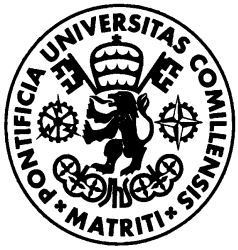

UNIVERSIDAD PONTIFICIA COMILLAS

ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

OFFICIAL MASTER´S DEGREE IN THE ELECTRIC POWER INDUSTRY

MASTER THESIS.

Analysis of the impact of free interconnection capacity on the liquidity of the Continuous intraday market.

Author: Fernando Baeza Vera

Supervisor: Nuria Trancho Tejerina

Madrid, July 2019

Master's Thesis Presentation Authorization

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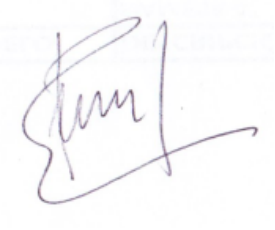

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1. SUMMARY

This thesis tries to analyze the liquidity of the new continuous intraday market developed within the XBID project. For this purpose, firs the results obtained after ten months of operation were analyzed with the aim of perform afterwards different correlations to help the explanation of the factors that influence the increase or the decrease of the market liquidity.

In addition to this study, the liquidity of the different European intraday continuous market managed OMIE, EPEX and NORDPOOL was also analyzed.

2. FOREWORD

I would like to dedicate the effort that has involved the development of this thesis, as well as all the achievements made during this university year to whom in a few months will be my wife. Throughout this year, she has been an essential support thanks to which I have been able to reach my goals. I am sure that without her I would not have succeeded.

I also want to thank my supervisor for all the help she has given me in the preparation of the project. All the knowledge he has shared has been very useful and has allowed me to successfully complete this great challenge.

Finally, I would like to thank the director of the Master for all the advices that he has given to me. These have been fundamental to complete a demanding academic course which I have combined with my daily work in OMIE.

3. INTRODUCTION

In the last decade a new paradigm has raised at least in a European framework. This new point of view defines several aspects inside the electric power industry which change with respect to the former situation.

The starting point was the third Energy Packed promulgated on December of 2008 by the European Commission which establish different targets such as the increase of the share of renewable in the technology mix, improvements in the efficiency in both the generation and demand side, decarbonization for the year 2050 with a continuous reduction of the European emission and finally an increase of the integration of the European market.

For that aim during these years, several regulations have been promulgated in order to achieve these before mentioned targets. Focusing on the market integration and analyzing from a market point of view, the day ahead market that was commissioned in 2014 and the intraday continuous market, are a step forward for achieving a better integration of the European market across Europe.

On the other hand, the increase of the share of the renewable energy in the technology mix in coordination with the increase of their competitiveness are affecting the final generation scheme. The result of this fact is a market which lower predictability due to the features of this new technologies.

For that reason, to create a tool that could manage in a proper way the new characteristic of the renewables was needed. For that aim the intraday continuous market was commissioned given the possibility to the market agents to have a new tool which could help them to hedge against the intermittence of these technologies.

This thesis tries to describe the main features of the intraday continuous market that was developed within the XBID project with the aim of giving an answer to all the topics mentioned before.

4. XBID PROJECT

Following the directives elaborated by the European Commission, finally, on the 13 of June of 2018 after several delays, the go-life of the so-called "first wave" XBID project took place. For this first go life several participants developing different roles, were involved. In future points of this thesis the main aspects of this new market will be analyze.

As first step for understanding the project, the following illustration could be useful, as it defines which NEMO manage the market in each of the European countries. It is important to bear in mind that inside certain zones exist several bidding areas, as is going to be seen later as well.

Besides, it is expected that in future waves other Nominated Electricity Market Operator (NEMO) that manage the energy market of other countries could join the projects providing new opportunities as far as the interconnection allow it.

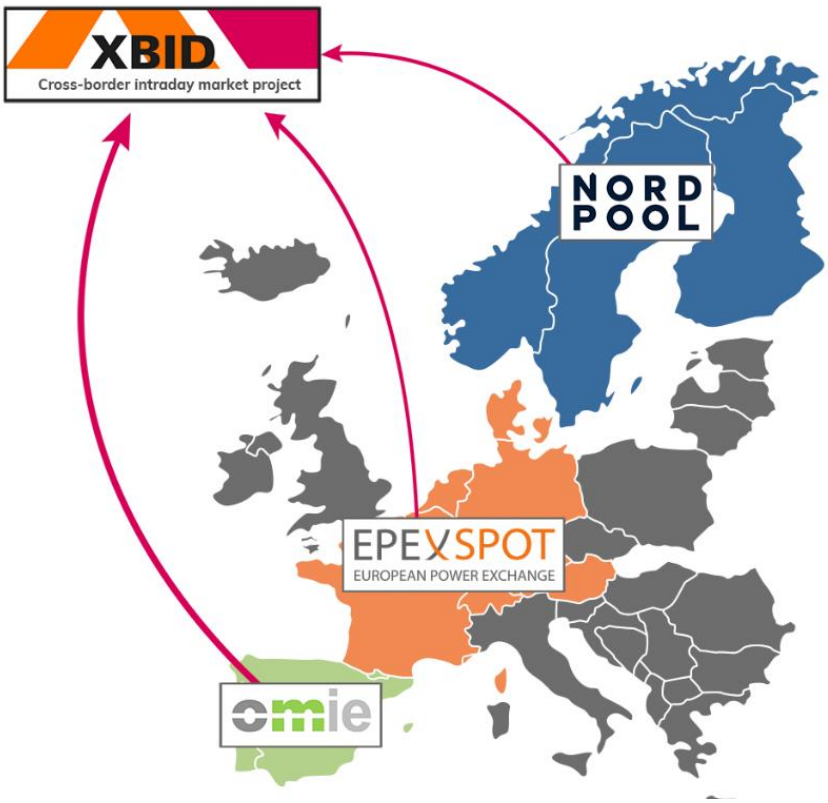


Illustration 1: European scheme regarding market operation

Finally, the current structure of the market is not the same as it was when the XBID project began. This fact is due to several changes in the operation of the market that has being applied

during this year. An important section of this master thesis would also analyze these changes in order to determine in more detail the behavior of the continuous intraday market.

4.1. NEMOS & OTHER INVOLVED PARTIES.

There are several companies related with the operation of the continuous intraday market playing each of them different roles as is going to be explained in this point.

- **NEMO:** This role is performed by a NEMO who is the one that manage all the market operation. In this project only three NEMO has been involved in the first wave. These three NEMO´s are OMIE, which is the market operator in the Iberian Peninsula, EPEX who is the market operator that manage several zones in Europe as France, Germany, Belgium and Netherlands and, who also manage countries as Finland, Norway…etc.

  This are the NEMO that will be analyzed in this thesis as they were involved in the first wave, however GME, who is market operator of Italy has been involved since the first day in the decisions of the XBID project however, it decided to not take part at least in the first wave.

  It is planned that in futures waves they can join the project as a NEMO and therefore obtaining all their responsibilities.

  In the following table is represented a relation between the NEMO involved in the first wave with the bidding areas that they manage and the country in which they operate.

Countries	Bidding Areas	NEMO
Spain	ES	OMIE
Portugal	PT	OMIE
France	FR	EPEX, NORDPOOL
Belgium	BE	EPEX
Netherland	NL	EPEX
Germany	DE	EPEX, NORDPOOL
Austria	AT	EPEX
Denmark	DK1, DK2	NORDPOOL
Finland	FI	NORDPOOL
Norway	NO1, NO2, NO3, NO4, NO5	NORDPOOL
Sweden	SE1, SE2, SE3, SE4	NORDPOOL
Estonia	EE	NORDPOOL

Lithuania	LV	NORDPOOL
Latvia	LT	NORDPOOL

Table 1: Relationship between NEMO´s countries and bidding areas

- **TSO:** Transmission System operator is the participant who manage flow of energies in the system. In the case for the intraday continuous market, the role that this actor will play is updating the cross-border capacity. This cross-border capacity is going to be analyzed in detail in following points, however, as a remark, this capacity is the base of the continuous intraday market.

  In the following table are represented the TSO involved in the XBID project and the country in which they operate.

Countries	TSO
Spain	REE
Portugal	REN
France	RTE
Belgium	ELIA
Netherland	TTN
Germany	AMP, 50Hz, TTG, TNG
Austria	APG
Denmark	ENDK
Finland	FI
Norway	SN
Sweden	SVK
Estonia	Elering
Lithuania	AST
Latvia	Litgrid

Table 2: Relationship between the XBID countries and the respective TSO

- Other parties involved:
  - **XBID platform SERVICE PROVIDER**: This company oversees the development of the XBID platform. When an unexpected issue occurs regarding the IT system, the NEMO CENTRAL Admin has to contact with this company in order to solve the problem.

- **Connectivity service provider:** This company is in charge of the connectivity between the NEMOs and the platforms developed by the service provider. And, between the TSO and the XBID platforms.

4.2. PLATFORMS.

The are several platforms inside the XBID project, that manage different aspects of the operation of the continuous intraday market. The main platforms and their respective functions are the following:

- **SOB:** This module manages all the information about the market. This information is related with the global status of the market, delivery area, bidding area, etc… Each NEMO has the allowance of changing their own parameters. Only in the case that there is a global problem the NEMO CENTRAL admin is the one that will control this module.

  On the other hand, if the problem is local, as it was mentioned before, the SOB nemo admin will be the one who will manage and take actions in the SOB.

- **Shipping Module (SM):** The main functions of this module are to define the path of the energy of cross border trades executed for each contract. The aim of this module is to define which is the counterparty for making the correct settlement.

- **Capacity Management Module (CMM):** This module is in charge of managing all the cross-border capacities. The corresponding TSO has to take care of its interconnections, and if it is possible, updating the available capacity for allowing the agents to perform cross border trades.

  It is important to highlight that the Transmission System Operator only have the last three minutes of each round for updating this capacity in the platform.

- **COMTRADER:** This last tool it is not considered as a module of the XBID project, however, is a very useful platform used by all the NEMO. The main aspects that it manages is the general overview of all the trades performed in the XBID market. This means that any transaction in the market, could be seen in this platform.

Once the main functions of these modules are explained, the following illustration shows the general structure of the XBID project.

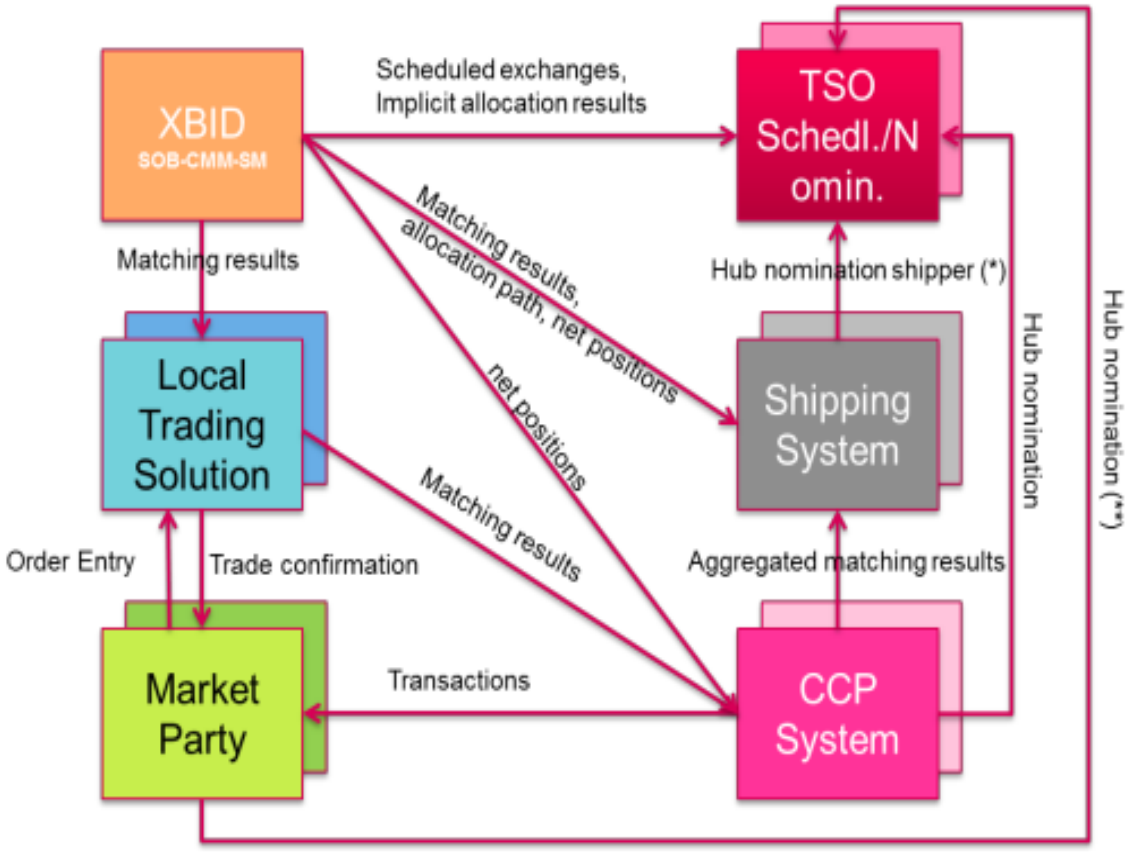


Illustration 2: Internal scheme of the XBID project

All the before mentioned modules are managed in terms of functioning by the service provider, however each NEMO develop and update its own platform called Local trading solution (LTS).

This platform is joining point between the agents and the XBID modules. It is important to highlight that in principle, the LTS is an internal platform that must not be shared with other NEMO. In the following point there will take place a description of the main features of the platform.

4.3. LOCAL TRADING SOLUCIÓN.

The local trading solution is a platform developed by each of the NEMO involved in the XBID project which main aim is to give the agents a platform where they could introduce sell or purchase orders for adjusting their market position. Also, this internal platform will stablish a link between NEMO´s market agents and the XBID platforms.

As it was mentioned, the aim of the platform is to be a place where the market agents could insert both purchase and sell offers. If these offers are competitive enough the platform will automatically perform the corresponding trade. The market agents only have to analyze the amount of quantity and price that they should introduce for maximizing their benefits.

The main principles of this market is to be a tool for adjust the global position for a period of time closer to the real time, however, if there is available capacity in the interconnection the market agents have the possibility to find opportunities that maximize their earnings.

It is important to remark that the LTS of the NEMO´s are different between each other as they have developed it privately. However, there are several aspects inside the platform that are common for all the PX involved in the projects.

The following illustration is the screen of a Local Trading Solution of one of the NEMO, as could be seen in a first view there is plenty information. This point will try to analyze the general's characteristic of this platform.

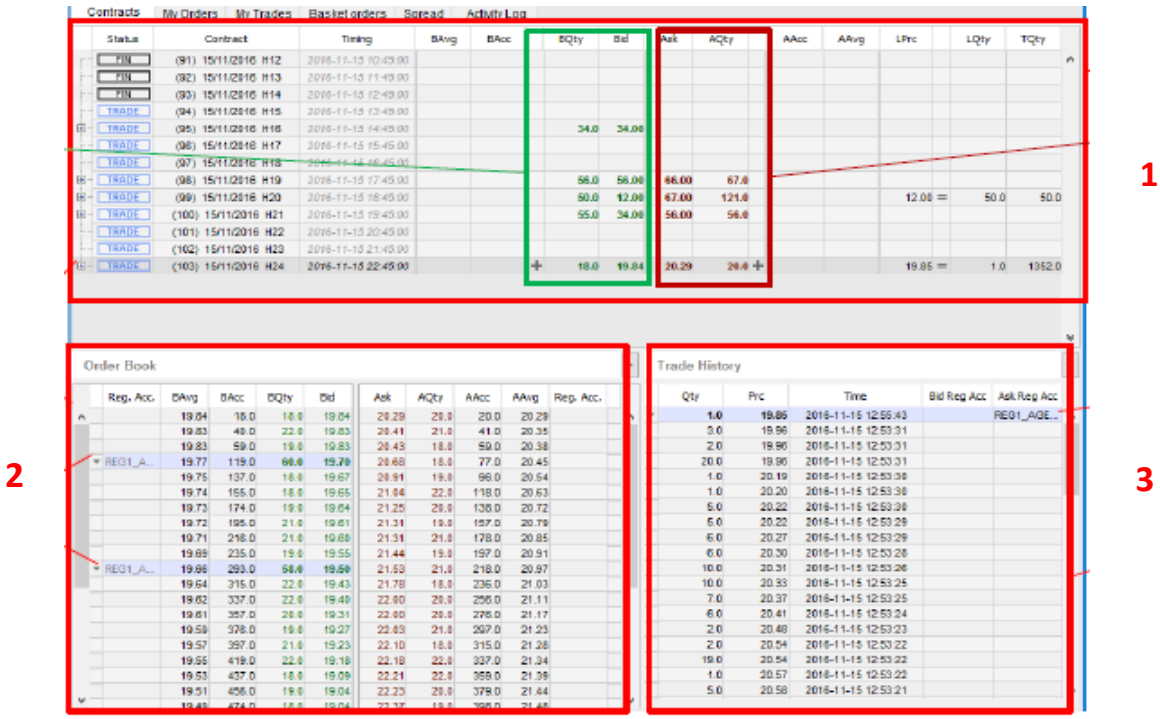


Illustration 3: Example of a Local Trading Solution

1. The first point to highlight inside the LTS is the contract list. The main labels that are presented are:

a. **Status:** Defines the status of the contract. These are the possible states of the contracts:

   i. **Closed**: When the gate closure time of the contract has arrived, and this contract will not be able to negotiate anymore. Normally the Local trading solution will show the last three closed contracts.

   ii. **Trading:** This status is shows that the contract is available to the agents for making trades. Depending on hour of the day, there will be much or less contracts opened. In the commissioning of the MODEL B, that is going to be explained before, the number of contracts open at the same time changed.

   iii. **Upcoming:** The status of upcoming represent all the contracts that will be opened when their opening times arrives. In the provided illustration it cannot be shown as there are several contracts opened.

   iv. **Interrupted**: This status will take place only when:

      - The corresponding NEMO has to clear an intraday auction. In this case the continuous intraday market must close in order to update the current information. When the contracts change to trading the information (maximum power that the agents could offer in the market and guaranties) will take into account the last intraday action.

      - In maintenance activities performed by the NEMO or by the Service provider.

b. **Contract:** This label defines the contract code. Depending the products that the NEMO offers, there will be different numbers of contracts. For this PX for instance, there are 24 contracts, so the hour of the day will coincide with the number of the contract. However, there are others PX with a greater number of contracts per day as they don´t offer hourly products.

c. **Timing:** This label defines the date and the gate closure time (time in which the contract will change to close status, meaning that it won't be possible to negotiate the contract again).

d. **Bid & Ask Offers:** The two zones colored in red and green is the place where the most competitive purchase and sell offers are located. The most competitive sell orders are the cheapest ones, however in the case of the purchase orders the most competitive are the expensive ones.

   These orders are ordered in a decreasing competitive manner. When the purchase order has a price higher than the sell order a trade will be performed.

   The other columns that could be seen in the illustration, represent the average and last price of the trades performed in the selected contract. This is a useful information for the rest of the agents as the can know which is the market price for the electricity.

2. The second point refers to the Order Book. First of all, it is important to remind that this is unique each contract so the characteristics the order book are going to be different.

   This part of the screen is one of the most important of the Local Trading Solution because it store all the purchase al sell offers in decreasing order of competences. Only the five most competitive of the list will be represented in the point 1.d. of this section.

   Inside this order book there are also valuable information about the liquidity because in the *"Bacc"* column represent the accumulated volume offered in this contract, that will be a very good indicator of the liquidity of the contract. As this information is not publish, for the following analysis it could not be considered.

3. Finally, the last point refers to the trade history, this part of the platform stores all the trades performed for each contract. These trades could be performed between internal agents (There is not cross border trading) or between different bidding areas depending always if there are available capacity in the interconnection.

Finally, these before mentioned points are the most useful information about the market that the Local trading Solutions provides, however, this platform also gives other valuable information about the corresponding agent. This other valuable information is for instance the global position of each of the bidding unit, the offers and the trades of the units managed by each agent…etc.

The following illustration shows another Local Trading Solution platform from another of the NEMO, as mentioned above, has similarities with the previous LTS studied.

1. This point is referred to the Contract list, where all the contract with its characteristics are ordered. In this case, the NEMO that manage this LTS has decided that the products that it provide are thirty minutes contract instead the 1-hour contracts.

2. The second point of the illustration refers too the order Book, as it was mentioned before, it presents the most competitive offers in decreasing order of competence for both the purchase and the sell offers.

3. In the third point it is shown the agent´s orders which are located on the different contracts of the order book. This tool allows the agent to control properly the orders that have been sent in the platform.

4. Finally, the fourth point is the trade history, as it was mentioned before it is the place where all the trades performed for each contract are stored.

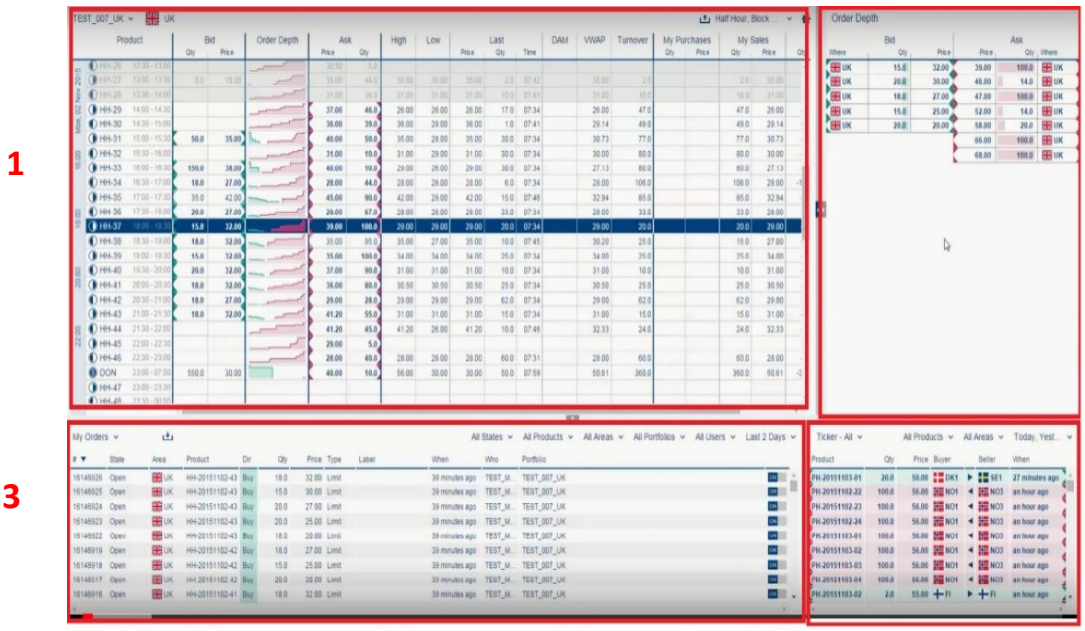


Illustration 4:Local Trading Solution

4.4. OPERATION OF THE CONTINUOUS MARKET.

Once the explanation of the necessity of this market and the structure of it has been explained, it´s the moment to focus on it operation. In this point the main features of the continuous intraday market will be described.

As it is mentioned before, the day ahead is the base for understanding how the Continuous intraday market function, so before starting with the explanation of this new market, a brief description of the day ahead will take place.

Day ahead market and its relationship with the Continuous intraday market.

The day ahead market coupling is performed every day by an algorithm called EUPHEMIA. This session take place at noon when all the European NEMO of the Price Coupling of Regions projects (PCR) send to a cloud called PMB their Order Book (Anonymous offers for the day ahead market). At 12:10 and only once all the order books are in the cloud, the famous EUPHEMIA stars the calculation.

This algorithm is developed by N-Side and during the market coupling session is running for 12 minutes searching the best solution that maximize the system welfare.

The results of this algorithm are the price of the electricity for each bidding area (A brief remind is that in some countries there are different prices as they have several bidding zones). Due to these prices, the flows between the interconnection are also defined being the normal direction of the flow from the cheaper bidding area to the expensive one.

This flow from each interconnection will be the starting point for the intraday continuous market, since the capacity don´t used in the interconnection for maximizing the system welfare will be transferred to the continuous intraday market.

Before starting with the analysis of the CIM market it is interesting to define some concepts related with the capacity:

- **Available Transfer Capacity:** This capacity is set by the TSO each day. Is the one used in the day ahead market coupling session for setting the maximum flow that could be exchanged in the interconnection between bidding areas. Depending the level of congestion of these lines the available capacity for the continuous intraday market will vary.

- **Flow Base capacity calculation:** This type of capacity calculation is also allowed in the PCR coupling session. This methodology takes in account both the topology and the load condition for determining the flow of the electricity. Normally is used in very meshed zones as are the CWE (Central West Europe).

- **Available interconnection Capacity:** This capacity refers to the not used ATC capacity in the interconnection in the day ahead market. This capacity will be transferred to the Continuous intraday market for allowing the agents to make trades with other bidding areas.

Once the basic concepts of continuous intraday market are defined it´s the moment to explain how this new market works.

The available interconnection capacity is defined once the day ahead markets clear. This capacity is transferred for each hour to the continuous intraday market allowing markets agents to perform cross border trades in the cases that exits this free interconnection capacity.

Continuous intraday market

This point will try to explain generically how the operators of the markets that are involved in the XBID project manage their operation.

First, although it seems obvious, electricity is the product that is traded in the market. For this, depending on the NEMO, certain time intervals are established for those in which this energy will be delivered or physically withdrawn from the system. These intervals are called contracts and can be:

- 1-hour contracts
- Half an hour contract
- Fifteen minutes contract

These contracts will be open until the gate closure time which is defined as the moment in which the negotiation of a contract ends. This moment also establishes very important characteristics of the market since the closer you get to real time, the longer the agents will have to adjust their program.

To establish this ending point of negotiation, it is necessary to have an agreement between the system and the market operator in each area. The reason of this fact is that the market operator

try to get as close as possible to real time to provide more opportunities to the agents, while the system operator seek to ensure a safe supply of energy where everyone is dispatched, and having less time margin would produce higher level of risk.

During the time that the contracts are open, the market agents can insert both purchase and sale offers. When a purchase offer is higher than the sell offers a trade is automatically performed. However, at what price? The price will be defined with the price of the passive offer, being the passive offer the bid that is waiting in the order book to the counterparty.

These offers, when they are competitive enough, could create a trade with agents within the same bidding zone, or if the capacity allows it, with offers from other bidding zones.

As mentioned, system operators have certain moments coinciding with the closing of contracts to update capacity if possible, between bidding areas. In the case that this occurs new offers will be seen in the corresponding order book, however if these new offers are competitive with the offers of the other bidding zone and being both a passive offer, a micro auction is carried out to know the price of that trade.

Main changes of the market structure

During this period that is analyzed in this master thesis (from 13 of June to 31 of March), is important to highlight that the normal operation has changed several times being the ENDURING MODEL that was commissioned in November, one of the biggest changes that affect the behavior of the market.

- **INTERNAL MODEL**: In this model the normal operation was structured as a complement to the intraday auctions. At that time, the aim of the market was mainly to be an adjustment market closer to the real time. For that reason, only the contracts that were not included in the time horizon of the previous auction, were those that would be opened until the next auction.

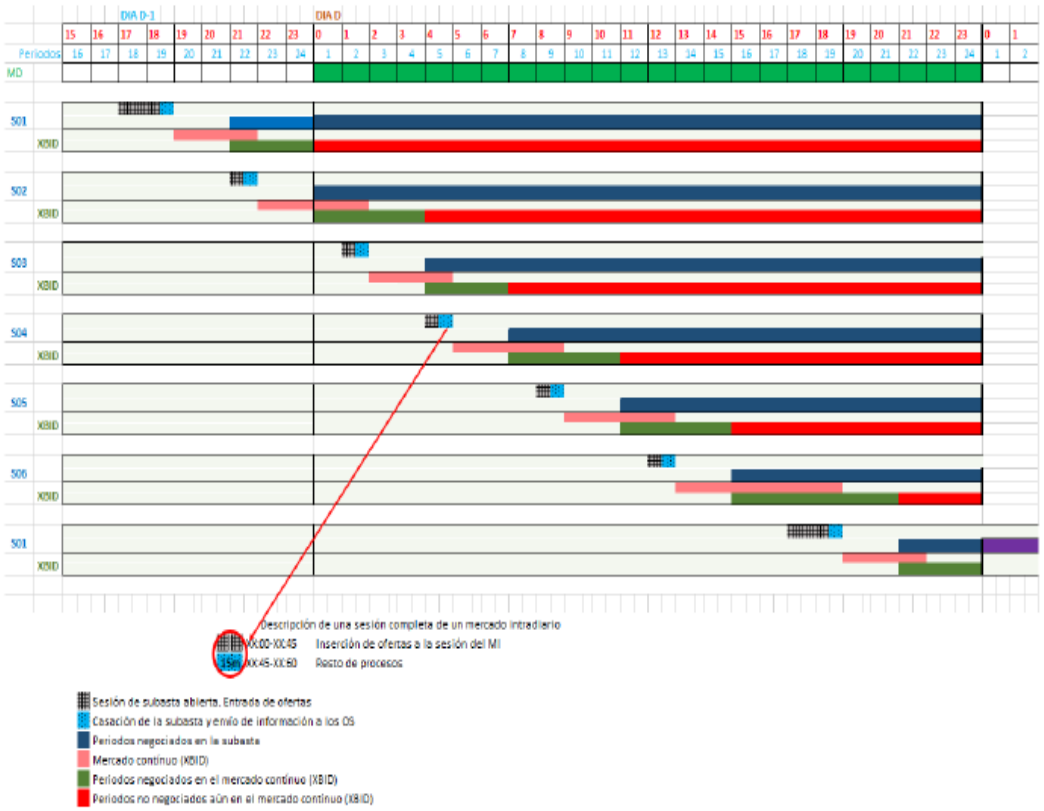


Illustration 5: Internal Model Scheme

- **ENDURING MODEL:** On the other hand, the model that is currently applying, is structured in a different way. Now all the contracts open at 10 pm and from that moment the 24 hours of the following day are available for make trades.

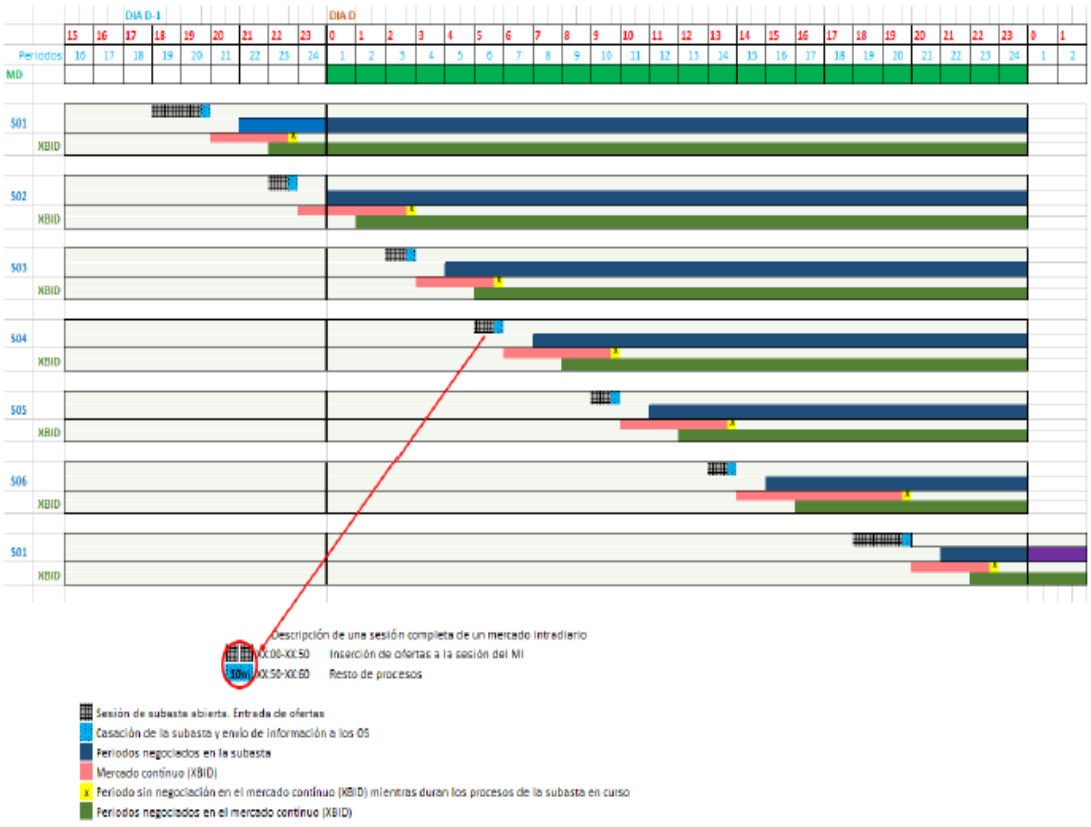


Illustration 6: Enduring Model Scheme

It is expected that in future models apply new changes such as changing the gate opening time of the contract from 10 pm to 3 pm, changing the number of intraday actions for accommodating the new so-called Pan-European auctions and introducing new type of contracts as could be the thirty and fifteen minutes contracts.

It is possible that these changes mentioned above, affect the behavior of this new market, however, the analyzes on which this thesis is based can be a reference on the characteristics of this market and can help the agents to define the possible opportunities that it provides in order to focus their resources and efforts to maximize the benefits at the lowest possible cost.

5. IBERIAN MARKET CAPACITY MANAGEMENT

The aim of this chapter will focus on stabilizing a relationship between the different parameters that affect the liquidity of the intraday continuous market. For that purpose, the IBM SPSS model is going to be the main tool that will allow the analysis of this relationship.

The first step of the research is to establish the fundamental variables that affect the behavior and ultimately the liquidity in the continuous intraday market.

- **Interconnexion capacity:** It is the capacity that the Spanish system operators establish as maximum for the day ahead market. In the case of the Iberian market, the interconnection capacity is the before mentioned ATC capacity.

  The value of it will delimits the level of energy that could flow in each direction (export and import direction). When this capacity is low, would cause the denominated market splitting that means that the interconnection is fully saturated therefore there would be differences on price between the interconnected bidding areas.

- **Day ahead prices:** Once Euphemia has established the prices for the Day Ahead market and therefore the flow of energy from the cheapest (most competitive) to the most expensive areas (least competitive) is set, the available capacity for the continuous market is obtained. For this reason, large differences between neighboring price zones, would cause a null available capacity for the Continuous intraday market due to the beforementioned phenomenon called market splitting.

- **Renewable Energy:** Renewable technology has several positive characteristics such as low carbon emission, reduce the prices in the market…etc.; However, its intermittency is not a positive point and should be managed. The aim of this market is to somehow support this intermittence allowing market agents with this type of technology installed to adjust their position closer to the real time. The gate closer time of a contract is not the same for all NEMO, depending on the country this moment is close or far away from the real time.

- **Forecasting:** Finally, the degree of forecast of renewable energies is an important aspect to bear in mind when analyzing the liquidity of the market. Forecasting models are generally developed by agents with the aim of adjusting their offers in the market as best as possible. A low correlation between the predictions and the real conditions

would cause an increase of volume of negotiation in the market, as the agent will try to adjust their programs trying to avoid the imbalance market which is less predictable and more risky

5.1. DESCRIPTION OF THE PROCESS

In order to create several relationships that explain the liquidity of the continuous intraday market, first was necessary to create a data base for store all the valuable information. Once with this information stored, the most important variables that affect the behavior of the market where selected and finally, two analysis were performed. The first analysis is based on historical data and the second one uses the IBM SPSS model for correlating the selected variables.

This point will define the steps that were followed for obtaining these results.

As this analysis is performed only for the Iberian market, several sources of information were needed. It is important to highlight that the scope of the thesis is from the 13th of June of 2018, which is the commissioning date of the project, to the 31st of March of 2019.

These are the sources used for collecting the data for the study.

- **OMIE webpage:** OMIE provided very useful information, however, the data downloaded was the following:
    - Day Ahead Prices
    - Maximum price for a contract in the intraday continuous market
    - Minimum price for a contract in the intraday continuous market
    - Volume of purchased energy for each contract in the ICM.
    - Volume of sold energy for each contract in the ICM.
    - Hourly power by technology (For the renewable analysis)
- **ENTSO-E Transparency platform:** This webpage of this organization of all the European TSO gathers information of all the European markets (Mainly it collects information about capacity and flows). From this webpage the Available transfer capacity (ATC capacity) for the day ahead market and the total energy flow was downloaded for each contract.

As it was mentioned before, once this data was downloaded, Excel was the selected tool for creating a database. First, all the data downloaded in Excel files per each day has to be gathered in one excel file. For that aim, several macros were developed in order to streamline the process

of storing this data. It is important to remark that Excel was the tool selected for creating the data base for his ease to make calculations with it.

With all the data gathered in the same file, the calculations of the available capacity and the flows was performed.

- **Available capacity** (***Don't confuse with Available Transfer Capacity**): Is the capacity of the interconnection line that has not been used in the day ahead market coupling.

$$Available\ Capacity = Available\ Transfer\ capacity - Day\ Ahead\ flow$$

- **Calculation of the Flows:** For these calculations was necessary to bear in mind the following equation:

$$Imported\ Volume + Internal\ negociated\ volume = Purchase\ Volume$$

$$Exported\ Volume + Internal\ negociated\ volume = Selled\ Volume$$

With these equations, the available capacity for the continuous intraday market and the flows of energy by the interconnection between the Iberian Market and France and between Spain and Portugal were defined.

5.2. HISTORICAL DATA ANALYSIS

The data collected for the Iberian Market is analyzed in this point. The scope for this analysis as was explained before, starts on the 13th of June of 2018 that was the commissioning date of the XBID project until the 31th of March of 2019.

This analysis is considered a first step for another research that will take place in the point 5.3. This first step will try to stablish certain guidelines regarding the liquidity of the Iberian market that later with a statistical model will be checked with the aim of assessing if the objectives of the continuous intraday market are being fulfilled.

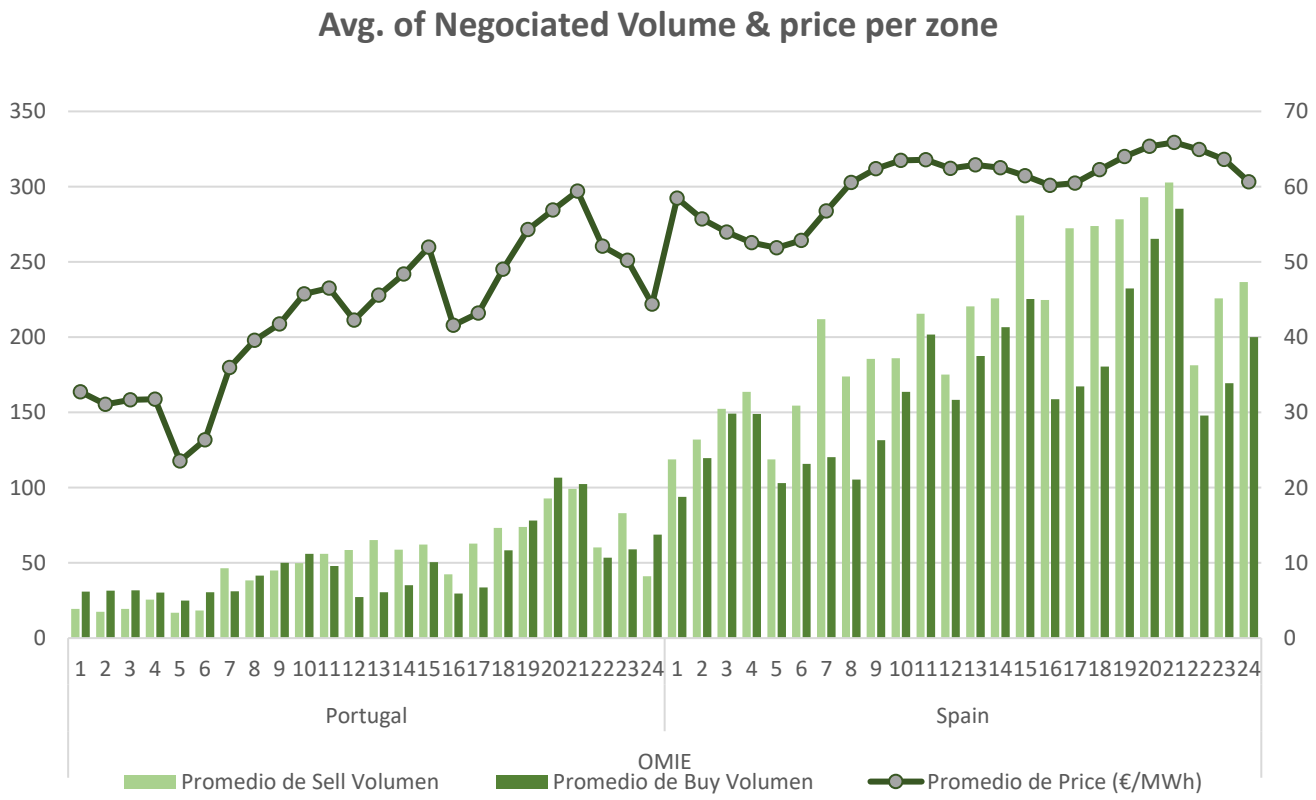
The results obtained from analyzing the historical data for the Iberian market are the following:

- **Average purchase & sell Volume and price in each of the zones:**
  These figures represent the average values of the buy & sell volume and the average price per bidding area in OMIE´s zone. It is important to highlight that figures that try to give a global perspective of these two bidding areas.

OMIE	Avg. Buy Volume (€/MWh)	Avg. Sell Volume (€/MWh)	Avg. Price (€/MWh)
Portugal	47.49	51.06	42.73
Spain	168.21	208.47	60.36

Table 3: Average of Volume and prices in MIBEL

However, the graph below tries to define these average values in more detail, for that reason it differentiates the same figures presented in the table 4 but considering the bidding zone (Spain or Portugal) and the contract.



Graph 1: Average of Negotiated Volume & Price per zone and contract

It is observed that the volume negotiated in both directions in Spain is bigger than in Portugal and that the last hours of the day (Form the 16 to the 24 contract) are the ones that most volume of energy is negotiated. This last fact could be explained because these contracts are the ones which has the most numbers of hours in a trading status.

- **Percentage of available capacity in each of the sides of the interconnection:**

The following table represent the percentage of the hours inside the studied period in which there is available capacity in the interconnection for performing trades against other bidding areas.

As the Iberian market is composed by two bidding areas (Spain & Portugal) and the interconnection with Europe is France, the figures below represent the available capacity for making cross border trades.

- Europe and the Mibel
- Spain with Portugal.

	Capacity available	
	Import [MW]	**Export [MW]**
EUROPE-MIBEL	38.50%	87.69%
SPAIN-PORTUGAL	98.20%	95.69%

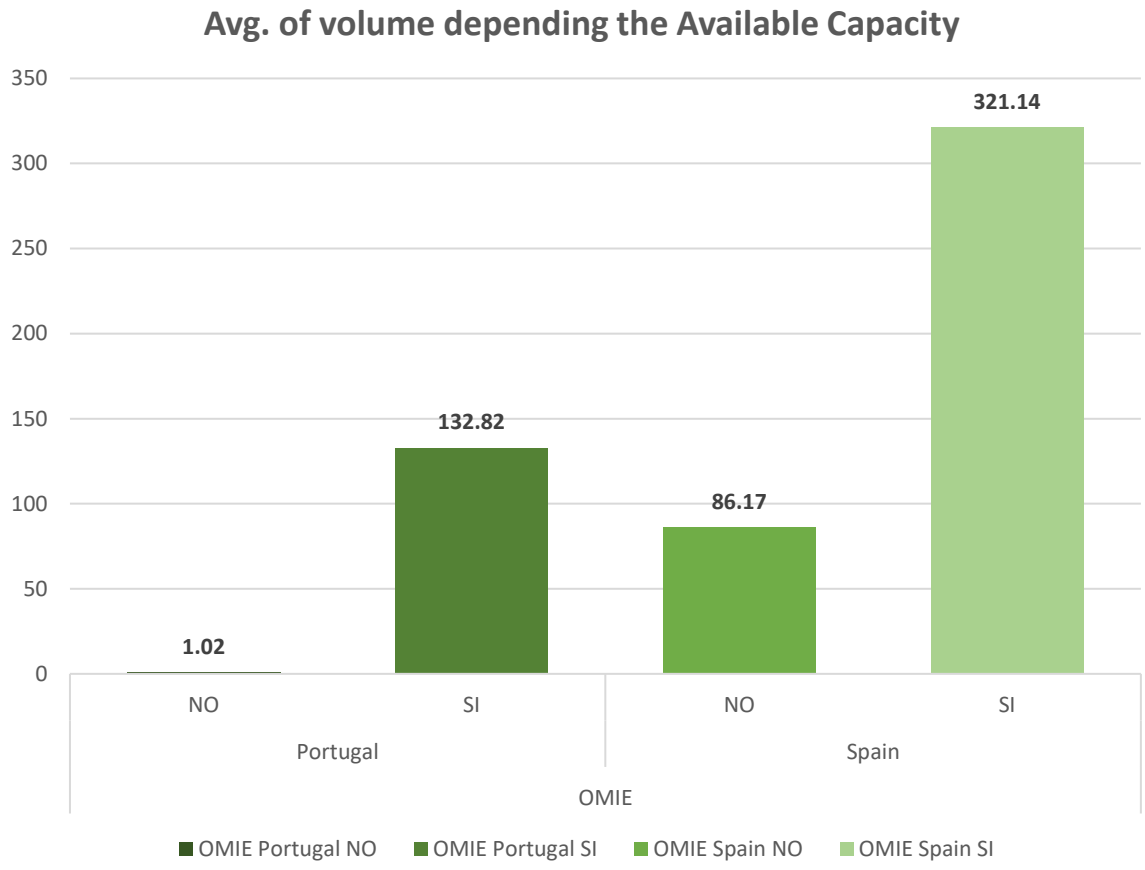
Table 4: Percentage of Available capacity for cross border trading

- **Average of purchase and sell Volume in each zone bearing in mind if there is available capacity in the interconnection:**

This last table and graph want to define how the liquidity of the market varies based on historical data. Once the average of volume traded and average of available capacity have been analyzed, now the two concepts will be jointly studied with the aim of assessing how the liquidity change.

Portugal	
Available Capacity (MWh)	**Avg. Total Volume (MWh)**
NO	1.02
YES	132.82
Spain	
Available Capacity (MWh)	**Avg. Total Volume (MWh)**
NO	86.17
YES	321.14

Table 5: Volume traded depending on the available capacity in the interconnection



Graph 2: Volume traded depending the available capacity in the interconnection

As can be seen by analyzing the historical data, the volume negotiated in each of the areas highly depend on the capacity available in the interconnection.

For instance, in case of Portugal almost any volume is negotiated when there is no interconnection neither with Spain nor with France, however, as it has been demonstrated previously, this case is very unlikely since almost the majority of the time the price of the daily market in Spain and Portugal is the same

The case of Spain is more representative since in many cases the volume exchanged with France is zero, since there is no available capacity in the optimal direction of the line. For this reason, the large difference in the negotiated volume in the cases in which there is or not available capacity, is significant.

In the next point it going to take place an analysis of the veracity of this fact using data correlation models.

5.3. MODELING THE LIQUIDITY IN THE INTRADAY CONTINUOUS MARKET

The results presented in the former point could give a preliminary estimation of how the available capacity affect the liquidity of the Continuous intraday market. However, a further analysis of this topic is needed for estimating the real correlation between the considered most important aspects that affect the behavior of the market.

In this point these relevant aspects that affect the liquidity are defined. A priori, these are:

- The volume exchanged through the interconnection
- The available capacity in the line.

Once these concepts have been defined the variables that could affect them are also studied with a lineal o multivariable correlation.

Although in previous points the main characteristics of this market have been commented, at this point, before starting the analysis a quick remind of the main concepts will take place. This refreshment is necessary since most of the concepts will be part of the analysis.

The Continuous intraday market was created mainly to enhance the integration of the electricity sector in Europe and to provide a market in which the agents could come to adjust their position much closer to real time.

This last fact it´s a very important point for the renewable energy producers, due to the intermittency of this technology. With this market they could manage their position easily as they can purchase o sell energy until at least one hour before the real time. With this new market, they would avoid the imbalance markets which have greater volatility on prices and therefore higher risk.

In order to asses if the objectives of the directives promulgated by the European Commission are being fulfilled and taking as the starting point the historical analysis studied in the former point, a correlation between several variables and the liquidity of the Iberian market is performed.

For that aim, as it was mentioned before, the IBM SPSS model was the tool selected since it has a very visual learning with an easy use and understanding. This tool was also selected due to all the possible calculations that can be performed with it. However, for this research the two main calculations that has been done are multivariable regressions, and linear correlations.

Finally, the sources of data were the same that the data used for the historical analysis.

Multivariable regression analysis on the AVAILABLE CAPACITY.

The IBM SPSS model was the tool used for performing a multivariable regression. This model iteratively establishes different correlations between the independent variables and their combined relationship with the depended variable. Once the iteration is performed the model present the most valuable solutions.

In this case, the dependent variable that has been selected is the available capacity in the interconnection between France and Spain, while the independent variables are those previously mentioned, the ATC capacity and the Day ahead prices.

It is important to highlight that the Available transfer capacity with France is the selected variable since it stablishes the limit of energy flow with the rest of the European markets through the interconnection.

On the other hand, the differences on prices in the Day Ahead market between France and Spain was also considered as an independent variable due to the fact that the prices on this bidding zones will affect the direction of the energy flow, and the level of congestion of the lines.

These independent variables were selected based on own considerations. Since, due to its characteristics, they could largely affect the behavior of the continuous intraday market.

The following table represent the results of the multivariable regression analysis of the two considered dependent variable against the independent variable.

Independent Variable	Dependent variable
- Available transfer capacity - Differences of day ahead prices	- Available capacity in the interconnection

Table 6: Variables for the Available capacity study

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.262[a]	.069	.069	1096.374
2	.279[b]	.078	.078	1090.988

a. Predictors: (Constant), Day ahead Prices

b. Predictors: (Constant), Day ahead Prices, Capinter

Table 7: Multivariable Regression Analysis for the Available Capacity

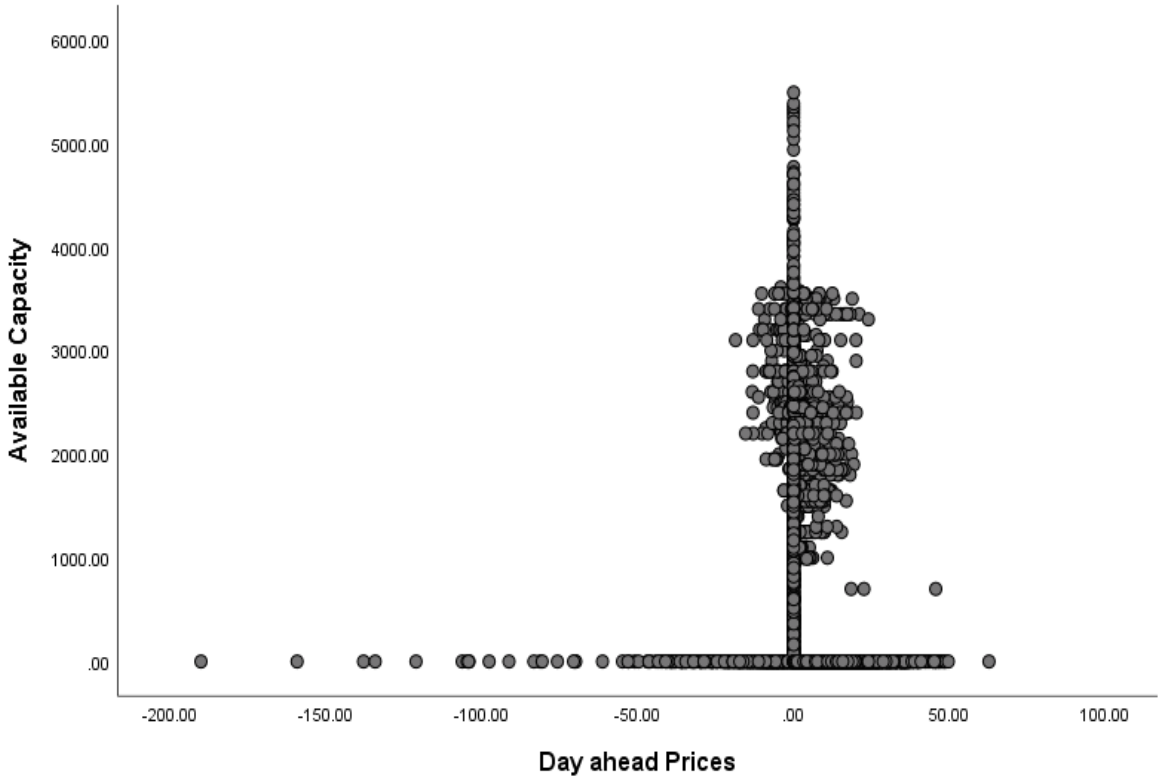
Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	944.587	14.541		64.962	.000
	Day ahead Prices	-23.322	1.025	-.262	-22.742	.000
2	(Constant)	1409.718	57.323		24.592	.000
	Day ahead Prices	-21.160	1.053	-.238	-20.104	.000
	Capinter	-.202	.024	-.099	-8.386	.000

a. Dependent Variable: Available Capacity

Table 8: Coefficients of the linear correlation on the available capacity analysis

Surprisingly, the results of the multivariate analysis were not as expected since the R^2 which is considered the best indicator for determining the level of linear correlation between variables shows a low linear correlation. However, by studying these independent variables separately, the correlation gives more relevant conclusions as can be seen in the following graphs.



Graph 3: Dispersion graph between the differences of prices in the day ahead and the available capacity

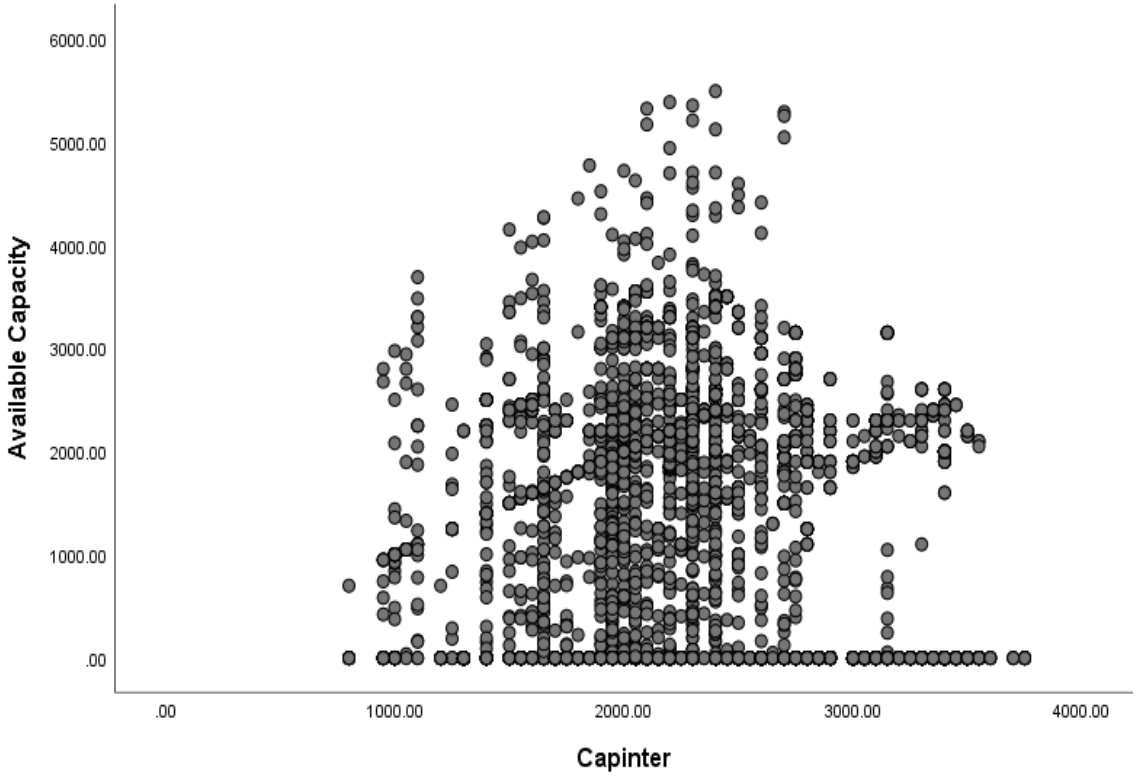
As it is shown, there is only available capacity in the interconnection when the price difference between Spain and France is between -5 and 5 €. This dispersion graph confirms that although the linear correlation is low, the relationship between the available capacity in the interconnection and the prices in the day ahead market exists.

As it was mentioned, only when the differences of prices are zero or close to this value there is available capacity in the interconnection for cross border trading. When the prices are equal means that competitiveness of both markets are similar. This fact is easily defined when the maximization of the profits for the day ahead doesn´t need to export or import energy until the congestion of the lines.

The total interconnexion capacity or also called the available transfer capacity, can also be an important factor that could affect the liquidity of the market. This capacity is set by the system operator for each the hour of the day and is sent to the market operator for including this data as an input for the Euphemia algorithm.

Depending on the total Available Transfer Capacity, the volume exchanged in the day ahead could be affected. For example, if this value is low, normally will imply high differences in the prices in the day ahead.

Using a lineal correlation between the available capacity and the available transfer capacity, the graph shows that there is no linear correlation. Although it is true that, a priori, the independent variable of interconnection capacity could have a direct relationship with the available capacity, the results show that this is not the case at least in a linear correlation analysis.



Graph 4: Dispersion graph between the Available transfer capacity (Capinter) and the available capacity in the interconnection

The results obtained in the analysis performed in this point shows that the available capacity on the interconnection is highly dependent on the differences of prices in the day ahead market between Spain and France as the dispersion graph has defined. However, the Available Transfer Capacity which was the other independent variable considered in the research, do not present a direct relationship with the available capacity in the interconnection when it is analyzed with a lineal correlation model.

Lineal correlation & Multivariable regression analysis on the TOTAL VOLUME.

Once the analysis about what would cause an increase in the available capacity in the interconnection has finished, the thesis will focus now on the causes that can affect the liquidity in the intraday continuous market.

For this aim, two fundamental aspects of this project are going to be studied in order to define the effect of them on the liquidity of the market. These two important variables are the volume exchanged by the interconnection with other bidding areas and the intermittency of renewable energy. The forecasting analysis performed by market participants has not been considered since these data is not published by the companies.

As in the case of the available capacity, this analysis was based on own considerations of the variables that could largely affect the total volume traded in the continuous intraday market.

First, a linear correlation is performed between both variables with the total volume traded in the market, to then perform a multivariate regression for these same variables.

Independent Variable	Dependent variable
- Volume exchanged - Renewable production	- Total volume traded

Graph 5: Variables for the total Volume traded study

Regarding the Renewable energies, the values that have been taken into account are the generation on the day ahead market of intermittent renewable energies from the 1 of January of 2019 until the 31 of March of the same year. These intermittent renewable energies considered are the following:

- Eolic.
- Solar Photovoltaic.
- Solar Thermal.

These technologies are considered as renewable energy with intermittency features as they highly depend on the weather conditions for producing electricity. The hydroelectric technology has not been considered as if there is water in the dam this source of energy is not intermittent.

The following table present R^2 index for the linear correlation between the renewable production and the total volume traded in the market.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.189[a]	.036	.035	237.691

a. Predictors: (Constant), Renewable

Table 9: Lineal correlation analysis between the renewable production and the total volume traded

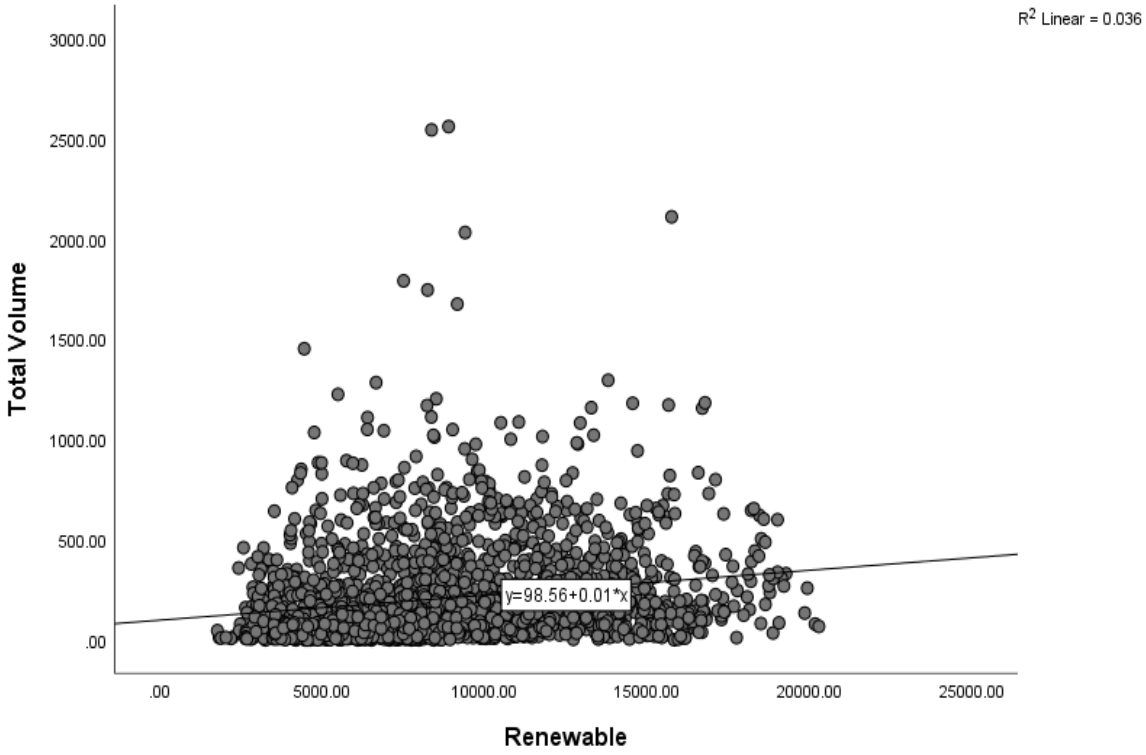
Additionally, the coeficient of the lineal correlation are the following:

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	98.559	13.211		7.461	.000
	Renewable	.012	.001	.189	8.917	.000

a. Dependent Variable: Total Volume

Table 10:Coefficients of the linear correlation between the renewable production and the tottal volume traded



Graph 6: Dispersion Graph between the renewable production and the Total Volume traded

As can be seen, a priori, this type of technology has not a linear correlation with liquidity of the continuous intraday market.

Regarding the other lineal correlation studied between the volume exchanged and the total volume, the flows between neighborhood bidding zones has been obtained through the ENTSO-E website for the period studied in the Thesis (13 of June 2018 until 31 March of 2019).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.918[a]	.843	.843	125.207

a. Predictors: (Constant), Volume Exchanged

Table 11: Lineal correlation between the Volume exchanged and the Total volume traded

As it is presented in the above table, the value of the R^2 index is very high achieving an 84% of correlation between these two variables, meaning this fact the lineal correlation is very

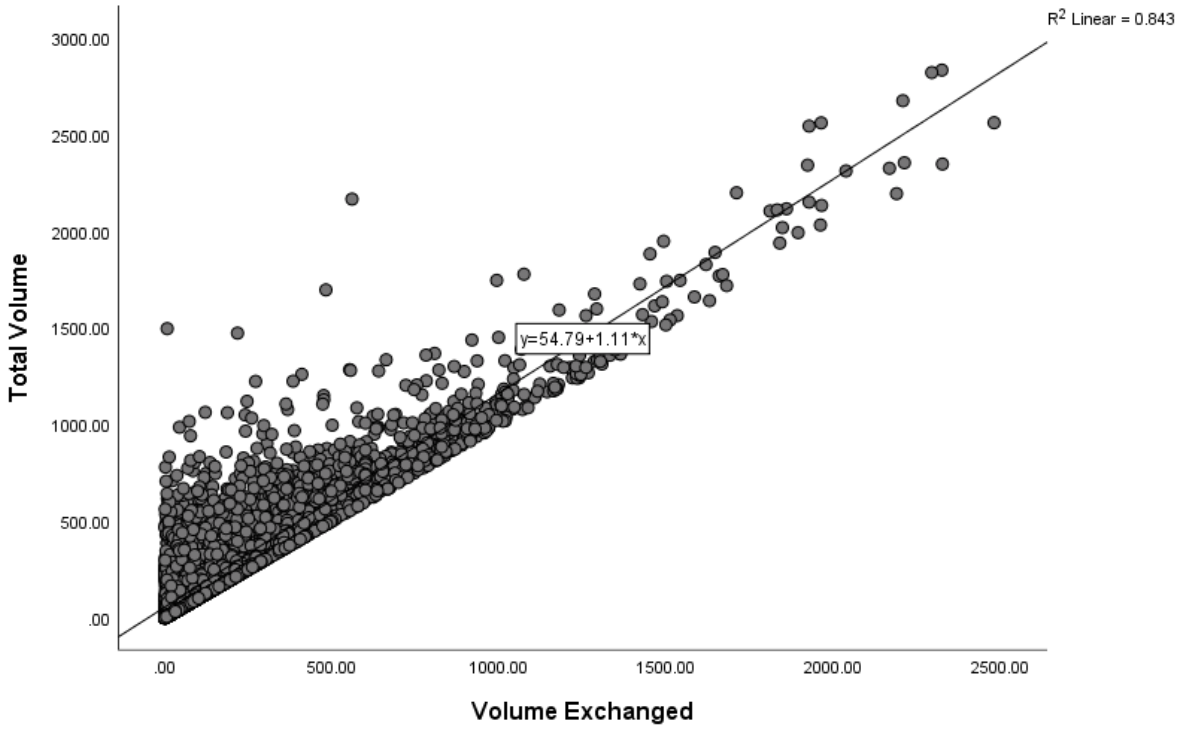
representative. The coefficients that define this linear correlation are represented in the table below.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	54.792	1.908		28.715	.000
	Volume Exchanged	1.107	.006	.918	184.401	.000

a. Dependent Variable: Total Volume

Table 12: Coefficients of the lineal correlation between the Volume exchanged and the Total Volume traded



Graph 7: Linear correlation between the Volume exchanged and the Total Volume traded

Now a multivariable analysis is going to be performed in order to asses if both variables could explain better the liquidity of the Continuous intraday market.

As was explained before this analysis iteratively perform different regression analysis between the selected independent variable, and only the most valuable results are the one presented.

The results obtained for this analysis are the following:

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.886[a]	.785	.784	112.340
2	.889[b]	.790	.790	111.013

a. Predictors: (Constant), Volume Exchanged

b. Predictors: (Constant), Volume Exchanged, Renewable

Table 13: Results of the lineal regression analysis for the Total Volume traded

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	110.632	2.652		41.720	.000
	Volume Exchanged	1.071	.012	.886	88.630	.000
2	(Constant)	69.954	6.179		11.322	.000
	Volume Exchanged	1.059	.012	.876	87.934	.000
	Renewable	.005	.001	.072	7.270	.000

a. Dependent Variable: Total Volume

Table 14: Coefficients of the lineal correlation of the multivariable analysis

Comparing the results between the linear and the multivariate correlation, several important conclusions could be extrapolated. In the multivariable analysis a higher correlation is obtained for the scenario in which the exchange volume and the production of renewables are considered.

Since the amount of data studied for the multivariate analysis (only from the 1st of January to the 31st of March) is less than for the linear correlation, it could be expected that both variables

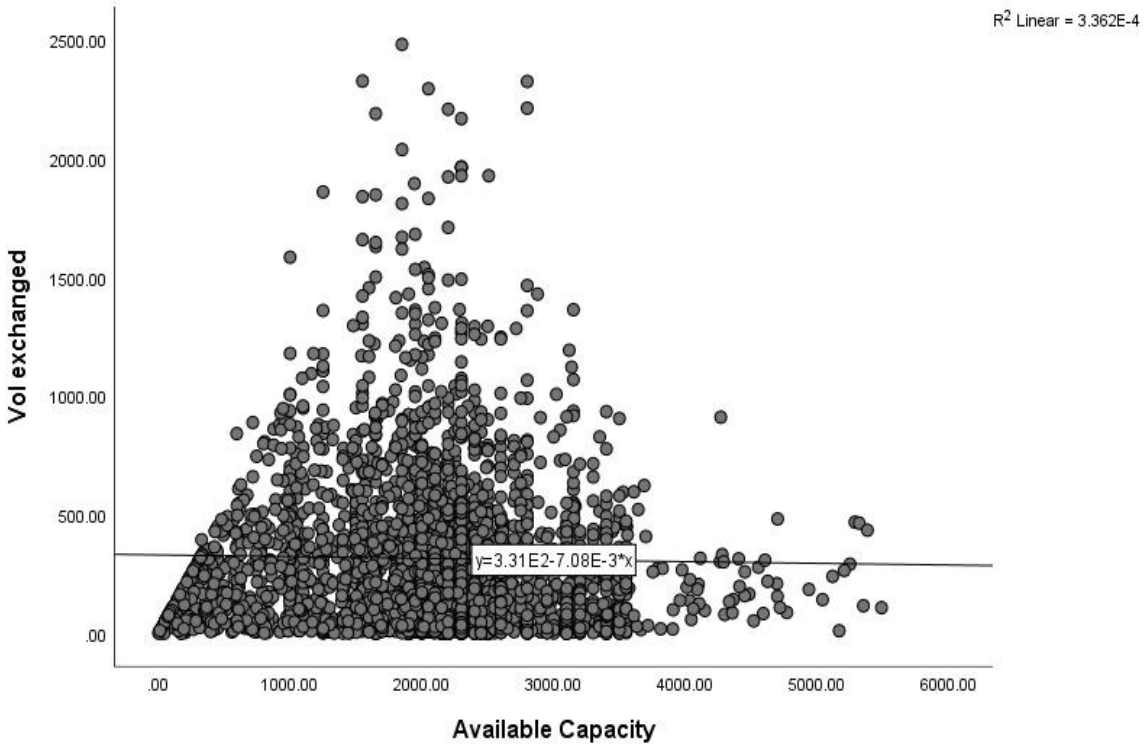
when they are studied for the whole period of study (13th June to 31 of March), reflect a greater correlation with the total volume than they reflect when they are studied separately. Bearing in mind that the volume exchanged is the critical variable of the correlation.

Linear Correlation between the available capacity in the interconnection and the Volume exchanged.

Finally, the last correlation is performed with the aim of assessing if the total exchanged volume in the intraday continuous market for each hour depend on the available capacity in the interconnection. This is considered at the beginning of this chapter as the main analysis that this thesis would define.

Until now the analysis that has been performed tried to assess the different aspect that affect the two variables that affect the liquidity of the Continuous intraday market as are the available capacity in the interconnection and the total volume traded. However, in this last analysis would try to define if these two variables are correlated between them.

In the following linear regression is represented the correlation between these variables. In this case as can be seen in the graph, the correlation between the available capacity in the interconnection and the total volume exchanged in the market is very low. This fact means that the available capacity doesn´t have a lineal correlation with the total volume traded.



Graph 8: Dispersion graph between the available capacity and the Total Volume exchanged

It is important to clarify the two concepts presented in the previous graphs. The total volume highly depends on the volume exchanged by the interconnection. However, when there is available capacity in the interconnection, it doesn´t imply an increase in the volume of negotiation.

It was expected that these two variables analyzed in this point were correlated, however this was not the case, so there has to be other external variables that affect the Continuous intraday market and they are not presented in the lineal correlation. In the following point the aspects that could affect this no lineal correlation will be analyzed.

5.4. CONCLUSION

Several conclusions could be extracted from the former results.

1. The capacity available is only feasible when the prices obtained in bidding areas are very similar. This fact occurs because the prices are very competitive in both bidding areas. In this case, Euphemia in order to increase the welfare sometimes leaves available capacity to be used in the continuous market.

Besides, the analysis has also shown that the effect of the Available Transfer Capacity interconnection has a very low linear relationship with the available capacity in the interconnection.

2. As it was expected, the level of negotiation in the Iberian market highly depend on the level of volume exchanged by the interconnection. When this volume is exchanged, normally the level of volume negotiated proportionally increase.

   Besides, the inclusion of renewable technologies, despite not being a powerful variable in the study, indicates that the confluence between the volume exchanged and the presence of intermittent renewable generation has a greater correlation with the total volume negotiated than separately.

3. The third conclusion of this analysis is the low correlation between the available capacity in the interconnection and the volume exchanged by it. This conclusion was not expected at the beginning, However, if it is analyzed carefully, several reasons can be found for which the relation between these two variables don´t present a direct correlation. This fact can be explained by the following reasons:

   - **The Order Book:** As it was explained, the Order book is the place within the LTS platform where the offers are accumulated in order to increase their competitiveness. One of the characteristics of OB is that it´s not possible to choose the desired offer, agents could only make trades with the most competitive one.

     In the case that there is free capacity in the interconnection it means that the offers of both bidding areas are competitive and will be ordered in such way in the Order Book. This fact can explain that although there is capacity in the interconnection, this is not always used.

   - **The Behavior of agents:** This market is relatively new, where their participants, have not become aware of all the opportunities that it can offer. For this reason, as this market is not totally mature regarding the market participants, could explain why the free capacity is not always used in the interconnection.

- **Use of the non-conventional flow direction:** There is also a strange situation that has been observed by the exhaustive analysis of the data, in which cross border trading take place when there is no interconnection capacity in that direction.

  This fact occurs due to the high volatility of the prices in other bidding areas such as France and Germany. This high volatility provokes that trades could be executed in the non-conventional direction released capacity in the other interconnection direction. This fact could distort the normal behavior of the market and could explain why the available capacity in the normal direction is not being used.

6. EUROPEAN LIQUIDTY ANALYSIS

This section analyzes the liquidity of the different markets that are involved in the XBID project. For that aim historical data from the 13th of June of 2018 to 31th of March of 2019 is analyzed.

The way in which the information has been compiled follow a similar methodology than in the previous analysis. First the prices and the total volume for each bidding area managed by the NEMO that take part in the project was downloaded from their own webpages. Once this information was stored a data base was created using excel macros.

The before mentioned data is gathered in a single excel file from which the analysis of the liquidity of the European market is performed. It is important to highlight that this research is based on two factor that reflect the quality of a market from a liquidity perspective.

These two indexes that reflect the liquidity of the market are the volume traded and the spread.

- **Volume Negotiated**: Represent the volume negotiated in each contract. This index is a good liquidity indicator because as much energy you have negotiated more energy you have had in the order book for performing trades.

- **Spread:** This index represents the differences between the maximum and the minimum price of a trade executed for each contract. This index is also considered a good reflection of the liquidity of a market since the less spread there is among the trades executed in a contract, the little the risk in that market. Being able to increase or decrease the position of the agent offers with almost any cost.

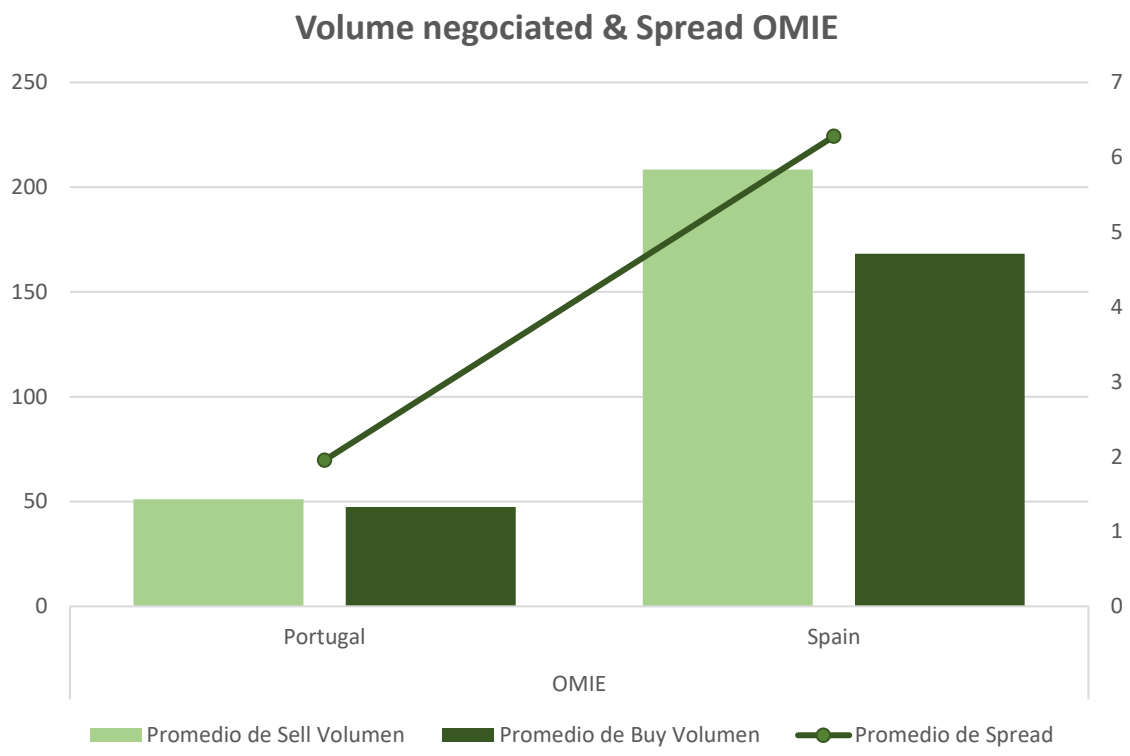
Based on other studies on liquidity in the markets, it was decided that the volume traded and the spread when they are analyzed together, are sufficiently representative indicators for assessing the level of liquidity of a market.

Before starting with the presentation of the results is important to explain that sometimes the countries that has been considered for the study don't match with bidding areas (zones with different prices). There are some countries that count with several bidding areas as are Sweden, Norway, Denmark…etc, for these countries the data collected has been merge in order to provide comparable results.

The results for each NEMO are present in the following points.

6.1. OMIE.

The following graphs represent the average volume negotiated and the average spread in Portugal and Spain which are the countries managed by OMIE.



Graph 9: Purchase & Sell Volume and market spread for Omie

It is interesting to highlight the differences between the volume exchanged between these two countries. In Portugal this volume is fourth part of the traded volume in Spain, being this last country mainly exporter. This exported volume, can be thought that is bought by Portugal, however the graph also defines that the position of this country is Seller.

The fact presented before could be explained with the data provided in the point 5.2. of this document that show the percentage of available capacity for an exporting direction and for an importing direction. This table show that importing direction have available capacity the 38.50 % of the times, however in the exporting direction the percentage increase until the 89.60 % of the times. This high percentage joint with the high volatility of the prices in Europe led that sometimes the competitive offer come from Spain giving the Iberian market a Seller position.

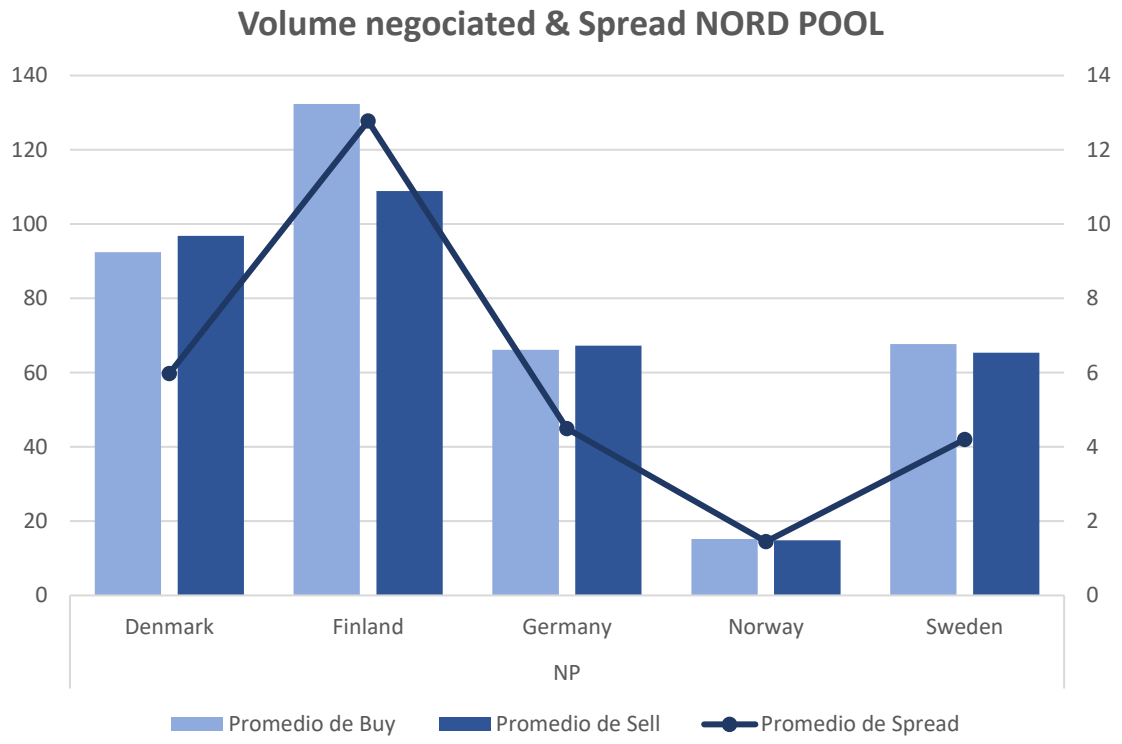
Regarding the spread, that it is also presented in the graph, it can be considered that it has low values in both countries. It is true that this index is higher for Spain, however, as is going to be defined in following points, the spread in Spain is one the lowest of the European markets.

6.2. NORD POOL.

In this point, before starting with the analysis, is needed to remind that Germany, Norway Denmark and Sweden have several bidding areas inside the country. These areas are defined by a price zone and for this thesis, the bidding areas have been merged trying to preset the result with the same structure.

It also relevant to bear in mind that this NEMO also manages other bidding areas associated with countries such as Estonia, Latvia, Lithuania, however these have not been taken into account for the study due to its low volume of trading in the continuous intraday market.

The case of Nord Pool is truly peculiar because is the NEMO who manages the greatest number of bidding areas from different countries, however, as it would be presented in the graph, the total negotiated volume is very low in most of them.



Graph 10: Purchase & sell Volume and Spread for Nord Pool

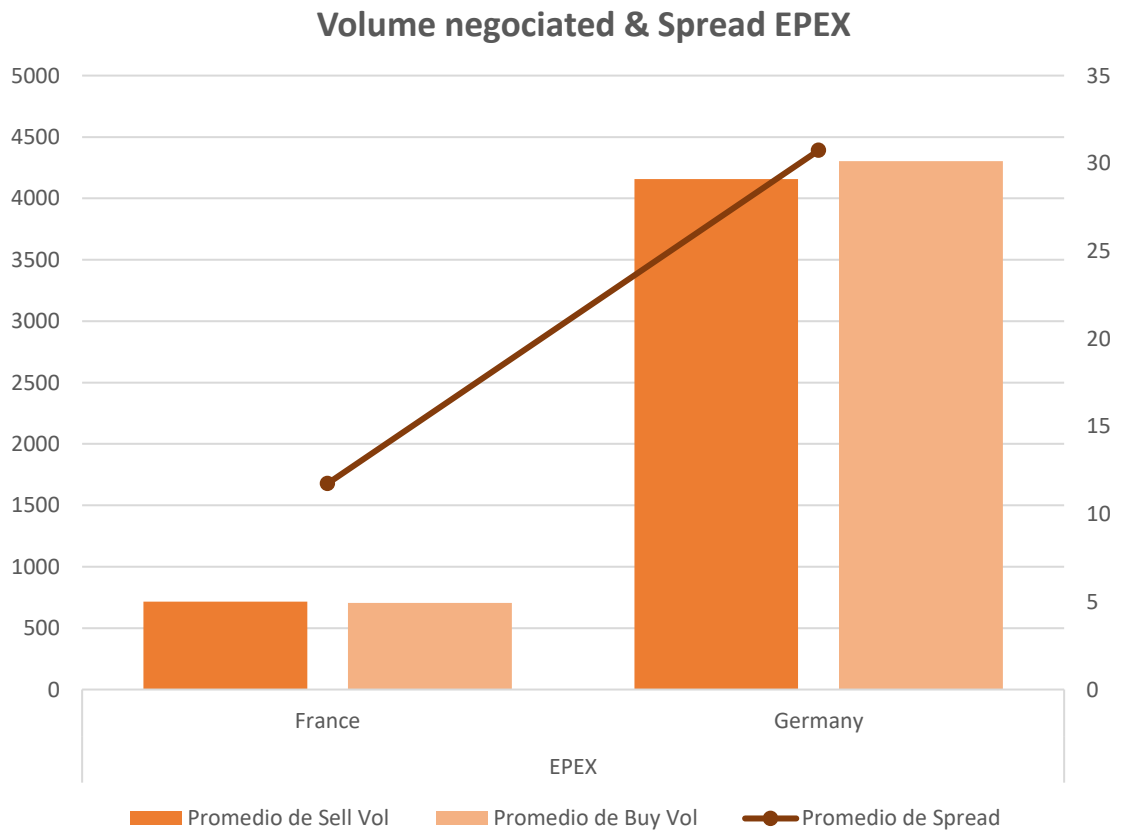
In the case of Nord Pool, as mentioned, the negotiated volume is small, considering the number of bidding areas it manages together with the large number of interconnections it has.

Additionally, in terms of the spread this is very small too, which is a good feature if it is accompanied by an acceptable level of negotiation, however, this is not the case.

6.3. EPEX.

Finally, Epex, who manages large and important price areas such as France, Germany, Belgium, Netherlands and United Kingdom.

However, for this study only the areas of France and Germany have been taken into account since the others do not publish their trading volumes per hour, so it would not be possible to make a precise comparison



Graph 11: Purchase and sell Volume and Spread of Epex

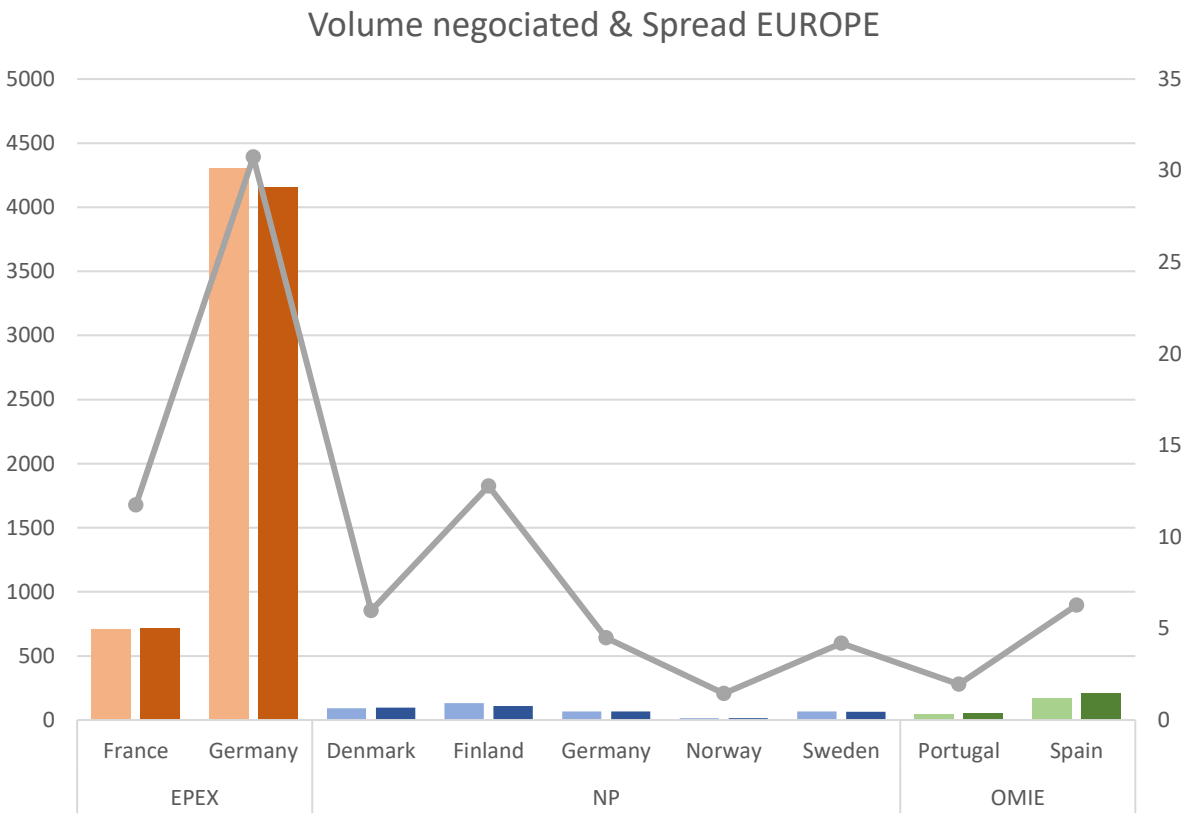
As you can see the volume traded in both areas is the largest compared with the other two NEMO (OMIE and NORD POOL) however, as it is presented the spread is also very high.

As mentioned before, a high level of spread it is not a good indicator because it gives the market a lot of risk, since perhaps the price for which an agent has bought or sold is no longer the optimal price afterwards.

This market could be very useful for a trader perspective, as they could find very good opportunities to earn money, however, from the point of view of an energy producer or consumer, such level of spread negatively affects when adjusting the position in that market.

7. CONCLUSION

In this graphic summary, it is compared the negotiated volume and the spread of all the countries managed by the different PX.



Graph 12: Resume of the liquidity of the European Market

- **EPEX**

Regarding the negotiated volume, the great difference between Germany and France, two zones managed by EPEX, with the rest of the countries included in the XBID project is clearly observed.

The fact of this great liquidity of the market managed by this NEMO, is strongly linked to its characteristics. Epex only have one intraday auction to adjust the position of the sales units for this reason the continuous intraday market is considered a very useful tool for unpredicted unavailability.

Additionally, the large amount of renewable energy, especially in Germany, allows to increase the volume traded in this country as they use this market for hedge against the before mentioned problem of this technologies as is the intermittency.

Regarding the spread of EPEX and focusing in the two countries that it manages, it is very high as was mentioned before. This fact can be seen from two very different perspectives. On one hand, if a robust market with low risk is sought, this market would not be adequate due to the high volatility of its prices. However, for traders that search for opportunities to earn money, this would be the most recommended market to do so.

It is also important to highlight two important characteristics of this market that will surely help to increase the liquidity. In the first place, this market is already mature. Before the implementation of the XBID project, EPEX already had a continuous market with different types of products (hourly, half an hour and fifteen minutes' products). For this reason, it is considered that the agents are already used to managing their positions with a continuous market.

Finally, a last factor very correlated with the liquidity of the market, is the number of times electricity is negotiated. In the case of Germany, it is a very relevant example since the energy that is negotiated in this country is six times higher than the total demand, while for example in Spain it barely exceeds 1 time. Therefore, the fact that this energy is negotiated several times can be explained with the volatility of the prices, and these led to a great liquidity on the market.

- **NORDPOOL.**

The case of NORDPOOL is very interesting because in October of 2018 this NEMO decided to remove the two intraday auctions that they had for adjust the position of the agents along the day. Since that moment, only the continuous intraday market was the only possibility for reschedule their position.

In addition, another possible cause for which the liquidity of this market is so low can be its generation mix. In these countries the predominant technologies are mainly the hydraulics and the thermal. Therefore, the intermittency that is one of the causes of the increase in liquidity cannot be an aid to increase it in this market.

On the other hand, the spread in countries managed by NORD POOL differ along the zones. There are areas with a high level of spread as Finland, while the rest of the areas have a low spread. As mentioned above, this index is always representative when it´s analyzed together with the negotiated volume, otherwise, the spread is not representative in any case.

- **OMIE**

In the case of OMIE with Spain and Portugal, it can be said that it has a strong position within the European electricity market considering its low level of interconnection.

Regarding its negotiated volume Spain is, after Germany and France, the country that the most quantity of energy negotiates, but is still far from the values that these countries have. This fact is mainly due, as it has been seen in the regression analysis, to the low level of interconnection with the rest of the European countries (the lowest in all Europe).

In terms of spread, it is also one of the countries with the lowest level of separation between its most expensive and cheapest trade. This fact, together with its traded volume, allows the market to be defined as one of the most interesting within the XBID project since it groups together a certain trading volume and a low spread.

These qualities allow it to be relatively easy to find a counterpart in the market to adjust the agent position and always within a context of no risk and price stability.

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