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The impact of wind power on electricity market competition in the Baltic countries

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Summary

In the 1990s, Nordic electricity market inaugurated as a pioneer regional market. Baltic countries (Estonia, Latvia, Lithuania) deregulated their power markets and joined the Nord-Pool market during 2010-2013.
Today, major share of electricity in Baltic countries is produced from fossil fuels. Main energy source for electricity generation is natural gas, in Latvia and Lithuania respectively followed by oil shale in Estonia.
Over the past few years, the increasing penetration of renewable energy systems intensified in order to meet EU-wide targets and policy objectives (40-27-27 target by 2030 within the EU). Regional cooperation is an opportunity to meet 2030 RES targets of Baltic countries. In particular, installing wind power dramatically rises as a result of a great potential especially in Northern Europe. In Baltic countries, Lithuania is forerunner in wind power by over 500 MW capacity followed by Estonia and Latvia with 309.96 MW and 78 MW respectively.
A change in capacity mix could affect competition in the electricity market.
This thesis attempts to provide an overview of the market power scenario over the years in Baltic countries. Herfindahl-Hirschman Index (HHI), a market concentration index, is chosen to conduct this exploratory study. The Herfindahl-Hirschman Index (HHI) is a common measure of market concentration and is used to determine market competitiveness. HHI index trend in Baltic countries from 1991 (dissolution of Soviet Union and independence of Baltic countries) to recent years is evaluated and then compared with the change in wind power to investigate the impacts.
The results show how Baltic area is a highly concentrated marketplace, as put in evidence by the high HHI index values.

Sommario

Negli anni '90, il mercato elettrico del Nord Europa è stato inaugurato come un mercato regionale pionieristico. I Paesi Baltici (Estonia, Lettonia, Lituania) hanno liberalizzato i propri mercati elettrici aderendo ad un unico mercato gestito da Nord Pool negli anni 2010-2013.
Oggigiorno, i combustibili fossili rappresentano la maggiore fonte per la produzione di energia elettrica. La principale fonte di energia per la produzione di elettricità è il gas naturale, rispettivamente in Lettonia e Lituania, seguito dallo scisto bituminoso in Estonia.
Negli ultimi anni, la crescente entrata delle fonti energetiche rinnovabili si è intensificata al fine di raggiungere i nuovi target Europei (40-27-27 entro il 2030 nell'Unione Europea). La cooperazione regionale è un'opportunità per raggiungere i nuovi obiettivi nei Paesi Baltici. In particolare, l'installazione di energia eolica negli ultimi anni è aumenta notevolmente grazie al potenziale presente nel Nord Europa. Nei Paesi Baltici, la Lituania è il precursore dell'energia eolica con oltre 500 MW di capacità installati, seguita da Estonia e Lettonia con rispettivamente 309,96 MW e 78 MW. Un cambiamento nel mix di generazione di elettricità potrebbe influire sulla concorrenza nel mercato elettrico.
Questa tesi fornisce una panoramica dello scenario di potere di mercato nel corso degli anni nei Paesi Baltici. Inizialmente, l'Herfindahl-Hirschman Index (HHI), un indice di concentrazione del mercato, è stato scelto per condurre questo studio esplorativo. L'indice Herfindahl-Hirschman (HHI) è una misura comune della concentrazione di mercato e viene utilizzata per determinare la competitività di una società nel mercato. L'andamento dell'indice HHI nei Paesi Baltici dal 1991 (scioglimento dell'Unione Sovietica e indipendenza dei Paesi Baltici) agli ultimi anni è stato valutato e confrontato con l'aumento dell'energia eolica per indagarne l'impatto.
I risultati mostrano come i Baltici sono un mercato fortemente concentrato, come evidenziato dagli alti valori dell'indice HHI.

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Last but not least, I would like to thank God for the strength and for the desire to know He donated me.

Thank you all for the end of this wonderful experience.

"But the wisdom from above is first pure,
then peaceable, gentle, open to reason,
full of mercy and good fruits, impartial
and sincere."
(The Bible - James 3:17)

Table of contents

List of figures

List of tables

List of Abbreviations

BIPS	Baltic Integrated Power System
CACM	Capacity Allocation and Congestion Management
CET	Central European Time
CHP	Combined Heat and Power
EGC	Electricity Generation Capacity [Megawatt electrical]
EU	European Union
EUR/MWh	Euro per Megawatt-hour
GW	Gigawatt
HHI	Herfindahl-Hirschman Index
HPP	Hydro-power plant
HPSP	Hydro Pumped Storage Plant
MSP	Market Share Percentage
MSW	Municipal Solid Waste
MW	Megawatt
MWe	Megawatt electrical
MWh	Megawatt-hour
NEMO	Nominated Electricity Market Operator
NG	Natural Gas
PP	Power Plant
PS	Primary Source
PV	Solar Photovoltaic
RES	Renewable Energy Sources

SS	Secondary Source
TSO	Transmission System Operator
TWh	Terawatt-hour
VRE	Variable Renewable Energy
W/m^2	Watt per meter square
$/MWh	Dollar per Megawatt-hour

Chapter 1

Introduction

During 1990s, economic and political crises weakened the impact regionally and globally of the Soviet Union. After years of dependence, in Baltic Countries there were first revolts, ended with violent attempts of Soviet Union trying to stop the uprisings. Nevertheless, the drive to independence was not possible to be stopped. As an outcome, the Estonians declared full independence on 21st August 1991; the Latvian Parliament made a similar declaration the same day. On 6th September 1991, the Soviet Government finally recognized the independence of all three Baltic states. [1]

Since the independence, Baltic countries electricity sector has undergone changes. Full integration into the European grid and market is a priority for the Baltic countries, as - for historical reasons - the Baltic integrated power system (BIPS) operates synchronously with the integrated/unified power system (IPS/UPS), including the Russian and Belarusian electricity grids [2]. The situation improved with new connections such as: Estlink 1 and 2 lines between Estonia and Finland, the LitPol Link line between Lithuania and Poland, and the Nordbalt line between Sweden and Lithuania. The construction of new power interconnections to the European grid will improve the energy security of the region and the competitiveness of its power market. However this transition is a complex and onerous process.

This thesis examines how the market power scenario in Baltic Countries changed with the higher entrance of renewable energy sources, in particular the wind power. Market power can be defined as the capability of the seller to manage the market price and to have higher control on competitors [3]. Analysing market powers in different electricity markets, identifies strength and weak points that can be considered by market enters or in the decision-making phase.

Particular attention is given to the Estonian increase of installed wind capacity and to the Lithuanian market power with the shutdown of the Ignalina Nuclear Power Plant that covered almost 40% of the overall consumption of the Baltic countries [4].

1.1 Structure of the thesis

The purpose of the thesis is to investigate how market power has changed since 1991 (independence of Baltic states) to recent years in Baltic countries. The thesis focuses on the development of the market power scenario over the years. Particular attention is given during the last year, with the strong entrance of RES (Renewable Energy Sources) in the electricity mix, above all wind power. The thesis is a combination of literature (scientific paper and reports) study and data analysis.

Firstly, the introduction provides the overview about the main topics covered and the theoretical background of the thesis.

After the introduction part, a background of Nordic electricity market is explained in the chapter 2. In particular, Nordic electricity market structure is described with particular attention to the Baltic States market.

Thesis proceeds with the theoretical background of the market power in electricity market. Market manipulation practices are then presented, followed by the definition of some market power measures.

Afterwards, in the fourth chapter, market power in Baltic countries is studied and discussed. In each section an initial overview on national electricity generation mix is given. It is followed by the description of the case study that reports main power plants with the relative electricity generation capacity in three reference years (1992-2010-2017). Market share percentages and Herfindahl-Hirschman Index are calculated considering the total installed capacity per each Country. Results are then discussed.

Finally conclusion ends the thesis in the chapter 5.

Chapter 2

Nordic Electricity Market

In the early 1990s, Nordic countries decided to create a common electricity market, deregulating their power markets. In 1991, Norwegian parliament deregulated the electricity market. Subsequently, in 1996 a Norwegian-Swedish joint for power exchange was established and Nord Pool ASA was formed.
Finland and Denmark joined Nord Pool ASA respectively in 1998 and 2000. Estonia, Latvia and Lithuania joined the Nord Pool market in 2010-2013.
In the meantime, Nord Pool Spot was appointed NEMO across ten European markets.
The Nordic electricity market is traded in NASDAQ OMX Commodities and in Nord Pool AS.
Nordic electricity market is divided into bidding areas, where different prices are set during the market process.

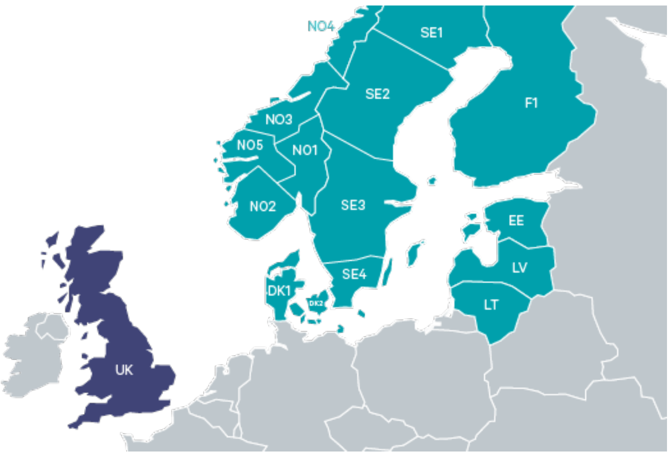

Figure 2.1. *Bidding areas [5]*

It comprises five bidding areas in Norway, four areas in Sweden, two (Eastern and Western) in Denmark and one in Finland, Estonia, Latvia and Lithuania. Nevertheless, bidding areas are not divided each others. During the last years, power production and transmission capacity increased, and power exchange and communication between different areas of the market increased consequently as a result of the willingness to create a single European cross-zonal power market. In fact, more intensive power exchanges between countries help to overcome grid issues: thus, improvements in both the security and safety of the network have been observed. Moreover, managing larger power availability in a large region results to be more efficient compared to providing energy in a smaller one. [5] Apart from electricity exchanges between Nord Pool market's countries, there are several electricity interconnections with Russia, Netherlands, Poland, Belarus and Germany. As shown in the fig. 2.2, during the last six years, Russia has always been the main importer with 11.7 TWh net imported. Then Belarus and Germany are the other main importers. On the other hand, Netherlands and Poland constitute main exporter countries with respectively 3.7 TWh and 3.6 TWh exported.

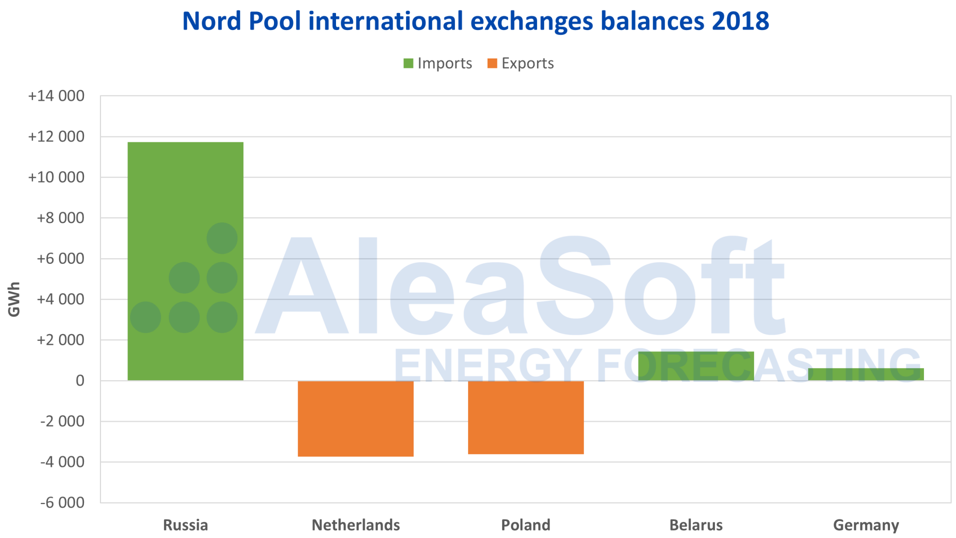

Figure 2.2. *Nord Pool international exchanges balances in 2018. Source: Prepared by AleaSoft using data from Nord Pool [6]*

The Nordic electricity market is structured in different parts depending on the aim to achieve as shown in the following fig. 2.3. In the next sections, each market is described.

Figure 2.3. *Electricity Market structure in Nordic Countries. Source: Courtesy of Jussi Jyrinsalo, Fingrid [7]*

2.1 Financial market

Financial markets are managed by Nasdaq Commodities. Nasdaq Commodities offers financial contracts to Nordic Markets for price hedging and risk management. Trading contracts can be daily, weekly, annual or can have a time horizon up to 10 years. In this market phase, there is not a physical delivery of financial power contracts. Furthermore, technical issues such as grid congestions and access to capacity are not considered. Nevertheless, this market part is fundamental for buyers and sellers to manage the risks related to physical markets. [5]
The Nasdaq Commodities offers: Futures, Deferred Settlement Futures (DS Futures), Options and Electricity Price Area Differential (EPAD) contracts.

- **Futures contracts** are daily mark-to-market[1] in which profits and losses are evaluated on a daily basis;
- **Deferred Settlement Futures (DS Futures)** are financially settled contracts.

[1]Mark-to-market is a method that has the aim to measure the fair value and to provide the realistic value of an account affected by fluctuations over the time. [8]

- An **Option Contract** is a right to buy or sell an underlying contract at a predetermined price at a predefined date in the future. The options combined with the futures are tools used to manage risk and to hedge the strategies.

- **EPAD Contracts (Electricity Price Area Differential)** permits the members to hedge and to manage the price risk related to the market. This part takes into account the difference between the area price and the Nordic system price, which differs for the transmission grid congestions. [9]

2.2 Day-ahead market

The day-ahead market (known before as ELSPOT) is a closed auction, where customers can sell or buy energy for the next 24 hours. At 10:00 CET of each day, available capacities are published, and market participants can submit the offer until 12:00 CET after which the hourly results for next day are published. The market price is set by the equilibrium between the demand and supply. In order to optimize the use of electricity, supply failures must be avoided. Each day, the consumers order the volume needed (MW per hour), on the other hand, producers offer a quantity of energy at a specific price (EUR/MWh) they are willing to sell. Demand and supply curves are shaped and the final market price, at a certain time and in each bidding zone, is set. Between Nordic and Baltic bidding areas the transmission system operators (TSOs) determine the trading capacity between bidding areas. [10]
Nord pool day-ahead participants are: Finland, Sweden, Norway, Denmark, Estonia, Latvia, Lithuania, Austria, Germany, Netherlands, Belgium, France and Great Britain.
Supply curve is composed of the power plants which participate to the market, sorted by the marginal cost and the volume in MWh. Renewable energy sources have fewer marginal costs respect to conventional power plants, mainly because of there is no fuel needed to produce energy. On the other hand, gas-fired turbines have the highest marginal costs compared to the other technologies, thus the market price for all electricity purchasers is determined by the last (and so the most expensive) power plant which participates on the market to meet the demand.
The method of price formation is shown in fig. 2.4 where the curves for sell price and buy price meet, taking into account network constraints.

Trading of energy in the day-ahead market is based on four different order types [11]:

- **Single hourly order** is the main order type in the day-ahead market. The member specifies the purchase and/or sales volume for each hour and may

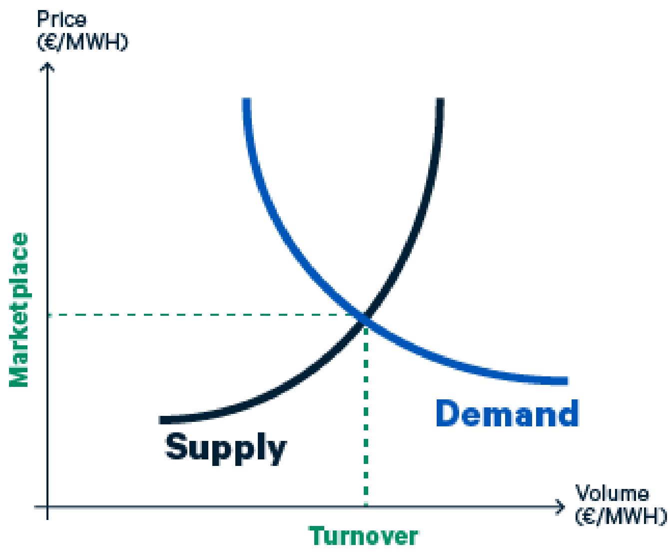

Figure 2.4. *Demand and supply curves [10]*

choose between a price dependent and a price independent order. Price independent orders are orders where maximum and minimum prices are set and buy or sell volume will be placed at that minimum and maximum price for all the intended hours. On the other hand, Members who submit price dependent orders, accept that Nord Pool will make a linear interpolation of volumes between adjacent pair of submitted price steps to find the correct traded volume for that member [12];

- A **block order** consists of volume at a specified price for a certain number of consecutive hours in the same day. This type of order is useful for participants who want to run power and to participate at the market for a longer period than one hour. This option has the advantage for these producers to minimize the related start and stop costs [13];

- An **exclusive group** is a cluster of sell and/or buy blocks out of which only one block can be activated. In the figure 2.5, it is shown an example of exclusive groups from the day-ahead web, where price, volume and operational hours are reported [14];

- A **flexi order** is a block order with a maximum duration of 23 consecutive hours. The interval limit can span any period from 00:00 to 24:00. The starting hour of flexi order is not defined by the user but will be determined by the algorithm considering the optimization of the social welfare. [15]

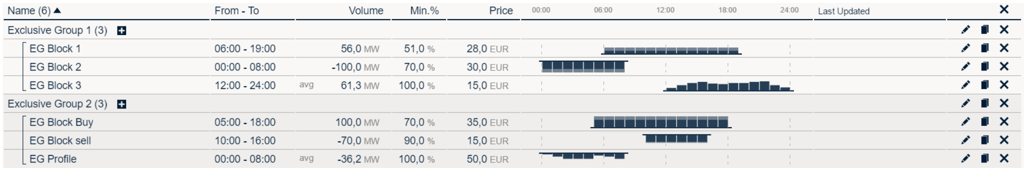

Figure 2.5. *Example screenshot from Day Ahead Web with exclusive groups [14]*

Customers can buy/sell any one or a combination of the order types, depending on their requirements [11].

2.3 Intra-day market

The intra-day market (known before as ELBAS market) is a correction market where actors can adjust any trading if previous forecasts were wrong. The intra-day market is an essential tool that allows market participants to consider unexpected changes in consumption and outages. Due to VRE deployment, the intra-day market has become more relevant. Prices are set based on a first-come, first served principle, where best prices come first – highest buy price and lowest sell price get served first. The intra-day market managed by Nord Pool offers 15-minutes, 30-minutes, hourly and block products. The trading takes place every day, since the day before until 1 hour before the delivery [16]. The prices are set in a pay-as-bid process used for continuous trading (method for transacting security orders characterized by an immediate execution of orders upon their receipt by market makers and specialists [17]). It means that the price for participants is set to the price of their bids. Each order is ranked by the order price and if two or more orders have the same order price, they will be ranked by the time at which each order was registered in Trading Platform, with the earliest orders first (see fig. 2.6).

As for the day-ahead market, Nord Pool is responsible for the intra-day market. Nord Pool intra-day participants are: Finland, Sweden, Norway, Denmark, Estonia, Latvia, Lithuania, Austria, Germany, Netherlands, Belgium, France and Great Britain.

Transmission system operators provides capacities in the intra-day market. There are five order types in the intra-day trading [19]:

- **Limit order** is a buy or sell order with a price limit. Buy orders can be executed at the limit price or lower, sell orders at the limit price or higher;
- **User-defined block order** consists of one or several consecutive orders (maximum of 24) that can be executed only entirely (all or nothing orders);
- **Predefined block order** are UK-specific block orders;

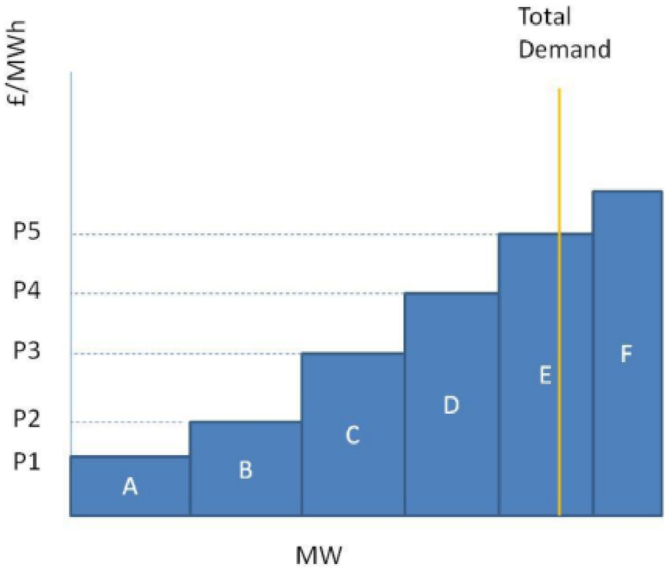

Figure 2.6. *Pay-as-bid pricing [18]*

- **Iceberg order (IBO)** is a type of limit order, usually with a large volume, with the purpose of hiding the full size of the order by dividing it into smaller clips. The first clip is shown to the market and the next clips will be visible when the previous ones have been fully matched;

- There are two types of **Execution constraints**: Fill-or-Kill (FoK) and Immediate-or-Cancel (IoC).
  Fill-or-Kill (FoK) is an order where the volume will be immediately submitted or withdrawn from the market.
  Immediate-or-Cancel (IoC) is a limit order where as much as possible of order volume is immediately submitted and the remaining volume is withdrawn from the market.

2.4 Balancing market

The balancing market is operated through automatic and manual reserves by the Nordic transmission system operators in order to guarantee the power balance and the safety of the network.
Since the 1st January 2018, Baltic electricity transmission system operators (Elering AS, AS Augstsprieguma Tīkls and LITGRID AB) decided to join a single common balancing market. The objective is to keep the frequency constant within the range 49.95-50.05 Hz.

Balancing market is operated through automatic and manual frequency regulations. System regulations type are the following:

- **Frequency containment reserves (FCR)** is an automatic regulation activated in momentary frequency deviation. According to the operation type, FCR process is divided into:
  1. **FCR-N (Frequency Containment Reserve for Normal operation)** is constantly used to keep constant frequency in normal state;
  2. **FCR-D (Frequency Containment Reserve for Disturbances)** is activated in the case there are disconnections of large production units.
- **Frequency restoration reserves (FRR)** is a regulation activated if the frequency is not restored within a few minutes from FCR. FRR can be automatic and manual (aFRR and mFRR) and has the aim to restore the correct functioning of FCR into use. Furthermore, FRR regulation is activated after $\simeq$ 15 minutes FCR and FRR work is guaranteed from the Russian Power System;
- **Replacement reserves (RR)** is a manual frequency regulation activated if required after the FRR operation activated after $\simeq$ hours. RR operation is provided also by Baltic power systems.

[20]
In the balancing market, submission of orders are 45 minutes before the operational hour. [21]
Baltic states are in a single synchronous zone with Unified Power System of Russia (UPS). Nevertheless, since Baltic States joined European Union in 2004, they have been following the EU energy policies. Moreover, in next years, EU energy policies aim to desynchronise the power grid of the Baltic States from UPS [22].

2.5 Market integration

In 2015 the EU Regulation 2015/1222 (CACM regulation) set up detailed guidelines on cross-zonal capacity allocation and congestion management in the day-ahead and intra-day integrated electricity markets. The main aim is to form an interconnected (European) market for electricity that can be defined as market coupling. Market coupling is intended to link control areas and market areas in order to improve security of energy supply, increase competitiveness and reduce the prices. Thus, market integration implements efficiently a Single Day-Ahead Coupling (SDAC) and a Single Intra-day Coupling (SIDC), however, in order to realize it, there needs to be a high level of coordination between the Nominated Electricity Market Operators (NEMOs) and the Transmission System Operators (TSOs). [23]

The aim of Single Day-ahead Coupling (SDAC) is to create a single pan European cross zonal day-ahead electricity market. An integrated day-ahead market will increase the overall efficiency of trading by coupling wholesale electricity markets from different regions through a common algorithm called PCR EUPHEMIA.
Price Coupling of Regions (PCR) is the supplier to Single Day-Ahead Coupling which has the aim to develop a single price coupling in Europe having the advantage to improve the social welfare and the efficiency. Developing this project would mean to harmonise the European electricity markets creating a single system with many advantages.
EUPHEMIA is the algorithm used in PCR (Price Coupling of Regions) to solve the issues related to the coupling in the Day-ahead market. It can solve market coupling problems containing hundreds of thousands of orders in less than ten minutes. [24]
All the orders are matched in the pan-European market coupling process - the Single Day-Ahead Coupling (SDAC) – through the EUPHEMIA algorithm. [10]
Once the participants, submitted their offers, EUPHEMIA algorithm starts to work and as results, give which orders can be executed and which are rejected calculating final prices across Europe. In order to receive a positive answer following issues must be met:

- The social welfare which is the sum of consumer surplus, producer surplus and congestion rent, is maximal;
- The power flows induced do not exceed the capacity of the network elements. [23]

With the reference to the day-ahead market, large parts of Europe joined the Single Intra-day Coupling (follows the XBID project). The main aim of this project is to provide a single pan-European cross-zonal intra-day power market, it means to have a single market in which buyers and sellers (market participants) can work together and trade the electricity. Main outcomes are: getting high overall efficiencies promoting the competition and using in a more efficient way the generation across the Europe, increasing the market liquidity and giving the possibility for market participants to manage better unexpected changes.
To implement the XBID solution, Local Implementation Projects (LIPs) were set up. A LIP consists of one or more borders, one or more TSOs and one or more NEMOs. LIP's main tasks are adaptation of local arrangements (i.e. procedures, shipping, contracts), IT (information technology) system adjustments, secure equal treatment between NEMOs and implicit/explicit access and ensuring readiness for the participation in the XBID LIP testing [25].

Chapter 3

Market Power in electricity market

Following chapter describes what market power in electricity market is. Particular behaviour of the firms in the electricity market, followed by market power measures are then presented and described.
In order to study market power scenario in Baltic Countries, the concept of market power must be understood.
Market power is the company's ability to drive the spot price over a competitive level, control the total output, or exclude competitors from relevant market for a significant period of time [3]. A company with market power can manipulate the market price and thereby control its profit margin, and possibly the ability to increase obstacles to potential new entrants into the market. Firms that have market power could be defined as "price makers" because they can establish or adjust the marketplace price of an item without relinquishing market share. The concept of the market power can be explained through the figure 3.1. A firm has market power if it is able to increase the market clearing price above the competitive level, from λ to $\lambda^{'}$, increasing his surplus, from the area λAE to area $\lambda^{'}ABE'$ and reducing the output, from Q to $Q^{'}$. The social surplus is reduced, from area AED to $ABE^{'}D$, by the dead weight loss S^{-}. As shown in the figure 3.1 the increase of market power can cause undesirable effects such as reduction in the traded quantity, price increase, social surplus reduction and increase in dead weight loss [26].

A marketplace can be classified in three categories that differ for distinct features.
The first is marketplace in ideal condition of perfect competition. In perfect competition there are several companies that produce the same or similar product and there are no barriers to new companies entering the marketplace.
The opposite of perfect competition is a monopoly in which one company completely controls the market for a product or service, or at least a portion of the total market,

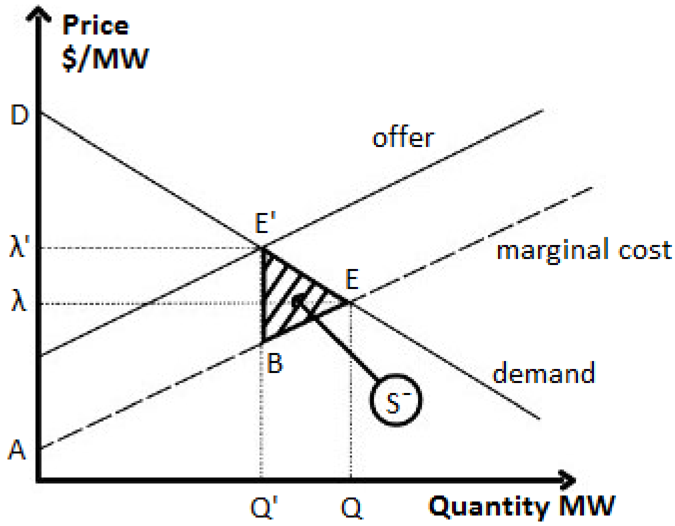

Figure 3.1. *The hourly market clearing under strategic bidding [26]*

and is able to adjust pricing at will. However their ability to raise prices is usually limited by government authorities. In this specific conditions, market power could hamper the competition in power production, service quality and technological innovation.
Finally, an oligopoly refers to a marketplace controlled by a limited number of firms and there are barriers for new firms to enter in the market. [27]

3.1 Capacity withholding (market manipulation practice)

In the electricity market, the behaviour of the participants can change market results. Irrational bidding behaviour of a market participant artificially inflates (or dampens) prices to uncompetitive high (or low) levels. Capacity withholding can be qualified as manipulative practice to artificially cause prices to be at a level not justified by market forces of supply and demand(including actual availability of production, storage or transportation capacity) [28].
In the following paragraphs, electricity generation capacity withholding forms in different market scenarios are explained.

3.1.1 Physical withholding

Physical withholding represents a behaviour of market participants in a more concentrated marketplace to increase market price (and profits) at not justified level having a high power market.
As an example, considering a situation of perfect competition and assuming that there are five power plants that participate to market. They supply offers at their marginal cost as shown in the fig. 3.2, being the requested demand equal to 55 MWh, system marginal price will be $40/MWh, thus all the participants' price is shifted to that equilibrium price.
Now considering that the same firm owns power plants A and D. If the firm decides

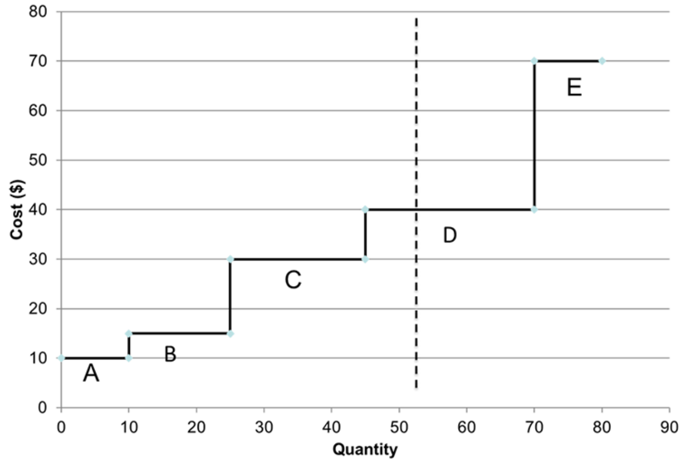

Figure 3.2. *An electricity market with five generators. Source: Seth Blumsack [29]*

to remove power plant D from the market, new system marginal price will be equal to $70/MWh as shown in fig.3.3. The physical withholding of power plant D would result in the System Marginal Price increasing to $70/MWh and the profit of the firm would be ($70/MWh - $10/MWh) * 10 MWh [29].

However, the possession of high generation capacity as shown in the previous figure, does not necessarily equal with more actual generation. In the case of hydro electric generators, the lack of water resources reduce power generation. Fuel limitations for thermal generators or transmission network constraints and the bidding strategy of participants are other reasons for this discrepancy [3].

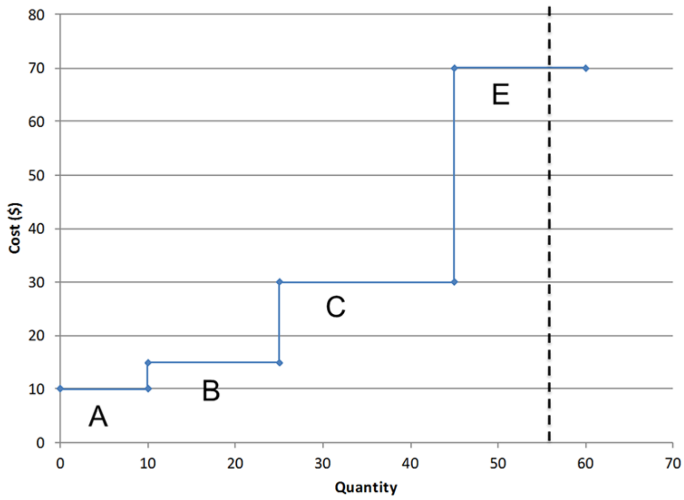

Figure 3.3. *The System Marginal Price in the electricity market increases to $70/MWh if Generator D is withheld from the market. Source: Seth Blumsack [29]*

3.1.2 Economic withholding

The other strategy that can be used by power generation firms is the economic withholding. The economic withholding is a form of electricity generation capacity withholding that takes into account transmission constraints. It tends to be a good strategy when transmission constraints are binding, limiting the amount of local competition for a specific power plant. As an example, supposing to have two node networks as shown in the figure 3.4. Generators offer electricity at their marginal price, thus marginal costs are $20/MWh and $40/MWh respectively for generator 1 and generator 2 and the transmission line capacity is 50 MW. If the market demand is

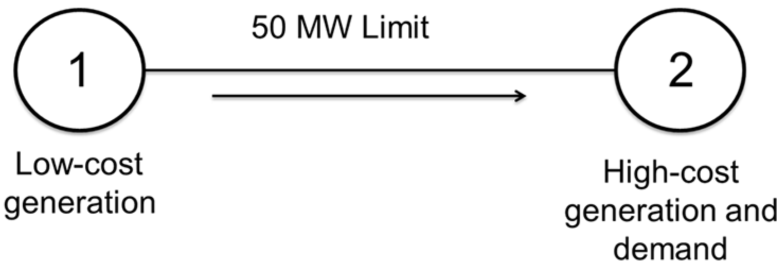

Figure 3.4. *A two-node network that creates localized market power for Generator 2. Source: Seth Blumsack [30]*

80 MWh, generator 1 will produce 50 MWh (because of transmission line capacity) and generator 2 must produce remaining 30 MWh in order to meet the demand. With the hypothesis of perfect competition, generator 1 will offer 50 MWh at its

marginal price ($20/MWh), indeed generator 2 will offer 30 MWh at $40/MWh. However, generator 2 would never submit an offer at $40/MWh because it knows that the demand at node 2 is 80 MWh and since the transmission line capacity is 50 MW, it has the monopoly on serving power at any level. This monopoly power results specifically from the low capacity of the transmission line. If the capacity of the transmission line were to be increased, this would erode some of the market power possessed by Generator 2 [30].
As seen before, in the electricity markets, firms may possess market power not just because they are more efficient than their competitors. In the previous example, it was demonstrated that generator 2 has market power because of its position in the transmission grid. It is not fundamental if generator 2 is large or small compared to generator 1 (generator 2 in the example produced less electricity than generator 1). In that case, generator 2 had market power entirely because of the configuration of the grid. That is a reason why in the market power analysis, network constraints should be considered as demonstrated by previous example.

3.2 Measuring Market Power

There are several ways to measure market power in electricity market. One of them is the calculation of the indices. Hereinafter, some of them are described. They may be classified broadly into different categories with reference to the cause or effect of market power that they use for its quantification [26]. The concentration indices, based on the market shares of different players, are one of the market indices that measure it. Some of these are: Learner Index, Market share concentration ratio, Herfindahl Hirschman Index (HHI) and Entropy Coefficient.

3.2.1 Lerner index

Lerner index is a measure of the market power of a firm. It evaluates the firm's ability to increase its market price respect to the marginal cost. It is calculated as the proportional difference between price and marginal cost as indicated in the following formula:

$$\mathbf{Lerner\ Index} = \frac{(\mathbf{P} - \mathbf{MC})}{\mathbf{P}}$$

where MC is the marginal cost and P is the price at which the electricity is offered. A Lerner index of zero means that the prices at numerator are equals and market is competitive. Bringing back to the case described in the economic withholding paragraph, Generator 2 could increase its profit because of transmission constraints (in the next paragraph it is discussed), thus supposing a P = $70/MWh, the Lerner index will be equal to ($70/MWh - $40/MWh) / ($70/MWh) = 0.43. A Lerner

index greater than zero implies some exercise of market power. Indeed, if Generator 1 (see example in the paragraph economic withholding) will supply electricity at its marginal price, Lerner Index will be equal to 0.
The Lerner index is also called the price-cost markup since it measures the deviation in price from the competitive level [30].

3.2.2 Market share concentration ratio

Market share concentration ratio is the index that indicates the share percentage in the market. Market share of participants can be calculated through two different approaches:

- **energy based approach** where market share percentage of a firm is calculated basing on total generation produced (annually, monthly or daily) by all participants;
- **capacity based approach** where market share percentage of a firm is calculated considering total installed capacity of all participants in a marketplace (country, bidding area etc...).
  For electricity market, market shares are better defined in terms of capacity and not energy production, as they then provide a better assessment of potential exercise of market power. Capacity market shares are indirectly related to the firm's ability to set prices above marginal costs. [3]

3.2.3 Herfindahl-Hirschman Index (HHI)

HHI is a common measure of market concentration and is used to determine market competitiveness. It is calculated by squaring the market share of each firm competing in a market and then summing the resulting numbers as shown in the following formula

$$\mathbf{HHI = s_1^2 + s_2^2 + s_3^2 + ...\ s_n^2}$$

where s_n is the market share percentage of firm n. It can range from close to 0 to 10,000. A market with an HHI of less than 1,500 is indicated as a competitive marketplace, an HHI of 1,500 to 2,500 a moderate marketplace and an HHI greater than 2,500 is considered to be a highly concentrated marketplace. Higher is the index, closer to a monopoly is the market with a small number of firms, on the other hand, lower index, more competitive the market is. If, for example, there were only one firm in an industry, that firm would have 100% market share, and the Herfindahl-Hirschman Index (HHI) would equal 10,000, indicating a monopoly. If there were thousands of firms competing, each would have nearly 0% market share, and the HHI would be close to zero, indicating nearly perfect competition.

Main advantage of the HHI is the simplicity of the calculation necessary to determine it and the small amount of data required for the calculation.
Main disadvantages of the HHI is related to the fact that it is such a simple measure that it misses to take into account the complexities of various markets in a way that allows for a genuinely accurate assessment of competitive or monopolistic market conditions.
In the electricity market, limitations are related to the fact that the possession of high generation capacity does not necessarily equal with more actual generation. An example could be provided by an Hydro Power Plant in the case of lack of water resources that restrict the generation [3]. Another problem in defining a market and considering market share can arise from geographic factors and transmission constraints. These problems can occur when there are companies within an industry that have roughly equal market share, but they each operate only in specific areas of the country because of transmission limitations, so that each firm, in effect, has a monopoly within the specific marketplace in which it does business (local market power). A feasible solution to this issue could be the increase of transmission capacity obtaining as benefits cheaper power and higher competition among generators.
For these reasons,to conduct a correct study and to overcome these barriers, for the HHI to be properly used, other factors must be taken into consideration and markets must be very clearly defined. [31]

3.2.4 Entropy coefficient

Entropy Coefficient is another index that measures market power. This index indicates the market share weighted by the logarithm of the market share and is calculated as

$$\mathbf{Entropy\ Coefficient} = \sum_{i}^{\mathbf{N}}{}_{\mathbf{1}} \mathbf{S_i \log_2(\frac{1}{S_i})}$$

where N and S_i represent the number of market participants and each player's market share (S_i is between zero and one), respectively.
The entropy coefficient considers the non-linearities that one assumes in other indices. This index varies from zero (monopoly) to infinity (perfect competition); therefore it is not restricted to [0, 10,000], as HHI. The more the entropy coefficient is, the less the potential for exercising market power [3].

Chapter 4

Market Power in Baltic electricity market

In this chapter, market power is studied and discussed in Baltic Countries. The chapter describes how market power scenario changed over the years especially with the strong entrance of new renewable based firms. Particular attention is given to wind power, where after 2008 there has been a high growth, especially in Estonia and Lithuania.
In each section an initial overview on national electricity generation mix is given. It is followed by the description of the case study that reports main power plants with the relative electricity generation capacity in three reference years (1992 after the independence of the Baltic Countries, 2010 after the closure of the Ignalina Nuclear Power Plant that completely changed the electricity market in the Baltic area and 2017 for recent years). Due to lack of data, power plants whose owner was unknown, have not been considered for the calculations. However, it is about limited powers. Subsequently, market share percentage of the main firms (based on total electricity installed capacity approach) is calculated per each country in different years. Capacity-based approach is used because for electricity, inasmuch market shares are better defined in terms of capacity and not energy production, as they provide a better assessment of potential exercise of market power. Capacity market shares are indirectly related to the firm's ability to set prices above marginal costs [3].
Afterwards, in the result section, the Herfindahl–Hirschman index and the market share concentration ratio are calculated in order to analyse and discuss market power scenario in Baltic Countries in three years (1992-2010-2017). The results show how Baltic area is a highly concentrated marketplace, but wind power is partly changing this trend.

4.1 Estonia

4.1.1 Electricity generation mix

Electricity generation in Estonia is dominated by oil shale reserves. Since 1990s, oil shale resulted the main source in the electricity generation sector (see fig. 4.1).

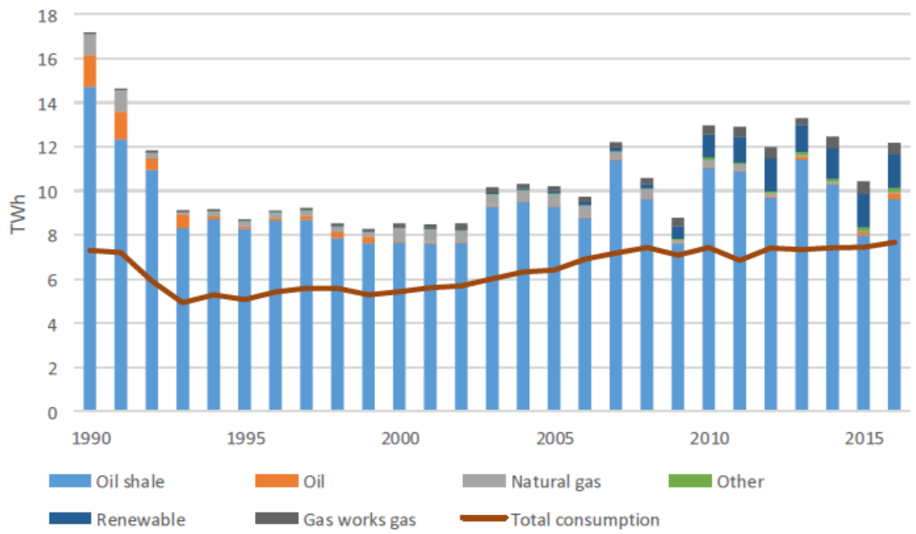

Figure 4.1. *Electricity generation by energy source and total consumption in Estonia in 1990-2016 [32]*

In 1992 there was a net reduction of electricity generation as can be noticed on the figure above. Main reason was the fall of the Soviet Union where electricity demand suffered for a net reduction. One of the main grounds for the drop in consumption was the negative GDP-growth right after the break-up of the Soviet Union. Furthermore the decline of the consumption can also be described by the introduction of more cost-based pricing, and that there used to be some heavy, electricity-intensive industry in operation in the Baltic States before the break-up of the Soviet Union, that has since ceased to exist [33].
Since 2008, even though the growth of renewable energy (see fig. 4.2 below), oil shale remained the main source. In 2017, biomass/waste and wind installed capacity was 386 MW and 312 MW respectively [34]. Furthermore, according to Estonian wind power association, the goal is to install a capacity of 1800 MW of new wind farms in Estonia by 2030 [35]. In the next future, Enefit Green is planning to install 1 GW offshore wind in the Gulf of Riga (Estonian government has already initiated construction permit procedure). It has been agreed in the Pärnu marine spatial plan that the building permit area is well suited for the development of wind energy [36]. Following figure (fig. 4.3) shows the great potential in the northern region

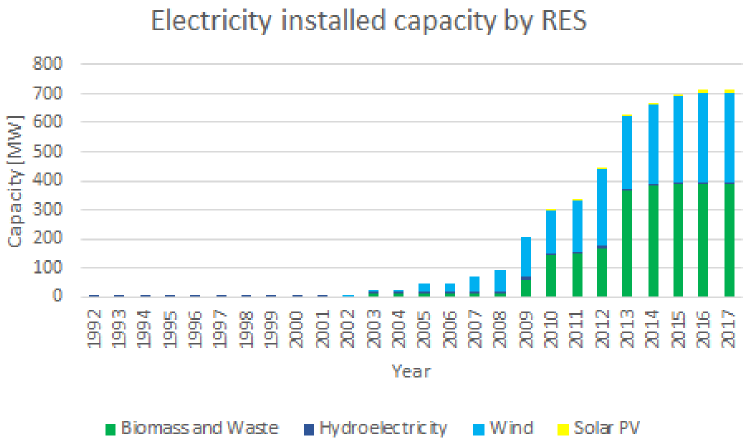

Figure 4.2. *Installed power capacity (in MW) by renewable energy source in Estonia in 1992-2017 [34]*

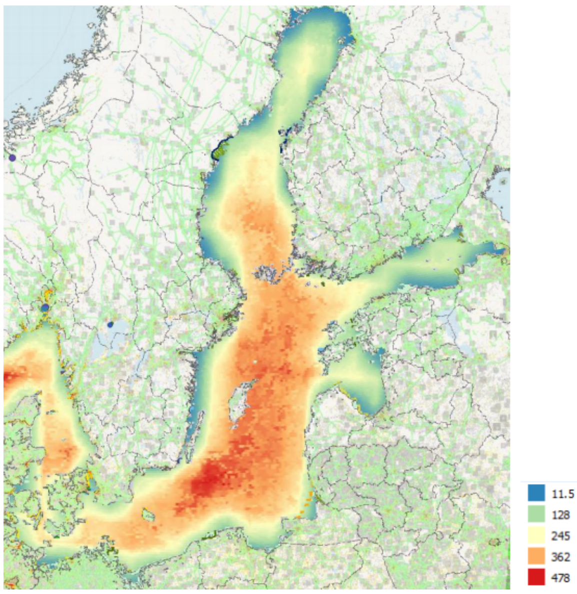

Figure 4.3. *Usable power density [W/m^2] of wind speeds in the Baltic Sea based on numerical simulated data from coastDat. Usable power density implies the wind power available based on the wind speed distribution [37]*

However not only wind installed capacity increased during the last years, in 2018, Estonia increased tenfold solar PV installed capacity reaching 107 MW. The recent installation of solar is the result of a new policy for solar and renewables introduced by the Estonian government [38].

4.1.2 Market power

Actually, power market in Estonia is mainly dominated by Eesti Energia and its subsidiary Enefit Green. Since 1992, Narva Power Plants (a power generation complex in Narva, near the border with Russia) were the major electricity source. Eesti Power Plant located in Auvere and Balti Power Plant located in Narva formed the generation complex with an electricity generation installed capacity of 1610 MW and 1390 MW respectively (see table 4.1 below). These two oil-shale-fired power stations in Estonia produced the great bulk of Estonia's power, as well as exported to Russia and Latvia. Together they accounted for about 95% of Estonia's electricity production. Both used pulverized oil shale for fuel [39]. These two biggest power plants were owned by Eesti Energia.

Table 4.1. *Main Estonian power plants in 1992 [34],[39]*

1992				
POWER PLANTS	**PS**	**SS**	**EGC [MWe]**	**OWNER**
Eesti Power Plant	oil shale		1610	Eesti Energia
Balti Power Plant	oil shale		1390	Eesti Energia
Kohtla-Järve Power Plant	oil shale	oil shale gas	39	VKG Soojus (Viru keemia grupp)
Ahtme Power Plant	oil shale		20	VKG Soojus (Viru keemia grupp)
Iru Power Plant	natural gas	oil	190	Eesti Energia
Diesel power stations	oil		9	Eesti Energia
Hydro-Power Plants	water		1	others
others			147	others
TOTAL			**3406**	

Third biggest Power Plant was Iru PP (Power Plant) owned by Eesti Energia too. It is formed by two units fed by natural gas as primary fuel and oil as secondary. These were the biggest power plants that formed the majority of the total installed capacity. As said before, Eesti Energia was the owner of the three Power plants. Market share percentage of the firms have been calculated using the capacity-based approach. Results are shown in the table 4.2. In 1992 Eesti Energia owned 93.92% of total electricity installed capacity in Estonia (almost a monopoly). The second biggest firm was VKG Soojus that owned only 1.73%. VKG Soojus managed two oil shale-based power plants, Kohtla-Järve Power Plant and Ahtme Power Plant with an installed capacity of 39 MW and 20 MW respectively.
In 2010, scenario slightly changed. The reduction of total installed capacity was

Table 4.2. *Market share percentage of firms in Estonia in 1992*

1992		
OWNER	**TOTAL CAPACITY** [MW]	**MSP OF FIRM** [%]
Eesti Energia	3199.00	93.92
VKG Soojus (Viru keemia grupp)	59.00	1.73

Table 4.3. *Main Estonian power plants in 2010 [34],[35],[40],[41],[42]*

2010				
POWER PLANTS	**PS**	**SS**	**EGC** [**MWe**]	**OWNER**
Eesti Power Plant	oil shale		1615.0	Eesti Energia
Balti Power Plant	oil shale	biomass	765.0	Eesti Energia
Iru Power Plant	natural gas	oil	128.0	Eesti Energia
Kohtla-Järve Power Plant	oil shale	oil shale gas	39.0	VKG Soojus
Ahtme Power Plant	oil shale		30.0	VKG Soojus
Tartu CHP plant	wood chips		25.0	Fortum
Pärnu CHP plant	wood chips		24.0	Fortum
Väo Power Plant (Tallinn Power Plant)	wood chips	peat	25.0	OÜ Utilitas
Wind farms:	wind		**150.0**	
	wind		90.4	Nelja Energia OÜ
	wind		42.4	Eesti Energia
	wind		12.0	Skinest Energia AS
	wind		3.0	Telewind AS
	wind		1.6	Baltic Wind Energy OÜ
	wind		0.3	Sangla Turvas AS
	wind		0.3	Rotorline OÜ
Linnamäe HPP	water		1.2	Eesti Energia
Keila-Joa HPP	water		0.4	Eesti Energia
Other Hydro-Power Plants	water		4.4	others
Solar PV	sun		0.1	others
TOTAL			**2807.1**	

mainly caused by the closure of the blocks in Balti PP (the installed capacity reduced to 765 MW). Furthermore the entrance of renewable energy sources, with new firms, slightly decreased the market share percentage of Eesti Energia (see table 4.4 below). The installation of new wind farms and biomass/waste power plants, increased total installed capacity of renewable energy sources to 298.1 MW [34] (fig. 4.2). Notwithstanding, the entrance of the RES, Eesti Energia kept the main potential for exercising market power (90.91% of market share percentage in 2010).

Table 4.4. *Market share percentage of firms in Estonia in 2010*

2010		
OWNER	**Total capacity [MW]**	**MSP OF FIRM [%]**
Eesti Energia	2552.00	90.91
Nelja Energia OÜ	90.40	3.22
VKG Soojus (Viru keemia grupp)	69.00	2.46
Fortum	49.00	1.75
OÜ Utilitas	25.00	0.89
Skinest Energia AS	12,00	0.43
Telewind AS	3.00	0.11
Baltic Wind Energy OÜ (1,2 võrku)	1.60	0.06
Sangla Turvas AS	0.30	0.01
Rotorline OÜ	0.30	0.01

In 2017, installed capacity of fossil fuels sharply decreased due to the shutdown of six blocks at the Narva PP in 2016 and the closure of the Ahtme CHP (combined heat and power) plant in 2011 [41]. An occurrence that changed market power scenario was the foundation of Enefit Green. In 2016, Enefit Green was established to unite all the group's renewable energy production units into a single company [43]. Even if it is a subsidiary, both firms are considered separately in the analysis (see table 4.6). Eesti Energia and Enefit Green had in 2017 the highest market share concentration ratio, respectively (66.24% and 16.04%). Another reason for the reduction of Eesti Energia's market concentration was the entrance of new small firms especially in biomass sector such as Fortum and OÜ Utilitas that own respectively 49 MW and 46.40 MW of CHP plants [40].
Kiisa PP (built by Elering) has not been considered for the calculation of the indices because it is an emergency reserve station which would only be activated in an emergency and is not part of the electricity market [41].

Table 4.5: *Main Estonian power plants in 2017 [34],[35],[40],[44],[45]*

2017

POWER PLANTS	**PS**	**SS**	**EGC [MWe]**	**OWNER**
Narva Power Plants:			1615,00	Eesti Energia
Eesti Power Plant	oil shale			
Balti Power Plant	oil shale			
Auvere Power Plant	oil shale	up to 50% biomass		
Kohtla-Järve Power Plant	oil shale	oil shale gas	39,00	VKG Soojus
Kiisa PP (for emergency)	natural gas	light fuel oil	250,00	Elering
Väo PP (Tallinn PP)	wood chips	peat	46,40	OÜ Utilitas
Iru Power Plant	NG/MSW[2]	fuel oil	207,00	Enefit Green (Eesti Energia)
Tartu CHP plant	wood chips	peat	25,00	Fortum
Pärnu CHP plant	wood chips		24,00	Fortum
Wind farms:	wind		**312,00**	
	wind		199,45	Enefit Green (Eesti Energia)
	wind		64,35	Eesti Energia
	wind		3,00	Telewind AS
	wind		1,60	Baltic Wind Energy OÜ
	wind		0,30	Sangla Turvas AS
	wind		0,30	Rotorline OÜ
	wind		12,00	Skinest Energia AS
	wind		5,90	Baltic Workboats AS
	wind		1,50	Stacey OÜ
	wind		18,00	Lietuvos Energija
	wind		1,80	OÜ Green Electric
	wind		3,00	Eleon AS
	wind		0,66	Meritrade OÜ
Linnamäe HPP	water		1,20	Eesti Energia
Keila-Joa HPP	water		0,37	Enefit Green (Eesti Energia)
Hydro Power Plants	water		6,10	others

[2]Natural Gas in units 1 and 2 and Municipal Solid Waste in unit 3 [44]

Table 4.5 continued from previous page

Solar PV			11,00	others
TOTAL			**2537,07**	

Table 4.6. *Market share percentage of firms in Estonia in 2017*

2017		
OWNER	**Total capacity [MW]**	**MSP OF FIRM [%]**
Eesti Energia	1680.55	66.24
Enefit Green (Eesti Energia)	406.82	16.04
Fortum	49.00	1.93
OÜ Utilitas	46.40	1.83
VKG Soojus	39.00	1.54
Lietuvos Energija	18.00	0.71
Skinest Energia AS	12.00	0.47
Baltic Workboats AS	5.90	0.23
Telewind AS	3.00	0.12
Eleon AS	3.00	0.12
OÜ Green Electric	1.80	0.07
Baltic Wind Energy OÜ	1.60	0.06
Stacey OÜ	1.50	0.06
Meritrade OÜ	0.66	0.03
Sangla Turvas AS	0.30	0.01
Rotorline OÜ	0.30	0.01

4.2 Latvia

4.2.1 Electricity generation mix

In Latvia three largest hydro-power plants on the river Daugava form the main share of the entire generation mix. The annual gross electricity generation by hydro-power varied from 2 TWh to 5 TWh during 1990-2016, which accounted for 40-67% of the gross electricity generation (see fig. 4.4). Annual production depends on the availability of water resources. [32]
The other main source used to generate electricity is natural gas. It accounted for 20-40% of the total share during the period 1990-2016 [32]. Remaining share of electricity consisted of net import and other renewable energy sources. Latvia is a net importer electricity country. Electricity is mainly imported from Estonia and Russia, although before the closure of Lithuania's Ignalina nuclear power plant, Lithuania was also notable exporter of electricity. The upcoming gradual decommission of Estonia's Narva power plants also diminished the role of Estonia as supplier of electricity highlighting the importance of electricity connections to Europe. [46].

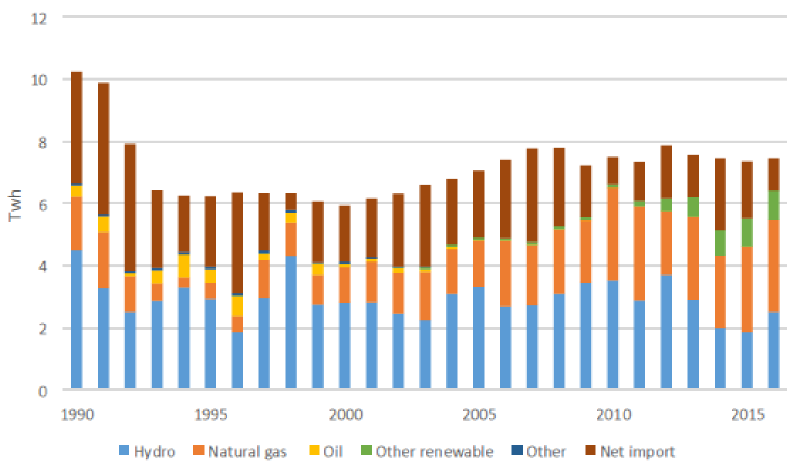

Figure 4.4. *Electricity generation by energy source in Latvia in 1990-2016 [32]*

For renewable energy sources, hydro-power form almost the entire generation mix (see fig. 4.5). Hydro-power is already in use and as a consequence there will be only minor changes in hydro-power production in the future. Wind power is one of most promising renewable energy technologies in Latvia, although further development requires support schemes. The potential of off-shore wind plant is recognized. In addition, utilization of biomass and biogas is growing but subsidies are necessary. [32]

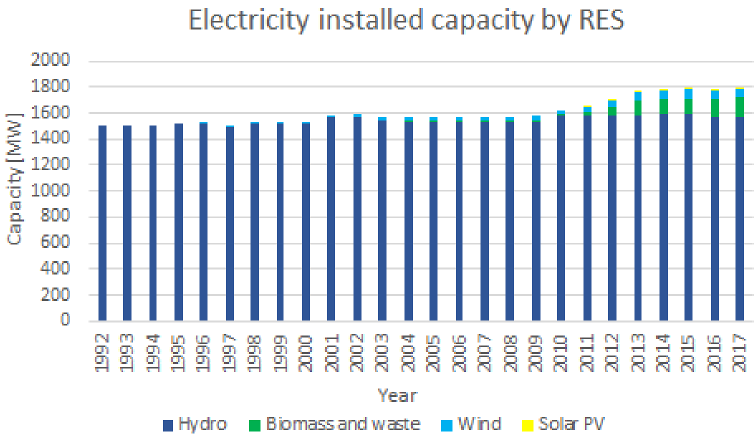

Figure 4.5. *Installed power capacity (in MW) by renewable energy source in Latvia in 1992-2017 [47]*

4.2.2 Market power

Since 1992, Latvenergo has been imposing its market power in Latvia. As cited before, Daugava HPPs (Hydro-power plants) provide the majority of the total electricity generation mix. Latvenergo owns these HPPs.
In 1992 as indicated by the table 4.7, Daugava HPPs, formed almost the total installed capacity due to the great hydro source potential in Latvia. Daugava hydropower plants complex is formed by three HPPs which are: Plavinas HPP, the biggest one. In 1992 it had an installed capacity of 825 MW. Riga HPP and Kegums HPP complete the complex with an installed capacity of 402 MW and 192 MW respectively.
Riga TEC-1 and Riga TEC-2 (today CHPP-1 and CHPP-2) fed by natural gas, complete the total generation mix. These thermal PPs are owned by Latvenergo too. In 1992, market share percentage of Latvenergo equalled 95.36% (almost a monopoly).
The remaining power plants are small HPPs and thermal PPs, not considered in the calculation of the HHI.

In 2001, the reconstruction of the Ķegums HPP and the overhauling of six hydropower units of the Pļaviņas HPP increased the electrical capacity to 248 MW and 908 MW respectively.
Furthermore, in 2005 and 2009 respectively, there was the reconstruction of CHPP-2 and CHPP-1 with the increase of the installed capacity to 142 MWe and 662 MWe [48]. Table 4.9 shows main power plants in 2010.
Respect to 1992, there was the entrance of new firms in the wind power sector and the restoration in 1993 of Aiviekste HPP owned by Latvenergo too.

Table 4.7. *Main Latvian power plants in 1992 [48]*

1992				
POWER PLANTS	**PS**	**SS**	**EGC [MWe]**	**OWNER**
Daugava hydro powerplants:	**water**		**1419.0**	Latvenergo
Plavinas HPP	water		825.0	
Riga HPP	water		402.0	
Kegums HPP	water		192.0	
others (small HPP)	water		79.2	others
Riga TEC-1 CCGT	natural gas		129.0	Latvenergo
Riga TEC-2 CCGT	natural gas		390.0	Latvenergo
others	fossil fuels		15.0	others
TOTAL			**2032.2**	

Table 4.8. *Market share percentage of firms in Latvia in 1992*

1992		
OWNER	**Total capacity [MW]**	**MSP OF FIRM [%]**
Latvenergo	1938.00	95.36

Comparing the years analysed, in 2010 there was a slight decrease of the market share percentage (see table 4.10), mainly owed to the increase of the total installed capacity and the entrance of new firms especially in wind power and fossil fuel sector. Nevertheless, Latvenergo kept its market potential with a market share percentage of 92.67%.

After 2010, the reconstruction of CHPP-1 and CHPP-2 further increase the electrical capacity respectively to 144 MWe and 881 MWe in condensation mode (832 MWe in co-generation mode). [48],[49].
Among renewable energy sources, biomass and waste is the most used solution -after hydroelectricity- even if it represents a low percentage respect to hydro and natural gas sources. In 2017 the installed capacity was 154 MW [47]. It is one of the main reasons that slightly decreased Latvenergo's market concentration ratio (see table 4.11) to 88.19% (highest value of Baltic Countries).
Regarding wind power sector, the theoretical potential could be up to 1,000 MW (as shown by the figure 4.6) that reports the great potential in the Country, especially coast-wise), but considering various barriers to deployment, around half of this theoretical potential is more realistic. Furthermore, approximately one-third of

Table 4.9. *Main Latvian power plants in 2010 [48],[49],[50],[51]*

2010				
POWER PLANTS	**PS**	**SS**	**EGC [MWe]**	**OWNER**
Daugava hydro powerplants:	**water**		**1558.00**	Latvenergo
Pļaviņas HPP	water		908.00	
Riga HPP	water		402.00	
Kegums HPP	water		248.00	
Aiviekste HPP	water		0.80	Latvenergo
Small HPP	water		18.00	others
CHPP-1	natural gas		142.00	Latvenergo
CHPP-2	natural gas		662.00	Latvenergo
Liepaja plants	natural gas	woodchips	6.00	Liepājas enerģija
Ventspils Thermal Power Station	coal	biomass	20.00	SIA ”Ventspils Energo”
others	fossil fuels	biomss	120.45	others
Zalenieki power station	biogas		0.55	others
Ainazi	wind		1.20	Latvenergo
Arsenal	wind		0.85	Arsenal
Baltnorvent	wind		2.00	Baltnorvent
BK Energia	wind		2.00	BK Energia
Impakt	wind		1.00	Impakt Ltd
Liepaja	wind		2.00	Lenkas Energo LTD
Seteri	wind		0.85	Seteri
Veju parks	wind		19.80	Veju parks
TOTAL			**2557.50**	

the total electricity is produced by large combined heat and power (CHP) plants, thus wind cannot immediately replace gas-fired CHPs to provide district heating (unless combination use with heat pumps) [52]. In 2017, installed wind capacity in Latvia was 66 MW [47], clearly lower than Estonia and Lithuania as a result of the already high share of renewable energy sources (hydropower plant above all).
The second biggest firm in that year was Fortum due to the construction in 2013 of the CHP plant Jelgava. It was the first large-scale biomass CHP unit in the country and provides as much as 85% of the heat necessary for Jelgava's district heating. It has an electricity capacity of 23 MWe [53].

Table 4.10. *Market share percentage of firms in Latvia in 2010*

2010

OWNER	**Total capacity [MW]**	**MSP OF FIRM [%]**
Latvenergo	2370.00	92.67
SIA "Ventspils Energo"	20.00	0.78
Veju parks	19.80	0.77
BK Energia	2.00	0.08
Baltnorvent	2.00	0.08
Lenkas Energo LTD	2.00	0.08
Impakt Ltd	1.00	0.04
Seteri	0.85	0.03
Arsenal	0.85	0.03

Table 4.11. *Market share percentage of firms in Latvia in 2017*

2017

OWNER	**Total capacity [MW]**	**MSP OF FIRM [%]**
Latvenergo	2591.30	88.19
Fortum	31.00	1.05
SIA "Ventspils Energo"	20.00	0.68
SIA Getliņi EKO	6.30	0.21
Enefit green (Eesti energia)	2.40	0.08
Kuldigas Siltumtikli	0.70	0.02
Tukums DH	0.73	0.02
Pope wind	20.70	0.70
Veju parks	19.80	0.67
Enercom plus	2.70	0.09
Lenkas Energo Ltd	2.00	0.07
Baltnorvent	2.00	0.07
BK Energia	2.00	0.07
Impakt Ltd	1.00	0.03
Arsenal	0.85	0.03
Seteri	0.85	0.03

Table 4.12: *Main Latvian power plants in 2017 [40],[48],[49],[50],[51],[54],[55]*

2017				
POWER PLANTS	**PS**	**SS**	**EGC [MWe]**	**OWNER**
Daugava HPPs:	**water**		**1558.00**	Latvenergo
Pļaviņas HPP	water		908.00	
Riga HPP	water		402.00	
Kegums HPP	water		248.00	
Aiviekste HPP	water		0.80	Latvenergo
Small HPP	water		13.60	others
CHPP-1	natural gas		144.00	Latvenergo
CHPP-2	natural gas		832.00[3]	Latvenergo
CHPP-2	natural gas		881.00[4]	Latvenergo
Ventspils PP	coal	biomass	20.00	SIA "Ventspils Energo"
Daugavpils	gas		8.00	Fortum
Jelgava CHP plant	biomass		23.00	Fortum
Liepājas enerģija biomass CHP	woodchip		2.30	Liepājas Enerģija
Liepājas enerģija gas CHP	natural gas		4.00	Liepājas Enerģija
Getlini power station	Landfill gas		6.30	SIA Getliņi EKO
Valka power station	biomass		2.40	Enefit Green (Eesti Energia)
Kuldiga power station	woodchip		0.70	Kuldigas Siltumtikli
Tukums power station	biomass		0.73	Tukums DH
Zalenieki power station	biogas		0.55	others
Vecauce power station	biogas		0.26	others
others	fossil fuel	biomass/waste	205.76	others
Ainazi	wind		1.20	Latvenergo
Arsenal	wind		0.85	Arsenal
Baltnorvent	wind		2.00	Baltnorvent
BK Energia	wind		2.00	BK Energia
Enercom plus	wind		2.70	Enercom plus
Impakt	wind		1.00	Impakt Ltd

[3] In cogeneration mode

[4] In condensation mode

Table 4.12 continued from previous page

Liepaja	wind		2.00	Lenkas Energo Ltd
Pope	wind		20.70	Pope wind
Seteri	wind		0.85	Seteri
Veju parks	wind		19.80	Veju parks
others	wind		12.90	others
Solar PV	sun		1.00	others
TOTAL			**2938.40**	

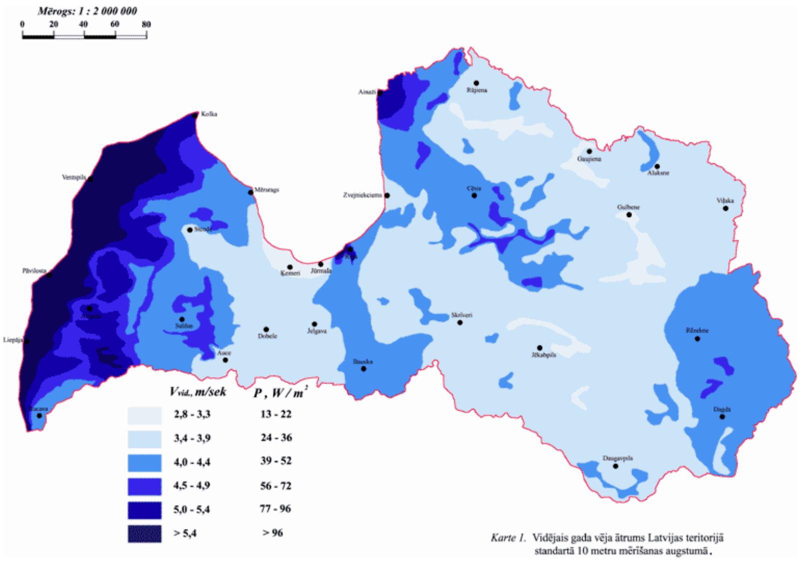

Figure 4.6. *The average speed of wind in Latvia at a height of 10 metres [56]*

4.3 Lithuania

4.3.1 Electricity generation mix

The Lithuanian power sector faced significant changes during the last years. Ignalina Nuclear power plant played a key role in the Lithuanian electricity sector inasmuch the main part of the total share relied on it. Along with nuclear power, natural gas and oil have been important in electricity generation as figure 4.7 shows. [32]
Nuclear power and fossil fuels have been strongly present in the electricity sector

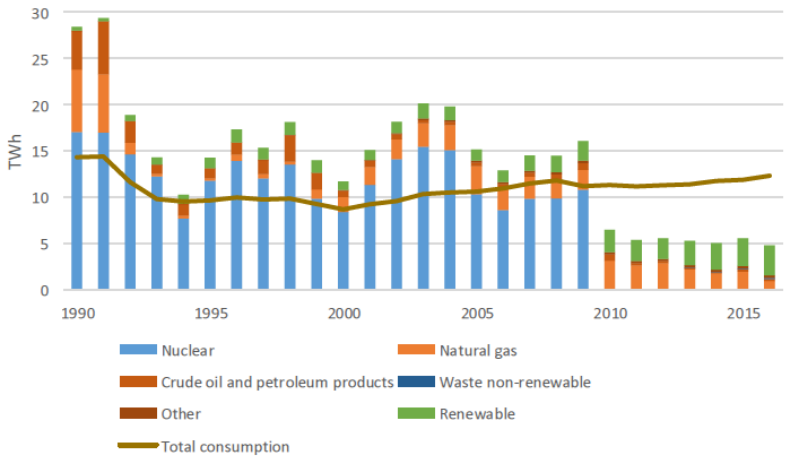

Figure 4.7. *Electricity generation by energy source and electricity consumption in Lithuania in 1990-2016 [32]*

but production from renewable energy sources has been gaining ground since the early 1990s, notably after the decommissioning of Ignalina.
Figure 4.9 shows the development over the years of the main renewable energy sources. For the period 1992-2001, data of hydroelectric pumped storage are not available [47]. Biomass, wind and hydropower are the most promising renewable energy technologies in Lithuania. Biomass could be used especially in CHP plants of large cities. However, the most promising development potential is in wind power. In 2017 the electricity installed capacity was 518 MW [57] (see fig. 4.9). Furthermore in the future construction of new wind farms is planned [58] as also demonstrated by the figure 4.8 that shows great potential of wind in the region.
Before the closure of the nuclear power plant, Lithuania exported power to other Baltic states, Russia and Belarus. Since the end of 2009, with the decommissioning of the two units of Ignalina Nuclear power plant, Lithuania became an importer country, importing mainly from Russia, Belarus and Sweden. In fact, during the last years, the interconnection of Lithuania with other European countries increased with LitPol Link line between Lithuania and Poland, Nordbalt line between Sweden

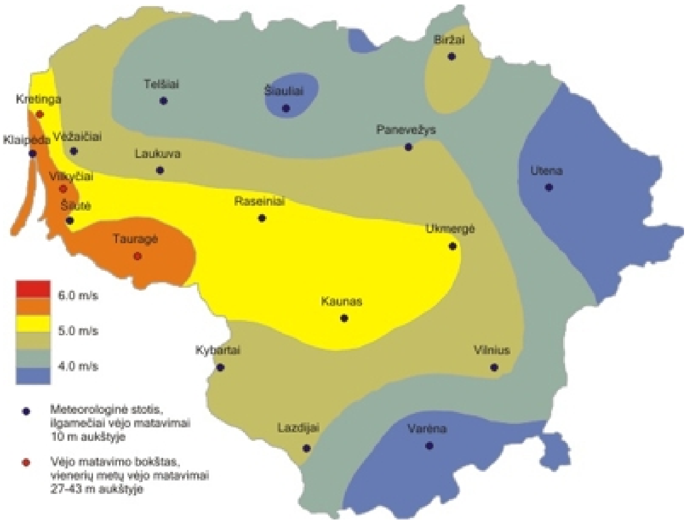

Figure 4.8. *Annual average speed of wind in Lithuania at a height of 50 metres [59].*

and Lithuania and lines under construction between Estonia, Latvia and Lithuania [60].

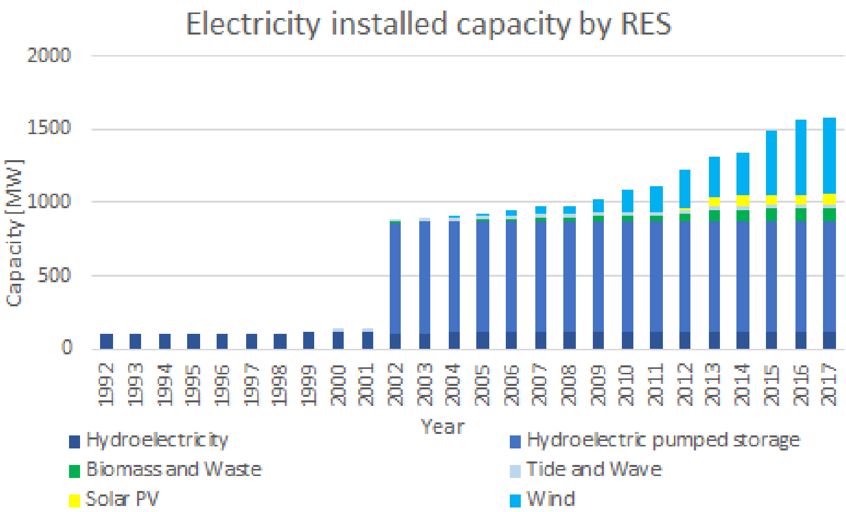

Figure 4.9. *Installed power capacity (in MW) by renewable energy source in Lithuania in 1992-2017 [57]*

4.3.2 Market power

In Lithuania, since 1992, market power was shared between different companies. Ignalinos Atomine Elektrine was the main firm in Lithuania owning the biggest power plant in Baltic Countries (Ignalina Nuclear power plant see table 4.13) and a market share percentage of 53.38% (see table 4.14).
Natural gas is the other main source in the electricity sector. Lietuvos Elektrine Complex owned by Lietuvos Energija (today Ignitis group) had a capacity of 1800 MW and was the biggest natural gas power plant [61]. Ignalina Nuclear Power Plant appeared to be the major supplier of cheap electric energy. Therefore, the power plant was used as a reserve unit for the Ignalina Nuclear Power Plant in case of a sudden shutdown, and to cover electricity demands during total blackouts.
With the changes in the economic situation, there was a demand for alternative fuel sources. Due to the increase in oil prices, the combustion of heavy fuel oil, previously widely used, had to be limited [61]. Lietuvos Energija possessed also Kaunas HPP with a capacity of 90 MW. Total market share percentage of that firms was 33.63% in 1992. The other power plants and owners are reported in the following tables (see tables 4.13 and 4.14).

Table 4.13: *Main Lithuanian power plants in 1992 [57],[61],[62],[63],[64],[65],[66]*

1992				
POWER PLANTS	**PS**	**SS**	**EGC [MWe]**	**OWNER**
Lietuvos Elektrinė Complex	Natural gas	Orimulsion[5]	1800	Lietuvos Energija (Ignitis group)
Vilnius Power Plant 3	Natural gas	Mazut[6]	360	Vilniaus Energija UAB
Kaunas CHP	Natural gas	Mazut	170	Clement Power Venture inc.
Mažeikiai Power Plant	Natural gas	Mazut	160	ORLEN Lietuva
Vilnius Power Plant 2	Natural gas	Mazut	24	Vilniaus Energija UAB
Kaunas HPP	water		90	Lietuvos Energija (Ignitis group)
Other HPPs	water		16	others
Ignalina Nuclear Power Plant			3000	Ignalinos Atominė Elektrinė
TOTAL			**5620**	

A significant event happened at the end of 2009 when Ignalina power plant

[5]Orimulsion is a bitumen based fuel
[6]Mazut is a heavy, low quality fuel oil

Table 4.14. *Market share percentage of firms in Lithuania in 1992*

1992		
OWNER	**Total capacity [MW]**	**MSP OF FIRM [%]**
Ignalinos Atominė Elektrinė	3000,00	53.38
Lietuvos Energija (Ignitis group)	1890,00	33.63
Vilniaus Energija	384.00	6.83
Clement Power Venture inc.	170.00	3.02
ORLEN Lietuva	160.00	2.85

was closed due to the agreement with the European Union that defined the facility dramatically dangerous since the reactors were based on the same models that failed at Chernobyl in 1986 [67]. In fact this plant provided roughly 80% of the country's power needs and enabled Vilnius to export 12 billion kilowatt-hours of electricity in 2003. Moreover, its closure transformed Lithuania from a net exporter of electricity into an importer -with no coal, oil or gas resources to fall back on.
After the shutdown of the Ignalina Nuclear Power Plant, Lietuvos Elektrine PP became the largest source of electricity generation in Lithuania (see table 4.15 below) [61]. The end of the Nuclear sector in Lithuania paved the way to Lietuvos Energija in the national power market. Natural gas followed by hydro became the main source, where Lietuvos Energija owned 71.30% (see table 4.16 below) of the total installed capacity. Besides, the growth of wind power sector was still limited in that year. Vilniaus Energija was the second biggest firm in Lithuania owning 384 MWe (Vilnius PP 3 and Vilnius PP 2) and a market share percentage of only 10.23%, not comparable with Lietuvos Energija's market power.

Table 4.15: *Main Lithuanian power plants in 2010 [61],[62],[63],[64],[65],[68]*

2010				
POWER PLANTS	**PS**	**SS**	**EGC [MWe]**	**OWNER**
Lietuvos Elektrinė Complex	Natural gas	Orimulsion	1800.00	Lietuvos Energija (Ignitis group)
Vilnius Power Plant 3	Natural gas	Mazut	360.00	Vilniaus Energija UAB
Kaunas CHP	Natural gas	Mazut	170.00	Clement Power Venture inc.
Mažeikiai Power Plant	Natural gas	Mazut	160.00	ORLEN Lietuva
Vilnius Power Plant 2	Natural gas	Mazut	24.00	Vilniaus Energija UAB
HPPs	water		876.00	Lietuvos Energija (Ignitis group)

Other power plants using RES:			55.10	others
Wind farms:	wind		**154.00**	
	wind		44.90	JSC Energogrupe
	wind		36.40	UAB Renerga
	wind		35.90	Veju Spektras
	wind		2.63	Dalis gero
	wind		2.00	Energoplius AS
	wind		32.17	others
TOTAL			**3753.10**	

Table 4.16: *Market share percentage of firms in Lithuania in 2010*

2010		
OWNER	**Total capacity [MW]**	**MSP OF FIRM [%]**
Lietuvos Energija (Ignitis group)	2676.00	71.30
Vilniaus Energija	384.00	10.23
Clement Power Venture inc.	170.00	4.53
ORLEN Lietuva	160.00	4.26
JSC Energogrupe	44.90	1.20
UAB Renerga	36.40	0.97
Veju Spektras	35.90	0.96
Dalis gero	2.63	0.07
Energoplius AS	2.00	0.05

Nevertheless, in later years there was a substantial reduction of its market power. Due to the high gas prices and low wholesale prices for power, at the end of 2014 there was a reduction of the installed capacity of Lietuvos Elektrine PP (see table 4.17) [69]. Besides the strong entrance of new firms in wind power sector, reduced market share percentage of Lietuvos Energija to 58.10% (see table 4.18). However, market concentration ratio continues to be very high, demonstrated also by the HHI in the next results section.

Table 4.17: *Main Lithuanian power plants in 2017 [57],[61],[62],[63],[64],[65],[68],[70]*

2017				
POWER PLANTS	**PS**	**SS**	**EGC [MWe]**	**OWNER**
Lietuvos Elektrinė Complex	Natural gas	Orimulsion	1055.00	Lietuvos Energija (Ignitis group)
Vilnius Power Plant 3	Natural gas	Mazut	360.00	Vilniaus Energija
Kaunas CHP	Natural gas	Mazut	170.00	Clement Power Venture inc.
Mažeikiai Power Plant	Natural gas	Mazut	160.00	ORLEN Lietuva
Panevėžys CHP	Natural gas		35.00	Panevėžio Energija AB
Vilnius Power Plant 2	Natural gas	Mazut	24.00	Vilniaus Energija
HPP and HPSP:			**1028.00**	
Kaunas HPP	water		101.00	Lietuvos Energija (Ignitis group)
Kruonis HPSP	water		900.00	Lietuvos Energija (Ignitis group)
HPP connected to distr. net.[7]	water		27.00	others
Wind farms:			**517.71**	
			139.65	Enefit Green
			73.50	Amberwind
			45.60	IKEA
			44.90	JSC Energogrupe
			43.90	UAB Renerga
			35.90	Veju Spektras
			24.00	Eurakras (Renagro)
			6.00	Dolomitas
			6.00	BNE
			6.00	Sarens
			2.63	Dalis gero
			2.00	Energoplius AS

[7]Hydro connected to distribution networks

			1.40	Eglitana
			0.90	Kuprijus
			0.55	Formula-Verner
			0.50	RES
			0.16	Versupis
			0.15	Saulimaras
			83.97	others
Klaipėda CHP	biomass/waste		20.00	Fortum
Šiauliai Biomass PP	biomass		11.00	Siauliu Energija
biomass and waste			59.00	others
Solar PV			74.00	others
Tide and wave			25.00	others
TOTAL			**3538.71**	

Table 4.18. *Market share percentage of firms in Lithuania in 2017*

2017

OWNER	**Total capacity [MW]**	**MSP OF FIRM [%]**
Lietuvos Energija (Ignitis group)	2056.00	58.10
Vilniaus Energija	384.00	10.85
Clement Power Venture inc.	170.00	4.80
ORLEN Lietuva	160.00	4.52
Enefit green	139.65	3.95
Amberwind	73.50	2.08
IKEA	45.60	1.29
JSC Energogrupe	44.90	1.27
UAB Renerga	43.90	1.24
Veju Spektras	35.90	1.01
Panevėžio energija AB	35.00	0.99
Eurakras (Renagro)	24.00	0.68
Fortum	20.00	0.57
Dolomitas	6.00	0.17
BNE	6.00	0.17
Sarens	6.00	0.17
Dalis gero	2.63	0.07
Energoplius AS	2.00	0.06
Eglitana	1.40	0.04
Kuprijus	0.90	0.03
Formula-Verner	0.55	0.02
RES	0.50	0.01

4.4 Results

Results show that in Baltic countries since 1992 there are few power suppliers large enough to affect the market price. In a highly concentrated marketplace, dominant suppliers have the ability to selectively withdraw capacity during peak periods and increase profit [71].
Herfindahl-Hirschman Index (HHI) has been calculated per each country in different

years and results are discussed below.
In Estonia, Eesti Energia still owns the highest market share percentage. Between 1992 and 2010 market concentration remained almost the same passing from an HHI value of 8824.43 to 8284.71 (see below fig. 4.10) because of the entrance of first wind power firms (in 2010 Nelja Energia OÜ owned 90.4 MW after which Enefit acquired the company) that slightly decreased the value. In order to meet energy policies, in 2009-2011 there was the mothballing of two blocks at the Balti power plant (-302 MW) and in 2016 the shut-down of six blocks at the Narva power plants [41] that decreased Narva PP's total generation capacity to 1615 MW. In the meantime, Eesti Energia invested in renewable energy sources installing 263.8 MW of wind power (in 2017) and 207 MW of municipal solid waste commissioning Iru power plant in 2013 [35]. As said in the previous paragraph, Enefit Green was established to unite the renewable sector in one group (see table 4.19). Even if it is a subsidiary, both firms are considered separately in the analysis. In fact, in 2017 HHI reduced to 4655.09. In the next future, Enefit Green is planning to install 1 GW offshore wind in the Gulf of Riga (Estonian government has already initiated construction permit procedure) [72].

Table 4.19. *Major market share percentages of firms [%] in 1992-2010-2017 in respective countries*

	Year		
Owner	**1992**	**2010**	**2017**
Latvenergo (LV)	95.36 %	92.67 %	88.19 %
Ignitis group (LT)	33.63 %	71.30 %	58.10 %
Eesti Energia (EE)	93.92 %	90.91 %	66.24 %
Ignalinos Atominė Elektrinė (LT)	53.38 %	-	-
Enefit Green (Eesti Energia) (EE)	-	-	16.04 %
Clement Power Venture inc. (LT)	3.02 %	4.53 %	4.80 %
ORLEN Lietuva (LT)	2.85 %	4.26 %	4.52 %
Enefit Green (Eesti Energia) (LT)	-	-	3.95 %
Fortum (LV)	-	-	1.05 %

In Latvia, the major electricity is fed by Daugava HPP and by CHPP-2, both owned by Latvenergo. The HHI in 1992 equalled 9094.41 (almost a monopoly) as shown in the figure 4.10. Over the years, the index slightly decreased due to the entrance of natural gas power plants owned by other firms (e.g. Fortum, SIA

"Ventspils ENERGO") reaching the value of 8588.71 (in 2010). In 2017 electricity market competition remained basically equal since Latvenergo owned 88.19% of market share percentage with an HHI of 7779.63 (see fig. 4.10). Biomass and waste represent a low percentage compared to hydro and natural gas sources. In the last years, Latvian electricity market became the highest concentrated marketplace in the Baltics, where Latvenergo has the main potential for exercising market power.

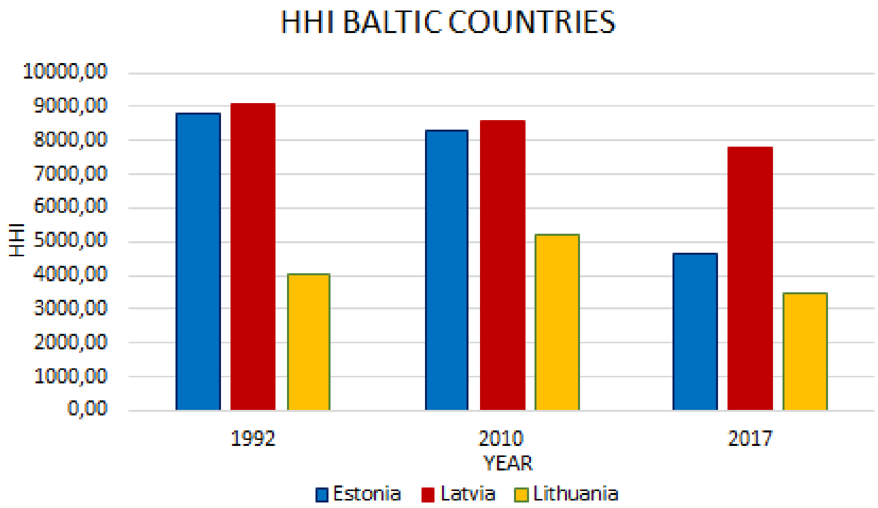

Figure 4.10. *HHI in Baltic countries in 1992-2010-2017*

Regarding wind power, the theoretical potential could be up to 1000 MW, but considering various barriers to deployment, around half of this is more realistic. Furthermore, approximately one-third of the total electricity is produced by large combined heat and power (CHP) plants, thus wind cannot immediately replace gas-fired CHPs to provide district heating (unless combination use with heat pumps) [52]. In 2017, installed wind capacity in Latvia was 66 MW (see fig. 4.11), clearly lower than Estonia and Lithuania as a result of the already high share of hydropower.

Finally in Lithuania, since the independence from Russia, the electricity sector was mainly dominated by Nuclear source. As shown in fig. 4.10, the HHI in 1992 equaled 4044.42, i.e., a highly concentrated marketplace. Ignalina power plant was closed in 2009 due to agreement with the European Union that defined the facility dramatically dangerous, being the reactors the same type as Chernobyl [67]. This plant provided roughly 80% of the country's power needs and enabled Lithuania to export 12 billion kilowatt-hours of electricity in 2003. Its closure transformed Lithuania from a net exporter of electricity into an importer— with no coal, oil or gas resources to fall back on. In fact, in 2012 Russia provided 63% of Lithuania's electricity. However, in 2016, after the construction of LitPol (the connection between Lithuania and Poland) and NordBalt (the connection between Lithuania and Sweden that accounted for 27% of Lithuania's electricity consumption in that year), Russian imports reduced to less than one-third of Lithuania's electricity needs [73].

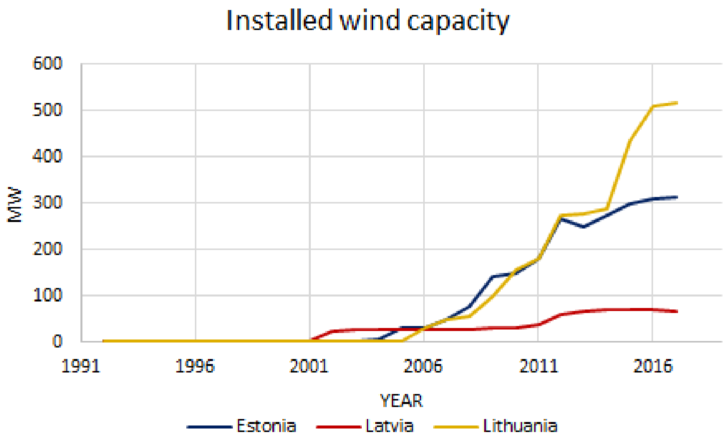

Figure 4.11. *Installed wind capacity in Baltics over the years (1992-2017)* [34],[47],[57]

As expected, in terms of market power in 2010 the HHI increased considerably to 5230.51. The index increased also due to the construction of Kruonis Pumped Storage Plant owned by Lietuvos Energija (Ignitis group). Natural gas followed by hydro, became the main source, where Lietuvos Energija was the main owner. In those years, the growth of the wind sector was still limited to 154 MW installed (see fig. 4.11). However, the modernization of Lietuvos Elektrinė power plant with the further rise of the installed wind (518 MW in 2017) changed the market power scenario [57]. Notwithstanding, marketplace remained highly concentrated being the HHI equal to 3446.43 in 2017.

In the near future, the construction of a wind farm up to 700 MW, i.e. 2.5-3.0 TWh, is planned in Lithuania [74]. This would be 25% of the country's current electricity demand. According to Klaipėda University, approximately 3.35 GW of wind power capacity can be installed in Lithuania's Baltic Sea territory [75]. Enefit Green is planning to install three new wind farms in Lithuania with a total volume of 350 MW proving to be the largest wind energy producer in the Baltics and enlarging its market power potential in other countries [76].

Even despite the significant entrance of wind power firms, Baltic area continues to be a highly concentrated marketplace as demonstrated by the results above.

Chapter 5

Conclusion

This thesis addresses market power scenarios in Baltic countries over the years.
First part describes the technical aspects related to the Nordic Electricity Market and the entrance of the Baltics. In 2010-2013 Baltic States decided to join this common market deregulating their power markets.
In the subsequent chapter, market power and particular behaviours in electricity market are described. As the basis for the case study, market power measures are discussed.
In the second part of the thesis HHI is calculated to estimate the development of market concentration with growing renewable generation. Firstly, an initial overview of the electricity generation mix per each Country is given. In Estonia, oil shale is the main source since 1992. After 2008, there was a high growth of renewable energy sources, above all biomass and wind, however oil shale remained the main source. In Latvia, hydro-power and natural gas are the main sources in the electricity generation sector. Different is the situation in Lithuania, where imports became essentials after the decommissioning of the Ignalina Nuclear PP. However, production from renewable energy sources (biomass, wind and hydro-power) is increasing during the last years. After that, index is calculated and the results show how over the years, the electricity sector in the Baltics is a highly concentrated marketplace. Thus, market entries could be difficult solely on market basis (i.e. without support policies).
From 1992 to 2010 (before the strong entrance of renewable energy sources in the market layout), Latvia and Estonia had the highest HHI values. After 2010 the entry of wind power firms decreased the HHI.
Estonia had the highest decrease of the index due to the division of Eesti Energia with its subsidiary Enefit Green. Enefit Green will expand its market power also in Lithuania.
In Lithuania, market power was mainly owned by Ignalinos Atominė Elektrinė and Ignitis group. After the closure of Ignalina Nuclear power plant, the Ignitis Group's

market share became larger. The heavy entrance of wind power firms slightly reduced the index, still over 3000.
Indeed, Latvia has the highest HHI, due to the significant market power potential of Latvenergo over the years that owns the biggest hydro and natural gas power plant of the country. Notwithstanding the region offers great potential for wind power (theoretical potential is around 1000 MW), the installed capacity is still limited (66 MW installed in 2017).
In conclusion, electricity market in Baltic area continues to be a highly concentrated marketplace as demonstrated by the HHI, even despite the significant entrance of wind power firms.

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