UNIVERSIDAD PONTIFICIA COMILLAS

**ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)**

OFFICIAL MASTER'S DEGREE IN THE
ELECTRIC POWER INDUSTRY

Master's Thesis

# Analyse the effect of the implementation of the European Continuous Intraday Market in the markets and system processes in Spain

**Author:** **Jaime Larrañaga Juez**
**Supervisor:** **Juan Bogas Gálvez**

**Madrid, July 2019**

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# Table of Contents

# Figure Index

# Table Index

# Abstract

This Master Thesis aims to assess the impact that the implementation of the Single IntraDay Coupling (SIDC) has had on the domestic electricity markets and system processes in Spain. It deeply studies the impact regarding to liquidity and designs a synthetic liquidity index for the SIDC.

In order to estimate the impact on domestic electricity markets and system processes, it has been needed to develop an extended study regarding all the markets and system processes affected before and after the implementation of the SIDC. The markets considered that could have being potentially affected by the SIDC are: Day-ahead, Intraday Auction, Tertiary Reserve, Balit and Imbalances. This Master Thesis evaluates the impact that the SIDC has had on each market in terms of volume traded and argues if the impact could have being expected.

A synthetic liquidity index was created specifically for the SIDC. The index measures the liquidity of the SIDC market on an hourly basis; however a daily analysis was also carried out so valuation could be compared easily. The synthetic index has been designed as a weighted combination of relevant-for-liquidity market data. A justification of the use and weighting of those variables in order to obtain a robust and reliable index was included in this essay.

# 1. Introduction

The main objective of this Master Thesis is the development of a study and analysis of the effect that the implementation of the recently implemented Single intraday coupling market (SIDC) has had on domestic markets and processes in Spain. The project was called XBID (Cross Border Intra-Day) which in essence is an intra-day continuous market among European countries joined in the first wave. The implementation of this new market had been and still is in continuous development, as anyone can imagine the starting point of any new market is subject to modifications from the first initial draft. In fact, combining 14 different markets from different countries with a variety of different regulation, system processes or different domestic electricity markets, is not an easy task and reaching a fully functional and operable intraday market across Europe require that countries assume and accept some changes in their processes and regulation.

The creation of this market will allow the agents all over Europe to trade between them with fewer obstacles, whenever there is enough interconnection capacity between the exporter country and the importer one. European regulation therefore will be a key player in the implementation of the new market. Some changes regarding interconnection capacity allocation has been made, but at the moment there is not a unique way to allocate that capacity between agents. There is no standardized criterion for the right to use the interconnection, but Europeans law-makers are developing a common tool to solve this issue and use a single mechanism across Europe.

Another key role will be the one that Nominated Electricity Market Operators (NEMOs) have and the relation among them can be considered as a significant factor to take into account.

This Master Thesis was developed for OMIE, the Iberian Market Operator, which was interested on a further analysis of how the implementation of SIDC has affected the domestic processes and in particular how it has impact on the liquidity and volume of transactions among the domestic markets and the European intra-day continuous market.

Its implementation is considered as a further step of European unification of markets.

# 2. Motivation and Relevance of this Thesis

## 2.1. Motivation

It was 50 years ago that the European Union started its “merger” process. The main goal that European legislators wanted to achieve was the creation of a single market across all the European countries: free movement of capital, people and goods; Some other goals have been in mind of the euro-politicians, some already achieved and some others not yet, for example: Euro currency implementation, Common economic and fiscal policy…

Since electricity is considered in developed countries an essential need, lawmakers decided to merge and connect the domestic grids in order to create a larger single electricity market. The new market will be, in theory, more reliable, its quality of service will be higher and there will be less blackouts or shortages. The main physical problem that the creation of a European electricity market will create is the necessity of enough interconnection capacity between countries. The development of new interconnection capacity has been considered for long time and new capacity between countries is been built at the moment.

Due to the technical characteristics of the electricity, mainly its non-storability, it has to be generated and consumed in real time. Some positive synergies of merging domestic energy countries are the increase in reliability production but also a price reduction in the importing country as they will be consuming cheaper electricity.

So is it possible to trade electricity close to real time in order to be produced in Spain and consumed it in Germany?

On June 13th 2018, a new European Continuous Intraday Market was launched. The launching was a first step in order to reach a true European market.

It actually created a new market environment across Europe. The new market partially coupled with some domestic processes already implemented in 14 countries. Therefore, some operational changes and system processes were needed to be changed in order to combine already existing domestic markets with the new Single Intra-Day Coupling (SIDC).

The creation of a new market at first may be somehow risky, but at the end it will create trading opportunities and trade-offs between countries that were not possible before. This new market may affect for different reasons to local processes, like regional auctions or system operations processes. Many effects can be analysed, from different points of view, including market liquidity. Due to the fact that there are different markets, carried out by different operators, with different objectives, those timetables had been changed…, it is needed to analyse how the liquidity can be measured.

## 2.2. Relevance of this Thesis

There are some aspects that make the implementation of the new market relevant. Keeping in mind the European objective of a single market around the continent, some aspects have been affected due to the implementation of SIDC.

This master thesis will focus on the Spanish case and its peculiarities like the existence of a domestic intraday auction market or the lack of enough interconnection between the Iberian Peninsula and France.

The non-sufficient interconnection capacity may lead to higher prices in Spain and Portugal compared to the average European prices. This may lead to the Iberian system to become partially isolated and create locational issues.

The implementation of renewable energy sources (RES) may also impact on the system flexibility and the necessity of a close to real time gate closure, so the RES and load energy predictions can obtain a better predictability, reduce their imbalances and help the system operator to achieve an easier operation balancing.

The SIDC market goals are to increase quality of services, security of supply, system stability and renewable energy sources power generation, which combined will increase the social welfare across Europe

Interconnection capacity allocation should be allocate on a market base system which in the case of Spain will be based on explicit and implicit capacity auctions, as it will be explained in the next section of the master thesis.

### 2.2.1. European National Markets

Due to the good previous experience of the intraday domestic auction markets in some European countries, Market Operators, like OMIE, sustained not to eliminate intraday domestic auction markets and combine the SIDC with the intraday auction market, instead of creating a single market. The solution that was proposed by European Commission was to introduce an article in the regulation (EU) 2015/1222 which allows the existence and operability of regional auctions at the same time than SIDC.

*Article 63*

***Complementary regional auctions***

*Complementary regional intraday auctions may be implemented within or between bidding zones in addition to the single intraday coupling solution referred to in Article 51.*

The regulation mentioned above (EU) 2015/1222 is the regulation that establishes a guideline on capacity allocation and congestion management (CACM). On July 2015, CACM established the new conditions for access to the network for cross-border exchanges in the electricity European market. CACM main goal is "*The urgent completion of a fully functioning and interconnected internal energy market is crucial to the objectives of maintaining security of energy supply, increasing competitiveness and ensuring that all consumers can purchase energy at affordable prices*". It sets the rules of the newly created market, the Single IntraDay Coupling and encourages obtaining a more efficient market coupling where security of supply is not an issue, to increase coordination between Transmission System Operators (TSO) and Market Operators across the countries involved in the coupling and set the process of calculation of the cross-border capacity available at each market session in order to allocate the full capacity so social welfare can be maximized up to the technical limits of the cross-border lines.

In addition, CACM regulation sets the operational procedures of the market and establishes the schedule for the different sessions and products traded, as its gate opening and closure timing.

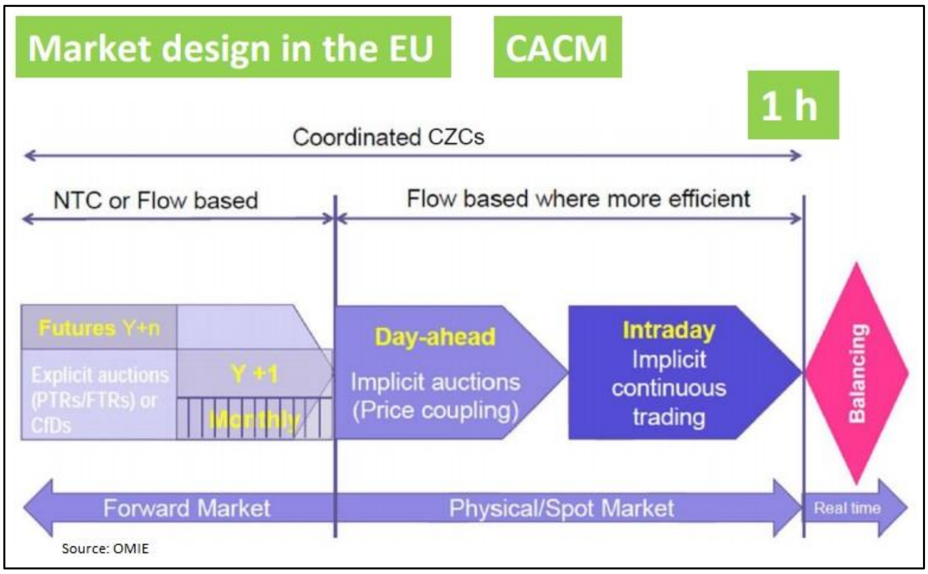



*Figure 1- Market design in the EU CACM*

In the case of Spain, resumed in the graph above is how the interconnection capacity is allocated among the time before delivery. A first, long term, explicit auction is set in order to agents gain access and fix their access to the interconnection. The remaining interconnection capacity, if any, is calculated by the TSO and sent to the Market Operator who will allocate the capacity in the continuous market until it is fulfilled or remain unused. Once the capacity is fully allocated in one direction, the bid-ask orders that the market operator will take into account will be the ones in the regional market, the ones in the non-congested direction and the ones coming from cross-border agents will not be taken into account, as the electricity from the latest will not be able to cross the border, as interconnection lines in that direction are already constrained.

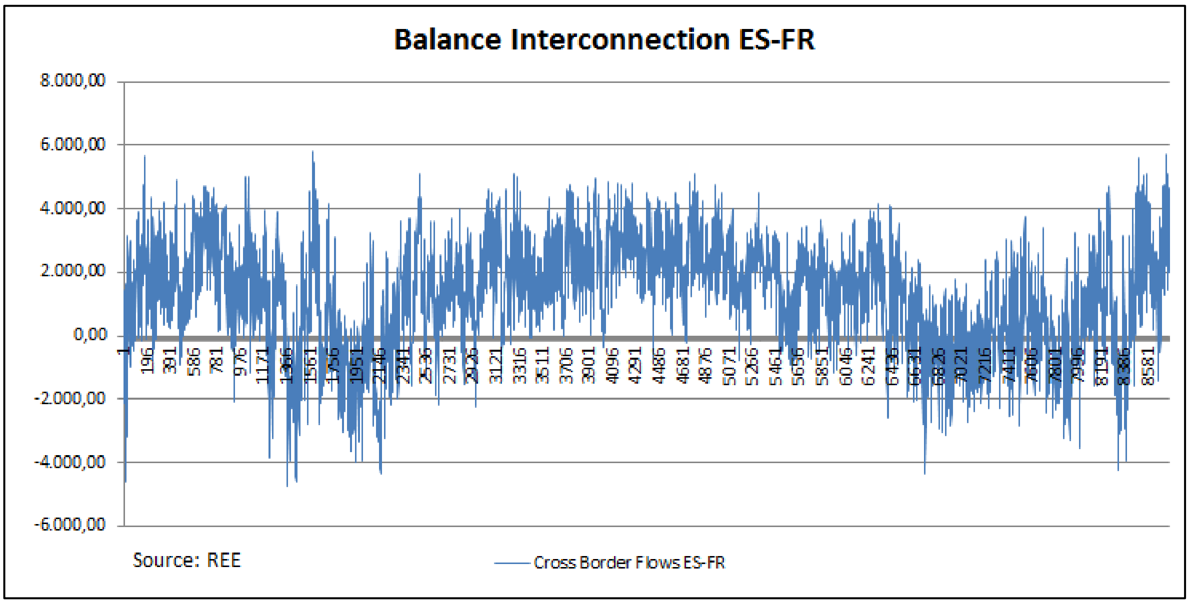



*Figure 2 - Balance Interconnection Spain-France*

The chart above shows the ES-FR cross border physical flows between Spain and France. The limited interconnection capacity with France that is about 2% of the peak demand limits the amount of energy exchanged. European regulation sets a target of at least 10% of interconnection capacity; however Iberia will not meet this target in the near future, as there is just one single project of installing a new line between Spain and France that is expected to be concluded by June 2025.

### 2.2.2. Competition

The history of the electricity sector has usually been played by large vertical integrated national firms. Market power in the sector has been a headache for National Regulatory Authorities (NRAs) and for European regulators. The reduction or control of market power along the domestic markets still is a conflict in some countries.

The creation of a large Pan-European market will have a diluting effect on market power, as large domestic companies will not be as large on a European market base and will not be able to apply their market power. In the Spanish case, the most used concentration index, the Herfindahl-Hirschman Index (HHI), shows that the market concentration is being reduced, due to the creation of new retailers that compete with the large utilities and due to the coupling implemented within Europe that allow international companies to trade in Spain.

Accordingly, the number of agents that trade across the domestic markets across Europe has increased, reducing market share of the big players and increasing competition in the domestic countries.

The creation of a SIDC market allows European agents to trade in domestic markets besides their regional ones. This may create an issue to small-size agents that may not have the same trading resources as the large utilities, like a 24 hour trading department for instance. However, small-size agents can trade on a 24 hours basis with the utilization of automated trading algorithms or robots, but it may have an extra cost which can be relevant in size if the agent is small in size or does not have enough capital for IT investments.

Therefore positive externalities have been created by the implementation of SIDC like the increase in competition across Europe, the reduction of market power of large domestic agents and the access to new electricity markets to agents.

### 2.2.3. Price

The European Single Market (1993) established a new common market which seeks to guarantee free movement of goods, capital, labour and services. The initial condition for agents to trade internationally, will be the price difference.

Extrapolating that to the electricity sector, consumers will buy electricity abroad if it is cheaper than buying it locally. These trade-offs will end up in a convergence of prices, and if no technical congestion occurs, there will be a single electricity price across Europe. The fact is that at the moment, there is not enough interconnection capacity between countries, for instance Iberian and France, and therefore trade-offs are subject to the congestion of the interconnection lines.

Besides SDIC benefiting a European price convergence, new interconnection capacity developments are needed in order to achieve the target of a common European electricity price.

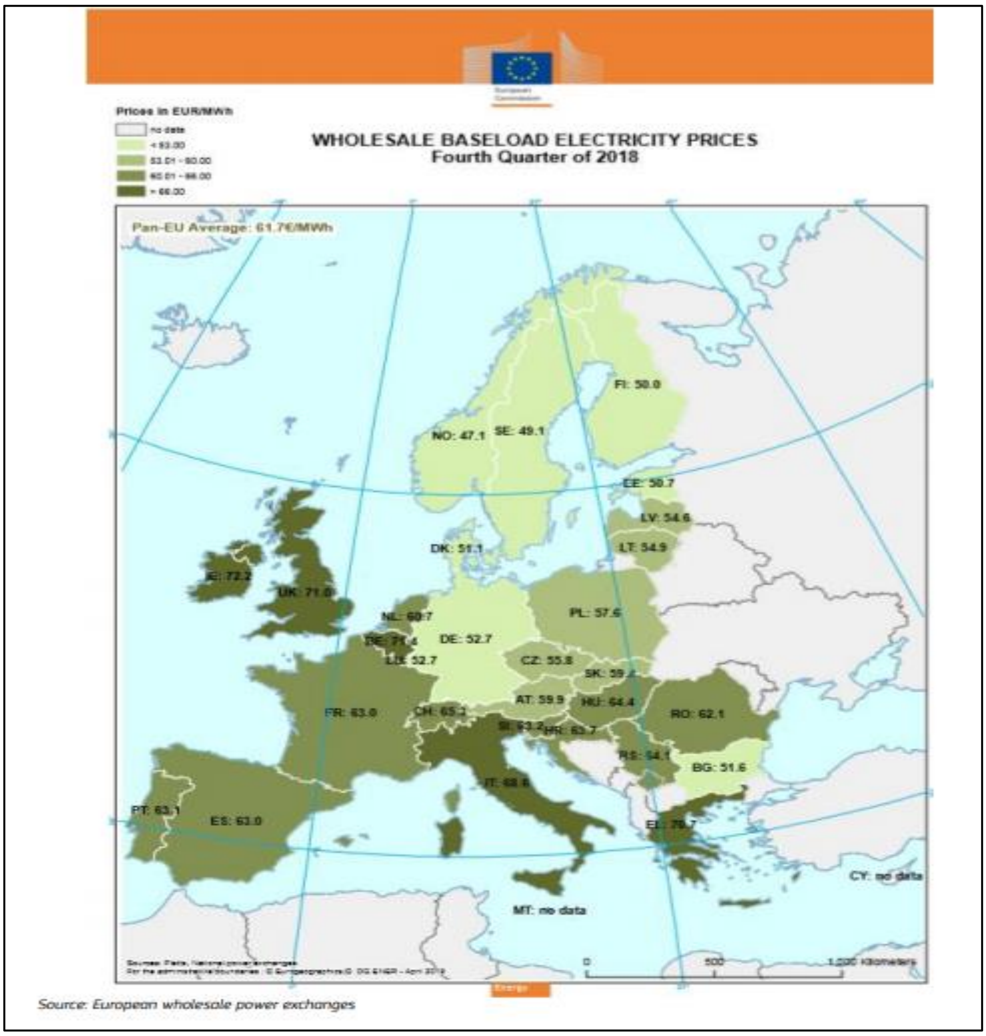



*Figure 3 - Wholesale Baseload electricity prices*

The two maps above and below show two different price scenarios. The one above shows the Average price of electricity in the different European regions for the fourth quarter or 2018. It is clearly visible the difference in prices. Germany and the Nordic countries in this case are the ones that have the cheapest electricity prices, and Belgium, UK, Ireland and Italy the ones with more expensive electricity. Therefore, there should be electricity flows from the cheapest ones to the more expensive ones until they reach the same price and makes no sense to export-import or until the interconnection capacity is congested, as it is the case in the map.

The map below shows a different situation across Europe. A price convergence is placed across many interconnected countries. In this second case, interconnection capacity is available between countries with a same electricity price, and interconnection congestion between countries with different electricity prices. The second map shows an ideally situation across Europe that until the moment is rarely reached, mainly to the lack of sufficient interconnection capacity between countries.

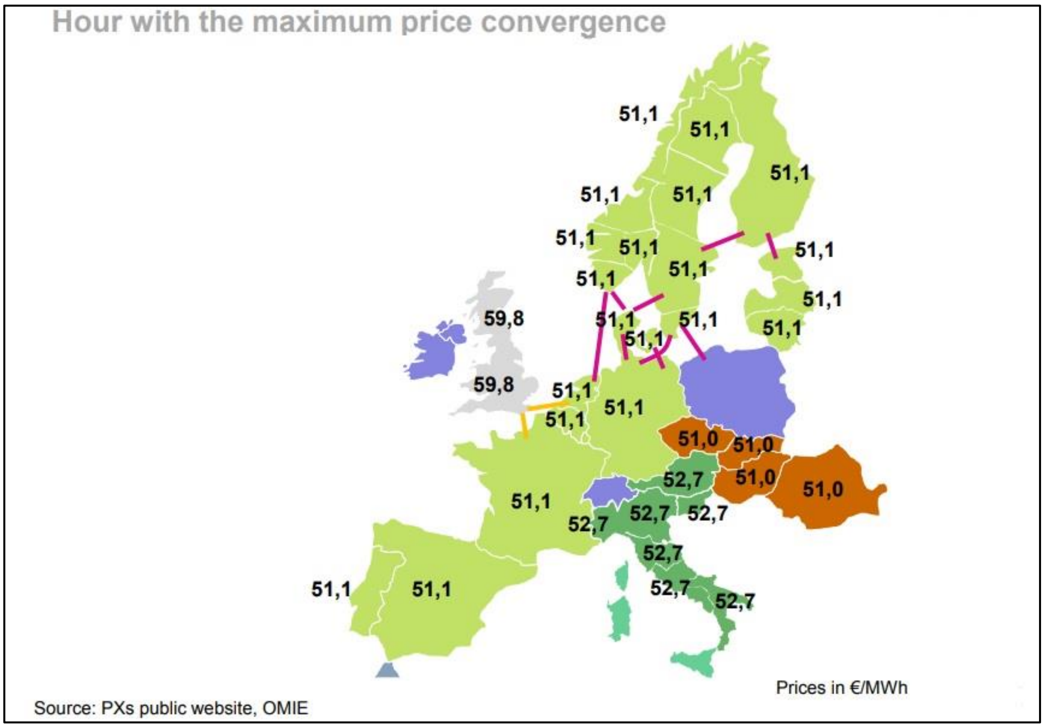



*Figure 4 - European electricity prices map*

The lack of price convergence shown in the first of the maps is clearly visible in the chart below. There is a huge difference in the prices that European citizens pay depending on their location, but it is not exclusively due to the wholesale market price. The chart also includes taxes, support for renewable energy sources, capacity mechanisms… that affect substantially to the final price that the electricity consumer has to pay, however the difference in wholesale electricity prices also affect to the final retail electricity price.

From the chart below it can be stated that Spain has one of the more expensive household electricity prices, and one with the largest cost variation depending on the electricity consumption.

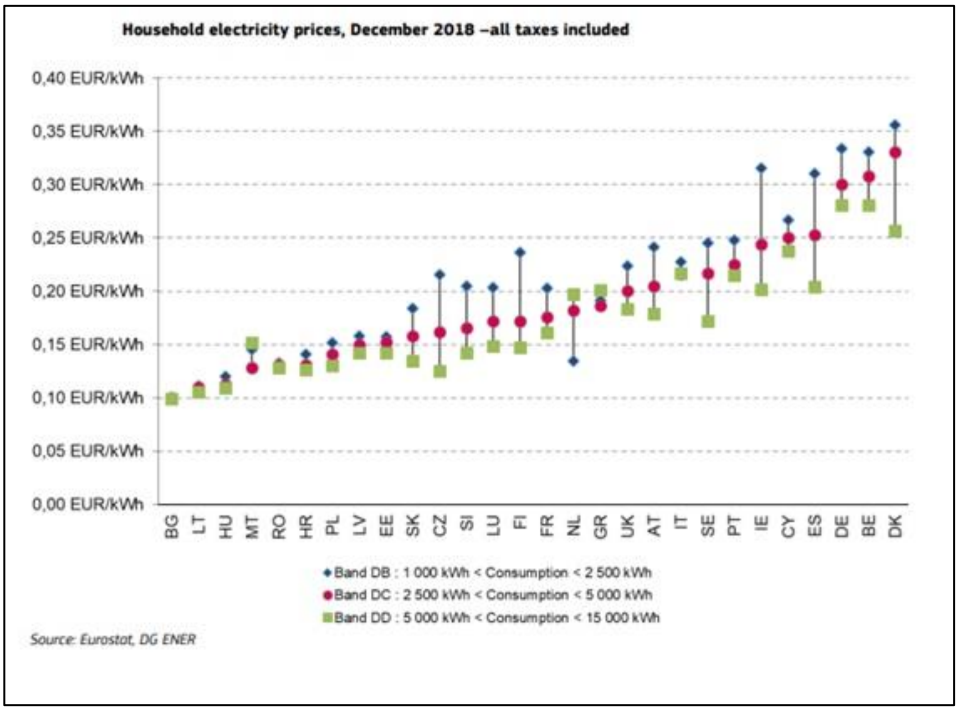



*Figure 5 - European Household electricity prices*

### 2.2.4. Liquidity

Related to competition, the issue of liquidity arises. The implementation of SIDC will, in theory, increase liquidity as new international agents will be incentivize to trade on the international markets in order to benefit from higher prices abroad, and agents will be incentivize to buy electricity abroad if the prices are more competitive than in domestic markets. The new market participants will increase competition as commented on section 2.2.2 and will affect liquidity as this thesis will demonstrate in section 7.

Further comments on liquidity will appear on sections 5 and 6 of this document.

Market liquidity can be measured by the use of several variables. Some experts on the field consider volume traded as the best liquidity index; however in this master thesis it is not going to be the unique variable considered. Some other experts consider the churn rate to be a good enough liquidity indicator. European Directorate General for Energy defines the Churn rate as "*the ratio of the total volume of power traded (including exchange executed and OTC markets on the spot and the curve) and electricity consumption in a given time period*". In other words, the churn rate measures how many times a unit of electricity is traded before it is finally consumed.

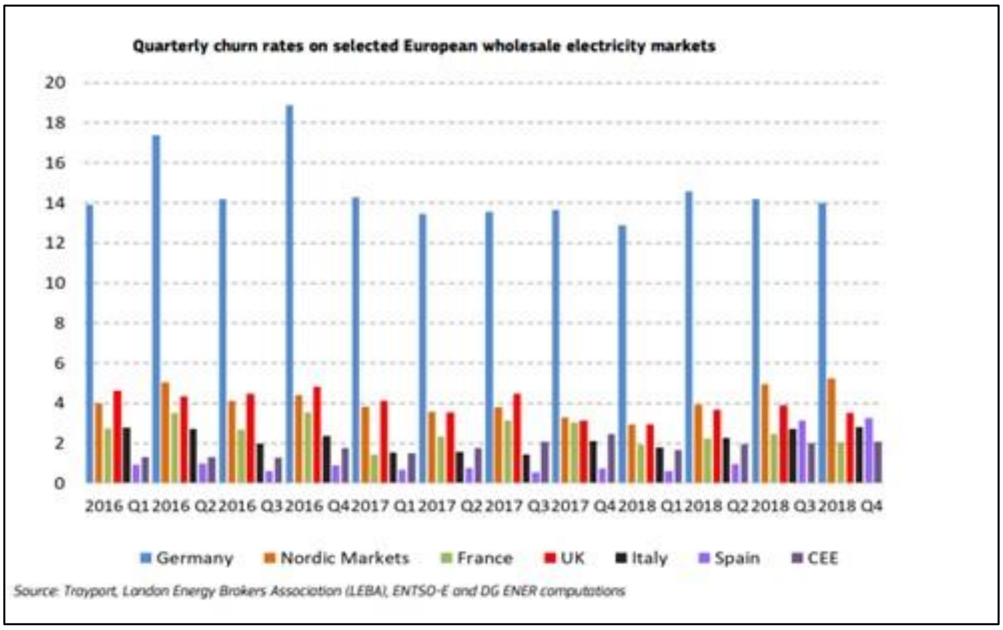



*Figure 6 - Churn rates in European wholesale electricity markets*

The chart below shows the quarterly churn rates on a variety of European wholesale electricity markets. The International Energy Agency estimates that a market with a Churn rate with a value equal or above to 10 can be considered as a liquid market. It is clearly visible that Germany is the country with the largest churn rate by far. This means that the German wholesale electricity market is the most liquid market across Europe with an average Churn rate of 14. Its economy, power system structure and strategic location in Europe are factors that make volume and therefore liquidity increase. On the other hand, none of the rest of European countries considered on the graph can be considered as a liquid market. The Spanish Churn rate has been at values around 1 since 2016; however during the last semester of 2018, it has increased and consolidated at around 3, in line with other European countries.

Nordic countries, France and UK are countries that have a large amount of interconnection capacity have an average Churn rate of 3.5 that is considerably smaller than Germany.

### 2.2.5. Efficiency of resources

It is a fact that the increase in competition and liquidity along with a Renewable Energy Sources (RES) policy which boost the use of these technologies, will allocate in a more efficient and ecological manner the energy resources available. The target for RES electricity generation is clear, and is updated to get to the objective set by the Clean Energy Package for all Europeans.

Some mechanisms are been implemented in order to incentivize the construction of new RES facilities, which otherwise may not be profitable, and therefore need those mechanisms to compete with existing generation facilities.

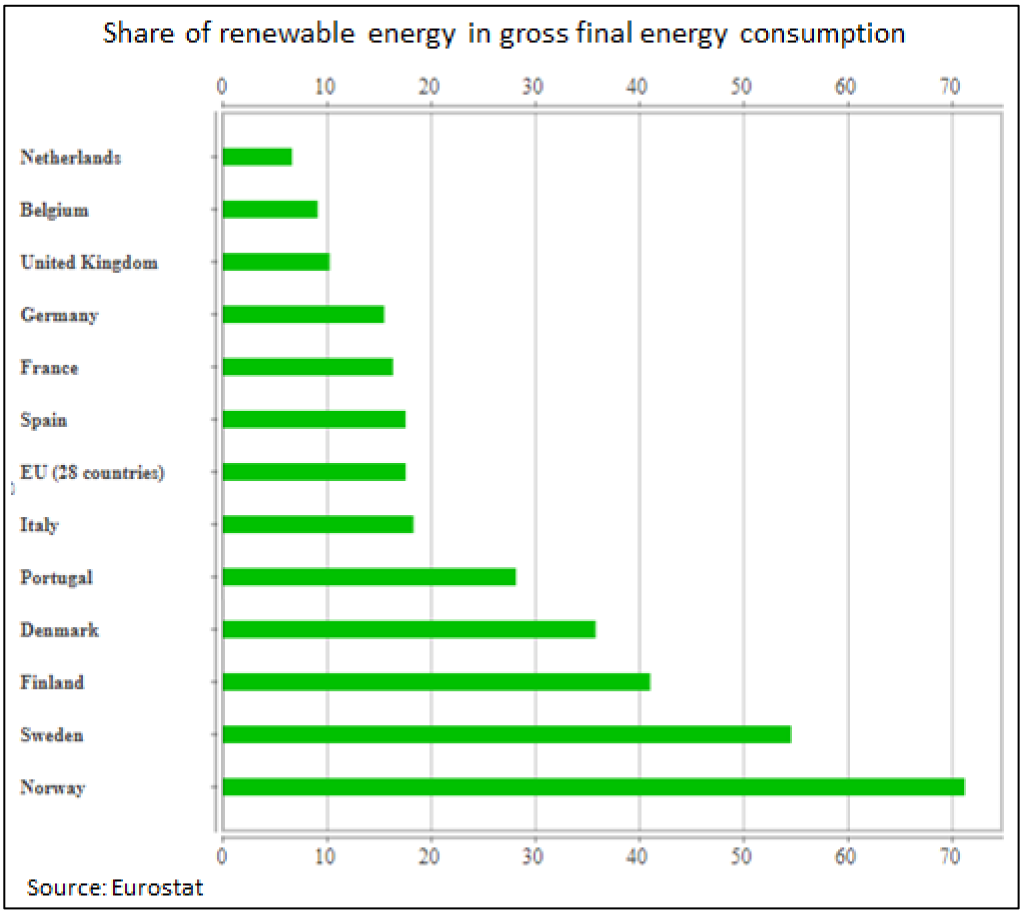



*Figure 7 - Share of renewable energy sources in European countries*

As it can be seen in the chart above, there is a huge mix in the share of RES across European countries. The European goal for 2020 is to achieve a 20% of share and the updated goal for 2030 that has being included in the Clean energy for all Europeans package approved in 2018 sets a goal of 32% of electricity generation coming from renewable energy sources. The interconnection between power systems and their variety in the generation assets will be a key point in order to obtain a more efficient use of the resources.

Summing up the factors commented above, combined with the existence of a larger Pan-European market, the final result is a better allocation of resources, where fewer contaminant and cheaper generation facilities are producing at full capacity whereas contaminant and more expensive generation facilities do not produce at all or just during peak demand hours.

### 2.2.6. Reliability of the system

The mere existence of a larger number of generators connected increase the reliability of the system as a whole. Primary and secondary reserve capacity will be located on a better position as before, as there will be more generators online, ready to increase or decrease production if needed. The effect of a failure in a generation unit will therefore be distributed among a larger number of generators and those will not be forced to severe ramp-ups or ramp-downs.

The interconnection of generators located in different geographical locations joined together by a market increase the overall reliability of the electric system.

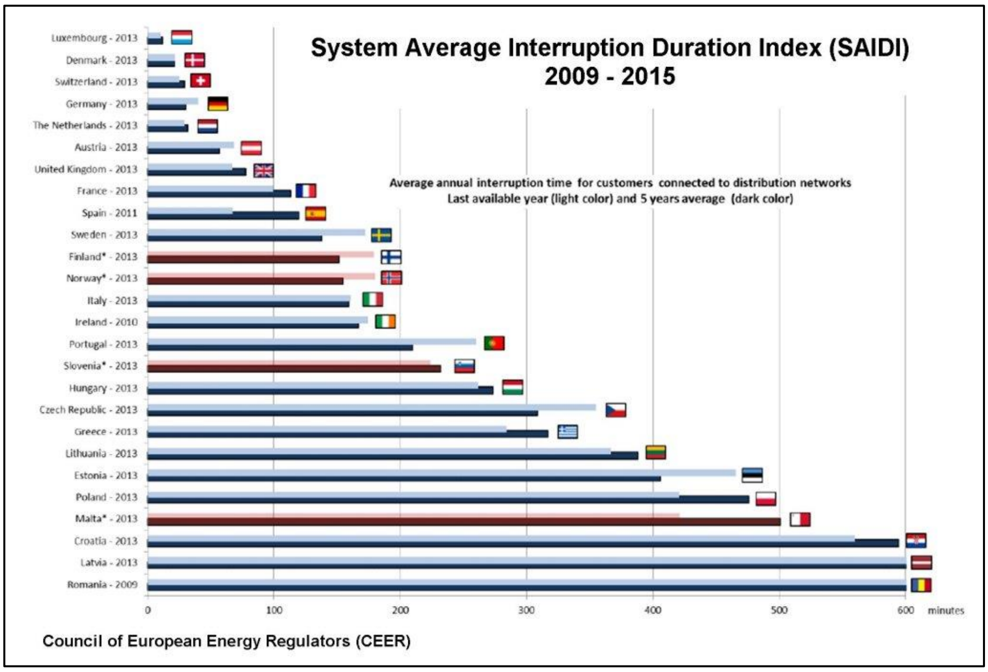



*Figure 8 - SAIDI in European countries*

Stated in the figure above, is the System Average Interruption Duration Index (SAIDI) across the European countries. As it can be appreciated, there are huge differences regarding the different countries. Mainly this is due to specific physical characteristics of the power grid in each country. The interconnection capacity and the market coupling could positively affect SAIDI and reduce the index values.

Interconnecting domestic electricity markets will improve the reliability of the system as a whole as each country has a different generation scheme and a different load curve, due to the different social culture. For instance, the load curve in France and Spain may be different and peak at different hours that will imply different electricity necessities depending on the hour of the day.

# 3. Objectives of this Thesis

As it has been already commented so far, the main objective of this Master thesis is to analyse the impact that the implementation of the Single IntraDay Coupling market has caused into the Spanish system.

A detailed analysis of the effect on liquidity of the several domestic Spanish electricity markets will be done. It will be discussed how to measure liquidity, as it is a qualitative measure, and not a quantitative one. Therefore a composite or synthetic index will be created in order to obtain a proxy to liquidity. This index will evaluate the impact of the implementation of SIDC and it will compare the liquidity pre-implementation and post-implementation and will contrast the results with the already existing domestic markets.

In addition to the liquidity evaluation, the implementation of the SIDC has affected to the existing processes, mainly to the Transmission System Operator, but also to the schedule of the combination of domestic-only markets with SIDC.

## 3.1. Creation of a liquidity index relevant for SIDC

The creation of a liquidity synthetic index that is relevant for the implementation is a problematic issue, due mainly to the mere definition of liquidity that will be explained in section 6 of this Master thesis.

According to Investopedia, which is a main hub for market information, *"Liquidity describes the degree to which an asset or security can be quickly bought or sold in the market at a price reflecting its intrinsic value."* This definition requires a deep study of how an asset, electricity in the case of this Master thesis, can be bought or sold.

The intrinsic value of electricity in SIDC will be the value of the asset in any moment in time plus what is called transaction costs. Electricity market is a peculiar commodities market which is affected by many external factors like location, system structure, seasonality, other commodity prices, weather conditions… Therefore, there is a different price for electricity for every given moment of the day on a particular market zone.

The transaction costs are the costs in which agents incur when trading in the electricity market. Those costs can be the mere access to the market, if any fee applies by the market operator (not the case in Spain) or brokerage costs if trading is done via a broker. But the largest of these costs is usually related to the fact that there are different prices for buying and selling the same product at the exactly same moment in time. This is called the bid-ask spread, which in essence is the difference in prices of the most expensive buying order (bid) and the cheapest selling order (ask). Depending on the market structure, the bid-ask spread can be small or huge. Some other aspects also affect the bid-ask spread, like the number of agents trading in the market, the type of product and its supply and demand, the hour of the day…

The most liquid market in the world is the Foreign Exchange market, where currencies all over the world are traded. Bid-ask spread in these markets are usually very small, 1-5 cents. The small spread is mainly caused by the huge amount of volume traded every day and the quantity of agents that trade in those markets constantly.

The most liquid commodity market is the oil market. Depending on the product traded, bid-ask spread is usually small too, 1-10 cents. The huge competition among agents that try to buy or sell oil and the large number of agents trading lead to a reduced transaction costs.

Regarding the electricity market, as those markets are located within a region or country, the number of agents is usually limited, mainly generators, retailers or large consumers. Combining local markets with a few number of agents trading, this lead to a bid-ask spread that can vary from few cents to more than one euro depending on the product, time of the day or specific conditions of the market.

A good index in regard to the liquidity of a market will be therefore an index combination of volume traded and bid-ask spread. However, the latest is very volatile due to the fact that whenever an agent place an order, bid or ask order, it may change the bid-ask spread of that product. Bid-ask spread are real time data that can vary every second during the trading of a product. Bid-ask spread recording is not mandatory up to now in the power markets across Europe, and therefore that specific data is not available. There will be some changes within the European regulation to record the bid-ask spread of the market, but it has not been done yet. Some approximation to these values can be calculated by using the high-low prices of a product, but these will be discussed in section 6.2.2.

The liquidity index presented in this Master thesis has been created specifically for the SIDC market within the Spanish market. It could be used in some other markets across Europe however, several modifications should be made.

## 3.2. Analysis of liquidity and processes in Spain before and after SIDC

In section 3.1 it was commented the need of the creation of a synthetic or composite index specially created for the SIDC market within the Spanish market.

This thesis will analyse, compare and contrast the evolution of this index with regard the implementation of the SIDC. It will assess and describe the initial situation within the Spanish power market before the SIDC entered into operation. The different domestic markets will be evaluated and focus on their liquidity and will compare the results with the one obtained after the SIDC came into place on the 13th of June 2018. It has to be evaluated the effect that the implementation of SIDC had on liquidity of existing markets, so an analysis would have to be done on a combined manner, in order to check the overall effect on liquidity of the SIDC implementation.

Additionally, this Master thesis will comment the different operational processes that were in place before the implementation of SIDC, and if those processes have been affected due to the existence of the new intraday market. The agent´s operative will be also commented briefly, as it has changed (or not) due to the option to trade in a new market and the technical requirements regarding licenses, collateral deposits needed when trading SIDC or complexities due to additional option of trading the exactly same product in different markets and timing.

The conclusions of this Master thesis will comment on how the domestic Spanish power markets have changed due to the implementation of the new intraday market, how the trading volume has changed in the different markets, and will propose some actions that may be beneficial in order to increase market liquidity.

# 4. INTRODUCTION TO SIDC

Intraday markets are a key instrument for agents trading in the electricity market in order to balance their physical exposure between the Day Ahead market and real time generation or load, by buying or selling electricity close to real time delivery. These markets are becoming more and more relevant due to the increase in generation by renewable energy source, which its intermittency and lack of predictability need the existence of efficient close to real time markets.

The objective of the Single Intraday Coupling market is to establish a common cross border implicit continuous intraday trading solution across Europe, where all the cross border capacities are fully allocated.

## 4.1. Description of SIDC

The expert on the energy sector, Michal Glowacki, defined the Single intraday coupling (SIDC) as "*an implicit cross-zonal capacity allocation mechanism which collects orders for each bidding zone from wholesale market participants and matches them continuously into contracts to deliver electricity while respecting cross-zonal capacity and allocation constraints, and is available in the intraday market timeframe once the day-ahead market allocation process has taken place*".

For the case of Spain, the SIDC market can collect orders from the rest of the power exchanges across Europe whenever there is enough interconnection capacity in the France-Spain border, after the day-ahead allocation process has been matched. If the interconnection is constraint in one direction before the SIDC, the order book for the Spanish market will only show domestic orders and orders in the opposite direction of the interconnection constraint.

The cross-zonal transmission capacity is allocated through implicit continuous allocation. This model of capacity allocation has been set up by the Capacity Allocation and Congestion Management regulation (CACM) by the European Commission.

By the time SDIC was proposed as an idea that finally was successfully implemented, the regulatory and market context in Europe was that the Day-ahead market was already coupled across Europe in 2014. The European Commission´s development plan for new renewable energy source across the continent, due to the decarbonisation, will increase in an enormous manner the installed capacity of these type of generation facilities, which are characterized by a lack of flexibility and intermittency production. The aim of increasing security of supply and a fair electricity common price across Europe were the key elements that created the opportunity to create and integrate a new market within the day. The goal was to create a market which allows agents to trade as close as possible to real time delivery. However, due to the need of strict controls by the system operator to guarantee a safe operation of the grid, unless a more automatic system control arises, the real time operative will never take place in the electricity markets. A preventive time margin has to be left to the system operator to securely supply the electricity to every consumer.

The first steps of the process were complicated in the terms, because a full coordination of several agents across the initial countries involved was necessary. The SIDC initiative started as a joint initiative of some Power Exchanges, among some: EPEX, GME, Nord Pool and OMIE, and some Transmission System Operators. There were 12 countries involved in order to create the joint integrated cross-border market.

Regarding operational issues, the single intraday coupling market is based on a common IT system. The IT system was developed and provided by Deutsche Börse, which is the German Stock Exchange. The system was created taking into account the link with the domestic trading systems operated by Market Operators. Combining several Power Exchanges with TSOs in many different countries was a challenge. It was also difficult to combine this with the allocation of available cross-zonal interconnection capacity that is provided by the Transmission System Operators (TSOs).

The solution for this issue therefore includes explicit access to the available capacities on the borders, in the long term, that were previously approved by TSO. The IT solution consists of three main modules: a Shared Order Book (SOB), a Capacity Management Module (CMM) and a Shipping Module.

The output data of the Shared Order Book are the matched orders and local views on the SOB, which is only available to the market operators. The output data of the Capacity Management Module are the capacity allocation per border and the net flow per border. The output data of the Shipping Module are the trades concluded through the platform to all relevant parties of the post-coupling process.

Thus, orders submitted by any market agent in a given country can be matched with orders submitted by other market participants in any other country within the IT system´s reach, in the case there is available cross-zonal capacity or by market participants within the same bidding zone. The IT system also allows for the participation of several Market Operators in the case that there is more than one in a single bidding zone.

The implementation and design of the SIDC was a complex process. Huge coordination between Market Operators and Transmission System Operators was an essential need in order to achieve the goal and objectives set by the designers and promoters of the market.

The common market goal within the European Union has been the key driver of the regulation across the EU. Implementing a SIDC in addition to the existing day-ahead market is a further step to a European common market. The idea of a wind farm plant located for instance in the south of Spain and supplying electricity to a factory located in Germany can now be achieved on a more real-time basis.

Some complementary goals that the implementation of the SIDC market wanted to achieve are increasing security of supply, quality of service, improving the renewable energy sources generation in the system and increasing social welfare along the European Union Member States. A better management of the interconnection capacity will be a key point to obtain the maximum imports and exports and therefore maximizing social welfare.

Security of supply is a key element of public security, thus efficient functioning of the internal market in electricity and the integration of isolated electricity markets of Member States is connected to a secure energy supply. Integration of markets has to be done by the construction or upgrading of interconnection lines between those markets. Correct and secure operations of those interconnection lines is crucial for the stability of the system and improve security of supply and quality of service, as it will be commented below.

Improvements in the quality of service within the electricity market are usually related to the distribution part of the electric system; however a more efficient and effective transmission system also contributes to a better quality of service. The interconnection lines that connect two power systems are, on most cases, transmission lines, high voltage lines. The correct operation from Transmission system operators is key to increase the security of supply commented above and the quality of the electricity service.

The energy regulation that the European Union is putting on the table, like the Clean energy for all Europeans package, sets ambitious targets on energy efficiency, greenhouse emissions reduction and electricity generation coming from renewable energy sources. The technical characteristics of renewable energy sources combined with the intensive development that these technologies have been and will be having in the coming future, in addition to the economic viability of these plants, will make coordination of regional power systems key to actively achieve the European goal for renewable energy electricity generation.

Electricity prices for consumers across Member states in Europe are different between countries. It can be explained as the final electricity price that consumers are paying is a combination of different concepts. The concept that SIDC will benefit the most will be the one related to wholesale electricity prices. That is the cost of generating electricity. There are considerable differences in the generation assets across Europe. Thus wholesale electricity prices can vary significantly depending on the region, seasonally, the time of the day or the load. Increasing trade-offs across member states will benefit the European Union as a whole. Differences in peak load consumption could create the opportunity to new trading operations. The alternative of having international electricity generation instead of domestic one will be caused by the difference in price generation mainly. Other issues can increase the international trade offs like management of grid congestion or security of supply issues. All in all, the existence of international physical electricity transactions will increase the social welfare of the European economy. It will also lead to sending the right signal for agents trading, operating or willing to invest in the sector.

Summing up, the intraday solution supports continuous trading close to real time and aligns it to the European Union target model for an integrated intraday market. The SIDC purpose is the increase of the overall efficiency of intraday trading across Europe.

### 4.2. Geographic location and Market Operators involved

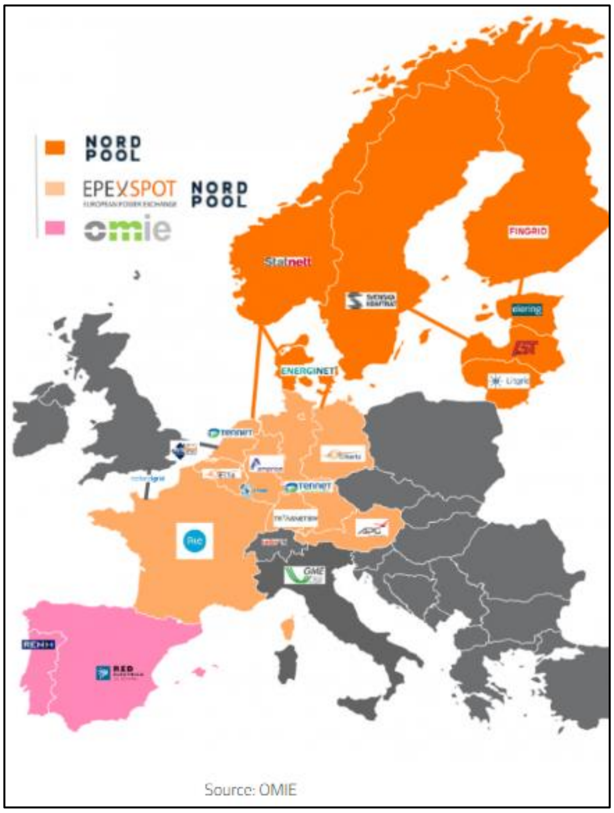



*Figure 9 - SIDC countries*

The Geographic location where SIDC was implemented on the 12th of June 2018 is the area that is coloured in the map above. It can be seen that there are three clearly differentiated zones, depending on the Nominated Electricity Market Operator (NEMO).

The Nordic countries, coloured in dark orange on the map, are operated by Nord Pool. The light orange countries on the map, France, Germany, The Netherlands and Belgium are operated by Nord Pool and Epex Spot. And finally, the countries coloured in pink, Spain and Portugal, are operated by OMIE.

As commented before, not every electric system across Europe has introduced SIDC as a continuous trading scheme. However, most of them will be joining the SIDC whenever the technology is ready to couple those markets.

The implementation will be done step by step and by groups of countries. The so called Go-Live Waves will be the schedule that is going to be followed in order to join the whole Europe.

On the map below, it can be seen how the waves will increase the SIDC trading environment. The first wave is the one corresponding to the initial step, when the Cross Border IntraDay (XBID) project was put in place by the 14 countries joining the project at the first wave in June 2018.

A second wave will include 7 additional countries to the intraday continuous trading market across Europe. The second wave is expected to take place during the last quarter of 2019; however, there is no confirmed date for the incorporation.

A final third wave will take place in the future to incorporate countries like Italy or UK (if no Brexit is finally applied). Due to the uncertainty with regard to Brexit, and some political debate that is taking place in Italy, the incorporation was scheduled for 2020; however that date is not confirmed yet due to the instability issues commented.

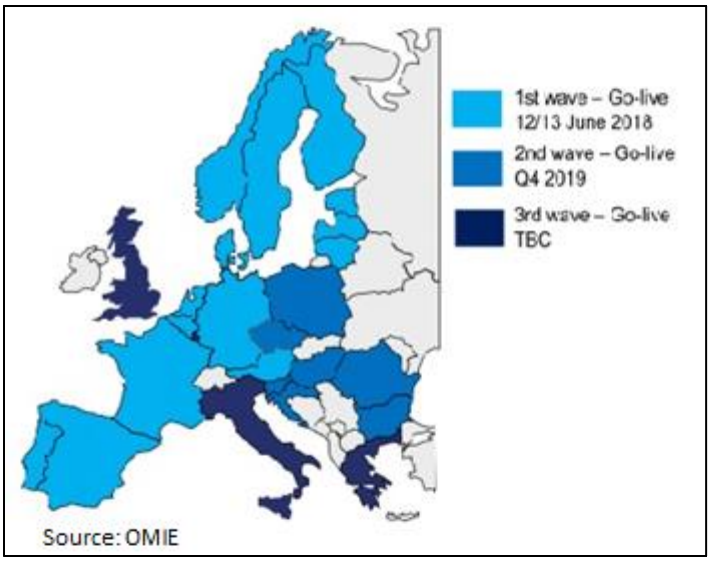



*Figure 10 - SIDC expansion*

## 4.3. EU regulation

European Union regulation is the main driver of the energy regulation. The approval of the Clean energy for all European package has set the targets to be achieved by European countries for 2030. Those targets are mainly related to energy efficiency, greenhouse gas emissions and renewable electricity generation. They are not directly connected to the regulation of the electricity markets in Europe; however, it affects to the market agents participating in those markets.

The need of improvement in how the interconnection lines are managed between member states was a keystone for the convergence of the regional energy markets. The reason of the publication of the Capacity Allocation and Congestion Management (CACM) (EU 2015/1222) was to tackle the interconnection capacity management and rules, to harmonise the electricity trading activity across Europe and to move towards an integrated electricity market. It was established in July 2015 and defines the detailed guidelines on cross-zonal capacity allocation and congestion management in the day-ahead and intraday markets, including the requirements for the establishment of common methodologies for determining the volumes of capacity simultaneously available between bidding zones, criteria to assess efficiency and a review process for defining bidding zones. Available capacity should be allocated in the intraday market time-frame using continuous implicit allocation, which is a method that allocates electricity and capacity at the same time.

Security of supply issues were not left behind in the CACM regulation, as the well-functioning electricity markets, networks and assets associated with electricity supply are vital for public security, economic competitiveness and welfare of the citizens of the European Union.

A common grid model, harmonised between transmission system operators, was established and should include electricity generation estimates, load and network status for every hour. The grid model will show at any hour the available cross-border capacity, as it will be a key input data for the coupling process and will allow taking into account all European bids and offers in the more economically optimal manner.

A common algorithm will be used, so bids and offers are made available to all power exchanges on a non-discriminatory basis depending on the available capacity allocation.

Related to power exchanges and nominated electricity market operators, will require cooperation and coordination between competing entities, and they must oversight and comply with competition rules. They should exploit synergies arising from capacity allocation and congestion management and contribute to the development of the internal market in electricity. The regulation also establishes rules for sharing among market operators, TSOs and regulatory authorities the costs of the implementation of the market so delays and disputes can be reduced.

### 4.4. Issues of the implementation of SIDC

The implementation of the SIDC market during the first wave was not an easy task. This was mainly due to the diversity of systems and processes across the countries involved. Every region had, at first, a different intraday market structure, different processes of trading, different schedules or trading rules.

Those issues will be commented in this section of this Master thesis; however a deep analysis will be made within the Iberian market.

One of the main issues to tackle was the existence of a variety of interconnection capacity allocation between neighbouring countries. Some of them had explicit auctions, some other implicit ones and some implicit allocation within trades.

Another issue that has not being solved yet is to put a price to the price difference between interconnections. Additionally, in order to implement a method (explicit auction in the intraday timeframe) there will be another problem related to trading schedules. As it can be seen in the table below, there is not a common opening time for trading across the SIDC. There is a consultant taking place at the moment, in order to solve this issue, and if a common opening time is obtained it will be applied, but it is not an easy task as it will drastically change the electricity trading activity in some bidding zones.

| | German TSO areas | Austria | France | NL & Belgium | Nordics | Baltics | Iberia^^ |
|---|---|---|---|---|---|---|---|
| **Opening times^** | 22:00** | 18:00 | 22:00 | 22:00 | 14:00** | 18:00*** | 22:00 |
| **Closing times** | D-60 min* | | | | | | |
| **Notes** | *Estlink Closing time D-30 min; for FR-DE, same GCT applies to both half hours of a given hour. For DE-AT the same GCT applies for all products of a given delivery hour.<br>**DE-AT, DE-DK2 (Kontek) and DE-DK1 opening at 18:00. NorNed opening at 21:00<br>***Pending decision by ACER to move it to 14:00 as is today<br>^Pending regulatory approval at ENTSO-E / NRA level<br>^^The capacity will be released in several batches during the day | | | | | | |

Source: OMIE

*Table 1 - Opening and closing times SIDC*

In the case of Spain, the opening time of the SIDC is a little bit more complicated as there is already a domestic intraday market in place. This intraday market has 6 different auctions, taking place between 18:50 D-1 and 12:50 D. It will be needed to modify the current schedules of the intraday sessions to adapt them to the ACER requirements schedules. It may confuse market agents, who might decide to trade in a market or the other and therefore affect market equilibrium, volatility and liquidity and may create arbitrage opportunities between markets. Thus, in order to properly achieve a better functioning of the SIDC, trading hours should be the same for every bidding zone, however, when fixing a common opening time some other considerations should be taken into account.

The table below shows how the SIDC is combined with intraday auction market in the case of Spain. It has to be said that the chart and therefore the trading schedule for the SIDC was modified the 27th of November 2018 (model B). Prior to that date, the SIDC products available to trade were limited to trading in time as shown in the table (model A). This decision has taken into account in this Master Thesis, as limiting the trading time in some of the hourly products available, may have affected to the liquidity index created in this essay.

| | | | | | | | Before 27/11/2018 | After 27/11/2018 |
|---|---|---|---|---|---|---|---|---|
| Schedule | | | | | MIBEL auction | | Continuous Market (XBID) | Continuous Market (XBID) |
| Day | Continuous round* | Period | Start time of period | End time period | Auction number | Trading periods included in the auction horizon | Open trading periods Hourly products | Open trading periods Hourly products |
| D | 20 | 18 | 17:00 | 18:00 | 1 | | 20,21 (D) | 20-24 (D) |
| D | 21 | 19 | 18:00 | 19:00 | 1 | 22-24 day D, 1-24 Day D+1 | 21 (D) | 21-24 (D) |
| D | 22 | 20 | 19:00 | 20:00 | - | | 22,23,24 (D) | 22-24 (D) |
| D | 23 | 21 | 20:00 | 21:00 | - | | 23,24 (D) | 23-24 (D) |
| D | 24 | 22 | 21:00 | 22:00 | 2 | 1-24 day D+1 | 24 (D) | 24 (D) |
| D | 1 | 23 | 22:00 | 23:00 | - | | 1,2,3,4 (D+1) | 1-24 (D+1) |
| D | 2 | 24 | 23:00 | 0:00 | - | | 2,3,4 (D+1) | 2-24 (D+1) |
| D+1 | 3 | 1 | 0:00 | 1:00 | - | | 3,4 (D) | 3-24 (D) |
| D+1 | 4 | 2 | 1:00 | 2:00 | 3 | 5-24 day D+1 | 4 (D) | 4-24 (D) |
| D+1 | 5 | 3 | 2:00 | 3:00 | - | | 5,6,7 (D) | 5-24 (D) |
| D+1 | 6 | 4 | 3:00 | 4:00 | - | | 6,7 (D) | 6-24 (D) |
| D+1 | 7 | 5 | 4:00 | 5:00 | 4 | 8-24 day D | 7(D) | 7-24 (D) |
| D+1 | 8 | 6 | 5:00 | 6:00 | - | | 8,9,10,11 (D) | 8-24 (D) |
| D+1 | 9 | 7 | 6:00 | 7:00 | - | | 9,10,11 (D) | 9-24 (D) |
| D+1 | 10 | 8 | 7:00 | 8:00 | - | | 10,11 (D) | 10-24 (D) |
| D+1 | 11 | 9 | 8:00 | 9:00 | 5 | 12-24 day D | 11 (D) | 11-24 (D) |
| D+1 | 12 | 10 | 9:00 | 10:00 | - | | 12,13,14,15 (D) | 12-24 (D) |
| D+1 | 13 | 11 | 10:00 | 11:00 | - | | 13,14,15 (D) | 13-24 (D) |
| D+1 | 14 | 12 | 11:00 | 12:00 | - | | 14,15 (D) | 14-24 (D) |
| D+1 | 15 | 13 | 12:00 | 13:00 | 6 | 16-24 day D | 15 (D) | 15-24 (D) |
| D+1 | 16 | 14 | 13:00 | 14:00 | - | | 16,17,18,19,20,21 (D) | 16-24 (D) |
| D+1 | 17 | 15 | 14:00 | 15:00 | - | | 17,18,19,20,21 (D) | 17-24 (D) |
| D+1 | 18 | 16 | 15:00 | 16:00 | - | | 18,19,20,21 (D) | 18-24 (D) |
| D+1 | 19 | 17 | 16:00 | 17:00 | - | | 19,20,21 (D) | 19-24 (D) |
| D+1 | 20 | 18 | 17:00 | 18:00 | 1 | | 20,21 (D) | 20-24 (D) |
| D+1 | 21 | 19 | 18:00 | 19:00 | 1 | 22-24 day D, 1-24 Day D+1 | 21 (D) | 21-24 (D) |

Source: OMIE

*Table 2 - Intraday and SIDC schedule in Spain*

There are also additional products offered for trading in the different bidding zones, as it can be seen in the table below. Some bidding zones offer 15 minutes products or 30 minutes products, and all of them offer hourly products.

| | | German TSO areas | Austria | France | NL & Belgium | Nordics & Baltics | Iberia |
|---|---|---|---|---|---|---|---|
| Size | | Min vol. increment 0.1 MW | | | | | |
| Price Tick | | EUR 0.01 per MWh | | | | | |
| Price Range | | -9 999 €/MWh to 9 999 €/MWh | | | | | |
| Products | 15-min | X | X | | | | |
| | 30-min | X | | X | | | |
| | Hourly | X | X | X | X | X | X |
| | User Defined Blocks* | X | X | X | X | X | |
| Notes | | * Hourly blocks (not 15 or 30 min blocks) | | | | | |

Source: OMIE

*Table 3 - SIDC specifications*

From the table it can also be stated that there is a unified minimum size for the trading orders, that is 0,1MW and the minimum price variation considered, the price tick, is 0.01€/MWh. Regarding the price range that is stated in the table, -9999€/MWh to 9999€/MWh, has to be said that those are maximum values; however national regulation, may or may not depending on the bidding zone, limit the price range to one according to their national rules. That is the case of Spain, for instance, where the bidding price range is set between 0€/MWh and 180.30€/MWh. However, in 2020 a new regulation will modify these values in order to make them equal across European markets.

There are also differences in the interconnection capacity allocation. The Spain-France interconnection capacity (ES-FR) before the SIDC was allocated by explicit auctions through a capacity rights mechanism. Agents willing to trade between Spain-France and vice versa in the day-ahead market should have obtained the right to do so before delivery in two explicit long-term interconnection capacity auctions. After SIDC was implemented, the negotiation of the interconnection capacity will be possible via auctions, through the day-ahead market. Additionally, if there is still interconnection capacity available after clearing day-ahead market, it will be allocated through the intraday continuous market.

It can be seen in the chart below that the interconnection ES-FR is almost always congested. This is due that the price in France, due to nuclear mainly, is cheaper than in Spain thus importing electricity from France is cheaper than generating it in Spain. The lack of enough interconnection capacity is an issue that will take longer to solve, as it will take long time to build new lines that connect both countries.

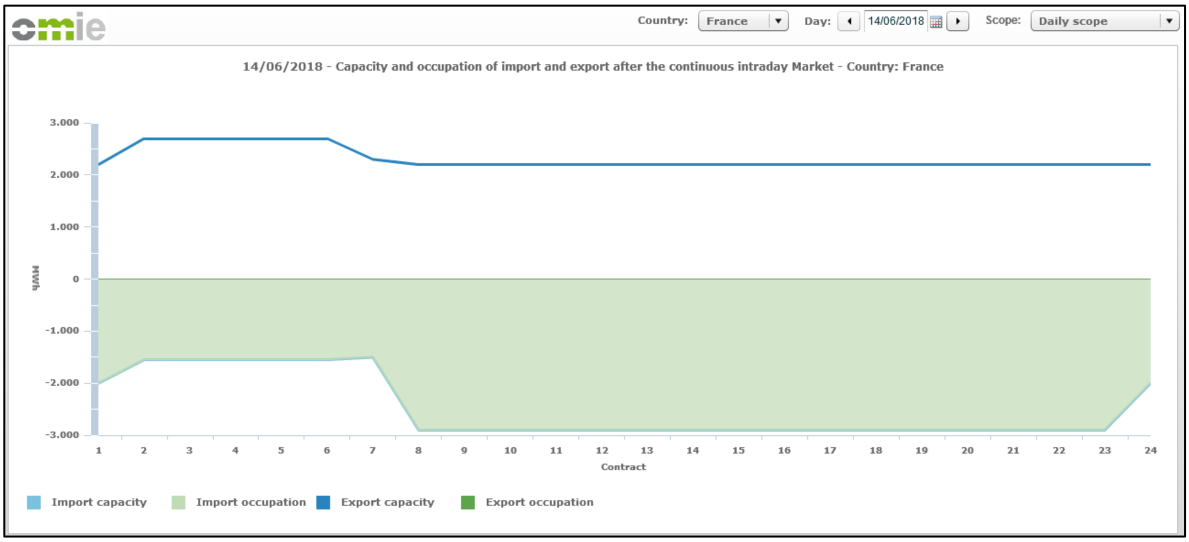



*Figure 11 - Capacity and occupation of ES-FR interconnection*

# 5. Effect of SIDC on domestic markets and processes

The implementation of a newly created market across Europe has caused some modifications in the processes and already existing markets in Spain.

Before the SIDC was implemented, in Spain there were mainly two wholesale markets: the already created single day-ahead coupling (SDAC) and the intraday domestic market. However supporting those wholesale markets, the imbalance management has to be considered for this thesis, as it was the method used by the system operator to match the imbalances between generation and load that appeared between the latest intraday market auction and the real time delivery. Its purpose was to be a link between tertiary reserve and the intraday markets.

## 5.1. Changes in schedules

The addition of the European continuous intraday market has not affected to the schedules of the day-ahead market. SDAC´s gate closure is set at 12:00pm all across Europe, as the algorithm (EUPHEMIA) is run all across the continent at the same time.

The intraday market in Spain, which consists of six different auctions, where market agents can place their orders to adjust their generation or load day-ahead position, has not been affected until now; however as it is going to be explained in section 5.2, the combination of intraday domestic market and SIDC suppose a critical issue on how those markets should be combined.

At the moment, there is not a single gate opening for the SIDC across the member states participating in it; however, European regulators are considering setting a common gate opening across Europe. In regions where there are domestic intraday markets, the national regulations usually favour domestic markets in the sense of time of operation. In the Spanish case, two of the six auctions in the intraday national market are held before the gate opening of the SIDC.

### 5.2. Combining markets

The Spanish National Regulatory Authority (CNMC), Transmission System Operator, Market Operator and market agents, when negotiating the terms and conditions of the SIDC, did not want to remove the intraday auctions market that was working well in Spain. Therefore, they decided to negotiate a clause that allows the coexistence of markets, the intraday auctions market and the intraday continuous market. A specific article was included in the CACM regulation. This article 63 was commented on section 2.2.1 of this master thesis. It allows the existence of the newly created intraday continuous market with the regional auctions market. For the purpose of this master thesis, the coexistence of two intraday markets is very relevant due to the fact that both markets may overlap one with the other and that may affect to the volume traded, number of market participants and prices. The intraday auction market is a six auction market held during the previous day of delivery (two of the six auctions) and during the delivery day (four remaining auctions). Whereas the SIDC is a continuous pay-as-bid market which opens for trading at 22:00 on the previous day of delivery and continue trading up to one hour before delivery. The SIDC trading is continuous, but as at the same time some intraday auctions may be running, there is a 10 minutes halt in trading whenever the auctions is being cleared. This 10 minute pause allows Transmission System Operator to recalculate the remaining interconnection capacity after the auction is cleared.

In relation to the operability of the two intraday markets, both markets can be traded through Spanish Market Operator (OMIE). Trading in different markets comply with some issues that may be not easy to solve for some firms. The need of a registration as a SIDC market agent, the obligation to deposit extra collateral as guarantee to get the possibility of trading in the SIDC, as well as a double software trading platform or the separate billing, invoicing and regulation obligations as REMIT are tasks that have to be complied by market agents willing to trade in both markets.

# 6. Introduction to liquidity

There has been a lot of research about how liquidity can be measure. This is due to the fact that there is no straightforward way to calculate or assess a value to liquidity. This section will try to define liquidity as it is understand by market agents and will comment the variables that could affect in one way or another to liquidity.

## 6.1. Definition of liquidity

Liquidity is a measure of the ability to buy or sell a product – such as electricity - without causing a major change in its price and without incurring significant transaction costs. When talking about transaction costs what it is referring to is to the bid-ask spread that is the difference between the highest price someone wants to buy and the lowest price someone wants to sell the exact same product under the same conditions at the same moment. The closer or smaller the bid-ask spread is, the more liquid can be considered a product. That could actually mean that agents trading in that market have different price valuation of the asset, different expectations, or simply, that there are more agents willing to buy or sell in the market. At this point, speculation in a market may bring more liquidity to the asset and reduce the bid-ask spread, or it may cause higher volatility in prices, and affect the market equilibrium. Trading agents in the Spanish electricity markets are usually utilities, generators or retailers. These agents may or may not implement arbitrage or speculative strategies across the different markets.

A high degree of liquidity, therefore, is the best evidence of strength in any market. In turn, a good level of liquidity will mean that commodity prices better reflect changes in supply and demand fundamentals and are not affected by speculation. Thus, decisions on consumption or investment in electricity or gas will be efficient. This price information will send the right signal in order to develop investments (generation capacity, interconnection capacity, transmission, distribution, storage, etc.). In addition, a liquid market will be characterized by the participation of a large number of buyers and sellers (market players or agents) who will be willing to negotiate and trade a product at any time.

In relation to the volume of transactions, the market should be able to absorb a certain volume of trades without affecting the market price in excess. It can be considered that a market is not liquid enough when a particular agent who is willing to trade cannot execute a transaction due to the lack of volume or due to the market price change that will create the execution of that trade. In order to solve or minimise the impact of peaks in prices when trading, market regulation allows agents to use different kind of orders to agents so they can use them to limit the effect on prices of that trade. The most common orders to avoid price peaks when trading are Limit Orders or Iceberg Orders. Limit orders are a type of trading order that allow the agent to fix a maximum price it is willing to buy, therefore limiting the price peak created by that order. Iceberg orders are similar to limit orders in the sense that a maximum price can be set, but agents can hide the volume of the trade that appear in the price ladder of the market. By doing this, other market agents cannot see the total volume of that specific Iceberg order, and cannot act accordingly to obtain a benefit from the introduction in the market of a large-volume Iceberg order.

Another aspect to consider is the transaction or liquidation costs on the market. To this end, we analyse the so-called bid-ask spread, which is the difference between the maximum price at which market agent wants to buy (bid) and the minimum price at which a market agent wants to sell (ask). A narrow spread reduces transaction costs and increases the certainty about the price level to be achieved. Therefore, the lower the spread, the greater the liquidity will be in the market. There are some other costs that are considered transaction costs. IT costs, Collateral deposits costs or Market access imply an additional cost that the agent must take into account when trading in a market. However, those costs are not considered in this thesis, as there is no market access fee for the Spanish electricity market, IT costs are considered as an external cost for agents and there is no software fee. Regarding the Collateral deposits are standardised for agents and anyone trading in OMIE is required the same amount of Collateral per MWh traded. It can be considered as a barrier of entry for small retailers but it should not be treated as a liquidity harmful issue.

Finally, the average time between transactions is also useful to measure the level of liquidity in any market. A large number of transactions in a given moment in time can give an idea of how fast a purchase or sale of a product can be made at any time. However, it has to be carefully analysed as a large quantity of trades at a given moment may lead to a huge increase or decrease in market price, creating volatility in the market.

In this regard, the so-called churn rate, briefly commented in section 2.2.4, is frequently used. This ratio is defined as the proportion of the trading volume to physical demand. Churn rate measures the frequency with which the product (gas or electricity) is negotiated; thus a high ratio means a good level of liquidity in the market.

## 6.2. Measurement of liquidity

As commented in previous sections of this Master thesis, liquidity is a qualitative measure; the way to measure it is not straight-through.

This Master Thesis has studied the use and has evaluated the incorporation to the synthetic index created, of some of the most well-known variables which in one way or another can be related with liquidity.

### 6.2.1. Volume

Volume is the total amount exchanged of a product within a period of time. It does not take into account the price at which those trades have been done or the quantity exchanged by each agent.

Volume traded in a specific market is considered by some financial experts as the best way to check if a product is liquid or not. However, the mere existence of traded volume in a particular market does not necessarily mean that it is liquid.

Of course it has to be considered, and in fact it is considered in this essay, but cannot be said that is the only market data needed to get a final liquidity value.

Volume is an important indicator in analysis as it is used to measure the relative trustworthiness of a market move. If a product traded in a specific market suddenly changes its market value (price) due to a strong price movement, then the strength of that movement depends on the volume for that period. The larger the volume during the price move, the more significant the market price change.

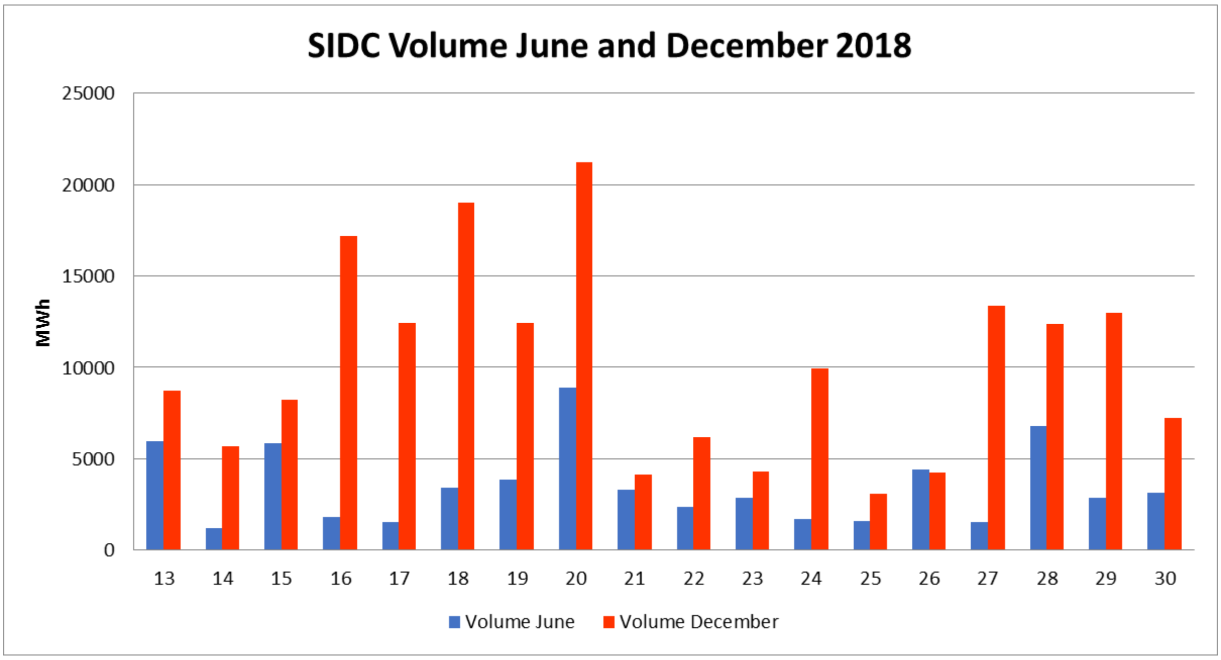



*Figure 12 - SIDC Volume in Spain*

The chart above shows the total volume traded during the first month of operation of SIDC on a daily basis and the volume traded in December of 2018. As it can be appreciated, the total volume traded in June compared with the volume traded in December is quite low. It can be due to the fact that that period was the first 18 days of trading of the market, but that will be studied further when analysing the variables to be included in the synthetic index created in this master thesis.

The SIDC market is primarily used to implement adjustments of generation or consumption. As it can be expected the average volume per trade is 5,15MWh, which is small compared to the average of 45MWh that corresponds to the second intraday auction in Spain.

### 6.2.2. Bid-Ask spread

Broadly speaking, the bid-ask spread is the difference in prices that occur in every instant when any market is open for trading between the highest price someone wants to buy and the lowest price someone wants to sell the same asset with the same specific conditions.

The bid-ask spread is considered a transaction cost. This is due to the fact that agents willing to trade in a market will always incur in some cost by the simple fact of the difference between bids and asks quotes.

| Status | Contract | Timing | BAvg | BAcc | BQty | Bid | Ask | AQty |
|---|---|---|---|---|---|---|---|---|
| TRADE | (98) 15/11/2016 H19 | 2016-11-15 17:45:00 | | | 56.0 | 56.00 | 66.00 | 67.0 |
| TRADE | (99) 15/11/2016 H20 | 2016-11-15 18:45:00 | | | 50.0 | 12.00 | 67.00 | 121.0 |
| TRADE | (100) 15/11/2016 H21 | 2016-11-15 19:45:00 | | | 55.0 | 34.00 | 56.00 | 56.0 |
| TRADE | (101) 15/11/2016 H22 | 2016-11-15 20:45:00 | | | | | | |
| TRADE | (102) 15/11/2016 H23 | 2016-11-15 21:45:00 | | | | | | |
| TRADE | (103) 15/11/2016 H24 | 2016-11-15 22:45:00 | | | 18.0 | 19.84 | 20.29 | 20.0 |

Source: OMIE

*Figure 13 - SIDC Trading screen*

The table above shows as an example what a market agent sees in the trading screen. For the contract H19, the best bid quote in that moment is 56€/MWh and the best ask quote is 66€/MWh. This bid-ask spread is 10€/MWh which is extremely large. It can be due to the fact of small number of market agents or to the different price expectations of agents. An agent who is willing to trade in H19, will see the quotes and if a trade is finally done, the transactions costs incurred by the agent will be half of the bid-ask spread (considering that market equilibrium price is half of bid-ask spread). Thus, the agent will incur in a 5€/MWh transaction cost, as the agent is paying that amount on top of the equilibrium price in that precise moment.

The size of the spread is definitely one of the most important variables to take into account when trading electricity on a continuous market. If the market is not mature enough or there are not enough agents trading on it, the price that an agent will end up paying will be much larger than the equilibrium price and the market will not send the right signals to agents.

### 6.2.3. Transaction costs

In the previous section, the concept of transaction cost arises. Bid-ask spread can be considered as a transaction cost, depending on how large the spread is; however, it is not the only transaction cost that agents may incur in when trading.

Costs that can increase the final overall price that agents pay at the end can be broker costs, market access costs, software charges… Those charges can be considered as sunk costs, due to the fact that every agent will have to pay these costs.

In the case of Spain, such costs are limited. Agents have the option to trade by using a broker, or trading by themselves on the market directly. The broker option will have a cost, usually some cents per MWh traded.

OMIE, Iberian Market Operator, does not charge anything to market agents for market access or software utilisation. However, every single market agent contributes to cover OMIE expenses via regulated tariffs to installed capacity (for generators) and contracted capacity (for consumers). This methodology may benefit the smallest market agents and control market power of large utilities.

### 6.2.4. Number of agents or counterparty

The number of counterparties is usually a key issue in order to get an idea of the interest of traders in that specific market. If the number of agents is very limited, the market can be seen as not attractive for trading, as the trading opportunities will be fewer and they will be executed by similar agents.

In the Iberian market, the number of market agents is very high. By December 31st there were 1156 domestic agents trading that market, where many of them are represented by a specialized third party in order to reduce operating costs. The number of International agents is not a relevant issue due to the fact that every agent has participated through his bidding zone.

### 6.2.5. Average time between transactions

The time of the transactions carried out is also useful to measure the level of liquidity in any market. A large number of transactions in a given time give an idea of how fast a purchase or sale of a product can be made at any time.

When trading on a continuous market, the closer the delivery time or gate closure is the more information is available for agents, and the more likely is that a larger number of trades happens in the last minutes of trading. However, the SIDC is a little bit different, in the sense of that is a market used to balance expected generation or load with already settle exposure.

Therefore, if an agent who was committed to generate 50MWh during hour h, and will finally generate only 30MWh due to plant failure, less wind or a more than expected cloudy day, the market agent of the plant will manage to balance or not 20MWh of generation that will not be producing depending on the market or on their expectation of imbalance price. The agent may wait until before gate closure to close that trade however he may face higher risks.

Average time between trades is key in electricity markets, as market agents trade during the whole trading session.

In the Iberian SIDC, when it first came into place, the trading schedule was set by the model A, were there was a time limitation for hourly products, and just the products available for trade were the ones up to the next intraday auction. That actually limited a lot the time between trades. The average time between trades with model A was set in 4 minutes and 49 seconds, on average for any hourly product. When Model B was implemented, and the ability to trade for the 24 hourly products available, the average time between trades was set in 12 minutes and 15 seconds. It can be seen that there is a huge difference on the averages between model A and model B. It cannot be said that model B is less liquid than model A, just because trades happen more often, time limitation was key in model A, where all trades were concentrated in the time between intraday auctions.

#### 6.2.6. Volatility

Volatility is a statistical measure of the dispersion of returns for a given asset or market index. In most cases, the higher the volatility, the riskier the asset is.

In the commodities markets, the volatility is usually higher than in any other market as stocks, bonds or currencies. This is due to the fact of the fast changes in that specific commodity needs. For example, from one day to another, there could be severe changes in weather conditions that will change the need for electricity or heating. There are also different events that can affect load under specific conditions, like a football world cup championship or a national strike.

In the electricity market specifically, there are patterns in consumption, what is called the load curve. That shows the actual needs of electricity of a country.

The chart below shows how this load varies during a winter day in Spain. It can be seen the morning peak and the evening peak.

That difference in electricity consumption is transferred to the markets which will reflect it in different prices along the day, higher prices when demand is higher.

This price dispersion makes electricity markets one with the most volatility mainly due to the seasonal consumption pattern that consumers follows during a day, a week, a season or a year.

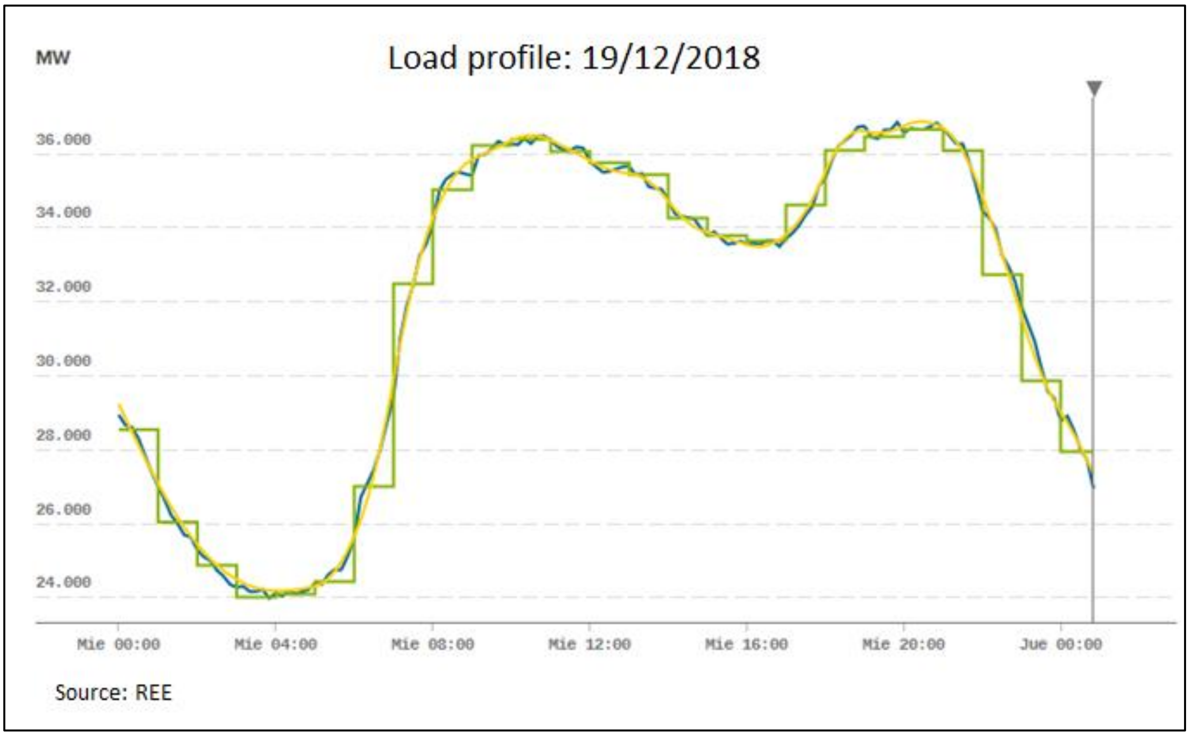



*Figure 14 - Load profile in winter in Spain*

Volatility by definition is not bad; however a market with a huge volatility will be riskier than one with a moderate volatility. In the electricity markets, volatility will make close to real time markets to provide a better reference price for that hourly product as a better and more accurate load and generation information will be available for agents.

### 6.2.7. Market depth

Investopedia defines market depth as “the market's ability to sustain relatively large market orders without impacting the price of the security”. Market depth is therefore much related to the size of orders and to the liquidity of the market.

Market depth can be measure by looking at the order book of an hourly product in a given moment, and realising the number of orders, their volume and price of execution. Market depth, as liquidity, does not have a measure as such; however it can be estimated or valued by using the variables cited above.

In the case of Spain, market depth shown to market agents is limited to the best fifty prices of bid-ask orders, no matter their quantity. This market depth gives the agent trading an overall view of the market status at any given moment. The use of the different type of orders commented on section 6.1, is key for market depth, as limit orders will be taken fully into account but iceberg orders will just show on the order book the specified volume.

# 7. Creation of a liquidity Index

## 7.1. Reasoning behind a new liquidity index

There have been a lot of studies about how liquidity affects any asset traded in a market. However, there is no perfect unit to measure liquidity. Being liquidity a qualitative characteristic of an asset makes its measure complex. Some studies relate liquidity with volume traded or number of trades during a given period of time. This master thesis has studied how the implementation of a new market, the SIDC, in Europe, including the Iberian region has affected already existing domestic markets, and has evaluated the liquidity of the newly implemented market. To do so, in this Thesis, a new synthetic liquidity index has been designed in order to give a value to liquidity.

As commented before, there is no established formula to value liquidity, and most of the research agrees that a good way to approximate to a liquidity value is by using volume. However, due to the special characteristics of the SIDC, the synthetic index created has taken into account some other variables that the author considered that have an effect into liquidity and that have to be included in a liquidity index. The variables included will be commented in the following section.

## 7.2. Synthetic index Formula explanation

As stated in the former section, the author has considered that in order to obtain a better liquidity index, some variables have to be included in the synthetic or composite index. The goal of the synthetic index is to value liquidity by using a different approximation as by just using volume traded.

The Index Formula is the one below:

$$Index = 20\% * Agents + 30\% * Trades_{total} + 20\% * Trades_{International} + 20\% * Time_{trades} + 10\% * MaxMinPrice$$

- Agents: measures the number of different market agents that have traded an hourly product during the trading hours of the contract.
- Trades_total: measures the total number of trades within an hourly product during the trading hours of the contract.
- Trades_international: measures the number of trades in which an international agent has taken part within an hourly product during the trading hours of the contract.
- Time_trades: measures the average time between trades of an hourly product during the trading hours of the contract.
- MaxMinPrice: measures the difference in price between the maximum and minimum price of an hourly product during the trading hours of the contract.

The author has considered including the variables defined above and no others due to the following reasons:

- Agents: The addition of this variable to the index was very relevant for the author as the number of market agents is usually not considered in mature and very globalized markets; however for the Iberian SIDC case, data was found to be correlated with the volume traded and thus with liquidity in the market. The 20% weighting of this variable shows the importance of this variable in the index.
- Trades_total: The reader may question why volume traded has not been included in the index formula. The answer for this question is that volume traded and number of trades are 95% correlated, thus for the index to be more relevant in unit size, the author has considered to not introduce volume and overweight the total trades variable. It is the variable which has the largest weighting of all; this can realized the importance given by the author to the volume traded measured in total number of trades.
- Trades_international: The interconnection between Spain and France has been proven to be a key element when trading in the SIDC. Whenever there is available interconnection capacity to import electricity from France to Spain, the volume traded boosts, thus liquidity. This is why, the author has considered including in the index, the number of trades where an international agent takes part, weighting it with a 20%.
- Time_trades: The average time between trades is a good indicator of how agents trade in a specific market. The shorter the average time between trades is, the more trades

happens in a market and thus the more the volume is. To calculate this variable, the author has designed a binary variable which evaluates if the average time between trades is smaller than the average considering average time for model A, from 13/06/2018 to 26/11/2018 and average for model B, from 27/11/2018 to 31/12/2018. Those averages have been commented in section 6.2.5, whose values differ significantly. A weighting of 20% has also being given to this variable due to the importance that international trades have on SIDC volume traded.

- MaxMinPrice: This variable is, in essence, the price difference between the maximum and minimum price for any hourly product. The author has considered this variable as a proxy of the bid-ask spread, since data for the latest is not available at the moment. The weighting given is 10% due to the fact that SIDC can be considered as a balancing market, which is close to real time, where agents may prefer to balance their positions instead of getting a better price.

# 8. Application of Liquidity Index to Data

The liquidity index explained in the previous section was applied to real market data. The data base used is public and free of access to everyone who is willing to use it. The market data used was data from 12/06/2018 to 31/12/2018. The starting date is the first day when SIDC was open for trading across Europe. The terminal date chosen was the last day of 2018, as full set of data is published with a 90 day delay.

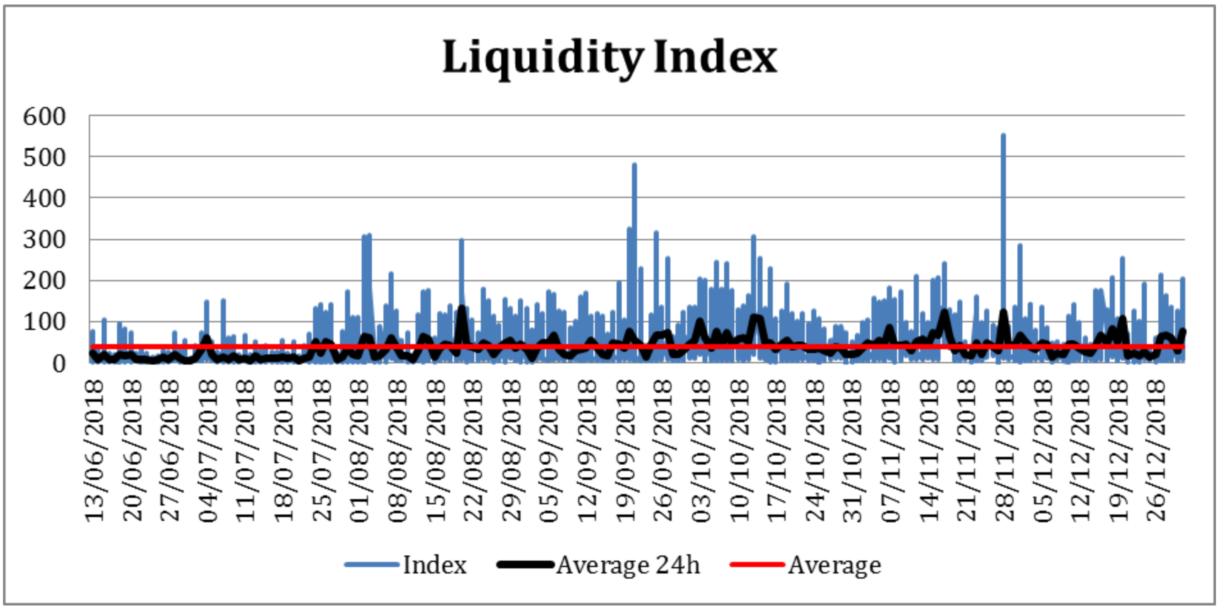



*Figure 15 - SIDC Liquidity Index*

The liquidity results obtained are shown in the chart above. The line in blue corresponds to the actual hourly liquidity values. It can be seen that there are some spikes on it. Those spikes correspond to hours where liquidity was high due to the fact that there were a large number of agents trading actively during those hours and because there was available interconnection capacity available to trade internationally. The red line on the chart shows the average of all the values of the period considered. A value of 31 was obtained on an overall analysis, however due to the characteristics of the SIDC market, a 24 hour average was calculated, as it can be seen in the chart (black line). The aim of the 24 hour average is to soften the peak values that happened during certain periods and obtain daily liquidity index values.

It can also be seen that during the first month more or less, the liquidity values obtained were on average well below the mean values. It can be justified as agents may have a lack of experience and prefer trading on an intraday auction than in the SIDC.

If data is extrapolated to an hourly basis, considering that besides weekends or holidays, an hourly liquidity index can be created, as shown in the chart below.

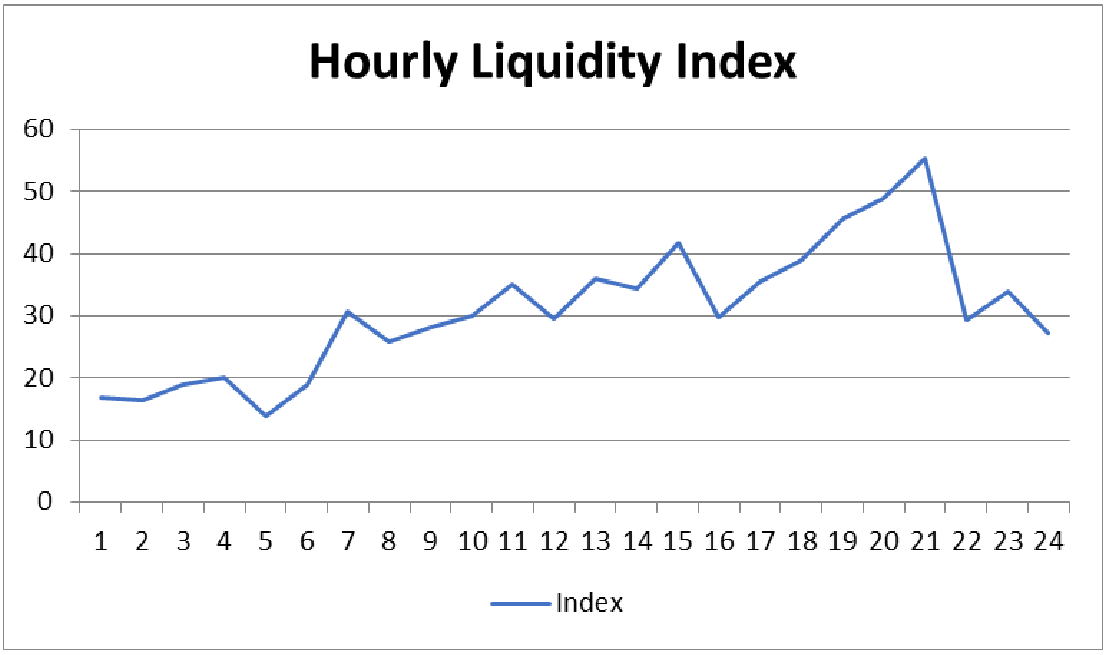
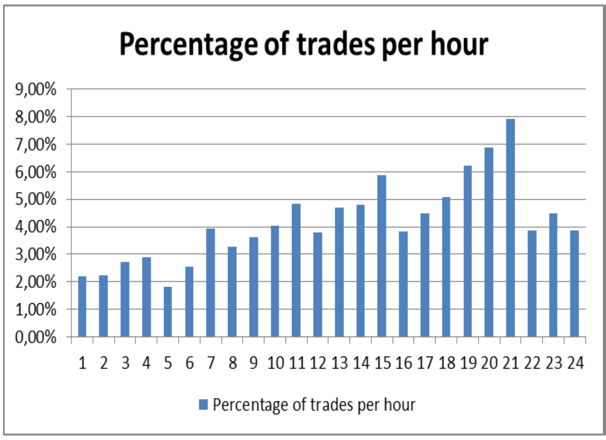



*Figure 16 - SIDC Hourly liquidity Index*

Values for the chart above have been calculated by averaging hourly values. It can be seen that the more liquid hours are the ones that corresponds to the evening peak, between 19h and 22h. That can be justified as those are the hour where the largest volume is traded, thus the more trades are executed, and liquidity increases significantly.



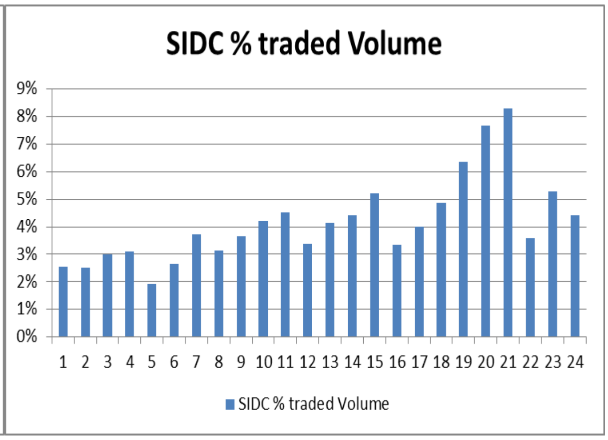




*Figure 17 - Percentage of SIDC trades per hour*

*Figure 18 - SIDC percentage of traded volume*

An hourly analysis of the number or trades and the volume traded was done, in order to analyse and justify the use in the index of the number of trades instead of the volume traded. It can be seen, by comparing the two charts above, that the correlation between number of trades and volume traded is very large, and therefore, both of the charts should have the same pattern. A statistical analysis was made to evaluate the correlation between those two variables, and the results obtained were that they have a correlation of +95%.

As the number of trades is the largest weighting on the index, the time when number of trades is largest corresponds with the hours when liquidity peaks, between 19h and 22h.


*Figure 19 - Percentage of hours with international trades*

If the variable to be analysed is the availability of interconnection capacity between Spain and France, it is shown in the chart above, the percentage of hours that at least had one trade where an international agent has taken place. The chart shows that there are two different peaks within the hours of the day, one correspond to the morning peak, that was not really visible in the hourly liquidity chart, and the other corresponding to the evening peak, the same as liquidity, volume and number of trades.

The two charts below may be the most interesting ones, due to the fact that during the period when data base was collected, the regulation changed the trading schedule of the SIDC. The change from model A, where the open hourly products for trading was limited to the ones up to the next upcoming intraday auction, to model B, where the products that were open for trading were the hourly products until the end of the delivery day.

To correctly interpret the chart, it has to be taken into account, that the shortest the average time between trades, the more liquid can be considered that hourly period.

On this first chart, it can be seen that there can be considered two periods of the day when it takes a longer time between one trade and the next one. The first peak happens between H2 and H7 approximately. The second peak happens during the evening that is between H22 and H24. The first of the peak can be justified, as during the night, load is smaller, and renewable energy sources like Solar PV are not generating, thus are not trading or adjusting any imbalance. However, the second of the peaks is not in line with the other measured variables, like volume or number of total or international trades.

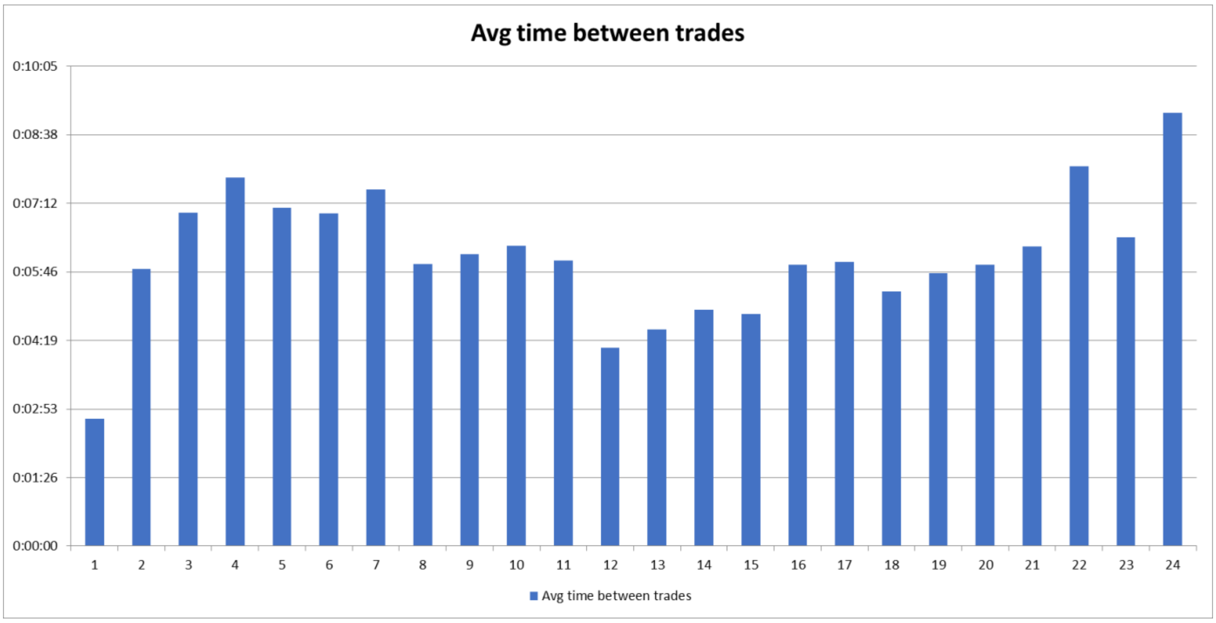



*Figure 20 - Average time between SIDC trades*

Therefore a deeper analysis has to be made in order to check what has happened and why those values have been obtained.

The answer of the second peak was found when the same analysis was made separately to model A data and model B data. Results can be found in the next chart.

It is clearly visible that the effect that the implementation of model B, where all the products available for trading are the hourly ones corresponding to the delivery day hours, has increased significantly the average time between trades. Opening for trade at 22:00 d-1 the contracts to be delivered between H21 and H24 had an effect that had to be considered when analysing liquidity, and that was the main reason why the Time_trades variable consider two different values for the average time between trades when included in the liquidity index.

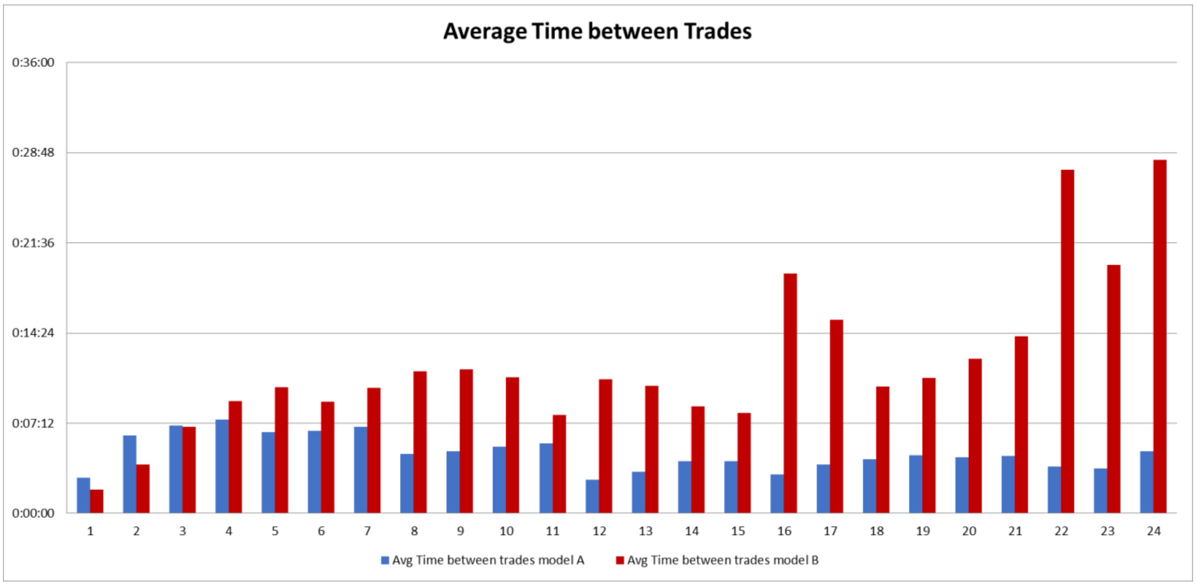



*Figure 21 - Average time between SIDC trades in model A and B*

Finally, the variable used as a proxy for assessing the bid-ask spread was the difference between the maximum price and the minimum price traded during the trading session of that hourly product. The author considered, as the bid-ask spread data was not available, to extrapolate bid-ask spread and take into account the maximum and minimum prices traded in any hourly product. In fact, maximum and minimum prices are considered as a valid approximation to bid-ask spread during a certain period of time.

Overall, it can be said that the difference between maximum price and minimum price is limited. The average price difference for an hourly product is about 6,34€. Considering that the average day ahead price for the period considered was 63,79€/MWh , obtaining a 10% spectrum of prices, and considering electricity as one of the most volatile commodities, the spread can be considered as low.

There are some values that are extremely high, however those can be due to the external facts like generation plant trip out. Those values can be considered as extraordinary and rare.

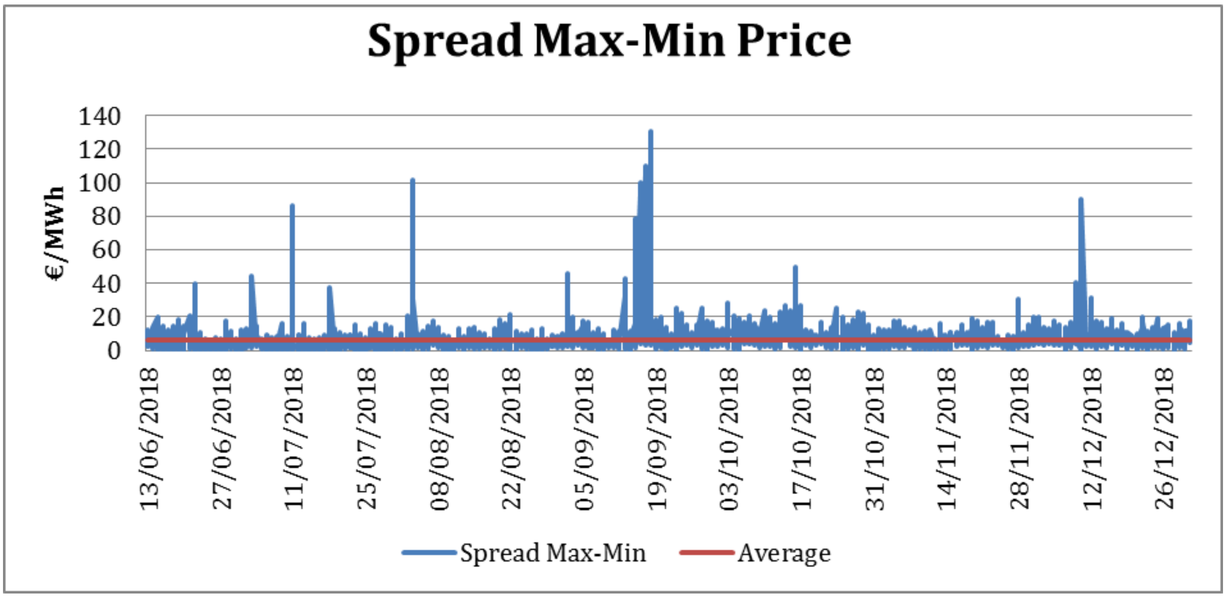



*Figure 22 - SIDC Spread Maximum and minimum price*

## 8.1. Analysis of the results

The implementation of the SIDC has caused several issues regarding the whole markets in Spain. The co-existence of domestic intraday auction market at the same time than SIDC may have caused an operability effect on the auction market, as agents may choose between trading in one or the other.

The effect studied has been assessed by considering volume of trading that is the total amount of MW exchanged during a period of time given. To compare those markets correctly, the author has made the assumption of considering only the second intraday auction. It is justified as the second intraday auction is the one that is executed at 22h, and is the latest one that allows agents to trade the full 24 hours of delivery day.

As it can be seen in the chart below, the volume traded in the second auction is considerably larger than the one corresponding to SIDC. There has been an increase in volume traded in the SIDC; however, the volume traded in the second auction market, as remain at the same levels. So it can be concluded that the implementation of SIDC has not had any effect on intraday auction markets.

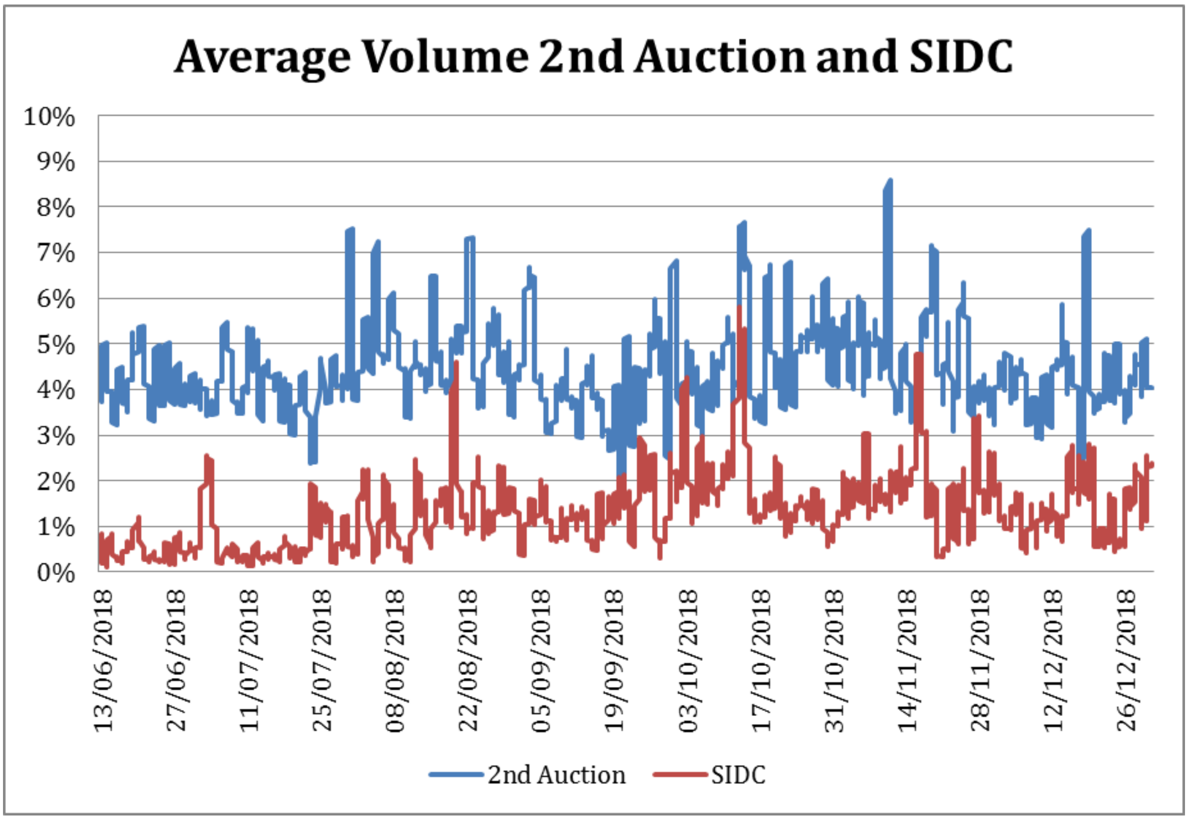



*Figure 23 - Average volume second intraday auction and SIDC*

Another market that could be potentially be affected by the implementation of SIDC was the Imbalances. This market, on essence, is the volume difference that occurs when trading position does not match with delivery or consumption. That is, a generator who commits to generate 300MWh during hour h, but finally generates 270MWh due to whatever reason. The plant will be charged for that 30 MWh that where not delivered.

Theoretically, reducing the time when trading ceases to a closer to delivery one, will reduce the overall volume of the imbalances due to possibility of adjusting the position closer to delivery.

The chart below shows the volume corresponding to year 2018 of the Imbalances in Spain. The average volume before SIDC was introduced was 30 MW on an hourly basis, whereas after the implementation of SIDC the volume was reduced to 10,9 MW on an hourly basis. The results obtained were the ones expected from a theoretically point of view.

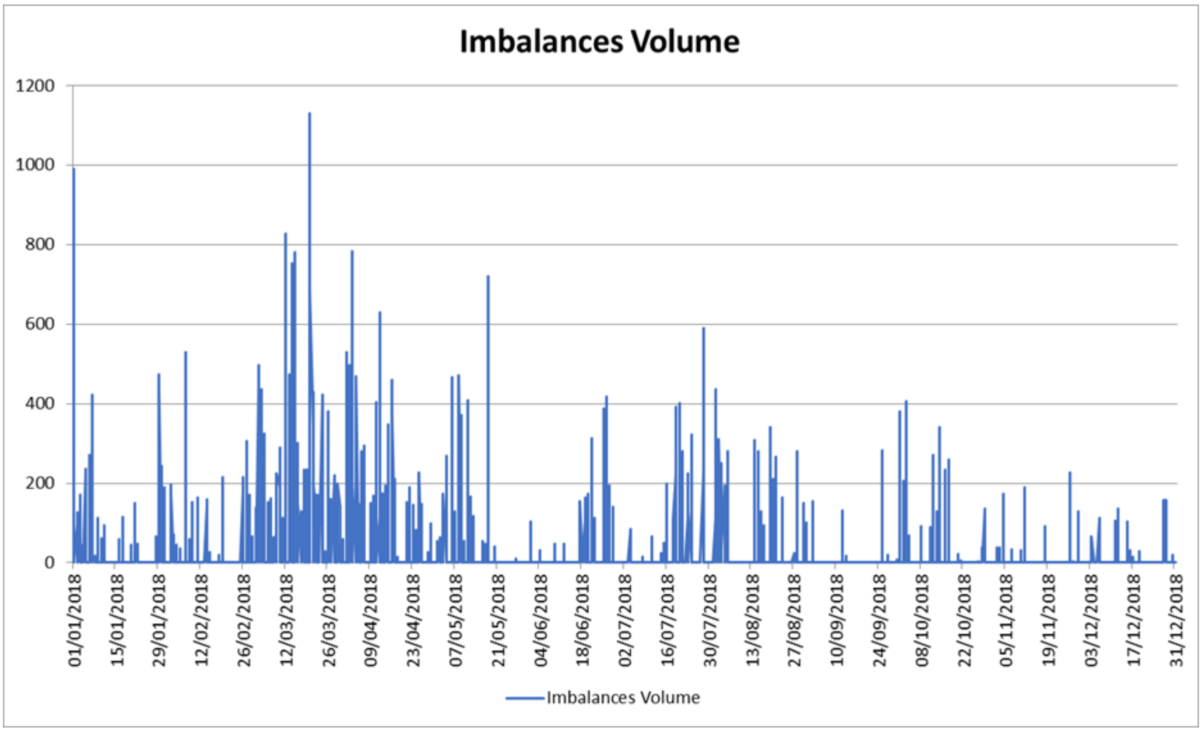



*Figure 24 - Imbalances volume*

Finally, to complete the market or processes that may have been affected by the implementation of the SIDC; this thesis has study the effect on the volume traded of two different processes, Tertiary Reserve and Balit platform.

The chart below shows the volume traded on both processes. The tertiary reserve is a mechanism by which the system operator can increase or decrease manually the output of a generation plant. The chart clearly shows the difference on volume before and after SIDC was implemented in Spain. Tertiary reserve volume was reduced a 49,8% on average after the SIDC came into place in June 2018.

The Balit platform is an exchange by which Iberia and France can exchange capacity reserves. The volume observed is substantially smaller than in the Tertiary reserve, due to the limited interconnection capacity of the two power systems. The reduction in traded volume in Balit was approximately of a 40% reduction due to the implementation of SIDC.

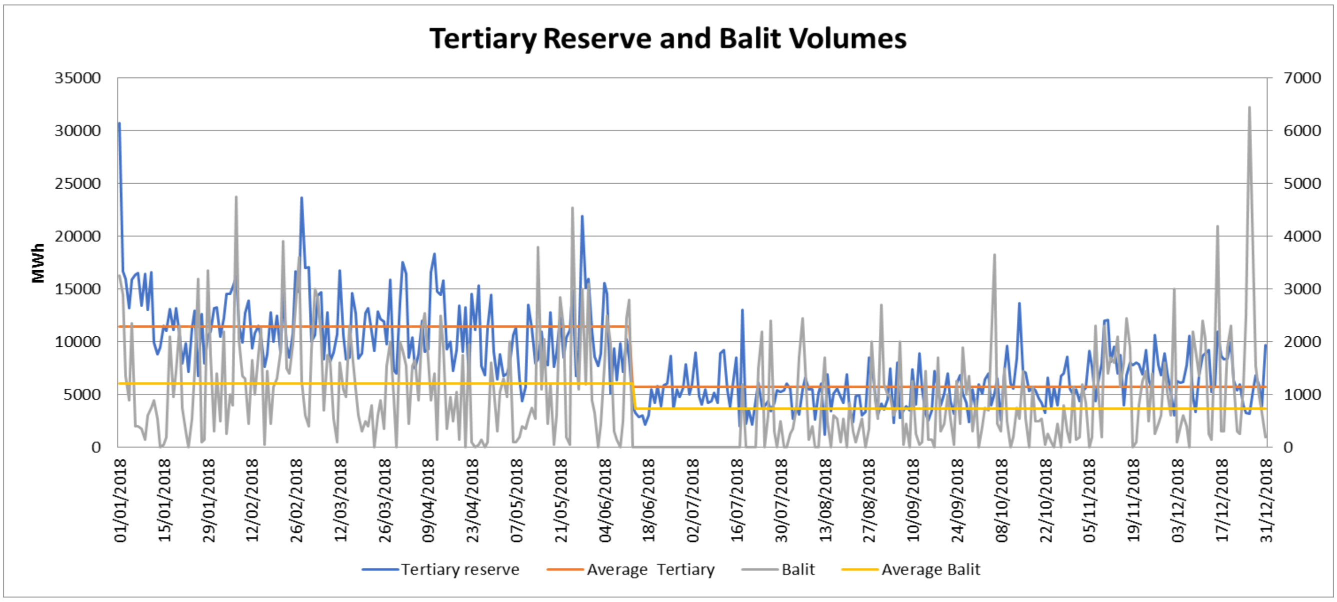



*Figure 25 - Tertiary reserve and Balit volume*

Figure 26 below, shows how the traded volume has changed along the time before and after SIDC was implemented. Before SIDC, most of the volume was traded in the Tertiary Reserve market and some residual volume was traded via Balit platform.

After SIDC was introduced it can be seen that the tertiary reserve volume was heavily reduced and traded in SIDC. Volume traded via Balit platform was also reduced in favour of SIDC market.

After analysing data, the overall volume traded in the markets considered increased by 24% mainly due to the increase in SIDC traded volume.

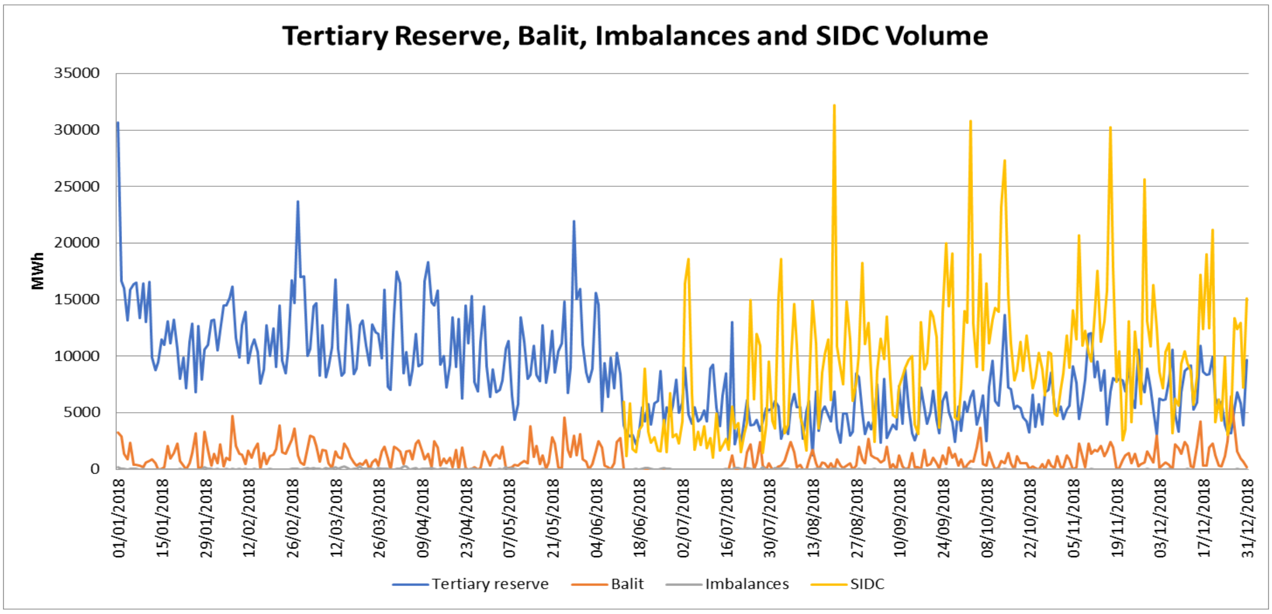



*Figure 26 – Tertiary Reserve, Balit, Imbalances and SIDC Volume*

# 9. Conclusions

After concluding this study, it can be said that the implementation of the SIDC market in Spain has had an impact on the Spanish electricity market.

The implementation of the SIDC gave market agents the possibility to trade closer to real time electricity delivery and the opportunity to trade in a continuous European market.

The impact that the implementation had on the day-ahead market was negligible, due to the fact that both markets have different purposes and different trading schedules.

The effect that the SIDC has had on the intraday auction market was a little bit more significant than the one in the day-ahead market due to the fact that both markets have the same purpose which is to adjust the market position close to real time; however, the effect was relatively small. There is barely any reduction in volume traded in the intraday auction market.

The markets that have been affected the most are Tertiary Reserve market, Balit platform and Imbalances market. The traded volume on those markets after the implementation of the SIDC has been reduced by 50%, 40% and 66% respectively. In essence, the volume reduction in those markets was due to the closer-to-delivery of the SIDC. A closer to real time operation allow market agents to better estimate their generation or consumption by having better real time information (weather, load, generator failure…) and also to access to offers beyond our borders.

A deep analysis of liquidity was carried out in this Master thesis. The author has evaluated several market data variables that can affect the SIDC market liquidity. An assessment of those variables was done by the author in order to include or reject them from the synthetic index formula. The utilization of proxy variables of missing data and the incorporation of a binary variable for the average time between trades were some of the methodology applied to create a robust and reliable index.

The chart below shows the hourly results for the created synthetic index. It can be noticed the lower liquidity during night hours and the increase in liquidity during evening peak hours. The reasoning behind this can be justified as the larger volume traded during those hours because those hourly products are open for trading for a longer period of time.

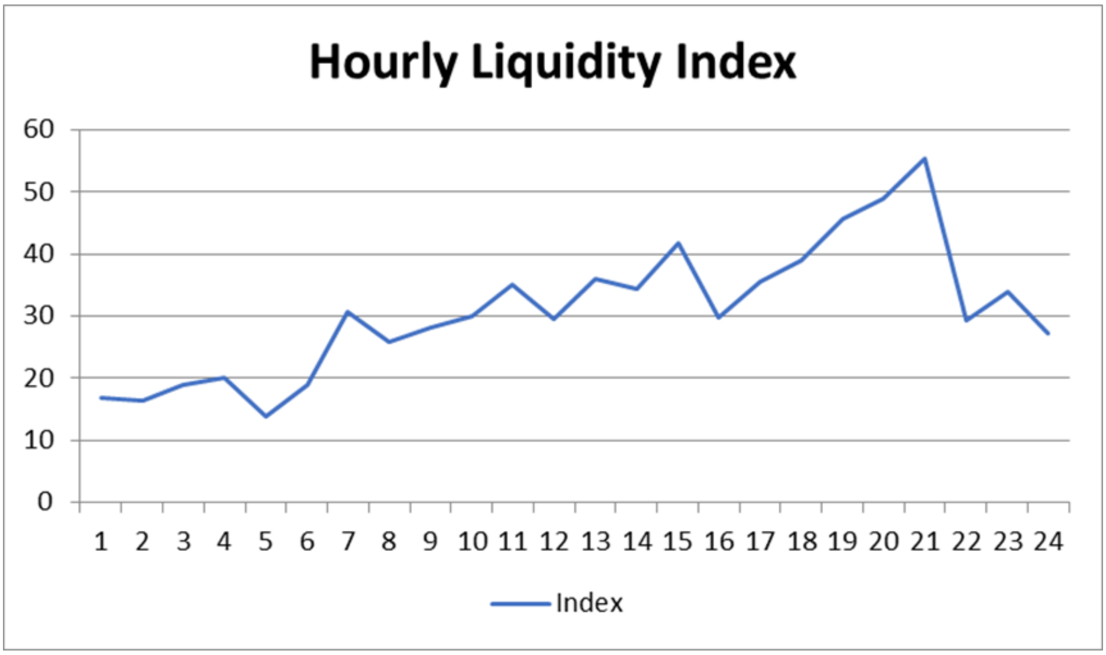



*Figure 27 - SIDC Hourly liquidity Index*

As commented in this essay, the implementation of the SIDC was done in addition to the already existing domestic intraday auction markets. European regulation, CACM, allowed the co-existence of both markets. The implementation, in the case of Spain, was accomplished in two steps, which differ in the schedule of trading. Model A was in place from June 12th 2018 to November 26th 2018. It allowed continuous trading of the hourly products available up to the next intraday auction, hence limiting the open-for-trade time of the products. Model B started on November 27th and is the definitive model that the SIDC is going to use. It allows continuous trading of all the hourly products for delivery day as of the opening hour. Therefore, a market agent can trade on a continuous manner as of 22:00 on d-1until one hour before delivery.

International interconnection capacity management was also modified as the remaining capacity after day-ahead is now allocated via the SIDC.

The common market in Europe will continue to spread; differences in domestic electricity market structures will converge into standardize one. New market implementations will be taking place in the short run across Europe. The implementation of three intraday Pan-European electricity auctions will be carried out during 2020. The effect of these three new intraday auctions that will substitute the intraday domestic auctions could be an extension of this Master thesis after the implementation of these auctions takes place. Additionally, the intraday Pan-European auctions will somehow affect the SIDC market that has been studied in this essay. The effect caused on the SIDC could be relevant and may affect the liquidity studied in section 7. A main goal of the intraday Pan-European auctions will be to price somehow the interconnection cost, via congestion surplus.

Market unification in Europe will increase security of supply, quality of service and will benefit the process of decarbonising the economy and specifically the electricity generation industry. However if there is not enough capacity, as currently happens in Iberia, Spanish and Portuguese electricity markets will not be able to take advantage of this market. Iberia will continue being partially isolated if the interconnection with France is not increased significantly.

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