Aalto University
School of Engineering

Tuomas Pulkkinen

Influence of New Requirements for Nordic Electricity Market Imbalance Settlement

Thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Technology.

Espoo, 27.08.2018
Supervisor: Professor Sanna Syri
Advisor: M.Sc. (Tech.) Jonni Laine

Aalto University
School of Engineering

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

Abstract of master's thesis

Author Tuomas Pulkkinen

Title of thesis Influence of New Requirements for Nordic Electricity Market Imbalance Settlement

Degree programme Master's Programme in Energy Technology

Major/minor Energy Technology **Code** ENG21

Thesis supervisor Prof. Sanna Syri

Thesis advisor(s) M.Sc. (Tech.) Jonni Laine

Date 27.08.2018 **Number of pages** 59+10 **Language** English

Abstract

In December 2017 EU commission established a guideline on electricity balancing in order to develop and harmonize European electricity markets. It includes many new requirements and harmonizable subjects for Nordic imbalance settlement model. The objective of this study is to identify the impacts on Nordic imbalance settlement. This is done by studying the current imbalance settlement model, EU commission guideline and proposals and decisions of different working groups. The influence on different functions of Nordic imbalance settlement model is then evaluated.

The major changes concern the imbalance settlement period, the calculation of imbalance and the pricing of imbalance. The imbalance settlement period will change from hour to 15 minutes. It will affect all messages and views which include time series as well as the calculation of imbalances which will be made for every 15-minute period in the future. The imbalance calculation will change in a way that there won't be a separate production and consumption imbalances. The two imbalances are replaced by a single imbalance which is the combination of the two. Currently the production imbalance has different prices for positive and negative imbalance while the consumption imbalance has same price for both. The new pricing model will have same price for positive and negative imbalances during normal situation, but in specific conditions a dual pricing may be applied.

The new requirements will simplify the model and they should financially encourage the market participants to balance the electricity grid. It should also be possible to perform the changes to the imbalance settlement system. However, in case some data can only be metered with hourly resolution it may cause some imbalances. There is also a risk that the financial incentives don't support the balance of the grid or that there will be unexpected increases or decreases in the imbalances. As a whole, with great changes there is always an increased risk that something goes wrong, so a lot of planning and preparation is needed in order to go through with the changes.

Keywords imbalance settlement, balancing, Nordic electricity markets, imbalance model, imbalance settlement period, guideline on electricity balancing, harmonizing

Aalto-yliopisto
Insinööritieteiden korkeakoulu

Aalto-yliopisto, PL 11000, 00076 AALTO
www.aalto.fi
Diplomityön tiivistelmä

Tekijä Tuomas Pulkkinen

Työn nimi Uusien vaatimusten vaikutus Pohjoismaisten sähkömarkkinoiden taseselvitykseen

Koulutusohjelma Master's Programme in Energy Technology

Pää-/sivuaine Energy Technology **Koodi** ENG21

Työn valvoja Prof. Sanna Syri

Työn ohjaaja(t) DI Jonni Laine

Päivämäärä 27.08.2018 **Sivumäärä** 59+10 **Kieli** englanti

Tiivistelmä

Joulukuussa 2017 EU-komissio laati asetuksen sähköjärjestelmän tasehallintaa koskevista suuntaviivoista Euroopan sähkömarkkinoiden kehittämiseksi ja harmonisoimiseksi. Se käsittää lukuisia uusia vaatimuksia ja harmonisoitavia osa-alueita myös Pohjoismaisen taseselvitysmallin osalta. Tämän työn tarkoitus on tunnistaa Pohjoismaiseen taseselvitykseen kohdistuvat vaikutukset. Vaikutuksia on selvitetty perehtymällä nykyiseen taseselvitysmalliin, EU-komission asetukseen sekä eri työryhmien ehdotuksiin ja päätöksiin. Niiden perusteella on arvioitu vaikutuksia Pohjoismaisen taseselvitysmallin eri osa-alueisiin.

Suurimmat muutokset koskevat taseselvitysjakson pituutta, tasepoikkeaman laskentaa ja tasepoikkeaman hinnoittelua. Taseselvitysjakson pituus lyhenee tunnista 15 minuuttiin. Se vaikuttaa kaikkiin sanomiin ja näyttöihin, jotka sisältävät aikasarjoja, sekä tasepoikkeaman laskentaan, joka tehdään jokaiselle 15 minuutin jaksolle tulevaisuudessa. Tasepoikkeaman laskenta muuttuu siten, ettei jatkossa ole enää erillistä tuotanto- ja kulutustasetta. Kahden tasepoikkeaman tilalle tulee yksi tasepoikkeama, joka on näiden yhdistelmä. Nykyisessä hinnoittelussa tuotantotaseella on eri hinta positiiviselle ja negatiiviselle tasepoikkeamalle ja kulutustaseella positiivisen ja negatiivisen tasepoikkeaman hinta on sama. Uudessa hinnoittelumallissa positiivisen ja negatiivisen tasepoikkeaman hinta on normaalisti sama, mutta tietyissä olosuhteissa voidaan soveltaa kahta eri hintaa.

Uudet vaatimukset yksinkertaistavat mallia ja niiden pitäisi antaa markkinaosapuolille taloudellinen kannustin sähköverkon tasapainottamiseen. Taseselvitysjärjestelmän pitäisi myös kyetä käsittelemään tarvittavat muutokset. Kuitenkin siinä tapauksessa, että osa aikasarjoista voidaan mitata vain tuntitasolla, voi siitä muodostua tasepoikkeamia. On myös olemassa riski siitä, että taloudelliset kannustimet eivät tuekaan sähköverkon tasapainoa tai että tasepoikkeamien volyymit odottamattomasti nousevat tai laskevat. Kokonaisuutena, suurien muutosten myötä kasvaa riski siitä, että jotain menee pieleen. Siksi muutosten läpivienti vaatii huolellista suunnittelua ja valmistautumista.

Avainsanat sähkön taseselvitys, tasepoikkeama, tasapainotus, Pohjoismaiset sähkömarkkinat, taseselvitysmalli, taseselvitysjakso, sähköjärjestelmän tasehallintaa koskevat suuntaviivat, harmonisointi

Acknowledgements

This thesis has been done for eSett Oy as a response for the established guideline on electricity balancing which will greatly affect the Nordic imbalance settlement. The evaluation has required a close cooperation between eSett and Nordic Transmission System Operators; Fingrid Oyj in Finland, Statnett SF in Norway, Svenska kraftnät in Sweden and Energinet in Denmark. The objective of the thesis is to evaluate the impact caused by the new requirements and projects, but also to provide a short analysis of the probable solutions.

First, I would like to thank eSett and my colleagues for providing this opportunity and my advisor Jonni Laine for the support during the process. Finally, I wish to thank the members of Nordic settlement working group and my thesis supervisor for doing their part in the process.

Espoo 27.8.2018

Tuomas Pulkkinen

Table of Contents

Nomenclature

E_e	[MWh]	1 MWh = 3,6 GJ	electrical energy
P	[€]		price
P_e	[MW]	1 MW = 1 MJ/s	electrical power
S_1	[€]		invoiced fees
S_2	[€]		invoiced imbalance amounts
V_1	[€]		consumption volume
V_2	[€]		bilateral and PX trade sales volume
f	[Hz]	1 Hz = 1 1/s	frequency
m	[–]		multiplier

Abbreviations

ACER	Agency for the Cooperation of Energy Regulators
aFRR	Automatic Frequency Restoration Reserves
BRP	Balance Responsible Party
BSP	Balance Service Provider
CET	Central European Time
DSO	Distribution System Operator
EET	Eastern European Time
EU	European Union
FCR	Frequency Containment Reserves
GL EB	Guideline on Electricity Balancing
HTR	Higher Time Resolution
IGCC	International Grid Control Cooperation
INC	Imbalance Netting Cooperation
ISP	Imbalance Settlement Period
ISR	Imbalance Settlement Responsible
MARI	Manually Activated Reserves Initiative
MBA	Market Balance Area
MEC	Market Entity Connection
mFRR	Manual Frequency Restoration Reserves
MGA	Metering Grid Area
NEMO	Nominated Electricity Market Operator
PICASSO	The Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation
PU	Production Unit
RE	Retailer
RO	Regulation Object
RR	Replacement Reserves
SNT	Swedish Normal Time
SP	Service Provider
TERRE	Trans European Replacement Reserves Exchange
TSO	Transmission System Operator

1 Introduction

This chapter presents the background for the Master's thesis by introducing the balancing of the electrical power-distribution network and the need for imbalance settlement. The motivation for the thesis is also described as well as the objectives and research questions of the study. The last part of introduction defines the scope and structure of the thesis.

The electrical power-distribution network needs to be balanced all the time. It means that the production and consumption must to be kept at the same level each second. Typically, the balance is achieved by varying the production. So, if consumption increases or decreases, the production adapts to the change. The balance is achieved in decent level by planning the production in advance. To ensure the balance, there exists the balancing power market where the transmission system operators (TSO) can procure balancing power.

All Nordic production, consumption and trades in different energy markets divide between balance responsible parties (BRP). They try to match them with their original planned production and imbalance adjustments procured in the balancing power market. However, there are uncertainties in plans and failures in generation, consumption and grid which produces imbalances for the BRPs. Imbalance settlement is needed to calculate the imbalances of each BRP. Basically, the BRP may end up having surplus energy if they consumed less or produced more than planned, or they may end up having deficit energy if they consumed more or produced less than planned. The surplus energy is then compensated for the BRP and deficit energy is debited from the BRP. The sum of surplus and deficit energies of BRPs is always zero per market balance area (MBA).

In a commercial based electricity market, the imbalance settlement is a necessary function and a natural monopoly. Formerly, the imbalance settlement was done separately in Finland, Norway and Sweden by their TSOs; Fingrid, Statnett and Svenska kraftnät. From the beginning of May 2017, the imbalance settlement has been carried out by a new imbalance settlement responsible organization; eSett Oy. It is jointly owned by the three Nordic TSOs with equal share and it is responsible for performing the imbalance settlement and invoicing BRPs for imbalances and balancing services.

In Nordic countries, there has been an on-going harmonization process to create a common Nordic end user market for electricity in the Nordic region. The establishment of the new imbalance settlement responsible was one significant step in the harmonization process. The main reasons for the harmonization are creation of larger and thus more competitive end user market and lowering the threshold of acting as BRP as there is a common access to all three countries. Previously, the national markets caused a situation that only few retailers operated in multiple countries. Because of the harmonization, the rules and standards for information exchange, settlement and joining the market draw closer step by step.

Currently the imbalance settlement model is based on separating the balances for production and consumption which are calculated and settled separately. This model is called two-price imbalance price model. Since a new EU commission regulation about establishing a Guideline on Electricity Balancing (GL EB) was introduced late in 2017, the Nordic TSOs have evaluated the effects to the Nordic electricity markets. As a result, a plan has been made to change the model from two-price to one-price imbalance price model. It means that the production and consumption imbalances wouldn't be separated but combined.

Additionally, the new guideline introduces a new imbalance settlement period (ISP) of 15 minutes which will be applied in Europe starting from the end of year 2020. Since Nordic imbalance settlement model is currently based on hourly settlement, this new resolution is included into the analysis of the new model.

1.1 Motivation

This thesis is done for eSett Oy which is the imbalance settlement responsible in Finland, Norway and Sweden. It has been planned by eSett's owners Fingrid, Statnett and Svenska kraftnät to change the imbalance settlement model by the end of 2020. The current model with separate imbalances for production and consumption will change to a model where only one imbalance will be calculated. It will likely cause fundamental effects on eSett's core processes; imbalance settlement, financial settlement and market communication and data exchange.

The planning and implementation of the new model needs to be done by eSett and it will take a considerable amount of time. Before any planning or implementation can be started all the affected business process areas needs to be identified and the effects analyzed. An analysis of the new model, Guideline on Electricity Balancing and the differences to the current model is needed as a background information.

1.2 Objectives

The main focus of the thesis is to identify the changes in the imbalance settlement model and the influence on the imbalance settlement and settlement systems. To support the main focus, several other things have been included to the thesis. The current imbalance settlement model is described and the reasons behind the change is included so that it would be easier to understand the new model. Finally, since the Guideline on Electricity Balancing and the plan of the Nordic TSOs don't provide a ready model but boundaries for it, the possibilities of the new model need to be studied to understand the effects in different cases.

The objective of this thesis is to answer to following questions:

- What sort of imbalance settlement model will possibly be put into operation in Finland, Sweden and Norway?
- What are the most important issues in the change of the imbalance settlement model from eSett's point of view?
- How wide impact does the new imbalance settlement model have to eSett's processes and systems?

The thesis is based on literature research, specialist interviews and the EU commission regulation: Guideline on Electricity Balancing. The amount of scientific research on Nordic imbalance settlement is low and the regulation entered into force on December 2017. For that reason, the objectives must be achieved via above-mentioned means.

1.3 Scope and Structure of the Thesis

The new Guideline on Electricity Balancing covers several areas that concerns the European TSOs. They need to make a lot of planning and deal with several issues but only a portion of the areas are related to imbalance settlement. This thesis has been outlined to cover only issues related to imbalance settlement.

A detailed description of the imbalance settlement model would be unnecessarily extensive; thus, it is not fully covered. The model description is limited to cover only the matters that are necessary for understanding the imbalance settlement on a reasonable level. Also, the matters that are related to the changes in the imbalance settlement model have been included. An exception to this is the market behavior monitoring which is part of the Nordic imbalance settlement model, but it is not covered in this thesis. The reason for this is that analyzing different key performance indicators would turn the scope of this thesis to unreasonably large.

The structure of thesis consists of five main chapters where the first chapter is the introduction. All chapters have been divided into multiple subchapters. Second chapter describes the theoretical background about imbalance settlement by explaining the different sections of the Nordic imbalance settlement model. The new imbalance settlement model is presented in the next chapter. It contains the reasons for the change, imbalance settlement related matters in EU commission regulation, possible versions of the new model according to the plans of Nordic TSOs and the differences to the current model. Chapter four provides more detailed descriptions about the influences on different sections in imbalance settlement and settlement system. Finally, the fifth chapter compiles the findings on imbalance settlement models and systems and provides an overview on what should be considered in future preparations.

2 Theoretical Background

Chapter two presents the Nordic imbalance settlement model and its different functions. This includes different roles, responsibilities, structures, relevant data, imbalance calculation model and financial side. Sections and details that are unnecessary for creating an adequate general view about the matter have been left out, unless they are related to the changes in the model.

The balance between electricity generation and demand is maintained in the Nordics by monitoring the system frequency. A lack of production reflects to the frequency by making it decrease from the nominal 50 Hz value. Respectively, the lack of demand increases the frequency value. The normal frequency range in the Nordic electricity system varies in a range of 49,90…50,10 Hz. (Xu et al. 2008.) This relationship between electricity balance and frequency has been illustrated in Figure 1.

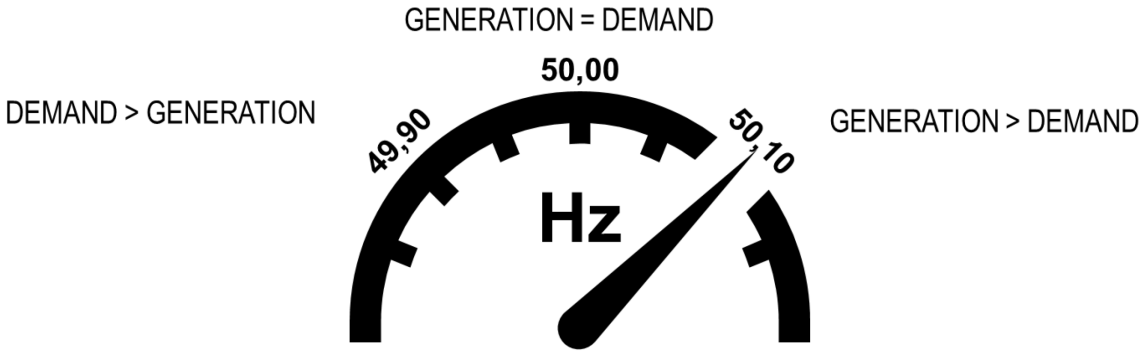

Figure 1 The relation between frequency and balance of electricity generation and demand.

Each BRP estimates the consumption that is under their responsibility and based on that estimation they can plan their production and buy or sell energy in energy markets. BRPs aim for balance for each hour but TSOs are responsible for maintaining the constant balance between generation and demand in the national electricity grids. To keep the balance in the national grids, TSOs use balancing power markets to buy balancing power. There are multiple balancing services and sub services available for different purposes. Basically, if TSO buys balancing power, it may mean adjustment in production or consumption and the direction of the adjustment may be an increase or decrease in the production or consumption. From imbalance settlement point of view, multiple balancing power objects of one market participant may be put into one imbalance adjustment, which may have up and down quantity for each hour. (ENTSO-E 2006, van der Veen & Hakvoort 2009.)

All this leads to a situation where BRPs often come up with imbalances due to

- differences between forecasted and actual consumption and production
- events that cause unforeseeable loss of production or consumption. (ENTSO-E 2016.)

The imbalances represent the difference between the BRPs allocated volumes and their final position. This imbalance needs to be calculated for each imbalance settlement period as the BRPs have right to be compensated for surplus and they have obligation to pay for shortage.

As a result of imbalance settlement, a financial balance is achieved after operation hour. Each BRP has to strive to be balanced or help the power system to be in balance and it is supported by setting the imbalance prices so that it creates positive incentives for market participants to keep the system in balance and their own imbalances in reasonable level. (Commission Regulation (EU) 2017/2195.)

2.1 Nordic Electricity Markets

The common imbalance settlement is only one part of the Nordic electricity market. The electrical power-distribution networks of Nordic countries; Denmark, Finland, Norway and Sweden, have strong interconnections which has physically enabled the integration of the national electricity markets.

Nordic electricity market is considered to be a well working market and a global forerunner. The beginning of the integration of Nordic markets is in the 1990s when the electricity generation and retailing were opened for competition. The Norwegian TSO, Statnett, established a Nord Pool power market and other Nordic countries joined to the market some years later. It is an "energy only" power market that includes separate day-ahead and intraday trading markets. In day-ahead market companies can put out purchase and sales bids and the bids are then arranged in a sequence and the point where supply and demand meet sets the "system price" of the hour. Intraday market is supplementary for the day-ahead market and it is an auction that is open until one hour before delivery. The Nord Pool power market is a key feature in the Nordic electricity markets. (Amundsen & Bergman 2006, Ma et al. 2016.)

Inside a market balance area (MBA) market parties may perform bilateral trades but all trades between different MBAs must go through Nord Pool power market (Ma et al. 2016). It enables coordination of power transmission because in some situations, there occurs transmission congestion between joint MBAs. In practice it means that the market participants can buy only limited amount of cheaper energy from the other MBA and rest must be covered by more expensive energy bids and thus same system price can't be applied for the two MBAs. The cross-border trade goes via TSOs and in case of price difference they earn bottleneck income because they purchase the power with the lower price and sell it with higher price. (Amundsen & Bergman 2006, Makkonen & Viljainen 2012.) Due to the EU legislation (Regulation 714/2009), the bottleneck income must basically be used to improve the transmission network or connections.

Mauritzen (2013) has noticed that it also works to the opposite direction if the transmission capacity is high. Due to high wind power capacity in Denmark, a strong wind likely presses down the prices not only in Danish MBAs but also in Norwegian MBAs that are strongly connected to Denmark. This can be seen in Figure 2 which shows the Nordic MBAs and the day-ahead prices for a single hour. It also shows that there is not enough transmission capacity to have the same price in the whole Nordics. However, the transmission capacity between Nordic MBAs is quite high and the prices are often equal in multiple MBAs.

In addition to Nord Pool and bilateral trades, there are national balancing markets where market participants offer imbalance adjustments to both directions and TSOs buy these production and consumption adjustments to keep the balance in the grid. The balancing rules are common in the Nordics and TSOs try to keep the whole Nordic area in balance with co-operation. However, TSOs have national monitoring systems and the rules for bidding and

payments may differ. (Ma et al. 2016, ENTSO-E 2016.) From the system balancing perspective, the Nordic power generation is very well adjustable. The amount of hydro power is nearly 100 % of annual production in Norway, about 50 % in Sweden and about 20 % in Finland. Hydro power production can be quickly increased or decreased for balancing purposes and it is also provides a seasonal energy storage for the Nordic markets. It helps in keeping the prices on relatively low level. (Kristiansen 2017.)

The relatively high level of co-operation has created quite good consensus of development of the Nordic electricity market. There are long-term plans to improve the transmission capacity both between and inside countries. The aging of current infrastructure needs to be considered as well in the planning. From 2009, the high-level transmission grid development and planning has been done in the European Network of Transmission System Operators (ENTSO-E) which is the co-operation association of European TSOs. Its long-term plan is harmonization of European electricity markets and Nordic TSOs have actively participated in its operations and promoted the interests of Nordic electricity markets. (Makkonen & Viljainen 2012.)

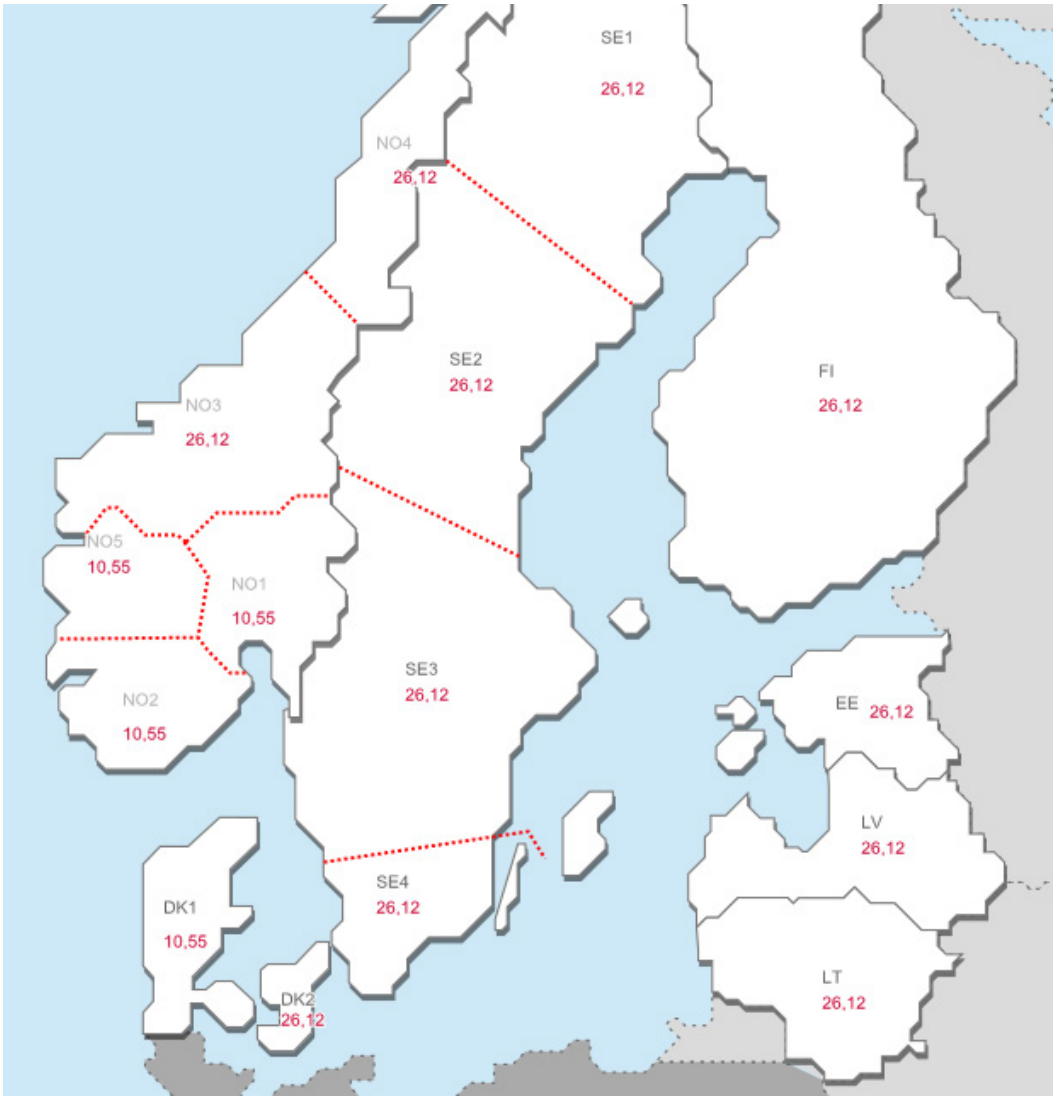

Figure 2 The Nordic market balance areas and their Nord Pool day-ahead prices in euros per megawatt hour (€/MWh) for one hour in September 2017. (Statnett SF 2018.)

2.2 Nordic Imbalance Settlement Model

The Nordic imbalance settlement model was created as a part of harmonization of Nordic energy markets and operations. It is a common model for Finland, Norway and Sweden. In 2009, TSOs agreed on the main principles such as use of two balances, national imbalance power pricing, cost structures, payment components and gate closure times for reporting settlement data. The first design report was published in 2011 and the model has seen several smaller updates after that. Finally, the model was taken into use at the beginning of May 2017 when eSett Oy started to perform imbalance settlement and financial settlement processes on behalf of TSOs. (eSett 2017.)

There are three main functions in the model and they are presented in Figure 3. First one is the imbalance settlement, which has five different steps. In step one, the settlement structures need to be created to the settlement system and revised. Thus, different entities are correctly related and reported data can be allocated correctly. After that, the market parties report all relevant data to the system. From the saved data, imbalance volumes will be calculated in the settlement and the BRPs are then invoiced based on the settled volumes. Finally, eSett creates, distributes and publishes various reports. Second main function is the management of financial risk. A large sum of money is transferred in the invoicing so there is a high financial risk for eSett if malpractices occur among BRPs. For this reason, each BRP has set a collateral which is controlled and monitored by eSett. The last main function is market performance monitoring. It includes monitoring of e.g. imbalances and data quality so that they are on a fair level and abuse of imbalance settlement will be noticed. (eSett 2017.)

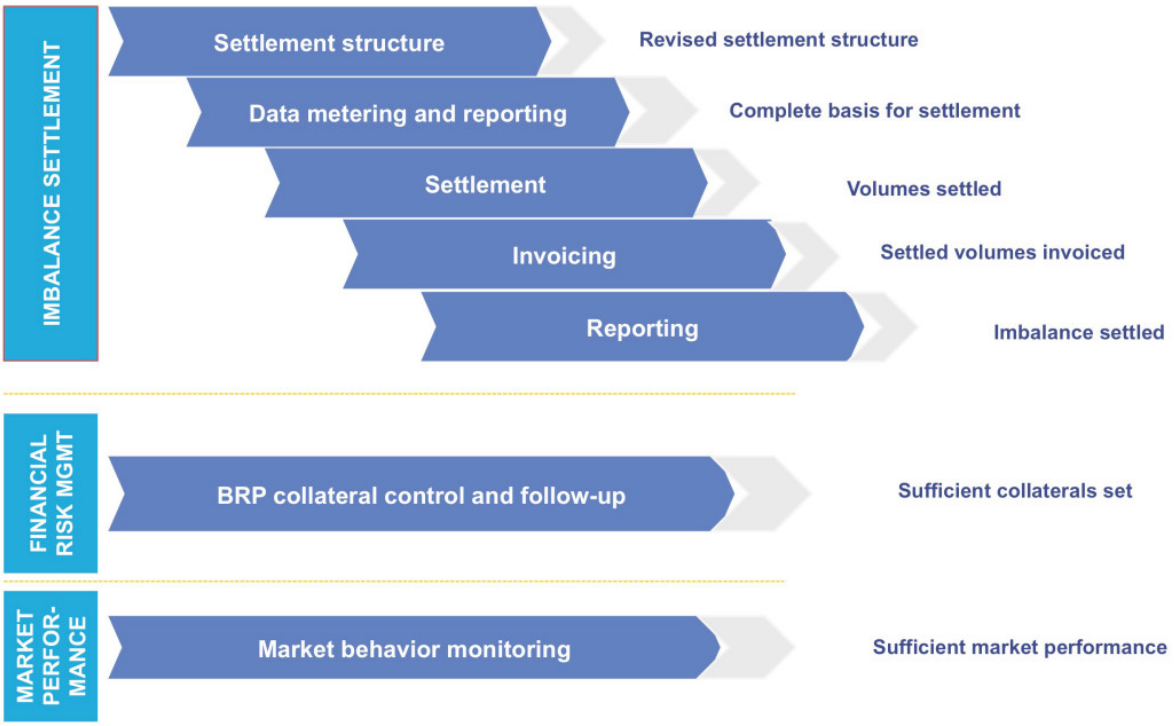

Figure 3 The Nordic imbalance settlement model functions. (eSett 2017.)

There are several market roles that are somehow involved in the imbalance settlement processes. Different roles have different responsibilities in the imbalance settlement and one company can operate with several roles e.g. a company could have one BRP role and two

retailer roles in the system. Nordic imbalance settlement model has following roles (eSett 2017):

- Imbalance Settlement Responsible (ISR) which is eSett, performs the imbalance settlement calculation and the financial settlement. eSett also maintains the settlement structure data in the settlement system and reports imbalance settlement data and other market information.
- Transmission System Operator (TSO) is responsible of the balance in the national electricity grid and they operate the balancing power market. They report to eSett the prices of imbalance adjustments and imbalance power and the production plans and activated imbalance adjustments of BRPs.
- Distribution System Operator (DSO) is responsible of single or multiple local grids that may be used for example power generation or distribution. They register all production and consumption per retailer in their metering grid areas (MGA) and all energy exchange from or to connected MGAs.
- Balance Responsible Party (BRP) has valid agreements with eSett and local TSO and they act as a financial counterpart for imbalance settlement. They provide the production plan information to TSOs and bilateral trade information to eSett. They manage the retailer balance responsibility information since all retailers need to have valid BRP if they wish to operate in the Nordic electricity markets.
- Retailer (RE) sells the electricity to final consumers, produces electricity or trades in electricity market or bilaterally. The production, consumption and trades are on retailer level but the volumes are processed in the imbalance settlement of the retailers BRP.
- Nominated Electricity Market Operator (NEMO) operates an electricity market in Nordic area and reports the volumes of day ahead and intraday trades. The trades are mainly reported per retailer. They also report the cross border trade volumes.
- Service Provider (SP) provides services to BRP, DSO or retailer. They may for example report data, verify imbalances or handle collateral management on behalf of market participants.

2.2.1 Settlement Structure Management

The imbalance settlement structures consist of the market participants, market entities and market entity connections (MEC). The market participants were described in the previous chapter 2.2. An example of different structure elements and their relations is presented in Figure 4. There are four market entities which are market balance area, metering grid area, production unit and regulation object and they are defined as follows (eSett 2017):

- Market balance area (MBA) is an area of electricity grid. Inside market balance area the Nordic electricity market price is the same. It functions as a basis of imbalance settlement as the imbalances are calculated per MBA.
- Metering grid area (MGA) is a physical area inside MBA where it is possible to meter production, consumption and exchange. Each MGA is responsibility of some DSO which reports the data related to the area. There may be production and consumption in the area or only one of those.
- Production unit (PU) is a single generator in a power plant or a combination of multiple generators within the same plant. In Finland and Norway, a production unit can have either production type normal or minor. Units with under 1 MW capacity

in Finland and under 3 MW capacity in Norway can be considered as minor. All production units in Sweden have are normal. Production units are linked to MGA and retailer.

- Regulation object (RO) is a group of production units or aggregated adjustable consumption object inside MBA. The production units in the regulation object must have same type (hydro, nuclear, wind, etc.) and same BRP via retailers' balance responsibility. BRPs' production plans and imbalance adjustments are reported per regulation object.

Market entity connections (MEC) are objects where the market time series data is reported and stored, and they are linked to market participants and market entities. For example, a bilateral trade in Figure 4 is linked to the retailers RE_1 and RE_2 who are trading between each other and to their BRPs: BRP_1 and BRP_2. Another example is production of PU_1 that is linked to market parties and market entities. It is linked to production unit PU_1 and thus to MGA_2 and MBA_2. It also has DSO_2 who reports the time series values, retailer RE_2 to whom the values are reported and the BRP_2 of the retailer. Market entity connections that are used in Nordic imbalance settlement model are metered and profiled consumption, production, MGA exchange, MGA exchange trade, PX market trade, PX market flow, bilateral trade, production plan, imbalance adjustment and MGA imbalance. (eSett 2017.)

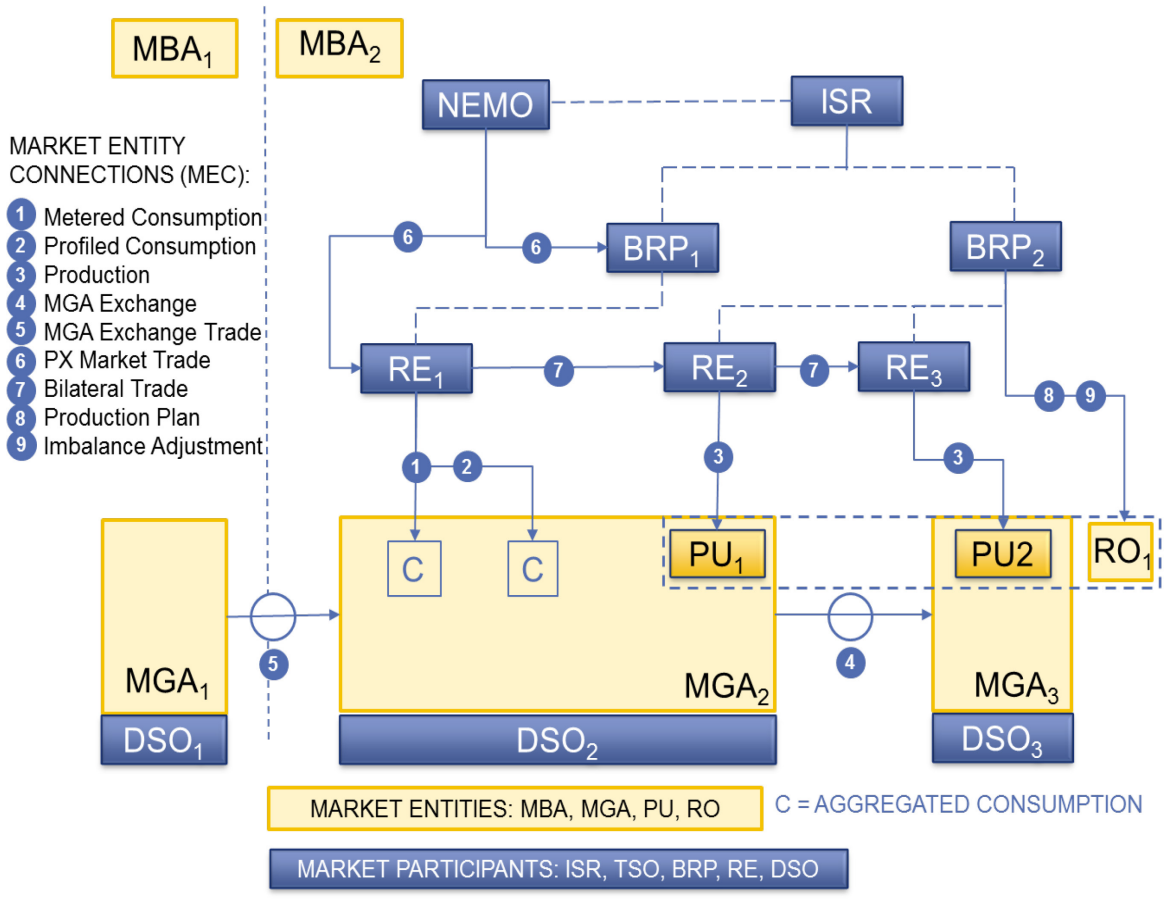

Figure 4 Example of structure elements and their relations (eSett 2017).

2.2.2 Metering and Reporting

The imbalance settlement is for the most part based on metered data of consumption, production and exchange. According to national laws, DSOs are required to provide measurement data and other information on electricity production, consumption and exchange needed for fulfilling the imbalance settlement (Energy Act, LOV-1990-06-29-50 § 4-3; Electricity Market Act, 2013/588 § 22; Electricity Act, 1997:857 Chapter 3 § 10). DSOs perform the metering for each of their MGA and they are responsible for aggregating the production and consumption data of each hour per retailer per MGA. Similarly, each hour of exchange data between two adjacent MGAs is metered and aggregated by the DSOs. In Finland and Norway there are also minor production units and the minor production can be netted with the retailer's consumption in that area. It means that the consumption value is decreased by the production volume and the production is not considered at all. In Nordic imbalance settlement model, the consumption is divided into several subtypes that are

- metered consumption
- profiled consumption
- metered losses
- profiled losses
- metered PU own consumption (only in Finland)
- profiled PU own consumption (only in Finland)
- metered pumped (only in Norway)
- profiled pumped (only in Norway)
- metered pumped storage (only in Norway)
- metered interruptible (only in Sweden)
- metered industry over 50 MW (only in Sweden). (eSett 2017.)

Since eSett doesn't have access to any metered data, the imbalance settlement is done entirely based on the values that are reported to eSett. Different market roles are required to report different data types. Reported data is approved when sent within reporting period and before gate closure. The reporting periods and gate closures differ between types of data. Due to national legislations, there are some differences with reporting periods of some data. eSett also reports data towards market parties. Data includes e.g. confirmations about received data, values reported to eSett and final imbalance settlement results. (eSett 2017.)

In Nordic imbalance settlement model market roles have different reporting responsibilities and the time schedule for reporting of data differs depending on the type of data. Table 1 presents all settlement related basic data which is reported between market participants. The data includes everything that is needed for the imbalance settlement calculations. In addition, the Table 1 presents that BRPs must send information regarding the reserves and production plans to TSO before delivery hour and the TSO then reports the values to eSett for imbalance settlement. Also, eSett reports intermediate and final confirmation reports for bilateral trades and MGA exchanges as those can be reported by both involved market parties. The confirmation reports include information whether both parties have reported same values or not and the difference between reported values if they differ. (eSett 2017.)

The basic reporting schedule in the model goes so that preliminary values for settlement data should be reported at latest D + 2 days, where D represents the delivery day. The reporting period is open until D + 13 days at 12:00 Central European Time (CET). Basically, it concerns data reported by DSOs and TSOs as BRPs have different reporting schedule for

their data and NEMOs send the preliminary values already before delivery. However, differences apply due to national rules and legislation. In Finland, DSOs have to report final values at latest D + 12 days at 00:00 Eastern European Time (EET). In Norway they have to report for each week at latest 3 working days after the week. In Sweden the national deadline for reporting is D + 13 days at 00:00 Swedish Normal Time (SNT). (eSett 2017.)

Special reporting schedule is applied for data sent by BRPs and NEMOs. BRP's have to send regulation bids (activated reserves) and production plans to TSO 45 minutes before delivery. Also, bilateral trades must be delivered 45 minutes before delivery to eSett except in Finland where the deadline is 20 minutes before delivery. After bilateral trade delivery, BRPs can accept bilateral trade values reported by counterparty BRP if there has been difference in the reported values. Counterparty values can be approved until next working day at 12:00 CET after the delivery day. NEMOs report day-ahead trades after daily price calculation and intraday trades continuously. However, the final values have the normal reporting period until D + 13 days 12:00 CET. (eSett 2017.)

Table 1 Nordic imbalance settlement reporting responsibilities and schedules (eSett 2017).

Responsible Market Participant	Before Delivery Hour	After Delivery Hour (1-13 days)	After Reporting Period (13 days)	Counter Party
BRP	Activated Reserves [a]			TSO
BRP	Production Plans			TSO
BRP	Bilateral Trades	Bilateral Trades [b]		eSett
DSO		Consumption		eSett
DSO		MGA Exchanges		eSett
DSO		Production		eSett
NEMO	Day-ahead Trades	Final Day-ahead Trades		eSett
NEMO	Day-ahead Flows	Final Day-ahead Flows		eSett
NEMO	Day-ahead Prices	Final Day-ahead Prices		eSett
NEMO	Intraday Trades	Final Intraday Trades		eSett
NEMO	Intraday Flows	Final Intraday Flows		eSett
TSO		Activated Reserves		eSett
TSO		Production Plans		eSett
eSett		Bilateral Trade Confirmation Reports (Intermediate & Final)		BRP
eSett		MGA Exchange Confirmation Reports (Intermediate)	MGA Exchange Confirmation Reports (Final)	DSO
eSett			MGA Imbalance Results	DSO & BRP
eSett			Settlement Results	BRP
eSett			Invoices	BRP

[a] BRP places bids of reserves per types, FCR, FFR, RR and subtypes in the balancing market.
[b] BRP may only accept counter party's values until delivery day + 1 at 12:00 CET.

Since bilateral trades and MGA exchanges can be reported by two parties, there is a possibility that they report different values for same entity. For those hours following correction rules will be used (eSett 2017):

- If both parties report sale/export, zero will be used.
- If both parties report purchase/import, zero will be used.
- If one party reports sale/export and the other reports purchase/import, the lowest absolute value will be used.
- If one party reports zero value, zero will be used despite what the other party reports.
- If only one of the parties reports values, those values will be used.

The contents of the incoming data are validated by the imbalance settlement system. It ensures that the data can be used in imbalance settlement calculations. Unusable data sets which could contain e.g. letters instead of numeric values or negative production values, are automatically rejected and the reporting party is informed about the rejection. Missing settlement data is considered to have zero value in calculations but the data itself will remain empty. The market participants are responsible for the accuracy and quality of the data that they report. The data is published in eSett's Online Service web portal where it's visible to the market parties whom it relates. (eSett 2017.)

2.2.3 Imbalance Settlement Calculation

The Nordic imbalance settlement model consists of two imbalances; production imbalance and consumption imbalance. Both imbalances are calculated and settled separately. The price model is different for the two imbalances as "two-price model" is used for production imbalance and "one-price model" for consumption imbalance. The pricing models are explained in more detail in chapter 2.2.4 Pricing and Fees. (eSett 2017.)

The production imbalance calculation has fewer terms as it basically consists of production, planned production and imbalance adjustments of production. The calculation is presented in equation (1). Adjustment up is subtracted from production and adjustment down is added to the production. The result is calculated for each hour and the used values are aggregated from the reported data. In the aggregation the used values are always per BRP in MBA. If the production imbalance power is a positive value, there is surplus and eSett purchases the power from BRP. Respectively negative value means deficit and eSett sells power to BRP. In Finland minor production (i.e. production under 1 MW) can be netted with the consumption before reporting and thus it is settled in consumption imbalance. (eSett 2017.)

$$Production - \begin{matrix} Planned \\ production \end{matrix} \mp \begin{matrix} Production \\ imbalance \\ adjustment \end{matrix} = \begin{matrix} Production \\ imbalance \\ power \end{matrix} \quad (1)$$

In consumption imbalance calculation, consumption is balanced with planned production, all purchases and sells, imbalance adjustments of consumption and MGA imbalance. The calculation is presented in equation (2). Consumption, sales, consumption adjustment up (i.e. increase of consumption) and MGA imbalance surplus have negative signs in the equation. If the result is positive, there is surplus which eSett purchases and if the result is negative, there is deficit and eSett sells imbalance power to the BRP. (eSett 2017.)

$$Consumption + \begin{matrix} Planned \\ production \end{matrix} \mp Trade \mp \begin{matrix} Consumption \\ imbalance \\ adjustment \end{matrix} + \begin{matrix} MGA \\ imbalance \end{matrix} = \begin{matrix} Consumption \\ imbalance \\ power \end{matrix} \quad (2)$$

The MGA imbalance used is calculated from the consumption, production, MGA exchange import and MGA exchange export of that MGA. The calculation is presented in equation (3). Consumption and export are negative, and production and import are positive values. There is surplus if the result is positive and deficit if the result is negative. Normally the MGA imbalance should be close to zero because the sum of "incoming" and "outgoing" energy should be zero. However, due to inaccuracy or incorrect reporting some MGA imbalance may occur. (eSett 2017.)

$$Consumption + Production + \begin{matrix} MGA\ exchange \\ import \end{matrix} + \begin{matrix} MGA\ exchange \\ export \end{matrix} = \begin{matrix} MGA \\ imbalance \end{matrix} \quad (3)$$

Imbalance settlement calculations are done even if there is some missing data. The value 0 is used for the missing data in the calculation. Possible errors won't be corrected once the invoice for the erroneous period has been submitted. It means that the parties whom it concerns, have to handle the error bilaterally without involvement from eSett. An exception to the procedure is if the error is committed by eSett or TSO or if there are extraordinary circumstances. If eSett is unable to perform the imbalance settlement according to the time schedule, it will be done as soon as possible after the disturbance situation. (eSett 2017.)

2.2.4 Pricing and Fees

Each one-hour long imbalance settlement period is priced separately, and the price may be different in each market balance area (MBA). In addition, there are separate prices for production imbalance sale, production imbalance purchase and consumption imbalance. The pricing model is different as production imbalance has two prices and consumption imbalance has only one price. In Nordic imbalance settlement model, the prices are based on hourly PX market price and up and down regulation prices. Each hour is marked as up-regulation hour, down-regulation hour or an hour with no regulation. If there has been more up-regulation than down-regulation during the hour, it is marked as up-regulation hour and vice versa. If there would be a situation that there is no regulation or the amount of regulation in both directions is equal, it would be marked as hour with no regulation. (eSett 2017.)

The production imbalance amounts are calculated according to the so-called "two-price model". The sale and purchase prices are different so that eSett sells imbalance volume with higher price to BRPs who have deficit and eSett purchases imbalance volume with lower price from BRPs who have surplus. The imbalance prices depend on the main direction of regulation and it has been summarized in Table 2. (eSett 2017.)

Table 2 Production imbalance prices in different situations (eSett 2017).

	Up-regulation hours	Down-regulation hours	Hours with no direction
Negative production imbalance of BRP (deficit)	Up-regulation price	PX market price	PX market price
Positive production imbalance of BRP (surplus)	PX market price	Down-regulation price	PX market price

The consumption imbalance has only one price so positive and negative consumption imbalance have same price in the same MBA. This is called "one-price model" and since

there is no price difference, it doesn't provide income to the TSOs. Table 3 summarizes the used prices for different hour types. (eSett 2017.)

Table 3 Consumption imbalance prices in different situations (eSett 2017).

	Up-regulation hours	Down-regulation hours	Hours with no direction
Negative consumption imbalance of BRP (deficit)	Up-regulation price	Down-regulation price	PX market price
Positive consumption imbalance of BRP (surplus)	Up-regulation price	Down-regulation price	PX market price

The income from imbalance settlement covers the national cost base including the operation costs of eSett and partially costs of reserves. A part of the income comes from the two-price model of the production imbalance and rest is covered with fees. The fees are an addition to the imbalance prices and they are country specific. The fees used in the Nordic imbalance settlement model are

- weekly fee (€/week)
- consumption fee (€/MWh)
- production fee (€/MWh)
- consumption imbalance fee (€/MWh)
- peak load reserve fee in Sweden (€/MWh). (eSett 2017.)

The fees are levied on the sum of absolute volumes of each product except weekly fee and peak load reserve fee. Weekly fee is levied for each week and country where the BRP has been active. Peak load reserve fee is levied on the sum of absolute volumes of consumption excluding losses between 16th of November and 15th of March on working days between 06:00-22:00 CET from BRPs which are active in Sweden. Each TSO set the fee levels to cover the national cost base. (eSett 2017.)

2.2.5 Invoices and Collaterals

The financial settlement is also handled by eSett and a part of it is the invoicing process. This chapter focuses on the basic processes and schedules and ignores for example banking setups, tax handling and currency treatment. Also, the basic concept and calculation of collaterals are described but other information regarding collaterals has been mostly ignored.

Invoicing is a weekly process where eSett invoices BRPs based on their imbalances, fees and imbalance adjustments. BRPs receive one invoice for each country where they are active. If one company has multiple BRP roles, each role is invoiced separately. Invoices contain total quantities, average prices and total amounts for sales and purchases of production imbalance, consumption imbalance and activated reserves as well as for all different fees. Quantities and amounts are aggregations for the invoiced week, but prices are different for each hour, so the given price is a calculated average. Sales and fees rows are positive and purchase rows negative, so purchases reduce the amount that BRP needs to pay to eSett. The total amount may be positive or negative and positive amount means that the invoice is a debit invoice and negative amount means that it is a credit invoice. (eSett 2017.)

The invoicing of settlement week is always handled three weeks later. During normal weeks, invoices are issued on Mondays and incoming payments are debited on Wednesdays and outgoing payments are credited on Thursdays. The settlement process, invoicing and payment schedule has been presented in Figure 5. All payments are handled as a same-day-value payments and debiting has to be done before crediting to ensure eSett's ability to handle the outgoing payments. If one or more Nordic holidays occur during the invoicing cycle, all invoicing events that should take place during the holiday or after it, move forward. Thus, there will be two working days between invoicing and incoming payments and three working days between invoicing and outgoing payments. However, it doesn't have effect on the schedule of the next week. (eSett 2017.)

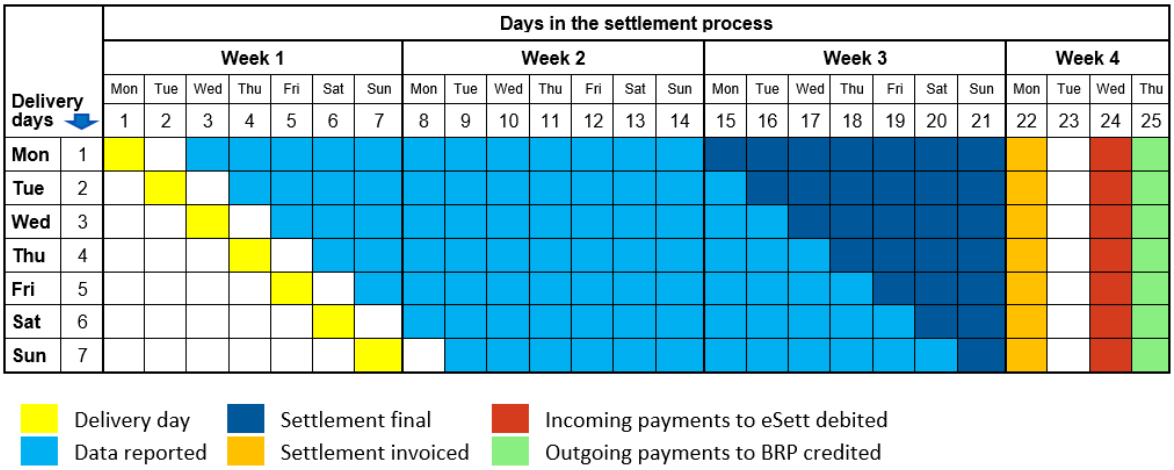

Figure 5 Schedule for settlement, invoicing and payment (eSett 2017).

Since eSett is a financial counterpart for all BRPs in Finland, Norway and Sweden, there is a significant counterparty risk if some BRP is unable to fulfil its obligations towards eSett. The risk arises basically from the negative imbalances of the BRPs during a period which has not been paid yet. Because of that risk, each BRP has to provide a collateral to eSett as security. The collateral is dynamic which means that it is recalculated every week based on the latest settlement data. Thus, it provides the best possible estimation of the counterparty risk. The overall risk consists from the period which has been invoiced but not yet paid to the future period where BRP will be active but there's no information about any volumes. Because there's a risk that a distressed BRP could accumulate high imbalances until it is notified, the future risk needs to be considered as well. (eSett 2017.)

The standard collateral formula is presented in equation (4). It is used unless there's a need to deviate from it because of special circumstances. Such special situations include but are not limited to public holidays, payment delays, market changes, new BRPs and financial distress of a BRP. The first half in the collateral equation estimates the amounts that have accumulated but haven't been paid. The second half tries to estimate the imbalances that a misbehaving BRP could accumulate before the behaviour can be identified. There's also a minimum requirement of 40 000 € per country in case the calculated collateral requirement would be lower than that. (eSett 2017.)

$$3 \times (S_1 + S_2) + m \times (V_1 + V_2) \times P = Collateral\ requirement \quad (4)$$

where S_1 is the average of the sums of weekly invoiced consumption fees, production fees and consumption imbalance fees per week from the last three invoiced weeks

S_2 is the average of the absolute amounts of the sums of weekly invoiced consumption and production imbalances from the last three invoiced weeks

m is a multiplier:

- $^3/_7$ for the share of ($V_1 + V_2$) that doesn't exceed 80 000 MWh
- $^1/_7$ for the share of ($V_1 + V_2$) that exceeds 80 000 MWh but doesn't exceed 400 000 MWh
- 0 for the share of ($V_1 + V_2$) that exceeds 400 000 MWh

V_1 is consumption volume from the last seven settled days

V_2 is bilateral and PX market day-ahead sales volumes from the last seven days for which the data has been reported

P is average of the consumption imbalance prices in the different MBAs from the last seven days for which the data is available, where the price of each MBA has been weighted according to the share of BRPs total turnover (consumption, bilateral sales and PX market sales) from the last three invoiced weeks. (eSett 2017.)

2.2.6 Calculation Example

The following calculation example shows how the imbalance volumes and amounts are calculated from the settlement data. The values are only for one BRP within one MBA for a single hour, so the example is greatly simplified but it illustrates the mechanics. Different fees and invoice contents are also included in the example. Table 4 presents the settlement data which has been used in the calculations. while Table 5 and Table 6 show the calculation of production and consumption imbalance volumes. Similar data, e.g. trades, are aggregated in the calculation examples.

Table 4 Imbalance settlement calculation example data for one hour for a BRP within one MBA.

Settlement data	Value (MWh)
Production plan	75
Metered consumption	-55
Profiled consumption	-10
Metered production	80
Bilateral trades (purchase)	15
Bilateral trades (sales)	-5
Day-ahead trades (purchase)	0
Day-ahead trades (sale)	-20
Intraday trades (purchase)	5
Intraday trades (sales)	-10
MGA imbalance (surplus)	-5
MGA imbalance (deficit)	10
Consumption imbalance adjustment up-regulation (purchase from TSO)	0
Consumption imbalance adjustment down-regulation (sale to TSO)	-5
Production imbalance adjustment up-regulation (sale to TSO)	-25
Production imbalance adjustment down-regulation (purchase from TSO)	5

Table 5 presents the calculation for production imbalance. The values of the different data types have been aggregated and they are on their own columns. The final column presents the calculation result after it has been calculated according to the equation (1).

Table 5 Production imbalance volume calculation example.

	Metered production (MWh)	Planned production (MWh)	Production imbalance adjustments (MWh)	*Production imbalance (MWh)*
Delivery hour	80	75	-20	*-15*

Table 6 presents the calculation for consumption imbalance. The values of the different data types have been aggregated and they are on their own columns. The final column presents the calculation result after it has been calculated according to the equation (2).

Table 6 Consumption imbalance volume calculation example.

	Metered and profiled consumption (MWh)	Planned production (MWh)	Bilateral, day-ahead and intraday trades (MWh)	MGA imbalance (MWh)	Consumption imbalance adjustments (MWh)	*Consumption imbalance (MWh)*
Delivery hour	-65	75	-15	5	-5	*-5*

As the imbalance volumes have been calculated and activated reserves are known, it is possible to calculate the invoice amount if prices and fees are known. The calculated hour in the example is an up-regulation hour. Up-regulation price for the hour is 40 €/MWh, PX market price is 30 €/MWh and down-regulation price is 20 €/MWh. Each activated reserve type has separate rows in the actual invoice and they usually have individual prices.

In order to simplify this example, the different types of activated reserves have been aggregated into imbalance adjustments and the used prices are same as regulation prices. The prices and fees of the example are visible in the Table 7 which contains the invoice amount calculation. The result of the invoice amount calculation is negative, so the invoice would be a credit notice and eSett would pay for the BRP.

Table 7 Invoice amount calculation example.

Invoicing information	Volume (MWh)	Price (€/MWh)	Amount (€)
Sale of production imbalance power to eSett	0	30	0
Purchase of production imbalance power from eSett	15	40	600
Sale of production imbalance adjustments (up-regulation) to eSett	-25	40	-1 000
Purchase of production imbalance adjustments (down-regulation) from eSett	5	20	100
Production imbalance purchases from eSett			700
Production imbalance sales to eSett			-1000
Total production imbalance amount			*-300*

Sale of consumption imbalance power to eSett	0	40	0
Purchase of consumption imbalance power from eSett	5	40	200
Sale of consumption imbalance adjustments (down-regulation) to eSett	-5	40	-200
Purchase of consumption imbalance adjustments (up-regulation) from eSett	0	20	0
Consumption imbalance purchases from eSett			200
Consumption imbalance sales to eSett			-200
Total consumption imbalance amount			*0*
Production fee	80	0.2	16
Consumption fee	65	0.4	26
Consumption imbalance fee	5	0.6	3
Weekly fee			50
Total fee amount			*95*
Total invoice amount			**-205.00**

3 New Imbalance Settlement Model

In this chapter the possible new imbalance settlement model is presented along with the background and the different reasons behind the change. This model hasn't yet been approved and it's merely a one way to enforce the single imbalance model. However, it's likely accurate enough to be used as a basis for the evaluation of influence on the Nordic imbalance settlement model.

This chapter begins with the motivation in European level which ultimately led to the European Union's Guideline on Electricity Balancing. The parts of the guideline which are relevant for this thesis are briefly analyzed. Finally, the results of the Nordic TSOs regarding the new model are described as well as the differences to the current imbalance settlement model.

3.1 Background for the Change of the Model

Electricity markets and systems are undergoing remarkable changes as energy industry strives for decarbonisation. Distributed and variable renewables i.e. wind and solar power, have an increasing share of the produced electricity. Market participants introduce new business models where they e.g. aggregate consumption and use it as a balancing power. Number of prosumers, entities which produce and consume electricity, is increasing and all this causes decentralisation and complexity. Digitisation and democratisation introduce another challenges and electricity markets and systems need to somehow adapt to all this. (Schmitt 2018, Erbach 2016.)

To tackle the new challenges, the European Commission has in co-operation with Agency for the Cooperation of Energy Regulators (ACER) established a guideline on electricity balancing. The commission regulation forces the market to co-operate and harmonize the current processes. Harmonization enables widening of different market areas in Europe with common rules. The framework set by the guideline forces the national markets to take into use e.g. 15-minute imbalance settlement period and a pricing model which gives correct price signals and creates positive incentives in keeping and restoring the system balance. Wider markets, common rules, more accurate pricing and shorter settlement period should provide for market participants possibility to utilize their flexibility in economical way. At the same time, it should support the system balance if the price signal is correct. (Schmitt 2018, Commission Regulation (EU) 2017/2195.)

Some processes need to be harmonized in the European level while other subjects are harmonized for synchronous areas i.e. areas that are connected and operate on the same synchronized frequency. For example, Finland, Norway, Sweden and Eastern Denmark form a synchronous area and Baltic countries form another synchronous area. Some processes can be handled by each TSO individually within the limits of the guideline. Generally, the guideline forces to harmonize used reserve products and to some extent their use, calculation and settlement. It also directs towards common settlement rules, pricing and calculation. (Commission Regulation (EU) 2017/2195.)

3.1.1 Projects and Working Groups on European Level

European Network of Transmission System Operators (ENTSO-E) has launched several projects and established working groups to cope with the new requirements of the Guideline on Electricity Balancing. Many of the projects are related to harmonization and creation of common platforms and rules for different reserves. Thus, they are not directly related to the changes in imbalance settlement processes. Some of the projects and working groups are introduced and shortly explained in the following paragraphs.

The Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation (PICASSO) is one of the projects and its target is to design, implement and operate a platform for automatic Frequency Restoration Reserves (aFRR). A similar project, Manually Activated Reserves Initiative (MARI), has been initiated with similar targets but for manual Frequency Restoration Reserves (mFRR). Those platforms should collect all reserve bids and adjustment needs from each TSO. With the available information, they will recognize available transmission capacity and distribute the resources accordingly. The platforms also keep track on the reserve trade purchases and sales. (Uusitalo 2018.)

Quite similar implementation projects as PICASSO and MARI have been initiated also for Frequency Containment Reserves (FCR) and Replacement Reserves (RR). The latter project goes under the name Trans European Replacement Reserves Exchange (TERRE). The fifth and sixth considerable implementation projects are related to imbalance netting and they are called International Grid Control Cooperation (IGCC) and Imbalance Netting Cooperation (INC). Currently, the imbalance netting projects involve only Central European TSOs. (ENTSO-E 2018a.)

Some changes and new roles have greater impact on the imbalance settlement processes than the reserve and imbalance netting projects. For example, the EU Commission Regulation (2017/2195) introduces a new role; Balance Service Provider (BSP). In short, it is a market party that may participate in the reserve markets without being a BRP. The design and implementation processes are still incomplete, but it may require some changes to imbalance settlement system. Eklund (2017) studied another such role; aggregator. Their role in the market would be to regulate and aggregate scattered flexible consumption and electricity storages to provide demand response.

Imbalance settlement harmonization working group in ENTSO-E is trying to find a common solution for the parts of Guideline on Electricity Balancing which need to be harmonized between all TSOs. Some major topics that the working group has been dealing with are

- imbalance price calculation’s main components
- definition for the term value of avoided activation
- finalization of imbalance adjustment, position and allocated volume
- conditions when dual price could be applied. (ENTSO-E 2018b.)

3.1.2 Projects and Working Groups on Nordic Level

Nordic TSOs are somehow involved in most of the projects and groups on the European level but at the same time there are projects on Nordic level as well as on national level.

Some of them originate from the new EU commission guideline and others have been ongoing already for a longer period. The main reasons behind all of the projects are however quite similar as the target is to have harmonized and functional Nordic electricity markets that can match the future needs.

During the spring of 2018 the Nordic TSOs have been working with the Nordic Balancing Concept and the work continues at least until the autumn. The concept is more like a high-level plan on how the Nordic market should be developed. The goals of this concept are to

- strengthen and improve the operational security in the Nordic Load-Frequency Control Block
- integrate the Nordic with European market platforms for balancing products
- improve development market and system operation efficiency
- achieve transparent and well-functioning markets to support security of supply, operational security and socio-economic welfare
- improve clarity for market participants with respect to responsibilities and freedom of action
- enable a transition to clean and intermittent power system. (Sandborgh et al. 2018.)

The Guideline on Electricity Balancing has a requirement that a 15 minutes imbalance settlement period has to be taken into use. However, the Nordic TSOs had already anticipated this change and initiated higher time resolution (HTR) project already in 2015. This change will affect nearly all actors in the Nordic electricity markets as for example the IT-systems, trades, production metering, consumption metering and pricing will sooner or later happen in 15 minutes resolution instead of current 60 minutes resolution. From the cost benefit analysis that was done in the first phases of the project, it was possible to draw a conclusion that the implementation of the HTR would enable better use of existing interconnectors, increased trading flexibility between countries and improved frequency quality as hour shift power adjustments would be smaller. The plan is to implement the 15 minutes imbalance settlement period simultaneously in the Nordic countries for maximum benefit. (Fosse et al. 2017.)

Launched by the HTR project after the publishing of the latest commission regulation, a separate Nordic working group has been working to develop the Nordic imbalance settlement model to cope with the new requirements for Nordic electricity market imbalance settlement. The requirements come partially from the commission regulation and partially from the Nordic TSOs who wish to develop the model. This master's thesis mainly focuses on the issues handled in this settlement working group. The different requirements and proposals have been explained in chapters 3.2.1 Framework from Guideline on Electricity Balancing, 3.2.2 Proposal by Imbalance Settlement Harmonization Group and 3.2.3 Proposal by Nordic Settlement Working Group.

Additionally, Finland, Norway and Sweden each have a datahub project at the planning stage and Denmark has already operational datahub. The datahubs are part of developing of Nordic electricity market. The projects are national, but the overall processes will be harmonized, and the main function is the same. The fundamental functionality is to access metering values and market changes such as supplier switches but also to provide market information. Some national differences will however remain. (Nordic Council of Ministers 2017.)

3.1.3 New Model's Association with the Other Projects

The planned new Nordic one imbalance model is related to many of the European and Nordic projects. Figure 6 presents these projects and their associations with the new Nordic imbalance settlement model. They have been divided into European and Nordic projects and whether they are related to the Guideline on Electricity Balancing or not. The requirements and changes to the model have been analyzed in more detail in the following chapters.

The European imbalance netting projects, IGCC and INC are not really related to the Nordic imbalance settlement model development even though they both originate from the commission guideline. The imbalance netting process is not currently in use in Nordic countries and thus it won't affect the new one imbalance model. The reserve projects (MARI, PICASSO etc.) on the other hand do affect also the Nordic markets but they are not directly related to the imbalance settlement. Currently TSOs report the activated reserves to eSett and the new reserve market platforms will not change any processes in the imbalance settlement.

The imbalance settlement harmonization group has major impact on the Nordic model. The group is responsible of harmonizing the subjects in the imbalance settlement which the guideline announced to be harmonized in EU. All their decisions have to be carefully evaluated so that the Nordic model will be in accordance with the requirements. In a way it sets the frames which can't be surpassed in the design of the Nordic model.

The Nordic Higher Time Resolution (HTR) project is working with implementation of the 15 minutes imbalance settlement period which is also a requirement in the guideline. The imbalance settlement model itself is scalable so the difference to the current model would be basically the change from 60 minutes imbalance settlement period to 15 minutes. However, the model doesn't take a stand on some of the technical aspects, such as it-systems or the electricity meters or the exact file format of messages. Since the technical implementation will likely be more complicated than the model change, it should be evaluated on some level.

National datahubs projects are not part of the electricity balancing guideline but part of the development of Nordic electricity markets. However, they are also related to the Nordic imbalance settlement model. Datahub will be a completely new market participant role and it will take over some responsibilities from the DSOs. Model needs to be designed to handle this kind of new market role and change of responsibilities in e.g. reporting and handling of market structures. Thus, the requirements set by these projects needs to be also included into evaluation.

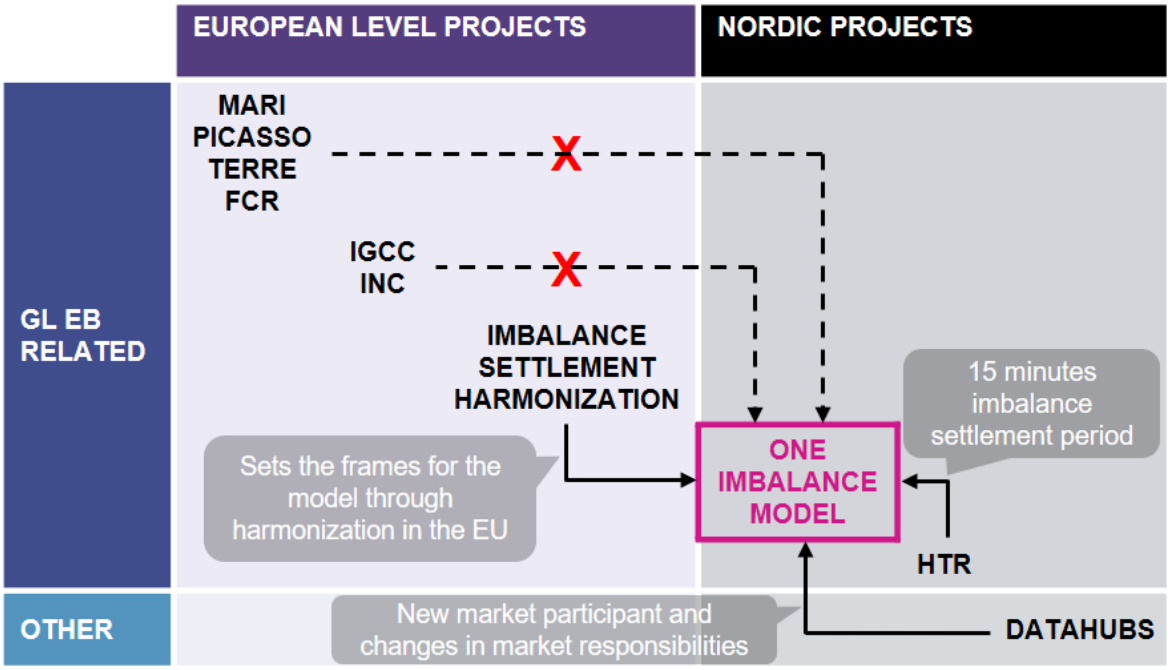

Figure 6 European and Nordic projects and their relations to the one imbalance model.

3.2 Guidelines for the New Model

The new Nordic imbalance settlement model has requirements on multiple levels. First and foremost, there is the Guideline on Electricity Balancing which defines how the imbalance settlement has to be done in Europe. The guideline is more of a high-level concept, so the Nordic TSOs have set up a Nordic settlement working group to define a more detailed model which would be used in Nordic countries. They also evaluate the model so that it will be in accordance with the European harmonized model.

Other development projects, mainly national datahubs, should also be taken into account. There will be some new features and changes due to these projects, so on the overall design it is necessary to consider also those requirements. The new model needs to be designed and implemented in a way that it will meet the requirements of each related project.

3.2.1 Framework from Guideline on Electricity Balancing

The Guideline on Electricity Balancing sets several requirements for imbalance settlement and the Nordic model needs to be in accordance with these requirements. Some of the requirements are specific while others are more general stating for example that some part simply needs to be harmonized in the EU.

Several terms have been defined in the guideline and it's essential to know the terms to understand the requirements that come from the EU Commission Regulation (2017/2195). Following terms occur in the guideline and are important for understanding of the requirements:

- “Allocated volume” is an energy volume physically injected or withdrawn from the system and attributed to a BRP, for the calculation of the imbalance of that BRP i.e. it represents all consumption and production of that BRP.
- “Position” is the declared energy volume of a BRP used for the calculation of its imbalance, i.e. it represents all trades of that BRP.
- “Imbalance” is an energy volume calculated for a BRP and represents the difference between the final position and allocated volume of that BRP, including imbalance adjustments applied to that BRP, within a given imbalance settlement period.

The article 52 in the EU Commission Regulation (2017/2195) forces the TSOs to propose a harmonized settlement rules for several processes. The common proposal must be done by December 2018 and it has to be implemented no later than eighteen months after approval by all relevant regulatory authorities. The deadline for implementation is estimated to be around the end of year 2020. The imbalance settlement harmonization working group in ENTSO-E is working with these topics. The processes which the harmonization concerns are at least

- the calculation of an imbalance adjustment, a position, an imbalance and an allocated volume
- the main components which are used in the imbalance price calculation including the value of avoided activation of balancing energy
- the use of single imbalance pricing and conditions where dual imbalance pricing could be applied.

Until the implementation of the above processes, it is allowed to calculate the imbalances with the current model with two imbalances but also with the use of single imbalance calculation. There is also a third option called “central dispatching model” but it doesn’t concern the Nordic countries.

Due to the EU Commission Regulation (2017/2195) article 53, all TSOs shall apply 15 minutes imbalance settlement period by December 2020. It’s possible for the TSOs of a synchronous area to jointly request an exemption from the requirement from the authorities. However, if an exemption is granted, a cost-benefit analysis about the harmonization of the imbalance settlement period has to be done at least every three years.

Pöyry Management Consulting Oy (2018) has done this cost-benefit analysis regarding Finland for Fingrid Oyj. The cost impact on balancing market is estimated to be 9-26 million euros per year and on intraday market to be from 0.7 to 2.2 million euros per year if Finland would postpone the implementation of 15 minutes imbalance settlement period. The cause of the costs is basically a decrease in cross-border trades as there would be only 60-minute products available in Finland. The Finnish market participants would have to trade only with block products in the other Nordic countries which would have both 15-minute and 60-minute products.

There are some requirements also for the imbalance calculation and these have been defined in article 54 of the EU Commission Regulation (2017/2195). Basically, it states that the imbalance adjustment, the imbalance and the allocated volume has to be calculated for each BRP, for each imbalance settlement period and for each imbalance area where imbalance area equals to MBAs in the Nordic countries. The shortage of BRP shall have negative sign

and surplus of BRP shall have positive sign. In addition, each TSO shall set rules for calculation and determination of

- final position of BRP
- allocated volume
- imbalance adjustment (in accordance with GL EB article 49)
- imbalance
- claiming of imbalance recalculation by BRP i.e. rules when BRP may request for recalculation of imbalance for example due to some error.

The imbalance price can be positive, zero or negative. The price and the direction of the imbalance defines the payment for the imbalances. The definition is presented in Table 8. The imbalance price shall be determined by each TSO for each imbalance settlement period, for each imbalance price area and for each imbalance direction. The imbalance prices have limitations as negative imbalance price shall not be less than "the weighted average price for positive activated balancing energy from frequency restoration reserves and replacement reserves". Similarly, the positive imbalance price shall not be greater than "the weighted average price for negative activated balancing energy from frequency restoration reserves and replacement reserves". If no activation of balancing energy in either direction has occurred during the imbalance settlement period, the price limits are determined by "the value of the avoided activation of balancing energy from frequency restoration reserves or replacement reserves". (Commission Regulation (EU) 2017/2195.)

Table 8 Payment for imbalance (Commission Regulation (EU) 2017/2195).

	Imbalance price positive	Imbalance price negative
Positive imbalance	Payment from TSO to BRP	Payment from BRP to TSO
Negative imbalance	Payment from BRP to TSO	Payment from TSO to BRP

The requirements per article which set the frames for the Nordic model, have been presented in short in Table 9. It also includes the deadline for each requirement from the guideline assuming that no delays or exemptions take place. The applicable parties are also included in one column which basically states whether each TSO separately or all TSOs together need to fulfil the requirement.

Table 9 Requirements for imbalance settlement by GL EB.

GL EB Article	Requirement	Deadline Month/Year	Applicable parties
Article 52	Proposal for harmonization of - calculation of imbalance adjustment, position, imbalance and allocated volume - imbalance price main components - conditions for applying of dual price	12/2018	All TSOs
Article 52	Implementation of the agreed proposal	12/2020	Each TSO
Article 53	Implementation of the 15 minutes imbalance settlement period	12/2020	All TSOs
Article 54	Implementation of one of the three following options for intermediate imbalance calculation process until article 52 is implemented: - Single final position - Final positions for production and consumption - Central dispatching model with multiple positions	12/2018	Each TSO
Article 54	Implementation of rules for calculation and determination of - final position of BRP - allocated volume - imbalance adjustment - imbalance - claiming of imbalance recalculation of the imbalance by BRP	12/2018	Each TSO
Article 55	Implementation of the rules for imbalance price calculation and payment for imbalance	12/2018	Each TSO

3.2.2 Proposal by Imbalance Settlement Harmonization Group

In May 2018 the all TSOs' proposal draft for specification and harmonization of imbalance settlement was published. In the proposal, imbalance adjustment of a BRP is calculated by the TSO for each imbalance settlement period. The imbalance adjustment is the netted volume of at least all activated bids of balancing energy and volumes activated by each connecting TSO. Further imbalance adjustment may be calculated for a BRP as a netted volume of at least all energy involved in the system defense plan instructions issued by the TSO and energy involved in all allocated cross-zonal capacity that is curtailed by the connecting TSO. (ENTSO-E 2018c.)

ENTSO-E (2018c) proposes that the calculation of a position would follow the EU commission guideline so that each BRP shall have one single final position which is equal to the sum of its external and internal commercial trade schedules. The imbalance for each BRP would be calculated for each imbalance area i.e. market balance area in Nordics and it would follow the definition of the guideline that it's the difference between a final position and an allocated volume. An allocated volume of a BRP would be the netted volume of its

- metered volumes per imbalance settlement period
- volumes assigned per imbalance settlement period over injections and withdrawals which are not metered with a granularity of imbalance settlement period.

The connection between the terms in the guideline and the used settlement data in the Nordic imbalance settlement model may not be obvious. Figure 7 tries to interpret how the position, allocated volume, imbalance adjustments and imbalance are formed. A position is the sum of all trade volumes of a BRP per imbalance settlement period. Respectively, an allocated volume is the sum of all physical volumes such as production and consumption. MGA imbalance is also included as it is basically an end product of incorrectly metered physical volumes. Imbalance adjustments are calculated from the activated reserve bids. They are included into calculation of imbalance which is the difference between the position and the allocated volume.

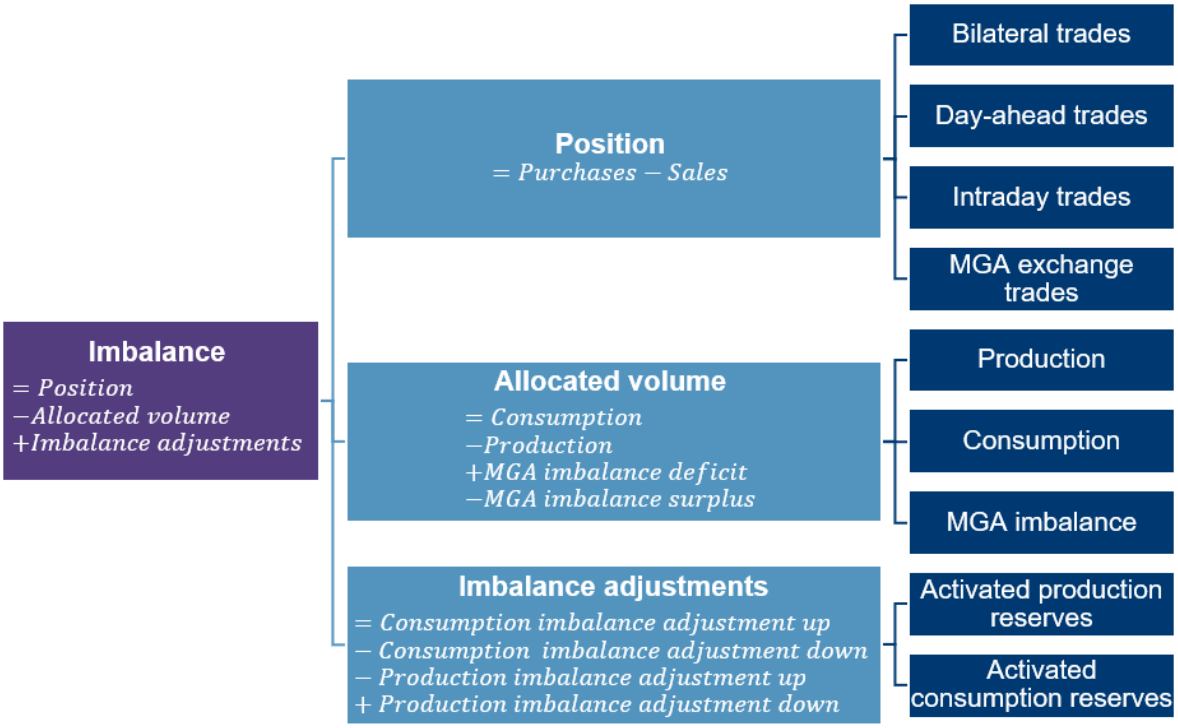

Figure 7 Interpretation of calculation of position, allocated volume and imbalance.

One part of the harmonization of imbalance settlement was to determine the main components used for the calculation of imbalance price for all imbalances. The proposal of ENTSO-E (2018c) suggests that main components used for calculating the imbalance price for each imbalance area, direction and imbalance settlement period, would be the following prices:

- value of avoided activation of balancing energy
- price or prices, per direction, for the volume of balancing energy for frequency restoration process activated by connecting TSO
- price or prices, per direction, for the volume of balancing energy for reserve replacement process activated by connecting TSO
- price or prices, per direction, for the volume of intended change of energy as a result of imbalance netting process
- price or prices, per direction, for the intended exchange of energy from a requesting TSO
- a scarcity component, in case a TSO identifies a need for stronger incentives in scarcity situations and proposes to relevant regulatory authority to apply one in imbalance pricing.

Additionally, the proposal states that each TSO could use only following volumes for calculating the imbalance price for each imbalance area, direction and imbalance settlement period:

- balancing energy volume for frequency restoration process, per direction and product, requested by TSOs
- balancing energy volume for reserve replacement process, per direction and product, requested by TSO
- intended change of energy volume as a result of the imbalance netting process. (ENTSO-E 2018c.)

The value of avoided activation shall be calculated by each TSO for each imbalance settlement period if there hasn't been activation of certain balancing energy in either direction in the imbalance price area. The value would be calculated if activation from frequency restoration reserves or replacement reserves is avoided. If dual imbalance pricing is applied for the imbalance settlement period, the TSO could calculate two values, one for each direction. The proposal of ENTSO-E (2018c) suggests that following volumes and prices would be used for calculation of the value of avoided activation:

- price or prices, per direction, for the volume of balancing energy for frequency restoration process activated by connecting TSO
- price or prices, per direction, for the volume of balancing energy for reserve replacement process activated by connecting TSO
- price or prices, per direction, for the volume of intended change of energy as a result of imbalance netting process
- price or prices, per direction, for the intended exchange of energy from a requesting TSO.

ENTSO-E (2018c) proposes that each TSO shall implement the use of single imbalance pricing as is stated in the guideline on electricity balancing. However, each TSO could apply dual pricing after proposal from the relevant regulator has been accepted. The proposal should be in accordance with the conditions and methodology of the imbalance settlement harmonization proposal. The definition of conditions and methodology for applying dual pricing for imbalance area and imbalance settlement period includes several possible conditions:

- The first condition that would allow the application of dual pricing is the use of imbalance settlement period which is longer that 15 minutes.
- If TSO requests activation of both positive and negative frequency restoration or replacement reserves during imbalance settlement period, the dual pricing could be applied.
- The third condition would be a case where no activation has occurred and there's no reason to set an incentive to one certain direction.
- If the BRPs which cause the imbalances, are also covering the costs of needed balancing energy, it's possible that single pricing method may result in deficit or lack of resources.

- The final condition would be if the imbalance price area or local electricity market requires dual pricing in order to provide proper incentives to BRPs to be in balance. This could be caused by following reasons:
    - The size of the electricity market or imbalance price area is relatively small.
    - Few BRPs cause majority of the imbalances.
    - The TSO observes a frequent need for activation of balancing energy or intended exchange in both directions.

3.2.3 Proposal by Nordic Settlement Working Group

In a common meeting the Nordic settlement working group (2018) went through the requirements of the commission guideline articles 54 and 55 for the intermediate imbalance settlement processes. The Nordic TSOs agreed that the current model fulfills the option 2 where there is basically one imbalance for production and another for consumption. There are also existing rules and determinations for the BRP's final position, allocated volume, imbalance adjustment, imbalance and claiming of imbalance recalculation. In addition, the current rules for imbalance price calculation and payment of imbalances are already in accordance with the article 55 requirements.

The Nordic TSOs anticipated that the harmonized European model which should take place in 2020, will be with single imbalance. Thus, the Nordic settlement working group (2018) agreed about the calculation of the new single imbalance volume. The proposal by eSett is to implement the new model at the same time with the 15 minutes imbalance settlement period and to implement these at the same time in all four Nordic countries. eSett could also calculate the imbalance settlement with the 15 minutes imbalance settlement period even if some data will be metered in hourly level. This way it would be possible to avoid having different imbalance settlement models or different imbalance settlement periods in different countries at the same time. However, eSett needs to prepare for the possibility that the countries would apply the new imbalance settlement period at different times.

Structural management will remain on a daily level as it is currently, and national time zones are applied also in the future. One minor change is that the minor production which has currently been under the BRP for consumption, will be under the BRP for production in the future. As there won't be separate imbalances for production and consumption, it was considered to be more suitable to have all production under the BRP for production. New market participants such as balance service providers, aggregators or datahubs may affect the structural management but the Nordic settlement working group (2018) considered it to be out of the scope of their mandate.

Some of the settlement data metering may remain in hourly level even after the changes. The Nordic settlement working group (2018) had a mutual impression that at least all bilateral trades, imbalance adjustments and intraday trades will be in 15 minutes level. Any hourly data will be divided into four proportions for imbalance settlement. The concept of the settlement data reporting won't change but due to the 15 minutes imbalance settlement period the reporting deadlines will follow the 15 minutes schedule instead of current hourly schedule. For example, deadline for reporting of bilateral trades will be 45 minutes (or 20 minutes in Finland) before each imbalance settlement period. Another change is that due to the new calculation model, the production plans won't be part of the settlement data but they may be used for key performance indicators.

The decisions about the pricing of the single imbalance was postponed so that the European imbalance settlement harmonization group could finish their work first. Only after the main components of pricing and situations where dual price is applied are known, it's possible for the Nordic settlement working group (2018) to design the pricing model for Nordics. It's possible that the harmonized model won't allow any flexibility which would mean that it will be used model as it is. The applied fees in Nordics will however remain with the minor adjustment that instead of consumption imbalance fee there will be similar imbalance fee. TSOs will still reserve a right to adjust the fee levels in a similar way as they currently do.

3.2.4 Requirements Due to Other Development Projects

The new role Balance Service Provider which was introduced by the electricity balancing guideline may cause changes to the Nordic imbalance settlement model. In Finland such role already exists outside the settlement but in Norway and Sweden the handling of the new role needs to be designed. If any of the Nordic TSOs decides that the BSP will be implemented into the imbalance settlement system, it will require some changes. What comes to the aggregators, the Nordic settlement working group (2018) assumed that the new role will be handled as a BSP. However, eSett hasn't yet received any decisions or requirements from Nordic TSOs regarding these roles so it is relatively difficult to evaluate if and what influences they will have on the imbalance settlement.

National datahub projects on the other hand are further in their design and implementation and the requirements from that project are known better. First, a new role for the datahubs needs to be defined in the imbalance settlement model. Each datahub will then take over some of the responsibilities of DSOs in the country where it operates. It will mainly affect structure managing and settlement data reporting responsibilities but in some cases also gate closures for reporting will be different. Some national differences need to be considered as for example in Norway all DSO data will be managed by datahub but in Finland there are DSOs which won't be affected at all by the datahub. (Nordic Council of Ministers 2017.)

3.2.5 Implementation within the Given Boundaries

The current Nordic imbalance settlement model is aligned with electricity balancing guideline requirements for the intermediate period. Thus, nothing has to be implemented due to those requirements until the harmonized European model will be applied which should happen approximately at the end of year 2020.

Before the first datahub will start operating the Nordic imbalance settlement model responsibilities for structure managing and reporting need to be updated. Possibly the reporting deadlines need adjusting and rights of the DSOs need to be limited in cases where datahub will take over the responsibility. The Norwegian datahub will be the first one to start operations as their go-live date is in February 2019.

The new model with calculation of a single imbalance has been designed by the Nordic settlement working group (2018). Before it will be implemented, it will be presented to customers for commenting and updated and finalized if the comments give a reason to do so. After the calculation model is finalized, it still needs approval before implementation.

The proposed and probable model for imbalance volume calculation is presented in equation (5) and it consists of same components as the current calculations. An exception is that there won't be planned production as the new equation is basically a sum of equations (1) and (2) and it would nullify itself.

$$Consumption + Production \mp Trade \mp \underset{adjustment}{\overset{Consumption}{imbalance}} \mp \underset{adjustment}{\overset{Production}{imbalance}} + \underset{imbalance}{MGA} = \underset{power}{Imbalance} \quad (5)$$

The basic principle of the calculation is same as in the current model and all the components of the calculation remain the same. The interpretation of the calculation and different terms are explained in more detail in chapter 2.2.3 Imbalance Settlement Calculation. In short, the calculation is similar to the calculation of consumption imbalance but there is production in the equation instead of production plan and production imbalance adjustments have been included into the calculation.

Even though the harmonized model will basically have only one price for the imbalance a two-price model need to be implemented so that the system could handle the possible situations where dual price could be applied. During "normal" situations when one price is applied, the other price will be equal to the one. The main components and formation of prices in Nordics are still unknown but as the prices will be sent to eSett by the TSOs, it shouldn't affect the system implementation. What comes to fees, the consumption imbalance fee is replaced by an imbalance fee and the fee levels need to be checked.

The collateral formula needs to be adjusted to correspond with the single imbalance, imbalance fee and the counterparty risk of eSett. Likely there won't be major changes; use of absolute imbalance amounts instead of sum of absolute production and consumption amounts and use of imbalance fee and price instead of consumption imbalance fee and price. However, any changes in calculation of collateral demand need to be approved by the Nordic TSOs and implemented after approval.

Finally, the 15 minutes imbalance settlement period needs to be implemented. Time series data i.e. data which is used in the imbalance settlement calculations, should support the use of the new shorter imbalance settlement period. Respectively it needs to be implemented to the messages which are used in the reporting of that data. In case that all data or countries won't support the 15 minutes level, there needs to be possibility to convert the hourly level data to 15 minutes level and vice versa.

3.3 Greatest Differences to the Current Model

The differences between the current imbalance settlement model and the upcoming imbalance settlement model are mostly in three different areas. The first major area is the calculation of imbalance volumes. Second, the pricing of imbalances will be different compared to the current situation. Finally, the change of imbalance settlement period from hourly to 15 minutes level.

3.3.1 Calculation of Imbalances

The greatest change will be the calculation of a single imbalance instead of calculation of production and consumption imbalances. The main principle of the calculation however remains as the same components are used both in current calculation and in the upcoming new calculation. Figure 8 presents the formation of current production and consumption imbalances from different components while Figure 9 presents the same thing with the new single imbalance. Planned production is the only component which is left out as it has different sign in production and consumption imbalance calculations which were presented in equations (1) and (2). In both figures the component production per PU has been presented twice but in the second occurrence it's only used for the calculation of MGA imbalance. The input data which comes from the market has to be always aggregated so that it's a sum per BRP and MBA as the imbalances are also calculated per BRP and MBA.

The first column in Figure 8 represents the data which eSett receives from market participants and which are the main components for the imbalance settlement calculations. The input data has to be aggregated at least once, so that it is a single value for each BRP for MBA. That way the data is usable for calculation of the production and consumption imbalances for each BRP for each MBA.

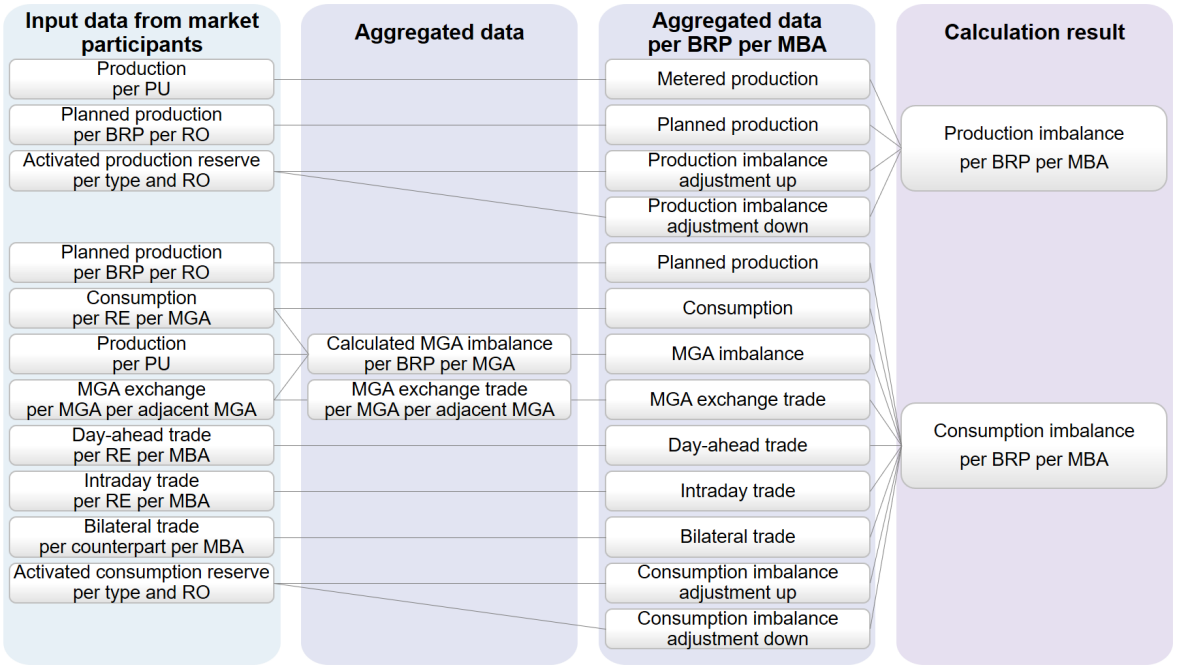

Figure 8 Components and calculation of current production and consumption imbalances.

Figure 9 is similar graphic example how the imbalance is calculated but for the new model. It contains all the same input data components and aggregations as Figure 8 which represents the current model. However, some components are crossed out from the figure as they will not be used in the new imbalance settlement calculation. Additionally, they aggregations are used to calculate a single imbalance instead of production and consumption imbalances.

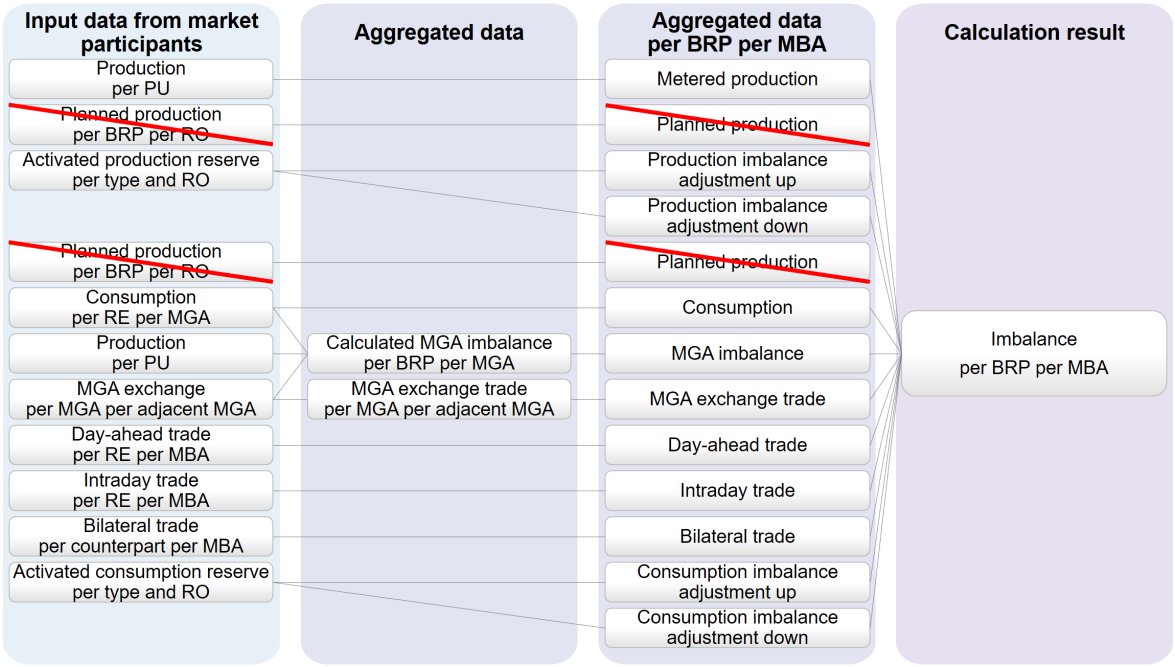

Figure 9 Components and calculation of the new single imbalance.

3.3.2 Pricing

Currently there are two different pricing models in use. A one-price model for consumption imbalances and a two-price model for production imbalances. The new model will have only one imbalance, but the pricing model will differ from both of the current pricing models. Table 10 tries to illustrate the difference between the current pricing and the new pricing models. An assumption is that during normal situations the new pricing model is quite similar as the current consumption imbalance price. The price of deficit and surplus of BRP will be same for each imbalance settlement period (ISP).

In the new model, there has been left a possibility for situations where two prices could be applied. These situations are defined in chapter 3.2.2 Proposal by Imbalance Settlement Harmonization Group but it's only a proposal and needs to be approved by the regulators. Since the dual pricing situations provide to the TSO a better chance to cover the costs of balancing energy, it's safe to assume that if majority of the imbalance adjustments are up-regulation, i.e. increase of production or decrease of consumption, a deficit of a BRP has higher imbalance price than a surplus of a BRP. In proportion, the situation is opposite if it will be a down-regulation imbalance settlement period. This would provide two-price income for the TSO. This supposed dual price situation would be quite similar to the current production imbalance pricing.

In the harmonization proposal there's a condition that dual price could be applied if no activations has occurred and thus there's no justification to set an incentive to a certain direction. In this case an assumption is that a value of avoided activation from the proposed main components for imbalance price could be used. It can be calculated for the imbalance settlement period for both directions, but the price may however be same for both directions.

A notable thing is that the imbalance prices of the new Nordic imbalance settlement model haven't been defined yet and same is with the situations where dual price will be used. If the

imbalance settlement harmonization proposal is accepted as it is, likely the imbalance price in the Nordic model will be or will be derived from value of avoided activation, frequency restoration price, replacement reserve price or price for intended exchange of energy. The proposed main components of imbalance price were introduced in more detail in chapter 3.2.2 Proposal by Imbalance Settlement Harmonization Group.

Table 10 Current and new pricing models of imbalance settlement.

	Imbalance type	Up-regulation ISP	Down-regulation ISP	ISP with no direction
Production imbalance pricing	Negative production imbalance of BRP (deficit)	Up-regulation price	PX market price	PX market price
	Positive production imbalance of BRP (surplus)	PX market price	Down-regulation price	PX market price
Consumption imbalance pricing	Negative consumption imbalance of BRP (deficit)	Up-regulation price	Down-regulation price	PX market price
	Positive consumption imbalance of BRP (surplus)	Up-regulation price	Down-regulation price	PX market price
New pricing model	Negative imbalance of BRP (deficit)	Imbalance price	Imbalance price	Imbalance price
	Positive imbalance of BRP (surplus)	Imbalance price	Imbalance price	Imbalance price
New pricing model in dual price situation (assumption)	Negative imbalance of BRP (deficit)	Higher imbalance price	Lower imbalance price	Value of avoided activation (up)
	Positive imbalance of BRP (surplus)	Lower imbalance price	Higher imbalance price	Value of avoided activation (down)

3.3.3 Imbalance Settlement Period

For most of the market participants the new resolution of 15 minutes imbalance settlement period is the most considerable change. That is because they need to adapt to it in multiple levels, not just with metering, reporting and imbalance settlement. Additionally, it will affect for example their customer, metering, pricing and invoicing systems.

In imbalance settlement, the new time resolution of imbalance settlement period basically means that the amount of aggregated input data will be four times higher than previously. The data will be either metered on 15 minutes resolution or if it's not possible, then the hourly data will be split into four proportions. Basically, the reporting of that data will happen similarly as it happens now but with 96 values per day instead of current 24. It will require that the message formats and IT systems are updated to support the new resolution. Same applies for both incoming and outgoing reporting and the imbalance settlement system itself. There will also be four times more calculation of imbalances but only for one imbalance instead of two.

It may be possible that some data types, such as consumption metering points with main fuse of 3 × 63 amperes or less in Finland, would remain in hourly metering as an intermediate solution. Also, there is possibility that some data would be reported with 15 minutes resolution already before it would be the official imbalance settlement period. One such case could be a national datahub that would start operating shortly before the new resolution is applied. The datahub would probably wish to avoid the need to report first on hourly level and soon after with the new resolution. These scenarios would require that the imbalance settlement system accepts both hourly and 15 minutes time resolution in the incoming data and it would be either split into four proportions or aggregated into hourly level depending on the incoming data and applied imbalance settlement period.

Table 11 illustrates the differences between the two imbalance settlement periods (ISP). There are three time series which are all based on the same values, but the metering type is different. First column presents the current hourly metered values and hourly imbalance settlement period. The second column is with 15 minutes metering and imbalance settlement period while the third column represents the situation where there is 15 minutes imbalance settlement period, but the metering has been done hourly and the split up into four parts.

Table 11 Illustrative example about different metering and imbalance settlement period resolutions with same source data.

Time period	Hourly metering and ISP (MWh)	15 minutes metering and ISP (MWh)	Hourly metering and 15 minutes ISP (MWh)
00:00 – 00:15	60	12	15
00:15 – 00:30		16	15
00:30 – 00:45		18	15
00:45 – 01:00		14	15
01:00 – 01:15	80	15	20
01:15 – 01:30		19	20
01:30 – 01:45		23	20
01:45 – 02:00		23	20

4 Influence on the Imbalance Settlement and Settlement System

This chapter elaborates the impacts of the new requirements on the Nordic imbalance settlement model. Additionally, the system which runs the imbalance settlement is included into the analysis. However, the analysis of influence on the imbalance settlement system is more on a high-level as it doesn't go into all details. The structure of this chapter is quite similar to the chapter 2.2 Nordic Imbalance Settlement Model which describes the current imbalance settlement model. First, the management of structural data is analysed and after that the metering and reporting of data. The other subchapters include the imbalance settlement calculations, pricing, invoicing and collaterals. Finally, there is an imbalance settlement calculation example similar to the one in chapter 2.2.6 Calculation Example.

4.1 Structural Data Changes

Once a datahub will start operating in Finland, Norway or Sweden, the responsibilities of the DSOs which will be part of the datahub project, will became responsibilities of the datahub. This will be problematic for defining of the responsible parties in the imbalance settlement model as the in some cases the responsible party will be DSO and some cases it will be datahub. A new term, metered data aggregator, solves this as it can refer to DSO or datahub depending on the situation.

Basically, in cases where the responsibility of structural data changes will move from DSO to datahub, it includes

- registering all relevant metered and profiled consumption types for retailers in the MGAs of the DSO
- registering all production unit information such as name, type, capacity and retailer and keeping the data updated
- registering the retailer for MGA imbalance for each MGA of the DSO.

However, the DSOs will still have the right to view all their data, but they are not allowed to edit it. The DSOs will have the responsibility of updating the information related to them, which includes for example user and contact information. Datahubs on the other hand are not authorized to edit the information of the DSOs or view their users.

For the imbalance settlement system, this means that the access rights need to be adjusted. DSOs would have only read rights for the imbalance settlement related structural changes and a datahub would be the one with the rights to edit. The information that is not related to imbalance settlement such as company, role and user management would be within DSOs control and datahub would at the most have the right to read the data.

Another change related to structural data is related to the handling of minor production. Minor production is a production type in Finland and Norway where the production capacity is lower than 1 MW in Finland and 3 MW in Norway. Currently the minor production is handled in the consumption imbalance and thus it's under the retailer balance responsibility of consumption. Since there will be only one imbalance, the minor production will be in the future under the retailer balance responsibility of production same way as normal production. Figure 10 presents the market entity connections which are on retailer level, under the retailer

balance responsibilities of production and consumption. The change in minor production has been highlighted to illustrate the fact that it won't be under the retailer balance responsibility of consumption after the change.

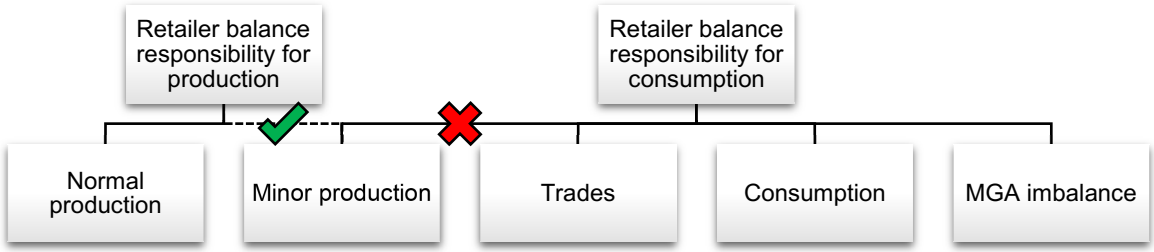

Figure 10 Market structures under the retailer balance responsibilities for production and consumption and the change in minor production.

The last change is related to the production plans. As the production plans will no longer be part of imbalance settlement, they need to be removed from the settlement structure part of the imbalance settlement model. TSOs still wish to keep the possibility to report the production plans to eSett, as they may use the plans for market behavior monitoring purposes. Thus, the imbalance settlement system has to be able to handle those structures also in the new model.

Otherwise, the structure management part will remain quite intact as the current and the new model are based on same settlement structures. The 15 minutes imbalance settlement period won't have any effect on the structure managing. Currently, hourly level structural changes aren't allowed even though the hourly imbalance settlement period is applied. It means that the handling of the structural changes will be on a daily level similarly as it currently is.

4.2 Changes in Metering and Reporting

Currently DSOs do the metering hourly, i.e. they read the metered value each hour to determine the energy volume which was consumed, produced or exchanged during the last hour. Once the new 15 minutes imbalance settlement period is fully in use, the metering should also follow the 15 minutes period. Thus, the DSOs would read the metered volumes each hour at xx:00, xx:15, xx:30 and xx:45.

It is not likely that all metering data could be metered with the new 15 minutes resolution after applying of the new imbalance settlement period. In the first phase the new resolution would be in use at least with MGA exchanges and normal production. However, there are still ongoing discussions in each country about which data should be metered with the 15 minutes resolution and when it should be applied. For example, in Finland it could be possible that in consumption sites with main fuse up to 3 × 63 A and with minor production units, the hourly metering would be allowed during some transition period. It's possible that Nordic countries will have their own exceptions and transition periods with different lengths.

There won't be any changes in metering data; the values of consumption, production and MGA exchanges will be based on metering also in the future. As some consumption is still based on profiled values, the possibility to use the profiled consumption will of course also remain. Each DSO will be responsible of the metering of the data even after a datahub

operates in the country. DSOs will then deliver the metered values to the datahub, but that process is outside of the scope of this thesis.

The change in metering resolution will also reflect to the reporting resolution. So, instead of hourly values, the reporting would contain values in 15 minutes level. It requires changes in the message forms so that they'll support the new resolution. That is responsibility of a Nordic Market Expert Group which maintains and develops the Nordic message standard. Market participants and eSett have to ensure that their systems are compatible with the updated standard.

The imbalance settlement system needs to be updated so that it can handle both hourly and quarterly metered values. In order to have a smooth transition to the new imbalance settlement period, there should be a transition period before and after the change. During the transition period before the change, the system should be able to handle inbound messages in both 60 minutes and 15 minutes resolutions. The values in 15 minutes resolution would then be aggregated to 60 minutes level. Respectively, during the transition period after the change the both resolutions are accepted but the values in 60 minutes resolution would be divided into 15 minutes level. The latter feature may be needed also if some metering will remain on hourly level.

The change in reporting resolution has also an effect on the data flows which have hourly closing reporting period. The values for bilateral trades are currently reported before each hour, so in the future the reporting period will close separately for each imbalance settlement period. The deadlines will remain the same, so the bilateral trades must be delivered to eSett 45 minutes before each 15-minute imbalance settlement period except in Finland where the deadline is 20 minutes before imbalance settlement period.

The introduction of national datahubs requires also some changes in the reporting. In cases where a datahub is responsible of the reporting on behalf of a DSO, the reporting from the DSO to the settlement system should be prevented. However, in cases where there is no responsible datahub, a DSO and a possible service provider (SP) of the DSO should both have the possibility to report data if the service provider has sufficient rights. Another change is that there should be possibility to send outbound messages from settlement system to multiple market parties, i.e. to DSO and service provider or datahub. The possible current and future combinations regarding incoming and outgoing messaging have been compiled into Table 12.

Table 12 Different combinations for current and future inbound and outbound data flows.

Combination	Inbound data flows – data to settlement system	Outbound data flows – data from settlement system
Current		
DSO	DSO	DSO
DSO + SP	DSO and/or SP	DSO or SP
Future		
DSO	DSO	DSO
DSO + SP	DSO and/or SP	DSO and/or SP
DSO + Datahub	Datahub	DSO and/or Datahub

Currently there are some national deadlines for reporting in each country and the reporting period is thus shorter than what the Nordic imbalance settlement model would require. When datahubs will be introduced, it's likely that DSOs will keep on reporting to datahubs according to the national reporting period. This would however leave little or none time for a datahub to report the values during the same national reporting period. Thus, there is a possibility that reporting period, which has been defined in the Nordic imbalance settlement model, will be applied for the datahubs. It would mean that the datahubs could report final values according to the normal reporting period until D + 13 days 12:00 CET.

Some other minor changes regarding reporting will also take place. Production plans will no longer be part of inbound and outbound settlement data reporting. Also, the reports published by eSett will alter so that there won't be reported separate consumption and production imbalance related data but data regarding the single imbalance. This includes for example such data as prices, imbalances and relative imbalances.

Finally, there is a part of imbalance settlement system that needs to be adjusted accordingly. Information service is an interface from where the market participants may request data from the imbalance settlement system. The requests and responses are message based and the formats and data flows should be adjusted to support the new 15 minutes imbalance settlement period. Similarly, the data types should be changed in the future as information service should support the single imbalance related data after the change takes place.

4.3 Modifications to the Imbalance Settlement

Due to the new 15 minutes imbalance settlement period, the imbalance settlement will be done on 15 minutes level instead of hourly level. It means that all hourly settlement values and aggregations which have been used in the imbalance settlement, will be converted to the new resolution. Basically, it means that the imbalances will be calculated for each 15-minute imbalance settlement period.

The model with separate imbalances for production and consumption will be replaced by a single imbalance model. The single imbalance is based on the combination of the production and consumption imbalances. All the components of the calculations will be combined into one calculation without production plans. Table 13 shows the components which are used in the different imbalances and also the sign of the components when they are added up in the equation. For example, in the single imbalance calculation the consumption has negative sign and production has positive sign, so in an equation it could be presented as production minus consumption. If there is no sign in an imbalance column, then it isn't used in the imbalance calculation.

The simplified equations are presented in for production imbalance in equation (1) and for consumption imbalance in equation (2) while MGA imbalance has been presented in equation (3) and the calculation of the new single imbalance in equation (5). Also, the formation of the calculation components is already presented in chapter 3.3.1 Calculation of Imbalances. Since those have been already presented elsewhere, they are not presented again in this chapter.

Table 13 The imbalance settlement calculation components and their sign in the calculation.

Calculation component per BRP and MBA	Description	Production imbalance	Consumption imbalance	Single imbalance
Consumption	Aggregated consumption of all types except of pumped storage		-	-
Consumption (pumped storage)	Aggregated consumption of type pumped storage	-		-
Production	Aggregated production of all PU with normal production type	+		+
Production (minor)	Aggregated production of all PU with minor production type		+	+
Production plan	Aggregated production plans per BRP and MBA	-	+	
Bilateral trade purchases	Aggregated quantity of bilateral trade purchases		+	+
Bilateral trade sales	Aggregated quantity of bilateral trade sales		-	-
Day-ahead trade purchases	Aggregated day-ahead trade purchases of all retailers per BRP and MBA		+	+
Day-ahead trade sales	Aggregated day-ahead trade sales of all retailers per BRP and MBA		-	-
Intraday trade purchases	Aggregated intraday trade purchases of all retailers per BRP and MBA		+	+
Intraday trade sales	Aggregated intraday trade sales of all retailers per BRP and MBA		-	-
MGA imbalance surplus	Calculated MGA imbalance surplus aggregated per BRP and MBA		-	-
MGA imbalance deficit	Calculated MGA imbalance deficit aggregated per BRP and MBA		+	+
Cons imbalance adjustment up	Aggregated consumption imbalance adjustment up per BRP and MBA		-	-
Cons imbalance adjustment down	Aggregated consumption reserves down per BRP and MBA		+	+
Prod imbalance adjustment up	Aggregated production reserves up per BRP and MBA	-		-
Prod imbalance adjustment down	Aggregated production reserves down per BRP and MBA	+		+
MGA trade import	Aggregated traded MGA exchange imports per BRP and MBA		+	+
MGA trade export	Aggregated traded MGA exchange exports per BRP and MBA		-	-

The retailer may have different BRP for its production data and consumption data. In this case the consumption data includes trades, MGA imbalances and consumption imbalance adjustments while the production data includes production imbalance adjustments and pumped storage consumption. The only difference will be in the handling of minor production. It is currently handled in the imbalance calculation of the BRP for consumption, but in the future, it will be handled in the imbalance calculation of the BRP for production.

The imbalance settlement system needs to be altered in a way that for all different views which show the settlement results for production and consumption imbalances, there needs to be a new view which shows the results for a single imbalance. The change needs to also affect the different reports which include the imbalance settlement results. Instead of production and consumption imbalance results there has to be the result of the single imbalance calculation.

4.4 Setting the Pricing and Fees

The basic principle of pricing will remain the same. For each imbalance settlement period and for each market balance area there will be a price or prices. The imbalance settlement period will be 15 minutes instead of hour and instead of production and consumption imbalance prices there will be a price or prices for the single imbalance. The pricing model will be in a way a combination of the current consumption imbalance with one price and production imbalance with two prices. Normally a single price will be applied but if certain specified preconditions are fulfilled a dual-price may be applied.

Likely the used price will be up or down regulation price of activated reserves or the value of avoided activation. The price which is used will depend whether the hour is marked as up-regulation hour, down-regulation hour or an hour with no regulation. The proposal about main components of imbalance price is part of chapter 3.2.2 Proposal by Imbalance Settlement Harmonization Group.

For the imbalance settlement system, the used prices are irrelevant as they are defined elsewhere for each imbalance settlement period. The imbalance prices will be sent to the system by TSOs. The system needs to be defined as a two-price model even though the prices would be same for both directions in normal situations. The imbalance purchase and sale prices which TSOs will send, will just have same value whenever a single price situation occurs. Currently the imbalance settlement system is able to calculate also a shadow price from the data which TSOs send and it is used to verify the correctness of the imbalance prices. With the new pricing model, the shadow price calculation will be abandoned.

Table 14 presents which prices will be defined to the imbalance settlement system. The main direction isn't a price, but it defines whether imbalance purchase price or sale price is used as imbalance price in normal situation. The imbalance purchase price represents the price which eSett pays to a BRP for purchasing their surplus imbalance. The imbalance sale price represents the price which eSett receives from a BRP for selling imbalance to cover their deficit. The prices will be same unless dual pricing is applied which would mean that the purchase price will be lower than the sale price. PX market day-ahead price won't have place in imbalance pricing but it will likely remain in the system as an informative value. Its standing needs to be re-evaluated if there will be multiple day-ahead markets in Nordic countries in the future.

Table 14 The prices used in imbalance settlement system.

Price	Unit
Imbalance purchase price per MBA	EUR/MWh
Imbalance sale price per MBA	EUR/MWh
Main direction of imbalance adjustment per MBA	–
PX market day-ahead price per MBA	EUR/MWh

During a dual pricing situation there is a need to define prices for both BRP surplus and deficit. During those situations, the basis for the imbalance purchase price will likely be the price of down-regulation i.e. decrease of production or increase of consumption, or the value of avoided down-regulation activation. Similarly, the basis for the imbalance sale price will likely be the price of up-regulation i.e. increase of production or decrease of consumption, or the value of avoided up-regulation activation.

The fee structure will remain as it is presented in chapter 2.2.4 Pricing and Fees with only one minor change. The consumption imbalance fee will be replaced by imbalance fee. The imbalance fee will be levied on sum of absolute quantities of a BRP's positive and negative imbalances.

The imbalance settlement system and the incoming and outgoing reports has to be changed so that all views which show the prices or fees, will support the new prices and fees. The number of different prices will be lower and the name and handling of one fee will change. Instead of production and consumption imbalance prices the views and reports will contain the prices of the single imbalance.

4.5 Effects on the Invoicing and Collaterals

The invoicing process won't be greatly affected due to the new requirements. Invoicing will remain to be a weekly process where eSett invoices BRPs based on their imbalances, fees and imbalance adjustments. The invoicing of settlement week will be handled three weeks later. In a normal weekly process, the invoices are issued on Monday, debited on Wednesday and credited on Thursday. The process has been described in more detail in chapter 2.2.5 Invoices and Collaterals.

There will be minor changes in the contents of the invoices as few of the invoice products will change. The purchase and sale of production and consumption imbalances will be replaced by purchase and sale of imbalance. In the fees, the consumption imbalance fee will be replaced by imbalance fee. Third change is that the current invoice data, which is aggregation of the 168 hours of a week, will in the future consist of the 672 15-minutes imbalance settlement period of the week.

There will be need for a collateral from the BRPs also in the future. The basic principle of the collateral calculation won't change. The collateral calculation still tries to estimate the amount which BRP has accumulated but hasn't paid yet and the imbalance which a misbehaving BRP could accumulate before the behaviour can be identified. Thus, there is no compelling need to alter the equation (4) for collateral calculation itself. However, at least some of the terms of the calculation has to be updated to be in accordance with the new single imbalance and imbalance fee.

4.6 Transition Period and Risk Management

A one important part of the evaluation of the influence on the imbalance settlement system is the handling of transition period and risks. Figure 11 presents three possible scenarios which have been identified and eSett has to prepare for each one. The first row presents a scenario where the current model and imbalance settlement period is still in use but some of the data is reported with the 15 minutes imbalance settlement period. This could be the case if for example some new 15-minute balancing product is introduced while the current model is still in use or if there will be a transition period where reporting with 15-minute resolution is allowed even though the current model is still in use. This scenario requires some extra module which would aggregate the input values that are reported in 15-minute resolution into hourly resolution values.

In the second scenario a one balance model would be in use, but the current hourly imbalance settlement period would still be used. The input data would have both 15-minute and hourly resolutions. This kind of situation would occur if the use of 15 minutes imbalance settlement period will be delayed in the Nordics. As in the previous scenario, a module which would aggregate the values into hourly resolution is needed for this scenario. Additionally, it has to be possible to implement the new imbalance settlement model separately from the new imbalance settlement period. So, they have to be designed in a way that they are not dependent on each other.

If some part of the Nordic electricity market will not be ready for the new 15 minutes imbalance settlement period, the third scenario will occur. In that case, the imbalance settlement system would use the new model and imbalance settlement period, but some data would be reported with hourly resolution. An extra module would be needed as in the previous scenarios, but this time it would need to split the hourly values into four equal parts for the 15-minute resolution.

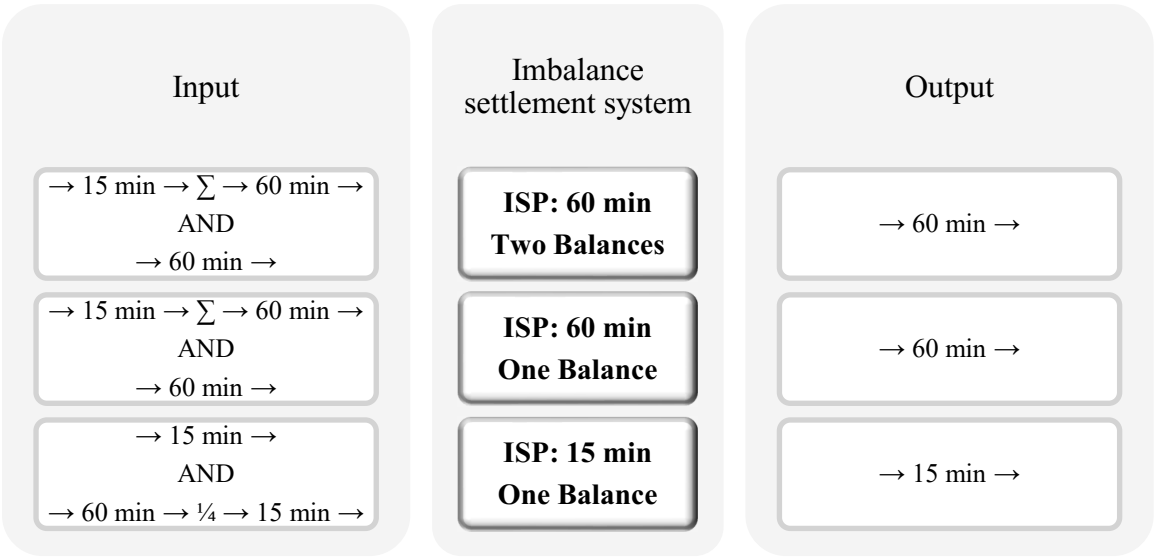

Figure 11 Three identified scenarios for transition period and risk management.

Additionally, there will be a time period when both models will be used at the same time. It takes multiple days before the reporting for a day is closed and the invoices are issued. Thus, at some point the reporting period is open and imbalances have to be calculated for both models at the same time. This transition has to be designed in way that it will be possible and smooth.

4.7 Example of the New Settlement Calculation

The following calculation example shows how the imbalance volumes and amounts are calculated from the settlement data with the new imbalance calculation. The same values are used as in the example in chapter 2.2.6 Calculation Example and the results are shortly compared at the end of the example. There are values only for one BRP within one MBA for a single imbalance settlement period. The example is greatly simplified but it illustrates the mechanics and gives some results which can be compared with the current model. Different fees and invoice contents are also included in the example. Table 15 presents the settlement

data which has been used in the calculations. while Table 16 shows the calculation of imbalance volume.

Table 15 Imbalance settlement calculation example data for one imbalance settlement period for a BRP within one MBA.

Settlement data	Value (MWh)
Metered consumption	-55
Profiled consumption	-10
Metered production	80
Bilateral trades (purchase)	15
Bilateral trades (sales)	-5
Day-ahead trades (purchase)	0
Day-ahead trades (sale)	-20
Intraday trades (purchase)	5
Intraday trades (sales)	-10
MGA imbalance (surplus)	-5
MGA imbalance (deficit)	10
Consumption imbalance adjustment up-regulation (purchase from TSO)	0
Consumption imbalance adjustment down-regulation (sale to TSO)	-5
Production imbalance adjustment up-regulation (sale to TSO)	-25
Production imbalance adjustment down-regulation (purchase from TSO)	5

Table 16 presents the calculation for imbalance. The values of the different data types have been aggregated and they are on their own columns. The final column presents the calculation result after it has been calculated according to the equation (5). The result is basically the sum of production and consumption imbalance calculations from Table 5 and Table 6.

Table 16 Imbalance volume calculation example.

	Metered and profiled consumption (MWh)	Metered production (MWh)	Bilateral, day-ahead and intraday trades (MWh)	MGA imbalance (MWh)	Imbalance adjustments (MWh)	*Imbalance (MWh)*
Delivery hour	-65	80	-15	5	-25	*-20*

With calculated imbalance volume, known activated reserves and known prices and fees, it is possible to calculate the invoice amount. The imbalance settlement period in the example has a single price of 40 €/MWh which is also the up-regulation price. The down-regulation price is 20 €/MWh.

There are separate rows for each imbalance adjustment in the example, but in the actual invoice each activated reserve type will have its own row and price. Each imbalance adjustment is also invoiced with the regulation price in the example. This is done to simplify it. The prices and fees of the example are visible in the Table 17 which contains the invoice amount calculation. The result of the invoice amount calculation is negative, so the invoice would be a credit notice and eSett would pay for the BRP.

Table 17 Invoice amount calculation example.

Invoicing information	Volume (MWh)	Price (€/MWh)	Amount (€)
Sale of imbalance power to eSett	0	40	0
Purchase of imbalance power from eSett	20	40	800
Sale of production imbalance adjustments (up-regulation) to eSett	-25	40	-1 000
Purchase of production imbalance adjustments (down-regulation) from eSett	5	20	100
Sale of consumption imbalance adjustments (down-regulation) to eSett	-5	40	-200
Purchase of consumption imbalance adjustments (up-regulation) from eSett	0	20	0
Imbalance purchases from eSett			900
Imbalance sales to eSett			-1 200
Total imbalance amount			*-300*
Production fee	80	0.2	16
Consumption fee	65	0.4	26
Imbalance fee	20	0.6	12
Weekly fee			50
Total fee amount			*104*
Total invoice amount			**-196.00**

In this example, the total amount which would be credited to the BRP is a bit lower than in the initial calculation example with separate production and consumption imbalances. Even with the new single pricing, the amount of purchased imbalance power doesn't change, because the price happens to be the same. A minor impact is due to the use of imbalance power instead of consumption imbalance power, as it raises the fee amount from 3 EUR to 12 EUR. The impact of the new 15 minutes settlement period hasn't been evaluated in the example.

Since the example is very constricted, it is reasonable to evaluate the effects with actual data of a BRP for one invoiced week. Figure 12 presents invoiced imbalance quantities and amounts of three BRPs. The data is from the actual invoices of the BRPs. On the right side next to the initial imbalance quantity and amount columns, there are calculated columns which represent the corresponding value if the imbalance quantity and amount would have been calculated according to the new model. The quantities and amounts have been calculated in a similar way as in the previous example but for each imbalance settlement period which is invoiced for the week. The actual calculation and data can be found from Appendix 1. The impact of 15 minutes imbalance settlement period hasn't been evaluated since there isn't suitable data for the evaluation, so hourly imbalance settlement period is used. Also, the impact due to change from consumption imbalance fee to imbalance fee is excluded from the calculations.

The use of the new model with single imbalance caused the total deficit of BRP 1 to decrease about 38 percent and the surplus to decrease about 19 percent. The amounts due to the imbalance sold to BRP and bought from BRP, decreased with nearly same rates. The deficit and surplus quantities of BRP 2 on the other hand increased approximately 30 percent, but the imbalance amount sold to BRP increased 24 percent and the amount bought from BRP

increased about 37 percent. With BRP 3 the quantities decreased about 24 percent (deficit) and 29 percent (surplus), while the respective imbalance amounts decreased with nearly same rates.

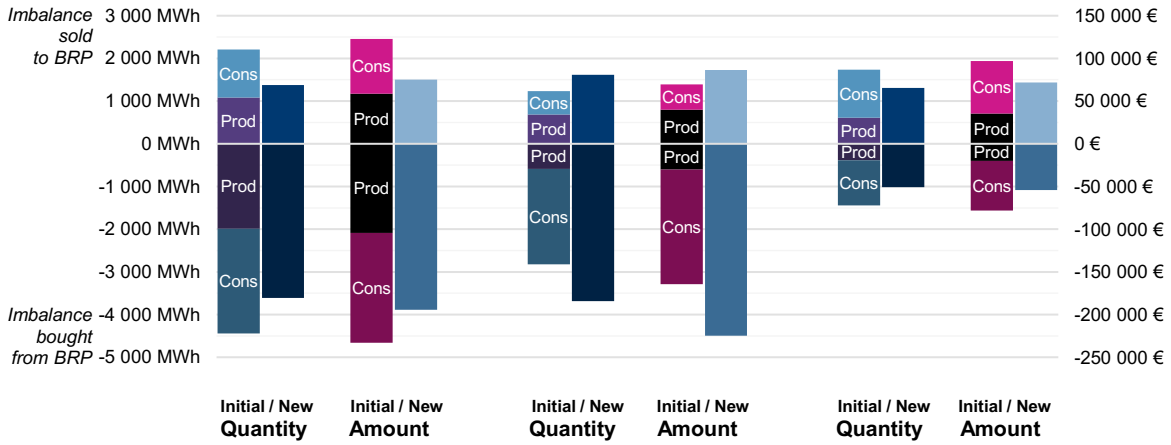

Figure 12 The impact of the new imbalance settlement model to the imbalance quantities and amounts of a week for three BRPs.

The sampling in Appendix 1 is still very constricted as there are over 150 BRPs and only three BRPs have been used in the example. Also, the evaluation of only one week is quite insufficient as the imbalance levels of a single BRP may fluctuate quite much in different weeks. However, with such a small sampling there were both increases and decreases that were over one third of the initial values, so it can be assumed that the imbalance levels may and will change due to the new imbalance settlement model.

5 Discussion and Conclusions

This chapter contains short analysis and discussion about the topics. First the requirements and changes to the Nordic imbalance settlement model are analyzed and concluded shortly in the findings chapter. Similar analysis and conclusion are done also for the imbalance settlement system and for the changes and requirements that it has to meet. Finally, there is some discussion about how eSett should proceed with the new requirements, what is important and what should be monitored and considered during the upcoming years.

5.1 Findings on Imbalance Settlement Models

One strong area with the new Nordic imbalance settlement model is its simplicity if compared to the current model. There is only one imbalance calculated for each BRP for each MBA instead of having separate imbalances for consumption and production. Also, the plans are left out from the calculations and only the realized values are considered in the imbalance calculations. The second strong factor is related to the 15 minutes imbalance settlement period which will enable more accurate activation of reserves, calculation of imbalances and pricing of both activated reserves and imbalance adjustments. The accuracy makes the model fairer for all parties.

However, the model also contains a weakness as it is very likely that not everything is immediately measured with 15 minutes imbalance settlement period. It is demonstrated in Figure 13 which presents the MGA imbalance calculation for a simple distribution area with MGA exchange and consumption. In the example, imported electricity is measured with 15-minute resolution. Two MGA imbalances are calculated, one where the consumption of the imported electricity is measured with 15-minute resolution and another with hourly resolution which is then split into 15-minute resolution. The measurement with 15-minute resolution allows consumption to follow the MGA exchange curve and the MGA imbalance is basically zero. If the measurement is done with hourly resolution and then split into 15-minute periods, it can't so accurately follow the import curve thus causing MGA imbalance.

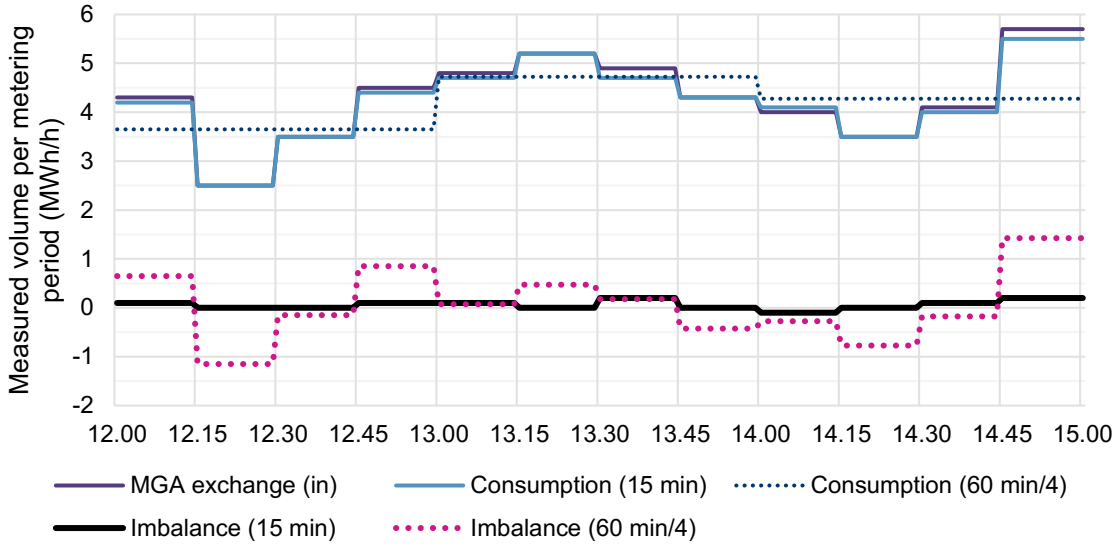

Figure 13 The impact on MGA imbalance if some data is metered with 15-minute resolution and other with hourly resolution.

The purpose of the MGA imbalance is to correct the possible flaws in metering, reporting or calculation of losses, so that the energy would be included into the imbalance settlement calculations. However, in many cases the BRP in which imbalance calculation the consumption ends up is different than the BRP which will deal with the MGA imbalance in its imbalance calculation. So, if the consumption was measured with hourly resolution, for the first 15 minutes imbalance settlement period in Figure 13, the BRP for consumption would have surplus as it doesn't consume all the imported energy and the BRP for MGA imbalance would have deficit due to the MGA imbalance.

The new model provides some opportunities also. For instance, as the imbalance settlement model should be very similar in European countries after the harmonization, it could enable a possibility for eSett to provide imbalance settlement services also outside the Nordic countries. In proportion it should lower the threshold for energy companies from outside the Nordic area to join the Nordic electricity markets. Another opportunity relates to the pricing and calculation of the imbalances. If the pricing and calculation of the imbalances of the new model prove to be successful, it should financially encourage the BRPs to support the balance of the electricity system.

With the new requirements and changes there arises also threats. One of them is leaving out the production plans from the imbalance settlement calculations. Since the production plans won't affect on the imbalances of the BRPs, they won't have anymore a financial incentive to keep the production plans updated. Having outdated or inaccurate production plans may threaten the balance of the electricity system.

Finally, the effect to the imbalance quantities and amounts of BRPs due to the new model hasn't been studied extensively. Chapter 4.7 Example of the New Settlement Calculation and Appendix 1. Single Imbalance Calculation Examples shortly introduced how the quantities and amounts behave with the new calculation and pricing, but not many conclusions can be made from them. However, with only three BRPs a great changes in the imbalance levels were identified for the examined week. There were both increases and decreases of more than one third of the initial imbalance level. It is safe to assume that quite major changes may be expected due to the change. The unawareness of the behavior in large scale may pose a threat if it turns out for example that the model doesn't support the BRPs to be in balance.

5.2 Findings on Imbalance Settlement System

The imbalance settlement system has multiple strong areas regarding the changes due to the requirements. For example, the system has been designed in way that the time resolution should be scalable, so an hourly resolution can be changed to 15 minutes resolution. The scaling is not entirely problem free approach, but the possibility makes the changes easier. Another strength of the system is that it calculates the production and consumption imbalances so there shouldn't be an issue in calculating the single imbalance in a similar way from the same input data. Also, many parts of the system will remain nearly intact as there won't be new incoming data flows or major changes in handling of structures and the impact on fees, invoicing and collateral parts of the imbalance settlement system is relatively small.

There is however a weakness in the system as it has to be designed in a way that it can support both old and new models in a way that at least the visibility to the old data will remain. Additionally, there will be a transition period where the reporting for the new model is ongoing while the imbalance settlement and financial settlement for the old model still needs to be done. These may prove to be difficult for the system.

The change also provides some opportunities with the imbalance settlement system. During great changes it is easier to update also other aspects. For example, the whole imbalance settlement platform could be updated to the newest version at the same time. Some sections can be redesigned if they operate incorrectly or in way that is unwanted or simply if ways to improve the section can be found. There is still time left to carefully plan and design the changes which can enable a smoother change.

The main threat is that the planned schedule or change fails in some country and the single imbalance model or 15 minutes imbalance settlement period or both would be launched at different times in different countries. It would require from the system a possibility to at least convert data between 15 minutes and hourly resolution, and in the worst case to run separate models in different countries. The amount of data also increases significantly due to the new imbalance settlement period and it increases the risk that the system will be unable to handle all the needed data. Finally, the more changes are made the higher the risk is that something goes wrong with the design or implementation, or that something which is needed, is by mistake left out of the scope of the change.

5.3 Future Preparations

Perhaps the first and foremost step in preparation process would be to identify all changes that will take place. Once the changes have been identified, it is possible to start to plan and design the new model as it will take time. During the same time, it would be important to identify the different threats related to the changes. It gives a possibility to consider and be prepared for those in the planning and designing. Possible other changes which are wanted to the imbalance settlement system should be considered and included to the planning and design phase.

While things are proceeding according to the planned timeline, it's also important to keep monitoring the international harmonizing process. It is possible that something will change from the draft proposals as the national regulators still need to approve the proposals. If changes will take place, they need to be evaluated and the possible impact considered in the designing process.

The testing of the system changes should be properly planned so that everything is covered by different test cases. All new features and changes should be carefully tested, and a special attention should be paid into the testing of transition period. If possible, the testing of alternative plans should be done in case some worst-case scenario is realized. eSett could also consider a possibility to allow market participants to test the changes in some test environment. It could allow the market participants to more easily adapt to the changes and provide to eSett some important experiences with the new model and the possible problems in the system.

During the upcoming years eSett should also monitor other large changes in the Nordic electricity markets. These include the progress of national datahubs, which of course need to be considered already in this change process. Other changes are for example the new roles; balance service provider and aggregator, which may need to be designed and implemented at some point. Finally, there is a considerable probability that Denmark would also join the common Nordic imbalance settlement at some point during the upcoming years. If it happens, it will likely require adaptation and resources from both sides.

References

Amundsen, E. S. & Bergman, L. 2006. *Why has the Nordic electricity market worked so well?*. Utilities Policy. Vol 14:3. P. 148-157. Available at: doi: 10.1016/j.jup.2006.01.001. ISSN 0957-1787.

Commission Regulation (EU) 2017/2195 (32017R2195). *Guideline on electricity balancing*. Official Journal of the European Union, L 312/6. 28.11.2017. Brussels, Belgium. Entered into force 18.12.2017. Available at: http://data.europa.eu/eli/reg/2017/2195/oj.

Eklund, M. 2017. *Aggregators and storage of the Nordic imbalance settlement model*. Master's thesis. Aalto University, School of Engineering. Espoo. 58 pages.

Electricity Act, 1997:857 including amendments up to 26.5.2015. Sweden. Available at: https://www.ei.se/Documents/Publikationer/lagar_pa_engelska/Electricity_Act_.pdf.

Electricity Market Act, 2013/588. Finland. Available (only in Finnish and Swedish) at: https://www.finlex.fi/fi/laki/ajantasa/2013/20130588.

Energy Act, LOV-1990-06-29-50. Norway. Available (only in Norwegian) at: https://lovdata.no/dokument/NL/lov/1990-06-29-50.

ENTSO-E. 2006. *Agreement regarding operation of the interconnected Nordic power system*. Agreeing parties: Energinet.dk, Fingrid Oyj, Statnett SF & Affärsverket Svenska kraftnät. [System operation agreement.] 13.6.2006. [Accessed on 25.1.2018.] Available at: https://www.entsoe.eu/Documents/Publications/SOC/Nordic/System_Operation_Agreement_2014.pdf.

ENTSO-E. 2016. *Nordic Balancing Philosophy*. Balancing rules and procedures guideline for Nordic TSOs. [Electronic document.] 16.6.2016. [Accessed on 1.2.2018.] Available at: https://www.svk.se/contentassets/bc60c82ceaec44c0b9ffbf3ee2126adf/nordic-balancing-philosophy-160616-final_external.pdf.

ENTSO-E 2018a. *Electricity Balancing*. Implementation projects, updates and events related to the Guideline on Electricity Balancing. [Web page.] Updated on May 2018. [Accessed on 4.6.2018.] Available at: https://electricity.network-codes.eu/network_codes/eb/.

ENTSO-E 2018b. *Notes of the informal workshop*. Imbalance settlement harmonization working group. [Electronic document.] 23.3.2018. [Accessed on 5.6.2018.] Available at: https://electricity.network-codes.eu/Documents/Events/2018/20180323-Workshop_imbalance_settlement-Summary.pdf.

ENTSO-E 2018c. *All TSOs' proposal to further specify and harmonise imbalance settlement in accordance with Article 52(2) of the Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing*. Imbalance settlement harmonization working group. [Electronic document.] 22.5.2018. [Accessed on 19.7.2018.] Available at: https://www.entsoe.eu/Documents/Network%20codes%20documents/NC%20EB/20180522-ISH_proposal-Draft_info.pdf.

Erbach, G. 2016. *Understanding electricity markets in the EU*. European Parliament briefing. [Electronic document.] 11.11.2016. [Accessed on 18.5.2018.] Available at: http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/593519/EPRS_BRI(2016)593519_EN.pdf.

eSett Oy. 2017. *Nordic Imbalance Settlement Handbook*. Instructions and Rules for Market Participants. [Electronic document.] 8.12.2017. [Accessed on 2.2.2018.] Available at: https://www.esett.com/handbook/.

European Parliament Regulation 714/2009 (32009R0714). *Conditions for access to the network for cross-border exchanges in electricity*. Official Journal of the European Union, L 211/15. 14.8.2009. Brussels, Belgium. Entered into force 3.9.2009. Available at: http://data.europa.eu/eli/reg/2009/714/oj.

Fosse, L. O. & Moe, A. & Joki-Pesola, M. & Christensen, H. & Winai, M. 2017. *Higher Time Resolution: Information to Stakeholders*. [Electronic document.] 16.11.2017. [Accessed on 12.6.2018.] Available at: https://www.svk.se/siteassets/om-oss/nyheter/svenska-kraftnat-initierar-tillsammans-med-de-ovriga-nordiska-tsoerna-projekt-med-malsattning-att-infora-15-minuters-avrakningsperiod/nordic-higher-time-resolution----information-to-stakeholders-2017-11-16.pdf.

Kristiansen, T. 2017. *Fundamental indexation: An application to the Nordic wholesale electricity market*. Energy Strategy Reviews. Vol 17. P. 1-5. Available at: doi: 10.1016/j.esr.2017.05.001. ISSN: 2211-467X.

Ma, Z. & Prljaca, Z. & Jørgensen, B. N. 2016. *The international electricity market infrastructure-insight from the nordic electricity market*. In: 13th International Conference on the European Energy Market. [Conference paper.] Porto, Portugal. 6-9.6.2016. P. 1-5. Available at: doi: 10.1109/EEM.2016.7521314. ISSN: 2165-4093.

Makkonen, M. & Viljainen, S. 2012. *Costs of insufficient transmission network investments – Case: The Nordic electricity market*. In: 9th International Conference on the European Energy Market. [Conference paper.] Florence, Italy. 10-12.5.2012. P. 1-8. Available at: doi: 10.1109/EEM.2012.6254742. ISSN: 2165-4093.

Mauritzen, J. 2013. *Dead Battery? Wind Power, the Spot Market, and Hydropower Interaction in the Nordic Electricity Market*. The Energy Journal. Vol 34:1. P. 103-124. Available at doi: 10.5547/01956574.34.1.5. ISSN: 1944-9089.

Nordic Council of Ministers. 2017. *Nordic data hubs in electricity system: Differences and similarities*. Copenhagen: Nordic Council of Ministers. 51 pages. ISBN 978-92-893-5323-6 (pdf). Available at: http://www.nordicenergy.org/wp-content/uploads/2017/12/Nordic-Data-Hubs-in-Electricity-System-1.pdf.

Nordic settlement working group. 2018. *Minutes of a meetings*. Involved parties: eSett Oy, Affärsverket Svenska kraftnät, Energinet.dk, Fingrid Oyj & Statnett SF. Meetings 1/2018 - 7/2018.

Pöyry Management Consulting Oy. 2018. *15 Minutes Imbalance Settlement Period – Market Impacts of Late Implementation*. [Report.] 15.6.2018. [Accessed on 2.7.2018.] Available at: https://www.fingrid.fi/globalassets/dokumentit/fi/sahkomarkkinat/varttitase/final_15_min_isp_derogation_report_poyry.pdf.

Sandborgh, U. & Andreasen, P. & Ruusunen, J. & Kahlroth, J. & Rue, Ø. 2018. *Nordic balancing cooperation*. Agreeing parties: Affärsverket Svenska kraftnät, Energinet.dk, Fingrid Oyj, Kraftnät Åland Ab & Statnett SF. [Cooperation Agreement.] 8.3.2018. [Accessed on 8.6.2018.] Available at: https://en.energinet.dk/-/media/94DA9CE2EEE347F28D9B8D1B5DB656C3.pdf.

Schmitt, L. 2018. *European electricity markets*. Fingrid Magazine. 6.3.2018. [Accessed on 18.5.2018.] Available at: https://www.fingridlehti.fi/en/european-electricity-markets-en-translation/.

Statnett SF. 2018. *State of the Nordic Power System Map*. Interactive map with Nordic day-ahead market prices and energy flows. [Accessed on 26.2.2018.] Available at: http://statnett.no/en/Market-and-operations/Data-from-the-power-system/Nordic-power-flow/.

Uusitalo, J. 2018. *Guideline on Electricity Balancing presentation*. Meeting with development manager of Fingrid Oyj. [Meeting presentation.] 16.1.2018.

van der Veen, R. A. C. & Hakvoort, R. A. 2009. *Balance responsibility and imbalance settlement in Northern Europe – An evaluation*. In: 6th International Conference on the European Energy Market. [Conference paper.] Leuven, Belgium. 27-29.5.2009. P. 1-6. Available at: doi: 10.1109/EEM.2009.5207168. ISBN: 978-142444455-7.

Xu, Z. & Østergaard, J. & Togeby, M. & Isleifsson, F. R. 2008. *Evaluating frequency quality of Nordic system using PMU data*. In: 2008 IEEE Power and Energy Society General Meeting - Conversion and Delivery of Electrical Energy in the 21st Century. [Conference paper.] Pittsburgh, Pennsylvania, USA. 20-24.7.2008. P. 1-5. Available at: doi: 10.1109/PES.2008.4596468. ISSN: 1932-5517

List of Appendixes

Appendix 1. Single Imbalance Calculation Examples

Appendix 1 presents the tables which include the initial consumption and production imbalance quantities and amounts as well as the quantities and amounts with the single imbalance calculation. Hourly imbalance settlement period is used in the single imbalance calculation. The data contains the hourly values for one week and the calculation has been done for three BRPs, which are simply referred as BRP 1, BRP 2 and BRP 3. The price which has been used in the single imbalance calculation is the price of the imbalance to the main direction. Dual pricing has not been applied to any hour. All volumes have been rounded to three digits and amounts to two digits to improve the readability of the tables.

In tables 3-5 there are sum rows of imbalance purchases and sells for each imbalance type for the week. Those contain the aggregations of quantities and amounts. The production and consumption imbalance totals were invoiced from the BRPs and the single imbalances show alternative results for the new imbalance model calculations. An exception is that the 15 minutes imbalance settlement period wasn't used and the impact on fees isn't evaluated in these calculations. A graphical summary of the results is presented in Figure 12.

Appendix table 1 Imbalance prices to main direction which are applied for single imbalance calculation of BRP 1 and BRP 2.

	D1	D2	D3	D4	D5	D6	D7
00-01	47,53	50,27	54,81	54,20	51,52	51,99	52,60
01-02	47,53	49,10	54,81	54,20	50,23	45,90	51,14
02-03	47,90	44,83	47,90	53,15	49,64	45,90	50,29
03-04	47,72	44,83	46,28	49,70	48,12	45,90	49,89
04-05	43,30	42,19	42,06	41,39	46,42	43,82	47,00
05-06	44,36	38,40	47,88	45,70	49,18	43,82	44,79
06-07	48,30	46,90	50,14	51,05	52,47	44,86	44,79
07-08	50,17	49,05	53,47	54,09	59,85	46,90	44,79
08-09	66,00	50,00	61,00	56,96	62,51	56,90	52,46
09-10	66,00	59,19	54,12	57,01	62,81	58,42	48,96
10-11	66,00	59,97	56,11	58,03	59,90	58,42	55,00
11-12	66,00	60,59	56,08	58,29	59,26	58,42	55,00
12-13	63,56	66,00	77,00	62,12	149,00	58,42	53,16
13-14	61,97	62,00	80,00	60,69	99,00	57,38	52,96
14-15	51,23	58,98	99,00	58,08	90,00	57,38	48,44
15-16	51,23	57,11	99,00	57,07	61,27	56,90	47,39
16-17	84,00	90,00	99,00	56,84	59,98	56,34	47,39
17-18	51,23	80,00	99,00	56,24	60,21	58,42	47,39
18-19	52,00	63,00	84,00	57,10	58,50	59,99	47,39
19-20	57,96	50,00	50,60	57,96	57,93	59,99	51,04
20-21	55,96	57,00	54,10	56,57	57,44	59,99	52,70
21-22	57,00	56,54	55,80	55,05	57,44	59,99	53,12
22-23	57,00	56,30	56,00	54,35	54,67	58,94	56,24
23-00	56,51	54,32	56,00	51,90	47,52	57,38	48,96

Appendix table 2 Imbalance prices to main direction which are applied for single imbalance calculation of BRP 3.

	D1	D2	D3	D4	D5	D6	D7
00-01	52,00	48,37	47,24	52,50	51,33	52,71	51,05
01-02	52,70	47,68	51,60	49,50	50,29	52,71	49,22
02-03	52,90	46,65	50,20	49,09	49,84	52,71	48,03
03-04	48,00	45,70	50,20	49,03	49,07	52,71	46,85
04-05	45,00	39,33	50,50	48,63	48,43	47,20	46,05
05-06	44,20	39,40	46,71	49,60	49,92	48,23	48,02
06-07	44,30	45,18	47,77	51,05	52,44	49,66	48,93
07-08	46,07	47,31	55,07	55,81	57,00	50,37	45,94
08-09	46,07	47,70	57,51	52,70	53,88	52,51	46,00
09-10	47,00	47,84	57,75	75,00	65,56	56,00	47,00
10-11	46,07	48,00	60,21	134,00	63,07	56,00	52,34
11-12	46,07	48,00	57,75	280,00	63,09	55,87	52,37
12-13	46,07	48,00	57,65	119,00	63,03	55,87	47,00
13-14	46,60	49,43	56,81	53,00	61,97	55,87	47,00
14-15	46,60	49,43	57,70	56,10	59,25	53,30	47,00
15-16	46,80	49,43	58,67	56,39	57,36	53,00	47,00
16-17	46,60	54,37	68,00	55,20	55,20	51,20	47,00
17-18	46,60	56,00	68,00	55,44	51,24	51,69	52,47
18-19	47,13	57,05	58,80	50,81	52,71	53,45	53,10
19-20	53,06	57,38	58,60	50,81	56,57	54,32	54,25
20-21	52,73	56,08	55,83	50,81	49,13	55,00	54,61
21-22	51,94	50,00	55,73	52,93	49,13	54,22	54,87
22-23	54,00	49,43	55,73	52,93	50,00	55,01	55,03
23-00	50,80	47,31	53,10	51,16	50,18	49,02	53,26

Appendix table 3 Imbalance volumes and amounts for BRP 1.

Period	Consumption Imbalance [MWh]	Consumption Imbalance Amount [EUR]	Production Imbalance [MWh]	Production Imbalance Amount [EUR]	Single Imbalance [MWh]	Single Imbalance Amount [EUR]
D1 00-01	-15,930	-757,16	-12,888	-612,59	-28,819	-1369,75
D1 01-02	-44,146	-2098,26	5,026	246,30	-39,120	-1859,40
D1 02-03	-33,905	-1624,03	9,375	449,08	-24,529	-1174,95
D1 03-04	-38,701	-1846,83	11,163	532,70	-27,538	-1314,13
D1 04-05	-35,684	-1545,11	-26,414	-1143,73	-62,098	-2688,85
D1 05-06	-26,176	-1161,17	-31,738	-1407,90	-57,914	-2569,07
D1 06-07	-16,219	-783,38	6,609	350,62	-9,610	-464,15
D1 07-08	-6,430	-322,60	-19,001	-953,30	-25,432	-1275,90
D1 08-09	9,546	630,02	-10,219	-606,72	-0,673	-44,45
D1 09-10	-19,145	-1263,56	0,820	54,14	-18,325	-1209,42
D1 10-11	4,512	297,82	9,329	615,71	13,841	913,53
D1 11-12	11,218	740,40	9,650	636,89	20,868	1377,29
D1 12-13	28,743	1826,90	-0,071	-4,49	28,672	1822,40
D1 13-14	-0,258	-16,01	-12,214	-756,88	-12,472	-772,89
D1 14-15	6,531	334,61	-16,532	-846,96	-10,001	-512,35
D1 15-16	6,804	348,58	-46,062	-2359,76	-39,258	-2011,18
D1 16-17	-4,007	-336,61	18,742	1574,33	14,735	1237,72
D1 17-18	-10,519	-538,89	-10,765	-551,50	-21,284	-1090,38
D1 18-19	-12,898	-670,68	10,601	614,03	-2,296	-119,41
D1 19-20	-8,613	-499,21	-2,955	-171,26	-11,568	-670,48
D1 20-21	-4,667	-261,19	-6,809	-381,03	-11,476	-642,21
D1 21-22	-1,778	-101,37	-2,371	-131,72	-4,150	-236,53
D1 22-23	-11,694	-666,55	-8,565	-466,69	-20,259	-1154,74
D1 23-00	-16,531	-934,18	-7,138	-370,06	-23,670	-1337,58

D2 00-01	-44,548	-2239,42	-17,549	-882,21	-62,097	-3121,63
D2 01-02	-15,809	-776,21	-11,401	-559,79	-27,210	-1336,00
D2 02-03	-89,244	-4000,79	36,597	1757,77	-52,646	-2360,13
D2 03-04	-42,808	-1919,10	-13,002	-582,90	-55,811	-2501,99
D2 04-05	4,858	204,97	-15,360	-648,03	-10,501	-443,05
D2 05-06	-15,423	-592,25	-22,519	-864,71	-37,942	-1456,97
D2 06-07	5,239	245,71	-21,530	-1009,77	-16,291	-764,07
D2 07-08	13,173	646,12	8,736	489,85	21,909	1074,64
D2 08-09	15,477	773,87	-5,665	-283,23	9,813	490,64
D2 09-10	0,930	55,04	12,866	761,56	13,796	816,61
D2 10-11	-1,833	-109,90	-25,986	-1558,38	-27,819	-1668,28
D2 11-12	4,715	285,71	4,653	281,94	9,369	567,65
D2 12-13	13,473	889,23	-7,249	-447,29	6,224	410,77
D2 13-14	13,009	806,53	-31,384	-1945,79	-18,375	-1139,25
D2 14-15	-10,116	-596,63	-31,583	-1862,78	-41,699	-2459,40
D2 15-16	20,167	1151,73	-4,343	-248,04	15,824	903,70
D2 16-17	28,474	2562,70	-21,295	-1146,95	7,179	646,15
D2 17-18	17,453	1396,28	2,008	160,62	19,461	1556,90
D2 18-19	4,775	300,82	-17,101	-960,73	-12,326	-776,54
D2 19-20	-0,655	-32,74	32,078	1846,71	31,423	1571,14
D2 20-21	3,751	213,83	-26,875	-1493,43	-23,123	-1318,04
D2 21-22	-9,588	-542,13	-13,827	-744,99	-23,415	-1323,90
D2 22-23	-12,326	-693,96	-21,751	-1161,73	-34,077	-1918,55
D2 23-00	-60,530	-3287,97	-38,303	-1965,71	-98,833	-5368,59
D3 00-01	-52,849	-2896,63	-50,248	-2506,35	-103,096	-5650,70
D3 01-02	-38,846	-2129,16	-34,837	-1674,28	-73,684	-4038,60
D3 02-03	-74,818	-3583,80	-20,951	-1003,56	-95,769	-4587,36
D3 03-04	-76,527	-3541,69	-4,866	-225,22	-81,394	-3766,90
D3 04-05	-89,644	-3770,44	-4,099	-172,42	-93,744	-3942,87
D3 05-06	-77,347	-3703,37	7,362	352,51	-69,984	-3350,85
D3 06-07	-54,507	-2732,97	8,746	438,51	-45,761	-2294,46
D3 07-08	0,664	35,53	34,833	1862,52	35,497	1898,05
D3 08-09	5,229	318,95	67,795	4135,52	73,024	4454,47
D3 09-10	60,106	3252,93	-71,859	-3889,02	-11,753	-636,09
D3 10-11	-22,330	-1252,94	-21,232	-1191,30	-43,562	-2444,24
D3 11-12	-49,587	-2780,86	-6,833	-383,20	-56,420	-3164,05
D3 12-13	-43,242	-3329,61	-14,420	-797,87	-57,662	-4439,97
D3 13-14	-23,039	-1843,16	-6,604	-354,09	-29,643	-2371,45
D3 14-15	1,609	159,27	-9,823	-525,71	-8,214	-813,18
D3 15-16	16,540	1637,45	-10,389	-554,45	6,151	608,96
D3 16-17	17,192	1701,97	-23,030	-1225,87	-5,838	-577,97
D3 17-18	-0,530	-52,50	-18,457	-990,79	-18,988	-1879,77
D3 18-19	-16,805	-1411,64	-19,964	-1081,67	-36,770	-3088,65
D3 19-20	-27,074	-1369,94	0,455	24,69	-26,619	-1346,94
D3 20-21	-17,016	-920,54	95,016	5140,39	78,001	4219,84
D3 21-22	-3,858	-215,28	-17,419	-935,73	-21,277	-1187,24
D3 22-23	-18,782	-1051,79	-33,768	-1780,60	-52,550	-2942,81
D3 23-00	-33,283	-1863,84	-4,734	-236,13	-38,017	-2128,94
D4 00-01	-20,534	-1112,96	-28,302	-1422,20	-48,837	-2646,95
D4 01-02	-13,079	-708,90	8,394	454,98	-4,685	-253,93
D4 02-03	5,291	281,20	-3,924	-186,26	1,367	72,65
D4 03-04	22,884	1137,33	27,906	1386,93	50,790	2524,26
D4 04-05	84,302	3489,26	52,024	2153,28	136,326	5642,54
D4 05-06	33,761	1542,89	54,011	2495,86	87,772	4011,20
D4 06-07	18,226	930,45	30,240	1543,76	48,467	2474,22
D4 07-08	25,643	1387,04	18,415	996,05	44,058	2383,09
D4 08-09	27,053	1540,97	5,513	314,03	32,567	1855,00
D4 09-10	14,619	833,44	-11,636	-663,39	2,983	170,05
D4 10-11	32,576	1890,40	-10,780	-625,57	21,796	1264,82
D4 11-12	27,090	1579,06	-2,352	-137,11	24,738	1441,96
D4 12-13	32,069	1992,14	-13,019	-808,71	19,051	1183,43
D4 13-14	9,050	549,24	-7,243	-439,56	1,807	109,68
D4 14-15	17,097	992,97	-6,381	-370,60	10,716	622,37
D4 15-16	-31,978	-1825,01	-24,716	-1410,54	-56,694	-3235,55
D4 16-17	21,656	1230,94	-1,804	-102,56	19,852	1128,38
D4 17-18	13,688	769,82	26,186	1472,73	39,875	2242,55
D4 18-19	-3,310	-189,02	-2,599	-148,41	-5,909	-337,43
D4 19-20	-20,854	-1208,73	-29,692	-1720,92	-50,546	-2929,65
D4 20-21	-14,165	-801,34	17,896	1012,40	3,731	211,06
D4 21-22	-11,255	-619,57	3,904	214,90	-7,351	-404,67
D4 22-23	-26,087	-1417,81	4,331	235,40	-21,755	-1182,41
D4 23-00	-21,913	-1137,28	-26,425	-1371,44	-48,338	-2508,72
D5 00-01	-15,534	-800,31	-15,912	-819,77	-31,446	-1620,08
D5 01-02	-3,404	-170,96	4,751	238,65	1,347	67,68

D5 02-03	6,287	312,10	-28,887	-1433,95	-22,600	-1121,85
D5 03-04	64,305	3094,35	-42,058	-2023,82	22,247	1070,53
D5 04-05	-53,197	-2469,42	-24,156	-1121,32	-77,353	-3590,74
D5 05-06	-44,473	-2187,21	17,332	852,41	-27,141	-1334,80
D5 06-07	-38,828	-2037,29	44,030	2310,26	5,202	272,97
D5 07-08	-8,404	-502,99	51,416	3077,28	43,012	2574,28
D5 08-09	11,590	724,48	10,757	672,40	22,347	1396,89
D5 09-10	2,039	128,08	-23,936	-1503,39	-21,896	-1375,32
D5 10-11	11,880	711,59	-43,967	-2633,61	-32,087	-1922,02
D5 11-12	15,670	928,63	-15,684	-929,41	-0,013	-0,78
D5 12-13	4,938	735,74	-6,191	-394,93	-1,253	-186,74
D5 13-14	4,799	475,12	-16,410	-1065,17	-11,611	-1149,47
D5 14-15	-30,299	-2726,92	-17,786	-1132,41	-48,085	-4327,62
D5 15-16	-30,857	-1890,60	-15,515	-950,60	-46,372	-2841,20
D5 16-17	-20,874	-1252,03	-2,766	-165,88	-23,640	-1417,91
D5 17-18	-18,439	-1110,21	-14,097	-848,79	-32,536	-1959,00
D5 18-19	-40,832	-2388,67	-5,234	-306,22	-46,066	-2694,88
D5 19-20	-25,609	-1483,53	-14,692	-851,11	-40,301	-2334,65
D5 20-21	-17,117	-983,19	-22,441	-1270,39	-39,558	-2272,20
D5 21-22	9,901	568,74	-17,069	-945,29	-7,168	-411,71
D5 22-23	12,844	702,16	36,408	1990,44	49,252	2692,60
D5 23-00	-0,703	-33,42	35,685	1875,96	34,982	1662,33
D6 00-01	72,820	3785,92	-34,806	-1809,54	38,015	1976,38
D6 01-02	8,067	370,27	-52,828	-2424,80	-44,761	-2054,53
D6 02-03	10,481	481,07	-5,807	-266,56	4,673	214,51
D6 03-04	20,301	931,84	-26,523	-1217,40	-6,221	-285,57
D6 04-05	13,058	572,22	-31,374	-1374,82	-18,316	-802,61
D6 05-06	26,678	1169,04	-39,919	-1749,23	-13,240	-580,19
D6 06-07	15,532	696,75	-1,692	-75,92	13,839	620,83
D6 07-08	7,363	345,35	-2,980	-139,75	4,384	205,60
D6 08-09	23,760	1351,92	92,964	5289,66	116,724	6641,58
D6 09-10	5,734	334,96	-10,930	-601,61	-5,197	-303,60
D6 10-11	-1,695	-99,00	-6,336	-349,02	-8,030	-469,12
D6 11-12	-3,418	-199,67	-3,581	-197,58	-6,998	-408,85
D6 12-13	-3,821	-223,22	-15,097	-826,11	-18,918	-1105,19
D6 13-14	-4,064	-233,17	-17,988	-967,38	-22,051	-1265,31
D6 14-15	4,319	247,82	-10,337	-550,53	-6,018	-345,30
D6 15-16	16,821	957,09	-15,547	-822,15	1,273	72,44
D6 16-17	16,837	948,58	-9,608	-506,61	7,229	407,29
D6 17-18	6,603	385,78	-9,809	-524,10	-3,206	-187,27
D6 18-19	2,192	131,51	2,408	144,44	4,600	275,95
D6 19-20	-4,347	-260,78	10,140	608,32	5,793	347,54
D6 20-21	2,789	167,29	13,193	791,46	15,982	958,74
D6 21-22	-19,485	-1168,93	-9,867	-539,55	-29,353	-1760,88
D6 22-23	-20,415	-1203,24	8,430	496,86	-11,985	-706,38
D6 23-00	1,080	61,99	5,989	343,67	7,070	405,66
D7 00-01	15,890	835,83	-15,326	-806,17	0,564	29,66
D7 01-02	15,178	776,20	11,435	584,77	26,613	1360,97
D7 02-03	-43,426	-2183,88	-5,921	-297,76	-49,347	-2481,64
D7 03-04	-22,524	-1123,71	-15,194	-758,05	-37,718	-1881,76
D7 04-05	-33,476	-1573,37	21,032	1015,44	-12,444	-584,86
D7 05-06	-58,161	-2605,01	-10,894	-487,94	-69,055	-3092,95
D7 06-07	-28,923	-1295,47	-3,020	-135,26	-31,943	-1430,74
D7 07-08	-34,535	-1546,84	25,129	1292,61	-9,407	-421,33
D7 08-09	-35,979	-1887,45	21,950	1151,50	-14,029	-735,95
D7 09-10	-38,741	-1896,74	9,869	521,87	-28,872	-1413,55
D7 10-11	-19,635	-1079,92	-2,847	-152,26	-22,482	-1236,53
D7 11-12	-20,782	-1143,02	-30,198	-1621,94	-50,980	-2803,92
D7 12-13	-12,054	-640,80	12,098	643,11	0,044	2,32
D7 13-14	-32,171	-1703,80	-34,267	-1814,80	-66,439	-3518,60
D7 14-15	-22,829	-1105,85	-8,026	-388,77	-30,855	-1494,62
D7 15-16	-13,997	-663,33	-12,559	-595,16	-26,556	-1258,49
D7 16-17	-6,755	-320,13	-22,581	-1070,14	-29,337	-1390,27
D7 17-18	0,755	35,78	-6,606	-313,07	-5,851	-277,29
D7 18-19	-8,396	-397,88	4,002	212,65	-4,394	-208,23
D7 19-20	-34,169	-1743,98	-8,635	-440,74	-42,804	-2184,72
D7 20-21	-35,078	-1848,61	-2,408	-126,92	-37,486	-1975,53
D7 21-22	-23,977	-1273,64	-15,464	-821,44	-39,441	-2095,08
D7 22-23	-4,506	-253,42	-22,550	-1268,20	-27,056	-1521,62
D7 23-00	-20,868	-1021,70	-39,953	-1956,10	-60,821	-2977,81
Total Purchase	**-2450,240**	**-128421,98**	**-1991,151**	**-104460,02**	**-3608,254**	**-194447,79**
Total Sell	**1129,707**	**63932,32**	**1080,303**	**58720,47**	**1376,873**	**75164,47**

Appendix table 4 Imbalance volumes and amounts for BRP 2.

Period	Consumption Imbalance [MWh]	Consumption Imbalance Amount [EUR]	Production Imbalance [MWh]	Production Imbalance Amount [EUR]	Single Imbalance [MWh]	Single Imbalance Amount [EUR]
D1 00-01	-8,445	-401,41	10,304	526,64	20,319	965,77
D1 01-02	2,035	96,71	6,955	340,85	22,216	1055,94
D1 02-03	-3,023	-144,79	3,970	190,15	13,345	639,20
D1 03-04	-2,654	-126,63	-0,605	-28,88	11,725	559,53
D1 04-05	-24,032	-1040,57	1,968	93,57	-10,480	-453,80
D1 05-06	-18,833	-835,42	-8,316	-368,91	-24,568	-1089,84
D1 06-07	34,857	1683,58	11,716	621,53	49,272	2379,83
D1 07-08	19,543	980,46	9,002	507,91	23,494	1178,69
D1 08-09	3,237	213,64	21,462	1416,48	48,243	3184,02
D1 09-10	-8,763	-578,37	6,169	407,19	26,466	1746,75
D1 10-11	14,306	944,20	12,503	825,19	47,161	3112,65
D1 11-12	8,073	532,79	15,782	1041,64	45,819	3024,03
D1 12-13	5,177	329,03	-0,696	-44,24	37,394	2376,75
D1 13-14	19,214	1190,66	-18,249	-1130,87	37,280	2310,21
D1 14-15	9,587	491,15	-29,052	-1488,34	17,726	908,10
D1 15-16	25,472	1304,92	-23,914	-1225,12	30,388	1556,79
D1 16-17	14,031	1178,62	-15,946	-923,74	-16,652	-1398,79
D1 17-18	-5,142	-263,43	3,357	192,54	-19,116	-979,34
D1 18-19	-2,164	-112,54	9,233	534,78	-21,857	-1136,58
D1 19-20	1,750	101,41	10,467	606,69	-13,143	-761,76
D1 20-21	6,931	387,85	11,372	636,39	-17,912	-1002,34
D1 21-22	16,052	914,98	25,703	1465,08	-11,367	-647,90
D1 22-23	27,645	1575,75	31,378	1788,57	14,292	814,62
D1 23-00	11,521	651,07	7,117	402,18	-22,604	-1277,34
D2 00-01	-17,338	-871,56	8,187	411,54	-4,776	-240,11
D2 01-02	0,973	47,78	2,231	109,56	17,858	876,83
D2 02-03	5,900	264,51	-0,852	-38,19	18,192	815,53
D2 03-04	10,971	491,82	-9,151	-410,25	12,913	578,87
D2 04-05	-11,076	-467,28	-16,841	-710,54	-5,069	-213,85
D2 05-06	2,128	81,72	-12,907	-495,62	7,946	305,14
D2 06-07	4,959	232,59	-13,523	-634,21	-14,800	-694,13
D2 07-08	-39,493	-1937,15	7,471	418,92	-18,955	-929,72
D2 08-09	-89,779	-4488,93	-2,864	-143,21	-91,038	-4551,89
D2 09-10	-17,901	-1059,55	-0,367	-21,70	-19,263	-1140,19
D2 10-11	-33,791	-2026,44	-12,076	-724,20	-40,458	-2426,29
D2 11-12	-18,323	-1110,19	0,621	37,60	-12,871	-779,84
D2 12-13	1,259	83,07	-1,955	-120,62	5,533	365,20
D2 13-14	-8,772	-543,84	-8,150	-505,30	-10,290	-637,99
D2 14-15	0,387	22,81	-1,106	-65,21	0,496	29,27
D2 15-16	-55,753	-3184,06	0,964	55,05	-63,882	-3648,30
D2 16-17	-38,691	-3482,22	13,057	1175,17	-45,389	-4084,98
D2 17-18	-29,142	-2331,37	11,783	942,61	-37,936	-3034,90
D2 18-19	4,292	270,40	22,878	1441,32	-0,018	-1,12
D2 19-20	-0,224	-11,20	19,523	1123,95	-1,307	-65,36
D2 20-21	-36,953	-2106,33	21,809	1243,14	-25,336	-1444,15
D2 21-22	-15,751	-890,56	5,770	326,24	-61,373	-3470,02
D2 22-23	-16,420	-924,47	6,995	393,81	-36,153	-2035,42
D2 23-00	-11,068	-601,22	21,040	1142,92	-26,674	-1448,93
D3 00-01	-36,286	-1988,81	10,662	584,36	-58,785	-3222,00
D3 01-02	-17,337	-950,23	5,313	291,20	-43,584	-2388,84
D3 02-03	-14,148	-677,68	-1,111	-53,22	-37,559	-1799,06
D3 03-04	-1,055	-48,84	2,755	127,52	-18,478	-855,15
D3 04-05	-13,932	-585,99	2,479	104,25	-35,446	-1490,86
D3 05-06	-27,775	-1329,88	4,964	237,67	-52,234	-2500,98
D3 06-07	-22,811	-1143,74	0,633	31,75	-77,564	-3889,05
D3 07-08	-24,129	-1290,18	-3,393	-181,44	-119,738	-6402,38
D3 08-09	-46,692	-2848,18	-28,851	-1604,99	-113,231	-6907,12
D3 09-10	-46,313	-2506,44	-5,485	-296,87	-119,337	-6458,50
D3 10-11	-68,349	-3835,04	-18,628	-1045,19	-136,830	-7677,56
D3 11-12	-28,847	-1617,76	-11,362	-637,20	-86,818	-4868,75
D3 12-13	8,357	643,49	2,621	201,81	-14,837	-1142,44
D3 13-14	-20,282	-1622,56	-0,492	-26,38	-61,364	-4909,09
D3 14-15	-0,694	-68,74	-6,200	-331,85	-14,151	-1400,93
D3 15-16	-11,339	-1122,57	-14,462	-771,85	-19,366	-1917,20
D3 16-17	-29,722	-2942,48	-14,492	-771,42	-28,566	-2828,04
D3 17-18	-24,173	-2393,17	-0,811	-43,54	-34,924	-3457,50
D3 18-19	-4,755	-399,42	-2,462	-133,38	-19,916	-1672,94
D3 19-20	12,882	651,85	-11,269	-570,23	-16,621	-841,04

D3 20-21	-5,321	-287,87	-4,827	-261,15	-63,235	-3421,01
D3 21-22	-3,627	-202,37	-6,258	-336,20	-56,959	-3178,30
D3 22-23	-8,679	-486,05	-15,471	-815,78	-52,317	-2929,74
D3 23-00	9,396	526,20	-5,094	-254,09	-25,579	-1432,41
D4 00-01	3,211	174,04	-11,185	-562,05	-34,006	-1843,11
D4 01-02	-9,286	-503,28	-17,345	-850,78	-43,516	-2358,56
D4 02-03	-26,005	-1382,18	-13,227	-627,91	-54,080	-2874,37
D4 03-04	0,407	20,21	-10,308	-433,23	-7,232	-359,45
D4 04-05	7,593	314,26	-6,573	-272,05	7,311	302,59
D4 05-06	-21,742	-993,62	-11,866	-542,29	-17,877	-816,96
D4 06-07	-36,103	-1843,06	-6,840	-349,16	5,109	260,81
D4 07-08	-55,054	-2977,89	-23,519	-1272,14	-33,590	-1816,90
D4 08-09	-47,738	-2719,13	14,713	838,07	-48,332	-2752,98
D4 09-10	47,043	2681,90	31,361	1787,90	98,181	5597,29
D4 10-11	10,217	592,86	-6,940	-402,72	-20,158	-1169,77
D4 11-12	-35,369	-2061,66	-1,831	-106,74	-79,460	-4631,72
D4 12-13	-73,662	-4575,86	6,727	417,86	-91,108	-5659,62
D4 13-14	-81,670	-4956,55	12,289	745,81	-104,776	-6358,84
D4 14-15	-25,260	-1467,10	9,338	542,35	-59,504	-3456,02
D4 15-16	-11,216	-640,07	9,295	530,47	-34,488	-1968,23
D4 16-17	-17,652	-1003,34	-17,591	-999,87	-80,021	-4548,40
D4 17-18	-20,709	-1164,69	8,309	467,28	-55,224	-3105,82
D4 18-19	-12,382	-706,99	0,573	32,71	-38,483	-2197,37
D4 19-20	-57,649	-3341,33	0,460	26,65	-71,626	-4151,46
D4 20-21	-21,436	-1212,64	-2,953	-167,02	-29,837	-1687,87
D4 21-22	-5,806	-319,65	-0,410	-22,59	5,418	298,23
D4 22-23	-8,133	-442,00	-3,144	-170,86	13,395	728,04
D4 23-00	11,291	585,98	-4,044	-209,87	34,382	1784,44
D5 00-01	-2,580	-132,92	-0,591	-30,45	5,902	304,06
D5 01-02	-13,574	-681,84	-0,181	-9,07	-5,905	-296,61
D5 02-03	-16,773	-832,60	-4,289	-212,91	-12,897	-640,19
D5 03-04	-6,862	-330,19	-10,813	-520,32	-1,575	-75,78
D5 04-05	-7,807	-362,41	-9,050	-420,09	-6,264	-290,78
D5 05-06	-11,765	-578,62	-9,163	-450,64	-11,294	-555,44
D5 06-07	-16,673	-874,81	-11,099	-582,36	-20,579	-1079,77
D5 07-08	-15,097	-903,57	-4,884	-292,29	-24,274	-1452,77
D5 08-09	-4,372	-273,31	-0,474	-29,62	-51,089	-3193,57
D5 09-10	-17,724	-1113,23	-2,452	-154,03	-65,627	-4122,05
D5 10-11	-13,858	-830,09	-0,049	-2,96	-57,222	-3427,59
D5 11-12	-17,620	-1044,18	9,389	556,37	-51,922	-3076,88
D5 12-13	-29,347	-4372,65	-2,380	-151,85	-67,486	-10055,38
D5 13-14	-41,730	-4131,31	-4,920	-319,39	-71,187	-7047,47
D5 14-15	-22,545	-2029,07	5,724	515,17	-19,979	-1798,13
D5 15-16	0,362	22,20	7,481	458,37	8,320	509,78
D5 16-17	3,865	231,85	2,984	178,97	4,124	247,35
D5 17-18	-11,640	-700,83	-1,536	-92,48	-10,226	-615,71
D5 18-19	-1,103	-64,54	1,660	97,08	17,150	1003,26
D5 19-20	-8,922	-516,88	5,232	303,09	4,635	268,52
D5 20-21	-15,522	-891,60	0,996	57,23	-18,190	-1044,81
D5 21-22	-19,987	-1148,06	-3,694	-204,55	-46,062	-2645,79
D5 22-23	-4,532	-247,75	0,404	22,07	-31,832	-1740,23
D5 23-00	-2,229	-105,90	-6,988	-332,09	-38,947	-1850,75
D6 00-01	17,163	892,32	2,006	104,31	28,263	1469,37
D6 01-02	12,076	554,28	-1,930	-88,58	33,316	1529,20
D6 02-03	-1,226	-56,26	-0,275	-12,63	19,143	878,66
D6 03-04	4,645	213,19	-2,613	-119,95	22,732	1043,38
D6 04-05	10,505	460,34	-4,907	-215,04	24,324	1065,86
D6 05-06	-6,479	-283,90	-0,716	-31,39	15,279	669,55
D6 06-07	2,857	128,15	2,257	114,03	27,797	1246,99
D6 07-08	0,930	43,62	-0,584	-27,37	56,103	2631,22
D6 08-09	-3,425	-194,89	1,285	73,12	19,148	1089,52
D6 09-10	-22,200	-1296,91	6,805	397,55	17,832	1041,72
D6 10-11	1,739	101,60	-0,176	-9,69	25,742	1503,84
D6 11-12	-9,546	-557,69	2,890	168,85	18,722	1093,72
D6 12-13	-6,765	-395,19	2,910	169,99	20,499	1197,58
D6 13-14	-24,166	-1386,64	2,609	149,71	7,554	433,42
D6 14-15	-1,903	-109,20	3,915	224,62	26,106	1497,99
D6 15-16	0,066	3,77	6,595	375,27	27,793	1581,40
D6 16-17	0,635	35,79	2,138	120,43	23,668	1333,45
D6 17-18	-11,204	-654,52	1,455	85,00	5,260	307,28
D6 18-19	3,742	224,46	0,310	18,59	16,537	992,06
D6 19-20	-44,047	-2642,38	12,722	763,17	-36,480	-2188,42
D6 20-21	-21,916	-1314,73	13,514	810,73	-16,165	-969,76
D6 21-22	-1,239	-74,31	-6,941	-379,53	-31,820	-1908,89

D6 22-23	-5,425	-319,77	8,378	493,78	-33,719	-1987,42
D6 23-00	2,886	165,62	10,102	579,64	8,243	472,98
D7 00-01	-27,792	-1461,87	4,361	229,93	-12,644	-665,08
D7 01-02	-5,879	-300,64	4,022	205,69	17,363	887,93
D7 02-03	-12,407	-623,93	4,227	212,55	10,869	546,62
D7 03-04	0,454	22,65	0,961	47,94	19,897	992,66
D7 04-05	-11,743	-551,94	1,051	50,73	3,895	183,08
D7 05-06	-10,884	-487,50	1,312	64,26	6,652	297,92
D7 06-07	-0,942	-42,21	5,982	299,78	19,039	852,76
D7 07-08	-0,586	-26,24	5,007	257,57	19,151	857,76
D7 08-09	-10,349	-542,93	6,339	332,52	10,964	575,15
D7 09-10	-26,859	-1315,04	7,488	395,96	9,231	451,94
D7 10-11	-18,110	-996,02	14,402	792,09	35,219	1937,04
D7 11-12	-70,906	-3899,81	10,404	572,23	-45,828	-2520,55
D7 12-13	-12,528	-666,01	20,072	1067,00	14,435	767,34
D7 13-14	15,126	801,09	2,826	149,65	32,827	1738,52
D7 14-15	16,010	775,55	-8,726	-422,67	17,815	862,96
D7 15-16	28,076	1330,53	-8,321	-394,31	36,687	1738,61
D7 16-17	-10,712	-507,65	-6,499	-308,01	0,041	1,93
D7 17-18	-22,036	-1044,27	-1,858	-88,07	-9,600	-454,96
D7 18-19	15,316	725,80	-4,138	-196,11	22,825	1081,69
D7 19-20	16,077	820,58	2,156	118,89	31,624	1614,07
D7 20-21	9,840	518,59	6,553	368,22	35,423	1866,79
D7 21-22	2,882	153,09	6,432	365,64	26,921	1430,03
D7 22-23	7,408	416,62	0,624	35,12	28,169	1584,21
D7 23-00	19,026	931,51	1,350	72,05	59,431	2909,72
Total Purchase	**-2240,204**	**-134117,38**	**-585,263**	**-30301,66**	**-3682,855**	**-224648,01**
Total Sell	**552,382**	**29835,51**	**682,609**	**39861,83**	**1614,538**	**86346,03**

Appendix table 5 Imbalance volumes and amounts for BRP 3.

Period	Consumption Imbalance [MWh]	Consumption Imbalance Amount [EUR]	Production Imbalance [MWh]	Production Imbalance Amount [EUR]	Single Imbalance [MWh]	Single Imbalance Amount [EUR]
D1 00-01	3,980	206,95	-3,527	-172,57	0,453	23,55
D1 01-02	5,441	286,73	-2,822	-134,07	2,619	138,02
D1 02-03	-0,398	-21,05	3,799	200,95	3,401	179,90
D1 03-04	-2,833	-135,98	6,475	310,81	3,642	174,84
D1 04-05	-6,324	-284,56	13,752	618,85	7,429	334,29
D1 05-06	6,731	297,50	-0,502	-22,20	6,229	275,31
D1 06-07	14,186	628,44	-0,659	-29,20	13,527	599,24
D1 07-08	2,022	93,17	2,040	109,16	4,062	187,13
D1 08-09	-10,572	-487,06	4,000	215,44	-6,572	-302,79
D1 09-10	-6,026	-283,20	-1,444	-67,85	-7,469	-351,05
D1 10-11	-20,834	-959,82	-3,419	-157,51	-24,253	-1117,33
D1 11-12	-4,095	-188,67	3,200	175,94	-0,896	-41,26
D1 12-13	10,013	461,30	-6,737	-310,38	3,276	150,92
D1 13-14	11,702	545,31	-3,734	-173,99	7,968	371,32
D1 14-15	-25,087	-1169,06	0,612	33,66	-24,475	-1140,53
D1 15-16	-31,048	-1453,06	-0,042	-1,97	-31,091	-1455,04
D1 16-17	-1,971	-91,84	6,317	331,79	4,347	202,56
D1 17-18	-11,212	-522,48	7,215	378,48	-3,997	-186,28
D1 18-19	-5,403	-254,63	1,816	95,55	-3,587	-169,04
D1 19-20	0,992	52,66	4,591	243,61	5,584	296,27
D1 20-21	-0,292	-15,42	-1,344	-70,85	-1,636	-86,27
D1 21-22	-1,170	-60,75	8,553	444,22	7,383	383,47
D1 22-23	2,118	114,39	1,032	55,71	3,150	170,11
D1 23-00	7,228	367,19	-1,824	-90,70	5,404	274,55
D2 00-01	9,961	481,82	2,848	137,75	12,809	619,57
D2 01-02	5,050	240,80	7,918	377,51	12,968	618,31
D2 02-03	13,433	626,63	3,556	165,91	16,989	792,54
D2 03-04	12,302	562,20	-1,045	-47,75	11,257	514,45
D2 04-05	-2,420	-95,19	0,777	34,98	-1,644	-64,64
D2 05-06	-29,354	-1156,56	2,459	118,50	-26,895	-1059,67
D2 06-07	16,473	744,24	-1,951	-88,13	14,522	656,11
D2 07-08	24,308	1150,02	-3,103	-146,80	21,205	1003,22
D2 08-09	-2,981	-142,19	-1,719	-81,98	-4,700	-224,17
D2 09-10	-19,894	-951,74	11,237	676,70	-8,657	-414,16
D2 10-11	10,526	505,24	-1,429	-68,60	9,097	436,64
D2 11-12	-16,971	-814,62	-4,805	-230,64	-21,776	-1045,26
D2 12-13	-42,558	-2042,79	-3,289	-157,89	-45,847	-2200,68
D2 13-14	-17,778	-878,79	5,819	333,21	-11,959	-591,14

D2 14-15	15,234	753,02	1,491	83,44	16,725	826,70
D2 15-16	11,314	559,25	0,476	26,25	11,790	582,77
D2 16-17	-9,058	-492,48	4,979	270,71	-4,079	-221,77
D2 17-18	-15,826	-886,27	5,818	325,80	-10,008	-560,47
D2 18-19	-2,744	-156,57	8,370	477,50	5,625	320,93
D2 19-20	-4,287	-246,00	13,040	748,22	8,753	502,22
D2 20-21	25,872	1450,91	-9,953	-558,19	15,919	892,72
D2 21-22	-2,709	-135,43	-15,047	-752,34	-17,755	-887,77
D2 22-23	-8,963	-443,02	-3,417	-168,88	-12,379	-611,90
D2 23-00	-24,583	-1163,00	-1,849	-87,47	-26,432	-1250,47
D3 00-01	3,945	186,36	5,734	283,70	9,679	457,22
D3 01-02	2,450	126,44	10,588	546,33	13,038	672,77
D3 02-03	12,611	633,05	11,142	559,31	23,752	1192,36
D3 03-04	-13,649	-685,19	22,578	1133,43	8,929	448,24
D3 04-05	-26,052	-1315,64	23,055	1164,30	-2,997	-151,35
D3 05-06	-30,648	-1431,58	10,247	495,56	-20,401	-952,92
D3 06-07	-24,820	-1185,64	-3,328	-158,95	-28,147	-1344,60
D3 07-08	-0,115	-6,32	-1,154	-63,56	-1,269	-69,88
D3 08-09	-0,894	-51,43	15,970	918,41	15,075	866,98
D3 09-10	3,051	176,19	25,176	1453,92	28,227	1630,11
D3 10-11	-20,730	-1248,16	13,590	818,26	-7,140	-429,90
D3 11-12	-8,155	-470,97	-1,011	-58,38	-9,166	-529,36
D3 12-13	16,588	956,29	-3,146	-181,34	13,442	774,94
D3 13-14	-5,483	-311,51	11,299	641,92	5,816	330,41
D3 14-15	17,115	987,52	0,288	16,61	17,403	1004,13
D3 15-16	35,870	2104,46	4,509	264,56	40,379	2369,03
D3 16-17	50,407	3427,69	-3,043	-170,16	47,364	3220,74
D3 17-18	33,153	2254,43	2,830	192,41	35,983	2446,84
D3 18-19	22,038	1295,82	7,601	446,95	29,639	1742,77
D3 19-20	13,277	778,06	2,418	141,69	15,695	919,75
D3 20-21	-4,822	-269,19	0,895	49,96	-3,927	-219,23
D3 21-22	10,231	570,20	2,055	114,54	12,287	684,74
D3 22-23	28,211	1572,22	1,036	57,76	29,248	1629,97
D3 23-00	1,876	99,63	-12,287	-633,78	-10,411	-552,83
D4 00-01	-1,730	-90,81	-16,761	-843,77	-18,491	-970,78
D4 01-02	4,729	234,08	-5,194	-257,11	-0,465	-23,03
D4 02-03	5,521	271,04	1,248	61,27	6,769	332,31
D4 03-04	5,704	279,67	-6,733	-330,12	-1,029	-50,44
D4 04-05	-8,081	-393,00	2,670	129,86	-5,411	-263,13
D4 05-06	-4,756	-235,88	10,762	533,82	6,007	297,94
D4 06-07	-4,867	-248,46	-0,707	-36,11	-5,574	-284,56
D4 07-08	-14,972	-835,57	-6,790	-378,94	-21,762	-1214,51
D4 08-09	-5,710	-300,91	0,171	12,59	-5,539	-291,92
D4 09-10	1,374	103,07	3,609	270,65	4,983	373,72
D4 10-11	14,142	1894,97	12,342	1653,79	26,483	3548,76
D4 11-12	-11,692	-3273,86	7,812	2187,48	-3,880	-1086,38
D4 12-13	-33,009	-3928,10	5,809	691,22	-27,201	-3236,88
D4 13-14	-31,832	-1687,09	3,246	186,17	-28,586	-1515,07
D4 14-15	11,266	632,02	4,957	278,11	16,223	910,12
D4 15-16	9,947	560,89	5,777	325,77	15,724	886,66
D4 16-17	-24,250	-1338,59	-0,185	-9,90	-24,435	-1348,80
D4 17-18	-33,565	-1860,86	-1,939	-107,53	-35,505	-1968,38
D4 18-19	-37,039	-1881,93	-11,595	-589,17	-48,634	-2471,09
D4 19-20	-26,306	-1336,62	-0,441	-22,42	-26,747	-1359,04
D4 20-21	-35,978	-1828,05	-1,971	-100,16	-37,949	-1928,20
D4 21-22	-10,255	-542,79	1,352	73,76	-8,903	-471,25
D4 22-23	-10,362	-548,45	-0,831	-43,98	-11,193	-592,43
D4 23-00	-19,280	-986,34	1,724	88,19	-17,556	-898,15
D5 00-01	13,833	710,07	-5,874	-301,49	7,960	408,58
D5 01-02	4,697	236,22	-0,120	-6,04	4,577	230,18
D5 02-03	2,071	103,21	1,346	67,09	3,417	170,30
D5 03-04	-7,112	-348,97	-0,862	-42,32	-7,974	-391,29
D5 04-05	-13,053	-632,13	-0,188	-9,09	-13,240	-641,23
D5 05-06	-7,296	-364,23	-2,416	-120,61	-9,712	-484,84
D5 06-07	-15,163	-795,14	-3,972	-208,27	-19,134	-1003,41
D5 07-08	-19,172	-1092,82	2,142	122,22	-17,030	-970,71
D5 08-09	-2,114	-113,92	-0,405	-21,80	-2,519	-135,72
D5 09-10	10,910	715,28	-3,310	-217,02	7,600	498,26
D5 10-11	6,446	406,54	-3,542	-223,40	2,904	183,14
D5 11-12	0,903	56,98	3,327	209,90	4,230	266,89
D5 12-13	1,892	119,25	-2,820	-177,73	-0,928	-58,48
D5 13-14	-3,039	-188,34	-0,239	-14,82	-3,278	-203,16
D5 14-15	-0,953	-56,47	4,549	269,55	3,596	213,08
D5 15-16	-13,872	-795,68	4,321	247,86	-9,551	-547,82

D5 16-17	-9,738	-537,53	0,367	20,24	-9,371	-517,30
D5 17-18	10,294	527,45	0,473	25,84	10,766	551,67
D5 18-19	-4,088	-215,46	-4,185	-220,62	-8,273	-436,08
D5 19-20	21,181	1198,21	-1,885	-106,66	19,296	1091,55
D5 20-21	0,272	13,37	-8,306	-408,09	-8,034	-394,72
D5 21-22	-14,640	-719,27	0,719	39,14	-13,921	-683,92
D5 22-23	-19,830	-991,51	19,455	1057,20	-0,375	-18,75
D5 23-00	-25,136	-1261,32	18,449	957,88	-6,687	-335,55
D6 00-01	3,266	172,16	-6,265	-326,82	-2,998	-158,04
D6 01-02	-2,619	-138,03	-3,006	-152,63	-5,625	-296,49
D6 02-03	27,947	1473,09	1,366	71,99	29,313	1545,07
D6 03-04	32,492	1712,65	2,724	143,58	35,216	1856,24
D6 04-05	21,869	1032,23	-4,000	-188,78	17,870	843,45
D6 05-06	19,886	959,09	13,860	668,49	33,746	1627,58
D6 06-07	8,412	417,76	10,655	529,11	19,067	946,87
D6 07-08	-9,371	-472,02	5,155	259,67	-4,216	-212,35
D6 08-09	-17,206	-903,50	8,438	443,10	-8,768	-460,40
D6 09-10	-9,027	-505,48	-4,075	-214,79	-13,101	-733,68
D6 10-11	3,249	181,97	-6,111	-321,79	-2,861	-160,23
D6 11-12	-7,134	-398,56	-14,326	-753,97	-21,460	-1198,95
D6 12-13	3,543	197,96	-10,798	-561,93	-7,255	-405,32
D6 13-14	12,535	700,34	-12,093	-624,84	0,442	24,71
D6 14-15	-0,502	-26,77	0,185	9,85	-0,317	-16,92
D6 15-16	-7,500	-397,51	18,654	988,65	11,153	591,13
D6 16-17	6,720	344,07	22,699	1162,18	29,419	1506,25
D6 17-18	12,754	659,27	2,644	136,69	15,399	795,96
D6 18-19	0,944	50,46	-16,729	-894,15	-15,785	-843,69
D6 19-20	4,626	251,28	-6,295	-341,93	-1,669	-90,66
D6 20-21	-5,220	-287,11	1,361	74,85	-3,859	-212,27
D6 21-22	6,022	326,49	-21,343	-1157,22	-15,321	-830,73
D6 22-23	15,521	853,80	-11,089	-610,00	4,432	243,79
D6 23-00	5,678	278,34	-7,559	-370,52	-1,881	-92,19
D7 00-01	22,560	1151,69	2,161	110,30	24,721	1261,98
D7 01-02	13,231	651,23	3,453	169,96	16,684	821,18
D7 02-03	19,328	928,34	-0,019	-0,92	19,309	927,41
D7 03-04	11,645	545,59	-2,516	-117,88	9,129	427,71
D7 04-05	8,994	414,17	-3,396	-156,38	5,598	257,78
D7 05-06	2,980	143,11	7,420	356,29	10,400	499,40
D7 06-07	12,242	599,00	2,615	127,95	14,857	726,96
D7 07-08	-4,850	-222,83	-0,330	-15,14	-5,180	-237,97
D7 08-09	-10,058	-462,65	-4,333	-199,30	-14,390	-661,96
D7 09-10	-3,369	-158,34	-13,102	-615,78	-16,471	-774,11
D7 10-11	-9,884	-517,32	-1,151	-60,27	-11,035	-577,59
D7 11-12	18,650	976,71	4,293	224,83	22,943	1201,53
D7 12-13	48,252	2267,86	0,015	0,76	48,267	2268,55
D7 13-14	19,651	923,58	2,630	136,59	22,280	1047,18
D7 14-15	21,734	1021,51	6,137	317,98	27,872	1309,96
D7 15-16	4,591	215,77	4,326	223,46	8,917	419,11
D7 16-17	1,336	62,77	0,392	20,42	1,728	81,22
D7 17-18	-15,488	-812,64	20,680	1085,08	5,192	272,44
D7 18-19	4,865	258,31	23,367	1240,78	28,232	1499,09
D7 19-20	14,326	777,16	14,542	788,92	28,868	1566,08
D7 20-21	15,739	859,52	8,438	460,81	24,177	1320,33
D7 21-22	39,498	2167,27	-18,886	-1036,25	20,613	1131,01
D7 22-23	77,755	4278,85	-24,382	-1341,74	53,373	2937,11
D7 23-00	-22,031	-1173,35	-3,365	-179,21	-25,395	-1352,56
Total Purchase	**-1055,907**	**-58414,07**	**-384,067**	**-19925,54**	**-1016,041**	**-54344,86**
Total Sell	**1127,735**	**61211,85**	**608,039**	**35552,16**	**1311,840**	**71838,94**