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Master Thesis

Demand Side Participation in European Electricity Markets:

Assessment of the Greek Interruptibility Scheme and the Participation of the Hellenic Petroleum Aspropyrgos Industrial Complex

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Sotirios Pitropakis

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ABSTRACT

Demand Side Response (DSR) concept, although not a contemporary idea in the energy policy field, has sprung during the recent years. European Union's Energy and Climate policy framework has adopted various forms of the concept at all levels of consumption, from large industrial customers up to small households. Having as a policy spearhead the energy efficiency, DSR has been integrated to and promoted through various legislative initiatives within the EU, such as the Energy Union, various energy related directives (Electricity, Energy Efficiency, State Aid), the Network Codes and the Clean Energy Package. DSR programs vary to a large extend and they can be adjusted to many different electricity markets schemes, exhibiting a rather complex classification. In Europe, numerous DSR programs have been established in many countries. In Greece in particular, although the energy market cannot be characterized as a mature one, there is a specific scheme that engages large industrial consumers (HV and MV) to the DSR concept. This is the so called Interruptible Load Service Auction (ILSA) scheme, which runs during the last 4 years under the auspices and management of the Greek TSO. The program is based on load curtailment on-demand from the Greek TSO side towards the consumers. The consumers are being remunerated for their availability to curtail specific loads that have been contracted through an auction procedure that takes place several times throughout a year. In this thesis, the ILSA scheme is analyzed in detailed, both as far as its legal and operational framework is concerned, as well as far as the types of consumers that participate to it. Following the abovementioned analysis, the participation of the Hellenic Petroleum Aspropyrgos Industrial Complex (HELPE-AIC) is assessed as a case study, while at the section of the concluding remarks, some noticeable suggestions for the further penetration of the scheme to the Greek energy market are presented, as well as for HELPE-AIC's further engagement to the scheme.

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ABBREVIATIONS

ACER	Agency for the Cooperation of Energy Regulators
ADL	Auction Declared Load
ADMIE	Greek TSO (Independent authority – please see ΑΔΜΗΕ as well)
aFRR	automatic Frequency Restoration Reserve
AIL	Average Interruptible Load
AMI	Advanced Metering Infrastructure
AMP	Auction’s Marginal Price
AOL	AOL
ASP	Auxiliary Services Panel
A/S	Ancillary Services
BMS	Building Management Systems
BRP	Balancing Responsible Parties
CL	Consumption Location
CPP	Critical Peak Pricing
DB&BB	Demand Bidding & Buy-Back
DLC	Direct Load Control
DSO	Distribution System Operator
DSM	Demand Side Management
DSR	Demand-Side Response
EDP	Emergency Distribution Panel
EDR	Emergency Demand Response
EEC	European Economic Community
EED	Energy Efficiency Directive
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
FCR	Frequency Containment Reserve
HELPE	Hellenic Petroleum
HELPE-AIC	Hellenic Petroleum Aspropyrgos Industrial Complex
HELPE-TIC	Hellenic Petroleum Thessaloniki Industrial Complex
HV	High Voltage
ILC	Interruptible Load Contract
ILR	Interruptible Load Register
ILS	Interruptible Load Service
ILSA	Interruptible Load Service Auction
ILST	Interruptible Load Service Type

IMF	International Monetary Fund
I/CL	Interruptible / Curtailable Load
IBP	Incentive-Based Programs
LSS	Load Shedding System
LV	Low Voltage
MCC	Motor Control Center
MCL	Maximum Contracted Load
MEUCR	Main Electrical & Utilities Control Room
mFRR	manual Frequency Restoration Reserve
MV	Medium Voltage
MHP	Maximum Historical Power
MIL	Maximum Interruptible Load
MOIL	Maximum Offered Interruptible Load
MSP	Maximum Semestral Power
NECP	National Energy & Climate Plans
PBP	Priced-Based Programs
PC	Power Center
PPC	Public Power Corporation (“ΔΕΗ” in Greek)
PRO	Power Reduction Order
PTR	Peak Time Rebates
PV	Ptotovoltaic
RAE	Regulatory Authority for Energy
RR	Replacement Reserves
SEDC	Smart Energy Demand Coalition
SLPD	Shifting Load Participation Declaration
SPRTT	System Peak Response Transmission Tariffs
TFEU	Treaty on the Functioning of the European Union
TIP	Total Interruptible Power
TMC	Total Monthly Comensation
TRP	Real Time Pricing
ToU	Time of Use
TSO	Transmission System Operator
VPP	Variable Peak Pricing
ΑΔΜΗΕ	Ανεξάρτητος Διαχειριστής Μεταφοράς Ηλεκτρικής Ενέργειας

INTRODUCTION

The liberalization of the energy markets during the last decades has faced many challenges. Major obstacles have been identified in the path from applying a theoretical framework that will set both the wholesale and retail markets truly open and functional under a fully liberated and well regulated concept.

A major structural problem – a disconnection between wholesale and retail energy markets – has become apparent during the transition to competitive wholesale power markets. Wholesale prices pikes have occurred on occasion as a result of a confluence of factors, including: unexpectedly high demand levels, little if any price responsive loads, short-term capacity shortages, and, some argue, market power on the part of generators. In contrast, nearly all retail customers face prices that are fixed across long periods of time, so they see no incentive to reduce usage during infrequent periods of high wholesale prices. This lack of price responsive load, or demand response, robs the wholesale market of a natural mechanism for relieving temporary pressures on prices, thus exacerbating the price spike problem [43].

The up-to-nowadays traditional model of the electricity system, whereby power is sent from centralized plants to customers, is required to be shifted to a new, more dynamic, multiplayer-oriented system, in order to eliminate the abovementioned phenomenon. This transition of course, will require investments in infrastructure, changes to price signals, implementation of market codes, business models which deliver increasing flexibility to the grid and a more energetic participation of the consumer's side.

From a technological perspective, although contemporary electrical systems are characterized by multidirectional flows and dynamic and fluctuating demand, mature solutions exist that can contribute towards the direct and active participation of consumers, with smart appliances to be at the top of this technological chain. The rise of smart technologies looks set to change the role that consumers play in the energy market and paves the way for active market participation. Moving away from predictable energy usage to a more dynamic consumption pattern, the consumers' role is transitioning along with the wider energy system. Smart technologies and dynamic, system-cost reflective pricing can unlock the potential for demand response flexibility. For instance, through shifting energy use from an expensive time-period to another, efficiency opportunities can be capitalized upon. Flexibility providers can therefore help network operators ensure that the balance between supply and demand of electricity is maintained, with potential for savings for customers as well. Analysis published by the European Commission suggests that demand-side response can deliver between €3 - €5 billion worth of net social benefit by 2030 [76].

Retail demand response to wholesale market conditions, where it can occur, has many important benefits. In particular, it can relieve generation and transmission constraints, reduce the severity of wholesale price spikes, reduce potential market power on the part of generators, and lead to lower overall energy prices to all consumers. These benefits are achievable, however, only if markets are designed in a way that allows wholesale market information to reach consumers directly (e.g., through dynamic, time-varying retail prices, such as real-time pricing), or if consumers are able to express their willingness-to-pay for services in a manner that can reach the wholesale market (e.g., through load reduction programs in which customers offer to reduce consumption during certain hours in return for a financial payment).

In this thesis, an overview of the demand side concept in the EU is presented, starting from the legislative framework that surrounds it. Different types of demand side tools and means are analyzed, while their importance to the EU strategic goals in the energy sector is highlighted. Greece's energy strategy is bonded to that of EU, and under this prism, demand side participation policies have to be implemented as well. In this context the Greek Interruptibility Scheme has been in operation since early 2016. A throughout presentation of the scheme is provided (legislative framework, procedures, etc), while a detailed analysis of its results up to nowadays highlights some interesting aspects concerning the type of consumers that participate to it. An assessment of the participation of Hellenic Petroleum Aspropyrgos (HELPE-AIC) Industrial Complex to the scheme is followed. Finally, suggestions on how HELPE-AIC can further strengthen its participation to the scheme are provided, as well as to how the scheme should evolve in the years to follow.

CHAPTER 1: EUROPEAN UNION'S ENERGY & CLIMATE POLICIES

1.1 EU Climate & Energy Framework

EU has a solid climate and energy framework which is frequently being updated, so as to follow the needs of its citizens and the advancements in technology. Both aspects – climate and energy – are strongly bonded through this framework. Goals set, affect the energy policies which must be designed and applied to a great extent.

The policy objectives lie in three main fields which drive the framework. These are the greenhouse gas emissions, the renewable energy sources and the energy efficiency. For each one of these fields, specific and binding targets for all member states have been set. More specifically, the key targets for the year 2030 are:

- At least 40% cuts in greenhouse gas emissions, compared to 1990 levels
- At least 32% share for renewable energy
- At least 32.5% improvement in energy efficiency

We note that the general framework was adopted by the European Council in October 2014. Yet, the targets for renewables and energy efficiency were revised upwards in 2018.

1.2 The Concept of the Energy Union

The emergence of energy security as a global issue in the last decades – and especially after the OPEC's embargo in the 70's – along with the vision of a common European market and Economic Community (EEC) gave birth to some new ideas pertinent to the energy policies that have to be adopted in the future. The fact that EU is the biggest energy customer in the world, while at the same time it relies on foreign (outside EU) suppliers [1], strengthened these tensions.

The EU leaders soon perceived that actions on multiple aspects of energy policy have to be taken, so as to ensure to the maximum possible extent that the EU shall be resilient to any external factors that could set energy flows into danger. The above gave birth to the Energy Union, a strategy through which the goal for providing secure, sustainable, competitive and affordable energy to the EU's households and businesses can be achieved, under a forward-looking climate change policy. It is a European Commission's project through which a fundamental transformation of Europe's energy system shall be coordinated and implemented, in order to reach to the abovementioned goal.

1.2.1 History and Formation

1.2.1.1 Early Grounds

Long before Energy Union's launch in early 2015, the concept of introducing a mandatory and comprehensive EU energy policy had been gaining ground among the energy policy makers of the EU, as well as among many member states' officials. Although legislation efforts pertinent to energy issues were quite dynamic, there was a common belief that the need for the creation of a more specific and binding normative frame was more than prominent.

Yet, despite of the more than a half of a century negotiations and proceedings on the formation and transformations of the European Union, it was only during a meeting of the informal European Council on 27 October 2005 at Hampton Court that the concept of introducing a mandatory and comprehensive EU energy policy was approved [1]. The idea kept on flourishing during the next decade, having as an important milestone the Lisbon Treaty (2007, with date of effect the 1st of December 2009), where it was formalized with the creation of a provision (Article 194 of the Treaty on the Functioning of the European Union (TFEU)) that dealt specifically with energy policy.

1.2.1.2 Formalization of the Idea and Launch

In 2010, European Parliament's president Jerzy Buzek and the former European Commission's president Jacques Delor made an initial proposal regarding the implementation of Energy Union, which was backed-up by an in-depth report of the "*Notre Europe*" think tank. The report analyzed the challenges of such an initiative. Four years later, the newly elected president of the European Commission Jean-Claude Juncker, set as a major priority of his mandate the implementation of the idea.

The major commitments that were announced, indicating the severity under which the project of implementing the Energy Union was dealt with, focused in gradually shifting suppliers other than Russia, to render EU number one in renewables utilization and to significantly improve EU energy efficiency. The task was accompanied by appointing a dedicated Energy Union vice-president (Maros Sefcovic), thus highlighting the commitment towards the achievement of Energy Union's launching [1].

Energy Union was launched in February 2015 by the European Commission.

1.2.2 The Dimensions of Energy Union

The Energy Union Strategy is made up of five closely interrelated and mutually reinforcing dimensions, designed to bring greater energy security, sustainability and competitiveness [2]:

i. **Energy security, solidarity and trust**: Diversifying Europe's sources of energy and making better, more efficient use of energy produced within the EU.
ii. **A fully-integrated internal energy market**: Using interconnectors which enable energy to flow freely across the EU - without any technical or regulatory barriers. Only then can energy providers freely compete and provide the best energy prices.
iii. **Energy efficiency contributing to moderation of demand**: Consuming less energy in order to reduce pollution and preserve domestic energy sources. This will reduce the EU's need for energy imports.
iv. **Decarbonizing the economy**: Pushing for a global deal for climate change and encouraging private investment in new infrastructure and technologies.
v. **Research, innovation and competitiveness**: Supporting breakthroughs in low-carbon technologies by coordinating research and helping to finance projects in partnership with the private sector**.**

As it can be clearly seen, energy efficiency as a phrase, is encountered in two of the five Energy Union's dimensions, – not overlooking the fact that it constitutes a dimension on its own (the third one) – while, as it is analyzed in the following paragraphs, has a role to play in all five dimensions. The importance given to efficiency is not a choice of luck or trends. On the contrary, close examination of some important energy indexes of EU, lead to the assumption that the maximization of energy efficiency is more than crucial for achieving the Energy Union and strengthening and securing EU's energy system.

1.3 Correlation of Energy Union and EU Climate and Energy Framework

1.3.1 Common Governance

EU officials soon identified that both EU Climate and Energy Framework, as well as the Energy Union, required a strong governance scheme. Moreover, the similarities and dependencies between the targets set, highlighted the need for a common governance scheme.

Facing this reality, on 24 December 2018 the Regulation on the Governance of the Energy Union and Climate Action ((EU)2018/1999) entered into force [3]. The governance mechanism is based on integrated national energy and climate plans (NECPs) covering ten-year periods starting from 2021 to 2030, EU and national long-term strategies, as well as integrated reporting, monitoring and data publication.

In short, NECPs incorporate all necessary actions on behalf of each Member State, so as the latter to form policies being in line with EU Climate and Energy Framework mandates and the goals of the Energy Union. The transparency of the governance mechanism is ensured by consulting wide public on the NECPs. Under the regulation, each Member State was required to submit a draft NECPs by the end of 2018, which was then assessed by the Commission. On 18 June 2019, as mandated under the governance regulation, the Commission published its global assessment of the cumulative impact of these draft plans. This included recommendations for each Member State to improve their draft plans in order to meet the EU targets. The final NECPs were to be submitted by the end of 2019.

Further enhancement of the governance is promoted by EU through a set of new rules, under which each Member State is required to develop a national long-term strategy that will be consistent with its respective NECP. As of January 1st 2020, Member states are required to develop and submit such a national strategy. Towards this direction, the EU Commission has recently presented (November 2018) its strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050, underlying the extended time frame under which the Member State's national long-term strategies have to take into account.

1.3.2 The Importance of Energy Efficiency

As already mentioned, one of the priorities of the Energy Union strategy is to increase energy efficiency in an attempt to reduce energy consumption by 32.5 % by 2030. Setting such a high goal can be clearly justified due to the fact that EU is quite energy dependent, based on official data.

In 2017, the EU produced around 45 % of its own energy, while 55 % was imported from third countries [2]. These percentages, although they are in EU's intention to be maximized and minimized respectively, are not expected to drastically change in the near future. Moreover, EU's import dependency is particularly high for crude oil (90%) and natural gas (69%). The total import bill is more than €1 billion per day [4]. Despite the strict and binding goals in the percentage of renewables' energy forms penetration in EU's energy mix, not many other energy forms have been found that can greatly increase the percentage of EU's energy production and reduce its dependency from third countries.

Under these concerns, he European Commission released its Energy Security Strategy in May 2014. The Strategy aims to ensure a stable and abundant supply of energy for European citizens and the economy. The Strategy proposed long-term measured in five key areas, one of which is increasing the energy efficiency. Thus, it is more than obvious, that further to the advancement of renewables, the energy efficiency aspect has to be closely introduced, so as to contribute to the minimization of EU's energy dependency.

The Energy Security Strategy target pertinent to efficiency is fully compatible and interconnected with the Energy Unions' dimensions, since energy efficiency is one of the five Energy Unions' dimensions. The importance that EU is giving is depicted in Maros Sefcovic phrase "*The energy we don't use is our first fuel*" [5] and this can be verified by the fact that the remaining four dimensions of Energy Union are somehow correlated with the energy efficiency.

As we already mentioned, energy security is affected by energy efficiency, while the de-carbonization of the economy and the research innovation and competitiveness dimensions, further to calling for greater penetration of renewables, push for the application of more efficient technologies in areas were the fossil fuels cannot be easily by-passed. Interestingly, the dimension of a fully integrated internal energy market has its own bonds with energy efficiency, analyzed in the next paragraph.

1.4 Energy Efficiency and Energy Union's Integrated Internal Energy Market Dimension

Energy Union's Integrated Integral Energy Market dimension, seeks to create a framework under which the energy shall flow freely across the EU. In order to implement such a framework, several aspects have to be closely become interconnected and be developed mutually. Infrastructure allowing the flow of energy among EU countries has to be strengthened, technical and regulatory barriers have to be surpassed, markets have to become more liberalized on the one hand and allow access to many new players on the other, irrespectively of their origin (complying to EU regulations).

The idea of free energy flow in such a large geographical area like EU, could promote more efficient production and use of energy, since either cheaper, more available or cleaner (e.g. from renewables) energy produced in one Member State could flow to another Member State in order to satisfy the demand. Especially when it comes to the electricity sector, the notion of a common internal network multiplies the benefits, since choices of primary fuel are many, thus competition among the sellers of the primary fuel can be increased, leading to more efficient production schemes of electrical energy. Yet, in the electricity sector, energy efficiency is not only correlated with the production/supply sector. The notion of common electricity networks, allows for new ideas to rise, such as the demand side response concept, which couples the clients directly with the energy market in terms of their willingness to consume energy in specific times, when the energy prices are high. Thus, by pushing the demand to swift away from peaks, the electrical and primary production systems' efficiency increase.

For sure, the difficulties in implementing the integrated internal energy market are many and considerable. Objectives with respect to market competition, market integration and coupling, deployment of flexibility in the power sector, including development of short term markets, demand response competitiveness of energy markets, and roll-out of smart technologies and smart grids, have to be closely examined, while the assessment of the implications of planned infrastructure investments and of developments in energy production on wholesale and retail energy prices and on market integration with other Member States and Contracting Parties has to be taken into account.

CHAPTER 2: THE DEMAND SIDE RESPONSE CONCEPT IN THE EUROPEAN UNION

2.1 DSR Placement in the European Electricity Markets

In order to acquire a better notion of how DSR matches to the services that the electricity markets provide, it is useful to familiarize with some basic terms and characteristics of both the European electricity markets and the way the ENTSO-E provides control services to the European electricity system.

2.1.1 Brief Overview of European Electricity Markets

In Figure 1 an overview of the general scheme under which a typical electricity market of a European country operates is provided. The major way the electricity markets are organized and sorted is based on how far away they are placed from the moment when the electrical energy has to be consumed, either prior the exact time spot where the energy is consumed (forward, day-ahead, intraday) or after that point (intraday, balancing).

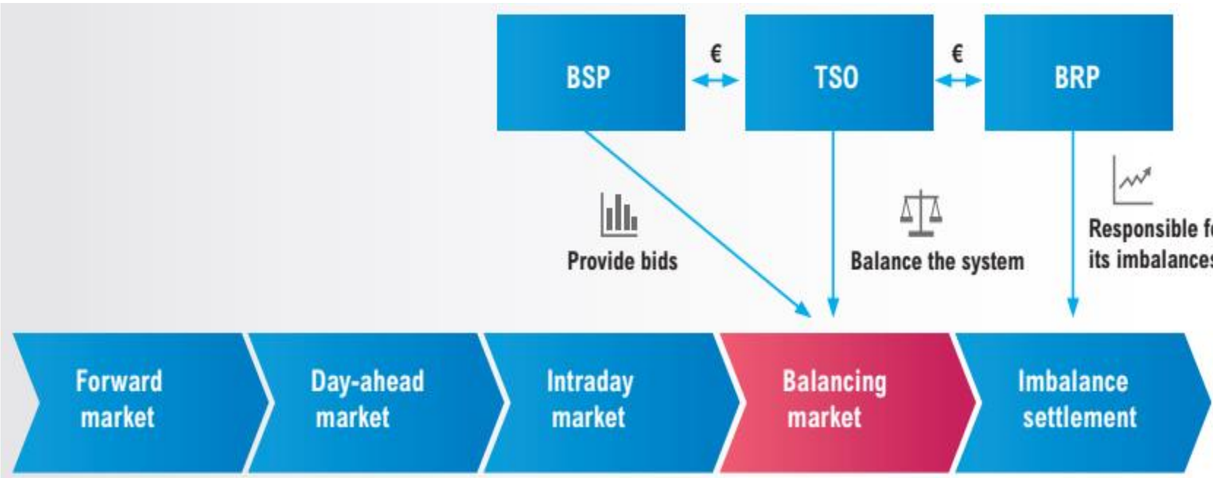


Figure 1:

Typical Scheme of Electricity Markets in Europe [69]

The forward markets are the markets into which electrical energy amounts are traded days, months or even years prior its consumption time. They complement the spot markets (day-ahead, intraday and balancing) for wholesale electricity so as to reduce risk, mitigate market power, or even coordinate new investment (capacity markets). They can be both medium term and long term, with the latter to usually be referring to capacity markets. Capacity markets are – as their name implies – markets to which capacity (i.e. electrical power) is traded, rather than electrical energy. They are considered a form of forward market, which they complement. Their basic target is to create incentives for new power plants which will cover the future energy needs, while at the same time to lead to the built-up of improved technological power plants, so as old, low-efficient plants to become obsolete. In the medium term, a forward energy market lets suppliers and demanders lock in energy prices and quantities for one to three years. In the long term, a forward reliability market assures adequate resources are available when they are needed most. The forward markets reduce risk for both sides of the market, since they reduce the quantity of energy that trades at the more volatile spot price.

Day-ahead markets – as their name implies – are financial markets where market participants purchase and sell electric energy at financially binding day-ahead prices for the following day. These markets are the financially binding schedule of commitments for the purchase and sale of energy the TSOs develops each day according to the bid and offer data that market participants submit to the market. Day-ahead markets are typically cleared around noon the previous day to the day in which energy is to be delivered. A supply offer or a demand bid will generally clear the day-ahead market if its associated price is less than or equal to the hourly marginal price, as system conditions allow. Day-ahead market allows buyers and sellers to hedge against price volatility in the Real Time Energy Market by locking in energy prices before the operating day [72].

Intraday power trading refers to continuous buying and selling of power at a power exchange that takes place on the same day as the power delivery. Intraday trading can be short-term or long term. The former generally refers to trading power in quarter-hour or one-hour intervals prior the delivery time, while the latter is characterized by larger intervals. These intervals are the so-called “lead times”. Over the years, lead times for intraday trading have gotten shorter and shorter. For example, for trading within Germany, the lead time for each quarter-hour interval was reduced from 45 to 30 minutes on 16 July 2015. This has since been reduced to just five minutes in Germany. Lead times in Austria have come down from 75 minutes and are now 30 minutes prior to delivery. One main difference to day-ahead trading is the pricing on the intraday market. While day-ahead trades are related to market clearing price principles, where the last accepted bid sets the price for all transactions, the prices in intraday trading are set in a "pay-as-bid" process. This means prices are assessed in continuous trading based on each transaction that is completed. This is why bid prices are often used in intraday trading. The result is that there are no fixed prices for products on the intraday market. It is much more common to have different prices for the same product depending on the time the trade occurs [71].

Intraday trading exists primarily to limit shortfalls or surpluses in an entity's own balancing group as much as possible through short-term, same-day trading activity. This helps meet forecasting commitments in balancing group contracts and reduce potential imbalance costs. Power assets are becoming increasingly flexible, and day trading is also useful for using these assets to quickly produce power based on demand. This also maximizes profit and stability within the system. Intraday trading is particularly useful for adjusting to unforeseen changes in power production and consumption by putting market mechanism to use before control reserves become necessary. This allows a power plant operator who suddenly loses production in a single block to buy additional power from other participants on the market and maintain the balancing group. Intraday trading is therefore a key component for direct marketing of power produced by renewable energies when quickly-changing weather forecasts result in an unplanned shortfall or surplus of power from solar or wind power plants [71].

The balancing markets are the last stage for trading electric energy. They are organized market supervised by a TSO, where players with dispatchable units (and/or loads) can make balancing bids (also called regulation bids). With the balancing bids, participants offer regulation services, in a sense that they offer to increase or decrease their power production (or consumption) for a given hour of operation. Markets other than those are usually cleared well in advance of energy delivery and thus the production and consumption levels scheduled in these markets can significantly differ from the actual production and consumption at balancing time. Balancing markets play an essential role, as production and consumption levels must match during the operation of electric power systems. The balancing market is the institutional arrangement that establishes market-based balance management in an unbundled electricity market. They can be considered the last in a sequence of electricity markets, after year-ahead, month-ahead, day-ahead and intra-day markets. Conventional producers, usually, participate at the balancing market for providing regulating power, both in upward (i.e., increasing production) and downward (i.e., decreasing production) directions. As far as the DSR concept concerns, the consumers can also participate, by reducing their consumption at given time frame, if requested by the TSOs [73], [74].

Settlement of the imbalances between scheduled values of power production, consumption, exchange and the actual metered values is the last step in the sequence of the energy markets. Before the actual delivery of electrical power, all market players commit themselves to ensure the scheduled supply and demand. ”Ensuring the scheduled supply” means that the producers must generate and the buyers must purchase the scheduled supplied power. ”Ensuring the scheduled demand ”means that the loads must consume and the sellers must sell the scheduled demanded power. In case some market players fail to fulfill their commitment, imbalances between the scheduled supply and/or demand and the actual supply/demand will appear [75]. These market players will have to pay the costs for the imbalances under the specific terms that their offers have been contracted as a result of the various markets clearances.

2.1.2 Balancing & Ancillary Services Structure

DSR have a significant presence to the balancing and ancillary services and markets in the recent years, contrary to other markets such as capacity or even day-ahead and intra-day, thus a special analysis of these services could be useful in understanding how DSR bundles with such services.

As already mentioned, ENTSO-E has standardized the way that the balancing and ancillary services are provided and the corresponding markets are in general following this standardization. The main physical unit that the balancing and ancillary services aim to control is frequency. Electrical energy cannot be stored in large quantities using conventional means. For this reason, at any given point in time, the amount of electricity produced must correspond precisely to the amount being used. This balance guarantees the secure operation of the electricity grid at a constant frequency of 50 Hz (hertz). Unforeseen fluctuations between the feed-in and/or withdrawal of electrical energy from the grid must be balanced out at short notice by rapidly increasing or reducing the power plant output of the suppliers of what is referred to as the control reserve. Frequency control is required if, in the current capacity balance of a control area, the sum of the actual capacities of all feed-in and withdrawal deviates from the sum of the expected capacities. This deviation can originate on the grid load side (for instance, as a result of meteorological influences or natural inaccuracy in the load forecast) and on the production side (for example, due to production restrictions or stop-pages or additional output from hydroelectric power plants due to heavy precipitation). Each transmission system operator must therefore continually use control power to offset balance capacity variations in its control area. Technically this is achieved within the ENTSO-E by using a three-stage control procedure (primary, secondary, and tertiary control).

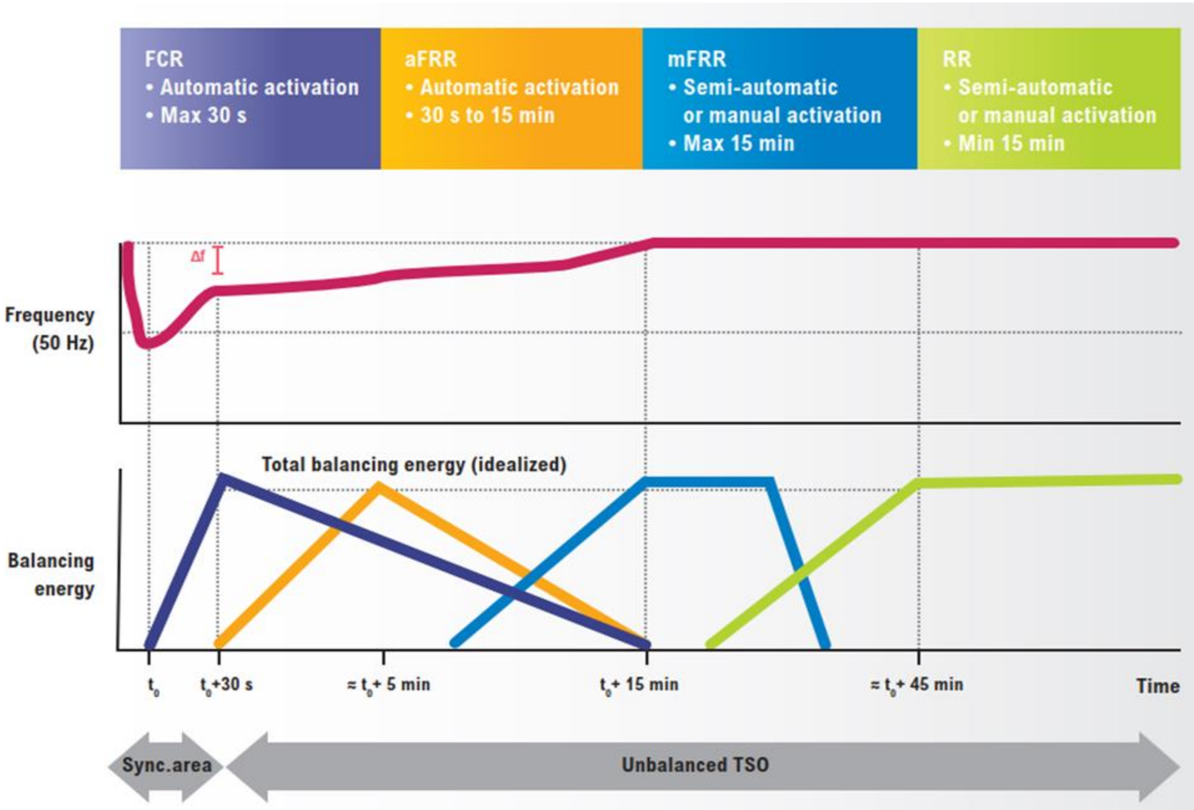


Figure 2:
Balancing Market Processes for Frequency Restoration [69]

Primary control, usually referring to FCR in the balancing and ancillary markets, restores the balance between power generation and consumption within 30 seconds of the disturbance occurring. During this operation, the frequency is stabilized within the permissible limit values. Activation takes place directly in the power stations by means of turbine regulators. In this phase, the grid frequency is monitored and, in the event of deviations, the primary control power needed is activated. All transmission system operators represented in the synchronous area must fulfill the requirements in their country in accordance with the ENTSO-E rules.

Secondary control, usually referring to aFRR in the balancing and ancillary markets, is used to maintain the desired energy exchange of a control area with the rest of the synchronous area, using simultaneous, integral support to maintain the frequency at 50 Hz. In the event of an imbalance between production and consumption, secondary control power in the connected power stations is automatically actuated by the central grid controller (signals dispatch from a TSO is the most common case). As a prerequisite, these power stations must be in operation but must not be generating the maximum or minimum possible nominal capacity in order to meet the requirements of the central load frequency controller at all times. Secondary control is activated after a few seconds (usually after the 30s that the FCR act) and is typically completed after 15 minutes. If the cause of the control deviation is not eliminated after 15 minutes, secondary control gives way to tertiary control.

Tertiary control reserves, usually referring to mFRR in the balancing and ancillary markets, are used to replace the secondary control reserve in order to restore a sufficient secondary control band. The tertiary control reserve is primarily necessary for adjusting major, longer-lasting control deviations, particularly after production outages or unexpectedly long-lasting load changes. The TSO dispatcher effectuates activation by sending special electronically transmitted messages (either semi-automatic or even manual) to the providers, who must then intervene in power plant production to ensure the supply of tertiary control power within 15 minutes, irrespective of the schedule matrix [68]. It is worth to mention that in the tertiary control reserves, the RR are also considered although they are referring to active power reserves (and not frequency). Yet, due to the fact that these reserves are utilized to restore or support the required level of FRR in order to be prepared for additional system imbalances, they are also considered to belong to the tertiary control reserves.

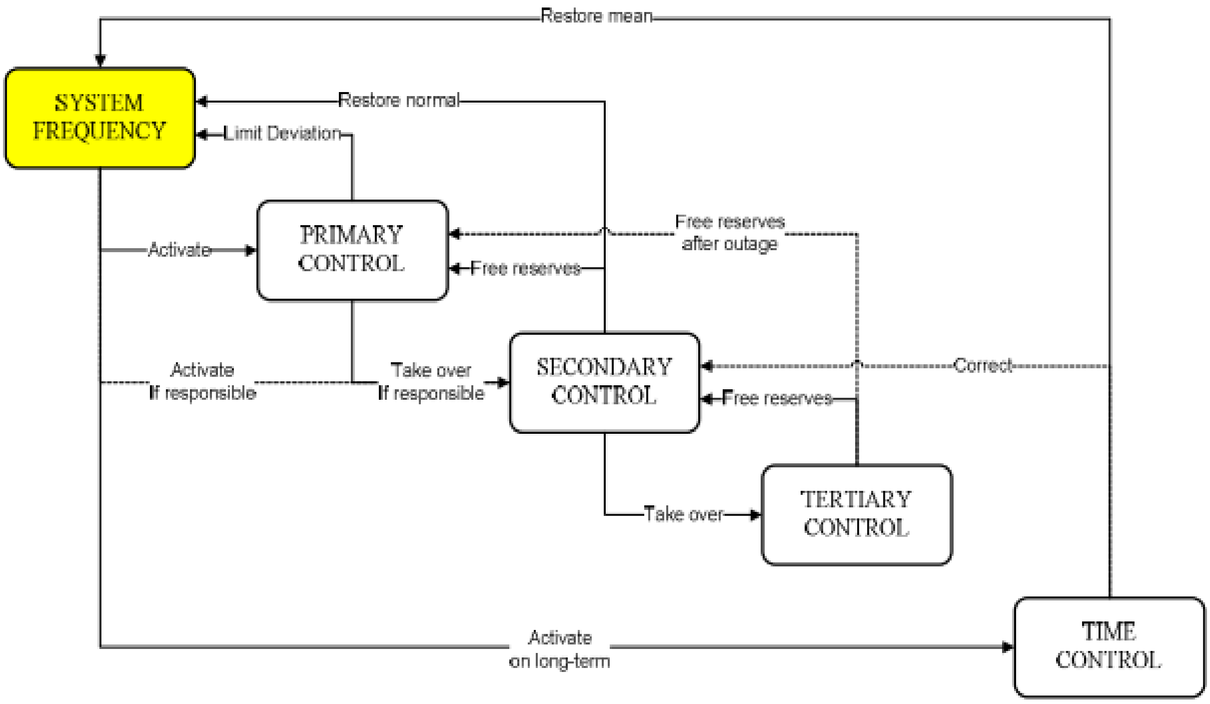


Figure 3:
Frequency Control Stages & Synergies [Source: ENTSO-E]

2.2 Demand Side Response (DSR) - Definition

Demand Side Response (DSR) is the intentional modification of normal consumption patterns by end-use customers in response to incentives from grid operators [6]. In particular, EU has, very recently (Directive 2019/144), officially defined demand side response as "*the change of electricity load by final customers from their normal or current consumption patterns in response to market signals, including in response to time-variable electricity prices or incentive payments, or in response to the acceptance of the final customer's bid to sell demand reduction or increase at a price in an organized market as defined in point (4) of Article 2 of Commission Implementing Regulation (EU) No 1348/2014 (17), whether alone or through aggregation*".

DSR is a class of Demand Side Management programs (DSM). DSM is broader concept covering a number of aspects that can be manipulated from the consumer side and subsequently have an impact in the energy supply and consumption patterns of an electrical power system. Such aspects cover the energy efficiency of the equipment that the consumer operates (from simple house apparatus, up to large scale industrial machinery, such as welding machines, large induction motors, etc), the capability of the consumer to produce energy in small scales (e.g. <50MW, thus becoming a "prosumer"), the capability of the consumer to operate in an isolated electrical power system and of course, the capability of the consumer to manipulate his/her load demand, which is summarized in the DSR concept..

In DSR, utilities offer customers incentives to reduce their demand for electricity during periods of critical system conditions or periods of high market power costs. Interest in DSR has increased during the past decade, especially in US, although these programs have existed for nearly 25 years. Many utilities and independent system operators in deregulated markets have long recognized the benefits of DSR. Utilities can purchase load demand from their customers for lower rates than they would pay to provide it, lowering the utility system's peak demand and help reduce peak wholesale power market prices. In addition, customers can also be asked to reduce load during non-peak periods to help maintain grid reliability, defer or eliminate generation capacity expansion, or defer or eliminate transmission/distribution capacity expansion [25]. The main idea is to discourage electricity consumption during times of high electrical energy demand (thus when electricity prices are high), or when issues of electrical system's reliability arise (e.g. transfer lines overloads).

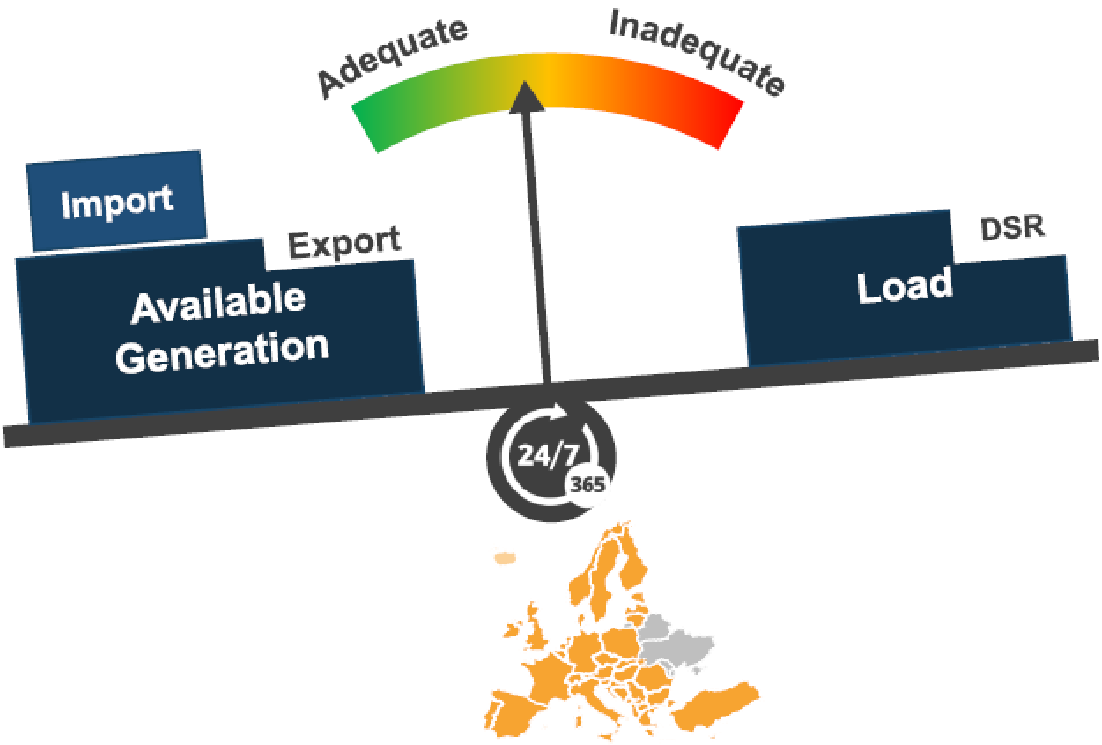


Figure 4:
DSR contribution in balancing electric energy markets and electric networks in EU [15]

DSR may take different forms depending on consumers' consumption volumes and patterns. For example, industrial or large commercial sites can rearrange their production or operation schedule in order to shift electricity consumption to times when prices are lower. Large sites may even have dedicated staff in charge of optimizing consumption and piloting demand response.

For smaller businesses and households, demand response can be about shifting electric heating and air conditioning away from electricity price peaks, charging or discharging an electric car at times of interesting prices or delaying the use of a washing machine while being rewarded for reducing consumption at peak times. Consumers' flexibility potential strongly depends on the appliances they own and operate, but also on their lifestyles and more generally on their individual preferences. Engaging such smaller consumers successfully requires clear demand response signals and tools that are easy to set and use. Demand response will develop on a larger scale when consumers see a real value in these services and hence wish to engage.

Tailored information and feedback can help consumers better understand their consumption habits. Demand response also brings them more choice through a range of innovative services. Most importantly, demand response allows consumers to value their flexibility and to ultimately reduce their energy bills or be rewarded to modify their consumption accordingly. However the benefits of demand response must outweigh consumers' efforts as well as investment costs in e.g. automation equipment or communication tools. It is important to highlight that the benefits brought about by demand response crucially depend on consumption volumes and patterns, and such services may not always be worth implementing.

While demand response has been and could continue to be deployed by suppliers without smart metering or connected appliances, these technologies will facilitate more advanced dynamic pricing and new demand response services. For households and small businesses for instance, smart meters combined with in-home displays help raise awareness of electricity consumption, while automation technologies make it easier to participate. Open communication interfaces and information exchanges will also be needed to ensure that heating control systems, hot water production units, storage systems, electric cars, cooling systems, household appliances, etc. can participate in demand response.

2.3 The Importance of DSR for the European Union

2.3.1 General

The European Power Grid is one of the most complex and energy consuming grid in the world. It is regulated by numerous TSOs which are under the close monitoring and organizational management of the ENTSO-E. As it can be seen in Figure 2, the amount of energy exchanged inside the European Grid is colossal, while the number participants – no matter at which level examined, e.g. number of countries involved, numbed of TSOs, citizens, etc – is similarly great.

DSR can play a very important role in the sustainable development of the European electricity system in a three way concept, since it can provide solutions for economic efficiency, system reliability and environmental protection. The economic can be attributed to lowering wholesale market prices by displacing the most expensive peak generation resources, and mitigating price volatility by smartly responding to the electricity price. In addition, the flexibility of demand is key to ensuring wholesale market efficiency and to maintain the system reliability. DR resources can be used to reduce capacity constraints, and to provide ancillary services such as reserves or balancing by quickly increasing or decreasing demand. Finally, DSR boost environmental and/or social targets of sustainability, by reducing energy consumption and developing clean generation units, thus increasing energy efficiency and reducing GHG emissions [66].

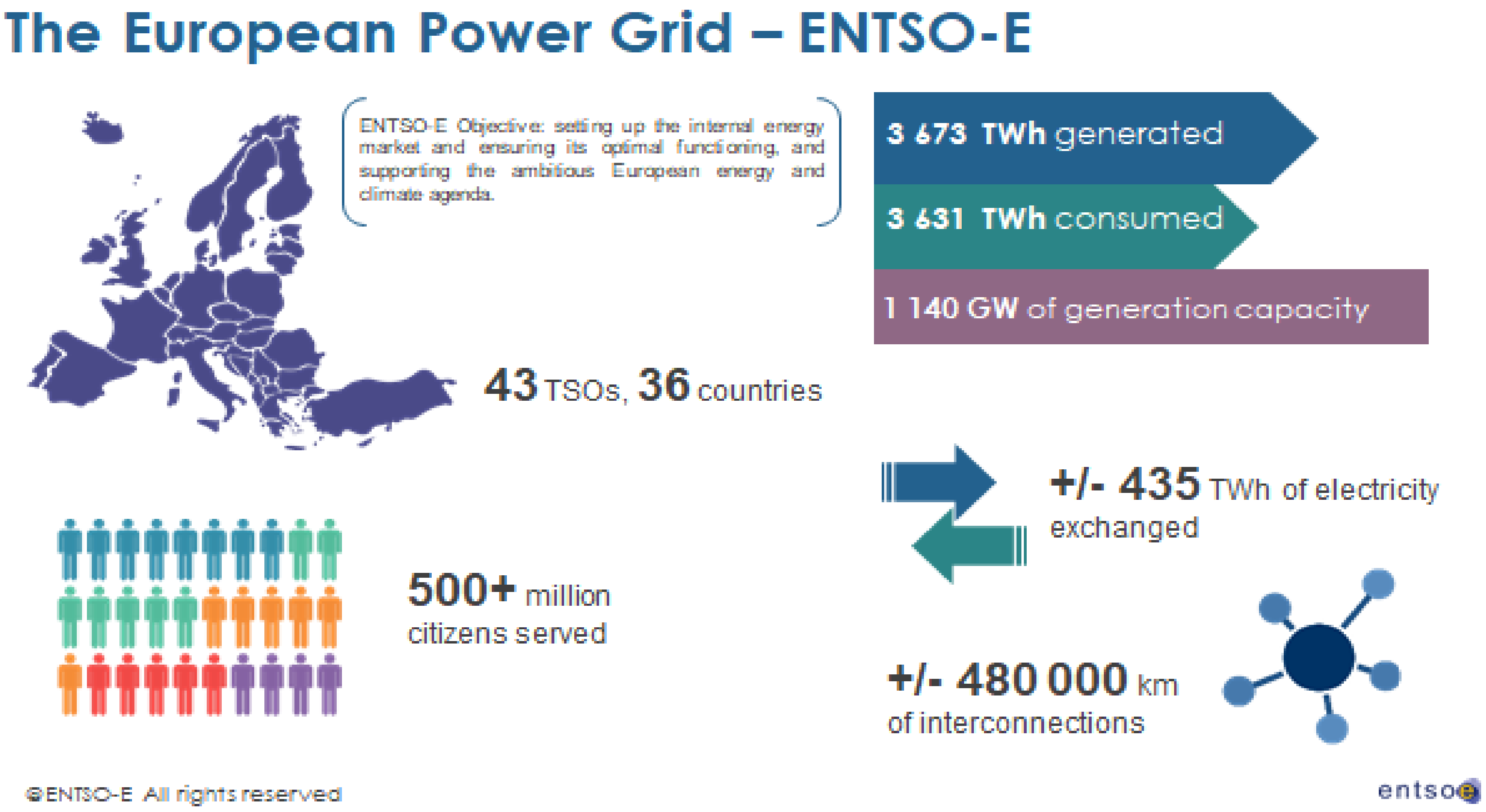


Figure 5:
The European Electrical Power Grid [38]

2.3.2 Extended Concept of DSR

The DSR concept extends far beyond the reduction or shifting the consumption. In fact it encompasses all possible ways through which a customer can affect both his consumption patterns and the electricity production patterns of the suppliers. Under this prism DSR can extent to the generation field (e.g. by dispatching small back-up power units for supporting his internal grid and consumption) and to the storage field (e.g. by utilizing batteries for providing electricity to his internal grid for short terms). Figure 6 provides an overview of the interaction of the flexibility sources in the electricity system, while at the same time it demonstrates the degree to which DSR can provide, both the unique services such as peak load reduction, and some of the services offered by traditional generation and storage resources [66].

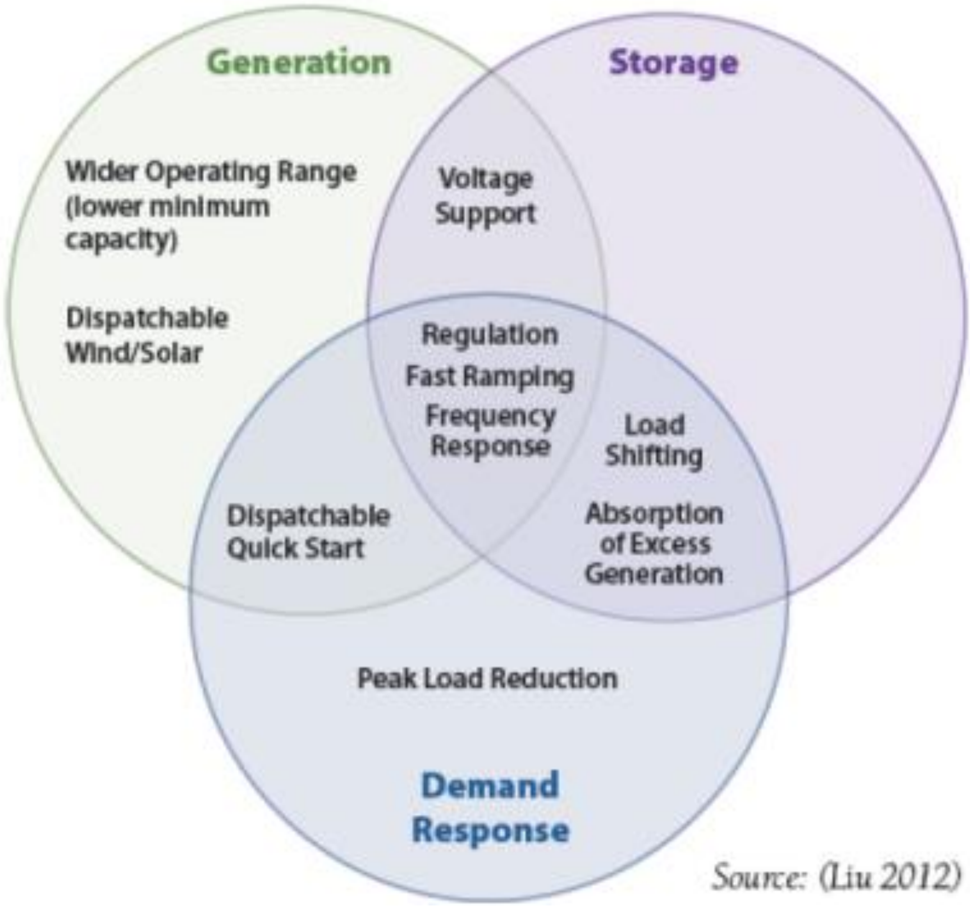


Figure 6:
Types of Demand Response Services [67]

Demand Response is competitive, especially given that the up-regulation from generation is generally more expensive than the down-regulation. The combination of generation down-regulation and load curtailment is usually the best solution.

2.3.3 DSR Effect on Market Prices

Consumers' usage of electricity is usually fairly inelastic in short time frames since the consumers do not pay for the real price of production. Should they did pay a price according to the real price, strong incentives would appear so as them to choose to change their consumption patterns according to prices. The above notion suits in general to all retail customers. Exceptions to this notion could be large industrial consumers who are elastic when their operations process changes cost are lower than electricity cost.

Electricity is produced by generation units which are dispatched in order, starting first with generators with the lowest marginal cost (lowest variable cost of production) until the instantaneous electricity demand is satisfied. In most power systems, the wholesale price of electricity represents the marginal cost of the highest cost generator that is injecting energy.

The introduction of the DSR concept alters the above mentioned by indirectly affecting marginal price of the system. This is clearly shown in Figure 7, which shows DSR effect on electricity demand elasticity. The inelastic demand in the electrical power market is represented by curve D1. Supply curve S is based on the marginal cost, cheaper generations produce first. The high price P1 associated with the inelastic demand D1 is extrapolated off the point of intersection of the supply curve S and the demand curve D1. When DR measures are introduced, demand becomes more elastic, represented with curve D2. The new equilibrium point given by the same supply curve S and the more elastic demand curve D2 gives a much lower price. Given this analysis and based on current electricity markets organization, a small reduction in demand will result in a big reduction in general cost and, in turn, a reduction in electricity price.

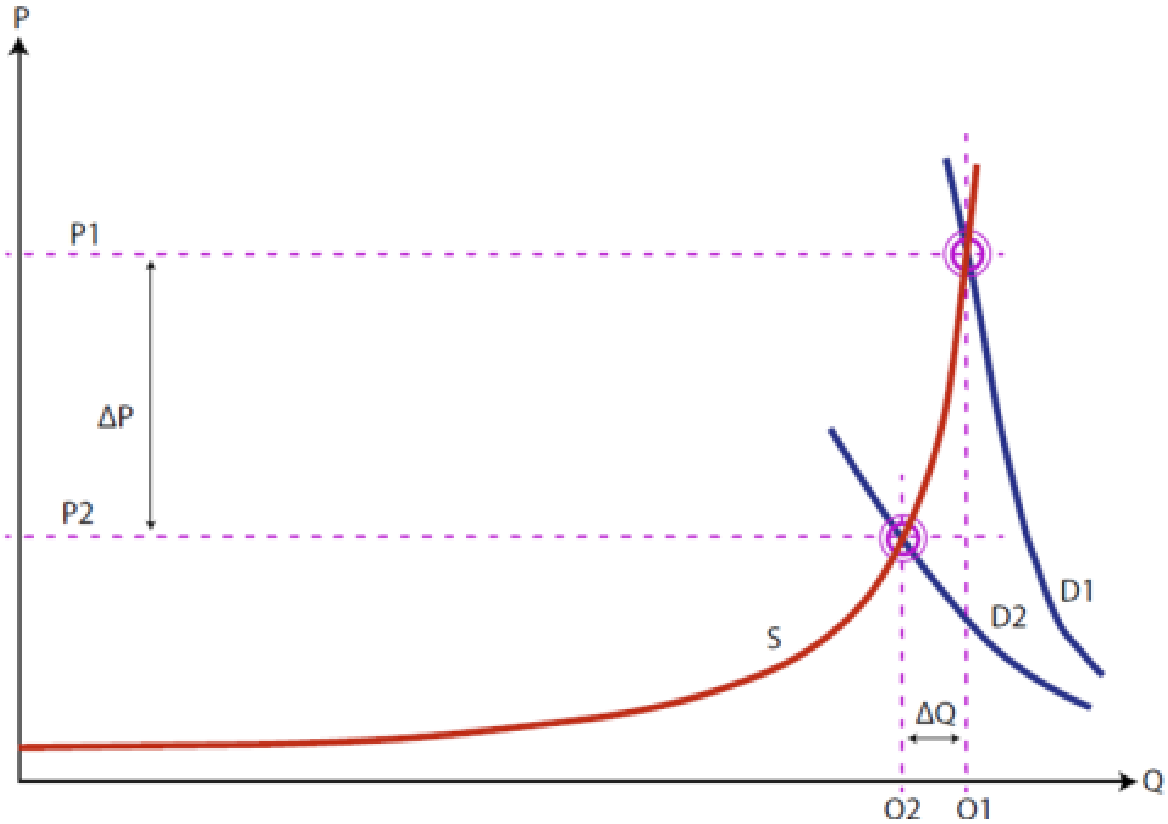


Figure 7:

DR effects on a quantity (Q)-price (P) graph [23]

2.4 European Legislative Framework around Demand Side Response

During the last decade, DSR has been noticeably promoted by EU's governing bodies. DSR concept has been included in several legislative texts, whose aim is to either form the Energy and Climate policy of EU or to provide guidelines for the formation of a common energy market in EU [9]. The main documents pertinent to DSR concept promotion are briefly presented in the following paragraphs.

2.4.1 The Electricity Directive – 2009/72/EC

In the current Electricity Directive of the Third Energy Package, the correlation of energy efficiency and DSR has been identified and a definition of the concept of "energy efficiency/demand-side management" has already been provided. Benefits such as the positive impact on environment, on security of supply, on reducing primary energy consumption and peak loads have been acknowledged. In particular, in article 25, paragraph 7 the requirement for network operators to consider Demand Response and energy efficiency measures when planning system upgrades has been set. In addition, in article 3, paragraph 2 it is also stated that "*In relation to security of supply, energy efficiency/demand-side management and for the fulfillment of environmental goals and goals for energy from renewable sources, [...] Member States may introduce the implementation of long-term planning, taking into account the possibility of third parties seeking access to the system*". This language was strengthened further within the Energy Efficiency Directive (EED) [9], [10].

2.4.2 The Energy Efficiency Directive (EED) – 2012/72/EU

A major milestone towards the development of DSR in Europe was The Energy Efficiency Directive (2012/27/EU). It was the first time that the more specific term "Demand Response" was utilized broadly in an EU legislative text, coupling it with the operation of many participating bodies in the energy markets, in an obligatory notion in many cases [9], [12].

As an example of the urge that EU posed towards this goal article's 15 paragraph 2 text of the directive is referenced. According to it, Member States should ensure by 30 June 2015 "*that an assessment is undertaken of the energy efficiency potentials of their gas and electricity infrastructure, in particular regarding transmission, distribution, load management and interoperability*", and " *that concrete measures and investments are identified for the introduction of cost-effective energy efficiency improvements in the network infrastructure, with a timetable for their introduction*".

In the same direction, article 15 paragraph 4 required Member States to:

- "*Ensure the removal of those incentives in transmission and distribution tariffs that are detrimental to the overall efficiency (including energy efficiency) of the generation, transmission, distribution and supply of electricity or those that might hamper participation of Demand Response, in balancing markets and ancillary services procurement*".
- "*Ensure that network operators are incentivized to improve efficiency in infrastructure design and operation, and, within the framework of Directive 2009/72/EC, that tariffs allow suppliers to improve consumer participation in system efficiency, including Demand Response, depending on national circumstances*".

The paramount importance that EU pays in DSR is also shown in article 15, paragraph 8, which is the one that establishes consumer access to the energy markets, either individually or through aggregation. In detail the article states:

- "*Member States shall ensure that national regulatory authorities encourage demand side resources, such as Demand Response, to participate alongside supply in wholesale and retail markets*."
- "*Subject to technical constraints inherent in managing networks, Member States shall ensure that transmission system operators and distribution system operators, in meeting requirements for balancing and ancillary services, treat Demand*

Response providers, including aggregators, in a non-discriminatory manner, on the basis of their technical capabilities."

- "*Member States shall promote access to and participation of Demand Response in balancing, reserves and other system services markets, inter alia by requiring national regulatory authorities […] in close cooperation with demand service providers and consumers, to define technical modalities for participation in these markets on the basis of the technical requirements of these markets and the capabilities of Demand Response. Such specifications shall include the participation of aggregators*."

2.4.3 The Network Codes

The Network Codes are a set of rules drafted by European Network of Transmission System Operators for Electricity (ENTSO-E), with guidance from the Agency for the Cooperation of Energy Regulators (ACER) and the oversight of the European Commission, to facilitate the harmonization, integration and efficiency of the European electricity market. These codes will be critical for the development of Demand Response, because they describe the terms and conditions under which demand-side flexibility providers will be able to participate in the electricity markets [9].

Network Codes consist of a family of documents (usually referred as "Family of Codes"). The published network codes become regulations. Much have been drafted and published during the last five years on how the electricity market should be structured. More specifically, in the Electricity Balancing Code [13] there are numerous references to DSR and how this should be coupled with the energy market. Another example on how crucial DSR is being considered, is introduction of the Demand Connection Code [12], in which many technical aspects of the utilities that are willing to adopt the DSR concept are analyzed in detail.

2.4.4 State Aid Guidelines for Energy and Environment

In early 2014, the European Commission adopted new rules on public support for projects in the field of environmental protection and energy. The new guidelines aim at helping Member States to design state aid measures that contribute to reaching their 2020 climate targets and provide sustainable and secure energy, while ensuring that those measures are cost-effective for society and do not cause distortions of competition or a fragmentation of the Single Market. The guidelines will be in force until the end of 2020 [17].

Among other issues, the new Guidelines clarify under what conditions state aid to secure adequate electricity generation is permitted. This allows Member States to introduce so-called "capacity mechanisms", for example to encourage producers to build new generation capacity or prevent them from shutting down existing plants or to reward consumers to reduce electricity consumption in peak hours. Although the text still refers to "generation adequacy", it requests the primary consideration of "alternatives" to capacity mechanisms, such as DSM and DSR. The rules state that, once set up, the capacity mechanisms must provide adequate incentives to existing and future generation, DSR and storage [9]. By carefully extracting some of the phrases of its provisions hereunder, it is more than obvious that the DSR concept plays very important role in the proposed guidelines [18]:

- (Paragraph 3.9.1, clause 221) "[...] *Member States should therefore primarily consider alternative ways of achieving generation adequacy which do not have a negative impact on the objective of phasing out environmentally or* *economically harmful subsidies, such as facilitating demand side management and increasing interconnection capacity*".

- (Paragraph 3.9.3, clause 227) "*The measure should be open to and provide adequate incentives to both existing and future generators and to operators using substitutable technologies, such as demand-side response or storage solutions.* [...]"
- (Paragraph 3.9.6, clause 232) "*The measure should be designed in a way so as to make it possible for any capacity which can effectively contribute to addressing the generation adequacy problem to participate in the measure, in particular, taking into account the following factors:*
    (a) the participation of generators using different technologies and of operators offering measures with equivalent technical performance, for example demand side management, interconnectors and storage."

2.4.5 Clean Energy Package

Driven by the Paris Agreement commitments for reducing greenhouse gas emissions, EU has agreed a comprehensive update of its energy policy framework to facilitate the transition away from fossil fuels towards cleaner energy. A new energy rulebook was formed which was called The Clean Energy Package or "Winter Package" [19].

On 30 November 2016 the Commission published its so-called 'Winter Package' of eight proposals to facilitate the transition to a 'clean energy economy' and to reform the design and operation of the European Union's electricity market. The proposals can be grouped into three categories: proposals amending existing energy market legislation; proposals amending existing climate change legislation; and proposals for new measures [20]. Provisions pertinent to DSR can be found in many provisions of the rules that the Package sets, but it is worth mentioning the two most characteristic cases.

2.4.5.1 The Electricity Regulation 2019/943/EU – European Resource Adequacy Assessment

Regulation (EU) 2019/943 sets the principles of the European Resource Adequacy Assessment by placing resource adequacy in a central position in the European energy policy context. ENTSO-E is required to develop a methodology for a European resource adequacy assessment, which should consider scenarios without existing or planned capacity mechanisms and where applicable, with such mechanisms, increased temporal granularity and sensitivities, flow-based capacity calculations and sectoral integration, among others. In addition to the methodology for the European resource adequacy assessment, ENTSO-E is tasked by the Electricity Regulation to develop a methodology for calculating the value of lost load, the cost of a new entry in generation and/or demand response and for a reliability standard, based on objective and verifiable criteria [16].

As per Article 23 of the Electricity Regulation mentions, "*The European resource adequacy assessment shall be based on a transparent methodology which shall ensure that the assessment appropriately takes account of the contribution of all resources including existing and future possibilities for generation, energy storage, sectoral integration, demand response, and import and export and their contribution to flexible system operation*" [21].

2.4.5.2 The Electricity Directive – 2019/944/EU

Directive (EU) 2019/944 takes DSR concept a step further since it introduces the obligation for all Member States to introduce a legal framework for DSR aggregators, to enable their access to the market and to define roles and responsibilities. Numerous paragraphs involve DSR concept in the rules set for the common EU market, while Article 17 of the directive is dedicated in setting rules for the participation of DSR aggregators in the Member States markets [22].

2.5 Classification of DSR

DSR concept can be implemented in various ways. Market models and proposals designed to achieve the response in electric usage and in electricity markets expand to a great degree. All DSR programs – irrespectively of the category in which they belong – have a common characteristic: they are all capable to coordinate the electricity use with power system operation, at least in theory, should the appropriate legislative and operational framework is in force by the state.

DSR programs can be classified according to diverse criteria. One such criterion is the aim for which they are to be utilized. The three main aims are reliability (e.g. of the power system under specific disturbances for technical reasons), security (i.e. protection against unexpected energy shortages such as a sudden collapse of a large supplier from another country, or denial on from his side to supply the agreed energy) and of course economic (avoidance of high electricity prices and /or formation of lower, more affordable ones). Under the prism of these three main aims, these DSR programs are usually called emergency-based, technical-based and economic benefit-based respectively. Thus, in order to achieve a reliable electrical network, emergency-based DSR programs are developed, while in order to confront with security of supply issues, technical-based DSR programs are usually developed. Similarly in order to affect electricity prices, economic benefit-based DSR programs are used.

Another classification criterion is the type of signal that triggers DSR. Under this prism, DSR programs can be identified as technically-triggered or price-triggered DSR programs. While price-triggered programs are – as their name implies – all “priced based” programs (presented in the next paragraph), the technically-triggered programs spread to a variety of different programs on the basis of the technical parameter that is considered critical to be controlled. As such, programs based on triggering signals such as load (need to keep the load demand lower compared to the generated load), frequency (need to be kept within the predefined safety limits of the equipment used), voltage (same as frequency), power quality (need to keep a minimum level of harmonics for example), etc. are widely used. In the technically-triggered DSR programs, capacity can be considered another such signal. The notion of capacity signals is to develop DSR programs that push to the development of technologies and infrastructure that can increase the DSR capacity as scheme in the mid-term and long-term strategic energy programing.

DSR programs can be either classical or market-based. Classical DSR programs are those which are usually based on bilateral agreements between a utility company and a customer. Specific contracts incorporating specific terms characterize these programs, which are usually tailor made to the needs of both the utility company and the customer. On the other hand, market-based DSR programs are formed under the prism of the market needs and they are usually governed by the market rules. Market-based programs usually have common characteristics for all customers (or groups of customers with a set of common characteristics, e.g. residential or industrial customers). Market-based DSR program have a further sub-categorization. They are classified as either retail market or as wholesale market DSR programs. Retail programs usually have terms which are set by the utilities and/or TSO/DSOs based on the retail market trends and conditions, while wholesale programs are usually governed and controlled by independent wholesale market authorities which set the rules that will form the prices and conditions of these programs (e.g. just like in stock markets).

Yet, beyond all abovementioned classification schemes, the final and probably most commonly used classification is the categorization in implicit and explicit DSR programs. These are described in detail in the following paragraph [23].

2.5.1 DSR Categories – Implicit and Explicit

DSR can be either implicit or explicit, forming the two most common DSR programs categories. Figure 2 depicts DSR programs classification based on these two categories. Further analysis of the programs, shown in acronyms in Figure 8, is provided in the next paragraphs.

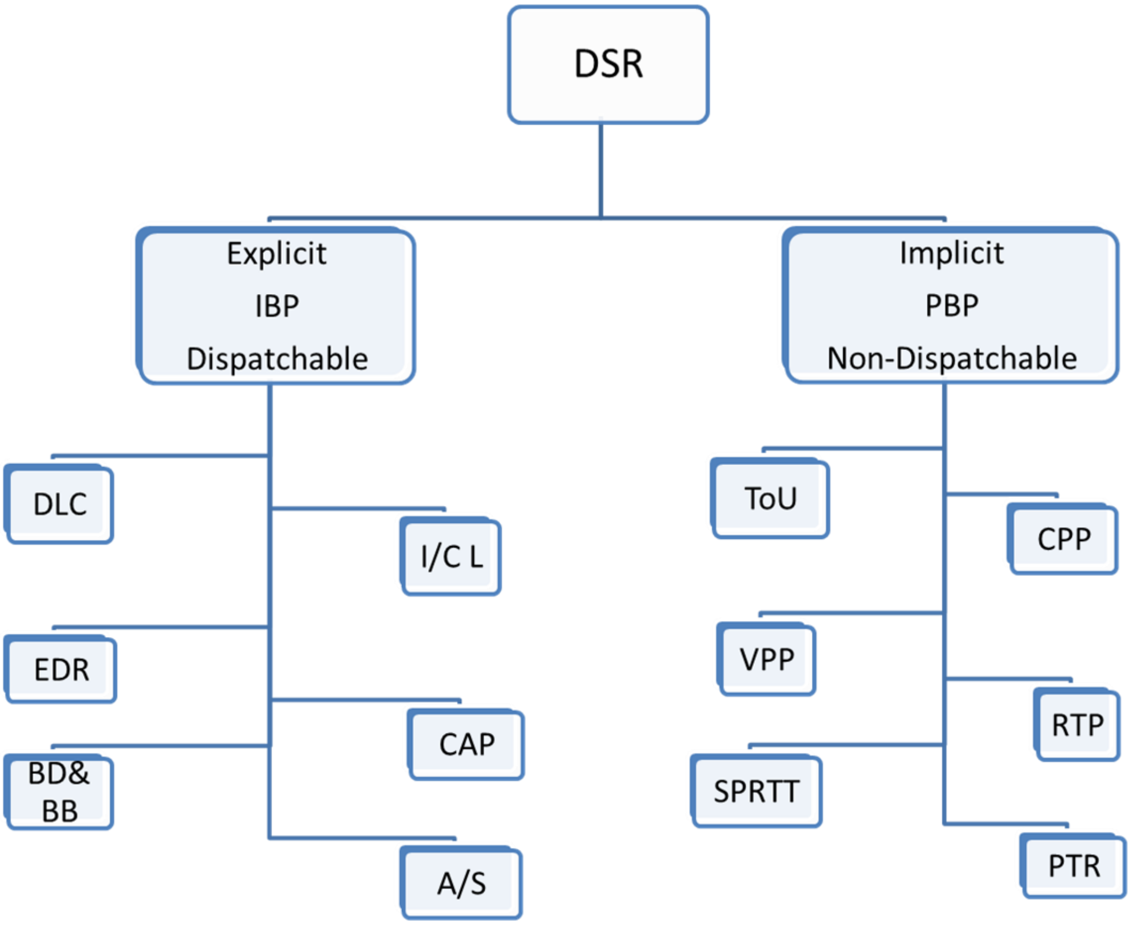


Figure 8:

DSR Programs Basic Classification

Implicit demand response (also sometimes called “price-based / PBP” or “non-dispatchable”) refers to consumers choosing to be exposed to time-varying electricity prices that reflect the value and cost of electricity in different time periods. Programs belonging to this category are based on electricity tariffs which vary customers’ patterns of energy consumption depending on their criteria to time-varying electricity prices/network tariffs [23], [42]. Consumers can decide – or automate the decision – to shift their electricity consumption away from times of high prices and thereby reduce their energy bill.

Perhaps the most identifiable common characteristic of implicit DSR programs, is that they all incorporate the parameter of time in their pricing patterns. That for they are usually referred as “Time-Sensing” DSR programs in the international literature. One other common characteristic of the implicit DSR programs is that they are market-based, but they are only developed and traded in the retail market. Specific contracts with specific terms exist as in the case of telecommunication contracts. These contracts are formed based on the needs of each retail market and are so divided, so as to cover a large proportion of the total number of customers (who can choose the program that best suits to their needs). Under this prism, implicit DSR programs have no commitment to be followed (e.g. a customer might choose a contract with specific reduced rates during predetermined hours during daytime or nighttime, but he is not obliged to consume during this predetermined time – should of course he does so, then he benefits from these reduced rates). Figures 2 and 3 provide a graphical overview of the most important implicit DSR programs.

The main objectives of PBP DSR programs are, on the one hand to flatten the demand curve by offering a high price during peak periods and lower prices during off-peak periods, while on the other hand to balance supply-demand in every moment based also on a dynamic pricing [23]. Time-varying prices are offered by electricity suppliers and can range from simple day and night prices to highly dynamic prices based on hourly wholesale prices. Examples include time-of-use pricing, critical peak pricing, and real-time pricing. In addition, some countries have adopted or are investigating time-of-use distribution network tariffs, which aim at shifting consumption to avoid grid constraints [8].

Explicit demand response schemes (sometimes called “incentive-based / IBP” or “volume-based” or “dispatchable”) are considered those in which the result of demand response actions is sold upfront on electricity markets, sometimes directly for large industrial consumers or through demand response service providers. Consumers receive a specific reward to change their consumption upon request, triggered by high electricity prices, flexibility needs of balance responsible parties or a constraint on the network [8]. They are usually implemented with pre-defined contracts which permit to have a control of the possible effects and do not take into account the parallel savings on the final electricity bill of electricity users. Their main objective is to serve the needs of the wholesale, balancing and ancillary services markets, either by addressing directly to large consumers or incorporating aggregation [23].

2.5.2 DSR Program Types – A Deeper Analysis

There are many DSR programs that have been applied in markets worldwide. International literature has adopted general guidelines on how a generic categorization can be identified. Yet, many DSR programs can be considered to belong to different categories at the same time, since depending on the market and/or electrical system conditions, these programs might serve multiple causes and be triggered by many signals simultaneously. In the following paragraphs an attempt to present the most important and dominant DSR programs shall be made. Moreover, a more analytical classification of DSR shall be attempted, under further criteria, other than those that lead to the IBP and PBP categorization [25]. In Figure 9, a summary of the findings is presented.

DSR Classification	Aim			Classical	Market – Based		Triggering Signal		Implicit PBP Non-Dispatchable	Explicit IBP Dispatchable
	Reliability (Emergency –Based)	Security (Technical – Based)	Economy (Economic Benefit – Based)		Retail Market – Based	Wholesale Market – Based	Technically - Triggered	Price – Triggered		
ToU			✓		✓			✓	✓	
CPP			✓		✓			✓	✓	
VPP			✓		✓			✓	✓	
RTP	✓		✓		✓		✓	✓	✓	
SPRTT	✓				✓		✓	✓	✓	
PTR			✓		✓			✓	✓	
DLC	✓	✓	✓	✓			✓			✓
I/C L	✓	✓		✓			✓			✓
EDR	✓					✓	✓			✓
CAP		✓				✓	✓			✓
DB&BB			✓			✓	✓			✓
A/S	✓	✓				✓	✓			✓

Figure 9:
DSR Programs Analytical Classification

2.5.2.1 Time of Use (ToU) Programs

Time of Use (ToU) programs is the basic type of PBP and it is a time-sensing program. In plain language, they are different rates of electricity price in different blocks of time along the day. The rate formation and distribution within the day is so selected so as to reflect the average cost of electricity during different periods. The definition of ToU periods differs widely among utilities, based on the timing of their peak system demands over the day, week, or year. ToU programs can be as simple as having only two-time blocks (e.g. rates for the peak and the off-peak periods of a day); sometimes a shoulder or partial-peak rate is added, or they can extent in 24-hour division of a day (i.e. one rate per hour within a day). In some cases these prices apply year-round, and in others they differ by season [23], [26].

The aim of ToU rates is to reduce the fluctuations in demand and reduce the generation infrastructures for the same total consumption, optimizing the efficient usage of the grid, generation, transmission and distribution resources. This is accomplished by setting expensive tariffs during peak periods (e.g. noon) and cheap rates during off-peak periods (e.g. late evening or weekends). ToU rates require meters that register usage during the different usage blocks. The additional cost of providing and operating these meters is often reflected in a separate customer charge [26].

Some advantages of ToU pricing program are that are easy to follow and have a stable daily participating ratio. Same ToU pricing portfolios during the same season help consumers to understand, follow, and plan easier their daily electricity consumption portfolios with very simple automation. On the other hand, a fixed price is a disadvantage due to the fact that it can lead to peaks from peak demand hours to off-peak hours. Thus, in some cases the overall electricity demand during peak hours is reduced, but at the same time, a new much bigger demand peak during the off-peak hours can be created, which might require new infrastructure so as to be satisfied (e.g. if the previous peak was during daytime and could be covered – partially at least – with photovoltaics. Another good example of this phenomenon is the electric heating that uses ToU pricing during a cold day [23].

2.5.2.2 Critical Peak Pricing (CPP) Programs

Another type of program that falls in the PBPs and time-sensing programs categories is CPP programs. This type of program is superimposed on ToU rates or to normal flat rates. CPP is usually combined with other PBP to maximize the benefits. Normally, CPP rates are higher than ToU pricing values. CPP prices are applied during high wholesale electricity prices so the frequency of their use is limited. Their main difference with VPP (presented in the next paragraph) is that their rates are predetermined advanced for a fixed time frame. CPP is a hybrid of the TOU and RTP (presented in paragraph 2.3.2.4) programs and is harder to implement. The base program is TOU and a much higher peak pricing is used in specified conditions (e.g. when system reliability is compromised or when supply costs are very high).

This type of pricing incorporates rates that can be informed to customers even some months in advance. These tariffs are determined in advance and customers carry out their activities according to the contract. The contract prices could have been negotiated and designed to benefit involving parties. Some advantages of this program are that it is easy to follow, it is effective on shifting peak energy consumption, and its incentives can be visualized [23].

2.5.2.3 Variable Peak Pricing (VPP) Programs

VPP programs can be considered a subcategory of CPP programs. This type of program is superimposed on ToU rates or to normal flat rates, in a similar way that CPP programs do, but they are higher than ToU and CPP pricing values. VPP prices are applied during high wholesale electricity prices so the frequency of its use is limited. Their rates are formed based on both static and dynamic parameters of the market. Their main characteristic is that the price in peak-demand times, is formed dynamically (i.e. the price established for the on-peak period varies by utility and market conditions), while the rest pricing profile is similar to ToU and CPP programs. Thus, they are used only a few numbers of days or hours per year by larger commercial and industrial customers [23], [32].

VPP rates have high per-unit rates for usage during periods that are designated to be critical peak periods by the utility. Unlike ToU blocks, the days in which critical peaks occur are not designated in the tariff, but dispatched on relatively short notice as needed, for a limited number of days during the year. Different colors (green, red, blue) in Figure 2 illustrate different (variable) peak rates that it may or may not be dispatched on a given day [26].

2.5.2.4 Real Time Pricing (RTP) Programs

RTP programs fall in PBPs and of course, they are time-sensing, as their name implies. RTP programs reflect the real cost of electricity in the wholesale market, which is only a part of the total cost of electricity for the customer. Thereby wholesale prices vary continuously and customers are informed about them some hours ahead [23]. RTP rates vary continuously over time in a way that directly reflects the wholesale price of electricity, rather than at pre-set prices as in virtually all other rate designs. Most frequently, RTP rates provide different prices for each hour of the day, every day of the year, and these prices are made known to customers one day in advance [26].

RTP programs are considered one of the best time-sensing ways to manipulate electrical energy demand, but their implementation is quite difficult – especially in residential customers – since they require a lot of technological infrastructure. Advanced Metering Infrastructure (AMI) is needed for its application, as well as extensive and reliable communication networks [32].

2.5.2.5 System Peak Response Transmission Tariffs (SPRTT)

As their name imply, these programs target at providing increase tariffs during high congestion of the transmission network. They rather focus on the reliability of the system and their main triggering cause is the insufficiency of the transmission network in technical terms. They are characterized as PBPs and are classified as time-sensing programs [23], [29].

2.5.2.6 Peak Time Rebate (PTR) Programs

PTR programs reward customers who reduce electricity consumption during periods of high-cost electricity (peak times) with monetary rebates. Those who do not reduce usage during peak events are simply charged the normal rate. A major advantage of these programs is that they do not require any changes in rate design. Assuming PTR rebate levels are set correctly, PTR programs can benefit both customers and utilities, resulting in a win-win outcome. PTR programs typically have very low upfront costs. Costs to the utility are mainly incurred in the form of rebates to the customers in exchange for demand reductions; therefore, ongoing costs will be a function of how many peak events are called each year. If the utility's event call strategy is managed properly, ongoing costs should be lower than the savings attributable to the peak reduction [30]. PTR are classified as PBPs.

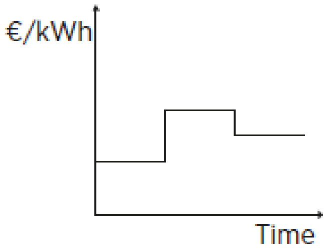
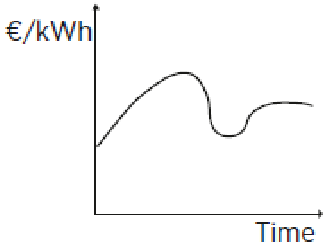
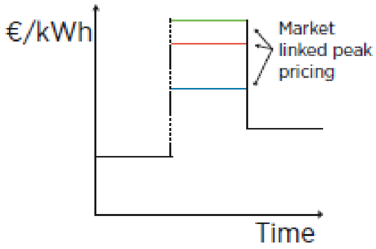
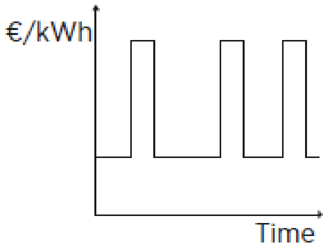
Type of tariffs	Nature of pricing	Illustrative graphical representation	Features
Static ToU pricing	Static		This typically applies to usage over large time blocks of several hours, where the price for each time block is determined in advance and remains constant. It can use simple day and night pricing to broadly reflect on-peak and off-peak hours, or the day can be split into smaller segments, allowing several slack periods. Seasonality can also be taken into account.
Real time pricing	Dynamic		Prices are determined close to real-time consumption of electricity and are based on wholesale electricity prices. Electricity prices are calculated based on at least hourly metering of consumption, or with even higher granularity (e.g., 15 minutes). Such tariffs are mostly composed of the wholesale price of electricity plus a supplier margin.
Variable peak pricing	Combination of static and dynamic		A hybrid of static and dynamic pricing, where the different periods for pricing are defined in advance, but the price established for the on-peak period varies by market conditions.
Critical peak pricing	Combination of static and dynamic		A rate in which electricity prices increase substantially for a few days in a year, typically during times the wholesale prices are the highest. E.g., French Tempo tariff is a contract with a fixed price all year except for a maximum of 22 days with very high prices. Customer are notified of

Figure 10:
Overview of the four ToU, RTP, VPP and CPP DSR programs [27]

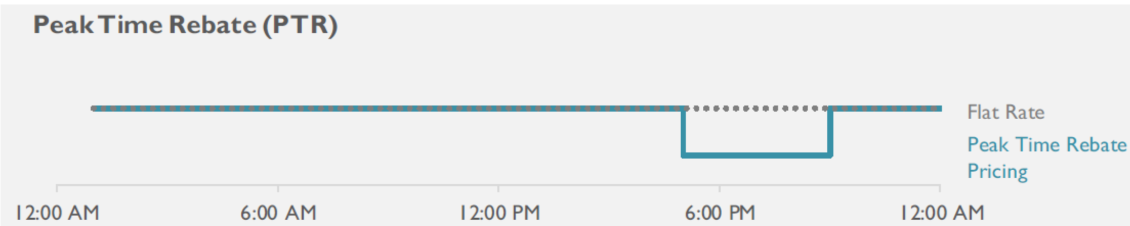


Figure 11:
Overview of a PTR DSR program [32]

2.5.2.7 Direct Load Control (DLC) Programs

DLC programs fall into the IBP category. Under these programs suppliers are able to control remotely client's (consumer) electrical equipment. They can either alter the loading of the equipment, or they can even shut it down on a short notice. In turn, he consumers are awarded by a way of financial incentive such as recurring annual payment of fixed monthly payments credited to the utility bill. From DSO point of view this DSR program can be used it times when the network infrastructure is overloaded or to manage voltage control which is a local problem. Retailers can be motivated to balance their portfolio and maximize their financial benefits.

DLC concept is mainly considered to be simple and inexpensive in its implementation for low voltage residential customers, especially through aggregation. A large aggregator can lead more efficiently residential customers to be accepted to be controlled on his behalf, leaving the aggregator to deal with a supplier of the energy markets on how much and when energy must be cut-down. This is because the aggregator can more easily develop a closer relation with the residential customer, to whom standardized control equipment can be offered and be installed for controlling specific power appliances. Such equipment is installed directly to end-use devices or through other controls such as building energy management systems (BMS) or simple thermostats. Equipment using these programs is typically air conditioners and water heaters used by voluntary residential customers and small commercial customers [23], [25]. For this kind of loads, the program design will focus on reducing load through equipment cycling. Heating and/or cooling systems will be switched and cycled on a rhythm agreed in advance [28].

As part of the DLC program, the utility (either directly or through an aggregator) establishes agreements with customers that specify the maximum number of events per year (e.g. up to 30) and the maximum duration of any given event (between 2 and 8 hours, but typically 4). Because the utility controls the customer loads directly, very little advance notification is given prior to initiating an event (3 minutes or less). Most DLC programs allow the customer to override an event if they experience discomfort, but some programs impose penalties for overrides. These programs offer utilities assurance that loads can be curtailed when needed or called upon [24].

DLC programs are considered classical DSR programs, since they usually offer custom made solutions to a customer (or a group of customers), under a very flexible negotiation scheme over the economic benefits and constraints on load control from the customer side.

2.5.2.8 Interruptible / Curtailable Load (I/C L) Programs

I/C L DSR programs are probably the most frequently utilized programs of the IBPs category. In I/C L programs participants are asked to reduce their load to predefined values to thereby reduce peak demand. In some cases, although these are not so common, this load reduction might be commanded by the utility company, depending on the terms of the program, by utilizing remote control technologies. As with DLC programs, customers participating in I/C programs receive upfront incentive payments or – less frequently – rate discounts. In general, this type of program is mandatory. Participants who do not respond can face penalties, depending on the program terms and conditions [23], [25].

As already mentioned, the most frequent way of reducing the load in I/C L programs is from the customer's side and this is usually being realized through load shedding systems, mainly utilized from medium to large industrial customers. Whilst not functionally different from DLC programs, this term is used to refer to large industrial users who can shed larger portions of load. Through these systems, customers can switch off loads or adjust settings manually or automatically, depending on the agreement and availability of their production units. Thus, I/C L programs are relative simple to be implemented, because the technological infrastructure that is required is already incorporated in the abovementioned systems [28].

So-called I/C L contracts will be placed by companies who operate industrial processes which are flexible in terms of time of operation (not necessarily duration). Participants agree to reduce or turn off specific loads for a period of time when notified by the utility. Utilities must notify customers before a curtailable load event. Advance notice is typically given minutes to hours ahead, but some programs notify participants up to a day ahead. The utility usually has to specify upfront the maximum number of events and durations (hours per incident) per year ("capped" interruption). Typical examples include water companies' irrigation programs, chemical production facilities and large furnace or boiler processes [24], [28], [33].

I/C L programs differ from the emergency demand response (EDR) and capacity market program (CAP) alternatives, mainly because they are typically offered by an electric utility or load serving entity and the utility/load service entity has the ability to implement the program when necessary, meaning that the customer shall be remunerated upfront for its availability and willingness to be curtailed. Thus, the payments are guaranteed, no matter whether or not the utility company judges that there is need for specific load reduction due to the utility's inability to cover all demand (and a subsequent signal for load interruption/curtailment is dispatched). The same applies for the DSO/TSO's (if they are to regulate these programs, under a specific market schemes). Should the DSO/TSOs judge that the system is outside safety and reliability limits, then, there will be a need for signals to be dispatched to customers participating to the interruptibility / load curtailment market [33]. Of course, as already mentioned penalties shall be enforced, should the customer does not curtail.

2.5.2.9 Emergency Demand Response (EDR) Programs

EDR programs also fall in the IBP category and are the most usual demand response program when an event occurs. They could be considered a hybrid of I/C L programs, but with two major differences. The first one is that they so designed so as to be applied only in emergency situations (as their name implies), where sudden energy shortages occur, or imbalances on the electrical network arise. The second main difference is that they work on a voluntary basis, meaning that the customer/participant is not obliged to react and reduce load, although he has declared participation in the EDR program.

EDR programs provide incentives for customers to reduce loads during reliability events, although the curtailment is voluntary. Yet, due to the fact that EDR programs (in contrast to the I/C L programs) are market based programs, they remunerate the participants gets on the basis of their performance (e.g. how much load they have reduced upon the emergency event and/or during it), while if they do not react, then participants do not get any remuneration. No penalty is assessed if customers do not curtail, while the curtailment rates (per kW and/or per hour) are pre-specified through bidding processes in organized markets, though no capacity payments are received. Customers can choose to either allow the DSO/TSO to interrupt their service or to individually proceed to curtailment with their own means [33].

2.5.2.10 Capacity Market (CAP) Programs

Another IBP DSR program is CAP program. In CAP programs, customers get paid for a commitment to be able to reduce demand at some point in the future, just as power plants get paid for a commitment to be operational and increase supply at some point in the future. Actually, in these programs, customers offer load curtailment as system capacity to replace conventional generation or delivery resources, so as the DSOs/TSOs to confront future demand increase. An example of such a customer could be a large chemical industry which has two identical units in different areas of an electrical distribution system. In this case, satisfying minimums of its productions by either one of its two units (in a notion that the one unit is utilized as a spare of the other one) for specific time-frames can render this industry a stable participant in capacity demand response markets, serving in solving electrical network congestion issues. In fact, should the DSO/TSO judges that investing in network infrastructure if more expensive than creating a stable capacity demand response market, then erecting a spare unit by the industry's side could be a more profitable strategy then concentrating its total production in a specific spot of the electrical network (and potentially be paying greater electricity fees). Energy conservation investments, such as low-energy buildings, can also be eligible for capacity payments since they measurably reduce overall electricity demand [36].

2.5.2.11 Demand Bidding & Buy-Back (DB&BB) Programs

In BD&BB programs electricity consumers exchange the curtailment of the electricity consumption for revenue in the form of power load curtailment bidding. These programs are market mechanisms that mainly refer to the access to intraday market trading. Customers participate by bidding, a bid to be accepted need to be lower than the market price. When a bid is accepted, the customer must curtail his load by the amount and under the conditions (date, duration, etc) specified in the bid or face penalties. The load reductions are then scheduled and dispatched in a manner similar to the scheduling and dispatch of generators (in case of supply side). When using these programs, consumption parties are able to negotiate the price according to the amount of load reduction, through an organized wholesale market [23]. DB&BB programs fall in the IBP DSR programs category and are wholesale market-based programs, as their name implies.

2.5.2.12 Ancillary Services (A/S) Programs

In A/S programs customers bid load curtailments in DSOs/TSOs markets as operating reserves. If their bids are accepted, they are paid the market price for committing to be on standby. The stand-by capacities can be used by the DSO/TSO as FCR, aFRR, mFRR or even RR [40], [41], [42]. If their load curtailments are needed, they are called by the DSO/TSO, and may be paid the spot market energy price. A/S programs fall in the IBP DSR programs category and are wholesale market-based programs, as well [23], [39].

2.5.3 DSR Programs in Relation to Load Commitment Timescale

The following figure (Figure 12) shows the distribution of DSR Programs in relation to their applicability in various time frames of the power and load reduction delivery process. It can be clearly seen that the DSR concept fits either for short, mid and long terms energy management goals and that its applicability extents to the majority of energy markets (day-ahead, intraday, balancing, capacity, etc)

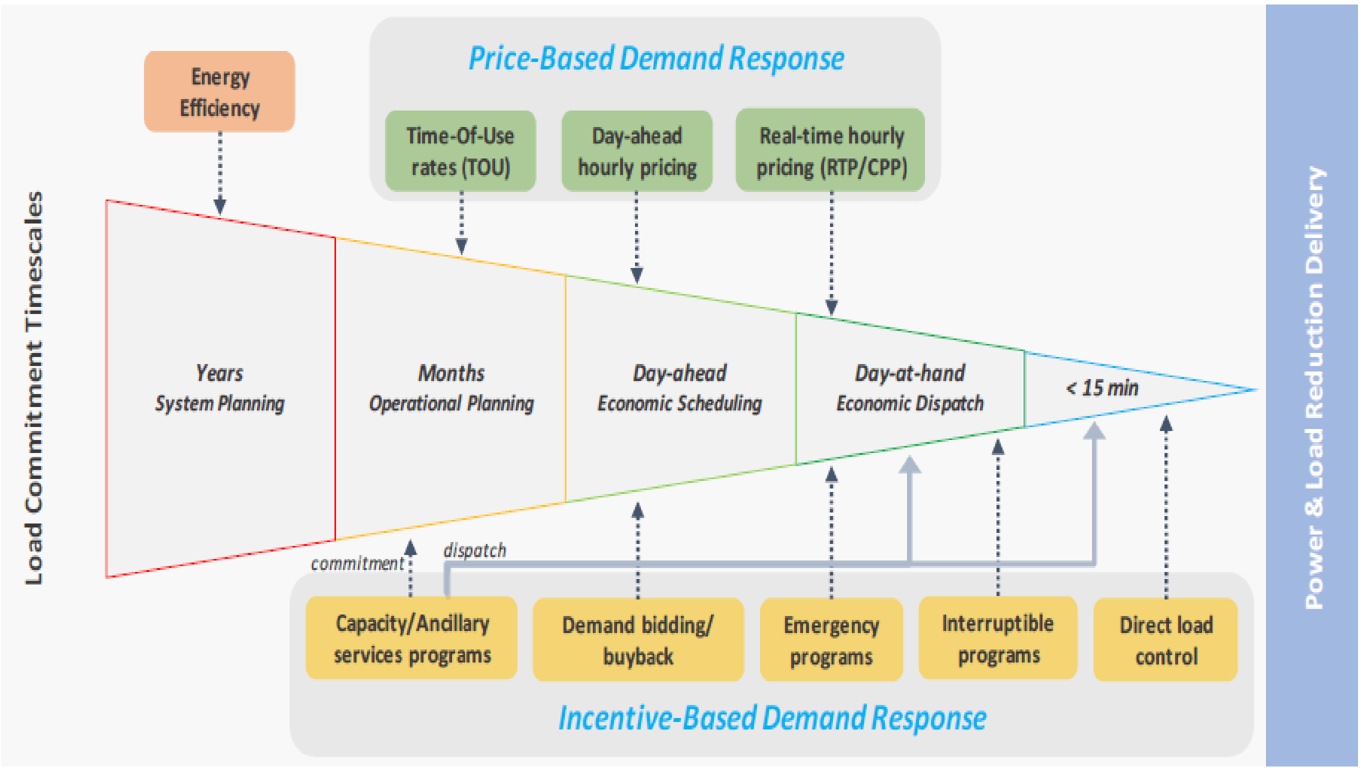


Figure 12:
DSR Programs timescale [37]

2.6 Brief Status of DSR in Europe

DSR concept is widespread throughout EU and especially in Northern and Western countries. Many different types and categories can be encountered in almost all markets, either retail or wholesale. Yet, the explicit DSR programs seem to occupy the greatest part of the share. DSR schemes, often participate to day-ahead, intraday and balancing markets, while in several cases they offer solution to capacity markets or to other ancillary services markets. In the following paragraphs, a brief overview of the applications of the DSR concept in the following European countries is presented, as this was extracted by the most recent reports either from EU [63] or from SEDC [9]. We note that the focus is majorly given to the explicit DSR programs, as the implicit ones are presented in almost all countries (not to the same extent of course), especially through simple static ToU programs.

<u>Austria</u>

Austria has enabled DSR to its balancing markets and ancillary services pertinent to aFRR and mFRR, either directly by large customers' participators or through aggregators. There are several provision for the participation of DSR to the day-ahead market.

<u>Belgium</u>

DSR participates in the FCR and mFRR, as well as in the Interruptible Contracts programme, classified under the Tertiary Reserve. However, the Secondary Reserve is not yet open. Additionally, a share of demand-side capacity is participating in the Strategic Reserve, introduced in 2014 to ensure a sufficient level of security of supply during the winter periods. Yet, wholesale markets are closed to DSR, while in general, aggregation is not really supported, especially for residential consumers.

Denmark

The use of DSR in Denmark remains quite limited. Mainly because there is no significant demand for flexibility from TSOs or DSOs. This is due to sufficient capacity in Denmark and compared to other European markets, a well-functioning electricity market. In theory, electricity consumers are allowed to participate in all the balancing and ancillary services in Denmark, as well as to the day-ahead and intra-day wholesale markets. However, due to a weak business case as well as a regulatory environment which makes it difficult for independent aggregators to develop innovative DSR businesses in the market, DSR participation within the markets remains limited.

Estonia

The Estonian balancing (mFRR) and wholesale markets are open to DSR in principle. However, explicit DSR participation is currently very limited to non-existent.

Finland

Active market participation of DSR is possible in all markets, but limitations still exist, especially in some aspects pertinent to aggregation. Today, aggregators operate in the frequency control, in the tertiary reserve and in the spot market, while only pilot projects are underway in the secondary reserve and in the frequency normal reserve. The large minimum bid size for some products limit the full potential of Demand Response. The payments are quite attractive for the ancillary products, but with some penalization compared to the generation ones. The TSO Fingrid has also contracts with the largest industrial consumers to provide emergency reserves.

France

France is one of the first countries that embraced the DSR concept, as it has set provisions for the DSR participation from year 2003. ince 2003, large industrial customers been participated in the balancing mechanism, and from 2007, the first pilots were run in order to introduce aggregated residential load to the mechanism. In 2014, for the first time an industrial consumer provided its energy reduction as a FCR or Primary Reserve. DSR are very active in all wholesale markets (day-ahead, intra-day, balancing) but to ancillary and capacity mechanisms as well. Aggregation is strongly supported to all the above schemes. France has also strong support to implicit DSR programs, especially ToU tariffs, while it is one of very few countries in Europe where the tariff promotes DSR programs based on CPP [23].

Germany

The German market regulation creates significant barriers to most forms of DSR program types, including both those provided by retailers and independent aggregators. Yet, since from a regulatory point of view, most of the markets (day-ahead and intraday) accept DSR, while there are provisions for the support of various balancing and ancillary services (FCR, aFRR, mFRR, interruptible load services), by DSR schemes, Germany is considered to have made significant steps to promoting the DSR concept. A major barrier for the expansion of DSR in Germany is the growing gap between the continuously low wholesale market prices and the much higher balancing market prices, due to the fact that large amounts of renewable energy generation are available within intra-day market. Network Tariffs (an equivalent to SPRTT) is also applied in Germany by various DSOs.

Great Britain

Great Britain (GB) was the first country to open several of its markets to consumer participation in Europe. Today, all balancing service markets are open to DSR and aggregated load is accepted. However, unfortunately in recent years it seems that the process has not been as effective as would be hoped in a mature market. As a result, measurement, baseline, bidding and many other procedural and operational requirements are still inappropriate for demand-side resources, noticeably reducing the number of demand-side MWs in the system. Thus, the DSR concept is in name open to the markets. Up to mid-2017, almost all balancing and ancillary services were open to DSR and aggregated load was accepted, although the product design was not optimal for customer participation. Capacity mechanisms were also open to DSR, but not on comparable terms to generation. Balancing services and the wholesale markets remained closed to independent aggregators. DSR only directly participated in the British day-ahead and intraday markets in the form of flexibility of retailers and large industrial customers that were already trading members. Regarding implicit DSR, due to the existing, extensive smart-metering infrastructure the ToU tariffs are very popular, either static, or dynamic (after 2018). Moreover, industrial consumers forecasting of peak demand periods and their management of injection/withdrawals during the periods are very well paid.

Ireland

Although balancing market programs still remain closed to DSR, participation has increased in Ireland in recent years. Having fully implemented its main scheme in early 2013, Ireland modified the Electricity Market Rules to allow DSR providers to enroll as Demand Side Units (DSU) in its electricity market, allowing them to become eligible for capacity payments. The first DSU became operational in July 2012 and the second in December 2012. It is noticeable that although there is a great need for flexibility due to the great share of renewables in Ireland's grid and the lack of interconnections, the Ancillary services are basically closed to DSR. The only ancillary scheme is basically an interruptible program (STAR). DSR participates in the wholesale electricity market from the point of view of bidding and dispatch, however DSR providers do not earn an energy payment for this. Participation in the wholesale market is required to earn capacity payments in the capacity market only. This is in clear contradiction to generation, which earns energy payments from providing supply side resources in the wholesale market and is not expected to participate for free.

Greece

Greece has still some barriers to surpass in order to fully liberalize its markets. Under this perspective, the DSR concept is rather under-developed in the Country. On the implicit DSR side, there are several programs which offer different energy pricing to retail customers. These are offer from either PCC or other private energy suppliers. Regarding the explicit DSR concept, Greece markets are fully closed to all sorts of programs. The only scheme that exists is the ILSA scheme, which in fact offers two different interruptible load services to HV or MV consumers. The selection of the successful participant is based on energy bidding through auctions that are being held.

Italy

Italy's electricity market has been characterized by rapid growth of renewable generation and by a decrease of electricity consumption. Italy relies mostly on hydro and gas for its flexibility needs, while the frameworks for DSR participation in the ancillary service market, the balancing or the wholesale market, are not yet in place. The only exception is the interruptible contracts program, which is a dedicated DSR program separate from the balancing market. As an exception, there is some provision for the participation of large industrial consumers to the spot market in a single or aggregated form (as dispatching user), with demand bids with indication of price as part of their supply contract. Finally, some serious steps have been made towards the DSR participation to the capacity market, but it is too early for results to be assessed.

The Netherlands

The Netherlands has enabled a considerable amount of implicit DSR programs with relatively simple market structures, namely clear and timely price signals –

particularly to green-house owners, who in fact are prosumers, due to the extensive use of PVs for self-generation and the spreading of smart metering devices for facilitating the latter operation. Residential prosumers' have the right to feed self-generated electricity into the grid, for which grid operators must provide a contract to prosumers. Compensation to prosumers is determined by the net metering scheme. Under the net metering scheme, the electricity bill summarizes how much electricity the prosumer has produced and the supplier has delivered, respectively, and the prosumer is only invoiced for the difference (i.e. net consumption). Regarding the explicit DSR part, the largest share of DSR flexibility is used in "passive balancing/passive contribution". It is based on voluntary contributions from consumers or prosumers to balance the grid, without being actively selected via a bidding ladder. This structure is unique to the Netherlands and therefore not easily repeatable in other Member States. DSR participates to all balancing and ancillary services, except primary control (FCR). Regarding DSR participation to the wholesale markets, offers can be bided into them through the retailers' supply contract. Regarding aggregation, the aggregators cannot participate directly to the market (either wholesale or balancing and ancillaries' services), but only through BRPs which are held responsible towards the Dutch TSO for providing balancing services and optimizing imbalances.

Norway

Although network flexibility in Norway is fully served through the great hydropower resources that it has, the country has made significant steps for promoting DSR and facilitating its participation to the markets. Wholesale markets fully accept DSR, while DSR also participates to almost all balancing and ancillary services (strategic reserves are excluded). Aggregation is supported, but aggregators must be BRPs themselves or co-operate with a BRP which takes on the balance responsibility for them. Unfortunately, due to the hydropower resources, there is no considerable participation of DSR.

Poland

Due to Poland's heavy dependency on goal for electricity generation, DSR can play an important role to the stability of its electrical system. Yet, up to the recent years, DSR in Poland could only participate in the Emergency Demand Response Program (EDRP), while the opening of the balancing markets to DSR – which was introduced on July 1st 2014, has not provided up to now satisfying results. Nowadays, the legislative and operational framework has changed further. All types of DSR are eligible to participate in the wholesale electricity markets, including day-ahead and intraday. DSR units can also participate in the balancing market and provide balancing services. This is done by submitting balancing energy offers to the Polish balancing market, where such offers can influence the balancing price formation. DSR may also participate in the capacity market [64].

Portugal

Portugal does not have a solid legal framework for supporting DSR. The only DSR services that are currently legislated in Portugal are a set of interruptibility contracts. Fortunately, Portugal is quite active in the implicit DSR program (mainly through static ToU programs) due to the very active customer participation in retail electricity market. Illustratively, 21% of Portuguese households switched their electricity supplier in 2016, which was the highest rate in Europe [65].

Spain

Spain was the first country in the world where the default price for households is based hourly spot prices, leading the way to implicit DSR. Yet, the status of the explicit DSR is far away from these initiatives. Just recently, some measures to regulate competition mechanisms for the allocation of DSR through interruptibility have been taken. Aggregation is illegal and all consumers interested to participate to the interruptibility programs have to be linked directly to the Spanish TSO. No other developments for the participation of DSR to the wholesale markets and/or to balancing and ancillary services have taken place.

Slovenia

DSR in Slovenia participates to balancing market, through aggregation (except to primary reserves), in all frequency control schemes (FCR, aFRR, mFRR). Whole sale markets are closed to DSR.

Sweden

Similarly to Norway, flexibility issues are dealt through the vast capacity of hydro power. Thus, no major incentives exist for the development of DSR, although all wholesale markets and balancing and ancillary services are open to DSR.

Switzerland

Switzerland is another country which manages the flexibility issues through the vast capacity of hydro power. Yet, due to projection of water scarcity to the extent desirable to solve all flexibility issues, the DSR concept is strongly promoted. All wholesale markets and balancing and ancillary services are open to DSR. Capacity mechanisms though, are still not supporting DSR.

Czech Republic

DSR in the Czech Republic is mainly based an old system utilizing the so called “ripple control”. The ripple control system is similar to radio teleswitch, in that it can be controlled centrally, only that it uses the power line communication. Ripple control is linked to the electric heating appliances, providing the technicalities for a ToU pricing. Though the technology and the price system are rather outdated only small changes have been implemented towards modern DSR integration, and DSR cannot move towards a broader application, unless a major step is taken. Legally, the wholesale and balancing markets are available for DSR, but in practice this is limited to the ripple control mechanism and aggregation is not happening. Participation of DSR to the wholesale markets is limited to very large consumers, while balancing and ancillary services are almost exclusively implemented through ripple control.

Hungary

Legally, all markets are open for large and aggregated consumers, but its scale is limited and is not linked to the ideal from the EED. Participation is based on consumption balancing rather than capacity balancing, since Hungary has an overcapacity of power plants.

Romania

Demand response is allowed on both the wholesale and balancing market, and aggregation is legally frameworked, however, no incentives are provided, while due to important system development barriers (system extensions are mainly state aided) and technical barriers (lack of smart metering), the DSR concept cannot flourish.

In Figure 13 the DSR evolution in EU is portrayed. The figure has been extracted from the SEDC 2017 report [9] and has been suitably altered to include both implicit and explicit DSR developments provided from the European Commission 2016 report.

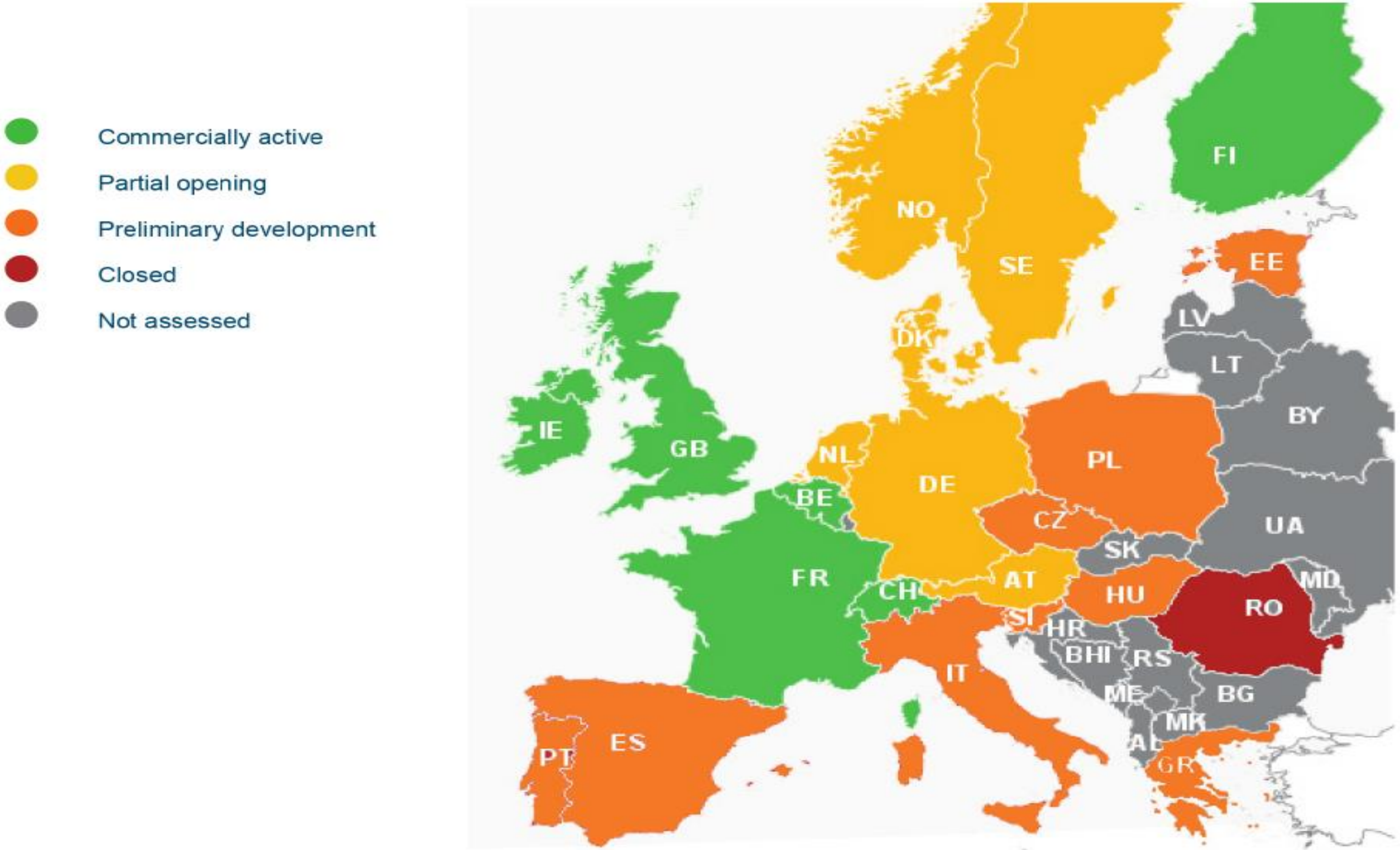


Figure 13:
DSR Evolution in Europe

CHAPTER 3: DEMAND SIDE RESPONSE IN GREECE – PRESENTATION OF THE GREEK INTERRUPTIBILITY SCHEME

3.1 DSR in Greece – An Introduction

Although DSR concept in Greece is relative new (mainly introduced due to the developments in the EU energy policy during the last decade), there are several acts that could be partly considered predecessors of what the EU would understand as a need in the energy field and be named DSR. These are analyzed further in the following paragraph, in a form of a historical review of the DSR concept in Greece, either this was a product of a conscious attempt to form a new national energy policy, or it was the result of other contemporary needs, such as the reduction of electrical power production solely.

During the closing of the last decade, a major set of EU legislative initiatives (as analyzed in Chapter 2) pushed for changes in the way the Member States perceived the energy section throughout EU. Having as a starting point the Electricity Directive in 2009, EU made clear that the DSR concept had to be officially introduced to Member States national energy policies. Greece, as an EU member, was gradually obliged to make reforms so as to comply with the EU framework that was under design and thus introduce DSR schemes in the energy market and the electrical transmission and distribution network operation. As a result, after 2014, important legislative and framework efforts have been made, that introduced the DSR concept in various forms in the Greek electricity sector, having to present as a crest – so far at least – the ILSA scheme for HV and MV industrial customers.

3.1.1 Historical review

Although the DSR concept was inexistent in Greece prior the early 2010's, there were several schemes that had as a target – among other ones – to alter the consumption patterns of the participants as consumers in the electrical grid. These schemes, although they did not participate in the market in any way, (Greece's electricity market was de-facto closed up to the early 2010's) could easily be perceived as early DSR programs, since they incorporated many of the characteristics of the family of contemporary DSR programs.

For more than 30 years ago, up to the early 2010's PPC provided with special tariffs some industrial consumers such as aluminum, metal and paper industries. Although these reduced tariffs had a major target to attract heavy industrial investments in the country, at the same time they could be considered as an early form of a DSR scheme, which pushed industries to connect to the HV part of the network. That could be interpreted as potential savings for the network operation, since no extensive lower voltage networks needed to be constructed and maintained by the DSO (which happened to be PPC at the time), due to the fact that the complete development and maintenance of the internal distribution network of the HV consumer was in his responsibility. Moreover, savings on the transmission of the electrical energy could be made due to the reduced losses in HV lines [44].

Another example of early DSR schemes could be considered the schedules from the TSO (PPC) about the interruption of irrigation (a policy that was under the Ministry of Development and the Regulatory Authority for Energy decisions). There were decisions that allowed about 3 or 4 days per year as a maximum under requested demand reduction. Under the same philosophy, the Ministry of Development and RAE had issued some decisions pertinent to the load reduction for the summer period of the year 2005 and 2006, which mainly affected 150kV and 20kV industrial end-users. In the same context, the lignite mines (which also belonged to PPC) could be requested to cease operation during demand peaks, in order to ensure the electrical network's stability and safety [44].

Yet, the most characteristic example of early DSR measures, which still holds up to nowadays with minor alterations (either due to PPC policy, or due to other producers and/or electricity suppliers policy), could be considered the different pricing between different time zones throughout a day (in 24h basis). The main target of this policy of PPC is to regulate the demand profile basically in the low level of demand (decrease the difference between maximum and minimum demand). This scheme could be considered as an early ToU DSR program. Typical examples could be considered the reduced residential tariffs during the night (Γ1N tariffs), the generic industrial medium voltage tariffs (B1B and B2B tariffs) and the generic commercial medium voltage tariffs (B1 and B2 tariffs) [45], [46].

3.1.2 Contemporary Programs and Schemes

Despite the gradual linearization of energy market in Greece during the last decade, not much has been achieved in the DSR electricity section. The main developments have been confined in the area of energy efficiency of appliances and electrical equipment (either commercial or industrial). Yet, some notable advancement has been made.

One very important development can be considered the introduction of more producers (other than the PPC) and/or suppliers (who do not necessarily produce the energy that they supply, but they rather but it from the organized wholesale market and distribute it to the final customers). These producers and suppliers offer similar ToU programs as those provided by the PPC back in the earlier years PPC's monopoly. Although these programs are not that complex, since they rather assimilate PPC's programs' characteristics, they offer a notion of variety of different choices regarding the consumption profiles that one residential consumer could choose. PPC of course, still offers special ToU programs either in LV or in MV, which have been increased in number and changed their designation/name (ΒΓ, ΒΧ, ΒΥ tariffs), while special programs are offered for irrigation purposes, which include the option of supply interruption in case the PPC request it so (ΒΑΓ tariffs). ΒΑΓ tariffs incorporate penalties in case the consumer does not accept the interruption (e.g. by reverting to other tariffs for the time frame during which he does not comply) [47].

Yet, all the above can be considered existing schemes which have just altered their characteristics due to the energy market linearization and not real efforts to introduce the DSR concept in the Greek electricity market and electrical grid. The only major scheme that has been differentiated from the above is the ILSA scheme of the Greek TSO (ΑΔΜΗΕ) that firstly operated in 2016, having its operational framework approved from 2014 by the EU. In the next paragraph this scheme is presented in detail, along with the results to which it has led up to nowadays.

3.2 Description of the ILSA Scheme of Greek TSO

In response to the EU legislative framework that started to be developing after 2009 around the introduction of DSR concept in the EU energy market, Greece designed the Interruptible Load Service Auction (ILSA) scheme. The scheme was initially communicated to the European Commission on 5th May 2014 (at the Competition Directorate) so as the latter to assess should this would be considered as a state aid and thus could not be applied to the market, since it would then be considered as unfair competition towards the other players of the electricity market (such as producers) [49]. On 15th October 2014, the European Commission concluded that the ILSA scheme did not constitute state aid and thus allowed its implementation. Yet, due to the dynamic evolution of the EU energy markets and pertinent legislation, the scheme got an initial release for implementation without being considered as a state aid for a period of three years (from 15.10.2014 to 14.10.2017 specifically). In the following paragraphs details on the scheme are presented.

3.2.1 Greek Legal Framework

The ILSA scheme has based its operation in the legal framework comprised of a series of legislative acts and their modifications and amendments that have formed the energy market in Greece throughout the last decade [49], [50], [51], [52]. Yet, the main legislative act that enabled the ILSA to become operational, both in legal and technical terms was the Ministerial Decision ΑΠΕΗΛ/Γ/Φ1/οικ.184898/11.12.2015, issued in the Governmental Gazette, page (ΦΕΚ) Β' 2861/2015, titled "Interruptible Load Service, type and content of Load Interruptibility Contracts, according to the provisions of article 17 of law 4203/2013" [53]. In this decision, all operational and technical details of the scheme were analyzed. The validity of this Ministerial Decision was for 3 years (i.e. up to 15.10.2017), having as a start-up date the 15.10.2014 which was the date of the issue of the decision of the European Commission's Competition Directorate regarding the non-characterization of the ILSA scheme as a state aid.

On 18th December 2017, the Minister of Environment and Energy issued a Ministerial Decision which extended the duration of the ILSA scheme until 31st December 2019. It was also published in the Governmental Gazette, page (ΦΕΚ) Β' 4546/2017 on the 21st December 2017 [54]. The provisions of this decision were identical to the 2015's one, with slight modifications which are mentioned in the analysis followed in the next paragraphs and summarized at their end. Prior to the decision's publication, the European Commission, had issued decision (letter) B.2/CS/RV/2017/118968/12.12.2017 confirming that the three-year service and its financing mechanism do not constitute state aid and had already approved a further extension until 31th December 2019 [55]. Following the termination of the extension program, Greek government negotiated with the European Commission in order a further extension of the ILSA scheme to be granted. Under the pressure of the recent Covid-19 pandemic developments and the urgent need for supporting the energy consuming industries, this extension was finally granted in mid-2020. A new Ministerial Decision was published in the Governmental Gazette, page (ΦΕΚ) Β' 2997/2020 on 20th July 2020 [70], which extended the ILSA program up to 30th September 2021, with some alterations to its existing structure. We note that the definition of the terms mentioned in the following paragraphs are given as they are provided in the Greek legislation.

3.2.2 Main Idea and Organizational Aspects

In brief, the main idea of the scheme is to provide a mechanism that compensates certain large consumers connected in the Greek interconnected system that enter into contracts with the Greek TSO (ΑΔΜΗΕ) to agree to reduce their electricity consumption (through "load shedding") for a given period of time and given a stated notice time ("Power Reduction Order" – PRO). This mechanism would be structured in such a way so that it could provide services to primary, secondary or tertiary frequency control schemes, as these are defined by the ENTSO-E and EU. The scheme was initially decided to operate for 3 years and additionally two due to the extension that was granted by the EU. Under the latest extension another year of life was provided.

Greek TSO (ΑΔΜΗΕ) organizes and operates the scheme. There are specific technical and operational documents that supplement the legal documents which constitute the legal framework, which have been developed by the Greek TSO in order to facilitate the consumers who want to participate in the scheme on the one hand and to standardize participation procedures on the other hand. The most important document is the Regulation of the Interruptibility Load Service Auction [56], while there are some other supporting documents and forms such a handbook for the familiarization with the electronic services pertinent to the ILSA scheme that the Greek TSO provides in his web site and a set of forms that have to be filled in by the consumers. In addition, the Greek's Market Settlement Manual incorporates important information and examples on the scheme [57].

A key element of the scheme is the different patterns that have been designed by the Greek state (Greek TSO and RAE), under which the costumers are to shed load, during their participation in the ILSA. These patterns are called "Interruptible Load Services". Different types of these services might exist. The total number of different such services defines the different types of auctions that take place. Up to nowadays, two specific such services have been utilized and they are described in the following paragraph. We note, that although information for contemporary legislation pertinent to the ILSA scheme is presented (i.e. the 2020 law), due to the fact that there are slight – but important – differences between the laws around ILSA scheme, these differences are highlighted. Moreover, the graphical analysis following the law presentation, is based on the first (2015) and the second (2017) laws, since under the 2020 law, just one auction has taken place, and thus, the auctions sample under the third law is in reality inexistent.

3.2.3 Interruptible Load Services Types (ILST)

Number of Interruptible Load Services Types (ILST) is a critical element of the ILSA scheme, since the selection process (auctions) of the customers who will finally offer load reductions, are based on how many different types of ILSs exist. Up to nowadays, two types of ILSs exist, each one having the characteristics shown is the table below (2020 law):

Interruptible Load Service Type (ILST)	Notice Time	Maximum Duration of each Power Reduction Order (PRO)	Maximum Duration of Load Shedding per year	Minimum period between two consecutive Power Reduction Orders	Maximum number of Power Reduction Orders per month
1	5 minutes	48 hours	288 hours	1 day	3
2	1 minute	1 hour	36 hours	5 days	4

Table 1:

Interruptible Load Services Type [54]

A simplified definition for the Power Reduction Order (PRO) could be considered as "the notification from the Greek TSO towards a consumer that he has to shed according to what is stated in Interruptible Load Contract (ILC) that has been contracted between the Greek TSO and the consumer". It can be identified that PROs, further to their time characteristics that are shown in Table 1, incorporate a set of provisions which are included in the ILC. The ILC, in plain words, is the contract that the Greek TSO shall sign with a customer that will be successful in the auction process. The content of the ILC – and subsequently of the provisions that affect the PROs is explained in detail in paragraph 3.2.6.

We note that under the 2015 law, for the ILST 1, the Notice Time was 2 hours and the Maximum Duration of Load Shedding per year was 144 hours. This constituted a major change (at least as far as the Greek TSO perceives the frequency control services he utilizes for securing and stabilizing the electrical network) between the two laws, since the ILST 1 could now be considered to be more like a primary response or secondary frequency control mean rather than a tertiary mean as back in 2015. Yet, as it will be seen in the next paragraphs and in the graphical analysis, this change did not had an important effect on the consumers/participants behavior regarding their participation in the ILST 1 auction. Compared to the 2017 law, the 2020 remained the same.

Under both 2015 and 2017 laws, for the ILST 2, the Notice Time was 5 minutes and the Maximum Duration of Load Shedding per year was 24 hours. The reduction of the Notice Time to 1 minute under the 2020 law, constitutes a major change, since the ILST 2 can now be clearly considered as primary response frequency control mean (under a 5 minutes Notice Time, ILST 2 was considered somewhere among a primary and secondary frequency control mean). The response of the consumers to this change is yet to be seen and evaluated in the near future.

3.2.4 Eligibility Criteria

In the ILSA scheme the customers that can participate are large industrial HV and MV consumers which are interconnected to the Greek mainland grid (i.e. all islands are excluded). In order such a customer to be eligible to participate to the scheme, he has to register in the Interruptible Load Register (ILR) kept by the Greek TSO. The ILR has effect for a time frame of a calendar year, thus very year the Greek TSO re-requests from the potential interested parties (i.e. HV & MV customers) to renew their registration. This is mainly due to the fact that the consumption patterns might have been altered and thus the same to have happened to the characteristics (e.g.) amount of the offered interruptible load.

Further to the above, the criteria that have to be fulfilled in order for a HV and/or MV consumer to register in the ILR are:

a. To declare the Maximum Offered Interruptible Load (MOIL) per Interruptible Load Service Type (ILST) for each Consumption Location (CL – i.e. a location were power flows towards the customer's installation/infrastructure and is being measured with AMI that is being interconnected with the TSO and/or DSO).
b. The MOIL per ILST and per CL not to be less than 2MW (could be 5MW under the 2015 law and 3 MW under the 2017 law) and not more than what the TSO has announced for the specific call of registration in the ILR.
c. The MOIL has to be declared with an accuracy of 0,1MW per ILST for each CL and it cannot be altered throughout the year for with the ILR is valid.

MOIL can be perceived as the maximum potential that the consumer considers that he has to offer as a load throughout a calendar year. It is not necessarily the load up to which he might accept to shed, should he be selected to participate in the scheme. It is just a measured indication that this consumer is willing, under specific conditions that he are pertinent to his consuming patterns and that might change throughout a year, to shed up to this load, should these conditions are fulfilled.

The consumer can register to the ILR for any ILS and provide any of them, by declaring different interruptible load amounts for each auction that takes place for each

ILST. Yet, it is highlighted that the MOIL for registering to the type 2 ILS ILR refers only to the additional load that the consumer can offer, further to that he has already offered for the type 2 ILS ILR.

The ILR depicts a “pool” from which the Greek TSO can have a rough estimation of the total potential load that can be interrupted in the interconnected system, should the customers select to participate to the auctions of the scheme. It is noted that eligibility in participating to the scheme for a customer, does not necessarily mean that the customers is willing to participate to the scheme, nor that he will be chosen to participate, but only that he can be considered as a potential pre-selected tenderer in the ILSA scheme selection process, which is based on auctions organized by the Greek TSO.

In Figure 9, a simplified procedure for the registration in the ILR is depicted. It is highlighted that the procedure is followed once every year and for each CL, while all number designations after each abbreviation refer to the respective ILST. Thus, for example, the MOIL 1 is the MOIL offered for the type 1 ILS.

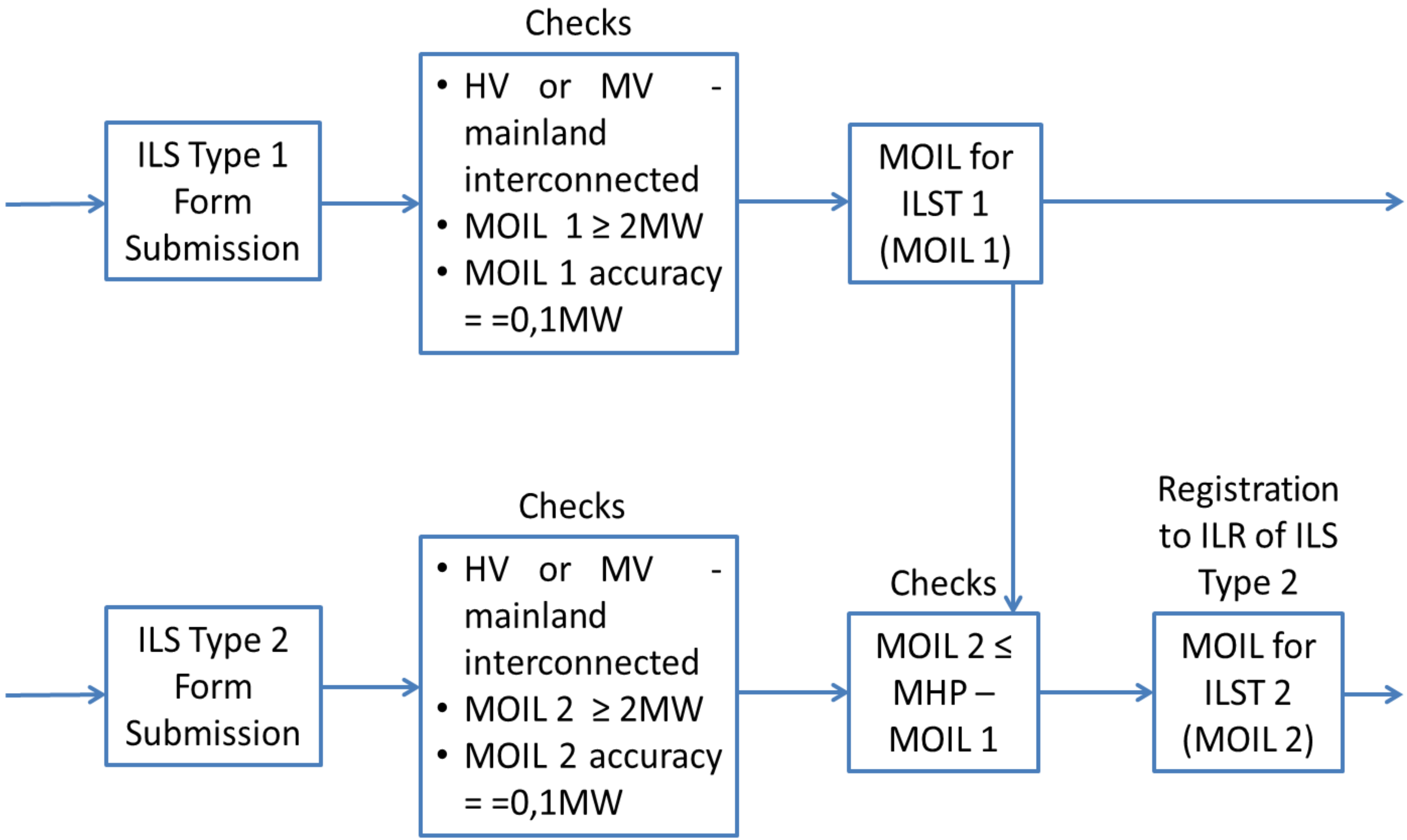


Figure 14:

Registration procedure to the ILR

3.2.5 Auctioning Process

The selection of the consumers who will finally offer load reductions (usually referred as “beneficiaries”, since they subsequently benefit from these reductions) is being made through an auctioning system, similar to the one utilized in a typical simple day-ahead market worldwide.

For a specific time frame within a year (usually for a duration around a complete semester or less) Greek TSO evaluates the potential needs in load reductions that might have to be made in the electrical interconnected grid, so as to face stability, security as well as transmission congestion problems. This load amount is mentioned as “Total Interruptible Power” (TIP). The TIP is calculated (evaluated) for each different ILST that the Greek TSO includes in the scheme (up to nowadays for the two ones shown in Table 1). After having calculated (evaluated) the TIP, Greek TSO announces that an auction shall take place, to which all eligible consumers can participate. The announcement is made with an issuance of a call of interest in its web site and on the press. TIP is calculated for each ILST for which an auction is to take place.

Following the announcement, the potential beneficiaries have to state, up to a specific date (prior to that of the auction), the amount of load that they are willing to shed upon receiving a PRO. This load is the Auction Declared Load (ADL) and is declared by the consumer by submitting to the Greek TSO a corresponding form for each type of auction (which corresponds to each ILST). For each ADL, a bid (price) is offered by the potential beneficiaries. The bid is given in Euros per Megawatt per Year (€/MW per year). It is noted that for each ILST, the consumer has to declare a different ADL, while the ADL itself can have different segments (i.e. one customer can offer one part of sheddable load amount for a price, while the remaining part to be offered with a higher price. Moreover, the ADL cannot be more than the MOIL of each consumer, as this is stated in the ILR.

It is highlighted that the ADL is not always the load amount with which the consumer will participate to the auction. Thus an additional term has been introduced in the ILSA scheme, the Auction Offered Load (AOL). The AOL is always the same as the ADL in the case of type 1 ILS. Yet, in the case of type 2 ILS, the AOL might be higher than the type 2 ILS ADL. This is due to a procedure that has been introduced with the 2017 law, through which an option is provided to the consumers to declare that any unselected ADL of type 1 ILS (or part of it) after the type 1 ILSA (due to high bidding price from the consumer’s side) can be offered for the type 2 ILSA (auction load “swift” from the type 1 ILSA to the type 2 ILSA). Thus, in this case, the AOL for the type 2 ILSA for a customer shall be the sum of the ADL for this type plus the part of the AOL of type 1 ILS that was not selected in the type 1 ILSA procedure. In order for the customer to participate to this procedure, a specific form has to be filled-in and submitted to the Greek TSO, the so called Shifting Load Participation Declaration (SLPD). If the consumer does not submit a SLPD, then the abovementioned load “swift” from type 1 ILSA to the type 2 ILSA, shall not apply, and thus the AOL for each type of ILSA shall be identical to the ADL for each ILSA. It is noted, that the consumer can offer sheddable load to any for any of the two ILST.

Beneficiaries are selected on the basis of uniform price auctions, in which the lowest-price bids will be selected, given the volume of each service requested (one of the two types mentioned earlier). Clearing of the auctioning process leads to a uniform auction price. This price is the one of the bid selected either in full or partially up to the limit of the offered capacity and constitutes the marginal price of the ILSA scheme (Auction’s Marginal Price – AMP) for this specific auction (see Chart 1).

We note that the Greek TSO has set down an upper limit on the bids that can be placed for each ILST. The maximum bid that can be placed for a type 1 ILS is at 65.000 €/MW per year, while for type 2 ILS it is at 45.000 (€/MW per year). An explanation on setting such limit can be perceived on the basis of the immaturity of the specific market and scheme (i.e. to provide a relatively controlled market environment, so as the Greek TSO to assess the willingness and capability of the interested parties / consumers to bid for the specific scheme). It is highlighted that under the 2015 law, the abovementioned upper limit was 50.000 (€/MW per year) for both ILS types, while under the 2017 law it was 70.000 €/MW per year for ILST 1 and 50.000 (€/MW per year) for ILST 2. More to the above, in its initial stages (as well as nowadays), the scheme had a specific financing mechanism with relatively low capitals for supporting it. Thus, setting down an upper limit could increase the likelihood for a number of players to symmetrically benefit from it.

The clearing procedure defines the Maximum Interruptible Load (MIL) for each beneficiary (and for each CL that he has declared), which is defined as “the maximum load that each beneficiary is willing to shed, as a result of the auction procedure”. This load is accepted by the Greek TSO to have slack (accuracy) of 0,1MW due to possible limitations of the measuring infrastructure and due to other communication constraints.

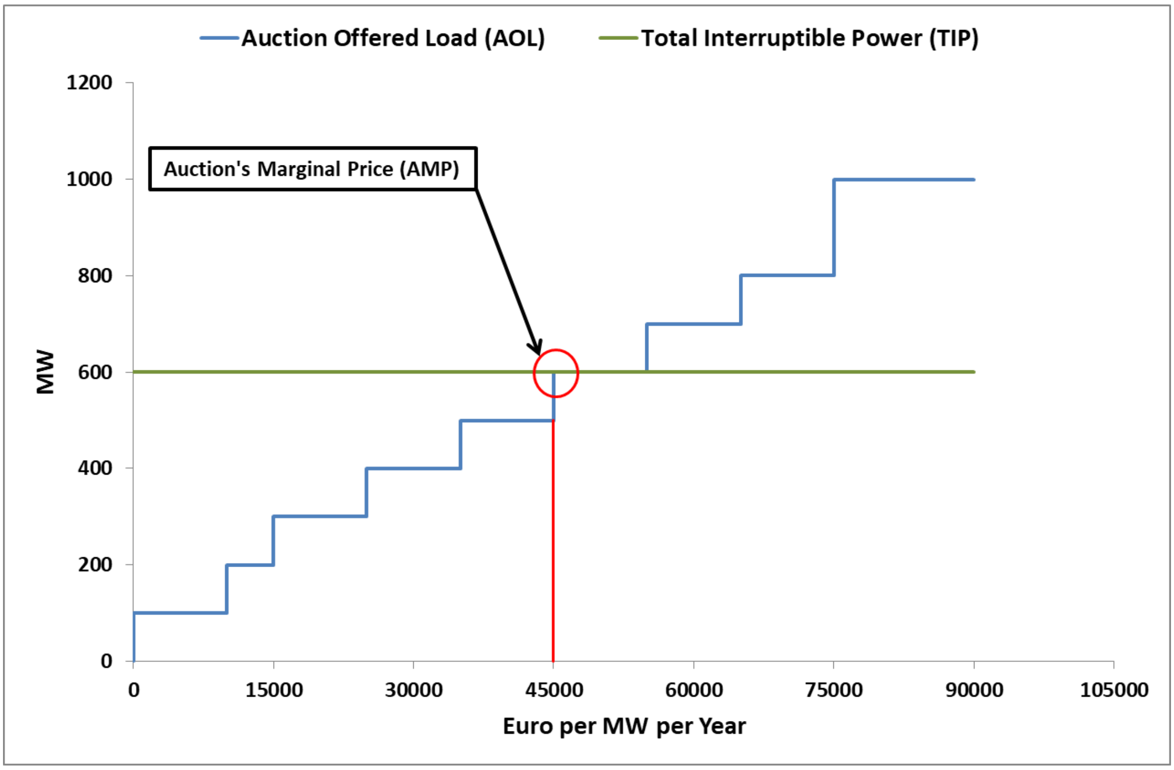


Chart 1:

Indicative Auctioning Process for selecting Marginal Price

Once the customer is registered in the ILR, he can participate in the auctions of the ILSA scheme that the Greek TSO announces throughout the year for which the MOIL is valid. There are two types of auctions, same as the ILSTs that exist and they take place on different (but usually consecutive) days. It is highlighted that the MOIL is declared for each type of ILST. Thus, it can be considered that two ILRs exist, that is as much as the ILSTs (or that the ILR has two different sub-registers for each customer).

In Figure 10, a simplified auction procedure is depicted. It is highlighted that the procedure is followed whenever the Greek TSO declares it and for each CL, while all number designations after each abbreviation refer to the respective ILST. Thus, for example, the AOL 1 is the AOL offered for the type 1 ILSA, while ILC 1 is the contract of type 1 ILS among the customer and the Greek TSO.

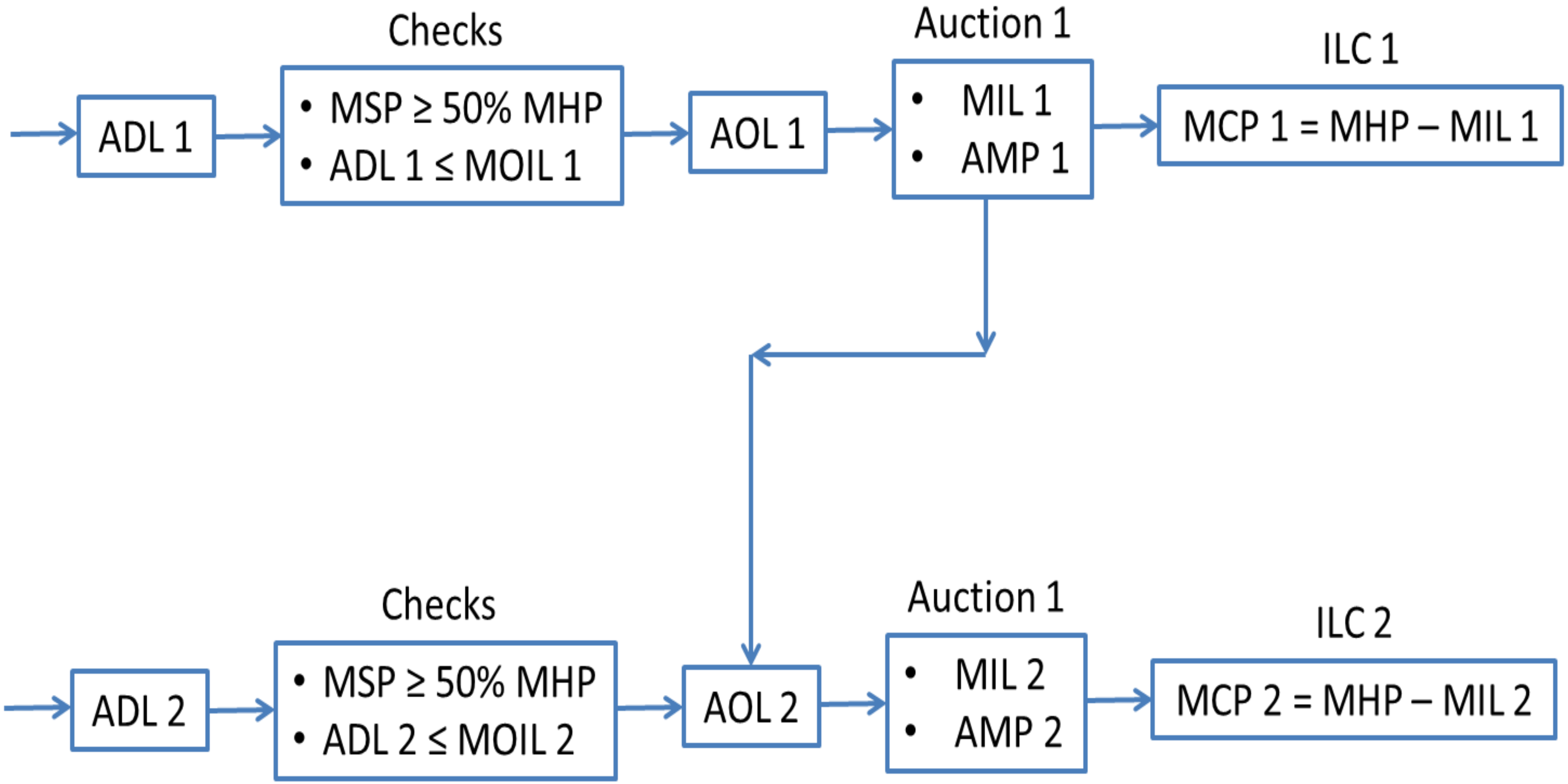


Figure 15:
Typical Auctioning Procedure

3.2.6 Interruptible Load Contract (ILC) – Main Terms & Implementation

The Interruptible Load Contract (ILC) is a set of provisions that the beneficiary agrees with the Greek TSO, as a result of the former being successful in the auction and should he is to receive a PRO during the time frame that the ILC holds.

The most important term in the ILC, which bonds most of the terms surrounding the ILSA scheme, is the "Maximum Contracted Load" (MCL). MCL applies for each one of the beneficiaries and it is defined as "the difference between the Maximum Historical Power (MHP) and the Maximum Interruptible Load (MIL) that was awarded to the beneficiary in the auction held". PROs are strongly correlated with MCL, since a PRO does not inform the beneficiary to shed a specific portion of the MIL, but it rather commands him to reduce its real time consumption (active power) up to a point but not lower than the MCL.

MHP, which applies too for each one of the beneficiaries, is a calculated value that is valid for one year (the so called year "N") is defined as the maximum hourly energy consumption (thus MWh per hour) for each CL for a period over the 1st December of the year N-3 (it was N-6 under 2015 law) up to the 30rd November of the year N-1. The MHP is calculated with up to 0,1MW slack (accuracy).

MHP serves a dual purpose. First, by utilizing MHP to calculate the MCL (which is the active power value under which the beneficiary is not obliged to curtail), the beneficiary is protected from being obliged to shed further than its minimum acceptable operational limits. To make this clear the following example is presented. Supposing that a HV industry has an MHL of 70MW, a MIL (as a result of an ILSA for a specific type) of 10MW, then the MCL shall be agreed at 70-10=60MW. Now, if the industry operates at 65MW at a given time point and the Greek TSO dispatches a PRO, the PRO can have as a maximum request for the beneficiary to reduce 5MW of his consumption. It is noted that although the MIL offered can be up to 10MW, due to the operational scheme of the beneficiary in this certain time point, he cannot – and he is not obliged to – reduce up to 55MW.

A secondary aim of the MHP is to provide a solid proof that the beneficiary is in full operation (since if during the last 5 years he consumes substantial amount of electrical energy, then the MHP should depict his potential to generally consume and subsequently to curtail his consumption) and thus, that his participation in the ILSA scheme and compliance to a PRO, is somehow detrimental for his operations, production and subsequently economic results. In this way, customers whose operations have ceased cannot really comply to any PRO, since, usually, the MHP is very low (or even zero) and thus they are discouraged to participate into an auction. Further to the above, the MHP can be utilized by the Greek TSO as an indirect proof that the customer is not eligible to register to the ILR and thus, to be excluded from the ILSA scheme for the year N.

It is worth to mention that the MHP is also related with the MOIL declaration. The sum of MOIL declarations (one for each ILST) cannot exceed the MHP of each consumer. This is an obvious – one could say – remark, since the probability that the beneficiary to exceed the MHP during the year N (which is the year during he participates to the ILSA scheme with this corresponding MHP) is considered extremely low.

Responsibility for measurement the MHP lies in the Greek TSO, by installing AMI is each CL which are interconnected to its informatics systems (the cost of this infrastructure might burden the customer, fully or partly). Yet, each customer can utilize its own AMI in order to double-check that the measurements are correct and to have data for the resolution of any potential disputes.

Reverting back to the PRO definition, we now understand that it is not just a notification from the Greek TSO to the beneficiary to shed load. The PRO incorporates the following characteristics:

a. It is different for each CL
b. It is different for each ILST
c. It incorporates a lower acceptable active power limit (the MCL), under which the beneficiary is not obliged to curtail, no matter the amount of MIL he has been awarded in the auction. Thus, the Greek TSO cannot request from the beneficiary to shed as much load as it is stated in the MIL, but just as much as it is allowed to reach the MCL.
d. It has specific time-oriented characteristics (notice times prior its execution, maximum time frames during which it can be valid, minimum period between two orders, maximum number of orders per month – see Table1)

3.2.7 Supplemental Provisions & Terms

The legislation framework of ILSA scheme defines few more terms, so as to complete the procedures pertinent to the auctions.

One such term is the Maximum Semestral Power (MSP) which is an index that has to be calculated for each consumer, prior each auction procedure of an ILST. The MSP is defined as the maximum hourly energy consumption (thus MWh per hour) for each CL for a period over the last semester which precedes the month that the specific auction takes place. The MSP is calculated in MWs with up to 0,1MW slack (accuracy).

The main aim of the MSP is to provide an indication to the Greek TSO, that the customer has not recently ceased or extensively minimized its operations and subsequently, that the ADL and/or the AOL with which he intends to participate in the auction, can be considered as a reliable statement. In order some sort of assurance to be provided upon the abovementioned concerns, in case that the MSP is lower than the 50% of the MHP, then the customer has to submit an essay to the Greek TSO, explaining the reasons why this deviation appears and to provide solid proof of his ability to offer to any of the ILSAs. In a sense, the MSP stands to the participation of a specific ILSA, what the MHP stands for the registration in the ILR. They both provide some sort of credibility regarding the participation of the consumers to the ILSA sheme.

Another term that is utilized is the Average Interruptible Load (AIL). The AIL is defined as the difference of the mean hourly energy consumption (in MWh per hour) and the MCL. AIL is calculated for each CL and for each ILST and it is calculated in MWs with up to 0,1MW slack (accuracy). This index is utilized in the calculation of the compensation of the beneficiaries (explained in the following paragraph).

3.2.8 Compensation of the Beneficiaries

Compensation to beneficiaries is paid according to their ability to reduce electricity consumption and the AMP is a key factor for determining it. Compensation is independent of the number, level or duration of PROs that are issued, in a sense that beneficiaries are not entitled to compensation for actually reducing active power following a PRO by the Greek TSO, but eventually, they are compensated in advanced, for their potential to shed load upon a PRO, whether the latter is dispatched or not. This can be clearly perceived by examining the formula through which the calculation of the compensation is made:

$$TMC_m = \sum_i (MILP_i \times MIL_i + AILP_i \times AIL_i)$$

Where:

- TMC_m denotes the beneficiary's total monthly financial compensation (Total Monthly Compensation) expressed in euros (EUR) for month 'm'
- $MILP_i$ denotes the rate per MW (Power) of Maximum Interruptible Load for service 'i', expressed in euros (EUR) and as resulting from the corresponding tender procedure, according to the following formula:

  $MILP_i$ = (1/12)* AMP*80%

- MIL_i denotes the "Maximum Interruptible Load" per MW for service 'i'
- $AILP_i$ denotes the rate per MW (Power) of "Average Interruptible Load" for service 'i', expressed in euros (EUR) and as follows from the corresponding tender procedure, according to the following formula:

  $AILP_i$ = (1/12)*AMP*20%

- AIL_i denotes the "Average Interruptible Load" per MW for service 'i' and month 'm'.

We note that the abovementioned formula is applied for each CL of the consumer. There is a cap up to which no further compensation per month can be provided. Under this cap, the total financial compensation for any one month cannot exceed a limit of €15 per MWh of electricity consumed by the beneficiary during the month. Applying the cap on the monthly consumption of a consumer is intended to ensure that only consumers that were really consuming energy during a month and thus could actually provide the interruptibility service will be reimbursed.

Under the 2017 the formula had the following form:

$$\mathrm{TMC}_m = \sum_{\mathrm{i}=1}^{2} (\mathrm{MILP}_i \times \mathrm{MIL_i} + \lambda_\mathrm{m} \times \mathrm{AILP}_i \times \mathrm{AIL_i})$$

The λ_m multiplier represented a coefficient who was dependant on the amount of energy consumed during the peak hours determined in the Management Code of the ILSA scheme for month 'm' and could take the following values (Table 2):

Percentage of energy consumed during peak hours	Coefficient λ_m
0 %-30 %	100 %
30 % - 60 %	100 %
60 %-100 %	100 %

Table 2:
Coefficient's λ_m values

Under the 2015 law the formula was exactly the same having a k multiplier in front of the sum:

$$TMC_m = \kappa \times \sum_i (MILP_i \times MIL_i + \lambda_m \times AILP_i \times AIL_i)$$

This multiplier represented a coefficient which was dependent on the total number of ILSTs provided by the consumer and could take the following values (Table 3):

Number of ILSTs provided	Coefficient κ
1	100 %
2	70 %

Table 3:
Coefficient's κ values

Closely examining the compensation formula, it can be understood that the total compensation is made up of two elements:

a. The first element aims to reimburse consumers for their long-term potential to reduce their load upon request during the time frame that a specific ILC is in effect. Indirectly, since that MCL of an ILC embodies the MHP as a variable in its calculation, it can be also considered that the first element is indirectly based on the peak load of the last five years. So, consumers with frequent peaks which are not flexible in being distributed in different time zones and/or days, are less likely to offer high AOLs (which in turn lead to low MILs)
b. The second element is based on the average metered load for the month. This takes into account the metered average potential of the consumer to provide interruptibility services for the month. The second addend is also affected by a coefficient λ_m, introduced in order to compensate consumers that can interrupt their load on specific hours that have been deemed crucial by the Greek TSO. In brief, the second element reimburses clients for being sort of "more available" to shed during a specific month during which the abovementioned ILC is in effect, compared to another month.

3.2.9 Penalties for Non – Compliance

Failure to comply with a PRO will result in penalties, intended to mitigate the risk that consumers might be tempted to proceed with the execution of an ILC, while being unable (or unwilling) to actually provide the service. For each PRO that the Greek TSO dispatches to a consumer, the following variable is being calculated:

$$NCC = \left[1 + \frac{\sum_1^{N_{NC}} \left(\frac{L_t - MCL_i}{MIL_i}\right)}{N_{NC}}\right]^{3/4} \times \left(1 + \frac{N_{NC}}{N_t}\right)^{3/4} - 1$$

Where:

- MCL_i denotes the Maximum Contracted Load per type 'i' of ILS
- MILi denotes the "Maximum Interruptible Load" per MW for service 'i'

- t denotes a specific period of time within the time frame that the PRO is considered active (i.e. has not been withdrawn from the Greek TSO) and is set at 15 minutes
- L_t denotes the Mean Load of the consumer, as this is calculated by measuring the consumed energy in the PRO's CL for 15 minutes
- N_{NC} denotes the number of the fifteen-minute periods t that the PRO was not followed by the consumer
- N_T denotes the total number of the fifteen-minute periods t that a PRO consists of.

Should the result of the calculation of the NCC variable is more than 0,2 (NCC≥0,2), then, the consumer is considered not to have complied with the PRO and thus, a penalty shall be applied to the consumer. The applied penalty has to forms:

a. For a first failure to comply, the penalty will be equal to the total remuneration the consumer has received up to this specific time point (under the provisions of the specific ILC that has been agreed) multiplied by the NCC variable. Yet, in any case the penalty cannot be more than 110% of the total contractual payment he was entitled to up to this time point.
b. In case of a second failure to comply, the agreement (ILC) with the Greek TSO is automatically terminated and the consumer is required:
    i. to return all payments already received and
    ii. to pay in addition a penalty equal to 20% of the total remuneration deriving from the contract had it not been terminated.

We note than in case of a second failure to comply, the consumer is automatically being unregistered from the ILR for the specific CL that he did not complied with the PRO.

Under the 2015 law the formula had the following form and the NCC value should have been more than 0,25 (NCC≥0,25) so as a beneficiary to have been considered that he had not complied to a PRO:

$$NCC = \left[1 + \frac{\sum_{1}^{N_{NC}} \left(\frac{L_t - MCL_i}{MIL_i}\right)}{N_{NC}}\right] \times \left(1 + \frac{N_{NC}}{N_t}\right) - 1$$

3.2.10 Collateral Clauses

Ministerial decision published in the governmental gazette 4546/2017, included further clauses that supplemented the ILSA scheme and had to deal with collateral issues such as procedural information regarding the registration to the ILR, details on the dispatch procedure of a PRO (either in a HV consumer or a MV consumer), consumers' technical and safety obligations, the impact that each electrical power generation technology had in the necessity of interruptible load services such as the ones of the ILSA scheme and the economic viability of the scheme and its financing mechanisms.

The analysis of these collateral clauses lies beyond the scope of this thesis, since the main aim is to assess the results of the ILSA scheme up to nowadays in the Greek energy market and especially the up to nowadays participation of the Hellenic Petroleum Aspropyrgos Industrial Complex (Refinery) and the latter's opportunities under this scheme. Thus, as a next step a general overview of the up to now activity around the ILSA scheme is provided.

3.3 Summary of the Main Differences of 2015, 2017 and 2020 Laws

In the following table (Table 4) the main differences between the 2015, 2017 and the 2020 laws are summarized.

2015 vs 2017 vs 2020 Laws on ILSAs - Main Differences			
Aspect	**Under 2015 Law**	**Under 2017 Law**	**Under 2020 Law**
Calculation on Maximum Historical Power	5 previous years taken into consideration in the calculation	2 previous years taken into consideration in the calculation	2 previous years taken into consideration in the calculation
ILST 1 Notice Time	2 h	5 min	5 min
ILST 2 Notice Time	5 min	5 min	1 min
ILST 1 Maximum Duration of Load Shedding per year	144 h	288 h	288 h
ILST 2 Maximum Duration of Load Shedding per year	24 h	24 h	36 h
Maximum Bidding Limit for ILST 1	50.000 €/MW per year	70.000 €/MW per year	65.000 €/MW per year
Maximum Bidding Limit for ILST 2	50.000 €/MW per year	50.000 €/MW per year	45.000 €/MW per year
Minimum MOIL (per ILST and per CL)	5 MW	3 MW	2 MW
Compensation Formula	Affected by the number of ILST provided by the beneficiary ("κ" factor included) and the percentage of energy consumed during peak hours (λ_m coefficient)	Not affected by the number of ILST provided by the beneficiary ("κ" factor excluded) but affected by the percentage of energy consumed during peak hours (λ_m coefficient)	Not affected by the number of ILST provided by the beneficiary ("κ" factor excluded),neither from the percentage of energy consumed during peak hours (λ_m coefficient)
Penalty (for non-compliance) Formula	Without 3/4 power factor	With 3/4 power factor	With 3/4 power factor
NCC values above which non-compliance is	≥ 0,25	≥ 0,2	≥ 0,2
Shifting Load Participation Declaration (SLPD)	No	Yes	Yes

Table 4:
Main Differences of 2015, 2017 and 2020 Laws on ILSA

CHAPTER 4: ASSEMENT OF THE GREEK INTERRUPTIBILITY SCHEME – CONTRIBUTION TO THE GREEK ENERGY MARKET

4.1 Historical Flashback

Following the establishment of the Greek legislative framework, the Greek TSO made the first public announcement pertinent to the ILSA scheme in the 12th of January of 2016 [59]. In this announcement, Greek TSO called all interested parties to register for the first time to the ILR. Few days later, in the 20th of January [60], Greek TSO called for a public commentary on the Regulation of the Interruptibility Load Service Auction, while about 2 months later, in the 8th of February, the regulation started to become applicable. Almost concurrently, the electronic platform for submitting consumers' offers and the pertinent manuals were launched. The first auctions – one for each ILST – took place in February 2016 and the results were published in Greek TSO's web page in the 29th of February 2016.

4.2 Data Analysis of Auctions

Up to nowadays, thirty-six different auctions have taken place (eighteen for ILS Type 1 and eighteen for ILS Type 2) [61]. In the following paragraphs an attempt to present the most important numerical information of the results of these auctions shall be made. Furthermore, a statistical analysis of some (selected) of the outcome figures shall be presented, as well the introduction of several indexes that characterize the auctions and lead to interesting remarks, shall be made. Data utilized for this analysis were mined from the Greek TSO (ADMIE) web page. A summary of these data is shown in the Attachments "A" and "B" of this Thesis.

We note that the analysis has not included the seventeenth and eighteenth auctions, since these two were based on the most recent law, and thus, the sample for evaluation is considered too small.

4.2.1 AMP & TIP Statistics

In tables (Tables 5 & 6) and charts (Chart 2 & 3), the AMP value of all auctions that have taken place since 2016 is depicted. Table 5 and Chart 2 depict the ILS type 1, while Table 6 and Chart 3 depict ILS type 2. We note that in the tables, both nominal values of the AMP of the corresponding years is shown, as well as the corrected (present) values by applying the inflation in the AMP values [62]. Yet, as the calculations of the present value of AMP show, there is no substantial difference between them (compared to their reference year), since the inflation rate throughout the last four years is low (from 0% up to 2% maximum). Close examination of the data lead to some interesting observations.

The first two auctions resulted in very low AMPs (compared to the auctions in the following years), both for ILST 1 & 2. This can be attributed to the fact that since the consumers had no previous data on how this new market is valued, they were reluctant to bid high and risk not to be selected to participate. Especially consumers who could more easily adjust their consumption patterns – and thus the opportunity cost to cut-down power was less to them compared to other consumers who took part in the auctions – could pretty easily bid low, in order to be successful and become beneficiaries of the scheme and subsequently gain more experience on how they could evaluate their participation (e.g. assess how often they are called to reduce consumption and how this affects their production patterns and financial results, their future bidding strategies on the next auctions in order to maximize their benefit from their participation, etc).

It is also noticeable that in these two first years, the AMP values – for the ILST 2 especially – were formed way below the prices of the following years, at one fifth (for the 1st ever auction) up to less than a half (for the 2nd auction) of the latter, compared to the ILST 1 corresponding values (which are at about three fifths of the following years). A possible explanation on this, could be the fact that the ILST 2 would be more attractive to the consumers back then, since it only requires reducing the consumption for a period of 1 hour, while in addition, the maximum duration of load shedding per year is narrowed to 24 hours (in comparison to the 144 or 288 hours that ILST 1 required or requires), rendering it a less risky choice. So, even if the customer's initial estimations on the financial benefits he could have, compared to the financial losses due to the abruptions in the production processes where wrong and led to damages in the overall financial results, the time exposure to such a state would be far more less compared to the ILST 1 obligations (144 or 288 hours per year of potential compliance versus only 24 hours). Of course, after gaining the required experience on how consumers can cope with the obligations they have to carry out, it seems that both ILSTs gain ground on the consumers interest and thus, the AMP for both of them has risen in the following years/auctions.

A final observation is that in relatively short time (less than half a year for both ILST 1 and ILST 2) the AMPs have reach very close to the maximum bid value that has been set as allowable from the Greek TSO. The actual AMP has reached the maximum bid limit within half a year from the ILSA scheme's establishment. This phenomenon can also be attributed to the same reasons mentioned in the previous paragraph, but can also indicate that the potential benefit for the consumers/beneficiaries is quite high, compared to the losses they endure due to their production processes. The assessment on how high the bidding value should be allowed to be, lies beyond the scope of this thesis, but commenting on how fast and close the AMP reached whose limits for each ILST, it is a wiseful remark for re-evaluating the ILSA scheme as a market tool.

More to the above, in these tables and in Chart 4, the TIP that the Greek TSO declared (as another necessary instrument for the proper operation of the Greek electrical system in terms of security, stability and economic efficiency) is presented, just to have a rough overview of the evolution of the TIP value and subsequently of the electrical system's needs during the last four years (i.e. during the total time that the ILSA scheme fully operates). It can be noted that during the ILSA scheme operation, both ILSTs follow the same patterns in relation to their fluctuations from auction to auction. During the first two years of the scheme operation, the TIPs' fluctuations were noticeable. There are several reasons to which this phenomenon might be attributed. The immaturity of the market to which this scheme was addressed played an important role, but most probably the fact that Greece was under the fiscal control of the support mechanism of the IMF (which severely affected the growth of the Greek economy and thus the production patterns and schedules of large electrical power consumers) was a more crucial factor. Substantial differences in electricity demand from time to time (due to large consumers setting their production units to work intermittently throughout a calendar year) might have led the Greek TSO to evaluate that the Greek electrical system required substantially different amounts of sheddable power even between adjacent time periods within a calendar year in order to operate safely and efficiently.

A final remark on the TIP's evolution is that during the last two years it has stabilized to relative low levels (even if compared with the mean values of the first two years). The stabilization to relative low values might have an indirect connection with the formation of the AMPs values, since the latter have also been stabilized very close to the maximum allowable bid limits. Thus, the Greek TSO might have reduced the amount of the sheddable load he requires for ensuring the safe and efficient operation of the electrical power grid, so as to push the consumers that are eager to participate in the ILSA scheme to bid lower in order to become beneficiaries. Of course, the Greek TSO should have to introduce other tools for balancing the shortage in the potential sheddable load, such as hot stand-by power generation units or other means which aim to the increase of electrical power production instead of the curtailment of the consumption.

Auction No	Year	Auction code	Auction Validity Period	Total Interruptible Power (TIP - in MW)	Auction Marginal Price (AMP - in €/MW per year) at reference year	Auction Marginal Price (AMP - in €/MW per year) nowadays (Present value - 2020)
1	2016	201601_LT	01/03/2016-31/03/2016	500	30000	30600
2	2016	201602_LT	01/04/2016-30/04/2016	650	30000	30600
3	2016	201603_LT	01/05/2016-30/09/2016	750	48600	49572
4	2016	201604_LT	01/10/2016-31/12/2016	550	49900	50898
5	2017	201701_LT	01/1/2017-31/03/2017	750	50000	51000
6	2017	201702_LT	01/4/2017-30/06/2017	500	50000	51000
7	2017	201703_LT	01/7/2017-30/09/2017	580	41200	42024
8	2018	201801_LT	17/1/2018 - 28/2/2018	600	55000	55550
9	2018	201802_LT	01/03/2018-31/05/2018	620	56900	57469
10	2018	201803_LT	01/06/2018-30/09/2018	600	59700	60297
11	2018	201804_LT	01/10/2018-31/12/2018	600	60450	61054,5
12	2019	201901_LT	01/01/2019-31/03/2019	600	59350	59943,5
13	2019	201902_LT	01/04/2019-30/06/2019	600	59120	59711,2
14	2019	201903_LT	01/07/2019-30/09/2019	600	63000	63630
15	2019	201904_LT	01/10/2019-31/12/2019	600	62200	62822
16	2020	202001_LT	01/01/2020-06/02/2020	600	65800	65800

Table 5:

Type 1 ILS Auctions' Clearing Results (AMP formation) [Source: ADMIE]

Auction No	Year	Auction code	Auction Validity Period	Total Interruptible Power (TIP - in MW)	Auction Marginal Price (AMP - in €/MW per year) at reference year	Auction Marginal Price (AMP - in €/MW per year) nowadays (Present value - 2020)
1	2016	201601_ST	01/03/2016-31/03/2016	500	10000	10200
2	2016	201602_ST	01/04/2016-30/04/2016	850	21900	22338
3	2016	201603_ST	01/05/2016-30/09/2016	900	47600	48552
4	2016	201604_ST	01/10/2016-31/12/2016	650	49300	50286
5	2017	201701_ST	01/1/2017-31/03/2017	900	48000	48960
6	2017	201702_ST	01/4/2017-30/06/2017	500	47500	48450
7	2017	201703_ST	01/7/2017-30/09/2017	900	44000	44880
8	2018	201801_ST	17/1/2018 - 28/2/2018	450	42000	42420
9	2018	201802_ST	01/03/2018-31/05/2018	450	44000	44440
10	2018	201803_ST	01/06/2018-30/09/2018	430	43000	43430
11	2018	201804_ST	01/10/2018-31/12/2018	430	49000	49490
12	2019	201901_ST	01/01/2019-31/03/2019	430	49800	50298
13	2019	201902_ST	01/04/2019-30/06/2019	430	49900	50399
14	2019	201903_ST	01/07/2019-30/09/2019	430	49900	50399
15	2019	201904_ST	01/10/2019-31/12/2019	430	49900	50399
16	2020	202001_ST	01/01/2020-06/02/2020	430	49900	49900

Table 6:

Type 2 ILS Auctions' Clearing Results (AMP formation) [Source: ADMIE]

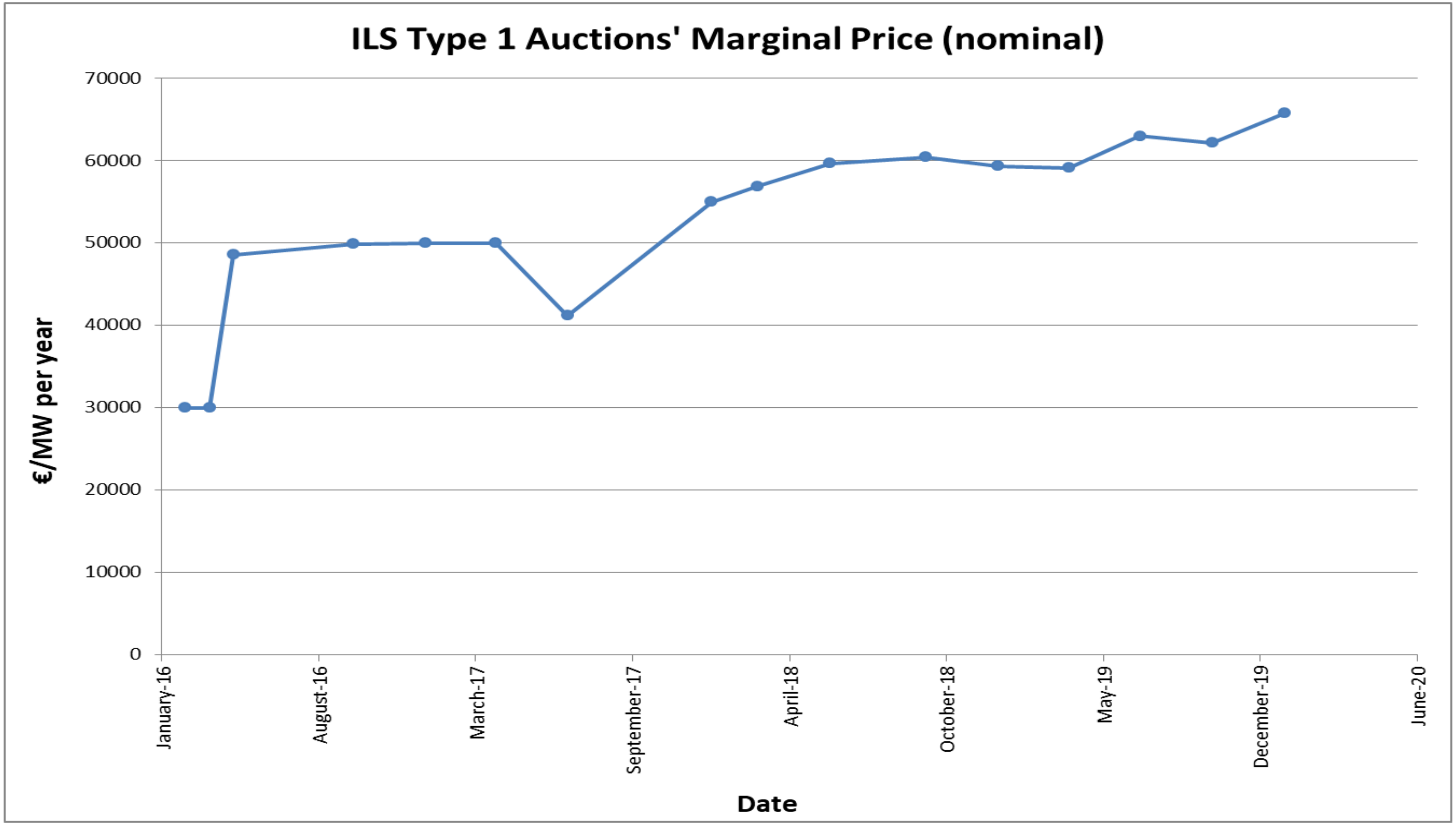


Chart 2:

Type 1 ILS Auctions' Clearing Results (AMP formation) [Source: ADMIE]

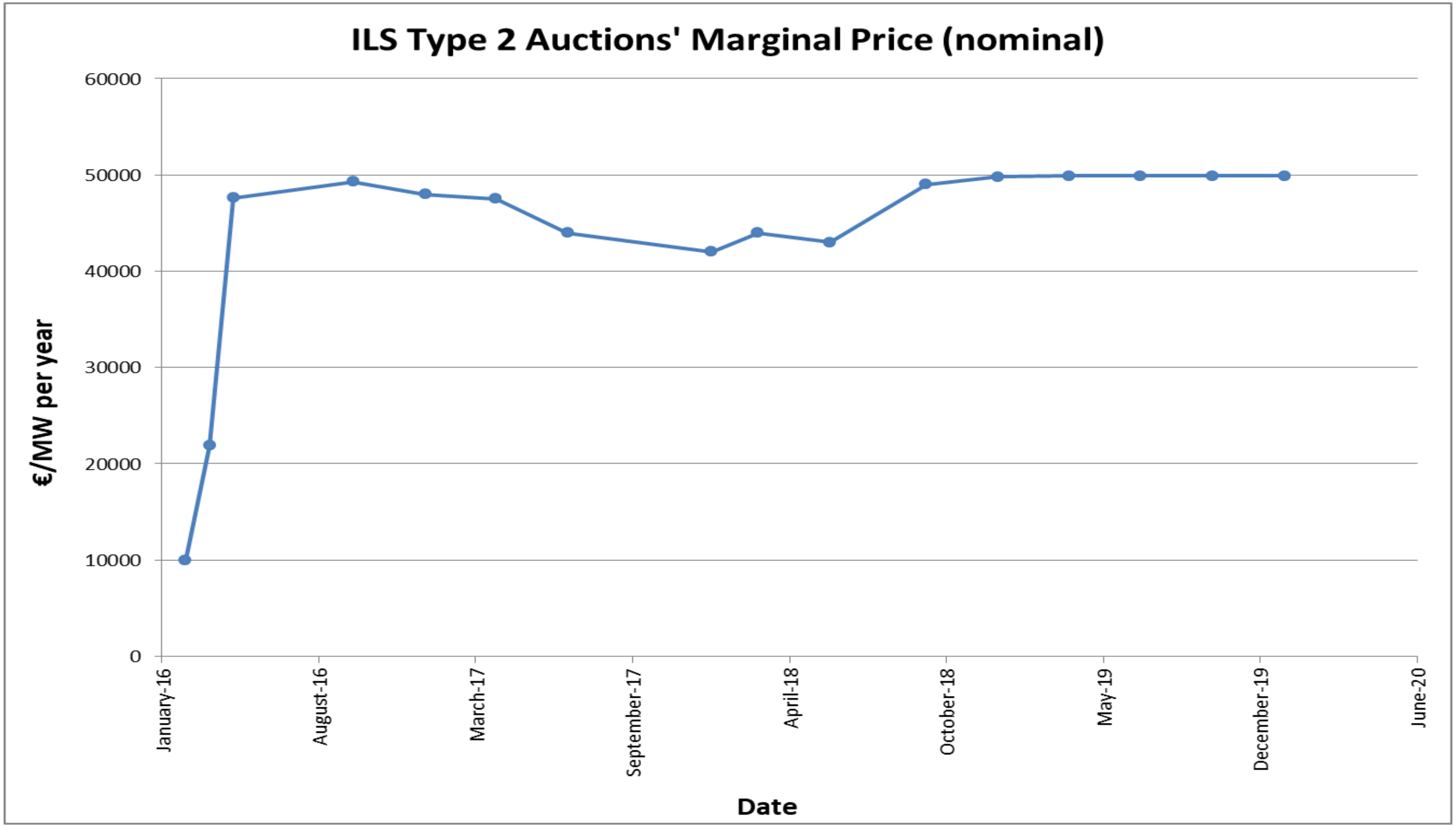


Chart 3:
Type 2 ILS Auctions' Clearing Results (AMP formation) [Source: ADMIE]

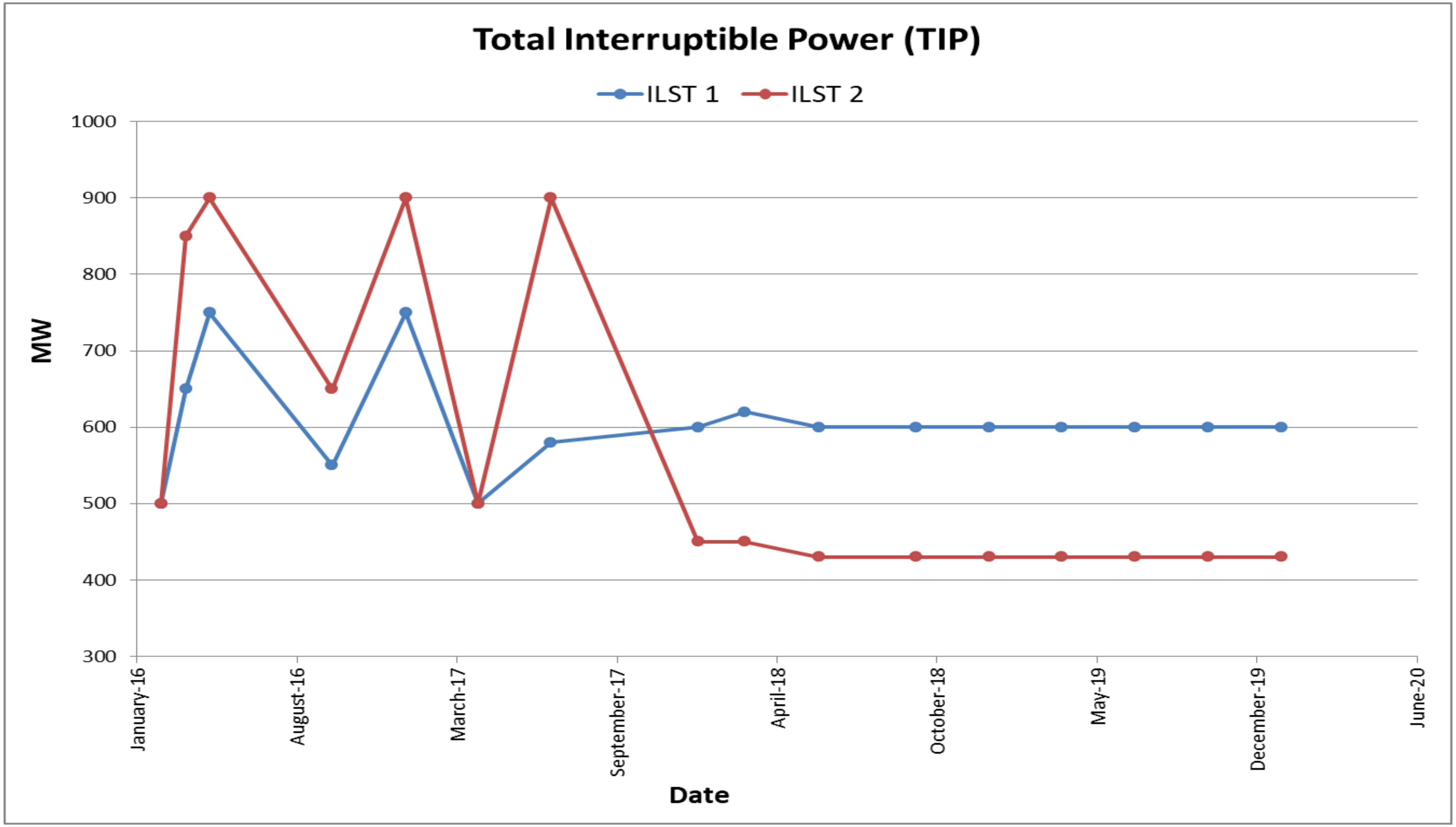


Chart 4:
Total Interruptible Power (TIP) evolution per ILST [Source: ADMIE]

4.2.2 Analysis of Bidders Profile

The ILSA scheme has attracted several HV and MV consumers, taking into account the fact that Greece is not a heavily industrialized country. In the following charts (Charts 5 & 6) the overall participation of all bidders in any of the two auctions (either for ILST 1 or ILST 2) are presented. In each chart two important pieces of information are presented (per ILST): (a) the total number of bidders that have ever participated in least one auction and (b) the total number of bidders that ever had at least one successful participation.

Also, a further segregation of this information is attempted, by presenting it either by how many CLs have even participated at least one time or have ever become successful at least one time (i.e. no matter if they belong to the same company), or irrespectively of the total number of CLs that the bidders are providing (i.e. how many different companies have ever become successful at least for one time).

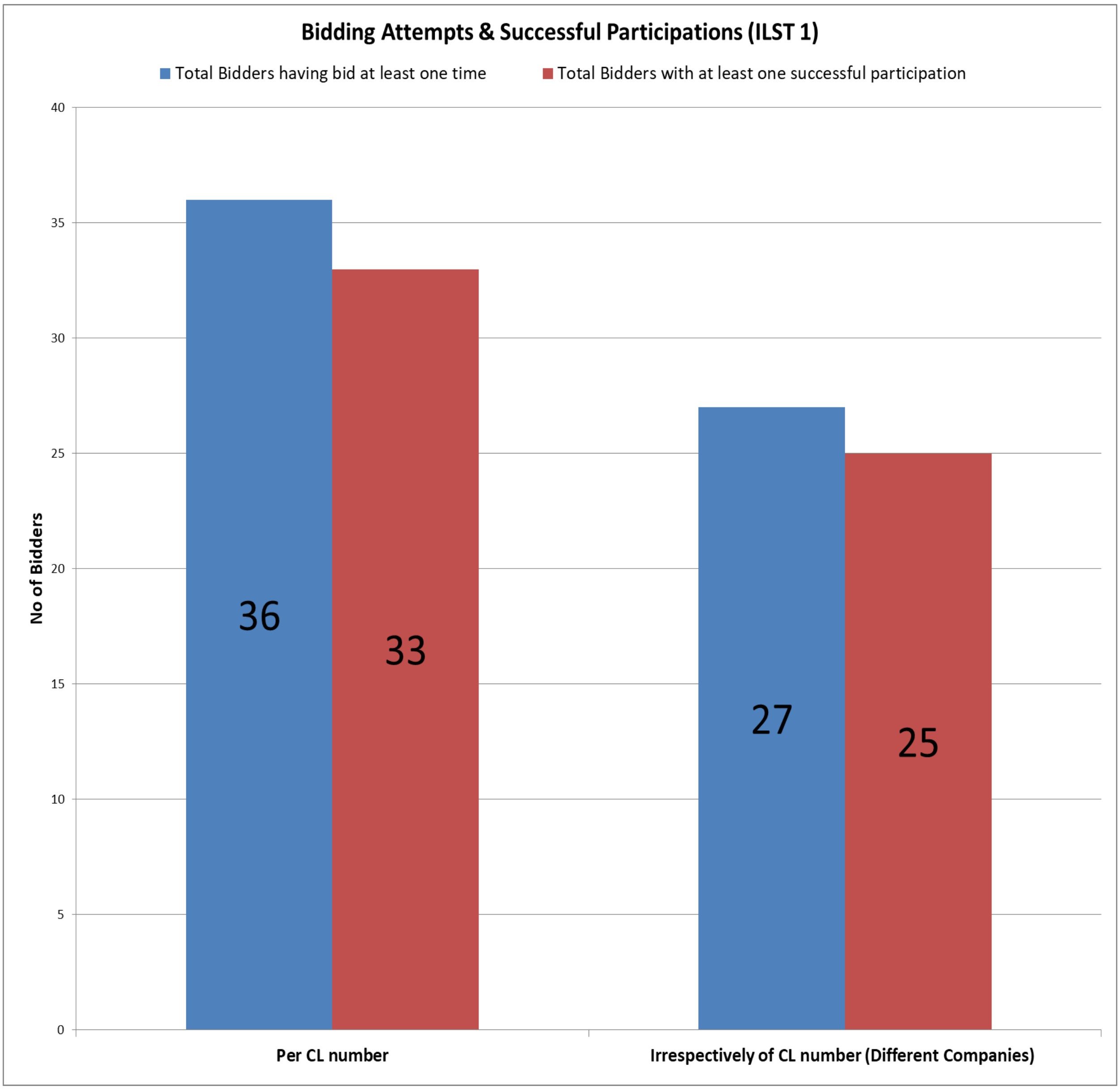


Chart 5:
Bidders' cumulative participation to ILSA Type 1 bidding procedure and corresponding success from ILSA scheme establishment [Source: ADMIE]

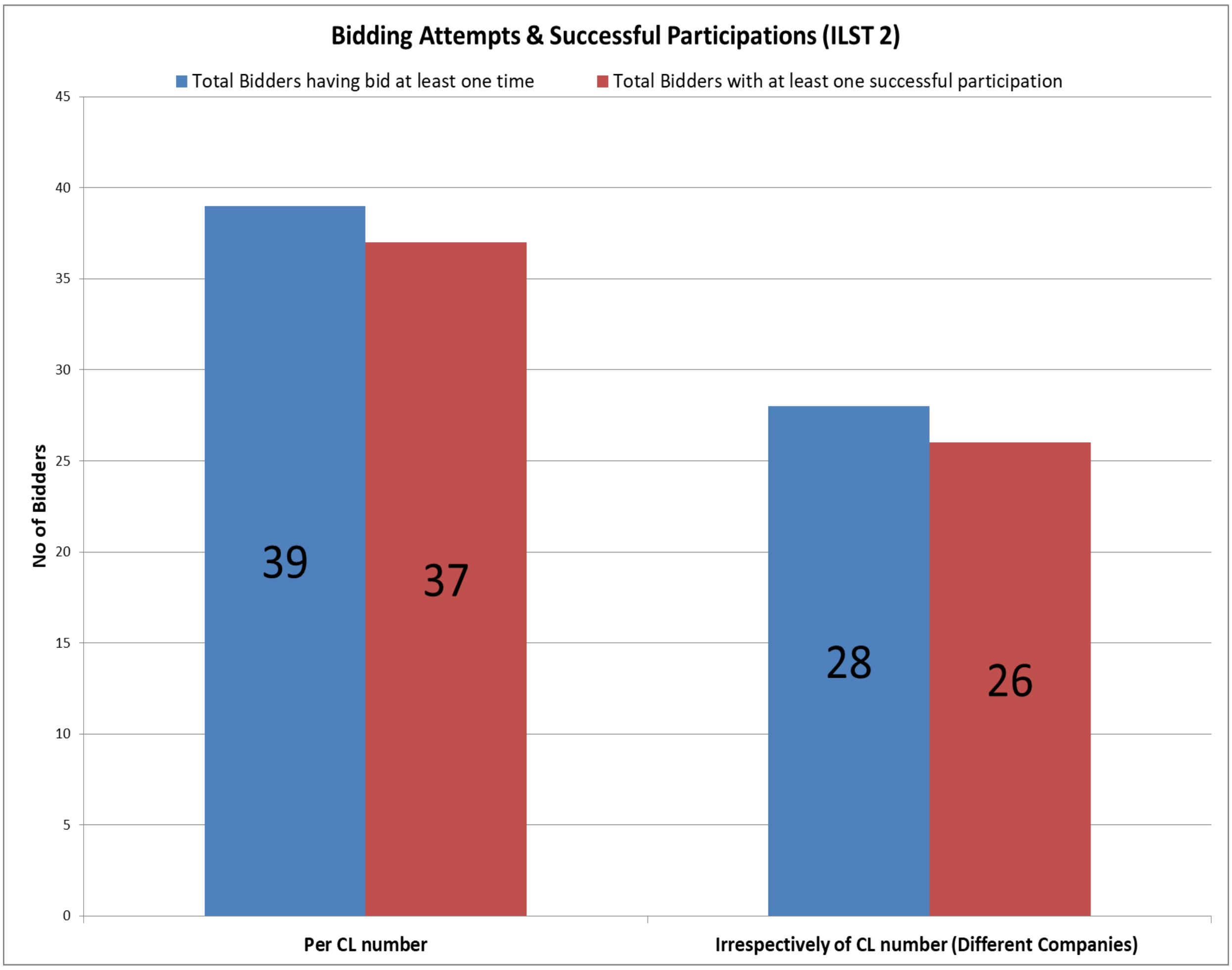


Chart 6:
Bidders' cumulative participation to ILSA Type 2 bidding procedure and corresponding success from ILSA scheme establishment [Source: ADMIE]

From the comparison of the two different columns in the above charts ("*Different Companies*" vs "*Per CL number*"), it can be easily be understood that the vast majority of the companies that have become successful in at least one auction, only has 1 CL. This is further depicted in Chart 9. This is another indication that Greek industrial sector has few major industries with different production units, which could be utilized as CLs. Most companies only possess one major industrial unit, which is feasible to participate to the ILSA scheme. Another interesting fact is that almost all bidders that have ever submitted a bid, have become successful at least one time during the ILSA scheme operation.

Useful remarks can be extracted if Charts 7 and 8 are examined. In these, the number of consumers that have participated (submitted at least one bid) in each auction procedure is shown, grouped in the following three groups: (a) having bid to 1-3 auctions, (b) having bid to 4-9 auctions and (c) having bid to 11-16 auctions. It is clearly seen that more than half companies interested on the ILSA scheme for Type 1 service are bidding quite often (16 with more than 11 participations versus 6 and 5 respectively having less). Most of them are utilizing most of their CLs, since when it comes to an analysis based on CLs, the corresponding number is launched to 24 Cls. Taking a closer look to the ILST 2, we can see that there is equality on the groups corresponding to 4-9 auctions and 11-16 auctions. Although this could be initially interpreted as the ILST 2 to be less appealing to the consumers, on the contrary, this matching can be attributed to the Shifting Load Participation Declaration (SLPD) procedure that has been introduced with the 2017 law.

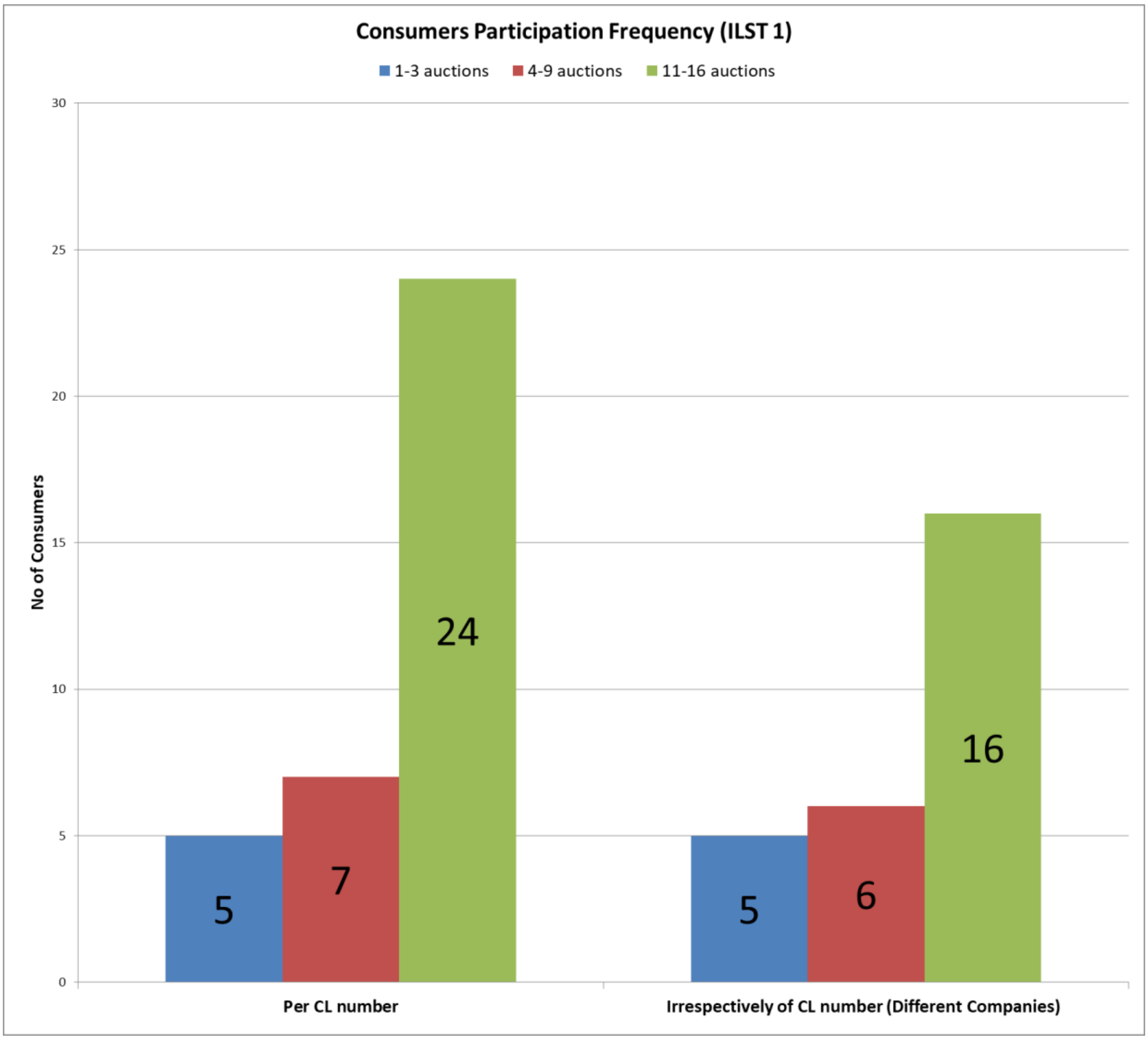


Chart 7:
Grouping of Consumers in respect to the number of auctions that they have submitted at least one bid to the ILSA Type 1 [Source: ADMIE]

Under the SLPD procedure, a consumer could indirectly bid for both services (either ILST 1 or 2), provided he was not successful in the ILSA Type 1. Thus, this rendered feasible for any consumer interested in participating to ILSA type 2 to realize it, although he did not had enough CLs to bid for both service types. Before the establishment of this procedure, there was a noticeable number of consumers that bid less than 11 times (as Chart 8 shows) for the ILST 2, since they had to choose between the two IL services, and as a result, should they participated to the ILST 1, they could not participate to the ILST 2.

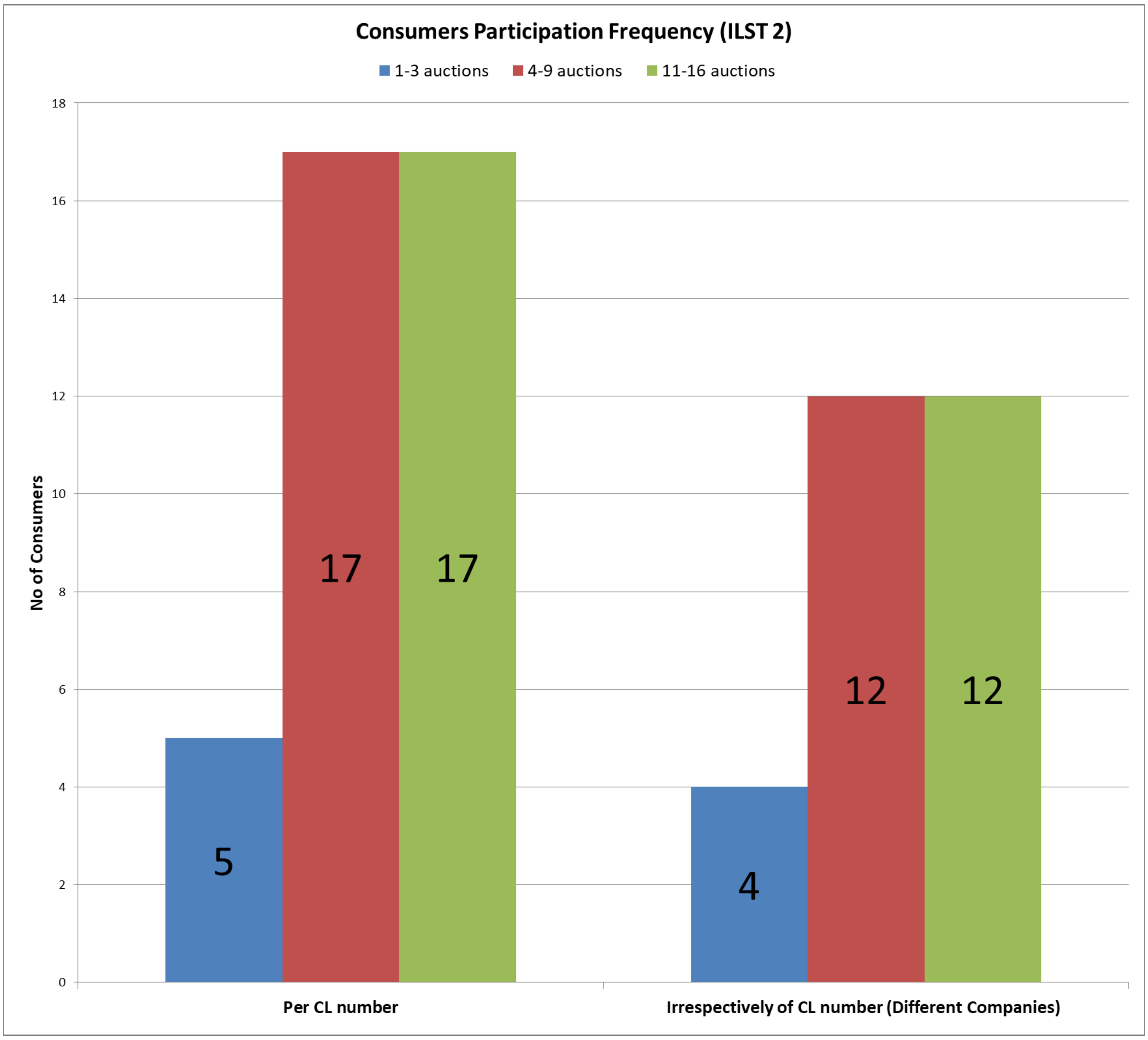


Chart 8:
Grouping of Consumers in respect to the number of auctions that they have submitted at least one bid to the ILSA Type 2 [Source: ADMIE]

4.2.3 Analysis of Beneficiaries Profile

Since form the previous analysis, the number of bidders almost coincides with the number of successful participants (beneficiaries), the focus of the analysis turns to the latter. As already mentioned in the previous paragraph, the number of CLs per beneficiary is depicted in Chart 9 and it is clearly shown that most of the beneficiaries are offering just one CL.

Focusing on industry-specific analysis, there are several interesting remarks that can be made. Firstly, the ILSA scheme seems to be quite attractive – and probably more feasible for them to participate – to the steel industry, since five different companies have managed to succeed in the auctions. Cement industries with three different companies follow, while two different companies can be identified in oil & gas and paper-pulp industries. Cables manufacturing industries also appear with two different participants, but since their overall participation in MWs (as this is analyzed in the following paragraphs) is low, they are not mentioned as key players. These remarks are graphically presented in Chart 10.

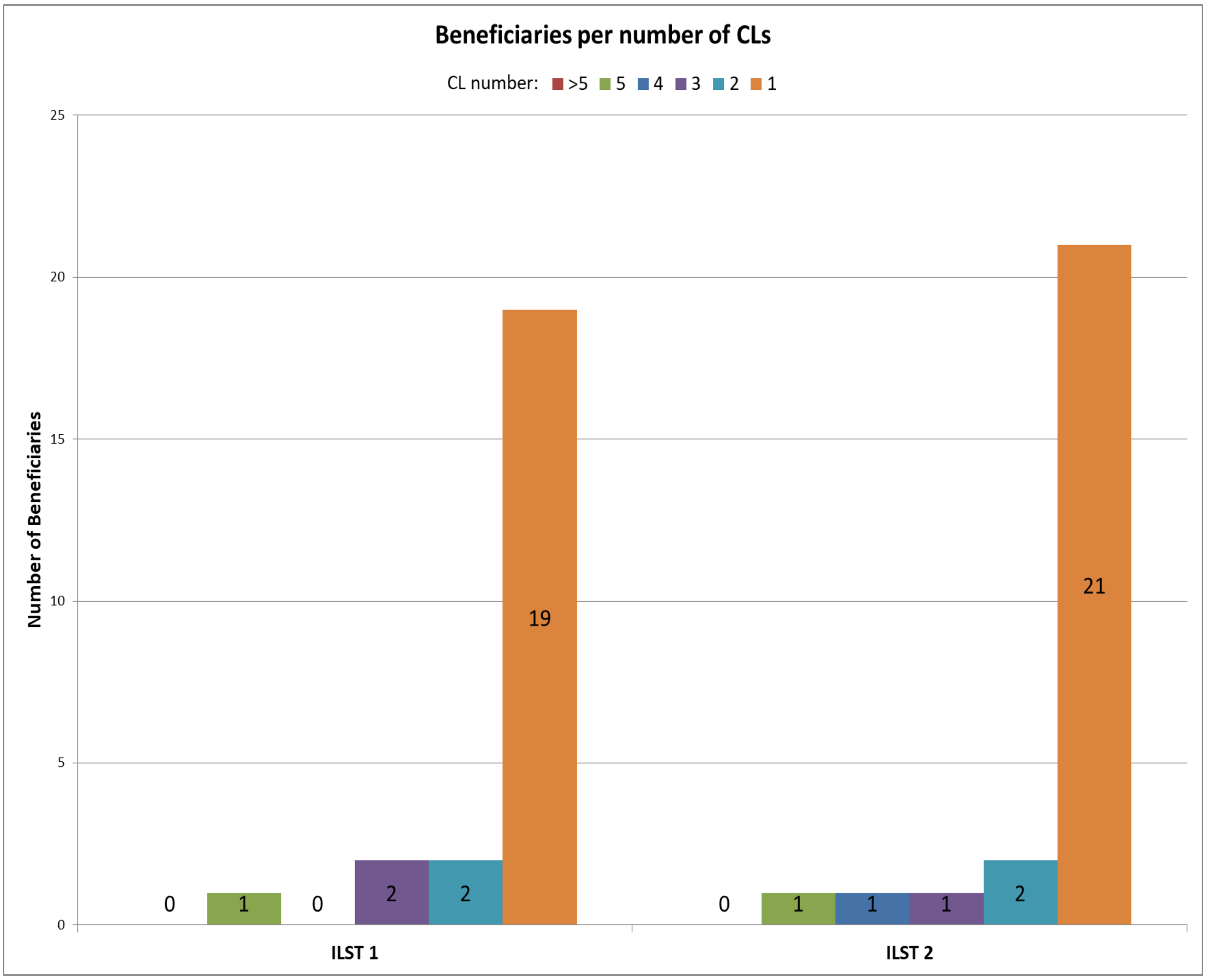


Chart 9:
Beneficiaries per Number of CLs (that have at least become successful once in any auction) [Source: ADMIE]

If the CLs are analyzed, then the abovementioned remarks are further strengthened, while the mining industry seems to also fit well in the ILSA scheme. Yet, it has to be highlighted that almost all CLs pertinent to the mining industry belong to the PPC (PPC lignite mines). These mines are the lignite mines that supply with fuel the old electrical power generation units. There is a strong tendency from the Greek TSO to dispatch as little as possible the old (and highly polluting) generation units, thus, the fact that PPC can easily offer these mines for participation to the ILSA scheme might be attributed to the fact that the lignite extraction is severely being diminished during the last years as a results of environmental constraints pertinent to the electrical power generation from old thermal power stations utilizing this fuel. Moreover, the other industry that has mining activities, Larko S.A., faces severe financial problem in its operation and thus, interruptions in the mining processes might be boosted from that fact. These remarks are graphically presented in Chart 11.

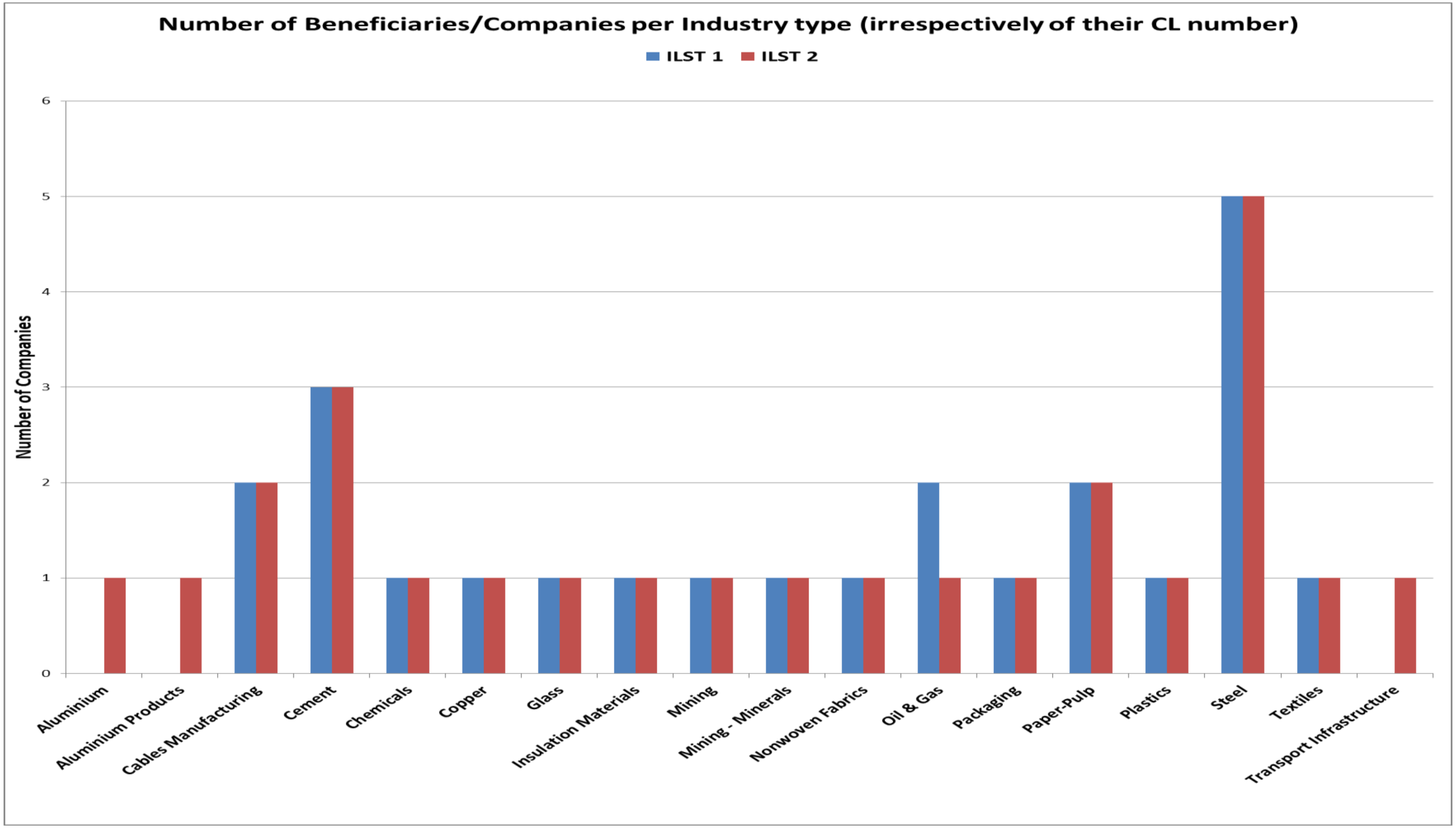


Chart 10:
Number of Beneficiaries/Companies per Industry type (irrespectively of their CL number) for each ILST [Source: ADMIE]

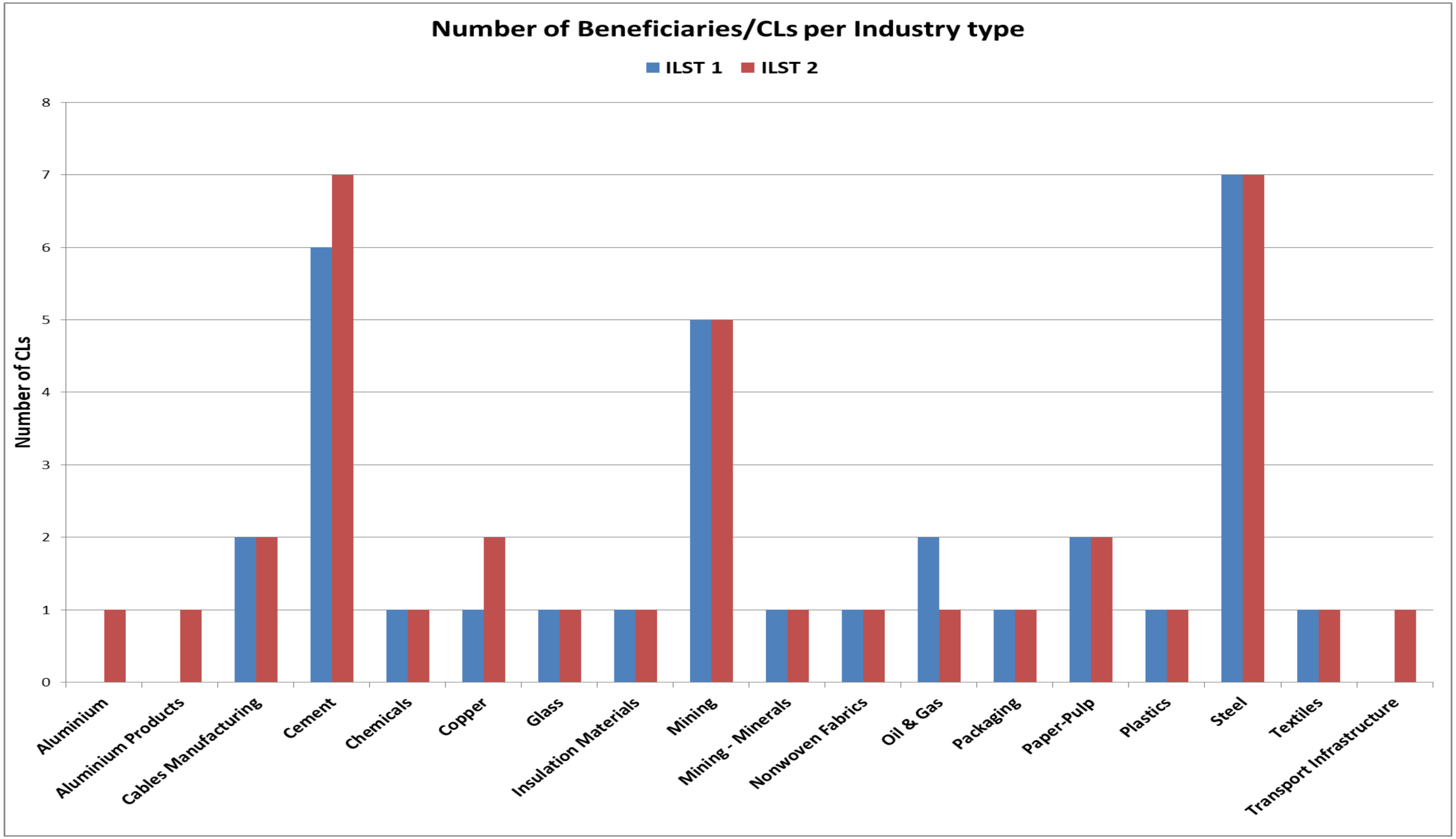


Chart 11:
Number of Beneficiaries/CL per Industry type for each ILST [Source: ADMIE]

Another interesting remark, regarding which type of industries mostly become beneficiaries of the ILSA scheme, comes into light by observing the Charts 12 and 13. In the first chart, the companies who have succeeded more than six times (taking into account any successful CL – i.e. if they have a CL with 0 successful participations and another CL with 8 successful participations, they are considered as successful) in an auction from the ILSA scheme establishment are shown. In the second one, the mean average of successful participations (having at least 3 participations per CL) of the type of industries who have succeeded more than 6 times in an auction, is presented.

There are 14 companies which have become beneficiaries for more than 12 times for ILST 1, while just 1 with 8 participations and 1 with 6. It is noticeable that no company has managed to succeed 9 to 11 times. Most of the companies which have become beneficiaries belong to the cement, steel, mining, textiles, paper-pulp, insulation materials, oil & gas, mining-minerals, packaging and chemicals industry. This remark is further strengthened by observing Chart 13. Yet, by choosing to depict the mean average of participations, the cables manufacturing industry falls below the 12 times ceiling. This is due to the fact that there are 2 participants in this category, and the participations of one of them are quite less than the ones of its competitor.

Focusing on ILST 2, we see that 12 companies have become beneficiaries for more than 10 times, while 1 company for 7 times, 1 for 8 times and 1 for 9 times. Under industry-specific analysis, the industries that present the most participations (more than 11) are the aluminium, aluminium products, cables manufacturing, copper, glass, insulation materials, mining, mining-minerals, nonwoven fabrics and plastics industries. We see that in ILST 2 several industries appear that do not in general participate in ILST 1, such as aluminium, aluminium products, copper, glass, insulation materials, cables manufacturing, non-woven fabrics and plastics industries.

Based on the analysis of the mean averages of Chart 13 (industries with more than 10 participations) and the total industries types that have ever had one beneficiary on the ILSA scheme (see Charts 10 & 11 showing all sort of industry types ever to have a company to become beneficiary), it is noted that the majority of industries participating to ILST 1, do not participate in ILST 2 and vice versa. This is depicted in Table 7. A possible explanation for this might be the fact that the ILST 2 provided up to nowadays more flexible terms regarding the maximum time of a PRO (just 1 hour within 24 hours, with a total maximum duration of load shedding per year of 24hours), which combined with the production line characteristics of these specific industries (easiest stopping/starting of the production lines), made the ILST 2 more attractive to these specific industries. Yet, another explanation could be that the companies of these industries were rejected during the ILST 1 auction procedure (since they bid higher than the other companies which belong to other industry types) and they just benefited form they participation to the ILST 2 scheme, taking into account the limited number of large electricity consumers in the Greek territory and electrical grid/system.

Industry Type (Companies >10 Participations)	
ILST 1	**ILST 2**
Cement	Aluminium
Chemicals	Aluminium Products
Insulation Materials	Cables Manufacturing
Mining	Copper
Mining - Minerals	Glass
Oil & Gas	Insulation Materials
Packaging	Mining
Paper-Pulp	Mining - Minerals
Steel	Nonwoven Fabrics
Textiles	Plastics

Table 7:

Comparison of Industries/Companies Types that participate to each ILSA Type.

Further analysis of the profile of different industries is provided in paragraph 4.2.4, where a combination of MIL provided by each beneficiary along with its participations is presented.

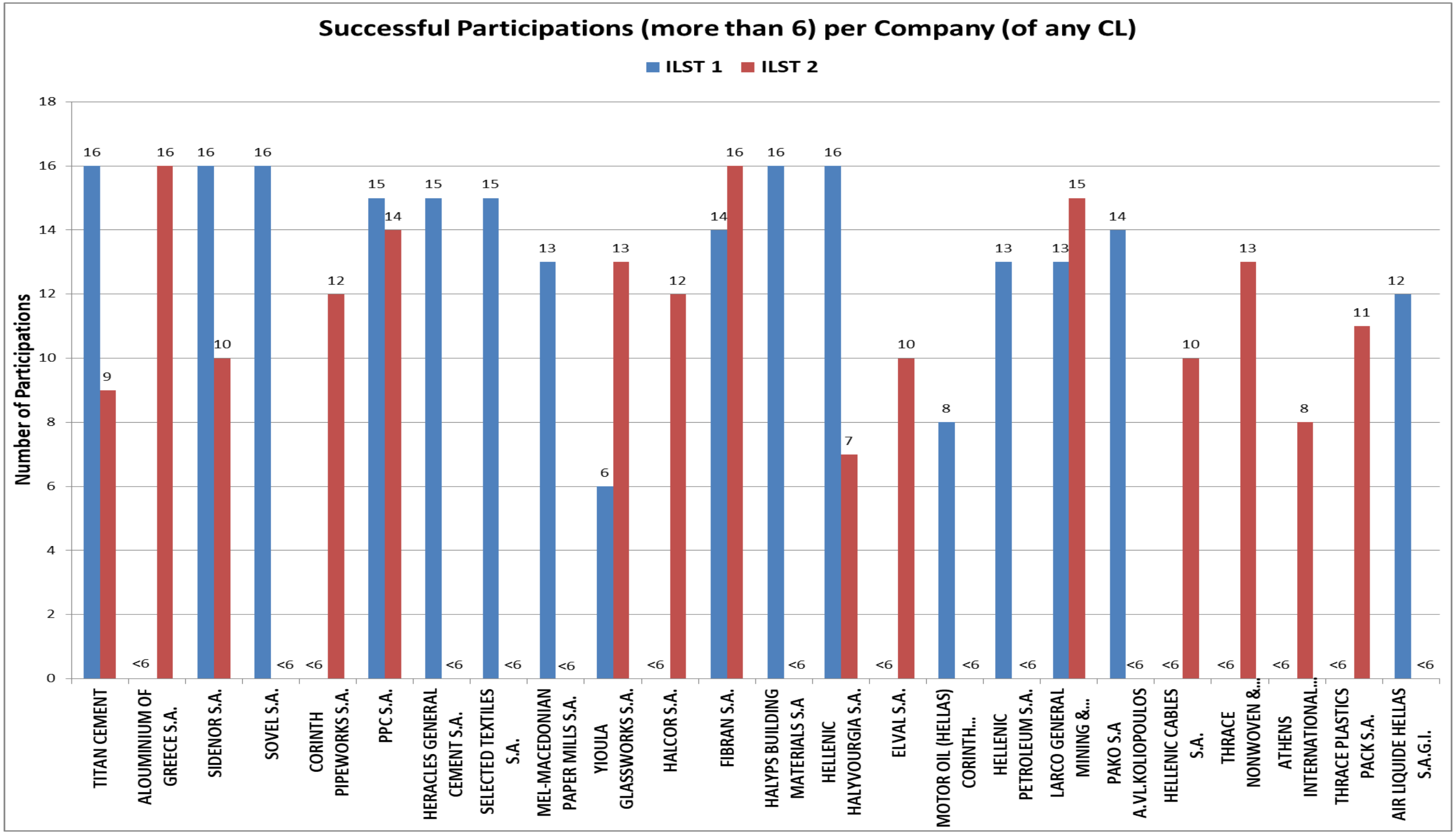


Chart 12:
Successful Participation (more than 6) per Beneficiary/Company for each ILST [Source: ADMIE]

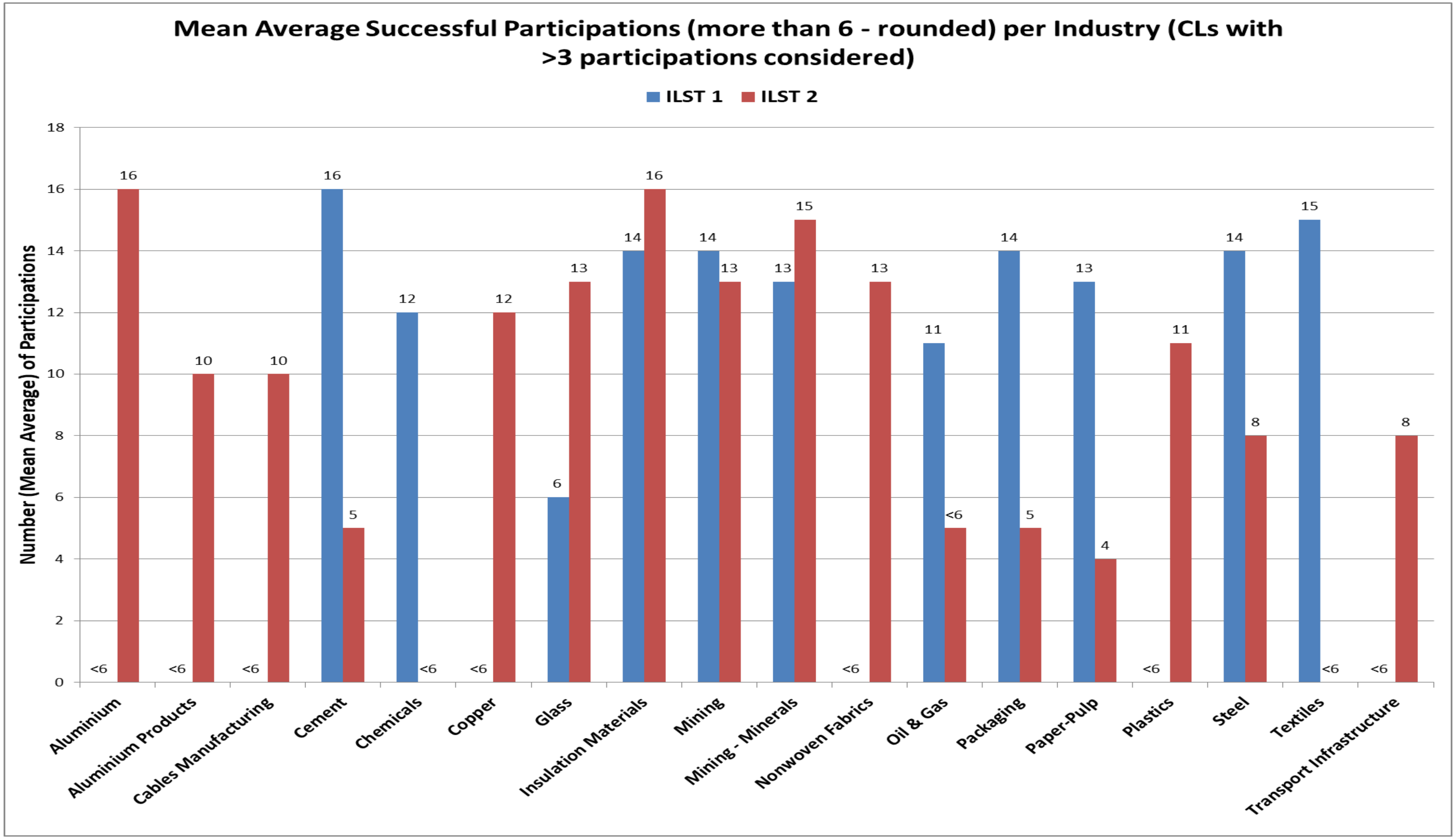


Chart 13:
Mean Average Successful Participations (more than 6) per Industry for each ILST [Source: ADMIE]

4.2.4 Analysis of MIL Data

Another interesting aspect of the analysis is to focus on the MIL that has been offered throughout these years. At Attachment "A", the total MIL of every bidder for all 16 auctions that have taken place, is shown. It is clearly shown that there are substantial differences on the amount of load between different companies taking into account these cumulative numbers.

Focusing on a more concise index, the average MIL per successful participation ("Mean MIL per ILS Type Auction), provides a better overview of the capabilities of each CL to the ILSA scheme. Further continuing in the analysis by adding the above values per company (and not by CL, as it is depicted in Attachment "A"), the capability of each company can be identified. For this step of the analysis only CLs that have succeeded at least 6 times are considered. By segmenting the results to 4 different sections (Average MIL < 10MW, 10MW < Average MIL < 20MW, 20MW < Average MIL < 30MW, 30MW < Average MIL), it is clearly shown that most of the companies only offer less than 10MW (7 companies for ILST 1 and 9 for ILST 2). There is a small number offering 10MW to 30 MW (6 for ILST 1 and 4 for ILST 2). It is noticeable that very few companies offer more than 30MW (3 for ILST 1 and 2 for ILST 2). The results are shown in Chart 14.

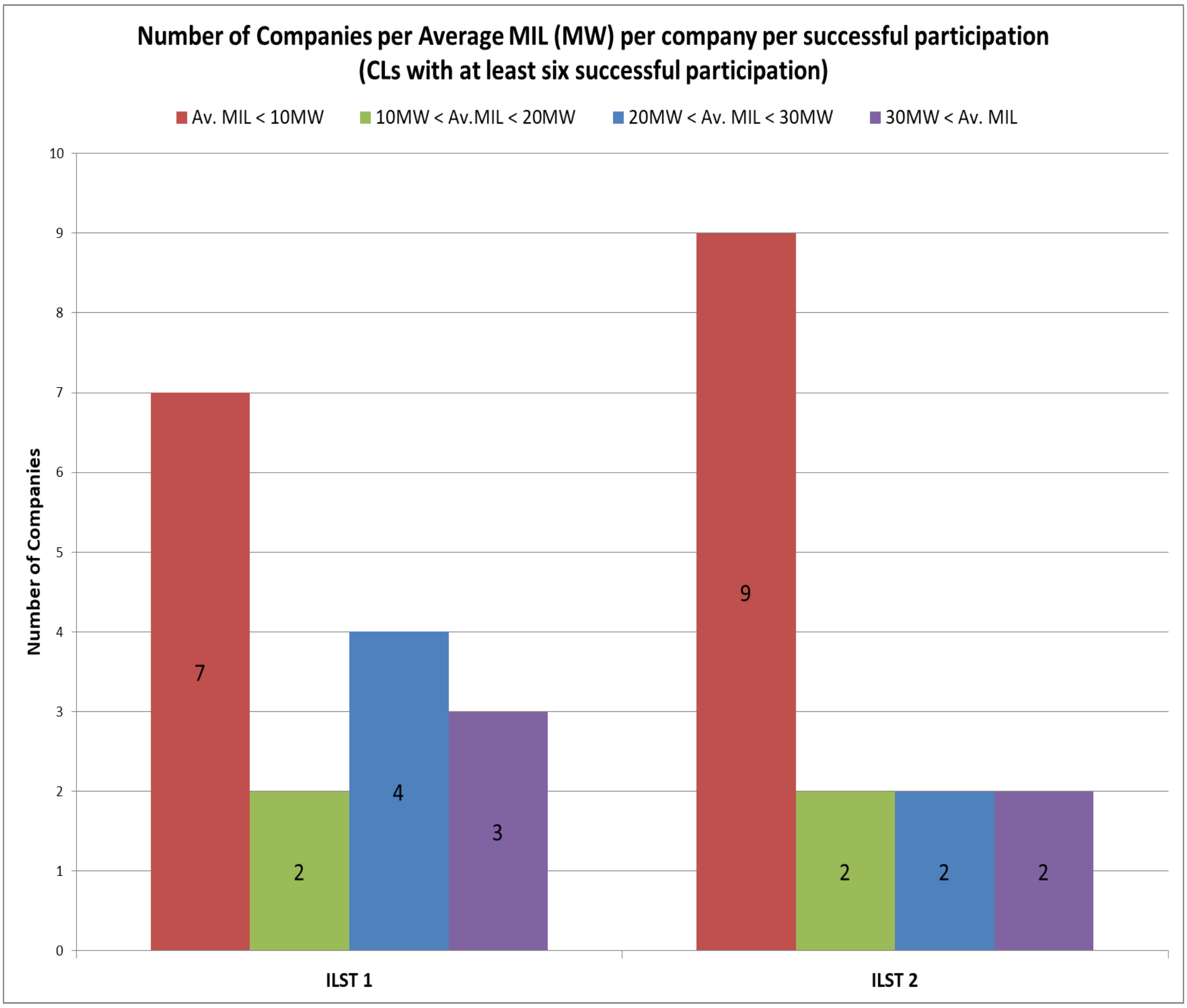


Chart 14:
Beneficiaries (Companies with at least six successful CLs) per Average MIL offering [Source: ADMIE]

Under a closer look of the results, the companies that are offering more than 30MW are either the PPCs (public company) mining facilities or several steel companies that are facing operational problems due to the recent recession or due to other administrative reasons (e.g. Larco). Under this prism, it emerges that – in fact – there are no major key players that can easily support the grid by providing substantial amounts of load. Thus, the usefulness of the scheme as a tool for the Greek TSO is ranked quite low, a fact that might affect its viability in the future. Of course, these thoughts are based on the contemporary status of the Greek economy.

4.2.5 Analysis of Tendering Data

Consumers' interest in participating to the ILSA scheme can be measured by examining the tendering data of the procedure. Based on the Greek TSO's available data, index StT was calculated for each of the 16 auctions for each ILS Type. The index is defined as the ratio of the sum of the successful bids in each auction to the sum of the total bids submitted. The results are shown in Charts 15 & 16.

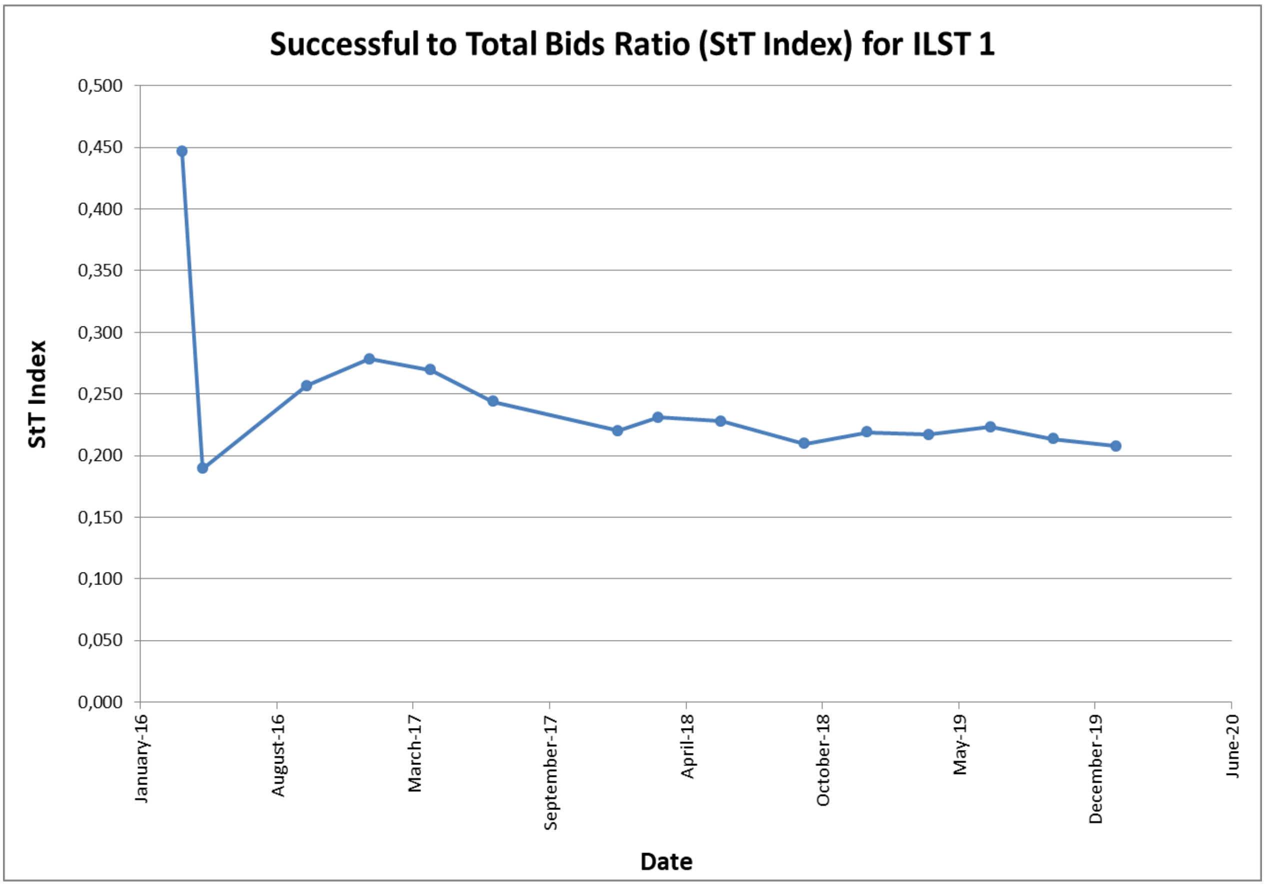


Chart 15:
Successful to Total Bids Ratio (StT Index) for ILST 1 [Source: ADMIE]

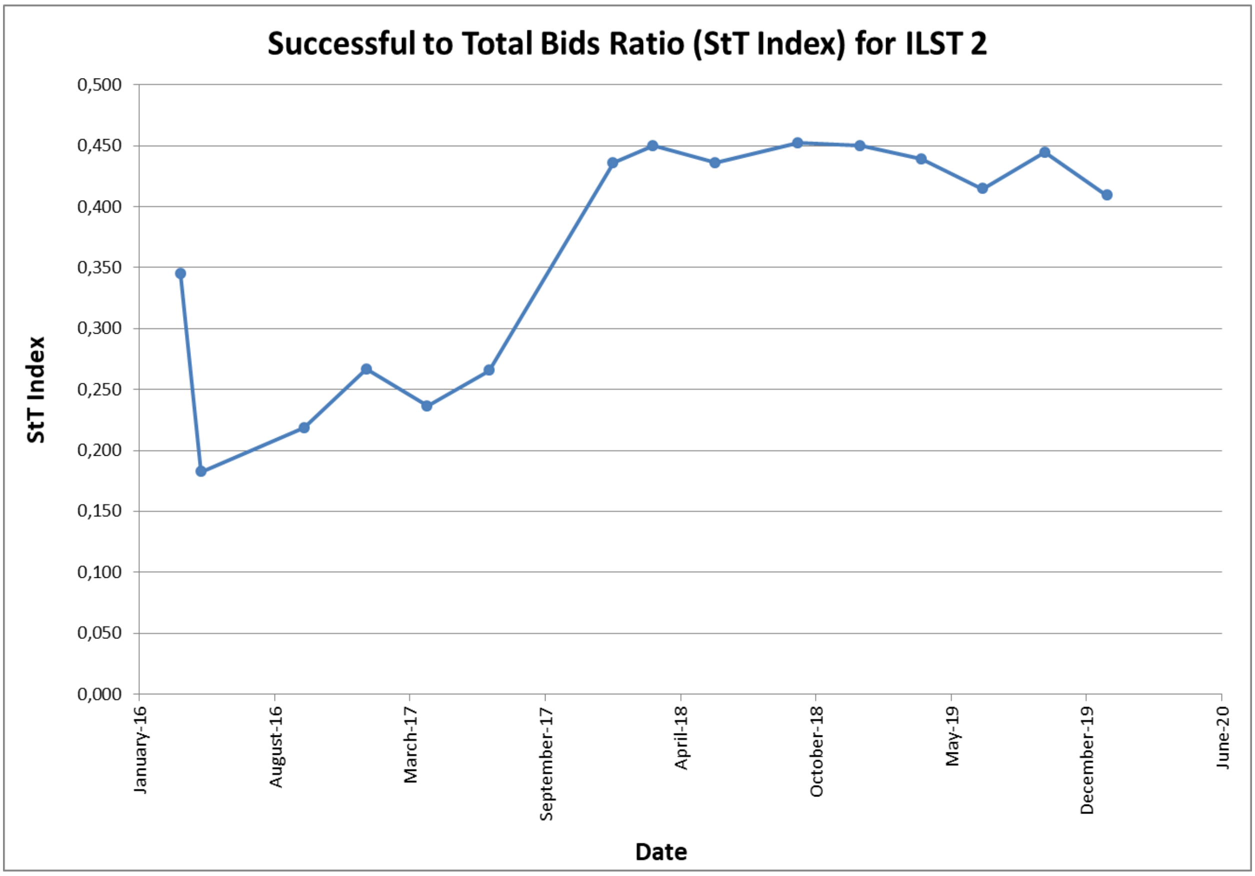


Chart 16:
Successful to Total Bids Ratio (StT Index) for ILST 2 [Source: ADMIE]

It is noticeable that up to the introduction of the 2017 law ((ΦΕΚ) Β' 4546/2017 on the 21st December 2017), the StT index follows the same path for both ILS Types and takes similar values. Yet, after the establishment of the 2017 the StT index for the ILST 2 is has been almost doubled. This of course is due to the Shifting Load Participation Declaration (SLPD) procedure that has been introduced ever since. Due to the SLPD and the fact that there are few players interesting in the ILSA scheme, the majority of the interested parties (consumers), utilized the SLPD procedure and thus, almost all consumers participating to the ILSA of Type 1, participated to the ILSA Type 2. Adding them to those who only declared for the ILSA Type 2 led to an increased number of total bids for all auctions of Type 2 ILS after the year 2017.

A final remark, is that the StT index – with exception to the ILST 2 for the years after 2017 – is averaging around 0,2 to 0,25. Taking into consideration the few players participating in the bidding procedures, it is anticipated that many player segment their bids to many different parts with different dibbing prices (i.e. they bid many different ADLs, each with different price).

4.2.6 Analysis of Consumers per Voltage Level Supply

Although the total number of participants in the ILSA scheme can be described as low, there are substantial customers from the MV grid. In the following chart (Chart 17), the distribution of successful participants (bidders who had at least one successful CL after the establishment of the ILSA scheme) is shown.

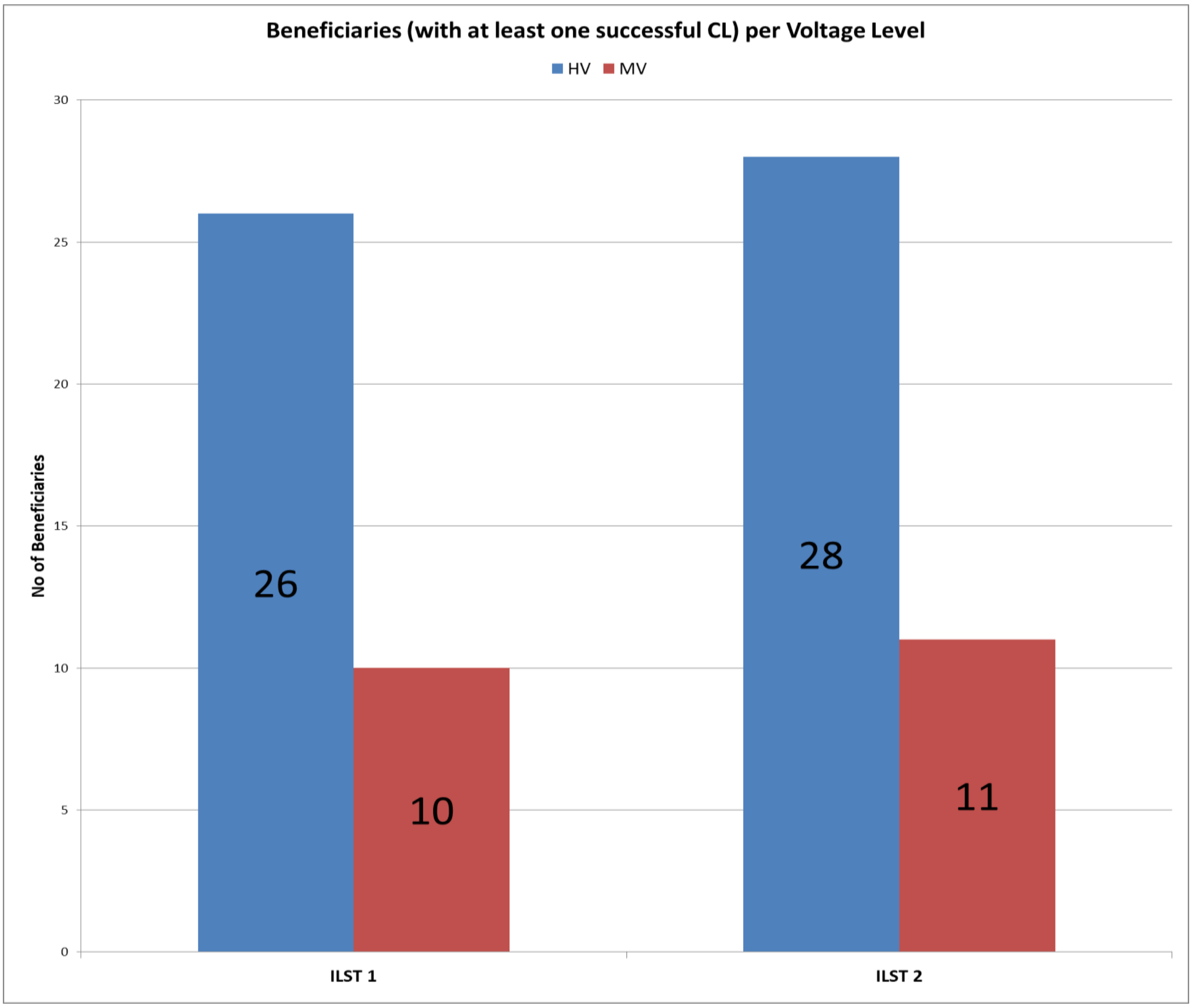


Chart 17:
Beneficiaries (per CL) per Voltage Level [Source: ADMIE]

4.2.7 PRO's & Remunerations Historical Review

Dispatch of a PRO during the operational life of the ILSA scheme has only become twice as follows:

- 23/12/2016 : Type 1 for 48 hours and Type 2 for 1 hour
- 10/01/2017 : Type 1 for 24 hours and Type 2 for 1 hour

The PROs were dispatched to all participants since the system faced severe stability threats due to various reasons. Among which there was a problem to the natural gas supply system (which led to problem in supplying electricity generation units which could be dispatched under normal circumstances), severe icing conditions (rendering the lignite extraction impossible) to the lignite mining fields which supplied which lignite the back-up thermal units utilized for electricity generation, and a technical issue to France's nuclear power stations (which impeded power imports to the Greek electrical system).

Regarding the amount of remuneration that the scheme has provided to beneficiaries up to nowadays, in 2016 and 2017 the total amount reached 35 million euros for each year, while in 2018 the total remuneration was at around 50 million euros.

CHAPTER 5: ASSESSMENT OF THE PARTICIPATION OF THE HELLENIC PETROLEUM ASPROPYRGOS INDUSTIAL COMPLEX IN THE ILSA SCHEME

5.1 General

In this chapter a review of the HELPE-AIC's participation to the ILSA scheme is presented. Furthermore, the potential for further engagement to the scheme is assessed. For the latter, a simplified presentation of the shedding capabilities of the refinery is provided, while basic assumptions are made on the way its production processes are organized. Assessing in detail the refineries capabilities is a laborious procedure that engages highly skilled, multidisciplinary personnel (electrical, process, economics, etc), that cannot be exhausted in this thesis. Yet, under the basic and simplified assumptions made in this thesis, guidance is attempted to be given so as to which key elements the refinery has to pay much of attention so as to successfully participate to the ILSA scheme in the near future.

5.2 Brief Review of HELPE-AIC Participation to the ILSA Scheme

HELPE-AIC had never become a beneficiary of the ILSA scheme in any of the two types of interruptible load during the first two phases of the scheme (i.e. under 2015 & 2017 laws). Yet, it is registered to the ILR for the ILS type 1 with a MOIL of 13MW for the year 2019 and 12MW for 2020. HELPE-AIC has never registered to the ILR for the ILS type 2.

HELPE-AIC's first successful attempt to participate to the scheme came in July 2020, under the 2020 law. It succeeded to the ILST Type 1 with a MIL of 7MW and an AMP of 63.800 €/MW per year. Their second successful attempt came in September 2020, under the same law. It succeeded to the ILST Type 1 with a MIL of 7MW again and an AMP of 63.850 €/MW per year.

5.3 HELPE-AIC's Electrical Network

HELPE-AIC has an extensive 6kV distribution network whose supply is based both on the national HV grid and on HELPE-AIC's generators, which form part of the internal distribution network. HELPE-AIC's internal distribution network, along which its supply points and scheme from the national HV grid is shown in Figure 16. It is mentioned that during the 2020 shut-down (i.e. shut-down is a period – usually repeated every 4 years – during which the refinery's operation is almost fully seized so as preventive maintenance and major development works to take place, that could not be implemented under normal circumstances, as those encountered during the refinery's full operational routine) there is a major development project planned to take place pertinent to the increase of the refinery's potential to consume more electrical power. Under this project, an extension of the refinery's network shall be realized, both in terms of its distribution network and its supply gates. In Figure 17, the HELPE-AIC network is shown, as this is design to be altered under the 2020 shut-down works. The analysis of the refinery's capabilities and potential pertinent to the ILSA scheme is not affected by this change, but it is thoughtfully mentioned in order to depict the actual electrical network status of the refinery in the years to come.

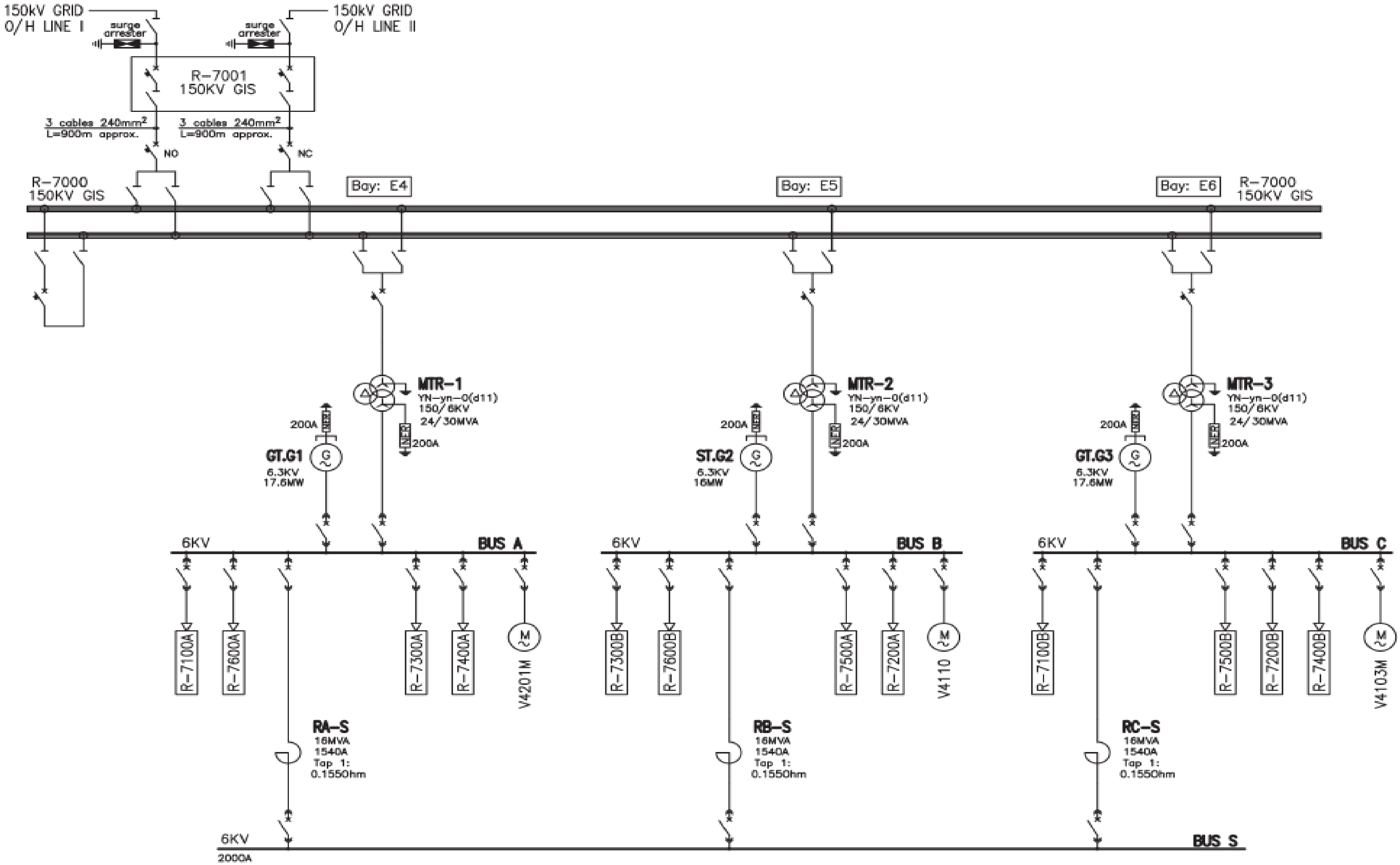


Figure 16:

HELPE-AIC'S Electrical Network (Previous Status)

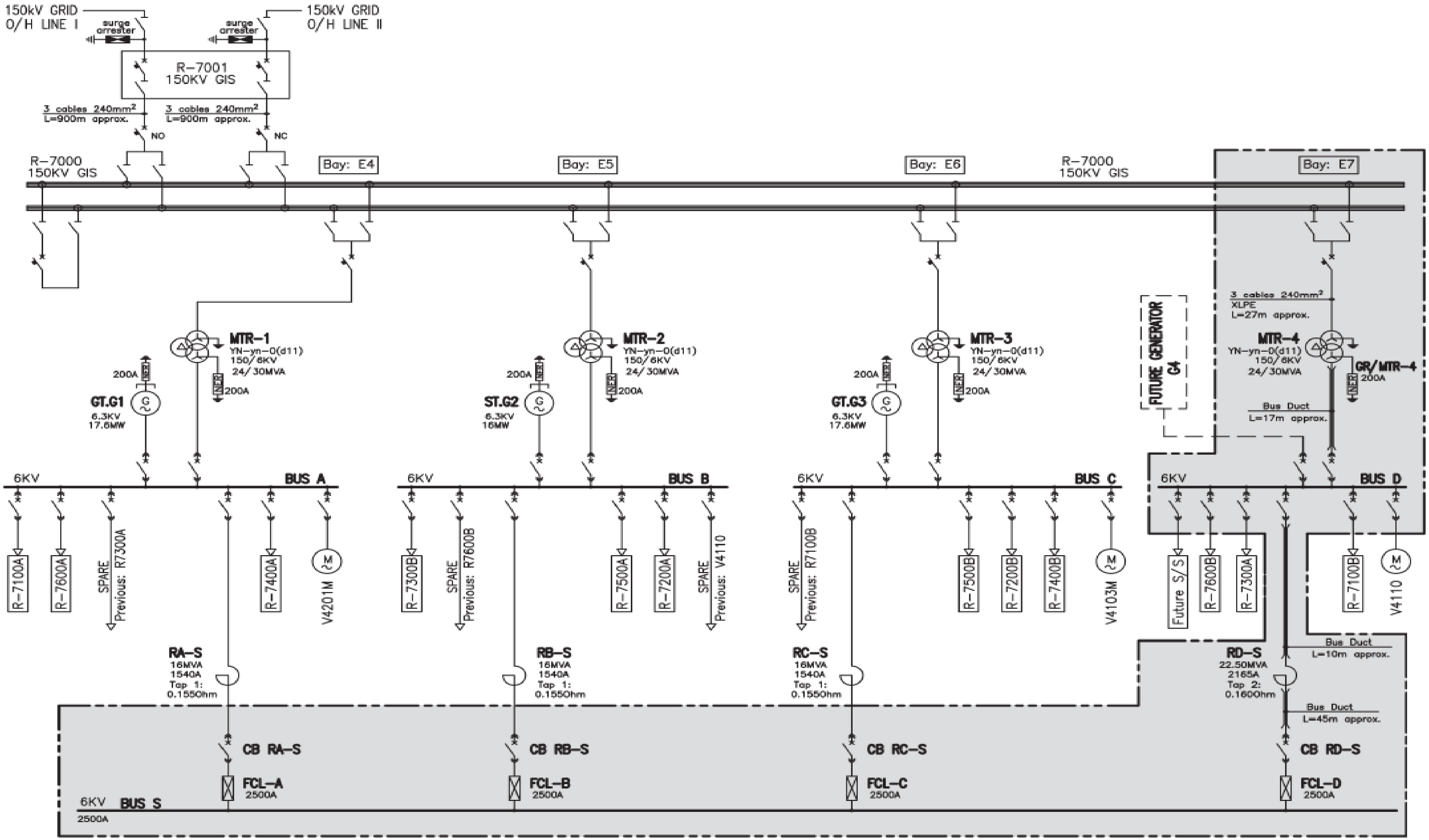


Figure 17:

HELPE-AIC'S Electrical Network (New Status)

5.3.1 Network Overview

HELPE-AIC is supplied through three similar step-down HV to MV transformers (150kV/6kV). All three transformers can be connected to two HV lines (one at a time) which pass just outside the refinery's yard. The substation hosting all HV breaking equipment for separating the refinery's network with the national network's supply lines is the R-7001. Each transformer is connected to a dedicated 6kV distribution bus (A, B & C) all of which constitute the central distribution mains of the refinery. The substation hosting these buses and respective transformers is the R-7000.

Each central bus, further to being supplied by its dedicated 150kV/6kV transformer, it is supplied by a generator. Buses A & C are supplied by one 6kV gas turbine generator each (Generators G1 & G3), while main B is supplied by a 6kV steam turbine generator (Generator G2). Gas turbine generators have a maximum of 17MWs, while the steam turbine has a maximum output of 16MW. All three generators are always – except when they are out for service reasons – operating above their operation minima and they are ready to support the refinery's network in case of loss of supply from the national HV grid for whatever reason (transformers failure, network unbalance/failure, etc).

The three buses (A, B & C) are interconnected to a common synchronizing bus (bus S) through a dedicated reactor for each bus. Under this scheme, any of the three buses can be supplied by a different transformer or a different generator should this is required (e.g. it times when a generator or a transformer is under routing maintenance). There are some constraints pertinent to the maximum power that each reactor can support (maximum 16MWs), but in general the scheme works adequately so as to support all loads of the refinery. Under the 2020 R-7000 extension project, these constraints shall be further reduced, leaving more power capabilities to the refinery's internal network so as to support more loads in the near future.

The distribution scheme below R-7000 mains is based on 6kV. There are outgoing supply feeders to six central distribution substations (R-7100, R-7200, R-7300, R-7400, R-7500 & R-7600), all of which have 6kV to 0,4kV step-down transformers for supplying low voltage to distribution boards (PCs, MCCs, ASPs, EDPs) which serve the refinery's low voltage loads, and under certain cases 6kV distribution boards for supplying MV loads. In the cases where 6kV distribution boards are present, there might be further distribution to secondary substations (e.g. R-7620), where similarly to the central substations, step-down transformers exist so as to serve the low voltage supply network of these secondary substations.

It is worth to mention that for increasing the reliability of the internal distribution network, each central substation is supplied from two different mains of R-7000. Under this scheme, should a failure of the supply side of one main of R-7000 occur, than the complete central substation can be supplied from the other outgoing feeder of the other main of R-7000.

5.3.2 Shedding Capabilities

The refinery's operation is being supported by a Load Shedding System (LSS), which has been installed in mid 80s. The system has undergone various important upgrades since then (the latest was in 2018). It is a very complex system regarding its operation which stood as a pioneering innovation back at the time which it was installed (only 2 refineries in Europe had pertinent shedding systems back then).

The LSS's primary operational target is to ensure that in a potential interruption of the supply from the national HV grid, it will shed as much load required, so a both the generators to be able to support the remaining refinery's load without imbalances to occur, and the production scheme of the refinery at that time to be affected at the least possible way. The “least possible way” is referring to the goal of shedding as little load as possible so as to interrupt a less as possible the production lines (refining process) of the refining, or else to the goal of shedding the least important productions units, either from an economical perspective, or from an operational point of view (i.e. there are some production processes and/or units that required substantial time to cool-down prior re-entering them to the refinery’s network in full capacity).

The LSS is comprised of various central and local (or peripheral) computers. The central computers are located to the central electrical control room (MEUCR) and the R-7000, while the peripheral ones inside some of the distribution substations of the refinery. The central computers are utilized to constantly measure the power balance at the R-7000 buses (input power versus output power for each A, B & C bus), monitor and control the generators operation and measure the frequency of the internal network. The peripheral computers are utilized to identify the dedicated substation’s loads that are operating and measure the power that they consume. Their main work is to communicate to the central computers the available amount of load that each substation can shed, should this is requested by the latter. From a communications infrastructure perspective, the LSS is comprised of four independent loops which are interconnected with fiber optics.

Should a contingency occurs (i.e. loss of HV grid), or a major imbalance (e.g. extremely low frequency), the central computers identify the need for a shed. They have already pre-calculated the required amount of load that each substation has to shed and they communicate a shed command to the peripheral computers, which execute it, by tripping the required loads. The pre-calculation of the amount of load that is required to be shed is constantly being made by the central computers. It is a fast, dynamic process which takes into account the loading of each bus of R-7000, the potential of each generator to produce excess power and the available load to be shed in the peripheral substations.

As already mentioned, not all production processes of the refinery have the same importance and criticality. There are loads which can be switched off and on very easily and they do not even affect the production processes (e.g. offices), while there are critical process units which require special treatment each time that they are being shut off or shut on, either from time perspective, safety procedures, or other operational aspects. As it can be understood, the loads of less operational importance can be considered as those who could be shed first in case this would be required.

In order to facilitate the refinery operation in terms of loads criticality and process uniformity (i.e to belong to the same process unit and/or procedure), the notion of Load Groups has been introduced. Refinery’s loads have been assigned to 17 different Groups. Due to the fact that the production patterns might be altered throughout a year (or even during an even smaller time frame) and the fact that it is not technically convenient to constantly alter the Group assignment of a load, the notion of Priorities has been introduced as well. Under this notion, a Group is assigned with a Priority. The lowest the Priority of the Group, the less important the Group is for the operation of the Refinery, and thus it shall be shed first. For example if a certain Group has Priority 1, while two others both have Priority 2, the first Group shall be considered by the LSS as the first to be selected should a shed is required.

The notion of Groups and Priorities is extremely important for properly deciding which loads the Refinery is willing to sacrifice, either due to loss of supply from the national HV grid, or due to its willingness to shed load in order to reduce its consumption and thus be able to participate to the ILSA scheme. Properly organizing low importance loads into Groups and subsequent assignment of a low priority to them is a key aspect of determining the ADL that the refinery can bid for in an auction of the ILSA scheme.

5.4 ADL Analysis of the July & September 2020 Bids

The way that HELPE-AIC's loads have been distributed to Groups does not easily facilitates the selection of specific loads that can be consistently shed, so as to form a solid and reliable batch of power – under any potential production scheme – that can be offered as ADL. This is due to various reasons, which are elaborated in paragraph 5.6. The latter difficulty (i.e. contemporary distribution of loads to load shedding Groups) has detained HELPE-AIC from participating to the scheme, as it could not offer a load that could be reliably be available for shedding (so as to reach the contracted MCP) in a 24/7 basis throughout the time frame of the interruptibility contract with the Greek TSO.

Yet, there was some potential of reaching offering a reliable-to-reach ADL in an indirect way, which was is by increasing HELPE-AIC's internal power production. In this way, the energy flow from the PCC network towards the HELPE-AIC's internal distribution network would be reduced, thus leading to a seemingly reduction in power demand from the PCC's network. There were some potential ways that this could be achieved.

One could be starting-up the various diesel generators that each central or secondary distribution substations has in case of a total loss of power (black-out) for whatever reason (electrical fault within the refinery, PCC supply interruption, etc). Yet, this idea has not gained the required ground for some reasons. The first one was that these diesel generators are in general of low capacity (i.e. power output), as the range up to about 150kVA as a maximum. Thus, in order just to meet the minimum ADL, a relatively large number of them should be dispatched at the same time, which reduced the reliability of providing the proper ADL should any of them would fail to start for whatever reasons. Moreover, fast control of these generators was not available, since these were not equipped with neither remote nor automated – on operators demand (i.e. there are equipped with an automated start-up system in case of PCC loss) – control features. Under this perspective, a technician had to be dispatched to each substation to manually start-up them. This, as it can be easily understood, led to start-up times which were higher than Notice Times that the ILSA scheme required.

The other way was to engage one of the three main generators (G1, G2 or G3) of the refinery, which are being constantly in operation (i.e. the do not require time to start-up). More specifically, during the last years, the refinery had been utilizing the G2 generator (steam turbine) to a minimum power output production of 6 to 8 MWs. This had been decided for various reasons. Firstly, the excess of steam required to operate G2 to high power outputs was expensive to be produced, compared to consuming electrical power from the PPC for supplying the refinery's loads, while secondly, in an uncontrolled event of PPC supply loss, maybe an increased need for steam would appear for other various process operation, so should G2 would consume great amount of steam there would be no sufficient steam for the former, many of which were critical both for the refinery's operations and for some safety functions.

Under the abovementioned constrains, the main idea was to conduct a feasibility study so as to see should G2 could operate at higher output under a controlled operational scheme (i.e. under a PRO dispatch) and should under these controlled conditions (PPC supplying the refinery) posed a potential problem to the availability of the steam required. By setting the G2 to a higher output, the refinery could bid in order to offer an ADL which could be defined as the difference of the high output that could be decided that the G2 could operate under a PRO minus the power that it would be decided that it could be constantly be operating during the frame of the interruptibility contract with the Greek TSO

After closely examining the economic benefit (remuneration) of the participation to the ILSA scheme could compared to the losses of producing the excess of the steam required, HELPE-AIC decided that it was for their benefit to adopt the idea of utilizing the G2 generator in order to increase its power output and thus to seemingly reduce the power supplied by the PPC. Under this philosophy, HELPE-AIC decided to participate in both July’s 2020 and September’s 2020 ILSA Type 1 auction and to succeed a MIL of 7MWs in each auction, after the clearing procedure.

5.5 Review of Potential Load as ADL for Participation to the ILSA Scheme

5.5.1 General

As it has already been mentioned, HELPE-AIC’s approach to their participation to the ILSA scheme did not include the logic of reducing their consumption needs, but rather to increase their internal production to as to request less energy from the PCC, should a PRO is dispatched. In this paragraph, an attempt to identify loads that could serve the opposite logic – that of really reducing the power required – is made.

In order to identify the potential load that the refinery can declare as ADL, close examination of low importance loads has to be made. For the contemporary operation of the refinery, it is wiseful to focus to the Groups to which low Priorities have now been assigned. The main goal is two try to identify at least 2MWs of loads (the minimum MOIL that a participant must have) that could be shed. We note that, although this load has to be constantly available to be shed, due to the fact that the G2 generator participates in order to bridge the gap between the actual power needs of the requirements and the MIL that might be requested to shed under a PRO, the 2MWs load that we will try to identify, does not have to be constantly available (unless it is so important for the production procedure that all or part of it might be required to be enabled after having been shed under a PRO).

Under this assumption, there are low importance load that can be considered as potentially selectable so as to reach this 2MWs power, although they are not always available (present) to be shed. A typical example are all office loads. These loads can be available during day-time and upon their selection to be shed, they provide the choice not to increase the G2 production in order to reach the MCP of a specific PRO. This can lead to further economic benefit for the refinery, since it saves the cost of producing the additional steam that would otherwise be required so as the G2 generator to produce 2 additional MWs. Of course, there are occasions under which the office loads are not available (or otherwise phrased “selectable”) to be shed since they are not “on-line”. A typical such occasion is during the night hours, where the office personnel does not work. In that case, the G2 generator would be commanded to produce these additional 2MWs.

This approach is rather conservative, it is of low-risk and can be implemented without distorting any process production schemes, whose alteration or loads identification regarding their importance or time availability cannot be easily assessed. It worth to note, that even if the 2MW limit cannot be reached, there is a benefit in any case, since any potential load that can be shed leads to reduced G2 power output, and thus lower steam production and costs. So in any case, the attempt to identify potential loads does not have to be limited by the minimum MOIL that has been set by the law. In this point, it is also worth to mention that the last MHP of the refinery was 58,677MW.

5.5.2 Loads Selection (Proposal)

In order to proceed with the analysis of the loads that might constitute potential loads for shedding in order to participate to the ILSA scheme, we focus on non-process loads such as office building, warehouses and other support services buildings which are considered of low importance and/or criticality.

A selection of the following loads has been made as shown in the following table (Table 08). In this table the nominal power of each load is shown, as well as a typical mid-day consumption is shown. The latter can be considered as representative to what it can be shed, should this load is considered to be a nominee to form that MOIL and/or ADL.

HELPE-AIC's Potential Loads for MOIL and/or ADL Formation		
No	**Load Tag/Description**	**Typical Mid-day Consumption (kW)**
1	R-7630 (Administration Building)	550
2	Maintenance Building (ΤΣΗΟ)	380
3	Projects' Supervision Building (ΤΜΚ)	130
4	Chemistry Building (Χημείο)	120
5	1 Desalting Unit (U-5710, or U-5720, or U-5730)	700
6	Instrument Air reduction (Air Compressors)	120
TOTAL		**2000**

Table 8:
HELPE-AIC's Potential Loads for MOIL and/or ADL Formation.

It is can be clearly seen that HELPE-AIC has a strong potential to form a block of 2MWs in order to participate to the ILSA scheme without upstream regulation (i.e. by increasing its internal electricity production), but rather by choosing to reduce load (i.e. by load shedding). As already mentioned, since the capability of the G2 generator to increase power output always exists, the occasion into which the abovementioned (Table 08) loads are not available for shedding (e.g. night hours) does not constitute a deterrent for not considering them selectable for MOIL and/or ADL formation. Moreover, should these loads are not available, this shall not constitute a problem for reaching the MCP should a PRO is dispatched. Taking into account that these are loads that contribute to the peak of the refinery's energy consumption, that automatically means that the consumed power at that moment is closer to the MCP (i.e. less than 2MW shall be required for curtailment should a PRO is dispatched during the hours which these loads are not in service, e.g. during night hours).

In the abovementioned analysis, it has to be mentioned that these loads have to be individually be connected (measuring power, shedding command and running status) to the LSS system (should these are not already connected) and be programmed at a single Group, so as the LSS operator to manually shed it should a PRO is dispatched by the TSO. The latter amendments are relative easy to be realized from a technical point of view.

5.5.3 Determination (Proposal) of ADL and Interruptible Load Type Selection

Regarding the selection of ILT that the refinery should choose to service the Greek TSO, a conservative choice would be to participate to ILSA of Type 2 load as well. The main reason is that ensuring that the refinery can offer continuously for 48h even the least load determined poses more risk that just providing it for 1 hour. A pointer towards this direction is HELPE-TIC, which has a moderate presence to the ILSA scheme in terms of frequency, but it constantly selects to participate directly to the ILSA of Type 2 load and not to that of Type 1. Most probably, binding for 48h continuously (as the Type 1 ILS dictates) even a small amount of consumption, is detrimental for its production processes, while by selecting to shed for just 1h at a time (e.g. for every PRO) is more manageable.

5.6 Barriers in determining optimum ADL

As already mentioned, there are several simplified assumption made in order to propose a feasible ADL. One of the assumptions is that the refinery can successfully keep the accuracy requirements that are requested in the ILSA scheme. The 0,1MW accuracy calls for rather precise measurements towards the LSS both on the R-7000 buses, as well as on the distribution substations.

Another barrier is the careful assignment of loads into Groups and subsequently to Priorities. An assignment of a non-important load (in terms of production scheme and refinery's proper operation) to a Group with high Priority, leads to reduced ADL, while on the other hand the assignment of an important load to a Group with a low Priority, renders the danger of distorting the production process in an event of a shed, and subsequently to damages and/or economic losses greater than the benefit of the ILSA scheme's remuneration.

Moreover, the up to nowadays implementation of the LSS, is based on measuring and shedding batches of LV loads, rather than being capable of measuring and shedding them individually. This creates difficulties in defining their consumption needs with high accuracy, as well as to the in-depth selection of loads as potential ADL.

Finally, although in the assumptions made in this thesis, the loss of power to the means the maintenance and office labor utilizes is considered to have a negligible effect, there might be cases into which a certain work (e.g. replacement of a certain measuring instrument which is critical for a process) has to be completed within the specific time frame during which a PRO has been dispatched. The potential economic losses from such a case cannot be easily be determined. Of course, carefully assigning some maintenance loads to Groups with higher Priority (e.g. not to shed the complete maintenance building infrastructure) can resolve problems like this.

CHAPTER 6: CONCLUSIONS & SUGGESTIONS

6.1 General

Although small amendments between the three different laws pertinent to the ILSA scheme have been made, the central core of its operation has not been affected. The scheme is operating almost 5 years as an independent tool for the Greek TSO, other than those provided by the electricity markets.

Under this prism and following the analysis provided in this thesis, some noticeable remarks can be made that can contribute to the goals that the scheme has set. Moreover, some useful recommendations can be provided for rendering HELPE-AIC's participation to the scheme more active and beneficial

6.1.1 Proposals for Preparing HELPE-AIC Towards a Successful Participation to the ILSA Scheme

The contemporary electrical control system (LSS) of the refinery has been developed strictly for shedding capabilities during electrical network upsets and its notion is to protect and secure the refinery's production processes under unexpected and uncontrolled events (e.g. PPC supply loss). The system, which has been installed at the early 80s, has not been designed to contribute to the electrical system of the refinery as an electrical management system. Thus, automated decisions which are based on process-wised and economic-wised variables cannot be easily supported. A classic example of such decisions is the dilemma of choosing to increase the refineries internal power production versus stopping some loads through shedding for reducing the amount of electrical power supplied by the PPC.

Unfortunately for the HELPE-AIC's refinery, the concept of DSR has a basic prerequisite – and it strongly pushes towards this direction – the elaboration of smart technologies. The ILSA scheme, as part of a broader notion of the DSR concept, is not an exception to the above. Thus, in order a large industrial consumer to maximize its benefit from its participation to the scheme, investments to the automation of its electrical system have to be made. Under this prism, and taking into account that the LSS cannot be fully replaced by a new power management system, there are several lighter amendments that could be made to the system so as this to be rendered more flexible in its operation and adoptable to the ILSA scheme philosophy.

One such amendment is to gradually increase the number of digital and analogue input and output cards of the system, so as to connect all loads to it individually. As already mentioned the contemporary way of connecting the LV loads to the system is in batches, which leaves the LSS with reduced flexibility. Should each load would be individually connected it would be much easier to form dedicated Groups that could suffice to form higher MOIL and/or ADLs. It is highlighted that properly measuring the power that is load is consuming is essential. Proper and often calibration of these measuring devices has to be organized, since the decision on which load can be shed is highly based on these measurements. Should this amendment could be realized, the next step is to re-assigned all refinery's loads to Groups, by creating more shedding Groups and by in-depth studying the interactions of each load, so as to maximize the potential load that could be shed (i.e. not to keep running a load that does not have to be running should closely related processes to it have already been stopped through shedding).

6.1.2 Comments on the ILSA Scheme Operation and Suggestions for further Adaptation to Energy Markets

Concluding this thesis, a set of noticeable comments on the operation of the ILSA scheme up to nowadays is provided. Moreover, some crucial suggestions on how the scheme has to be transformed in order to meet the future challenges of a dynamically shaping worldwide energy market.

As already mentioned, the ILSA scheme operates independently from the electricity markets, in a sense that the consumers willing to cut their consumption are not directly competing with the producers of electrical energy, the latter who, participate to the day-ahead, intra-day and balancing markets. This practice is often considered to be on the edge of legitimacy when it comes to rules and laws which comprise the framework around free markets and competitiveness. Nevertheless, the scheme manages up to nowadays to get the approvals by the EC so as to operate outside the framework of the free energy markets in Greece. Irrespectively of the justification of such a decision from the EC side and taking into account that there are several oppositions to the scheme from the producers side in the way this is implemented (i.e. by excluding the consumers from directly competing with the producers), the scheme has gradually to alter its operational framework and participate to the balancing market directly. A robust framework which shall eliminate the auctions procedures and shall render the consumers in direct competition with the electrical energy producers has to be introduced, so as to further increase the efficiency of the consumers' participation. By directly competing the producers' prices, the consumers shall be further pressed to optimize their production processes and organize them in such a way that they will be more flexible to energy demand.

Another issue that will press towards to this direction could be the MSP to be more than 50% of the MHP. In this way, truly high energy consuming industries could have the precedence over participating to the scheme, while less energy consuming industries could face more difficulties in participating. In this way more financial resources could be available to the former industries, providing the capability to the Greek state to remunerate more and thus to give the way for investments on these industries, pertinent to low consuming production processes and to automation that will provide flexibility on their consumption patterns.

Finally, an important amendment of the scheme's rules towards increasing the energy efficiency of the electrical network, as well as providing further protection to the environment, would be the not accepting up-regulation in a CL (from the consumers' self-generation capability inside its local distribution network) upon a PRO. All three laws pertinent to ILSA scheme utilized up to nowadays, allowed the consumers to conform to a PRO by only increasing their internal generation, so as to seemingly meet their obligation to consume up to the MCP in the CL for which the PRO had been issued. In fact, they were not at all obliged to shed any power pertinent to the production scheme they were applying at the moment of the PRO issuance. In that way, many industries which had the capability to increase their internal generation had no incentive of re-organizing their production and – subsequently – their consumption patterns. Thus, one of the primary goals – that of minimizing the energy usage – of the ILSA scheme as a DSR program could not be achieved. Taking into account that "awkward" mean for complying with what the scheme required, in order to further strengthen its goals, electrical power generation from the consumer's side during a PRO could only be allowed as a mean for achieving the requested accuracy of load curtailment requested (e.g. the 0,1MW limit). The load sheding/curtailment should be the only accepted mean of reaching the MCP. Of course, this decision would require monitoring techniques from the Greek TSO, of the production capabilities of each consumer, so some sort of communication infrastructure investments would be needed.

In all, the common denominator of the suggestions is to set the scheme more efficient and have as a primary target the reduction of the power required to be generated irrespectively if the latter would be produced by energy producers or by the consumers (prosumers) which are all connected to the same grid.

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ATTACHMENT "A" - ILST 1 Beneficiaries Data

No	Beneficiary	Beneficiary (Greek)	Industry Type	Voltage Level	Consumption Location (CL) No	Consumption Location (CL) Name (Greek)	Maximum Interruptible Load (MIL) per ILS Type 1 Auction (MW)																	Total Biddings in the ILS Type 1 Auction	Total Failed Biddings in the ILS Type 1 Auction	Total times not participating in the ILS Type 1 Bidding	Total Successful Participations in the ILS Type 1 Auction	Mean MIL per ILS Type 1 Auction (MW)
							2016 No1	2016 No2	2016 No3	2016 No4	2017 No1	2017 No2	2017 No3	2018 No1	2018 No2	2018 No3	2018 No4	2019 No1	2019 No2	2019 No3	2019 No4	2020 No1	Total					
1	TITAN CEMENT	Α.Ε. ΤΣΙΜΕΝΤΩΝ ΤΙΤΑΝ	Cement	HV	No1	ΘΕΣΗ ΚΑΜΑΡΙ ΒΟΙΩΤΙΑ, 19012 ΣΤΕΦΑΝΗ	23,0	29,0	40,4	40,4	40,4	40,4	40,4	40,6	40,6	40,6	40,6	40,7	40,7	40,7	40,7	40,7	619,9	16	0	0	16	38,74
2	TITAN CEMENT	Α.Ε. ΤΣΙΜΕΝΤΩΝ ΤΙΤΑΝ	Cement	HV	No2	ΡΙΟ, 26504 ΡΙΟΝ	11,0	19,0	25,5	20,7	25,5	25,5	25,5	23,5	23,5	23,5	23,5	23,5	23,5	23,5	23,5	24,9	365,6	16	0	0	16	22,85
3	TITAN CEMENT	Α.Ε. ΤΣΙΜΕΝΤΩΝ ΤΙΤΑΝ	Cement	HV	No3	ΕΥΚΑΡΠΙΑ, 54600 ΕΥΚΑΡΠΙΑ	16,0	18,0	23,4	19,0	20,9	20,9	15,0	20,8	20,8	20,8	20,8	20,8	20,8	20,8	20,8	23,5	323,1	16	0	0	16	20,19
4	SIDENOR S.A.	ΣΙΔΕΝΟΡ ΒΙΟΜΗΧΑΝΙΚΗ ΧΑΛΥΒΑ Α.Ε.	Steel	HV	No1	12 ΧΛΜ Π.Ε.Ο. ΘΕΣΣΑΛΟΝΙΚΗΣ ΒΕΡΟΙΑΣ	71,0	20,0	71,5	71,5	79,6	79,6	79,6	79,0	73,5	68,0	72,6	65,7	60,5	57,7	69,8	58,4	1078,0	16	0	0	16	67,38
5	SOVEL S.A.	ΣΟΒΕΛ Α.Ε. ΕΛΛΗΝΙΚΗ ΒΙΟΜΗΧΑΝΙΑ ΕΠΕΞΕΡΓΑΣΙΑΣ ΧΑΛΥΒΟΣ	Steel	HV	No1	ΤΣΙΓΓΕΛΙ ΑΛΜΥΡΟΥ 37100 ΑΛΜΥΡΟΣ ΜΑΓΝΗΣΙΑΣ	110,6	111,0	111,5	111,5	118,8	118,8	111,6	118,0	118,0	118,0	118,0	118,0	118,0	120,0	120,0	120,0	1861,8	16	0	0	16	116,36
6	CORINTH PIPEWORKS S.A.	ΣΩΛΗΝΟΥΡΓΕΙΑ ΚΟΡΙΝΘΟΥ Α.Ε. ΒΙΟΜΗΧΑΝΙΑ ΣΩΛΗΝΩΝ & ΕΚΜΕΤΑΛΛΕΥΣΗΣ ΑΚΙΝΗΤΩΝ	Steel	MV	No1	ΒΙΠΕ ΘΙΣΒΗΣ ΔΟΜΒΡΑΙΝΑ ΒΟΙΩΤΙΑΣ 32010 ΘΙΣΒΗ	5,0	0,0	0,0	0,0	1,0	5,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	11,8	16	13	0	3	3,93
7	PPC S.A.	ΔΕΗ Α.Ε.	Mining	HV	No1	ΛΙΓΝΙΤΙΚΟ ΚΕΝΤΡΟ ΔΥΤΙΚΗΣ ΜΑΚΕΔΟΝΙΑΣ ΟΡΥΧΕΙΟ ΚΑΡΔΙΑΣ	0,0	21,4	21,4	21,4	23,2	23,2	23,2	19,8	19,8	19,8	19,8	19,8	19,8	19,8	19,8	19,8	312,0	16	1	0	15	20,80
8	PPC S.A.	ΔΕΗ Α.Ε.	Mining	HV	No2	ΛΙΓΝΙΤΙΚΟ ΚΕΝΤΡΟ ΔΥΤΙΚΗΣ ΜΑΚΕΔΟΝΙΑΣ ΟΡΥΧΕΙΟ ΝΟΤΙΟΥ ΠΕΔΙΟΥ (ΧΑΡΑΥΓΗ)	0,0	65,5	65,5	65,5	62,2		62,2	42,2	42,2	42,2	42,2	42,2	42,2	42,2	42,2	42,2	700,7	15	1	1	14	50,05
9	PPC S.A.	ΔΕΗ Α.Ε.	Mining	HV	No3	ΛΙΓΝΙΤΙΚΟ ΚΕΝΤΡΟ ΔΥΤΙΚΗΣ ΜΑΚΕΔΟΝΙΑΣ ΟΡΥΧΕΙΟ ΑΜΥΝΤΑΙΟΥ	0,0	45,2	45,2		45,2			3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	3,4	166,2	13	1	3	12	13,85
10	PPC S.A.	ΔΕΗ Α.Ε.	Mining	HV	No4	ΛΙΓΝΙΤΙΚΟ ΚΕΝΤΡΟ ΔΥΤΙΚΗΣ ΜΑΚΕΔΟΝΙΑΣ ΟΡΥΧΕΙΟ ΚΥΡΙΟΥ ΠΕΔΙΟΥ (ΟΡΥΧΕΙΑ ΛΙΠΤΟΛ)	0,0	20,0	20,0		20,0	20,0	20,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	15,0	235,0	15	1	1	14	16,79
11	PPC S.A.	ΔΕΗ Α.Ε.	Mining	HV	No5	ΛΙΓΝΙΤΙΚΟ ΚΕΝΤΡΟ ΜΕΓΑΛΟΠΟΛΗΣ (ΧΩΡΕΜΙ)	0,0	23,5	23,5	23,5	22,5		22,5	18,6	18,6	18,6	18,6	18,6	18,6	18,6	18,6	18,5	282,8	15	1	1	14	20,20
12	HERACLES GENERAL CEMENT S.A.	ΑΝΩΝΥΜΟΣ ΓΕΝΙΚΗ ΕΤΑΙΡΕΙΑ ΤΣΙΜΕΝΤΩΝ ΗΡΑΚΛΗΣ	Cement	HV	No1	ΑΓΡΙΑ - ΕΡΓΟΣΤΑΣΙΟ ΟΛΥΜΠΟΣ, 37300	31,0	22,3	41,0	41,0	42,5		42,5	42,0	42,0	42,0	42,0	36,4	36,4	36,4	36,4	32,3	566,2	15	0	1	15	37,75
13	HERACLES GENERAL CEMENT S.A.	ΑΝΩΝΥΜΟΣ ΓΕΝΙΚΗ ΕΤΑΙΡΕΙΑ ΤΣΙΜΕΝΤΩΝ ΗΡΑΚΛΗΣ	Cement	HV	No2	ΜΗΛΑΚΙ-ΕΡΓΟΣΤΑΣΙΟ ΜΗΛΑΚΙ 34500 ΑΛΙΒΕΡΙ	16,4	11,9	21,9	21,9	24,4		24,4	12,1	23,3	23,3	23,3	22,7	22,7	22,7	22,7	22,4	316,1	15	0	1	15	21,07
14	SELECTED TEXTILES S.A.	ΕΠΙΛΕΚΤΟΣ ΚΛΩΣΤΟΫΦΑΝΤΟΥΡΓΙΑ ΑΕΒΕ	Textiles	MV	No1	7ο ΧΛΜ ΦΑΡΣΑΛΩΝ - ΛΑΡΙΣΗΣ	6,2	6,2	12,6	12,6	12,2	12,2	12,2	11,5	11,5	11,5		11,5	11,5	10,8	10,0	10,0	162,5	15	0	1	15	10,83
15	MEL-MACEDONIAN PAPER MILLS S.A.	ΜΕΛ-ΜΑΚΕΔΟΝΙΚΗ ΕΤΑΙΡΕΙΑ ΧΑΡΤΟΥ Α.Ε.	Paper-Pulp	HV	No1	ΒΙ.ΠΑ.ΘΕ, ΚΑΤΩ ΓΕΦΥΡΑ ΘΕΣΣΑΛΟΝΙΚΗΣ 57011	6,3	7,0	8,5	8,5	8,5	8,5		8,8	8,8	8,8	8,8	8,8	9,0	9,0	0,0	0,0	109,3	15	2	1	13	8,41
16	YIOULA GLASSWORKS S.A.	ΥΑΛΟΥΡΓΙΚΗ ΒΙΟΜΗΧΑΝΙΑ ΓΙΟΥΛΑ ΑΕ / ΒΑ ΥΑΛΟΥΡΓΙΑ ΕΛΛΑΔΑΣ	Glass	MV	No1	ΟΡΥΖΟΜΥΛΩΝ 5 ΑΙΓΑΛΕΩ	0,5	3,0	5,0	5,0	3,3	3,4											20,2	6	0	10	6	3,37
17	HALCOR S.A.	ΧΑΛΚΟΡ ΑΝΩΝΥΜΗ ΕΤΑΙΡΕΙΑ ΕΠΕΞΕΡΓΑΣΙΑΣ ΜΕΤΑΛΛΩΝ	Copper	MV	No1	60ο ΧΙΛ. ΕΘΝ. ΟΔΟΥ ΑΘΗΝΩΝ - ΛΑΜΙΑΣ, 32011, ΟΙΝΟΦΥΤΑ ΒΟΙΩΤΙΑΣ-ΕΡΓΟΣΤΑΣΙΟ ΧΥΤΗΡΙΟΥ								0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	9	9	7	0	-
18	FIBRAN S.A.	ΦΙΜΠΡΑΝ ΔΗΜΗΤΡΙΟΣ ΑΝΑΣΤΑΣΙΑΔΗΣ ΑΝΩΝΥΜΟΣ ΕΤΑΙΡΕΙΑ	Insulation Materials	MV	No1	ΤΕΡΠΝΗ ΔΗΜΟΣ ΒΙΣΑΛΤΙΑΣ Π.Ε. ΣΕΡΡΩΝ	0,0	9,6	9,6		10,3	10,3	10,3	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,7	117,8	15	1	1	14	8,41
19	HALYPS BUILDING MATERIALS S.A	ΧΑΛΥΨ ΔΟΜΙΚΑ ΥΛΙΚΑ Α.Ε.	Cement	HV	No1	17ο ΧΛΜ Ε.Ο. ΑΘΗΝΩΝ ΚΟΡΙΝΘΟΥ 19300 ΑΣΠΡΟΠΥΡΓΟΣ	5,2	7,0	11,0	10,4	10,0	10,0	10,0	9,0	9,0	9,0	9,0	9,0	9,0	9,0	9,0	9,0	144,6	16	0	0	16	9,04
20	HELLENIC HALYVOURGIA S.A.	ΧΑΛΥΒΟΥΡΓΙΑ ΕΛΛΑΔΟΣ ΒΟΛΟΣ_VMS	Steel	HV	No1	ΒΙ.ΠΕ.ΒΟΛΟΥ 38500 ΒΟΛΟΣ	50,0	50,0	50,0	50,0	50,4	52,6	50,0	49,0	49,5	49,5	49,5	49,2	49,2	49,5	49,5	49,3	797,2	16	0	0	16	49,83
21	HELLENIC HALYVOURGIA S.A.	ΧΑΛΥΒΟΥΡΓΙΑ ΕΛΛΑΔΟΣ ΒΟΛΟΣ_VRM	Steel	MV	No2	ΒΙ.ΠΕ.ΒΟΛΟΥ 38500 ΒΟΛΟΣ	9,0	9,0	9,0	9,0	9,0	9,4	8,9	8,5	9,0	9,0	9,0	9,2	9,2	9,0	9,0	10,9	146,1	16	0	0	16	9,13
22	HELLENIC HALYVOURGIA S.A.	ΧΑΛΥΒΟΥΡΓΙΑ ΕΛΛΑΔΟΣ ΑΕ	Steel	HV	No1	17ο ΧΛΜ Ε.Ο. ΑΘΗΝΩΝ ΚΟΡΙΝΘΟΥ 19300 ΑΣΠΡΟΠΥΡΓΟΣ	56,0																56,0	1	0	15	1	56,00
23	ELVAL S.A.	ΕΛΒΑΛ ΕΛΛΗΝΙΚΗ ΒΙΟΜΗΧΑΝΙΑ ΑΛΟΥΜΙΝΙΟΥ	Aluminium Products	HV	No1	ΟΙΝΟΦΥΤΑ ΒΟΙΩΤΙΑΣ								0,0	0,0	0,0	0,0		0,0	0,0	0,0	0,0	0,0	8	8	8	0	-
24	MOTOR OIL (HELLAS) CORINTH REFINERIES S.A.	ΜΟΤΟΡ ΟΙΛ (ΕΛΛΑΣ) ΔΙΥΛΙΣΤΗΡΙΑ ΚΟΡΙΝΘΟΥ Α.Ε.	Oil & Gas	HV	No1	ΔΗΜΟΣ ΑΓ. ΘΕΟΔΩΡΩΝ, Ν. ΚΟΡΙΝΘΙΑΣ	5,0								14,5		14,9	14,9	14,9	14,0	14,0	14,0	106,2	8	0	8	8	13,28
25	HELLENIC PETROLEUM S.A.	ΕΛΛΗΝΙΚΑ ΠΕΤΡΕΛΑΙΑ Α.Ε.	Oil & Gas	HV	No1	7ο ΧΛΜ ΠΑΛΑΙΑΣ ΕΘΝΙΚΗΣ ΟΔΟΥ ΘΕΣΣΑΛΟΝΙΚΗΣ - ΒΕΡΟΙΑΣ, ΔΗΜΟΣ ΔΕΛΤΑ	6,4	6,4			8,9	8,9	8,9	3,0	3,0	3,0		3,0	3,0	3,0	3,0	3,0	63,5	13	0	3	13	4,88
26	HALYVOURGIKI HELLENIC STEEL INDUSTRY S.A.	ΧΑΛΥΒΟΥΡΓΙΚΗ Α.Ε.	Steel	HV	No1	20ο ΧΙΛ ΕΟΑΚ 19200 ΕΛΕΥΣΙΝΑ	71,4							6,7	6,7	6,7	6,7						98,2	5	0	11	5	19,64
27	LARCO GENERAL MINING & METALLURGICAL Co. S.A.	ΓΕΝΙΚΗ ΜΕΤΑΛΛΕΥΤΙΚΗ & ΜΕΤΑΛΛΟΥΡΓΙΚΗ ΑΝΩΝΥΜΟΣ ΕΤΑΙΡΕΙΑ ΛΑΡΚΟ	Mining - Minerals	HV	No1	ΛΑΡΥΜΝΑ ΦΘΙΩΤΙΔΑΣ ΤΚ 35012		145,0	129,8	0,0	94,3	33,6		50,8	50,0	50,0	45,0	50,0	55,0	57,3	55,0	65,0	880,8	14	1	2	13	67,75
28	PAKO S.A A.VL.KOLIOPOULOS	ΑΝ. ΒΛ. ΚΟΛΙΟΠΟΥΛΟΣ - ΠΑΚΟ Α.Ε.	Packaging	MV	No1	ΠΕΛΑΣΓΙΑ ΦΘΙΩΤΙΔΑΣ / ΕΠΑΡΧΙΑΚΟΣ ΔΡΟΜΟΣ ΠΕΛΑΣΓΙΑΣ - ΒΑΘΥΚΟΙΛΟΥ 35013 ΠΕΛΑΣΓΙΑ			3,7	3,7	3,7	3,7	3,7	3,7	3,7	3,7	3,7	4,0	4,0	4,0	4,0	3,9	53,2	14	0	2	14	3,80
29	HELLENIC CABLES S.A.	ΕΛΛΗΝΙΚΑ ΚΑΛΩΔΙΑ ΕΛΛΗΝΙΚΗ ΒΙΟΜΗΧΑΝΙΑ ΚΑΛΩΔΙΩΝ ΑΝΩΝΥΜΗ ΕΤΑΙΡΕΙΑ	Cables Manufacturing	MV	No1	69 ΧΛΜ ΠΕΟ ΑΘΗΝΩΝ - ΘΗΒΩΝ			0,0	3,9	0,6	4,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	8,6	14	11	2	3	2,87
30	FULGOR S.A.	FULGOR Α.Ε. ΕΛΛΗΝΙΚΗ ΒΙΟΜΗΧΑΝΙΑ ΚΑΛΩΔΙΩΝ	Cables Manufacturing	HV	No1	ΣΟΥΣΑΚΙ ΑΓΙΟΙ ΘΕΟΔΩΡΟΙ 20000			0,0	0,0	0,6		0,0	0,0	0,0	0,0	0,0						0,6	8	7	8	1	0,60
31	FTHIOTIS PAPER MILL S.A.	ΧΑΡΤΟΠΟΙΪΑ ΦΘΙΩΤΙΔΑΣ ΑΕ	Paper-Pulp	HV	No1	ΔΑΜΑΣΤΑ ΦΘΙΩΤΙΔΑΣ, 35100, ΛΑΜΙΑ				3,0													3,0	1	0	15	1	3,00
32	AIR LIQUIDE HELLAS S.A.G.I.	AIR LIQUIDE HELLAS ΑΕΒΑ	Chemicals	MV	No1	59ο ΧΛΜ Ε.Ο. ΑΘΗΝΩΝ ΛΑΜΙΑΣ, ΠΑΤΗΜΑ ΣΧΗΜΑΤΑΡΙΟΥ, 32009 ΣΧΗΜΑΤΑΡΙ				7,5		6,1	6,1	6,1	6,1	6,1	6,1	6,1	6,1	6,1	6,1	6,1	74,6	12	0	4	12	6,22
33	THRACE NONWOVEN & GEOSYNTHETICS S.A.	THRACE NONWOVEN & GEOSYNTHETICS ABEE	Nonwoven Fabrics	MV	No1	ΜΑΓΙΚΟ ΞΑΝΘΗΣ, 67100, ΞΑΝΘΗ					9,0												9,0	1	0	15	1	9,00
34	THRACE PLASTICS PACK S.A.	ΠΛΑΣΤΙΚΑ ΘΡΑΚΗΣ PACK ΑΒΕΕ	Plastics	HV	No1	ΒΙΠΕ ΙΩΑΝΝΙΝΩΝ 45500 ΙΩΑΝΝΙΝΑ					3,0	3,0	3,0										9,0	3	0	13	3	3,00
35	HALCOR S.A.	ΧΑΛΚΟΡ ΑΝΩΝΥΜΗ ΕΤΑΙΡΕΙΑ ΕΠΕΞΕΡΓΑΣΙΑΣ ΜΕΤΑΛΛΩΝ	Copper	HV	No2	62ο ΧΙΛ. ΕΘΝ. ΟΔΟΥ ΑΘΗΝΩΝ - ΛΑΜΙΑΣ, 32011, ΟΙΝΟΦΥΤΑ ΒΟΙΩΤΙΑΣ-ΕΡΓΟΣΤΑΣΙΟ ΣΩΛΗΝΟΥΡΓΙΟΥ								0,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	9	8	7	1	0,40
36	SYMETAL S.A.	ΣΥΜΕΤΑΛ ΒΙΟΜΗΧΑΝΙΑ ΑΛΟΥΜΙΝΟΧΑΡΤΟΥ Α.Ε	Aluminium Products	HV	No1	ΑΓ.ΘΩΜΑΣ 32011,ΟΙΝΟΦΥΤΑ ΒΟΙΩΤΙΑΣ														0,0	0,0	0,0	0,0	3	3	13	0	-
Total Successful Bids per ILS Type 1 Auction							18	21	21	20	27	21	20	24	24	23	22	23	23	23	22	22						
Total Bids per ILS Type 1 Auction							No data	47	111	78	97	78	82	109	104	101	105	105	106	103	103	106						
Successful Bids to Total Bids Index (StT Index) for ILS Type 1 Auction							-	0,447	0,189	0,256	0,278	0,269	0,244	0,220	0,231	0,228	0,210	0,219	0,217	0,223	0,214	0,208						

ATTACHMENT "B" - ILST 2 Beneficiaries Data

No	Beneficiary	Beneficiary (Greek)	Industry Type	Voltage Level	Consumption Location (CL) No	Consumption Location (CL) Name (Greek)	Maximum Interruptible Load (MIL) per ILS Type 2 Auction (MW)																	Total Biddings in the ILS Type 2 Auction	Total Failed Biddings in the ILS Type 2 Auction	Total times not participating in the ILS Type 2 Bidding	Total Successful Participations in the ILS Type 2 Auction	Mean MIL per ILS Type 1 Auction (MW)
							2016 No1	2016 No2	2016 No3	2016 No4	2017 No1	2017 No2	2017 No3	2018 No1	2018 No2	2018 No3	2018 No4	2019 No1	2019 No2	2019 No3	2019 No4	2020 No1	Total					
1	TITAN CEMENT	Α.Ε. ΤΣΙΜΕΝΤΩΝ ΤΙΤΑΝ	Cement	HV	No1	ΘΕΣΗ ΚΑΜΑΡΙ ΒΟΙΩΤΙΑ, 19012 ΣΤΕΦΑΝΗ	0,0	28,0	29,0	0,0	40,4	0,0	40,4										137,8	7	3	9	4	34,45
2	TITAN CEMENT	Α.Ε. ΤΣΙΜΕΝΤΩΝ ΤΙΤΑΝ	Cement	HV	No2	ΡΙΟ, 26504 ΡΙΟΝ	1,0	18,0	17,9	25,5	25,5	0,0	25,5										113,4	7	1	9	6	18,90
3	TITAN CEMENT	Α.Ε. ΤΣΙΜΕΝΤΩΝ ΤΙΤΑΝ	Cement	HV	No3	ΕΥΚΑΡΠΙΑ, 54600 ΕΥΚΑΡΠΙΑ	0,0	16,0	17,0	23,4	0,0	0,0	20,9										77,3	7	3	9	4	19,33
4	TITAN CEMENT	Α.Ε. ΤΣΙΜΕΝΤΩΝ ΤΙΤΑΝ	Cement	MV	No4	ΕΛΕΥΣΙΣ, 19200 ΕΛΕΥΣΙΝΑ	0,2	5,0	5,4	5,4								3,0	3,0	3,0	3,0	3,0	31,0	9	0	7	9	3,44
5	ALOUMINIUM OF GREECE S.A.	ΑΛΟΥΜΙΝΙΟΝ ΤΗΣ ΕΛΛΑΔΟΣ ΒΙΟΜΗΧΑΝΙΚΗ ΚΑΙ ΕΜΠΟΡΙΚΗ ΑΝΩΝΥΜΟΣ ΕΤΑΙΡΕΙΑ ΒΕΑΕ	Aluminium	HV	No1	ΑΓΙΟΣ ΝΙΚΟΛΑΟΣ,ΤΚ 32003, ΒΟΙΩΤΙΑ	285,1	285,1	250,0	230,0	260,5	192,3	213,3	276,0	270,0	245,5	238,5	239,1	233,9	233,5	227,2	228,2	3908,2	16	0	0	16	244,26
6	SIDENOR S.A.	ΣΙΔΕΝΟΡ ΒΙΟΜΗΧΑΝΙΚΗ ΧΑΛΥΒΑ Α.Ε.	Steel	HV	No1	12 ΧΛΜ Π.Ε.Ο. ΘΕΣΣΑΛΟΝΙΚΗΣ ΒΕΡΟΙΑΣ	0,0	53,6	46,5	0,0	0,0		0,0		5,5	11,0	6,4	13,3	18,5	27,0	10,2	21,6	213,6	14	4	2	10	21,36
7	SOVEL S.A.	ΣΟΒΕΛ Α.Ε. ΕΛΛΗΝΙΚΗ ΒΙΟΜΗΧΑΝΙΑ ΕΠΕΞΕΡΓΑΣΙΑΣ ΧΑΛΥΒΟΣ	Steel	HV	No1	ΤΣΙΓΓΕΛΙ ΑΛΜΥΡΟΥ 37100 ΑΛΜΥΡΟΣ ΜΑΓΝΗΣΙΑΣ	0,0	105,0	106,0	0,0	113,3		113,3										437,6	6	2	10	4	109,40
8	CORINTH PIPEWORKS S.A.	ΣΩΛΗΝΟΥΡΓΕΙΑ ΚΟΡΙΝΘΟΥ Α.Ε. ΒΙΟΜΗΧΑΝΙΑ ΣΩΛΗΝΩΝ & ΕΚΜΕΤΑΛΛΕΥΣΗΣ ΑΚΙΝΗΤΩΝ	Steel	MV	No1	ΒΙΠΕ ΘΙΣΒΗΣ ΔΟΜΒΡΑΙΝΑ ΒΟΙΩΤΙΑΣ 32010 ΘΙΣΒΗ	0,0	0,0	0,0	9,0	5,8		5,8	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	110,6	15	3	1	12	9,22
9	PPC S.A.	ΔΕΗ Α.Ε.	Mining	HV	No1	ΛΙΓΝΙΤΙΚΟ ΚΕΝΤΡΟ ΔΥΤΙΚΗΣ ΜΑΚΕΔΟΝΙΑΣ ΟΡΥΧΕΙΟ ΚΑΡΔΙΑΣ	0,0	10,7	10,0		22,5		23,2	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	93,4	14	1	2	13	7,18
10	PPC S.A.	ΔΕΗ Α.Ε.	Mining	HV	No2	ΛΙΓΝΙΤΙΚΟ ΚΕΝΤΡΟ ΔΥΤΙΚΗΣ ΜΑΚΕΔΟΝΙΑΣ ΟΡΥΧΕΙΟ ΝΟΤΙΟΥ ΠΕΔΙΟΥ (ΧΑΡΑΥΓΗ)	0,0	32,8	55,2		62,0	62,2	62,2	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	301,4	15	1	1	14	21,53
11	PPC S.A.	ΔΕΗ Α.Ε.	Mining	HV	No3	ΛΙΓΝΙΤΙΚΟ ΚΕΝΤΡΟ ΔΥΤΙΚΗΣ ΜΑΚΕΔΟΝΙΑΣ ΟΡΥΧΕΙΟ ΑΜΥΝΤΑΙΟΥ	0,0	22,6	36,0	45,2				3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	130,8	13	1	3	12	10,90
12	PPC S.A.	ΔΕΗ Α.Ε.	Mining	HV	No4	ΛΙΓΝΙΤΙΚΟ ΚΕΝΤΡΟ ΔΥΤΙΚΗΣ ΜΑΚΕΔΟΝΙΑΣ ΟΡΥΧΕΙΟ ΚΥΡΙΟΥ ΠΕΔΙΟΥ (ΟΡΥΧΕΙΑ ΛΙΠΤΟΛ)	0,0	10,0	12,0	20,0	19,5		20,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	108,5	15	1	1	14	7,75
13	PPC S.A.	ΔΕΗ Α.Ε.	Mining	HV	No5	ΛΙΓΝΙΤΙΚΟ ΚΕΝΤΡΟ ΜΕΓΑΛΟΠΟΛΗΣ (ΧΩΡΕΜΙ)	0,0	11,8	20,0		23,0	23,5	23,5	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	128,8	15	1	1	14	9,20
14	HERACLES GENERAL CEMENT S.A.	ΑΝΩΝΥΜΟΣ ΓΕΝΙΚΗ ΕΤΑΙΡΕΙΑ ΤΣΙΜΕΝΤΩΝ ΗΡΑΚΛΗΣ	Cement	HV	No1	ΑΓΡΙΑ - ΕΡΓΟΣΤΑΣΙΟ ΟΛΥΜΠΟΣ, 37300	16,5		23,0	0,0	42,5	0,0	42,5										124,5	6	2	10	4	31,13
15	HERACLES GENERAL CEMENT S.A.	ΑΝΩΝΥΜΟΣ ΓΕΝΙΚΗ ΕΤΑΙΡΕΙΑ ΤΣΙΜΕΝΤΩΝ ΗΡΑΚΛΗΣ	Cement	HV	No2	ΜΗΛΑΚΙ-ΕΡΓΟΣΤΑΣΙΟ ΜΗΛΑΚΙ 34500 ΑΛΙΒΕΡΙ	8,2		11,4	0,0	0,0	0,0	22,4										42,0	6	3	10	3	14,00
16	SELECTED TEXTILES S.A.	ΕΠΙΛΕΚΤΟΣ ΚΛΩΣΤΟΫΦΑΝΤΟΥΡΓΙΑ ΑΕΒΕ	Textiles	MV	No1	7ο ΧΛΜ ΦΑΡΣΑΛΩΝ - ΛΑΡΙΣΗΣ	0,0	6,2	6,2	0,0													12,4	4	2	12	2	6,20
17	MEL-MACEDONIAN PAPER MILLS S.A.	ΜΕΛ-ΜΑΚΕΔΟΝΙΚΗ ΕΤΑΙΡΕΙΑ ΧΑΡΤΟΥ Α.Ε.	Paper-Pulp	HV	No1	ΒΙ.ΠΑ.ΘΕ, ΚΑΤΩ ΓΕΦΥΡΑ ΘΕΣΣΑΛΟΝΙΚΗΣ 57011	0,0	0,0	8,5	0,0	0,0	5,5									9,0	9,0	32,0	8	4	8	4	8,00
18	HALCOR S.A.	ΧΑΛΚΟΡ ΑΝΩΝΥΜΗ ΕΤΑΙΡΕΙΑ ΕΠΕΞΕΡΓΑΣΙΑΣ ΜΕΤΑΛΛΩΝ	Copper	MV	No1	60ο ΧΙΛ. ΕΘΝ. ΟΔΟΥ ΑΘΗΝΩΝ - ΛΑΜΙΑΣ, 32011, ΟΙΝΟΦΥΤΑ ΒΟΙΩΤΙΑΣ-ΕΡΓΟΣΤΑΣΙΟ ΧΥΤΥΡΙΟΥ	0,0	0,0	0,0	5,1	4,5		4,5	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,0	4,6	50,7	15	3	1	12	4,23
19	YIOULA GLASSWORKS S.A.	ΥΑΛΟΥΡΓΙΚΗ ΒΙΟΜΗΧΑΝΙΑ ΓΙΟΥΛΑ ΑΕ / ΒΑ ΥΑΛΟΥΡΓΙΑ ΕΛΛΑΔΑΣ	Glass	MV	No1	ΟΡΥΖΟΜΥΛΩΝ 5 ΑΙΓΑΛΕΩ	0,0	5,0	5,0	5,0	5,0	3,0	3,0	4,8	4,8	4,8	4,8	4,8	4,8		4,8	0,0	59,6	15	2	1	13	4,58
20	FIBRAN S.A.	ΦΙΜΠΡΑΝ ΔΗΜΗΤΡΙΟΣ ΑΝΑΣΤΑΣΙΑΔΗΣ ΑΝΩΝΥΜΟΣ ΕΤΑΙΡΕΙΑ	Insulation Materials	MV	No1	ΤΕΡΠΝΗ ΔΗΜΟΣ ΒΙΣΑΛΤΙΑΣ Π.Ε. ΣΕΡΡΩΝ	5,1	7,3	7,3	7,3	8,8	8,8	8,8	3,0	3,0	3,0	3,0	4,2	4,2	4,2	4,2	4,2	86,4	16	0	0	16	5,40
21	HALYPS BUILDING MATERIALS S.A	ΧΑΛΥΨ ΔΟΜΙΚΑ ΥΛΙΚΑ Α.Ε.	Cement	HV	No1	17ο ΧΛΜ Ε.Ο. ΑΘΗΝΩΝ ΚΟΡΙΝΘΟΥ 19300 ΑΣΠΡΟΠΥΡΓΟΣ	0,0	9,0	11,0	8,0	0,0												28,0	5	2	11	3	9,33
22	HELLENIC HALYVOURGIA S.A.	ΧΑΛΥΒΟΥΡΓΙΑ ΕΛΛΑΔΟΣ ΒΟΛΟΣ_VMS	Steel	HV	No1	ΒΙ.ΠΕ.ΒΟΛΟΥ 38500 ΒΟΛΟΣ	49,0	49,0	49,0	49,0	49,0	47,0	47,0										339,0	7	0	9	7	48,43
23	HELLENIC HALYVOURGIA S.A.	ΧΑΛΥΒΟΥΡΓΙΑ ΕΛΛΑΔΟΣ ΒΟΛΟΣ_VRM	Steel	MV	No2	ΒΙ.ΠΕ.ΒΟΛΟΥ 38500 ΒΟΛΟΣ	8,5	8,5	8,5	8,5	8,4	8,0	8,4										58,8	7	0	9	7	8,40
24	HELLENIC HALYVOURGIA S.A.	ΧΑΛΥΒΟΥΡΓΙΑ ΕΛΛΑΔΟΣ ΑΕ	Steel	HV	No3	17ο ΧΛΜ Ε.Ο. ΑΘΗΝΩΝ ΚΟΡΙΝΘΟΥ 19300 ΑΣΠΡΟΠΥΡΓΟΣ	56,0																56,0	1	0	15	1	56,00
25	ELVAL S.A.	ΕΛΒΑΛ ΕΛΛΗΝΙΚΗ ΒΙΟΜΗΧΑΝΙΑ ΑΛΟΥΜΙΝΙΟΥ	Aluminium Products	HV	No1	ΟΙΝΟΦΥΤΑ ΒΟΙΩΤΙΑΣ	0,0	0,0	0,0	18,0	0,0		10,0	5,0	5,0	7,0	10,0		7,0	5,0	5,0	5,0	77,0	14	4	2	10	7,70
26	HELLENIC PETROLEUM S.A.	ΕΛΛΗΝΙΚΑ ΠΕΤΡΕΛΑΙΑ Α.Ε.	Oil & Gas	HV	No1	7ο ΧΛΜ ΠΑΛΑΙΑΣ ΕΘΝΙΚΗΣ ΟΔΟΥ ΘΕΣΣΑΛΟΝΙΚΗΣ - ΒΕΡΟΙΑΣ, ΔΗΜΟΣ ΔΕΛΤΑ		6,4			8,9	8,9	8,9				3,0						36,1	5	0	11	5	7,22
27	MOTOR OIL (HELLAS) CORINTH REFINERIES S.A.	ΜΟΤΟΡ ΟΙΛ (ΕΛΛΑΣ) ΔΙΥΛΙΣΤΗΡΙΑ ΚΟΡΙΝΘΟΥ Α.Ε.	Oil & Gas	HV	No1	ΔΗΜΟΣ ΑΓ. ΘΕΟΔΩΡΩΝ, Ν. ΚΟΡΙΝΘΙΑΣ	0,0								0,0		0,0						0,0	3	3	13	0	-
28	HALYVOURGIKI HELLENIC STEEL INDUSTRY S.A.	ΧΑΛΥΒΟΥΡΓΙΚΗ Α.Ε.	Steel	HV	No1	20ο ΧΙΛ ΕΟΑΚ 19200 ΕΛΕΥΣΙΝΑ	70,4																70,4	1	0	15	1	70,40
29	LARCO GENERAL MINING & METALLURGICAL Co. S.A.	ΓΕΝΙΚΗ ΜΕΤΑΛΛΕΥΤΙΚΗ & ΜΕΤΑΛΛΟΥΡΓΙΚΗ ΑΝΩΝΥΜΟΣ ΕΤΑΙΡΕΙΑ ΛΑΡΚΟ	Mining - Minerals	HV	No1	ΛΑΡΥΜΝΑ ΦΘΙΩΤΙΔΑΣ ΤΚ 35012		160,0	161,3	171,3	171,3	126,3	171,3	110,0	110,1	110,1	112,7	114,0	110,0	108,7	115,0	110,0	1962,1	15	0	1	15	130,81
30	PAKO S.A A.VL.KOLIOPOULOS	ΑΝ. ΒΛ. ΚΟΛΙΟΠΟΥΛΟΣ - ΠΑΚΟ Α.Ε.	Packaging	MV	No1	ΠΕΛΑΣΓΙΑ ΦΘΙΩΤΙΔΑΣ / ΕΠΑΡΧΙΑΚΟΣ ΔΡΟΜΟΣ ΠΕΛΑΣΓΙΑΣ - ΒΑΘΥΚΟΙΛΟΥ 35013 ΠΕΛΑΣΓΙΑ			3,8	3,8	3,0	0,0	3,8		3,0								17,4	6	1	10	5	3,48
31	HELLENIC CABLES S.A.	ΕΛΛΗΝΙΚΑ ΚΑΛΩΔΙΑ ΕΛΛΗΝΙΚΗ ΒΙΟΜΗΧΑΝΙΑ ΚΑΛΩΔΙΩΝ ΑΝΩΝΥΜΗ ΕΤΑΙΡΕΙΑ	Cables Manufacturing	MV	No1	69 ΧΛΜ ΠΕΟ ΑΘΗΝΩΝ - ΘΗΒΩΝ			0,0	0,0	3,0		3,0	3,0		3,0	3,0	3,0	3,0	3,0	3,0	3,0	30,0	12	2	4	10	3,00
32	FULGOR S.A.	FULGOR A.E. ΕΛΛΗΝΙΚΗ ΒΙΟΜΗΧΑΝΙΑ ΚΑΛΩΔΙΩΝ	Cables Manufacturing	HV	No1	ΣΟΥΣΑΚΙ ΑΓΙΟΙ ΘΕΟΔΩΡΟΙ 20000			0,0	3,8	0,0		0,0	0,0									3,8	5	4	11	1	3,80
33	THRACE NONWOVEN & GEOSYNTHETICS S.A.	THRACE NONWOVEN & GEOSYNTHETICS ABEE	Nonwoven Fabrics	MV	No1	ΜΑΓΙΚΟ ΞΑΝΘΗΣ, 67100, ΞΑΝΘΗ				8,7	9,0	8,5	8,5	8,1	8,1	8,1	8,1	8,1	8,1	8,1	8,1	7,9	107,4	13	0	3	13	8,26
34	FTHIOTIS PAPER MILL S.A.	ΧΑΡΤΟΠΟΪΙΑ ΦΘΙΩΤΙΔΑΣ ΑΕ	Paper-Pulp	HV	No1	ΔΑΜΑΣΤΑ ΦΘΙΩΤΙΔΑΣ, 35100, ΛΑΜΙΑ				3,0													3,0	1	0	15	1	3,00
35	AIR LIQUIDE HELLAS S.A.G.I.	AIR LIQUIDE HELLAS AEBA	Chemicals	MV	No1	59ο ΧΛΜ Ε.Ο. ΑΘΗΝΩΝ ΛΑΜΙΑΣ, ΠΑΤΗΜΑ ΣΧΗΜΑΤΑΡΙΟΥ, 32009 ΣΧΗΜΑΤΑΡΙ				0,0	3,1	0,0	3,1										6,2	4	2	12	2	3,10
36	ATHENS INTERNATIONAL AIRPORT S.A.	ΔΙΕΘΝΗΣ ΑΕΡΟΛΙΜΕΝΑΣ ΑΘΗΝΩΝ Α.Ε.	Transport Infrastructure	HV	No1	ΔΙΕΘΝΗΣ ΑΕΡΟΛΙΜΕΝΑΣ ΑΘΗΝΩΝ, ΣΠΑΤΑ, 19019					3,0	3,0		3,0	3,0		3,0	3,0			3,0	3,0	24,0	8	0	8	8	3,00
37	THRACE PLASTICS PACK S.A.	ΠΛΑΣΤΙΚΑ ΘΡΑΚΗΣ PACK ABEE	Plastics	HV	No1	ΒΙΠΕ ΙΩΑΝΝΙΝΩΝ 45500 ΙΩΑΝΝΙΝΑ					3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0		33,0	11	0	5	11	3,00
38	HALCOR S.A.	ΧΑΛΚΟΡ ΑΝΩΝΥΜΗ ΕΤΑΙΡΕΙΑ ΕΠΕΞΕΡΓΑΣΙΑΣ ΜΕΤΑΛΛΩΝ	Copper	HV	No2	62ο ΧΙΛ. ΕΘΝ. ΟΔΟΥ ΑΘΗΝΩΝ - ΛΑΜΙΑΣ, 32011, ΟΙΝΟΦΥΤΑ ΒΟΙΩΤΙΑΣ-ΕΡΓΟΣΤΑΣΙΟ ΣΩΛΗΝΟΥΡΓΙΟΥ					5,0		3,7	5,1	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	57,8	11	0	5	11	5,25
39	SYMETAL S.A.	ΣΥΜΕΤΑΛ ΒΙΟΜΗΧΑΝΙΑ ΑΛΟΥΜΙΝΟΧΑΡΤΟΥ Α.Ε	Aluminium Products	HV	No1	ΑΓ.ΘΩΜΑΣ 32011,ΟΙΝΟΦΥΤΑ ΒΟΙΩΤΙΑΣ														0,0	0,0	0,0	0,0	3	3	13	0	-
Total Successful Bids per ILS Type 2 Auction							10	20	23	19	24	13	26	17	18	17	19	18	18	17	20	18						
Total Bids per ILS Type 2 Auction							No data	58	126	87	90	55	98	39	40	39	42	40	41	41	45	44						
Successful Bids to Total Bids Index (StT Index) for ILS Type 2 Auction							-	0,345	0,183	0,218	0,267	0,236	0,265	0,436	0,450	0,436	0,452	0,450	0,439	0,415	0,444	0,409						