Modeling the Effects of Generation Adequacy Policies Implemented in North West European Countries on the Dutch Electricity Market

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List of Abbreviations

ACER	Agency for Cooperation of Energy Regulators
APX	Amsterdam Power Exchange
DNM	Distribution Network Manager
EdF	Électricité de France
EnBW	Energie Baden-Württemberg AG
ENTSO-E	European Network of Transmission System Operators for Electricity
Eurostat	Statistical office of the European Union
GDP	Gross Domestic Product
NETA	New Electricity Trading Arrangements
NWE	North West Europe
OTC	Over The Counter
PJM	Pennsylvania, New Jersey and Maryland
RES	Renewable Energy Sources
RKOM	Regulation Power Options Market
RTE	RTE-EDF Transport SA
SO	System Operator
TSO	Transmission System Operator
VOLL	Value Of Lost Load

1. Introduction

1.1. Problem description

Electricity production plays a crucial role in The Netherlands to support the functioning and development of the entire society. Therefore, it is in the best interest of the country to keep the Dutch wholesale electricity market well functioning, in order to meet the current and future demand of electricity. However, some countries of North West Europe[1]—*From now on NWE*— such as Germany[2], France, United Kingdom and Norway[3] are worried about security of supply in their electricity systems; according to generation adequacy forecasting of ENTSOE, an important reduction of generation adequacy could take place in 2016 (Euroelectric, 2011). As a result, the aforementioned countries of NWE are implementing generation adequacy policies better known as capacity mechanisms. These generation adequacy policies implemented in neighboring countries under European market integration concerns the Dutch regulator since the cross-border effects of capacity mechanisms have not been studied and their effects on the performance of the Dutch wholesale market is unclear.

The objective of this research is to explore the cross-border effects of capacity mechanisms on prices and generation adequacy on the Dutch wholesale market and more importantly to analyze how the Netherlands should react under the implementation of capacity mechanism by its neighbors in NWE.

1.2. Scope of the study

The geographical scope of this study is mainly the Netherlands and the countries of NWE directly interconnected with the Dutch electricity system, namely Germany, France, United Kingdom and Norway. The other members of NWE have only been

[1] North West Europe cluster countries such as the Netherlands, Belgium, France, Germany, United Kingdom, Norway, Denmark, Finland and Sweden.
[2] Germany has a temporary arrangement to contract production capacity in winter. It fits within the description of a capacity mechanism
[3] Norway has already implemented a capacity mechanism

considered in the first part of the study where a description of the generation adequacy policies in NWE is provided. It should be noted that the members of NWE that were not considered in this research, namely Belgium, Denmark, Finland and Sweden, are not implementing capacity mechanisms in their electricity systems.

The study focuses on modeling the wholesale market of the Netherlands and the aforementioned countries of NWE under different demand scenarios with and without capacity mechanism. Special attention is paid to the cross-border effects of capacity mechanisms implemented in NWE on Dutch electricity prices, profits, payments for capacity mechanisms and reliable production in the short-term. These variables are used to analyze the improvement or deterioration of the reliability and affordability of electricity in the Netherlands and, subsequently, to design simple policy alternatives to reduce undesirable cross-border effects of capacity mechanism on Dutch wholesale market.

1.3. Research question and chosen methodology

This study aims to give a suitable answer to the following research question:

- *How should the Netherlands react to the implementation of capacity mechanisms by neighboring countries in NWE?*

Since this question is very wide to be answer directly, it has been split in seven sub questions as depicted beneath:

Table 1 Methodologies employed to answer the research question, inputs and outputs

Sub question	Methods	Inputs	Outputs
What electricity generation adequacy policies are currently implemented in NWE?	Desk research/expert opinions	1. Research articles of generation adequacy in NWE 2. Reports of European commission and Nma regarding capacity mechanisms and generation adequacy 3. Question for experts about the functioning of capacity mechanisms	1. List of capacity mechanisms implemented or being discussed in NWE. 2. Analytical description of capacity mechanisms in NWE. ***Described in Chapter 2***

2 What is the current electricity generation adequacy in NWE?	Desk research	1. Electricity generation mix of NWE (from Euroelectric Data 2010) 2. Power demand in NWE. (From ENTSO-E)	1.Figures of electricity generation capacity and peak demand in every country belonging to NWE 2. List of generation mix and cost of technologies in NWE ***Described in Chapter 2***
3 What are the policy goals for the electricity sector in the Netherlands?	Desk research	1.European commission and Nma reports regarding policy goals of the electricity industry	1. List of Dutch policy goals and its meaning ***Described in Chapter 5***
4 What are the potential short run effects of capacity mechanisms implemented in NWE on prices and demand in the Dutch electricity market?	Static equilibrium modeling/ Scenario analysis	1. Data of generation mix and marginal costs of electricity production of NWE in 2010. (From Euroelectric Data 2010 and other reliable sources) 2. Power consumption of NWE in 2010. (From ENTSO-E) 3. Exploratory scenarios which combine scarcity and no scarcity of electricity production	1. Model of the wholesale markets of the Netherlands, France, United Kingdom and Norway. 2. Changes on prices and demand in the Dutch electricity market. ***Described in Chapter 3 and 4***
5 What are the potential effects of capacity mechanisms implemented in NWE on generation adequacy in the Dutch electricity market?	Static equilibrium modeling/ Scenarios analysis	1. Data of generation mix and marginal costs of electricity production of NWE in 2010. (From Euroelectric Data 2010 and other reliable sources) 2. Power consumption of NWE in 2010. (From ENTSO-E) 3. Exploratory scenarios which combine scarcity and no scarcity of electricity production	1. Model of the wholesale markets of the Netherlands, France, United Kingdom and Norway. 2. Changes in total producer surplus and total profits in the Dutch electricity market. ***Described in Chapter 3 and 4***
6 What policy options are available for the Netherlands to cope with the effects of capacity mechanisms implemented in NWE on the Dutch electricity market?	Desk research	1. List of generation adequacy policies earlier implemented in the Netherlands 2. Brainstorming of plausible options based on empirical knowledge and literature	1. List of policies for a decentralized Dutch electricity market ***Described in Chapter 5***
7 What are the effects of the available generation adequacy policy options on the Dutch electricity market?	Qualitative policy analysis	1. List of policies for a decentralized Dutch electricity market	1. Assessment matrix for the Dutch policy options ***Described in Chapter 5***

The research methods employed in this research were selected to provide the most robust and reliable answer for the aforementioned research sub-questions within the timeframe set for this research and according to the resource availability to perform the research. Furthermore, since the sub-questions differ in terms of their scope, a combination of qualitative and quantitative methods has been used to conduct this research. Qualitative methods have been employed in cases where the insight and knowledge about a topic is more important than an accurate numerical answer (Enserink et al 2010). In contrast, Quantitative methods have been applied for those questions for which there are large data sources and rich theory to base the analysis (Hevner, March, Park, & Ram, 2004)

1.4. Contribution of the Author

The author contributes with an analysis of capacity mechanism that combines the policy context of the countries of NWE with empirical data of electricity production capacity. Furthermore, the author has developed a static model and methodology to analyze cross-border effects of capacity mechanisms in NWE.

1.5. Document outline

This document is outlined as follows. A description of the capacity mechanisms and an analysis of generation adequacy in NWE are provided in Chapter 2. This is followed by a detailed description of the approach used to model the Dutch, German, French, British and Norwegian wholesale markets portrayed in Chapter 3. In chapter 4, the cross-border effects of capacity mechanisms such as strategic reserves in Germany, “Obligation de Capacité” in France, “capacity markets” in United Kingdom and operating reserves in Norway are carefully analyzed. In chapter 5, the policy goals of the Dutch electricity industry are explained and a qualitative policy analysis and assessment is conducted to evaluate the effectiveness of the policy options designed to deal with undesirable cross-borer effects of capacity mechanism in NWE. This study ends with Chapter 6, in which not only a recommendation to the Dutch regulator is provided but also a reflection on the conducted research is performed including issues related to capacity mechanisms to be further researched.

2. Generation adequacy policies implemented in the electricity industry of NWE

Understanding the context driving the implementation of capacity mechanisms at the European level is a key issue to analyze the effects of those generation adequacy policies on the wholesale electricity market of the Netherlands. Therefore, this chapter aims to answer the following research sub-questions:

- *What electricity generation adequacy policies are currently implemented in NWE*
- *What is the current electricity generation adequacy in NWE?*

To do so, it starts with a brief explanation of how electricity systems work in theory, followed by a short description of the capacity mechanism available in the literature. Then a description of and comparison of the generation mix and capacity mechanisms implemented in NWE is provided. This chapter is concluded with a quantitative analysis of the generation adequacy in NWE and a brief description of potential effects of those generation adequacy policies on the Dutch wholesale electricity market.

2.1. Textbook model of electricity systems

Electricity is an essential good not only due to its contribution to the GDP of a country but also due to its important role in the industry and other sectors that support the well-functioning of the entire society (De Vries, Correljé, & Knops 2011). The electricity has been broadening its field of application. Nowadays it is the main energy source used by the industry for the manufacturing of goods and for production processes. In the transport sector, long-distance trains across Europe and electric vehicles within cities use electricity. In European households, electricity is mostly used for heating and lighting, but also for supplying power to numerous appliances.

However, electricity is a particularly complex good. It is time limited and economically hardly storable. As a consequence, supply and demand of electricity must be continuously balanced. Furthermore, there is no possibility of marginal increase of electricity production in the short term when all available generation units are producing. Finally, demand of electricity is highly inelastic since most of the electricity applications are hardly replaceable and in most of the cases electricity real time price information is not available for the customers (De Vries, Correljé, & Knops 2011). Therefore, throughout the years the design of the electricity systems has been improved in order to deal with the nature of electricity as a good.

Nowadays, to supply a final consumer with electricity, several activities and interaction among actors take place within the electricity system prior to the delivery of this good. The main activities, actors and interactions between them are depicted in figure 1[4]. This electricity system comprises two layers, a physical-technical layer and an economical-institutional layer.

The physical layer consists of all the technical activities required to deliver the electricity to the final consumer. This starts with the production of electricity called as generation, followed by its transport, which is divided in transmission and distribution activities according to the configuration and allocation of the network. Finally, there is the consumption activity, which is called the load and represents all the electricity demanded by the consumers.

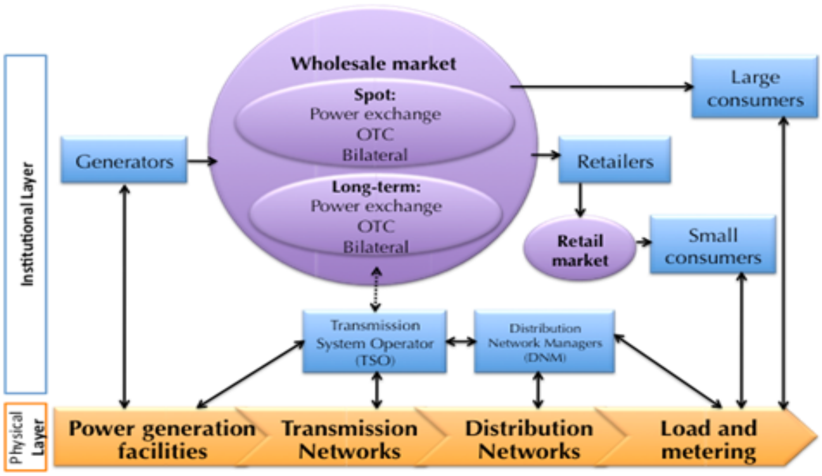

Figure 1 Physical and institutional layer of the electricity system[5]

The economical-institutional layer covers all the actors, which perform the physical activities and other economic activities necessary to deliver electricity. This layer starts with electricity producers that are portrayed by the companies owning power generation plants and generating electricity, and which are looking to optimize their generation production portfolio. Additionally, they are the parties who offer

[4] The figure portrays the textbook model of an electricity system and therefore can be used to describe and understand the electricity systems in NWE

[5] This diagram has been modified from the original description of the electricity systems portrayed in De Vries, Correljé and Knops (2011).

electricity in the wholesale market at a price that at least allows them to recover their costs. Other actors taking part in the wholesale market are large consumers and retailers. Large consumers are usually industries, which consume large quantities of electricity on a regular basis. Therefore, they have an economic incentive to actively participate in the wholesale market by purchasing large quantities of electricity. Retailers are companies that sell electricity to many small consumers, such as households and commercial establishments; they purchase the aggregated electricity demand of the small-scale consumers in the wholesale market. Transmission System Operator—*TSO*— and Distribution Network Managers—*DNM*— are other actors of the economical-institutional layer. The TSO is actively involved in the electricity system. It is responsible for operating the transmission network and is also in charge of contracting the ancillary services needed to deliver electricity to the consumers within the technical standards of frequency and voltage. Those services consist of contracting balancing power and allocating transmission capacity for power exchange within and outside the country, as well as load shedding when required. The DNM is a regional or city level version of the TSO and its main task consists of monitoring, operating and controlling the distribution network that connects the consumers with the electricity network.

The institutional-economic layer of the electricity system consists of institutions such as the wholesale and retail markets, which might differ from country to country in NWE. The wholesale market allows generators and consumers—*large consumers and retailers acting on behalf of small consumers*— to sell and buy electricity in one market place. Besides, it can be categorized in short-term and long-term wholesale market according to the time frame covered by the electricity transaction. Short-term trading, also called spot electricity trading, plays a crucial role to meet the demand of the electricity system at any moment of the day. This is because spot trading allows TSOs and consumers to buy or sell balancing power for short periods of time, especially in cases of deficit or surplus of electricity. In contrast, long-term electricity trading is mostly used to hedge producers and consumers against the risk of price volatility.

Electricity sales and purchases throughout spot and long-term trading are performed in several market places. The usage rate of the market places differs among countries of NWE as it depends on the characteristics of the electricity system. More precisely, the market places comprise power exchange, over the counter—*OTC*— and bilateral contracts. Power exchange market is performed throughout a power exchange entity such as the APX in the Netherlands or Noordpool in Scandinavia, which are actors in charge of organizing the bids from buyers and sellers in a standardized trading platform. This market place offers anonymity and low transaction costs to their users (APX, 2012). The second market place, OTC, allows retailers or large consumers to buy electricity through brokers. Lastly, bilateral market enables market participants to buy electricity directly from a generator. Here a contract is signed between the two market parties, which defines the amount of electricity to be bought, its purchasing price and other details related to the transaction.

Electricity system, as it was described above, is the result of many years of restructuring the electricity sector and of the experiences of many countries such as UK and the US, as well as other countries in Europe. Before 1990, the general belief was that the electricity system should be centrally planned and operated by a single vertically integrated company, most of the time state owned or under regulated private ownership (Newbery, Refining Market Design, 2005). After that period, the attempts have been shifted towards a more technically efficient and cost efficient electricity system. To achieve these goals structural changes such as unbundling and liberalization have been introduced in the design of the electricity system. Electricity unbundling has resulted in accounting, legal and ownership separation of the activities performed by vertically integrated companies throughout the supply chain. As a consequence, vertically integrated companies have had to separate accountability books, or to start new companies focused in a specific activity of the electricity supply chain or to sell part of their assets to meet the unbundling laws. Finally, electricity liberalization has brought in more competition where possible. In other words, competition was introduced in electricity generation and retailing, while electricity transmission and distribution are considered natural monopolies. Those monopolistic activities are regulated and constantly monitored by the regulatory agencies to guarantee equal access and fair tariffs.

2.2. Presentation of Capacity Mechanisms available in literature

A capacity mechanism can be defined as an additional stream of income given to power generation units, which in response should provide adequate electricity production capacity to the system. These mechanisms are in practice steering instruments for policy makers to deal with security of electricity supply issues.

However, there are other reasons behind the implementation of capacity mechanisms and those are summarized in De Vries (2004). In that document, De Vries argues that capacity mechanisms offer more stable investment incentives to power generators than price spikes in energy only markets. In principle, in energy only markets, generators are only paid for the electricity they sell to the consumers in the wholesale market. Electricity prices are based on the marginal cost of electricity production and fluctuate over the day as a result of demand variations. Consequently, generators are expected to recover their fixed cost of production in periods of peak demand of electricity when the marginal cost of production is very high resulting in price spikes. However, price spikes in some immature wholesale markets are not frequent or high enough to ensure the recovery of the fixed cost of electricity production, which discourages investments in new generation units. In contrast, under the implementation of capacity mechanisms, generators obtain the regular payment for electricity in the wholesale market plus the compensation for the production capacity they make available to the electricity system. Therefore, generation companies are fostered to invest in new generation units since they are ensured with more stable revenues that allow them to at least recover their long run marginal costs. At the same time they are transferring the risk of investing to the customers who pay for the consumed electricity and the capacity mechanism. Similarly, De Vries (2004) elucidates the usefulness of those mechanisms as transitional or temporary solutions to deal with imperfections that can be found in wholesale electricity markets, such as imperfect information regarding future demand of electricity, electricity price restrictions and regulatory restrictions to invest in new generation units. Finally De Vries (2004) argues that capacity mechanisms must be discouraged once the markets reach an appropriate level of maturity.

As explained above, capacity mechanisms might be implemented to serve several purposes concerning wholesale markets and generation adequacy. Therefore, it is possible to allocate capacity mechanisms between the physical-technical and the economical-institutional layers of the electricity system depicted in the figure below. Firstly one should look at the specific elements, institutions and actors that are affected by those mechanisms. In theory, capacity mechanisms impact the amount of power generation available for the electricity system; therefore they can have an important effect on its generation adequacy. Also, the mechanisms could influence the investment strategies and investment decisions on new generation units in the long run. As a result, a redesign of the electricity system is required to implement a capacity mechanism. These changes in the electricity system, if needed, would take place mostly on the institutional and economic layer, where new institutions would need to be designed and implemented in the system.

The details concerning whether, what and how to restructure this layer rely on the type of capacity mechanism to be implemented. Some of the mechanisms may not require any redesign, since they are simple additional payments that do not change the institutional layers of the electricity system. Other mechanisms, depending on their type, may require new institutional arrangements such as a capacity market among others. Hence, to acquire more understanding of this issue the main capacity mechanisms available in the literature are briefly described below; the description is mostly based on the work of De Vries (2004).

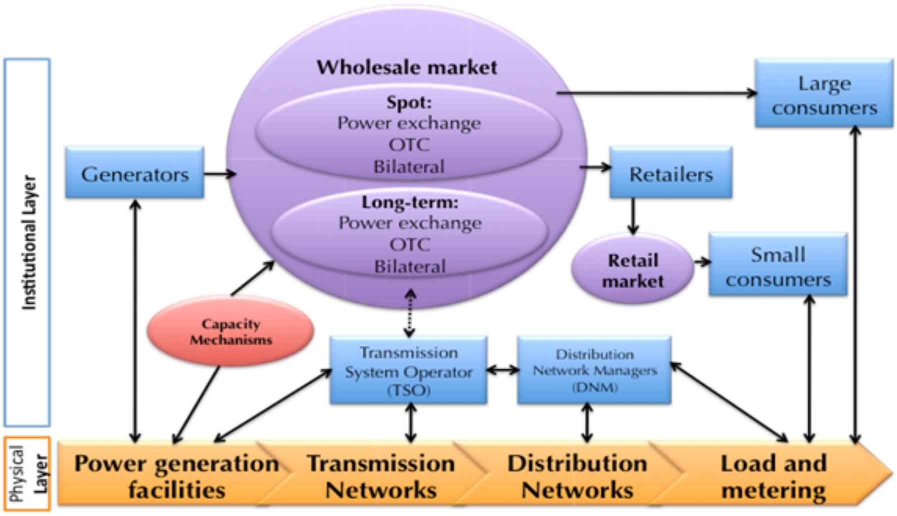

Figure 2 Physical and institutional layer of the electricity system with capacity mechanisms

2.2.1. Capacity Payments

Capacity payment is one of the first and simplest versions of capacity mechanisms described in the literature. This instrument provides an additional payment —*besides the payment obtained for the energy sold in the energy only market*— to all power generation units—*available or installed capacity*—. Theoretically, this payment would increase the revenues of power generators, which allow them to recover more easily all the costs incurred in the production of electricity and maintenance of their infrastructure. This in turn would provide power generators with enough revenues to invest in new power generation capacity, which would be compensated with more stable and lower prices in the wholesale market (Vásquez, Rivier, & Pérez Arriaga, 2002). A centralized agent is usually responsible for calculating the suitable payment and for setting the payment, which goes to the bill of the final customers (De Vries, 2004).

The main advantage of such a system is that it is compatible with decentralized electricity systems in NWE and it can be easily implemented at low costs. In contrast, the main disadvantages concern setting the payment level accurately. It has also been found ineffective to attract new investments since there is no contractual obligations or penalizations for generators in case they do not make new electricity production capacity available (Vásquez, Rivier, & Pérez Arriaga, 2002).

2.2.2. Strategic Reserve

Strategic reserves can be considered a simple alternative to capacity payments. The main idea is to set a group of generation units, which do not produce electricity under normal circumstances and are kept available only for emergencies. In practice, this mechanism has been nicknamed as "Mothball reserve" since most of the reserve volumes of electricity capacity come from old generation units that are close to be dismantled. The level of reserve capacity required by the electricity system is defined by an independent agent who may contract or own the reserve. Those independent agents are usually system operators—*SOs*— or TSOs and their tasks are to forecast the level of reserve capacity required by the electricity system and to procure the reserve capacity through tenders[6] or auctions. Once the strategic reserve is available for the independent agent, it can be dispatched at a price defined by this agent—*the price depends on the specific implementation of the capacity mechanism, usually there is a tradeoff between procuring a small amount of reserve with a high price or vice versa*—, which should allow the generators to participate in the wholesale market and to recover their marginal costs of production. Besides, the dispatch of these reserve units can be done by using a technical or economic trigger. The first refers to running the reserve units due to the demand exciding generation capacity at a certain point of the year. The latter concerns producing electricity from the reserves as a consequence of high electricity prices in the wholesale market (De Vries 2004).

[6] Nowadays, when the reserve capacity is tendered, the literature call it as "tender for targeted resource (TTR)

The main advantage of this capacity mechanism relies on the low costs and time of implementation in the electricity system such as the NWE decentralized electricity system (De Vries 2004). In contrast, the main shortcoming relates to the distortions it might cause on the electricity prices in the wholesale markets. Additionally, it is difficult to objectively define the amount and price of reserve capacity required in the system.

2.2.3. Operating Reserve

Operating reserve mechanism is similar to strategic reserves. Their main difference relates to the procedure by which the capacity is contracted. In operating reserve, an independent actor sets the total reserve capacity required by the system and procures it in the wholesale market. More precisely, the SO or TSO contracts the required volume of electricity capacity in the balancing market on a daily basis as if it were dealing with small unbalances in voltage and frequency caused by the normal operation of the system. Operating reserve capacity is priced, in theory, according to the willingness to pay of the TSO in the balancing market (De Vries 2004). This operating reserve capacity is considered part of the ancillary services and therefore the generator receives an additional payment for being available in the balancing market and, if dispatched, obtains the payment for the electricity sold.

The main advantage of this mechanism is the low effect it has on the merit order in the wholesale electricity market and the low institutional cost of its implementation. In contrast, the main shortcomings relate to the difficulty of setting the volume of electricity capacity required in the system. In practice, it is usually hard to assess if this is a suitable mechanism to attract new investments in power generation units.

2.2.4. Capacity Requirements

This mechanism has been implemented recently in the Pennsylvania, New Jersey and Maryland—*PJM*— market of the USA, which is considered one of the most competitive centralized pool electricity markets of the world. The idea behind this instrument is that load serving entities—*commonly represented by large consumers and retailers, which* *at the same time purchase electricity on behalf of small consumers* — must contract capacity credits in advance from power generators to cover their peak demand plus a reserve margin. As a result the electricity system is ensured with enough and reliable electricity production capacity to cover the total demand of electricity at any moment.

The capacity credits to be purchased by every single load serving entity are centrally determined by the SO according to the electricity demand forecasting, which includes single peak demand of the load serving entities and coincident peak demand in the system. In this capacity mechanism, the load serving entities are obliged to buy as much capacity credits as the SO stipulates based on its estimations. The capacity credits are purchased by load serving entities in a new market place called capacity market, where the electricity producers offer reliable capacity credits and the commercial interaction with buyers result in a market price for the capacity credits. Similarly, power generators are encouraged to offer capacity credits according to their total production capacity since in return they will get additional income for the capacity credits sold in the capacity market. This means that electricity producers who obtain payments for capacity credits sold in the capacity market should make available the electricity production capacity when it is required by the electricity system. In addition to this, the cost of the capacity credits bought by load serving entities is charged to the final consumer in the electricity bill. Finally, to guarantee that the capacity credits offered by power generators reflect reliable volumes of electricity capacity in the system, the regulator constantly monitors this production capacity (De Vries, 2004).

The main advantage of this mechanism relates to the transparency in calculating the volumes of electricity capacity required by the system. This is because the capacity required is defined by an independent agent that in principle does not have any biased interest on the prices of capacity credits. In contrast, the main disadvantages concern the institutional cost incurred in the implementation of the mechanism as well as the possibility of gamming by power generators (De Vries 2004). Indeed, they might sell credits in the local market but offer electricity in other markets reducing the reliability of the capacity credits offered.

2.2.5. Reliability Contracts[7]

This alternative instrument emerged to solve the shortcomings of the capacity requirements mechanism implemented in the PJM system. Reliability contracts are financial capacity mechanisms in which the power generators are provided with economic incentives to make the capacity contracted available in periods of electricity scarcity. The incentives consist of additional incomes for those electricity producers who offer reliable capacity by signing these contracts, and monetary penalizations for those who signed the reliability contracts but do not make capacity available in the periods that are defined in the contract.

The core of the reliability contracts concerns the purchase of a call option by the TSO in behalf of the customers. The contract defines a fixed payment given to electricity producers for the reliable electricity they commit to deliver in periods of production scarcity. The costs of the options are charged in the bill of the final consumers. Furthermore, the call option contract states explicitly the strike price—*which can be considered as the price where electricity production is scarce in the wholesale market*— above which the power generators have to give back to the consumers the difference between the market price minus the strike price times the volumes of reliable electricity also defined in this contract (Vásquez, Rivier, & Pérez Arriaga, 2002). However, a generator is penalized if he signed a reliability contract and is not able to offer the reliable volumes of electricity. The penalization consists of reimbursing the difference of the market price minus the strike price times the volumes of electricity not delivered. Here, the difference is that the generator does not get revenues to cover the loss (De vries et al. 2004).

The independent entity defines the volume of electricity to be purchased throughout the reliability contracts. For this purpose, the forecast of the coincident peak demand and of the available capacity in the electricity system—*similar methodology used in the PJM market*— are considered. Moreover, the independent agent is in charge of calculating the strike price of the purchased option; the strike price needs to be set above the cost of the last marginal unit in the system in order to reduce the effects of

[7] The latest version of this capacity mechanism is called reliability options and it has been implemented in Colombia as a result of the studied contracted by the Association of Colombian Power Generators (ACOLGEN). A detailed description of the mechanisms is explained in Vázquez, Rivier and Pérez-Arriaga (2002)

the mechanism on the price formation in the wholesale electricity market (De Vries, 2004).

The main advantages of the reliability contracts mechanism concern the provision of reliable volumes of electricity generation in periods of scarcity. Furthermore, capacity does not leak to other markets, as it might be the case of the capacity credits in the PJM. Additionally, the price volatility is capped by the strike price, which is advantageous for final users and could be useful for retailers in systems with retailing competition. In contrast, the shortcomings of this mechanism relate to the institutional cost of implementation and the possibility of gamming in the auctions where the independent entity purchases reliability contracts. Finally, the mechanism in its original form[8] is not compatible with the decentralized electricity systems of NWE, which does not allow its broader implementation.

2.2.6. Capacity Subscriptions

Capacity Subscriptions might be considered the most market oriented of all the capacity mechanism studied in the literature. It relies on the use of electronic devices, electronic fuses, which are installed in the demand side to control and limit the maximum load when they are activated. It creates a virtual capacity market in which producers and consumers actively interact. Producers adjust their power generation capacity and consumers reduce their electricity demanded according to electricity prices (De vries, 2004). This mechanism allows consumers to react to scarcity signals embedded in the electricity prices, and encourages generators to offer the capacity that is required by the system. Generators in this case will count with a more stable stream of incomes to recover the costs of the electricity production capacity required by the system.

The advantages mostly concern the transparency of the mechanisms to allocate volumes of generation capacity among consumers, because it is actually the consumers that can affect the prices by deciding to limit their maximum consumption, according to their willingness to pay for reliable electricity. In contrast, the main shortcomings are

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[8] Despite reliability contracts was not designed for decentralized electricity markets, a modification proposed in Vázquez et al (2003) provides a framework to implement reliability contracts in decentralized electricity markets.

related to the large cost of implementation. This cost is associated to the electronic devises—*smart meters*— to be installed in the electricity system. Furthermore, this mechanism does not deal with the problem of leaking capacity to other electricity markets since power generators do not have the incentive—*economic penalization*— to make available the capacity when needed in the electricity system with capacity subscriptions (De Vries et al, 2011).

2.2.7. Summary of capacity mechanisms

Based on the description of the capacity mechanisms performed earlier, a summary of the capacity mechanisms and their main advantages and disadvantages are depicted in the table below.

Table 2 Overview of the advantages and disadvantages of capacity mechanisms found in the literature.

Type of mechanism	Advantages	Disadvantages
Capacity payments	1. Compatible with the design of electricity systems in NWE 2. Low institutional cost of implementation	1. Is difficult to set the level of payment for capacity 2. There is not contractual obligation or penalizations for generators that obtain capacity payments
Strategic reserve	1.Compatible with the design of electricity systems in NWE 2. Low time and institutional cost of implementation	1. Is difficult to set the amount and price of reserve capacity 2. It distorts prices in the wholesale market
Operating reserve	1.Compatible with the design of electricity systems in NWE 2. Low time and institutional cost of implementation 3. Low distortion of electricity prices in the wholesale market	1. Is difficult to set the amount and price of operating reserve capacity 2. Is not clear if it attract new investments
Capacity requirements	1. Transparency in setting reliable production capacity volumes 2. Improves availability of production capacity in the system	1. Low compatibility with the design of electricity systems in NEW. 2. Possibility of gamming by power generators
Reliability contracts	1. Improves availability of production capacity in the system 2. No leaking of production capacity to other markets	1. In its original form is not compatible with the design of electricity systems in NWE
Capacity subscriptions	1. Transparency in setting reliable production capacity volumes	1. High institutional cost of implementation

2.3. The current state of generation adequacy policies in NWE

In the previous sections a description of the functioning and layers of the textbook electricity system was depicted. This was followed by a summary of the main features of generation adequacy instruments or capacity mechanism available in the literature, which focused on the functioning, advantages and disadvantages of capacity mechanisms in the electricity system. Then, to understand the European perspective on generation adequacy, this section provides a brief description of the electricity industry and the capacity mechanisms already implemented or currently discussed in the countries belonging to NWE.

2.3.1. France

This is the most particular case of liberalization of the electricity sector in the whole Europe. France as European member state should follow the electricity sector directives provided by the European Union. Especially the 1996 electricity directive was very rigorous regarding the liberalization of the electricity sector and the opening of the electricity markets that were expected to be adopted by European member states. In France, however, the state owned monopoly in the electricity system keeps operating (Newbery, 2005), which makes the French wholesale electricity market very particular in terms of competition.

France is on average the second biggest producer of electricity in NWE; it produced 550.2 TWh of electricity in 2011 (Euroelectric, 2012) and its capacity installed reached 123,7 GW in 2011 (Euroelectric, 2012). Moreover, electricity contributes to 23% of the energy that is required in the country. Electricity is primarily used in transport, households and industry (European Commission, 2012). Besides, heating systems for households rely on electricity, which makes France dependent on electricity to meet the peak demand for heating during winter seasons. In addition, the development of the electricity system in France has led to the power generation mix that is depicted in the figure below. The French company Électricité de France—*EDF*— owns most of the capacity installed in the country. In this system, electricity production comes mainly from nuclear power plants, which makes France the largest nuclear producer in NWE. In addition, electricity is produced from fossil fired and hydro power plants, and the smallest share of capacity installed belongs to renewable energy sources.

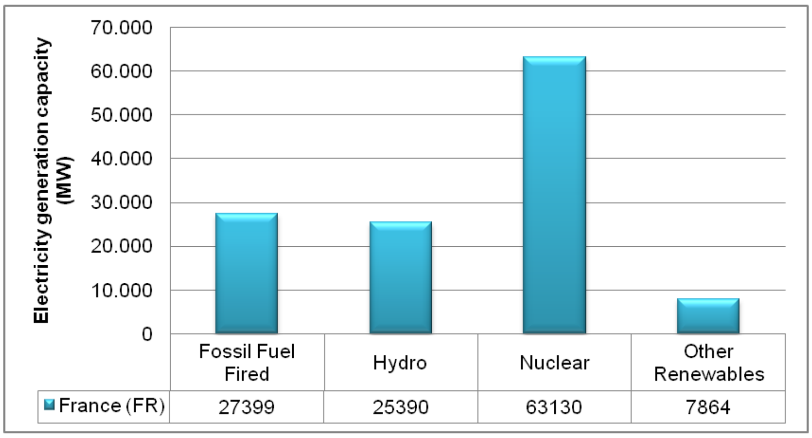

Figure 3 Electricity generation mix of France in 2010. Based in the data from **(Euroelectric, 2012)**

To transport the volumes of electricity required by the consumers, France relies in the company called RTE, which develops the function of a TSO in the electricity system. This company is also in charge of the exchanges of power with other countries. This is possible due to the six transmission lines built in France, of which three allow direct exchange of power with UK, Germany and Belgium (Supponen, 2011). Moreover, the European Union directives, aiming to integrate the electricity markets in Europe, have encouraged power exchange among European electricity markets.

Despite the evolution of the electricity system in France, security of supply is still an issue that is being discussed. Therefore the French government is currently implementing a capacity mechanism as is explained below.

Capacity mechanism in France

According to the experts of the French regulator, capacity mechanisms emerged in France as a result of the reduction in excess capacity in the electricity system, which has raised concerns about the security of supply in the coming winter seasons. Furthermore, they come from political preferences in the country, which are oriented towards central planning of the electricity system and sustaining reasonable levels of reliability.

The capacity mechanism is not yet implemented in France. However, it will be based on the model called "capacity requirements" employed in the PJM system of the USA. The French version, called "Obligation de Capacité", requires that (i) the suppliers cover in advance obligations of peak electricity demand and (ii) the producers offer capacity credits to the suppliers in advance. In this version, there will be capacity credits available according to the technology portfolios of each producer, meaning that the more reliable production technologies will be able to offer more capacity credits than less reliable production technologies. The capacity credits will not be priced through an organized market; this is a difference between the Frech design and the original capacity requirements implemented in the PJM electricity system in USA—*the original model implemented in the PJM prices the capacity in a capacity market where the price comes from the interaction between suppliers and consumers*—. Moreover, the capacity mechanism will apply to every generation unit, meaning that every power generator should be required to offer capacity credits. It is likely that the capacity offered and represented by the credits will be kept in the French system when needed by isolating it from neighboring systems (Ministére'de léconomie, des finance er de líndustrie, 2011) (RTE, 2012)

Since the capacity credits are not allocated in a formal and organized market, a central entity will have the task of assigning electricity capacity credits and their price. For this purpose, interconnection capacity will be taken into account by assessing its contribution to meeting electricity demand through probabilistic modelling. To do this, the calculated import capacity is subtracted from the capacity obligation of the supply companies. In addition, there will be penalties for performance for both power generators and consumers. The former will be punished if their generation units are not available to produce electricity when the system requires it. The latter will be penalized in case they do not contract in advance the capacity required to meet their peak demand of electricity. To avoid a shortage in capacity, suppliers and generators will be asked to sell and buy the capacity certificates four years in advance (Ministére'de léconomie, des finance er de líndustrie, 2011). However, as a transition to the implementation of the capacity mechanisms, the ministry will call for a tender 2 years ahead (Ministére'de léconomie, des finance er de líndustrie, 2011)

Finally, French capacity mechanism will not deal with the impact of RES in the generation adequacy issue. Additionally, the mechanism will not include any price cap as it was implemented in PJM in the USA. Hence, the effect of the capacity mechanism seems to be only on physical capacity, not directly on the French market dynamic.

2.3.2. United Kingdom

The UK was the country leading the liberalization of the electricity sector. The restructuring and privatization efforts date back 1990, when the implementation of wholesale electricity markets started to be feasible. The experience in this country has shown that the ownership unbundling of power generation and transmission is the breakpoint towards cost reductions and more economically efficient electricity systems. The original design of the wholesale market was based on the electricity pool model, where every generator and consumer had to send their bids to a centralized entity (SO) that dispatched the power generators according to their marginal cost of production and the technical constraints of the electricity system. Nowadays, electricity trade is carried out differently in this country. The new electricity trading arrangements —*NETA*— replaced the electricity pool model. The new decentralized model attempts to reduce the opportunities of manipulation from power generators and is more compatible with the decentralized trading models implemented in the electricity systems of Europe (Newbery, Refining Market Design, 2005).

The UK is the third largest consumer of electricity in NWE. It demanded 383,88 TWh in 2011 (Euroelectric, 2012), while its power generation capacity reached 89,2 GW in 2011 (Euroelectric, 2012). Additionally, electricity contributes to 20% of the energy that is required in this country. Most of it is used in the sectors such as transport, households and industry. 86% of heat is primarily produced from gas (European Commission, 2012), which makes the UK less dependent on electricity to meet the peak consumption of heat during winter seasons.

The development of the electricity system in the UK has led to the power generation mix portrayed in the below figure. In this system, electricity production comes mainly from fossil fired power plants, which makes UK the second largest electricity producer form fossil fuels in NWE. In addition, electricity is produced from nuclear and other renewable power plants to a minor extent, and the smallest share of capacity installed belongs to hydro resources.

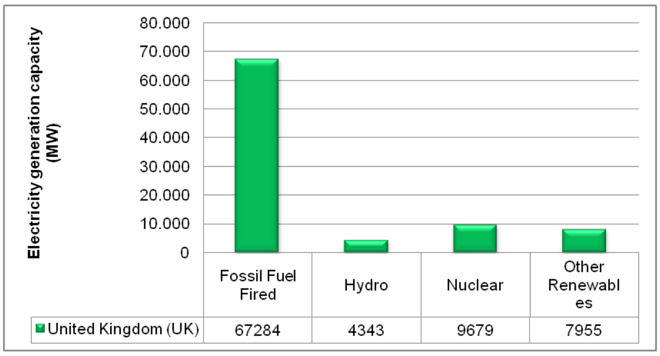

Figure 4 Electricity generation mix of United Kingdom in 2010. Based on the data from **(Euroelectric, 2012)**

To transport the large volumes of electricity from generation facilities to the consumers, UK relies on National Grid, which develops the function of a TSO in the electricity system. This company is also in charge of exchanges of power with other countries. This is possible due to three transmission lines built in UK, from which two of them allow direct exchange of power with France and Netherlands (Supponen, 2011).

Despite of the evolution of the electricity system in UK, security of supply is still an issue in the UK. Therefore the government is currently deciding which capacity mechanism should be implemented in this country.

Capacity mechanisms in United Kingdom

Capacity mechanisms have recently emerged in the UK as a result of governmental decisions to restructure the electricity industry in the coming years. The redesign of the electricity sectors in UK aims to accomplish the new EU policy goals concerning security of supply and CO2 reduction in electricity production (DECC, 2011).

Currently, there are two capacity mechanism models that are being studied. One is called targeted model—*Known as strategic reserves in the literature*— and the other is named as capacity market in the form of reliability contracts (DECC, 2011). The Department of Energy and Climate Change have conducted the assessment of the two options. This analysis consisted of a quantitative and qualitative comparison of the total expected costs and benefits of the two models once implemented in the electricity system. As a main conclusion, DECC (2011) states that a capacity market based on reliability options would perform better in the context of the electricity industry of UK.

Is for this reason that only the option based of capacity market will be described and further consider in this study.

The preferred model in the UK—*capacity market in the form of reliability options*— would be characterized by the increase of responsibilities given to the TSO. This entity would be in charge of calculating the capacity to be contracted in the capacity market. This would consist of the peak load plus 10% of excess power generation capacity. According to DECC (2011), the capacity should be contracted 4 years ahead in a central auction to give time for the construction of the mentioned capacity. In addition to this, there would be systems of penalties— *Characteristic embedded in the model of reliability contracts*— to be applied if the electricity capacity procured is not delivered to the electricity system. The level of the penalty to be paid by the power generators would be calculated with a strike price of 500 pounds/MWh. Furthermore, this mechanism would consider two separate markets. The first only for trade of energy and the second for electricity production capacity and both energy and capacity would be paid by the consumers.

The Analysis performed by the DECC (2011) has contributed to narrow down the discussion of capacity mechanisms in the UK. However, there is not yet a final decision about which mechanism will be implemented.

2.3.3. Germany

Prior the liberalization, the electricity supply industry in Germany was regulated and private investors carried out most of its activities. Later in 2005, the German government launched the energy act to follow the restructuring process driven by the EU electricity directives (Newbery, Refining Market Design, 2005). As a result, a new regulatory institution—*Budesnetzagentur*— emerged to ensure access to all the parties interested in using the transmission networks, while setting regulated tariffs for that purpose (Newbery, Refining Market Design, 2005). However, the restructuring effort in the electricity industry has been highly criticized because it led to more market concentration and market power, specially, due to the merger of vertically integrated electricity and gas firms such as E-on and Ruhrgas (Newbery, Refining Market Design, 2005). These events have contributed to deviate from the theoretical benefits of liberalization in the German electricity sector.

Germany is the largest electricity producer in NWE. This country supplied 591,2 TWh (Euroelectric, 2012)of electricity in 2011 and its power generation capacity reached 166,5 GW (Euroelectric, 2012) in the same year. In Germany, electricity contributed to 20% of the energy that was required in this country. The remaining share comes from fossil fuels. Most of the energy is used in sectors such as households, transport and industry. 81% of heat is primarily produced from gas and solid fuels (European Commission, 2012), which makes the Germany less dependent on electricity to meet the peak consumption of heat during winter seasons—*However, Households demand the largest part of the energy, which might have an important effect on the peak consumption of electricity*—.

The development of the electricity system in Germany has led to the power generation mix depicted in the below figure. In this system, electricity production comes mainly from fossil fired power plants, which makes Germany the largest electricity producer form fossil fuels in NWE. In addition, electricity is produced from other renewable—*Germany is the largest producer of electricity from other renewable energy sources*— and nuclear power plants to a minor extent, and the smallest share of capacity installed belongs to hydro resources.

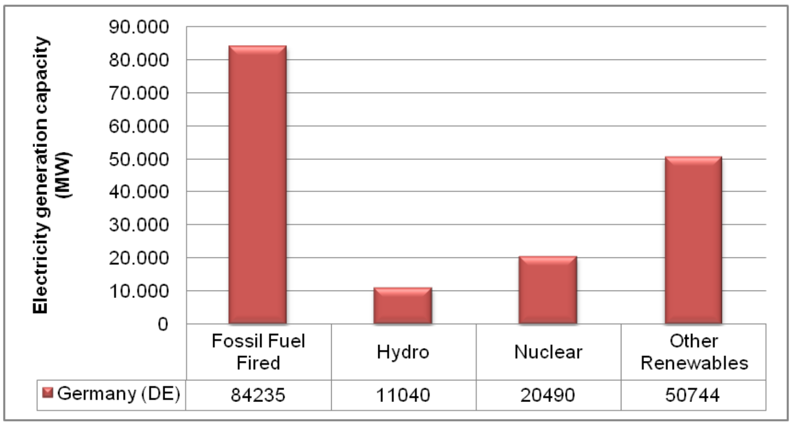

Figure 5 Electricity generation mix of Germany in 2010. **.** *Based on the data from* **(Euroelectric, 2012)**

To transport the large volumes of electricity from generation facilities to the consumers, Germany relies on five companies[9] such as EnBw, RWT, EON, Vatenfall and VKWnetz, which develop the function of TSOs in the electricity system. Those companies are also in charge of power exchanges with other countries. This is carried

[9] . This is a unique case in NEW since the other countries only possess a single TSO.

out throughout seven transmission lines built in Germany, from which four of them allow direct exchange of power with Sweden, France, Denmark and Netherlands (Supponen, 2011).

Despite of the evolution of the electricity system in Germany, security of supply is still an issue in this country. Therefore, the government is currently discussing whether to implement a capacity mechanism or not in the coming years.

Capacity Mechanisms in Germany

According to the experts of the German regulator *Budesnetzagentur,* Germany has decided to analyze more carefully the implementation of capacity mechanisms. The Ministry of Economic Affairs with the help of the energy regulator is performing this task. Their core analysis concerns with security of electricity supply in the coming years. More precisely, the discussion is about whether to implement a local capacity mechanism— *Only to guarantee enough electricity generation capacity in Germany without the option to be shared with neighboring countries*— or an integrated and harmonized European capacity mechanism. No decisions have been made yet regarding this issue.

A definitive capacity mechanism would be implemented in Germany to cope with technical unbalances, decommissioning of power plants and impact of the RES in the electricity prices of the wholesale market. From the regulator's viewpoint, not only active capacity is required by the electricity system. In addition to this, technical issues of compensation of reactive power also need to be tacked by the TSO. This capacity should be installed locally or regionally due to the difficulties of transporting reactive power for long distances. Similarly, capacity mechanisms are being considered to deal with the dismantling of nuclear facilities in the past. This reduction of available capacity has been suffered in the south of the country and might be problematic to meet peak demand in the coming winter—*2012 and 2013*— (Bundesnetzagentur, 2012). Specially, since the transmission capacity might not be enough to transport the power required during peak hours. Finally, capacity mechanisms might contribute to reduce the price volatility in the wholesale electricity market caused by the large implementation of RES. This is critical to this country since it has the largest amount of RES installed in the electricity system.

Temporarily, there is a capacity mechanism implemented in Germany. This was implemented as a consequence of continuous reduction of nuclear power capacity and the lack of time for a rigorous implementation of a generation adequacy policy (Bundesnetzagentur, 2012). In Germany, the regulator and TSO's only had 2 or 3 months to decide how to guarantee enough availability of electricity during the highest period of electricity consumption. Therefore, the TSOs were temporarily responsible for contracting peak power reserve capacity[10] from Austria to deal with electricity shortages in the short term[11]. This mechanism has been implemented to deal with the electricity demand in the winter period of 2011-2012 (Bundesnetzagentur, 2012).

2.3.4. Scandinavian countries

The Nordic countries Norway, Sweden, Finland and Denmark share a common experience regarding the restructuring of the electricity industry. This restructuring effort started in 1991, when the Scandinavian governments deregulated the electricity market (Newbery, Refining Market Design, 2005). To do so, they firstly unbundled and liberalized the activities performed in the supply chain of electricity. Secondly, they designed a new electricity market and privatized the incumbent generation companies. Lastly, the governments encouraged regional cooperation with the Nordic countries aiming to deal with regional electricity shortages. As a result of the restructuring process, the Nordic countries have organized the trade of electricity in a distinctive regional power exchange market known as Noordpool. In this wholesale market every single Scandinavian country offers the electricity production and demand to be dispatched to the whole region. Noordpool is an unique market design in NWE. Specially, since Noordpool market comprises a day-ahead market—*Elspot*— and an electricity market to trade futures—*Eltermin*—. Both electricity markets contribute to set the price and the volumes of electricity in the different zones of the Scandinavian electricity system and most of the time the electricity price converge in all the regions (Statnett, 2012).

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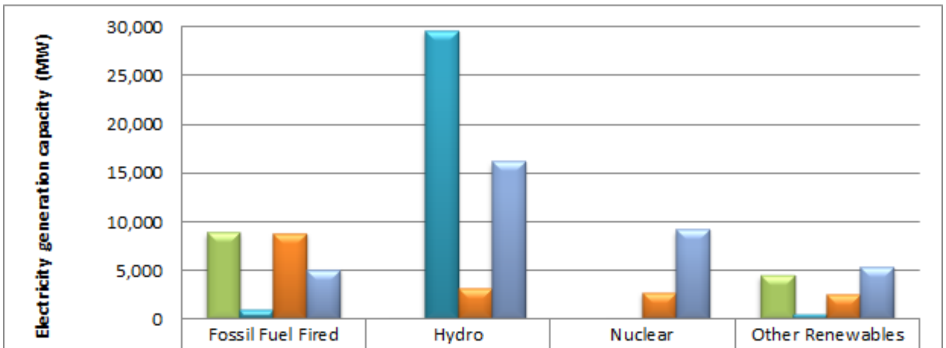
[10] In this sense it is possible to consider the temporary measure implemented in Germany as the capacity mechanisms called strategic reserve. The main difference is that the reserve capacity is not procured locally but in a foreign country such as Austria.

[11] Some studies are being conducted to assess if the solution should be extended for the next winter too.

Scandinavia as a whole is one of the most important regional electricity producers in NWE. This cluster of countries supplied 418,24 TWh of electricity in 2011 and its power generation capacity reached 97,38 GW in the same year (Euroelectric, 2012). In Scandinavia, the electricity contribution differs considerably among the countries. On average electricity supplies 27% of the energy that is required in the Nordic countries. The remaining share of energy consumption comes from petroleum products and gas. Most of the energy is used in sectors such as Industry, transport and households. Furthermore, on average 44,3% of the heat is primarily produced from gas and solid fuels (European Commission, 2012). This is an important feature of Scandinavia in comparison with other trends in energy utilization in NWE. Indeed, Scandinavia is considerably dependent on electricity to meet the peak consumption of heat during winter seasons, which requires enough electricity production capacity during those periods.

The development of the electricity systems in Scandinavia has led to the power generation mix depicted in the below figure. In this system, electricity production considerably differs among the Nordic Countries. For instance, Norway and Sweden are the largest Hydropower producers in Scandinavia. In contrast, Denmark and Norway are the countries with more fossil fired power capacity. Those features make Scandinavia the major Hydropower producer in NWE.



	Fossil Fuel Fired	Hydro	Nuclear	Other Renewables
Denmark (DK)	8893	9	0	4517
Norway (NO)	900	29636	0	430
Finland (FI)	8817	3124	2696	2500
Sweden (SE)	5035	16200	9151	5315

Figure 6 Electricity generation mix of Scandinavian countries in 2010. *Based on the data from* **(Euroelectric, 2012)**

To transport the large volumes of electricity from generation facilities to the consumers, Scandinavia counts with four companies such as Energinet.dk—*Denmark*—, Fingrid—*Finland*—, Statnett—*Norway*— and Svenska Kraftnat—*Sweden*—. Those companies perform the function of TSOs in the electricity system and therefore they are also in charge of power exchanges within Scandinavia and between Scandinavia and other countries in NWE. This is possible due to the eleven lines built in the whole Nordic region, from which four of them allow direct exchange of power with Germany and The Netherlands (Supponen, 2011).

Capacity mechanism in Scandinavia

The Scandinavian debate of capacity mechanisms has been divided in two groups. Firstly, the cluster comprised by Sweden and Finland, which opted for a capacity mechanism based on strategic reserves. Secondly, the group is formed by Norway and Denmark, which decided to introduce operating reserves as a capacity mechanism.

Sweden and Finland decided to implement a capacity mechanism in the Elspot market in January 2009—*known as "Peak Load Arrangements"*—. It was designed as a transitional measure to hedge the electricity system against a possible shortage of electricity on winter seasons. This capacity mechanism has been introduced due to political reasons. More precisely, the government was in the quest of an instrument to offer a higher level of security of supply than energy only markets. Furthermore, such transitory instrument offered the government the tools to monitor and control the electricity production capacity bid in the wholesale electricity market (NordREG, 2009).

The idea underlying "peak load arrangements" was to create a backup of electricity production capacity to be dispatched only in extreme cases when electricity demand is not satisfied by commercially available power supply. In this respect, these arrangements can be framed within the theoretical capacity mechanism known as strategic reserves. In this version, the two TSOs, Fingrid and Svenska Krafnat have to procure the peak load reserves required by the system in winter seasons. Currently, the capacity contracted has reached 2600MW, 600 MW in Finland and 2000 MW in Sweden (NordREG, 2009). In Finland, reserve capacity mainly comes from old coal condensing production units, which have not been decommissioned. In Sweden, peak reserve capacity is obtained throughout a mix of production bids and demand response bids from large costumers. Moreover, if needed, those peak reserves are activated in the spot market and balancing market aiming to create minimum distortions in the wholesale prices. Therefore, those peak reserve units will be dispatched at a price that is not below the last commercial unit (0,1 Euro/MWh difference) but not above the 2000 Euros/MWh, which is the price cap of the Elspot market. Finally, "Peak Load Arrangements" might be used until 2020 attempting to reduce the reserve capacity and encouraging demand response every year (NordREG, 2009).

Norway and Denmark count with operating reserves to make available enough electricity production capacity to the electricity system even in peak demand periods. Despite both countries counts with operating reserve, there are differences in the implementing details of such capacity mechanism in the two countries. For instance, Denmark does not make any distinction between peak load reserve and operating reserve capacity—*only used to cope with disturbances of voltage and frequency in the electricity system*— (NordREG, 2009). Therefore, trading electricity from the day-ahead market and the balancing market allows satisfying demand of electricity in any interval of time. In contrast, Norway has a more organized capacity mechanism, which is called the Regulation Power Option Market—*RKOM*—. The RKOM is a market place created in 2000 and embedded in the balancing market where the operating reserves are procured by the TSO in case of unbalances. In the RKOM, electricity producers may offer electricity production capacity or customers might bid demand reduction at a certain price. The capacity offered should be minimum 25 MW for a specific geographical area and is required for a period of one week. Besides, capacity offered in RKOM is priced according to the price of the last marginal bidder (Amundsen & Bergman, 2006). As a result, a power generation company offering capacity and accepted in the RKOM market would get two payments: the option payment for capacity offered and the regulating price for the power delivered. In exchange the power generators must make available their capacity when it is required by the electricity system. However, if the accepted power generators offer their capacity in other markets, the option payments may be withdrawn totally according to the rules designed by Statnett (Statnett, 2005).

2.3.5. Belgium

Liberalization of the electricity industry in Belgium followed the common history of other countries in Europe. This process dates back 1996, when the European Commission launched the electricity directive—*96/92.EC*— concerning the common rules to be applied in the electricity markets. Despite of the efforts of 1996, full liberalization of the electricity industry took longer and was reached in 2007. However, the restructuring process has not been completely successful since there are still important signals of market concentration. Specially, since the vertically integrated electricity company "Electrabel" enjoys a dominant position in the wholesale electricity market of Belgium—*90,6% of concentration ratio*— (Kupper, et al., 2008) and therefore might deter the entry of new generation companies. Nowadays, Belgium regulator, CREG, has been encouraging market integration and building more transmission capacity in the Belgium borders to introduce more competition in the wholesale electricity market (Kupper, et al., 2008).

Belgium is one of the smallest electricity producers in NWE—*After Denmark and Finland*—. This country produced 87,8 TWh of electricity in 2011 and its power generation capacity reached 17,5 GW in the same year (Euroelectric, 2012). In Belgium, electricity contributes to 19% of the energy that is demanded in this country and the remaining share comes from petroleum products and gas. Most of the energy is used in sectors such as Transport, industry and Households. 89% of heat is primarily produced from gas (European Commission, 2012), which makes Belgium less dependent on electricity to meet the peak consumption of heat during winter seasons.

The development of the electricity system in Belgium has led to the power generation mix portrayed in the below figure. In this system, electricity production comes mainly from fossil fired power plants, nuclear power plants, and the smallest share of capacity installed belongs to hydro resources and other renewables.

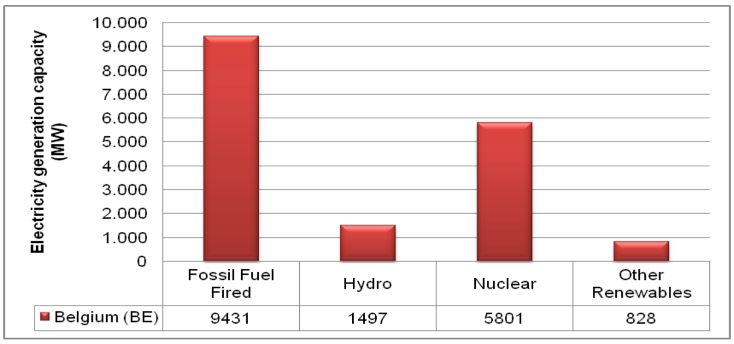


Figure 7 Electricity generation mix of Belgium in 2010. *Based on the data from* **(Euroelectric, 2012)**

To transport the large volumes of electricity from generation facilities to the consumers, Belgium relies on Elia, which develop the function of TSO in the electricity system. This company is also in charge of the power exchange with other countries, which is carried out throughout three transmission lines connecting Belgium with UK, The Netherlands and France (Supponen, 2011).

Capacity mechanism in Belgium

Belgium does not count with a capacity mechanism and currently it is not a relevant issue for this country. Apparently, the power capacity locally installed and the imports from other countries are enough to cover the volumes of electricity demanded in the coming years. This can be explained for some of the characteristics of the electricity system in Belgium. For instance, peak electricity consumption is not as sensible to winter seasons as it is in other countries of NWE such as France. Therefore, it is possible that Belgium does not need large reserves of power capacity to meet the electricity demanded in winter. Another explanation might be related to the dominant position of "Electrabel". This company controls most of the electricity production units in Belgium and therefore it has more complete market information, which allows it to continuously invest in the new capacity required by the electricity system.

2.3.6. The Netherlands

The Dutch restructuring of the electricity industry started in 1996, when the European commission introduced the electricity directive towards the liberalization of the electricity sector in Europe. Later in July 2004, retail competition was introduced mainly to protect consumers from high electricity prices (NMa, 2009). Throughout the restructuring process, The Netherlands managed to bring competition to the wholesale electricity market without giving too much power to a single generation company. Besides, competition has been encouraged due to the imports of electricity from neighboring countries, which has led to a concentration ratio—*CR(1)*[12]— of 28,88% (Kupper, et al., 2008). This level of competition is good in comparison with other countries in NWE such as France and Belgium. Additionally, power generators and consumers trade electricity on a daily basis in the Amsterdam Power Exchange—*APX*—. The usefulness of this market for the electricity trading parties and coupling with other markets has boosted the electricity trade in the APX. In fact, the electricity exchanged

[12] The concentration ration CR(1) gives the sum of the market shares of the largest electricity generation company in the electricity market

in APX has reached 25 TWh, which has contributed to improve the liquidity of such electricity market in the Netherlands (NMa, 2009).

The Netherlands is a small electricity producer in NWE. This country produced 111 TWh of electricity in 2011 and its power generation capacity reached 26,62 GW in the same year (Euroelectric, 2012). In the Netherlands, electricity contributes to 18% of the energy that is demanded in this country and the remaining share comes from gas and petroleum products. Most of the energy is primarily used in transport, industry and households and 78% of heat is produced from gas (European Commission, 2012). These features make the Netherlands less dependent on electricity to meet the peak consumption of heat during winter seasons. However, the demand of electricity in the Dutch wholesale market might change considerably in the future due to the integration with electricity markets which demand of electricity grows considerable in winter.

The development of the electricity system in The Netherlands has led to the power generation mix portrayed in the below figure. In this system, electricity production comes mainly from fossil fired power plants—*Gas units*—, other renewable power plants, and the smallest share of capacity installed belong to nuclear resources and Hydro power plants. The energy mix of the Netherlands and specially the high participation of gas in power generation drive the wholesale electricity prices. Those are usually high in comparison with wholesale electricity prices in neighboring countries. However, electricity prices have been reduced as a result of the electricity imports and market coupling with NWE.

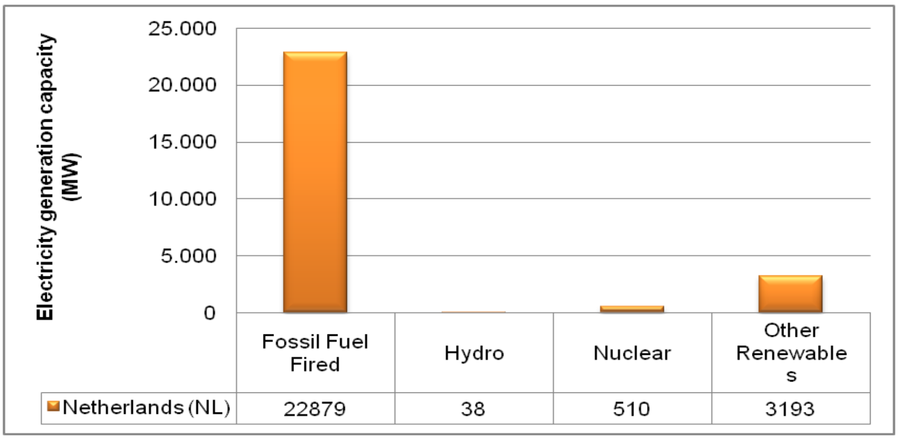


Figure 8 Electricity generation mix of The Netherlands in 2010. *Based on the data from* **(Euroelectric, 2012)**

To transport the large volumes of electricity from generation facilities to the consumers, the Netherlands relies on Tennet, which develop the function of TSO in the electricity system. This company is also in charge of the power exchange with other countries, which is carried out throughout four transmission lines connecting The Netherlands with Norway—*700 MW*—, UK—*1000MW*—, Germany—*3925 MW*— and Belgium—*2150 MW*—. The last can be considered as a transit country that allows the Netherlands to import electricity from France (Supponen, 2011).

Capacity mechanism in The Netherlands

The Netherlands has not implemented a capacity mechanism. However, the electricity act of 1998 attempted to hedge the electricity system against a possible shortage of electricity capacity. More precisely, the act makes the ministry responsible to perform a study concerning the security of electricity supply every year. If the study concludes that the electricity system is not able to meet the demand of electricity within five years period, then the minister should proceed according to the law to make available new electricity production capacity. Additionally, the act forces the TSO to hold enough reserves of electricity generation capacity to satisfy short and long term demand (Ministry of Economics and Ministry of Justice, 1998). Later, in 2003, there was a proposal to implement a capacity mechanism in the Netherlands based on the reliability options model. However, it was never implemented event though there was a research study, which provided the framework for its implementation (Vazquez, Batlle, Rivier, & Perez-Arriaga, 2003).

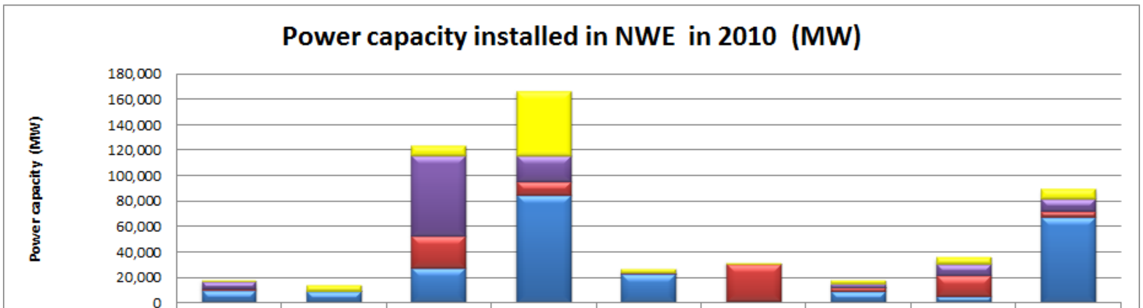
Nowadays, the security of supply is not an issue in the short term and medium-term since there is enough electricity generation capacity installed in the Dutch electricity system. Moreover, according to experts from the Dutch regulator new generation units will be running in the coming years. Nevertheless, the implementation of capacity mechanisms in neighboring countries and their effects on the wholesale electricity markets is a relevant issue for the Netherlands, as it will be explained in Chapter 3.

2.4. Comparison of generation adequacy levels in NWE countries[13]

As it was described in the above sections, the context in which of every country in NWE has restructured the electricity sector has led to different features of the electricity systems. Specially, it has led to a particular peak demand of electricity, energy mix and power capacity installed in every country of NWE. The demand of electricity strongly fluctuates throughout the year as a consequence of the applications of electricity in a specific country. In fact, the largest differences between peak and off-peak consumption of the year 2010 can be found in countries such as Sweden, France, and Norway. These countries particularly rely on electricity to feed their heating systems, which are mostly used to heat households in cold days of the winter season. These features may explain those large electricity consumption differences in the aforementioned countries. In contrast, Germany, Belgium and The Netherlands, which fuels their heating systems with gas, depicted the lowest difference between peak and off-peak power consumption. Consequently, they might be less susceptible to the effects of temperature on the consumption of electricity. Therefore, they should, in principle, require less excess volumes of electricity generation capacity than the other countries in NWE.

Similarly, the generation mix of every country of NWE is related to the generation adequacy of the electricity system. In fact, every country requires a generation mix that allows the country to produce enough volumes of electricity to meet its peak demand. The lack of enough volumes of reliable electricity production might increase the likelihood of disrupting the electricity service in a country. The generation mix and power capacity installed of NWE in 2010 is portrayed in the below figure. The results of the figure allows clustering Germany, France and UK in the group of the largest electricity producers as it was described in the previous section. Besides, it is possible to conclude from the figure that the electricity generation mix is very diverse in NWE, which might influence the preference for some technologies in the future generation investments.

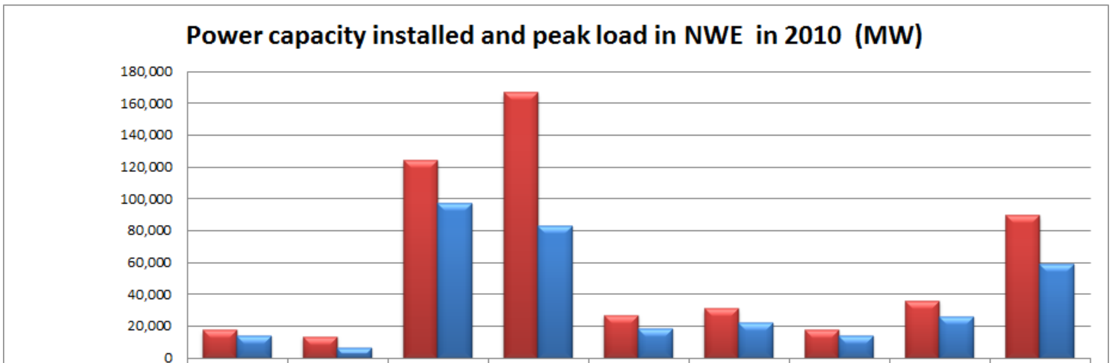
[13] The comparison and analysis provided in this section is based on data of 2010 since most of the information concerning capacity installed and electricity demand was not available for 2011 and 2012.



	Belgium (BE)	Denmark (DK)	France (FR)	Germany (DE)	Netherlands (NL)	Norway (NO)	Finland (FI)	Sweden (SE)	United Kingdom (UK)
Other Renewables	828	4517	7864	50744	3193	430	2500	5315	7955
Nuclear	5801	0	63130	20490	510	0	2696	9151	9679
Not Specified	0	0	0	0	0	0	157	0	0
Hydro	1497	9	25390	11040	38	29636	3124	16200	4343
Fossil Fuel Fired	9431	8893	27399	84235	22879	900	8817	5035	67284

Figure 9 Power generation capacity installed in NWE in 2010. Based on the data from **(Euroelectric, 2012)**

Furthermore, the issue of generation adequacy also has to do with the electricity generation capacity implemented in the electricity systems. Indeed, the capacity installed of electricity production in every country of NWE was adequate to cover the peak consumption in 2010, as it is depicted in the below figure. Countries such as Denmark, Germany, United Kingdom and the Netherlands had the largest capacity installed in comparison with the peak of electricity demand in their systems. In contrast, Finland, France and Belgium have the lowest capacity installed to cover peak demand of electricity. The case of France is atypical since it portrays the highest peak demand of electricity in the region and therefore it should count with the largest capacity installed. However, as it was explained in section 2.3.1 the evidences suggest that it is one of the reasons to implement a capacity mechanism in such country.



	Belgium (BE)	Denmark (DK)	France (FR)	Germany (DE)	Netherlands (NL)	Norway (NO)	Finland (FI)	Sweden (SE)	United Kingdom (UK)
Total power capacity	17557	13419	123783	166509	26620	30966	17294	35701	89261
Peak Load	13,810.0	6,312.0	96,710.0	83,090.0	18,187.0	21,852.0	13,923.0	25,807.0	59,008.0

Figure 10 Total power capacity installed and maximum peak load consumption in NWE in 2010. Based on data from **(Euroelectric, 2012)** and **(entsoe, 2012)**

Moreover, not all the total capacity installed in NWE can be considered available to satisfy peak demand of electricity. In fact, power generation units fueled by other renewable energy sources such as wind and solar cannot be considered as a reliable capacity for the electricity system because their intermittent nature in producing electricity. As a result, the panorama of generation adequacy in 2010 for NWE is better described in the figure portrayed beneath. From the figure, it is possible to conclude that Finland, Sweden and France own the lowest margin of reliable excess capacity for electricity production. However, only Finland does not reach the target of 10% of reliable excess capacity usually considered in Europe. It is assumed that an electricity system requires 10% of reliable excess production capacity to ensure that electricity demand in peak periods is satisfied. This considers the probability of failure of some power plants, which are caused by breakdowns or maintenance of generation units.

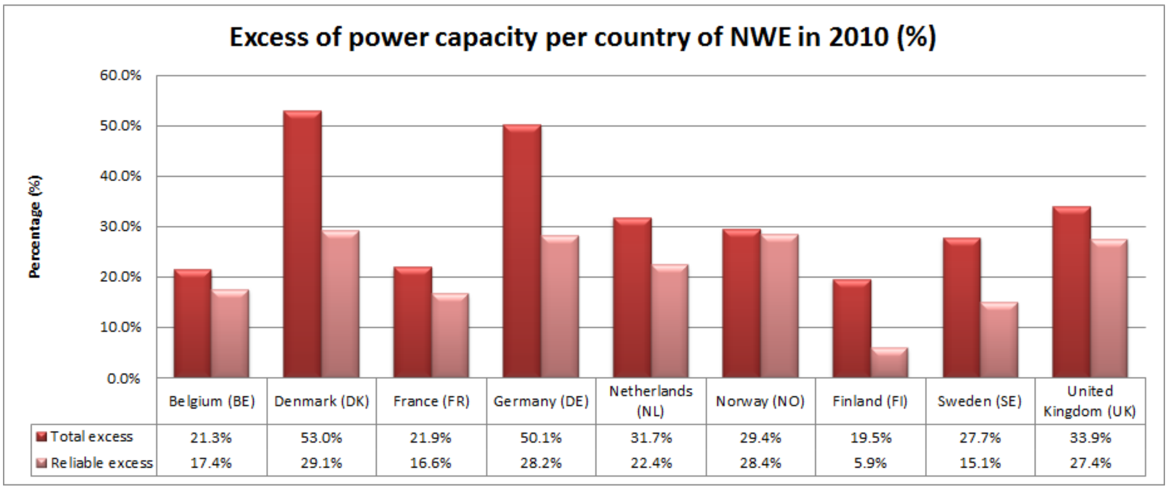


Figure 11 Total and reliable excess of power capacity installed in NWE in 2010. Based on data from **(Euroelectric, 2012) and (entsoe, 2012)**

Finally, based on the figures depicted above, it is difficult to foresee an important change in the generation adequacy for most of the countries from 2010 to 2014 if the peak demand for every country grows at 3% and there is not dismantling of old electricity production units. However, it is relevant to highly that the most vulnerable countries to increases in peak demand are still Finland, Sweden and France. As their reliable excess production capacity is already low in comparison with the 10% target and production capacity in other countries of NWE.

2.5. Conclusions of Chapter 2

The electricity as a commodity has a couple of physical features that make it different from any other good. As a consequence, the electricity system has been designed physically and institutionally in such a way that deals with the characteristics of electricity and facilitates its delivery to the customers. However, electricity systems in NWE do not perform equally even though they share a common restructuring history and theoretical design. This is especially evident if some attention is paid to the degree of wholesale competition experienced in every country of NWE, electricity prices and reliability of the electricity system in the geographical area.

On the other hand, the discussion surrounding capacity mechanisms in NWE have individual connotations. For instance, France is looking for a capacity mechanisms based on capacity subscriptions due to political preferences and to cope with peak demand of electricity in winter. UK is focused in restructuring the electricity sector to meet the EU targets and therefore this country is deciding to implement strategic reserves or capacity markets in the form of reliability contracts. Scandinavian countries are more advanced that the rest of NWE; they have implemented strategic reserves and operating reserves as the simplest way to cope temporarily with the peak demand of electricity during winter seasons. Finally, the position of the other countries such as Netherlands, Germany and Belgium is long term oriented. They are seeking a suitable solution that does not distort the price formation in the wholesale electricity markets and guarantee adequate generation at a European level.

Finally, the current state of NWE and especially the Netherlands is clear concerning generation adequacy in the short term. There was enough reliable electricity production capacity in 2010. However, this situation might change once the countries implement capacity mechanism. The implementation of the capacity mechanisms in France, UK and Scandinavia might not only have a local effect on generation adequacy and in some cases in price formation in wholesale electricity prices but also in the patterns followed by the Netherlands to invest in new power generation units and in some cases in the electricity prices experienced in the Dutch wholesale market. However, those plausible effects are analyzed carefully with the help of a simple quantitative model and quantitative-qualitative analysis of the wholesale markets in NWE in following section.

3. Modeling the Wholesale Markets Linked to the Netherlands

In the previews section a descriptive analysis of the generation adequacy in NWE in 2010 was performed. It suggested that the levels of generation capacity and reliable power production are adequate to satisfy peak electricity consumption in the short run. However, It was also mentioned that some countries implemented or are deciding to locally introduce capacity remuneration mechanism for different purposes; even though the policy goals in Europe are seeking to integrate the electricity markets. As a result, the effects of those mechanisms in neighboring countries such as The Netherlands are very uncertain and depend on the implementation parameters and context where the electricity markets will work in the future. Therefore, this section attempts to capture the behavior of the Dutch electricity market and its interconnected neighbors as well as to quantitatively model the interaction between them. This will contribute to set the terrain to give answer to the following questions:

- What are the potential short run effects of capacity mechanisms implemented in NWE on prices and demand in the Dutch electricity market?
- What are the potential effects of capacity mechanisms implemented in NWE on generation adequacy in the Dutch electricity market?

This chapter starts with problem formulation and actor identification to be considered in the model. It is followed by the system identification and composition. Then the concept and model formalization and described in detail. After that, the software implementation of the model as well as its verification is explained. Finally, this chapter concludes with the verification of the model and firsts conclusions of the main characteristics of the modeled wholesale electricity markets.

3.1. Problem Formulation and Actor Identification

The integration of the electricity markets all over Europe has been encouraged by the EU, which has been looking forward to foster competition, to ensure security of supply and to improve the reliability of the electricity system. As a result, European market integration has emerged to bring more competition to electricity markets and to improve the security of supply by facilitating the transfer of electricity to the countries that need it the most. However, despite the market integration at the European level, some countries such as France, UK and the Scandinavian member states are attempting to implement different capacity mechanisms to deal with local security of supply issues. The effects of those national efforts have not been either studied by researchers or experimented in the real electricity system and therefore it is not clear what would be the result of their implementation on the prices and demand as well as generation adequacy in wholesale electricity markets at the EU level.

Reducing the problem to the case of interest in this research, the Dutch regulator is currently focused on understanding what would happen on electricity prices—*Affordability of electricity in the Netherlands as it will be explained in Chapter 4*—, demand and producer surplus and profits—*generation adequacy and reliability in the Netherlands as it will be explained in Chapter 4*— in the Dutch wholesale market if France, UK, Germany and Norway respectively implement a capacity mechanisms such as capacity subscriptions, reliability contracts, strategic reserves and operating reserves. Therefore, the supply and demand features of the Dutch electricity market and its neighbors mentioned above are to be captured and modeled, attempting not only to replicate their behavior rather than their precise historical values but also to explore what would effects might be experienced in the Dutch electricity market if its neighbors decide to implement the capacity mechanisms aforementioned.

3.2. System Identification and Composition

As it was portrayed in the above section, the model's purpose is to get understanding and explore the possible effects of capacity mechanisms implemented in neighboring countries on the Netherlands. Therefore, it imposes a first boundary of the model given by the geographical area of interest, which consists of the countries belonging to NWE. In addition to this, a second boundary is provided by the sector of interest to be modeled, which is the wholesale electricity market of NWE. However, the system object of study is narrowed down due to two additional features of the real world. The first concerns the availability of transmission lines interconnecting the Dutch electricity system to the electricity systems of NWE. The last has to do with the countries interconnected to The Netherlands, which are currently deciding to implement a capacity mechanism. As a result of the identified boundaries, the system to be modeled comprises the wholesale electricity markets of The Netherlands, France, Germany and Norway.

To succeed in modeling the system aforementioned, the following assumptions have been used to simplify the real system. The assumptions are presented below, followed by the main reasoning supporting them.

→ Wholesale electricity markets represented as a single power exchange market—*as the APX of the Netherlands*— where there is no difference between short-term and long-term market.

- Reduce unnecessary complexity in the model
- Information about the bilateral contracts of electricity are hardy available—*in public sources*— for the countries object of study
- The model attempts to model the behavior in price formation, therefore it can be done by modeling a power exchange market which is usually a reference for the electricity prices in the long-term electricity markets (Kirschen and Strabac 2004)

→ There is no entry or exit of power generation units

- Since the model is static in nature, those long-term dynamics of the real system are not considered.
- Building or dismantling capacity takes time due to the formal procedures and regulations that must be followed. Therefore, it can hardly affect the model, which is modeled for a time interval of one year.

→ There are not changes in technology, which means that renewable power generation is fixed

- Technological innovation takes place in the medium-term or long-term. Therefore, it is not likely that innovation influences the static model in the period of study.
- Development of renewable energy sources for electricity production is very uncertain nowadays. Hence it is difficult to objectively implement such an effect on the model.

- Since the model is based on static equilibrium explained by neoclassical economic theory, implementing technological changes would require a dynamic modeling approach, which is out of the scope in this research.

→ There are no changes in the consumer behavior or preferences. This concerns the fact that the demand is assumed to be inelastic for the period in consideration.

- Demand in the short term is highly inelastic due to the lack of real time price information accessible for most of the consumers (De Vries 2004)

→ Cross border trade of electricity is limited between the Netherlands and its interconnected neighbors

- Increase of cross border capacity is not possible in the timeframe of one year considered in the model. Specially, since building new infrastructure for transmission of power requires a considerable period of time to be constructed.
- The model attempts to capture the real constraints of the trade between the wholesale electricity markets. Capacity of transmission lines plays an important role in the price formation in the a strongly interconnected Dutch wholesale market

→ There are no changes in regulations affecting price formation in the wholesale markets

- Regulatory uncertainty is a variable difficult to measure in a quantitative model.
- Under the current situation in Europe. It is hard to assess the direction of the regulations and their implications for the wholesale markets. Therefore for the sake of simplicity and robustness of the results, it is more suitable to consider regulatory uncertainty as a fixed exogenous factor equal for every generator and consumers.

→ There are no national network constraints affecting the production of electricity and price in the electricity markets object of study

- The model is based on neoclassical theory of the interaction between supply and demand. Therefore, it is not possible to introduce local network constraints.

- Considering National network constraints would require full information and characterization of the transmission networks in NWE, which would require a different modeling and software approach.

→ Electricity supply curve is constructed out of the electricity generation mix most recently available for the markets of interest.

- More recent information would allow the modeler to capture the behavior of the wholesale electricity markets. As a result, more credible and robust conclusions can be drawn
- Most complete data found for the year 2010.

→ Power generators are price takers and therefore offer their electricity at the marginal cost of production.

- It comes from the economic theory supporting the model. In which, electricity producers cannot exercise market power.
- In theory, producers do not behave strategically and therefore they recover their fixed cost of production during price spikes in the wholesale electricity markets.

→ Marginal cost defined as the average fuel cost of electricity production

- Capture the main component driving the behavior of the wholesale market at a reasonably implementation time.
- CO2 prices are expected to rise considerably. Therefore, introducing those might add noise to the current price formation in the wholesale electricity markets
- Turn on and off costs of power generation units are hardly available for all the countries and electricity production technologies

→ Model parameters and data based on the most recent available figures—*2010*—

- Year for which more complete information and data has been found. Specially, data concerning electricity generation capacity installed and fuel costs.
- If more recent data is found, the model can be easily updated with such new data.

3.3. Concept formalization

The real system of study comprises the wholesale electricity markets of Netherlands, UK, France and Norway. As described in chapter 2, every wholesale market is designed in such a way that allows the interaction of four actors such as generators, TSO, retailers and large consumers. These actors interact in the electricity system and have different roles that need to be considered for the modeling purposes. These roles and are explained below.

Generators offer their volumes of electricity production in MW at a certain price in Euros/MWh to the wholesale market for a defined time period. These volumes of electricity production depend on the generation portfolio owned by every generation company and their cost of electricity production is given by the marginal cost of every generation technology belonging to the company's generation portfolio. Furthermore, generators offer their volumes of electricity production to the wholesale market at a price equal to their marginal cost of production, which for the purpose of this model is equal to the fuel cost associated to the generation technology. The fuel cost is calculated out of the fuel price at which generation companies purchase fuels to power generation units affected by the electrical efficiency of the power generation technology. As a result, the supply curve of electricity is built adding up the offers from all generation companies in the system.

In this model the TSO does not have such an important role as it does in the real system. This is because technical constraints related to network operation are not considered in this model since they are very complex to model, which requires much more time resources and a different modeling approach. Instead, in this model the TSO is only in charge of allocating the cross-border interconnection capacity between the Netherlands and its neighbors in NWE. This is depicted by the constraints for buying and selling electricity in the wholesale markets linked to the Netherlands.

Retailers and large consumers play the same role in this model. They represent the demand side, which is fully inelastic for every defined period of study as is one of the main modeling assumptions earlier mentioned. A retailer is in charge of purchase electricity on behalf of a group of small consumers in a specific country. They calculate and aggregate the electricity demanded by their clients in a single demand offer for different time periods. In contrast, large consumers are actors with important levels of electricity consumption that can purchase directly electricity volumes in the wholesale market. Both types of electricity consumers aggregated form the demand curve that is measured in MW at a specific moment of the day.

3.3.1. Concept construction

Two steps must be followed to construct the model of the real system described earlier. Firstly, every single wholesale market of the countries of NWE interconnected to the Netherlands needs to be characterized and built. This is because there is no previous characterization or models of this type for the year 2010,which is the reference period in this study. Lastly, the Dutch wholesale electricity market needs to be coupled with its neighboring markets since without coupling the wholesale markets of NWE, no electricity trading between these countries and the Netherlands would be possible. For this purpose, In this model, the Dutch market is coupled one by one with the other wholesale markets rather than all the markets together. This procedure will allow understanding and exploring better the single effects of the every country of NWE on the wholesale electricity market of the Netherlands.

The wholesale electricity markets of Netherlands, UK, France, Germany and Norway are characterized by the interaction between generators, retailers and large consumers, which as it was explained in Chapter 2, respectively depict the supply and demand side. Supply curve in this model is built from two elements such as volume of electricity offered and its marginal cost of production—*see the below figure*—. The blocks of electricity offered by power generators are organized in merit order, which means that the electricity offered is ranked from the cheapest to the most expensive one. Those blocks of electricity offered in a local wholesale market correspond to the total installed capacity in the electricity system of a specific country and denotes the upper limit for electricity produced locally. Similarly, electricity demand curve is built from the aggregated demand of all customers in the electricity system of a country in a specific moment. This electricity demanded in a single wholesale market is represented by a vertical line, which simulates the inelasticity of electricity demand in the short term. The interaction between supply and demand results in a market clearing, which is the intersection between supply and demand. The result of market clearing is the wholesale market price of electricity in Euros/MWh.

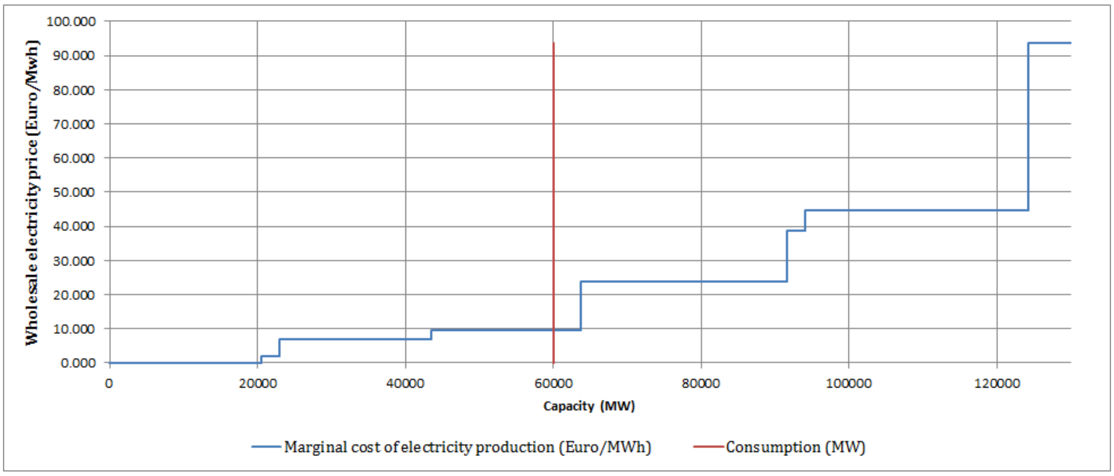


Figure 12 Model of the wholesale electricity market, interaction between supply and demand. *Based on data for Germany depicted in appendix 1 and 2*

Finally, once the wholesale markets of the Netherlands, UK, France, Germany and Norway are built it is necessary to proceed with the second step aforementioned. This consists in coupling the Dutch market with its neighbors to allow the exchange of power between the countries—*Trading of electricity*—. At this point the model is split in four sub models, which simulate the interaction between the wholesale electricity markets of Netherlands and France, Netherlands and UK, Netherlands and Germany and lastly Netherlands and Norway. In this sense, every pair of countries is coupled to simulate and understand the patterns of the purchases and sales between the Dutch wholesale electricity market and its neighbors. Moreover, the physical exchange and trade of power from the Netherlands to its neighbors is constrained by the capacity of the transmission line linking these countries as depicted in the figure below. As a consequence, a fairly simple congestion management method called market splitting is used to couple the wholesale electricity market of the Netherlands with the mentioned countries while taking in to account the maximum possible physical exchange and trade of power among those systems. Market splitting has been modeled as described on De Vries et al (2011). It starts clearing separately the wholesale markets of the Netherlands, UK, France, Germany and Norway. Then one of the subsystems, which comprise the Dutch, and one of the above wholesale electricity markets is analyzed. In this subsystem the country with the lower wholesale electricity price sells power to the more expensive country. The exchange of power between the two countries raises the electricity price in the cheaper wholesale market and reduces the electricity price in the expensive one up to the price in both wholesale markets converge or the capacity of the transmission line is fully used. The market splitting method is modeled to the four subsystems according to the features of the wholesale electricity markets embedded in every of the countries of interest.

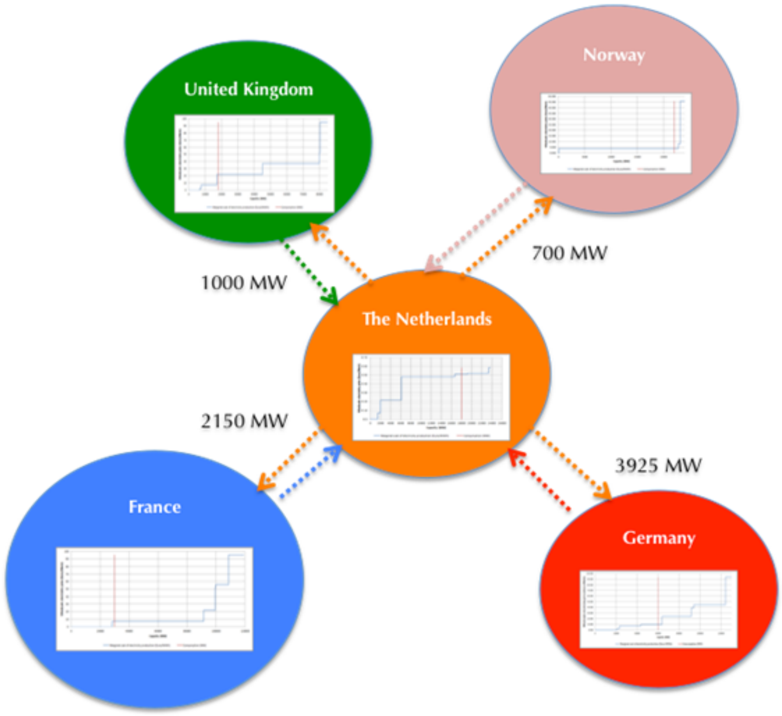


Figure 13 conceptual models of the power exchanges between the Netherlands and NWE wholesale electricity markets.

3.4. Model formalization

After the model is conceptualized it needs to be formalized and translated in computer instructions. Therefore, this section specifies the relations among variables, parameters and programming code.

First of all, every single wholesale electricity market was constructed for the countries of interest in NWE. These five wholesale electricity markets are composed by supply curve and demand curve. The supply curve is non-continuous function, which is modeled by two vectors such as capacity offered vector and price vector. The last is a vector, which contains the value of demanded load in a specific moment of the year. These can be considered the main inputs of the model.

3.4.1. Formalization of electricity supply in the model

The capacity offered vector represents the electricity production capacity installed in the electricity system of a country. This production capacity is formed by the total capacity installed for every electricity production technology in a system. Similarly, the price vector is linked to the capacity offered vector since every electricity production technology has associated a marginal cost of production. This marginal cost differs among technologies due to several factors in the real system. However, in this model marginal cost varies since every generation technology has associated particular electrical conversion efficiency and a specific fuel price of production. This can be confirmed in the supply curve built for the Netherlands, which capacity offered and price vectors are depicted below. For the purpose of this research, the capacity offered and price vectors remain constant in the model for the elapsed time of simulation.

Electricity production technology	Capacity Offered vector (MW)	Price vector (Euros/MWh)	
Hydro	38	€	-
Solar	60	€	-
Wind Onshore	2,000	€	-
Wind Offshore	228	€	-
Waste	545	€	-
Nuclear	510	€	7.04
Coal	4,161	€	21.69
CCGT	10,531	€	47.85
Gas Plant	2,507	€	51.12
OCGT	3,845	€	51.71
Biomass	350	€	52.09
Gas turbine	334	€	58.48

Table 3 Capacity offered and price vector for the Netherlands in 2010. Based on appendix 1

Furthermore, supply curves and its associated capacity offered and price vectors differ among the wholesale electricity markets of NWE. This is due to the variation in the capacity offered, the generation mixes and the marginal cost of production. These differences can be found by looking at the vectors corresponding to the supply curves for Germany, France, UK and Norway, which are depicted in appendix 1.

3.4.2. Formalization of electricity demand in the model

Demand vector comprises 14 load values taken from load duration curves built with real data of power consumption in 2010 from ENTSO-E. These 14 load values were carefully chosen to simulate peak, shoulder and off-peak power consumption in the wholesale market of the Netherlands and its interconnected neighboring electricity markets. In the selection of the 14 demand points more attention was paid to power consumption in peak demand as these are the periods were power consumption fluctuates the most and therefore higher prices are expected to be realized in the modeled wholesale markets of NWE. In addition to this, the reason for taken 14 values of the load duration curve relies on the fact that the model could not be simulated for the 8760 demand values of 2010—*every point in the load duration curve represents the power demanded for every hour of a year, as a result there are 8760 different load values in a year*—. To construct the load duration curves of the countries of the Netherlands and the other countries of NWE, a processing of the power consumption data was performed. This consisted in constructing a histogram for the countries of NWE in Excel 2010 with the data of power consumption in 2010. Every histogram provided an organized table with the frequency of occurrence of power consumption in MW. 24 categories and their frequencies of occurrence resulted from the constructed histogram—*number of times that certain value of power consumption took place. This can be turned in percentage if a specific frequency is divided by the sum of all frequencies* —. Those frequencies were turned in to the number of hours per year that a value of power consumption—*category of the histogram*— took place in every of the countries object of study of NWE in 2010. This resulted in a discrete load duration curve, which provided 24 values of power consumption for 24 specific hours of the year 2010. Since these discrete load duration curves do not provide enough information to simulate different level of power consumption for the Netherlands or the other countries of NWE, a regression analysis was performed to link the 24 points of the discrete load duration curve and build a new continuous load duration curve. The regression analysis was performed in Matlab and one of the load duration curves fitted in this program, the Netherlands, is depicted below and the other curves as well as the programming code are portrayed in appendix 2.

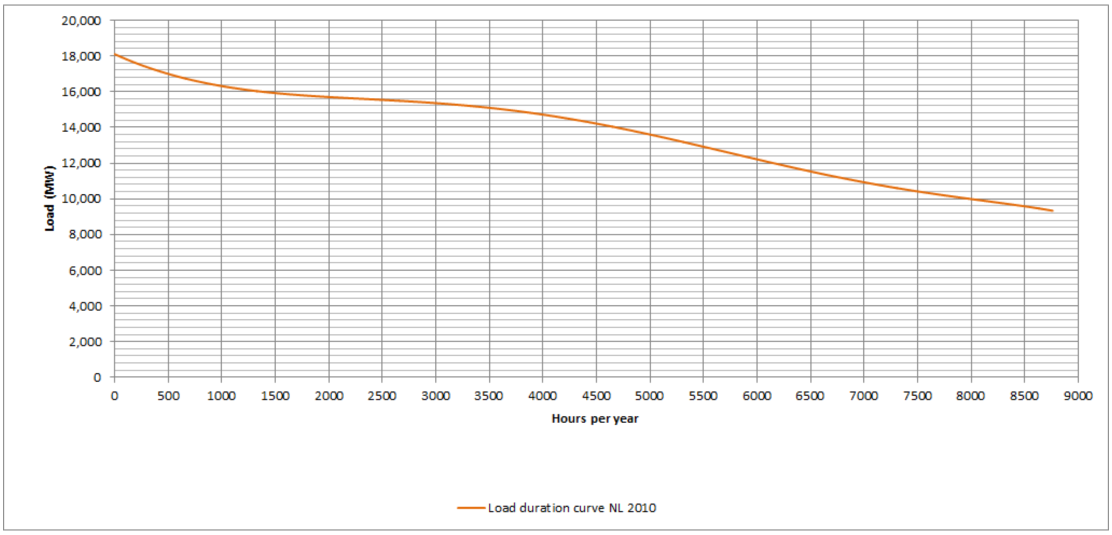


Figure 14 Load duration curve for the Netherlands in 2010. *Based on data for the Netherlands depicted in appendix 2*

3.4.3. Formalization of electricity trading in the model (Market splitting)

Once the power offered and price vectors as well as demand vector were modeled and parameterized for every wholesale electricity market, power exchange between these markets was modeled in Excel. For this purpose other variables such as maximum capacity of the link and market with the higher price as well as additional logic was implemented. Since the procedure earlier discussed was performed for electricity trading between to countries, the Netherlands and one of its interconnected neighbors, four sub-models emerged, one for every pair of wholesale markets. The sub-models implemented in Excel 2010 implicitly run five sequential steps prior the provision of the outputs. Those steps are the basis of the logic implemented in Excel 2010 and thus they are explained below with the example of the wholesale market sub-model of The Netherlands and Germany:

1. Ordering the capacity offered vector in price ascending order in both wholesale electricity markets—*Merit order*—
2. Define the power consumption level in a specific period of the year from the Dutch and German load duration curves.
3. Match supply and demand functions to obtain the market equilibrium price of electricity. This is done for the Netherlands and Germany separately and in parallel—*Clearing of the Dutch and German wholesale markets*—.

4. Compare electricity prices in both wholesale markets:
    a. If electricity price is higher in the Dutch wholesale market, buy power from the German wholesale market. This is done up to the point the electricity price in both markets converge or the capacity of the transmission line between Germany and the Netherlands is fully used.
    b. If electricity price is higher in the German wholesale market, buy power from the Dutch wholesale market. This is done up to the point the electricity price in both markets converge or the capacity of the transmission line between Netherlands and Germany is fully used.
5. Since there is a transfer of power from one wholesale market to the other, the real purchases of power in both wholesale markets lead to new electricity prices. Then, the third step is conducted again to clear the markets and get the new wholesale market equilibrium prices after the transfer is completed.

The main outputs of the model in a period of study of one year are listed as follow and graphically shown in the below figure:

- Indication of the electricity prices in Euros/MWh in the wholesale markets of Netherlands and Germany—*or the country object of study*—
- Estimation of the optimal purchases in MW in both wholesale electricity markets under unlimited capacity of the transmission link
- Real demand and exchange of power in MW between the two wholesale electricity markets
- Estimation of the producer's net surplus and profits in Euros/Year for the two wholesale electricity markets.

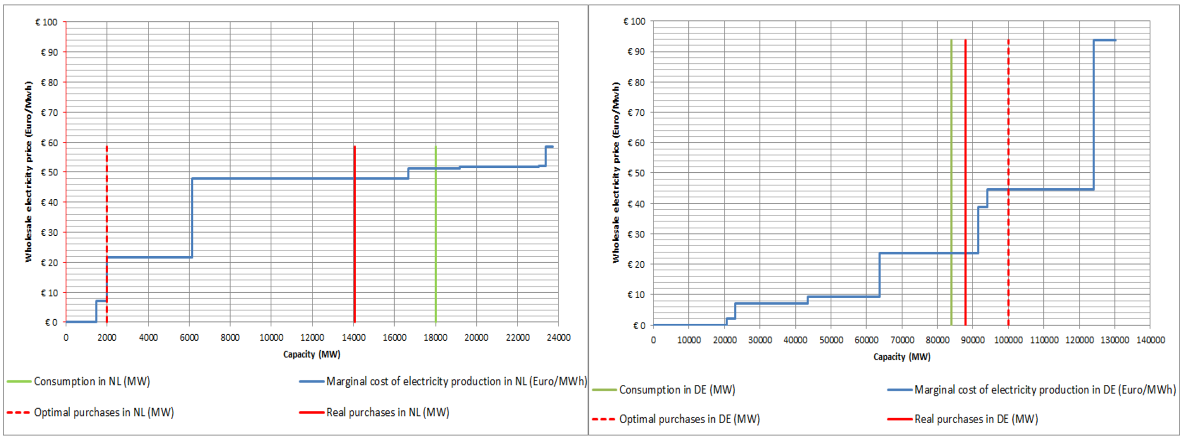


Figure 15 graphical representations of the modeling outputs for the interaction between the wholesale electricity market of the Netherlands and Germany. *Based on the modeled outputs of the NL-DE system depicted in appendix 3*

The outputs of the model described above, are the basis to experiment the effects of capacity mechanisms to be implemented in France, Germany, UK and Norway. The implementation of the capacity mechanisms in the model and their main outputs will be discussed in chapter four.

3.5. Software implementation

As described in the previous sections the model required considerably data processing for its inputs but flexibility to further experiment with it. Consequently, a blend of software such as Matlab and Microsoft Excel was used to processes the data and to run the model.

Matlab was used to process data due to its high performance in working with NxM matrixes and the familiarity of the modeler with the software. More precisely, it was employed to construct the load duration curves of the electricity systems of The Netherlands, France, UK, Germany and Norway. It required polynomial fitting of the consumption data with a high level of accuracy in the regression coefficients. Besides, it is compatible with the software used to build the model of the Dutch and neighboring wholesale electricity markets.

Microsoft Excel was used to model the interaction between the Dutch wholesale electricity market and the other countries object of study in NWE. This is due to Excel is a very flexible software which allows the modeler to implement algorithms with predefined functions in a simple modeling environment. Moreover, it offers a large number of visual tools such as graphs and warning messages, which help to verify and validate the results of a simulation. Furthermore, it very useful to follow step by step the simulation process and therefore reduce efforts in verifying and validating the outcomes of a simulation. Additionally, it offers a large set of tools to work and organize databases and matrixes while being compatible with software such as Matlab.

3.6. Model verification and experimentation

The model has been verified following two steps and conducting a couple of simple experiments. Firstly, reviewing that the coded model implemented in Excel followed the conceptual design. Lastly, checking that equations and parameters corresponded to the original data of the system.

The model was verified following the code carefully from the beginning to the end. This process was divided in two parts according to the software used. The first part consisted in following the programming code implemented in Matlab used to build the load duration curves. Here, special attention was paid to the data inputs and outputs of the model. In fact, the data inputs were exported directly from data files created in excel, which labels specified the country from which the data came from. Besides, text titles were used in programming the code in Matlab to reduce the time in searching for coding problems. Additionally, once the code was run, the outputs—*fitted load duration curve*— were compared with the input data representing power consumption in 2010. The last part comprised a check of the instructions programmed in Excel. In this test, especial attention was paid again to the input data in the spreadsheets. Once the inputs were reviewed, a check of the sequence of the calculations was performed. For instance, it was checked that the market clearing price in the Netherlands and the other wholesale market corresponded to the value in the prices vector for such a demand of electricity. Then, it was confirmed that there were a transfer of power from the cheapest to the more expensive wholesale market, in case of price differences between the two countries. After that, a verification of the maximum transfer of power from the cheapest to the more expensive country was conducted. Finally, after calculating the new electricity price in both markets and following the same procedure for the other sub-models, it is possible to say that the coded model is an excellent representation of the conceptual model.

Similarly, a second test was performed to verify that the coded model fully represents the conceptual model. In this case the parameters and equations used in the modeling were verified. The parameters were easily verified since most of them came from organized databases made by institutions such as ENTSOE or EUROSTAT. Besides, these data were available in Excel formats or from tables in books and reports. The parameters were easily verified due to the visual interface of Excel. The equations used were very simple and were mostly used to build the supply curve. More precisely, the calculation of the marginal cost of production was carefully followed since this is a key factor affecting direction of the purchases and sells of electricity the model. In this sense, the marginal cost of a power generation technology, which is a function of the calorific power of the fuel and its price as well as the efficiency of the generation unit, was carefully verified by looking at the cells in Excel containing its equation and parameters.

After performing both tests and using the visual interface of Excel as well as graphs which depicted the outputs of several steps in the simulation, it is possible to say, the model is correctly coded and represents perfectly the conceptual model. Therefore, it is ready to be validated.

3.7. Model Validation

The purpose of validating a model is to guarantee that it is a fair representation of the real system and therefore it can be further used for experimenting. However, there are some models, which purpose is to explore the future rather than to predict it. These exploratory models focus on capturing the key characteristics driving the behavior of the real systems rather than to follow its historical output figures. This is the nature of the model discussed throughout this document and therefore validation tests and analysis of their outputs are tuned according to its nature. As a result, two validation tests such as technology cost comparison and expert validation were performed.

3.7.1. Technology comparison test

The technology cost comparison test consisted in a careful review of the structural characteristics of the model, which has been sub-divided in four sub models as it has been explained earlier. Every sub-model comprises structural features of the supply and demand curves and the exchange of power between the modeled wholesale markets.

The first aspect to validate is the modeled supply curves of the Netherlands, France, Germany, United Kingdom and Norway. From the supply curves depicted in appendix 1, it is possible to identify those electricity production units running on renewable technologies such as wind and solar offer their electricity at a marginal cost of zero Euros/MWh. It is consistent with the real system due to fuel cost of for electricity production from renewable sources is zero Euros/MWh and their marginal cost of electricity production is close to zero Euros/MWh. Therefore, it is valid to model the capacity offered from renewable sources as the bottom of the supply curves in all the wholesale markets modeled. Additionally, after the renewables, the supply curve is composed by nuclear facilities, which fuel powering is usually uranium and are characterized for a low marginal cost of production in comparison with generation units running on fossil fuels such as coal, gas and oil. In the real systems, such as the wholesale French market which is highly characterized by a large share of electricity production from nuclear units, this units are the second cheapest to be run after renewable electricity production and it is consistent with the real wholesale markets. After renewables and nuclear production the supply curves in the wholesale markets are composed by fossil fuel generation units, out of which coal units produce electricity cheaper than gas units and gas produce cheaper than oil units. This is due to the efficiency of the generation technologies is similar but the price of the powering fuels differ substantially between coal and gas and between gas and oil. This is the theoretical organization of the power offered in a wholesale electricity market, which is consistent with the merit order realized in the wholesale market of France for instance (RTE, 2012). The modeled supply curve for the Netherlands depicted below helps to understand better the merit order in which electricity production units are dispatched in the real system.

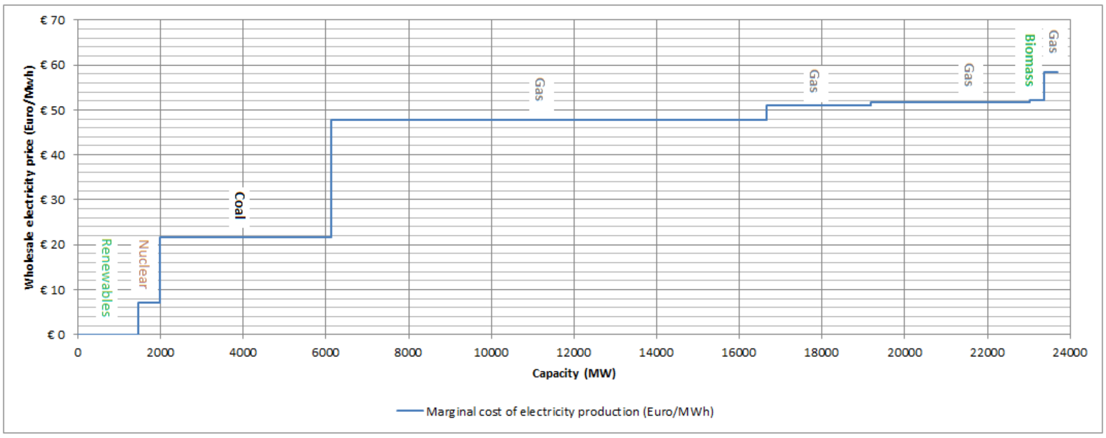


Figure 16 Modeled merit order per fuel used for electricity production in the Netherlands in 2010. *Based on the supply curve depicted in appendix 1*

The demand curve has been modeled as a straight vertical line, which attempts to capture the fact that electricity consumption in the short term is highly inelastic. This implies that electricity consumption in a specific time of the year is constant and its interaction with the supply curve results in a single electricity price. The modeled demand curve has been validated throughout the real electricity consumption data provided by the European Transmission system operator. Basically, this test consisted in analyzing whether or not the modeled demand curve could take any value of demand consumption. The ranges of values of demand consumption were taken from the load duration curves, which have been built out of the real power consumption in 2010 as described in appendix 2. A simple example of the range of values demand can take in the modeled Dutch wholesale market is portrayed beneath.

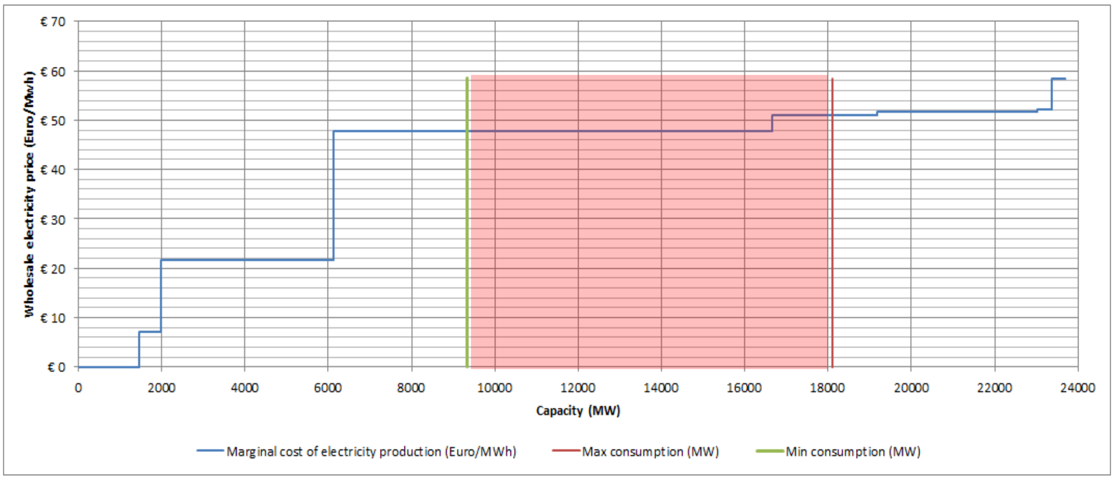


Figure 17 Range of values for the modeled demand in the Dutch Wholesale electricity market. *Based on the load duration curve for the Netherlands depicted in appendix 2*

3.7.2. Validation by experts

A second validation methodology based on expert opinions was applied to this model. For this purpose a couple of experts from the Netherlands competition authority were asked to assess the validity of the modeled wholesale electricity markets of Netherlands, France, United Kingdom and Norway. These experts focused in assessing the magnitude of the electricity prices mainly in the Dutch wholesale electricity market but also in the linked electricity markets. The average electricity prices resulting from the modeled power exchange between the Dutch wholesale market and its neighbors is portrayed in the below table.

Sub-model	Country	Average electricity price (Euros/MWh)		Average demand (MW)	Capacity of the cross border link
NL-DE	Netherlands	€	45.58	13,706	3925
	Germany	€	20.80	68,131	
NL-FR	Netherlands	€	47.85	13,706	2150
	France	€	7.88	64,044	
NL-UK	Netherlands	€	47.94	13,706	1000
	United Kingdom	€	26.92	41,056	
NL-NO	Netherlands	€	47.94	13,706	700
	Norway	€	3.79	15,769	

Table 4 Average electricity prices for the Netherlands and its linked neighbors. *Based on the results of the simulations portrayed in appendix 3*

The experts agreed the magnitude of the electricity prices in the Dutch wholesale market and the embedded power exchange between the Netherlands and its neighbors. In fact, the magnitude of wholesale electricity prices in the Netherlands depicted in the above table are similar to the electricity prices experienced in the real spot market of this country portrayed in the Dutch energy market report of 2009. The price similarity between the real system and the model is due to electricity prices in the Netherlands is most of the time set by gas technologies and the modeled Dutch wholesale electricity market captures this fact. Besides, assessing carefully the results it is possible to understand the underlying behavior of the wholesale markets. For instance, since electricity prices in Germany and in the earlier mentioned countries are on average lower than in the Netherlands, the later is encouraged to purchase electricity in neighboring wholesale markets up to the capacity of the cross-border links is fully used. The results of the model suggest that the Netherlands is on average an importing country relying mainly on electricity purchases from Germany, which is consistent with the real performance of the Dutch electricity market (NMa, 2009). Furthermore, the biggest impact on the average Dutch electricity prices are caused by the countries with the largest cross-border capacity. As a result, Germany and France affect considerably the electricity prices in the Netherlands—*see the above table*—. Finally, after assessing the results summarized in the above table and depicted in detail on appendix 3, the experts agreed not only on the magnitude of electricity prices in the Dutch wholesale market but also in the underlying behavior of the Dutch wholesale market and its power exchange interaction with the neighboring markets in NWE.

3.8. Conclusions of Chapter 3

Electricity markets in NWE are evolving toward European integration. Those markets differ considerably in terms of electricity mix, consumption of electricity and electricity prices. This has resulted in diverse generation adequacy levels, which has raised the concerns about security of supply in the future. Is for this reason, that countries such as Germany, France, United Kingdom and Norway are considering the implementation of capacity mechanisms to guarantee that enough power generation capacity will be available in their electricity systems. As a consequence, the Netherlands, which is directly linked to those countries, is concerned about the effects those capacity mechanisms implemented in neighboring countries might cause to the Dutch wholesale markets. Therefore, an exploratory model of the Dutch wholesale market and its linked neighbors was built.

The model based on the economic theory of static equilibrium between supply and demand appears to be valid to experiment with capacity mechanisms in Chapter 4, and to answer the following research sub-questions:

- What are the potential short run effects of capacity mechanisms implemented in NWE on prices and demand in the Dutch electricity market?

- What are the potential effects of capacity mechanisms implemented in NWE on generation adequacy in the Dutch electricity market?

As discussed in this Chapter the model has been constructed using the most recent data found for the real system—*2010*— and its implementation was performed in Excel 2010 and Matlab. The model has been subdivided in four sub-models, which simulates power exchange and price formation in the wholesale market of the Netherlands and its neighbors. Moreover, the exchange of power is driven by the prices in both wholesale electricity markets. In the model, the wholesale market with the higher electricity price buys from the cheaper wholesale market resulting in a physical power exchange limited by the capacity of the cross-border link between the Dutch and a neighboring wholesale market.

The model captures the main characteristics driving the behavior of the Dutch wholesale market and its neighbors in NWE. More precisely, the modeled wholesale markets yields electricity prices and values of electricity consumption similar in magnitude to those experienced in the real system. Additionally, the model has been constructed in a simple way; however, it captures the flows of power and the direction of the purchases and sells of electricity between the Dutch wholesale market and its neighbors. As a result, it can be used for further experimentation to analyze the effects of capacity mechanisms implemented in neighboring countries on the Dutch wholesale electricity market in the next chapter.

4. Effects of NWE capacity mechanisms on the Dutch wholesale market

The implementation of capacity mechanisms to the model is discussed in this Chapter. Also, the model's outputs are analyzed with the help of an analytical framework, which relates the main outputs of the modeled capacity mechanisms with policy goals of the Dutch electricity industry. Taking into account the limitations and assumptions of the model, as well as the theoretical background of capacity mechanisms, conclusions are drawn about the effects of capacity mechanisms implemented in neighboring countries on the Dutch wholesale market. This conclusions aim to give a proper answer to the research sub-questions depicted beneath

- What are the potential short run effects of capacity mechanisms implemented in NWE on prices and demand in the Dutch electricity market?
- What are the potential effects of capacity mechanisms implemented in NWE on generation adequacy in the Dutch electricity market?

This chapter is structured as follows: firstly, the scenarios formulated and framework of analysis used to analyze cross-border effects of capacity mechanisms is discussed. Then, an analysis of the effects of strategic reserves implemented in Germany on the Dutch wholesale market is depicted. It is followed by the analysis of the effects of "Obligation de Capacité" to be implemented in France on the Dutch electricity market. After that, an exploration of the effects of "capacity markets" currently discussed in UK on the Dutch wholesale market is portrayed. It is followed by the analysis of the effects of operating reserves employed in Norway on the Dutch wholesale market. Finally, this chapter ends with conclusions about the effects of the modeled capacity mechanisms on the Dutch wholesale market.

4.1. Scenario formulation

To explore the effects of the different capacity mechanisms implemented in the modeled wholesale markets of the NWE four scenarios were built —*see table below*— These scenarios were constructed to compare the performance of the Dutch and its neighboring electricity markets under different exploratory futures. The implementation or not of capacity mechanisms on the electricity markets of NWE is the fundamental factor for the formulation of these scenarios. Additionally, since capacity mechanisms are quite often activated when production capacity is tight, scarcity is also taken into account. Therefore, to understand and analyze the main effects of ”strategic reserve”, “obligation de capacité”, “capacity markets” and “operating reserves” on the Dutch wholesale market, the capacity mechanism implementation scenarios are combined with scarcity and no scarcity of electricity production in the Netherlands and in the NWE countries.

Scenario	Capacity mechanism modeled	Netherlands	Germany / France / United Kingdom / Norway
1	Yes	No scarcity	No scarcity
	No		
2	Yes	No scarcity	Scarcity
	No		
3	Yes	Scarcity	No scarcity
	No		
4	Yes	Scarcity	Scarcity
	No		

Table 5 Exploratory scenarios built to run the modeled capacity mechanisms in the wholesale markets of NL-DE,NL-FR,NL-UK and NL-NO

In order to simulate scarcity in the modeled wholesale markets and to explore the near future—*2016*— assumptions need to be made about the changes in the current capacity and demand. As explained in Chapter 3, the developed model is static and based on data from 2010; therefore electricity production capacity in this study is a fixed parameter. This fact is determinant of the way the scenarios were implemented, as the only control variable to reflect the scenarios is the demand.

The current growth rates in demand, forecasted by ENTSOE for the period 2010-2025, are not high enough to reflect scarcity in the developed static models. The main reason is that ENTSOE analyses maintain a broader scope on the system, for example taking into account potential dismantling of power plants and other mechanisms, that for the sake of simplicity are neglected in this study. In fact, according to the analysis of ENTSOE some European countries might face an important reduction of electricity production capacity in 2016 if they do not invest in power generation facilities (Euroelectric, 2011). Therefore, a higher demand growth rate, that can reflect scarcity, has been considered.

The above assumption does not affect the qualitative conclusions of the study, nor the direction of the changes, even though the effect on the magnitude of the output variables is significant. The model is exploratory on the policy level rather than predictive; therefore, the assumption was considered acceptable within the scope of this research study.

4.2. Framework development for model output analysis

To analyze the effects of the modeled capacity mechanisms in the Dutch wholesale market an analytical framework based on the policy goals of the Dutch electricity industry was designed. Such policy goals comprise "reliability", "affordability" and "sustainability/ environmental awareness", and they will be discussed in detail in Chapter 5— *in this study the policy goal of sustainability/ environmental awareness is not assessed, as it will be explained in chapter 5*—. This analytical framework relates the relevant outputs of the model to the policy goals and is based on the neoclassical economic theory, commonly used to analyze electricity markets. The cluster of variables used to measure the effects of the capacity mechanisms on the aforementioned policy goals are depicted in the beneath figure; the causal relations between the outputs of the model and the concepts of "reliability" and "affordability" are described below.

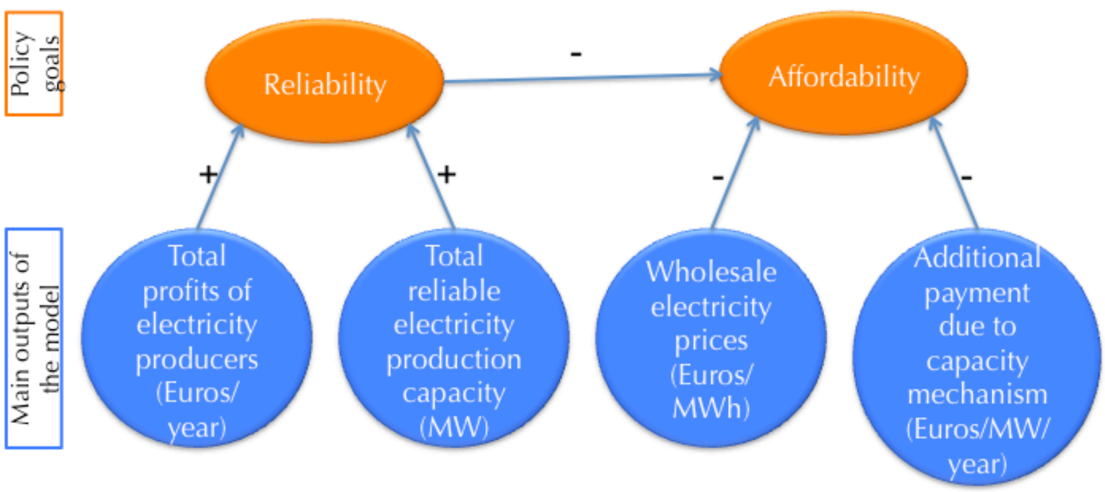


Figure 18 Variables and causal relations used to measure the effects of the modeled capacity mechanism on the Dutch policy goals

(Kirschen & Strbac, 2004) explain from an economical point of view the main relations between electricity market variables and reliability and affordability of the electricity service. Their arguments are used to explain the causal relations as follows:

- Total profits of electricity producers → Reliability

According to (Kirschen & Strbac, 2004), generator's profits drive the amount of total capacity available in the electricity system, which consequently results in a more reliable electricity service. Since power generators are rational investors they will finance a production facility if they believe that the new power plant will make a satisfactory profit over its lifetime. To decide on such an investment, the power generator computes the long run marginal cost of the plant and forecasts the price at which the output of this plant might be sold.

In the adoption of this reasoning in the present study, one should bear in mind the rather short-term frame of the developed model. The ability of the model to provide information about long-term effects of capacity mechanisms on the Dutch reliability is limited by the fact that the model is static in nature; the outputs of this model are valid for a 1-year time frame.

- Total reliable electricity production capacity → Reliability

The total reliable capacity is directly related to the reliability of an electricity system. More production capacity offered in the wholesale market makes the system more reliable, as it is prepared to satisfy higher demand of electricity and avoid rolling blackouts.

- Wholesale electricity prices → Affordability

Wholesale electricity prices are used as a proxy variable to assess the affordability of electricity under the following reasoning. Electricity bills paid by consumers consist of a number of charges, one of which is the price at which electricity is bought in the wholesale market. As a result, higher wholesale electricity prices lead to higher electricity bills, which result in a less affordable electricity service. Furthermore, high prices are unacceptable because they force vulnerable consumers to cut back on their consumption of electrical energy used for essential purposes Kirschen and Strabac (2004).

- Additional payment due to capacity mechanism → Affordability

Additional payments due to capacity mechanisms are quite often charged in the electricity bill. Therefore, under the implementation of capacity mechanisms consumers not only pay for electricity purchased in the wholesale market but also for the capacity mechanism. The higher the payment results in a higher electricity bill and consequently to a less affordable electricity service.

There is also a relation between "reliability" and "affordability". In order to improve the reliability of the service more investments in production capacity need to be performed by generators, which expect to recover their costs through higher electricity prices, paid by the consumers.

Finally, it is relevant to clarify that the above explained framework for analysis attempts to turn the model outputs into objective and reliable conclusions, taking into account the limitations of the model, such as the time frame and the underlying assumptions on production capacity and costs. Furthermore, since most of the studies on capacity mechanism, such as the studies by De Vries (2004), (Vazquez, Batlle, Rivier, & Perez-Arriaga, 2003) among others, are not focused on the cross-border effects of capacity mechanism, no published framework was found to be used as a guideline. Therefore the model analysis and conclusions will rely on the above framework combined with some theoretical concepts of capacity mechanisms.

4.3. Effects of the temporary implemented strategic reserves of Germany on the Dutch wholesale market

As it was analyzed in Chapter 2, Germany has implemented a temporary capacity mechanism that fits in the theoretical description of strategic reserves. This capacity mechanism is added to the original model of the wholesale markets of Germany and the Netherlands built in Chapter 3. The implementation of strategic reserves in the model on Dutch wholesale electricity market was conducted following the steps described below.

4.3.1. Addition of strategic reserves to the current model NL-DE

The procedure employed to add the strategic reserves to the model is the following:

1. Set a volume of capacity to be considered as strategic reserve. This capacity is usually determined by an independent agent or the government and can be procured in an auction or a tender. For the purpose of this research, 1295 MW of strategic reserves has been considered because this amount of production capacity was contracted by Germany for the year 2011/2012 (Bundesnetzagentur, 2012)
2. Define the procedure to run the strategic reserve in the German wholesale electricity market. From the theory, strategic reserve is only dispatched when there is no match between supply and demand curves in the wholesale market. Therefore, for the purpose of this study, the 1295 MW of strategic reserve is dispatched in the German wholesale market only when demand of electricity is bigger than the capacity offered in the wholesale market—*the total electricity production capacity offered in Germany considers the transfer of power from the Netherlands to Germany*—.
3. Set the price at which the strategic reserve is dispatched in the German wholesale market. For this analysis, the running price of strategic reserve has been defined according to the strategic reserve pricing theory and the practices in Scandinavia—*peak load arrangements, where the reserve units are dispatched at a price just above the price of the more expensive unit offering power in the wholesale market*—. It was allocated above the price offered by the last marginal unit participating in the German electricity market— *oil powered generation unit*—. Besides, It was set above the marginal cost of electricity production of the generation technology contracted as strategic reserve. Finally, the running price of strategic reserve was set below the value of lost load (VOLL)[14].
4. Clear the interconnected markets and calculate the operational profits also called producer surplus per hour and total per year for Dutch and German

[14] The Value of Lost Load is the maximum price consumers are willing to pay for every MWh of electricity. Above this price, the electricity purchased is more costly than the utility or satisfaction obtained by the consumer. The reference parameters of VOLL have been taken from Losa, I., & Bertoldi, O. (2009). *Regulation of continuity of supply in the electricity sector and cost of energy not supplied.*

producers. In this model, the operational profits per hour consist of the difference between the market price and marginal cost of production times the power sold in the market. Similarly, the total operational profits consist of the sum of the operational profits per hour times the hours of a year.

5. Calculate total profits of electricity producers in the Dutch and German wholesale market and the level of the payment given to the contracted German strategic reserve. The payment given to the strategic reserve units is calculated as the operational profits of the reserve units minus the total cost of production over the total production capacity contracted as strategic reserves. The result of this calculation is a value in Euros/MW/year
6. Repeat the previous steps for every scenario.

By following the six steps aforementioned, the model produced main outputs such as electricity prices—*Euros/MWh*—, Operational profits of Generators—*Euros/year*—, Reliable production capacity—*MW*— and payment for strategic reserves—*Euros/MW*—. The equations for their calculation are depicted in Appendix 4.

4.3.2. Outputs of strategic reserves implemented in the NL-DE model

The model for the wholesale electricity market of the Netherlands and Germany was run for the four scenarios with and without capacity mechanism as described in Chapter 4.1. To run the model of NL-DE with strategic reserves in Germany, the six steps earlier discussed were followed. For this, Excel 2010 was again used. The model of NL-DE without capacity mechanisms was simulated for the four scenarios to obtain a clear picture of the differences in the model outputs caused by the implementation of strategic reserves in Germany. The results and implementation details of those simulations are portrayed in Appendix 4 and a summary of those results is depicted beneath.

Scenario	Capacity mechanism implemented in the model	Country	Average electricity price (Euros/Mwh)	Average demand (GW)	Total profits of electricity producers (million Euros/year)	Total reliable electricity production capacity (GW)	Payment given to the strategic reserve units (Euros/MW /year)
1	Yes	NL	45,58	13,7	€ (410)	23,7	-
		DE	20,80	68,1	€ (5.072)	131,5	40.791
	No	NL	45,58	13,7	€ (410)	23,7	-
		DE	20,80	68,1	€ (5.072)	130,2	-
2	Yes	NL	48,86	15,5	€ (116)	23,7	-
		DE	80,73	110,5	€ 55.412	131,5	-
	No	NL	48,86	15,5	€ (116)	23,7	-
		DE	80,73	110,5	€ 55.074	130,2	-
3	Yes	NL	98,93	21,2	€ 10.193	23,7	-
		DE	23,32	74,1	€ (3.446)	131,5	40.791
	No	NL	98,93	21,2	€ 10.193	23,7	-
		DE	23,32	74,1	€ (3.446)	130,2	-
4	Yes	NL	86,63	18,9	€ 7.667	23,7	-
		DE	80,75	108,1	€ 55.430	131,5	-
	No	NL	224,21	18,9	€ 36.235	23,7	-
		DE	218,33	108,1	€ 211.973	130,2	-

Table 6 Summary of the relevant outputs of the modeled wholesale markets of the Netherlands and Germany under the implementation of strategic reserves in Germany[15]

From the table portrayed above, it is important to emphasize that the main differences between the system with and without capacity mechanisms are realized for the fourth scenario in which both countries are tight in production capacity. However, in most of the simulated cases the outputs of the model show differences only for Germany. Specially, the variable called "total reliable electricity production capacity".

4.3.3. Analysis of results: strategic reserves implemented in the NL-DE model

The detailed results of the modeled strategic reserve in Germany portrayed in Appendix 4 are the basis for this analysis. These results differ for every modeled scenario and therefore their analysis is performed per scenario by using the analytic framework discussed in Chapter 4.2.

[15] Negative numbers are depicted within brackets. Total profits of electricity producers refer to the profits made by producers due to the sale of electricity and the capacity mechanism.

Scenario 1:

Under this scenario, the implementation of strategic reserves in Germany does not show important effects on the affordability of electricity for Dutch consumers. This is because electricity prices in the Dutch wholesale market do not fluctuate—*45.8 Euros/MWh on average*— as a consequence of the 1295 MW procured through strategic reserves in Germany. In fact, the electricity production capacity installed in both countries is enough to cover their coincident peak demand. Therefore, there is no need to dispatch the strategic reserve units in the German wholesale market.

The model outputs show that German consumers obtain a more reliable service since the reliable production capacity is increased in 1295 MW. In exchange, they pay for the contracted reserve units even though these units never produced electricity. This results in slightly larger bills for German consumers, which results in slightly less affordable service.

The results of the model concerning total profits of electricity producers — *a loss of 409,730,301 Euros/year*— suggests that Dutch peak generators are not dispatched frequently enough to recover their total costs of production. Additionally, the losses generated for the (peak) producers of the Dutch wholesale market might lead them—*if possible according to the law*—, as rational actors (Kirschen & Strbac, 2004), to offer their production capacity in Germany as strategic reserve, which would generate profits. At the same time, through such actions of the producers, the reliability of the Dutch electricity system would be reduced in the short-term. When discussing these results, it should be kept in mind that the model is limited and aims to provide only a rough estimation of the short-term profits obtained on the basis of simple electricity trading between two countries; it would be, therefore, essential to conduct additional research on the long-term effects of this issue, incorporating the full integrated electricity market. *This effect holds for scenario 2 as well since in this scenario Dutch producers face negative profits.*

Scenario 2:

Under this situation, the model outputs insinuate that reliability and affordability of the Dutch electricity service do not get compromised by the 1295 MW contracted as strategic reserve in Germany. This is explained by the stable electricity prices of the

Dutch electricity market—*48.86 Euros/MWh on average*—. The scarcity of electricity production in the German market induces higher average electricity prices in this system—*80.73 Euros/MWh on average*— than in the Dutch wholesale market. However, this effect is caused by the fact that the German system is tight in production capacity and not because the capacity mechanism has been implemented in Germany. Furthermore, the big difference in market prices in both wholesale markets shifts the current power trading dynamics between those electricity markets. In the present, the Netherlands quite often imports electricity form Germany (Supponen, 2011).

Scenario 3:

Under this scenario, average prices in the Dutch wholesale market are high due to scarcity of production capacity in the Dutch system. The contracted 1295 MW of strategic reserves by Germany do not show important effects on the reliability and affordability of electricity in the Netherlands. Indeed, electricity prices remain stable even though they are high as a consequence of production scarcity in the Dutch system. As a result of high prices, Dutch producers obtain large profits—*10,193,171,270 Euros/year in total*— that help Dutch generators to easily recover their total costs of production. Since electricity producers are rational actors, large profits would encourage electricity producers to offer all their power capacity in the Dutch wholesale market contributing to the reliability of the Dutch system in the short-term.

Finally, the model outputs shows that with strategic reserves, German consumers obtain a more reliable service since the reliable production capacity is increased by 1295 MW. In exchange, they pay for the contracted reserve units resulting in slightly larger bills for German consumers, which result in slightly less affordable service.

Scenario 4:

Under this scenario, the model outputs suggest that the implementation of a capacity mechanism in Germany leads to an improvement of the affordability of electricity in the Dutch system. This can be explained by the lower electricity prices of the Dutch wholesale market—*86.33 Euros/MWh on average in contrast to 224.21 Euros/MWh on average* — caused by the exchange of power with a more reliable German wholesale market. In this case, Germany counts with 1295 MW of additional production capacity that improves the ability of the German system to react to high peak demand. Strategic reserves in Germany results in lower electricity prices on the German wholesale market—*80.75 Euros/MWh on average in contrast to 218.33 Euros/MWh on average* — that encourage the exports of electricity to the Netherlands. This is possible because of the large cross-border capacity of transmission line linking the Dutch and German system.

The results of the model also suggest a reduction of the total profits earned by Dutch generators as a consequence of the 1295 MW of electricity production procured by Germany through the capacity mechanism. However, the reduction in profits of Dutch generators do not seem to cause a large impact on the reliability in the Netherlands — *36.25 million Euros/year in contrast with 7.66 million Euros/year* —since profits in both cases, with and without strategic reserves in Germany, are enough to cover the total cost of electricity production of Dutch electricity producers. Furthermore, one should keep in mind that the accuracy of the model outputs is limited and that the time frame of the study is short-term; one should therefore not generalize conclusions into the long-term profits earned by power generators.

Finally, under this scenario, reliability of the electricity supply in the Netherlands would strongly rely on the generation adequacy of Germany and the volumes of electricity production capacity contracted as a reserve. This would mainly happen due to the price difference in both wholesale markets and the flexibility of Germany to procure additional capacity as strategic reserve. This effect deserves more attention since it could be lower; in the real system, the Dutch wholesale market not only trade electricity with Germany, but simultaneously with other countries of NWE.

4.4. Effects of the "Obligation de Capacité" to be implemented in France on the Dutch Wholesale market

As it was analyzed in Chapter 2, France is currently implementing a capacity mechanism called "Obligation de Capacité" that fits in the theoretical description of capacity requirements. This capacity mechanism is added to the original model of the wholesale markets of France and the Netherlands built in Chapter 3. The implementation of "Obligation de Capacité" in the model on Dutch wholesale electricity market was conducted following the steps described below.

4.4.1. Addition of strategic reserves to the current model NL-FR

1. Set a volume of capacity to be covered by the "Obligation de Capacité". An independent agent such as the TSO or the regulator usually determines this capacity. To simulate the implementation of "Obligation de Capacité" in this model, an additional 10% of the peak demand has been considered as the capacity margin required by the French system. In other words, the power generators are asked to offer capacity credits, which depict their reliable generation capacity. These capacity credits are bought by the consumer's trough an additional payment. The capacity required or the capacity credits to be purchased by consumers would account for 110% of the peak demand in the French system. In the French proposal, it is not defined the amount of capacity credits to be covered by the "Obligation de Capacité". Nevertheless, the French system operator will be in charge of determining such capacity.
2. Define the procedure to run the power generation capacity, which participates in the "Obligation de Capacité" in the French wholesale market. From the theory, generation units being paid extra for the capacity credits offered to the system are dispatched as a regular production unit participating in the wholesale market.
3. Set the price at which the production units paid by "Obligation de Capacité" are dispatched in the French wholesale market. In this model, power plants offer their electricity at the marginal cost of production since they are paid extra for the ca offered to the capacity credits sold to the French system. Therefore, they will recover their total costs of electricity production.
4. Clear the interconnected markets and calculate the operational profits also called producer surplus per hour and total per year for Dutch and French producers. In this model, the operational profits per hour consist of the difference between the market price and marginal cost of production times the power sold in the market. Similarly, the total operational profits consist of the sum of the operational profits per hour times the hours of a year.
5. Calculate total profits of electricity producers in the Dutch and French wholesale market and the level of the payment given to the French units as a result of the implemented "Obligation de Capacité". In this model, such level of payment is calculated as absolute value of the difference between producer

surplus and total costs of production over the volume of capacity covered by the "Obligation de Capacité"—*In case producer surplus is bigger than total cost of production, the level of payment is zero due to the fact producers are recovering their total costs of production and therefore they do not need additional payments*—. The output of this step is a level of payment in Euros/MW/year.

6. Repeat the previous steps for every scenario

By following the six steps aforementioned, the model produced main outputs such as electricity prices—*Euros/MWh*—, Operational profits of Generators—*Euros/year*—, Reliable production capacity—*MW*— and payment for "Obligation de Capacité"—*Euros/MW*—. The equations for their calculation are depicted in Appendix 5.

4.4.2. Outputs of "Obligation de Capacité" implemented in the NL-FR model

The model for the wholesale electricity market of the Netherlands and France was run for the four scenarios with and without capacity mechanism as described in Chapter 4.1. To run the model of NL-FR with "Obligation de Capacité" in France, the six steps earlier discussed were followed. For this, Excel 2010 was again used. The model of NL-FR without capacity mechanisms was simulated for the four scenarios to obtain a clear picture of the differences in the model outputs caused by the implementation of "Obligation de Capacité" in France. The results and implementation details of those simulations are portrayed in Appendix 5 and a summary of those results is depicted beneath.

Scenario	Capacity mechanism implemented in the model	Country	Average electricity price (Euros/Mwh)	Average demand (GW)	Total profits of electricity producers (million Euros/year)	Total reliable electricity production capacity (GW)	Payment given per capacity credit to recover costs (Euros/MW/year)
1	Yes	NL	47,85	13,7	€ (288)	23,7	€ -
		FR	7,88	64,0	€ -	119,1	€ 146.896
	No	NL	47,85	13,7	€ (288)	23,7	€ -
		FR	7,88	64,0	€ (15.813)	119,1	€ -
2	Yes	NL	48,29	15,5	€ (222)	23,7	€ -
		FR	14,31	75,6	€ -	125,0	€ 84.533
	No	NL	48,29	15,5	€ (222)	23,7	€ -
		FR	15,19	75,6	€ (9.528)	119,1	€ -
3	Yes	NL	99,41	20,0	€ 10.270	23,7	€ -
		FR	10,65	69,6	€ -	125,0	€ 118.236
	No	NL	99,41	20,0	€ 10.270	23,7	€ -
		FR	10,65	69,6	€ (13.460)	119,1	€ -
4	Yes	NL	294,67	20,0	€ 50.814	23,7	€ -
		FR	16,25	75,6	€ -	125,0	€ 70.861
	No	NL	101,61	20,0	€ 10.725	23,7	€ -
		FR	16,52	75,6	€ (8.275)	119,1	€ -

Table 7 Summary of the relevant outputs of the modeled wholesale markets of the Netherlands and France under the implementation of "Obligation de Capacité" in France[16]

From the table portrayed above, it is important to emphasize that the main differences between the system with and without capacity mechanisms are realized for the fourth scenario in which both countries are tight in production capacity. However, in most of the simulated cases the outputs of the model show differences only for France. Specially, the variable called "total profits of electricity producers", "total reliable electricity production capacity" and "payment given per capacity credit to recover costs".

4.4.3. Analysis of results: "Obligation de Capacité" implemented in the NL-FR model

The detailed results of the modeled "Obligation de Capacité" in France is portrayed in Appendix 5 are the basis for this analysis. These results differ for every modeled

[16] Negative numbers are depicted within brackets. Total profits of electricity producers refer to the profits made by producers due to the sale of electricity and the capacity mechanism.

scenario and therefore their analysis is performed per scenario by using the analytic framework discussed in Chapter 4.2.

Scenario 1:

Under this scenario, the model results indicate that the implementation of "Obligation de Capacité" in France does not affect the affordability of electricity in the Dutch system. This is because electricity prices in the Dutch wholesale market remain stable—*47.85 Euros/MWh on average*— as a consequence of the 107,649 MW covered by the capacity mechanism in France. As shown in Chapter 2, electricity production capacity in both countries is enough to cover their coincident peak demand—*even in case of complete isolation of the electricity systems*—.

The model outputs show that French consumers obtain a reliable service since the reliable production capacity is above the peak electricity consumption. In exchange, they pay for the reliable production capacity—*146,896 Euros/MW/year*—. This results in larger bills for French consumers, which yield to a deterioration in the affordability of the service.

The results of the model concerning total profits of electricity producers — *a loss of 287,714,046 Euros/year*— suggests that some Dutch generators are not dispatched frequently enough to recover their total costs of production. Additionally, the losses generated for the (peak) producers of the Dutch wholesale market might lead them—*If possible according to the law*—, as rational actors (Kirschen & Strbac, 2004), to offer their production capacity in France as they would benefit from the French capacity mechanism, which would generate profits. At the same time, though such actions of the producers, the reliability of the Dutch electricity system would be reduced in the short-term. When discussing these results, it should be kept in mind that the model is limited and aims to provide only a rough estimation of the short-term profits obtained on the basis of simple electricity trading between two countries; it would be, therefore, essential to conduct additional research on the long-term effects of this issue, incorporating the full integrated electricity market. *This effect holds for scenario 2 as well since in this scenario Dutch producers face negative profits.*

Scenario 2:

In this case, the model outputs insinuate that affordability of electricity in the Dutch wholesale market is not deteriorated for the implementation of "Obligation de Capacité" in France. This is explained by the stable electricity prices in the Netherlands—*47.29 Euros/MWh on average*— in the case of a French system with and without capacity mechanism.

In France, scarcity of electricity production calls for the construction of new power plants or availability of more production capacity, which is partly paid by "Obligation de Capacité". This results in an improvement of the reliability of the French system, which would obtain 5913 MW of additional electricity production capacity. Average electricity prices in France slightly decline as a consequence of the implementation of a capacity mechanism. However, French consumers would have to pay for the reliable production capacity in addition for the electricity purchased in the French wholesale market.

Scenario 3:

Under this scenario, the model outputs suggest that affordability of electricity in the Dutch wholesale market is not deteriorated for the implementation of "Obligation de Capacité" in France. This is because electricity prices in the Netherlands remain stable—*99.41 Euros/MWh on average*— in the case of a French system with and without capacity mechanism. The prices on the Dutch wholesale market can be considered high in contrast with scenario 1—*47.85 Euros/MWh on average*— and 2—*48.29 Euros/MWh on average*—. However, this price increase is not caused by the French capacity mechanism but by the scarcity of capacity production in the Dutch system.

High prices in the Dutch wholesale market suggest that Dutch generators get positive short-term profits—*10,270,116,045 Euros/year*— helping them to easily recover their total costs of production. Additionally, since electricity producers are rational actors, large profits would encourage electricity producers to offer all their power capacity in the Dutch wholesale market contributing to the reliability of the Dutch system in the short-term. However, no conclusions can be drawn about the long-term reliability and investments as the model is static and only provides estimation of the total profits of Dutch generators for a period of 1 year.

Scenario 4:

Under this scenario, the model outputs depict a lower affordability of electricity for Dutch consumers as a consequence of the capacity mechanism implemented in France. This is explained by the increase of prices in the Dutch wholesale market—*294.67 Euros/MWh on average in comparison with 101.61 Euros/MWh—,* which are paid by Dutch consumers in the electricity bill. High prices are explained due to France is not able to export electricity when its system is tight since the French system requires the all the reliable capacity paid by the "Obligation de Capacité". This is one of the implementation rules of the capacity mechanism in France, which aims to isolate the system to satisfy local consumption.

The model outputs also suggest that reliability of the Dutch electricity system would be improved as Dutch generators obtain larger profits—*50.8 million Euros/year in comparison with 10.7 million Euros/year—* as a result of the implementation of "Obligation de Capacité" in France. However, this result has to be analyzed in context since the increase in profits is caused by the high prices in the Dutch market and as it was earlier mentioned the withholding of capacity in France causes it. Therefore, this could result in more rolling blackouts in the Netherlands suggesting that the reliability of the Dutch system does not seem to be improved in the short-term.

Finally, as explained by De Vries et al. (2011), high electricity prices in one market encourages the imports from a market with lower electricity prices. Therefore, since electricity prices in the Netherlands—*294.67 Euros/MWh on average—* appear to be higher than in France—*16.25 Euros/MWh—, the* Netherlands would import excess production capacity from the French system. As a consequence, some of the electricity produced by French generators is purchased in the Netherlands and therefore is paid by Dutch consumers, contributing to the operational profits of generation units in France. This distributional effect, which is caused by the coupling and trade between the two markets seem to be more important under the implementation of a capacity mechanism in France. This is because the trade of excess electricity production from the French system—*electricity production capacity that is not required in periods of low* *electricity consumption in France—* would reduce the payment for "Obligation de Capacité" given to French generators to recover their total costs of production without improving the reliability of the Dutch electricity system in the short-term. However, since the model is based on the assumption isolating the French system under stress conditions— as it suggest its implementation described in Chapter 2— and it might change in the final implementation of the "Obligation de Capacité", the effect earlier discussed should be reviewed once a the final implementation details are available.

4.5. Effects of the "Capacity Market" to be implemented in United Kingdom on the Dutch wholesale market

As it was analyzed in Chapter 2, United Kingdom considering the implementation of a capacity mechanism called "capacity market" that fits in the theoretical description of reliability contracts. This capacity mechanism is added to the original model of the wholesale markets of United Kingdom and the Netherlands built in Chapter 3. The implementation of "capacity market" in the model on Dutch wholesale electricity market was conducted following the steps described below.

4.5.1. Addition of strategic reserves to the current model NL-UK

1. Set a volume of electricity production to be contracted "Capacity Market". An independent agent such as the TSO or the regulator usually determines these electricity production volumes. To simulate the implementation of "Capacity Market" in this model, it was assumed that all power producers would be able to sign reliability contracts since they will get an additional fixed payment in return.
2. Set the strike price of the contract between electricity producers and the TSO. As explained in section two, this is the maximum price generators would get in the end for selling electricity in the wholesale market of United Kingdom. For the purpose of this study, the strike price was set in 570 Euros/MWh—*500 British pounds*—, which was taken from the cost benefit analysis of the capacity mechanisms performed by DECC (2011) in United Kingdom.
3. Define the procedure to run the electricity production units, which participate in the "capacity market" by signing reliability contracts with the TSO of UK. In

this model, power plants are dispatched as usual in the wholesale market. However, if the market price goes above the strike price, then electricity producers who signed reliability contracts would reimburse the difference between market and strike price times the capacity to the TSO and finally to the consumers.

4. Set the price at which the production units paid by "capacity markets" are dispatched in the wholesale market of United Kingdom. In this model, power plants offer their electricity at the marginal cost of production since they are paid extra for the reliable volumes of electricity made available to the wholesale market of the United Kingdom. Therefore, they will recover their total costs of electricity production.
5. Clear the interconnected markets and calculate the operational profits also called producer surplus per hour and total per year for Dutch and British producers. In this model, the operational profits per hour consist of the difference between the market price— *or strike price in the case market price is above the strike price— and* marginal cost of production times the power sold in the market. Similarly, the total operational profits consist of the sum of the operational profits per hour times the hours of a year.
6. Calculate total profits of electricity producers in the Dutch and British wholesale market and the level of the payment given to the British units as a result of their participation in the "Capacity Market". In this model, such level of payment is calculated as absolute value of the difference between producer surplus and total costs of production over the volume of capacity contracted in the "capacity market"—*In case producer surplus is bigger than total cost of production, the level of payment given per MW contracted is zero due to the fact producers are recovering their total costs of production and therefore they do not need additional payments*—. The output of this step is a level of payment in Euros/MW/year.
7. Repeat the previous steps for every scenario

By following the seven steps aforementioned, the model produced main outputs such as electricity prices—*Euros/MWh*—, real electricity prices paid by consumers—*Euros/MWh*— operational profits of Generators—*Euros/year*—, reliable production capacity—*MW*— and payment given to generators due to capacity market—*Euros/MW*—. The equations for their calculation are depicted in Appendix 6.

4.5.2. Outputs of capacity markets implemented in the NL-UK model

The model for the wholesale electricity market of the Netherlands and United Kingdom was run for the four scenarios with and without capacity mechanism as described in Chapter 4.1. To run the model of NL-UK with "capacity markets" in United Kingdom, the seven steps earlier discussed were followed. For this, Excel 2010 was again used. The model of NL-UK without capacity mechanisms was simulated for the four scenarios to obtain a clear picture of the differences in the model outputs caused by the implementation of "capacity markets" in United Kingdom. The results and implementation details of those simulations are portrayed in Appendix 6 and a summary of those results is depicted beneath.

Scenario	Capacity mechanism implemented in the model	Country	Average electricity price (Euros/Mwh)	Average real price paid by consumers (Euro/MWh)	Average demand (GW)	Total profits of electricity producers (Million Euros/year)	Total reliable electricity production capacity (GW)	Payment given to generators due to " capacity market" (Euros/MW/year)
1	Yes	NL	47,94	47,94	13,7	€ (274)	23,7	€ -
		UK	26,92	26,92	41,1	€ -	84,8	€ 49.895
	No	NL	47,94	47,94	13,7	€ (274)	23,7	€ -
		UK	26,92	26,92	41,1	€ (4.454)	84,8	€ -
2	Yes	NL	48,81	48,81	15,5	€ (146)	23,7	€ -
		UK	104,12	41,64	60,7	€ 3.338	84,8	€ -
	No	NL	48,81	48,81	15,5	€ (146)	23,7	€ -
		UK	104,12	104,12	60,7	€ 49.752	84,8	€ -
3	Yes	NL	99,30	99,30	18,9	€ 10.248	23,7	€ -
		UK	30,38	30,38	44,6	€ -	84,8	€ 34.574
	No	NL	99,30	99,30	18,9	€ 10.248	23,7	€ -
		UK	30,38	30,38	44,6	€ (3.086)	84,8	€ -
4	Yes	NL	295,55	295,55	19,4	€ 50.998	23,7	€ -
		UK	104,12	41,64	60,7	€ 3.338	84,8	€ -
	No	NL	295,55	295,55	19,4	€ 50.998	23,7	€ -
		UK	104,12	104,12	60,7	€ 49.752	84,8	€ -

Table 8 Summary of the relevant outputs of the modeled wholesale markets of the Netherlands and United Kingdom under the implementation of "capacity markets" in United Kingdom[17]

From the table portrayed above, it is important to emphasize that the main differences between the system with and without capacity mechanisms are realized for the second and fourth scenario in which United Kingdom is tight in production capacity. However,

[17] Negative numbers are depicted within brackets. Total profits of electricity producers refer to the profits made by producers due to the sale of electricity and the capacity mechanism.

in all of the simulated cases the outputs of the model show differences only for United Kingdom. Specially, the variables called "average real price paid by consumers", "total real producer surplus", "total profits of electricity producers" and "payment given to generators due to capacity markets".

4.5.3. Analysis of results: capacity markets implemented in the NL-UK model

The detailed results of the modeled "capacity market" in United Kingdom is portrayed in Appendix 6 are the basis for this analysis. These results differ for every modeled scenario and therefore their analysis is performed per scenario by using the analytic framework discussed in Chapter 4.2.

Scenario 1:

Under this scenario, the model results suggest that the implementation of "capacity market" in United Kingdom does not affect the affordability of electricity in the Dutch system. This is because electricity prices in the Dutch wholesale market remain stable—*47.98 Euros/MWh on average*— despite the 84,904 MW contracted trough the "capacity market" in the UK. This electricity prices would not affect the electricity bills of Dutch consumers since they only pay for electricity and not for capacity, as it is the case in the UK.

The model outputs indicate that reliability of electricity improves in United Kingdom in the short term since generators do not lose money—*0 Euros/year of profits*—in comparison with the scenario without the implementation of "capacity markets". This is consistent with the results of De Vries and Heijnen in which a capacity mechanism based in reliability contracts improves the reliability of the electricity system where it has been implemented.

Finally, the results of the model concerning total profits of electricity producers — *a loss of 274,081,429 Euros/year*— suggests that some Dutch generators are not dispatched frequently enough to recover their total costs of production. Moreover, the losses generated for the (peak) producers of the Dutch wholesale market might lead them—*If possible according to the law*—, as rational actors (Kirschen & Strbac, 2004), to offer their production capacity in the "capacity market" of the UK, as they would profit from the additional payment for capacity. At the same time, though such actions of the producers, the reliability of the Dutch electricity system would be reduced in the short-term but it would be limited by the relatively low cross-border capacity—*1000 MW that compared with the capacity of the links between the Netherlands and Germany and Netherlands and Belgium-France*— of the link between the Netherlands and United Kingdom. When discussing these results, one should be bear in mind that the model is limited and aims to provide only a rough estimation of the short-term profits obtained on the basis of simple electricity trading between two countries; it would be, therefore, essential to conduct additional research on the long-term effects of this issue, incorporating the full integrated electricity market. *This effect holds for scenario 2 as well since in this scenario Dutch producers face negative profits*.

Scenario 2:

Under this scenario, the model results suggest that the implementation of "capacity market" in United Kingdom does not affect the affordability of electricity in the Dutch system. This is because electricity prices in the Dutch wholesale market remain stable—*48.81 Euros/MWh on average*— despite the 84,904 MW contracted trough the "capacity market" in the UK. This can be explained by the fact that the "capacity market" implemented in the model is based on the theoretical description of reliability contracts. Since it is a financial instrument, it does not affect price formation in the wholesale market only the internal price paid by consumers (Vásquez, Rivier, & Pérez Arriaga, 2002).

The model results indicate that scarcity of electricity production in the British wholesale electricity market results in high electricity prices—*104.12 Euros/MWh on average*—. However, those prices do not deteriorate the affordability of electricity for British consumers since they pay a lower real price—*41.64 Euros/MWh on average*— as a consequence of the capacity mechanism implemented. This is because the "capacity market" sets a financial price cap in the British wholesale electricity market that limits the electricity prices paid by consumers to go above 500 Pounds/ MWh— *As earlier explained in Chapter 2 producers participating in the "capacity market", which signed reliability contracts must return to the TSO the difference between the market price and the strike price times the volumes of electricity defined in the reliability* *contracts—*. One should keep in mind that the difference between the electricity price in the British wholesale market and real price paid by British consumers depicted in this study is a rough estimation and its magnitude would strongly rely on the specific rules of implementation, and especially on the strike price.

Scenario 3:

Under this scenario, the model results suggest that the implementation of "capacity market" in United Kingdom does not affect the affordability of electricity in the Dutch system. This is because electricity prices in the Dutch wholesale market remain stable—*99.3 Euros/MWh on average*— despite the 84,904 MW contracted trough the "capacity market" in the UK. Electricity prices are higher In the Dutch wholesale market; nevertheless, it is caused by scarcity of electricity production in the Netherlands under this scenario rather than by the "capacity market" implemented in United Kingdom.

High prices in the Dutch wholesale market suggest that Dutch generators get positive short-term profits—*10,2 million Euros/year*— helping them to easily recover their total costs of production. Additionally, since electricity producers are rational actors, large profits would encourage electricity producers to offer all their power capacity in the Dutch wholesale market contributing to the reliability of the Dutch system in the short-term. However, no conclusions can be drawn about the long-term reliability and investments as the model is static and only provides estimation of the total profits of Dutch generators for a period of 1 year—*This analysis holds for scenario 4* as well—.

Scenario 4:

As in all previous scenarios, the model suggests that the implementation of "capacity market" in United Kingdom does not affect the affordability of electricity in the Dutch system. This is because electricity prices in the Dutch wholesale market remain stable—*295.55 Euros/MWh on average*— despite the 84,904 MW contracted trough the "capacity market" in the UK. Electricity prices are higher In the Dutch wholesale market; however, it is caused by scarcity of electricity production in the Netherlands under this scenario rather than by the "capacity market" implemented in United Kingdom.

The model results indicate that scarcity of electricity production in the Netherlands and the British wholesale electricity market results in high electricity prices for the UK—*104.12 Euros/MWh on average*—. However, those prices do not deteriorate the affordability of electricity for British consumers since they pay a lower real price—*41.64 Euros/MWh on average*— as a consequence of the capacity mechanism implemented. This is because the "capacity market" sets a financial price cap in the British wholesale electricity market that limits the electricity prices paid by consumers to go above 500 Pounds/ MWh— *As earlier explained in Chapter 2 producers participating in the "capacity market", which signed reliability contracts must return to the TSO the difference between the market price and the strike price times the volumes of electricity defined in the reliability contracts*—. One should keep in mind that the difference between the electricity price in the British wholesale market and real price paid by British consumers depicted in this study is a rough estimation and its magnitude would strongly rely on the specific rules of implementation, and especially on the strike price.

4.6. Effects of the operating reserves mechanism "RKOM" on the Dutch wholesale market

As it was analyzed in Chapter 2, Norway implemented a capacity mechanism called "RKOM" that fits in the theoretical description of operating reserves. This capacity mechanism is added to the original model of the wholesale markets of Norway and the Netherlands built in Chapter 3. The implementation of operating reserves in the model on Dutch wholesale electricity market was conducted following the steps described below.

4.6.1. Addition of strategic reserves to the current model NL-NO

1. Set a volume of capacity to be considered as operating reserve. This capacity is determined by Norwegian TSO—*Statnett*— in a regulating options market called RKOM. For the purpose of this research, operating reserves account for 10% of the peak demand in Norway. However, in the real system it fluctuates according to the balancing power needed in the Norwegian electricity system.

2. Define the procedure to run the operating reserve in the Norwegian wholesale electricity market. From the theory, operating reserve is procured in a secondary market or balancing market and it is only dispatched when there are imbalances of voltage or frequency in the electricity system. For the purpose of this model, strategic reserves are run if there is a lack of electricity production capacity in the wholesale market.
3. Set the price at which the operating reserve is dispatched in the Norwegian wholesale market. For this analysis, the running price of operating reserve has been defined according to the operating reserve pricing theory and the practices in Scandinavia. Therefore, they are dispatched at the marginal cost of production.
4. Clear the interconnected markets and calculate the operational profits also called producer surplus per hour and total per year for Dutch and Norwegian producers. In this model, generators selling electricity in the wholesale market get operational profits per hour, which consist of the difference between the market price and marginal cost of production times the power sold in the market. Similarly, the total operational profits consist of the sum of the operational profits per hour times the hours of a year.
5. Calculate total profits of electricity producers in the Dutch and Norwegian wholesale market and the level of the payment given to the contracted operating reserve for being available to the Norwegian system. In this model, the level of payment given to the operating reserve units—*Which in the real system comes from the interaction of operating reserve producers in the RKOM*— is calculated as the operational profits of the reserve units minus the total cost of production over the capacity contracted as operating reserves. This results in a payment per MW to be paid per year to the contracted reserve generators.
6. Repeat the previous steps for every scenario

By following the six steps aforementioned, the model produced main outputs such as electricity prices—*Euros/MWh*—, operational profits of Generators—*Euros/year*—, reliable production capacity—*MW*— and payment given to operating reserve generators—*Euros/MW*—. The equations for their calculation are depicted in Appendix 7.

4.6.2. Outputs of operating reserves in the NL-NO model

The model for the wholesale electricity market of the Netherlands and Norway was run for the four scenarios with and without capacity mechanism as described in Chapter 4.1. To run the model of NL-NO with operating reserves in Norway, the six steps earlier discussed were followed. For this, Excel 2010 was again used. The model of NL-NO without capacity mechanisms was simulated for the four scenarios to obtain a clear picture of the differences in the model outputs caused by the implementation of operating reserves in Norway. The results and implementation details of those simulations are portrayed in Appendix 7 and a summary of those results is depicted beneath.

Scenario	Capacity mechanism implemented in the model	Country	Average electricity price (Euros/Mwh)	Average demand (GW)	Operational reserves contracted (MW)	Total profits of electricity producers (million Euros/year)	Total reliable electricity production capacity (GW)	Payment given to operating reserve generators (Euros/MW /year)
1	Yes	NL	47,94	13,7	-	€ (274)	23,7	-
		NO	3,79	15,8	2.189	€ (3.104)	24,1	135.263
	No	NL	47,94	13,7	-	€ (274)	23,7	-
		NO	3,79	15,8	-	€ (3.400)	24,1	-
2	Yes	NL	49,00	15,5	-	€ (118)	23,7	-
		NO	50,56	17,9	900	€ 6.140	24,1	63.418
	No	NL	49,00	15,5	-	€ (118)	23,7	-
		NO	50,56	17,9	-	€ 6.390	24,1	-
3	Yes	NL	99,30	18,6	-	€ 10.248	23,7	-
		NO	3,79	16,4	1.271	€ (3.195)	24,1	155.779
	No	NL	99,30	18,6	-	€ 10.248	23,7	-
		NO	6,18	16,4	-	€ (2.915)	24,1	-
4	Yes	NL	89,15	18,1	-	€ 8.163	23,7	-
		NO	46,17	17,6	900	€ 5.249	24,1	63.418
	No	NL	89,15	18,1	-	€ 8.163	23,7	-
		NO	50,47	17,6	-	€ 6.374	24,1	-

Table 9 Summary of the relevant outputs of the modeled wholesale markets of the Netherlands and Norway under the implementation of operating reserves in Norway[18]

From the table portrayed above, it is important to emphasize that the main differences between the system with and without capacity mechanisms are realized for the third and fourth scenario in which Netherlands and Norway are tight in production capacity. However, in all of the simulated cases the outputs of the model show differences only

[18] Negative numbers are depicted within brackets. Total profits of electricity producers refer to the profits made by producers due to the sale of electricity and the capacity mechanism.

for Norway. Specially, the variables called "operational reserves contracted", "total profits of electricity producers" and "payment given to operating reserve generators".

4.6.3. Analysis of results: operating reserves implemented in the NL-NO model:

The detailed results of the modeled operating reserves in Norway portrayed in Appendix 7 are the basis for this analysis. These results differ for every modeled scenario and therefore their analysis is performed per scenario by using the analytic framework discussed in Chapter 4.2.

Scenario 1:

Under this scenario, the model results indicate that the implementation of operating reserves in Norway does not affect the affordability and reliability of electricity in the Dutch system. This is because electricity prices in the Dutch wholesale market remain stable—*47.94 Euros/MWh on average*— despite the 2189 MW contracted as operating reserves in Norway. The results suggest that the usual trading dynamic between the two wholesale markets is kept. Therefore, Netherlands imports electricity volumes from Norway due to the lower electricity prices in this country resulting from the large hydro resources employed for electricity production. The electricity trading is limited by the relatively low cross-border capacity linking the Netherlands and Norway.

Finally, the model outputs shows that reliability of electricity improves in Norway in the short term since generators lose less money—*losses of 3.1 million Euros/year in comparison with 3.4 million Euros/year*— in comparison with the scenario without the implementation of operating reserves. This is consistent with the results of De Vries and Heijnen in which a capacity mechanism based in operating reserves significantly improves the reliability of the electricity system where it has been implemented. However, one should bear in mind that the difference between total profits with and without capacity mechanism are simple estimations based on trade between two countries.

Scenario 2:

Under this scenario, the model results indicate that the implementation of operating reserves in Norway does not affect the affordability and reliability of electricity in the Dutch system. This is because electricity prices in the Dutch wholesale market remain stable—*49 Euros/MWh on average*— despite the 900 MW contracted as operating reserves in Norway.

The model suggests that high prices in Norway—*50.56 Euros/MWh on average*— shifts the current electricity trading dynamics between the two countries, which consist of Netherlands importing electricity from Norway. In this case, the Dutch wholesale market could provide the volumes of electricity required by Norway under tight production capacity. This can be explained by the fact that the Dutch system counts with reliable excess of electricity production capacity such as gas powered units.

Scenario 3:

As in the previous scenarios, the model results show that the implementation of operating reserves in Norway does not affect the affordability and reliability of electricity in the Dutch system. This is because electricity prices in the Dutch wholesale market remain stable—*99.3 Euros/MWh on average*— despite the 1271 MW contracted as operating reserves in Norway. The high price of electricity in the Dutch wholesale market is caused by tight production capacity in this scenario and not by the implementation of operating reserves in Norway. High prices allow Dutch electricity producers to earn enough profits—*10.2 million Euros/year*— to easily recover their cost of electricity production in the short-term. Therefore, since generators are rational actors aiming to optimize their profits, they would offer as much production capacity as possible to earn more profits and consequently contribute to improve the reliability of the Dutch system in the short-term. The long-term effects on reliability and consequently investments in new power plants cannot be analyzed with the outputs of this model as it is static in nature and its outputs are estimations that do not aim to forecast specific variables.

Finally, the model outputs suggest that the affordability of the Norwegian electricity system is improved as a result of the 1271 MW contracted as operating reserves this country. This is because as the operational reserve units are dispatched, electricity prices decrease from 6.18 Euros/MWh to 3.79 Euros/MWh in the Norwegian electricity system. However, the Norwegian consumers have to pay for the reliable production capacity—*155,779 Euros/MW/year on average*— procured in the balancing market as operating reserves.

Scenario 4:

As in the previous scenarios, the model results show that the implementation of operating reserves in Norway does not affect the affordability and reliability of electricity in the Dutch system. This is because electricity prices in the Dutch wholesale market remain stable—*89.15 Euros/MWh on average*— despite the 900 MW contracted as operating reserves in Norway. The high price of electricity in the Dutch wholesale market is caused by tight production capacity in this scenario and not by the implementation of operating reserves in Norway. High prices allow Dutch electricity producers to earn enough profits—*8.1 million Euros/year in total in the system*— to easily recover their cost of electricity production in the short-term. Therefore, since generators are rational actors aiming to optimize their profits, they would offer as much production capacity as possible to earn more profits. Consequently their actions contribute to improve the reliability of the Dutch system in the short-term. The long-term effects on reliability and consequently investments in new power plants cannot be analyzed with the outputs of this model as it is static in nature and its outputs are estimations that do not aim to forecast specific variables.

Finally, since the electricity prices in the Dutch wholesale market are higher on average than in Norway, as explained earlier, the last country would be encouraged to sell large volumes of electricity production. If possible due to the rules of the RKOM market, electricity exported to the Netherlands would come from operating reserve units contracted in Norway. This electricity purchases would contribute to increase the reliability of the Dutch system in the short-term. However, this improvement would be limited by the existent cross-border capacity between the Netherlands and Norway and additional attention should be paid to the impacts under simultaneous trading between the Netherlands and all its interconnected neighbors.

4.7. Conclusions of Chapter 4

Through this chapter the procedures used to add capacity mechanisms in the modeled wholesale electricity markets of NWE was explained. More precisely, strategic reserve was added to the modeled wholesale market of Netherlands and Germany; “Obligation de Capacité” or capacity requirements was implemented in the modeled wholesale market of the Netherlands and France; “capacity markets” in the form of reliability options was studied for the modeled wholesale market of the Netherlands and United Kingdom; lastly, a theoretical approach to operating reserves was researched for the modeled wholesale market of the Netherlands and Norway. To modify the original models and add the capacity mechanisms, six and in one case seven sequential steps were followed. Three of them focused on setting the procedure and parameters to dispatch generation units covered by the capacity mechanism such as volumes of electricity production and its price. The remaining steps concentrated on procedure to measure relevant outputs from the model such as wholesale electricity prices, producer surplus, total generator profits and payments due to capacity mechanism.

On the other hand, the four models composed by NL-DE, NL-FR, NL-UK and NL-NO were run according to four exploratory scenarios with and without the implementation of capacity mechanisms. Those scenarios, aimed to explore plausible futures in which electricity scarcity could occur and its combinations. Therefore, since capacity mechanisms in theory are mostly activated under scarcity situations or high electricity prices, the main effects on prices, demand and producer surplus on the Dutch wholesale market should be realized.

From the quantitative outputs of the simulations and the analytical framework designed in Chapter 4.2, the effects of capacity mechanisms implemented in neighboring countries on the Dutch wholesale electricity market were indentified and analyzed. These main effects, core of this research study, are summarized in the table depicted below. One should bear in mind when analyzing these effects that the outputs of the model are valid to conduct an exploratory analysis on a policy level. This means that it does not attempt to provide accurate quantitative measures of the cross-border effects of capacity mechanisms but the direction of the change, positive or negative regarding the variables used to measure reliability and affordability of electricity in the Dutch electricity system.

The table portrayed below is organized by the capacity mechanism, country where it has been implemented and direction of change in model outputs caused by the implementation of a capacity mechanism in a country linked to the Netherlands The symbol > means an increase in the measured variable; the symbol < means an increase in the measured variable and the symbol = no changes in the measured variable.

Table 10 Summary of the main effects capacity mechanisms might cause on the Dutch wholesale electricity market

Capacity mechanism	**Model**	**Scenario**	**Affordability**									**Reliability**					
			Electricity prices			**Payment due to capacity mechanism**			**Distributional effects**			**Total profits**			**Availability of production capacity**		
			>	<	=	>	<	=	>	<	=	>	<	=	>	<	=
Strategic reserves	NL-DE	1			NL; DE	DE		NL			NL; DE			NL; DE	DE		NL*
		2			NL; DE			NL; DE			NL; DE	DE		NL	DE		NL*
		3			NL; DE	DE		NL			NL; DE			NL; DE	DE		NL
		4		**NL; DE**				**NL; DE**			**NL; DE**		**NL; DE**		**DE**		**NL**
Obligation de Capacité	NL-FR	1			NL; FR	FR		NL			NL; FR	FR		NL			NL*;FR
		2		FR	NL	FR		NL			NL; FR	FR		NL	FR		NL*
		3			NL; FR	FR		NL			NL; FR	FR		NL	FR		NL
		4	**NL**	**FR**		**FR**		**NL**	**NL**	**FR**		**NL; FR**			**FR**		**NL**
Capacity markets in the form of reliability options	NL-UK	1			NL;UK	UK					NL;UK	UK		NL			NL;UK
		2		UK	NL			NL;UK			NL;UK		UK	NL			NL;UK
		3			NL;UK	UK					NL;UK	UK		NL			NL;UK
		4		UK	NL			NL;UK			NL;UK		UK	NL			NL;UK
Operating reserve	NL-NO	1			NL;NO	NO		NL			NL;NO	NO		NL			NL;NO
		2			NL;NO	NO		NL			NL;NO	NO		NL			NL;NO
		3		NO	NL	NO		NL			NL;NO		NO	NL			NL;NO
		4		NO	NL	NO		NL			NL;NO		NO	NL			NL;NO

It is relevant to highly from the analysis performed in this chapter that capacity mechanisms perform well in the electricity systems where they have been implemented. This is because these mechanisms contribute to improve the reliability of the systems by adding more reliable production capacity and also help to reduce electricity prices caused by production scarcity while providing positive profits to power producers. In contrast, cross-border effects of capacity mechanisms in the Dutch electricity markets differ with the sort of capacity mechanism implemented and its specific implementation rules.

Finally, the main distortions on the Dutch wholesale market are caused by the capacity mechanism implemented in Germany and to be implemented in France under a scenario of production scarcity in the Netherlands and the aforementioned countries. The case of Germany yields to positive effects in the affordability of electricity in the Netherlands as the implementation of strategic reserves in this country reduce electricity prices in the Dutch electricity market under scarcity conditions. In contrast, the case of France produces negative effects on the affordability of electricity in the Dutch market since electricity prices in the Netherlands increases substantially under scarcity of production in both countries—*Here it is relevant to bear in mind that this negative effect is mostly caused by the withholding of production capacity in France under scarcity conditions. This would change if isolation of the French system is not included in the implementation details of the last version of the French capacity mechanism*—.

5. Policy options to reduce potential undesirable effects on the Dutch wholesale electricity market by the capacity mechanisms implemented in neighboring NWE countries

On Chapter 4, the main effects of capacity mechanisms implemented in NWE on the Dutch electricity market were analyzed. Based on the earlier mentioned analysis, this chapter aims to give answer to the following research sub-questions:

- *What policy options are available for the Netherlands to cope with the effects of capacity mechanisms implemented in NWE on the Dutch electricity market?*
- *What are the effects of the available generation adequacy policy options on the Dutch electricity market?*

For this purpose, a description of the policy goals of the electricity sector in the Netherlands is provided. It is followed by the analysis of the policy alternatives. Finally, the chapter is concluded with a policy recommendation.

5.1. Policy goals driving the Dutch electricity sector

The restructuring of the electricity sector started at the European level. More precisely, the European Commission launched the European directive of 1996, which focused on the liberalization of the electricity industry in Europe. As a result, the Dutch government, following the European directive, released the electricity act in 1998, which defined the rules and considerations to be followed by the actors participating in the electricity system. Throughout the electricity act, the Netherlands managed to bring competition to the wholesale electricity market without giving too much power to a single generation company. Furthermore, competition has been encouraged due to the imports of electricity from neighboring countries, which has led to a concentration ratio—*CR(1)*[19]— of 28,88% (Kupper, et al., 2008). This level of competition is good in comparison with other countries in NWE, such as France and Belgium. The Dutch electricity sector is also characterized by a tendency to invest in electricity production capacity.

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[19] The concentration ration CR(1) gives the sum of the market shares of the largest electricity generation company in the electricity market

The Dutch electricity regulator is in charge of monitoring and controlling the efficient functioning of the Dutch wholesale market according to the principles of no discrimination, transparency and efficiency defined in the Dutch electricity act. Furthermore, In order to assess the performance of the electricity markets, they base the analysis on the traditional policy goals for public goods (De Vries et al 2011). According to experts of the Netherlands Competition Authority the general goals for the performance of the electricity industry can be summarized as follows:

- Reliability: Refers to the ability of the system to provide enough production capacity in the electricity system
- Affordability: Refers to the fairness of the electricity prices paid by the consumers
- Sustainability or environmental responsibility: Refers to the impact caused by the electricity system to the environment

The Dutch regulator constantly works towards a more efficient Dutch electricity market, based on the policy goals described above. This is a challenging task, as tradeoffs can be proven inevitable between policy goals (De Vries et al 2011). For instance, high levels of reliability can be costly and may result in higher electricity bills that are being paid by consumers. In this study, reliability and affordability are considered as the main policy goals. The environmental responsibility is only mentioned, but not further taken into account, since the focus of the study is on the performance of the wholesale market and not of the electricity system as a whole.

5.2. Possible policy alternatives to be implemented in the Netherlands

Once the policy objectives were identified and carefully analyzed, it is possible to design policy alternatives to deal with the undesirable effects of capacity mechanism depicted in Chapter 4. Furthermore, since it is difficult to measure directly reliability and affordability of electricity in a wholesale market, additional criteria were set in order to relate measurable factors with the targeted electricity policy goals. These criteria are based on the analytical framework designed in Chapter 4 to analyze the effects of capacity mechanism implemented in NWE on the Dutch wholesale market. This has been decided to keep the consistency of the study by measuring the effect of the aforementioned capacity mechanism and policy goals with very similar criteria. The specific criteria used to assess policy alternatives have been listed below.

→ Specific criteria for reliability:

- Producer profits: This criterion relates to the ability of Dutch generators to recover total costs of electricity production. According to Kirshen and Strabac (2004), generator's profits drive the amount of total capacity available in the electricity system, which consequently results in a more reliable electricity service. Since power generators are rational investors they will finance a production facility if they believe that the new power plant will make a satisfactory profit over its lifetime. To decide on such an investment, the power generator computes the long run marginal cost of the plant and forecasts the price at which the output of this plant might be sold. This is an important criteria as one of the effects of capacity mechanisms on the Dutch wholesale market identified in this study relates to distortions in the profits earned by Dutch generators
- Reliable capacity production: This criterion refers to the ability of the Dutch wholesale market to sustain or make available reasonable levels of electricity production for the Dutch electricity system. The total reliable capacity is directly related to the reliability of an electricity system. More production capacity offered in the wholesale market makes the system more reliable, as it is prepared to satisfy higher demand of electricity and avoid rolling blackouts. As it was analyzed in chapter 4, more stable sources of income in neighboring countries might reduce the availability of electricity production in the Dutch wholesale market in the short-term

→ Specific criteria for affordability:

- Electricity prices paid by Dutch consumers: This criterion concerns with the fairness of the electricity prices paid by Dutch consumers in the Dutch wholesale market. Wholesale electricity prices are used as a proxy variable to assess the affordability of electricity under the following reasoning. Electricity bills paid by consumers consist of a number of charges, one of which is the price at which electricity is bought in the wholesale market. As a result, higher wholesale electricity prices lead to higher electricity bills, which result in a less affordable electricity service. Furthermore, high prices are unacceptable because they force vulnerable consumers to cut back on their consumption of electrical energy used for essential purposes (Kirshen and Strabac 2004). This criterion is particularly important since very high electricity prices in the Dutch wholesale market caused by capacity mechanisms— *For instance the capacity mechanism in to be implemented in France could raise electricity prices in the Netherlands*—would not be socially acceptable.

- Transfer of money from the Netherlands to neighboring countries with capacity mechanism: This criterion refers to the transfer of money from Dutch consumers to neighboring power generators, which as a result enhance their operational profits but do not contribute with exports of production capacity to the Dutch wholesale market in periods of production scarcity in the Netherlands.

On the other hand, three alternatives emerged from a process of brainstorming. This methodology was employed since no theoretical evidence of cross-border effects of capacity mechanisms was found in the neither literature nor possible solution to cope with them. The brainstorming process began with a list of all the possible policy alternatives the analyst could think about. This list consists of the five policy alternatives depicted below:

- Do nothing
- Isolate the Dutch electricity system
- Increase the cross-border capacity between the Netherlands and other countries in NWE
- European capacity mechanism
- Dutch capacity mechanism

The list depicted above was reduced to 3 policy alternatives, which comprises "do nothing", "European capacity mechanism", "Dutch capacity mechanism". The other two alternatives were not considering for the policy assessment for the following reasons. Isolate the Dutch electricity system does not seem plausible since the European directives attempt to integrate the electricity markets of Europe. Moreover, it would be an extreme and unnecessary response from the Netherlands to the implementation of capacity mechanism since it has a large transmission infrastructure interconnecting its system with other countries of NWE. In crease the cross-border capacity between the Netherlands and other countries in NWE would be a solution which effects are not clear regarding the implementation of capacity mechanism. Therefore, those effects could not be analyzed in this study because it is out of the scope of the model used.

The main purpose of the proposed policy alternatives is to cope with the undesirable cross-border effects of capacity mechanism. For this reason, special attention has been paid to the undesirable effects of the French capacity mechanism. As it was explained in Chapter 4, the implementation of "Obligation de Capacité" in France could have the highest impact on reliability and affordability of electricity in the Netherlands. The remaining 3 policy alternatives resulting from the initial selection process are explained below.

- **Do nothing:** this alternative is the base case where the Dutch regulator is advised to keep the current situation. In case the effects of the capacity mechanism do not show a relevant impact on the above-defined criteria, then doing nothing could be considered as a less costly, and easily implemented policy.
- **European capacity mechanism:** This alternative consists of negotiating with all regulators in Europe in order to implement a coordinated capacity mechanism at the European level—*with the help of ACER*—. The joint efforts would attempt to optimize the total reliable excess capacity in the European system as a whole. This would contribute to ensure that coincident peak demand of electricity in the European wholesale markets is satisfied. Additionally, this option would be in line with the European vision of a integrated European electricity market.
- **Dutch capacity mechanism:** This alternative attempts to reduce the negative effects of capacity mechanism by implementing a capacity mechanism in the Netherlands. The idea behind this option is to implement a capacity mechanism in the Netherlands to hedge the Dutch system against coincident scarcity of production capacity in NWE.

5.3. Assessment of the policy options

The assessment of the policy alternatives aforementioned is based on a qualitative analysis of the 2 criteria concerning with reliability and the 2 criteria related to affordability. This is because a quantitative assessment of policy options is not a trivial issue in this case and would require important changes in the model used in this study.

The qualitative analysis of the policy alternatives attempts to combine the neoclassical economic theory applied to electricity systems provided by Kirshen and Strabac (2004) with logical arguments based on the understanding of the modeled capacity mechanisms. The results of the assessment of the 3 aforementioned policy options is summarized in a matrix of colors depicted below and described in appendix 8. In such matrix the colors have the following meaning:

- Green= Very good
- Yellow= Good
- Orange= Fair
- Red= Bad

Table 11 Assessment of the policy options that can be implemented in the Netherlands to reduce the impact of capacity mechanisms to be implemented in neighboring countries of NWE.

Policy goal	Specific criteria	Policy alternatives		
		Do nothing	European capacity mechanism	Dutch capacity mechanism
Reliability	Producer operational profits			
	Excess of reliable capacity production			
Affordability	Electricity prices paid by Dutch consumers			
	Transfer of money to neighboring countries with capacity mechanism			

5.4. Policy recommendation

The policy alternatives above discussed can be considered as a first attempt to deal with the lower affordability and to some extent low reliability of electricity in the Dutch system caused by the implementation of capacity mechanisms in NWE. The results must be analyzed carefully since they do not come from a quantitative analysis of the modeled wholesale markets. They need to be considered as a set of plausible and reasonable options, which would help to start a discussion about generation adequacy policies in the Netherlands.

The results of the policy alternative's assessment suggest that implementing a European capacity mechanism would reduce substantially most of the undesirable cross-border effects of capacity mechanisms implemented in NWE on the Dutch wholesale market. Mostly those effects caused by the implementation of "Obligation de Capacité" in France. However, it might be difficult to implement this policy option in the short term due to the individual efforts to guarantee security of supply followed by France and UK. This lack of coordination might be solved in the future through ACER, which would provide the policy context to implement this alternative.

Similarly, the results of the policy alternative's assessment shows that the implementing a Dutch capacity mechanism would be useful in the short term to deal with the undesirable effects of capacity mechanisms implemented in neighboring countries on the Dutch wholesale market. Despite the qualitative policy assessment suggests that this alternative would not perform as good as the European capacity mechanism, it might still be useful to improve the reliability of the Dutch system by adding more production capacity in the short-term. However, this alternative would require a deeper analysis as the selection of a specific capacity mechanism is not a trivial issue. Furthermore, when analyzing this option it is relevant to keep in mind that most of the undesirable cross-border effects of capacity mechanisms occur in the case of production scarcity in both countries. This scenario is not very likely, at least for the Netherlands, as the demand should grow at a much higher rate than the rate forecasted by ENTSO-E—*2.1%/year*—, and also no investments in new production capacity should take place.

Under the current context and generation adequacy levels in the Dutch electricity system, the alternative of doing nothing could be implemented in the short term. This is because most of the capacity mechanisms discussed in this study are temporary solutions to shortage of production capacity in winter. This is the case for strategic reserves in Germany. Another reason is that the implementation of capacity mechanisms in NWE could take a couple of years in the case of capacity market in UK. This would give more time to the Netherlands to react with a carefully designed policy alternative. Nevertheless, in the long-term, the Dutch electricity market could experience the undesirable effects of capacity mechanisms once they will be implemented in the electricity systems of NWE.

Finally, the main recommendation for the Dutch regulator is to use the analysis provided in this chapter and in Chapter 4 as relevant information to start a discussion around capacity mechanisms on a National, and if considered relevant, on a European level. Furthermore, the Dutch regulator is welcome to use the analysis of the policy alternatives performed earlier as a benchmark for a more detailed policy analysis in the Future once the final implementation rules of the French and British capacity mechanisms will be defined. Finally, the analysis performed in this document provides relevant information to the Dutch regulator. It can be used to help in the policymaking process regarding the Dutch wholesale market, and more importantly, concerning capacity mechanism.

6. Conclusions

6.1. Answers to the main research question

From the analysis of the real electricity system of NWE, it was possible to identify that generation adequacy in NWE is not a problem in the short term. Mostly for the Netherlands since there is enough reliable production capacity to satisfy peak demand of electricity. Furthermore, according to the experts of the competition authority additional production capacity will be available to the Dutch wholesale market in the coming years. The context of the other countries of NWE is different since they are dealing with different issues related to their electricity system. For instance France is close to the implementation of a capacity mechanism called "Obligation de Capacité" which is based the theoretical model of capacity requirements. Similarly, United Kingdom is still deciding whether or not to implement a capacity mechanism based on "capacity markets". Besides, Germany has implemented a temporary version of strategic reserves. Finally, Norway has already using operating reserves as capacity mechanism.

The results of the simulated model suggest that cross-border effects of capacity mechanisms implemented in NWE on the Dutch wholesale market differ according to the type of capacity mechanism implemented and whether there is scarcity or not of electricity production in the wholesale markets. In fact, under scenarios of no production scarcity in the Netherlands, the implementation of capacity mechanisms in NWE do not have important effects on price formation or generator profits in the Dutch wholesale market. However, capacity mechanisms and monetary losses of some Dutch generators could reduce the reliability of electricity in the Netherlands in the short – term. This is because under more stable sources of profits in the electricity systems with capacity mechanisms, Dutch power generators, as rational actors, could be encouraged to offer their production capacity to neighboring wholesale markets. Finally, the most interesting case is France, the implementation of a capacity mechanism in this country caused the largest effect on the Dutch wholesale market under scarcity of production capacity in both countries. These effects consist of reduction of the affordability of electricity in the Dutch wholesale market caused by high prices. This is followed by a reduction of the reliability of electricity in the Dutch market as a result of the withholding of production capacity in the French system in cases of scarcity in the system.

A static equilibrium model of the wholesale electricity markets comprising the Netherlands, France, United Kingdom and Norway supports the earlier mentioned results. This model was designed with the main purpose of getting more understanding of the capacity mechanisms and its functioning on integrated wholesale markets as well as to obtain a rough estimate of electricity prices, electricity demand, exchange of power among the wholesale markets and producer operational profits. Therefore, one should bear in mind that its results are valid to analyze short-term cross-border effects of capacity mechanisms implemented in NWE on the Dutch wholesale market

From the study of the Dutch electricity industry, 3 policy goals that apply to this industry were found. Those are reliability, affordability and sustainability or environmental responsibility. As the two first policy goals were in the scope of the study, 5 specific criteria were set in order to assess 3 policy options. Those policy alternatives comprise do nothing; join efforts to implement a European capacity mechanism or implement a Dutch capacity mechanism to reduce the possible effects caused by the French capacity mechanism in the Dutch wholesale market.

The results of the policy assessment performed in Chapter 5 suggest, that implementing a European capacity mechanism could reduce substantially, most of the undesirable effects caused by the French capacity mechanism. However, it is relevant to highly that under the current context it might be difficult to implement the policy option in the short term due to the individual efforts to guarantee security of supply followed by the countries of NWE. Furthermore, under the current context and generation adequacy levels in the Dutch electricity system, the alternative called do nothing could be implemented in the short term. This is because most of the capacity mechanisms discussed in this study are temporary solutions However, in the long term, once the described capacity mechanisms are implemented in the electricity systems of NWE, the Dutch electricity market could experience the undesirable effects caused by the implementation of the capacity mechanism implemented in neighboring countries.

6.2. Reflection on the research study

This research study aimed to answer a question relevant for the society and the scientific community. The societal relevance of the study relies on the fact that electricity is an important resource for the society and therefore the effect on prices capacity mechanisms implemented in neighboring countries might have is important for the society that pays for it. The study also attempted to analyze a known topic such as capacity mechanism from a new perspective. Capacity mechanisms in the literature have been researched from a local perspective. Therefore, the study of their cross-border effects provides new insights for the scientific community.

The methodologies employed in this study produced reasonably good results since they contributed to answer the research sub-question and consequently the main research question. However, it is important to highly that the main limitation of the methodologies used rely on the approach to model the capacity mechanism. As the model used was static and not dynamic, the results cannot be used to draw conclusions about the long-term effects of the capacity mechanism implemented in NWE on the Dutch wholesale market. This includes the effects on long-term investments in production units on the Dutch wholesale market. To cope with this issue a more dynamic model would be required.

Finally, despite the limitations of the methodology it provided interest insights about the cross-border effects of capacity mechanism on the electricity prices and profits earned by generators in the Dutch wholesale market. This insights, as relevant information, can by used to start a discussion around capacity mechanisms on a National, and if considered relevant, on a European level. Furthermore, the interested researchers or institutions could use the analysis of the policy alternatives performed earlier as a benchmark for a more detailed policy analysis in the Future. Finally, the analysis performed in this document provides relevant information that can be used to help in the policymaking process to improve the performance of the Dutch wholesale market or to deal with generation adequacy.

6.3. Further research

Due to the scope of this research project the number of policy alternatives to be considered was limited to three. This study could be further complemented with a more extensive analysis of policy options that consider not only a quantitative assessment of the criteria but also that include other implementation criteria such as cost and time of implementation. Additionally, the static modeling based on exploratory scenarios employed in this research raises a new question about the factors driving the current investment trend in power generation in the Netherlands. Therefore, this research could be complemented with a more dynamic modeling approach that leads to identify those underlying factors encouraging investments in new electricity production capacity in the Netherlands. Finally, this study could be complemented in the future once the capacity mechanism of France and United Kingdom will be implemented. This can be done by upgrading the current model with the specific implementation details of the capacity mechanisms such as level of payment, production capacity covered by the mechanism among others.

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8. Appendixes

8.1. Appendix 1: Supply curves of electricity for the countries object of study in NEW

The values of the capacity offered vector and price vector have been calculated form the equations depicted beneath:

$$Capacity\ Offered\ Vector_i = Installed\ Capacity\ _i * Availability_i$$

Where:

$Installed\ Capacity\ _i$: Production capacity in MW installed in the electricity system of every country for every technology i.This data has been taken from (ENTSO-E, 2012) for the year 2010.

$Availability_i$: Is the percentage of availability in a year for every technology i. This data has been taken from (IEA, 2010) for the year 2010.

i: Sub index that denotes the technology used for electricity production

$$Price\ Vector_i = Marginal\ cost\ of\ electricity\ production_i$$

$$Marginal\ cost\ of\ electricity\ production_i = Fuel\ cost\ of\ electricity\ production_i$$

$$Fuel\ cost\ of\ electricity\ production_i = \frac{Fuel\ price_i * conversion\ factor_i}{Electrical\ efficiency_i}$$

$$Electrical\ efficiency_i = \frac{E_{out_i}}{E_{in_i}}$$

Where:

$Marginal\ cost\ of\ electricity\ production_i$: Is the cost of producing and addi tional MWh of electricity with a technology$i$.

$Fuel\ cost\ of\ electricity\ production_i$: Is the cost of the fuel used to produce electricity in Euros/MWh for every technology i. For most of the values this fuel cost was taken from (IEA, 2010)

$Fuel\ price_i$: I s the price of the fuel used to empower the generation unit and produce electricity. Their units differ according to the type of fuel foe every technology i.

$conversion\ factor_i$: Is the factor used to convert the fuel price in Euros/MWh. Its value depends on the electricity production technology i

$Electrical\ efficiency_i$: Is the relation between the electrical energy produced by the power plant and the energy that comes in the power plant for every technology i

Table 12 Capacity offered and price vector for the Netherlands in 2010. Based on data from **(Euroelectric, 2012)**, **(IEA, 2010)** and **(Nma, 2012)**

Electricity Production Technology	Capacity Offered Vector (MW)	Price Vector (Euros/MWh)	
Hydro	38	€	-
Solar	60	€	-
Wind Onshore	2,000	€	-
Wind Offshore	228	€	-
Waste	545	€	-
Nuclear	510	€	7.04
Coal	4,161	€	21.69
CCGT	10,531	€	47.85
Gas Plant	2,507	€	51.12
OCGT	3,845	€	51.71
Biomass	350	€	52.09
Gas turbine	334	€	58.48

Table 13 Capacity offered and price vector for Germany in 2010. Based on data from **(Euroelectric, 2012)**, **(IEA, 2010)** , **(VGB, 2011)** and **(Word Energy Council, 2012)**

Electricity Production Technology	Capacity Offered Vector (MW)	Price Vector (Euros/MWh)	
Hydro	11,040	€	-
Solar	17,300	€	-

Geothermal	10	€ -
Wind Onshore	27,154	€ -
Wind Offshore	60	€ -
Waste	1,330	€ -
Biogas	2,450	€ 2.00
Nuclear	20,490	€ 7.04
Brown Coal	20,208	€ 9.42
Coal	27,867	€ 23.66
Biomass	2,440	€ 38.75
Natural Gas	25,500	€ 44.55
Derived Gas	4,650	€ 44.55
Oil	6,010	€ 93.79

Table 14 Capacity offered and price vector for France in 2010. Based on data from **(Euroelectric, 2012)**, **(IEA, 2010)**, **(Esurostat, 2012)**, **(Word Energy Council, 2012)**

Electricity Production Technology	Capacity Offered Vector (MW)	Price Vector (Euros/MWh)
Hydro	25,390	€ -
Solar	878	€ -
Wind	5,764	€ -
Waste	711	€ -
Biogas	230	€ 2.00
Nuclear	63,130	€ 7.04
Coal	7,942	€ 21.72
Biomass	282	€ 52.09
Natural Gas	8,963	€ 55.55
Oil	10,447	€ 95.34

Table 15 Capacity offered and price vector for United Kingdom in 2010. Based on data from **(Euroelectric, 2012)**, **(IEA, 2010)**, **(Esurostat, 2012)**, **(OPEC, 2011)** and **(Word Energy Council, 2012)**

Electricity Production Technology	Capacity Offered Vector (MW)	Price Vector (Euros/MWh)
Hydro	4,343	€ -
Solar	45	€ -
Wind Onshore	4,800	€ -
Wind Offshore	1,054	€ -
Waste	805	€ -
Biogas	943	€ 2.00
Nuclear	9,679	€ 7.04
Coal	27,889	€ 21.72

Natural Gas	34,811	€	36.89
Biomass	308	€	52.09
Oil	4,584	€	95.11

Table 16 Capacity offered and price vector for United Kingdom in 2010. Based on data from **(Euroelectric, 2012)**, **(Esurostat, 2012)**, **(Word Energy Council, 2012)** and **(VGB, 2011)**

Electricity Production Technology	**Capacity Offered Vector (MW)**	**Price Vector (Euros/MWh)**	
Wind Onshore	430	€	-
Conventional Hydro	28,366	€	3.79
Pumped and Mixed	1,270	€	7.96
Natural Gas	900	€	45.70

8.2. Appendix 2: Load duration curves in NWE and programming code for their construction

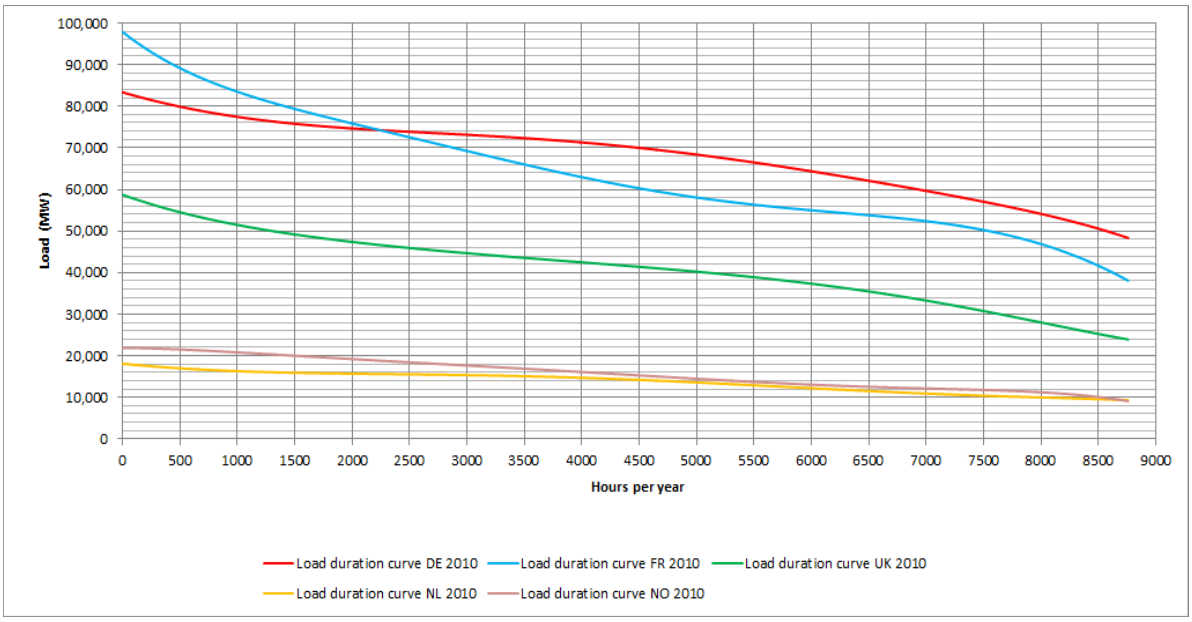

Figure 19 Load duration curves for the countries belonging to NWE in 2010. Constructed with data from **(ENTSO-E, 2012)**

Table 17 Descriptive statistics of the power consumption in 2010 (MW) Constructed with data from **(ENTSO-E, 2012)**

Country	**Min**	**Max**	**Average**	**Difference (Peak and off peak load)**	**Difference in %**
FR	38,062	97,863	64,025	59,801	61.1%
UK	23,926	58,723	41,046	34,797	59.3%
NO	9,083	21,899	15,760	12,816	58.5%
NL	9,334	18,096	13,705	8,762	48.4%
DE	48,328	83,345	68,104	35,017	42.0%

Table 18 Correlation coefficient of the load duration curves of Netherlands and the countries of NWE. **Constructed in Excel 2010 with data from (ENTSO-E, 2012)**

	DE	*FR*	*UK*	*NO*	*NL*
NL	0.930928	0.598407	0.917751	0.57116	1

Fitting of the load duration curves in Matlab

```
% reading the data files resulting from the histograms in Excel

DE=xlsread('Regression.xls','DE');
FR=xlsread('Regression.xls','FR');
GB=xlsread('Regression.xls','GB');
NL=xlsread('Regression.xls','NL');
NO=xlsread('Regression.xls','NO');

% Function to make the polynomial regression of the Load duration curves

function [f1,x1,f2,x2,p,S]= regression(Z)
x=Z(:,1);
y=Z(:,2);
[p,S]=polyfit(x,y,6)

% To calculate the error of the regression
f=polyval(p,x);
e=y-f
et=sum(e)

% To plot the values for the simulation

x1=[0 500 1000 1500 2000 2500 3000 4000 5000 7000 8760];
f1=polyval(p,x1);
x2=0:8760;
f2=polyval(p,x2);
plot(x,y,'o',x2,f2)
end


%fitting the curves

  % Load duration curve Germany (DE)

   [DEf1 DEx1 DEf2 DEx2 PDE SDE]=Regres(DE);

   % Results to be used in the simulation (11 points)
   DEsim= [DEx1' DEf1'];
   % Fitter curve for the 8760 hours of 2010
   DER=[DEx2' DEf2'];
   %writing the matrix in excel file
   xlswrite('Results_DE.xlsx',DER)


  % Load duration curve France (FR)

   [FRf1 FRx1 FRf2 FRx2 PFR SFR]=Regres(FR);

   % Results to be used in the simulation (11 points)
   FRsim= [FRx1' FRf1'];
   % Fitter curve for the 8760 hours of 2010
```

```
FRR=[FRx2' FRf2'];
%writing the matrix in excel file
xlswrite('Results_FR.xlsx',FRR)


% Load duration curve United Kingdom (UK)

[GBf1 GBx1 GBf2 GBx2 PGB SGB]=Regres(GB);

% Results to be used in the simulation (11 points)
GBsim= [GBx1' GBf1'];
% Fitter curve for the 8760 hours of 2010
GBR=[GBx2' GBf2'];
%writing the matrix in excel file
xlswrite('Results_GB.xlsx',GBR)


% Load duration curve Netherlands (NL)

[NLf1 NLx1 NLf2 NLx2 PNL SNL]=Regres(NL);

% Results to be used in the simulation (11 points)
NLsim= [NLx1' NLf1'];
% Fitter curve for the 8760 hours of 2010
NLR=[NLx2' NLf2'];
%writing the matrix in excel file
xlswrite('Results_NL.xlsx',NLR)

  % Load duration curve Norway (NO)

[NOf1 NOx1 NOf2 NOx2 PNO SNO]=Regres(NO);

% Results to be used in the simulation (11 points)
NOsim= [NOx1' NOf1'];
% Fitter curve for the 8760 hours of 2010
NOR=[NOx2' NOf2'];
%writing the matrix in excel file
xlswrite('Results_NO.xlsx',NOR)

% Graph of all LDC in NWE

plot(BEx2',BEf2', DEx2', DEf2',DKx2', DKf2',FIx2', FIf2',FRx2', FRf2',GBx2', GBf2',NLx2', NLf2',NOx2', NOf2',SEx2', SEf2')

title('Load duration curves for the countries belonging to NWE','fontsize',13,'fontweight','b')
grid on
xlabel('Load (MW)','fontsize',11,'fontweight','b')
ylabel('Hours per year','fontsize',11,'fontweight','b')
legend('BE','DE','DK', 'FI', 'FR', 'GB', 'NL', 'NO' , 'SE')
```

8.3. Appendix 3: Electricity prices in the Dutch wholesale market and its neighboring countries

The Producer surplus and total producer surplus has been calculated with the following equations:

$$Individual\ Producer\ Surplus_{i,t} = (Price_t - Marginal\ cost\ of\ electricity\ production_{i,t}) * Capacity\ Offered\ Vect$$

$$Producer\ Surplus_t = \sum_{i=1}^{n} Individual\ Producer\ Surplus_{i,t}$$

$$Total\ Producer\ Surplus_t = Producer\ Surplus_t * t$$

Where:

$Price_t$= Wholesale market price for the time interval t

$Marginal\ cost\ of\ electricity\ production_{i,t}$: Is the cost of producing an additional MWh of electricity with a technology i

$Capacity\ Offered\ Vector_{i,t}$: Is the capacity offered by the technology I for the time interval t

$Individual\ Producer\ Surplus_{i,t}$:It can be also called operation profits of a power generation technology I per hour

$Producer\ Surplus_t$: Is the sum of the individual producer surplus per hour

$Total\ Producer\ Surplus_t$: Is the total operational profits earned by electricity producers in the time interval t

Table 19 Electricity prices, demand and producer surplus for the modeled electricity wholesale markets of the Netherlands and Germany

Time interval (Hours/year)	NL				DE				Capacity of the Cross-border link
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	
0-50	18096	47.85	€ 199,811	€ 9,990,563	83345	23.66	€ 1,167,730	€ 58,386,477	3925
50-250	17714	47.85	€ 199,811	€ 39,962,253	82196	23.66	€ 1,167,730	€ 233,545,908	3925
250-500	17225	47.85	€ 199,811	€ 49,952,816	80658	23.66	€ 1,167,730	€ 291,932,385	3925
500-1000	16608	47.85	€ 199,811	€ 99,905,632	78556	23.66	€ 1,167,730	€ 583,864,770	3925
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	76525	23.66	€ 1,167,730	€ 583,864,770	3925
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	75164	23.66	€ 1,167,730	€ 583,864,770	3925
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	74231	23.66	€ 1,167,730	€ 583,864,770	3925
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	73492	23.66	€ 1,167,730	€ 583,864,770	3925
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	72322	23.66	€ 1,167,730	€ 1,167,729,539	3925
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	69988	23.66	€ 1,167,730	€ 1,167,729,539	3925
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	66483	23.66	€ 1,167,730	€ 1,167,729,539	3925
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	62079	23.66	€ 1,167,730	€ 1,167,729,539	3925
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	57049	9.42	€ 260,512	€ 260,512,285	3925
8000-8760	9682	21.69	€ 39,264	€ 29,840,305	51512	9.42	€ 260,512	€ 197,989,337	3925
			€ 2,636,810	**€ 1,628,330,409**			**€ 14,533,779**	**€ 8,632,608,398**	

Table 20 Electricity prices, demand and producer surplus for the modeled electricity wholesale markets of the Netherlands and France

Time interval (Hours/year)	NL				FR				Capacity of the Cross-border link
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	
0-50	18096	47.85	€ 199,811	€ 9,990,563	97863	21.72	€ 1,541,689	€ 77,084,445	2150
50-250	17714	47.85	€ 199,811	€ 39,962,253	94817	21.72	€ 1,541,689	€ 308,337,780	2150
250-500	17225	47.85	€ 199,811	€ 49,952,816	90978	21.72	€ 1,541,689	€ 385,422,225	2150
500-1000	16608	47.85	€ 199,811	€ 99,905,632	86053	7.04	€ 198,770	€ 99,384,850	2150
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	81297	7.04	€ 198,770	€ 99,384,850	2150
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	77566	7.04	€ 198,770	€ 99,384,850	2150
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	74195	7.04	€ 198,770	€ 99,384,850	2150
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	70890	7.04	€ 198,770	€ 99,384,850	2150
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	66002	7.04	€ 198,770	€ 198,769,700	2150
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	60277	7.04	€ 198,770	€ 198,769,700	2150
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	56332	7.04	€ 198,770	€ 198,769,700	2150
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	53791	7.04	€ 198,770	€ 198,769,700	2150
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	50252	7.04	€ 198,770	€ 198,769,700	2150
8000-8760	9682	47.85	€ 199,811	€ 151,856,560	43116	7.04	€ 198,770	€ 151,064,972	2150
			€ 2,797,358	**€ 1,750,346,665**			**€ 6,811,533**	**€ 2,412,682,174**	

Table 21 Electricity prices, demand and producer surplus for the modeled electricity wholesale markets of the Netherlands and United Kingdom

Time interval (Hours/Year)	NL				UK				Capacity of the Cross-border link
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	
0-50	18096	51.12	€ 254,342	€ 12,717,087	58723	36.89	€ 987,679	€ 49,383,967	1000
50-250	17714	51.12	€ 254,342	€ 50,868,347	57315	36.89	€ 987,679	€ 197,535,866	1000
250-500	17225	47.85	€ 199,811	€ 49,952,816	55448	36.89	€ 987,679	€ 246,919,833	1000
500-1000	16608	47.85	€ 199,811	€ 99,905,632	52879	36.89	€ 987,679	€ 493,839,665	1000
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	50241	36.89	€ 987,679	€ 493,839,665	1000
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	48224	36.89	€ 987,679	€ 493,839,665	1000
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	46615	36.89	€ 987,679	€ 493,839,665	1000
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	45271	36.89	€ 987,679	€ 493,839,665	1000
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	43541	21.72	€ 303,916	€ 303,915,562	1000
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	41390	21.72	€ 303,916	€ 303,915,562	1000
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	38897	21.72	€ 303,916	€ 303,915,562	1000
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	35477	21.72	€ 303,916	€ 303,915,562	1000
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	30771	21.72	€ 303,916	€ 303,915,562	1000
8000-8760	9682	47.85	€ 199,811	€ 151,856,560	25915	21.72	€ 303,916	€ 230,975,827	1000
			€ 2,906,419	**€ 1,763,979,282**			**€ 9,724,928**	**€ 4,713,591,626**	

Table 22 Electricity prices, demand and producer surplus for the modeled electricity wholesale markets of the Netherlands and Norway

Time interval (Hours)	NL				NO				Capacity of the Cross-border link
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	
0-50	18096	51.12	€ 254,342	€ 12,717,087	21899	3.79	€ 342	€ 17,097	700
50-250	17714	51.12	€ 254,342	€ 50,868,347	21840	3.79	€ 342	€ 68,387	700
250-500	17225	47.85	€ 199,811	€ 49,952,816	21659	3.79	€ 342	€ 85,484	700
500-1000	16608	47.85	€ 199,811	€ 99,905,632	21195	3.79	€ 342	€ 170,969	700
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	20423	3.79	€ 342	€ 170,969	700
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	19610	3.79	€ 342	€ 170,969	700
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	18818	3.79	€ 342	€ 170,969	700
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	18050	3.79	€ 342	€ 170,969	700
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	16899	3.79	€ 342	€ 341,937	700
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	15292	3.79	€ 342	€ 341,937	700
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	13730	3.79	€ 342	€ 341,937	700
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	12552	3.79	€ 342	€ 341,937	700
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	11787	3.79	€ 342	€ 341,937	700
8000-8760	9682	47.85	€ 199,811	€ 151,856,560	10456	3.79	€ 342	€ 259,872	700
			€ 2,906,419	**€ 1,763,979,282**			**€ 4,787**	**€ 2,995,369**	

8.4. Appendix 4: simulation results of the modeled strategic reserves on the system comprised by the German and Dutch wholesale market

Table 23 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Germany under the implementation of strategic reserves in Germany for the first scenario

Time interval (Hours)	NL				DE			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	18096	47.85	€ 199,811	€ 9,990,563	83345	23.66	€ 1,167,730	€ 58,386,477
50-250	17714	47.85	€ 199,811	€ 39,962,253	82196	23.66	€ 1,167,730	€ 233,545,908
250-500	17225	47.85	€ 199,811	€ 49,952,816	80658	23.66	€ 1,167,730	€ 291,932,385
500-1000	16608	47.85	€ 199,811	€ 99,905,632	78556	23.66	€ 1,167,730	€ 583,864,770
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	76525	23.66	€ 1,167,730	€ 583,864,770
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	75164	23.66	€ 1,167,730	€ 583,864,770
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	74231	23.66	€ 1,167,730	€ 583,864,770
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	73492	23.66	€ 1,167,730	€ 583,864,770
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	72322	23.66	€ 1,167,730	€ 1,167,729,539
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	69988	23.66	€ 1,167,730	€ 1,167,729,539
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	66483	23.66	€ 1,167,730	€ 1,167,729,539
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	62079	23.66	€ 1,167,730	€ 1,167,729,539
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	57049	9.42	€ 260,512	€ 260,512,285
8000-8760	9682	21.69	€ 39,264	€ 29,840,305	51512	9.42	€ 260,512	€ 197,989,337
			€ 2,636,810	**€ 1,628,330,409**			**€ 14,533,779**	**€ 8,632,608,398**

Table 24 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Germany (without capacity mechanism) under the first scenario

Time interval (Hours)	NL				DE			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	18096	47.85	€ 199,811	€ 9,990,563	83345	23.66	€ 1,167,730	€ 58,386,477
50-250	17714	47.85	€ 199,811	€ 39,962,253	82196	23.66	€ 1,167,730	€ 233,545,908
250-500	17225	47.85	€ 199,811	€ 49,952,816	80658	23.66	€ 1,167,730	€ 291,932,385
500-1000	16608	47.85	€ 199,811	€ 99,905,632	78556	23.66	€ 1,167,730	€ 583,864,770
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	76525	23.66	€ 1,167,730	€ 583,864,770
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	75164	23.66	€ 1,167,730	€ 583,864,770
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	74231	23.66	€ 1,167,730	€ 583,864,770
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	73492	23.66	€ 1,167,730	€ 583,864,770
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	72322	23.66	€ 1,167,730	€ 1,167,729,539
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	69988	23.66	€ 1,167,730	€ 1,167,729,539
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	66483	23.66	€ 1,167,730	€ 1,167,729,539
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	62079	23.66	€ 1,167,730	€ 1,167,729,539
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	57049	9.42	€ 260,512	€ 260,512,285
8000-8760	9682	21.69	€ 39,264	€ 29,840,305	51512	9.42	€ 260,512	€ 197,989,337
			€ 2,636,810	**€ 1,628,330,409**			**€ 14,533,779**	**€ 8,632,608,398**

Table 25 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and Germany for the first scenario

Scenario 1	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	DE	NL	DE
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 13,704,305,805	€ 2,038,060,711	€ 13,757,130,226
Producer surplus (Euros/year)	€ 1,628,330,409	€ 8,632,608,398	€ 1,628,330,409	€ 8,632,608,398
Profits of power generators (Euros/year)	€ (409,730,301)	€ (5,071,697,407)	€ (409,730,301)	€ (5,124,521,828)
Price of strategic reserve allowing generators to recover costs (Euros/MW/year)	€ -	€ -	€ -	€ 40,791
Total profits of power generators in the system (Euros/year)	€ (409,730,301)	€ (5,071,697,407)	€ (409,730,301)	€ (5,071,697,407)
Total reliable electricity production capacity of the system (MW)	23,704	130,169	23,704	131,464

Table 26 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Germany under the implementation of strategic reserves in Germany for the second scenario

Time interval (Hours)	NL				DE			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	20499	58.48	€ 423,757	€ 21,187,854	135224.4564	6120.00	€ 801,439,057	€ 40,071,952,849
50-250	20066	58.48	€ 423,757	€ 84,751,417	133360.2425	93.79	€ 9,208,093	€ 1,841,618,621
250-500	19513	58.48	€ 423,757	€ 105,939,271	130864.8893	93.79	€ 9,208,093	€ 2,302,023,277
500-1000	18814	51.71	€ 265,667	€ 132,833,483	127454.4651	51.71	€ 3,983,639	€ 1,991,819,476
1000-1500	18223	51.12	€ 254,342	€ 127,170,866	124159.236	51.12	€ 3,910,308	€ 1,955,153,932
1500-2000	17891	47.85	€ 199,811	€ 99,905,632	121951.0593	44.55	€ 3,095,195	€ 1,547,597,537
2000-2500	17690	47.85	€ 199,811	€ 99,905,632	120437.2982	44.55	€ 3,095,195	€ 1,547,597,537
2500-3000	17507	47.85	€ 199,811	€ 99,905,632	119238.2956	44.55	€ 3,095,195	€ 1,547,597,537
3000-4000	17097	47.85	€ 199,811	€ 199,811,263	117340.01	44.55	€ 3,095,195	€ 3,095,195,074
4000-5000	16098	47.85	€ 199,811	€ 199,811,263	113553.1736	44.55	€ 3,095,195	€ 3,095,195,074
5000-6000	14634	47.85	€ 199,811	€ 199,811,263	107866.4291	44.55	€ 3,095,195	€ 3,095,195,074
6000-7000	13065	47.85	€ 199,811	€ 199,811,263	100721.0874	44.55	€ 3,095,195	€ 3,095,195,074
7000-8000	11798	47.85	€ 199,811	€ 199,811,263	92560.08172	44.55	€ 3,095,195	€ 3,095,195,074
8000-8760	10967	47.85	€ 199,811	€ 151,856,560	83576.48565	23.66	€ 1,167,730	€ 887,474,450
			€ 3,589,581	**€ 1,922,512,662**			**€ 853,678,480**	**€ 69,168,810,584**

Table 27 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Germany (without capacity mechanism) under the second scenario

Time interval (Hours)	NL				DE			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	20499	58.48	€ 423,757	€ 21,187,854	135224.4564	6120.00	€ 793,635,387	€ 39,681,769,349
50-250	20066	58.48	€ 423,757	€ 84,751,417	133360.2425	93.79	€ 9,208,093	€ 1,841,618,621
250-500	19513	58.48	€ 423,757	€ 105,939,271	130864.8893	93.79	€ 9,208,093	€ 2,302,023,277
500-1000	18814	51.71	€ 265,667	€ 132,833,483	127454.4651	51.71	€ 3,983,639	€ 1,991,819,476
1000-1500	18223	51.12	€ 254,342	€ 127,170,866	124159.236	51.12	€ 3,910,308	€ 1,955,153,932
1500-2000	17891	47.85	€ 199,811	€ 99,905,632	121951.0593	44.55	€ 3,095,195	€ 1,547,597,537
2000-2500	17690	47.85	€ 199,811	€ 99,905,632	120437.2982	44.55	€ 3,095,195	€ 1,547,597,537
2500-3000	17507	47.85	€ 199,811	€ 99,905,632	119238.2956	44.55	€ 3,095,195	€ 1,547,597,537
3000-4000	17097	47.85	€ 199,811	€ 199,811,263	117340.01	44.55	€ 3,095,195	€ 3,095,195,074
4000-5000	16098	47.85	€ 199,811	€ 199,811,263	113553.1736	44.55	€ 3,095,195	€ 3,095,195,074
5000-6000	14634	47.85	€ 199,811	€ 199,811,263	107866.4291	44.55	€ 3,095,195	€ 3,095,195,074
6000-7000	13065	47.85	€ 199,811	€ 199,811,263	100721.0874	44.55	€ 3,095,195	€ 3,095,195,074
7000-8000	11798	47.85	€ 199,811	€ 199,811,263	92560.08172	44.55	€ 3,095,195	€ 3,095,195,074
8000-8760	10967	47.85	€ 199,811	€ 151,856,560	83576.48565	23.66	€ 1,167,730	€ 887,474,450
			€ 3,589,581	**€ 1,922,512,662**			**€ 845,874,810**	**€ 68,778,627,084**

Table 28 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and Germany for the second scenario

Scenario 2	**Model without capacity mechanisms**		**Model with capacity mechanisms**	
	NL	DE	NL	DE
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 13,704,305,805	€ 2,038,060,711	€ 13,757,130,226
Producer surplus (Euros/year)	€ 1,922,512,662	€ 68,778,627,084	€ 1,922,512,662	€ 69,168,810,584
Profits of power generators (Euros/year)	€ (115,548,049)	€ 55,074,321,279	€ (115,548,049)	€ 55,411,680,358
Price of strategic reserve allowing generators to recover costs (Euros/MW/year)	€ -	€ -	€ -	€ -
Total profits of power generators in the system (Euros/year)	€ (115,548,049)	€ 55,074,321,279	€ (115,548,049)	€ 55,411,680,358
Total reliable electricity production capacity of the system (MW)	23,704	130,169	23,704	131,464

Table 29 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Germany under the implementation of strategic reserves in Germany for the third scenario

Time interval (Hours)	NL				DE			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	28021	8600.00	€ 202,891,947	€ 10,144,597,358	90595.63657	44.55	€ 3,095,195	€ 154,759,754
50-250	27430	58.48	€ 423,757	€ 84,751,417	89346.67879	38.75	€ 2,549,582	€ 509,916,485
250-500	26673	51.71	€ 265,667	€ 66,416,742	87674.87977	38.75	€ 2,549,582	€ 637,395,606
500-1000	25717	51.71	€ 265,667	€ 132,833,483	85390.01531	23.66	€ 1,167,730	€ 583,864,770
1000-1500	24910	51.71	€ 265,667	€ 132,833,483	83182.32754	23.66	€ 1,167,730	€ 583,864,770
1500-2000	24457	51.71	€ 265,667	€ 132,833,483	81702.92672	23.66	€ 1,167,730	€ 583,864,770
2000-2500	24181	51.71	€ 265,667	€ 132,833,483	80688.75995	23.66	€ 1,167,730	€ 583,864,770
2500-3000	23932	51.71	€ 265,667	€ 132,833,483	79885.47031	23.66	€ 1,167,730	€ 583,864,770
3000-4000	23371	51.71	€ 265,667	€ 265,666,966	78613.68562	23.66	€ 1,167,730	€ 1,167,729,539
4000-5000	22005	51.12	€ 254,342	€ 254,341,733	76076.63822	23.66	€ 1,167,730	€ 1,167,729,539
5000-6000	20003	47.85	€ 199,811	€ 199,811,263	72266.71913	23.66	€ 1,167,730	€ 1,167,729,539
6000-7000	17859	47.85	€ 199,811	€ 199,811,263	67479.59113	23.66	€ 1,167,730	€ 1,167,729,539
7000-8000	16127	47.85	€ 199,811	€ 199,811,263	62012.00397	23.66	€ 1,167,730	€ 1,167,729,539
8000-8760	14992	47.85	€ 199,811	€ 151,856,560	55993.31011	9.42	€ 260,512	€ 197,989,337
			€ 206,228,960	**€ 12,231,231,981**			**€ 20,132,168**	**€ 10,258,032,726**

Table 30 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Germany (without capacity mechanism) under the third scenario

Time interval (Hours)	NL				DE			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	28021	8600.00	€ 202,891,947	€ 10,144,597,358	90595.63657	44.55	€ 3,095,195	€ 154,759,754
50-250	27430	58.48	€ 423,757	€ 84,751,417	89346.67879	38.75	€ 2,549,582	€ 509,916,485
250-500	26673	51.71	€ 265,667	€ 66,416,742	87674.87977	38.75	€ 2,549,582	€ 637,395,606
500-1000	25717	51.71	€ 265,667	€ 132,833,483	85390.01531	23.66	€ 1,167,730	€ 583,864,770
1000-1500	24910	51.71	€ 265,667	€ 132,833,483	83182.32754	23.66	€ 1,167,730	€ 583,864,770
1500-2000	24457	51.71	€ 265,667	€ 132,833,483	81702.92672	23.66	€ 1,167,730	€ 583,864,770
2000-2500	24181	51.71	€ 265,667	€ 132,833,483	80688.75995	23.66	€ 1,167,730	€ 583,864,770
2500-3000	23932	51.71	€ 265,667	€ 132,833,483	79885.47031	23.66	€ 1,167,730	€ 583,864,770
3000-4000	23371	51.71	€ 265,667	€ 265,666,966	78613.68562	23.66	€ 1,167,730	€ 1,167,729,539
4000-5000	22005	51.12	€ 254,342	€ 254,341,733	76076.63822	23.66	€ 1,167,730	€ 1,167,729,539
5000-6000	20003	47.85	€ 199,811	€ 199,811,263	72266.71913	23.66	€ 1,167,730	€ 1,167,729,539
6000-7000	17859	47.85	€ 199,811	€ 199,811,263	67479.59113	23.66	€ 1,167,730	€ 1,167,729,539
7000-8000	16127	47.85	€ 199,811	€ 199,811,263	62012.00397	23.66	€ 1,167,730	€ 1,167,729,539
8000-8760	14992	47.85	€ 199,811	€ 151,856,560	55993.31011	9.42	€ 260,512	€ 197,989,337
			€ 206,228,960	**€ 12,231,231,981**			**€ 20,132,168**	**€ 10,258,032,726**

Table 31 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and Germany for the third scenario

Scenario 3	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	DE	NL	DE
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 13,704,305,805	€ 2,038,060,711	€ 13,757,130,226
Producer surplus (Euros/year)	€ 12,231,231,981	€ 10,258,032,726	€ 12,231,231,981	€ 10,258,032,726
Profits of power generators (Euros/year)	€ 10,193,171,270	€ (3,446,273,078)	€ 10,193,171,270	€ (3,499,097,499)
Price of strategic reserve allowing generators to recover costs (Euros/MW/year)	€ -	€ -	€ -	€ 40,791
Total profits of power generators in the system (Euros/year)	€ 10,193,171,270	€ (3,446,273,078)	€ 10,193,171,270	€ (3,446,273,078)
Total reliable electricity production capacity of the system (MW)	23,704	130,169	23,704	131,464

Table 32 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Germany under the implementation of strategic reserves in Germany for the fourth scenario

Time interval (Hours)	NL				DE			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	24952	6120.00	€ 144,106,027	€ 7,205,301,358	132258	6120.00	€ 801,439,057	€ 40,071,952,849
50-250	24425	94.00	€ 1,265,723	€ 253,144,633	130435	94.00	€ 9,235,667	€ 1,847,133,451
250-500	23751	93.79	€ 1,260,702	€ 315,175,468	127994	93.79	€ 9,208,093	€ 2,302,023,277
500-1000	22900	58.48	€ 423,757	€ 211,878,542	124658	58.48	€ 4,824,259	€ 2,412,129,321
1000-1500	22181	51.71	€ 265,667	€ 132,833,483	121436	44.55	€ 3,095,195	€ 1,547,597,537
1500-2000	21777	51.12	€ 254,342	€ 127,170,866	119276	44.55	€ 3,095,195	€ 1,547,597,537
2000-2500	21532	51.12	€ 254,342	€ 127,170,866	117795	44.55	€ 3,095,195	€ 1,547,597,537
2500-3000	21310	51.12	€ 254,342	€ 127,170,866	116623	44.55	€ 3,095,195	€ 1,547,597,537
3000-4000	20811	51.12	€ 254,342	€ 254,341,733	114766	44.55	€ 3,095,195	€ 3,095,195,074
4000-5000	19595	47.85	€ 199,811	€ 199,811,263	111062	44.55	€ 3,095,195	€ 3,095,195,074
5000-6000	17812	47.85	€ 199,811	€ 199,811,263	105500	44.55	€ 3,095,195	€ 3,095,195,074
6000-7000	15902	47.85	€ 199,811	€ 199,811,263	98512	44.55	€ 3,095,195	€ 3,095,195,074
7000-8000	14361	47.85	€ 199,811	€ 199,811,263	90530	44.55	€ 3,095,195	€ 3,095,195,074
8000-8760	13350	47.85	€ 199,811	€ 151,856,560	81743	23.66	€ 1,167,730	€ 887,474,450
			€ 149,338,299	**€ 9,705,289,429**			**€ 853,731,561**	**€ 69,187,078,864**

Table 33 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Germany (without capacity mechanism) under the fourth scenario

Time interval (Hours)	NL				DE			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	24952	6120.00	€ 144,106,027	€ 7,205,301,358	132258	6120.00	€ 793,635,387	€ 39,681,769,349
50-250	24425	6120.00	€ 144,106,027	€ 28,821,205,433	130435	6120.00	€ 793,635,387	€ 158,727,077,395
250-500	23751	93.79	€ 1,260,702	€ 315,175,468	127994	93.79	€ 9,208,093	€ 2,302,023,277
500-1000	22900	58.48	€ 423,757	€ 211,878,542	124658	58.48	€ 4,824,259	€ 2,412,129,321
1000-1500	22181	51.71	€ 265,667	€ 132,833,483	121436	44.55	€ 3,095,195	€ 1,547,597,537
1500-2000	21777	51.12	€ 254,342	€ 127,170,866	119276	44.55	€ 3,095,195	€ 1,547,597,537
2000-2500	21532	51.12	€ 254,342	€ 127,170,866	117795	44.55	€ 3,095,195	€ 1,547,597,537
2500-3000	21310	51.12	€ 254,342	€ 127,170,866	116623	44.55	€ 3,095,195	€ 1,547,597,537
3000-4000	20811	51.12	€ 254,342	€ 254,341,733	114766	44.55	€ 3,095,195	€ 3,095,195,074
4000-5000	19595	47.85	€ 199,811	€ 199,811,263	111062	44.55	€ 3,095,195	€ 3,095,195,074
5000-6000	17812	47.85	€ 199,811	€ 199,811,263	105500	44.55	€ 3,095,195	€ 3,095,195,074
6000-7000	15902	47.85	€ 199,811	€ 199,811,263	98512	44.55	€ 3,095,195	€ 3,095,195,074
7000-8000	14361	47.85	€ 199,811	€ 199,811,263	90530	44.55	€ 3,095,195	€ 3,095,195,074
8000-8760	13350	47.85	€ 199,811	€ 151,856,560	81743	23.66	€ 1,167,730	€ 887,474,450
			€ 292,178,603	**€ 38,273,350,229**			**€ 1,630,327,611**	**€ 225,676,839,308**

Table 34 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and Germany for the fourth scenario

Scenario 4	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	DE	NL	DE
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 13,704,305,805	€ 2,038,060,711	€ 13,757,130,226
Producer surplus (Euros/year)	€ 38,273,350,229	€ 225,676,839,308	€ 9,705,289,429	€ 69,187,078,864
Profits of power generators (Euros/year)	€ 36,235,289,518	€ 211,972,533,503	€ 7,667,228,718	€ 55,429,948,638
Price of strategic reserve allowing generators to recover costs (Euros/MW/year)	€ -	€ -	€ -	€ -
Total profits of power generators in the system (Euros/year)	€ 36,235,289,518	€ 211,972,533,503	€ 7,667,228,718	€ 55,429,948,638
Total reliable electricity production capacity of the system (MW)	23,704	130,169	23,704	131,464

8.5. Appendix 5: simulation results of the modeled "Obligation de Capacité" on the system comprised by the French and Dutch wholesale market

Table 35 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and France under the implementation of "Obligation de Capacite" in France for the first scenario

Time interval (Hours/year)	NL				FR			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/ MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	18096	47.85	€ 199,811	€ 9,990,563	97863	21.72	€ 1,541,689	€ 77,084,445
50-250	17714	47.85	€ 199,811	€ 39,962,253	94817	21.72	€ 1,541,689	€ 308,337,780
250-500	17225	47.85	€ 199,811	€ 49,952,816	90978	21.72	€ 1,541,689	€ 385,422,225
500-1000	16608	47.85	€ 199,811	€ 99,905,632	86053	7.04	€ 198,770	€ 99,384,850
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	81297	7.04	€ 198,770	€ 99,384,850
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	77566	7.04	€ 198,770	€ 99,384,850
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	74195	7.04	€ 198,770	€ 99,384,850
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	70890	7.04	€ 198,770	€ 99,384,850
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	66002	7.04	€ 198,770	€ 198,769,700
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	60277	7.04	€ 198,770	€ 198,769,700
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	56332	7.04	€ 198,770	€ 198,769,700
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	53791	7.04	€ 198,770	€ 198,769,700
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	50252	7.04	€ 198,770	€ 198,769,700
8000-8760	9682	47.85	€ 199,811	€ 151,856,560	43116	7.04	€ 198,770	€ 151,064,972
			€ 2,797,358	**€ 1,750,346,665**			**€ 6,811,533**	**€ 2,412,682,174**

Table 36 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and France (without capacity mechanism) under the first scenario

Time interval (Hours/year)	NL				FR			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	18096	47.85	€ 199,811	€ 9,990,563	97863	21.72	€ 1,541,689	€ 77,084,445
50-250	17714	47.85	€ 199,811	€ 39,962,253	94817	21.72	€ 1,541,689	€ 308,337,780
250-500	17225	47.85	€ 199,811	€ 49,952,816	90978	21.72	€ 1,541,689	€ 385,422,225
500-1000	16608	47.85	€ 199,811	€ 99,905,632	86053	7.04	€ 198,770	€ 99,384,850
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	81297	7.04	€ 198,770	€ 99,384,850
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	77566	7.04	€ 198,770	€ 99,384,850
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	74195	7.04	€ 198,770	€ 99,384,850
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	70890	7.04	€ 198,770	€ 99,384,850
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	66002	7.04	€ 198,770	€ 198,769,700
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	60277	7.04	€ 198,770	€ 198,769,700
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	56332	7.04	€ 198,770	€ 198,769,700
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	53791	7.04	€ 198,770	€ 198,769,700
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	50252	7.04	€ 198,770	€ 198,769,700
8000-8760	9682	47.85	€ 199,811	€ 151,856,560	43116	7.04	€ 198,770	€ 151,064,972
			€ 2,797,358	**€ 1,750,346,665**			**€ 6,811,533**	**€ 2,412,682,174**

Table 37 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and France for the first scenario

Scenario 1	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	FR	NL	FR
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 18,225,889,423	€ 2,038,060,711	€ 18,225,889,423
Producer surplus (Euros/year)	€ 1,750,346,665	€ 2,412,682,174	€ 1,750,346,665	€ 2,412,682,174
Profits of power generators (Euros/year)	€ (287,714,046)	€ (15,813,207,249)	€ (287,714,046)	€ (15,813,207,249)
Price of the capacity credits allowing generators to recover costs (Euros/MW/year)	€ -	€ -	€ -	€ 146,896
Total profits of power generators in the system (Euros/year)	€ (287,714,046)	€ (15,813,207,248.70)	€ (287,714,046)	€ -
Total reliable electricity production capacity of the system (MW)	23,704	119,073	23,704	119,073

Table 38 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and France under the implementation of "Obligation de Capacite" in France for the second scenario

Time interval (Hours/year)	NL				FR				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Nominal capacity required in the system (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	20499	51.71	€ 265,667	€ 13,283,348	115499	127049	95.34	€ 9,343,003	€ 467,150,172.05
50-250	20066	51.71	€ 265,667	€ 53,133,393	111904	123094	56.55	€ 5,013,070	€ 1,002,613,911.59
250-500	19513	51.71	€ 265,667	€ 66,416,742	107373	118110	55.55	€ 4,904,444	€ 1,226,111,009.49
500-1000	18814	51.71	€ 265,667	€ 132,833,483	101560	111717	52.09	€ 4,559,762	€ 2,279,881,085.92
1000-1500	18223	47.85	€ 199,811	€ 99,905,632	95947.4	105542	21.72	€ 1,541,689	€ 770,844,450.48
1500-2000	17891	47.85	€ 199,811	€ 99,905,632	91544	100698	21.72	€ 1,541,689	€ 770,844,450.48
2000-2500	17690	47.85	€ 199,811	€ 99,905,632	87565.6	96322	7.04	€ 198,770	€ 99,384,850.12
2500-3000	17507	47.85	€ 199,811	€ 99,905,632	83665	92031	7.04	€ 198,770	€ 99,384,850.12
3000-4000	17097	47.85	€ 199,811	€ 199,811,263	77896.1	85686	7.04	€ 198,770	€ 198,769,700.23
4000-5000	16098	47.85	€ 199,811	€ 199,811,263	71139.4	78253	7.04	€ 198,770	€ 198,769,700.23
5000-6000	14634	47.85	€ 199,811	€ 199,811,263	66483.5	73132	7.04	€ 198,770	€ 198,769,700.23
6000-7000	13065	47.85	€ 199,811	€ 199,811,263	63484.6	69833	7.04	€ 198,770	€ 198,769,700.23
7000-8000	11798	47.85	€ 199,811	€ 199,811,263	59307.8	65239	7.04	€ 198,770	€ 198,769,700.23
8000-8760	10967	47.85	€ 199,811	€ 151,856,560	50885.9	55974	7.04	€ 198,770	€ 151,064,972.18
			€ 3,060,780	**€ 1,816,202,368**				**€ 28,493,815**	**€ 7,861,128,254**

Table 39 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and France (without capacity mechanism) under the second scenario

Time interval (Hours/year)	NL				FR				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Nominal capacity required in the system (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	20499	51.71	€ 265,667	€ 13,283,348	115499	115499	95.34	€ 9,226,634	€ 461,331,698.97
50-250	20066	51.71	€ 265,667	€ 53,133,393	111904	111904	95.34	€ 9,226,634	€ 1,845,326,795.90
250-500	19513	51.71	€ 265,667	€ 66,416,742	107373	107373	55.55	€ 4,904,444	€ 1,226,111,009.49
500-1000	18814	51.71	€ 265,667	€ 132,833,483	101560	101560	52.09	€ 4,559,762	€ 2,279,881,085.92
1000-1500	18223	47.85	€ 199,811	€ 99,905,632	95947.4	95947	21.72	€ 1,541,689	€ 770,844,450.48
1500-2000	17891	47.85	€ 199,811	€ 99,905,632	91544	91544	21.72	€ 1,541,689	€ 770,844,450.48
2000-2500	17690	47.85	€ 199,811	€ 99,905,632	87565.6	87566	7.04	€ 198,770	€ 99,384,850.12
2500-3000	17507	47.85	€ 199,811	€ 99,905,632	83665	83665	7.04	€ 198,770	€ 99,384,850.12
3000-4000	17097	47.85	€ 199,811	€ 199,811,263	77896.1	77896	7.04	€ 198,770	€ 198,769,700.23
4000-5000	16098	47.85	€ 199,811	€ 199,811,263	71139.4	71139	7.04	€ 198,770	€ 198,769,700.23
5000-6000	14634	47.85	€ 199,811	€ 199,811,263	66483.5	66483	7.04	€ 198,770	€ 198,769,700.23
6000-7000	13065	47.85	€ 199,811	€ 199,811,263	63484.6	63485	7.04	€ 198,770	€ 198,769,700.23
7000-8000	11798	47.85	€ 199,811	€ 199,811,263	59307.8	59308	7.04	€ 198,770	€ 198,769,700.23
8000-8760	10967	47.85	€ 199,811	€ 151,856,560	50885.9	50886	7.04	€ 198,770	€ 151,064,972.18
			€ 3,060,780	**€ 1,816,202,368**				**€ 32,591,010**	**€ 8,698,022,665**

Table 40 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and France for the second scenario

Scenario 2	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	FR	NL	FR
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 18,225,889,423	€ 2,038,060,711	€ 18,600,877,428
Producer surplus (Euros/year)	€ 1,816,202,368	€ 8,698,022,665	€ 1,816,202,368	€ 7,861,128,254
Profits of power generators (Euros/year)	€ (221,858,343)	€ (9,527,866,758)	€ (221,858,343)	€ (10,739,749,175)
Price of the capacity credits allowing generators to recover costs (Euros/MW/year)	€ -	€ -	€ -	€ 84,533
Total profits of power generators in the system (Euros/year)	€ (221,858,343)	€ (9,527,866,758.29)	€ (221,858,343)	€ -
Total reliable electricity production capacity of the system (MW)	23,704	119,073	23,704	124,986

Table 41 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and France under the implementation of "Obligation de Capacite" in France for the third scenario

Time interval (Hours/year)	NL				FR				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Nominal capacity required in the system (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	26405	8600.00	€ 202,891,947	€ 10,144,597,358	106377	117014	55.55	€ 4,904,444	€ 245,222,201.90
50-250	25847	58.48	€ 423,757	€ 84,751,417	103066	113372	55.55	€ 4,904,444	€ 980,888,807.59
250-500	25134	55.55	€ 355,324	€ 88,831,047	98892.7	108782	55.55	€ 4,904,444	€ 1,226,111,009.49
500-1000	24233	51.71	€ 265,667	€ 132,833,483	93539.2	102893	21.72	€ 1,541,689	€ 770,844,450.48
1000-1500	23473	51.71	€ 265,667	€ 132,833,483	88369.5	97206	7.04	€ 198,770	€ 99,384,850.12
1500-2000	23046	51.71	€ 265,667	€ 132,833,483	84313.9	92745	7.04	€ 198,770	€ 99,384,850.12
2000-2500	22786	51.71	€ 265,667	€ 132,833,483	80649.6	88715	7.04	€ 198,770	€ 99,384,850.12
2500-3000	22551	51.71	€ 265,667	€ 132,833,483	77057.1	84763	7.04	€ 198,770	€ 99,384,850.12
3000-4000	22023	51.71	€ 265,667	€ 265,666,966	71743.9	78918	7.04	€ 198,770	€ 198,769,700.23
4000-5000	20736	51.12	€ 254,342	€ 254,341,733	65520.8	72073	7.04	€ 198,770	€ 198,769,700.23
5000-6000	18849	51.12	€ 254,342	€ 254,341,733	61232.6	67356	7.04	€ 198,770	€ 198,769,700.23
6000-7000	16828	47.85	€ 199,811	€ 199,811,263	58470.6	64318	7.04	€ 198,770	€ 198,769,700.23
7000-8000	15197	47.85	€ 199,811	€ 199,811,263	54623.7	60086	7.04	€ 198,770	€ 198,769,700.23
8000-8760	14127	47.85	€ 199,811	€ 151,856,560	46866.9	51554	7.04	€ 198,770	€ 151,064,972.18
			€ 206,373,147	**€ 12,308,176,756**				**€ 18,242,718**	**€ 4,765,519,343**

Table 42 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and France (without capacity mechanism) under the third scenario

Time interval (Hours/year)	NL				FR				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Nominal capacity required in the system (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	26405	8600.00	€ 202,891,947	€ 10,144,597,358	106377	106377	55.55	€ 4,904,444	€ 245,222,201.90
50-250	25847	58.48	€ 423,757	€ 84,751,417	103066	103066	55.55	€ 4,904,444	€ 980,888,807.59
250-500	25134	55.55	€ 355,324	€ 88,831,047	98892.7	98893	55.55	€ 4,904,444	€ 1,226,111,009.49
500-1000	24233	51.71	€ 265,667	€ 132,833,483	93539.2	93539	21.72	€ 1,541,689	€ 770,844,450.48
1000-1500	23473	51.71	€ 265,667	€ 132,833,483	88369.5	88369	7.04	€ 198,770	€ 99,384,850.12
1500-2000	23046	51.71	€ 265,667	€ 132,833,483	84313.9	84314	7.04	€ 198,770	€ 99,384,850.12
2000-2500	22786	51.71	€ 265,667	€ 132,833,483	80649.6	80650	7.04	€ 198,770	€ 99,384,850.12
2500-3000	22551	51.71	€ 265,667	€ 132,833,483	77057.1	77057	7.04	€ 198,770	€ 99,384,850.12
3000-4000	22023	51.71	€ 265,667	€ 265,666,966	71743.9	71744	7.04	€ 198,770	€ 198,769,700.23
4000-5000	20736	51.12	€ 254,342	€ 254,341,733	65520.8	65521	7.04	€ 198,770	€ 198,769,700.23
5000-6000	18849	51.12	€ 254,342	€ 254,341,733	61232.6	61233	7.04	€ 198,770	€ 198,769,700.23
6000-7000	16828	47.85	€ 199,811	€ 199,811,263	58470.6	58471	7.04	€ 198,770	€ 198,769,700.23
7000-8000	15197	47.85	€ 199,811	€ 199,811,263	54623.7	54624	7.04	€ 198,770	€ 198,769,700.23
8000-8760	14127	47.85	€ 199,811	€ 151,856,560	46866.9	46867	7.04	€ 198,770	€ 151,064,972.18
			€ 206,373,147	**€ 12,308,176,756**				**€ 18,242,718**	**€ 4,765,519,343**

Table 43 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and France for the third scenario

Scenario 3	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	FR	NL	FR
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 18,225,889,423	€ 2,038,060,711	€ 18,600,877,428
Producer surplus (Euros/year)	€ 12,308,176,756	€ 4,765,519,343	€ 12,308,176,756	€ 4,765,519,343
Profits of power generators (Euros/year)	€ 10,270,116,045	€ (13,460,370,080)	€ 10,270,116,045	€ (13,835,358,085)
Price of the capacity credits allowing generators to recover costs (Euros/MW/year)	€ -	€ -	€ -	€ 118,236
Total profits of power generators in the system (Euros/year)	€ 10,270,116,045	€ (13,460,370,079.83)	€ 10,270,116,045	€ -
Total reliable electricity production capacity of the system (MW)	23,704	119,073	23,704	124,986

Table 44 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and France under the implementation of "Obligation de Capacite" in France for the fourth scenario

Time interval (Hours/year)	NL				FR				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Nominal capacity required in the system (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	26405	8600.00	€ 202,891,947	€ 10,144,597,358	115499	127049	95.34	€ 9,343,003	€ 467,150,172.05
50-250	25847	8600.00	€ 202,891,947	€ 40,578,389,433	111904	123094	95.34	€ 9,343,003	€ 1,868,600,688.19
250-500	25134	56.55	€ 378,694	€ 94,673,469	107373	118110	56.55	€ 5,013,070	€ 1,253,267,389.49
500-1000	24233	55.55	€ 355,324	€ 177,662,093	101560	111717	55.55	€ 4,904,444	€ 2,452,222,018.98
1000-1500	23473	51.71	€ 265,667	€ 132,833,483	95947.4	105542	21.72	€ 1,541,689	€ 770,844,450.48
1500-2000	23046	51.71	€ 265,667	€ 132,833,483	91544	100698	21.72	€ 1,541,689	€ 770,844,450.48
2000-2500	22786	51.71	€ 265,667	€ 132,833,483	87565.6	96322	21.72	€ 1,541,689	€ 770,844,450.48
2500-3000	22551	51.71	€ 265,667	€ 132,833,483	83665	92031	7.04	€ 198,770	€ 99,384,850.12
3000-4000	22023	51.71	€ 265,667	€ 265,666,966	77896.1	85686	7.04	€ 198,770	€ 198,769,700.23
4000-5000	20736	51.12	€ 254,342	€ 254,341,733	71139.4	78253	7.04	€ 198,770	€ 198,769,700.23
5000-6000	18849	51.12	€ 254,342	€ 254,341,733	66483.5	73132	7.04	€ 198,770	€ 198,769,700.23
6000-7000	16828	47.85	€ 199,811	€ 199,811,263	63484.6	69833	7.04	€ 198,770	€ 198,769,700.23
7000-8000	15197	47.85	€ 199,811	€ 199,811,263	59307.8	65239	7.04	€ 198,770	€ 198,769,700.23
8000-8760	14127	47.85	€ 199,811	€ 151,856,560	50885.9	55974	7.04	€ 198,770	€ 151,064,972.18
			€ 408,954,364	**€ 52,852,485,804**				**€ 34,619,975**	**€ 9,598,071,944**

Table 45 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and France (without capacity mechanism) under the fourth scenario

Time interval (Hours/year)	NL				FR				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Nominal capacity required in the system (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	26405	8600.00	€ 202,891,947	€ 10,144,597,358	115499	115499	95.34	€ 9,226,634	€ 461,331,698.97
50-250	25847	95.34	€ 1,297,523	€ 259,504,628	111904	111904	95.34	€ 9,226,634	€ 1,845,326,795.90
250-500	25134	95.34	€ 1,297,523	€ 324,380,784	107373	107373	95.34	€ 9,226,634	€ 2,306,658,494.87
500-1000	24233	55.55	€ 355,324	€ 177,662,093	101560	101560	55.55	€ 4,904,444	€ 2,452,222,018.98
1000-1500	23473	51.71	€ 265,667	€ 132,833,483	95947.4	95947	21.72	€ 1,541,689	€ 770,844,450.48
1500-2000	23046	51.71	€ 265,667	€ 132,833,483	91544	91544	21.72	€ 1,541,689	€ 770,844,450.48
2000-2500	22786	51.71	€ 265,667	€ 132,833,483	87565.6	87566	7.04	€ 198,770	€ 99,384,850.12
2500-3000	22551	51.71	€ 265,667	€ 132,833,483	83665	83665	7.04	€ 198,770	€ 99,384,850.12
3000-4000	22023	51.71	€ 265,667	€ 265,666,966	77896.1	77896	7.04	€ 198,770	€ 198,769,700.23
4000-5000	20736	51.12	€ 254,342	€ 254,341,733	71139.4	71139	7.04	€ 198,770	€ 198,769,700.23
5000-6000	18849	51.12	€ 254,342	€ 254,341,733	66483.5	66483	7.04	€ 198,770	€ 198,769,700.23
6000-7000	16828	47.85	€ 199,811	€ 199,811,263	63484.6	63485	7.04	€ 198,770	€ 198,769,700.23
7000-8000	15197	47.85	€ 199,811	€ 199,811,263	59307.8	59308	7.04	€ 198,770	€ 198,769,700.23
8000-8760	14127	47.85	€ 199,811	€ 151,856,560	50885.9	50886	7.04	€ 198,770	€ 151,064,972.18
			€ 208,278,770	**€ 12,763,308,315**				**€ 37,257,881**	**€ 9,950,911,083**

Table 46 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and France for the fourth scenario

Scenario 4	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	FR	NL	FR
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 18,225,889,423	€ 2,038,060,711	€ 18,600,877,428
Producer surplus (Euros/year)	€ 12,763,308,315	€ 9,950,911,083	€ 52,852,485,804	€ 9,598,071,944
Profits of power generators (Euros/year)	€ 10,725,247,604	€ (8,274,978,340)	€ 50,814,425,094	€ (9,002,805,485)
Price of the capacity credits allowing generators to recover costs (Euros/MW/year)	€ -	€ -	€ -	€ 70,861
Total profits of power generators in the system (Euros/year)	€ 10,725,247,604	€ (8,274,978,339.85)	€ 50,814,425,094	€ -
Total reliable electricity production capacity of the system (MW)	23,704	119,073	23,704	124,986

8.1. Appendix 6: simulation results of the modeled "capacity market" on the system comprised by the British and Dutch wholesale market

Table 47 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and United Kingdom under the implementation of "capacity markets" in the UK for the first scenario

Time interval (Hours/year)	NL				UK			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	18096	51.12	€ 254,342	€ 12,717,087	58723	36.89	€ 987,679	€ 49,383,967
50-250	17714	51.12	€ 254,342	€ 50,868,347	57315	36.89	€ 987,679	€ 197,535,866
250-500	17225	47.85	€ 199,811	€ 49,952,816	55448	36.89	€ 987,679	€ 246,919,833
500-1000	16608	47.85	€ 199,811	€ 99,905,632	52879	36.89	€ 987,679	€ 493,839,665
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	50241	36.89	€ 987,679	€ 493,839,665
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	48224	36.89	€ 987,679	€ 493,839,665
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	46615	36.89	€ 987,679	€ 493,839,665
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	45271	36.89	€ 987,679	€ 493,839,665
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	43541	21.72	€ 303,916	€ 303,915,562
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	41390	21.72	€ 303,916	€ 303,915,562
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	38897	21.72	€ 303,916	€ 303,915,562
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	35477	21.72	€ 303,916	€ 303,915,562
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	30771	21.72	€ 303,916	€ 303,915,562
8000-8760	9682	47.85	€ 199,811	€ 151,856,560	25915	21.72	€ 303,916	€ 230,975,827
			€ 2,906,419	**€ 1,763,979,282**			**€ 9,724,928**	**€ 4,713,591,626**

Table 48 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and United Kingdom (without capacity mechanism) under the first scenario

Time interval (Hours/year)	NL				UK			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	18096	51.12	€ 254,342	€ 12,717,087	58723	36.89	€ 987,679	€ 49,383,967
50-250	17714	51.12	€ 254,342	€ 50,868,347	57315	36.89	€ 987,679	€ 197,535,866
250-500	17225	47.85	€ 199,811	€ 49,952,816	55448	36.89	€ 987,679	€ 246,919,833
500-1000	16608	47.85	€ 199,811	€ 99,905,632	52879	36.89	€ 987,679	€ 493,839,665
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	50241	36.89	€ 987,679	€ 493,839,665
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	48224	36.89	€ 987,679	€ 493,839,665
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	46615	36.89	€ 987,679	€ 493,839,665
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	45271	36.89	€ 987,679	€ 493,839,665
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	43541	21.72	€ 303,916	€ 303,915,562
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	41390	21.72	€ 303,916	€ 303,915,562
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	38897	21.72	€ 303,916	€ 303,915,562
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	35477	21.72	€ 303,916	€ 303,915,562
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	30771	21.72	€ 303,916	€ 303,915,562
8000-8760	9682	47.85	€ 199,811	€ 151,856,560	25915	21.72	€ 303,916	€ 230,975,827
			€ 2,906,419	**€ 1,763,979,282**			**€ 9,724,928**	**€ 4,713,591,626**

Table 49 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and United Kingdom for the first scenario

Scenario 1	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	UK	NL	UK
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 9,167,253,975	€ 2,038,060,711	€ 9,167,253,975
Producer surplus (Euros/year)	€ 1,763,979,282	€ 4,713,591,626	€ 1,763,979,282	€ 4,713,591,626
Profits of power generators (Euros/year)	€ (274,081,429)	€ (4,453,662,349)	€ (274,081,429)	€ (4,453,662,349)
Payment given to power generators due to reliability contracts (Euros/MW/year)	€ -	€ -	€ -	€ 49,895
Total profits of power generators in the system (Euros/year)	€ (274,081,429)	€ (4,453,662,348.98)	€ (274,081,429)	€ -
Total reliable electricity production capacity of the system (MW)	23,704	84,804	23,704	84,804

Table 50 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and United Kingdom under the implementation of "capacity markets" in the UK for the second scenario

Time interval (Hours/year)	NL				UK				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Real price paid by consumers (Euro/MWh)	Real producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	20499	51.71	€ 265,667	€ 13,283,348	86753	11522.33	576.12	€ 46,445,039	€ 2,322,251,933
50-250	20066	51.71	€ 265,667	€ 53,133,393	84673	95.11	95.11	€ 5,654,157	€ 1,130,831,393
250-500	19513	51.71	€ 265,667	€ 66,416,742	81915	95.11	95.11	€ 5,654,157	€ 1,413,539,241
500-1000	18814	51.12	€ 254,342	€ 127,170,866	78119	36.89	36.89	€ 987,679	€ 493,839,665
1000-1500	18223	51.12	€ 254,342	€ 127,170,866	74222	36.89	36.89	€ 987,679	€ 493,839,665
1500-2000	17891	51.12	€ 254,342	€ 127,170,866	71242	36.89	36.89	€ 987,679	€ 493,839,665
2000-2500	17690	51.12	€ 254,342	€ 127,170,866	68865	36.89	36.89	€ 987,679	€ 493,839,665
2500-3000	17507	47.85	€ 199,811	€ 99,905,632	66880	36.89	36.89	€ 987,679	€ 493,839,665
3000-4000	17097	47.85	€ 199,811	€ 199,811,263	64324	36.89	36.89	€ 987,679	€ 987,679,330
4000-5000	16098	47.85	€ 199,811	€ 199,811,263	61146	36.89	36.89	€ 987,679	€ 987,679,330
5000-6000	14634	47.85	€ 199,811	€ 199,811,263	57463	36.89	36.89	€ 987,679	€ 987,679,330
6000-7000	13065	47.85	€ 199,811	€ 199,811,263	52411	36.89	36.89	€ 987,679	€ 987,679,330
7000-8000	11798	47.85	€ 199,811	€ 199,811,263	45459	36.89	36.89	€ 987,679	€ 987,679,330
8000-8760	10967	47.85	€ 199,811	€ 151,856,560	38285	21.72	21.72	€ 303,916	€ 230,975,827
			€ 3,213,047	**€ 1,892,335,456**				**€ 67,934,061**	**€ 12,505,193,371**

Table 51 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and United Kingdom (without capacity mechanism) under the second scenario

Time interval (Hours/year)	NL				UK				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Real price paid by consumers (Euro/MWh)	Real producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	20499	51.71	€ 265,667	€ 13,283,348	86753	11522.33	11522.33	€ 974,727,477	€ 48,736,373,845
50-250	20066	51.71	€ 265,667	€ 53,133,393	84673	95.11	95.11	€ 5,654,157	€ 1,130,831,393
250-500	19513	51.71	€ 265,667	€ 66,416,742	81915	95.11	95.11	€ 5,654,157	€ 1,413,539,241
500-1000	18814	51.12	€ 254,342	€ 127,170,866	78119	36.89	36.89	€ 987,679	€ 493,839,665
1000-1500	18223	51.12	€ 254,342	€ 127,170,866	74222	36.89	36.89	€ 987,679	€ 493,839,665
1500-2000	17891	51.12	€ 254,342	€ 127,170,866	71242	36.89	36.89	€ 987,679	€ 493,839,665
2000-2500	17690	51.12	€ 254,342	€ 127,170,866	68865	36.89	36.89	€ 987,679	€ 493,839,665
2500-3000	17507	47.85	€ 199,811	€ 99,905,632	66880	36.89	36.89	€ 987,679	€ 493,839,665
3000-4000	17097	47.85	€ 199,811	€ 199,811,263	64324	36.89	36.89	€ 987,679	€ 987,679,330
4000-5000	16098	47.85	€ 199,811	€ 199,811,263	61146	36.89	36.89	€ 987,679	€ 987,679,330
5000-6000	14634	47.85	€ 199,811	€ 199,811,263	57463	36.89	36.89	€ 987,679	€ 987,679,330
6000-7000	13065	47.85	€ 199,811	€ 199,811,263	52411	36.89	36.89	€ 987,679	€ 987,679,330
7000-8000	11798	47.85	€ 199,811	€ 199,811,263	45459	36.89	36.89	€ 987,679	€ 987,679,330
8000-8760	10967	47.85	€ 199,811	€ 151,856,560	38285	21.72	21.72	€ 303,916	€ 230,975,827
			€ 3,213,047	**€ 1,892,335,456**				**€ 996,216,500**	**€ 58,919,315,283**

Table 52 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and United Kingdom for the second scenario

Scenario 2	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	UK	NL	UK
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 9,167,253,975	€ 2,038,060,711	€ 9,167,253,975
Producer surplus (Euros/year)	€ 1,892,335,456	€ 58,919,315,283	€ 1,892,335,456	€ 12,505,193,371
Profits of power generators (Euros/year)	€ (145,725,255)	€ 49,752,061,308	€ (145,725,255)	€ 3,337,939,396
Payment given to power generatos due to reliability contracts (Euros/MW/year)	€ -	€ -	€ -	€ -
Total profits of power generators in the system (Euros/year)	€ (145,725,255)	€ 49,752,061,308.29	€ (145,725,255)	€ 3,337,939,396.27
Total reliable electricity production capacity of the system (MW)	23,704	84,804	23,704	84,804

Table 53 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and United Kingdom under the implementation of "capacity markets" in the UK for the third scenario

Time interval (Hours/year)	NL				UK				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Real price paid by consumers (Euro/MWh)	Real producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	24952	8600.00	€ 202,891,947	€ 10,144,597,358	63832	36.89	36.89	€ 987,679	€ 49,383,967
50-250	24425	58.48	€ 423,757	€ 84,751,417	62301	36.89	36.89	€ 987,679	€ 197,535,866
250-500	23751	51.71	€ 265,667	€ 66,416,742	60272	36.89	36.89	€ 987,679	€ 246,919,833
500-1000	22900	51.71	€ 265,667	€ 132,833,483	57479	36.89	36.89	€ 987,679	€ 493,839,665
1000-1500	22181	51.71	€ 265,667	€ 132,833,483	54612	36.89	36.89	€ 987,679	€ 493,839,665
1500-2000	21777	51.71	€ 265,667	€ 132,833,483	52419	36.89	36.89	€ 987,679	€ 493,839,665
2000-2500	21532	51.71	€ 265,667	€ 132,833,483	50670	36.89	36.89	€ 987,679	€ 493,839,665
2500-3000	21310	51.71	€ 265,667	€ 132,833,483	49209	36.89	36.89	€ 987,679	€ 493,839,665
3000-4000	20811	51.71	€ 265,667	€ 265,666,966	47329	36.89	36.89	€ 987,679	€ 987,679,330
4000-5000	19595	51.12	€ 254,342	€ 254,341,733	44991	36.89	36.89	€ 987,679	€ 987,679,330
5000-6000	17812	51.12	€ 254,342	€ 254,341,733	42281	21.72	21.72	€ 303,916	€ 303,915,562
6000-7000	15902	47.85	€ 199,811	€ 199,811,263	38563	21.72	21.72	€ 303,916	€ 303,915,562
7000-8000	14361	47.85	€ 199,811	€ 199,811,263	33448	21.72	21.72	€ 303,916	€ 303,915,562
8000-8760	13350	47.85	€ 199,811	€ 151,856,560	28169	21.72	21.72	€ 303,916	€ 230,975,827
			€ 206,283,490	**€ 12,285,762,451**				**€ 11,092,456**	**€ 6,081,119,163**

Table 54 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and United Kingdom (without capacity mechanism) under the third scenario

Time interval (Hours/year)	NL				UK				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Real price paid by consumers (Euro/MWh)	Real producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	24952	8600.00	€ 202,891,947	€ 10,144,597,358	63832	36.89	36.89	€ 987,679	€ 49,383,967
50-250	24425	58.48	€ 423,757	€ 84,751,417	62301	36.89	36.89	€ 987,679	€ 197,535,866
250-500	23751	51.71	€ 265,667	€ 66,416,742	60272	36.89	36.89	€ 987,679	€ 246,919,833
500-1000	22900	51.71	€ 265,667	€ 132,833,483	57479	36.89	36.89	€ 987,679	€ 493,839,665
1000-1500	22181	51.71	€ 265,667	€ 132,833,483	54612	36.89	36.89	€ 987,679	€ 493,839,665
1500-2000	21777	51.71	€ 265,667	€ 132,833,483	52419	36.89	36.89	€ 987,679	€ 493,839,665
2000-2500	21532	51.71	€ 265,667	€ 132,833,483	50670	36.89	36.89	€ 987,679	€ 493,839,665
2500-3000	21310	51.71	€ 265,667	€ 132,833,483	49209	36.89	36.89	€ 987,679	€ 493,839,665
3000-4000	20811	51.71	€ 265,667	€ 265,666,966	47329	36.89	36.89	€ 987,679	€ 987,679,330
4000-5000	19595	51.12	€ 254,342	€ 254,341,733	44991	36.89	36.89	€ 987,679	€ 987,679,330
5000-6000	17812	51.12	€ 254,342	€ 254,341,733	42281	21.72	21.72	€ 303,916	€ 303,915,562
6000-7000	15902	47.85	€ 199,811	€ 199,811,263	38563	21.72	21.72	€ 303,916	€ 303,915,562
7000-8000	14361	47.85	€ 199,811	€ 199,811,263	33448	21.72	21.72	€ 303,916	€ 303,915,562
8000-8760	13350	47.85	€ 199,811	€ 151,856,560	28169	21.72	21.72	€ 303,916	€ 230,975,827
			€ 206,283,490	**€ 12,285,762,451**				**€ 11,092,456**	**€ 6,081,119,163**

Table 55 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and United Kingdom for the third scenario

Scenario 3	**Model without capacity mechanisms**		**Model with capacity mechanisms**	
	NL	**UK**	**NL**	**UK**
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 9,167,253,975	€ 2,038,060,711	€ 9,167,253,975
Producer surplus (Euros/year)	€ 12,285,762,451	€ 6,081,119,163	€ 12,285,762,451	€ 6,081,119,163
Profits of power generators (Euros/year)	€ 10,247,701,740	€ (3,086,134,812)	€ 10,247,701,740	€ (3,086,134,812)
Payment given to power generators due to reliability contracts (Euros/MW/year)	€ -	€ -	€ -	€ 34,574
Total profits of power generators in the system (Euros/year)	€ 10,247,701,740	€ (3,086,134,811.61)	€ 10,247,701,740	€ -
Total reliable electricity production capacity of the system (MW)	23,704	84,804	23,704	84,804

Table 56 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and United Kingdom under the implementation of "capacity markets" in the UK for the fourth scenario

Time interval (Hours/year)	NL				UK				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Real price paid by consumers (Euro/MWh)	Real producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	25670	8600.00	€ 202,891,947	€ 10,144,597,358	86753	11522.33	576.12	€ 46,445,039	€ 2,322,251,933
50-250	25128	8600.00	€ 202,891,947	€ 40,578,389,433	84673	95.11	95.11	€ 5,654,157	€ 1,130,831,393
250-500	24434	95.11	€ 1,292,142	€ 323,035,392	81915	95.11	95.11	€ 5,654,157	€ 1,413,539,241
500-1000	23559	51.71	€ 265,667	€ 132,833,483	78119	36.89	36.89	€ 987,679	€ 493,839,665
1000-1500	22820	51.71	€ 265,667	€ 132,833,483	74222	36.89	36.89	€ 987,679	€ 493,839,665
1500-2000	22404	51.71	€ 265,667	€ 132,833,483	71242	36.89	36.89	€ 987,679	€ 493,839,665
2000-2500	22152	51.71	€ 265,667	€ 132,833,483	68865	36.89	36.89	€ 987,679	€ 493,839,665
2500-3000	21923	51.71	€ 265,667	€ 132,833,483	66880	36.89	36.89	€ 987,679	€ 493,839,665
3000-4000	21410	51.71	€ 265,667	€ 265,666,966	64324	36.89	36.89	€ 987,679	€ 987,679,330
4000-5000	20159	51.12	€ 254,342	€ 254,341,733	61146	36.89	36.89	€ 987,679	€ 987,679,330
5000-6000	18324	51.12	€ 254,342	€ 254,341,733	57463	36.89	36.89	€ 987,679	€ 987,679,330
6000-7000	16360	47.85	€ 199,811	€ 199,811,263	52411	36.89	36.89	€ 987,679	€ 987,679,330
7000-8000	14774	47.85	€ 199,811	€ 199,811,263	45459	36.89	36.89	€ 987,679	€ 987,679,330
8000-8760	13734	47.85	€ 199,811	€ 151,856,560	38285	21.72	21.72	€ 303,916	€ 230,975,827
			€ 409,778,155	**€ 53,036,019,117**				**€ 67,934,061**	**€ 12,505,193,371**

Table 57 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and United Kingdom (without capacity mechanism) under the fourth scenario

Time interval (Hours/year)	NL				UK				
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Real price paid by consumers (Euro/MWh)	Real producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	25670	8600.00	€ 202,891,947	€ 10,144,597,358	86753	11522.33	11522.33	€ 974,727,477	€ 48,736,373,845
50-250	25128	8600.00	€ 202,891,947	€ 40,578,389,433	84673	95.11	95.11	€ 5,654,157	€ 1,130,831,393
250-500	24434	95.11	€ 1,292,142	€ 323,035,392	81915	95.11	95.11	€ 5,654,157	€ 1,413,539,241
500-1000	23559	51.71	€ 265,667	€ 132,833,483	78119	36.89	36.89	€ 987,679	€ 493,839,665
1000-1500	22820	51.71	€ 265,667	€ 132,833,483	74222	36.89	36.89	€ 987,679	€ 493,839,665
1500-2000	22404	51.71	€ 265,667	€ 132,833,483	71242	36.89	36.89	€ 987,679	€ 493,839,665
2000-2500	22152	51.71	€ 265,667	€ 132,833,483	68865	36.89	36.89	€ 987,679	€ 493,839,665
2500-3000	21923	51.71	€ 265,667	€ 132,833,483	66880	36.89	36.89	€ 987,679	€ 493,839,665
3000-4000	21410	51.71	€ 265,667	€ 265,666,966	64324	36.89	36.89	€ 987,679	€ 987,679,330
4000-5000	20159	51.12	€ 254,342	€ 254,341,733	61146	36.89	36.89	€ 987,679	€ 987,679,330
5000-6000	18324	51.12	€ 254,342	€ 254,341,733	57463	36.89	36.89	€ 987,679	€ 987,679,330
6000-7000	16360	47.85	€ 199,811	€ 199,811,263	52411	36.89	36.89	€ 987,679	€ 987,679,330
7000-8000	14774	47.85	€ 199,811	€ 199,811,263	45459	36.89	36.89	€ 987,679	€ 987,679,330
8000-8760	13734	47.85	€ 199,811	€ 151,856,560	38285	21.72	21.72	€ 303,916	€ 230,975,827
			€ 409,778,155	**€ 53,036,019,117**				**€ 996,216,500**	**€ 58,919,315,283**

Table 58 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and United Kingdom for the fourth scenario

Scenario 4	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	UK	NL	UK
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 9,167,253,975	€ 2,038,060,711	€ 9,167,253,975
Producer surplus (Euros/year)	€ 53,036,019,117	€ 58,919,315,283	€ 53,036,019,117	€ 12,505,193,371
Profits of power generators (Euros/year)	€ 50,997,958,407	€ 49,752,061,308	€ 50,997,958,407	€ 3,337,939,396
Payment given to power generatos due to reliability contracts (Euros/MW/year)	€ -	€ -	€ -	€ -
Total profits of power generators in the system (Euros/year)	€ 50,997,958,407	€ 49,752,061,308.29	€ 50,997,958,407	€ 3,337,939,396.27
Total reliable electricity production capacity of the system (MW)	23,704	84,804	23,704	84,804

Table 59 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Norway under the implementation of operating reserves in Norway for the first scenario

Time interval (Hours/year)	NL				NO			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	total producer surplus (Euros/year)
0-50	18096	51.12	€ 254,342	€ 12,717,087	21899	3.79	€ 342	€ 17,097
50-250	17714	51.12	€ 254,342	€ 50,868,347	21840	3.79	€ 342	€ 68,387
250-500	17225	47.85	€ 199,811	€ 49,952,816	21659	3.79	€ 342	€ 85,484
500-1000	16608	47.85	€ 199,811	€ 99,905,632	21195	3.79	€ 342	€ 170,969
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	20423	3.79	€ 342	€ 170,969
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	19610	3.79	€ 342	€ 170,969
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	18818	3.79	€ 342	€ 170,969
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	18050	3.79	€ 342	€ 170,969
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	16899	3.79	€ 342	€ 341,937
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	15292	3.79	€ 342	€ 341,937
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	13730	3.79	€ 342	€ 341,937
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	12552	3.79	€ 342	€ 341,937
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	11787	3.79	€ 342	€ 341,937
8000-8760	9682	47.85	€ 199,811	€ 151,856,560	10456	3.79	€ 342	€ 259,872
			€ 2,906,419	**€ 1,763,979,282**			**€ 4,787**	**€ 2,995,369**

Table 60 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Norway (without capacity mechanism) under the first scenario

Time interval (Hours/year)	NL				NO			
	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Producer surplus (Euros/h)	total producer surplus (Euros/year)
0-50	18096	51.12	€ 254,342	€ 12,717,087	21899	3.79	€ 342	€ 17,097
50-250	17714	51.12	€ 254,342	€ 50,868,347	21840	3.79	€ 342	€ 68,387
250-500	17225	47.85	€ 199,811	€ 49,952,816	21659	3.79	€ 342	€ 85,484
500-1000	16608	47.85	€ 199,811	€ 99,905,632	21195	3.79	€ 342	€ 170,969
1000-1500	16087	47.85	€ 199,811	€ 99,905,632	20423	3.79	€ 342	€ 170,969
1500-2000	15794	47.85	€ 199,811	€ 99,905,632	19610	3.79	€ 342	€ 170,969
2000-2500	15616	47.85	€ 199,811	€ 99,905,632	18818	3.79	€ 342	€ 170,969
2500-3000	15455	47.85	€ 199,811	€ 99,905,632	18050	3.79	€ 342	€ 170,969
3000-4000	15093	47.85	€ 199,811	€ 199,811,263	16899	3.79	€ 342	€ 341,937
4000-5000	14211	47.85	€ 199,811	€ 199,811,263	15292	3.79	€ 342	€ 341,937
5000-6000	12918	47.85	€ 199,811	€ 199,811,263	13730	3.79	€ 342	€ 341,937
6000-7000	11533	47.85	€ 199,811	€ 199,811,263	12552	3.79	€ 342	€ 341,937
7000-8000	10415	47.85	€ 199,811	€ 199,811,263	11787	3.79	€ 342	€ 341,937
8000-8760	9682	47.85	€ 199,811	€ 151,856,560	10456	3.79	€ 342	€ 259,872
			€ 2,906,419	**€ 1,763,979,282**			**€ 4,787**	**€ 2,995,369**

Table 61 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and Norway for the first scenario

Scenario 1	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	NO	NL	NO
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 3,402,871,515	€ 2,038,060,711	€ 3,402,871,515
Producer surplus (Euros/year)	€ 1,763,979,282	€ 2,995,369	€ 1,763,979,282	€ 2,995,369
Profits of power generators (Euros/year)	€ (274,081,429)	€ (3,399,876,146)	€ (274,081,429)	€ (3,399,876,146)
Payment given to operating reserve generators (Euros/MW/year)	€ -	€ -	€ -	€ 135,263
Surplus operating reserve units	€ -	€ -	€ -	€ 75,493.38
Total costs of operating reserve units	-	-	-	296,165,294
Total profits of power generators in the system (Euros/year)	€ (274,081,429)	€ (3,399,876,146)	€ (274,081,429)	€ (3,103,786,345)
Total reliable electricity production capacity of the system (MW)	€ 23,704	€ 24,051	€ 23,704	€ 24,051

Table 62 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Norway under the implementation of operating reserves in Norway for the second scenario

Time interval (Hours/year)	NL					NO				
	Demand (MW)	Price (Euro/MWh)	Operational reserves sold to NL (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Operational reserves used in NO (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	20499	51.71	0.00	€ 265,667	€ 13,283,348	24807.25644	6886.67	900.00	€ 159,347,113	€ 7,967,355,668
50-250	20066	51.71	0.00	€ 265,667	€ 53,133,393	24740.42105	51.71	900.00	€ 1,108,286	€ 221,657,216
250-500	19513	51.71	0.00	€ 265,667	€ 66,416,742	24535.38368	51.71	900.00	€ 1,108,286	€ 277,071,520
500-1000	18814	51.12	41.64	€ 254,342	€ 127,170,866	24009.76301	45.70	858.36	€ 969,254	€ 484,626,954
1000-1500	18223	51.12	683.84	€ 254,342	€ 127,170,866	23135.23897	45.70	0.00	€ 969,254	€ 484,626,954
1500-2000	17891	51.12	0.00	€ 254,342	€ 127,170,866	22214.27	7.96	0.00	€ 95,379	€ 47,689,466
2000-2500	17690	51.12	0.00	€ 254,342	€ 127,170,866	21317.0899	3.79	0.00	€ 342	€ 170,969
2500-3000	17507	51.12	0.00	€ 254,342	€ 127,170,866	20447.09707	3.79	0.00	€ 342	€ 170,969
3000-4000	17097	47.85	0.00	€ 199,811	€ 199,811,263	19143.24063	3.79	0.00	€ 342	€ 341,937
4000-5000	16098	47.85	0.00	€ 199,811	€ 199,811,263	17322.82595	3.79	0.00	€ 342	€ 341,937

5000-6000	14634	47.85	0.00	€ 199,811	€ 199,811,263	15553.38741	3.79	0.00	€ 342	€ 341,937
6000-7000	13065	47.85	0.00	€ 199,811	€ 199,811,263	14218.94529	3.79	0.00	€ 342	€ 341,937
7000-8000	11798	47.85	0.00	€ 199,811	€ 199,811,263	13352.35087	3.79	0.00	€ 342	€ 341,937
8000-8760	10967	47.85	0.00	€ 199,811	€ 151,856,560	11844.58986	3.79	0.00	€ 342	€ 259,872
				€ 3,267,577	**€ 1,919,600,691**				**€ 163,600,308**	**€ 9,485,339,272**

Table 63 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Norway (without capacity mechanism) under the second scenario

Time interval (Hours/year)	NL					NO				
	Demand (MW)	Price (Euro/MWh)	Operational reserves sold to NL (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Operational reserves used in NO (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	20499	51.71	0.00	€ 265,667	€ 13,283,348	24807.25644	6886.67	0.00	€ 165,503,980	€ 8,275,198,981
50-250	20066	51.71	0.00	€ 265,667	€ 53,133,393	24740.42105	51.71	0.00	€ 1,108,286	€ 221,657,216
250-500	19513	51.71	0.00	€ 265,667	€ 66,416,742	24535.38368	51.71	0.00	€ 1,108,286	€ 277,071,520
500-1000	18814	51.12	0.00	€ 254,342	€ 127,170,866	24009.76301	45.70	0.00	€ 969,254	€ 484,626,954
1000-1500	18223	51.12	0.00	€ 254,342	€ 127,170,866	23135.23897	45.70	0.00	€ 969,254	€ 484,626,954
1500-2000	17891	51.12	0.00	€ 254,342	€ 127,170,866	22214.27	7.96	0.00	€ 95,379	€ 47,689,466
2000-2500	17690	51.12	0.00	€ 254,342	€ 127,170,866	21317.0899	3.79	0.00	€ 342	€ 170,969
2500-3000	17507	51.12	0.00	€ 254,342	€ 127,170,866	20447.09707	3.79	0.00	€ 342	€ 170,969

3000-4000	17097	47.85	0.00	€ 199,811	€ 199,811,263	19143.24063	3.79	0.00	€ 342	€ 341,937
4000-5000	16098	47.85	0.00	€ 199,811	€ 199,811,263	17322.82595	3.79	0.00	€ 342	€ 341,937
5000-6000	14634	47.85	0.00	€ 199,811	€ 199,811,263	15553.38741	3.79	0.00	€ 342	€ 341,937
6000-7000	13065	47.85	0.00	€ 199,811	€ 199,811,263	14218.94529	3.79	0.00	€ 342	€ 341,937
7000-8000	11798	47.85	0.00	€ 199,811	€ 199,811,263	13352.35087	3.79	0.00	€ 342	€ 341,937
8000-8760	10967	47.85	0.00	€ 199,811	€ 151,856,560	11844.58986	3.79	0.00	€ 342	€ 259,872
				€ 3,267,577	**€ 1,919,600,691**				**€ 169,757,174**	**€ 9,793,182,585**

Table 64 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and Norway for the second scenario

Scenario 2	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	NO	NL	NO
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 3,402,871,515	€ 2,038,060,711	€ 3,402,871,515
Producer surplus (Euros/year)	€ 1,919,600,691	€ 9,793,182,585	€ 1,919,600,691	€ 9,485,339,272
Profits of power generators (Euros/year)	€ (118,460,020)	€ 6,390,311,070	€ (118,460,020)	€ 6,082,467,757
Payment given to operating reserve generators (Euros/MW/year)	€ -	€ -	€ -	€ 63,418
Surplus operating reserve units	€ -	€ -	€ -	€ -
Total costs of operating reserve units	-	-	-	57,075,800
Total profits of power generators in the system (Euros/year)	€ (118,460,020)	€ 6,390,311,070	€ (118,460,020)	€ 6,139,543,557
Total reliable electricity production capacity of the system (MW)	€ 23,704	€ 24,051	€ 23,704	€ 24,051

Table 65 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Norway under the implementation of operating reserves in Norway for the third scenario

Time interval (Hours/year)	NL					NO				
	Demand (MW)	Price (Euro/MWh)	Operational reserves sold to NL (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Operational reserves used in NO (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	24599	8600.00	700.00	€ 202,891,947	€ 10,144,597,358	22780.63575	3.79	0.00	€ 14,244	€ 712,191
50-250	24080	58.48	636.16	€ 423,757	€ 84,751,417	22719.26046	3.79	0.00	€ 14,244	€ 2,848,765
250-500	23415	51.71	447.87	€ 265,667	€ 66,416,742	22530.97355	3.79	0.00	€ 14,244	€ 3,560,956
500-1000	22576	51.71	0.00	€ 265,667	€ 132,833,483	22048.29329	3.79	0.00	€ 342	€ 170,969
1000-1500	21868	51.71	0.00	€ 265,667	€ 132,833,483	21245.2132	3.79	0.00	€ 342	€ 170,969
1500-2000	21470	51.71	0.00	€ 265,667	€ 132,833,483	20399.48249	3.79	0.00	€ 342	€ 170,969
2000-2500	21228	51.71	0.00	€ 265,667	€ 132,833,483	19575.59722	3.79	0.00	€ 342	€ 170,969
2500-3000	21009	51.71	0.00	€ 265,667	€ 132,833,483	18776.67817	3.79	0.00	€ 342	€ 170,969
3000-4000	20517	51.71	0.00	€ 265,667	€ 265,666,966	17579.33986	3.79	0.00	€ 342	€ 341,937
4000-5000	19318	51.12	0.00	€ 254,342	€ 254,341,733	15907.64336	3.79	0.00	€ 342	€ 341,937

5000-6000	17560	51.12	0.00	€ 254,342	€ 254,341,733	14282.75852	3.79	0.00	€ 342	€ 341,937
6000-7000	15677	47.85	0.00	€ 199,811	€ 199,811,263	13057.33321	3.79	0.00	€ 342	€ 341,937
7000-8000	14158	47.85	0.00	€ 199,811	€ 199,811,263	12261.53494	3.79	0.00	€ 342	€ 341,937
8000-8760	13161	47.85	0.00	€ 199,811	€ 151,856,560	10876.94997	3.79	0.00	€ 342	€ 259,872
				€ 206,283,490	**€ 12,285,762,451**				**€ 46,493**	**€ 9,946,313**

Table 66 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Norway (without capacity mechanism) under the third scenario

Time interval (Hours/year)	NL					NO				
	Demand (MW)	Price (Euro/MWh)	Operational reserves sold to NL (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Operational reserves used in NO (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	24599	8600.00	0.00	€ 202,891,947	€ 10,144,597,358	22780.63575	45.70	0.00	€ 969,254	€ 48,462,695
50-250	24080	58.48	0.00	€ 423,757	€ 84,751,417	22719.26046	45.70	0.00	€ 969,254	€ 193,850,781
250-500	23415	51.71	0.00	€ 265,667	€ 66,416,742	22530.97355	45.70	0.00	€ 969,254	€ 242,313,477
500-1000	22576	51.71	0.00	€ 265,667	€ 132,833,483	22048.29329	3.79	0.00	€ 342	€ 170,969
1000-1500	21868	51.71	0.00	€ 265,667	€ 132,833,483	21245.2132	3.79	0.00	€ 342	€ 170,969
1500-2000	21470	51.71	0.00	€ 265,667	€ 132,833,483	20399.48249	3.79	0.00	€ 342	€ 170,969
2000-2500	21228	51.71	0.00	€ 265,667	€ 132,833,483	19575.59722	3.79	0.00	€ 342	€ 170,969
2500-3000	21009	51.71	0.00	€	€	18776.67817	3.79	0.00	€	€

				265,667	132,833,483				342	170,969
3000-4000	20517	51.71	0.00	€ 265,667	€ 265,666,966	17579.33986	3.79	0.00	€ 342	€ 341,937
4000-5000	19318	51.12	0.00	€ 254,342	€ 254,341,733	15907.64336	3.79	0.00	€ 342	€ 341,937
5000-6000	17560	51.12	0.00	€ 254,342	€ 254,341,733	14282.75852	3.79	0.00	€ 342	€ 341,937
6000-7000	15677	47.85	0.00	€ 199,811	€ 199,811,263	13057.33321	3.79	0.00	€ 342	€ 341,937
7000-8000	14158	47.85	0.00	€ 199,811	€ 199,811,263	12261.53494	3.79	0.00	€ 342	€ 341,937
8000-8760	13161	47.85	0.00	€ 199,811	€ 151,856,560	10876.94997	3.79	0.00	€ 342	€ 259,872
				€ 206,283,490	**€ 12,285,762,451**				**€ 2,911,523**	**€ 487,451,354**

Table 67 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and Norway for the third scenario

Scenario 3	Model without capacity mechanisms		Model with capacity mechanisms	
	NL	NO	NL	NO
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 3,402,871,515	€ 2,038,060,711	€ 3,402,871,515
Producer surplus (Euros/year)	€ 12,285,762,451	€ 487,451,354	€ 12,285,762,451	€ 9,946,313
Profits of power generators (Euros/year)	€ 10,247,701,740	€ (2,915,420,161)	€ 10,247,701,740	€ (3,392,925,202)
Payment given to operating reserve generators (Euros/MW/year)	€ -	€ -	€ -	€ 155,779
Surplus operating reserve units	€ -	€ -	€ -	€ 41,705.66
Total costs of operating reserve units	-	-	-	198,036,599
Total profits of power generators in the system (Euros/year)	€ 10,247,701,740	€ (2,915,420,161)	€ 10,247,701,740	€ (3,194,930,308)
Total reliable electricity production capacity of the system (MW)	€ 23,704	€ 24,051	€ 23,704	€ 24,051

Table 68 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Norway under the implementation of operating reserves in Norway for the fourth scenario

Time interval (Hours/year)	NL					NO				
	Demand (MW)	Price (Euro/MWh)	Operational reserves sold to NL (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Operational reserves used in NO (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	23906	6886.67	0.00	162279093.83	€ 8,113,954,692	24373.11017	6886.67	900.00	159347113.37	€ 7,967,355,668
50-250	23401	58.48	0.00	423757.08	€ 84,751,417	24307.44446	58.48	900.00	1265032.58	€ 253,006,515
250-500	22755	51.71	0.00	265666.97	€ 66,416,742	24105.9954	51.71	900.00	1108286.08	€ 277,071,520
500-1000	21940	51.71	461.83	265666.97	€ 132,833,483	23589.5735	7.96	438.17	95378.93	€ 47,689,466
1000-1500	21252	51.71	278.95	265666.97	€ 132,833,483	22730.35431	7.96	0.00	95378.93	€ 47,689,466
1500-2000	20865	51.71	0.00	265666.97	€ 132,833,483	21825.50301	3.79	0.00	341.94	€ 170,969
2000-2500	20630	51.71	0.00	265666.97	€ 132,833,483	20944.02426	3.79	0.00	341.94	€ 170,969
2500-3000	20417	51.71	0.00	265666.97	€ 132,833,483	20089.25698	3.79	0.00	341.94	€ 170,969
3000-4000	19939	51.71	0.00	265666.97	€ 265,666,966	18808.21904	3.79	0.00	341.94	€ 341,937
4000-5000	18774	51.12	0.00	254341.73	€ 254,341,733	17019.66303	3.79	0.00	341.94	€ 341,937

5000-6000	17066	47.85	0.00	199811.26	€ 199,811,263	15281.19104	3.79	0.00	341.94	€ 341,937
6000-7000	15236	47.85	0.00	199811.26	€ 199,811,263	13970.10269	3.79	0.00	341.94	€ 341,937
7000-8000	13759	47.85	0.00	199811.26	€ 199,811,263	13118.67435	3.79	0.00	341.94	€ 341,937
8000-8760	12790	47.85	0.00	199811.26	€ 151,856,560	11637.30033	3.79	0.00	341.94	€ 259,872

Table 69 Electricity prices, demand and producer surplus experienced in the wholesale electricity market of the Netherlands and Norway (without capacity mechanism) under the fourth scenario

Time interval (Hours/year)	NL					NO				
	Demand (MW)	Price (Euro/MWh)	Operational reserves sold to NL (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)	Demand (MW)	Price (Euro/MWh)	Operational reserves used in NO (MW)	Producer surplus (Euros/h)	Total producer surplus (Euros/year)
0-50	23906	6886.67	0.00	162279093.83	€ 8,113,954,692	24373.11017	6886.67	0.00	€ 165,503,980	€ 8,275,198,981
50-250	23401	58.48	0.00	423757.08	€ 84,751,417	24307.44446	58.48	0.00	€ 1,265,033	€ 253,006,515
250-500	22755	51.71	0.00	265666.97	€ 66,416,742	24105.9954	51.71	0.00	€ 1,108,286	€ 277,071,520
500-1000	21940	51.71	0.00	265666.97	€ 132,833,483	23589.5735	45.70	0.00	€ 969,254	€ 484,626,954
1000-1500	21252	51.71	0.00	265666.97	€ 132,833,483	22730.35431	45.70	0.00	€ 969,254	€ 484,626,954
1500-2000	20865	51.71	0.00	265666.97	€ 132,833,483	21825.50301	3.79	0.00	€ 342	€ 170,969
2000-2500	20630	51.71	0.00	265666.97	€ 132,833,483	20944.02426	3.79	0.00	€ 342	€ 170,969
2500-3000	20417	51.71	0.00	265666.97	€ 132,833,483	20089.25698	3.79	0.00	€ 342	€ 170,969
3000-4000	19939	51.71	0.00	265666.97	€ 265,666,966	18808.21904	3.79	0.00	€ 342	€ 341,937

4000-5000	18774	51.12	0.00	254341.73	€ 254,341,733	17019.66303	3.79	0.00	€ 342	€ 341,937
5000-6000	17066	47.85	0.00	199811.26	€ 199,811,263	15281.19104	3.79	0.00	€ 342	€ 341,937
6000-7000	15236	47.85	0.00	199811.26	€ 199,811,263	13970.10269	3.79	0.00	€ 342	€ 341,937
7000-8000	13759	47.85	0.00	199811.26	€ 199,811,263	13118.67435	3.79	0.00	€ 342	€ 341,937
8000-8760	12790	47.85	0.00	199811.26	€ 151,856,560	11637.30033	3.79	0.00	€ 342	€ 259,872
				€ 165,616,106	**€ 10,200,589,314**				**€ 169,818,884**	**€ 9,777,013,387**

Table 70 Additional indicators calculated from the modeled electricity wholesale market of Netherlands and Norway for the third scenario

Scenario 4	**Model without capacity mechanisms**		**Model with capacity mechanisms**	
	NL	**NO**	**NL**	**NO**
Total fixed cost of electricity production (Euros/year)	€ 2,038,060,711	€ 3,402,871,515	€ 2,038,060,711	€ 3,402,871,515
Producer surplus (Euros/year)	€ 10,200,589,314	€ 9,777,013,387	€ 10,200,589,314	€ 8,595,295,098
Profits of power generators (Euros/year)	€ 8,162,528,603	€ 6,374,141,872	€ 8,162,528,603	€ 5,192,423,583
Payment given to operating reserve generators (Euros/MW/year)	€ -	€ -	€ -	€ 63,418
Surplus operating reserve units	€ -	€ -	€ -	€ -
Total costs of operating reserve units	-	-	-	57,075,800
Total profits of power generators in the system (Euros/year)	€ 8,162,528,603	€ 6,374,141,872	€ 8,162,528,603	€ 5,249,499,383
Total reliable electricity production capacity of the system (MW)	€ 23,704	€ 24,051	€ 23,704	€ 24,051

8.2. Appendix 8: Assessment of the policy options

→Do nothing:

- Producer operational profits—*Green*—: Under the implementation of capacity mechanisms, mainly in France, electricity prices increases dramatically as it was explained in Chapter 4. Therefore, if the Netherland do nothing, the result would be very high prices in the Dutch market caused by the French capacity mechanism. Thus Dutch electricity producers earn very good profits. This results based on the modeling outputs are valid for the short-term.
- Excess reliable capacity production (Orange): The results of the model concerning total profits of electricity producers—*implementation of French capacity mechanism*—suggest that Dutch peak generators are not dispatched frequently enough to recover their total costs of production. Additionally, the losses generated for the (peak) producers of the Dutch wholesale market might lead them—*if possible according to the law*—, as rational actors (Kirshen and Strabac 2004), to offer their production capacity in Germany as strategic reserve, which would generate profits. At the same time, through such actions of the producers, the reliability production capacity in the Dutch electricity system would be reduced in the short-term
- Electricity prices paid by Dutch consumers (Red): As it was explained in Chapter 4, the implementation of a capacity mechanism in France would increase electricity prices dramatically. Therefore, if the Netherlands do nothing, electricity prices would still be high in the Dutch market. In case of scarcity in both countries the Netherlands experience very high electricity prices on average and therefore according to the assessment this is bad
- Transfer of money to neighboring countries with capacity mechanism (orange): As it was described in Chapter 4, high electricity prices in one market encourage imports of electricity from a market with lower electricity prices. Therefore, since electricity prices in the Netherlands appear to be higher than in France*, the* Netherlands would import excess production capacity from the French system. As a consequence, some of the electricity produced by French generators is purchased in the Netherlands and therefore is paid by Dutch consumers, contributing to the operational profits of generation units in France.

This distributional effect, which is caused by the coupling and trade between the two markets seem to be more important under the implementation of a capacity mechanism in France. This is because the trade of excess electricity production from the French system—*electricity production capacity that is not required in periods of low electricity consumption in France*— would reduce the payment for "Obligation de Capacité" given to French generators to recover their total costs of production without improving the reliability of the Dutch electricity system in the short-term.

→European Capacity mechanism:

- Producer operational profits (Yellow): The implementation of a single European capacity mechanism would provide the Netherlands with the theoretical benefits of a capacity mechanism. This is a reduction in profits under scarcity situations in comparison with the situation in which the Netherlands do nothing. The reduction in profits caused by the implementation of a capacity mechanism is supported by the results of the model analyzed in Chapter 4. It shows than under scarcity conditions and a local implementation of a capacity mechanism, profits earned by generators go down.
- Excess reliable capacity production (Green): Since the European capacity mechanism attempts to allocate optimally production capacity all over the European countries. It is reasonable to consider that due to the additional payments given to Dutch generators due the European capacity mechanism, Power generators would invest in new power plants and therefore the Netherlands would increase their production capacity in comparison to the do nothing situation
- Electricity prices paid by Dutch consumers (Yellow): Since the theoretical effect of a capacity mechanism is to depress electricity prices in the system where it has been implemented—this effect is also supported by the model results of Germany, United Kingdom and Norway—. It is reasonable to consider that it would reduce electricity prices in the Dutch wholesale market under scarcity of electricity production. Therefore it can be considered and improvement in comparison with the do nothing situation where electricity prices are very high

- Transfer of money to neighboring countries with capacity mechanism (Green): There are still distributional effects, which are caused by the trading of electricity between the Netherlands and the other countries of NWE. However, since in this version of European capacity mechanism all the European countries are paying for the capacity mechanism and in return their reliability is improved, it seems reasonable to think that the distributional effects are not longer important for the Netherlands as this can be considered part of the payment for a more reliable electricity system.

→Dutch capacity mechanism

- Producer operational profits (Yellow): The implementation of a Dutch capacity mechanism would provide the Netherlands with the theoretical benefits of a capacity mechanism. Dutch generator's profits in scarcity periods would decrease in comparison with the situation in which the Netherlands do nothing. The reduction in profits caused by the implementation of a capacity mechanism is supported by the results of the model analyzed in Chapter 4. It shows than under scarcity conditions and a local implementation of a capacity mechanism, profits earned by generators in the wholesale market decline.
- Excess reliable capacity production (Yellow): Since the Dutch capacity mechanism attempts to allocate production capacity only in the Netherlands it can be said that is not as optimal as the European mechanism. This is because in the Dutch capacity mechanism, reliable production would only be provided locally by Dutch producers. In contrast, with the European capacity mechanism, reliability of electricity would be supported by the production capacity of all European countries. It is reasonable to consider that due to the additional payments given to Dutch generators due the European capacity mechanism, Power generators would invest in new power plants and therefore the Netherlands would increase their production capacity in comparison to the do nothing situation
- Electricity prices paid by Dutch consumers (Yellow): Since the theoretical effect of a capacity mechanism is to depress electricity prices in the system where it has been implemented—*this effect is also supported by the model results of Germany, United Kingdom and Norway*—. It seems reasonable to consider that

a Dutch capacity mechanism would reduce electricity prices in the Dutch wholesale market in periods of scarce electricity production. Therefore it can be considered an improvement in comparison with the do nothing situation where electricity prices are very high. In contrast, there are no evident reasons to think that it will perform better or worse than the European capacity mechanism.

- Transfer of money to neighboring countries with capacity mechanism (Yellow): Under the implementation of a Dutch capacity mechanism there are still distributional effects, which are caused by the trading of electricity between the Netherlands and the other countries of NWE. However, since the Netherlands is already paying for a capacity mechanism, it seems reasonable to think that the distributional effects are still important for the Netherlands. This could be explained by the fact that some of the electricity produced by French generators is purchased in the Netherlands and therefore is paid by Dutch consumers, contributing to the operational profits of generation units in France. This distributional effect, which is caused by the coupling and trade between the two markets seem to be more important under the implementation of a capacity mechanism in France. This is because the trade of excess electricity production from the French system—*electricity production capacity that is not required in periods of low electricity consumption in France*— would reduce the payment for "Obligation de Capacité" given to French generators to recover their total costs of production without improving the reliability of the Dutch electricity system in the short-term.