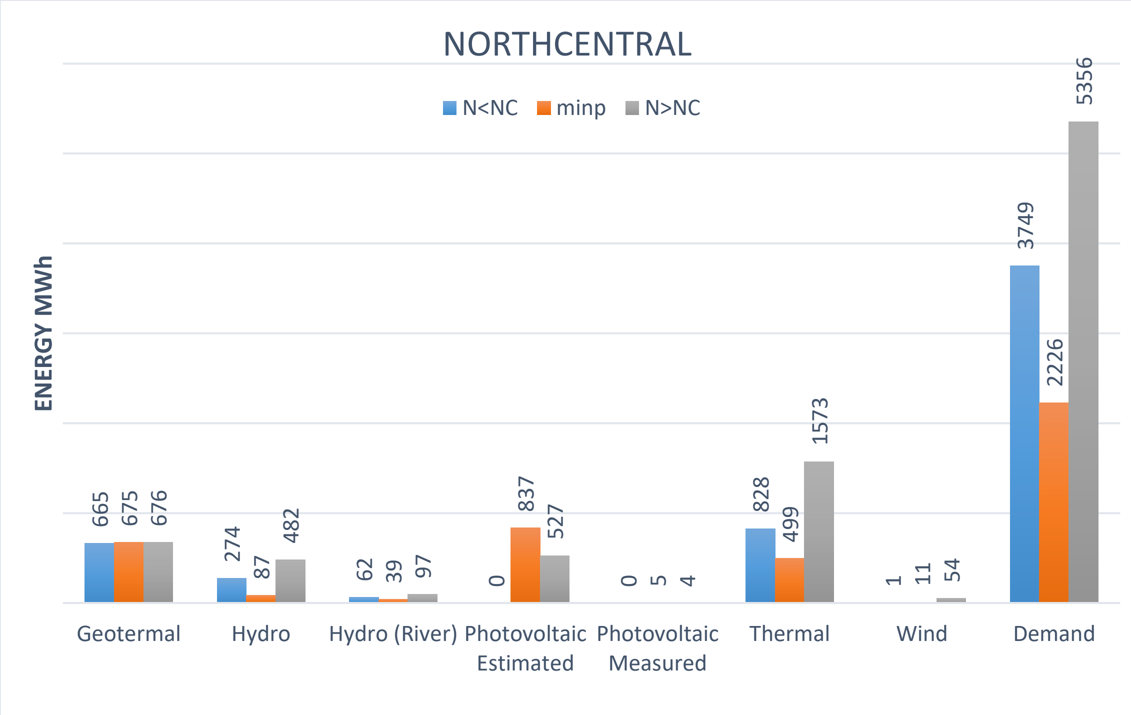


Figure 7 Comparison of the energy produced by the different sources in the Northcentral zone, in the 2017 lowest price hour (minp), on 25th January at 09:00 (N>NC) and on 5th June at 22:00 (N<NC)

The day when the Northcentral area was priced more expensive than the North in 2017 was 5th June at 22:00. At this time the demand starts to fall, so the prices usually follow it, but in this case the price increased brusquely already in the hour before and continued achieving 144,04 €/MWh, while the price of the North was of 56,82€/MWh, that is, two times and a half less (Figure 8).

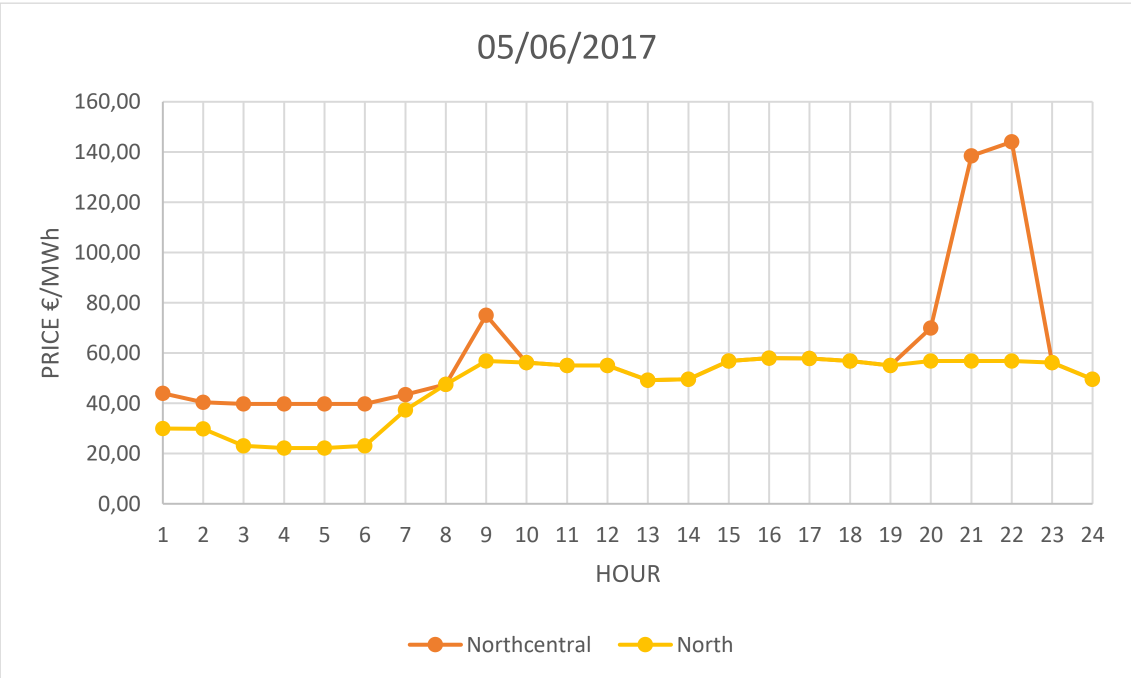


Figure 8 Price per hour of zone North and Northcentral

The demand of the Northcentral zone, at hour 22:00, was about 3749 MWh (Figure 9), that is one and a half more than the day hour with lowest price (Figure 7), and is a medium consumption. Analyzing the renewables sources found, obviously, the photovoltaic is void, because the period is on the night, and also the wind source is almost void seen that the contribution is only 1 MWh while the geothermal at the same levels of the other days are with 665 MWh. Also a good quantity of energy comes from the water resource with about 336 MWh, where was exploited 30% of the capacity. Passing to the traditional generation, the graph shows a contribution of 828 MWh, that is 19% of the entire fuel energy content.

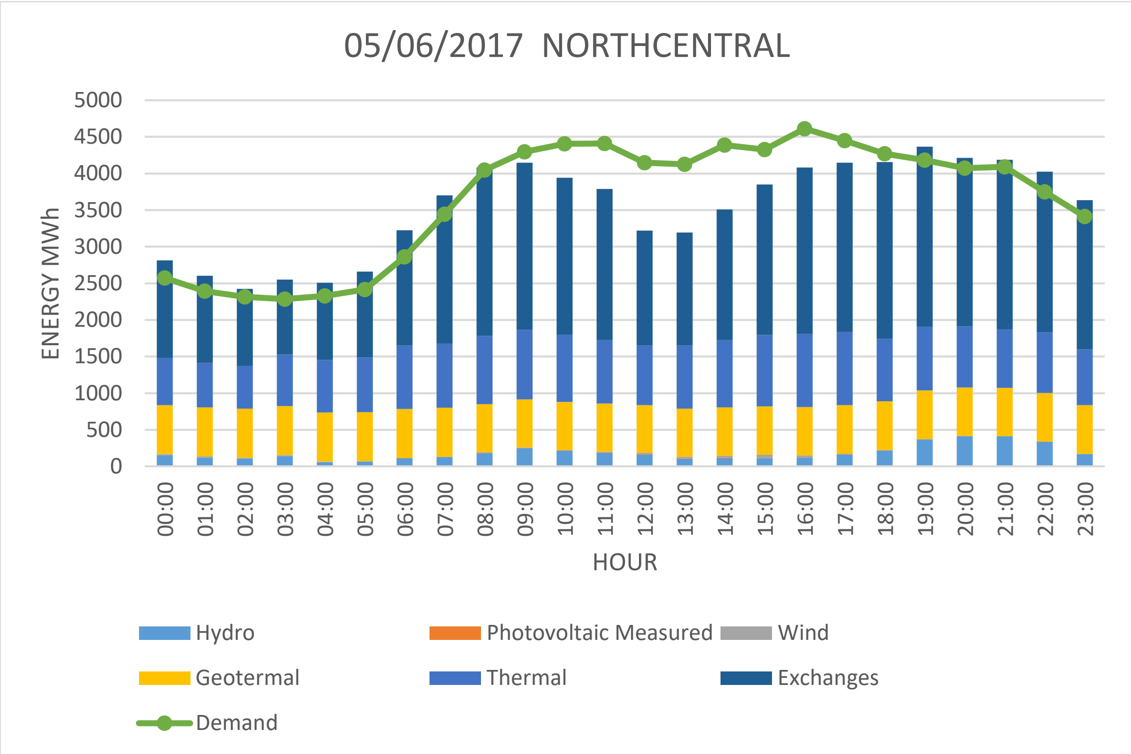


Figure 9 Demand and real energy produced by the sources per hour in the Northcentral area on 5th June

The demand of the North area this day at 22:00 was 19246 MWh (Figure 10), which is around the average for this hour. As said before, the solar energy is not available because it is considered a period in the night. Also in the North area the wind contribution is negligible, given that it generates only 1 MWh. But a great slice of energy is supplied by the hydro source with 6472 MWh, 39% of the whole water capacity of the North area. So the big contribution by the hydro source is a reason why the price is fairly contained, while the other reason is a reduced use of traditional source with 10725 MWh, that used 38% of the available power, that to be a night hour is not an high value.

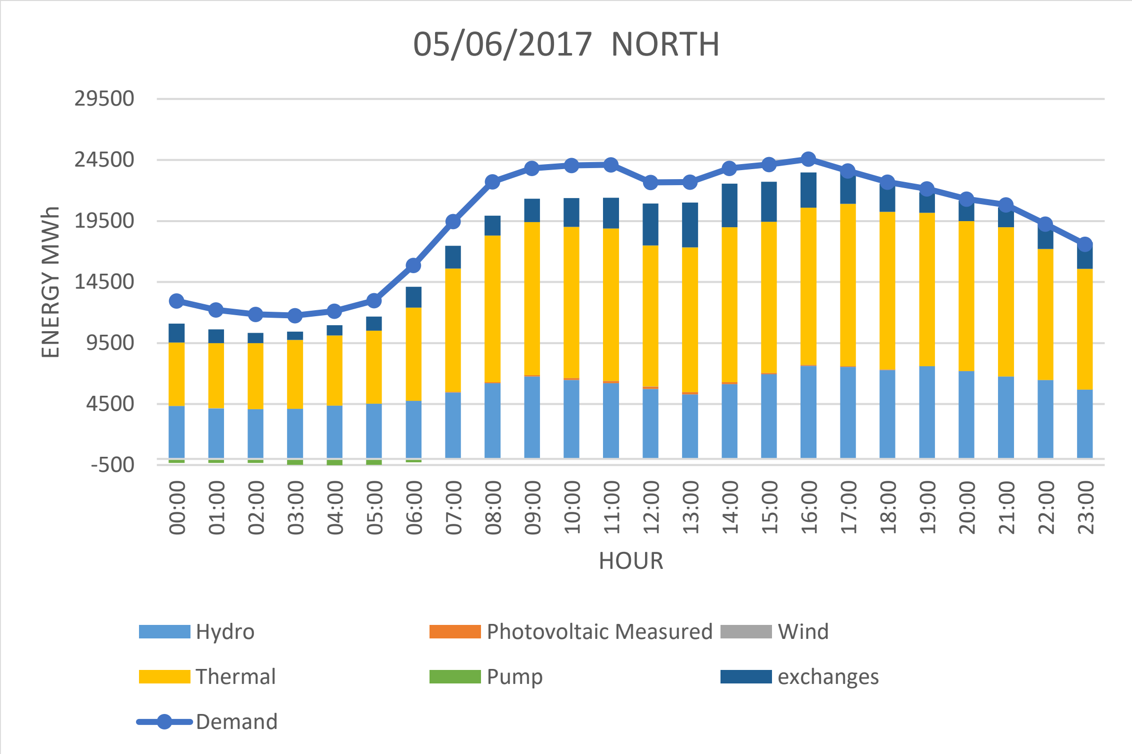


Figure 10 Demand and real energy produced by the sources per hour in the North area on 5th June

4.2. Northcentral-Southcentral maximum price differences

In 2017 the maximum price differences between the zone Northcentral and zone Southcentral were on 28th August at 16:00, where the first was more expensive; and on 21th March at 03:00, where the Northcentral is cheaper.

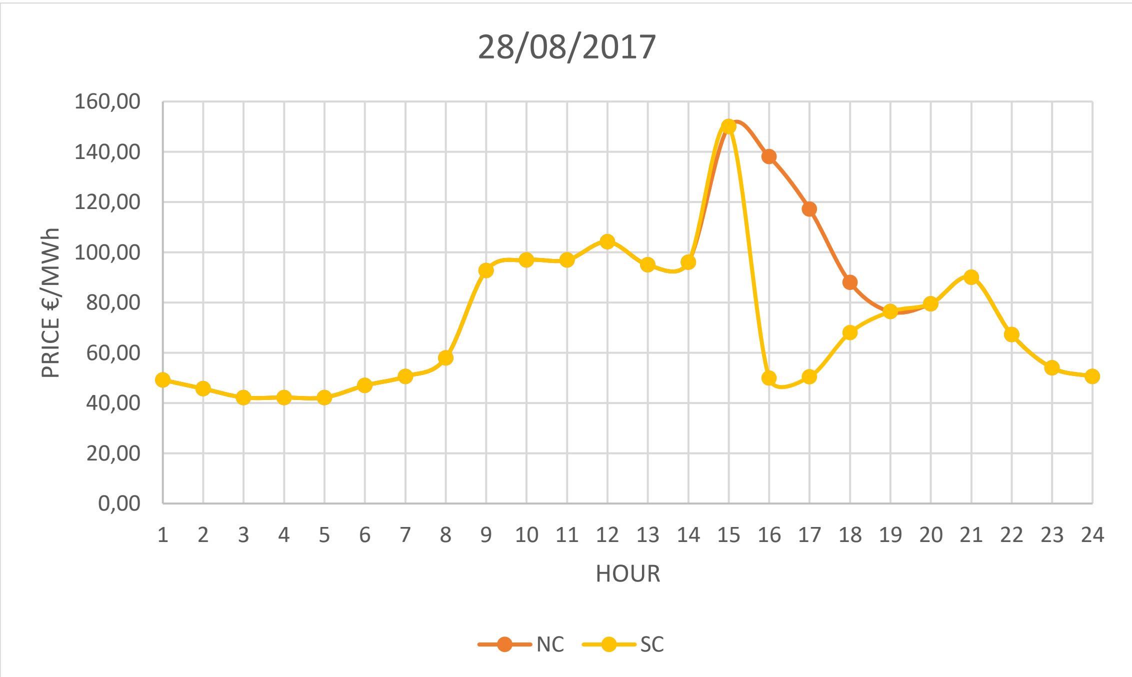


Figure 11 Price per hour of zone Northcentral (NC) and Southcentral(SC)

On 28th of August after the price peak, that was in common between the two areas, at hour 16:00 there was the maximum difference when the Northcentral zone had 138.03 €/MWh while the Southcentral had 49.92 €/MWh. So a difference of 88.11 €/MWh with a difference bigger than two times and a half. The demand asked in the Northcentral zone in that period was about 5147 MWh, and the majority of the demand is due to air conditioning given that it is the hottest period in the day.

The Northcentral zone has an efficient net productive power divided according to the sources:

- Hydro 1120 MW
- Photovoltaic 2333 MW
- Wind 145 MW
- Thermal 4300 MW

Analyzing the generation of the Northcentral zone (Figure 12) it is possible to see that the renewable sources like wind and hydro are very weak in this period, in fact the wind contributed with only 39 MWh, but in this part of Italy is not a great resource, and the hydro with 188 MWh, only 17% of this source capacity. The photovoltaic produced 5 MWh, using 0% of its ability and seen the time and the season it should be the first renewable contributor. The greater renewable contribution is provided by geothermal with 640 MWh. The thermal plants of this zone generated 1228 MWh, 29% of the zone capability, so a reduced use of the traditional source in this case does not mean low price, because the demand is so high that the production is not able to satisfy it.

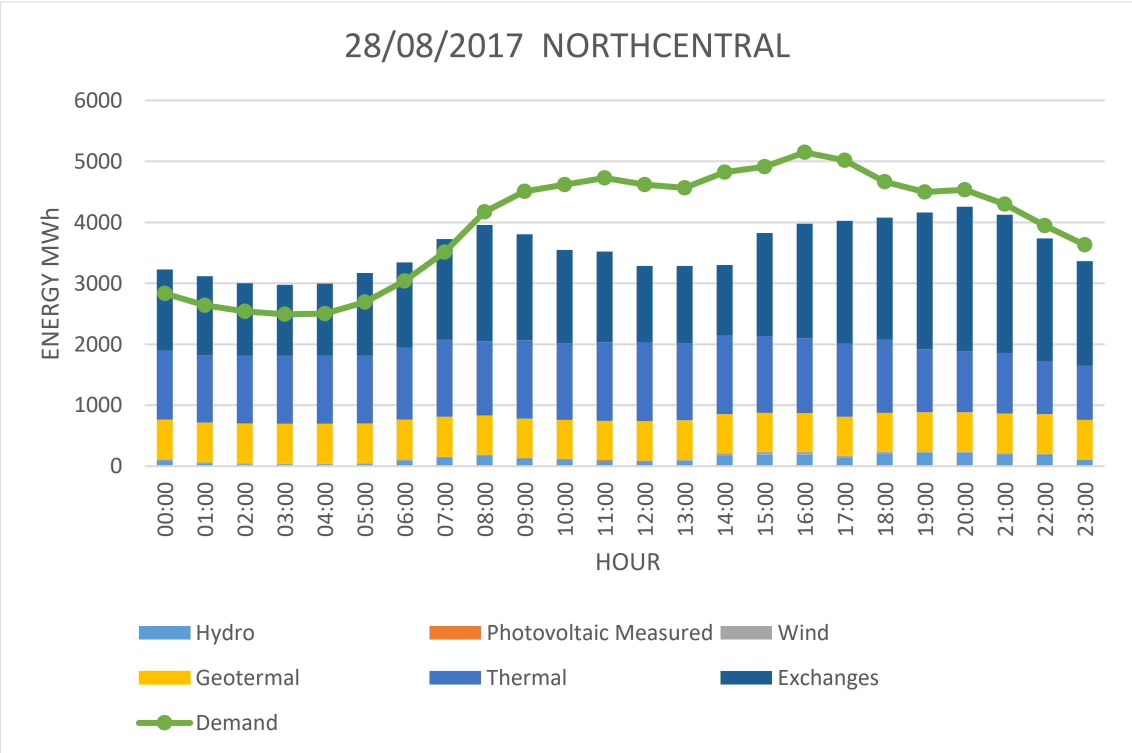


Figure 12 Demand and real energy produced by the sources per hour in the Northcentral area on 28th August

The Southcentral zone has an efficient net productive power divided according to the source:

- Hydro 2732 MW
- Photovoltaic 2832 MW
- Wind 1676 MW
- Thermal 9505 MW

The demand of the Southcentral zone on 28th of August was 7371 MWh (Figure 13), a consumption a little bit higher than the average for hour 16:00, but justified by the large use of air conditioning. The greatest part of the production is given by the traditional source with the generation of 4871 MWh, that used 51% of the available power. Passing to the renewable sources, the photovoltaic gave the smallest contribution with 143 MWh, using 5% of the capacity, then the wind source with 279 MWh, but with a modest supply if compared with the 705 MWh produced by the wind in the day with the lowest price (Figure 15). The last renewable source that produced was the hydro with 109 MWh, 4% of the capacity.

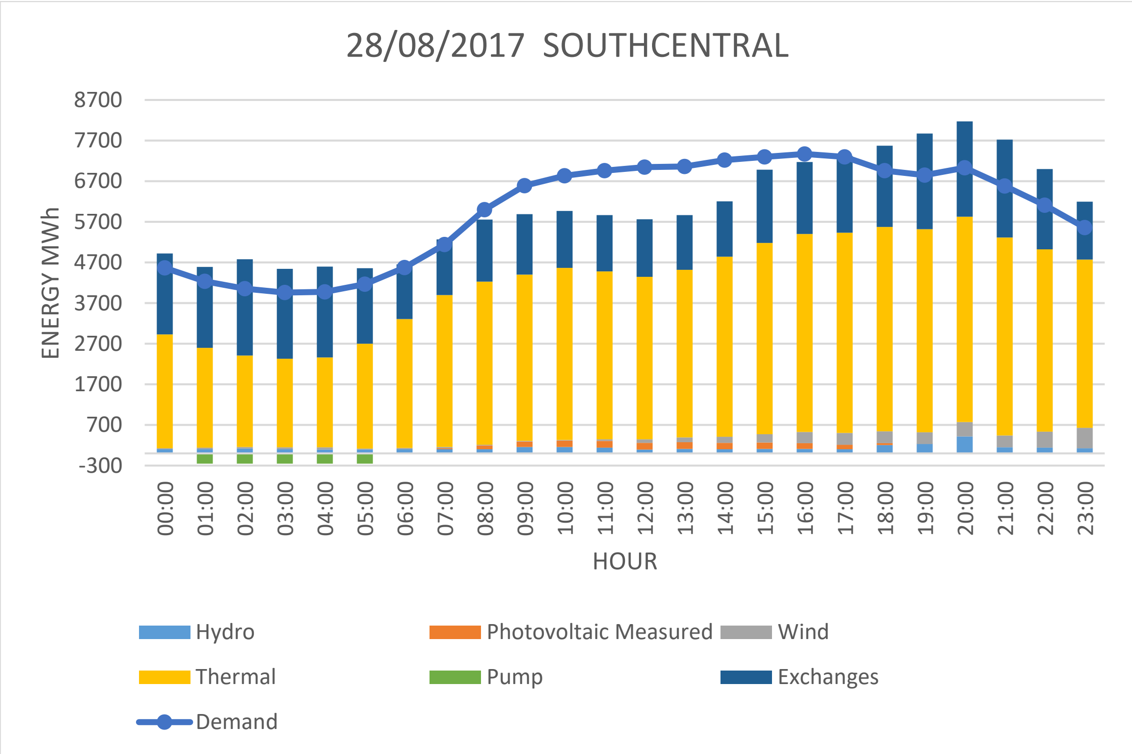


Figure 13 Demand and real energy produced by the sources per hour in the Southcentral area on 28th August

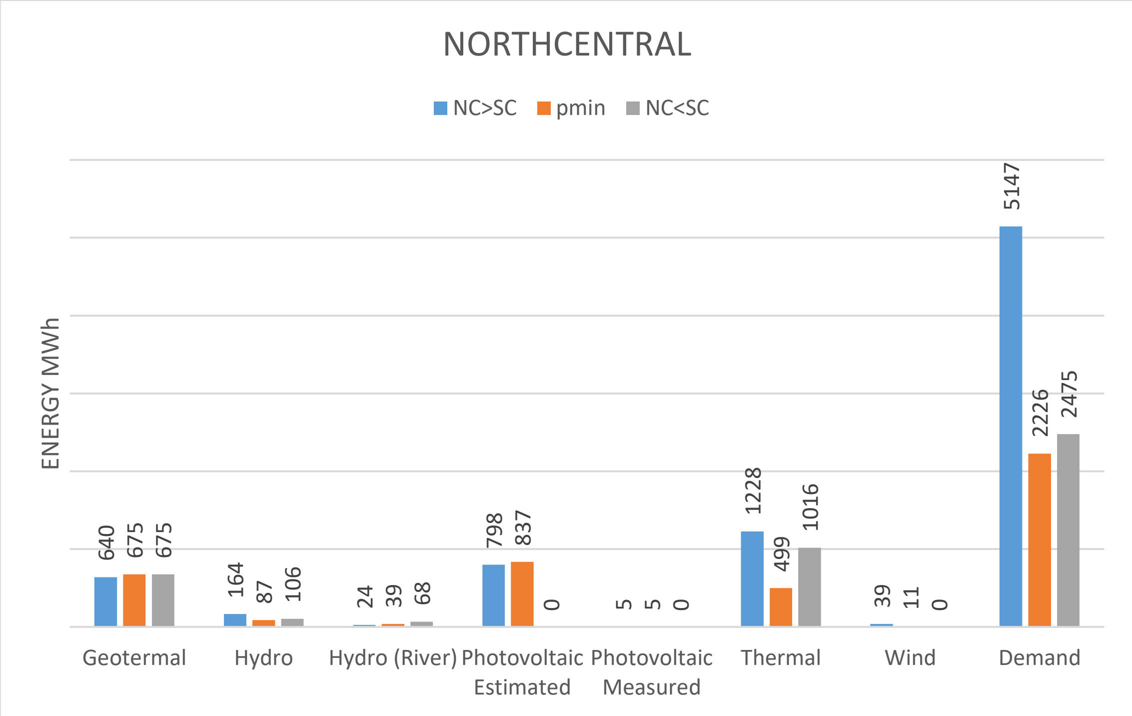


Figure 14 Comparison of the energy produced by the different sources in the Northcentral zone, in the2017 lowest price hour (minp), on 28th August at 16:00 (NC>SC) and on 21st March at 03:00 (NC<SC)

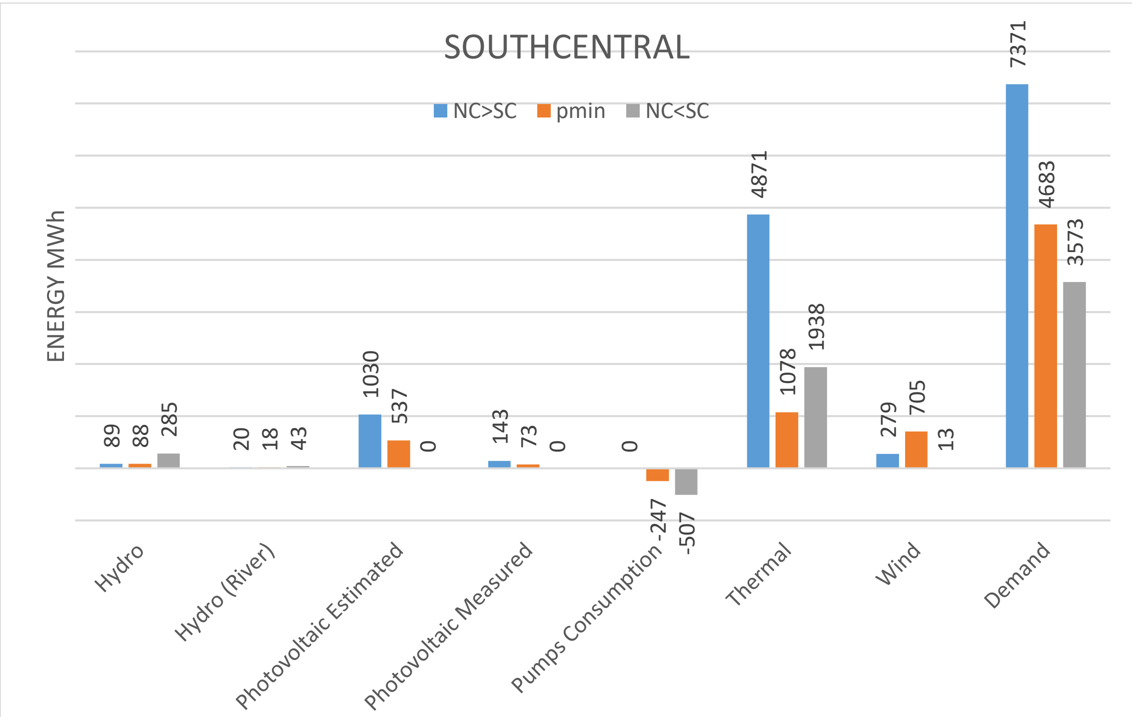


Figure 15 Comparison of the energy produced by the different sources in the Southcentral zone, in the 2017 lowest price hour (minp), on 28th August at 16:00 (NC>SC) and on 21st March at 03:00 (NC<SC)

On 21th March the two areas had the same price for almost all the day, only in the first hours the price of the Northcentral area decreases, making at 03:00 the biggest price difference where the Southcentral was more expensive with 47.29 €/MWh, while the Northcentral had 33.68 €/MWh. So it is rare that the Southcentral area is more expensive then the Northcentral area if in 2017 the maximum difference was 13.61€/MWh.

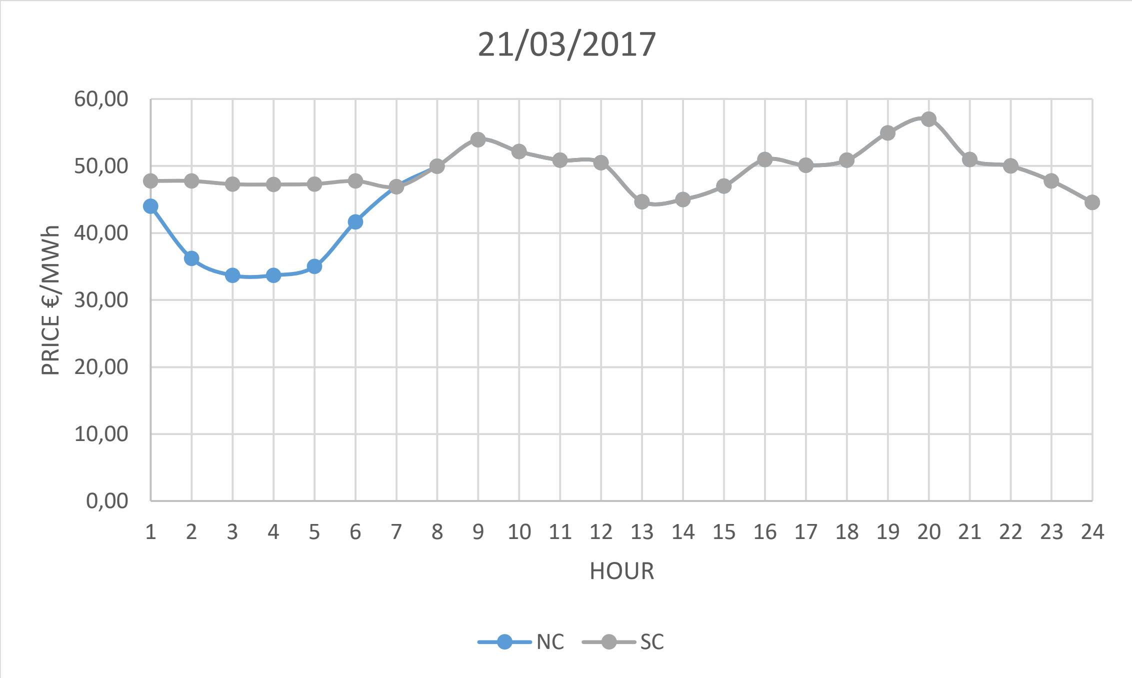


Figure 16 Price per hour of zone Northcentral (NC) and Southcentral (SC)

In this period the demand of the Northcentral zone is about 2475 MWh (Figure 17). The generation is composed especially of the traditional fuel plant with 1016 MWh, 24% of the total power. The second best contribution is supplied by the geothermal source with 675 MWh, and the hydro source follows by generating 174 MWh. Analyzing a night hour the solar energy says obviously 0 MWh, that this the same energy produced by the wind.

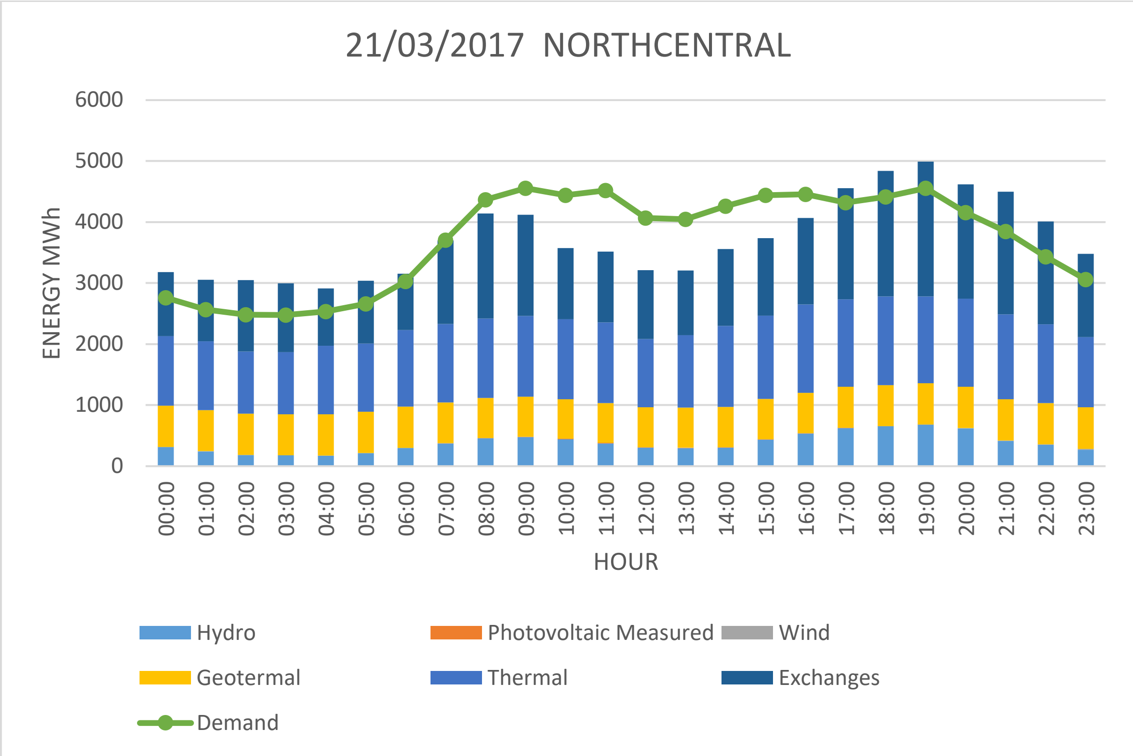


Figure 17 Demand and real energy produced by the sources per hour in the Northcentral area on 21th March

The demand owned by the Southcentral zone on 21st of March at 03:00 is about 3573 MWh (Figure 18), a value around the average of this period. It will be considered like a demand the energy pumped that is about 507 MWh. In this case the renewable source that produced more was the hydro 328 MWh, that are equal to 12% of the whole capability. While the other two sources are zero, the photovoltaic, and almost zero, the wind with 13 MWh. The most relevant contribution is provided by the thermal source with 1938 MWh, 20% of the traditional plants.

It is possible to conclude that in the period from 01:00 to 06:00 the price curve of the Southcentral area does not follow the one belonged to the Northcentral because in this period is pumped a great quantity of water spending 2793 MWh.

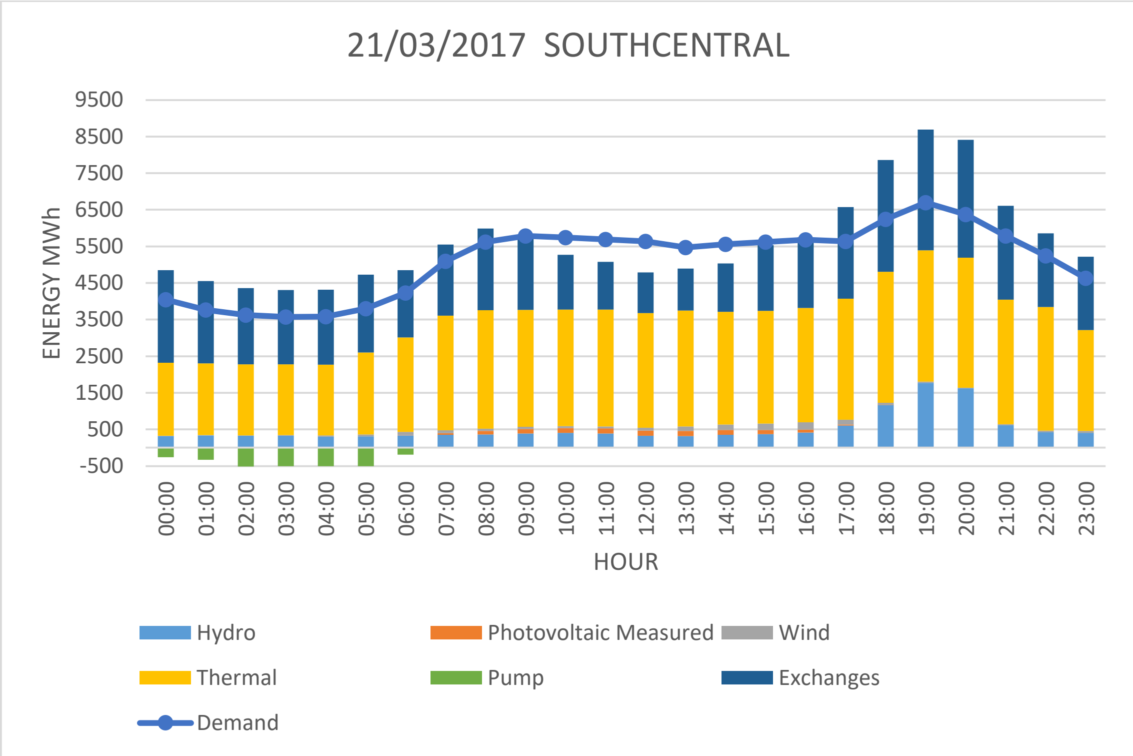


Figure 18 Demand and real energy produced by the sources per hour in the Southcentral area on 21th March

4.3. Southcentral-Sardinia maximum price differences

In 2017 the maximum price differences between the zone Southcentral and zone Sardinia were on 28th June at 18:00, where the first was more expensive; and on 05th December at 09:00, where the Southcentral is cheaper.

On 28th of June the prices of the two zones were the same except in the range between hours 13:00 and 19:00, when the maximum difference was exactly at 18:00 with 49.59 €/MWh for the Southcentral zone and 10 €/MWh for Sardinia, making a difference of 39.59 €/MWh almost four time smaller.

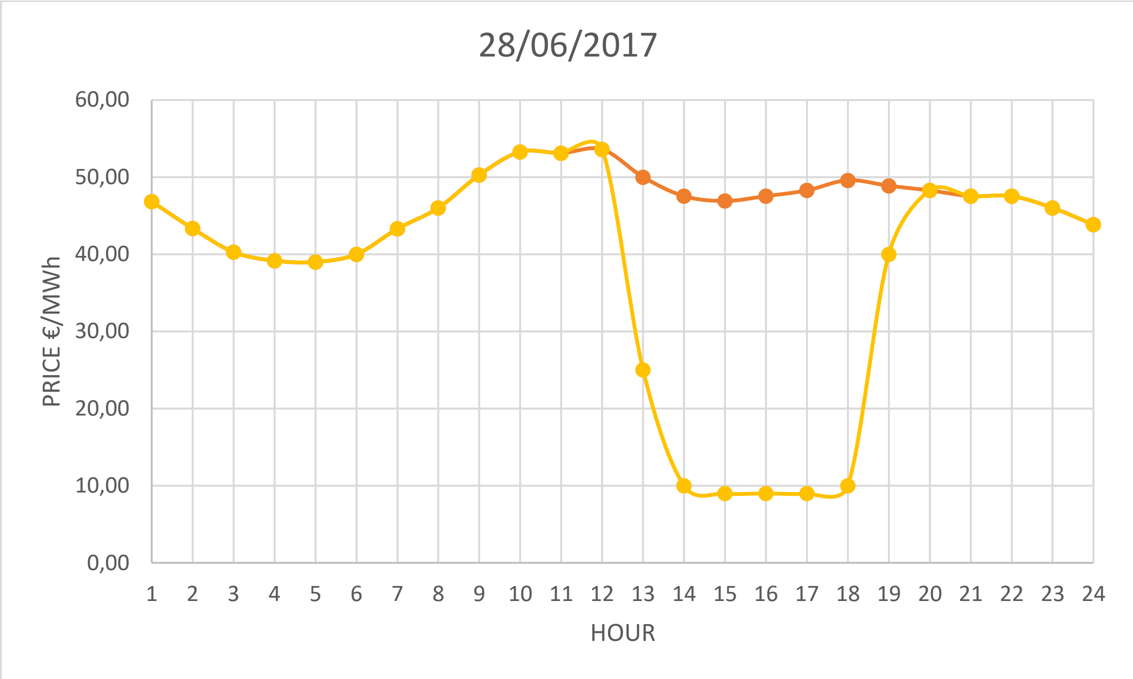


Figure 19 Price per hour of zone Southcentral (SC) and Sardinia (SAR)

The demand of the Southcentral zone at 18:00 is about 7281 MWh (Figure 20), an high consumption, bigger than the average, but reasonable for the season and the time when a lot of refreshing devices are working consuming a lot of energy. Comparing with the consumption of the day with the lowest price it is almost double (Figure 22).

The Southcentral zone has an efficient net productive power divided according to the sources:

- Hydro 2732 MW
- Photovoltaic 2832 MW
- Wind 1676 MW
- Thermal 9505 MW

The largest input between the renewable sources came from the wind, producing 579 MWh, 35% of its availability. It is the only relevant source between the renewables, because the others give a low contribution. In fact, at the second place there was the photovoltaic generation suppling 46 MW that used only the 2% of the plants and considering the season it is a weak supply. The hydro power injected in this hour 216 MWh, exercising only 8% of its capability. Seen the great demand and the low help from the renewables, the thermal plants worked hard generating 4909 MWh, equal to 52% of the energy available for the fuel source. And this means high zonal price.

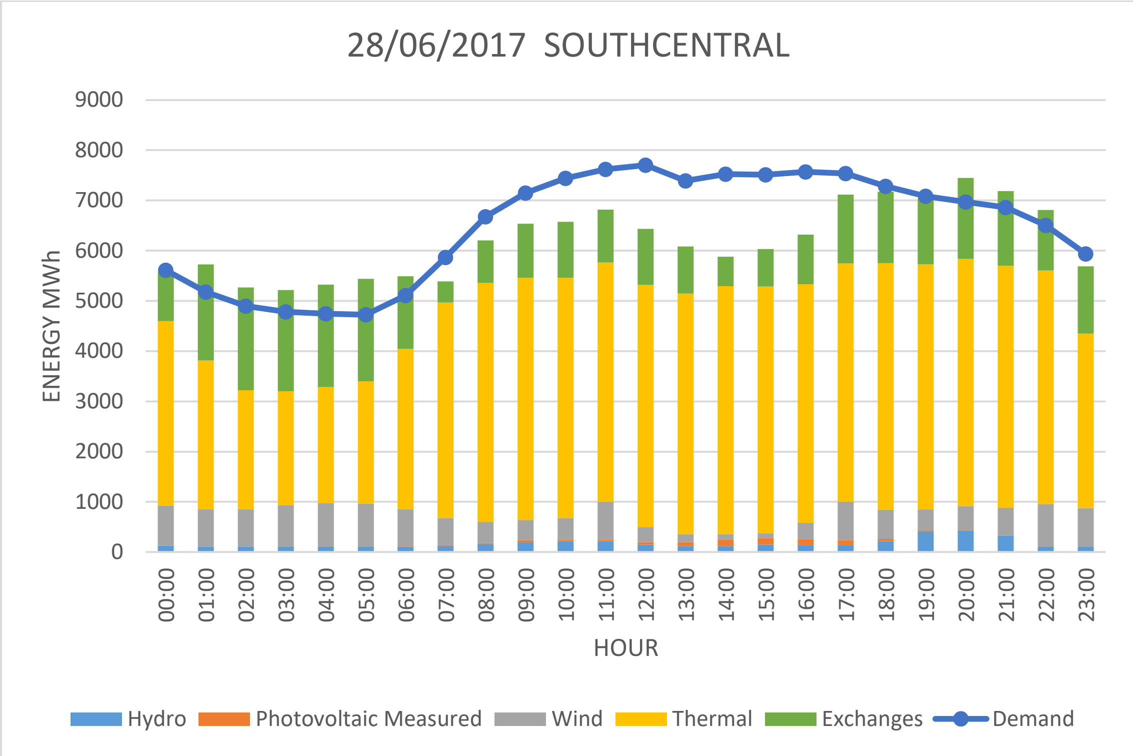


Figure 20 Demand and real energy produced by the sources per hour in the Southcentral area on 28th June

The demand in the same period in Sardinia is about 1221 MWh (Figure 21), lower than the other zone because is considered just the island, but it is a great consumption particularly bigger than the average. The elevate demand might be justified by the high temperature in this part of the year.

The Sardinia zone has an efficient net productive power divided according to the sources:

- Hydro 461 MW
- Photovoltaic 749 MW
- Wind 1024 MW
- Thermal 2279 MW

The generation in this hour is supplied mostly by the traditional source that introduces 1090 MWh, 48% of the fuel capacity. But a great power is injected by the wind as well,namely, 642 MWh, using 63% of the turbines located in the isle; while for the period of the year it is pretty low the energy provided by the solar panels that contribute with 12 MWh, that only 2% of the whole photovoltaic energy. Another little energy help is given by the hydro that produced 42 MWh, 9% of the hydro availability. This a perfect example of how the energy price decreases when there is a great presence of renewable sources and increases in the night when is not possible to exploit the solar energy. Furthermore, it is possible to see that in the range between hours 10:00 and 18:00 was pumped water as a result of the low area price.

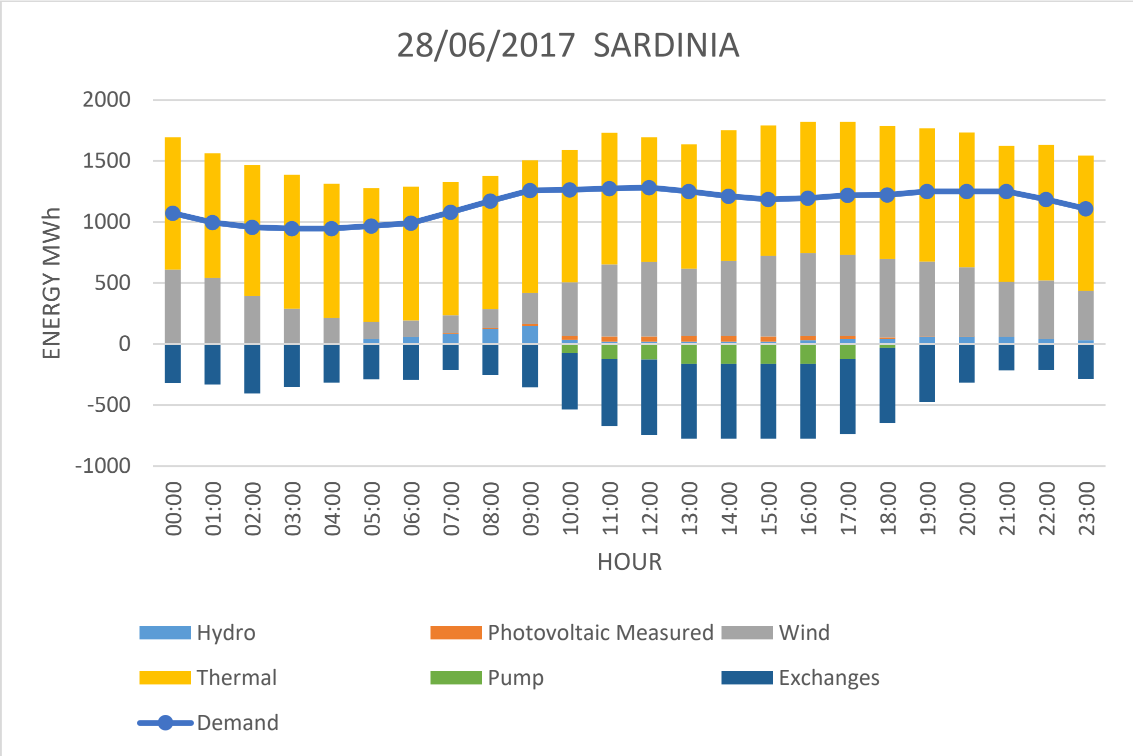


Figure 21 Demand and real energy produced by the sources per hour in the Sardinia area on 28th June

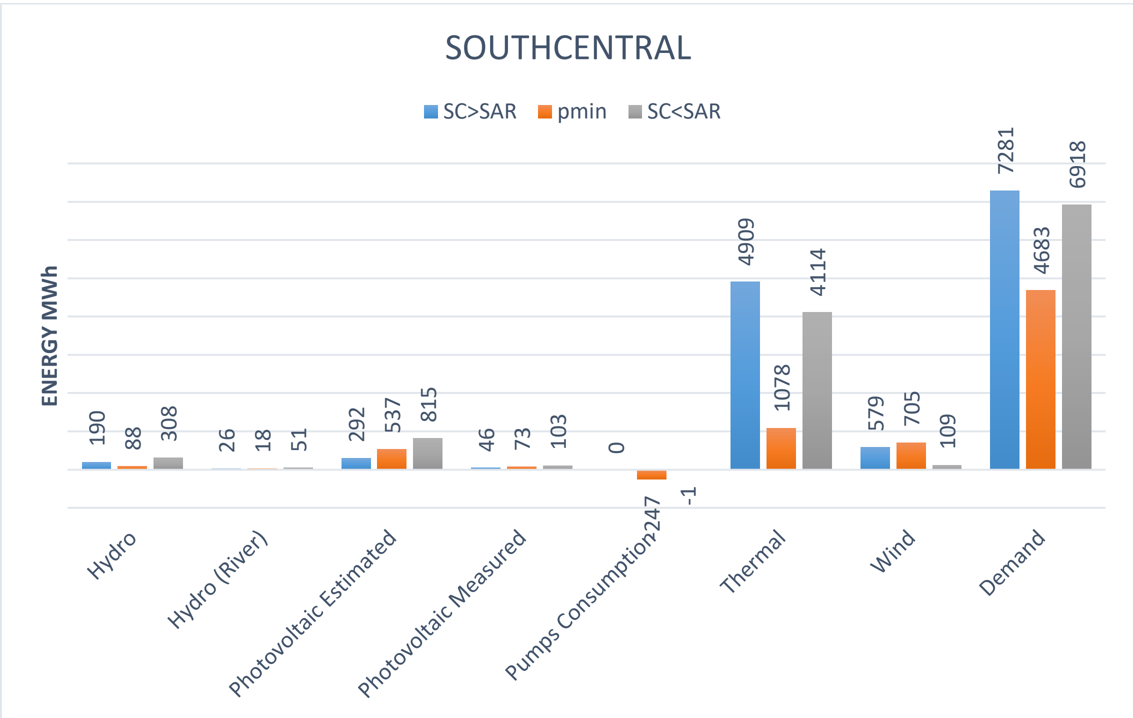


Figure 22 Comparison of the energy produced by the different sources in the Southcentral zone, in the 2017 lowest price hour (minp), on 28th June at 18:00 (SC>SAR) and on 5th December at 09:00 (SC<SAR)

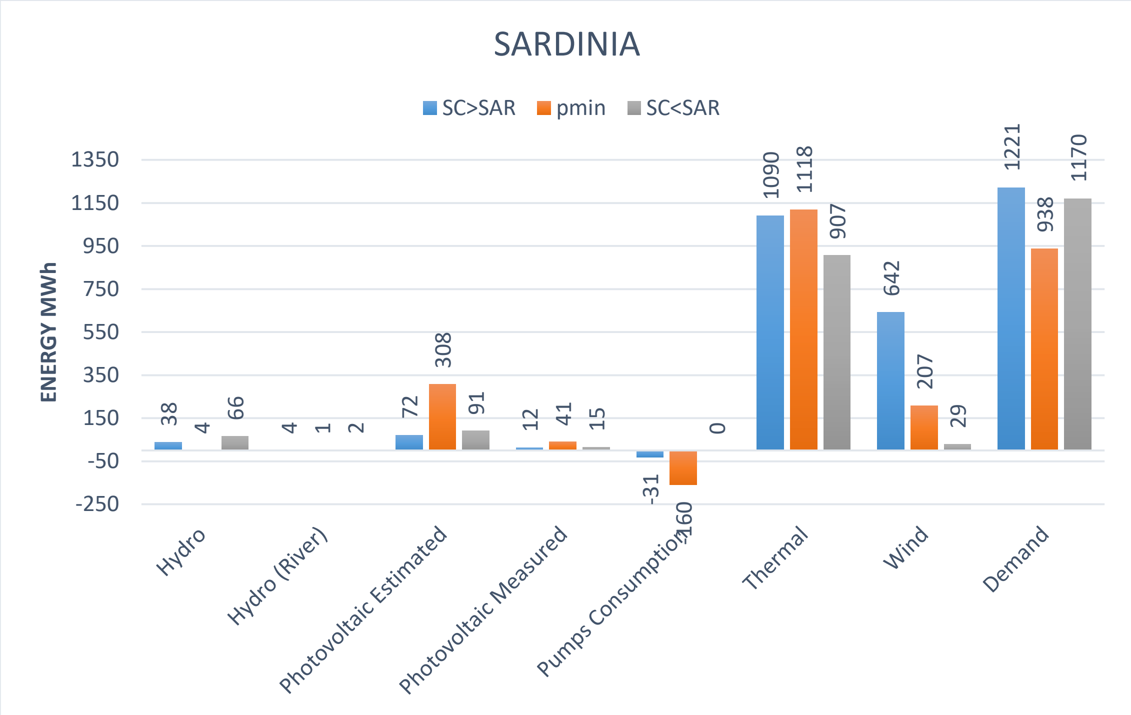


Figure 23 Comparison of the energy produced by the different sources in the Sardinia zone, in the 2017 lowest price hour (minp), on 28th June at 18:00 (SC>SAR) and on 5th December at 09:00 (SC<SAR)

The day with the maximum price difference where the Sardinia is more expensive than in the Southcentral zone is 5th December at hour 09:00, when the isle energy price is 135.56 €/MWh, while the Southcentral zone is 73.02 €/MWh, with a difference of 62.53 € per MWh, close to the double.

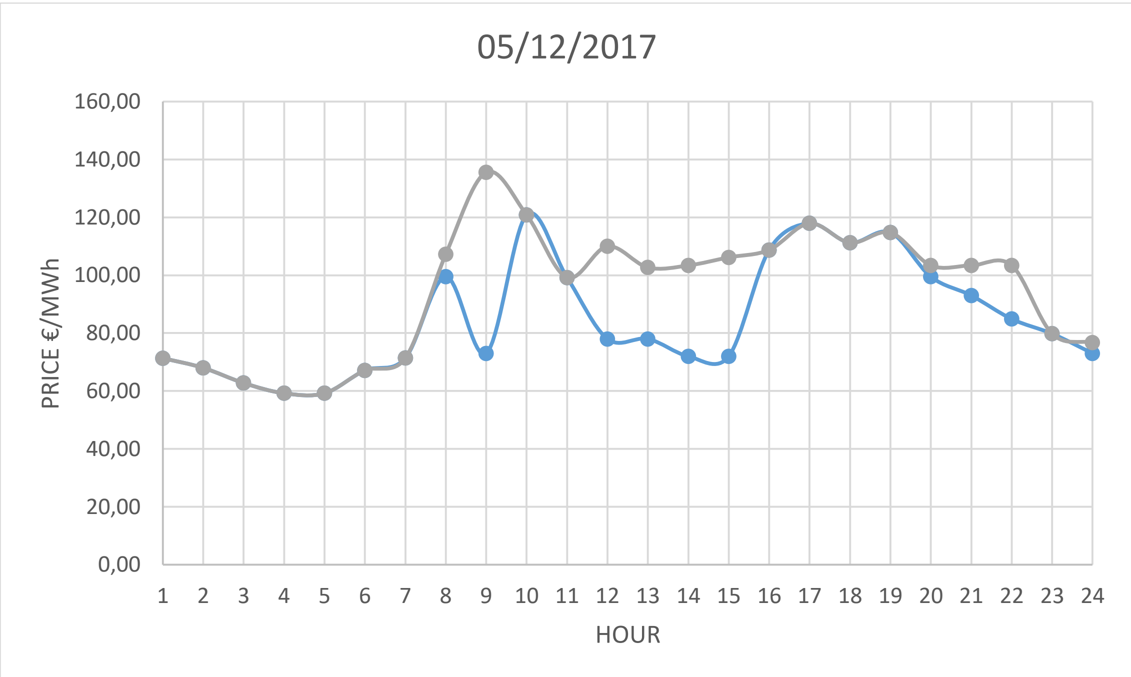


Figure 24 Price per hour of zone Southcentral (SC) and Sardinia (SAR)

The demand of the Southcentral area at this time is 6918 MWh (Figure 25), a value bigger than the average, but it is a morning of a week day so all the industries asked a lot of power and all the electric heaters are switched on. This demand is partially satisfied by the 103 MWh coming from 4% of the solar panels located in this area. The biggest renewable source at this hour is the hydro source that supplied 359 MWh, 13% of its available energy; while the last renewable source, the wind, generates only 109 MWh, 7% of the total energy of the turbines. So the missing energy will be delivered by the fuel plants, that produced 4114 MWh exploiting 43% of its capacity. The peak at hour 09:00 is justified because the thermal power decreases and the energy coming from the renewable sources like the photovoltaic and hydric increases a lot.

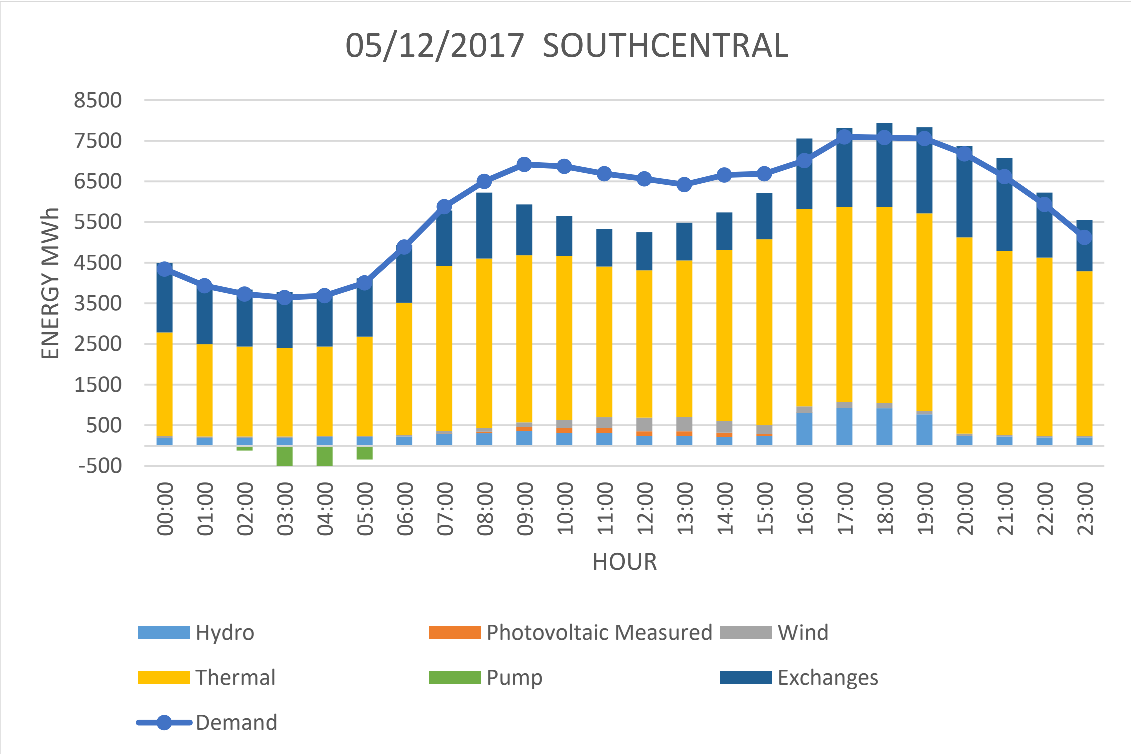


Figure 25 Demand and real energy produced by the sources per hour in the Southcentral area on 5th December

The isle, at hour 09:00, consumed 1170 MWh (Figure 26), a bit more than the average. The generation from renewable sources is particularly low, in fact the energy coming from the wind turbine was about 29 MWh, 3% of the turbines capacity; the energy supplied by the photovoltaic was 15 MWh, and being winter could be that was a cloudy morning because was used only 2% of the panels availability. The big contribution is provided by a renewable source is the hydro with 68 MWh that it is 15% of its capacity. Passing at the traditional generation, as shown in Figure 26, produced 907 MWh, that it is 40% of the energy available. So, it occurs the peak because the contribution provided by the hydro and wind decreases.

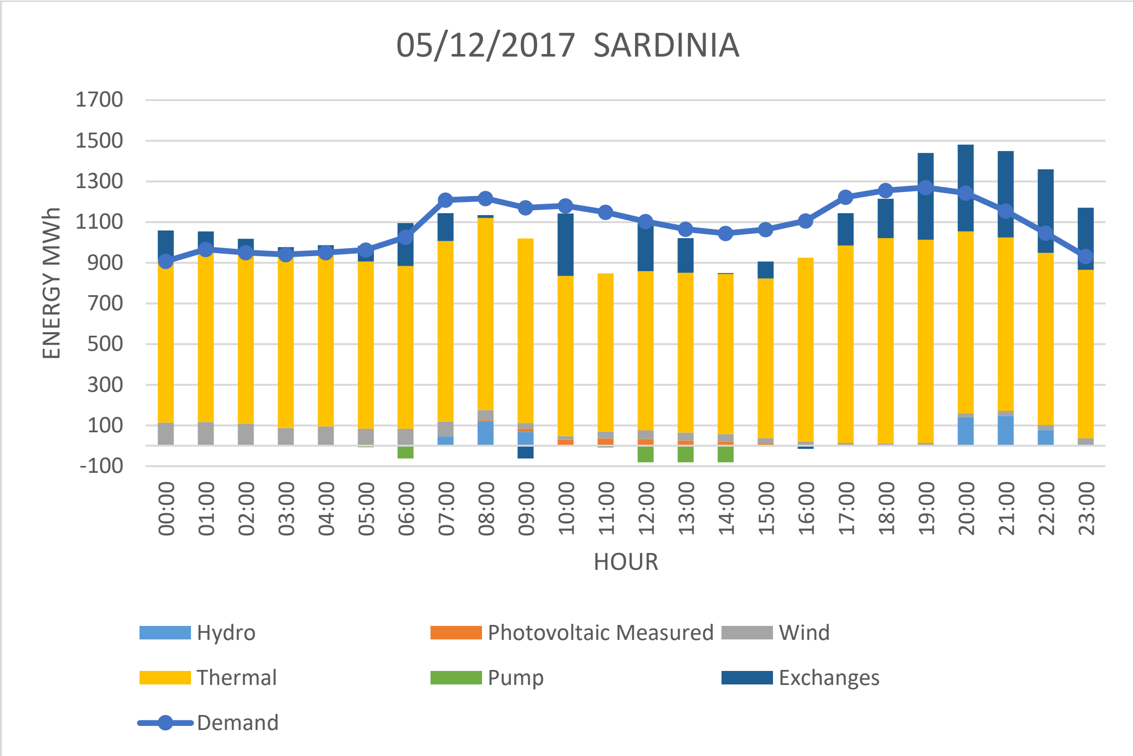


Figure 26 Demand and real energy produced by the sources per hour in the Sardinia area on 5th December

4.4. Southcentral-South maximum price differences

In 2017 the maximum price differences between the Southcentral zone and South zone was on 03rd August at 15:00, where the first was more expensive; but differently from the other connections, there is not an hour where the price of the South zone is bigger than the Southcentral, so it is analyzed a day where all the day the two areas had the same price, and it is chosen the 1st of January.

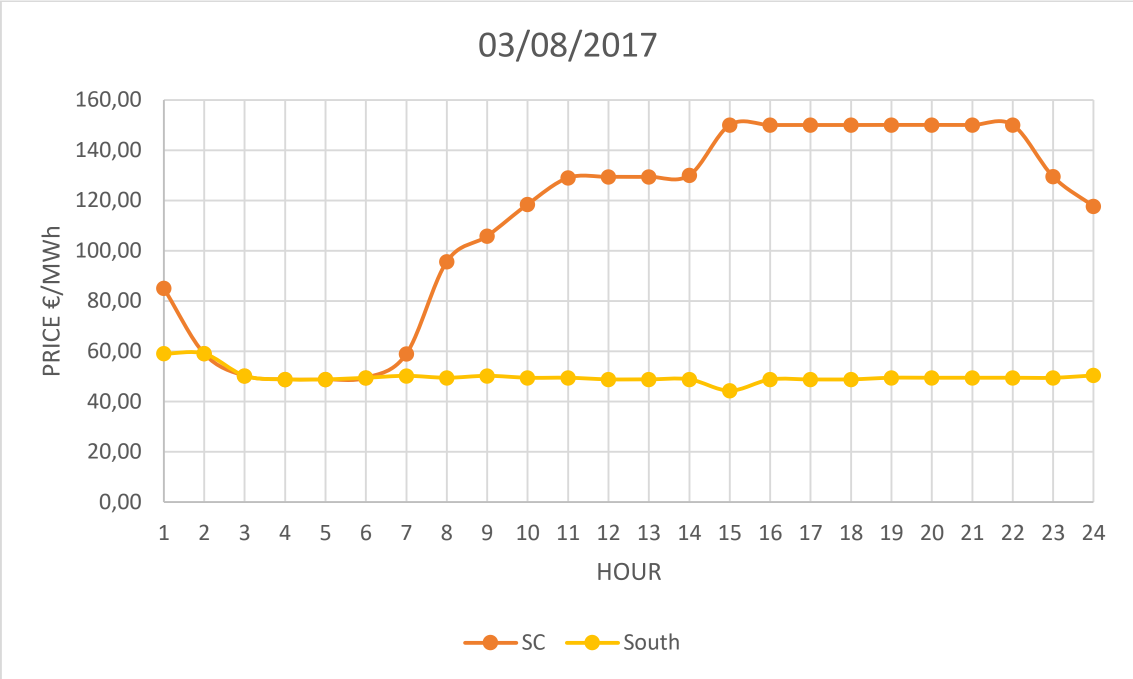


Figure 27 Price per hour of zone Southcentral (SC) and South

For the most part of the day 03rd August the price of the Southcentral zone is higher than the South (Figure 27), but the maximum difference is at hour 15:00 where the energy for the first one costs 150.01 €/MWh while in the South it costs 44.28 €/MWh; so it was bigger than three times and it caused many exchanges between the two zones, loading the system.

The demand of the Southcentral zone at hour 15:00 is 8251 MWh (Figure 28), that it is a value particularly high than the average for this time, but it is analyzed one between the warmest days of the year where a lot of energy is used through air conditioning. It is possible to see how bigger is this value if compared with the demand of the day with the lowest price (Figure 30), it is near the half.

The Southcentral zone has an efficient net productive power divided according to the source:

- Hydro 2732 MW
- Photovoltaic 2832 MW
- Wind 1676 MW
- Thermal 9505 MW

Passing to the zone generation in that time, the graph in Figure 28 shows as the traditional source is the one that tries to satisfy the high demand producing 4519 MWh that is equal at the 48% zone capability of this source. But considering that the period is located in the hottest part of the day, the generation coming from the solar panels is about 151 MWh, where was used the 5% of the source. The other contributions provided from the renewables sources are the wind with 190 MWh generated, and the hydro source with 142 MWh produced; where had exploited respectively 11% and 5% of their capacity.

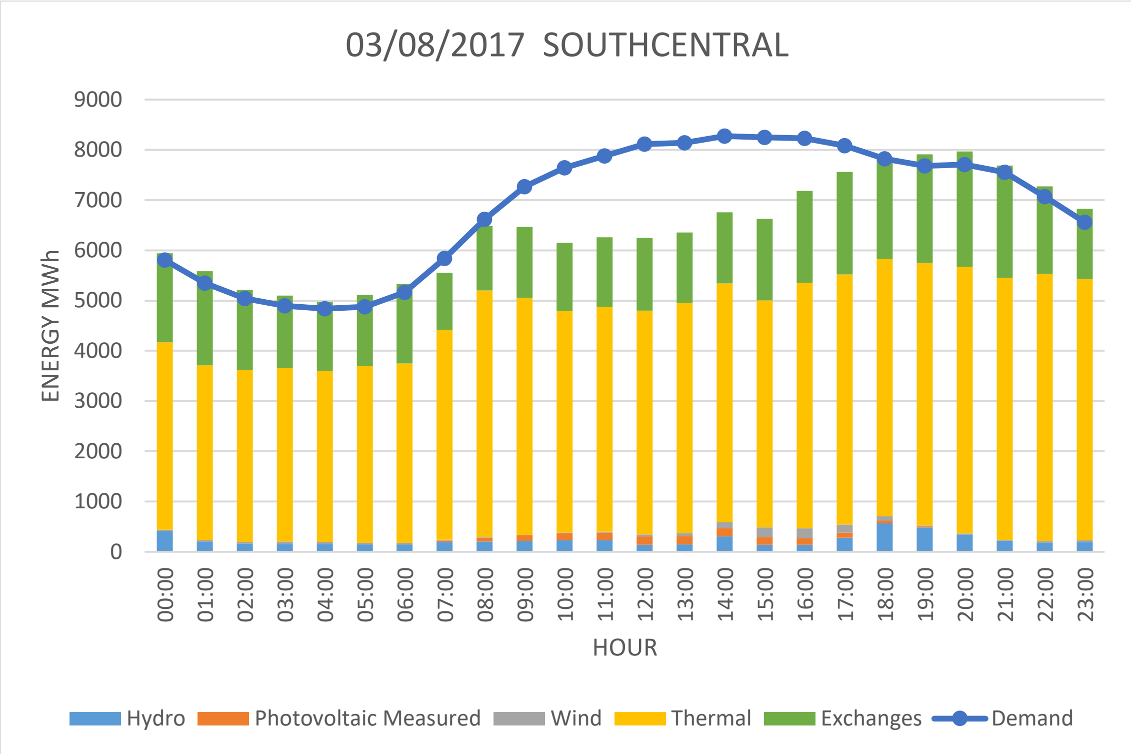


Figure 28 Demand and real energy produced by the sources per hour in the Southcentral area on 3rd August

In the same period, the demand of the South zone was 4382 MWh (Figure 29), and it is an huge value, bigger than the average as well, but is a day between the hottest, in the middle of summer, so the energy used to refresh is so elevated.

The South zone has an efficient net productive power divided according to the source:

- Hydro 980 MW
- Photovoltaic 3689 MW
- Wind 4992 MW
- Thermal 12379 MW

The production of the South zone at 15:00 on 3rd of August is conditionate fairly from the impact of the renewables sources, which made the price so low. In fact, the photovoltaic generation, in this time, used 3% of the source availability, generating 118 MWh. The wind contribution is quite good with 816 MWh that is 16% of the energy obtainable by wind turbines of this zone. The last renewable font is the hydro that produced 116 MWh, where used 12% of its capacity. Even here, the most part of the generation is the fuel source that contribute with 5235 MWh, exploiting 42% of the capability of the source.

In this day the great difference of price is made because the production of the Southcentral is always under the demand of its zone, while in the South is completely in the other way where the traditional generation and the great presence of the renewables sources for this day means low price and so many sells.

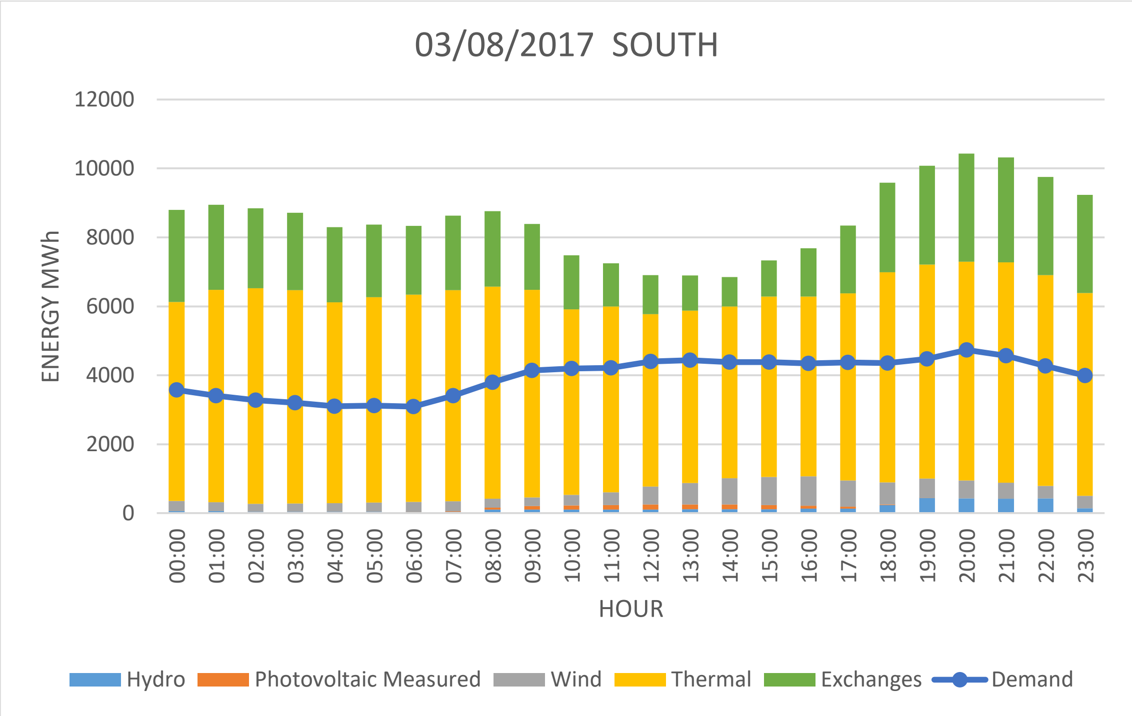


Figure 29 Demand and real energy produced by the sources per hour in the South area on 3rd August

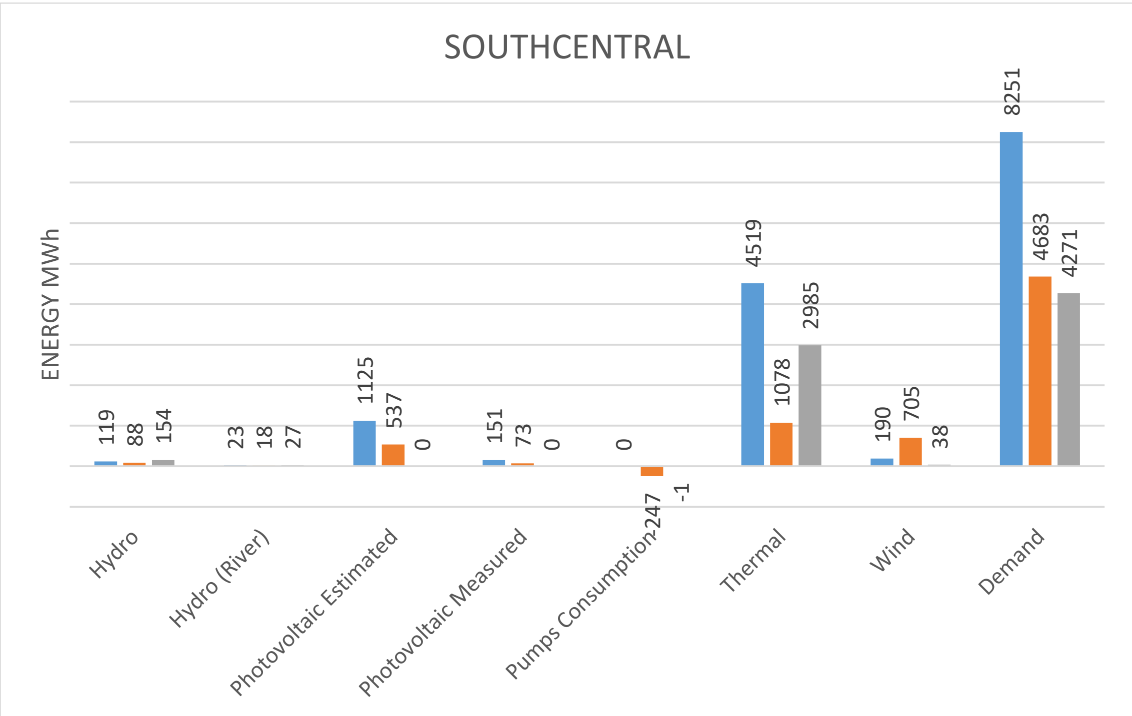


Figure 30 Comparison of the energy produced by the different sources in the Southcentral zone, in the 2017 lowest price hour (minp), on 3rd August at 15:00 (SC>S) and on 1st January a 01:00 (SC=S)

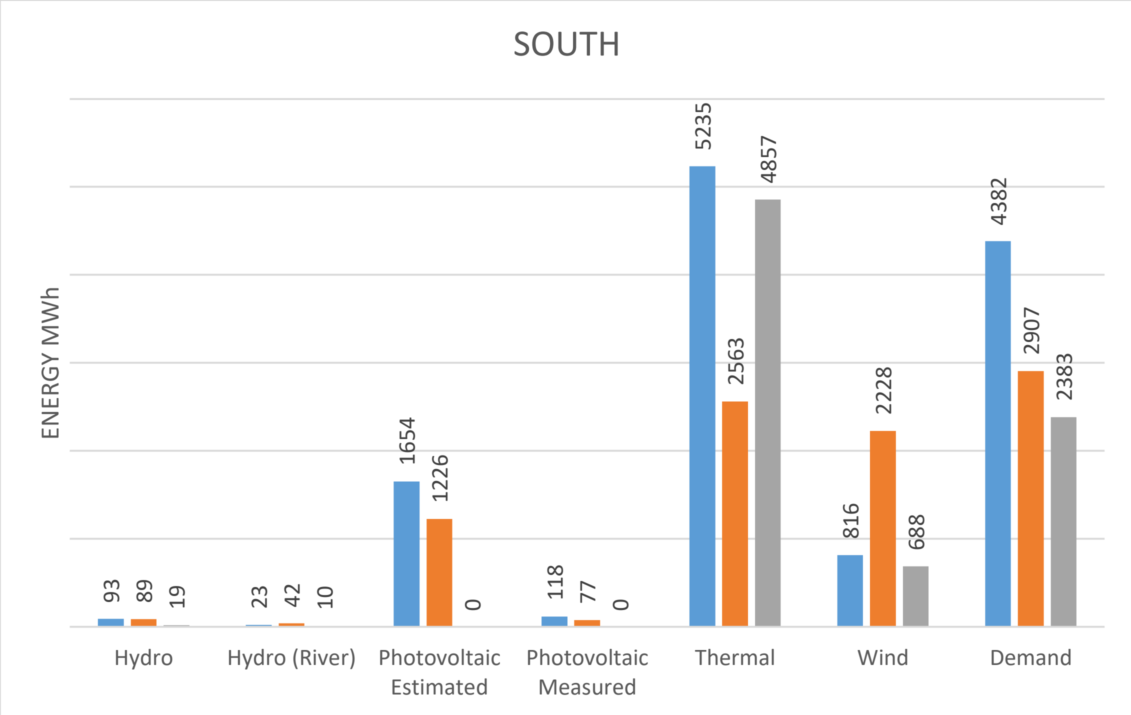


Figure 31 Comparison of the energy produced by the different sources in the South zone, in the 2017 lowest price hour (minp), on 3rd August at 15:00 (SC>S) and on 1st January a 01:00 (SC=S)

In the whole 2017 there is no time range where the energy cost of the South zone is bigger than the Southcentral zone, so it is chosen a day where the difference it is zero in all the hours (1st January), and the hours 01:00 is analyzed. In this period the energy price is, for both zones, 53€/MWh.

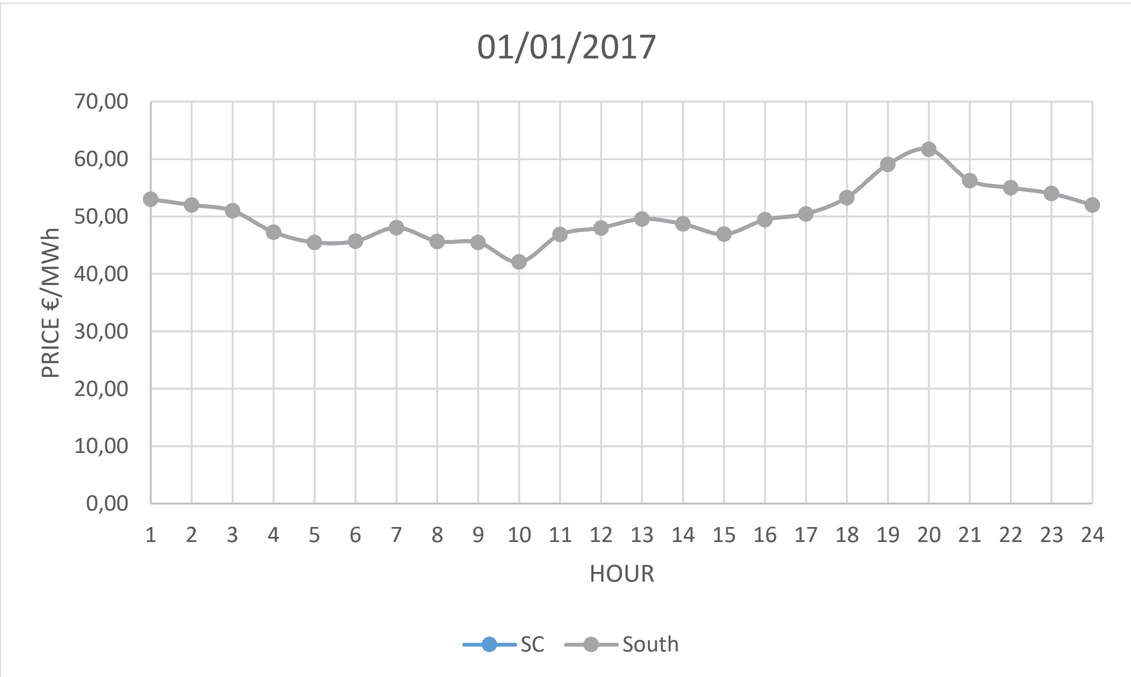


Figure 32 Price per hour of zone Southcentral (SC) and South

The demand of the Southcentral zone at the 01:00 of the first day of the year was 4271 MWh (Figure 33), and it is an average consumption for that period. The support of the renewable energies is very weak, starting to consider that being in the night the production of the photovoltaic source is void, while the most contribution arrives from the hydro source that put in the grid 181 MWh, equal to 7% of the whole water capacity. A negligible energy quantity, 38 MWh, is supplied by the wind source using less than 2% of the turbines' capacity. So the most relevant producing source was the fuel with the injection of 2985 MWh, that exploits 31% of the total area capacity.

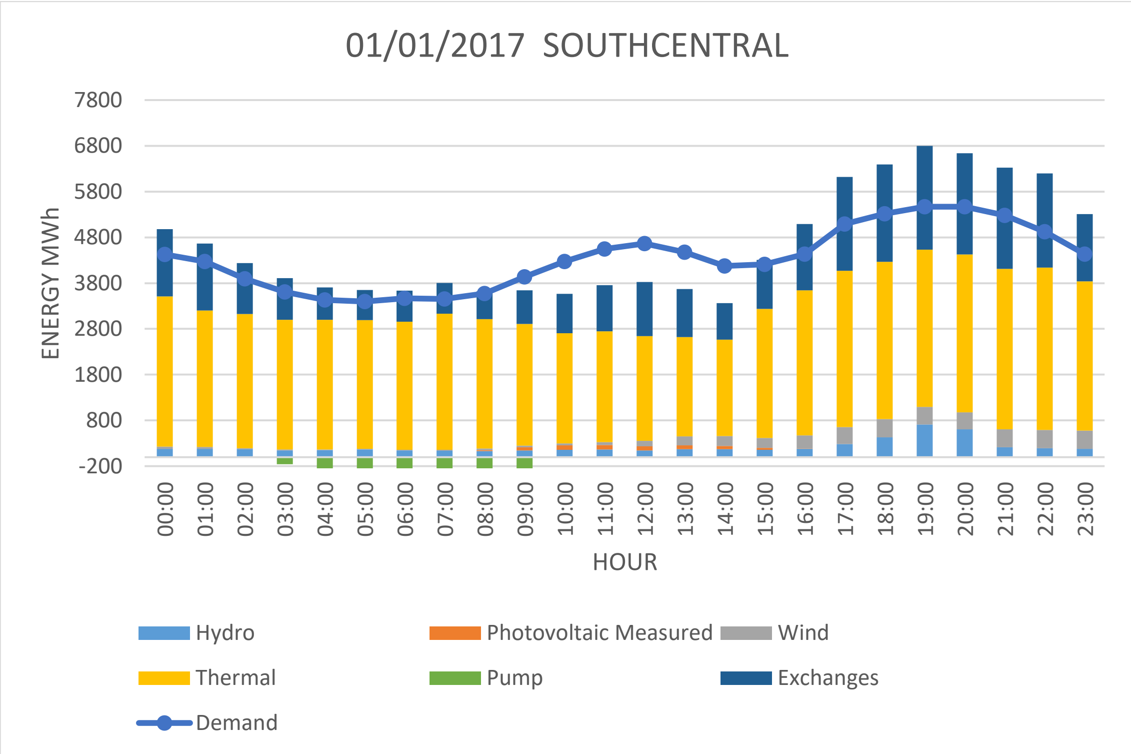


Figure 33 Demand and real energy produced by the sources per hour in the Southcentral area on 1st January

At the same time in the South zone the demand asked 2383 MWh (Figure 34), that is a value a bit higher than the hourly average but different from the other days because in this night most people are consuming electricity. At this time the prevailing source is the traditional one that, in fact, produced 4857 MWh, that is 39% of the local capability. While the renewable sources supplied lightly at the fulfillment of the demand, where the wind turbines produce 688 MWh, using 14% of the zonal wind energy. The solar energy is overlooked, being in the night. The hydro source injected only 29 MWh utilizing the 3% of the energy obtainable from water.

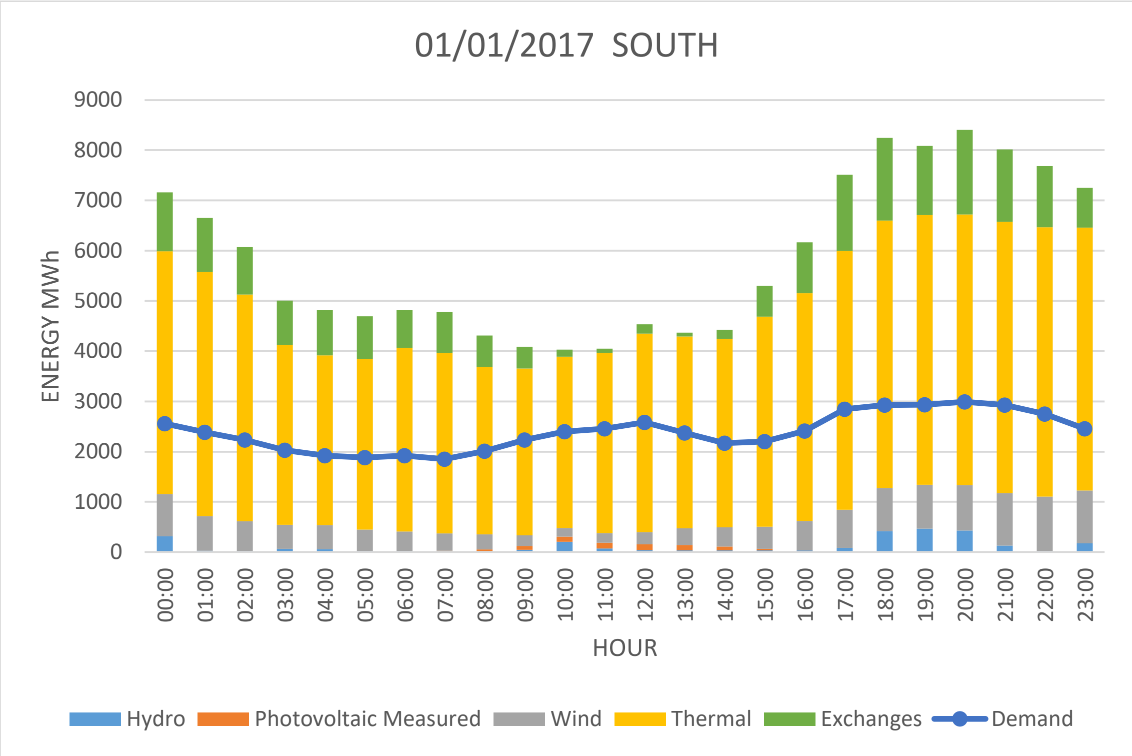


Figure 34 Demand and real energy produced by the sources per hour in the South area on 1st January

4.5. South-Sicily maximum price differences

In 2017 the maximum price difference between the South zone and Sicily zone was on 29th October at hour 12:00, where the Sicily was more expensive. Furthermore, the second largest price difference was on 06th February at 09:00, where the South was cheaper.

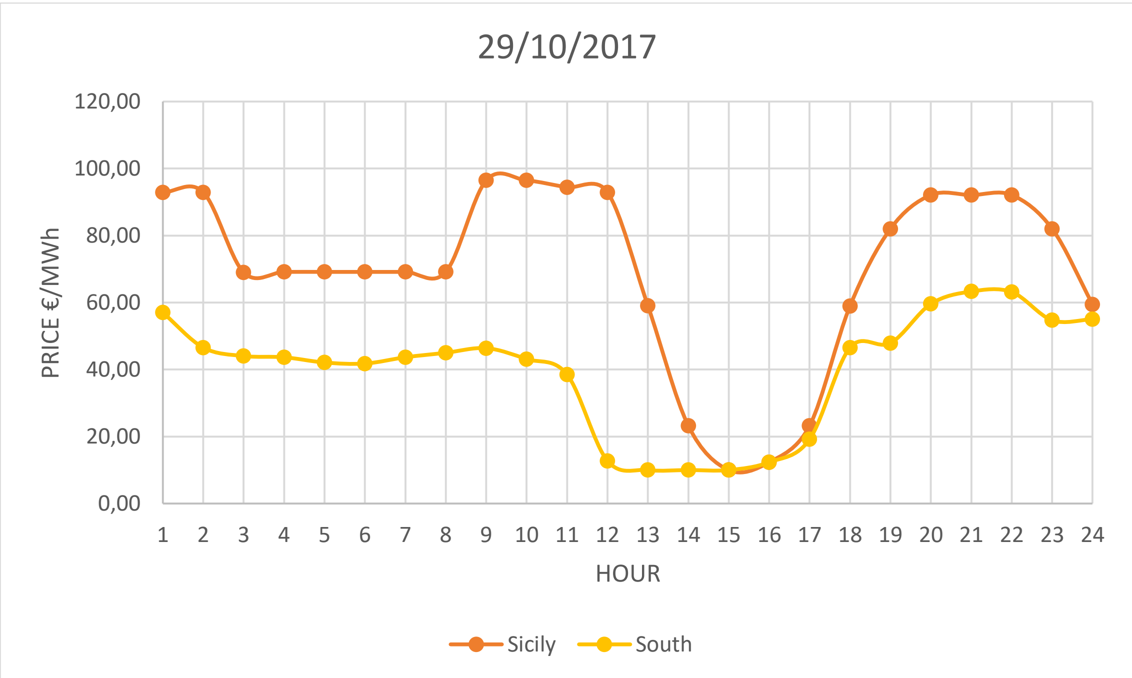


Figure 35 Price per hour of zone Sicily and South on 29th October

During all the 29th of October (Figure 35), the price of Sicily stayed above the South's one, excluding a part of the afternoon, where the maximum difference is registered at 12:00. Indeed the energy price of the biggest Italian isle was 92.90 €/MWh while the price per MWh in the South area was 12.74 €/MWh, so a difference about seven times bigger.

The demand of the Sicily in this period is 1745 MWh (Figure 36), and it is a value under the average, like it is even possible to see from Figure 38 comparing with the demand of the day with the lowest price, because was a Sunday in a part of the season where it is not necessary to use energy changing the temperature.

The Sicily zone has an efficient net productive power divided according to the source:

- Hydro 715 MW
- Photovoltaic 1377 MW
- Wind 1811 MW
- Thermal 5379 MW

The generation of energy in the analyzed period was established mainly from the traditional source, even if a significant contribution is injected by the renewable ones. Indeed, excluding the hydro source which produced only 2 MWh, and the solar panels injected 19 MWh exploiting 1% of the photovoltaic Sicilian energy; the wind supplied 442 MWh that is 24% of the zonal capability. The fuel plants provided the other part of the energy, introducing on the grid 1181 MWh that is 22% of the availability of the zone. Given the high quantity of MWh coming from renewables, the price went up, instead of lowering, because was exploited 297 MWh through the pump.

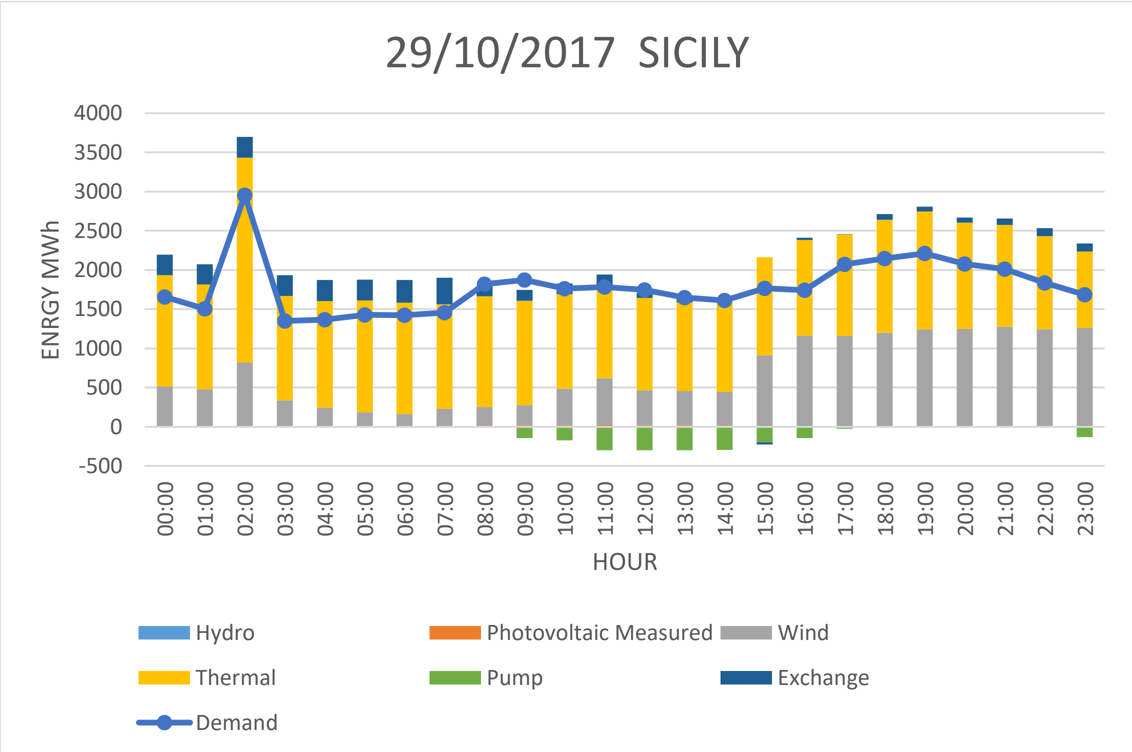


Figure 36 Demand and real energy produced by the sources per hour in the Sicily area on 29th October

On 29th October at 12:00 the South area asked a demand equal to 2375 MWh (Figure 37) that, for the reasons explained in the preceding sections, was lower than zonal average at this hour.

The South zone has an efficient net productive power divided according to the source:

- Hydro 981 MW
- Photovoltaic 3689 MW
- Wind 4992 MW
- Thermal 12379 MW

The generation from renewable sources is quite near to the fuel one, and the result is a zonal price very low. The energy produced by the solar panels was about 115 MWh where was used 3% of the available photovoltaic energy in this zone, and the energy supplied by the wind source was 1175 MWh that is equal to 25% of the wind turbine capacity. The hydro source contributes with a little generation about 31 MWh, using only the 3% of its capacity. Only 24% of the fuel plants, that produced 1948 MWh, were exploited.

The great difference of energy prices between this two areas involves a notable quantity of trades, but being an isle the number of connections is limited, so there would be the risk to overcharge the grid making congestions.

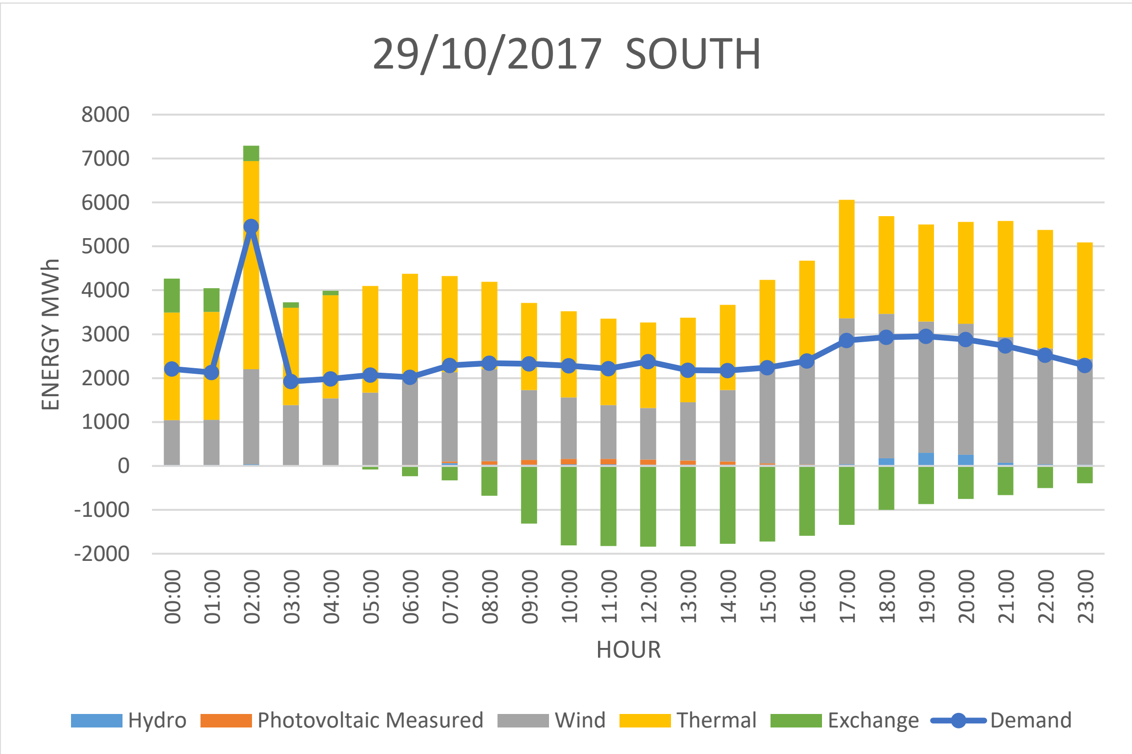


Figure 37 Demand and real energy produced by the sources per hour in the South area on 29th October

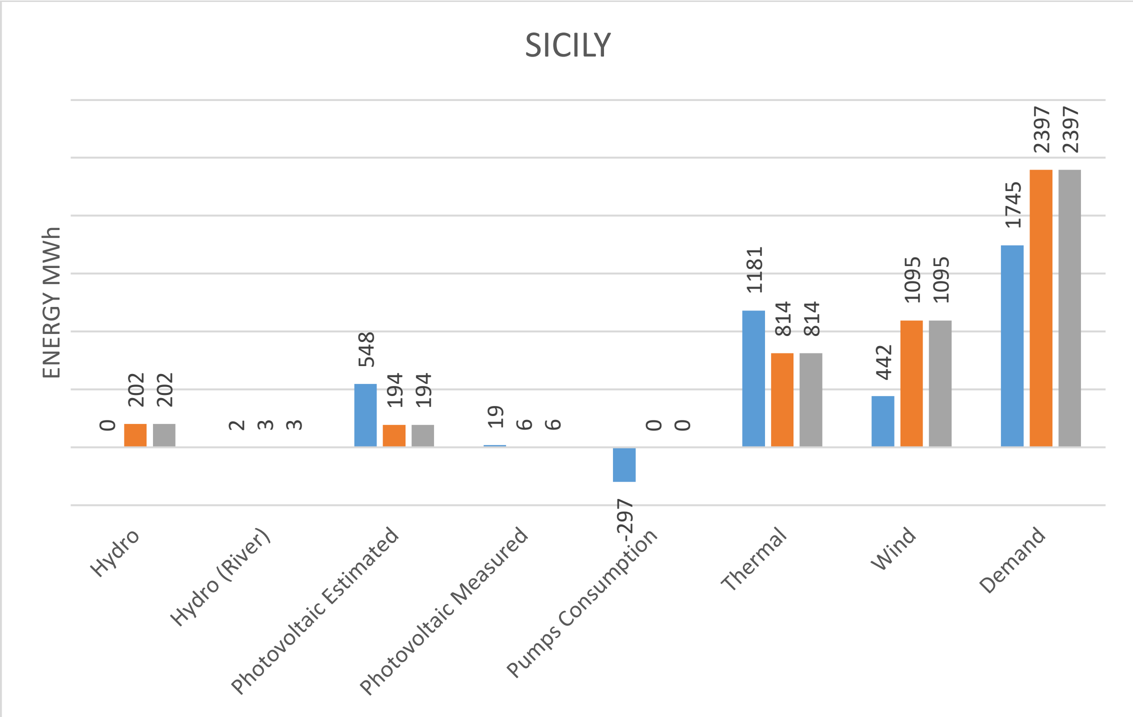


Figure 38 Comparison of the energy produced by the different sources in the Sicily zone, in the 2017 lowest price hour (minp), on 29th October at 12:00 (SIC>S) and on 6th February at 09:00 (SIC<S)

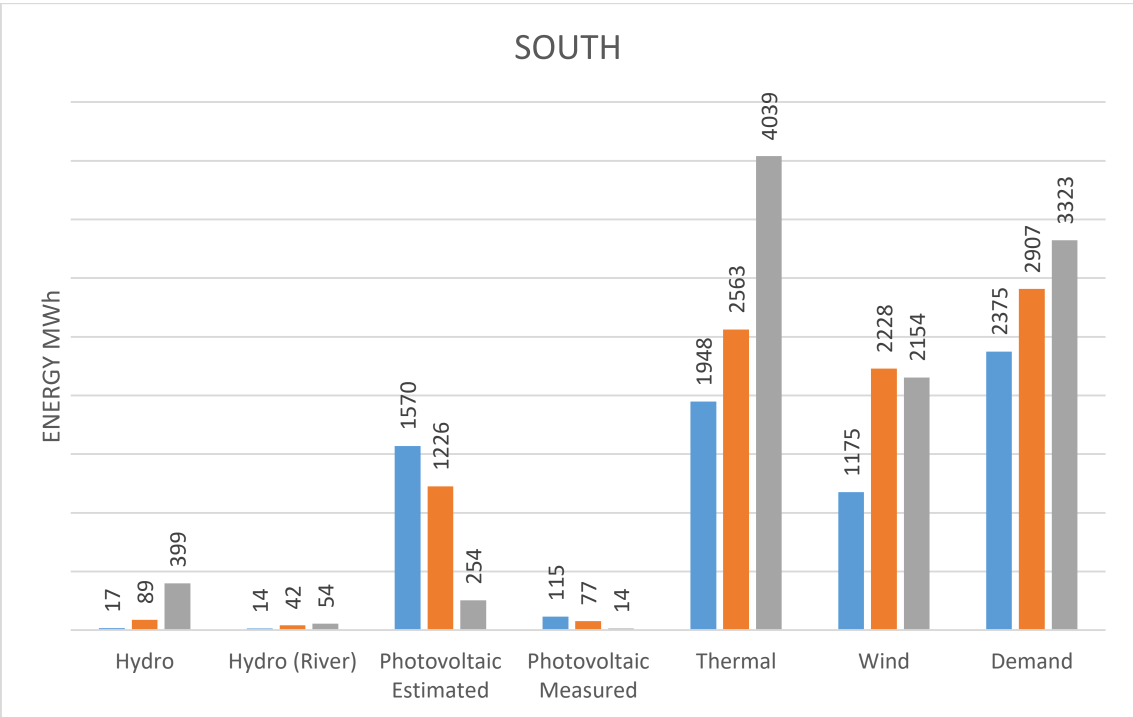


Figure 39 Comparison of the energy produced by the different sources in the South zone, in the 2017 lowest price hour (minp), on 29thOctober at 12:00 (SIC>S) and on 6th February at 09:00 (SIC<S)

On 6th February the two zones have the same prices (Figure 40), excluding the morning and the first part of the afternoon, where the maximum difference takes place at hour 09:00. At this time the island energy price was 0 €/MWh, because there was a huge presence of renewable sources, while the South area had a price about 70 €/MWh, so seven times more.

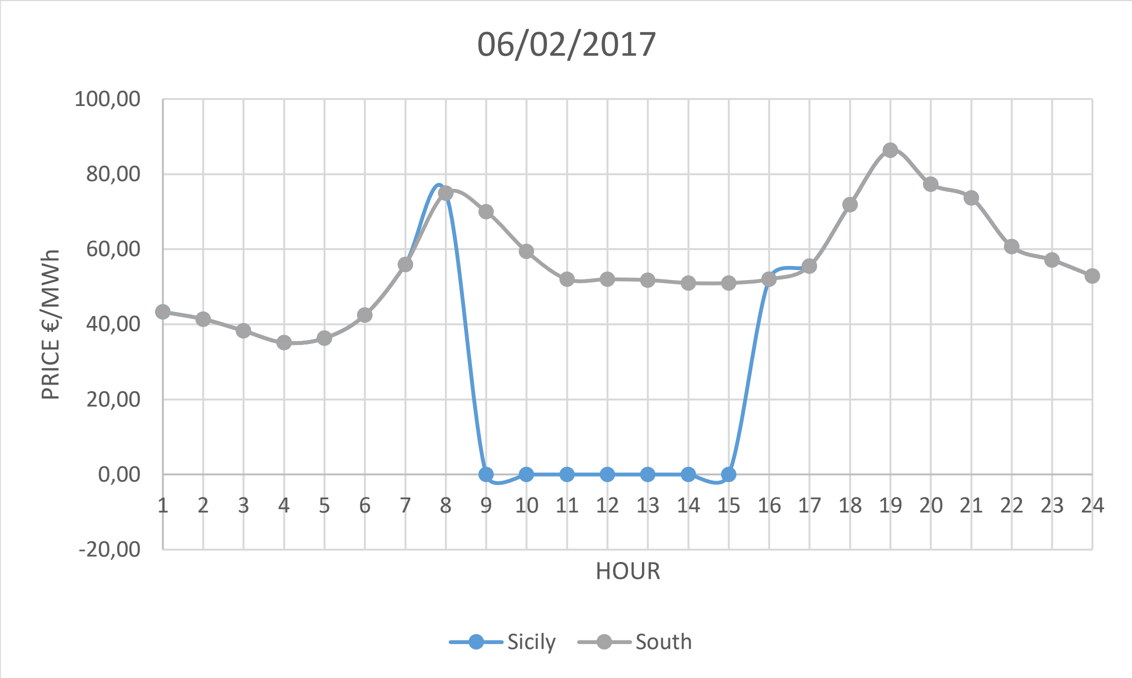


Figure 40 Price per hour of zone Sicily and South on 6th February

In this time range, the demand of Sicily requires 2397 MWh (Figure 41), a common value considering the hour. Considering the price void of the electricity, it is chosen this period as the hour with the lowest price, Figure 38). The low price is obtained by the great production from the renewable energies, in particular the wind source generated 1095 MWh using 60% of the turbines island supply. Only this source exceeds the contribution coming from the traditional source (814 MWh), which corresponds to only 15% of the fuel plants capacity. Also the other two renewable sources injected in the grid a good quantity of energy, the hydro generated 205 MWh using 29% of its availability, and the photovoltaic produced 6 MWh exploiting 0% of the whole solar Sicilian capacity, but considering the time and the season it was between the first hours of solar production where the radiation is not so intense.

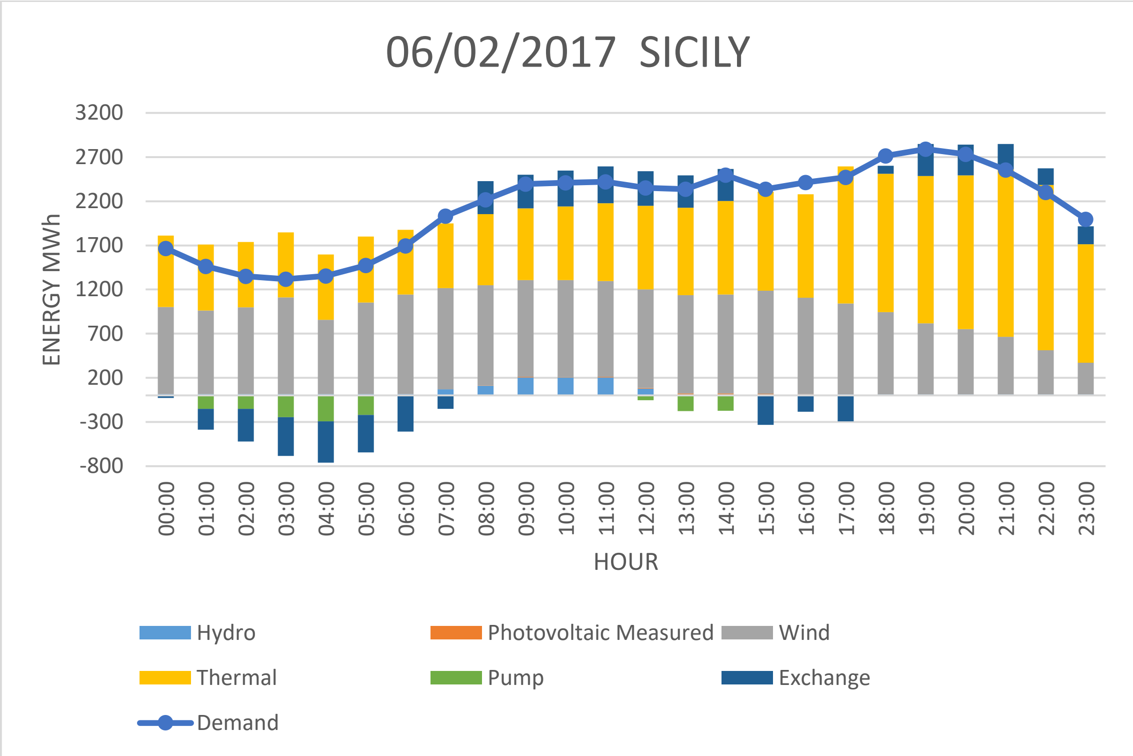


Figure 41 Demand and real energy produced by the sources per hour in the Sicily area on 6th February

In the same period, the South zone had an energy request about 3323 MWh (Figure 42), which is near to the hour zonal average. The great production from the fuel source, that was 4039 MWh, exploits 33% of the traditional source availability, and it is the cause why the zonal price was so high. At the same time a relevant quantity of energy was produced by the renewables, indeed from the hydro source came 454 MWh, which is 46% of its energy, and the wind turbines injected 2154 MWh, which is 43% of the zonal wind source capacity. In the end, as commented before, the photovoltaic contributes with a weak support producing 14 MWh.

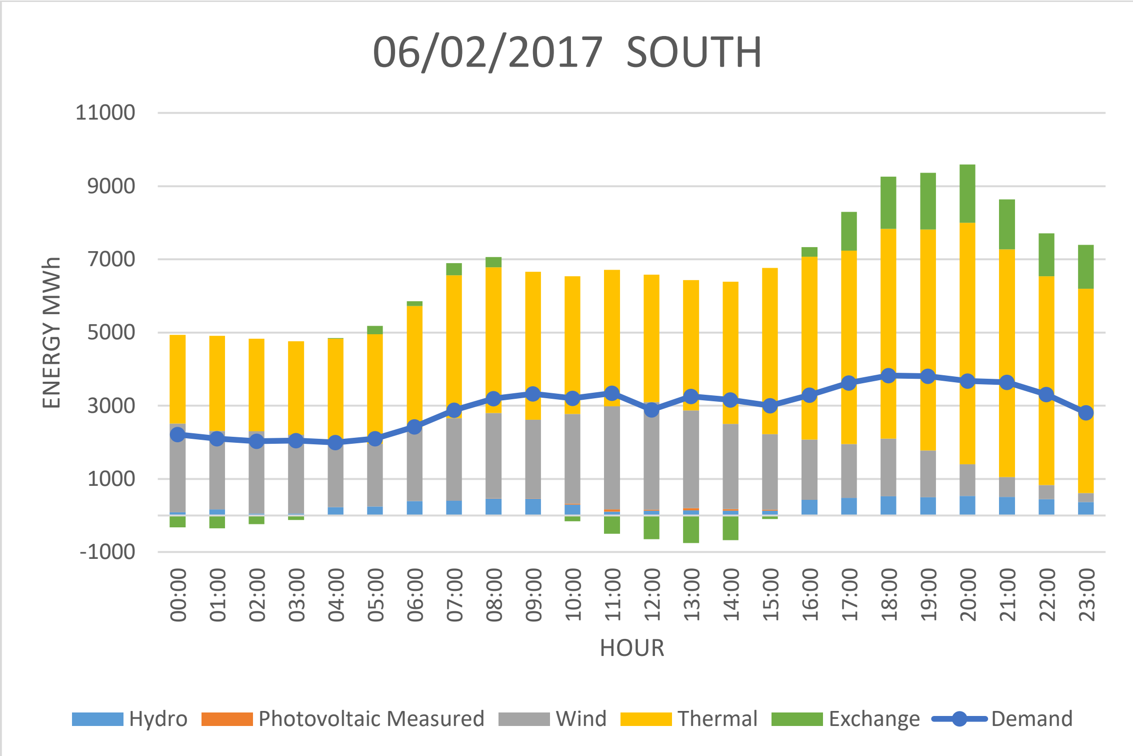


Figure 42 Demand and real energy produced by the sources per hour in the South area on 6th February

From the prices graph (Figure 40) it is possible to see like them are going up starting from the evening, when the renewable sources are weakest and the demand increases. A so big difference between the energy areas involves a great quantity of trades that the electric system is not able to stand, given that the isle owns a limited number of connections, making congestions.

5. Statistical solar and wind energy analysis in 2017

5.1. Solar energy

For this part of the study several data have been downloaded, from Terna, the MWh coming from the solar source for each hour of the year 2017. These data are divided in measured energy and forecast solar production. The aim of the analysis is to observe how much the prediction is accurate at the expense of the effective energy measured, and how it is going to affect the market. The key element of this study is the difference, for each hour, between the forecast and the measure respectively.

The first result obtained is the absence of even a single case wherein the measured solar energy is more than its respective prediction. This attitude in the MGP causes disadvantages for the producers of non-renewable sources, that with lower priority are going to remain out of the market, while if the forecast could be more precise they would have more chance to be selected.

The day in 2017 where was registered the biggest difference between predicton and real energy was on August 14th, in fact the daily amount of the difference was 72935 MWh. Table 1 shows for each hour the MWh coming from the solar energy in that day.

Table 1 Solar energy measured and estimated per hour on August 14th, 2017

Hour	Sol.Measured [MWh]	Sol.Estimated [MWh]
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	3	58
8	86	1148
9	263	3652
10	403	5835
11	503	7666
12	571	8826
13	611	9532
14	618	9671
15	594	9232
16	538	8352
17	453	6760
18	331	4744
19	166	2250
20	30	379
21	0	0
22	0	0
23	0	0
24	0	0

The biggest hour difference scored in 2017 was on April the 8th at 13:00, where the forecast passed the measured energy about 9137 MWh. Table 2 displays for each hour the MWh estimated and the real one in that day.

Table 2 Solar energy measured and estimated per hour on April 8th, 2017

Hour	Sol.Measured [MWh]	Sol.Estimated [MWh]
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	9
8	52	720
9	222	3070
10	392	5670
11	502	7637
12	574	9035
13	606	9743
14	604	9725
15	565	9229
16	504	8114
17	407	6305
18	261	3864
19	96	1321
20	7	89
21	0	0
22	0	0
23	0	0
24	0	0

5.1.1. Average

The first statistical tool to study the difference between the forecast solar energy and the measured solar energy is the average. Table 3 shows the difference between solar energy forecast and the effective one per hour for each month.

Table 3 Monthly per hour average about the difference of the solar energy measured and estimated in 2017

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
01:00	0	0	0	0	0	0	0	0	0	0	0	0
02:00	0	0	0	0	0	0	0	0	0	0	0	0
03:00	0	0	0	0	0	0	0	0	0	0	0	0
04:00	0	0	0	0	0	0	0	0	0	0	0	0
05:00	0	0	0	0	0	0	0	0	0	0	0	0
06:00	0	0	0	0	0	0	0	0	0	0	0	0
07:00	0	2	75	36	217	303	179	52	4	3	5	0
08:00	43	278	1052	726	1288	1413	1184	895	432	198	326	70
09:00	757	1524	3009	2471	3110	3195	3034	2880	2113	1535	1589	864
10:00	2198	2951	4845	4397	4874	4942	4919	4936	4002	3539	3032	2211
11:00	3637	3935	6237	5873	6242	6353	6452	6500	5459	5038	3972	3354
12:00	4375	4539	7018	6853	7141	7348	7476	7570	6419	5983	4285	3925
13:00	4486	4774	7274	7409	7585	7796	8048	8094	6797	6403	4184	3987
14:00	4093	4489	7023	7498	7582	7740	8155	8172	6814	6342	3673	3506
15:00	3070	3718	6215	7096	7214	7377	7778	7851	6418	5783	2688	2309
16:00	1520	2575	4889	6270	6371	6595	6954	6974	5624	4644	1217	956
17:00	303	1101	2993	4864	5078	5368	5657	5631	4237	2947	150	69
18:00	2	100	1102	3069	3381	3718	3937	3755	2375	1018	3	0
19:00	0	0	202	1169	1548	1892	1977	1615	616	52	0	0
20:00	0	0	8	121	325	535	505	257	20	0	0	0
21:00	0	0	0	0	11	50	37	3	0	0	0	0
22:00	0	0	0	0	0	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0	0	0	0	0	0
24:00	0	0	0	0	0	0	0	0	0	0	0	0

How is possible to see in Figure 43, where are analyzed the averages of the solar energy's difference in the light hour, the biggest differences are in the hottest months from April to August, and in the time central band, from 11:00 to 16:00. The highest peaks are achieved in July and August at 14:00, with 8155 MWh and 8172 MWh respectively.

Figure 44 represents the yearly per hour average about the solar energy's difference. It confirms the same results of the monthly average i.e. that the biggest differences between forecast and effective generation from the solar source are in the central hours of the day, between 11:00 and 15:00. The highest hour difference's average, in 2017, is owned by 13:00 with 6415 MWh. Obviously, the night hours noted 0 MWh of solar production.

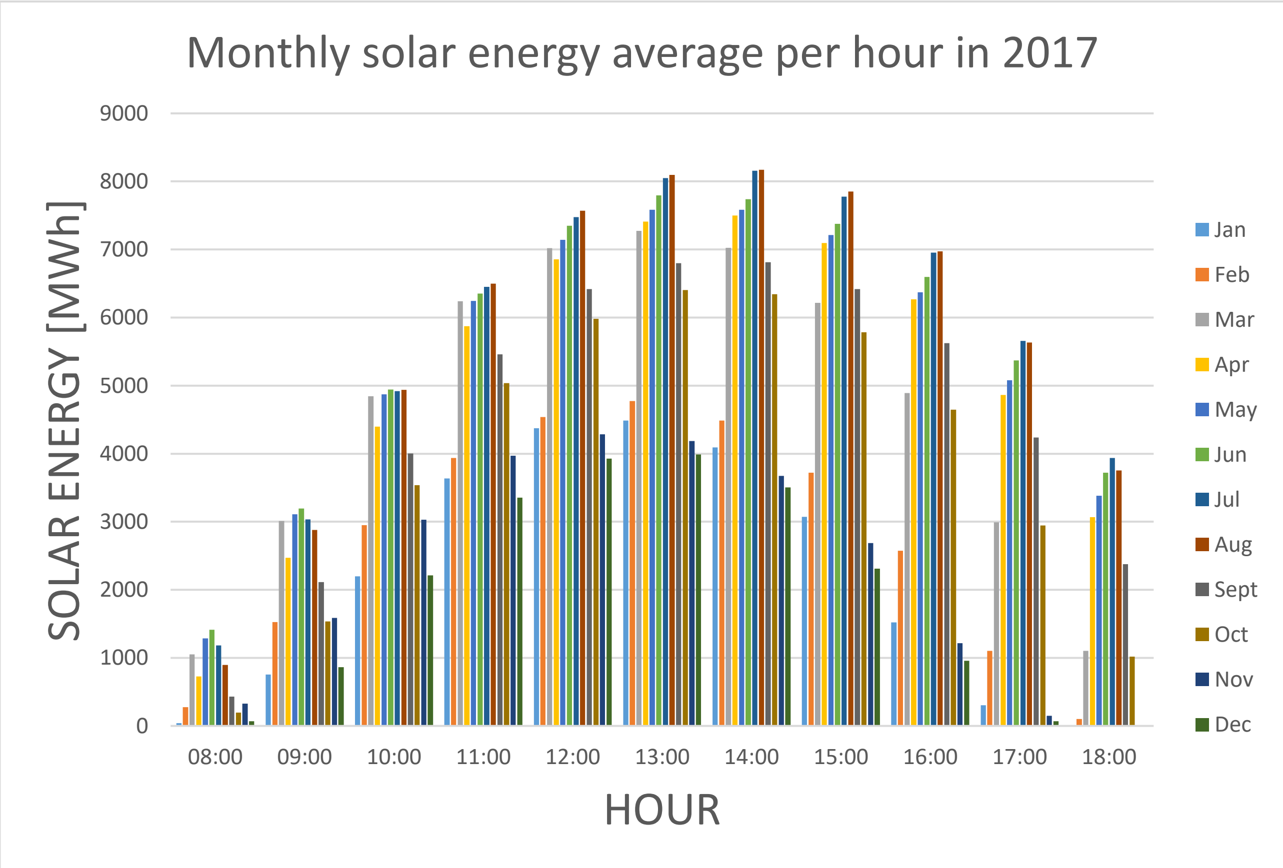


Figure 43 Monthly per hour average about the difference of the solar energy measured and estimated in 2017

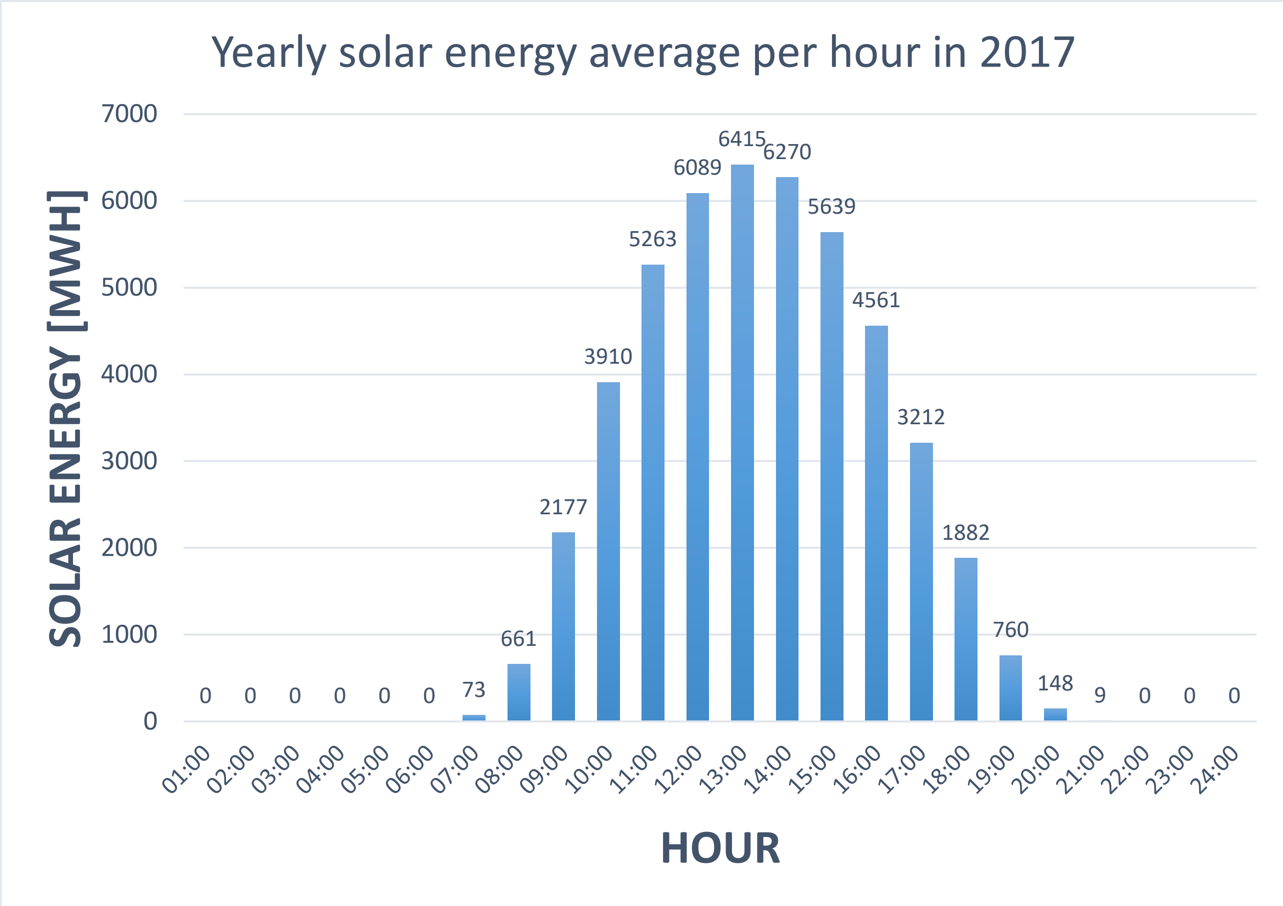


Figure 44 Yearly per hour average about the difference of the solar energy measured and estimated in 2017

5.1.2. Dispersion

Another statistical analysis used to verify the differences between the solar energy measured and its prevision is the dispersion. In Figure 45 each point corresponds to an hour difference, they are grouped according to the belonging hour and divided for different colors. The figure is focused only in the light hours.

It is possible to see that like in the average consideration the differences grown in the central band of the day and in the warm seasons, from April to the first September. Another aspect to note are the zero green points that represent the winter season where at 18:00 the sun is already gone down.

The highest point is the blue one on April the 8th with 9137 MWh.

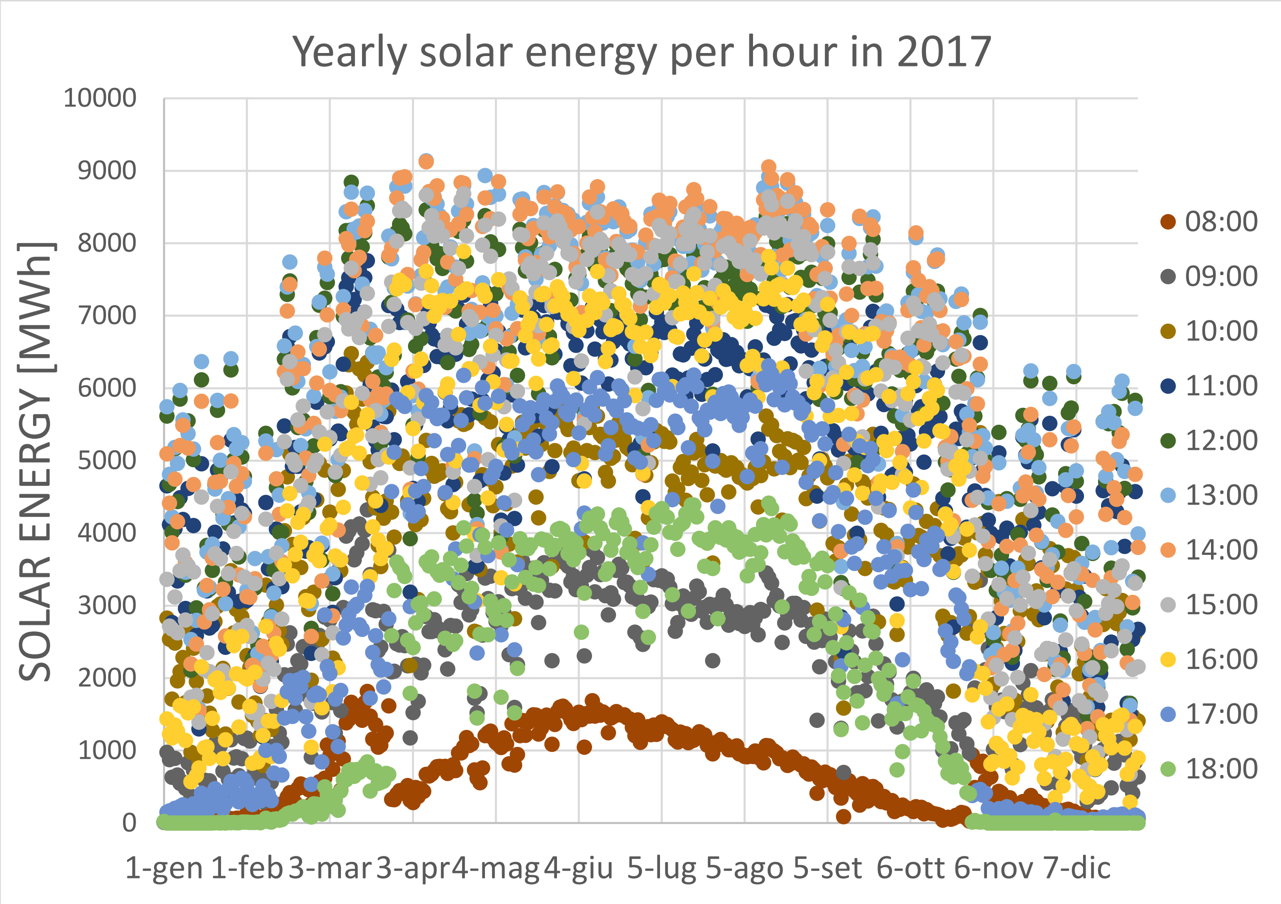


Figure 45 Solar energy's difference dispersion in 2017

5.1.3. Difference's hour curves

In this study the differences between solar prediction and solar effective generation are been separated from their dates and have been organized according a growth order. This kind of study allow to understand how large is the band of the differences for each hour. How is possible to see from Figure 46 this study follows the same trend of the preview ones, i.e. the biggest differences are located in the warmest hours.

Figure 47 and Figure 48 show the difference of the forecast and real solar energy produced in the hottest hour (hours13:00 and 14:00). For the first one, the range goes from 1574 MWh to the maximum year difference about 9137 MWh. For hour 14:00 the difference range goes from 1302 MWh to 9121 MWh. So, in 2017 the minimum value where the forecast passes the real energy quantity in the middle day is about 1400 MWh; these energies in MGP making the crossing point move significantly down because the solar energy production has the highest priority.

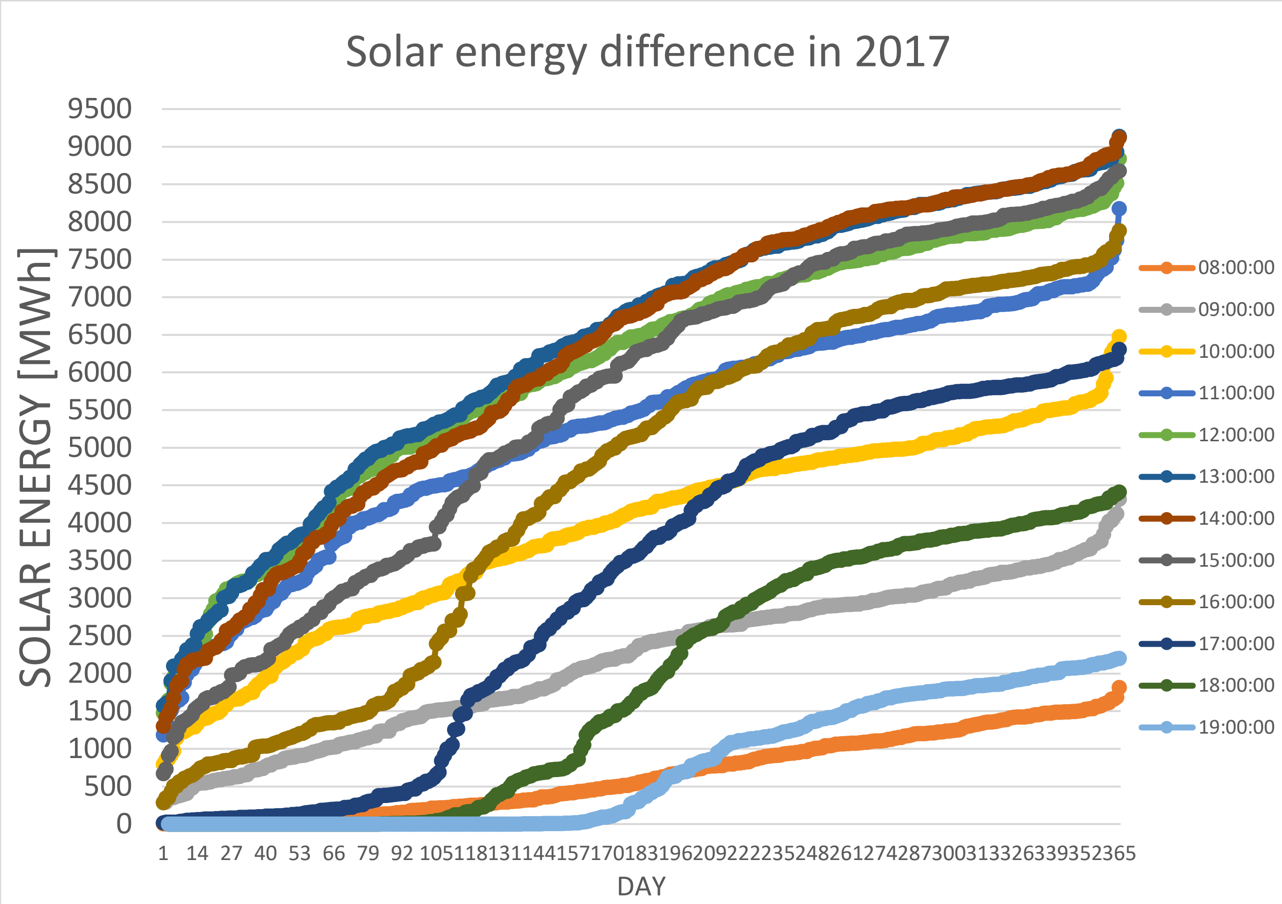


Figure 46 Solar energy difference of light hours in 2017

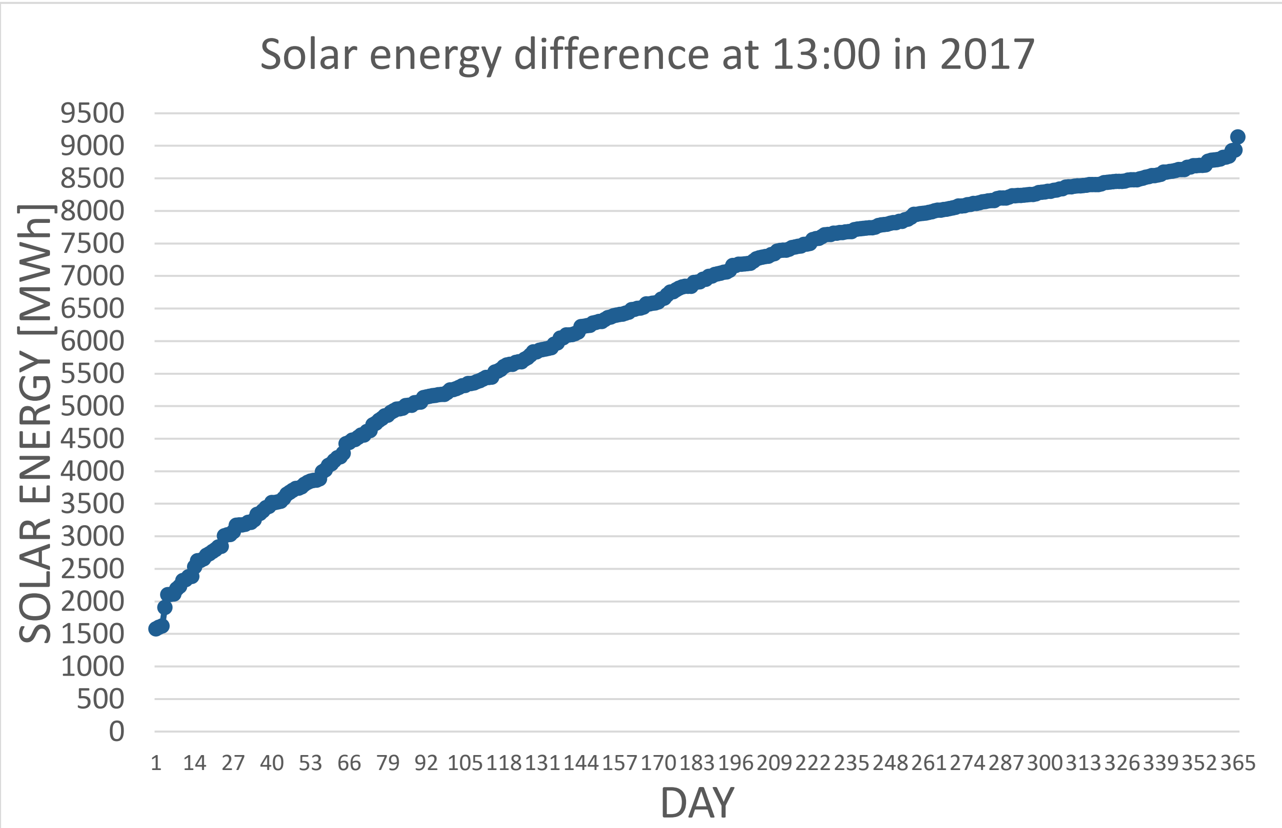


Figure 47 Solar energy difference at 13:00 in 2017

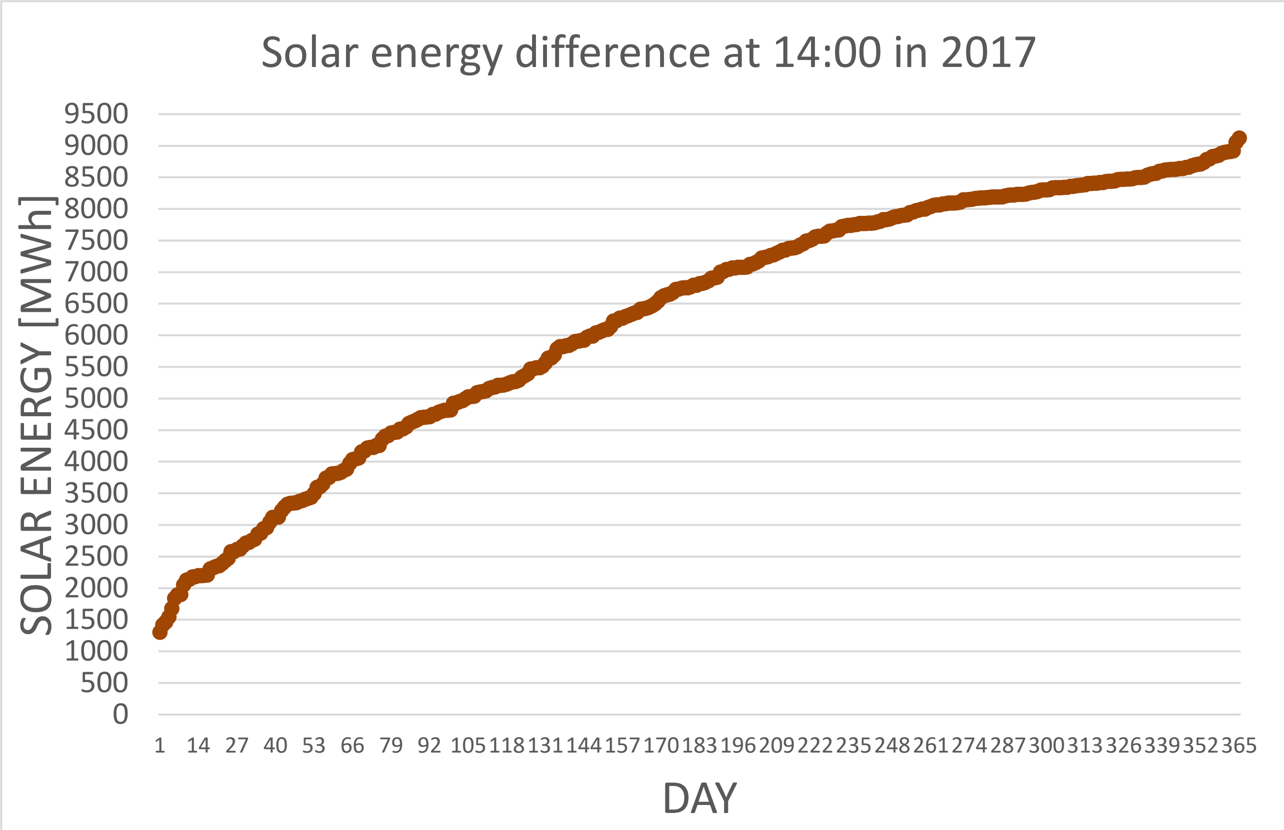


Figure 48 Solar energy difference at 14:00 in 2017

5.2. Wind energy

Like in the study of the solar energy, also for the wind energy data have been downloaded from Terna the MWh forecast and the effective energy supplied by the wind for each 2017 hour. The key element of this analysis is the difference from the energy predicted and the real one. The analysis wants to observe how the MGP making is affected by the difference of the renewable sources that have highest priority

Contrary to the solar energy, the difference between forecast wind energy and measured one is both positive than negative. The highest negative difference in 2017 when the energy produced by the wind source passes its prediction is in January 13th, at 12:00, it is about 4680 MWh. That day is also the one with the biggest difference in the whole year, amounting to 95733 MWh. Table 4 shows for each hour the wind energy produced and the measured, in this day the forecast is pretty lower the effective energy.

Table 4 Wind energy produced and forecasted in January 13th, 2017

Hour	Eol.Measured [MWh]	Eol.Estimated [MWh]
1	4445	1018
2	4742	1023
3	4869	1072
4	4977	1106
5	5063	1089
6	5091	1063
7	5190	1031
8	5357	1004
9	5456	967
10	5412	1024
11	5704	1176
12	6108	1428
13	6285	1690
14	5956	1837
15	5771	1942
16	5915	2021
17	5888	2020
18	5848	1972
19	5678	1995
20	5650	2019
21	5570	2070
22	5872	2152
23	6188	2222
24	5925	2287

In December 28th at hour 03:00 the biggest positive difference in 2017 was noticed, i.e. when the forecasted wind energy exceeds the real one about 1426 MWh. Table 5 shows for each hour the wind energy produced and measured.

Table 5 Wind energy produced and forecasted in December 28th, 2017

Hour	Eol.Measured [MWh]	Eol.Estimated [MWh]
1	4623	5488
2	4487	5421
3	3907	5333
4	3943	5229
5	3889	5132
6	3721	5134
7	4394	5214
8	4993	5286
9	5761	5342
10	6137	5403
11	6277	5557
12	6115	5721
13	5608	5815
14	5497	5838
15	5306	5768
16	5872	5681
17	5822	5570
18	5456	5431
19	5260	5290
20	5016	5139
21	4763	4991
22	4632	4842
23	4584	4656
24	4427	4444

5.2.1. Average

The first statistical tool to study the difference between the forecast wind energy and the measured wind energy is the average. Table 6 shows the difference's average between wind energy forecast and the effective one per hour for each month.

Table 6 Monthly per hour average about the difference of the wind energy measured and estimated in 2017

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
01:00	-579	-394	-266	-217	-219	-64	-128	-102	-201	-215	-94	-228
02:00	-591	-377	-288	-214	-248	-66	-128	-110	-220	-144	-42	-149
03:00	-567	-366	-265	-186	-243	-64	-111	-94	-229	-74	-50	-117
04:00	-528	-355	-292	-198	-215	-79	-78	-95	-163	-24	-105	-91
05:00	-499	-333	-325	-192	-217	-89	-65	-117	-184	-33	-150	-71
06:00	-490	-316	-358	-211	-227	-99	-69	-149	-221	-48	-184	-82
07:00	-516	-315	-353	-234	-213	-109	-68	-154	-241	-121	-233	-176
08:00	-564	-306	-288	-132	-121	-82	-5	-113	-234	-116	-211	-247
09:00	-616	-304	-213	-41	-70	-91	17	-91	-154	-63	-169	-260
10:00	-591	-289	-184	-74	-83	-70	22	-158	-141	-31	-151	-234
11:00	-566	-267	-202	-118	-59	-47	14	-168	-85	-53	-174	-281
12:00	-560	-251	-206	-89	-17	-55	-14	-130	-64	0	-200	-244
13:00	-547	-273	-161	-126	-51	-13	-67	-105	-93	23	-200	-174
14:00	-536	-286	-155	-209	-79	10	-84	-106	-90	45	-212	-126
15:00	-554	-313	-195	-184	-12	-32	-96	-137	-121	85	-176	-167
16:00	-579	-380	-265	-134	-53	-85	-81	-170	-129	15	-159	-238
17:00	-537	-389	-311	-228	-176	-110	-143	-179	-244	-144	-165	-275
18:00	-522	-366	-344	-251	-307	-145	-167	-175	-306	-208	-163	-314
19:00	-546	-395	-328	-188	-310	-158	-183	-139	-292	-233	-139	-280
20:00	-547	-361	-326	-123	-239	-88	-139	-76	-243	-235	-115	-221
21:00	-532	-340	-321	-138	-193	-49	-98	-88	-184	-228	-94	-206
22:00	-526	-345	-320	-138	-167	-53	-95	-103	-157	-238	-85	-203
23:00	-542	-337	-344	-113	-156	-100	-120	-126	-156	-223	-87	-227
24:00	-480	-364	-338	-146	-182	-108	-141	-140	-161	-217	-104	-215

The negative trend of the average study shows like the measured of the generation coming from the wind turbines are more than their predictions, so it means a MGP price bigger because there are some traditional producers that would not been entered inside the coupling market if the prediction would be more accurate.

Figure 49 and Figure 50 report the monthly average of the difference between the forecast and the real energy produced, the second shows also how they are distributed according to the twenty-four hours but a particular trend does not appear. However, Figure 49, shows for each month the averages of the daily hours. The average is quite constant during each month, excluding the first three months.

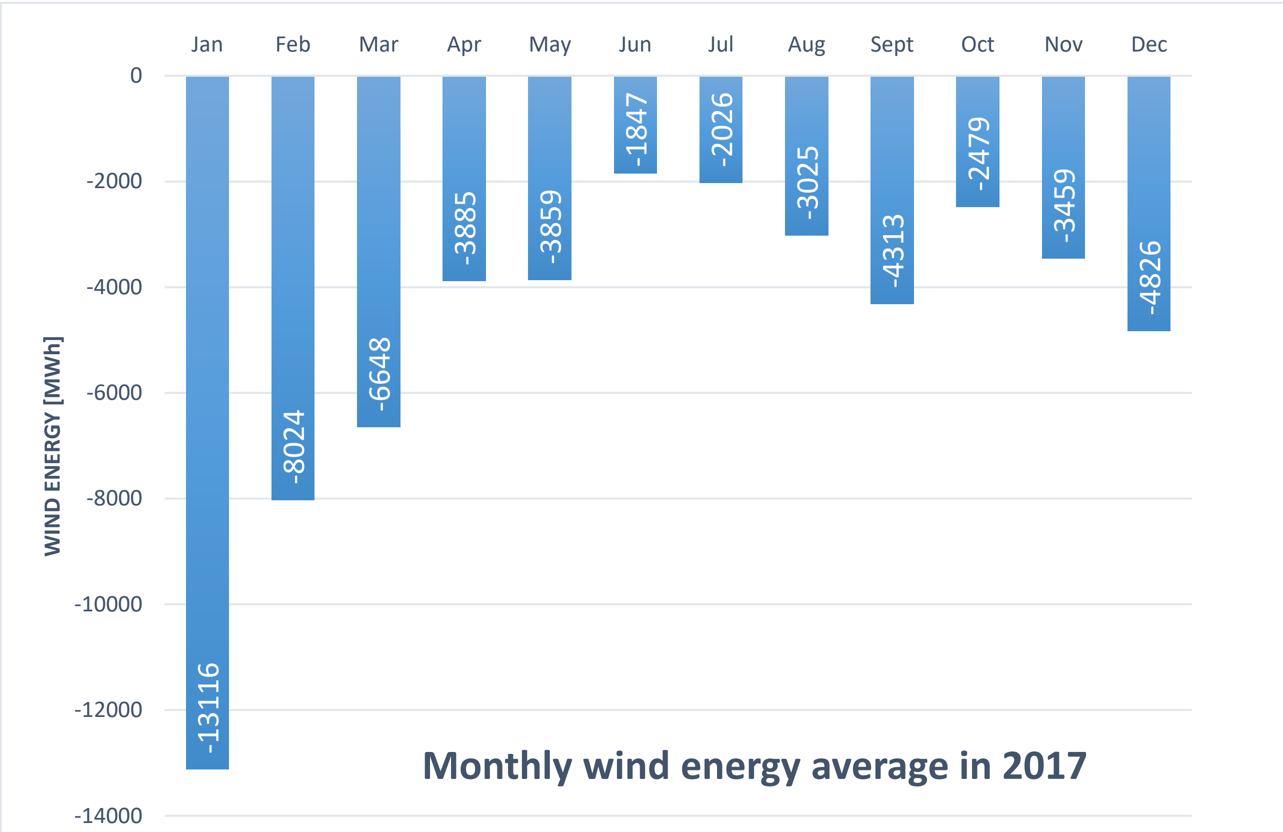


Figure 49 Monthly average about the difference of the wind energy measured and estimated in 2017

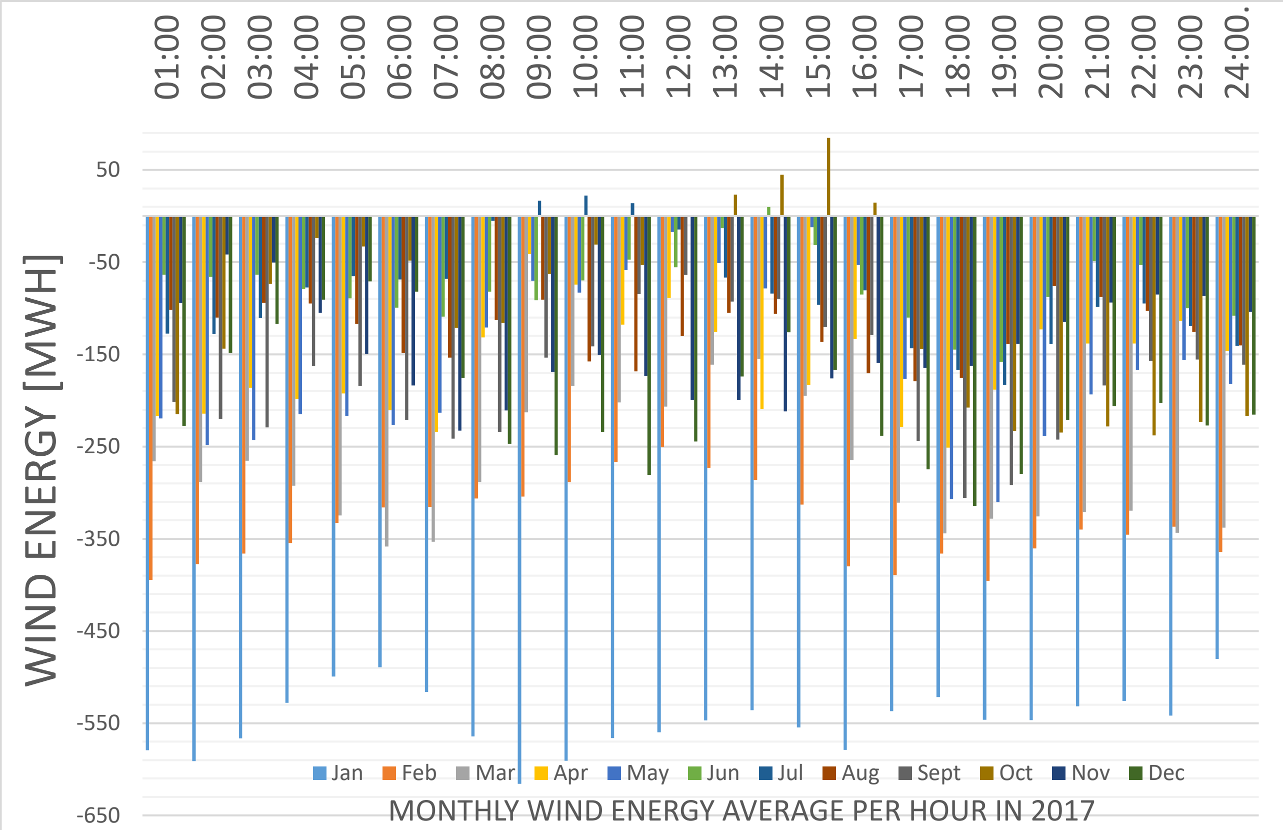


Figure 50 Monthly per hour average about the difference of the wind energy measured and estimated in 2017

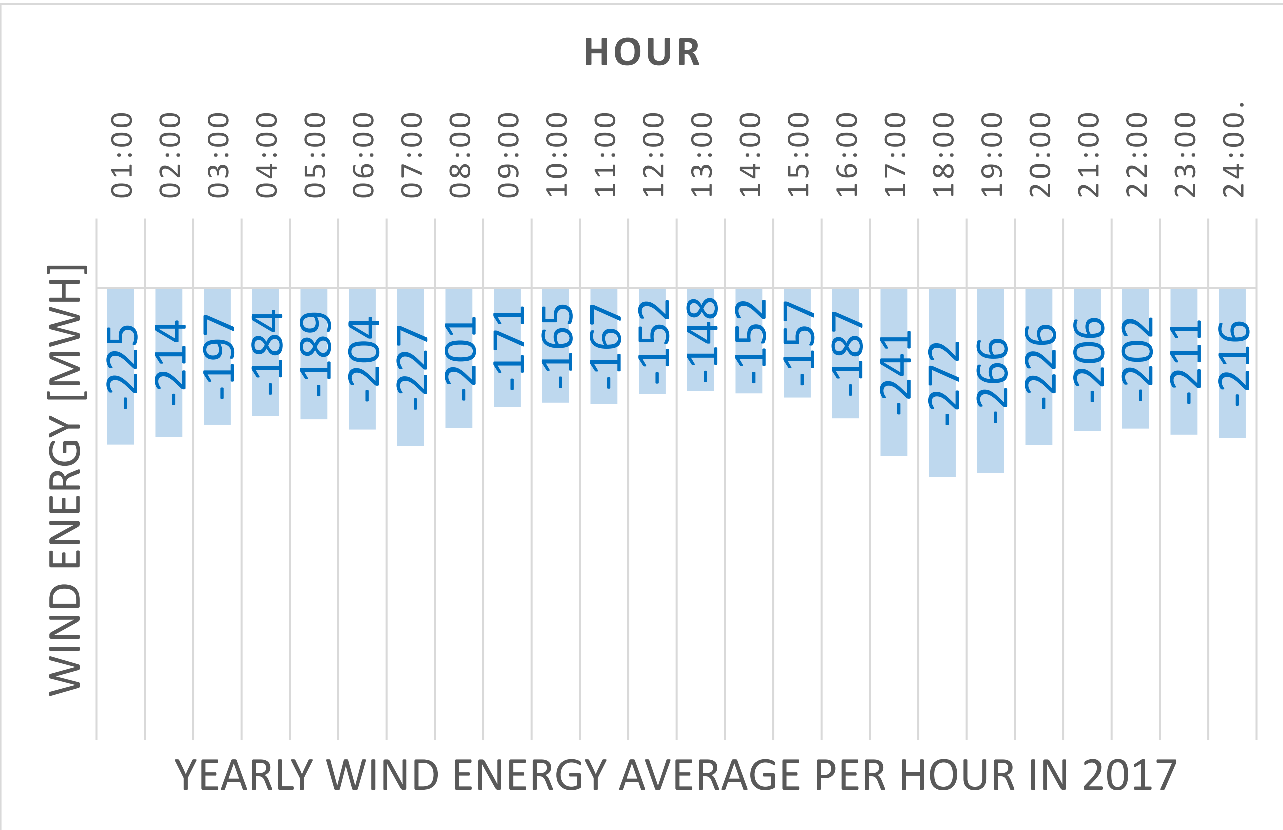


Figure 51Yearly per hour average about the difference of the wind energy measured and estimated in 2017

The biggest differences are recorded in January, where the amount of the averages in the twenty-four hours is about 13116 MWh not forecast. It is possible to observe like in the warm period, that the difference decreases and then growths up in the autumn.

Figure 51 analyzes the yearly difference average per hour, and also this graph confirms the trend that the measured wind energy is bigger than the prediction of it. The yearly average is quite constant about 200 MWh not anticipated, while the highest difference's average in 2017 was noted by the 18th hour.

5.2.2. Dispersion

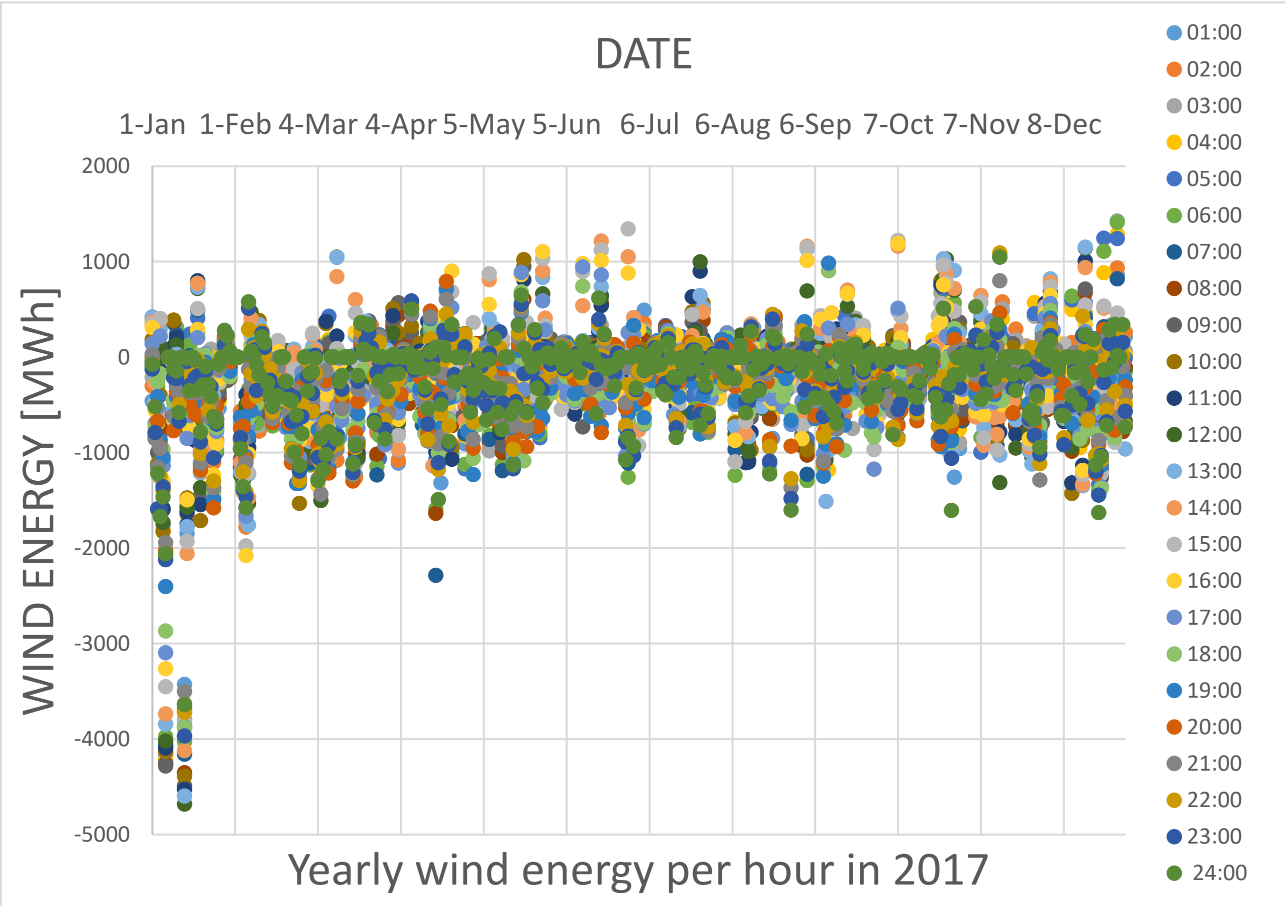


Figure 52 Wind energy's difference dispersion in 2017

Figure 52 represents the difference dispersion about the forecast wind energy and the energy produced by the source. This analytic method is obtained following the same path of the solar chapter (4.1.2), but in this case the points follow a random trend, getting positive and negative values around zero. The only exception is individually the first days of the year when are achieved great negative differences, so the measured energy is above than its preview.

From the graph it is possible to see the minimum value, in January 13th, when the wind energy difference is about 4680 MWh in favor of the real energy; while the maximum point is in December 28th, with 1426 MWh more in the forecast than in measured ones.

5.2.3. Difference hour curves

In this study the differences between wind prediction and wind effective generation have been separated from their dates and have been organized according to a growth order. This kind of study in the solar case shows like the hour impacts on the development of the curves, while for the wind energy, as shown in Figure 53, every time has the same trend.

How commented before, the difference about the wind energy estimated and the measured does not follow a specific criterion.

Figure 53 Wind energy differences per hour in 2017

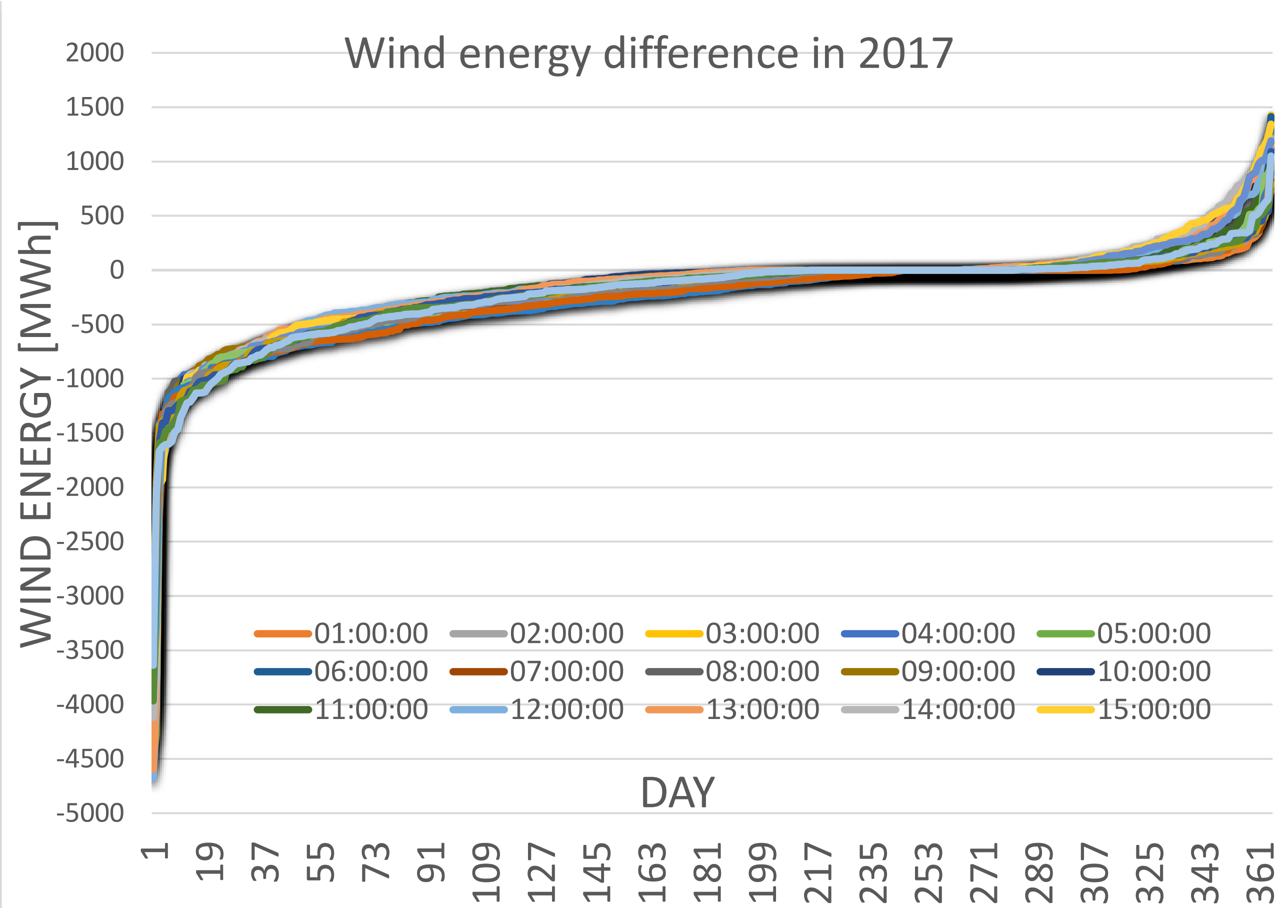


Figure 54 describes hour 13:00 in 2017, it is chosen this one because it is possible to compare with the respective curve of the solar energy (Figure 47). Here the smallest value is 4595 MWh and the minus sign means that the measure is bigger than the forecast; while the highest positive amount is 1151 MWh, so the estimation was greater than real production. These number are drastically lower than the respective values in the solar study, indeed the biggest difference was about 9137 MWh.

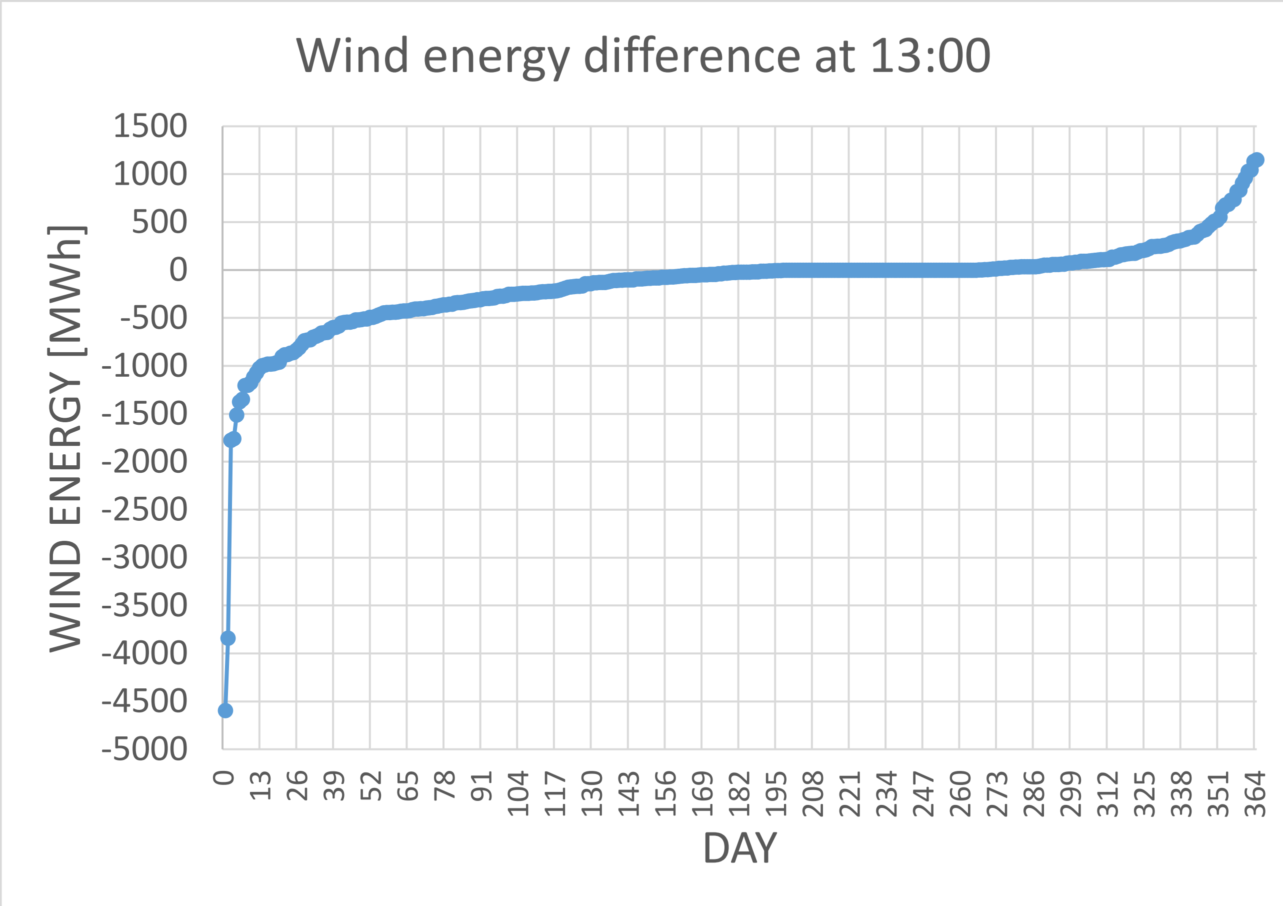


Figure 54 Wind energy differences at 13:00 hour in 2017

6. MCP if the renewable forecast were more accurate

Chapter 5 has described with different tools some statistics about the difference between the forecast of solar and wind energy and the real energy produced by the solar panels and by wind turbines. Basing especially on the average's tool it is possible to say that the prediction of solar energy is particularly above the real solar energy, according the period, while usually the wind energy measured is bigger than its respective prediction. But, analyzing the number of the two differences is clear that the difference about the solar energy is two times than the wind one. This impact drastically on the MGP making especially on the offer curve, because it is based on the forecast. Indeed, one of the elements of the merit order is the type of generation and the renewable suppliers own the highest priority. If the total prediction of the renewable sources is overestimated some traditional producers, or in general producers with lower merit order, cannot enter the market, while they could enter if the forecasts were more accurate.

The aims of this study are:

- To sum the two differences about the solar and wind energy in 2017 hours where there were not grid congestions
- To calculate the MCP of these hours with the offers located in the GME's site
- Translate the offer curve deleting the forecast part of energy that did not appear
- To calculate the new MCP after the translation of the offer curve
- To analyze the suppliers whose offers lie inside the range between the "old" and "new" MGP

The hours without congestions analyzed in 2017 are 1159. Since it is not possible to show every case, the Table shows the daily mean of MCP and energy quantity accepted, in the original market, together with the daily mean MCP and the energy quantity eventually accepted in the market with the offer curve translated. The cases where the daily average of the real market is bigger than the daily average of the translated one are the consequences of the statistical tool, because all 1159 hours present a "new" MCP bigger than the real one.

Table 7 Daily average of MCP and energy accepted quantity in the real market, and daily average of MCP and energy accepted eventually quantity with the offer curve translated

Date	Average daily Price [€/MWh]	Average Daily Quantity [MWh]	Average Daily Price Transl. [€/MWh]	Average Daily Quantity Transl. [MWh]
1-Jan	49,13	23367	52,07	23350
2-Jan	52,95	26210	53,00	26210
3-Jan	65,28	40095	65,00	40097
9-Jan	101,92	45428	100,00	45546
10-Jan	124,40	42164	130,53	42059
11-Jan	103,48	44789	110,36	44480
14-Jan	78,79	37501	75,90	37529
15-Jan	53,44	25153	53,44	25153
28-Jan	74,79	30750	76,31	30750
29-Jan	53,50	25159	53,50	25159
30-Jan	111,00	42046	129,42	41659
4-Feb	54,76	30395	53,07	30502
5-Feb	65,86	30097	61,60	30141
6-Feb	90,38	39021	87,82	39024
7-Feb	75,21	38568	75,00	38593
8-Feb	95,50	42525	101,79	42288
9-Feb	92,50	42808	92,90	42791
10-Feb	103,08	43565	103,08	43565
12-Feb	52,43	26738	61,63	26702
13-Feb	63,40	36747	63,39	36747
15-Feb	52,12	32100	52,00	32105
16-Feb	72,14	37161	76,67	37163
20-Feb	105,12	39615	138,29	38864
21-Feb	64,60	36996	70,32	37045
23-Feb	55,03	31796	55,03	31796
24-Feb	52,00	31772	51,83	31772
25-Feb	50,29	31082	59,51	31002
26-Feb	48,88	25881	56,11	25832
28-Feb	53,00	31328	53,00	31328
1-Mar	56,41	36047	56,88	36084
2-Mar	53,00	31585	52,00	31585
3-Mar	70,69	40127	68,25	40135
4-Mar	49,61	30002	51,91	29987
5-Mar	52,96	24977	58,90	24974
6-Mar	51,85	34339	56,28	34335
7-Mar	65,84	38229	62,87	38237
8-Mar	53,88	34595	53,38	34604
11-Mar	47,31	29551	49,58	29553
12-Mar	45,09	25893	55,30	25810
13-Mar	51,70	37795	75,65	37544

Date	Average daily Price [€/MWh]	Average Daily Quantity [MWh]	Average Daily Price Transl. [€/MWh]	Average Daily Quantity Transl. [MWh]
18-Mar	45,78	29729	50,06	29693
19-Mar	40,23	24280	47,29	24187
20-Mar	50,25	34876	68,36	34740
21-Mar	50,40	34315	60,77	34266
23-Mar	48,00	30026	48,62	30026
24-Mar	51,69	36348	67,00	36231
25-Mar	44,98	29862	61,03	29643
26-Mar	41,28	25446	48,43	25395
27-Mar	42,84	36886	53,28	36764
29-Mar	45,48	38222	65,47	38105
30-Mar	49,95	34196	52,32	34196
31-Mar	45,49	37306	73,86	37096
1-Apr	44,45	29541	60,08	29411
3-Apr	49,05	36272	62,96	36255
4-Apr	51,77	37493	98,88	36927
5-Apr	59,95	36642	85,24	36251
7-Apr	47,65	37126	77,68	36822
8-Apr	35,28	28146	55,37	27935
9-Apr	39,23	24249	51,22	24086
11-Apr	46,49	35900	75,24	35597
12-Apr	50,09	37485	91,59	36896
13-Apr	42,52	35882	57,46	35678
14-Apr	45,83	34449	70,24	34171
15-Apr	40,25	26230	52,02	26084
16-Apr	29,89	21194	42,89	21081
17-Apr	27,87	21941	42,27	21730
18-Apr	53,00	29614	53,50	29614
19-Apr	44,79	35599	62,48	35511
21-Apr	51,34	36942	65,66	36843
22-Apr	44,55	28466	59,17	28301
23-Apr	40,35	21499	40,71	21505
28-Apr	51,66	36047	60,60	35880
29-Apr	38,19	28464	51,11	28269
30-Apr	31,40	23697	48,45	23561
1-May	31,85	22976	46,77	22885
2-May	53,16	36051	90,22	35582
3-May	52,35	37485	74,05	37362
4-May	51,17	38567	79,23	38255
5-May	47,55	35738	71,15	35437
6-May	44,05	28100	53,81	27934
7-May	32,87	23481	41,16	23405

Date	Average daily Price [€/MWh]	Average Daily Quantity [MWh]	Average Daily Price Transl. [€/MWh]	Average Daily Quantity Transl. [MWh]
8-May	55,53	36321	84,84	36009
9-May	50,92	38377	74,71	38150
10-May	56,14	38306	114,32	37357
11-May	60,21	35349	63,28	35307
12-May	45,89	36538	71,21	36409
15-May	46,43	36057	73,79	35899
16-May	42,80	36238	57,30	36035
17-May	48,34	35979	68,10	35802
18-May	56,52	37136	105,27	36264
19-May	47,87	31327	51,58	31296
20-May	39,48	29696	50,79	29494
21-May	25,40	24292	45,16	23992
23-May	47,61	37912	98,75	37347
24-May	44,36	37689	89,88	37261
25-May	51,44	37649	104,14	36987
26-May	50,18	37869	78,12	37617
27-May	40,00	29801	54,42	29755
28-May	26,64	24100	49,19	24034
29-May	48,28	37968	96,54	37485
30-May	51,52	38845	113,00	37959
3-Jun	43,45	28298	65,16	28298
4-Jun	34,79	25266	53,06	25209
10-Jun	39,68	29841	53,57	29769
11-Jun	43,55	25621	47,56	25587
18-Jun	37,78	26341	44,90	26316
22-Jun	54,70	32411	57,00	32363
24-Jun	45,07	32885	59,43	32650
30-Jun	60,50	44813	99,16	44122
1-Jul	40,73	32147	57,86	32004
2-Jul	36,35	28060	48,44	27952
4-Jul	49,83	42271	67,63	41896
5-Jul	48,33	32333	48,79	32324
7-Jul	48,24	44121	89,75	43440
10-Jul	49,87	31509	49,87	31509
12-Jul	49,62	33582	49,87	33582
13-Jul	49,87	33312	49,87	33312
15-Jul	40,30	34234	61,72	33945
16-Jul	34,65	27945	48,56	27778
17-Jul	49,73	32920	51,99	32894
22-Jul	42,61	35040	73,94	34675
23-Jul	40,87	29361	62,50	29057

Date	Average daily Price [€/MWh]	Average Daily Quantity [MWh]	Average Daily Price Transl. [€/MWh]	Average Daily Quantity Transl. [MWh]
25-Jul	49,54	32461	49,54	32461
26-Jul	62,67	38455	80,24	38037
27-Jul	53,00	34784	56,09	34763
29-Jul	50,87	32978	106,46	32443
2-Aug	54,33	31732	54,33	31732
7-Aug	48,27	31630	78,49	31380
9-Aug	96,57	37928	103,27	37773
11-Aug	39,04	33443	50,59	33388
12-Aug	42,62	27414	85,68	27153
13-Aug	37,14	23988	51,94	23848
14-Aug	41,47	27711	66,89	27506
15-Aug	38,32	23717	53,38	23633
16-Aug	49,41	31185	114,62	30646
17-Aug	48,92	31066	88,73	30630
18-Aug	47,66	33282	97,27	32839
19-Aug	41,19	28425	63,19	28204
20-Aug	38,89	24255	54,95	24106
23-Aug	49,01	35420	97,14	34855
24-Aug	50,51	35848	142,31	34949
30-Aug	108,52	42112	111,74	42084
2-Sep	47,77	31576	64,84	31378
3-Sep	46,42	27146	54,14	27096
4-Sep	56,08	36823	126,19	35900
5-Sep	53,93	31292	53,93	31292
6-Sep	55,75	31682	53,25	31776
8-Sep	54,90	35032	74,08	34503
9-Sep	46,37	30541	57,10	30484
10-Sep	46,66	27873	47,10	27875
11-Sep	51,80	31817	52,48	31807
15-Sep	53,84	39105	97,71	38629
17-Sep	46,26	25493	49,42	25459
18-Sep	54,12	30991	54,72	30991
30-Oct	74,18	37363	92,18	36960
31-Oct	74,82	37105	95,66	36686
1-Nov	59,39	25878	73,33	25746
2-Nov	70,37	37811	109,65	37484
3-Nov	69,23	35291	86,44	35141
4-Nov	60,93	29929	74,56	29571
5-Nov	59,75	27337	65,32	27313
7-Nov	80,75	38988	85,59	38865
8-Nov	70,61	33882	70,28	33882

Date	Average daily Price [€/MWh]	Average Daily Quantity [MWh]	Average Daily Price Transl. [€/MWh]	Average Daily Quantity Transl. [MWh]
9-Nov	100,92	36961	104,46	36842
10-Nov	124,76	39279	131,90	39140
11-Nov	90,67	31708	112,65	31451
12-Nov	65,65	26992	69,53	26962
13-Nov	97,11	37291	94,63	37295
14-Nov	72,05	31975	72,05	31975
15-Nov	103,02	41425	100,56	41475
19-Nov	65,15	29843	69,80	29757
20-Nov	150,01	43644	150,01	43644
24-Nov	77,18	34481	77,18	34481
25-Nov	66,05	31877	66,03	31893
26-Nov	73,76	32711	73,76	32711
28-Nov	71,47	32861	70,82	32861
1-Dec	123,87	41017	125,64	41022
2-Dec	91,54	34617	90,99	34621
3-Dec	73,23	30980	78,92	30936
4-Dec	85,16	34409	84,89	34409
5-Dec	150,78	42110	144,20	42165
6-Dec	170,44	45120	169,41	45252
7-Dec	81,33	32937	81,00	32937
8-Dec	71,54	28225	72,45	28187
11-Dec	72,74	39725	72,41	39725
12-Dec	71,80	37954	71,80	37954
15-Dec	71,48	40914	70,91	41045
16-Dec	58,62	31994	64,50	31714
17-Dec	60,16	28833	73,50	28823
20-Dec	79,49	32807	79,28	32807
21-Dec	74,60	36333	71,85	36400
22-Dec	76,20	35645	72,32	35670
23-Dec	50,60	29849	51,76	29785
24-Dec	50,39	25584	59,48	25477
25-Dec	54,73	24070	63,69	23996
26-Dec	49,80	24776	51,64	24765
27-Dec	59,17	34708	58,00	34735
28-Dec	63,05	34621	63,53	34619
30-Dec	54,96	29145	60,16	29008
31-Dec	45,73	24400	47,85	24352

On Table 8 are revealed the supply operators that fall within the band of the two market clearing prices in the 1159 hours studied, and how many offers could had been included inside the market.

The most penalized appear the bilateral contracts, with 9233 offers rejected but that could be accepted, further analysis are required to investigate better about this category. For privacy reason is not possible insert the name of the operators so are been modified. The first twenty operators are lost some thousands of offers with because the forecast is largely overestimated.

For all the hours without congestion of 2017 the economic lost amount to 198.394.800 €, how the last row of Table 8 shows. The highest economic lost would seem to be the bilateral contracts with an import of 69.832.735 €. Not considering the bilateral contracts the Operator 8 was the most penalized by this trend, indeed it was registered a definecy of 51.084.330 €, with 2925 offers rejected. The second most disadvantaged generator is the Operator 6 with 3991 offers excluded from the MGP, equal to 15.434.770 €. The economic lost are not compulsory linked with the number of offers rejected, indeed the Operator 51 lost 1.409.877 €, with 77 offers rejected.

Table 8 Number of times where the generators are penalized

Operator	Number of times penalized	Total lost
Bilateral contracts	9233	69.832.735 €
Operator 2	6167	938.245 €
Operator 3	5616	556.760 €
Operator 4	5379	1.886.928 €
Operator 5	4607	3.381.203 €
Operator 6	3991	15.434.770 €
Operator 7	3440	2.259.015 €
Operator 8	2925	51.084.330 €
Operator 9	2914	589.879 €
Operator 10	2764	2.120.632 €
Operator 11	2631	4.218.646 €
Operator 12	1987	358.673 €
Operator 13	1885	5.476.274 €
Operator 14	1766	5.633.078 €
Operator 15	1723	3.743.998 €
Operator 16	1595	482.122 €
Operator 17	1348	269.740 €
Operator 18	1220	765.381 €
Operator 19	1069	2.653.726 €
Operator 20	991	6.533.242 €
Operator 21	905	426.350 €
Operator 22	792	222.784 €
Operator 23	603	4.631.734 €
Operator 24	597	1.774.915 €
Operator 25	566	3.494.330 €
Operator 26	530	274 €
Operator 27	450	55.504 €
Operator 28	433	181.231 €
Operator 29	393	58.701 €
Operator 30	385	493.786 €
Operator 31	368	1.336.452 €
Operator 32	330	65.530 €
Operator 33	319	1.341.925 €
Operator 34	311	281.310 €
Operator 35	270	33.884 €
Operator 36	255	585.921 €
Operator 37	227	101.930 €

Operator	Number of times penalized	Total lost
Operator 38	206	173.310 €
Operator 39	186	238.598 €
Operator 40	167	87.675 €
Operator 41	159	93.204 €
Operator 42	150	778.403 €
Operator 43	143	461.119 €
Operator 44	141	24.607 €
Operator 45	139	16.941 €
Operator 46	120	79.046 €
Operator 47	118	44.891 €
Operator 48	105	33.531 €
Operator 49	101	252.744 €
Operator 50	78	289.216 €
Operator 51	77	1.409.877 €
Operator 52	67	125.525 €
Operator 53	65	13.396 €
Operator 54	61	207.717 €
Operator 55	60	181.715 €
Operator 56	50	57.367 €
Operator 57	41	3.867 €
Operator 58	36	3.801 €
Operator 59	33	56.832 €
Operator 60	30	311.920 €
Operator 61	22	70.647 €
Operator 62	22	7.308 €
Operator 63	19	1.633 €
Operator 64	17	7.027 €
Operator 65	16	1.515 €
Operator 66	15	8.059 €
Operator 67	10	3.566 €
Operator 68	10	6.055 €
Operator 69	8	32.986 €
Operator 70	6	1.500 €
Operator 71	3	47 €
Operator 72	1	450 €
Operator 73	1	862 €
Operator 74	1	1.900 €
Total	**73469**	**198.394.800 €**

6.1. Focus on the most relevant cases

In this paragraph the attention is focused on the most relevant cases studied where are located huge price differences between the real MCP and the one obtained from the translated curve.

6.1.1. Cases 24/08/2017 at 13:00 and 14:00

The biggest differences are located in August the 24th in the warmest hours of the day, i.e. at hours 13:00 and 14:00. The trend of the two hours is similar; indeed, the prices are the same where the real price is 48,9 €/MWh while the price would be 150 €/MWh if was predicted the right energy quantity. At hour 13:00 156 offers are rejected, and 154 offers are rejected at hour 14:00, that could be located inside the MGP. The offer curve at 13:00 is translated by 8494 MWh, while for the 14:00 the prediction exceeded the measures of about 8617 MWh.

Table 9 Prices and energy quantities of the real curve and translated ones in August 24th at 13:00 and 14:00

Date	Hour	Energy Quantity [MWh]	Energy Price [€/MWh]	Energy Quantity Transl. [MWh]	Energy Price Transl. [€/MWh]
20170824	13	35372	48,9	34529	150
20170824	14	35087	48,9	34244	150

Figure 55 Real and translated offer curve and demand curve in August 24th at 13:00

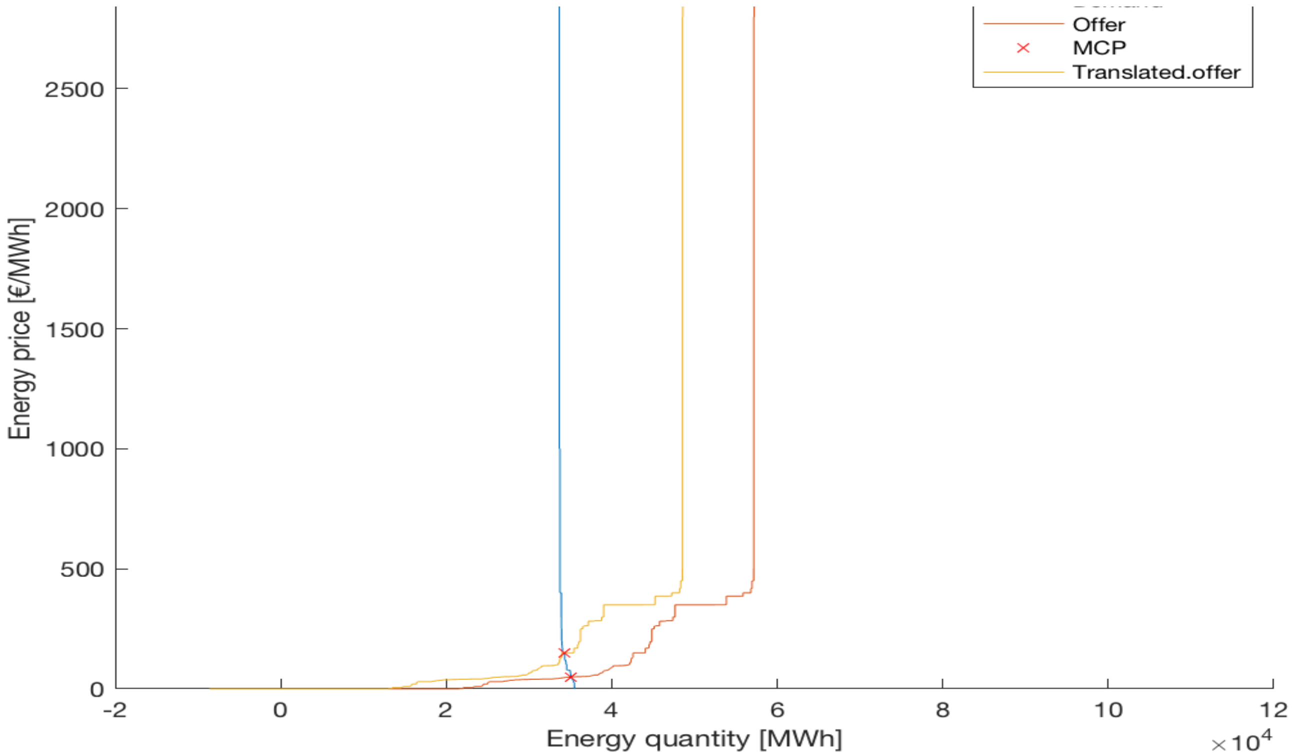
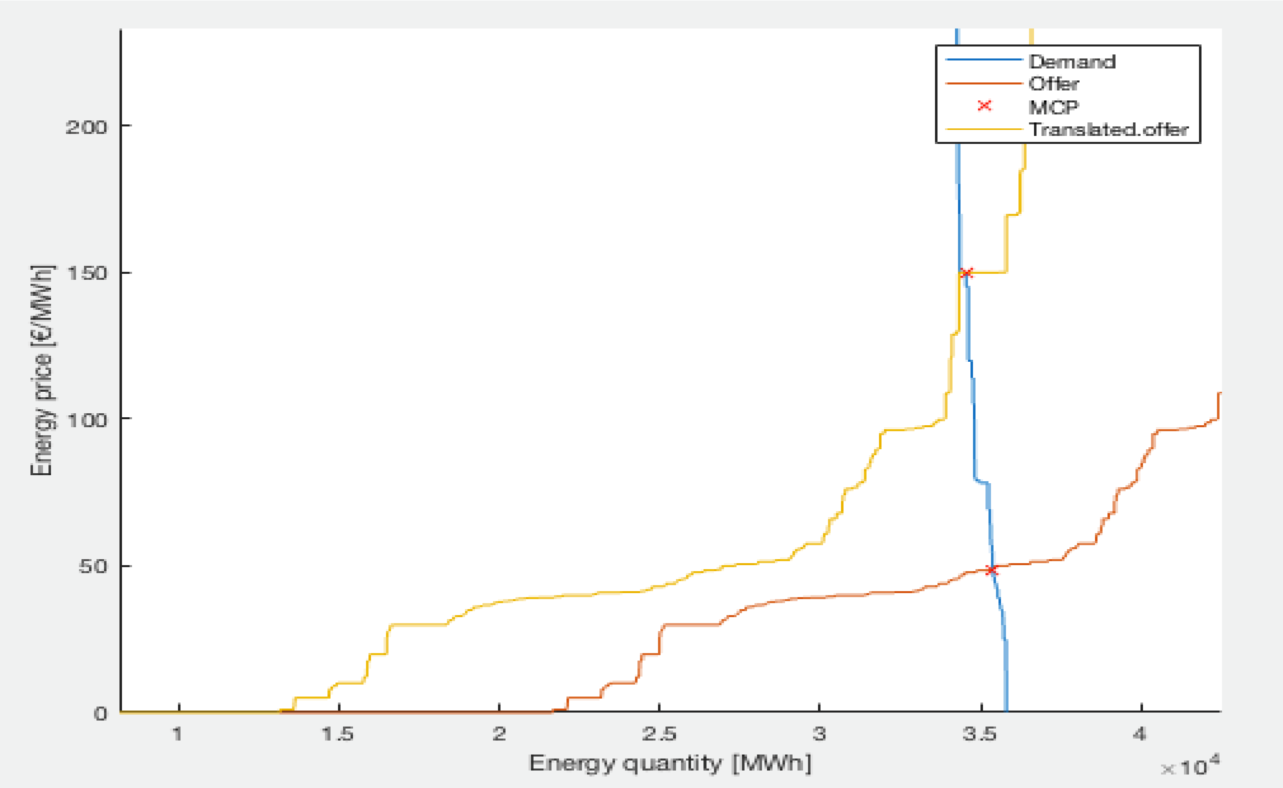


Figure 56 Real and translated offer curve and demand curve in August 24th at 13:00



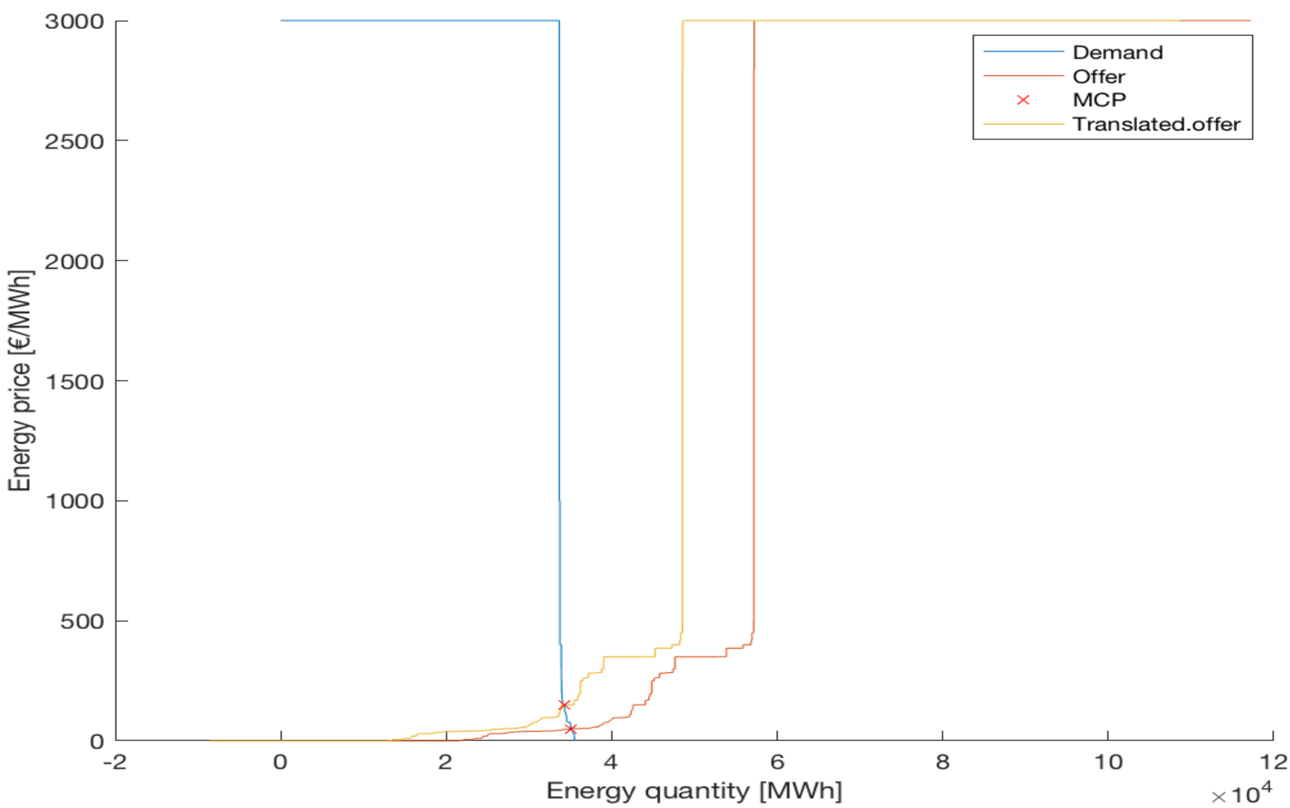


Figure 57 Real and translated offer curve and demand curve in August 24th at 14:00

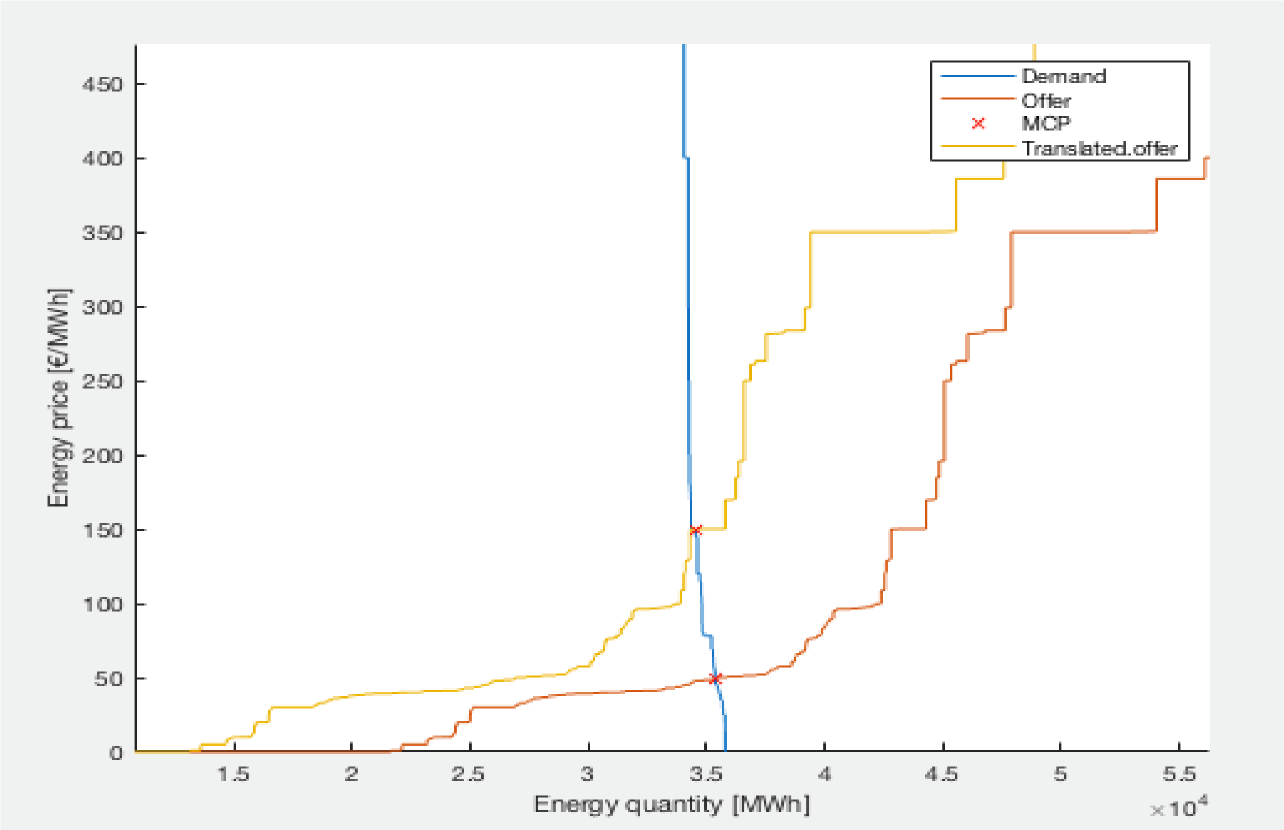


Figure 58 Real and translated offer curve and demand curve in August 24th at 14:00

Figure 55 and Figure 56 show the MCP for the 13:00 while Figure 57 and Figure 58 refers to hour 13:00, on August 24th, 2017.

6.1.2. Case 29/07/2017 at 13:00

The third biggest difference between the crossing point of the real curves and the one with the translated offer curve was in July 29th at 13:00. The price difference is about 100,46 €/MWh, indeed, how reported in Table 10, the real price is 49,54 €/MWh and the price had should been 150 €/MWh. In this case 178 offers are rejected due to the innacurate forecast. The offer curve in this case is translated by 8265 MWh.

Table 10 Prices and energy quantities of the real curve and translated ones in July 29th at 13:00

Date	Hour	Energy Quantity [MWh]	Energy Price [€/MWh]	Energy Quantity Transl. [MWh]	Energy Price Transl. [€/MWh]
20170729	13	34348	49,54	33534	150

Figure 59 Real and translated offer curve and demand curve in July 29th at 13:00

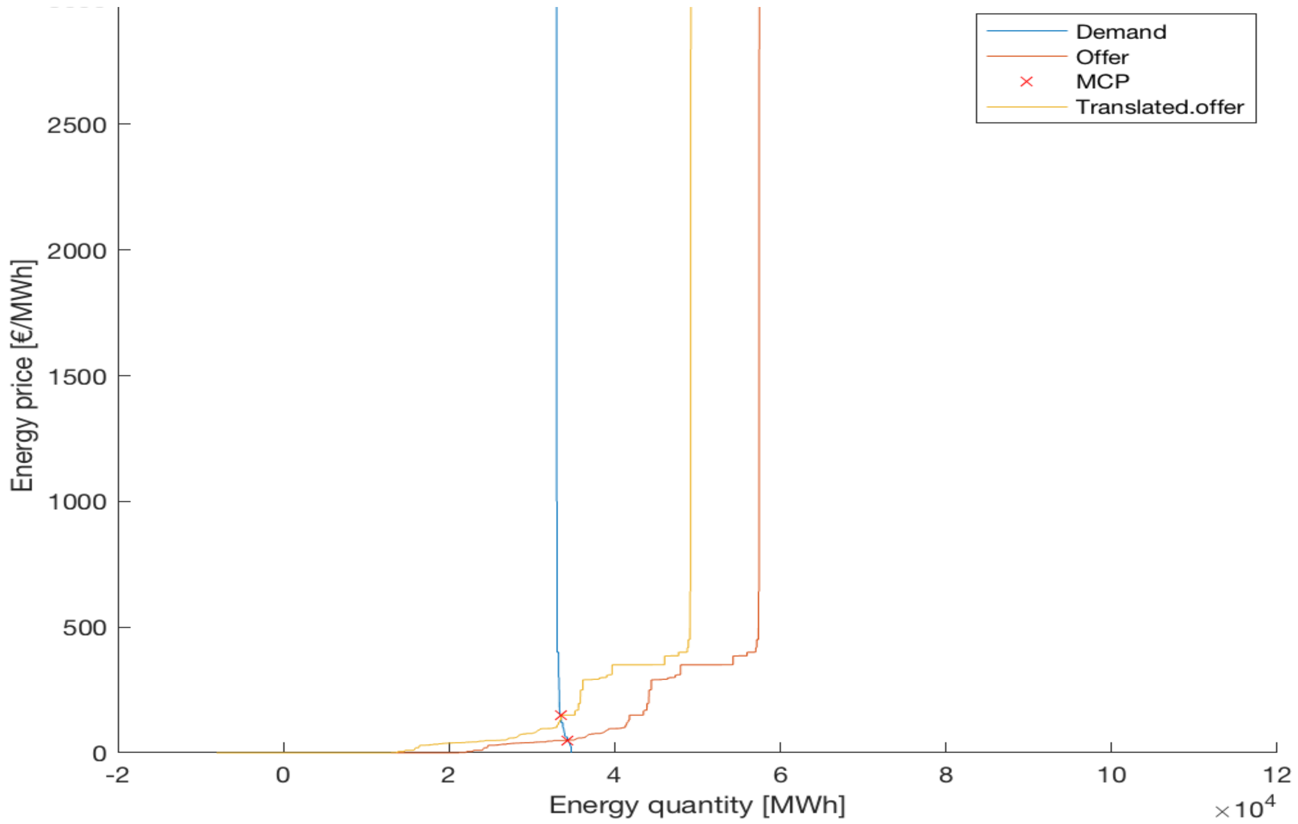
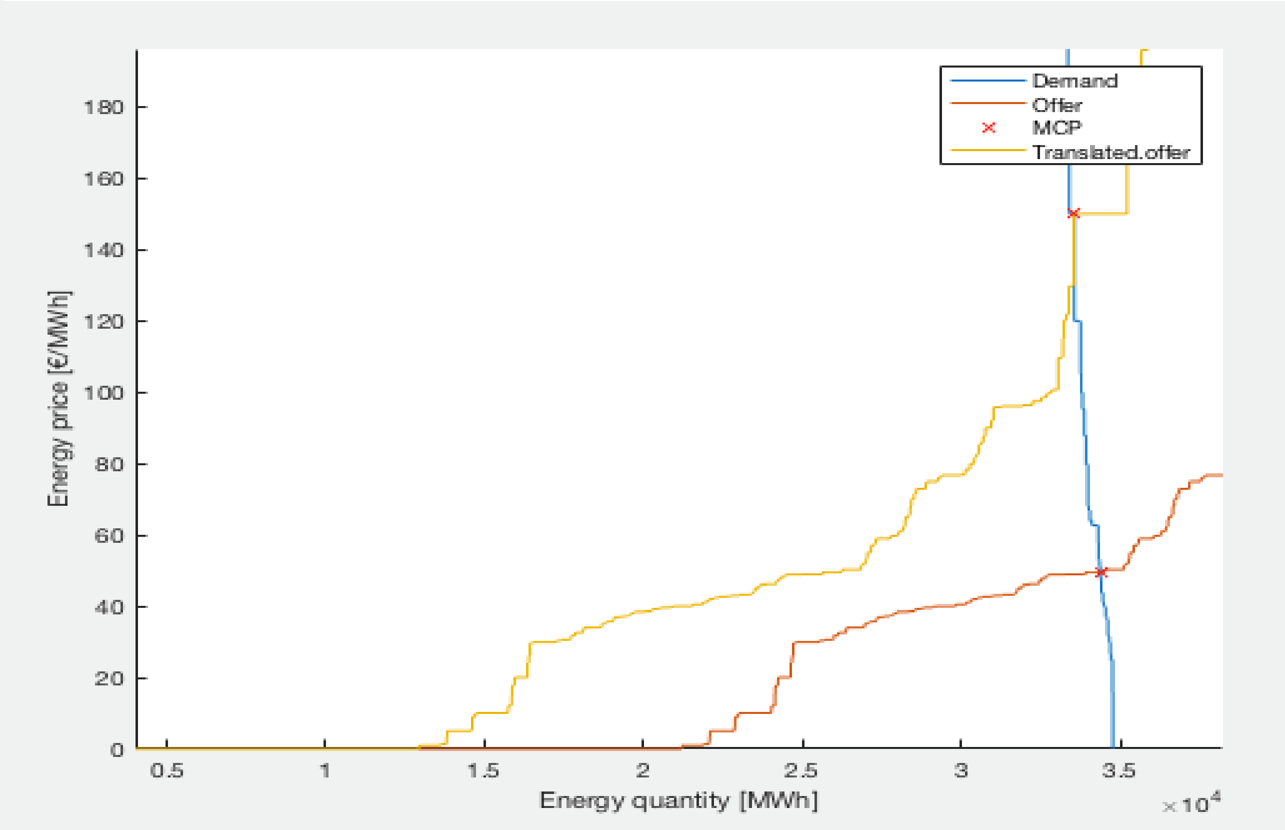


Figure 60 Real and translated offer curve and demand curve in July 29th at 13:00



6.1.3. Case 04/09/2017 at 13:00

The third different day with a huge difference between the MCP of the real curves and the MCP with the translated offer curve of 7652 MWh, was in September 4th at hour 13:00. The price difference is about 97,59 €/MWh, indeed, how reported in Table 11, the real price is 52,42 €/MWh and the price should have been 150,01 €/MWh. In this case 142 offers are precluded for the imprecise prediction.

Table 11 Prices and energy quantities of the real curve and translated ones in September 4th at 13:00

Date	Hour	Energy Quantity [MWh]	Energy Price [€/MWh]	Energy Quantity Transl. [MWh]	Energy Price Transl. [€/MWh]
20170904	13	38042	52,42	36771	150,01

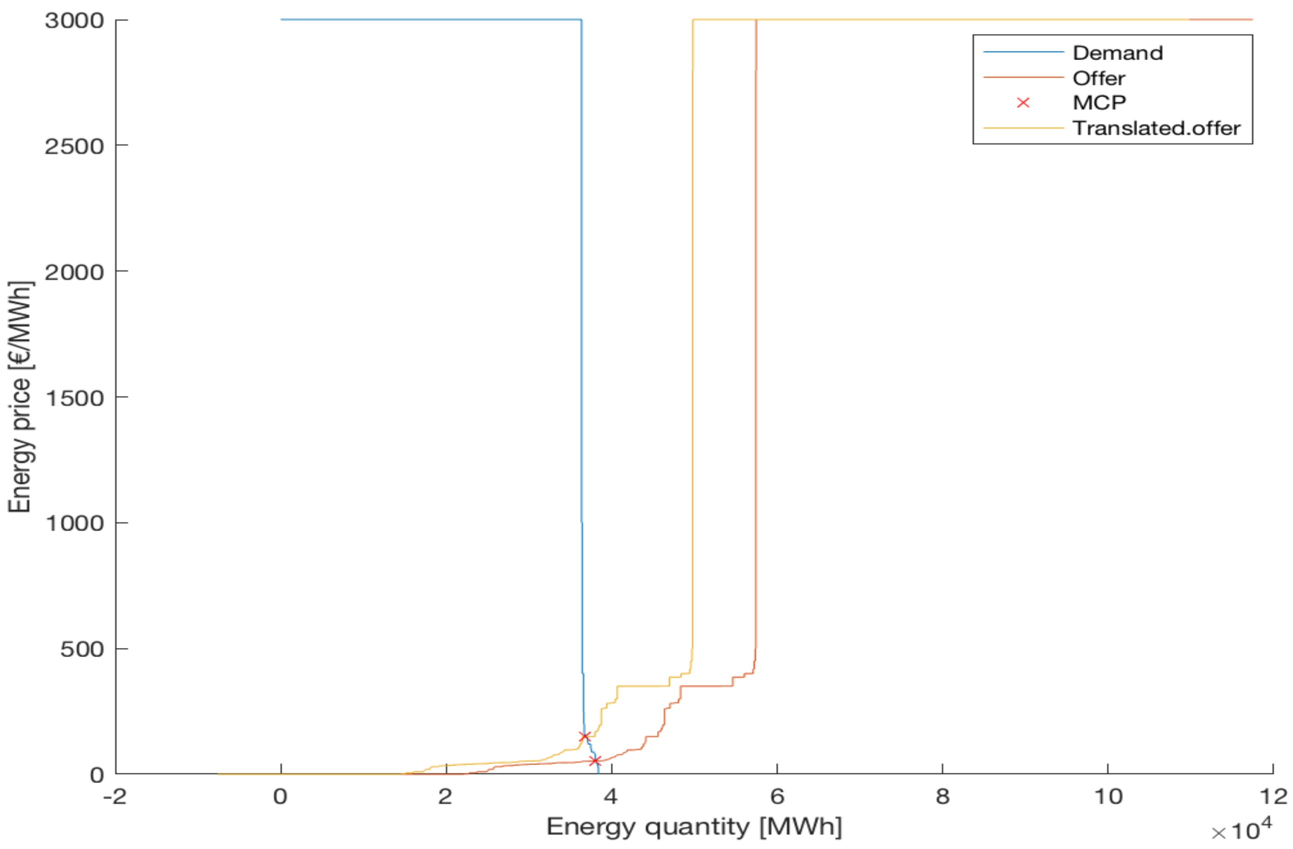


Figure 61 Real and translated offer curve and demand curve in September 4th at 13:00

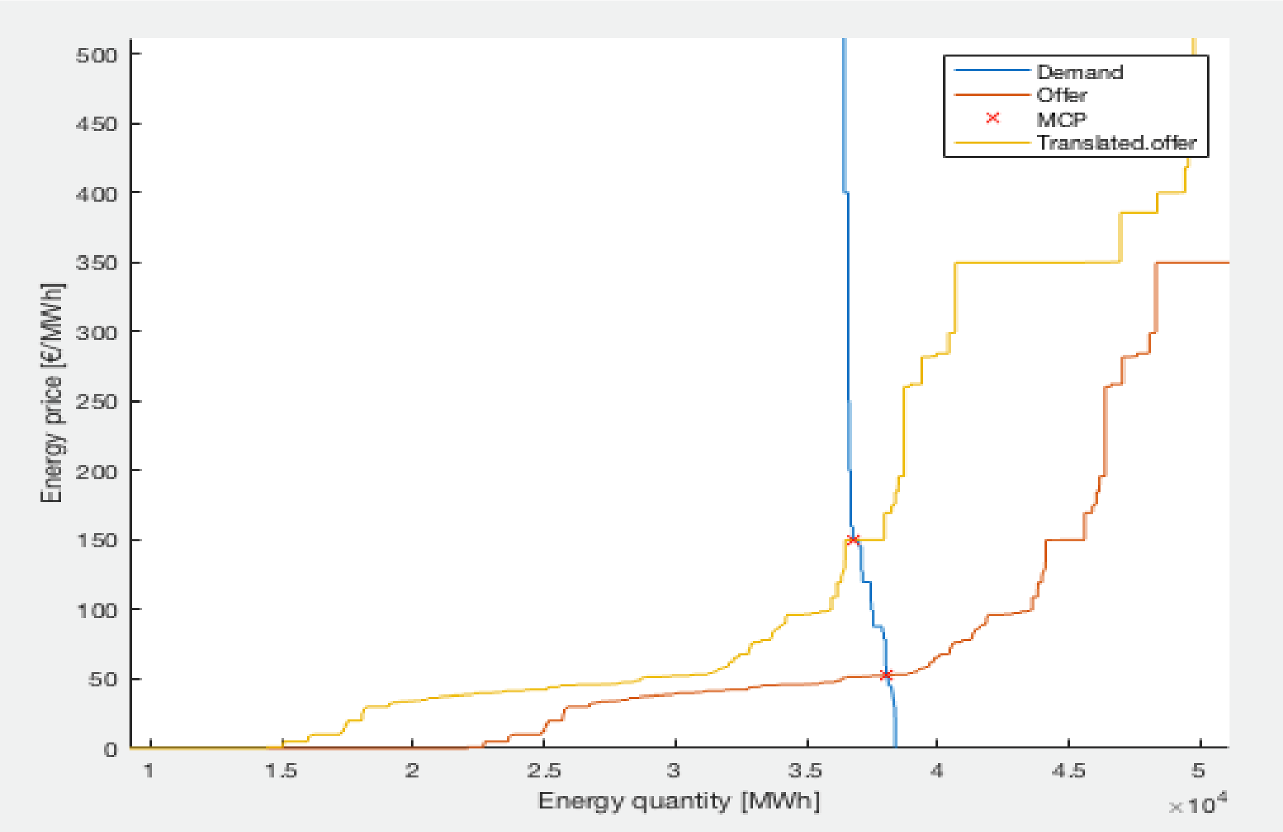


Figure 62 Real and translated offer curve and demand curve in September 4th at 13:00

6.1.4. Case 10/05/2017 at 11:00

The fourth different day with the biggest difference between the MCP of the real curves and the MCP with the translated offer curve of 5890 MWh, was in May 10th at 11:00. The price difference is about 78,9 €/MWh, indeed, how reported in Table 12, the real price is 71,12 €/MWh and the price had should been 150,02 €/MWh. In this case 101 offers are precluded for the imprecise forecast.

Table 12 Prices and energy quantities of the real curve and translated ones in May 10th at 11:00

Date	Hour	Energy Quantity [MWh]	Energy Price [€/MWh]	Energy Quantity Transl. [MWh]	Energy Price Transl. [€/MWh]
20170510	11	39759,242	71,12	38469,819	150,02

Figure 63 Real and translated offer curve and demand curve in May 10th at 11:00

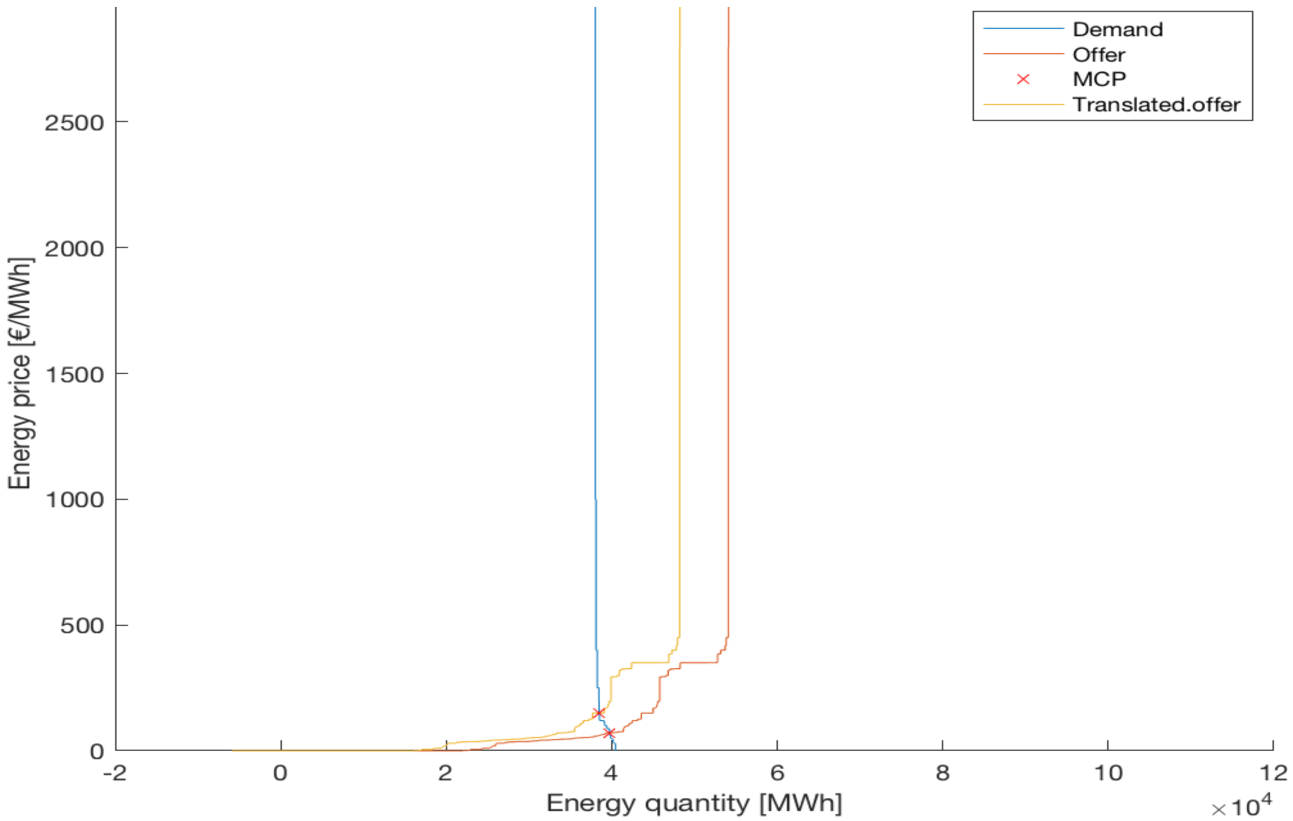


Figure 64 Real and translated offer curve and demand curve in May 10th at 11:00

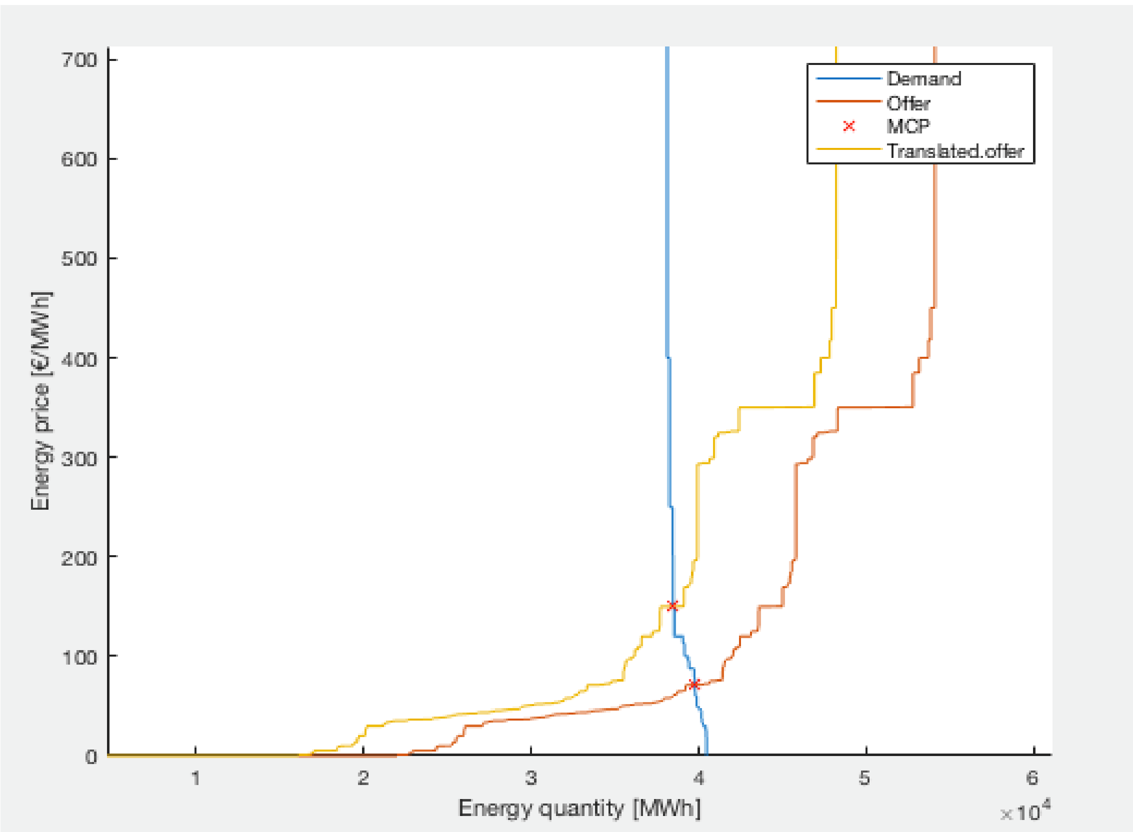


Table 13 shows for the five cases analyzed before the number of offers, for each operator, that are been rejected from the MGP because the renewable forecast was not accurate. It is possible to see how already for only five hours in a year some operators had lost a considerable number off offers, like the operator 11 that lost 177 offers, or the operator 4 with 93 ones ,also the bilateral contracts lost a considerable number, such as 78 offers.

Table 13 The number of offers and the economic lost, for each operator, that are been rejected from the MGP in the before cases

Operator	10-05-17	29-07-17	04-09-17	24-08-17 13:00	24-08-17 14:00	Total number	Total lost
Operator 21	1	7	5	6	6	25	19.141,97 €
Operator 14	10	3	7			20	144.118,06 €
Operator 30		2				2	2.142,00 €
Operator 5		18	8	10	10	46	38.876,34 €
Operator 25	2			1	1	4	27.813,00 €
Operator 26		1	2			3	1,70 €
Operator 9				1	1	2	2.180,49 €
Bilateral contracts	3	20	11	23	21	78	620.677,03 €
Operator 31		1	1			2	8.372,00 €
Operator 28	2	2	1	1	1	7	2.680,36 €
Operator 15	1	2	3	5	5	16	32.351,20 €
Operator 4	16	24	19	17	17	93	31.174,43 €
Operator 32		1		1	1	3	1.647,00 €
Operator 7		7	10	7	7	31	19.059,65 €
Operator 6	5	8	12	10	10	45	391.268,57 €
Operator 38		2				2	2.341,40 €
Operator 8	7	12	12	11	11	53	1.083.297 €
Operator 10	1	5	1	6	6	19	4.819,82 €
Operator 13		3	1	1	1	6	12.267,50 €
Operator 16				2	2	4	1.003,90 €
Operator 23	2	2	1	2	2	9	74.604,00 €
Operator 11	42	34	31	35	35	177	76.984,22 €
Operator 29		1	1	1	1	4	995,94 €
Operator 3	5	13	8	9	9	44	4.504,38 €
Operator 35	2	2	2	2	2	10	1.493,03 €
Operator 12		4				4	318,13 €
Operator 18	1					1	398,40 €
Operator 19		2	4	3	3	12	32.118,50 €
Operator 24		1				1	4.680,00 €
Operator 43	1	1	1	1	1	5	15.801,68 €
Operator 37			1	1	1	3	3,00 €
Total	**101**	**178**	**142**	**156**	**154**	**731**	**2.657.134 €**

7. Demand response in Italy

7.1. Interruptibility service

The interruptibility service is the oldest example of demand response. In fact, it is the only active service in Italy about this topic, where usually the big industries can break or shift their loads, obtaining discounts above the cost of the electricity. This service is used in condition of emergency, where usually the members of this service are notified with an advise when and how much they have to vary.

In the period between 2018 to 2020, 3900 MW were used for the interruptible service, divided in areas in the following way:

- 200 MW in Sicily;
- 400 MW in Sardinia;
- 3300 MW in all the boot.

7.1.1. Contract typology

The contracts about this service are different according to the duration and the typology, indeed they are divided in two kind: “instantaneous” and “emergency”. The first is so called because the interruption is achieved in 200 ms, while in the emergency interruption is allowed to disconnect the loads in five seconds:

- The three year period, from January 2018 to December 2020, where Terna tries to sell all the power in the session of instant interruptibility service, for each respective area. If any power not sold remains, it will be bought into the emergency interruptibility service session, with the same period and respecting the area division.
- Annual, where the contract extends from January to December of the year referred. In the instant interruptibility service’s session the quantity of power that has not been bought in the precedent step can be sold, as well as, the power that was assigned before but then resold to Terna. If after this session continues to be any power available, this power is tried to be sold in the annual emergency interruptibility service’s session.
- Interim, from the first month after the sale until December of the same year, so it will go from eleven to two months. So for each month there are, always, two sessions one of instant interruptibility service session and one of emergency interruptibility service session, where the power remain available from the initial 3900 MW, according the area subdivision is tried to be sold.
- Monthly, where the duration extends only for that month. So for each month there are, always, two sessions, one of instant interruptibility service session and one of emergency interruptibility service session.

7.1.2. Technical requirements

The users allowed to participate in the interruptibility service are the titular client of withdrawal points, that are able to reduce at least 1 MW and satisfy all the technical requirements about this service. So the user has to declare how many entire MWs are destined to the instant service, how many entire MW to use inside the emergency service; and if there are generation facilities inside this user plant, how much is able to produce eventually, this last aspect will be verified with the help of the distribution company.

To avoid the possibility that the user could open intentionally the circuit breakers, without the Terna's permission, the circuit has to be sealed. The interruptible loads must be tele-measured and actioned from a control which comes from Terna. This signal arrives at the peripheric load shedding unit (UPDC), which has to installed by the loads declared inside two kind of services. Additionally, between the UPDC and the circuit breakers' releasing coils, in a load inserted inside the instant interruptibility service, are forbidden tools like processing controllers or devices equipped with logic programming, because they can introduce delays to achieve the interruption, within 200 ms. While for the loads inserted inside the emergency interruptibility service, tools are not allowed that can manage dynamically the interruptible loads, because they can extend the reaction time that must be within 5 s.

In the event that the applicant is an aggregator of loads, it has to be declared how many withdrawal points are connected to the medium voltage, where the power always must be entire and bigger than 1 MW; and all of these have to submit the UPDC equipment; where the ones belonging at the instant service have an UPDC fixed just before the circuit breakers' releasing coils, and the emergency ones must not possess devices that can manage dynamically the interruptible loads, because they can introduce delays into reaction time. Besides, Terna wants to know all the measures about the single loads and of the total plant, without obviously modifying the data by the aggregator.

All these technical requirements shall be borne by the dispatch user; and the system operator can always verify the exact installation. If after an assignment, the equipment is out of standards automatically it will be retired.

7.1.3. Assignment and remuneration

For each area Terna will make two descending price auctions, one for the instant interruptibility service, and one for the emergency interruptibility service.

All the enabled users can send until ten offers; for each offer they have to choose how many entire MWs are available for the service, and the annual price expressed in €/MW/year. All the offers are ordered for price following a decreasing way, where the base price, called reserve price, is 105.000 €/MW/year for the instant interruptibility service, and 60.000 €/MW/year for the emergency interruptibility service. These are the reserve prices for the continental area, while the ones for the isles are increased by 20%. If all the offers present a price bigger or equal than the reserve price, it will be the marginal price.

In the event that there are more offers with the same annual price and the amount of their quantity passes the limit put by Terna, it is calculated a rationing coefficient made by the ration between the remaining power into the interruptible service and the amount of the offer quantities. After these offers will be accepted, only if multiplicated by the coefficient.

Terna, before withdrawing unsold energy, repossesses the power from contracts which have been settled. One time resold a quantity of power to Terna by the user, it is not allowed rebuy the same power, by the same operators, with a different period contract.

Each user, after a correct performance, is remunerated monthly with the product between the contracted power (MW) and the annual price assigned (€/MW/year) divided by twelve. Also, Terna monthly calculates the "Withdrawal Power" P_p

$$P_p = \frac{P_{bmi} \cdot \frac{P_{long\ term}}{P_C} \cdot H_{month}}{H_{month} - H_{maintanance} - H_{unavailability}}$$

and the "Withdrawal monthly Power" P_p^M

$$P_p^M = \frac{P_{bmi} \cdot \frac{P_{monthly}}{P_C} \cdot H_{month}}{H_{month} - H_{unavailability}}$$

where:

- H_{month} are the hours inside the month considered
- $H_{unavailability}$ are the hours where the interruptibility service cannot work for malfunctioning
- $P_{long\ term}$ is the amount of the contracted powers with duration longer than a month
- $P_{monthly}$ is the contracted power for the only month considered
- P_{bmi} the "Monthly average Power" is the average about hourly levies of each month
- P_C the "Contracted Power" is the nominal power assigned at this user plant to participate in the instant interruptibility service.

If P_p^M is lower than the "Minimum monthly Power" the gain earned by the user will be reduced. The gain will be multiplying with a factor obtained by the division between Withdrawal monthly power and the Minimum monthly Power. While for periods longer then month, if the P_p is under the "Minimum Power" the gain earned by the user will be reduced, multiplying it by a factor obtained by the division between Withdrawal power and the Minimum Power.

Inside a year is allowed to go down respect the Minimum Power three times, after this if the Withdrawal Power is less than the 90% of the Minimum Power, the user will be charged about 2000 €/MW/month. In the case that the Withdrawal monthly Power is less than the 70% of the Minimum monthly Power, the gain will be zero.

Terna also pays a supplementary monthly fee of:

$$n_d \cdot VPINF \cdot \left\{ \left[min\left(1; \frac{P_p}{P_{\min}}\right) \cdot P_{long\ term} \right] + \left[min\left(1; \frac{P_p^M}{P_{min}^M}\right) \cdot P_{monthly} \right] \right\}$$

where

- n_d is the number of times when the circuit breakers operated correctly
- $VPINF$ is a value expressed in €/MWh

7.2. Virtual Certified Unit of Consumption

The European balancing code forces all the countries members to open the demand to the ancillary service. The Authority about the electric energy the gas and the hydro system through the 300/2017/R/eel, a pilot project executed from June 2017, allows the demand facilities to participate at the MSD, and at the forward supply, only in a period from June to September, always by the demand facilities. The aim of this project is create the sources about tertiary reserve and balancing from the demand connected to high medium or low voltage.

7.2.1. UVAC's Structure

All the demand facilities that are allowed to participate at the ancillary service, must be able to regular their loads, and this capacity is managed by a Virtual Certified Unit of Consumption (UVAC). All the units of the same UVAC have to be inside the same market zone, and usually residing in the same province. Also, the demand facilities can change their consumption through the Peripheric Unit Load's Secondment (UPDC), following the instruction sent by Terna. The big users are linked directly with Terna, while the little ones, like domestic users, have an aggregator above them that receives the orders from Terna and actives the UPDC; this is called indirect link. After an order from Terna, an UVAC has fifteen minutes to reduce its load for at least four hours continuously.

The demand facilities are seen by the grid like a supply point because reducing their demand, is like introducing new energy in the net.

Each UVAC's titular has to communicate to Terna which are its demand facilities and the Maximum control power, that is how much MW the UVAC is able to reduce for putting them inside the grid. The minimum valor to participate at this program is 10 MW, so if a UVAC is composed by more facilities, the aggregator has to respect this requisite. The title UVAC allows to participate only at the ancillary market and not inside the energy one. In fact the Consumption Units (UC) are included inside the energy market, that concerned with the regulation of the unbalancing. The members of a UVAC have to belong to the same UC, and they can participate at only one UVAC, while more UVAC are allowed inside the same UC.

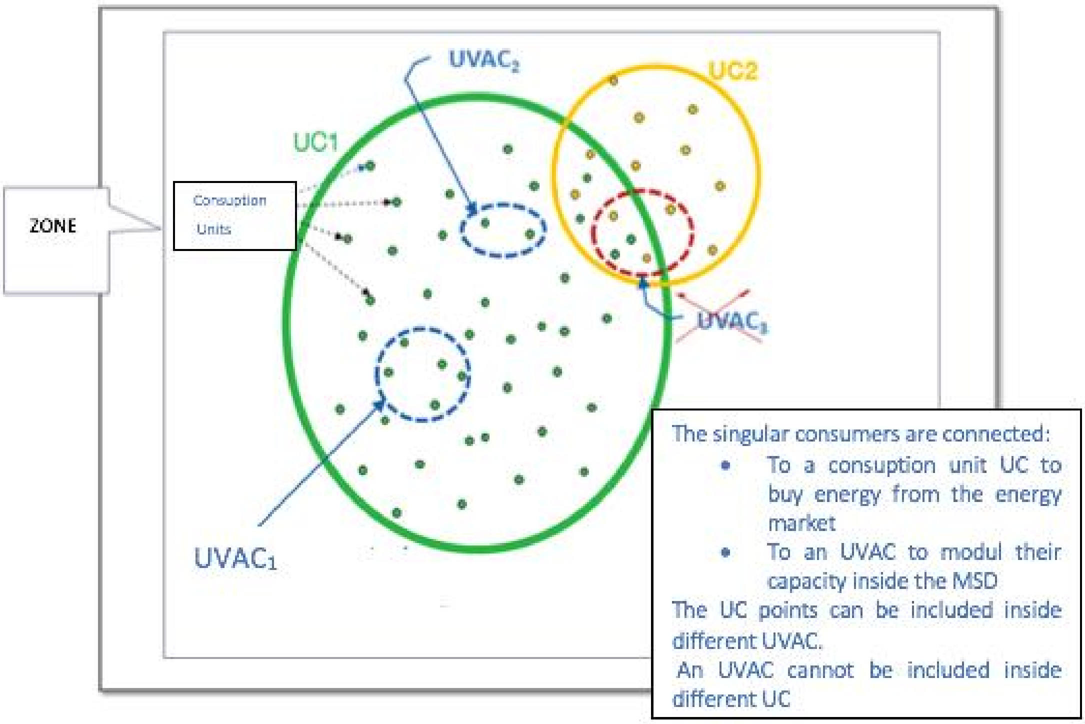


Figure 65 UVACs' suddivision inside some Unit of Consuption

The responsible of a UVAC manages it, in the specific, by sending the economic offers inside the MSD and the technical data to Terna, receives and executes the orders that come from the system operator. This figure could be:

- The owner of the demand facilities included inside the UVAC;
- The owner of the UC where are linked the demand facilities that are included inside the UVAC;
- An aggregator.

An UVAC, one time inserted inside the MSD, has the same duties of the supply units like the supervision of dispatch point, equipped with the Terna software that allow to receive the ancillary orders, by someone that always control and is ready to intervene. Also, they have the same procedures, of the supply producers, to follow or less the Terna's requests.

7.2.2. Load’s Reduction Modality

The UVAC has the same modality and time than the supply units, that participate at the ancillary market, to inform Terna about its technical data, using a specific platform. The UVAC’s manager has to sends data about each quarter hour. This data can be used to create the reserve in the MSD, or in the real time dispatch service if these information are sent at least thirty minutes before the starting of the quarter hour of interest. Terna considers, for each quarter hour, only the users that have sent the information of their plants about this period; and can decide to ask at the UVAC to reduce the demand in the quarters hour, when it declared to be available. The UVAC can choose to agree or not, running penalties.

When Terna requires from an UVAC to increase its placing, reducing the withdrawal from the underlying demand facilities, the steps to apply are the following:

a) In the period between the receipt of a dispatch order and the sum of Answering Time (it is maximum five minutes) and Activation Time, the UVAC has to keep its load unchanged, so has to remain to zero power;
b) At the amount of Answering Time and Activation Time, the UVAC has to introduce a power step until its Minimum Power, so the demand facilities change their load reducing of a step. The Minimum power is an unscored power so Terna must select all this power or anything;
c) After the UVAC follows to increase its power linearly until its Maximum point, with its rise gradient speed, or better the demands facilities decrease linearly their withdrawal. The Maximum power is less than the Maximum Control Power of the UVAC;
d) When the system operator sends a dispatch order, the UVAC starts to reduce linearly its power until its Minimum Power, with its descend gradient speed, in this way the loads linearly take more power from the grid;
e) The UVAC keeps the Minimum Power for all the Arrest Time, or more if Terna rules another service; and after comes back at zero power through a step variation. In the end the demand facilities comes to use the power that had before the first dispatch order, or chooses another power.

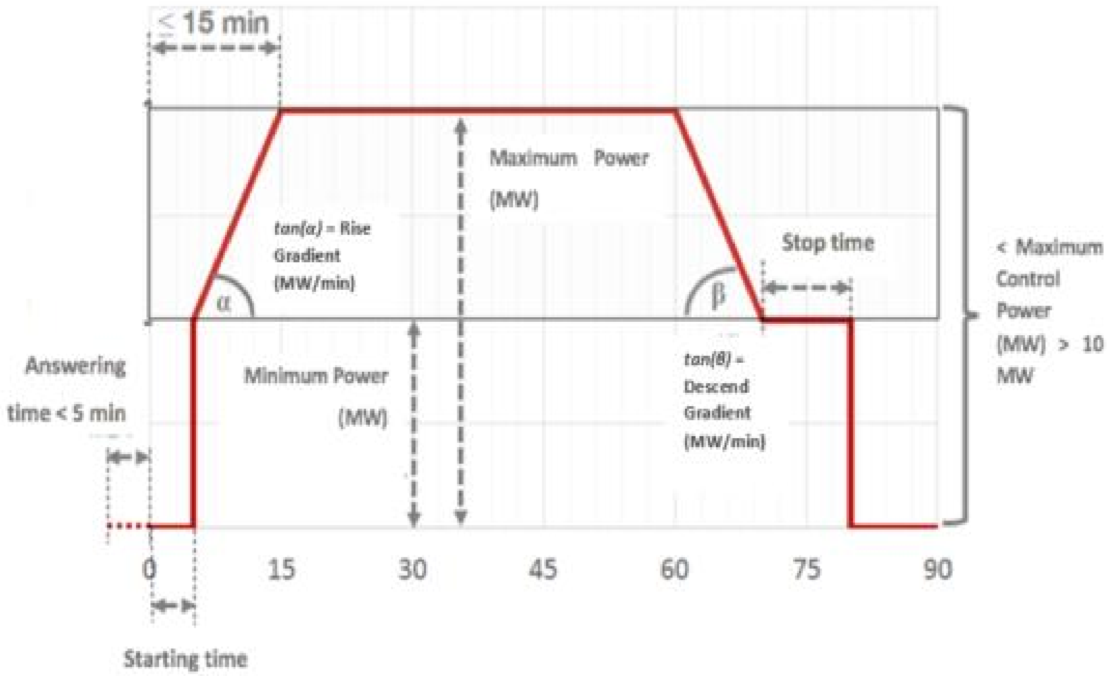


Figure 66 UVAC's compulsory steps after a dispatch order from Terna

Not compulsory must be asked all the maximum power of a UVAC, in fact Terna can order a power between the Minimum and the Maximum of a demand dispatch unit; but to add an UVAC inside an ancillary service in a specific quarter hour, Terna has to require at least the Minimum Power of the plant.

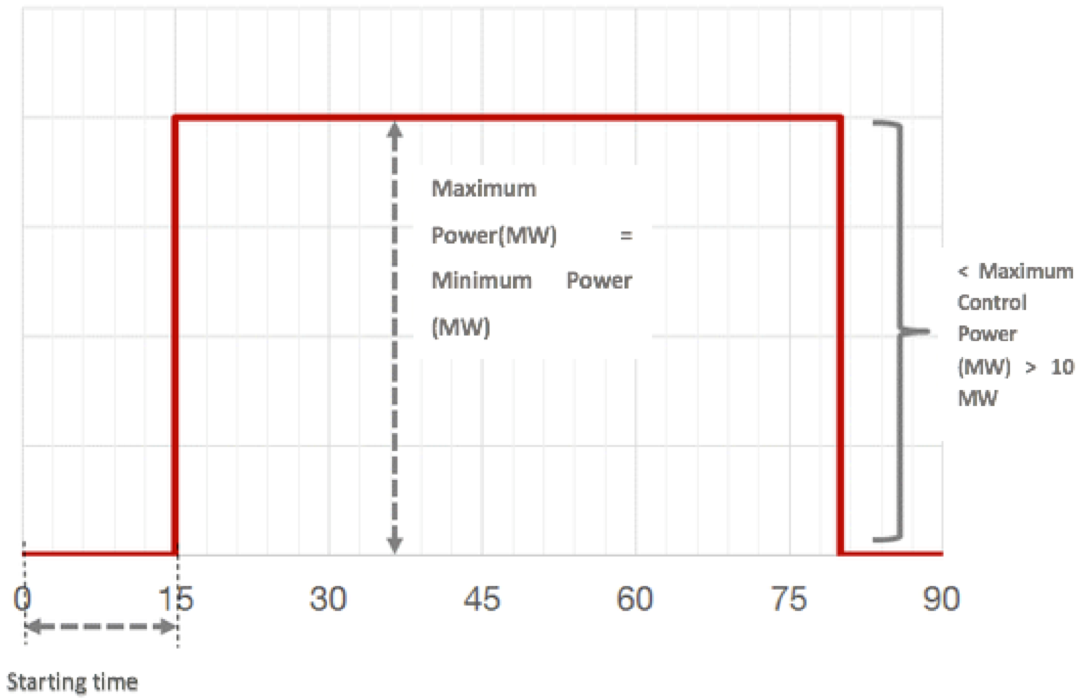


Figure 67 UVAC's request with minimum power

7.2.3. Remuneration and penalties

The UVAC can participate in the ancillary market with the same terms of the supply producers, specifically:

- Introducing its predefined offer, that can be used when the UVAC does not insert an offer during the MSD offer collection the day before of the topic day;
- Can contribute to the reserve service, introducing offers inside the MSD offer collection the day before of the topic day;
- Can participate in the Balancing Market at the same day. If there are no offers for this market, it is possible to use the ones belonging to the reserve service programming.

So an UVAC has to insert a price, for reducing the withdrawal from their loads, for each hour of the day after, or a price for each hour inside the four hour block in the Balancing Market.

If an offer will be accepted, the remuneration is equal to the product between the quantity accepted and the offer price. The quantity accepted is the medium value of the modulation profile inside the quarter hour required, while the offer price is the price of the hour where the quarter hour treated is located.

Terna verifies if each service is done correctly or not. In fact, after fifteen minutes of the dispatch order the system operator sees if the following formula is respected:

$$P_i \leq P_0 - P_d$$

where:

- P_i is the total absorbed power by the UVAC measured each four seconds inside the quarter hour of the service dealt after deduction of the minor between the relief power P_f and the power provided by the interruptible service. The relief power is the highest value between the contracted power about the interruptible service and the real interruptible power utilized in the last quarter hour before the dispatch order.
- P_0 is how much power is absorbed by the UVAC in the quarter of hour before the dispatch order, excluding the power provided by the loads that are working in the interruptible service. It is measured every four seconds.
- P_d is the power required by Terna to the UVAC, or better it is the power that the UVAC must reduce, and is equal to the average value of the power given by the UVAC in the quarter hour demanded but with the sign changed.

It is allowed a tolerance above the total absorbed power P_i, about 5% of the power required.

If this relation is verified, the power reduced by the UVAC is at least equal to the required one by Terna, the dispatch user will receive the price put in the offer. If the P_i is bigger than P_d the manager of the UVAC returns back a quantity equal to the product between the offer price and this value:

$$P_d - [(P_{tot\ ante} - P_{tot\ post}) - \max(0; P_{int\ ante} - P_{int\ post})]$$

where:

- $P_{tot\ ante}$ is the total absorbed power by the UVAC in the quarter of hour before the dispatch order;
- $P_{tot\ post}$ is the total absorbed power by the UVAC in the quarter of hour required by the dispatch order;
- $P_{int\ ante}$ is the power provided by the interruptible service in the quarter of hour before the dispatch order;
- $P_{int\ post}$ is the power given by the interruptible service in the quarter of hour required by Terna.

In the situation where the UVAC does not participate in the ancillary service bringing power, its manager has to return the product between 150% of the price offered and the following quantity:

$$P_d - [(P_{tot\ ante} - P_{tot\ post}) - \max(0; P_{int\ ante} - P_{int\ post})]$$

7.2.4. UVAC Inside the Forward Market

Inside the period from June until September 2017, it was possible for the UVAC to participate in the forward ancillary market, through an auction procedure. In this market can participate only the UVACs that are located in the North and Center-North zones.

The fundamental request to participate in this forward market is that the UVAC has to be available to provide at least for 70% of the duration of the month, a power, equal to its contracted power, for four hours inside the period between hours 14:00 and 20:00 from Monday to Friday. This request concerns both the programming and the real time managing.

The gain produced by this service is composed of:

- A fix price, given independently by the service activation, defined by a downward auction, with the kind pay as bid, respect a quantity that is between 25.000 and 30.000 €/MWh/year;
- A variable remuneration, given only if the offer is accepted inside the MSD and the service is provided. This price is like the offer one and not higher than the strike prize, that is around 300/400 €/MWh; if the price of the offer is bigger Terna gives a remuneration about the strike price.

If the power contracted is not made available for 70% of the month, or continuously for four hours inside the period from hours 14:00 to 20:00 between Monday and Friday, the fixed remuneration is not given. Conversely if the power contracted is made available continuously for more than four hours inside the period from hours 14:00 to 20:00, the fixed remuneration grows up until 110%, in case where it is satisfied all the six hours.

7.3. Virtual Certified Unit of Production

In 2017, for the first time the Italian Authority about the electric energy the gas and the hydro system (now ARERA), answering to the request about the opening of the demand to the ancillary service, through the 300/2017/R/eel, allows that the supply units from renewable sources could participate at the MSD, with a pilot project. The aim of this project is to create the sources about tertiary reserve power, balancing and programming to solve the grid congestions, always introducing or absorbing power by renewable plants.

7.3.1. UVAP's Structure

The virtual certified unit of production UVAP is an agglomerate of supply points connected in low medium or high voltage in the same area, which is allowed to participate in some services of the ancillary market (MSD), but not in the MGP and MI. The UVAP could be required to Terna by the holder of the supply points or by an aggregator, who asks the delegation from the owners of each point. An UVAP can provide a service to "go up" or "go down", or both.

- In the "go up" service, the UVAP feeds the power input. It is compulsory that the maximum modulated power, called "Maximum Control Power", that the UVAP is able to inject must have an absolute value at least about 5 MW. While the "Minimum Power of Inferior Control", that represents how many MWs the UVAP can draw, must have an absolute value equal to 2kW.

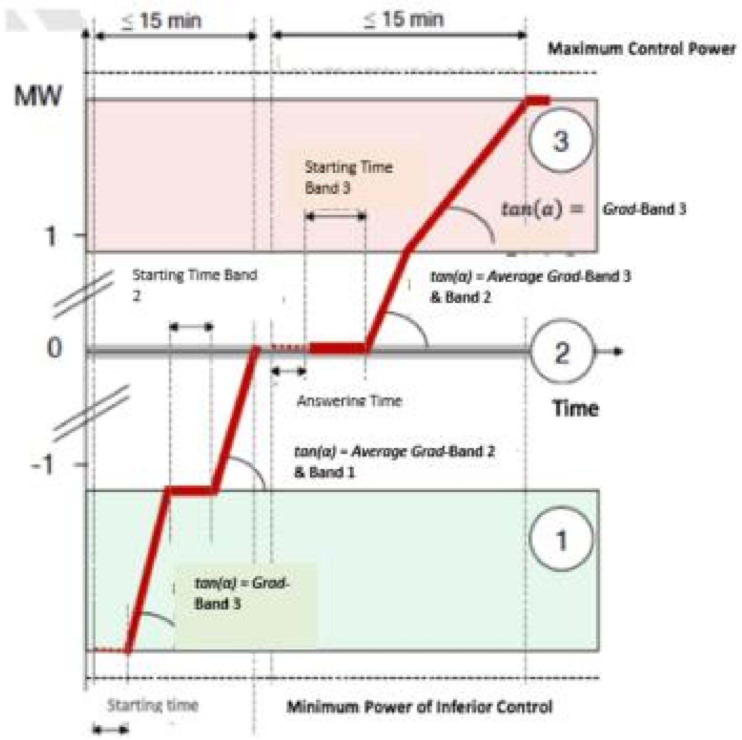


Figure 68 UVAP steps of go up service

- In the “go down” service, the UVAP absorbs power from the grid. It is compulsory that the maximum modulated power, called “Minimum Power of inferior Control”, that the UVAP is able to withdrawal must have an absolute value bigger than 5 MW. While the “Maximum Control Power”, that represents how many MWs the UVAP can introduce, must have an absolute value equal to -2kW.

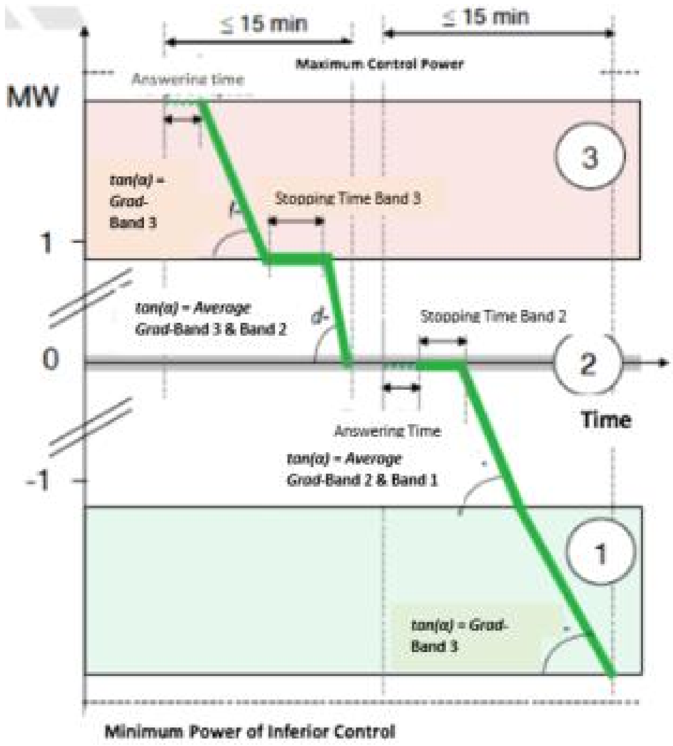


Figure 69 UVAP steps of go down service

In both services, the power amount of each supply point that belongs to the UVAP, to inject or to draw, has to be bigger, respectively, than the Maximum Control Power or than the Minimum Power of inferior Control.

To participate in a service it is compulsory introduce the Baseline, that is, the expectancy about power generation from each supply points of the UVAP, and not introducing it even for a quarter hour in a day, cuts off this UVAP, from the MSD, in that day. Also, the UVAP’s manager sends the technical data for th quarters hour of interest, in particular:

- For the participation into the programming reserve service must be respected the deadlines of the collecting phase,
- For the real time balancing are selected the UVAP that have sent their technical data until thirty minutes before the dispatch order.

Not sending the technical data for a quarter of hour means the unavailability to participate in the dispatch service in that period.

Between the most important requests, there are the answering time of a dispatch order, which is less than fifteen minutes; and the minimum continual providing time that is about three hours. So, if the manager for technical needs decides to change the baseline, the manager shall account for the time of fifteen minutes before Terna makes the variation.

To require an UVAP its manager selects which kind of service wants to provide, if to go up or to go down or both, and shows to Terna how many MWs can introduce or draw each supply point. Through a consult with the grid operator, Terna approves which supply points are going to make the UVAP and which not, because do not reach the technical requirements. An UVAP can add or remove supply points, or changing its kind of performance; to the modification follow the relative tests that Terna makes, which, in case of negative result, may get possible the closing of the UVAP too.

The most representative element of the technical requirements about the UVAP is the peripherical generation monitoring unit (UPMG). It is the connection between Terna and the UVAP. Each 4 seconds the measures about the total power generated of the plant have to arrive to the UPMG. The power is measured through a dedicated converter, or through impulse and decoder counters. In the case where there are not enough telecommunication lines for each UVAP, an aggregator collecting the measures of more UVAP and sends them to Terna. The UPMG has a duty to amount the powers exchanged in more connection points with the grid, which are under the same UVAP. And obviously the UPMG cannot change the measures coming from the UVAP. Additionally, between the technical requirements is included the electric system plant, where must be indicated the position of the general circuit breaker and of the generators.

7.3.2. Offering and its review

The UVAP, like dispatch user, has the right to make offers inside the MSD, like the traditional users do, with the same rules:

- Insert a predefined offer, after the creation of the UVAP, that will be used when there are no offers in the dispatch market of the day before.
- The possibility to present offers in the MSD programming, the day before the day which the UVAP wants to provide its contribution at the reserve service. The offer is made of the energy quantity, available to put or withdraw and it has to be bigger than 1 MW, and its price refers to a specific hour.
- The possibility to present offers in the MB, the same day the UVAP wants to provide its contribution to real time balancing service. If there are no offers for this category, the ones belonging at the MSD programming are used. The offer in the MB is made of the energy quantity, available to put or withdraw and it has to be bigger than 1 MW, and its price refers to a specific quarter of hour.
- After the collection Terna chooses which offers to accept. Usually the UVAP's offers are used for the live time balancing because it is very fast to execute the command.

Terna verifies the performance of an accepted offer, in each quarter of hour, after checking that following equation is proved:

$$|Q_{MSD}(i)| \geq \frac{0{,}5}{4}\ \text{MWh}$$

where:

$$Q_{MSD}(i) = \sum q_{EXANTE}^{sell}(i) - \sum q_{EXANTE}^{buy}(i) + \sum q_{EXpost}^{sell}(i) - \sum q_{EXPOST}^{buy}(i)$$

$Q_{MSD}(i)$ is the net balance of the accepted quantities of the programming step or balancing one

$q_{EXANTE}^{sell}(i)$ are the accepted quantities to input energy in the MSD programming

$q_{EXANTE}^{buy}(i)$ are the accepted quantities to withdraw energy in the MSD programming

$q_{EXpost}^{sell}(i)$ are the accepted quantities to input energy in the balancing market

$q_{EXPOST}^{buy}(i)$ are the accepted quantities to withdraw energy in the balancing market

A performance of a “go up” service will be execute positively if:

$$Ene_{mis}(i) \geq Eo(i) + |Q_{MSD}(i)|$$

While, a performance of a “go down” service will be execute positively if:

$$Ene_{mis}(i) \leq Eo(i) - |Q_{MSD}(i)|$$

where:

$Ene_{mis}(i)$ is the energy input by the UVAP’s supply points in the i-th quarter hour

$Eo(i)$ is the programmed energy, in the i-th quarter of hour, in which the UVAP’s supply points have to introduce in the grid and it is calculated with:

$$Eo(i) = \frac{Po(i) \cdot 1h}{4}$$

$Po(i)$ is the quarter hour Baseline added to corrective value Δ Baseline, that is max or min respectively if $Q_{MSD}(i)$ is positive or negative:

$$\Delta \text{ Baseline} = \max(\min)[\ \Delta \text{ Baseline}_{\text{before}};\ \Delta \text{ Baseline}_{\text{after}}]$$

$$\Delta Baseline_{after} = \sum j \frac{4Ene_{mis}(j) - Baseline(j)}{n_2}$$

$$\Delta Baseline_{before} = \sum j \frac{4Ene_{mis}(j) - Baseline(j)}{n_1}$$

n_1 is the number of quarters hour prior to the i-th, until eight, that have void quantities accepted, while the n_2 are similar but with the difference that are after the quarter hour i-th. The term $4Ene_{mis}(j) - Baseline(j)$ represents the difference between the effective power put by the UVAP‘s points and the programmed one, that was communicated at Terna through the baseline for each quarter of hour considered.

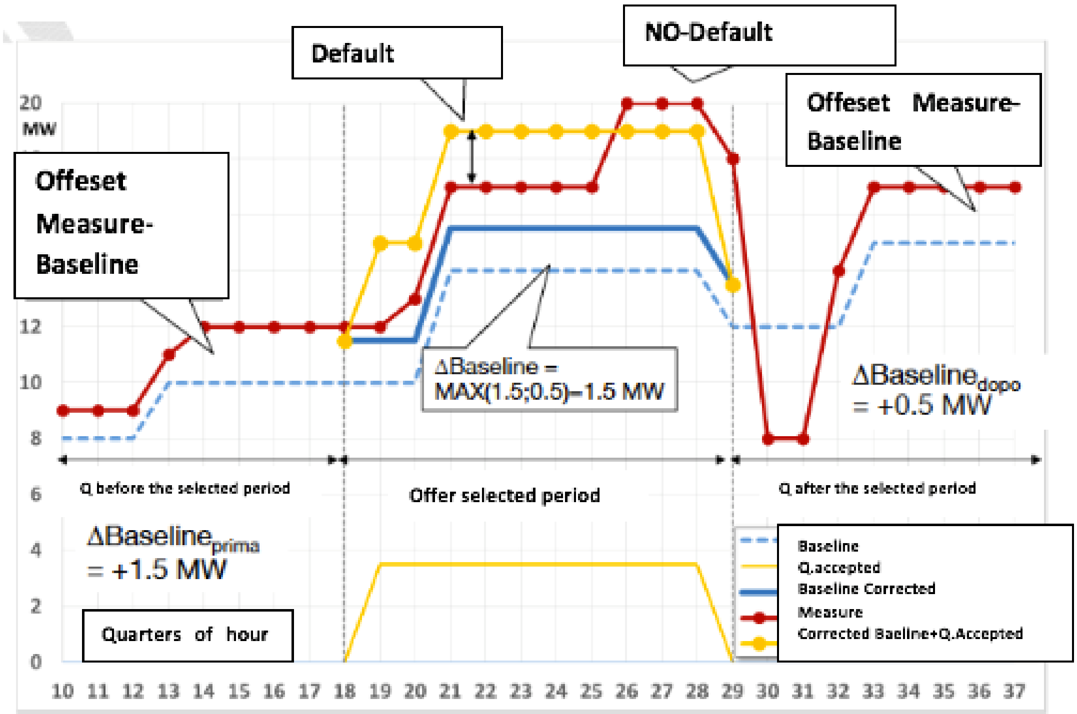


Figure 70 Different trands of UVAP

If the $Ene_{mis}(i)$ in a performance of a "go down" service is less than the amount of the $Eo(i)$ and $|Q_{MSD}(i)|$, in the case where there are more sales than purchases, the UVAP's manager has to come back a quantity equal to:

$$MPbuy = \max\left[150\% \cdot \left(\frac{c}{Q_{MSD}}\right); P_{MGP}\right] \cdot [Ene_{mis} - Q_{MSD} + Eo]$$

where c is the sum of the accepted offer prices, so the ration $\frac{c}{Q_{MSD}}$ represents the average price that Terna pays to the single UVAP for its service in the MSD. P_{MGP} is the zonal price of the UVAP's area.

But if there are more purchases than sales, and the previous condition is not respected, the manager has to give back the quantity:

$$MPbuy = \max\left[50\% \cdot \left(\frac{c}{Q_{MSD}}\right); P_{MGP}\right] \cdot [Ene_{mis} - Q_{MSD} + Eo]$$

When the UVAP exceeds the 15% of the Baseline more than the half times in a month, it is charged about 2% of the monthly earnings.

The acceptation of UVAP's offers inevitably changes the result of the market program about the entering of the Virtual supply unit, under which belonged the points of the UVAP. This quantity variation is called $\Delta P_k(i)$. So in case when $Q_{MSD}(\mathrm{i}) > 0$, Terna receives from the UVAP the product between $\Delta P_k(i)$ and the price of the zone that belongs to the UVAP's points. To pay this quantity to the dispatch users, the owners of those input points associated with UVAP. If the $Q_{MSD}(\mathrm{i})$ is negative, Terna receives the payment from the dispatch users, and pays the UVAP’s manager, at the same figure commented in the previous case.

8. Conclusions

The development of the technologies able to produce electricity from renewable sources, at the expense of the thermoelectrical plants, reduces the energy costs when these sources are available. Usually, indeed, after big support of renewable generation the price is high because the fuel plants try to recover the costs concerned during the non production period.

As seen in Chapter 4 the renewable production makes great differences between the market zone. These impacts especially on the connections between them, and if it is achieved the saturation, the market splitting takes places making a higher PUN and violating the purpose to create an unique European market with an unique price, that is the lowest possible, hour by hour.

An aspect that contributes to decrease the energy price is the high difference between the renewable forecast and the measurement of the effective energy generation from these sources. As explained in Chapter 6, the renewable generation has the highest merit order, so their offers enter in MGP, while other offers with lower merit order stay on the right of the market clearing price not selling. But if the predictions of renewable source swould be more accurate, more offers would pass from outside into the market. In the 2017 hours without congestions twenty operators have lost thousand of offers for this reason.

In 2017 it was identified a trend of the difference between the solar energy preview and the produced by the solar panels. Chapter 5 shows how the difference grows with the temperature, indeed the biggest difference stayed in the hottest hours and months. This trend had only one side and it is in favor of the prediction. For wind energy there is not a particular trend, but mainly is in favor of the energy measured by the wind turbines. To avoid other cases, more precise methods of renewable forecasting are still under development.

To limit the energy price, and to help the system to address the critical issues of the network, solving from congestions and reduce zonal and infra-zonal risk of blackouts the Demand Responde involves all those behaviors that determine a change, compared to normal consumption models, in the load profile of end users, in response to price signals coming from the market or emergency signals ordered by the system operator, when the security or reliability of the network is compromised. Through two pilot projects for the first time in Italy, in 2017, the demand users and the renewable generators are allowed to participate in the ancillary service. The first, the UVACs, are allowed to create the sources about tertiary reserve and balancing service reducing their load after Terna order. While the UVAPs are renewable energy plants which can create the sources about tertiary reserve power, balancing and programming and solve the grid congestions, introducing or absorbing power by renewable energy plants with “go up” and “go down” services.

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