The Estonian RES Subsidies Influence on the Market Participants in the Estonian Electricity Market

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Abstract

Due to coincidence of - the successful Nord Pool Spot market price area opening in Estonia; favorable climate conditions in west coast of Estonia; wind turbine being zero emissions and mature technology, with a short commissioning period after the decision; the high subsidy for the electricity produced from renewable energy sources - an extremely high interest to invest into wind power development in Estonia has arisen.

The analysis show the due to higher environmental costs Estonia will become net importing country already in the year 2016 as the conventional power system will not be competitive. By introducing large-scale wind power production, the electricity sector will become more competitive and the dependence from imported energy will decrease significantly. The total social welfare will increase with every MW of installed wind power capacity.

Foreword

This constitutes the final thesis in the M.Sc. programme in Sustainable Energy Planning and Management at Aalborg University, Department of Development and Planning. The study has been conducted during the period 01.09.2010 - 12.01.2010, under the supervision of external associate professor Anders N. Andersen.

The topic of the thesis has been chosen in connection with the changes in Estonian incentive schemes for the renewable energy producers, which has given birth to a large number of wind power investment projects and if these will be accomplished, the electricity production pattern will change significantly. Therefore the influence of these subsidies for different electricity spot market participants have been analyzed and socio-economic implications estimated.

I wish to express my thanks to my supervisor Anders N. Andersen for his precious insight to the topic, always illustrated with the relevant documentation, valuable comments and suggestions and not least for being understanding and guiding during the difficult times.

Besides the knowledge acquired during the studies, the knowledge regarding modeling and market analysis, put into this work, is gained through practice, while working for the Estonian transmission system operator Elering OÜ. This explains also, why not for all expressions and concepts used in this report have given detailed explanation or in depth definition. At this point I would also like to address that this report results does not express any other viewpoints than my own.

I would like to thank my colleagues from Elering OÜ for their understanding and for sharing their experiences and knowledge as well as making it possible to learn and work with this interesting issue. Special thanks to Mr. Mart Landsberg, who has been the guide from the beginning of my employment in Elering OÜ.

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Maiken Mets

Tallinn, 12 January 2011

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List of abbreviations

BALTSO	Cooperation organization of Estonian, Latvian and Lithuanian Transmission System operators
CHP	Combined heat and power
CO2	Carbon dioxide
DC	Direct current
EU	European Union
EUR	Euro (currency)
€	Euro (currency)
FI_R	Finland
GAMS	General Algebraic Modelling System
GDP	Gross Domestic Product
HVDC	High Voltage Direct Current
INPP	Ignalina Nuclear Power Plant
IPP	Independent Power Producer
MW	Mega watt (1,000,000 W = 1,000,000 J/s)
PP	Power Plant
RES	Renewable energy source
TSO	Transmission System Operator
TWh	Terawatt hour (1,000,000,000,000 watt hours)
WEO	World Energy Outlook
UCTE	Former Union for the Coordination of Transmission of Electricity (Europe)

1 Introduction

In this chapter the scope of the thesis introduced: the background and the context of the analysis will be outlined; the formulation of research question and its' sub-question together with general analytical framework applied to answer these is presented as well as the relevant issues not addressed in this project are discussed.

1.1 Background and the subject of the study

During the last decade the international community has acknowledged the causes and effects of the climatic changes today occurring across the earth: rising temperatures, melting glaciers, earthquakes, frequent droughts, hurricanes, conflagrations, floods, extensive desertification. A growing level of awareness and knowledge in the issue has lead to worldwide actions and political steps to be taken.

As a realistic long-term policy framework the European Union (hereinafter EU) has come up with a climate change strategy which foresees practical actions to be taken to prevent the temperature raise more than 2 degrees of Celsius above the pre-industrial levels. The key component of this action is the reduction of greenhouse gas emissions, which could be achieved by promoting renewable energy sources (RES) and developing the markets in energy sector.

In 2007, EU set itself a target for the year 2020, when 20% of energy consumption has to be from renewable source. To achieve this target, EU adopted a package of measures focusing the energy market more on sustainability and with this laid the foundation for common energy policy. At this point it is convenient to cite the EU directive 2009/28/EC, *whereas*

(1) The control of European energy consumption and the increased use of energy from renewable sources, together with energy savings and increased energy efficiency, constitute important parts of the package of measures needed to reduce greenhouse gas emissions and comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change, and with further Community and international greenhouse gas emission reduction commitments beyond 2012.

(14) The main purpose of mandatory national targets is to provide certainty for investors and to encourage continuous development of technologies which generate energy from all types of renewable sources.

(27) Public support is necessary to reach the Community's objectives with regard to the expansion of electricity produced from renewable energy sources, in particular for as long as electricity prices in the internal market do not reflect the full environmental and social costs and benefits of energy sources used.

As a contribution into combating with the climate change, the EU directions are to be adapted into the Member States national policies. In Estonian the Ministry of Economic Affairs Communications' *Development Plan of the Estonian Energy Sector Until 2018,* the target of 5,1% of electricity from gross domestic consumption has to be produced from renewable energy sources by 2010 and 15% by 2015. The share of cogeneration should form 20% by 2020.

According to the Article 4 of the above mentioned directive all EU Member States were required to submit national renewable energy action plans by 30 June 2010. These plans provide detailed roadmaps of the Member States expect to reach their legally binding 2020 targets for the share of renewable energy in their final energy consumption. *These 2020 binding targets for Baltics States are presented on a table below, in comparison with the renewable energy shares in 2005:*

Table 1.1-1 National overall share and targets for the share of energy from RES in gross final consumption of energy in 2020 (European Commission)

	Share of energy from renewable sources in gross final consumption of energy, 2005	Target for share of energy from renewable sources in gross final consumption of energy, 2020
Estonia	18 %	25 %
Latvia	32,6 %	40 %
Lithuania	15 %	23 %

In the national action plans the Member States have set out the sectorial targets, the technology mix that is expected to use, the trajectory that will be followed and the measures and reforms that will be undertaken to overcome the barriers for developing renewable energy.

In Estonian National Renewable Energy Action Plan the increase of electricity generation from renewable energy sources is foreseen to be based on wind power and cogeneration development, illustrated on a Figure 1.1-1 below. The main means to achieve this target are the set support scheme for electricity production from renewable energy resources.

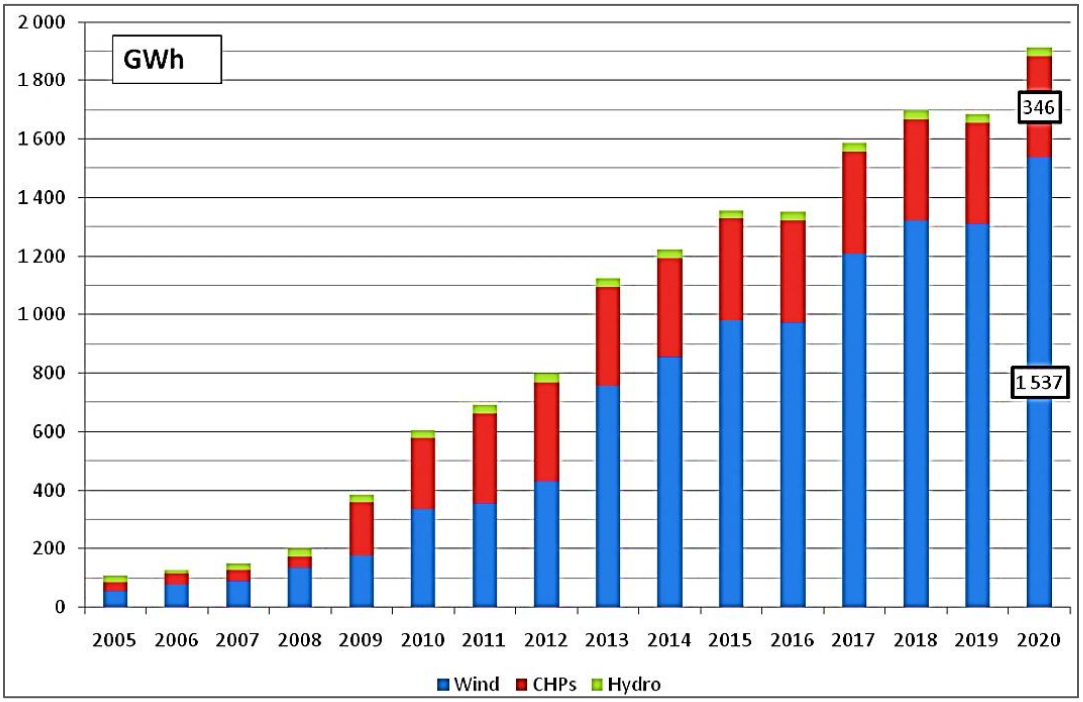


Figure 1.1-1 Electricity generation from renewables in 2020 foreseen in Estonian Renewable Energy Action Plan

The extensive scheme for subsidizing renewable energy sources was introduced back within Electricity Market Act back in May in 2007. After that several amendments to the Electricity Market Act are made. As result, the Narva Power Plants cogeneration unit has become eligible for the subsidy for burning wood chips in addition to oil shale fuel in electricity and heat cogeneration regime.

From February 2010, the electricity producers have the right to receive following subsidies:

- for the electricity produced from renewable sources, excluding biomass, 5,37 eurocent/kWh;
- for the electricity, if it is produced from biomass in cogeneration process, 5,37 eurocent/kWh;
- for the electricity produced in an efficient cogeneration process from waste as defined in the Waste Act, from peat or from the pyrolysis gas of oil shale processing 3,2 eurocent/kWh;
- for the electricity produced in an efficient cogeneration process in a production unit with the capacity not exceeding 10 MW, 3,2 eurocent/kWh;
- for the utilization of installed net capacity if an oil shale using production equipment, whereas the production equipment has to be started operation within the period of 1 January 2013 to 1 January 2016, depending on the CO_2 quota price, 1,4-1,6 eurocent/kWh.

The limit on wind power production, eligible for subsidies, is 600 GWh in a calendar year. (Parliament of Republic of Estonia, 2011)

As a result, partly of the amendments, the consumer paid green energy tax has increased to 0,81 eurocent/kWh in 2010 compared to the 0,17 eurocent/kWh in 2007, which is almost 6 times a difference.

Differently from aforesaid, the subsidies are paid also for the usability of the available oil shale using installed production capacity. The energy political objective of this subsidy is to ensure energy security for Estonia at any time and the main objective is the mitigation of the risks in investing into new oil shale based power production units in connection with the market risks involved in emission trade. The reason for it is that the electricity production from oil shale is very CO_2 intensive – with every MWh of electricity produced 1 ton of CO_2 is emitted. Therefore, the price for CO_2 has a high impact on the cost of the electricity produced and due to this reason the volume of the subsidy to the new oil shale unit is directly linked to the price of CO_2 quota; the subsidy is not paid if the CO_2 quota price is below 10 EUR per ton. (Estonian Competition Authority, 2010) (Parliament of Republic of Estonia, 2011)

Activities on the common electricity market of the Baltic and Nordic countries are not subject to subsidizing, but the subsidies have an effect to the electricity market. Compared to Latvia and Lithuania, where the electricity producers are getting support only for the production sold domestically, in Estonia payment of subsidy does not depend on the place of selling the electricity on the market.

Due to the tendency of ever rising electricity market prices the Estonian Competition Authority has carried through an analysis of the subsidy payment values. In the analysis the effect of support scheme to the electricity market competition and to consumers, as well as the justification of the current subsidy levels was evaluated. The Authority found that the current scheme is not sustainable and in a longer run there will be a situation, where to most of market participants subsidies are paid. Also, that the subsidies distort the market and set unjustified economic load on consumers in the form of green energy tax.

Motivated by the Energy Authority’s analysis the following research question and its sub-question are formulated:

“How will the existing Estonian RES subsidies influence the market participants on the Estonian electricity market?”

“What are the socio-economic implications of these subsidies for Estonia?”

1.2 Analytical framework applied to answer the research question

Compared to other EU countries the Estonian electricity market is small. Based on the statistics of 2009 the peak load was 1513 MW and total annual production, without losses, was 7,8 TWh, total import 3,0 TWh and export 2,9 TWh. The domestic consumption was 7,1 TWh.

In 1 May 2004, Estonia together with the joining EU, Estonia entered into bond to open the electricity market by 35% by 2009 and for all customers by 2013. Since, 1st of January 2009 all customers with annual electricity consumption of 2 GWh are qualified as eligible customers for being free to choose the supplier. From 1st of April 2010 the eligible customers has no right to procure electricity with the regulated tariffs.

In April 2010 the Nordic power exchange Nord Pool Spot (NPS) extended to Estonia by creating the NPS Estonia price area for day-ahead trading in the power exchange. On 22th of April in 2010 the three Baltic transmission system operators (TSOs) Elering, Litgrid and Augstspriema Tikls signed a joint Memorandum in which it was trilaterally agreed that the preconditions for opening NPS price areas in all three Baltic countries shall be fulfilled by 1 January 2011. Unfortunately, this process has not been so fluent as it was expected and the NPS price areas are expected to open in summer 2011.

Due to coincidence of the following developments and conditions: successful market opening in Estonia; good climate conditions in west coast of Estonia, with the average wind power capacity utilization factor 0,35-0,4; wind power zero emissions, mature technology, short commissioning period after the decision; and the high support for the electricity produced from renewable energy sources; an extremely high interest to invest into wind power generation has arisen in Estonia – there are applications for getting connection proposals from TSO for more than 4000 MW wind generation capacity .

In spring 2010 there was carried through a technical by the Danish Energy consultancy Ea Energy Analyses for finding out how much wind power capacity will it be technically possible to integrate into the Estonian power system. (Ea Energy Analyses, 2010)

The results of this study are as follows:

Table 1.2-1 ***Maximum wind power capacity in Estonia with different levels of curtailment and with different capacity of the interconnector between Estonia and Finland***

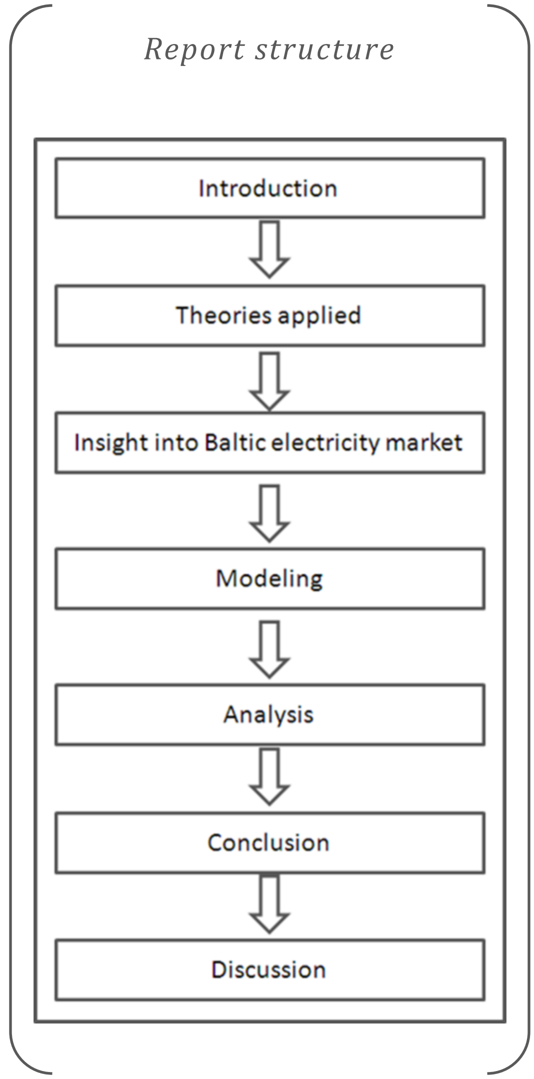
	With Estlink 1	With Estlink 1 and 2			
		Normal	Dry year	Wet year	NordBalt
0.1%	575 MW	1100 MW	1050 MW	900 MW	850 MW
5.0%	1250 MW	2050 MW	2150 MW	2100 MW	2175 MW
20%	2000 MW	3200 MW	3300 MW	3200 MW	3400 MW

From this point of departure –it is technically proved to be possible and there is a high interest to invest into large-scale wind power development into Estonia, the latest mainly driven by the renewable energy subsidies – the answer for the research question will be looked for.

The main focus in this thesis will be on wind power development in Estonia and on its influence to the other electricity spot (day ahead) market participants on the Estonian electricity spot market. Under the "other" electricity market participants the subsidized heat and power cogeneration (CHP) power producers, conventional power producers and consumers are referred. The research question: **"How will the existing Estonian RES subsidies influence the market participants on the Estonian electricity market?"** will be answered by analyzing RES subsidies driven large-scale wind power development in Estonia.

Additionally, on a side of focusing solely only on electricity market participants, the overall socio-economics will be analyzed. The large-scale wind power development for the society as whole will be investigated, whereas with the "society as a whole" in the context of these thesis is referred to Estonia. Among the influence on the power market participants, the influence on the national trade will be investigated. This overall socio-economic analysis will answer the research question's sub-question: **"What are the socio-economic implications of these subsidies for Estonia?"**

1.3 Report structure and methodology



The report is divided into six chapters, illustrated on a right-hand-side figure.

In the Introduction chapter the general background for formulation of the research questions and its' sub-question together with the context of the analysis and general analytical framework applied are introduced. In the end of the chapter the delimitations and assumptions made of the project are listed.

In the second chapter *Theories applied,* the theories relevant for understanding the electricity market concept are introduced. Also, the concept behind the applied analysis is presented.

The aim of the third chapter is to give an insight to the Estonian electricity markets as well as lighten the current status of the Baltic electricity market. In introducing some of the aspects of power markets, the theory is presented next to it.

In the *Modeling* chapter the model used by Ea Energy Analyses is introduced as well as the main model inputs presented.

In the *Analysis* chapter the setup of scenarios for answering the research question presented and the detailed study is formed. In socio-economic analysis the scenarios results are evaluated from the socio-economic point of view and the sub-question of the research question is answered.

In the *Conclusion* chapter the research question and its' sub-question are answered based on the analysis in this study. The cause of the limitations and assumptions made is discussed in the last chapter.

1.3.1 Methodology

For gathering data and knowledge a wide range of tools are used and methods applied:

1) Research papers from Estonian TSO as well the other Nordic TSOs and ENTSO-E;
2) Regional and national official documents and reports;
3) Scientific research papers issued in books relevant to the subject of study;
4) Sustainable Energy Planning and Management courses' lectures' slides;
5) Media articles, publications and presentations;
6) Internet research;
7) Working experience from working Estonian transmission system operator in field of electricity markets;
8) Different electricity market related training courses;
9) Data analysis.

The analysis is performed on the Ea Energy Analyses technical study results, presented in the sub-chapter 1.2. For the analysis the limited market scenario results for the year 2016 are chosen as it reflects the market situation today, where there is no open market in Russia.

All analysis is performed for three scenarios, which are based on different wind power production capacity levels: 600 MW, 900 MW and 1800 MW. For the two last scenarios the Ea Energy Analyses results are used and for the reference scenario with the wind power capacity of 300 MW and 600 MW scenarios, the additional model runs are performed, while all the other input parameters have remained unchanged.

The results from the market modeling are hourly outputs from Balmorel modeling tool:

- Unit generation
- Market area price for all modeled areas
- Flows in all modeled interconnections
- CO2 emissions

Based on these results the economic analysis of the RES subsidies influence, through large-scale development of wind power, on power market participants is analyzed. On the top of all scenario analyses the overall socio-economic analysis is performed.

It is worth to mention that the figures in the analysis chapter have not only an illustrative role but they are part of the results, present, describe and reflect the issues studied.

1.4 Assumptions and delimitations of the project

In this chapter the relevant limitations and the assumptions made in the project are addressed and the cause of non-inclusion of some of them is discussed.

General limitations

1) The analysis are based on spot market, the intra-day market and regulating markets as well as financial markets are not analyzed;
2) The analysis are focusing on Estonia, the impact on whole Baltic region is not considered;
3) The fixed import from Russia is assumed;
4) The other large-scale development of other renewable energy technologies is not studied (biomass BAT; small CHPs; hydro);
5) The alternative power production scenarios are not analyzed – nuclear power, oil shale, oil shale oil, hydro pump storage;

Modeling limitations

1) Only the year 2016 is analyzed and the analysis results are based on the annual results of this particular year;
2) The normal year in means of climate change is studied and no sensitivity studies are included;
3) The CO2 price modeled to be 30 €/MWh, which is the double of today;
4) The large scale-wind power development in Nordic countries is not considered – only 1500 MW of additional wind power capacity in Finland;
5) The nuclear power production in Lithuania is not includes;
6) The Nordbalt interconnection between Lithuania and Sweden is not included;
7) Deterministic model – everything is known, no forecast errors and therefore always an optimal dispatch of power units;

Socio-economic analysis

1) The change employment is not analyzed (social impact for the North-East Estonia; the result from alternative biomass/nuclear/oils shale scenarios);
2) The potential of innovation, development and production of renewable technologies in a country is not considered;
3) The subsidy foreseen for the new CFB unit is not taken into consideration – this is dependent on CO2 quota price and decided to guarantee the investors stable income due to security of supply reasons. The subsidy for the new CFB unit to be built is paid for keeping the capacity – the maximum annual cost for this is 38,35 M€ and is foreseen for

two 300 MW units of which on unit will be operational already in 2016, as could be seen from analyses and the other unit in 2017. This wil mean that these costs for the security of supply will be doubled in 2017 and form 76,7 M€ in total. To have these subsidies included in the socio-economic picture would change the results significantly. The consumer would be in the losers' side and the generators benefit would be significantly higher. As this subsidy is dependent on CO2 quota price, it would be an issue of this analysis.

2 Theories applied

In current chapter theoretical background relevant for understanding the electricity market concept is introduced. Also, the concept behind the applied analysis is presented.

2.1 Market modeling

The market modeling has been used for the optimization of resources. The same algorithms have now been used for the electricity markets modeling, where the optimization takes place for each hour for the modeled period in all modeled areas. The following figure illustrates the market equilibrium during different hours, depending on consumers' behavior.

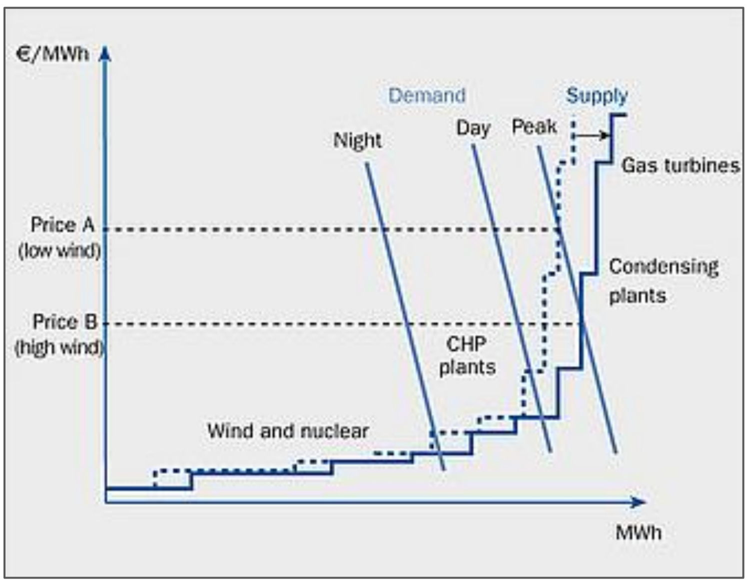


Figure 2.1-1 Electricity market supply and demand equilibrium during different hours (Source: Risø DTU)

2.2 The concept of socio-economic benefit

The total economic to society, also referred as the social welfare, is represented by the sum of consumer and producer surplus on a Figure 2.2-1 below.

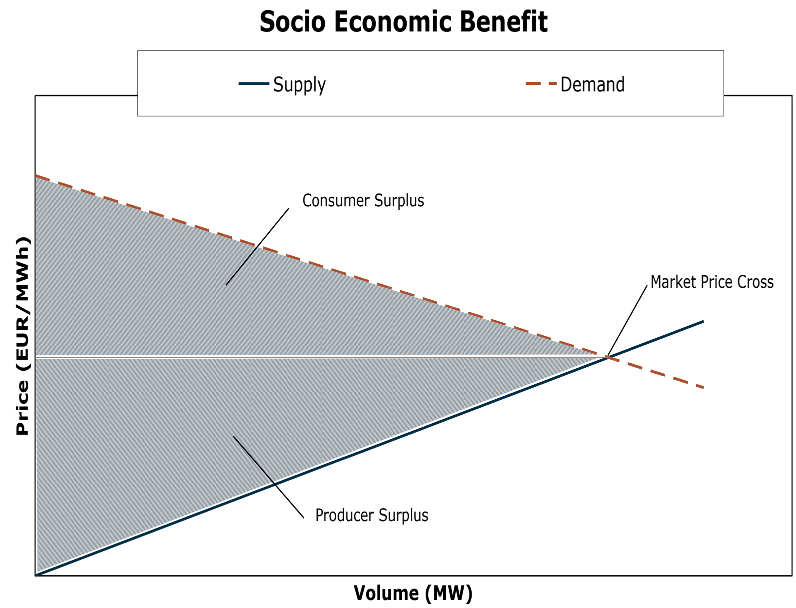


Figure 2.2-1 Producer and consumer surplus (Nielsen, 2010)

The total socio-economic benefit is maximized if the demand and supply are balanced by a price equal to marginal cost, market price cross on a figure above. The marginal cost is equal to short-run marginal cost (SRMC) of the producers and the area under the supply curve reflects the variable cost for operation of the set units. The consumer surplus, striped on the figure above, can partly be used to cover the fixed costs of the production system. (Wangensteen, 2007)

The optimal solution, represented by the market price cross, can be achieved by perfectly competitive market. In order it to be an optimal solution for the society, there should be no external costs. (Wangensteen, 2007)

For modeling more than one area, connected with the transmission lines, the limiting behavior of these lines could cause price differences in the modeled areas. The price difference, caused by the transmission line capacity constraints, is the price of congestion. This price is of the congestion is called congestion rent, illustrated on a figure below. In this case the total socio-economic benefit od the modeled areas includes additionally, to the consumer and producer surplus, the congestion rent. (Andràs Kiss, Péter Kaderjàk, Andràs Istvàn Tóth, Andràs Mezösi, Pàlma Szolnoki, 2007)

Congestion prices occur on competitive electricity markets and arise only in the case, when market participants want to use more capacity than available. This case is illustrated through market coupling examples on Figure 2.2-3and Figure 2.2-4 below.

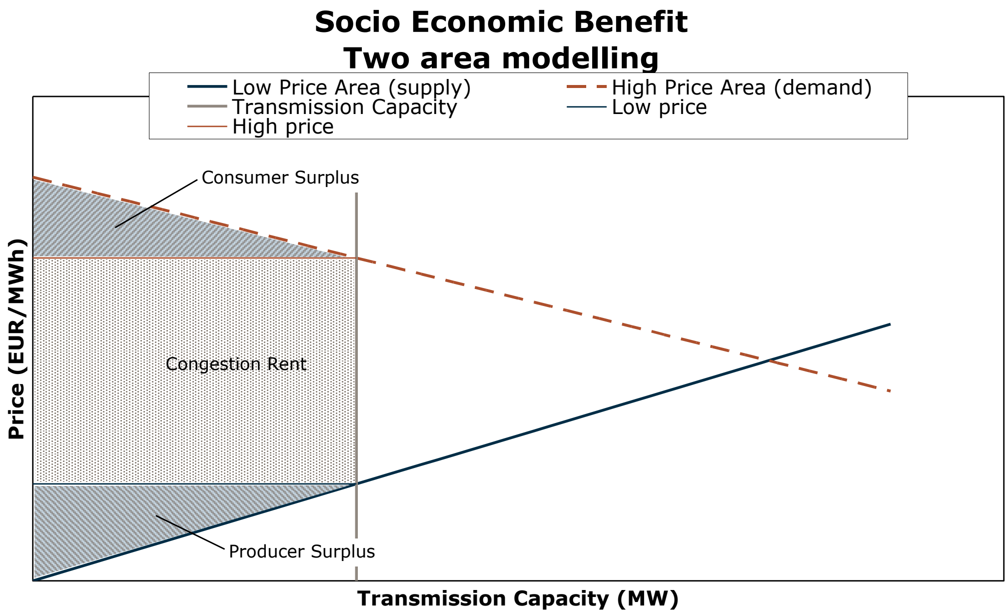


Figure 2.2-2 Congestion rent (Nielsen, 2010)

On the figure below the market price formulation in two price areas is illustrated. The same price areas, but with the transmission capacity of 1000 MW between them is presented.

NordPool Spot						
Simple example of spot trade in a certain hour tomorrow ***No connection between the two price areas***						
	Price area 1			**Price area 2**		
		Amount [MWh]	Bidding price [DKK/MWh]		Amount [MWh]	Bidding price [DKK/MWh]
Buying offer:		2000	*Priceindep.*		2500	*Priceindep.*
Sale offers:	Wind turbines	1500	0	Power plant 5	500	50
	Power plant 1	500	200	Power plant 6	500	100
	Power plant 2	500	250	Power plant 7	500	350
	Power plant 3	500	275	Power plant 8	500	400
	Power plant 4	500	325	Power plant 9	500	435
				Power plant 10	500	450
Spot price of the hour			**200**			**435**

Figure 2.2-3 Market area price formulation example (Andersen)

Now, it can be see that the market price in the area 1 has increased and in the area 2 has decreased.
The consumers in the price area 2 have gained in total 2500 MWh x (435 DKK/MWh – 350 DKK/MWh) = 212 500 DKK.

The consumers in the price area 1 have lost in total 2000 MWh x (275 DKK/MWh – 200 DKK/MWh) = 150 000 DKK.
As the consumers in total have gained more than lost, the total consumer surplus is 212 500 DKK – 150 000 DKK = 62 500 DKK.
As the interconnection capacity is limited and there will be congestion between to areas. The congestion rent in that hour due to different prices in areas will be 1000 MW x 1h (350 DKK/MWh -275 DKK/MWh) = 75 000 DKK. This income will be divided equally between the TSOs of the area 1 and area 2.

NordPool Spot						
Simple example of spot trade in a certain hour tomorrow ***1000 MW interconnector between the two price areas***						
	Price area 1			**Price area 2**		
		Amount [MWh]	Bidding price [DKK/MWh]		Amount [MWh]	Bidding price [DKK/MWh]
Buying offer:		2000	*Priceindep.*		2500	*Priceindep.*
Sale offers:	Wind turbines	1500	0	Power plant 5	500	50
	Power plant 1	500	200	Power plant 6	500	100
	Power plant 2	500	250	Power plant 7	500	350
	Power plant 3	500	275	Power plant 8	500	400
	Power plant 4	500	325	Power plant 9	500	435
				Power plant 10	500	450
Spot price of the hour			**275**			**350**

Figure 2.2-4 Market coupling example (Andersen)

In the area 1 the producers, due to increased demand (from area 2) have gained 275 DKK/MWh x 1500 MWh + 500 MWh x (275 DKK/MWh – 200 DKK/MWh) + 500 MWh x (275 DKK/MWh – 250 DKK/MWh)= 462 500 DKK
In the area 2 the producers have lost due to additional cheaper bids on the market during this hour 500 x (435 DKK/MWh – 50 DKK/MWh) + 500 MWh (435 DKK/MWh – 100 DKK/MWh) + 500 MWh (435 DKK/MWh – 350 DKK/MWh) + 500 MWh(435 DKK/MWh – 400 DKK/MWh) – ((500 x (350 DKK/MWh – 50 DKK/MWh) + 500 MWh x (350 DKK/MWh – 100 DKK/MWh)) = 295 000 DKK
The total socio-economic welfare is 62 500 DKK + 75 000 DKK + 462 500 DKK – 295 000 DKK = 305 000 DKK

This concept, introduced and illustrated above, is also used for the socio-economic analysis in this report.
The additional part of the theory will be presented in the following chapter together with the practical examples from Baltic electricity market.

3 Baltic electricity markets

This chapter describes the restructuring of Baltic power supply systems and the deregulated Nordic power systems, where the generation of power and sales are subject to competition. In Baltics the power supply has been undertaken by monopolistic utilities. Since so far the objective has been supplying consumers with electricity on a minimum costs.

The power system includes supply and demand side. In traditional approach attention was concentrated on the supply side. The idea of the restructuring of the electricity supply industry was to bring the competition into the electricity supply industry. Whereas, parts of the supply system remain natural monopolies and have to be treated accordingly. Therefore, the restructuring of power systems includes unbundling the system competitive and monopolistic activities. Basically it means unbundling the transmission system operator from vertically integrated Power Production Company. (Wangesteen, 2007)

The general theories together with practical solutions and illustrations are to large extent based on the Nordic power systems, but there are relevant parts from the Baltic power systems as well.

3.1 Restructuring of Electricity Supply Industry

The restructuring of electricity supply is a process and could say that it is part of the worldwide liberalization process (Wangesteen, 2007). Similar developments are present in different sectors: gas supply, telecommunications, and to some extent in transportation.

The basis of the monopoly is that economy of the scale enables a one company to produce with decreasing unit cost as the output increases, which makes it possible to supply the consumer with the commodity at lower total cost than two or more competing companies could. (Wangesteen, 2007)

The distribution of electricity is natural monopoly as it is not economically feasible to operate two or more distribution grid in parallel. The feasibility of the transmission grid is more questionable, but for several reasons, the operational coordination among them, the responsibility is left for the transmission grid company (Wangesteen, 2007).

The technical progress in power generation sector together with the information technology has decreased the efficient scale of different activities in the sector and could be said that the electricity generation have no significant economy of scale[1] anymore. This means that several power producers can operate in parallel without extra cost and thus, different providers can compete with each other without necessarily driving the rivals out of the market. It can be seen that the competition is a strong driver towards efficient operation and future investment decisions. Therefore, the competition is most preferred to regulate the sector (Andràs Kiss, Péter Kaderjàk, Andràs Istvàn Tóth, Andràs Mezösi, Pàlma Szolnoki, 2007), (Wangesteen, 2007).

One step towards competition in power supply sector was opening the grid to Independent Power Producers (IPPs). Access to the grid is vital presumption for efficient competition as it represents physical marketplace for the trade between producer and consumers. To facilitate transmission open access rigid and sound regulations are required. This was first introduced in US by the Carter administration in 1978 (Wangesteen, 2007). Similar legislation was implemented in Denmark, Germany, France, Spain and Italy by favoring especially production based on renewable energy sources (RES) and electricity and heat co-generation (Wangesteen, 2007).

These changes did not open up for retail sales for consumers. The power supply company kept the monopoly on the transmission lines and on sales to consumers, basically was the single buyer, who acted like a purchasing agency. The figure below illustrates the steps towards retail competition – the yellow colored columns show the increasing openness of the originally vertically integrated company.

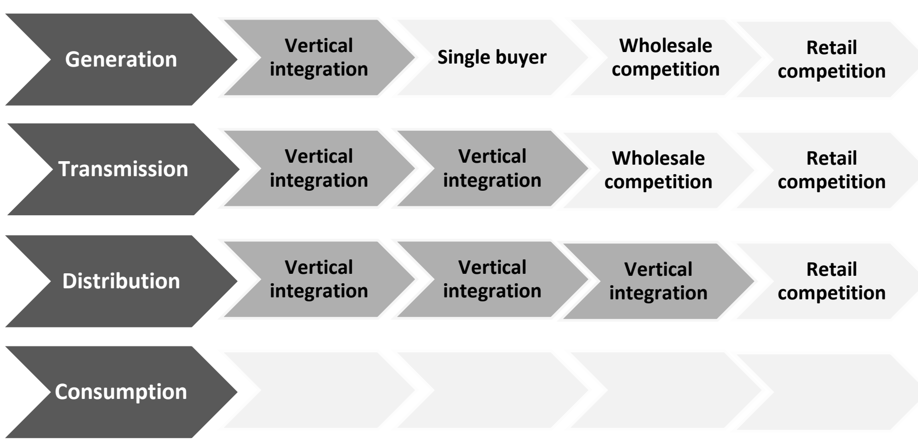


Figure 3.1-1 Different stages of grid openness

[1] Economy of scale in power generation has been a subject to discussion as there has been a certain belief that the generation cost per kWh is higher in small unit than in a large unit. The practice from last few years shows that the cost per unit decreases as the size of generating companies increases due to specialization, management, financing, marketing and other factors.

The step followed for the single buyer model was introduction of wholesale competition, giving distribution companies and large consumers (eligible consumers) the right to buy electricity directly from producers. The last step was to open access to the distribution network – to open up the retail competition (Wangesteen, 2007).

3.1.1 Restructuring/Liberalization

The liberalization/restructuring means opening the electricity production and sales to competition – opening the electricity market; whereas the distribution and transmission sectors remain natural monopolies and their activities will be regulated. (Wangesteen, 2007)

Competition is the main coal of liberalization. Ideally, the perfect market is the most desirable market structure. The perfect market structure could be characterized with the situation where all companies in the industry are price takers and there is freedom to enter and leave from the industry. The perfect market is classified according to the following three criteria: independence, product substitutability and entry criterion (Zamagini, 1987). In real markets, it is very rare that these criteria are satisfied. Considering the technical constraints, caused by the intrinsic characteristics of electricity, it can be deduced/presumed that perfect competition does not/cannot exist on the energy market. The performance of market is evaluated by its social welfare. "Social welfare is the combination of the cost of energy and the benefit of the energy to society measured by the society's willingness-to-pay for it." (Kwok Lun Lo, Yee Shan Yuen, 2001) Maximum social welfare could be achieved on the perfect market, but a real market frequently operates at a suboptimal level. (Kwok Lun Lo, Yee Shan Yuen, 2001)

The pioneer of restructuring its electricity sector in Europe was England and Wales in 1989, where the deregulation came with the Electricity Act. Norway followed in 1990 and the other Scandinavian countries together with Finland joined in the 1990s.

The Council of European Union issued and Internal Electricity Market Directive in 1996 (96/92/EC), which set the goals for gradual opening of the electricity market for all member states. In 2003 the new Directive set the goal to open the market for electricity and gas by 1st of July 2007. In 2009 in the framework of the Third Energy Package the Directive was adjusted.

In 2004 the Baltic States joined with the European Union. Concerning the Electricity Market Directive, the Lithuania and Latvia had to open their electricity markets in July 2007, which they did, but *de facto* nothing changed.

3.1.1.1 Restructuring process in Estonia

During the accession EU and Estonia reached to the compromise for further development and step-by-step opening of the electricity market in Estonia. The transitional period of opening the electricity market until 2013 (31.12.2012) was given. The other steps agreed were as follows:

- From 1.01.2009 at least 35% of the market had to be opened. The eligible customers, whose annual consumption exceeded 2 GWh got the freedom to choose between regulated price or contractual price directly from supplier. As this did not work that well and the consumers did not switch the supplier, the possibility to buy electricity with the regulated tariffs was repealed and they were pushed to the open market. Due to reduction in electricity demand the actual opening level has been around 28% (but the share is increasing, there have been a month with 35% share).
- From 2013 100% of the market has to be opened.

From 1999 until 2009 the market have been opened for the customers whose annual consumption is more than 40 GWh, they make up around 10- 12% of total consumption.

The ownership of the TSO was unbundled and since January 2010 the Estonian TSO (Elering OÜ) is an independent company. The shares of the company have been transferred from the vertically integrated company Eesti Energia AS to the Ministry of Economic Affairs and Communications

01.04.2010 the Estlink price area in NordPool Spot power exchange was opened. Since 01.04.2010 the eligible customers have no right to purchase the electricity with the regulated price. Today's market price is higher than the regulated price, for some consumers the price have risen even 50%.

3.1.1.2 Restructuring process in Lithuania

In Lithuania in the electricity market opened *de jure* in July 2007 as in other EU countries. This meant that all customers became eligible and could choose their electricity supplier. *De facto* nothing changed as it were difficult for the end customer to change the supplier.

On the 1st of January in 2010 the first power exchange market in Baltics – Baltpool started its operation. Today the Baltpool markets up to 70% of electricity consumed in Lithuania (Kubilius, 2010). Customers with connection 400 kW and above are pushed to the market as the possibility to buy the electricity with the regulated prices is abolished. Officially these customers should make up to 35% of electricity consumption. The step-by-step plan foresees the gradual reduction of the connection level up to 2013, when 65% of consumers are pushed to the market. This is done in order to facilitate practical implementation of the open electricity market and to accelerate the market relations in the regional as well as in the domestic power market. (Republic of Lithuania, 2008)

To ensure the compliance with regulations provided in European 3rd Energy Package the energy sector reform by unbundling energy production, transmission and distribution is undertaken. The four functional units – production, transmission, distribution and services will be formulated by January 2011. This would create the preconditions for Lithuanian energy sector to operate in the common competitive EU market.

3.1.1.3 Restructuring process in Latvia

The Latvian TSO Augstprieguma tikls is legally unbundled from June 2007.

In Latvia the dominating energy supplier is the state owned vertically integrated Joint Stock Company Latvenergo, which generates more than 90% of all domestic electricity production, ensures the import, and is responsible for the distribution and supply for the consumers.

According to the Electricty Market Law in Latvia the vertically integrated company Latvenergo has been nominated as a “public supplier”, thus having the obligation to supply all customers. By today as a result of liberalization and it reforms all functions of the electricity distribution system operator (DSO) have been taken over.

All households and non-household customers with less than 50 employees and yearly turnover less than 7 million LVL (9.786 million EUR) have the rights to use the universal service of electricity, which means they have the right to use the ability to be supplied by economically justified price. The customers not qualifying are obliged to buy electricity from traders with contract price. (Meņģelsons, 2010)

In Latvia 35,6% of total electricity is traded for non-regulated contract price. In year 2009 90 customers switched the supplier of which 4 switched back to Latvenergo on 1st of January 2010. The 8% of the free market customers purchase electricity from independent traders. (Meņģelsons, 2010)

If the electricity is imported from or exported to non-EU country (Russia) the perimeter fee 0,7 EUR/MWh has to be paid. (Meņģelsons, 2010)

Guidelines for the energy sector development from 2007-2016 in Latvia foresee further support market liberalization and competition by ensuring the competitiveness of economy, diversity of energy supplies and sustainable development. The steps forwards are seen in development of regulatory principles of commercial activities of energy companies.

At the EU level there was set up the Baltic Electricity Market Integration Project (BEMIP). With the BEMIP the integration of Baltic States into EU energy networks was one of the main objectives that will contribute to the stability and economic growth of the Baltic Sea Region. Also, the Baltic region was among the six priority areas identified by the European Commission in the Second Strategic Energy Review. The BEMIP plan set steps for power market liberalization foresee the market liberalization in Estonia, TSOs unbundling in Baltics, start-up of the Power Exchange and removing of the obstacles from producers to be active in the power market.

3.1.2 Insight into Baltic energy sector development

Drastic changes in Estonia's economy were brought with regaining the political and economic independence in 1991. These changes meant rapid increase in fuel and raw material prices and problems with oil products from Russia, though there was decrease in energy consumption. Today, the main oil-shale fired power plants units are more than 40 years old. Some of the units have been closed and two of them have been renovated during the last years. Today the domestic consumption and some of the electricity exports are covered by the existing production capacities but severe restrictions are expected in 2015. This is due the EU directive on limitation of emissions into the air from large combustion plants, with which the PPs have to comply. The directive is active from 2008, but during the accession negotiations with EU Estonia got the transition periods. Compared to 1990s, only 6% of the installed power plants can continue operating after the year 2015. Additionally to the investments needed into power generation, the substantial investments are needed to develop and modernize the electrical networks in hand with the implementation of environmental projects. (Landsberg, 2008)

During the last decade, the Latvian power system power capacity has been in deficit, this affects most the base load segment. The share of imported electricity has been around 30-40% in power balance. This cap is tend to increase as there is continues growth in electricity demand. This leads to increasing problem of security of electricity supply and in the light of the retirement of the power generation capacities in the neighboring countries the matter comes even more important.

Most of the electricity in Latvia is produced by the run-of-river hydro power plants (Daugava River), therefore the production depends heavily on hydrological climate conditions. There are also large CHP units in Riga, but they are operated according to the heat demand, which again depends on weather conditions. Also, the CHPs are ran on gas, which is an expensive fuel, imported from East – from Russia. The overview of the Latvian generation capacities is presented on the Figure 3.2-4.

Most important driving forces in Lithuanian energy sector are growth in economy, growing dependence on imported energy from Russia and the closure of Ignalina Nuclear Power Plant (NPP) in the end of 2009. The electricity consumption during the past years has shown the most rapid increase compare to the other forms of energy. After the closure of NPP, most of the power is supplied by the gas-fired power plants. The list of the power plants in operation in Lithuania in 2010 can be found from the Figure 3.2-5. In the light of opening the electricity markets and ever-rising CO2 prices, the closure of Ignalina NPP will mean increasing electricity prices for the entire Baltic region, especially for Lithuania and Latvia.

3.1.3 Important factors that influence the liberalization process in the Baltic States

Today there are a list of important factor that influence the liberalization process in Baltics, also many steps that are already taken:

- Closure of the Ignalina Nuclear Power Plant (NPP) in the end of 2009;
- Closure of Narva thermar power plants (PP) un-refurbished units by 2016;

  These steps have lead Baltics into generation deficit already from 2010 as Latvia was in deficit already before and now there is Lithuania depending on Russian import as well. Though, Estonia is currently only net exporting Baltic State, it will be in deficit from 2016.

The important steps in Estonia

- Full liberalization of Estonian power market in 2013;
- Decision to build second HVDC cable to Finland “EstLink 2” and have it in operation from 2014;
- The Parliament approved the amendments to the Electricity Market Act in February 2010, removing the regulated price option from 35% of the market from 1st of April 2010;
- Launch of NordPool Spot (NPS) price area Estlink on 1st of April 2010, on 1st of October 2010 renamed to NPS Estonia;
- Imports from third countries can be traded only via power exchange. (Kisel, 2010)

The important steps in Lithuania

- Start-up of the Baltpool Power Exchange from 1st of January 2010;
- Additional amendment to the electricity market legislation in June 2010, which lead to the formulation of independent system operator (ISO) Litgrid UAB. (Kisel, 2010)

First experiences from the power market

- Volumes of trade in power exchange have exceeded all the expectations;
- As average, power prices in NoPo Spot Estlink price area are lower than in Finland and Lithuania Russian power traders are not active in Estlink price area;
- Power prices in Estonia have increased to eligible customers by 50%;
- Price increase is mainly driven from high demand in Latvia and Lithuania. (Kisel, 2010)

The other important factor pushing forwards the Baltic markets integration with the common EU market is the fact that Baltic Republics rely solely on Russian gas imports (so does Finland). After closing down the Ignalina Nuclear power plant, the Baltics, especially Latvia and Lithuania have become deeper independent from energy import from Russia and Belarus. The gas imports are grown mainly due the increased production of local gas fired thermal power plants and construction of new 400 MW combined cycle CHP in Riga and two new 400 MW combined cycle gas turbine units in Lietuvos PP in Lithuania. Together with the increased gas import the electricity import has gone up as well due to strong deficit of the Baltic region. This makes Baltic States particularly vulnerable and the serious actions are needed to be taken, among which:

- The identification of new sources of energy supply;
- Strengthening the interconnections with neighboring European member states;
- Integration with the European power pools.

3.1.4 The interconnected Baltic power system countries

In order to understand the transmission system situation in Estonia, Latvia and Lithuania the short background information will be given.

Despite the common frequency of 50 Hz around the Baltic Sea region, there are three different power pools: ex Nordel (now entso-e), ex UCTE (now entso-e) and BALTSO (now entso-e). The power systems in the Baltic States (BALTSO) are in synchronous operation with the IPS/UPS pool of the Russian Federation, Ukraine, Belarus and the other CIS States (with the exception of Turkmenistan). In order to illustrate the differences in size, capacities and consumption the Figure 3.1-2 below is colored accordingly and the values are on the top. BALSTO is a part of the IPS/UPS.

The UPS (Unified power system of Russia) is Russian portion of the and includes a six regional transmission operators , UPS of Russia came into existence as a result of Russian Federation Decision on 11 the July 2001 "On the Restructuring of the Russian Federation United Energy

System". The Integrated Power System (IPS) portion of the network includes the national networks of Ukraine, Kazakhstan, Kyrgyzstan, Belarus, Azerbaijan, Tajikistan, Georgia, Moldova and Mongolia. (Reliable electricity system and requestedextensions towards CIS and Baltic countries, NorthAfrica and Middle East, 2004)

The Baltic States are relatively strongly interconnected with each other, but lack interconnections to rest of EU, but Finland electricity markets. Whilst the Nordic Countries are connected with the Central Europe through 9 HVDC links the Baltic countries can exchange energy only with Nordic countries through the one HVDC link (Estlink) from Estonia to Finland. The undersea cable was commissioned in 2006 and has the limited capacity of 350 MW. (Stockholm Environment Institute Tallinn Centre, 2008)

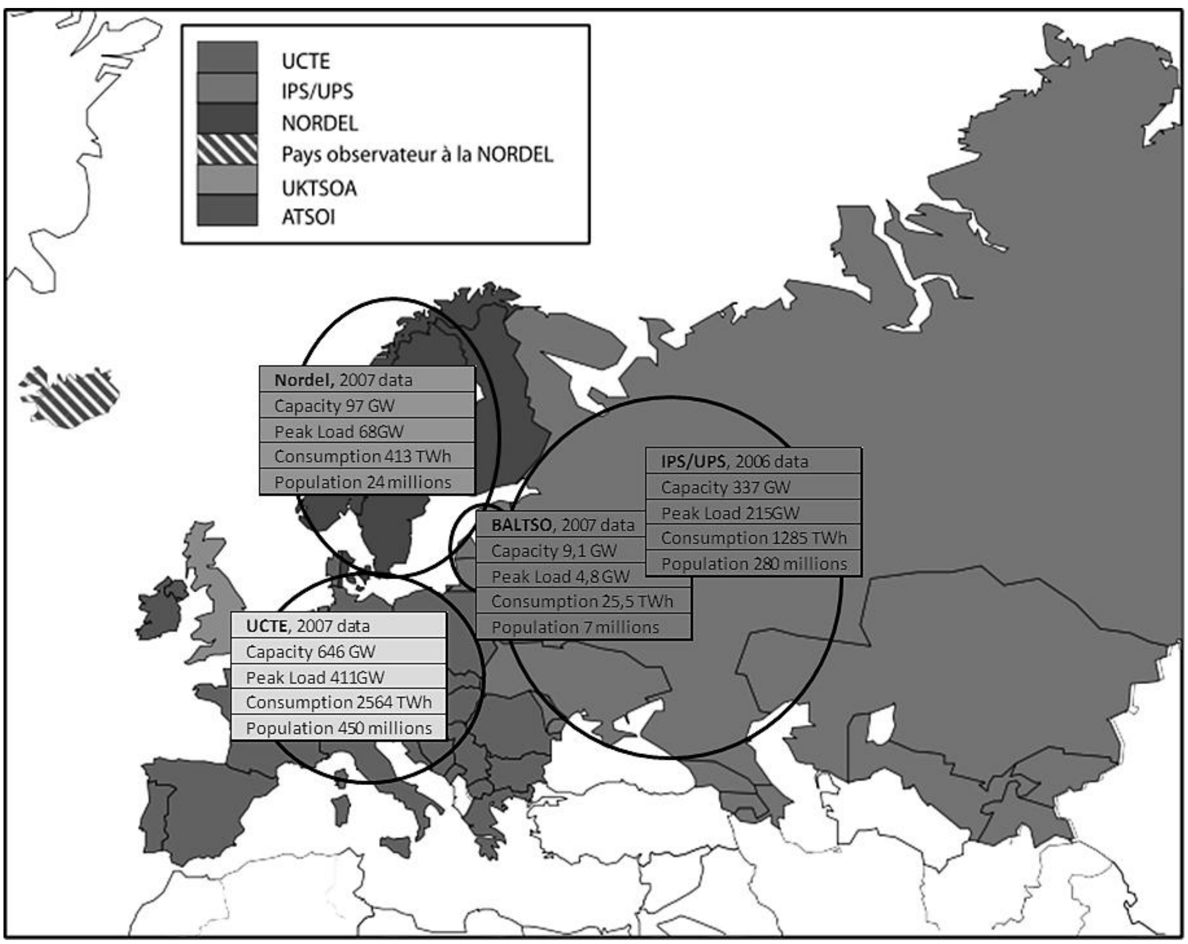


Figure 3.1-2 The different synchronous areas in Baltic Sea region. Inspired by the map of UCTE (Working Group Electricity Interconnections, 2009)

As the Baltic States are strongly connected to the Russian power system, there are loop flows from Russia to Belarus and flows from South to North, which strongly affect Baltic Republic grids. A further complexity is derived from the geographical location of the Kaliningrad region, which transmission system is connected with Lithuania. Hence, the loading in the Baltics, especially in the Lithuania and Latvia is affected by the power transfers from Russian Federation to the Kaliningrad region.

On the initiative of the Baltic power companies, an agreement on parallel operation in 2001 by five power companies (Lietuvos Energija, Latvenergo, Eesti Energia, RAO UES of Russia and Belenergo) was signed. On the basis of the agreement BRELL (Belarus – Russia – Estonia – Latvia – Lithuania) was established. The BRELL committee and the working groups solve the problems related to parallel operation of the united power system. The solutions coordinated by the committee are following the EU standards and requirements.

Today, highlighted in the BEMIP and accelerated by the European Economy plan for Recovery (EEPR), there are under construction additional HVDC links to the Nordic countries: the EstLink 2 of 650 MW between Estonia and Finland and NORDBALT of 700 MW between Sweden and Lithuania. This is part of the Baltic Electricity Market Interconnection Plan – to ensure the reliability and security of the Baltic energy systems and to move towards integrated common EU energy market. (InterLinks, 2010)

Additionally, there is planned interconnection from Baltics to Western European electricity system – a 400 kV overhead line between Poland and Lithuania with capacity of 1000 MW is planned. This would be the first connection to the South from Baltics and would contribute to the power independence in Baltics and Poland, guarantee the energy supply continuity and be part of the development of an integrated EU electricity market. (Link, 2009)

3.2 The Baltic generation system

The power industry in Baltics is becoming more and more dependent on imported natural gas. In Estonia the power production today relies on old oil-shale thermal PPs of which approximately 75% will be shut down in 2015; in Latvia the local production is mostly based on Daugava hydro power plants, but additional import of electric energy is needed to cover the demand and Lithuania today, after the closure of Ignalina NPP, is fully dependent on imported gas to fuel the local gas PPs.

There will be gap between production capacities and consumption (peak demand) in the amount of 3000 MW by 2015 and additionally around 1500 MW of capacities will be fuelled with the natural gas imported from Russia. This capacity cannot be considered fully reliable and due to high gas prices has upwards price pressure. Although there are planned new power plants to be developed, but as the construction requires huge investments and it is not probable to have these units completed by 2016.

The changes in generation are illustrated on the figure below.

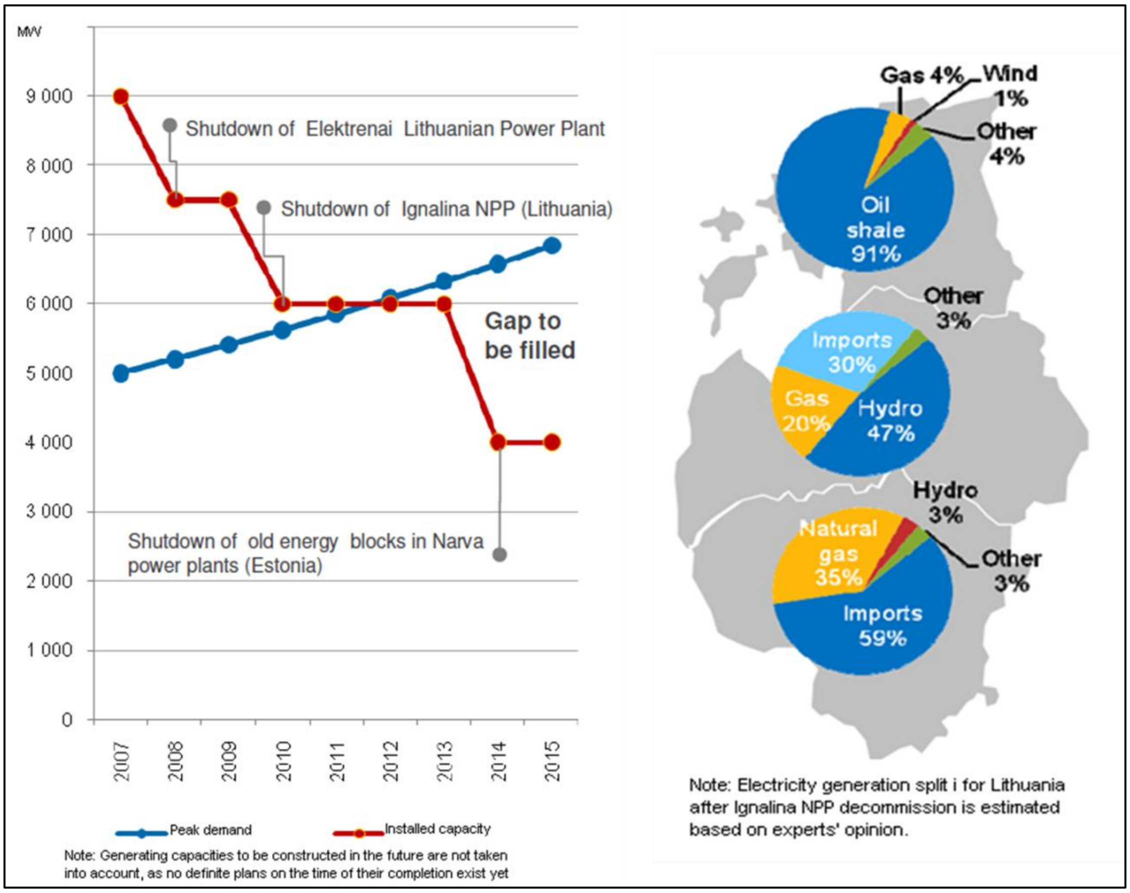


Figure 3.2-1 The changes in generation capacities in Baltics States. (Freenergy, Eesti Energia)

3.2.1 The power generation in Estonia

The power system in Estonia consists of vast thermal units in Narva, medium and small-scale electricity and heat co-generation units together with the energy produced from the renewable energy sources, mainly wind power production.

The main fuel for energy production in Estonia is the domestic fuel - oil shale. Approximately 95% of electricity and 25% of heat is based on oil shale combustion. The stone is extracted from the underground mines and open pit quarries in South-East of Estonia, the largest oil-shale mining company is the Eesti Energia Kaevandused AS. The electricity generation in concentrated close to the mains, which are in South-East of Estonia, close the city Narva, which actually has a border with Russia. There are two main thermal oil shale fuelled power plants, Eesti and Balti Power Plant (Narva Elektrijaamad AS). Historically, these plants were designed to supply North-West Region of USSR (Union of Soviet Socialist Republics; Союз Советских Социалистических Республик) and then approximately 50% of the electricity was exported. The *advanced* power sector was inherited from the USSR in 1991, when Estonia restored its independence.

The power plants are 21-45 years old by now and are very close to the operation limit. In 2015 most of the blocks will be closed due to the SO_2 limitations. There are plans to build two new blocks of 300 MW by 2018. These new units need improvement in technology as the existing units were designed to cover the base load.

There have been investments into new generation capacities but all these investments are heavily subsidized by green energy tax and even for the planned new domestic fuel (oil-shale) based units will be subsidized in accordance with the CO2 price on the market.

During the last years (2008-2010) there have been constructed three new CHPs, all 25 MW in biggest cities of Estonia: Tallinn, Tartu and Pärnu. Additionally to these CHPs, there are planned and under construction a number of wind parks. According to the best estimated scenario there would be 2800 MW wind turbines by 2015. This estimate is based on contracts signed with Estonian TSO and new connection applications. Today there are constructed approximately 150 MW of wind turbines and considering the annual production limit of 600 GWh for wind energy that will be subsidized, the 2800 does not sound very realistic. According to the wind study carried through by the Danish consultancy company Ea Energy Analyses, the technical limit of the system before construction of EstLink 2 would be 600 MW and after the construction of HVDC cable the limit would be around 900-1100 MW of wind turbines. These numbers are achieved in the framework of existing legislation, under which it is not possible for the TSO to cover the additional balancing costs from grid tariffs either letting the wind power producers pay. Also, the expansion of the wind power capacity limited with the fact that the there is missing mechanism which would allow to allocate the cost of the curtailed wind for the various stakeholders. (Ea Energy Analyses, 2010)

Today the biggest generator in Estonia is the state owned corporate company Eesti Energia AS (Enefit), which owns presently five thermal power plants: Balti PP, Eesti PP, Iru PP, Ahtme CHP and Kohtla-Järve CHP. The production of power plants owned by Eesti Energia forms approximately 95% of total Estonian electricity production, whereas, almost 90% of the power is produced in condensation units in the Eesti PP and Balti PP (Narva Elektrijaamad AS). The structure of the Estonian power generation system is illustrated in Figure 3.2-2 and in the Figure 3.2-3 Estonian power production portfolio in 2010

Power plant	Fuel	2010	2015	2016	2020
Conventional power plants	oil shale	1808	2058	1110	1380
Conventional power plants	gas, oil	200	367,5	367,5	367,5
CHPs	firewood, peat, biomass, waste	82,307	137,387	137,387	134,767
CHPs	gas, oil shale, non-ident.	244,15	247,75	272,75	292,75
Hydro	water	4	4	4	4
wind in use, contracts, offers	wind	147,265	2848,565	2848,565	2848,565
SUM *best estimate*		2485,722	5663,202	4740,202	5027,582

Figure 3.2-2 Best estimate of installed generating capacity in Estonia [MW] (Elering, Estonian Power System Adequacy Report, 2010)

Power Plant	Type of fuel	Installed electrical capacity, MW	Available electrical capacity, MW	Installed thermal capacity, MW
Estonian Power Plant	Oil shale	1495	1346	84
Estonian PP TG1	Oil shale	180	162	
Estonian PP TG2	Oil shale	180	162	
Estonian PP TG3	Oil shale	180	162	
Estonian PP TG4	Oil shale	180	162	
Estonian PP TG5	Oil shale	190	171	
Estonian PP TG6	Oil shale	190	171	
Estonian PP TG7	Oil shale	180	162	
Estonian PP TG8	Oil shale/Wood	215	194	
Balti Power Plant	Oil shale	714	630	160
Balti Power Plant TG9	Oil shale	155	140	
Balti Power Plant TG10	Oil shale	160	145	
Balti Power Plant TG11	Oil shale	215	180	160
Balti Power Plant TG12	Oil shale	184	165	
Iru Power Plant	Natural Gas	190	165	338
Iru EJ EP1	Natural Gas	80	67	110
Iru EJ EP2	NG/HFO	110	98	228
Väo Power Plant	Wood	25	23	
Tartu Power Plant	Wood/Peat	25	23	
Pakri Wind Park	Wind	18,4	18,4	
Viru-Nigula Wind Park	Wind	24	24	
Aulepa Wind Park	Wind	39	39	
VKG Power Plant	Oil shale	44	44	
Ahtme Power Plant	Oil shale	24,4	15,2	
Sillamäe CHP	Natural Gas	6	6	5,8
Horizon	Bio	6	5,5	
Small power plants	Various	30		
Total		**2640,8**	**2339,1**	**587,8**

Figure 3.2-3 Estonian power production portfolio in 2010 (Toptšilin, 2009)

3.2.2 The power generation in Latvia

The specific feature of the Latvian power system is the electricity production from hydro energy. The Daugava River, the main source of hydro energy has been used close to its potential by having three cascades of the hydro power plants (HPPs): Kegums HPP with the installed capacity of 264 MW, Palvinas HPP with the capacity of 869 MW and the Riga HPP with the capacity of 402 MW. Due to environmental restrictions the potential of smaller rivers cannot be fully utilized but the generation from existing HPPs could be increased by 10-12% by introducing new modern technologies. This power generating system is especially sensitive and its performance forecast complicated as both HPPs and CHPs are largely influenced by climate conditions – water flow in the Daugava River, precipitation and air temperature. The analysis show that during the winter, when the consumption level reaches its maximum the Daugava river inflow is minimal, the same situation is also observed in summer. As the main HPP are run-of-river plants, there is not possible to collect and store the water, consequently, this adds to the deficit of the generating capacities to cover the peak demand. (Latvia, 2006)

Beside the HPPs, there are two large gas-fired CHPs in the capital Riga, the TEC-1 with the installed electrical capacity of 142 MW and TEC-2 662 MW.

The fact is that the domestic HPPs and CHPs do not cover the full demand of the supply and the rest is imported from Russia and Estonia, to some extent also from Lithuania.

The main target for the electricity sector in Latvia is to reach self-sufficiency of the national power system. This is planned stepwise – 80% by the year 2012 and 100% by 2016. Regarding the renewable energy sources (RES) the share of 49,3% is planned for the current year (2010). The Latvian production portfolio for the year 2010 can be seen from the Figure 3.2-4.

According to the “Guidelines for Energy Sector Development 2007-2016” the government’s most important objective is to achieve the balance between electricity demand and supply. This is hoped to achieve with the promotion of energy-efficiency and by using local fuel and RES in efficient CHPs.

The development plan foresees an increase of CHPs to 650 MW by the year 2015 and the construction of new coal fired power plant by 2015. This is done to reach the government’s goals and to prevent excessive domination of imported natural gas. The share of RES based new investments is foreseen to be 650 MW by the year 2025. Also, there is political wish to participate in the construction of the new Lithuanian (Visaginas) NPP by having a share of 300 MW of the project. (Latvia, 2006)

Power Plant	Type of fuel	Installed electrical capacity, MW	Available electrical capacity, MW	Installed thermal capacity, MW
Riga TEC-1	Natural Gas	144	139	143
Riga TEC-2	Natural Gas	662	597	659
Plavinu HPP (Daugava cascade)	Water	869	860	
Riga HPP (Daugava cascade)	Water	402	397	
Kegums HPP (Daugava cascade)	Water	264	261	
Aiviekste HPP	Water	1	1	
Ainazi WPP	Wind	1	1	
Imanta CHP	Natural Gas	46	42	46
Small HPPs	Water	26	23	
Private WPPs	Wind	24	24	
Industrial CHP and Bio PPs	Natural Gas/Bio	100	72	
Total		**2539**	**2417**	**848**

Figure 3.2-4 Latvian power production portfolio in 2010 (Toptšilin, 2009)

3.2.3 The power generation in Lithuania

In terms of energy resources Lithuania is very dependent on Russia – all crude oil and natural gas imported from there. Also, the nuclear power was mainly imported from neighboring country. The consequence of this dependency is that the economy and politics are heavily affected by the Eastern neighbor.

Additionally to the pipeline from Russia, the supply of crude oil is also available from other countries - through two oil terminals. Coal can be supplied by rail from Poland and Russia. Since the end of year 2009, the Lithuanian energy sector was mainly based on nuclear power and due to that differed from other Baltic countries. The list of installed electricity production units in Lithuania in 2010 can be found from the Figure 3.2-5 below.

Today's main targets in the power sector in Lithuania are defined in the "National Energy Strategy". To compensate the closure of Ignalina NPP, the construction of the ninth 400 MW combined cycle gas turbine (CCGT) unit into the Lietuvos Elektrine is planned, will be completed by 2012 (Kubilius, 2010). The most important power sector targets are:

- construction of new Visaginas NPP with the capacity up to 3600 MW, in order to satisfy the needs of the country as well as the region;
- the interconnection of the Baltics with Western European and Nordic countries;

- More efficient use of PPs and the Krounis hydro pump storage power plant (HPSP);
- construction of new CHPs in Klaipeda, Šiauliai,Panevežis, Alytus, Marijampole and other cities with sufficient and well developed district heating systems or industrial enterprises requiring heat for its processes. (Lithuania, 2007)

On 10th of September in 2010 he Ministry of Energy requested potential strategic investors in the Visaginas Nuclear Power Plant (VNPP) to submit their binding bids. Also, there are introduced opportunities for local business sector to participate in the construction of VNPP. The potential of Baltic business sector to invest is estimated reach 30% of the total cost (approximately 1,2 billion euros) of the project. (Kubilius, 2010)

In Kruonis HPP has started the project to install the fifth hydro-aggregate, will be commissioned in 2014. This will enable to regulate the imbalances and balance the fluctuations caused from wind power generation.

Power Plant	**Type of fuel**	**Installed electrical capacity, MW**	**Available electrical capacity, MW**	**Installed thermal capacity, MW**
Lietuvos Elektrinei	**NG/HFO/orimulsion**	**1800**	**1732**	**174**
Lietuvos Elektrinei unit 1	NG/HFO/orimulsion	150	144	87
Lietuvos Elektrinei unit 2	NG/HFO/orimulsion	150	144	87
Lietuvos Elektrinei unit 3	NG/HFO/orimulsion	150	144	
Lietuvos Elektrinei unit 4	NG/HFO/orimulsion	150	144	
Lietuvos Elektrinei unit 5	NG/HFO/orimulsion	300	289	
Lietuvos Elektrinei unit 6	NG/HFO/orimulsion	300	289	
Lietuvos Elektrinei unit 7	NG/HFO/orimulsion	300	289	
Lietuvos Elektrinei unit 8	NG/HFO/orimulsion	300	289	
Vilnius CHP	**Natural Gas/HFO**	**384**	**366**	**707**
Vilnius CHP 2	Biofuel	24	22	102
Vilnius CHP 3	Natural Gas/HFO	360	344	605
Kaunas CHP	**Natural Gas/HFO**	**270**	**153**	**389**
Kaunas CHP 1	Natural Gas/HFO	110	96	203
Kaunas CHP 2	Natural Gas/HFO	160	57	186
Petrasiunai CHP	Natural Gas/HFO	8	7	74
Mazeikiai CHP	HFO	160	148	350
Klaipeda CHP	Natural Gas/HFO	11	9	44
Panevezya CHP	Natural Gas/HFO	35	33	
Krounis HPSP	**Water**	**900**	**760**	
Krounis HPS unit 1	Water	225	190	
Krounis HPS unit 2	Water	225	190	
Krounis HPS unit 3	Water	225	190	

Krounis HPS unit 4	Water	225	190	
Krounis Pump Station	Water	900	880	
Kaunas HPP	Water	100,8	50,4	
Small HPP	Water	26,4	26,4	
Wind PP	Wind	52	52	
Other Bio CHPs	Biofuel	7	7	
Lifosa CHP	Natural Gas	31	31	
Achema CHP	Natural Gas	21	21	
Industrial CHPs	Natural Gas	23	21	
Total		**3829,2**	**3416,8**	**1738**

Figure 3.2-5 Lithuanian power production portfolio in 2010 (Toptšilin, 2009)

3.3 Differences in Nordic and Baltic power markets liberalization

When comparing Estonian/Baltic power markets with the Finnish/Nordic power markets on the way towards open electricity markets the picture is very different, illustrated on the figure below.

After the first steps towards common market are done, there is still a list of challenges the Baltic States are facing with:

- The transit flows of Russian to Kaliningrad and loop flows through Estonia and Latvia to Belarus should not hamper the trade between Baltic countries;
- Fair pricing of electricity from third countries in EU from 2013 (including the imported energy (from non EU country) into the emission trading system (ETC));
- Regulation of Latvian and Lithuanian power markets (opening the retail market, fair treatment of all market participants);
- There is missing regulation for allowing power exchange in Latvia;
- Common principles for renewable energy support schemes and subsidies;
- Development of power exchange – NPS price areas for Latvia and Lithuania (incl. NPS to replace Baltpool);
- Opening Elbas intra-day market (from 19th of October opened in Estonia);
- Financial Market
- Investments into new capacities. (Kisel, 2010)

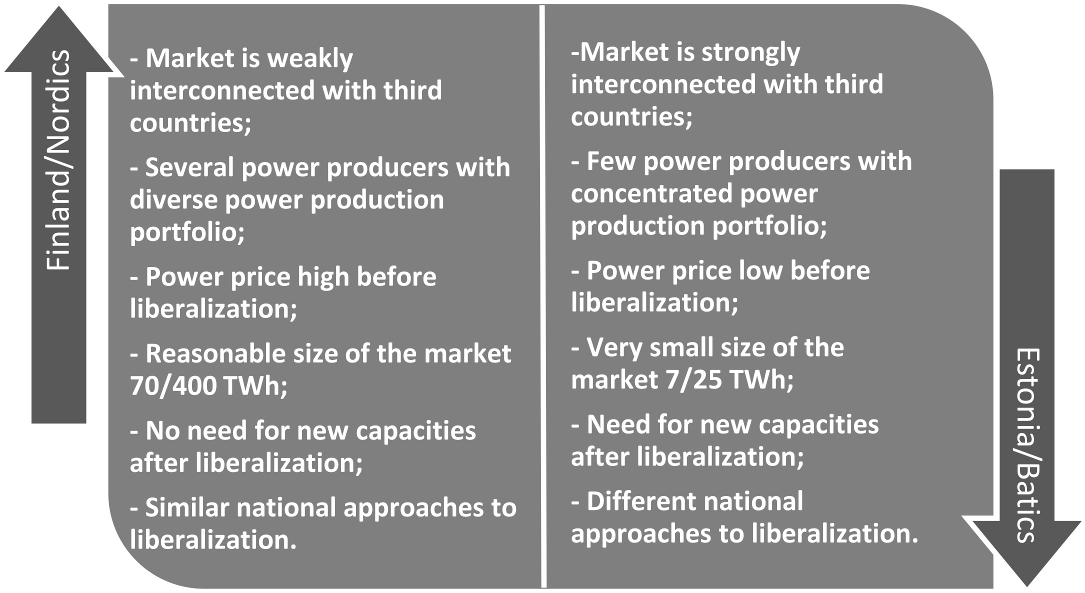


Figure 3.3-1 Difference between the Baltic and Nordic power markets (Kisel, 2010) (Kwok Lun Lo, Yee Shan Yuen, 2001)

3.3.1 Conclusions

The short conclusions about the liberalization process and market opening in three Baltic countries taking into consideration the given time and *aided* framework (EU & Nordic support) would be as follows:

- The Baltic power market in its characteristics/condition/figures is very different from Nordic power market;
- The BEMIP process has boosted the power market opening and its development in Baltics;
- There are challenges in Baltic countries national legislations as well as on EU level to be tackled.

3.4 Nord Pool Spot

"Nord Pool Spot runs the largest physical power market in the world, offering both day-ahead and intraday markets to its participants. 330 companies from 20 countries trade on the exchange. The Nord Pool Spot group has offices in Oslo, Helsinki, Stockholm, Fredericia

(Denmark) and London. Nord Pool Spot is owned by the Nordic transmission system operators. In 2009 the group had a turnover of 287 TWh representing a value of EUR 10.8 billion." (Mäkelä, 2010)

The function of Nord Pool Spot is to provide a liquid market for electrical energy, information to the market, equal opportunities for all market participants while being the central counterparty in all trades and guaranteeing settlement for trade. (Sutter, 2010)

3.4.1 The electricity market price formulation at NPS

The clear and compact explanation for the electricity market price formulation is provided by Lennart Hjalmarson from School of Business, Economics and Law at Göteborg University: *„The primary role of a market price is to establish equilibrium between supply and demand. This task is especially important in the power markets because of the inability to store electricity and the high costs associated with any supply failure. The Spot market at Nord Pool Spot is an auction based exchange for the trading of prompt physically delivered electricity. It is the central Marketplace for Nordic Electricity. The Spot Market carries out the key task of balancing supply and demand in the power market with a certain scope for forward planning. In addition to this, there is a final balancing process for fine adjustments in the real time balancing market. "* (Hjalmarason)

The Spot Market main task is to create equilibrium between consumer and suppliers. It is done by calculating hourly prices for coming day, which balances the opposing sides, based on producer bids and consumers offers received.

„A well-functioning and competitive power market produces electricity at the lowest possible price for every hour of the day. The balance price represents both:

i) The cost of producing one kWh of power from the most expensive source needed to be employed in order to balance the system - either from a domestic installation or from external imports. Or:

ii) The price that the consumer group is willing to pay for the final kWh required to satisfy demand. " (Hjalmarason)

„The primary function of an organized spot market for electricity is to maximize cost efficiency by supplying the demand for power from the most economic source available. It is difficult to achieve such optimization without a continuous price setting mechanism producing a transparent equilibrium price. The large differences in production costs for the different

generating units entail a high risk for losses of efficiency stemming from a poorly functioning pricing system. In addition, a much greater reserve capacity would be necessary in order to guarantee supply in a system without a successful spot market. " (Hjalmarason)

In summary – Price Levels in the spot market are determined by the balance of supply and demand and as such are only affected by changes in this relationship." (Hjalmarason)

When talking renewable energy production, it is important to keep in mind which influences it has on prices, the figures below illustrate the impact on price, whether there is a change in demand or supply.

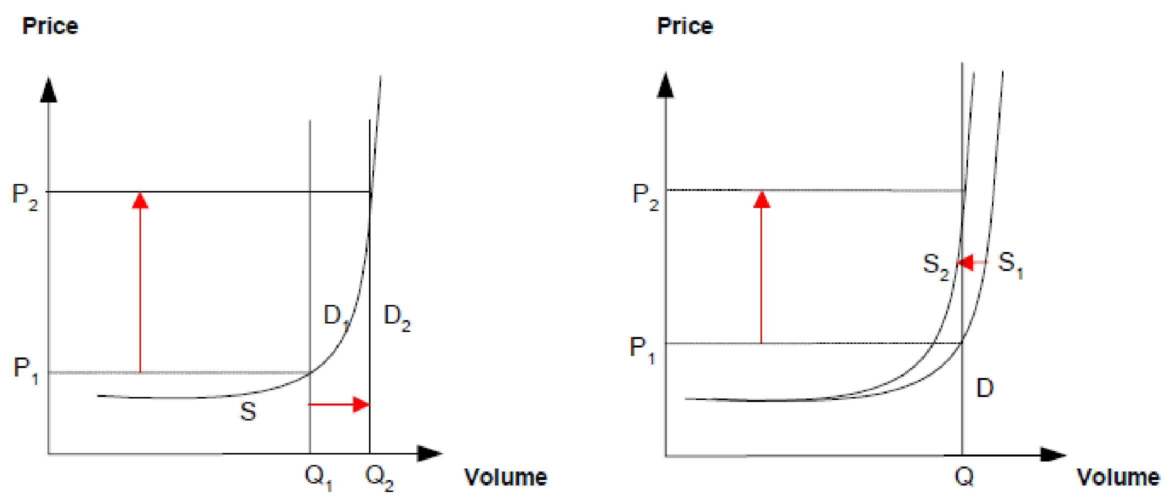


Figure 3.4-1 Impact of demand and supply shifts on prices: on short run (Kaderjàk, 2009)

3.4.2 The factors that influence electricity price

There are many factors that have an influence on the electricity market price.

The variable costs, made by power producer, depend on following factors:

- Hydro balance (in the areas with large-scale of hydro power capacity, Norway and Sweden for example);
- fuel price (the price for coal, gas and oil);
- CO2 market price;
- Start and stop cost of the power unit;
- The planned operation and maintenance and emergency repair works of the bigger power plants;
- The wind speed and the wind power production;

From demand side the power production depends on the following factors:

- The GDP growth;
- Political situation;
- Human behavior;
- Demand/consumption related to the lighting, outdoor temperature, weather etc.;

There additional factors are:

- Financial market data: prices, quantities;
- The transfer capacities, bottlenecks;
- Changes in legislation. (Toptšilin, 2009)

In Scandinavia the hydropower balance has a significant influence in the electricity market. It can be seen from the figure below that the negative balance of the hydro increases the electricity price.

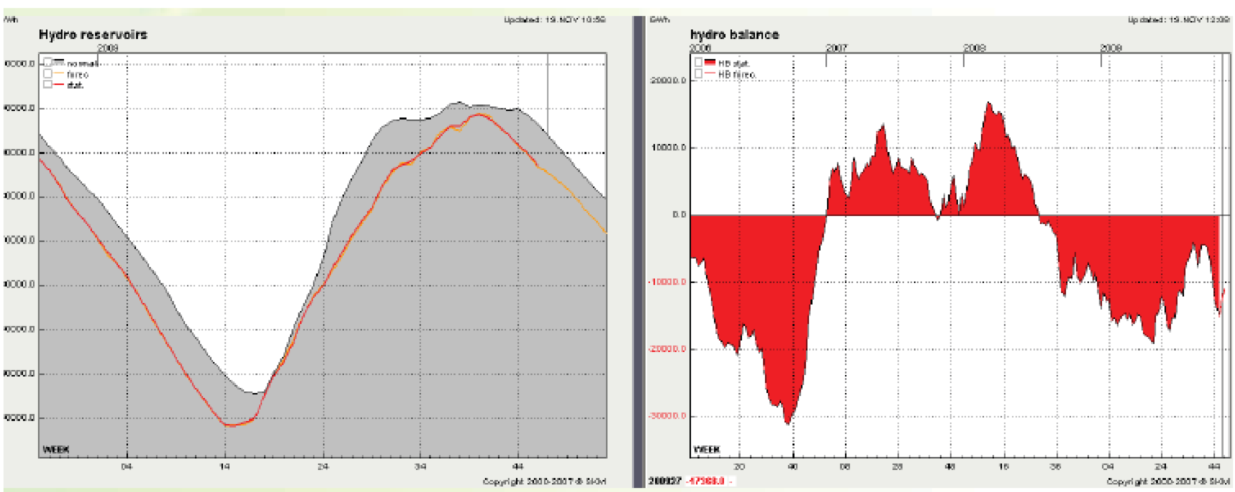


Figure 3.4-2 The hydro power balance influence on electricity price (Toptšilin, 2009)

It is estimated that around 76% of observed variation in Nord Pool spot price is explained by Nordic hydrological balance

According to the International Energy Agency and Eurostat the electricity prices in the Baltic countries are among the lowest in the EU.

3.5 The Baltic Power Market

As more and more countries and regions open their electricity markets up to competition, the question of prime importance is how to design the national electricity market in the best interests of consumers and suppliers.

The Baltic TSOs Augstsprieguma tikls, Elering and Litgrid agreed that from 1st of January 2011 the common Baltic electricity spot market will be activated with three price areas – Estonia, Latvia and Lithuania. The time-schedule foresees the harmonized market design/procedure application, the integration of Elbas market, latest in the end of 2013. (Mäkelä, 2010)
The NPS BEMIP project is originated to fulfill several of the targets described in the BEMIP, which is the EU indicative to achieve further integration of Estonia, Latvia and Lithuania with EU energy networks and energy markets. The project is a joint project formed by an agreement of the power exchange Nord Pool Spot AS, Elering OÜ, Augstsprieguma tikls and LITGRID UAb, Fingrid Oyj and Svenska Kraftnät.
The goal of the project is to make the sale and purchase of electricity for physical delivery between Baltic countries more efficient, whereas optimizing the utilization of cross border capacity. The project supports the expansion of the NPS market area to all Baltic countries by introducing both the day ahead spot market (Elspot) and intra-day (Elbas) market. (Ingrid Arus, Meribel Müürsepp, 2010) (Mäkelä, 2010)

The Intra-day market Elbas launched in Estonia on 19th of October 2010.

Figure 3.5-1 Expansion of NPS into all Baltic States (expected start from the year 2011)

Until 2011 it is agreed that 80% of the available transmission capacity (ATC) between Estonia and Latvia will be dividend according to the NPS procedure and the rest 20% will be divided weekly based explicit auctions and where the bought capacity could be used for two days ahead planning phase trades. This possibility is used by the market participants who own the bilateral contracts with the Latvian or Lithuanian market participants and also is used for the transit through Estonia. (Elering, 2010) (Müürsepp, 2010)

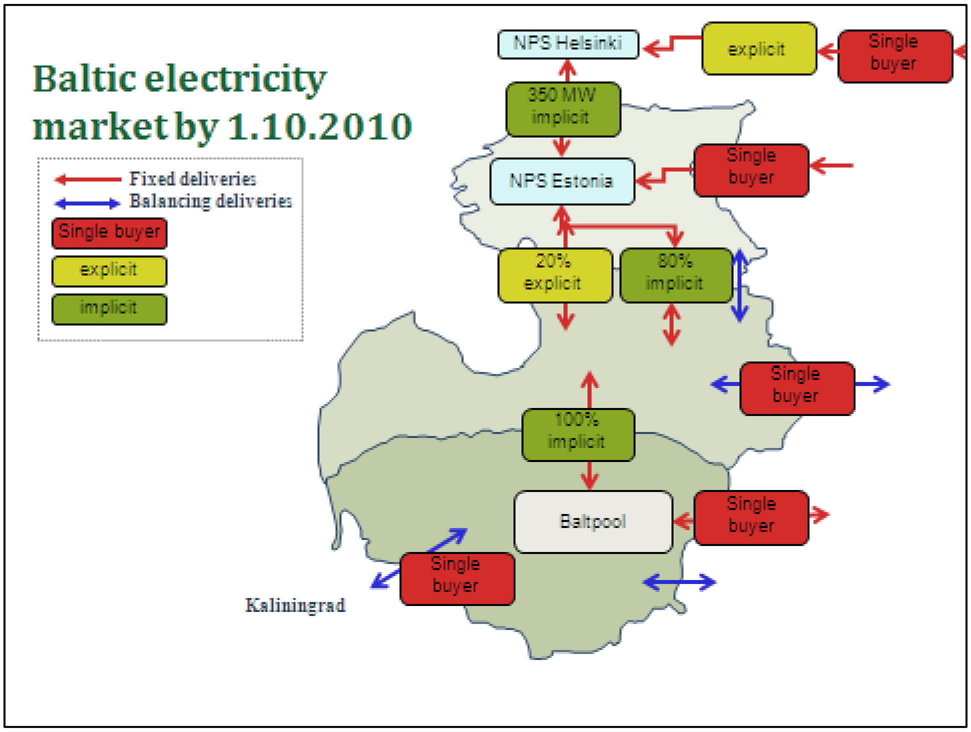


Figure 3.5-2 Baltic electricity market structure by 1st of October 2010 (Andres Tropp, Jaanus Arukaevu, 2010)

The capacity allocation in the borders of Estonia – Latvia and Estonia – Russia is done in the Sesam system using the capacity optimization method. (Müürsepp, 2010)

For this four bidding areas were created (illustrated on the figure below):

1. Estonia – used by Estonian market participants for making bids;
2. Latvia export – used by market participants from Latvia and Lithuania for purchasing electricity from Estonia price area;
3. Latvia import – used by market participants from Latvia and Lithuania for selling electricity to the Estonia price area;
4. Russia import – for market participants, who import Russian electricity to the Estonia price area. (Müürsepp, 2010)

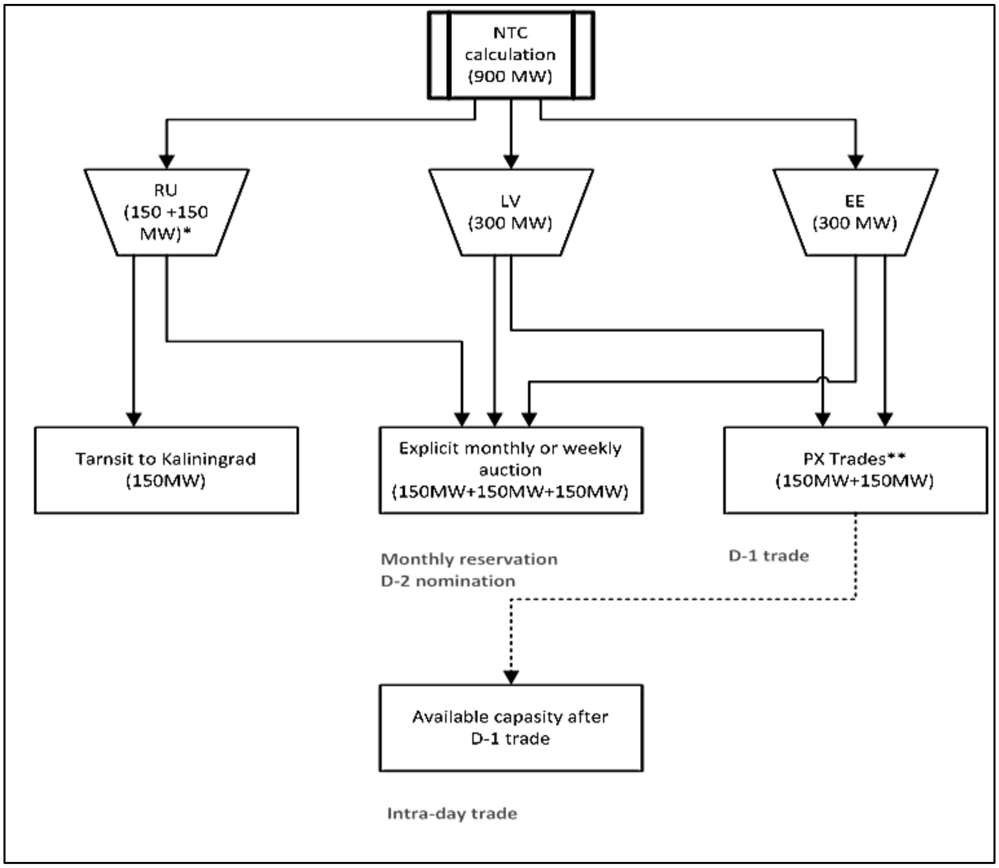


Figure 3.5-3 The transmission capacities allocation on the borders of Estonia-Latvia and Estonia-Russia. (Arus, 2010)

Compared to other European synchronous systems, the capacity determination used by Baltics is different due to Baltic Power system synchronous operation with Russian IPS/UPS and due to different security and technical standards.

The implemented method on the border of Estonia and Latvia do not work properly in practice due to the physical power flow distribution in BRELL (Belarus-Russia- Estonia-Latvia-Lithuania) loop. Also, the Russian transit to Kaliningrad does not take part of capacity allocation. (Baltic TSOs, 2010)

On the border of Latvia and Lithuania the capacity optimization is managed by BaltPool. During the year 2011 the capacity allocation will be overtaken by NPS.

The allocation of the HVDC interconnection capacity between Estonia and Finland is managed by NPS. The price area (before 1.10.2010 EstLink) was launched on 1st of April 2010. This new area connects Estonia/Baltics to the Nordic power market by offering a liquid market and a trustworthy reference electricity price.

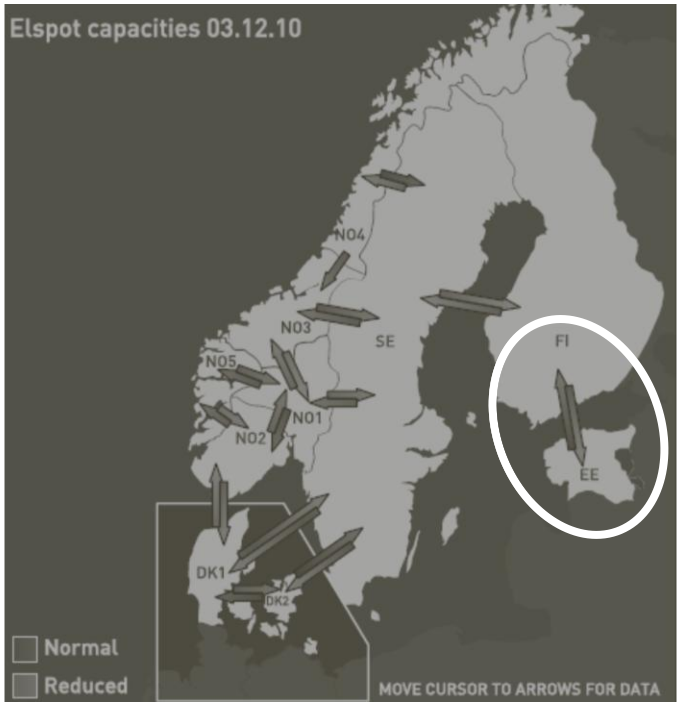


Figure 3.5-4 Estonian price area in Nord Pool Spot (Nord Pool Spot)

The capacity between Estonia and Finland is allocated by using the implicit auction method. The capacity optimization method under the implicit auction method is illustrated on the figure below.

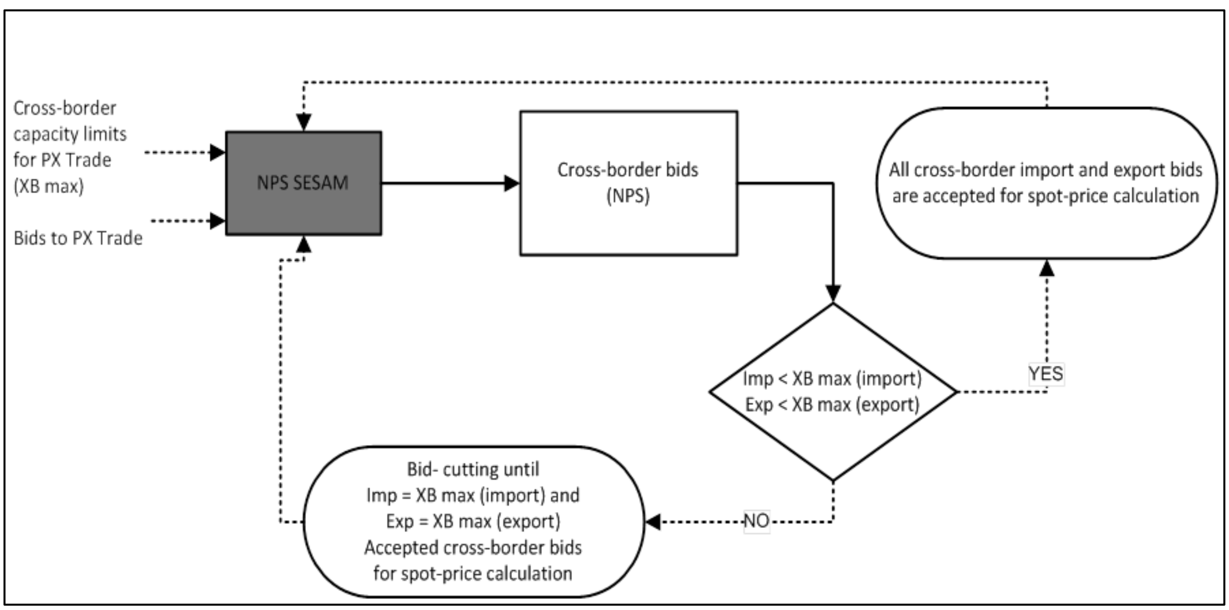


Figure 3.5-5 Capacity optimization method (Source: Ingrid Arus, Eleringi elektriturgude arendusjuht, Elering; Nõukoda 26.02.2010)

3.5.1 What makes the Baltic electricity market different

Despite the projections for the common future, there are several “buts” on the Baltic electricity markets, which makes them different from the Nordic power market:

- No common market principles;
- No harmonization in legislation;
- Not sufficient interconnections with the Europe;
- No common understanding in the energy imports from third countries, also at EU level;
- The competition with the energy produced in Russia, Belarus and Ukraine;
- The activeness of the market participants is low as the market is small for the efficient competition (the buy and sell volumes since the opening the price area are presented on the graph below, the flow directions depending on the area price are illustrated on the Figure 3.5-7 Average electricity price in Finland and Estonia compared to the number of hours the flow from Estonia to Finland and vice versa “);
- Balance energy prices are not market based – they are cost based (described in the next paragraph);
- The Lithuanian and Latvian biggest power producers are heavily depended on natural gas prices;
- Bilateral contracts between market participants;
- The possibility for the eligible consumers to buy electricity with the regulated price, Estonia excluded;
- Lithuania and Latvia are in deficit and forced to import from Russia and/or buy from NPS;
- The reduction of transmission capacities due to the closure of INPP. (Toptšilin, 2009)

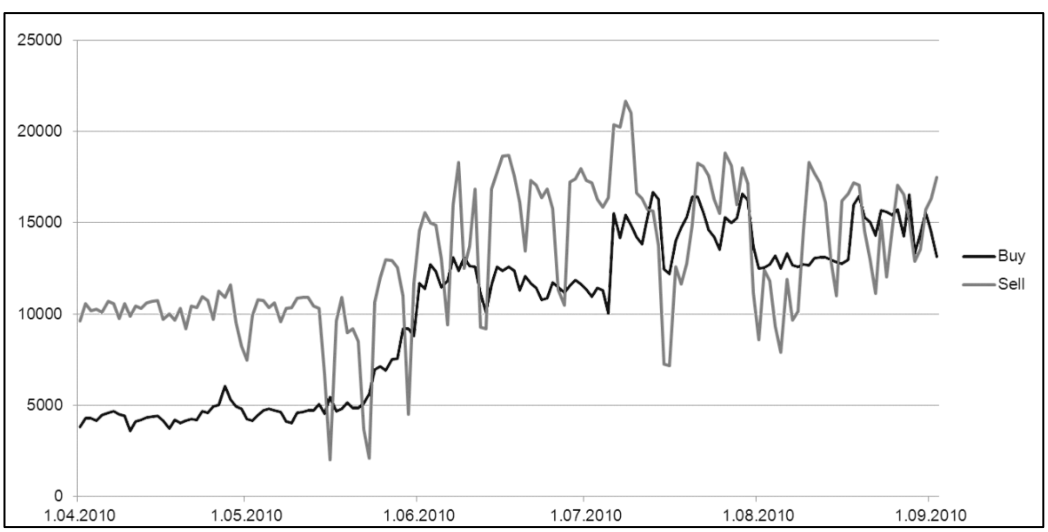


Figure 3.5-6 Buy and sell volumes on the energy market in Estonia (Nord Pool Spot)

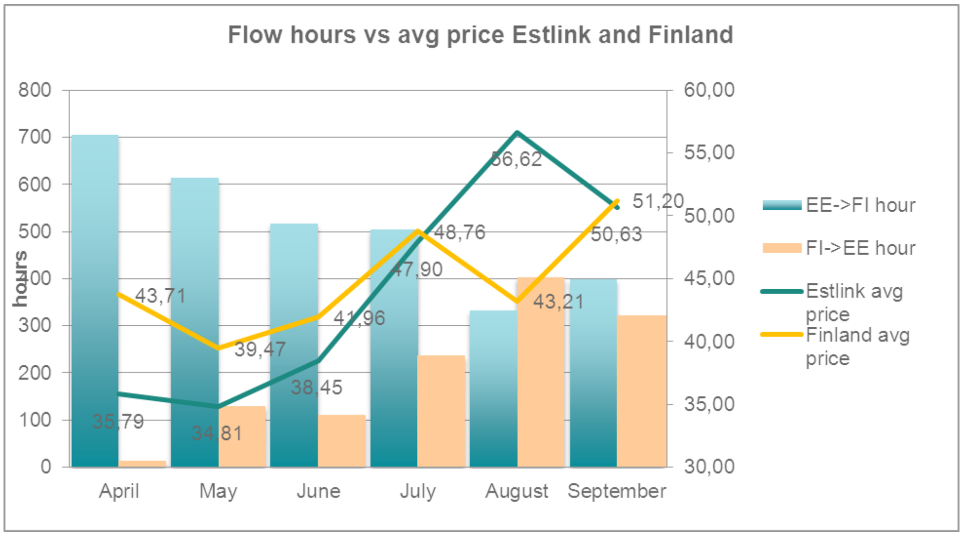


Figure 3.5-7 Average electricity price in Finland and Estonia compared to the number of hours the flow from Estonia to Finland and vice versa (Ingrid Arus, Meribel Müürsepp, 2010)

The situation on the market on 24th of August 2010 prevail the weaknesses of the small market with insufficient liquidity. The following graph illustrates the situation on the Estonian price area:

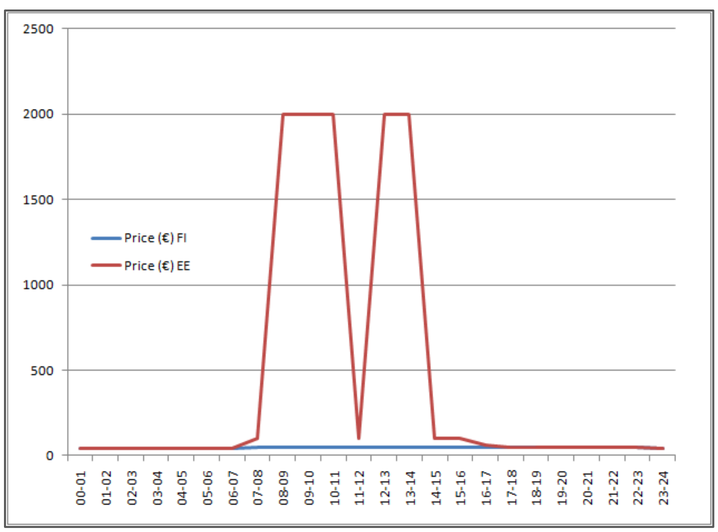


Figure 3.5-8 The Price hike on 24th of August in NPS Estonia price area (Nord Pool Spot)

3.5.1.1 What happened on 24th of August 2010 on NPS Estonia?

- In the Estonian Power Plant was unplanned outage of one 160 MW unit. Despite the fact the Estonian power production exceeded the consumption in every hour of the day;
- The Estlink 1 import capacity was in full usage;

Power generator capacities in Latvia and Lithuania were not in NPS market sispossal;

- 80% of the cross-border capacity between Estonia and Latvia were allocated to the NPS Estonia price area and due to that the demand was encouraged to go to the spot market. The other factor is that the prices in the NPS Estonia price area have usually been lower than the actual costs of marginal power producers in Latvia and Lithuania – therefore there is natural interest in these Baltic states to purchase the electricity from the market;
- Price-independent purchasing bids were put up in the spot market as the market price was not expected to hike and on the other hand risks were covered by hedging.

On 24th of August purchasing bids exceeded all supply bids due to significant price-independent demand bids from Latvia and Lithuania. The prices hit the NPS maximum price the 2000 EUR/MWh. The situation could be illustrated with right hand side graph below, where the situation is described. The conclusion would be that the market is efficient only if the demand and supply can meet each other in a natural way. For not letting the situation happen again the implementation of price areas in Latvia and Lithuania is needed otherwise the share of implicit allocation capacity on the border of Estonia and Latvia should be limited. (Andres Tropp, Jaanus Arukaevu, 2010)

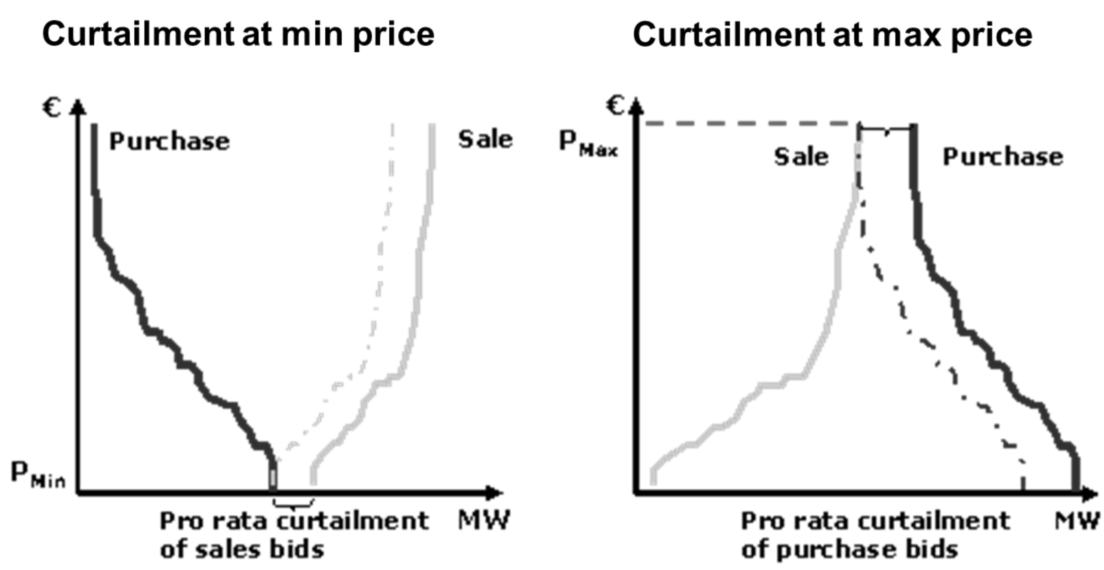


Figure 3.5-9 The curtailment at min and max price at NPS (Nord Pool Spot)

Right after the 24th August event the information publication agreement between NPS and Estonia was set up. From 1st of October the Estonian price area urgent market messages (UMM) are published on NPS web page. Since so far, the planned outages and the TSOs data were presented on the Elering webpage.

Further development of NPS in Baltis States

- Fair pricing of Russian electricity from 2013;
- Urgent Market Messages (UMM) from 1st of October 2010 in place in Estonia price area
- NPS price areas for Latvia and Lithuania (incl. NPS to replace BaltPool). *This will create transparent electricity market organization and surveillance based on NPS principles, also reduce the market concentration and higher the market liquidity;*
- Financial Market;
- Transparent conditions for the trade with non-EU countries. (Kisel, 2010) (Staniulis, 2010)

With the BEMIP and the EEPR (European Economy Plan for Recovery) help the infrastructure projects in Baltics have started – the EstLink 2 project (650 MW between Estonia and Finland), the NordBalt (700 MW between Lithuania and Sweden) and the 500-100 MW LitPol link between Poland and Lithuania.

3.5.2 The balancing/regulating energy in the Baltics

Under the balancing/regulating energy is meant the tertiary reserve energy (defined in the ENTSO-E Glossary.

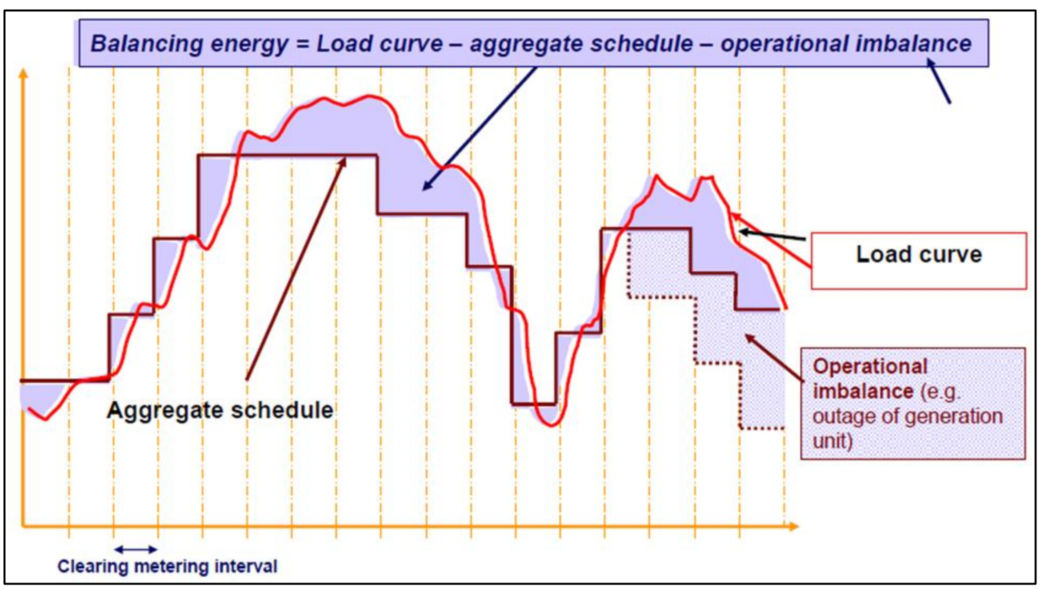


Figure 3.5-10 the balancing energy (Kaderjàk, 2009)

The Baltic States have an agreement with the Russia that they need to keep their load and supply in balance; the maximum load deviation for Estonia is 30 MW and for Lithuania and Latvia it is 40 MW – for Baltics together it is 120 MW. Also, the Baltics have agreed the each State keeps an emergency reserve of 100 MW, which could cover the N-1 criteria, the trip of the biggest power unit in the system. For example, when in Estonia the biggest power unit in Narva Power Plants trips, then the system loses approximately 200 MW of power supply. The reserve of 100 will be activated and also the neighboring country will provide its emergency reserve of 100 MW. These reserve capacities, kept in each country can be shared.

Concerning the regulation reserves (activated in 15 minutes), for example in Estonia these are bought from Latvia (Latvenergo) and Narva Power Plants, also there is possibility to have Fingrid buying these from the Nordic regulating market (TSOs market), but this possibility has not been used since so far as the prices are higher. This option will be used only, when there are no offers from NEJ or Latvenergo.

Concerning the primary and secondary balancing reserves, these are not needed as the frequency is controlled and kept by the IPS/UPS. As a fact the frequency during the last years has been better in the IPS/UPS system than in the Nordic power system, which has also become a slight problem from the Nordic countries.

3.5.2.1 Balance management in Estonia

The balance management will be looked in more detail with the focus on Estonia.

The Estonian system open supplier is AS Latvenergo (from Latvia). In the Estonian power market are four balance providers, who have an open supply agreement with the Estonian TSO Elering OÜ. All market participants have to have a contract with the balance provider in order to participate on the NPS Estonia.

Physical flows on the market will take place according to the balance providers plans. The TSO is responsible for balancing the national electricity system, which is done 24 hours a day from Power System Control Centre. In the Control Centre the deviations up to -/+ 30MW are corrected by regulations, whereas all regulations are done manually. The regulating deliveries take place via Estlink or are bought from Narva Power Plants, Latvia, and Lithuania or from Russia (bilateral contracts).

The price of imbalance energy is currently cost based, which means that it reflects the actual cost done for the regulations needed in the energy system. These costs will be covered/paid by the balance providers (balance responsible parties) whose plans were in imbalance.

Compared to the electricity market price, the balance energy purchase price is during some periods even lower that the market price. To illustrate the above mentioned situation, the September balancing energy prices are presented together with the market prices.

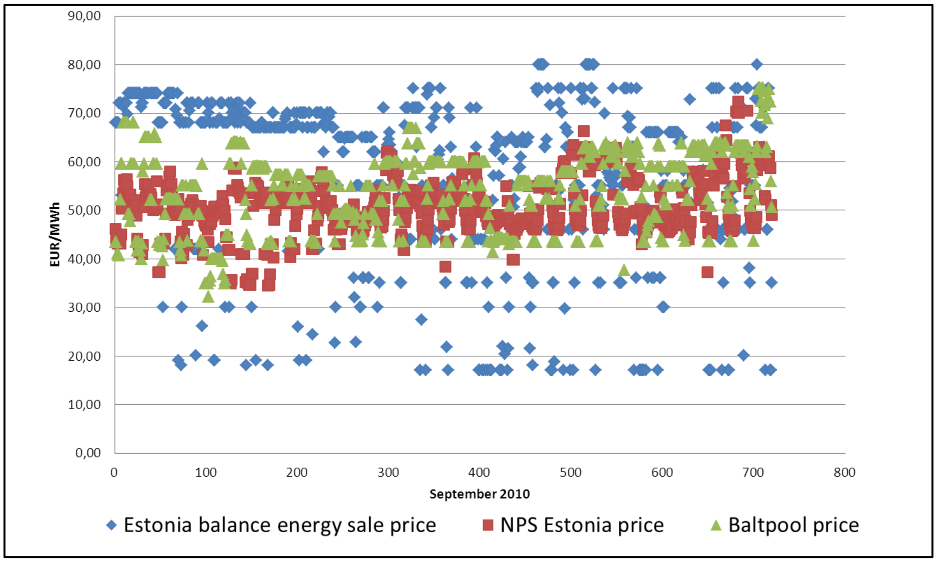


Figure 3.5-11 The Estonian upward regulating price versus NPS Estonia market area price and BaltPool market exchange price

In April 2010 approximately 60% of the import and 63% of export was traded via electricity market, approximately 40% of electricity was imported and 37% of electricity was exported according to the bilateral agreements. (Kalmet, 2010)

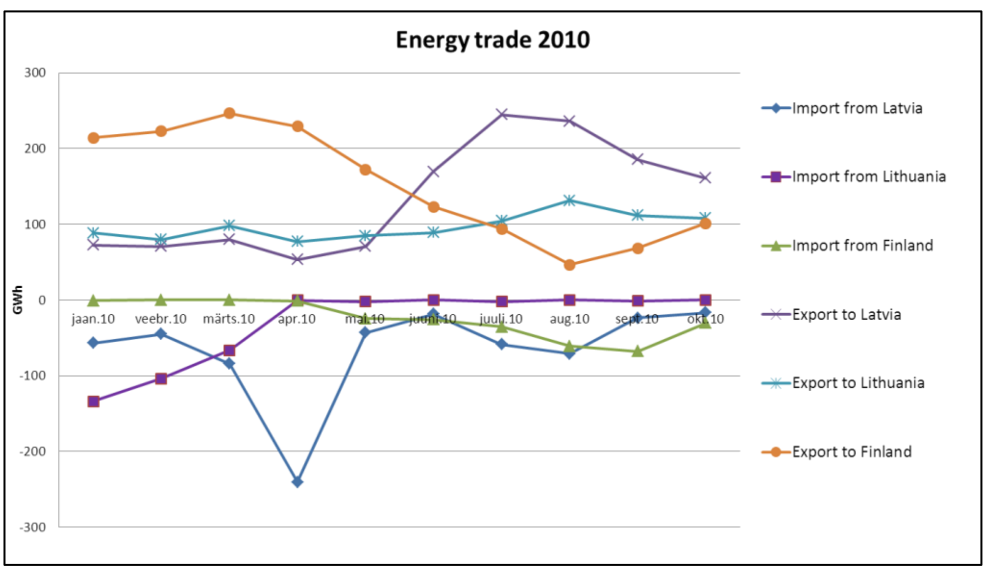


Figure 3.5-12 Energy trade balance in 2010 (Kalmet, 2010)

4 Modeling

For this report the modelling results from the energy system technical analyses conducted in the project Wind Power in Estonia by the Danish consultancy Ea Energy Analyse in spring 2010 are used as a main input for the socio-economic analysis. The main focus in the analysis will be on wind power development, whereas the influence on other market participants from the renewable energy and efficient cogeneration support scheme perspective will be analysed.

The overall purpose of the study, conducted by the consultant was to find the maximum possible value of installed wind power in the Baltic countries with focus on Estonia.

During the Estonian wind study several scenarios were analysed of which the limited market scenario results are chosen as an input for the socio-economic analysis. The reason for choosing the limited market scenario is that this scenario does not presume open market in Russia. Modelling the import, export and interconnection capacities in this scenario are solved in close cooperation with the Estonian transmission system operator.

In this chapter the main emphasis will be on the analysis. In the beginning a short introduction to the market model used for the study and its input data will be provided.

4.1 The market model

The energy system technical study results are based on the Balmorel model, which is a flexible technical/economical partial equilibrium model. The model structure is formulated in the GAMS modelling language and can be freely downloaded from the model homepage. (Ravn, 2001)

The model determines a least-cost solution for covering the electricity and district heating loads hour by hour with the given energy production system. Thereby the model simulates the detailed dispatch of the production units, taking into account:

- Electricity and heat demand;
- Technical and economic characteristics for each kind of production unit, e.g. capacities, fuel efficiencies, operation and maintenance costs, fuel prices, ramping rates, and start-stop costs;
- Environmental regulation;
- Transmission capacities between regions and countries. (Ea Energy Analyses, 2010)

The model produces estimates of electricity prices by assuming well-functioning markets with full competition (in this context it means optimal planning) among power producers and perfect dispatch of units.

The Balmorel model applied for the technical study includes data for the Baltic and Nordic countries as well as for Germany and North West Russia. Production patterns within these countries as well as power exchange between the countries are simulated by the model.

4.1.1 Core assumptions

The data representation of the power system was elaborated among the Baltic TSOs, the fuel prices were taken from the World Energy Outlook 2009 report and market development was foreseen for the Baltic countries together with construction of new interconnections to Finland and Sweden.

4.1.2 Outages

For the Baltic States all unit commitment plants were given its own profile with planned outages and 5% forced outages. Forced outages and random forced outages were spread out over each week. All other plants were de-rated in a way that the plant had only limited capacity of approximately 90% of the total capacity with an appropriate seasonal variation based on Nordic historic data. (Ea Energy Analyses, 2010)

4.1.3 Model areas

Emphasis was on Estonia, but the Baltic States together with the relevant neighbouring countries were included in the simulations. The model used by the consultant covers the Baltic countries, Russia, the Nordic countries and Germany.

4.1.4 Modelling year

In this report only the 2016 scenarios will be analysed as the future until that time is somewhat known and the major changes take place in the end of the year 2015, which makes it interesting to analyse.

4.1.5 Unit commitment

As the study was meant to be purely technical, it was carried through in very detail. In the detail dispatch of the units in an electricity system it is necessary to take into account the characteristics of the individual units with respect to:

- Maximum generating capacity
- Minimum production
- Minimum "up time", i.e. how many hours must the unit be running before shut down
- Minimum "down time", i.e. how many hours must the unit be shut down before starting up again
- Ramp rate, i.e. the maximum increase (or decrease) of production per hour
- Start-up costs
- Marginal production costs

With these inputs the model determined the least-cost solution hour by hour for the whole system. (Ea Energy Analyses, 2010)

The unit commitment was applied for the power production units in Estonia, Latvia and Lithuania. The units in the other countries were modelled without unit commitment (on a more aggregated level).

4.1.6 The development of the power system

The development of the power system is determined exogenous for the scenarios, which means that the system is pre-defined in the model and with the defined energy system the calculations for finding the least cost solution for balancing the demand are made.

4.1.7 Modelling of the interconnectors

The grid infrastructure in the Baltic Sea Region comprises the Baltic grid, the North West part of the Russian grid, the Nordic grid and the North German grid.

To represent conditions in Estonia and the Baltic States, resulting from loop flows from the Russian power system, a model for available transmission capacity was developed in close cooperation with the Estonian TSO (dispatch centre).

It is assumed that there is an exogenous import for power from Russia to the Baltic States of 500 MW. This is treated as an exogenous import of 150MW/150MW/200MW for Estonia, Latvia and Lithuania respectively. A fixed exogenous export to the Baltics states of 500 MW is imposed on the Russian power balance. The exogenous import from Russia means that it is independent from market flows and it will be there.

In addition to this 500 MW exogenous import there is 120 MW of transmission capacity between Russia and Baltics allocated on the market, which means that this energy import is dependent on market prices. On the electricity market the direction of flows is from lower market price are too the higher price area, which means that the hours the electricity price is lower than the Estonian price there will be import from Russia to the Estonia/Baltics.

In addition Russian export to the Baltic States a historical export profile is assumed between Russia and Belarus. This export profile is imposed on the Russian power balance as Belarus is not modelled explicitly. When the export from Russia to Belarus exceeds 500 MW it is assumed that loop flows through the Baltic States further limits transmission capacity by the amount in excess of 500 MW export. (Ea Energy Analyses, 2010)

There is northbound transmission capacity between the Baltic States which is independent on Russian power flows of 200 MW from Latvia to Estonia and 400 MW from Lithuania to Latvia. (Ea Energy Analyses, 2010)

The capacities are lower than the thermal capacities of the transmission lines. They reflect the need for secure operation of the grid, taking into account the possibilities of a breakdown of an interconnector (the n-1 criteria) as well as (from a Baltic IPS point of view) uncontrollable flows on the lines due to flows in the Russian system.

From the new Baltic-Nordic interconnections the EstLink 2 between Estonia and Finland with the capacity of 650 MW is included in all 2016 scenarios. For the Nordbalt connection between Lithuania and Sweden the sensitivity analysis are carried through, but not considered in the scenarios analysed in this report. (Ea Energy Analyses, 2010)

4.2 Input data

4.2.1 Geographical scope

The specific model version used for this scope of work contains the electricity and CHP system in the Nordic countries (Denmark, Finland, Norway and Sweden), the Baltic countries (Estonia, Latvia and Lithuania), Germany and West Russia.

4.2.2 Fuel prices

The development in prices of fossil fuels is based on the latest forecast from IEA's World Energy Outlook 2009 (WEO-2009) and is shown in the figure below. Biomass prices are based on a study made in 2009 by the Danish Energy Authority. (Ea Energy Analyses, 2010)

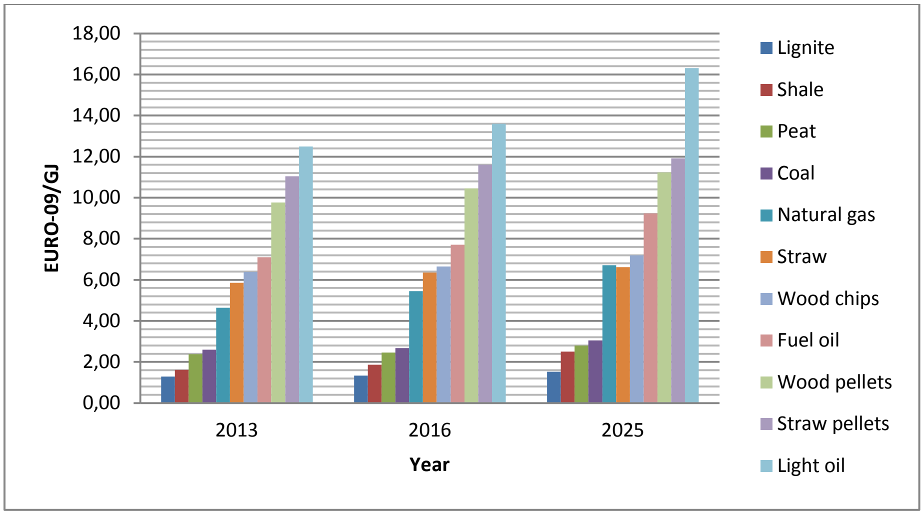


Figure 4.2-1 The development of fuel prices (Ea Energy Analyses, 2010)

4.2.3 Electricity demand and yearly variation

The heat and electricity demand data entered into the model are inputs from the representatives from each country. The demand is represented as the annual energy consumption and a time variation for both electricity and heat.

The yearly variation in heat and electricity demand as well as wind and hydro profiles presented used for the analysis are based on actual 2007 data.

4.2.4 CO2 prices

The international price of trading CO2 emission permits is difficult to predict, and the there is uncertainty regarding the next emission trading period from the year 2013, it is expected that the future level will be higher than today. A future level of around 30 €/ton is considered as the most realistic level and is used for all model runs. (Ea Energy Analyses, 2010)

On the following figure, the power units' short-run marginal costs, including the CO2 costs and fuel costs introduced, are presented.

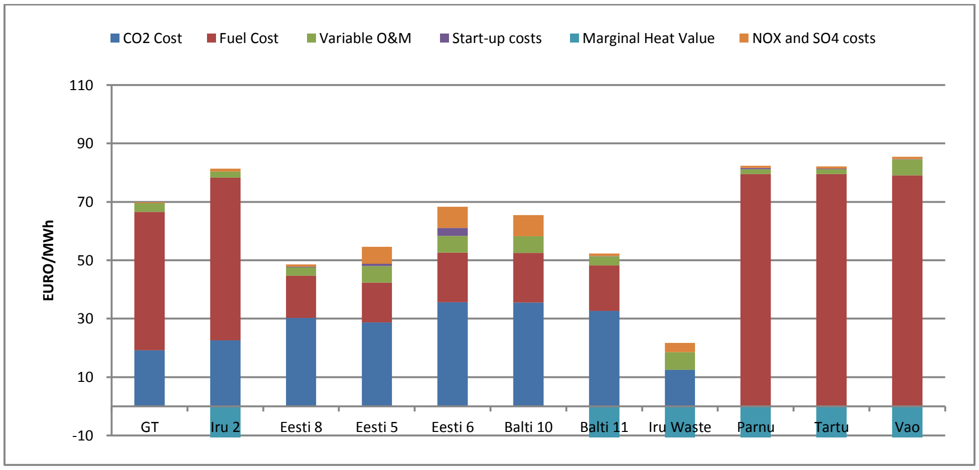


Figure 4.2-2: Short-run average variable cost of generation in Estonian Flexibility 900 MW 2013 scenario. (Ea Energy Analyses, 2010)

4.2.5 Wind profiles and full load hours

The full load for onshore wind is calculated on the basis of wind measured in 2007. The full load hours for offshore in all Baltic states are calculated on the basis of Estonian wind measurements on the island of Kihnu in West coast of Estonia. There are 2600 full load hours for onshore and 3500 for offshore wind parks in Estonia. (Ea Energy Analyses, 2010)

4.2.6 Model limitations

- No exchange limitations – only the transmission capacities are fixed;
- PPs emergency outages are not considered;
- No internal grid considered;
- It is assumed to have all units bidding on spot market;
- Deterministic model – no stochastic processes considered;
- Perfect dispatch of units (no forecast errors or deviations from planned schedules);
- Inability to model the seasonal water storages;
- Perfect regional/pan European perfect market versus profit maximizing PPs.

5 Analysis

The analysis chapter will focus on wind power development in Estonia and its' influence on the other participants in the electricity market in Estonia. The reason for having the emphasize on wind power is that due to high subsidies paid for the renewable energy, 53,7 € for every MWh energy produced, the interest to invest into the wind power production has sky rocketed, even though the subsidy is paid for the first 600 GWh produced on annual basis. For today, the Estonian transmission system operator has received applications for the grid connection proposals for more than 4000 MW of wind parks. Compared with the net installed power production capacity in Estonia it is almost double of it. As the existing power units are mainly oil shale based thermal units and new cogeneration plants, one or the other way subsidized, it would be necessary to investigate how will the existing power units be influenced by the large wind power integration? In order to answer this question the power balances in all scenarios are investigated in a detail, on a top of it quantitative analyses on annual basis are done, which again are looked from socio-economic point of view and from market participants economic point of view.

The analysis chapter is divided into following five sub-chapters:

- In depth look of all wind scenarios hourly power balances for two selected weeks;
- The quantitative analysis of the scenarios annual results;
- Socio-economic analyses of the annual aggregated results from all wind scenarios;
- Economic analyses of the market participants;
- Conclusion – the sub-chapters sub-conclusions are gathered and the results are discussed.

The analysis are performed for three different wind power generation capacity scenarios for the year 2016: 600 MW, 900 MW and 1800 MW wind power generation capacity scenario, whereas the reference scenario has 300 MW of wind power generation capacities installed. The 900 MW and 1800 MW scenario results are from the wind study. For the reference scenario with 300 MW of wind power capacity and the 600 MW wind scenario additional model runs with the Balmorel market model are made.

There are three different wind scenarios compared with the reference scenario are as follows:
Reference scenario: the total installed wind power capacity is 300 MW (which is double of the capacity installed today), of which 150 MW onshore and 150 offshore.
600 wind scenario: the total installed wind power capacity is 600 MW of which 300 MW are onshore and 300 MW are offshore wind parks. This number is in accordance with the Estonian National Renewable Action plan, which was released in the end of the year 2010.

900 wind scenario: the total installed wind power capacity is 900 MW, of which 450 MW onshore and 450 offshore.
1800 wind scenario: the total installed wind power capacity is 1800 MW, of which 900 MW onshore and 900 offshore.

The total wind power generation capacity in each scenario is equally divided between onshore and offshore generation units as it can be seen from the scenario set up. Developing large-scale wind generation development in Estonia will also influence the other Baltic States. For considering the potential vast wind generation development in the region, the wind generation is modeled to be developing equally in all three Baltic State. For example, if there is 600 MW of installed in Estonia, it will also mean the same wind power production capacity in Latvia and Lithuania, divided again, equally between onshore and offshore wind power parks.

5.1 Power balances of the 600 MW, 900 MW and 1800 MW wind scenarios

In order to understand the system and analyze the changes in different scenarios, a thorough look into the scenario results is made. The results are presented for all scenarios, including the reference scenario. The results are presented on the figures with the comments added, but in general the figures are very informative and contain a lot of important information, which makes the valuable source for presenting the results in this sub-chapter.

For each scenario the detailed analysis are done for one summer and one winter week. The main reason for having these specific weeks is that they are most interesting in terms of Estonian electricity spot market area price. The focus is on the weeks, where the lowest and the highest market prices in 600 MW wind scenario appeared. For the 600 MW of wind power generation capacity scenario the most interesting is the summer week number 29, where the Estonian price area price hits the bottom at 8,9 €/MWh and winter week number 50, where the area price peaks at 257,5 €/MWh.

5.1.1 Comments on the 300 MW wind scenario – reference scenario

The market model presumes the perfect market performance in all modeled scenarios (where all the production is optimized on the cost basis). It will mean that all power is traded on the electricity market. According to the 300 MW wind scenario, which is also the reference scenario, Estonia will become very dependent on imported electricity. From the figure below it can be observed that fixed import from Russia and the net import together will make up more than one third from the total balance in the winter weeks and more than half of the balance in summer week. On the graph below the total balance of the electricity consumption and production is presented. Additionally, the net import is added in order to cover all the consumption. The orange colored field, following the demand curve on the figure is the net electricity net import and the first blue row on the bottom of the graphs presents the fixed electricity import from Russia. The electricity import is also presented on figures below the power balance figures.

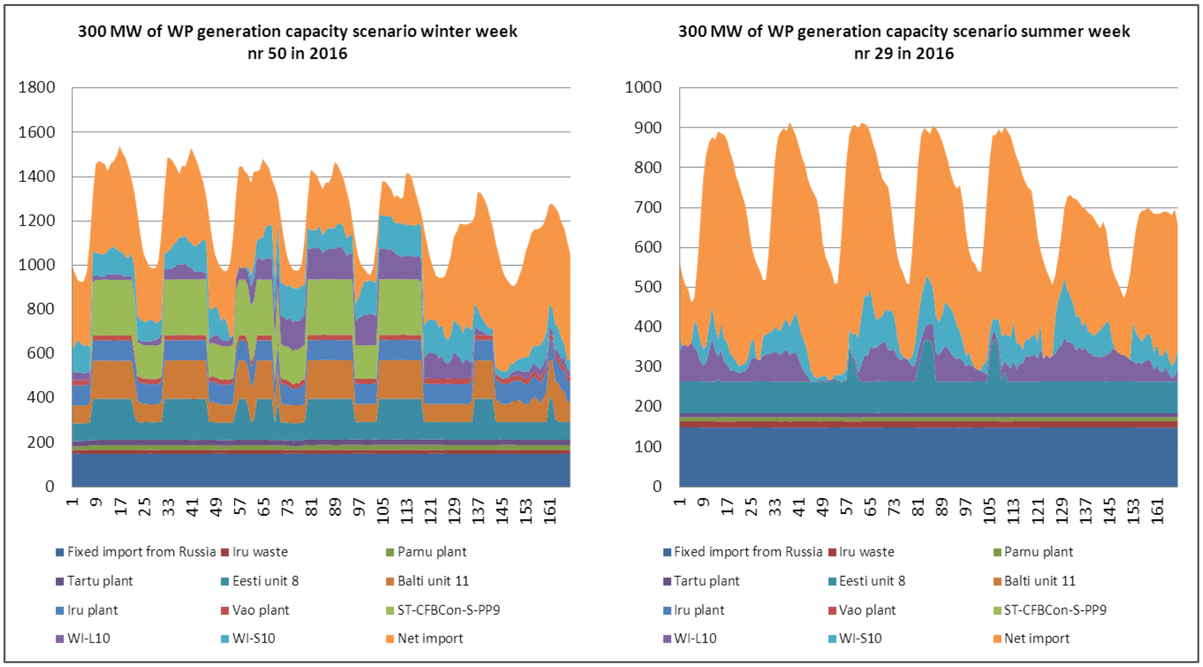


Figure 5.1-1 Reference scenario power balance for the winter week nr 50 and summer week nr 29 in the year 2016

The politics today in Estonia has been that there will no import from Russia allowed – Estonia has to be able to cover its' demand with the domestic production. As the electricity market liberalization process is ongoing and there is no clear view on the electricity import from third countries on EU level, there is free entrance for the electricity from Russia to the Baltic electricity market. Actually, this is nothing new for Latvia and Lithuania, since the Ignalina NPP was closed down in the end of 2009; both states have become more dependent on Russian electricity imports.

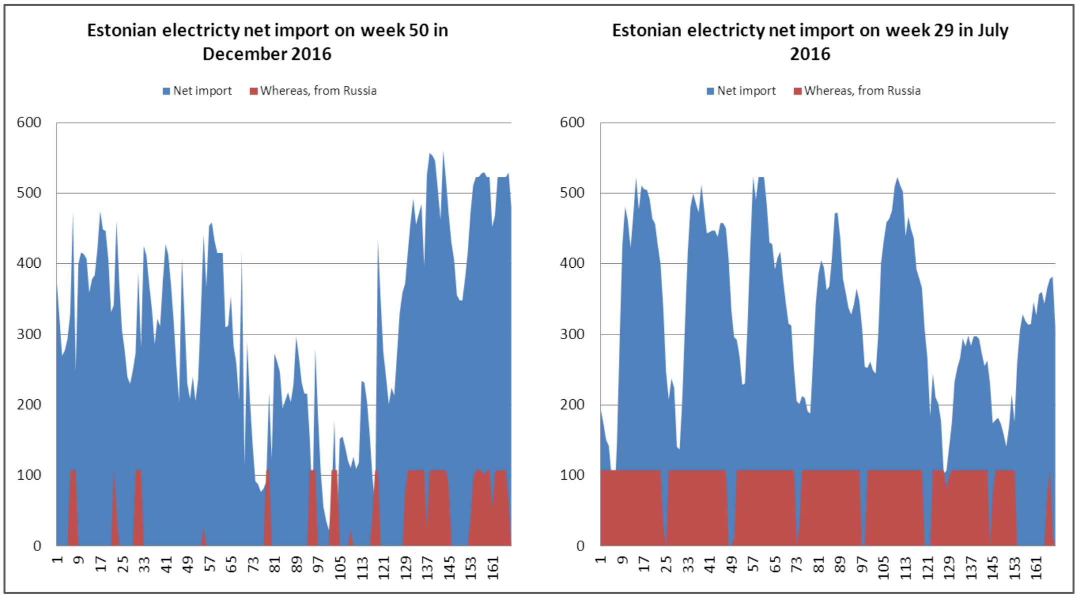


Figure 5.1-2 Reference scenario electricity net import for the winter week nr 50 and summer week nr 29 in 2016

On the one hand Estonia will benefit from the external interconnections but on the other hand it will be a threat for the national security of energy supply. The security issues are not looked in this report, but this is one of the topics which are high in the political agenda.

Differently from Southern neighbors, there are now limitations for the subsidized units today. The units can freely operate and actively participate on the spot and intraday market or have bilateral contacts with the consumers. The subsidy is an extra pay for the producers they get in addition for every kWh of energy produced and sold on the market. If this subsidy is received by large amount of wind power producers or other type of renewable energy production, then their spot bidding price will be among the lowest in the spot market in order to make sure that the would win the operating hours for the time periods there is the renewable resource available. For efficient CHPs and CHPs burning biomass the main criteria is the presence of heating demand as simultaneously with the electricity heat is produced. As the both type of CHPs are subsidized in Estonia they need to be sure that they will win the operation for the hours there is high heat demand.

From the graphs below it can be observed that all the subsidized units are in operation in winter as well as in summer week. The main units, which are not activated, are the conventional oil shale thermal units. Here it is also important to keep in mind that the oil shale units are highly dependent on CO_2 price – with every MWh of electricity produced one ton of CO_2 will be emitted. In this model setup the CO_2 price was estimated to be 30 €/ton, which in context of conventional oil shale units would mean additional cost of 30 €/MWh and therefor it is difficult to compete with the cleaner technology on the market. Will the import be cleaner is hard to say, but the European climate policy does not affect the energy production in third countries.

The following graphs present an hourly overview of the power generation during the winter week number 50 and summer week 29 together with the electricity spot prices in the neighboring countries by having the load curve on a back.

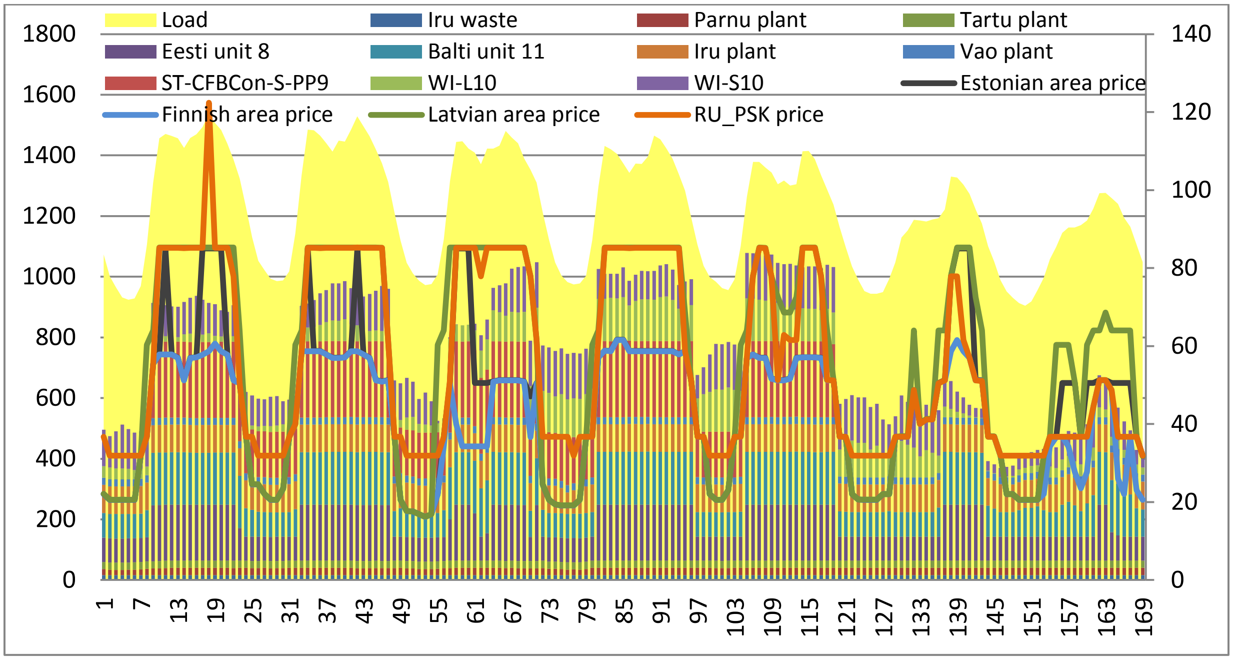


Figure 5.1-3 Reference scenario - Estonian demand and generation together with the connected areas electricity price on week 50 in December 2016

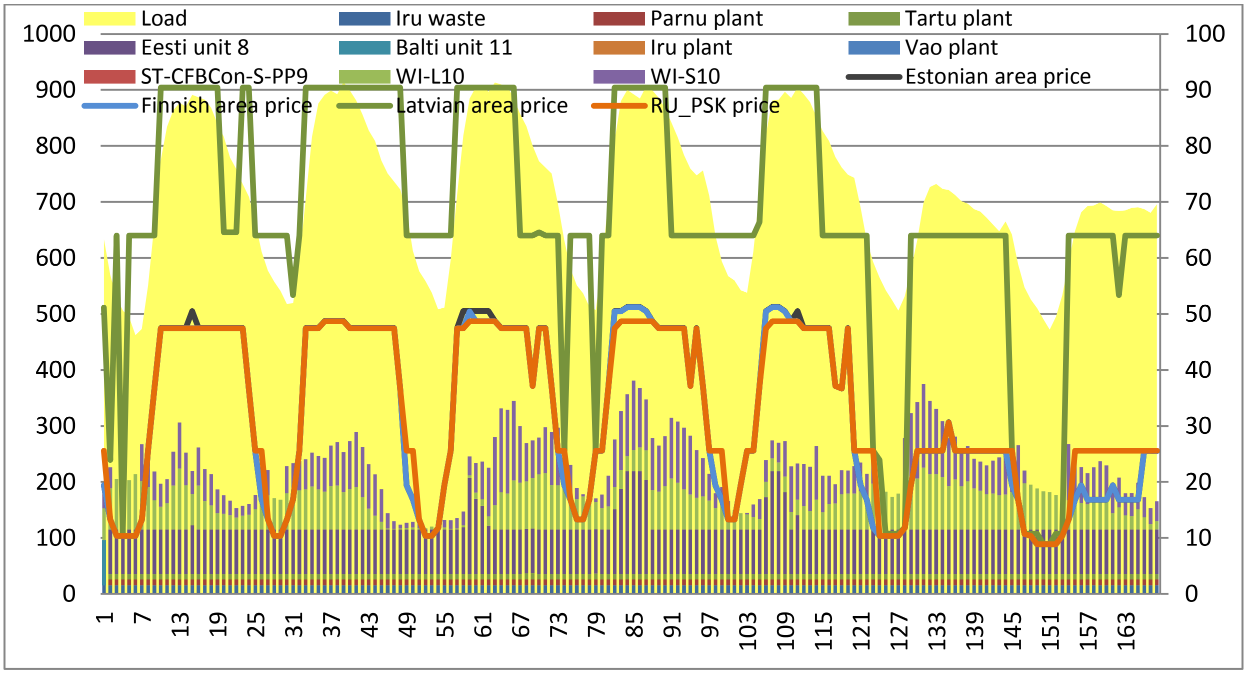


Figure 5.1-4 Reference scenario - Estonian demand and generation together with the connected areas electricty price on week 29 in July 2016

In the graphs above it might be confusing, but most of the hours the Estonian spot price follows the Finnish market area spot price. It means that during the hours there is no difference in the electricity prices, there is no congestion in the interconnection between Estonia and Finland – both countries can benefit from lower market prices.

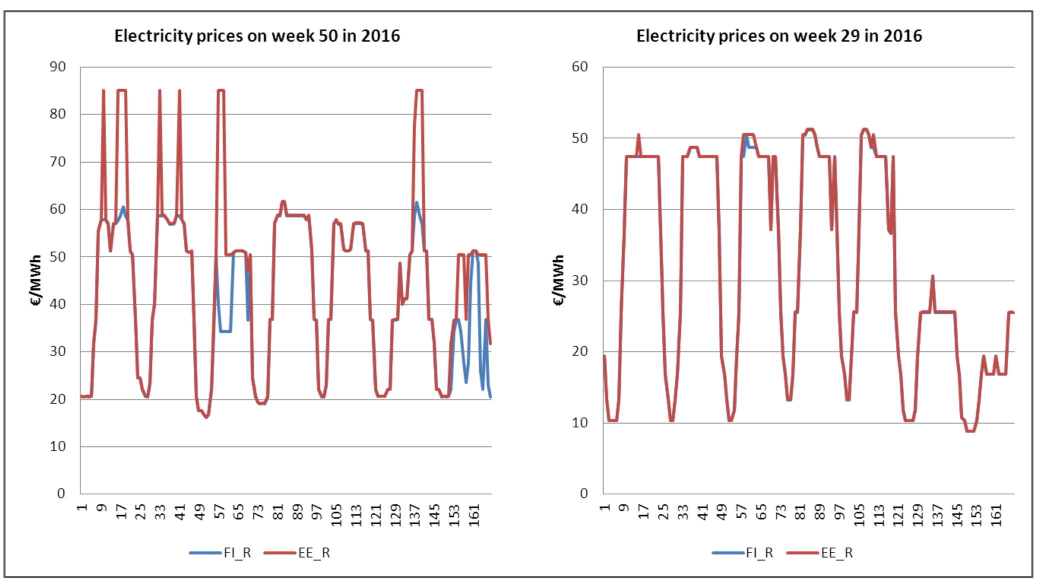


Figure 5.1-5 Reference scenario electricity spot market prices for the week nr 50 and week nr 29 in 2016

The same graphs presented in this sub-chapter will be presented also for the other wind scenarios.

5.1.2 600 MW wind power production capacity scenario

From the following graphs it can be seen that compared to reference scenario there is significant decrease in imported electricity. These additional 300 MW of wind turbines have contributed significantly into the domestic power generation, though high dependence on imported electricity can still be seen.

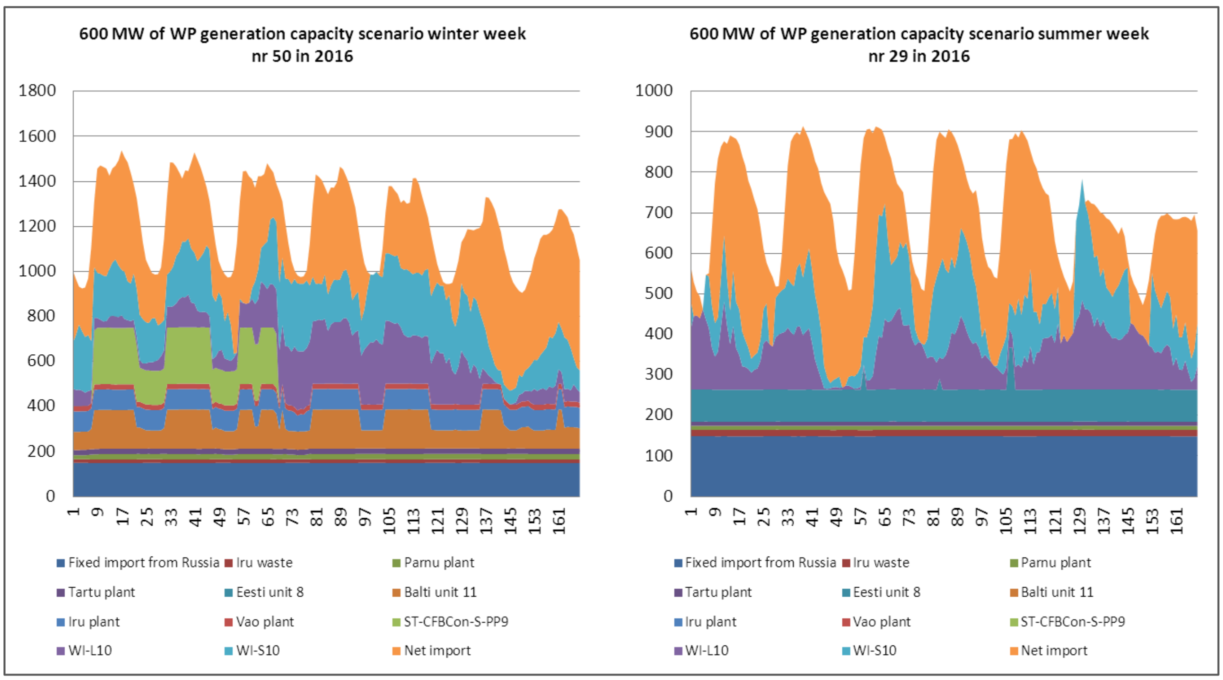


Figure 5.1-6 600 MW wind scenario power balance in week nr 50 and week nr 29 in 2016

From the figure below it can be seen that compared to the reference scenario the overall wind import has decreased but in the winter week the higher imported electricity peaks appear.

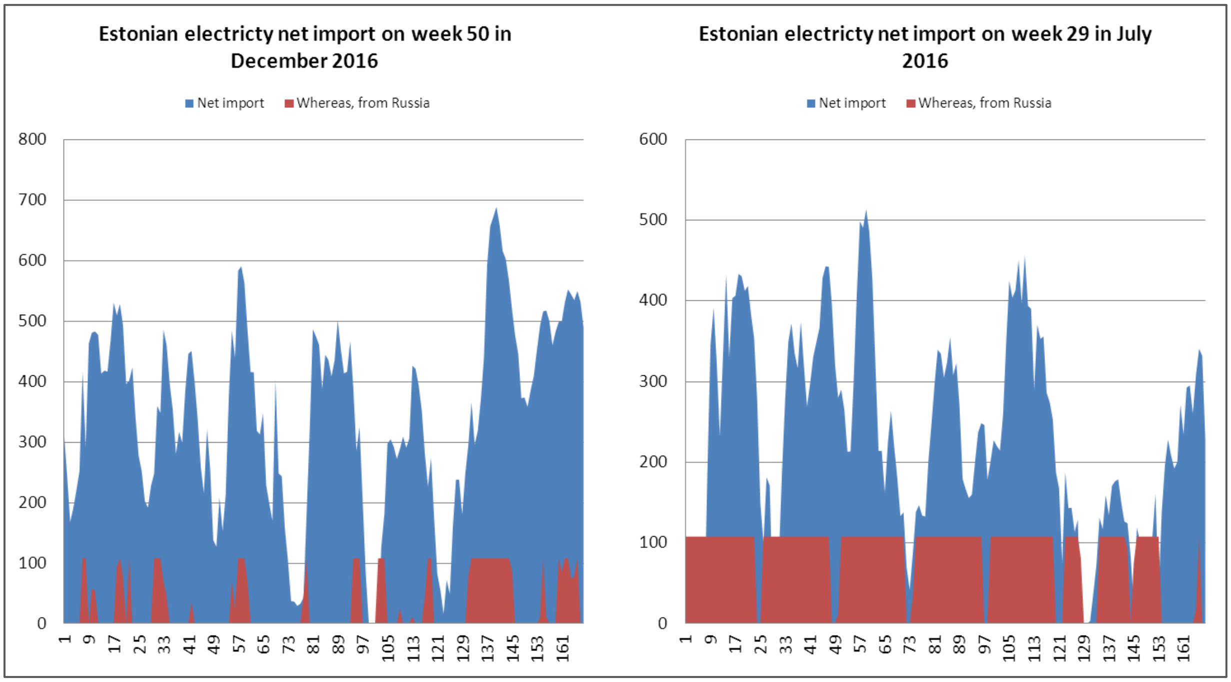


Figure 5.1-7 600 MW wind scenario electricity import on week nr 50 and week nr 29 in 2016

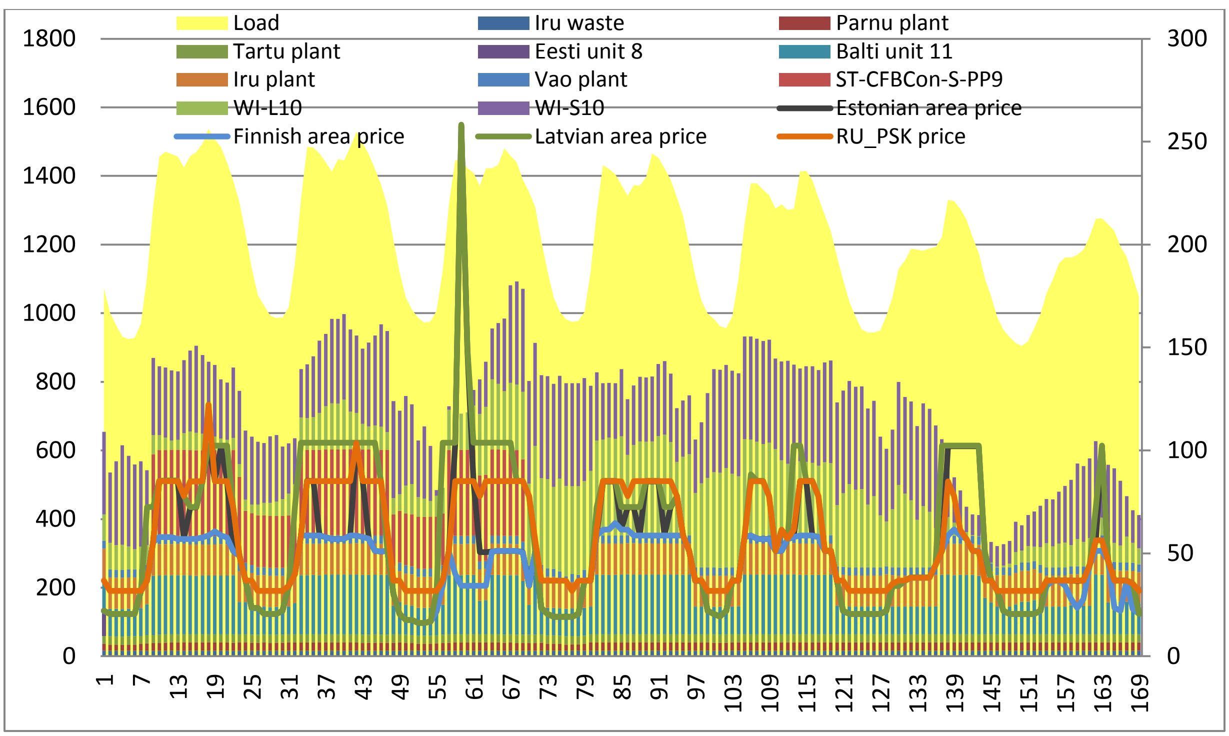


Figure 5.1-8 600 MW wind scenario - Estonian demand and generation together with the connected areas electricity price on week 50 in December 2016

Compared to the reference scenario week nr 50 there is an increase in electricity prices and during the one hour Latvian electricity spot price peaks for one hour at the electricity price above 250€/MWh which reflects the startup price of a new marginal unit in the price area.

In power production pattern some changes in the winter week can also be observed. It can be seen that the wind power production has replaced some of the oil-shale condensing unit nr 9 production in the 600 MW wind scenario and the oil shale condensing unit 8 is not in operation at all. Otherwise, the oil shale units are operating between their technical minimum and maximum electricity output.

In the summer week there are no changes in the power units in operation, just the wind power generation is increased. The main reason for it is that the small units will follow the heat demand for producing hot water and steam for industrial purposes and the for the grid stability reasons there has to be one oil shale unit in Narva Power Plants up and running. From both scenarios it can be seen that the condensing unit in Eesti Power Plant, which is one of the Narva power plants is up and operating on its technical minimum generatiog capacity.

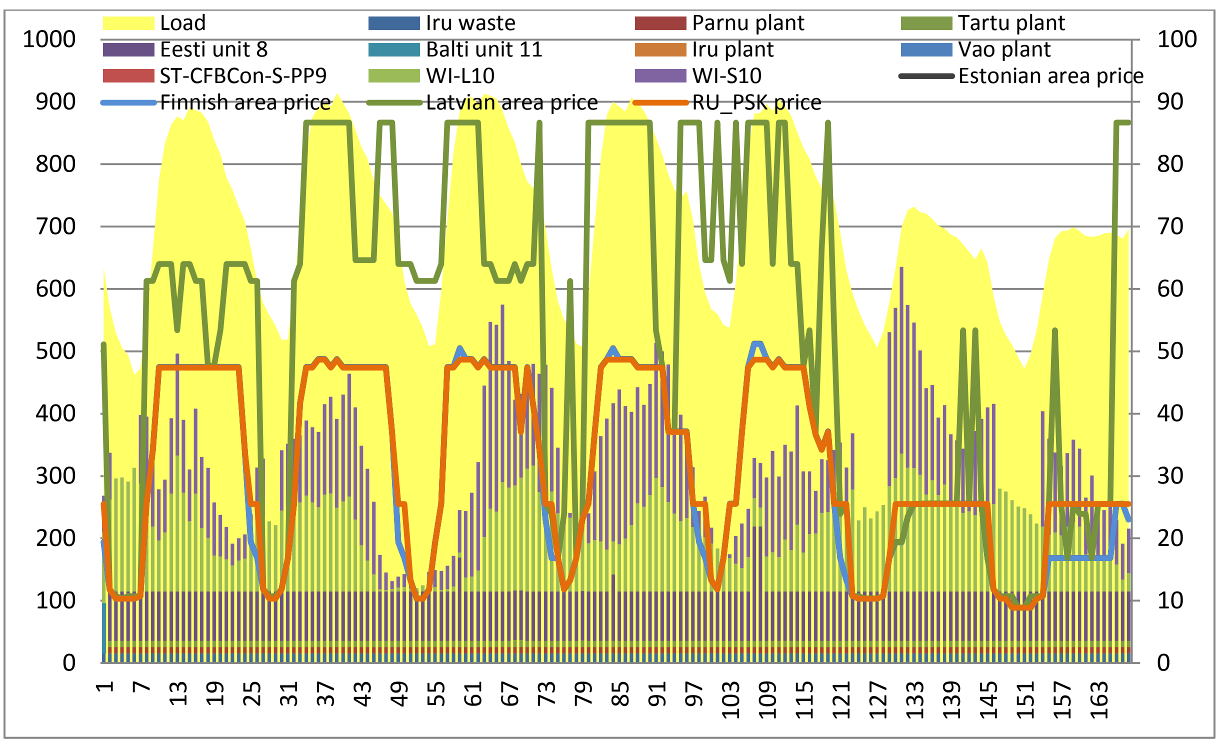


Figure 5.1-9 600 MW wind scenario - Estonian demand and generation together with the connected areas electricty price on week 29 in July 2016

Concerning the power prices in winter week nr 50 it can be noticed that there are higher prices during the peak hours and during these hours Estonia and Latvia have the same prices, which are remarkably higher than the Finnish prices. Otherwise, there are no significant changes on the price levels and most of the time Estonian and Finnish spot prices are equal.

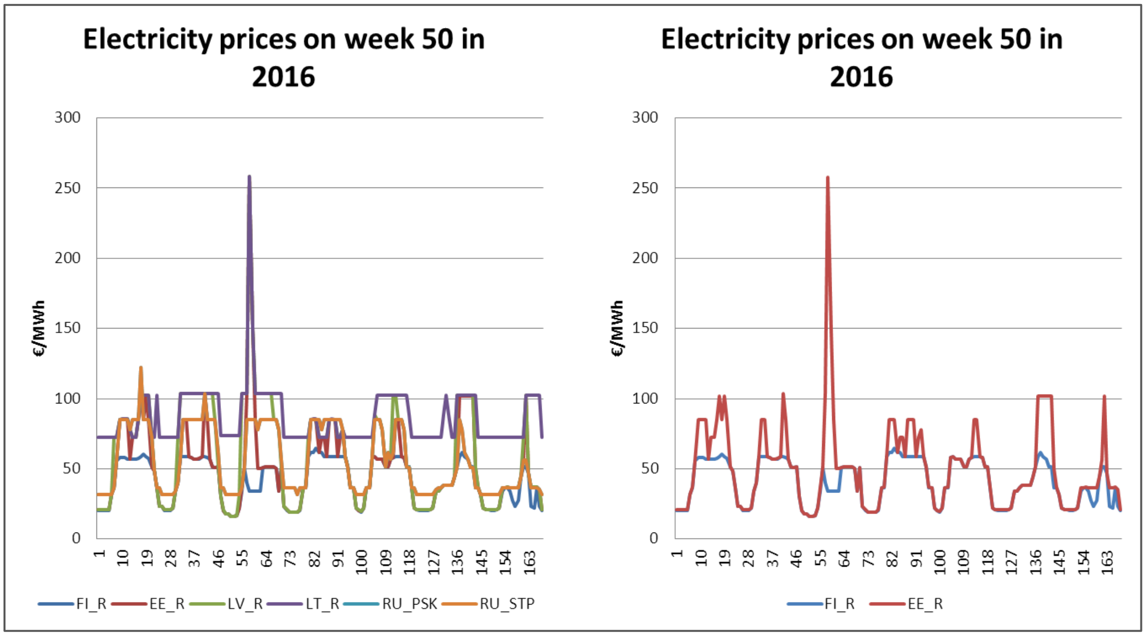


Figure 5.1-10 600 MW wind scenario electricity prices on week 50 in 2016

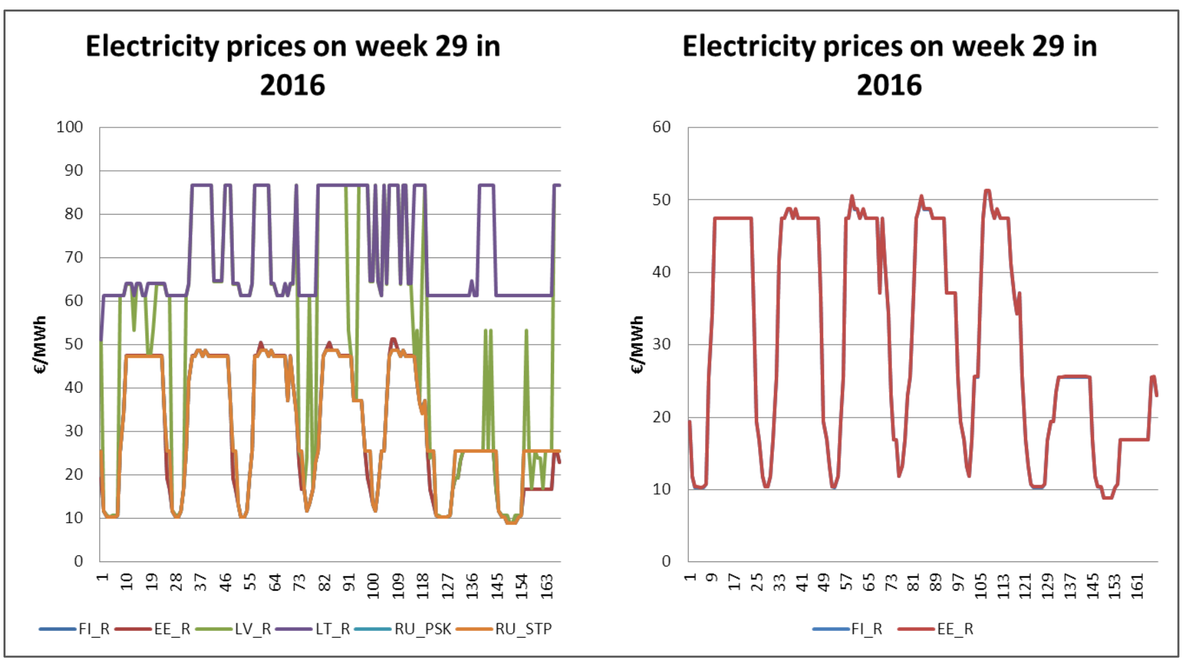


Figure 5.1-11 600 MW wind scenario electricity prices on week 29 in 2016

During the summer week no significant changes can be observed. The price level is the same with the reference scenario and there is no bottleneck between Estonia and Finland.

5.1.3 900 MW wind power generation capacity scenario

Comparing the reference scenario winter week with the three times higher wind generation capacity scenario no changes in the units in operation are observed. The main change is reduced dependency from the imported electricity. Still, it can be seen that during the peak hours there is a need for electricity import.

During the summer week there is the must run oil shale unit replaced with another condensing oil-shale unit, but no relevant changes in the production pattern, except the increased wind power production. Unlike during the winter week, the daily peak hours are covered with the domestic power generation.

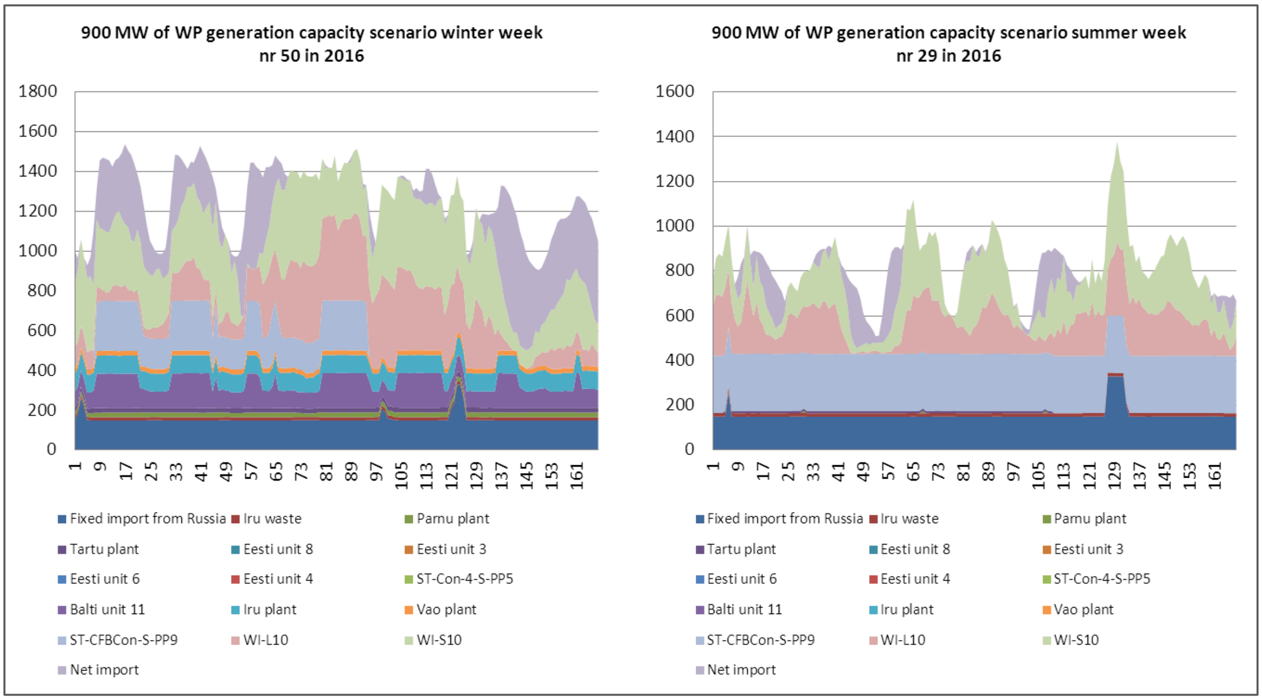


Figure 5.1-12 900 MW wind scenario power balance for the week nr 50 and week nr 29 in 2016

In winter compared to reference scenario the imported energy total volume have decreased substantially, but the hourly volumes in have raised – the difference is approximately 100 MW. During summer the situation is opposite, the imported hourly volumes have decreased – the difference is bit less than 200 MW.

It is also clear from the figure below that the electricity imports are fluctuating in high quantities. During the time periods, there is no wind power production; the electricity has to be imported. The current figures are for the net import, but as there is large-scale wind power development foreseen in all three Baltic countries and the NordBalt connection to Sweden is not considered, Estonia will be a connection to the Nordic power market and therefore the interconnection between Estonia and Finland will be used also for the electricity import to Latvia and Lithuania, when there is no wind. In case of excess power production the Estlink is used for electricity export by all Baltic States.

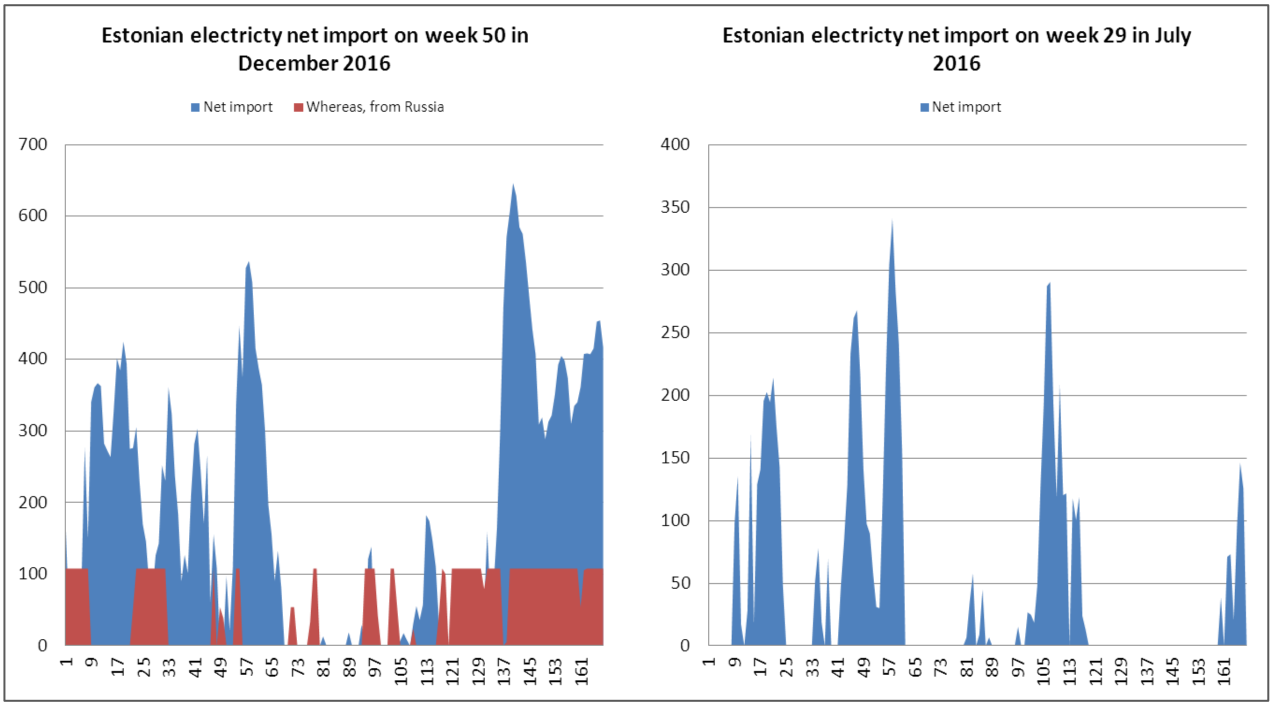


Figure 5.1-13 900 MW wind scenario electricity import in the week nr 50 and 29 in 2016

Concerning the power balance it can be seen from the following figure that the wind power has replaced entirely the condensing oil shale unit nr 8 production and some of the new CFB unit nr 9 production.

During the summer week there is an interesting change in power production – instead of the condensing unit nr 8 the new larger CFB unit is operation. The reason for this is the sufficient demand and for starting the unit as there is a high price in Latvia and during the poor wind periods it can provide energy for the Latvia. Also, as the unit was started the startup cost can be divided between more power production, which makes this unit more competitive.

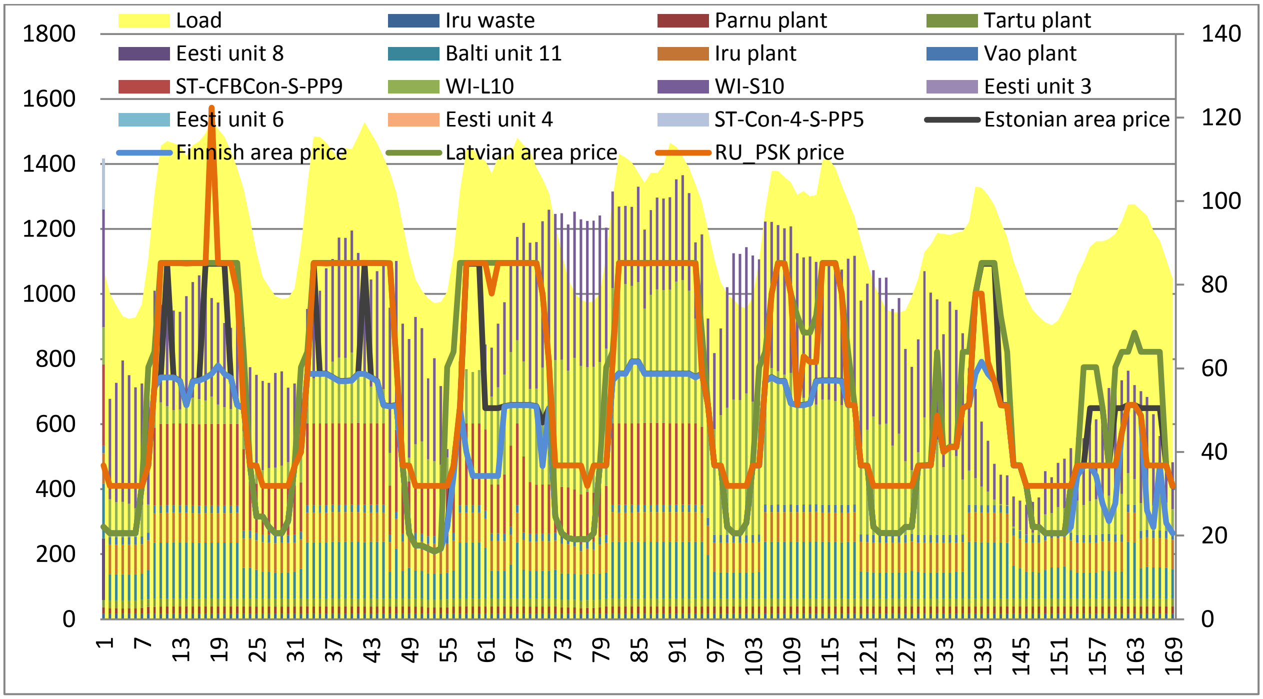


Figure 5.1-14 900 MW wind scenario - Estonian demand and generation together with the connected areas electricty price on week 50 in December 2016

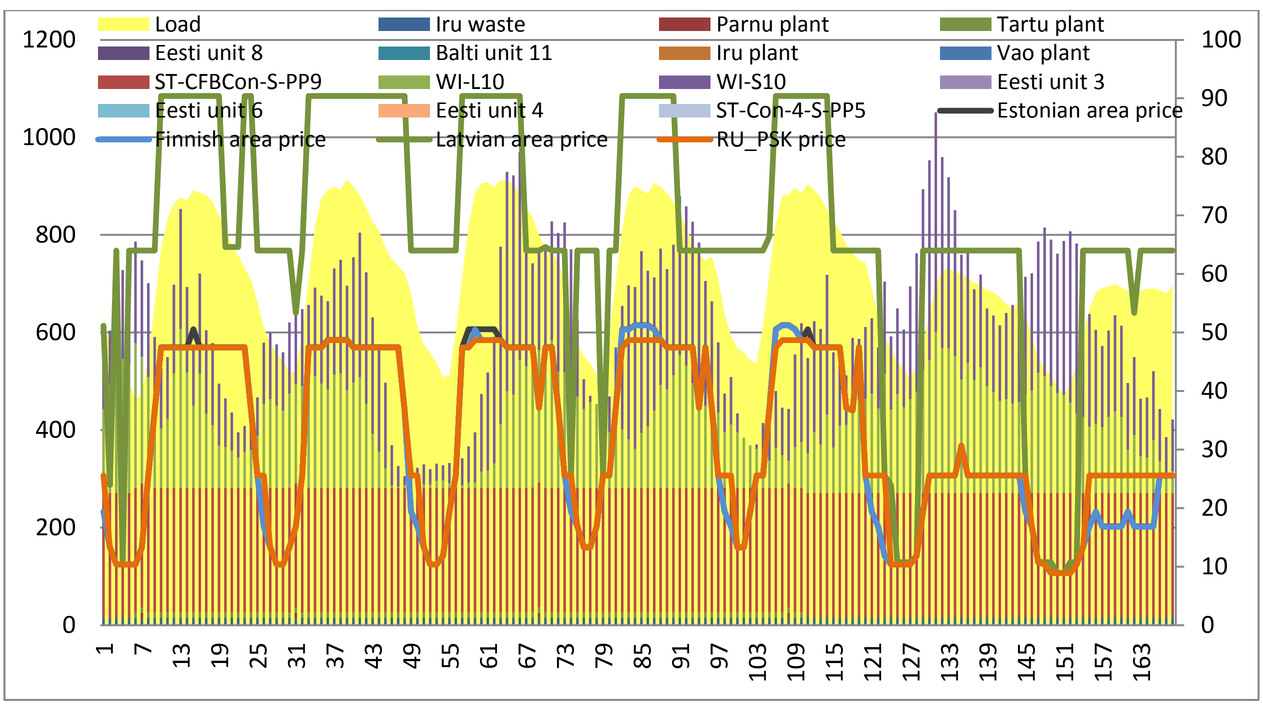


Figure 5.1-15 900 MW wind scenario - Estonian demand and generation together with the connected areas electricty price on week 29 in July 2016

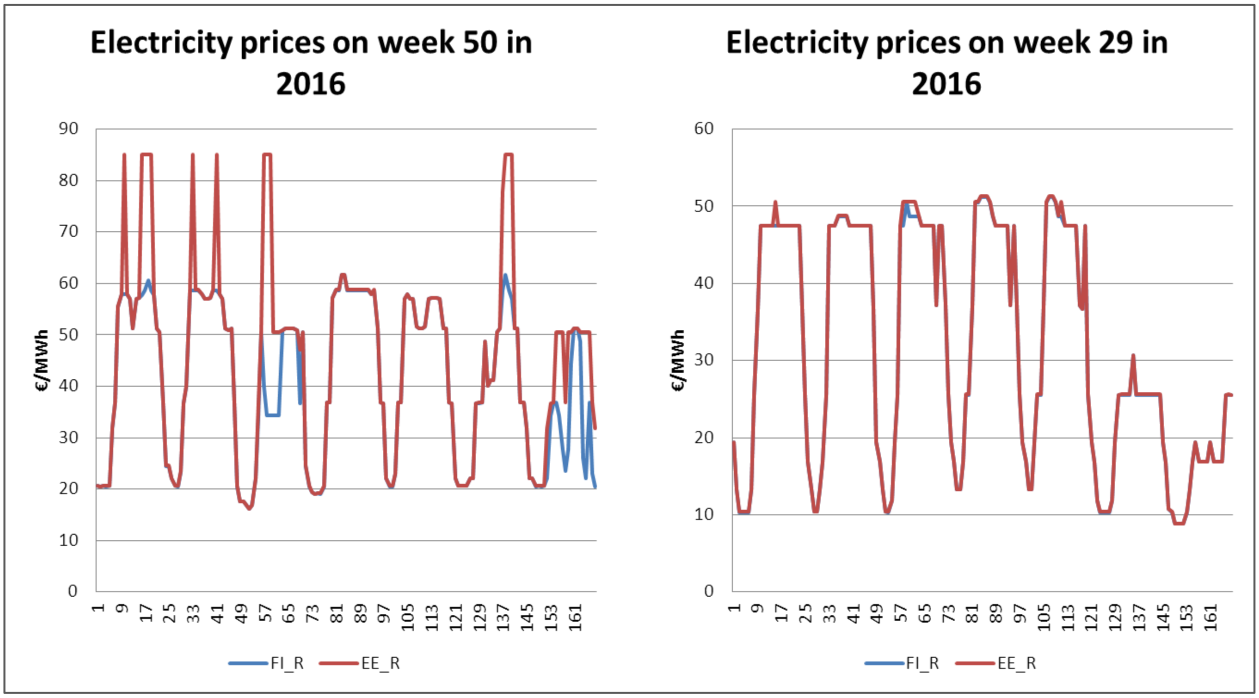


Figure 5.1-16 900 MW wind scenario electricity spot market prices for the week nr 50 and 29 in 2016

As there is no additional bottleneck observed between Estonia and Finland, there is no change in the electricity prices compared to the reference scenario. This is due the fact that the wind power producers are the price takers and until there is no bottleneck between Estonia and Finland the Finnish area price is received by all generators.

5.1.4 1800 MW wind power generation capacity scenario

Compared to the reference scenario the power production in Estonia exceeds its demand. Due to vast wind power production the power production in two condensing units during the winter week is replaced by the wind power production, whereas there are only few hours with the energy net import compared to highly dependent energy system in the reference scenario.

During the summer there are no changes in the units that are operating, but the increases fixed electricity import from Russia can be observed. The main reason for this is the vast wind power production in Latvia and Lithuania. As their demand will be covered and the only way to export the excess power is to do it through Estonia, the rest of the fixed electricity import from Russia to Baltic Stats will be accommodated in Estonia.

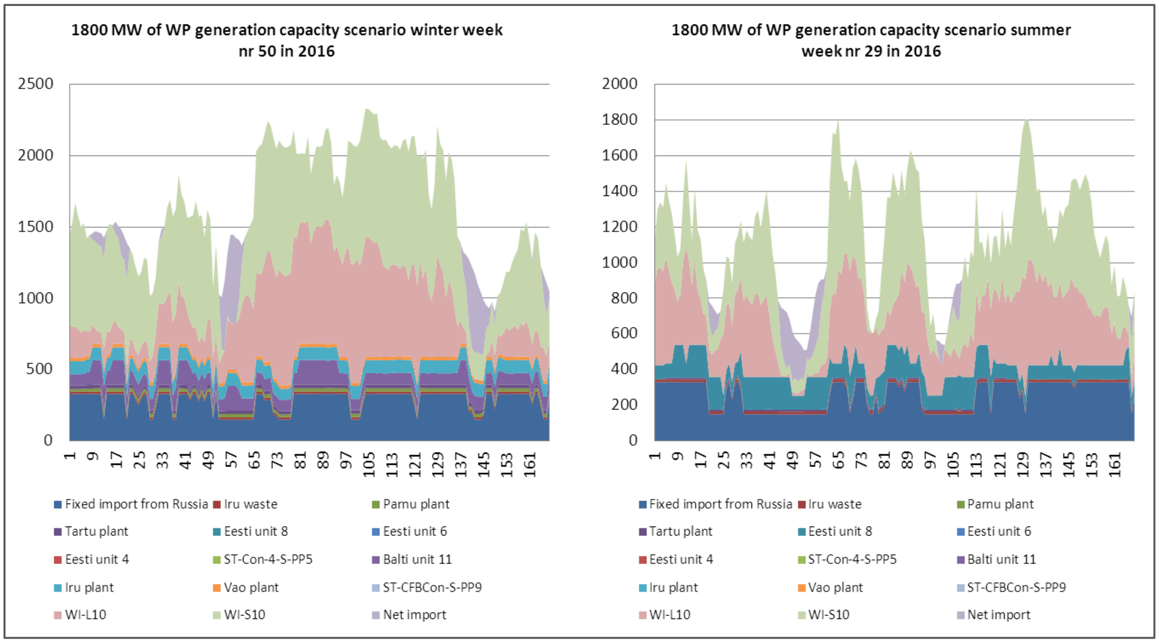


Figure 5.1-17 1800 MW wind scenario power balance for the week nr 50 and 29 in 2016

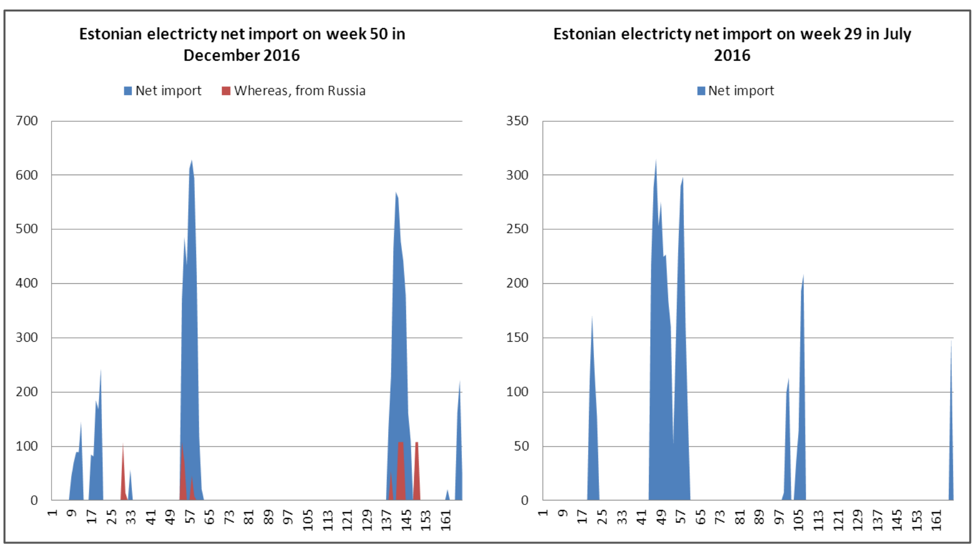


Figure 5.1-18 1800 MW wind scenario electricity import in the week nr 50 and 29

From the following power balance graphs it can be observed that the during the winter week the power production in thermal condensing power units is replaced with the wind power production. Only the cogeneration units are in operation. The oil shale based condensing unit, which also is the must run unit operates between it technically minimum and maximum generation capacity.

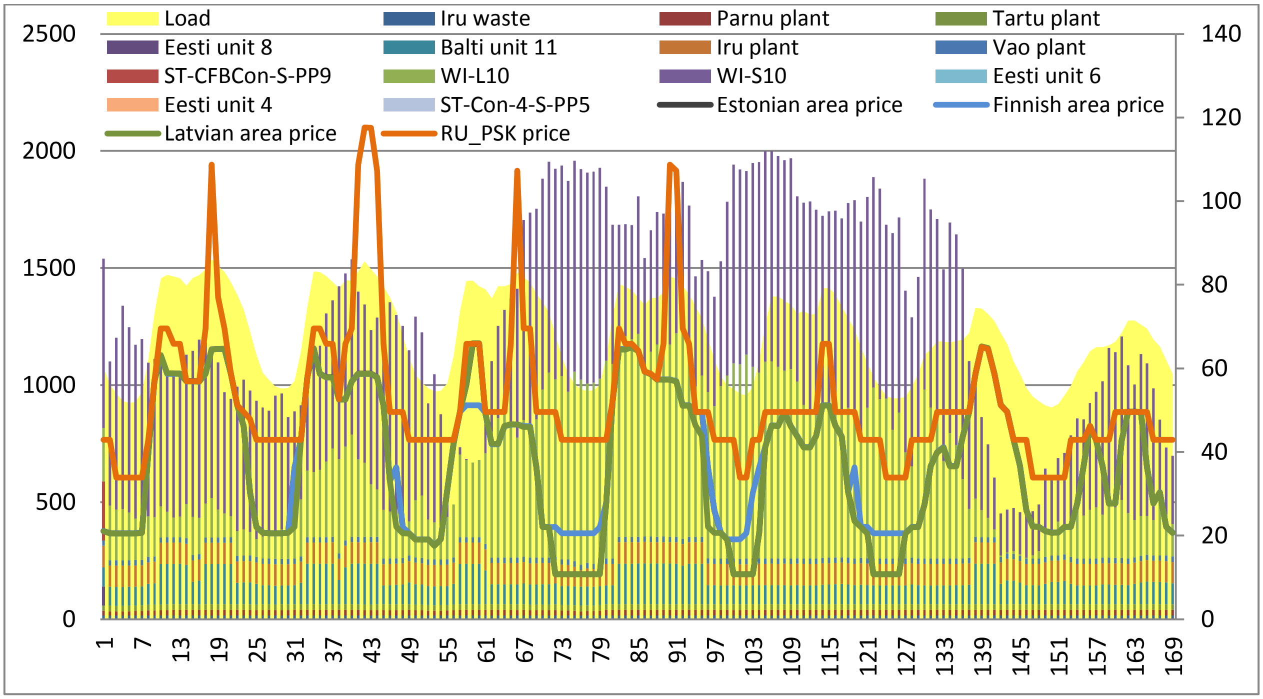


Figure 5.1-19 1800 MW wind scenario - Estonian demand and generation together with the connected areas electricity price in week 50 in December 2016

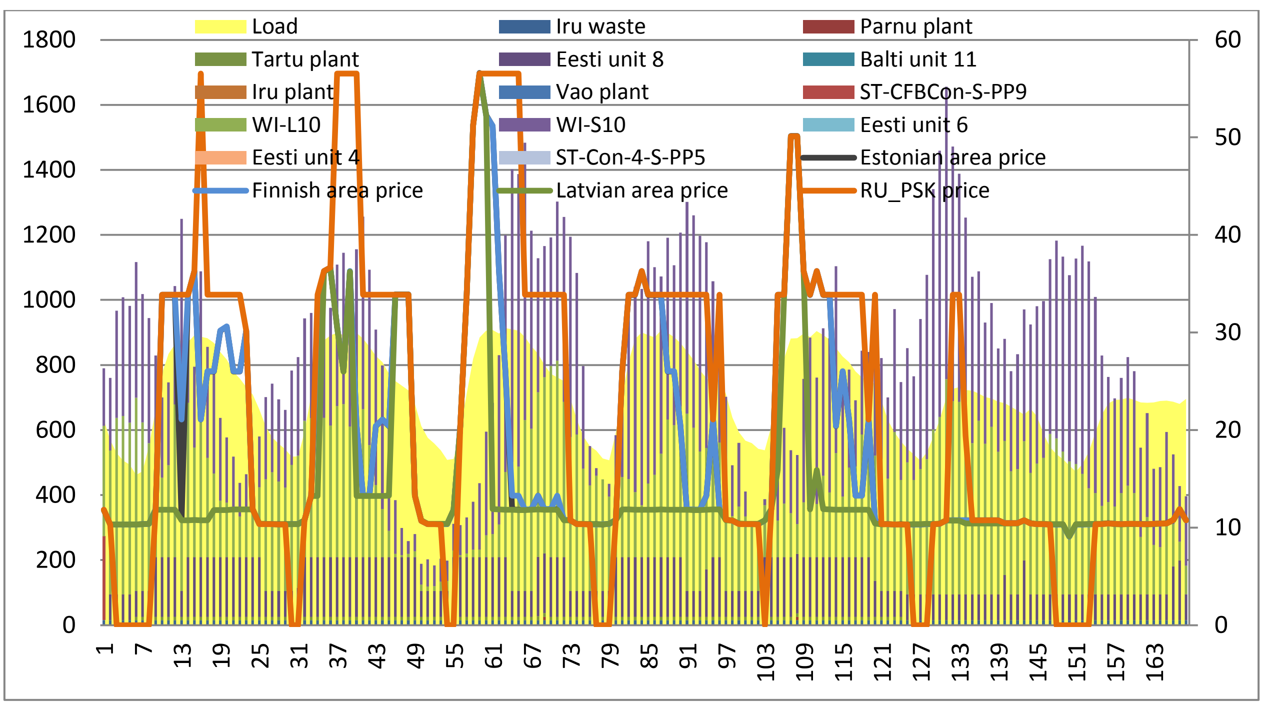


Figure 5.1-20 1800 MW wind scenario - Estonian demand and generation together with the connected areas electricity price in week 29 in July 2016

The summer week on a graph above is particularly interesting as the only units operating during the summer week are the wind generators and the must run unit in Narva Power Plants.

The other interesting and expected result can be read from the figure below – the electricity spot market prices have decreased. During the winter period the daily peak hour's prices have decreased, but otherwise the price level is almost the same. During the summer week the general price level has fallen.

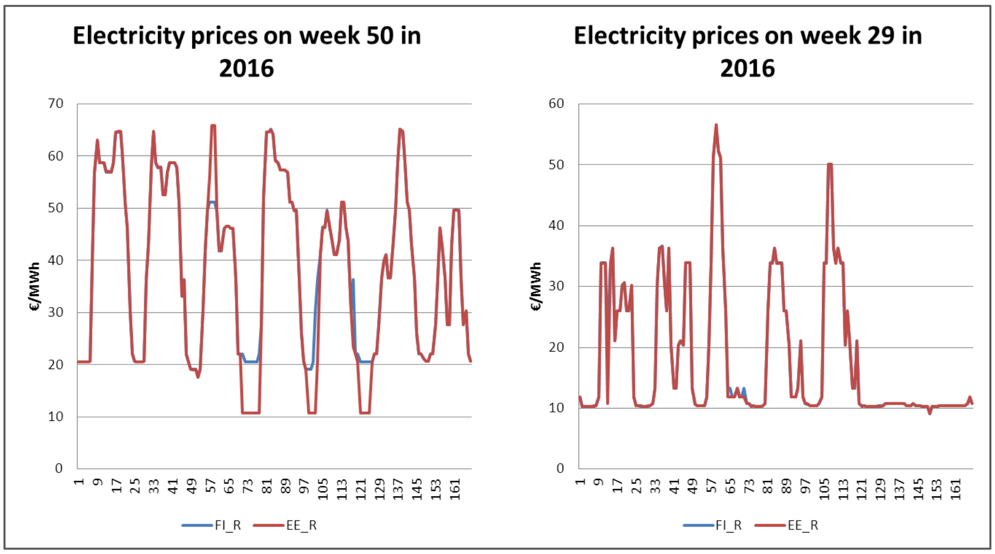


Figure 5.1-21 1800 MW wind scenario electricity spot market prices for the week nr 50 and 29 in 2016

In the next sub-chapter the scenarios results will be concluded and the quantitative figures of the changes in different scenarios will be presented. The next sub-chapter will have a broader understanding of the differences between scenarios and if this is what was observed on scenario basis widens for more than two weeks.

5.2 The quantitative analysis of wind scenarios scenario results

The idea of this sub-chapter is to present the important background figures that cannot be read from the graphs presented in the previous sub-chapter. These figures will give an insight of how are the power production units operated from one scenario to the other. Additionally to the power units the more important and interesting outcomes will be presented on the figures. As in this chapter are the quantitative figures presented, it does not mean that these figures would look the same in the prices/costs scale. This, what is the value of the figure results in terms of money will be introduced in the next sub-chapter.

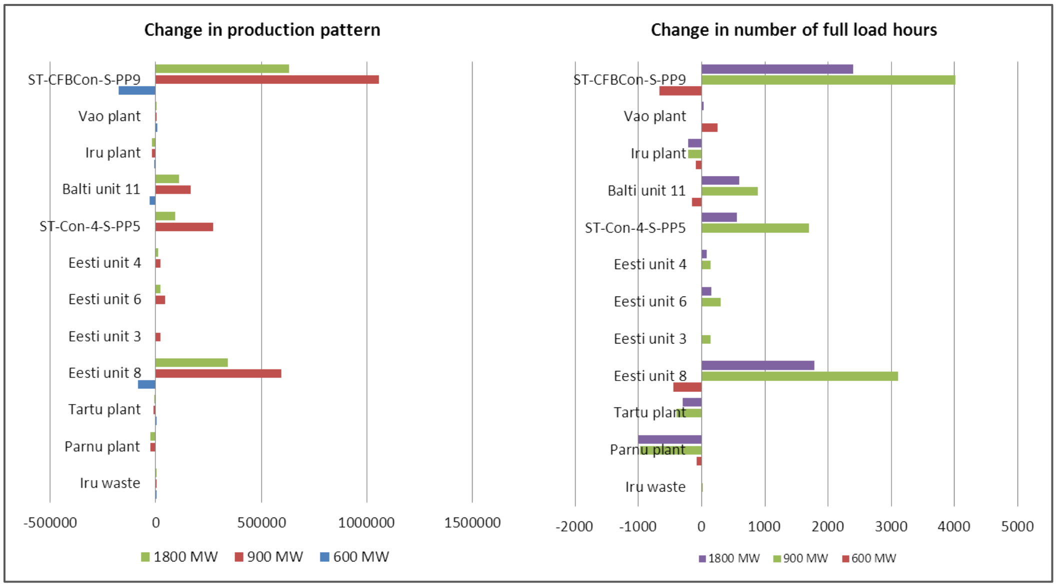


Figure 5.2-1 Change in production pattern and in number of full load hours

From these graph above, it can be seen that, when adding wind power capacity, the conventional power plants will gain in full generation hours as well in production, but the new subsidized power generators are losing in full load hours and electricity output. This is mainly caused by the need to regulate the wind power fluctuations. As these cogeneration units are more flexible than the conventional oil shale units the model has chosen these units to compensate the wind fluctuations.

From the graph below it could be seen that the CHPs are producing energy according to the heat demand. As these units are subsidized through renewable energy production or/and the efficient cogeneration support scheme, they receive subsidy for every produced kWh of energy. Naturally, they would optimize their profit and bid in the market price independent. Regarding the system technical point of view, these units are more flexible for downwards and upwards regulation (if there is any capacity left) and compared to the oil shale units they are cheaper to operate when used for regulating to the renewable energy fluctuations. Therefore these units are used more often to regulate wind power fluctuations. The following graphs for the 900 MW and 1800 MW wind power scenario will illustrate how the small cogeneration units are used for regulation.

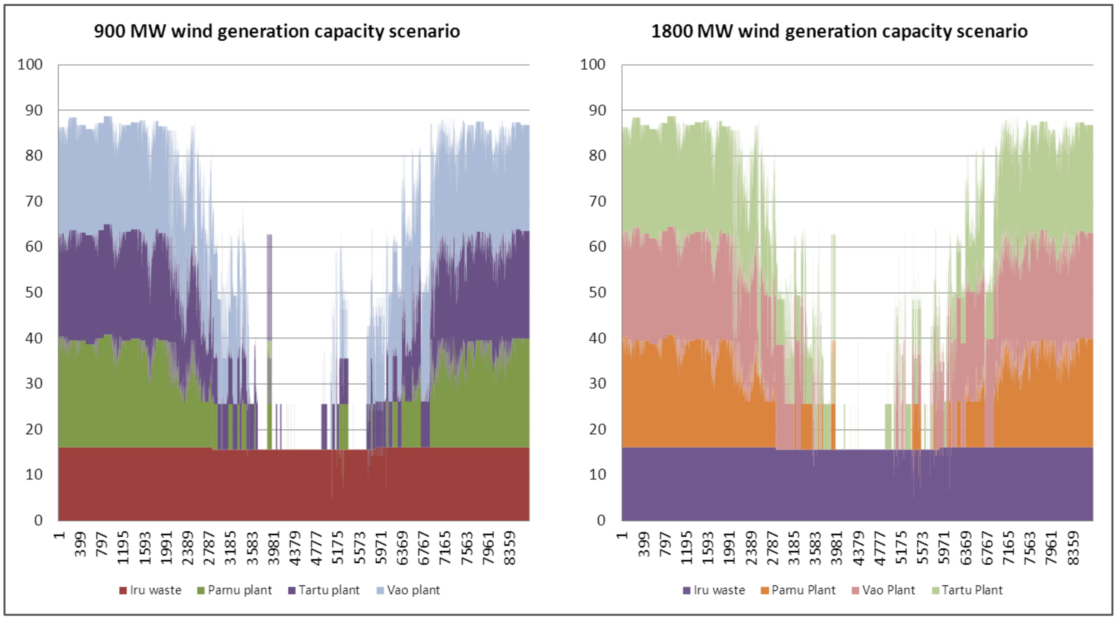


Figure 5.2-2 Power production from subsidized cogeneration units in 900 MW power scenario and 1800 MW power scenario

As the CHP units operation is dependent on climate conditions, mostly from the outdoor temperature, they have less operating hours during the summer, when there is no heating need. There will be only the need for hot water and steam for industrial processes. From the following graphs it could be seen that during the summer period the old oil shale based condensing power units are started for number of hours in order to provide energy in periods where there is no wind.

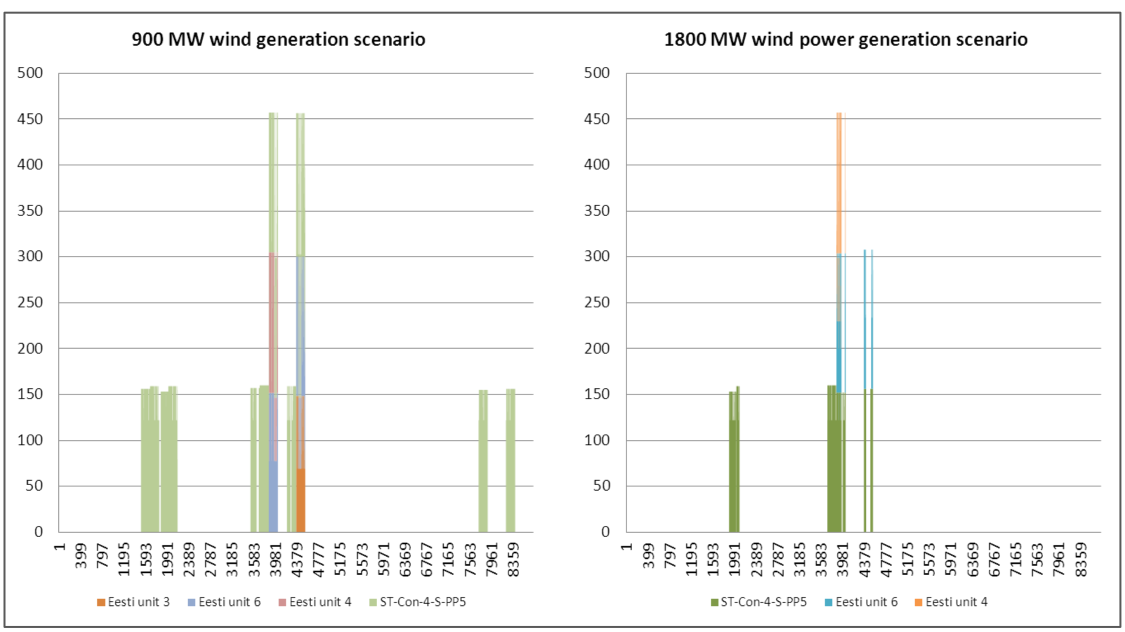


Figure 5.2-3 Oil shale units started up for low wind periods during summer

These older units are not in use in the reference and in the 600 MW wind power capacity scenario. Will it be feasible to keep these units in power production portfolio only for this limited number of hours of operation? Most probably it would not be feasible to keep the units for this few hours of operation in a year. It would mean either this capacity for these peaking hours is bought from regulating market or procured by the TSO from the old oil shale units (paid to be in the warm reserve). From the graphs below, it can be seen that the other oil shale units are up and running on their maximum capacity during these hours – no reserve for upwards regulation left any more.

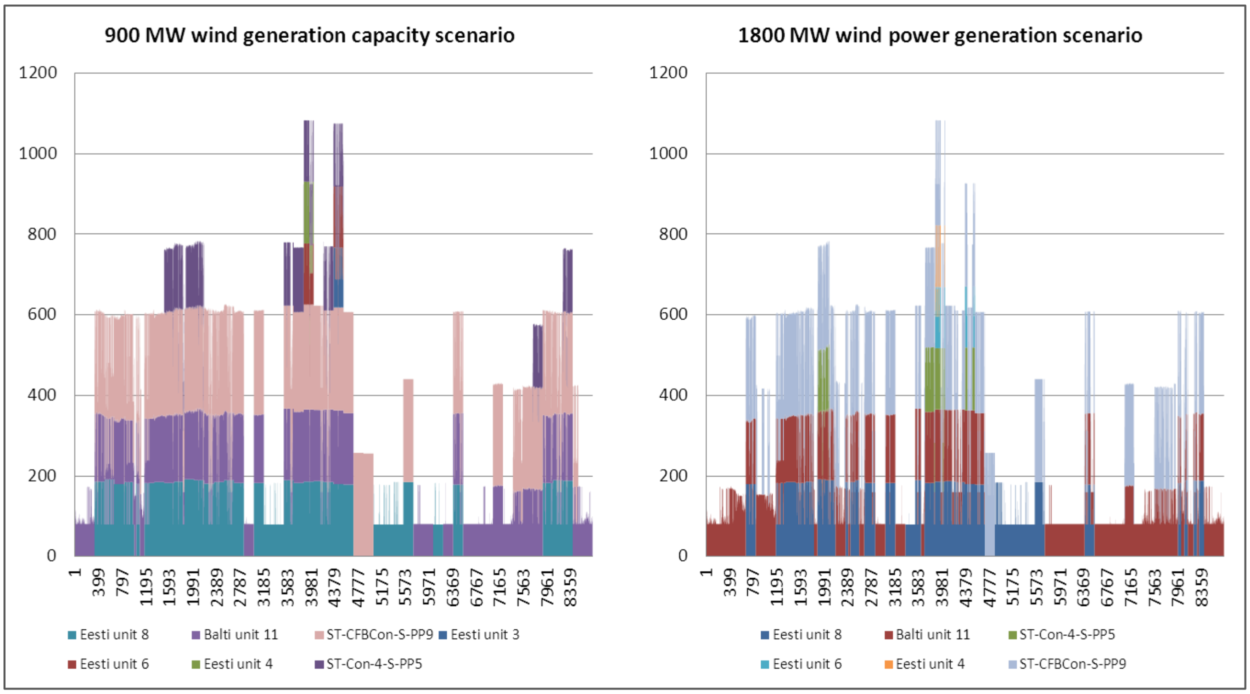


Figure 5.2-4 Oil shale units in operation in the 900 MW wind scenario and 1800 MW wind scenario

The figure below illustrates the change in becoming from import dependent country to the net exporting country due to vast wind power integration.

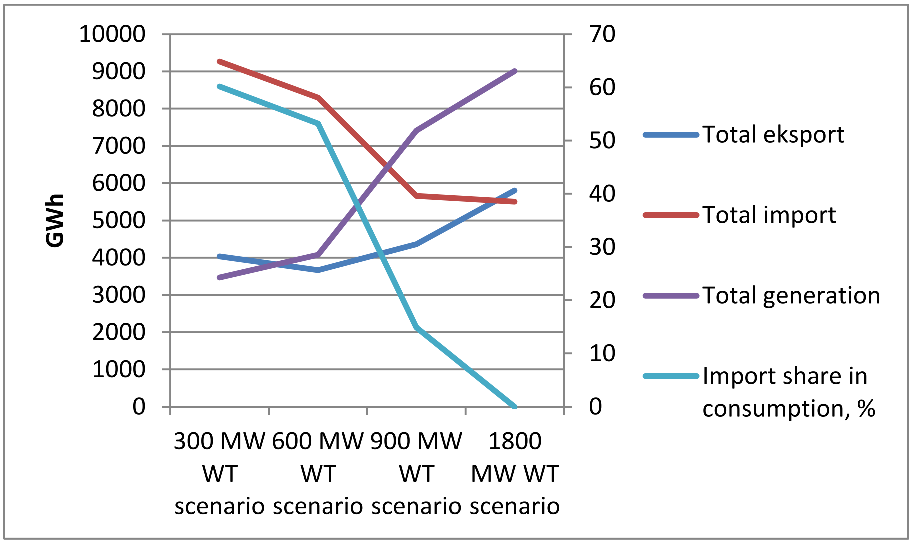


Figure 5.2-5 Change in dependence on the imported electricity

Even though the wind power is not emitting CO2, there is an increase in the CO2 emissions throughout the scenarios. The main reason is the shift from the imported electricity to the domestic production. From the figures above it could be observed that next to the increase of wind power production the power production was also increased in the oil shale power units, which has high contribution to the raise of CO2 emissions.

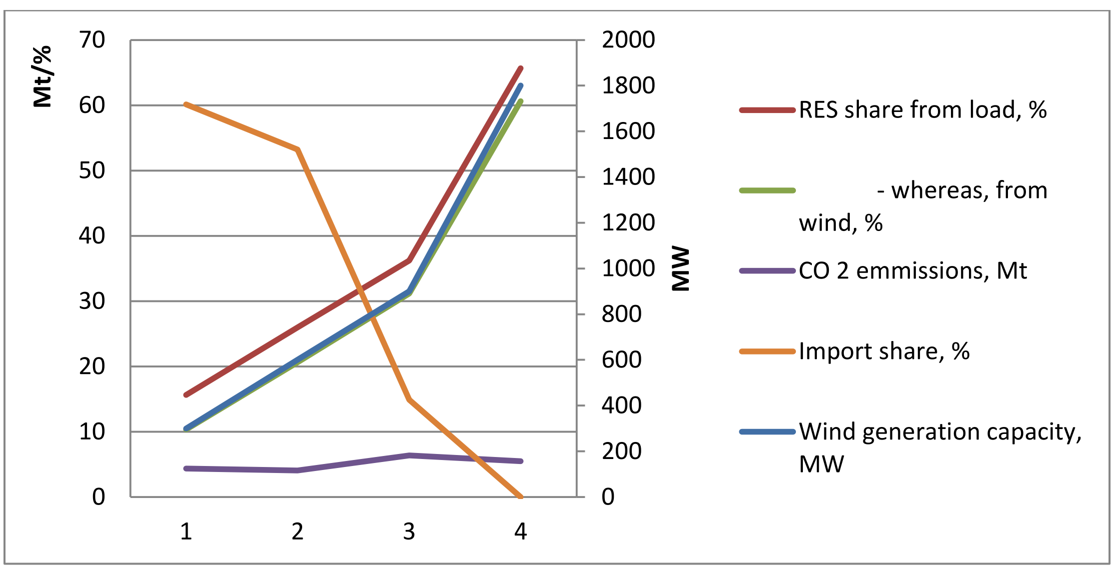


Figure 5.2-6 The CO2 emissions and renewable energy share from domestic electricity production in a light of different wind power generation capacity.

The cost and benefits of energy import and export as well as the domestic generation will be analyzed in next sub-chapter.

5.3 Socio-economic analysis of wind scenarios

First of all, the overall social-benefit will be looked at and later there will be more detailed analysis on market participant level having the power producers and consumers in main focus. This analysis is based on spot market study results, which means that the security of supply issues and the regulation needs are not studied, but will be touched in the discussion chapter.

For analyzing the socio-economic implications of the RES subsidies, the socio-economic welfare of the wind power development scenarios will be calculated. As the large-scale wind power development is carried by the relatively high subsidies paid, the wind power production will reflect the subsidies role in the analysis.

How the large-scale introduction will influence the other market participants, with the focus on power producers and consumers, is investigated in the following sub-chapter.

The large-scale wind power production socio-economic benefit for the society will be concluded according to table below, where there is each wind scenario compared to the reference scenario.

Table 5.3-1 Calculating the change in socio-economic benefit compared to the reference scenario

	300 MW	600 MW	900 MW	1800 MW
Scenario	Total, M€	Change, M€	Change, M€	Change, M€
Generator surplus	profit 300	profit 600 - profit 300	profit 900 - profit 300	profit 1800 -profit 300
Consumer surplus	surplus 300	(surplus 600 - surplus 300)	(surplus 900 - surplus 300)	(surplus 1800 - surplus 300)
Congestion rent	rent 300	rent 600 - rent 300	rent 900 - rent 300	rent 1800 - rent 300
Trade surplus	trade 300	(trade 600 - trade 300)	(trade 900 - trade 300)	(trade 1800 - trade 300)
Total		SUM	SUM	SUM

The table with the results from the scenarios:

Table 5.3-2 The change of socio-economic welfare compared to the reference scenario

	300 MW	600 MW	900 MW	1800 MW
Scenario	Total, M€	Change, M€	Change, M€	Change, M€
Generator surplus	217,8	-1,1	139,7	57,8
Consumer surplus	-426,6	36,0	2,1	134,5
Congestion rent	64,4	-20,1	-36,4	-52,8
Trade surplus	-205,4	34,9	141,8	192,3
Total		**49,7**	**247,2**	**331,8**

From the table above it can be seen that the total welfare in all scenarios increases, but the market participants, who gain most are changing from scenario to another.

In the 600 MW wind power generation scenario the reasons behind the increased total benefit are the trade surplus, which is achieved due to decreased electricity import and reduced consumer costs, which give a positive surplus. As the demand is modeled to be inelastic, the consumer costs for electricity in each scenario are analyzed. The inelastic demand means that the electricity consumption is independent from the spot market electricity prices – remains the same throughout all wind scenarios. Naturally, the spot prices have an effect on consumer behavior, when the prices are low, the consumption tends to increase and in case of higher electricity prices the consumption will decrease, which is the result of increased efficiency or the change in consumer behavior.

From the detailed scenario analyses it was seen that in the 300 MW wind scenario Estonia is heavily dependent on imported electricity and as there is always electricity import, the interconnections are more often congested and the trade surplus is highly negative. The reason for having less import in the higher wind scenarios is the increase in domestic wind power generation. This increased volume of wind power has an effect on Estonian spot market price, where wind power with lower marginal prices has supplant some of the more expensive units. This reduction in electricity prices is reflected through positive consumer surplus.

From the table it can be seen that even when there is net electricity import in the 1800 MW wind scenario, seen before, in terms of cost, the trade surplus is still negative. This means that the electricity import takes place during the hours, the market prices are low and import during the hours, the electricity spot prices is high.

In all scenarios it can be seen that the congestion income decreases – with every 300 MW of wind power capacity added there is approximately 25-30% of decrease in the congestion rent income. The main reason for the congestion income drop is the decreased number of bottleneck hours between Estonian and Finnish price areas – there is the same spot market price in increasing number of hours a year.

In the 600 MW wind scenario it can be seen that the consumers and the state in general, through increased trade surplus, are gaining, but the generators and the TSO, whereas the TSO is losing most – more than 30%, are the losers in this scenario. From the regional socio-economic point of view the interpretation of the congestion rent income as a benefit for the TSO and the reduced welfare for the society could be argued as from the reduced hours of congestion both sides gain by having lower spot market prices. On the other hand the reduced market price is expressed through the consumer surplus and the reduced hours of bottleneck through decreased import.

In total, the decrease in congestion rent and consumer surplus is lower than the increase in consumer and trade surplus, therefore the total welfare of the 600 MW wind power generation scenario is positive.

In the 900 MW scenario the picture has changed – some of the losers and gainers have switched the sides. The total socio-economic welfare is highly positive, compared to 600 MW wind scenario the change is almost five times higher.

The main reasons behind are the highly positive generator surplus, which is a result of the increased domestic competitive electricity production. This production also replaces the most of the energy import compared to the reference scenario. The other same important reason is the deep reduction in imported electricity, which adds to the trade surplus. Although, the trade surplus is highly positive, the total trade is still negative – the electricity export compared to electricity import is lower in terms of money. These aspects will be more thoroughly studied in the next sub-paragraph.

In this scenario the only loser is the TSO by having 57% of decrease in the congestion rent income. Although, the change in consumer surplus is positive, compared to the 600 MW scenario it is inconsiderable 6%.

Despite the steep drop in bottleneck income the total socio-economic welfare is highly positive – favoring the power generation sector and export-import balance.

The 1800 MW wind scenario is favoring mostly the consumers, which is the result of lower spot market prices due to large-scale wind power integration. Compared to the reference scenario, also, the generators are gaining, but compared to the 900 MW wind scenario this gaining is moderate, forming only 41% of what they could gain in less wind power capacity scenario. The closer look, how is this surplus divided between the generators will be given in the following sub-chapter. According to these results, the feasibility of investing into this large wind power generation capacity would be questionable.

As it could be seen from the Figure 5.2-5 Change in dependence on the imported electricity, it is the first scenario in which the physical energy export-import balance is positive - the net export exceeds the energy import, but in terms of money the trade surplus compared to the reference scenario is still negative, -13,1 M€.

How are the different power generators groups and the consumers affected throughout the scenarios will be studied in detail in the next sub-chapter. Also, the state energy sector economy in terms of trade surplus (and congestion income) will be looked at.

5.4 Market participants economic analysis of wind scenarios

5.4.1 Generator surplus

The generators are divided into four groups: wind parks, RES and CHPs, BEJ 11 and conventional units. The reason for having them in these four groups is to divide the subsidized and conventional units, whereas the subsidized units are divided according to their support scheme. In the calculations, the subsidies are included. The change compared with the reference scenario is calculated according to the table below.

Table 5.4-1 Calculating the change of generators surplus compared to the reference scenario

	300 MW	600 MW	900 MW	1800 MW
Scenario	Total, M€	Change, M€	Change, M€	Change, M€
Wind parks surplus	wind 300	wind 600 - wind 300	wind 900 - wind 300	wind 1800 - wind 300
RES&CHP surplus	RES 300	RES 600 - RES 300	RES 900 - RES 300	RES 1800 - RES 300
BEJ 11 surplus	BEJ 300	BEJ 600 - BEJ 300	BEJ 900 - BEJ 300	BEJ 1800 - BEJ 300
Conventional surplus	conv 300	conv 600 - conv 300	conv 900 - conv 300	conv 1800 - conv 300
Total		SUM	SUM	SUM

In the quantitative analysis sub-chapter the change in generators surplus was estimated, but this surplus is divided between generator groups differently from one scenario to another. The change compared with the reference scenario and the division between generators is presented in the table below.

Table 5.4-2 The change of generators surplus compared to the reference scenario (with subsidies)

	300 MW	600 MW	900 MW	1800 MW
Scenario	Total, M€	Change, M€	Change, M€	Change, M€
Wind parks surplus	66,5	23,3	68,7	79,0
RES&CHP surplus	47,9	-2,0	-2,8	-11,2
BEJ 11 surplus	48,0	-5,4	4,5	-12,6
Conventional surplus	55,4	-17,0	69,3	2,6
Total		**-1,1**	**139,7**	**57,8**

From the results it can be seen that the wind power generators surplus increasing in each scenario, but this increase per installed MW of capacity is different. In the 600 MW wind scenario the annual benefit for every additionally installed MW of wind power capacity is 0,078 M€; in 900 MW wind scenario the same benefit is 0,11 M€ and in the 1800 MW wind scenario it would be 0,05 M€. From this it can be concluded that at least until 900 MW wind power capacity every additional MW installed creates an additional benefit but integrating more wind power capacity will start decreasing the net benefit of all producers. Where the exact limits are, cannot be said according to this study.

If to calculate the same figures for the wind parks surplus without the subsidies, the picture would not change significantly, which is not the case for subsidized CHPs as it can be seen below.

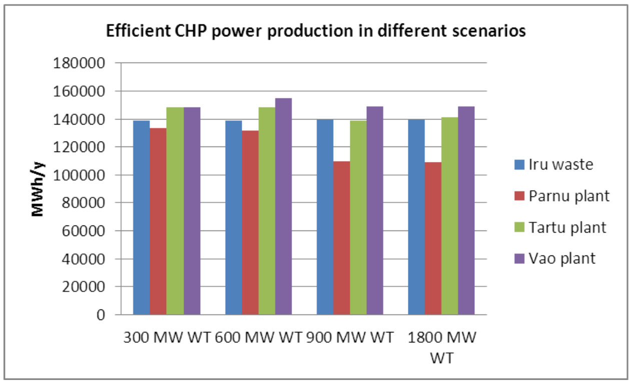
The RES and CHPs group of generators are the combined heat and power producers, who burn biomass and peat and receive RES subsidy for every kWh of energy produced from biomass. Also, the waste incineration plant is getting the RES subsidy. Additionally, to the RES subsidy these units are getting efficient cogeneration subsidy for every kWh of energy produced in efficient cogeneration mode. The precondition is that over 10 MWh units can get this subsidy if the power is produced from peat. The units usually burn different type of fuels together and therefore the subsidy is paid dependent on biomass and peat shares in the primary fuel intake. In producers surplus calculations the RES subsidy, which is 53,7 €/MWh and the efficient cogeneration subsidy, which is 32 €/MWh is taken into consideration. The estimated division of the subsidies is 75% and 25% for all CHPs production, except for the waste incineration plant.

Table 5.4-3 The change of generators surplus compared to the reference scenario (without subsidies)

	300 MW	600 Mw	900 MW	1800 MW
Scenario	Total, M€	Change, M€	Change, M€	Change, M€
Wind parks surplus	34	23	69	79
RES&CHP income	23	-2	-1	-10
BEJ 11 income	39	-5	3	-14
conv income	55	-17	69	3
Total		**-1**	**140**	**58**

From the calculations above it can be seen that the subsidized cogeneration units' group surplus is decreases throughout the scenarios. With first added 300 MW of wind power generation capacity, the decrease in generators' surplus will be 4,2%, with additional 300 MW (900 MW wind scenario) the decrease is 5,8% and in the 1800 MW wind scenario the decrease is extremely deep, 23,4%. This kind of decrease would put the recently built cogeneration units into very difficult situation as they have relatively high long-term costs, mostly due to the investment loans that have to be paid back to the banks. Without the subsidies this situation would even be worse in the 600 MW wind scenario and the 1800 MW wind scenario. The decrease in producer surplus would be 8,7% in the 600 MW wind scenario, 4,3% in 900 MW and deadly deep 43,5% in the 1800 MW wind scenario.

These changes in the producers' economy could not be observed from the following figure, where the physical deliveries of power plants are presented.



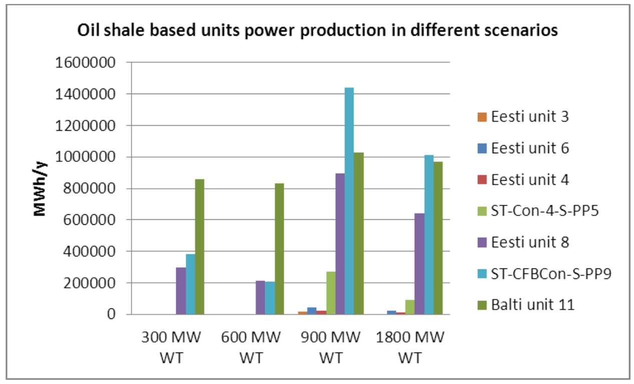


Figure 5.4-1 Efficient CHPs and oil shale based power units annual production in different wind scenarios

The BEJ 11 is the cogeneration oil shale unit in Narva Power Plants. This unit has given separate row, because Narva Power Plants burn biomass together with the oil shale in this unit and until the unit can operate with the total efficiency above 40%, subsidy the RES subsidy is paid for every kWh of electricity produced from biomass. It can be calculated from the tables above, that BEJ 11 receives 13,5% of the subsides in the reference scenario.

From the graphs above it can be observed that the power unit BEJ 11 surplus compared with the reference scenario in negative in 600 MW and 1800 MW wind scenario and positive in the 900 MW wind scenario. This is the case in the both calculations, with and without subsidies. The BEJ 11 surplus in 600 MW wind scenario is decreased 11,3 % in case the subsidies are included and 12,8% in case the subsidies are left out from the calculations; the same results for the 1800 MW wind scenario are 26,3% decrease with the subsidies included and 35,9% decrease, when the subsidies are not included. In the case of 900 MW wind scenario the situation is opposite, the BEJ 11 will gain. With the subsidy included, the surplus will increase 9,4% and without the subsidy the increase will be 7,7%.

The differences of the calculations with and without subsidies for the supported power units are illustrated on the figure below.

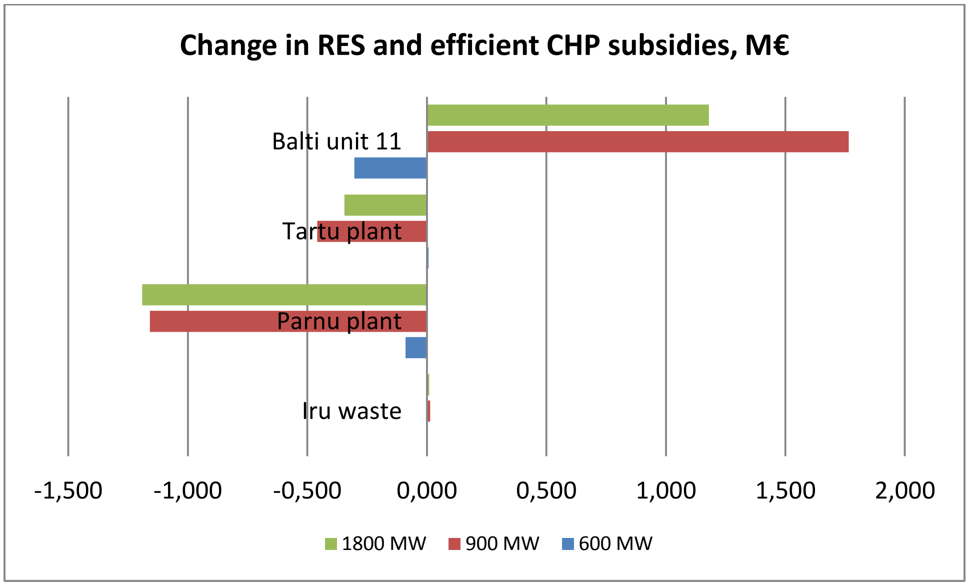


Figure 5.4-2 Change in RES and efficient CHP subsidies

For using the small CHPs on regulating purposes has a very high cost, which is not taken into consideration in the spot market prices. These subsidies are lost due to the reduced number of hours online. As the lost subsidies as well lost income are vital for these small CHPs there have to be mechanisms for allocating these costs among the power market participants. This is not the topic of this report, but in the end on consumer will pay for it, in current calculations it is not foreseen.

The situation with the conventional units is interesting, as according to the tables above, the surplus will decrease in the 600 MW wind scenario but increase in the other two scenarios. In percentages the decrease in surplus in 600 MW scenario would be 30,7% (without subsidies 30,9%) and the increase in two following scenarios; in 900 MW scenario 125,1% (without subsidies 125,5%), in 1800 MW scenario 4,7% (without subsidies 5,5%). In order to understand, from where this enormous increase in 900 MW wind scenario comes from it necessary to look into the following table; this confirms the observations done during the detailed scenario analysis before.

From the table it can be seen that the conventional units' surplus is increased due to starting up 4 older oil shale condensing units (EEJ 3, EEJ 4, EEJ 5 and EEJ 6) for limited number of hours a year. There will arise a question if it is feasible to keep a unit in operation if it gets only 138, 296, 141 or even 1 695 full load hours a year.

Table 5.4-4 Number of full load hours in all wind scenarios

Scenario	**Reference**	**600 MW wind**	**900 MW wind**	**1800 MW wind**
Wind parks				
WI-L10	2 355	2 355	2 355	2 355
WI-S10	3 437	3 431	3 477	3 311
Total	**5 791**	**5 786**	**5 831**	**5 666**
RES & CHPs				
Iru waste	8 614	8 616	8 630	8 626
Parnu plant	5 411	5 337	4 439	4 412
Tartu plant	6 112	6 119	5 721	5 817
Vao plant	6 009	6 266	6 019	6 036
Total	**26 147**	**26 338**	**24 809**	**24 891**
BEJ 11 (oil shale based CHP)				
Balti unit 11	4 693	4 535	5 578	5 282
Conventional power units				
Eesti unit 8	1 562	1 115	4 664	3 349
Eesti unit 3	0	0	138	0
Eesti unit 6	0	0	296	157
Eesti unit 4	0	0	141	81
ST-Con-4-S-PP5	0	0	1 695	563
Iru plant	4 845	4 753	4 634	4 634
ST-CFBCon-S-PP9	1 449	787	5 466	3 845
Total	**7 855**	**6 656**	**17 033**	**12 628**

Also, it can be observed from the table above, that in the 600 MW wind scenario the conventional units operational in reference scenario will in total lose 1 201 full load hours, but in 900 MW wind scenario gain 6 908 full load hours and in 1800 MW wind scenario gain 3 972 full load hours. According to this table it is also difficult justify the feasibility of a new CFB oil shale unit (PP9) in first two wind scenarios; the same goes for the existing condensing unit nr 8.

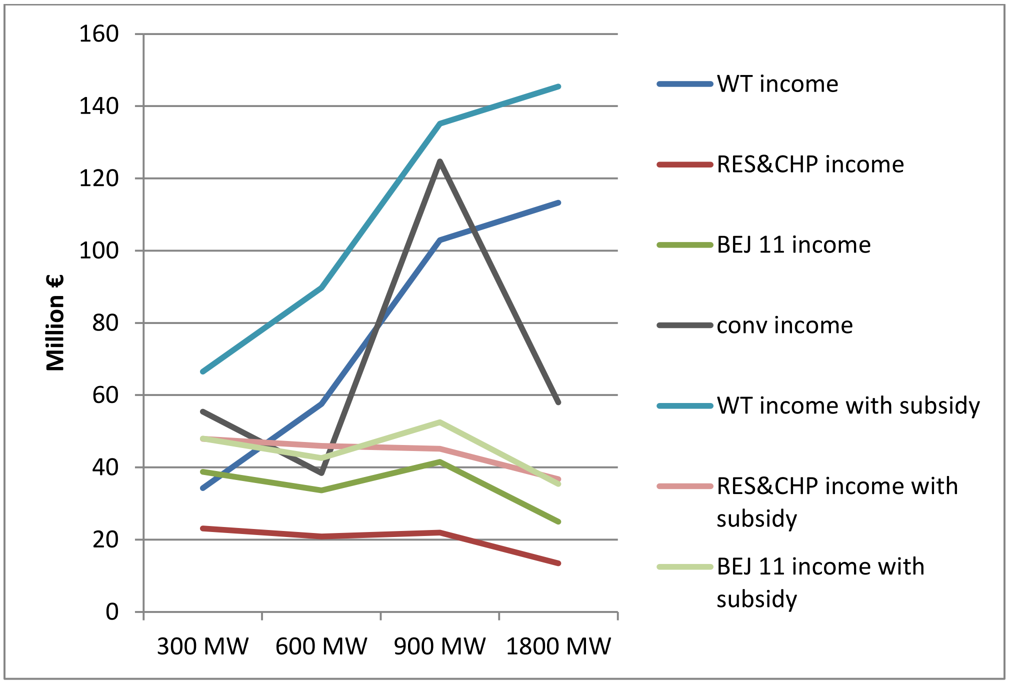


Figure 5.4-3 The changes in producer surplus in both cases – with and without subsidies

This graph illustrates the observations and calculations in this sub-chapter.

5.4.2 Consumer surplus

The consumer surplus is calculated according to the table below.

Table 5.4-5 Consumer surplus calculations

	300 MW	600 MW	900 MW	1800 MW
Scenario	Total, M€	Change, M€	Change, M€	Change, M€
Consumer surplus	(surplus 300)	(surplus 600 - surplus 300)	(surplus 900 - surplus 300)	(surplus 1800 - surplus 300)
Renewable energy tax	(tax 300)	(tax 600 - tax 300)	(tax 900 - tax 300)	(tax 1800 - tax 300)
Total		SUM	SUM	SUM

As the subsidy paid for the wind power producers is fixed with 600 GWh of wind power production annually, there will not be more than 32,2 M€ collected under green energy tax, for supporting wind power. From the table below it can be seen that the wind power supporting costs constitute more than 46% from total renewable energy tax collected from consumers in all wind power scenarios. The practice has also shown that when the wind power annual production approaches the support target (currently 600 GWh) it is "no problem" (the successful work of lobbyists) to increase the supported volume by 200 GWh, which would be additional burden, worth of 10,7 M€, for consumer. Nevertheless, this is not the case in this report.

Table 5.4-6 Consumer surplus

	300 MW	600 MW	900 MW	1800 MW
Scenario	Total, M€	Change, M€	Change, M€	Change, M€
Consumer surplus	-356,9	35,9	2,3	134,2
Renewable energy tax	-69,7	0,1	-0,2	0,3
Total		36,0	2,1	134,5

In the 600 MW wind scenario the gainers are consumers, in the 900 MW wind scenario, as it could be seen in the previous sub-chapter, the winners were generators. In the 1800 MW wind scenario the consumer surplus with green energy tax would be 31,5% and without the tax 37,6%. Nevertheless, this is an unlikely scenario as it could be seen from the previous sub-chapter that the marginal benefit from every additional MW of wind power capacity started to decrease at some point after 900 MW level. Also, the feasibility of this large-scale wind power integration with observed spot prices is questionable. The main reason behind the increase in surplus is the lowered spot market prices, which are a result of large-scale wind power introduction.

5.4.3 Congestion rent

The congestion rent is calculated according to the following table.

Table 5.4-7 Congestion income calculation

	300 MW	600 MW	900 MW	1800 MW
Scenario	Total, M€	Change, M€	Change, M€	Change, M€
Congestion rent	rent 300	rent 600 - rent 300	rent 900 - rent 300	rent 1800 - rent 300

From the calculations below it can be seen that the congestion rent income decreases from scenario to scenario. The main reason for this is increase in domestic power production due to which the need for imported electricity is decreased. This again leads to lower loads in interconnection. Due to added competitive suppliers in Estonia there are more hours with the same spot market price and due to that the interconnection is more hours uncongested, when no congestion income is collected.

Table 5.4-8 Congestion income

Scenario	300 MW Total, M€	600 MW Change, M€	900 MW Change, M€	1800 MW Change, M€
Congestion rent	64,4	-20,1	-36,4	-52,8

In the following figure the change in congestion rent income is presented together with the import and it can be observed that with decrease in import the congestion rent income also decreases. Apparently, the increase in export has no positive effect on congestion income. This is due the fact that the export takes place during the hours, when the spot prices are on their lower levels and import takes place, when there is power deficit.

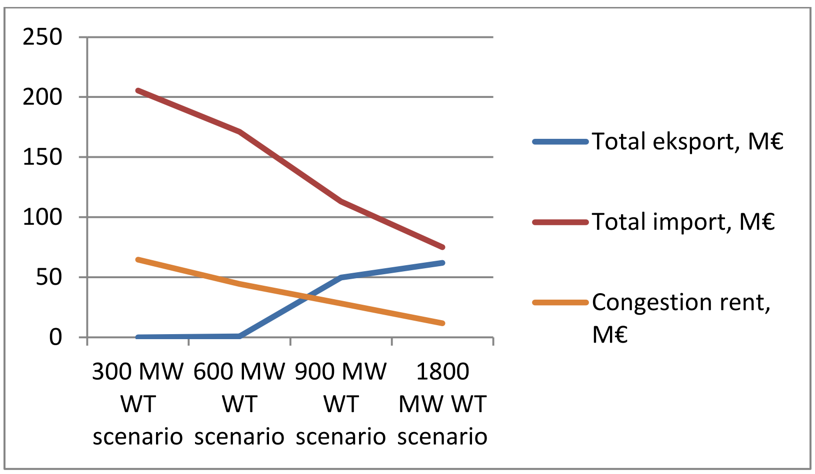


Figure 5.4-4 The congestion rent income dependence on cost for imported electricity

5.4.4 Trade surplus

The trade surplus is calculated according to the table below.

Table 5.4-9 Trade surplus calculation

Scenario	300 MW Total, M€	600 MW Change, M€	900 MW Change, M€	1800 MW Change, M€
Electricity import	(import 300)	(import 600 - import 300)	(import 600 - import 300)	(import 600 - import 300)
Electricity export	export 300	export 600 - export 300	export 600 - export 301	export 600 - export 302
Trade surplus		SUM	SUM	SUM

Table 5.4-10 Trade surplus

Scenario	300 MW Total, M€	600 MW Change, M€	900 MW Change, M€	1800 MW Change, M€
Electricity import	-205,4	34,3	92,2	130,4
Electricity export	0,0	0,6	49,6	61,9
Trade surplus		34,9	141,8	192,3

The trade surplus, calculated in the table above will reflect the electricity sector import-export balance of a country. The change in trade surplus was touched under the total socio-economic chapter.

From the graph below it can observed that even if the physical electricity export exceeds the import, the costs for the imported electricity are higher. This is due to the same phenomena, recognized in the previous sub-chapter, that the electricity is exported during the hours the spot market price is low and imported during the hours spot market price is high.

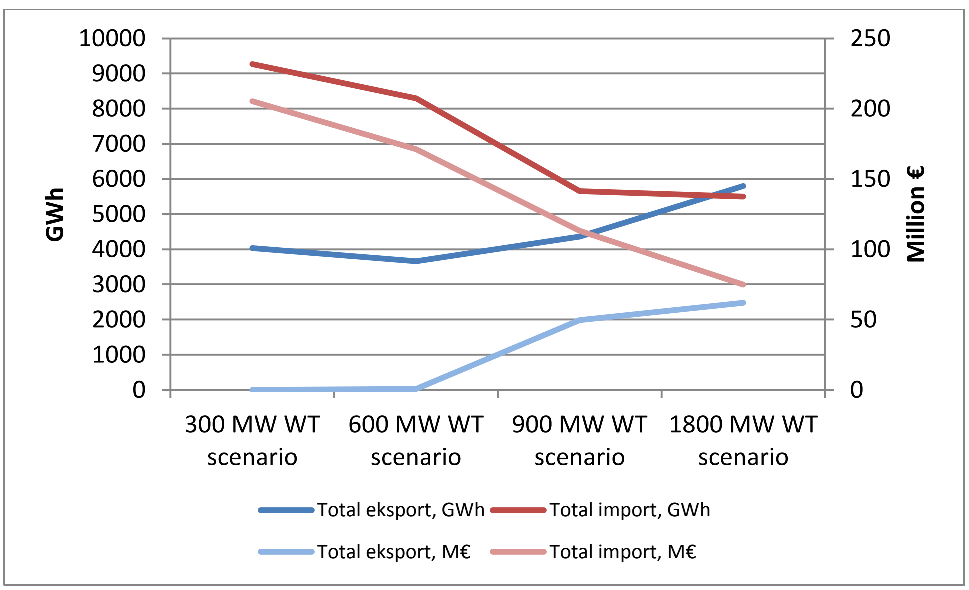


Figure 5.4-5 Electricity import and export volumes compared to the import costs and export benefits

6 Conclusion

Here the results from the analyzed scenarios will be presented and the research question answered. The relevant topics concerning the interpretation and judgment of the results will be introduced in the following *Discussion* chapter.

In order to answer the research question *"How will the existing Estonian RES subsidies influence the participants in Estonian/Baltic electricity market?"* and the sub-question: *"What are the socio-economic implications of these subsidies for Estonia?"* the three wind power development scenarios were analyzed.

On a larger picture the influence of the existing RES subsidies can be seen as the potential investors' high interest to invest in wind power generation in Estonia. What would the consequences for the other electricity market participants be, when the investors make their plans to come through, is studied through three wind power generation capacity development scenario. When studying the other electricity market participants, the different power generators groups are in main focus, also the influence on consumers is analyzed.

From the analysis it could be observed that the conventional domestic oil shale power production, due to high environmental costs (the CO2 quota price was set 30 €/ton, which is double of the price today), is not competitive with the electricity prices in Finland and Russia. As the RES subsidies encourage investments into wind power production, the wind power generators are becoming most beneficial among the other power producers on Estonian power market. It was also observed that in 900 MW wind power scenario the benefit for every installed MW of wind power capacity was higher than in 1800 MW wind scenario. From this it can be concluded among the analyzed scenarios the optimal wind power capacity in Estonia would be 900 MW. If this would be the case, the small subsidized cogeneration power plants would lose 6% in their income, the oil shale based cogeneration unit that is burning biomass would gain 9% and also the conventional units could benefit from the increased wind power production. As the conventional units and small cogeneration units are used for balancing the wind power fluctuations, the additional costs (lost subsidies, keeping inefficient units in operation etc.) occur and these are not reflected through spot market electricity prices. According to this scenario none of the named market participants is losing, but some gain more than the others and this time the winners are producers. The consumers will also gain, but this will be insignificant 0,5%. In other words, the consumers can benefit from domestic power production without paying for higher electricity price. How will be costs for the extra reserves (for balancing forecast errors) and for covering the lost subsidies allocated between the market participants is not analyzed.

For being able to answer the research question's sub-question, the socio-economic analysis for these wind development scenarios is performed.

From the national perspective, the analysis showed that the increased wind power production will decrease the dependence from imported electricity, but also this that developing solely wind power will not remove the need for imported electricity. It was seen that during the hours there is no wind high volumes of electricity had to be imported with significantly higher prices than the excess wind power production was exported. Nevertheless, total socio-economic benefit increased with increased number of wind power capacity installed. The main reason behind this was that the conventional power units were too costly to be operated and could not compete with the imported electricity. The introduction of large-scale wind power generation changed the import-export balance and the domestic power generation became competitive and could compete with the imported energy. The sub-question could be answered by saying that assuming perfect market performance, the total socio-economic welfare in analyzed scenarios, with every MW of installed wind power capacity, is increasing.

7 Discussion of the study results

There are several issues that have to be considered, when looking the results of the analysis.

First of all the perfect market is assumed, where all the decisions are made on cost minimization basis, which actually will not always be the case in practice – the power producers main goal is to maximize their profit. Also, all kind of support schemes applied for different type of power production units or fuels distort power market participants' behavior.

The detailed study results for the reference scenario showed and enormous electricity import, which until, there is enough domestic power production capacity, will most probably not be the case. The main reasons for having this high share of imported electricity are the higher CO2 prices (30 €/ton, which is double of today's price) and relatively cheap electricity spot prices in Finland and in Russia. All, these characteristics are questionable and would need sensitivity studies. There is no clear understanding what will happen with the CO2 prices during the next period, starting from 2013; there is no common understanding in EU level of how the electricity import from third countries should be handled and regarding the low electricity prices in Finland, it may be the result of opening the new nuclear power plant or the disability of the market model to maximize the hydro power plants profit by using seasonal storages – in the model the weekly shift of the water volumes is possible. Also, the analysis is performed for normal year, the dry and wet years are not analyzed, also the different wind conditions are not analyzed – the sensitivity analysis is not done. Today, it can be observed that the hydro deficit in Nordic countries has risen the electricity spot market prices significantly, which will make it for the more expensive units feasible to produce. Also, the low wind years will have a significant impact on import-export balance as well as on spot market prices.

An important issue is that the Nordbalt interconnection was not included in the study. This means that the southern neighbors' only passage to the Nordic power market and to export excess wind power production was through Estonia. This again had a pressure on lower electricity prices in the region.

As the wind turbines are the price takers on the market due to low short-run operation cost, there are no fuel cost, they will have significant influence on the market price. Wind generators can make their bids to the market with the zero-price, because it is definitely beneficial to produce when the wind blows. They could offer even with the negative price if it would be the case as they are getting subsidy independent from the market price for every kWh electricity produced, no matter if the energy is sold on the spot market or through bilateral contracts. These issue leads to the distortions in the market prices, the market prices will not show the real value of the electricity as the support mechanisms are not reflected in the electricity price.

This is similar in all subsidized renewable energy producers. As a result the more expensive units' operation hours are decreasing until it becomes infeasible to operate them at all.

The other concern is that due to the lack of the "market signals" there will no interest for new investors to come to the market, as they could not compete with the supported units. It could in the end, with the ever increasing base demand, take to the situation where there are no units without sort of the subsidy operating. Actually, this "end" is not very far away in Estonia.

If this, what was observed in the three different wind scenarios, additional to the reference scenario, will become a case, the conventional oil shale units will become infeasible to operate, except the refurbished units 8 and 11, new CFB unit and old Iru cogeneration power plant. The conventional units might still be kept artificially "alive" through reserve payment for keeping reserves or sort of payment to secure the energy supply under specific conditions. This will be topic of national security of supply policy. All other power plants participating on the spot market would be subsidized (except the oil shale unit 8 and Iru CHP).

Today the Estonian Electricity Market Act foresees subsidies for electricity production from renewable energy sources, efficient cogeneration and for two new 300 MW oil shale units. If these subsidized units are up and running there will be no incentives to invest into other type of generation in this decade.

On the other hand it will show that the environment has a value and the electricity is not for granted.

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