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Enabling a Smooth Transition to 15 Minute Balance Settlement

- A study of enabling shorter settlement to correspond with the increasing value transition from energy to power in the electricity market landscape

FINAL REPORT

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ENABLING A SMOOTH TRANSITION

TO 15 MINUTE BALANCE SETTLEMENT

This final report is prepared for the Finnish Energy Authority by Empower IM Oy in collaboration with VALOR Partners Oy on the basis of a public tender issued by the Finnish Energy Authority.

The views and information expressed in this report are those corresponding to the requirements set out by the public tender and represent the data gathered and work done in collaboration by the experts involved in the report project.

This work is scoped and limited by the public tender and does not constitute the single position of any of the participating companies, experts interviewed or studies used in the making of this report. The study is presented as is and does not constitute an obligation, specification or offer for anything other than the scope defined in the public tender.

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1 Executive Summary

Balance settlement is only one part of an overall market mechanism

Balance settlement is a part of the overall energy market system which defines how the value of energy is shared after trading between market parties. The markets themselves define value and are the driver for requirements in settlement and measurement. The main point of balance settlement is to ensure that the resulting costs or benefits imbalances with regard to contracted levels of power delivery or consumption are carried by those actually contributing to the physically required technical balance of consumption and generation at any given time.

The Nordic energy system is moving away from a situation where energy was the key value component to a mechanism where power and the capability for flexible change in power levels now drive actual value. This is becoming true for both consumption and generation as intermittent zero marginal cost generation levels increase. Interconnected markets between the Nordic countries create opportunities in sharing value and maintaining security of supply across the Nordic energy system. These opportunities are realized in setting up markets for time intervals of 15 minutes within the timeframe of the European legislation requiring 15-minute settlement, regardless of any possible derogation for the latter.

15 minute balance settlement will happen and affect Finland regardless of our own decisions

The balance settlement requirement for 15 minute time intervals in settlement has been decided as the common basis for settlement calculations in Europe. The Nordic countries will implement this as required by law by the 18th of December 2020. The option to seek a one time fixed date derogation applies only to the settlement mechanism and not other parts of the entire market. In this study we evaluate the option of using this derogation and look at different levels of market implementation that make use of the 15 minute balance settlement mechanism.

If Finland decides to derogate and step out of the implementation of the 15-minute settlement period, the Finnish market will effectively be islanded on the power level and balancing will have to be carried out by non-Finnish resources as the energy system will in any case be balanced out over these 15 minute periods regardless of what Finland decides. Previous studies suggest this creates an extra cost of at least several tens of millions of Euros without mitigating measures or full implementation.

This study answers the question raised about the usefulness of a possible derogation and addresses it in its intended context, ie. balance settlement only. This is in line with other countries where no other level is even possible until future changes are implemented. In addition we evaluate implementation built on the upcoming Finnish datahub and implications of not doing so. It should be noted however that the datahub itself is not equivalent to the implementation of the 15 minute balance settlement. This will be implemented by eSett as in the other neighbouring Nordic countries. The datahub will take over tasks now handled by the DSO and this creates a challenge for the implementation in order to avoid double investments.

Implementing balance settlement is not implementing measurement

The level of implementation of eligibility for resources on top of the settlement mechanism is not linked with decision making pertaining to the settlement calculation content. It is more about the value achievable by linking new resources to the underlying enabling mechanism of balance settlement. This is why in this study we primarily handle the question of settlement itself. We also point out the issues, such as measurement, which need a broader discussion on a National level to achieve the most suitable timeframe for the level of implementation that we now have with the 60 minute time interval.

Finland is the only country to have implemented the previous 60 minute time period throughout the entire value chain from consumers to TSO level trading and common market participation. This means

that changing the end component of settlement creates a different implementation from any other country, where at this time several non-measurement based calculations are made on different market levels and between different parties. Changing these is relatively easy, whereas implementing them again on levels where they have been discontinued in Finland is a different issue

Implementation of settlement can be done without double investment

The implementation of balance settlement will require capability to manage measurement and calculation information in 15 minute periods. This is within the specification of the upcoming datahub. DSOs currently manage all measurement data and settlement calculations on a retail level. As the 15 min settlement requirement comes sooner than the datahub, implementation without mitigation leads to lost double investments on the DSO level and in information exchange. Since derogating the entire settlement would mean costly market isolation and since derogation is bound legally to one fixed unchangeable date, it would not be feasible to connect derogating and datahub deployment to each other. It should also be noted that the single investment need based on transitioning to 15 minute balance settlement is unavoidable for all parties as the transition is already binding by law and the only question on the table is the timeline, not the content. With an interim conversion of data, no double investments are needed.

No derogation is needed, eSett provides interim capability, the Datahub will take over in 2021

During the study, a parallel effort was made by Fingrid to establish options for different implementation scenarios of 15 minute settlement. In this work a proposal was put forth for eSett to provide interim capabilities until full 15 minute settlement capabilities were available in Finland after datahub deployment. In this study we evaluated this approach by comparing distributed implementation and centralized implementation that would keep datahub deployment as a single investment for DSOs and market participants. We found that less changes and therefore less investment would be required by utilizing centralized conversion services in steps towards full 15 minute settlement when compared with other scenarios. The datahub coming online in 2021 will enable flexible use of different time series in different time periods. This will allow for continued full implementation of the settlement mechanism, while overlying changes in access and capability are being addressed.

Specific decisions on sharing of balancing market driven cashflow, measurement and end customer engagement are needed in addition to implementing balance settlement

Implementing 15 minute balance settlement with an interim conversion capability from eSett solves the basic scope of balance settlement without requiring a derogation. It does not solve distribution of balancing market driven cashflow, implementation of measurement changes or end customer engagement. These however are not driven by the settlement itself and should not be mixed up with making decisions on the settlement process. It is our view that all these require a separate structured discussion within the Finnish energy domain to create a series of steps towards the kind of integrated whole value chain energy market infrastructure we have today for the 60 minute time interval. This discussion is to be held in Finland among Finnish market participants as they are the only ones in the world with the experience of having the 60 minute system working as a whole. International collaboration is also valuable and we see that this discussion should also provide valuable results for international market development.

In this study we have raised issues in all of the three areas requiring further work and hope to contribute in creating a structured environment for this work. During this study we found that many of these issues were interlocked in discussion in ways that prevented actual solutions to be found. This is due to a wealth of factors, easiest handled by solving each part of the entire market puzzle at a time with a structured approach with clearly defined categories.

2 Background and premises of the study

2.1 Balance settlement is a part of the overall energy market system

Balance settlement is a part of the overall energy market system which defines how value of energy is shared. Balance settlement enables use of different commercial mechanisms by providing common time period to settle market trades. Energy markets are an integrated system, but the markets can be divided into different architectural components. In the context of this study, we highlight the difference between market access and market design (Figure 1). Market access is related to market stakeholders' actual capability to operate in markets with 15 min measured data and corresponding trading activity. Market design comprises of the rules, market enabling information systems and marketplaces where trading is done.

The coming transition to 15 min balance settlement has raised more concerns and criticism among Finnish electricity market stakeholders than in many other countries. As we have analysed these concerns and criticism, there seem to be two key drivers:

1. Firstly, electricity market stakeholders are generally satisfied with the current electricity market structure where a uniform 60 min time period is used throughout the whole energy value chain. The stakeholders are worried about breaking the value chain if different time periods are introduced in different parts of the value chain. This is elaborated on later in chapter 3.

2. Another driver behind the concerns is misunderstanding or omitting parts of the electricity market architecture presented in Figure 1. When in fact we are at a stage where a new market design is introduced at the same time with 15 min balance settlement, the majority of concerns are related to market access. Whilst open market access is vital in order to realise benefits of 15 min balance settlement described in chapter 3, it should be separated from market design. Common rules and regulation are needed in market design. It is important to ensure fair and open possibility for all market stakeholders to enter the markets. On the other hand market access (a market participant's capability to operate in the markets) is reasonable to organise based on commercial terms. In other words, if none of the market participants expect benefits higher than costs, why invest in market access?

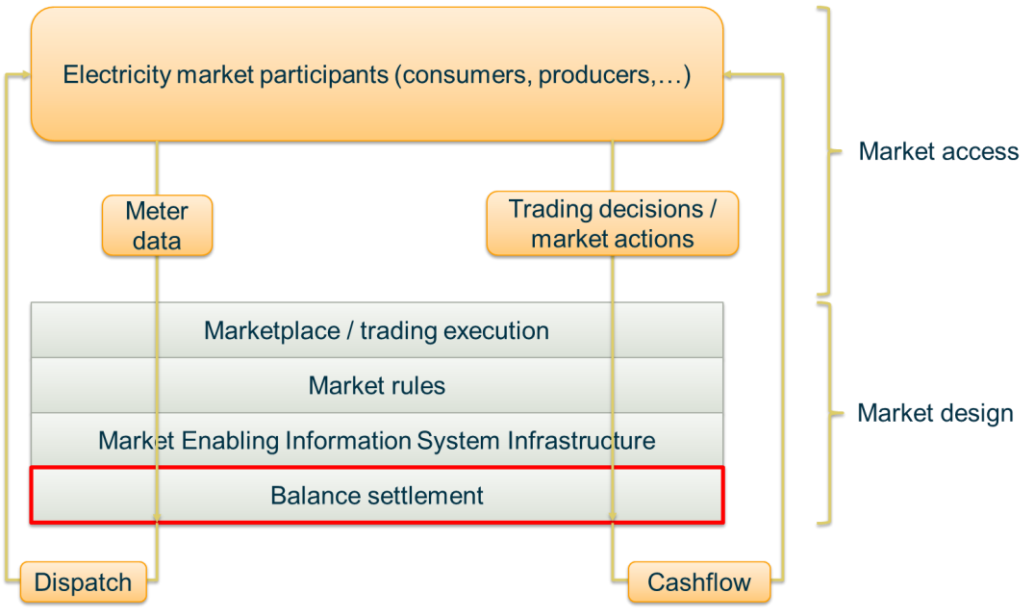

Figure 1. An Energy Market is an integrated system but it can be divided into different architectural components. In the context of this study, we highlight the difference between market access and market design, and note that balance settlement is only a part of market design, ie. it serves the market rather than defines it as the market rules do.

The transition to 15 minute balance settlement has raised criticism, of which the majority is related to worries that market access would be ruled upon by regulation even if in fact the regulatory decision is purely related to market design. These concerns are discussed in chapter 3 even if this study is not a detailed analysis on what kind of implementation strategy should be used to provide market access (i.e. 15 min measurement) to different electricity market participants.

2.2 New regulation concerning balance settlement

The European Union Commission has laid down regulation EU 2195/2017 (EU Commission, 2017) to establish common EU level guidelines and principles on electricity balancing. Among others, the regulation declares that all TSOs shall apply the imbalance settlement period[1] of 15 minutes within three years of the entry into force of the regulation - that is by December 18, 2020.

However, a national regulatory authority (The Energy Authority in Finland) may grant a derogation[2] from the regulation concerning the harmonisation of the imbalance settlement period at the request of a TSO or on its own initiative. The derogation for harmonisation of imbalance settlement period may be granted as an extension of the deadline only once and up to the date of January 1st 2025 at the latest.

Even though recent public discussion among the Finnish energy cluster has been focused on changing electricity meters and measurement to comply with the 15 minute time interval, it is noteworthy that neither the EU regulation nor a possible derogation constitute any kind of ruling about measurement. The regulation concerns only balance settlement, and does not regulate market design, measurement, billing or electricity data management.

When assessing the request for derogation or before granting a derogation on its own initiative, the relevant regulatory authority shall consider the following aspects according to the EU Commission regulation:

a) the difficulties related to the implementation of the harmonisation of the imbalance settlement period to 15 minutes in Finland;
b) the risks and the implications of the harmonisation of the imbalance settlement period to 15 minutes in Finland, in terms of operational security;
c) the actions taken to facilitate the implementation of the harmonisation of the imbalance settlement period to 15 minutes in Finland;
d) the impacts of non-implementation of the harmonisation of the imbalance settlement period to 15 minutes in Finland, in terms of non-discrimination and competition with other European market participants, in particular as regards demand response and renewable energy sources;
e) the impacts on overall economic efficiency and smart grid infrastructure;
f) the impacts on other scheduling areas and overall consequences on the European market integration process.

[1] Article 53, EU Commission regulation EU 2195/2017
[2] Article 62, EU Commission regulation EU 2195/2017

2.3 The Finnish market and measurement time period match is unique

A distinctive characteristic of the Finnish electricity market in comparison with any other EU market is that since 2014 the whole value chain has been using the same 60 min market time period. This includes also retail customers and their metering. The market players have been exceedingly satisfied with the current arrangement as all market decisions can be based on metered data and settled throughout the value chain without uncertainties stemming from estimated data. The uniform market, balance settlement and measurement period has enabled new tariffs dedicated to specific customer segments that allocate benefits from demand response to such customers that are able provide flexibility on hourly level. It is worth noticing that before hourly measurement was implemented in Finland, any behaviour that positively contibuted to balance of power system ended up to energy losses portfolios of DSOs and therefore market participants were not able to turn flexibility into profits[3].

The decision to harmonise the imbalance settlement period to 15 minutes has raised discussion and concerns among Finnish electricity market stakeholders. On the one hand, there is the question if introduction of a 15 minutes settlement period is actually a regressive step in development of the electricity markets, because it re-introduces estimated values for defining electricity consumption or generation for periods shorter than the available 60 min measurement data. Eventually this is temporary until DSO's have replaced existing AMR meters, of which ca. 40% are currently unable to measure at 15 min intervals according to Energiateollisuus (Energiateollisuus ry, 2018). On the other hand, DSOs are particularly worried about possible requirements to make replacement investments and renegotiate service agreements before planned end of life times of the current 60 min measurement fleet including adjoining services and systems such as MDM-systems and information management interfaces with integrational functionality.

[3] Additional note that even before 2014 when majority of customers in Finland were required to be in hourly measurement, there were large customers already in hourly measurement and DSOs were required to keep up double systems, one for hourly measurement and one for estimated load.

3 A finer time resolution benefits the Finnish power system and economy

3.1 Existing recent research covers key benefits and major concerns

In order to assess the pros and cons of different implementation schedules, it is necessary to understand the key benefits of having a shorter time period as a basis for markets and imbalance settlement towards the power system and its stakeholders. This is widely analysed in several recent reports and studies, and thus we, instead of adding one more detailed analysis, summarise the key findings here.

The recent reports typically describe the issue at hand from the point of view of only selected stakeholders of the power system (e.g. benefits to market players or cost in AMR meter replacement), therefore we see it is warranted to provide a synthesis from these reports to establish a holistic picture of the expected impact of transitioning to a 15 min market time period and imbalance settlement.

In this report we not only provide a synthesis of the recent research but add a new, more hands-on layer on top of the synthesis. Our experts have analysed practical changes needed in the implementation of the finer time resolution since this level of understanding is missing from the other research. As we are asked to provide support for the Energy Authority in its decision making, we see it is crucial to understand the hands-on level changes and possible time needed to prepare and execute the implementation of the 15 min imbalance settlement time period. This twin layer structure of this research is presented in Figure 2.

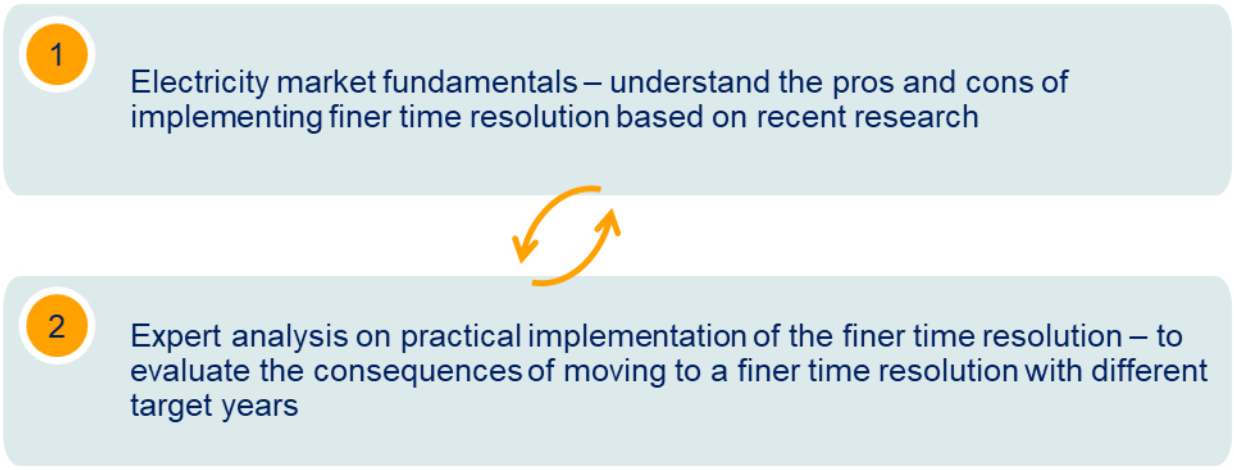

Figure 2. Our research has twin layer structure as we are summarising high-level pros and cons and reflecting them to hands-on implementation of a finer time resolution.

We have used the following recent reports and studies as a basis for the review of the existing research on the benefits of the finer time resolution:

1. Finer time resolution in Nordic power markets: A Cost Benefit Analysis (Copenhagen Economics, 2017)
2. Energy Authority Stakeholder survey [in Finnish] (Energiavirasto, 2018)
3. DSO survey [in Finnish] (Energiateollisuus ry, 2018)
4. 15 min balancing period SWOT-analysis [in Finnish] (Fingrid, 2018)
5. Market impacts of postponing introduction of 15 min balancing period [in Finnish] (Pöyry, 2018)

The key findings of the research can be categorised based on electric power system related (technical) attributes, common EU wide electricity market related (economic) issues and key concerns mainly related to costs of implementation. The categories are summarised in Figure 3 and analysed in more detail in following sections.

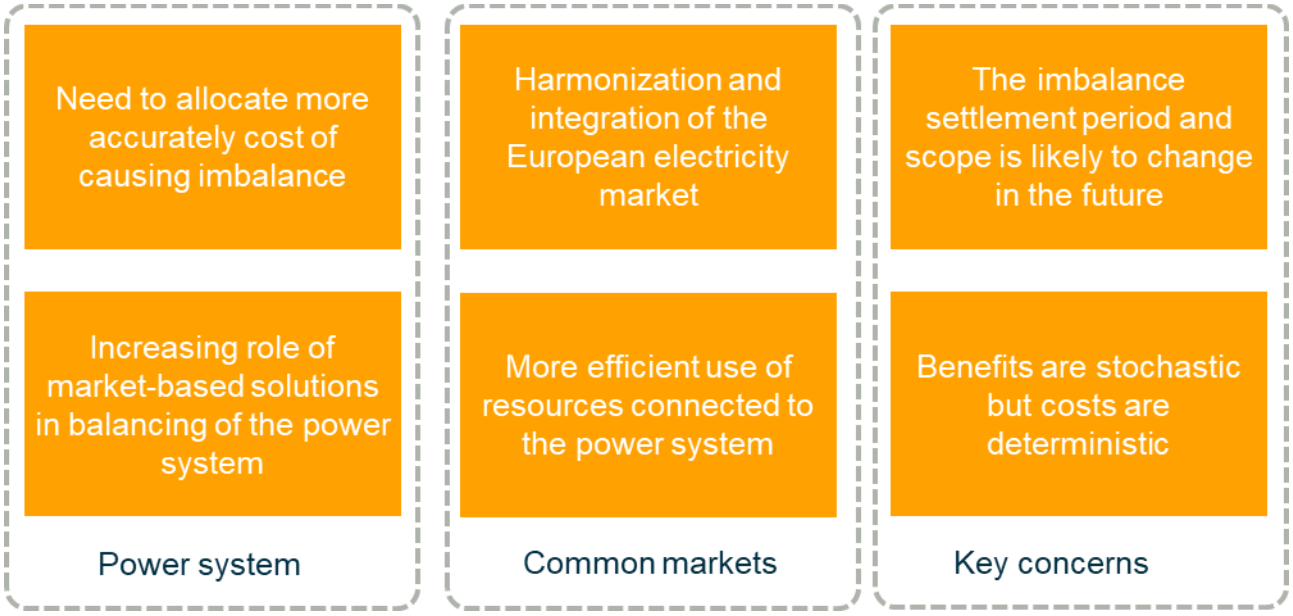

Figure 3. Current research results can be divided into three categories of benefits and costs.

3.2 Key takeaways from a power system point of view

3.2.1 Intermittent power generation growth reveals the need for more accurate imbalance cost allocation

When the Nordic market area in the 1990s was created, generation capacity was in balance between the Nordic countries. This enabled building an energy only market mechanism among major producers. Later when the electricity market was opened in the Nordic countries, large consumers (industry and retail suppliers) joined the wholesale market. An energy only based day ahead market was created with a built-in congestion management system dividing the market into price areas if the network does not have enough capacity to transfer power across the entire areas (so called *bottleneck principle*). Historically, value of power – or *"real-time value of energy"* as stated in (EU Commission, 2017) – has been fairly even during the 60 minutes market period. Therefore it has not been a major issue if imbalance in certain time of an hour is corrected at another time within the same hour as long as the total energy of the hour has been in balance (see Figure 4).

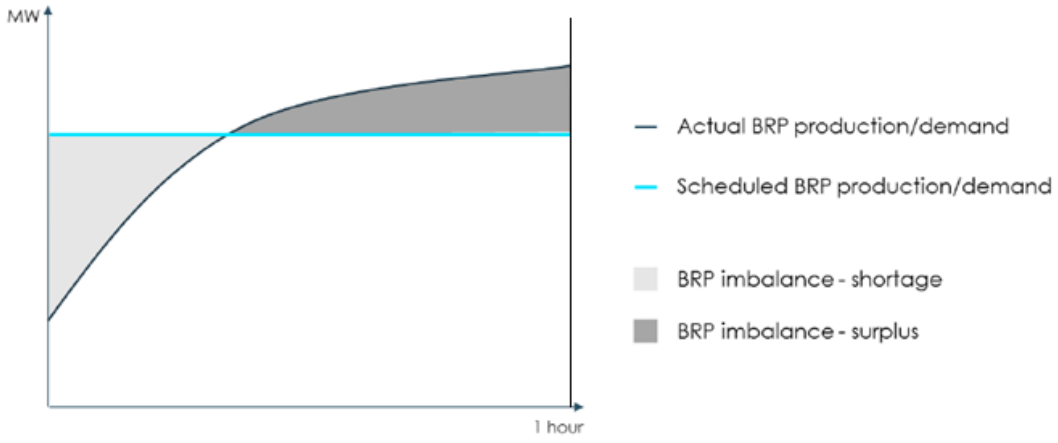

Figure 4. Historically value of power has been more or less constant during a 1-hour market period. Therefore it has not been a major issue if deficit at certain time of the hour is balanced with surplus at another time within the same hour as long as the total energy of the hour has been in balance. Picture source: (Copenhagen Economics, 2017)

Nowadays increasing intermittent power generation highlights and shows the concrete challenges stemming from the lack of controllable generation capacity that has emerged particularly in Finland during the past 10 years (Figure 5). The figure also underscores future need in showing that a peak demand increase occurs even at 60 minute intervals. In order to gain well functioning electricity markets, we need to make markets and the power system fit for the integration of increasing share of intermittent generation. This means that imbalance prices should reflect the *"real-time value of energy"*.

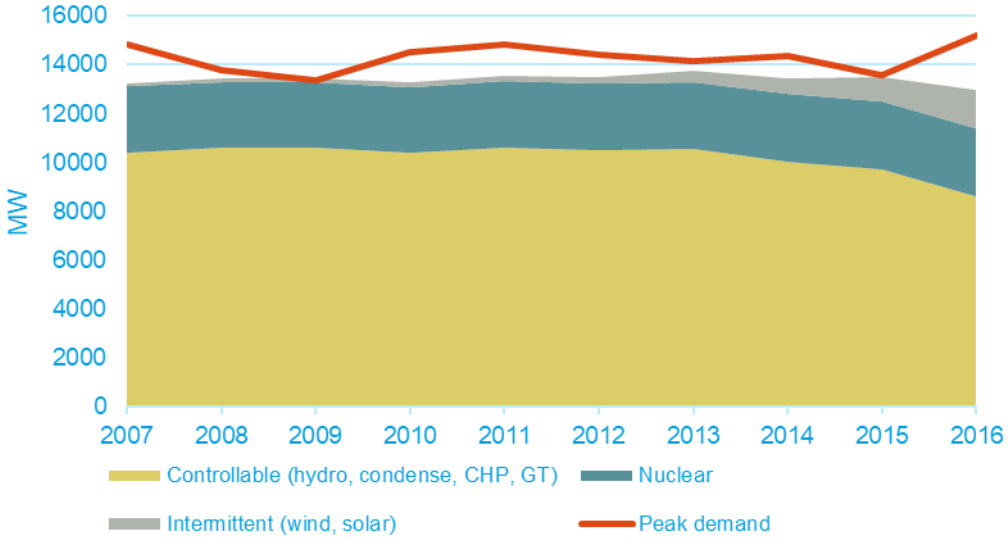

Figure 5. Controllable power generation capacity in Finland has decreased even when 60 minute peak demand shown here and intermittent generation have increased (Energiavuosi 2017, 2018).

We see that the fundamental principle to follow should be fair treatment of all market participants. A finer time resolution shares the cost of causing an imbalance more accurately between the market participants actually causing the imbalance. Unfortunately over-simplification of the issue from the standpoint of individual stakeholder groups has also lead to misinterpretations. Even if an increasing amount of intermittent generation has increased the need to shorten the balancing period, it is not justified to argue that heavily state subsidised intermittent generation should carry the costs or that traditional market players causing balance error should be compensated or exempt from their responsibilities to cover costs of the imbalance.

In our view, a finer time resolution is a change towards a fairer treatment of market participants: those causing problems for the power system would be more responsible for costs from solving the problems. Both generation as well as consumers should be responsible for their own imbalance. More accurate allocation of balancing costs to the participants causing them creates a better incentive to manage imbalance risk in terms of quantity and price.

Managing imbalances is important due to security of supply. Operational security of supply is measured by frequency quality in the power system. Deviations from the normal 50 Hz frequency reflect that demand and supply are deviating from each other. A minor deviation is not a problem as such but makes the power system less resilient to cope with a sudden trip of a large generation or consumption unit or interconnector. The frequency quality in the Nordic power system has a fading trend since 2000 and there is pressure for further deteriorating due to increasing amount of intermittent generation and reduced inertia in the system (Nordic TSOs, 2016).

In addition to total level of imbalances in the Nordic power system, there is also a particular systematic problem, imbalance jumps, at hour shifts. Imbalance jumps are illustrated in Figure 6. The power system is designed so that smooth or constant imbalances are not necessarily problematic but rapid jumps require more active management by TSOs (Copenhagen Economics, 2017). When using a finer time

resolution large imbalance jumps are likely to be reduced when balancing resources can more readily be offered to balance these in a working market.

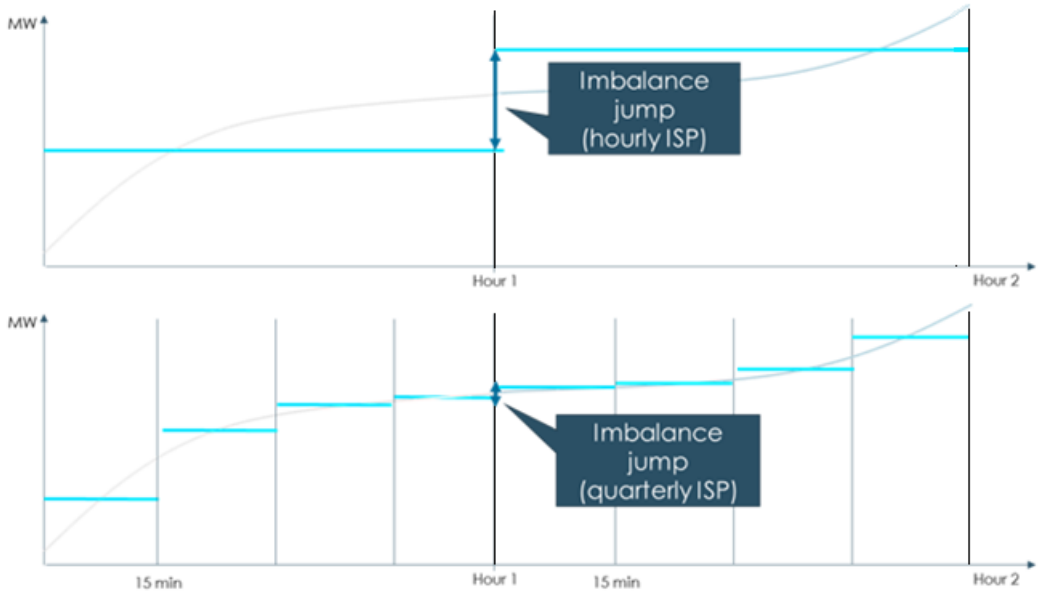

Figure 6. Rapid changes from surplus to deficit or vice versa (so called imbalance jumps) are more likely larger at hour shift when 60 minutes market time period is used (illustrative). Picture source: (Copenhagen Economics, 2017).

3.2.2 Increasing role of market-based solutions in balancing of the power system

Managing imbalances in the system can be accomplished by either market-based actions or TSOs activating balancing resources or setting restrictions to ramping generation / consumption with dedicated resources.

Some respondents in the Energy Authority's stakeholder survey (Energiavirasto, 2018) have argued that changing to a 15 min market time period would transfer costs from the TSO to market participants: TSOs would be responsible for a shorter time period – just one fourth of the current responsibility – and TSO costs would decrease similarly whilst market participants would carry higher costs. Even if this principle is correct, we see that the argumentation is somewhat misleading.

1. The TSO does not carry cost of balancing of the power system itself, but it is allowed to recover costs in TSO fees. Thus increasing the role of market participants in balancing would not cause additional costs for market players, *in corpore*, but actually re-allocate balancing costs away from being shared across all users of the transmission network, re-allocating them to the market participants causing the balancing errors in the first place.

2. We see that the increasing role of market-based solutions would eventually lead to a lower total cost of balancing the power system. The Finnish TSO Fingrid can just pass-through costs into TSO fees for users of the transmission system whilst market participants have an incentive to find efficient ways to keep costs in control in order to stay competitive in the electricity markets.

Electricity market stakeholder interviews (Copenhagen Economics, 2017) have revealed two market mechanism based reasons that also favour market based intraday trading more efficient than TSOs operating in regulating power market:

1. It is possible for power plants with long ramping time to participate in intraday trading while such plants are excluded wholly or partly from the regulating power market since their ramping time is not short enough to match required delivery time.

2. Intraday markets bear less intrinsic uncertainty (and therefore less risk premium) than regulating power market. In the regulating power market it is not known whether bids will be activated and for how long time until the bids are activated whereas in intraday market the buyer and seller agree about the delivery at the deal.

The 15-minute market period makes market players responsible of a larger share of imbalance that is currently netted out over the 60 minutes market period (Figure 7). However, market-based solutions gain a larger role only if the market mechanism provides incentives for market players to manage their balance more accurately in the day ahead and intraday markets and evolving new markets instead of leaving imbalance to be filled by involuntary means after settlement. It is required that market players are exposed to their respective potential imbalance costs. Only exposure to cost or potential gain leads market players to decide whether to participate in the balancing or to manage their imbalance risk in other ways.

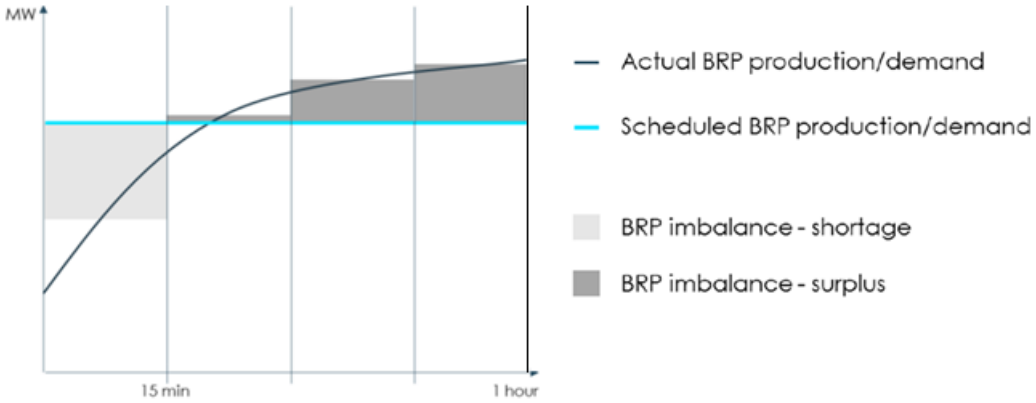

Figure 7. The 15-minute market period makes market players responsible of larger share of imbalance that is currently netted out over 60 minutes market period. Picture modified based on (Copenhagen Economics, 2017).

Even if market players should have also an option to leave themselves open to market settlement based balance energy allocations, a working market mechanism should decrease the need for involuntary balancing energy allocation after settlement. Naturally the market players choose the way that is the cheapest, or more broadly speaking the way with the least risk in terms of costs and efforts. The current market mechanism provides limited incentives for market players, and in order to fully exploit the benefits, introduction of the 15-minutes time period should be aligned with updates in intraday and balancing market mechanisms.

Larger role of market based solutions in the balancing of the power system is possible only if flexible resources are available and connected to the grid. Therefore, finer time resolution creates stronger market signals that are needed to reveal the competitiveness of flexible production and consumption. The finer market time period would change profitability of planned investments in two ways (Copenhagen Economics, 2017):

1. A finer time resolution shares the cost of causing imbalance more accurately to such market participants / technologies that are actually causing the imbalance and also awards the reward of correcting such a balance more accurately. That is, flexibility becomes more profitable and inflexibility becomes more expensive.

2. Improved ramping rates of HVDC interconnectors and market coupling to Central Europe increase demand for market based[4] flexibility and thus support the business case of having flexible generation or consumption.

[4] It is worth to notice that finer time resolution does not increase the overall demand for flexibility in the Nordic power system but shifts balancing activity from TSOs more to the responsibility of market players.

3.3 Key takeaways from a common EU wide electricity market point of view

3.3.1 Harmonisation and integration of the European electricity market

The common EU wide markets, whether in energy or in any other commodity or product, create value for EU citizens and companies through providing larger markets and therefore allowing the most competitive market players access the market. When applied to electricity markets, this means that common EU wide markets enable more efficient use of production and consumption resources connected to the power system.

Harmonization and integration of national electricity markets into a common EU wide market is on sustainable ground if joined markets are based on fair distribution of benefits and burden. In regard to electricity markets, harmonisation should not mean requiring others to solve the power system balancing problems for free but enable fair compensation through market mechanisms. The aim should be to create mutual benefits instead of transferring one party's power balance problems to other parties. To support this aim, a finer and shared time resolution would allow allocation of monetised costs and benefits of managing imbalance.

A common market requires a common market mechanism, which cannot work efficiently without a common information structure driven by common time resolution. A shared time unit for all market levels and availability of corresponding measurement data will enable interaction and integration of markets by providing market access through information compatibility across the board for all resources. Recent analysis (Pöyry, 2018) indicates that the Finnish power system has gained major benefits from cross-border trading in intraday and regulating power markets. This also means that if Finland is isolated from other Nordic markets with a different market time period, costs and lost opportunities will result. These are calculated to be at an annual level of 0,6-1,8 million € due to increasing price levels in intraday markets and 9-26 million € due to limited access to Nordic assets in the regulating power market (Figure 8). More detailed analysis of these figures is provided in the Pöyry analysis (Pöyry, 2018).

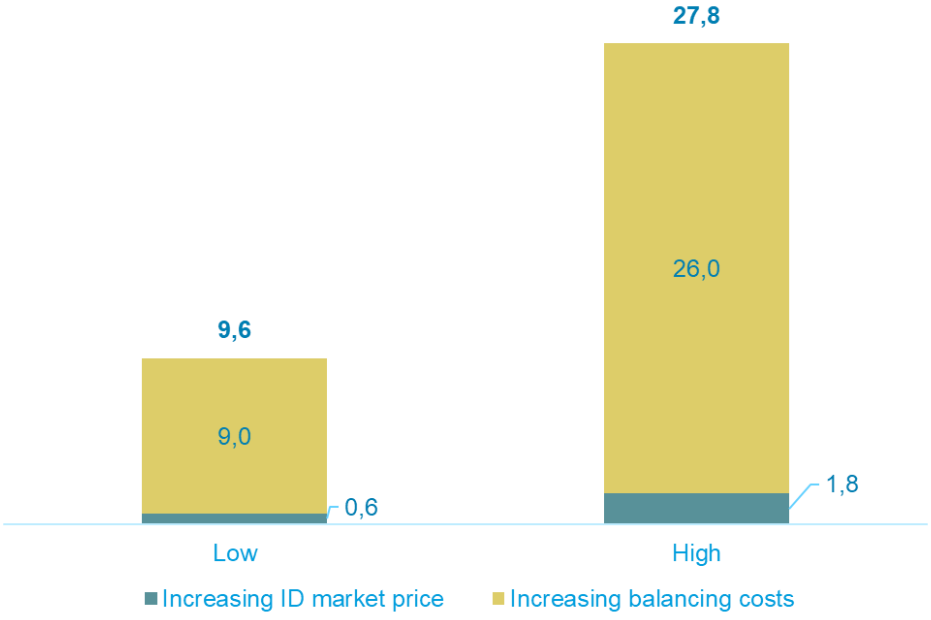

Figure 8. Estimated costs (M€ per year) if Finnish market is disconnected from common Nordic electricity market (Pöyry, 2018).

The analysis indicates that market players should have the possibility to operate on their preferred market (i.e. day ahead and/or intraday etc.) without different market time periods limiting their operating possibilities. Neither there should be any geographical (e.g. customers located in cities etc.) nor any other type of artificial limitation if we want to achieve full benefits from the wider markets.

3.3.2 More efficient use of resources connected to the power system

A finer time period that is aligned with the Central Europe, allows more efficient use of HVDC links between Nordic and European market areas in two ways:

1. More optimal capacity use within intraday markets as well as use of capacity not only to transferring energy but also power and frequency control
2. Improved utilisation of the interconnectors as their ramping rates could be enhanced

Currently, when a 60 min intraday market period is used in the Nordic market and a 15 min in Central Europe (or more precisely Germany and the Netherlands), flow in the HVDC links is defined by price differences in day-ahead markets, unless restricted by TSOs. Inconsistent market time periods have led to situations (Copenhagen Economics, 2017) that flow in HVDC links has been suboptimal as 15 min intraday prices in Central Europe have deviated from the spot price so that optimal direction of the HVDC flow would have changed during an hour. In addition, 15 minutes intraday trading into one direction would free up more capacity to the other direction during the other quarters of the hour. In conclusion, harmonisation of intraday market periods between Nordic and German markets would allow capacity to be more efficiently allocated not only for transferring energy but also power and frequency control. Benefits from the increased market coupling are estimated to be roughly 6 million euros annually at Nordic level, of which about 1.4…1.9 million euro from Finland-Estonia HVDC link (Copenhagen Economics, 2017). The benefits are expected to more than double when new interconnectors to the UK, Germany, and the Netherlands are taken into use in 2020's.[5]

There are also technical limitations for use of the HVDC links to other markets besides limitations caused by market mechanism as described above. The ramping rates (i.e. how fast the flow of energy can change in the interconnector) are limited by a physical restriction how large power differential the Nordic power system can manage. This means that in certain hours there are unutilised capacity in the HVDC links that cannot be allocated to the market due restricted ramping rate. When intraday trading will be distributed more evenly along quarter shifts instead of hour shifts, it is expected that ramping restrictions could be eased (Copenhagen Economics, 2017) are more capacity would be available for the markets. The benefits of faster ramping are realised particularly from DK1-NO2 interconnector and they are calculated to be annually 0.9…3.6 million euros total in Nordic electricity markets. The new interconnectors to the UK and Germany will bring additional benefits more than twice as much as the current HVDC links.

In addition to integrating geographical markets or synchronous electricity market areas, efficiency gains and increasing volumes of participating assets can be achieved also by opening market access for new types of resources or technologies already connected to the Finnish power system. A finer time resolution allows such resources, e.g. power batteries, industrial or household demand flexibility with limited capacity to operate in hourly markets, to enter the market more easily.

In this respect, there is a serious misunderstanding by certain market stakeholders according to Energy Authority's survey (Energiavirasto, 2018). Where it can be stated that the current 60 minutes market time period is a market entry barrier for batteries and demand flexibility, certain market stakeholders believe exactly the opposite. They argue that implementation of 15 min balance settlement "earlier than in 2025 would prevent electricity heated households [in terms of providing demand response] to participate in balancing or reserve power markets without significant investments"[6] and "if 15 min balancing period is implemented before 2025, it hinders consumers from selling distributed renewable energy in balancing power or reserve markets"[7].

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[5] The market coupling benefits are generally available for the all market player in the Nordic electricity market, although bottlenecks between market price areas may temporarily limit benefits to certain market areas.

[6] Quatation freely translated by authors, original in Finnish: "Vuotta 2025 aikaisempi aloitus poistaa myös Suomessa olevien sähkölämmittäjien osallistumisen säätö- ja reservimarkkinoille ilman merkittäviä investointeja."

[7] Quatation freely translated by authors, original in Finnish: " Jos varttitase otetaan käyttöön ennen vuotta 2025, hajautetun uusiutuvan energian myynti suoraan kuluttajilta säätösähkö- ja reservimarkkinoille vaikeutuu merkittävästi"

These beliefs have neither theoretical nor practical reasoning. Theoretically, shorter time period should just make it easier for demand response to participate in the market as such resources do not need to commit to full hour but only 15 min operation time. What comes to providing distributed renewable energy, such as solar PV, it is true that a finer time resolution may reduce profitability of such investments in case they would be responsible for the cost of imbalance they would cause in the power system. We see this is the whole point of changing to a shorter time period! The cost of balancing the system would be more correctly allocated to the resources causing the imbalance. The previously presented argument that a 15 min balancing period would hinder selling of renewable energy to balancing power markets is not based on any theoretical reasoning, rather the argument seems to indirectly defend profitability of investments in small scale intermittent generation.

3.3.3 A shorter time period reduces risks

The 15-minute market period reduces barriers to enter the balancing markets not only by reducing the time period to which market participants have to commit to in the delivery but it also allows to move intraday market closing closer to the time of delivery assuming that a rolling-gate closure is used. Currently market closing in intraday markets varies from 30 min (FIN-EST HVDC) to 45 min (regulating power market) to 60 min (Nord Pool ID) before the delivery hour. This means that the duration from market closing to the end of the delivery period varies from 90 to 120 minutes, which is the time for which market participants have to predict their production or consumption. A finer time resolution with a rolling gate closure would imply that players in the balancing markets would even by a conservative estimate need to forecast for a period of only 45…75 minutes (Figure 9). This would reduce market risk and therefore the cost of providing balancing power.

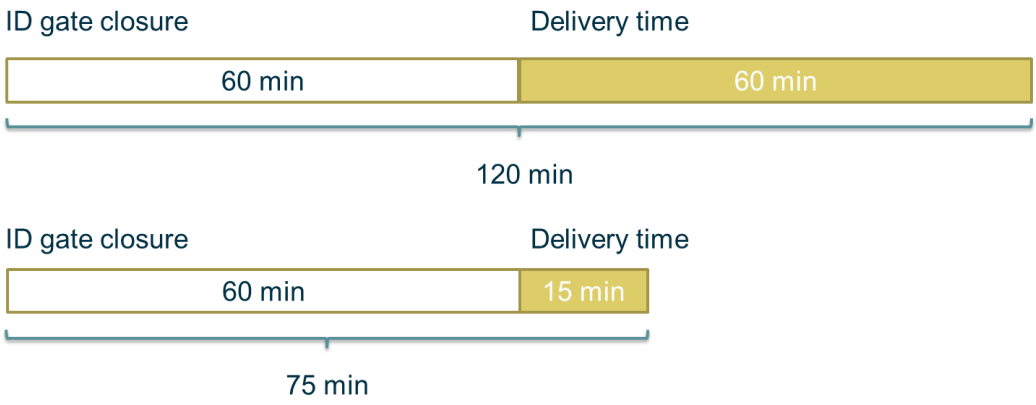

Figure 9. Shorter time period would reduce forecasting period even if it is assumed that intraday trading closure is not changed closer to the delivery period.

3.4 Key concerns are related to practical implementation

3.4.1 Benefits are stochastic, but costs are deterministic

The reviewed existing research reveals that one of the main sources of dispute among electricity market stakeholders comes from the different nature of benefits and costs of having a finer time resolution.

By definition a 15 min market period does not generate any direct benefits to DSOs since their role is to stay as an enabler for the well-functioning market and refrain from market actions. The DSOs (and eventually their customers) need to carry the costs but expected benefits, as described in earlier sections, are stochastic in nature. The benefits are either

1. lower costs, which eventually in an efficient market materialize into lower electricity costs for consumers, or
2. higher profitability for flexible consumption and generation assets, which materializes only for asset owners.

Expanding the electricity market, whether it is through integration with Central Europe or opening market access to new types of generation / consumption resources and technologies, leads to lower electricity or balancing power prices at certain periods and higher prices at other periods. The period with lower prices, the benefits will be realised towards consumers in Finland and in periods with higher prices the benefits will be realised towards producers in Finland.

It is out of the scope of this study to investigate whether consumers or producers benefit more as we see that a well-functioning market will eventually lead to an optimal balance between both sides. As we see that a 15 min market time period enables a better functioning market than the current 60 min resolution, it can be also be said that any adverse impact caused by a finer time resolution is actually just a correction of inefficient distribution of benefits due to the coarse time resolution. Obviously, the above stated does not apply to DSOs (and network customers as they are sourcing network services) as they are not market participants but only a platform for the electricity markets.

Overall, the benefits of a finer time resolution are realised only if market signals are transparent and solid enough so that market players change their behaviour. Thus realisation of the benefits is yet uncertain. On the other hand, costs to build required measurement and data management infrastructure are deterministic and inevitably land with network customers.

The key drivers for the costs are need for new investments as well as operational and contractual changes needed to implement the 15 min time period. These changes, and possibilities to affect the magnitude of costs originating from the changes, are described in more detail in the following sections.

While balance settlement does not require changes in measurement, enabling market entry for all relevant resources will eventually require measurement of electricity consumption and generation in the same period as used in the settlement. As discussed in the Chapter 2.1 earlier, this is beyond the scope of this study, but it should be noted that this issue is not limited to the measurement itself, but also how the acquisition of measured data has been handled by the DSOs. In many cases DSOs have arranged metering and meter data management as a service based on long-term service contracts. Termination of such contracts may be substantial costs and therefore a finer time resolution might be necessary to be agreed upon as an amendment to an existing contract, which is likely to be more expensive than if it could be arranged through a full competitive sourcing process. Naturally, additional costs caused by legally binding changes in market design should be reflected in the DSO regulation model. Bearing this in mind, existing infrastructure and lifecycle costs should be considered when deciding on the schedule for the implementation of the 15 min market period in order to avoid unnecessary cost burden to DSOs and their customers.

Another concern that is raised among respondents in the Energy Authority's stakeholder survey (Energiavirasto, 2018) is related to the measurement accuracy of electricity meters. The current

standard requires 10 Wh measurement accuracy. Shortening of the balance settlement period may lead to situations where individual user's consumption during 15 min may not exceed 10 Wh. Experts in measurement interviewed during the study (Saarinen;Nyberg;& Leppänen, 2018) do not share the concern, as meters register cumulative consumption. Hence if consumption in one period remained below 10 Wh, it would be registered as zero consumption for this period and added to the cumulative consumption in the following periods when the cumulative consumption exceeds 10 Wh. Meters and meter data management systems also are able to separate the registered zero consumption from missing data. In other words, consumption remaining below 10 Wh in one period is not misinterpreted as measurement error.

3.4.2 The imbalance settlement period and scope are likely to change further in future

Transitioning to a 15-minute imbalance settlement period is a necessary step in bringing many benefits to the Nordic and European electricity markets. Yet it takes time for market players to adjust to a new market context and tap potential benefits such as a better use of existing interconnectors, increased possibilities for trading flexibility with neighbouring countries and utilizing new resources capable of operating with a finer time resolution. Is the 15-minute period optimal for reaping all the benefits? Or is a shorter period needed in the future that should be the ultimate target of market time period?

The need for flexibility in the system is likely to increase. The scope of settlement is likely to transition from static to dynamic, creating new areas and number of individual resources will increase at the same time when median size of individual resources is decreasing.

The trend is towards even shorter market time period. The speed of change is limited by our capability to agree on implementation across markets and build the necessary systems, data exchange and measurement infrastructure. Thus, it is logical to ask would later implementation schedule allow us to directly to move to even finer time resolution, e.g. 5-minute imbalance settlement period in used Texas or piloted in the Netherlands and Sweden.

Finally, it is worth to notice that the transition to 15 min balance settlement is only a part of larger change in the European electricity markets (Figure 10). Particularly Finnish generation companies have raised a concern would we lag behind other European players if transition to 15 min balance settlement is postponed.

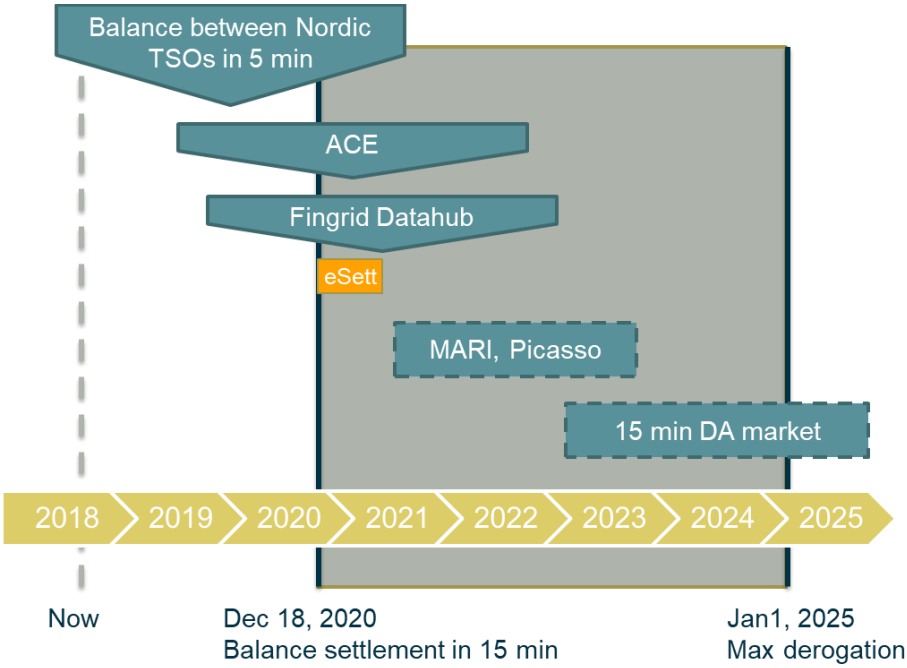

Figure 10. Changes in the electricity markets by the mid-2020's.

Balance settlement between Nordic TSOs will change to 5 min in 2020. Later in Q1 2021 modernised Area Control Error (ACE) is taken into use and each electricity market area will be separately responsible for balancing the electricity system in the area. The Datahub is planned to be in operation in Q2 2021. In Figure 10 we have highlighted also the special proposed interim role of eSett – a company proving imbalance settlement services in Finland, Sweden and Norway. The company is committed to start building conversion service to provide conversion capability from 60 min measurement data to 15 min imbalance settlement for Finnish electricity market participants and DSOs until the Datahub is in operation (Joki-Pesola, 2018). The Manually Activated Reserves Initiative (MARI) and the Picasso project for automatic frequency restoration reserves will establish European wide markets for balancing and reserve power in the early-2020's, and eventually it is expected that a common European day-ahead (spot) market with a 15 min market time period will emerge in the mid or late-2020's.

4 Scenarios for changes required to implement 15 min balance settlement

4.1 Market design and market access are separate but interlinked issues

Even if we scoped this study in the chapter 2.1 to focus on market design, we acknowledge that market access is in a vital role in order to realise the benefits described in the previous chapter. The 15 min balance settlement does not itself require measurement in 15 min but the settlement could be done with any data that is just converted computationally to 15 min time period. Grid users' market access to 15 min markets is not possible without measurement at the same time period. Furthermore, implementation of measurement also affects traceability of balance error, and thus accountability on costs and benefits of balancing the system (Figure 11).

In 2020, when balance settlement between Nordic TSOs will be changed to a time period of 5 min (first row in Figure 11), the Finnish TSO Fingrid will be responsible for balance error within 5-60 minutes. This is because Fingrid's customers (DSOs, large generation units and heavy industry) will still be measured in 60 min intervals and a computational split of 60 min measurements to 5 min balancing data causes residual balance error as the computational split inevitably differs from the real life result. The balance error will be an integral part of Fingrid's network losses portfolio, or in other words, one won't be able to separate balance error from technical network losses as no measurement information on the actual resources in the shorter time period is available. Naturally, the cost of the balancing error won't be carried by Fingrid. It will be spread between all its customers in transmission fees. In other words, costs previously covered across the entire market area or through other means will now be allocated between TSOs in 5 minute periods and these are then shared among all TSO connected market participants. Figure 11 illustrates this and other cases of different resolution groups.

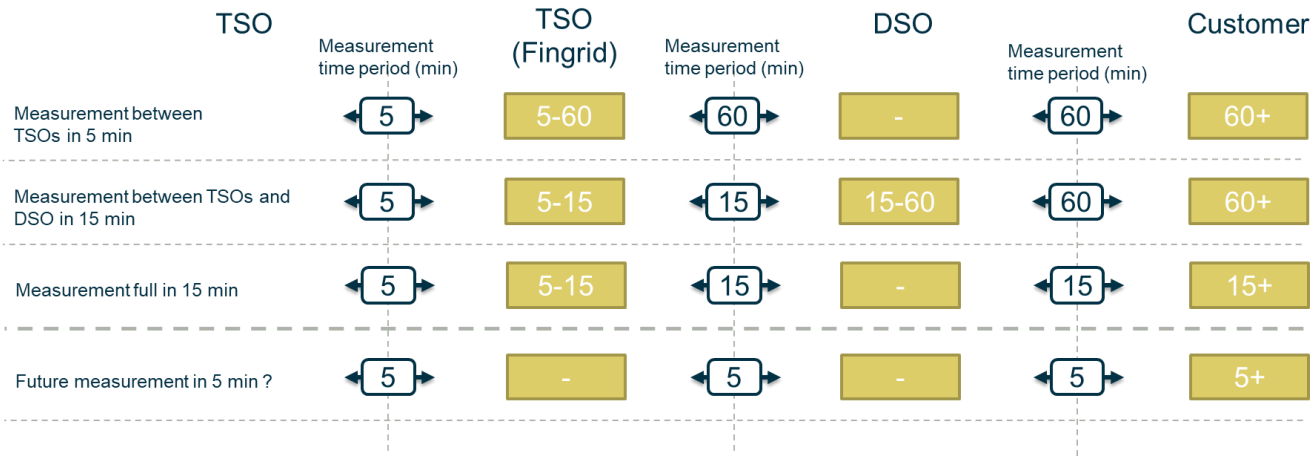

Figure 11. Accountability of balance error in certain time periods depends on measurement.

In the second row of Figure 11, grid exchange points between Fingrid and DSOs (or any other Fingrid customer) are changed to 15 min. This means that Fingrid's responsibility of imbalance is shortened from 5-60 to 5-15 minutes. If customers of the DSOs remain in 60 min measurement, the DSOs would carry responsibility of imbalance between 15-60 minutes and customers (or their balance responsible retail supplier) would be responsible only for balance error above 60 minutes since if they keep their aggregated hourly energy use in balance, any quarterly imbalance is not visible in the measurement data.

The third row in the Figure 11 shows the ultimate target state when also full rollout of measurement is eventually completed. The final row is a simple expectation about more distant future, showing that logical development would lead to 5 min measurement so that customers would be fully accountable for balance and TSOs and DSOs would not carry any residual balance error above five minutes.

4.2 Four implementation scenarios, from simple split of hourly values to full roll-out

In order to better understand practical changes that are needed to implement 15 min measurement to provide different market participants the access to the 15 min market, we have established four different implementation scenarios. These scenarios are used to identify required changes and estimate whether different implementation strategies have differences in realisation of costs and benefits. The analysis of the scenarios allows us to make preliminary conclusions of what would be a reasonable way to organise market access for all electricity market stakeholders.

The reference scenario (Figure 12) is based on staying at the hourly level in measurement. There is no 15 min measurement, but balance settlement is done by diving hourly measurement values into four equal size quarters. Middle scenarios limit the extent of 15 min measurement either by instinctive restriction or by impact on imbalance. The ultimate full-scale implementation scenario reflects a situation where all customers have 15 min metering.

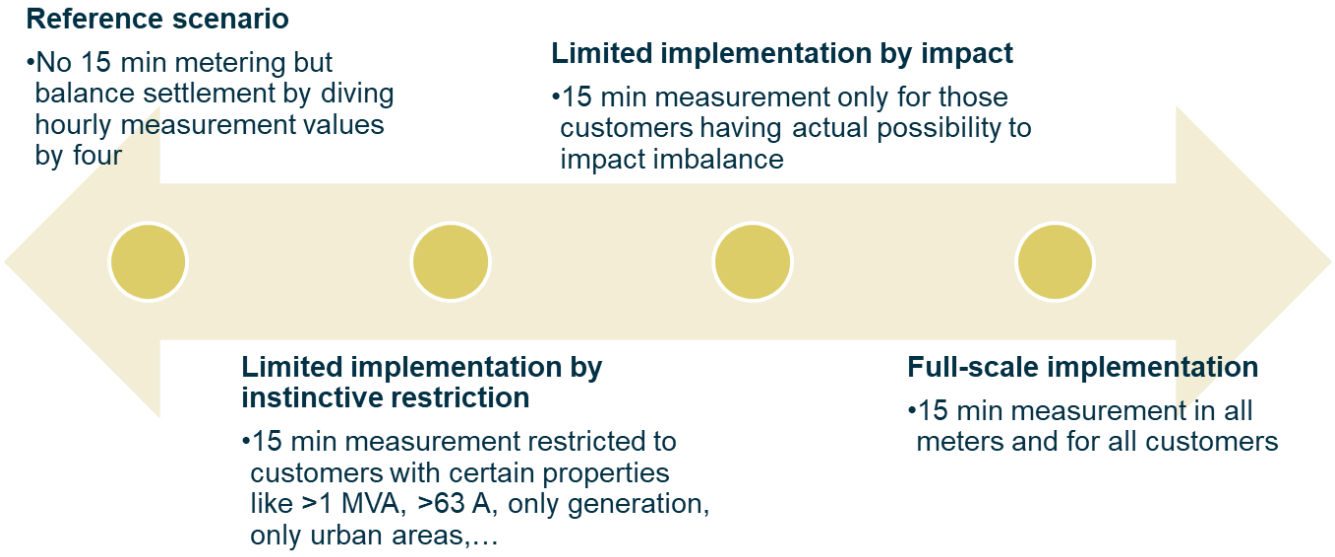

Figure 12. Four scenarios were developed to estimate costs and benefits of transition to 15 min balance settlement with different levels of 15 min metering.

Expert interviews conducted in the study (Pietilä & Nurminen, 2018) (Joensuu & Gröhn, 2018) (Saarinen;Nyberg;& Leppänen, 2018) revealed that services provided by the Fingrid Datahub are essential in order to keep required changes and implementation costs at reasonable level. Without the Datahub the need for information system changes is extensive and will be at least doubled when the implementation of the Datahub will require overlapping changes. This is because DSOs and electricity market players would be required to operate dual systems or provide the same data in two different time resolutions – one for those operating with hourly values and another for those with quarterly values.

The interviews also showed that differences in implementation cost are almost entirely related to the extent in which 15 min measurement data is gathered from the customers. In other words, implementation costs are strongly driven by number and kind of customers that are measured in 15 min resolution. This topic is analysed from DSO viewpoint in section 0 and from other electricity market stakeholders' viewpoints in the section 4.4.

4.3 DSO costs are more driven by 15 minute interval implementation than settlement

The cost of implementing a 15 min market resolution across all customers drives DSO costs more than the actual balance settlement. Implementation of the balance settlement mechanism itself should therefore be at the focal point of DSO cost evaluation when addressing the holistic transition to a 15 min market mechanism. The implementation cost of finer time resolution is largely carried by DSOs. A recent study (Energiateollisuus ry, 2018) that has surveyed expected implementation costs as described by 37 Finnish DSOs covering 2.6 M customers or 62% of all Finnish network customers (Figure 13). One should notice these costs include only costs for DSOs to provide the 15 min measurement data. Additional costs are likely to occur for market participants (see more details in following section 4.4).

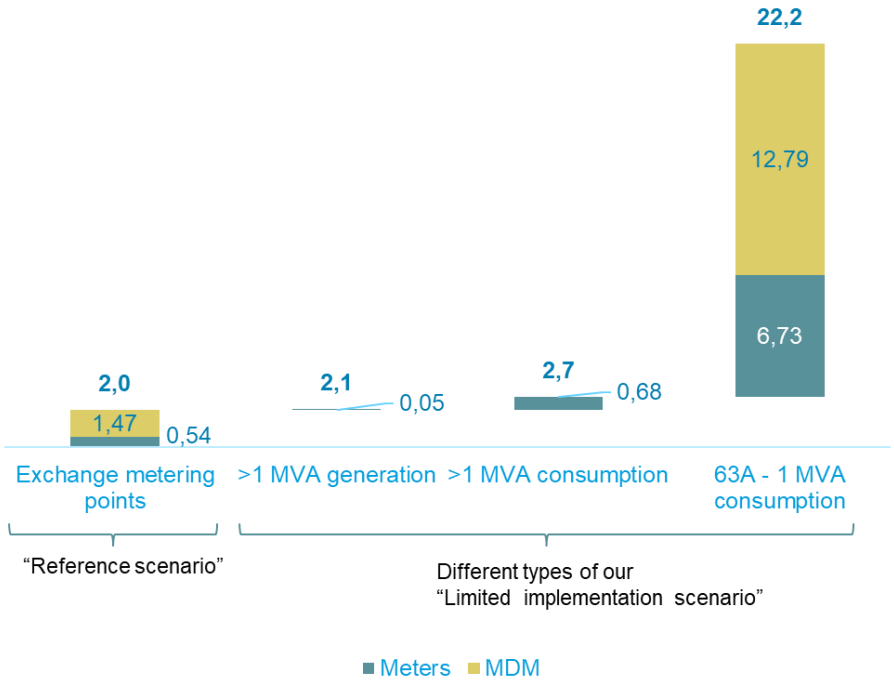

Figure 13. Cumulative costs (in M€) of metering and meter data management (MDM) to Finnish DSOs escalate the larger the extend of implementation. Note that analysis omits the option to extend 15 min metering to all meters. Source: (Energiateollisuus ry, 2018)

With regard to the scenarios presented in this study, we interpreted the results of the Energiateollisuus ry study so that metering and MDM (meter data management) costs related to grid exchange metering points correspond to our *"Reference scenario."* This is because the Finnish TSO can in its terms of connection require DSOs to arrange metering at this level independently of the timetable of implementation for 15 min balance settlement or any end customer measurement.

The rest of cases analysed in Figure 13 correspond to our intermediate *"Limited implementation scenario"*, regardless of whether the extent of 15 min metering is limited only to >1 MVA generation, consumption or to all 63A customers[8]. Even if only some customers are transferred to 15 min measurement resolution, it causes additional investments in DSOs meter data management systems (Saarinen;Nyberg;& Leppänen, 2018). The DSOs will need to analyse and validate the meter readings in order to provide market compliant data. Also, DSOs will need to update their customer reporting unless it is provided directly from the Fingrid Datahub.

[8] All these kinds of physical thresholds can be interpreted as a way to operationalise our "Limited implementation with instinctive restriction" scenario as they are not based on any market impacts of such restrictions.

Even in the *Limited implementation scenario* information system changes similar in magnitude to the Datahub project are required by the DSOs even if the scope would be more limited (Joensuu & Gröhn, 2018). This is because the systems themselves do not differ regarding information volume. Implementation scopes could be somewhat smaller due to smaller data volumes. It is also expected that availability of competent resources could be a bottleneck if DSOs are required to update their systems to 15 min resolution at the same time when all market participants are updating their systems to be Datahub compliant. IT system experts interviewed in this study estimate that such changes would be only temporary since they are not needed when the Datahub is in operation. The estimated cost varies a lot between 50 k€ and 500 k€ per organisation depending on the size of the organisation, or a total of 4-40 M€ for all Finnish DSOs depending on actual scope.

The survey does not cover costs of implementing our ultimate ”Full-scale implementation scenario” where all network customers are metered in 15 min resolution. However, based on our expert interviews (Joensuu & Gröhn, 2018), (Saarinen;Nyberg;& Leppänen, 2018) MDM costs are expected to increase only slightly as necessary expensive system changes are already needed to manage metering data of 63A - 1 MVA customers and additional MDM costs would be driven by larger hardware and data transfer capacity required to manage larger data sets. Consequently, the cost of meters would get more weight if implementation were extended to cover all customers. Costs would escalate rapidly (Figure 14). A large Finnish DSO willing to stay anonymous estimated that such full-scale replacement would cost “tens of millions euros” just for them. This would indicate that the total cost for such replacement for all Finnish DSOs would be at size of hundreds of millions euros[9].

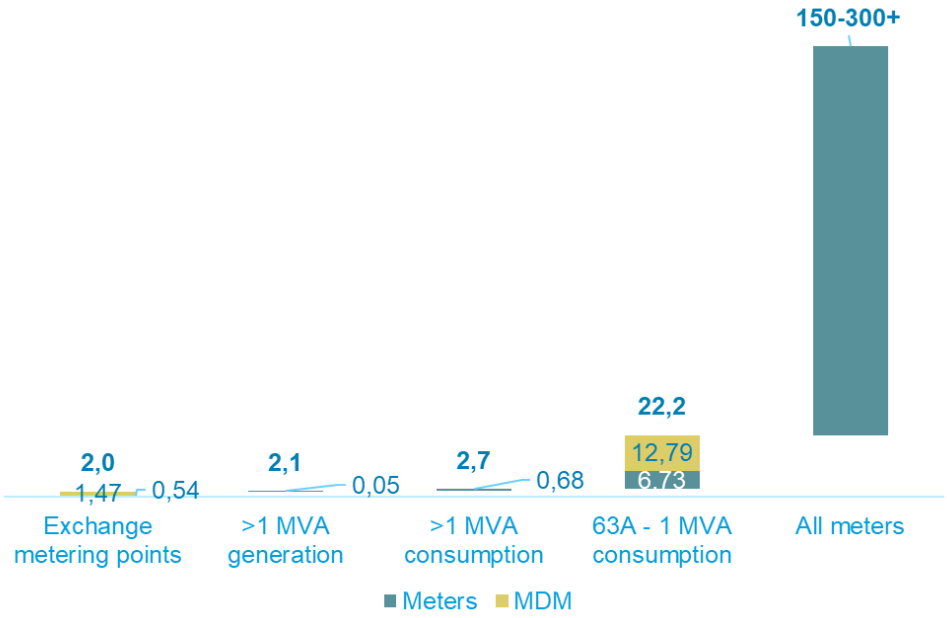

Figure 14. Requiring the change of all meters into 15 min resolution would escalate costs (in M€). We assume that 20...40% of meters would have to be replaced based on estimates by individual DSOs in (Energiateollisuus ry, 2018) and (Energiavirasto, 2018).

It is also highlighted that additional costs are likely to occur also to those DSOs that have meters capable of providing 15 min data simply with a software update[10]. When a service model is used to acquire metering data, changes in agreements will most likely to lead to increased costs (Energiavirasto, 2018). Existing service agreements are now typically valid until the mid-2020’s. Changing metering time resolution would require amendment to the agreements.

[9] Compare to total replacement value of roughly 3.5 million meters being about 700 million euros.
[10] According to (Energiavirasto, 2018) some meters can be updated remotely but some meters require software update to be done manually that would cost 10-12 euros per meter.

While the scope of this study does not cover a detailed analysis of implementation cost of Full-scale scenario, we can with high confidence assume that the cost would be higher by factor of ten when compared with the Limited implementation scenario. These costs are mainly driven by early replacement of the current AMR meters.

To conclude with the analysis of impacts on DSOs the expected investment costs should be compared to the expected benefits for the electricity system, and in more fundamental level to the principle providing fair access to the market equally for all customers. As presented above, on the one hand the costs are mainly driven by early replacement of current electricity meters. On the other hand, it is obvious that not all customers benefit from market access as they cannot provide flexibility to the market directly nor there is aggregator service that could coordinate a fleet (or a virtual power plant) of small sources of flexibility. Logically, 15 min metering and therefore market access should be first provided to those customers that expect benefits from the market, and the rest of customers could be provided access to the 15 min market when meters are replaced as originally planned. Judgement on whether meter should be replaced early should be at the customer and reflect true costs of meter replacement. This would be market based approach and also allow fair and equal access to the market for all customers.

4.4 Scenario implications for electricity market players

4.4.1 Reference Scenario

In the reference scenario hourly values are divided by four in order to populate 15 min data. Even if this is done, as the intraday and regulating power market are moving to 15 min market period, the market players will need to update their supporting data systems in any case (Pietilä & Nurminen, 2018). These systems include intraday time series management systems as well as reporting and billing systems for the trading. In a case a market participant wants to stay in “hourly operative mode” that would be possible since trading and balance management could be done with hourly block products.

On the other hand, there is no incentive for market players to change their behaviour as changed way of operating is not reflected in the imbalance or balance management. This may cause significant additional costs particularly when Nordic TSOs take into use the modernized Area Control Error (ACE) model in 2021, and Finland market area needs to be on average in balance. If market participants do not change their behaviour, costs for regulating power are expected to increase 9…26 million euros per annum (Pöyry, 2018).

Even if market participant would like to manage its balance more actively, lack of 15 min measuring data would limit market operations to hourly block products. The hourly blocks are likely to be less efficient products than quarterly products if other Nordic countries are in the quarterly markets. Additional cost for Finnish market participants is estimated to be 0.6…1.8 million euros per annum (Pöyry, 2018).

4.4.2 Limited implementation Scenario

One of our key findings is that there is clear incentive for market participants to switch to 15 min balance management mode even if only limited number of customers are in 15 measurement and balance settlement[11]. It does not matter in which way measurement is restricted to certain customers.

In theory market participants could have an option to operate with double systems, one for customers with 15 min and another for 60 min, but most likely the lowest cost alternative would be to change all customers to a single 15 min process (and e.g. split hourly measurement values for those customers that do not belong to 15 min measurement). Market participants that are not able to operate in 15 min

[11] Naturally these changes would be as likely also to directly balance responsible generators/consumers as they are for retail sellers that are analysed in more detail in this section.

markets are likely to face disadvantage in intraday and regulating power markets (see previous section) even if it could be possible to continue operating only with hourly block products.

The market participants need to update both their operative processes in balance management and key electricity data management systems in order to be able to analyse customers' electricity usage as well as customer information systems for managing billing and reporting.

Customer information systems may need more far-reaching updating if market participants introduce new 15 min based products or if it is required that customer reporting should be all in 15 min. Our experts (Joensuu & Gröhn, 2018), however, estimate that market participants capability to create additional value for customers is smaller when shifting to 15 min market time period than it was when hourly products were introduced. On the other hand, market participants specialising in providing services for new types of short-term demand response or demand side management may find certain customers highly attractive if they are in 15 min measurement. Therefore, particularly for virtual power plant concept developers, the limited implementation scenario creates unnecessary obstacles as part of the possible consumers/prosumers may not have access to the markets.

The DSOs need to be able to provide 15 min metering and meter data management for a certain part of their customers. Concerning equality and fair market treatment, it is a prerequisite that all similar types of customers should have similar measurement requirements independent of geography, network topology or their respective DSOs. For the rest of the customers either the DSOs or Datahub must be able to split hourly values into quarterly values. It is noted that such splitting leads to a situation that possible error between actual and calculated energies in splitting hourly values will be mixed with grid losses, depending on implementation of grid exchange point information handling or in other words, residual balance error cannot be separated from grid losses. The size of the phenomenon is not analysed in this study, but we highlight the importance of following the level of grid losses in order to prepare for possible mitigating actions.

4.4.3 Full-scale implementation Scenario

Our expert interviews concluded that moving from the *Limited implementation Scenario* to the *Full-scale implementation Scenario* initiates only minor differences for market participants but a large roll-out effort for DSOs to cover all customers with 15 min measurement.

Logically full-scale implementation brings the full benefits of the finer time resolution for the Finnish power system and economy. Imbalance will be allocated accurately to its source and separated from other grid losses. All stakeholders, including new resources currently incapable to operate in the hourly market period of the electricity market will have equal access to balancing markets and also benefit from market coupling to Central Europe.

4.5 Information management before and after the Finnish datahub implementation

If we accept that not all customers will be offered instant access to the 15 min market, the measurement data management could be handled in different ways. We already know that the Datahub won't be in operation when balance settlement is changed to 15 min as regulated by the EU Commission. Therefore, Fingrid is taking steps to agree on the provision of conversion services with electricity balancing service company eSett, which Fingrid owns together with Swedish and Norwegian TSOs. (Joki-Pesola, 2018)

The service provider eSett will convert 60 min data into 15 min from Dec 18, 2020 until the Datahub is in operation. This mitigates the schedule risk of the Datahub, as eSett can continue to provide the conversion service even if the Datahub launch is delayed. We see that this solution is more optimal than the two other extreme options (Table 1). If all electricity market parties were instantly required to be fully compliant from Dec 18, 2020 in 15 min measurement and balance settlement, it would require DSOs and suppliers / generators to operate a double mechanism: one for those customers already in 15 min measurement and another for the customers with 60 min measurement. DSOs and market participants would also need to invest twice: First in quickly updating their information systems to create capability to split the 60 min measurement data into 15 min data (note that this is not a Datahub compatible requirement) and later again as a new investment in order to update information systems to be compatible with the Datahub.

The other option to fully utilise the derogation and keep an isolated 60 min system in Finland only is also not very feasible due to reasons explained earlier. The other Nordic TSOs have informed that they are not going to ask for the derogation (Joki-Pesola, 2018). Therefore, eSett would have to have double mechanisms: 15 min for other countries but 60 min for Finland only. Finnish market participants as well as DSOs would get off easy as no changes would be needed – until in 2025 when 15 min balance settlement would in any case have to be taken in use.

It is critical to keep in mind that in the latter case there would also be market entry barrier for flexible resources in Finland as introduced earlier. As other countries are changing into 15 min there would be need, and therefore market demand, for flexible resources. If Finland were left out of the market, flexible resources would be invested in by Sweden and Norway. As the derogation in Finland would eventually end in 2025, the flexible resources in the other Nordic countries would already be the chosen instruments for use. They would thus gain competitive advantage as they would already have gained experience in operating in the 15 min market in Sweden and Norway as well as regained invested monies creating lower marginal cost for them to continue in the market.

These viewpoints support fast transition to 15 min balance settlement in line with the neighbouring countries. This can be best enabled with a conversion service so that DSOs have the possibility to plan and schedule investments in 15 min measurement, assuming that the countries enter 15 minute balance settlement as planned in legislation. This approach also does not limit voluntary implementation and use of 15 min measurement if such capability exists as eSett will have to have 15 minute data handling capability in any case. Implementing and scheduling this on a technical level are to be defined in detailed implementation planning of the eSett services offered and the transition to Datahub enabled settlement.

Table 1. Data management mechanism and costs before 15 min measurement roll out

Path to 15 min imbalance settlement	eSett	DSO	Market participant (supplier/generator)
15 min full requirements for all parties	1 mechanism Shared costs between Finland, Sweden and Norway	Double mechanism: 1. 15 min measurements 2.. 60 min measurements Double investment: 1. Datahub 2. splitting 60 to 15 min before Datahub	Double mechanism: 1. 15 min measurements 2.. 60 min measurements Double investment: 1. Datahub 2. splitting 60 to 15 min before Datahub
1 hour kept until max derogation 2025 after which full 15 min requirement anyway	Double mechanism Double investment Costs of double system carried by Finland only Market barrier for Finnish flexibility resources	No change	No change Market barrier for Finnish flexibility resources
1 hour to 15 min conversion service	1 mechanism Shared costs between Finland, Sweden and Norway Small conversion investment carried by Finland	No change until 15 min measurement in place (possibility to optimize investment timing until 2025)	Wholesale: 1 mechanism 1 investment Retail: Optional investment small conversion investment if 15 min result carried over to retail portfolio

5 Conclusions and summary of results

5.1 Trade-off of costs and benefits

We have analysed benefits and costs of transition to 15 min balance settlement and allowing market access to different market participants in the chapters 0 and 0. We have emphasised that the EU Commission regulation rules only about balance settlement and it does not have any direct control over markets, measurement, billing or electricity data management.

It is obvious that the full benefits of the transition to 15 min imbalance settlement are not realised until the whole value chain from generating energy to using it is in 15 min measurement. It is equally clear that the cost of roll out of 15 min measurement to cover all Finnish customers would be tremendous. This trade-off depicts the big picture of path to future energy markets, of which transition to 15 min balance settlement is only a part. However, it is the part that triggers all other necessary changes (Figure 15). The most productive way to manage the changes would be to discuss and decide each of them separately step by step and avoid unnecessary mixing of issues. In this study we have focused on 15 min balance settlement but noticed the strong link to implementation of 15 min measurement, for which we have given fairly large weight in the study and brought on the table key uncertainties in this respect, too.

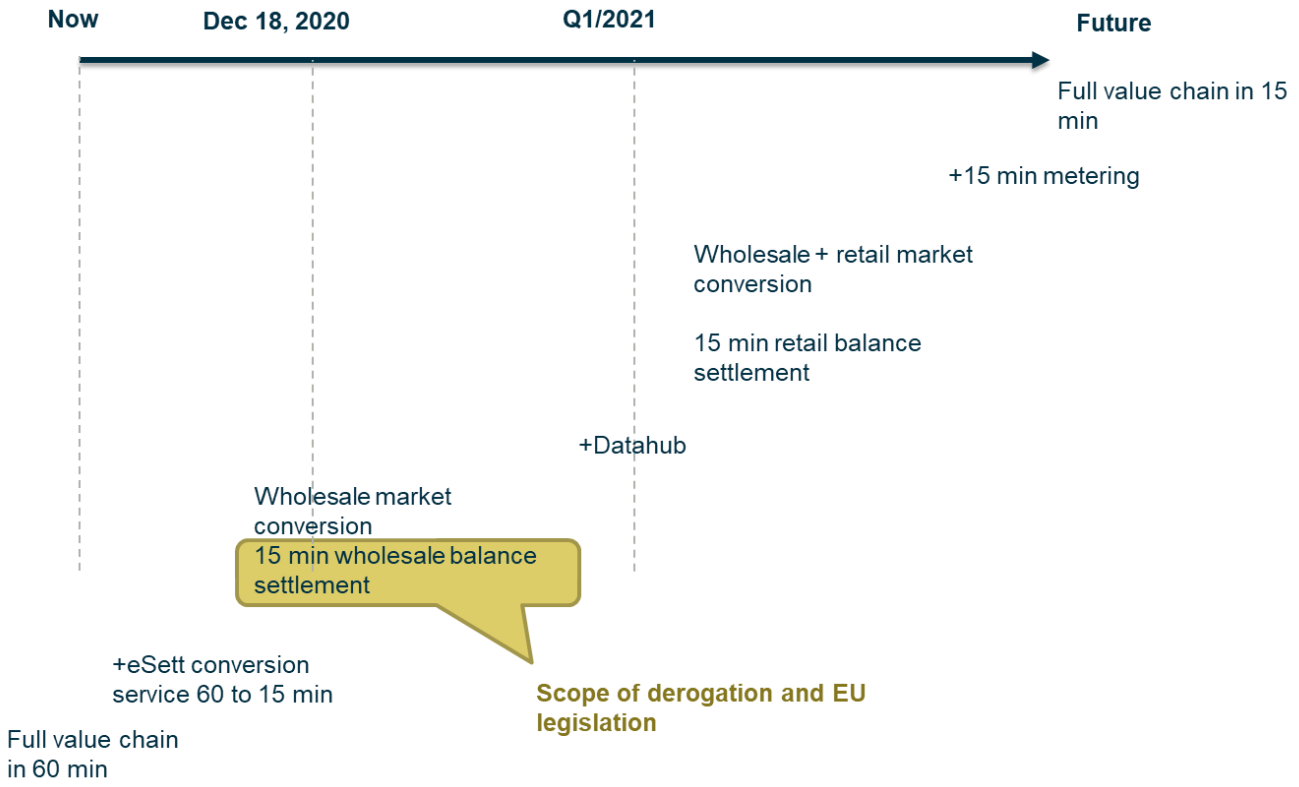

Figure 15. Transition to 15 min imbalance settlement is a vital step in the path to the future energy markets.

The sooner imbalance settlement is in 15 min time period, the sooner the question of which customers should be provided with access to new 15 min markets becomes relevant. Prioritisation and selection of customers that would be first provided with 15 min measurement should be done keeping in mind that leaving a customer out of 15 min measurement means that the cost of possible imbalances caused by the customer are shared between all other customers. Similarly, if the customer would provide flexibility to the system, opportunity cost would be lost if access to the 15 min market is not arranged. Therefore, we see that 15 min metering and market access should be first provided to those customers that expect the highest costs and benefits from the market. With regard to what is stated here, it is obvious that proposals requiring only generation to be measured and settled in 15 min are weak in

terms of solving the actual issue. Not only would this limit actual incentivising of positive consumer behaviour, but it would also socialize all of the actual errors that the generation would follow between all consumers. The minimum cost optimum of a power system requires that all resources, i.e. both generation and consumption, connected to the system carry their responsibility to provide balancing in the system in the form of behaviour or actual resource allocation.

5.2 Difficulties related to implementation of a 15 min settlement period in Finland

Difficulties related to implementation of a 15 min settlement period are listed in Table 2. A holistic view of the issues is presented below in Figure 16.

Table 2. Summary of difficulties related to implementation of 15 minutes settlement period.

Electricity system stakeholder	The difficulties related to the implementation of the harmonisation of the imbalance settlement period to 15 minutes in Finland
Generation companies	**Issue #1: Lack of data** Operating in 15 min market time period requires data for modelling and optimising generation and trading risks. **Issue #2: Market mechanism** Common Nordic intraday market mechanism must be in 15 min resolution otherwise expected benefits are not realised.
Heavy industries	**Issue #2: Market mechanism** Common Nordic intraday market mechanism must be in 15 min resolution otherwise expected benefits are not realised**.** **Issue #3: IT system updates** Change to finer time resolution needs to be done at all factories / sites. This takes time (~ 12…24 months) particularly due to IT system changes. It is not reasonable to start system changes until market rules are fixed. **Issue #4: Difficult to manage balance** Some industrial processes are difficult to forecast and they are causing balance error. Even if cost of imbalance would be allocated more accurately to the source of error, it may not be possible to reduce imbalance. Thus 15 min balance only increases costs.
Electricity retail sales companies	**Issue #2: Market mechanism** Common Nordic intraday market mechanism must be in 15 min resolution otherwise expected benefits are not realised. **Issue #3: IT system updates** Change to finer time resolution needs to be done at all factories / sites. This takes time (~ 12…24 months) particularly due to IT system changes. It is not reasonable to start system changes until market rules are fixed. **Issue #5: Lack of measurement data** Expected benefits, and thus new value proposition for customers, could realise only after actual metered data is available.
TSO (Fingrid)	**Issue #2: Market mechanism** Common Nordic intraday market mechanism must be in 15 min resolution otherwise expected benefits are not realised.
DSO's	**Issue #3: IT system updates** Change to finer time resolution needs to be done at all factories / sites. This takes time (~ 12…24 months) particularly due to IT system changes. It is not reasonable to start system changes until market rules are fixed. **Issue #6: Meter replacement/updates** Practically all meters needs to be updated either by software or hardware. This takes time (36…60 months) and escalates implementation costs particularly if meter hardware needs to be replaced. **Issue #7: Increasing OPEX** Service agreements for meter reading could be valid until mid-2020's and shorter meter reading resolution needs to be amended to the agreements. **Issue #8: Increasing OPEX** Memory capacity of metering devices may not be able to store increasing amount of data as long as today. This may lead to increasing maintenance costs in case of data transfer errors.

Retail customers / end users	**Issue #9: Meter replacement/updates** Cost of renewed meters at the same time as cost of weather-proofing the network. **Issue #10: Investment costs** Actively benefiting from 15 min market time period requires automation and suitable service offerings from retail sellers or aggregators.

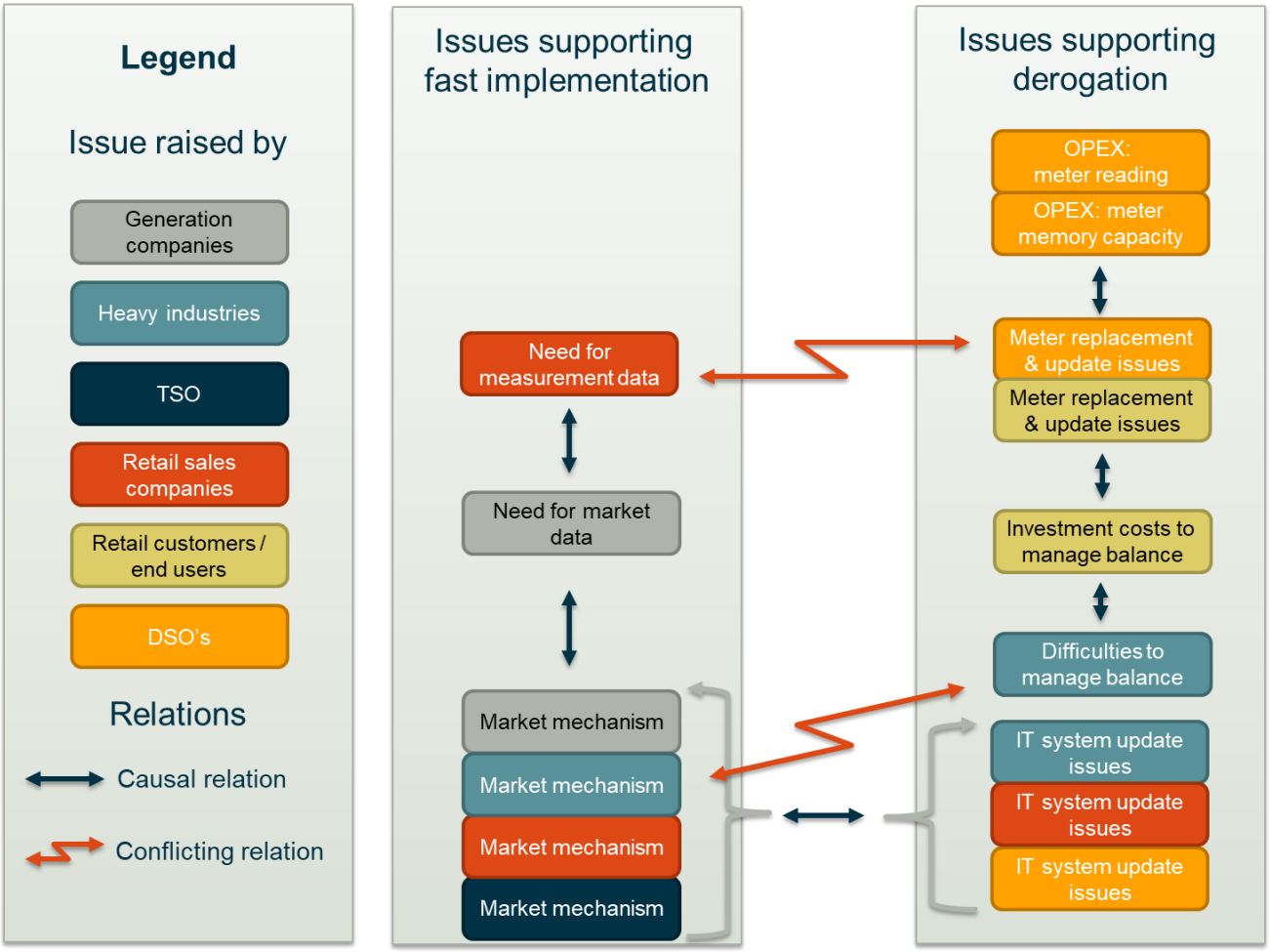

Figure 16. Relationships of identified key issues in implementation of 15 min balance settlement and corresponding market changes, supporting fast implementation vs. supporting derogation.

The Common Nordic intraday market mechanism is a joint concern among the key stakeholders except for DSO's and retail customers/end users. Expected benefits of the 15 min balancing period will not materialise unless intraday markets in Nordic market area are in 15 min resolution. The extent of the market mechanism changes causes some conflicts as in certain heavy industry processes it is difficult to manage balance and thus more austere responsibility of one's own balance would just cause additional costs instead of actually leading to smaller imbalances.

The importance of the common market mechanism is highlighted also by its tight relation with IT systems. Required IT system updates take time (typical estimates are 12…24 months) but it is not reasonable to initiate such changes until market rules are set.

The generation and trading companies have indicated the sooner they get market data the sooner they are able to optimise their production and trading models. The full benefits of the finer time resolution do not occur unless market participants change their behaviour or optimisation models.

In order to deliver the benefits of 15 min market time period to retail customers, retail sales companies (we include also separate aggregators into these) need to have measurement data from retail

customers. This is in conflict with DSOs' key difficulty that is meter replacements or updates causing both increasing capital and operational expenses. These additional expenses are in the end paid by end users bearing in mind that meter related costs may not be enough but end users may need to invest even more into automation that actively manages users' balance if they want actively benefit from the shorter time resolution.

5.3 Operational security risks and implications of 15 minute interval implementation

Technically, the transition to 15 min balance settlement does not introduce any new processes or operating methods to the Finnish electricity system. Thus we do not see that implementation of 15 min settlement period would create new risks in terms of operational security.

We acknowledge that the transition to 15 min balance settlement leads to fourfold data compared to the current situation. This could pose a technology risk stemming from the capability of IT systems in handling such data volumes without configuration or functional changes. However, as this functionality is taken into account in the Datahub and all IT system conversions, we see the risk to be mitigated along with the Datahub implementation project.

The increasing amount of data may cause problems with data transfer from distant meters out of cover of mobile data networks. We see that from operational security point of view the risk is negligible as number of such customers is expected to be limited and their consumption relatively small from system operational security point of view.

5.4 Actions taken to facilitate implementation of 15 min settlement period in Finland

The services provided by the Fingrid Datahub project once online are in practice a prerequisite for full practical implementation of 15 minute balance settlement in Finland. Practically all experts we have interviewed pointed out that the Datahub should be in use before changing to a shorter time period. The Datahub supports the implementation as it can provide necessary data conversions in case part of customers are in 15 min and part in 60 min measurement resolution. Otherwise all market participants, currently about 100 electricity retail sales companies and 80 DSOs would have to individually update their IT systems and be prepared to do so again after datahub implementation.

Fingrid has proposed to provide conversion services for interim use through electricity balancing service company eSett, which Fingrid owns together with Swedish and Norwegian TSOs. (Joki-Pesola, 2018).The service provider eSett will convert 60 min data into 15 min from Dec 18, 2020 until the Datahub is in operation. This mitigates the schedule risk associated with Datahub implementation, as eSett can continue to provide the conversion service even if the Datahub launch is delayed.

The XBID (cross-border intraday market) project is a European project that enables intraday trading across European market areas. In the first wave, which was launched in June 2018, intraday trading is possible in an area covering 14 countries incl. the Nordic and Baltic countries, Germay, Austria, the Netherlands, Belgium, France, Spain and Portugal. The XBID is implemented by local parties, in Nordic market area, by Nord Pool and EPEX. The XDIB allows for orders entered by market participants for continuous matching in one bidding zone to be matched by orders similarly submitted by market participants in any other bidding zone within the XBID area, as long as transmission capacity is available.

Table 3. Summary of actions taken to facilitate implementation of 15 min settlement period.

Action taken to facilitate the implementation of the harmonisation of the imbalance settlement period to 15 minutes in Finland	Electricity system stakeholder(s) affected and coverage	Difficulty to which the action is related	Status of the action	Further information
Datahub project	DSO, retail seller	Issue #3: IT system updates	IT system purchasing agreed on June 18, 2018. Planned start in Q2 2021.	Director Pasi Aho, Fingrid Datahub Oy, +358 30 395 5262
eSett conversion service 60 min measurement data into 15 min	DSO, retail seller, generation company, heavy industry, TSO	Issue #3: IT system updates	Agreed and possible to continue the service until the Datahub is in operation	
XBID project	Generation company, retail seller, heavy industry	Issue #2: Market mechanism	First trades done in June 2018.	Local implementation: Market manager Vassi Kujala, Nord Pool Spot, +358 44 558 2774

5.5 Impacts of non-implementation of 15 min settlement period in Finland

In terms of non-discrimination and competition with other European market participants, in particular as regards demand response and renewable energy sources, we have identified two key impacts of non-implementation of 15 min settlement period or even if DSOs do not provide 15 min metering but just splits hourly values into four quarters.

1. Possible derogation limits market participants access to balancing and regulating power markets and leads to higher electricity costs (Figure 17), and

2. Creates competitive advantage for those which have possibility to gain experience and market data of operating in 15 min markets during derogation (Figure 18).

As already discussed earlier in this report, non-implementation of shorter balance settlement period gains competitive advantage for intermittent renewable energy sources (typically wind and solar PV) as management of imbalance is less stringent. Correspondingly controllable renewable energy sources (biomass and hydro) lose part of their competitiveness as they are not able to fully benefit from better capability to manage balance. Eventually non-implementation of 15 min settlement period would encourage market participants to invest more in intermittent resources and less in controllable resources.

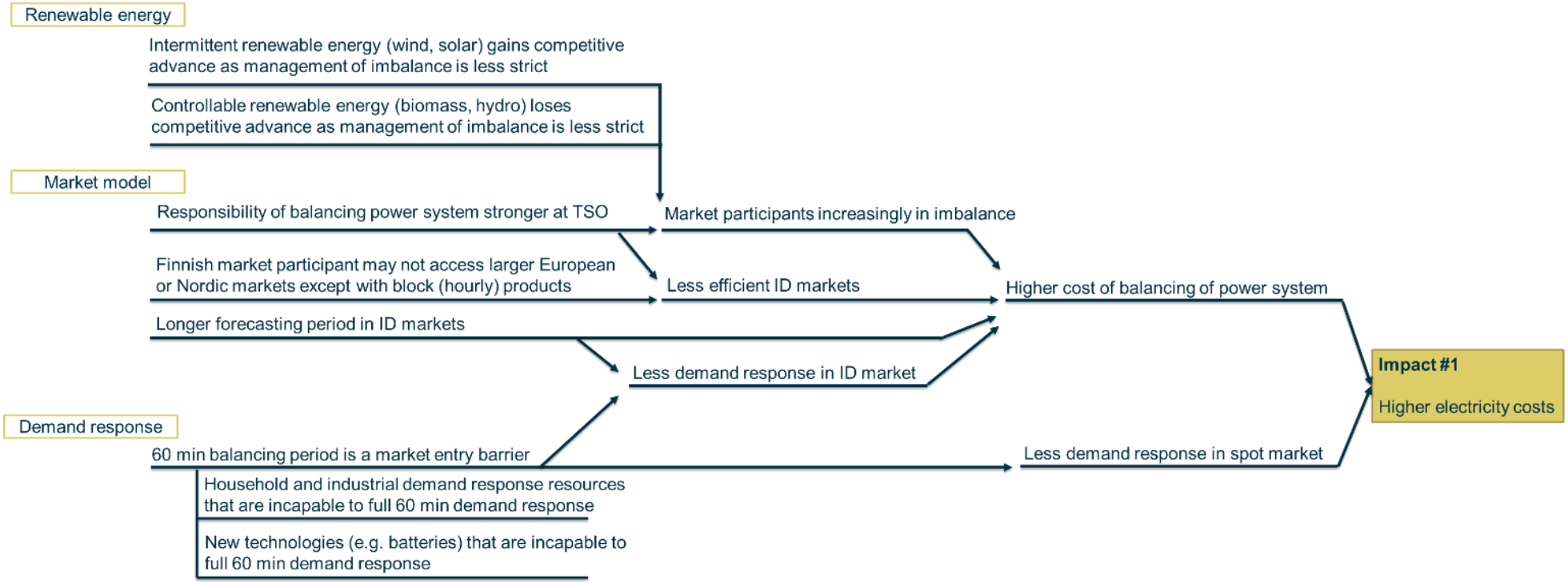

Figure 17. Impact #1 of non-implementation of 15 min settlement period is higher electricity costs in Finland.

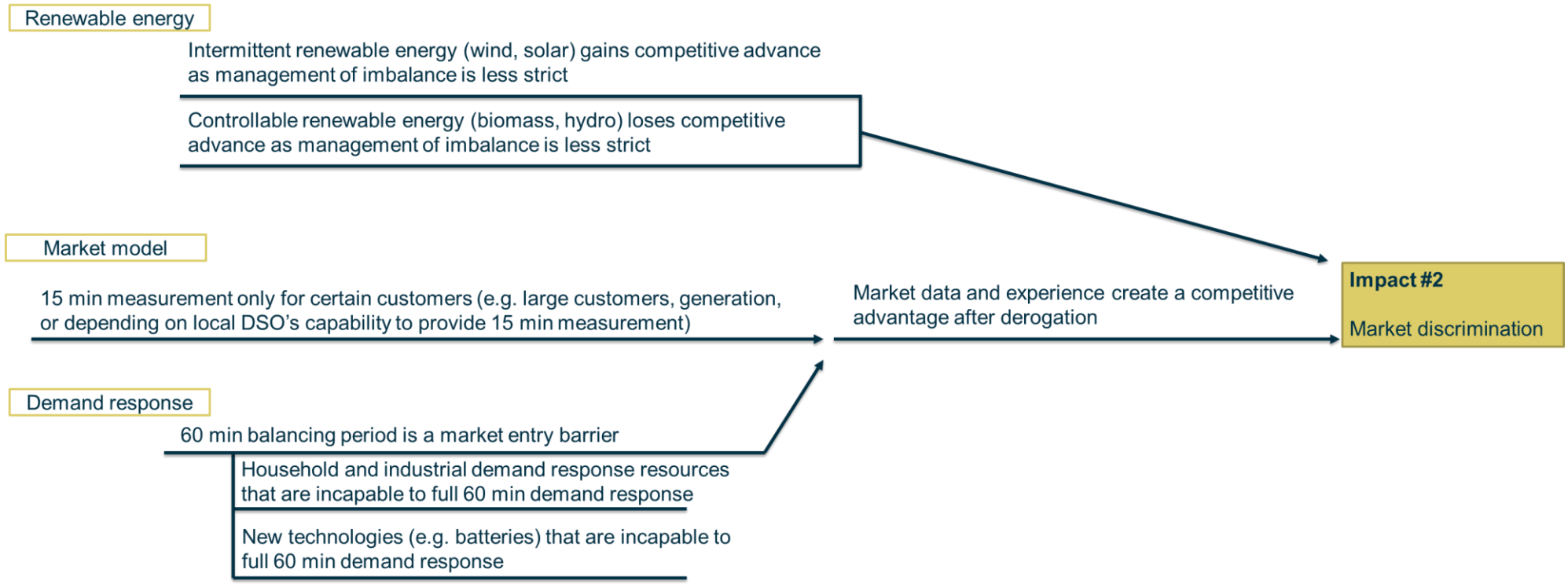

Figure 18. Impact #2 of non-implementation of 15 min settlement period is market discrimination favoring intermittent generation and allowing those customers and technologies having possibility to 15 min measurement to gain experience and data on operating in 15 min market.

5.6 Impacts on overall economic efficiency

Figure 19 on the following page summarises investment needs and expected economic gains[12] depending on implementation strategies. Investment cost in the Limited implementation scenario is based on updating information systems and 15 min measurement capability at TSO-DSO grid exchange points and at large industrial load and centralized generation points with balance relevant characteristics. The Full-scale implementation scenario adds the investment cost of replacing retail customer meters. Low and high scenarios of annual benefits indicate economic gains from intraday trading, balancing cost optimization and market coupling. These are based on the material presented in the earlier chapters and adjoining studies as introduced earlier.

The results indicate that based on this high level cost benefit analysis, introduction of 15 min balance settlement with a limited 15 min measurement implementation would have a payback time of a few years. For actual indication of more specific and focused costs benefits, we recommend Finnish electricity market stakeholders to conduct a more focused study in order to identify in detail which would be the right market participants to be prioritised in introduction of 15 min measurement in order to realize benefits from the investments as soon as practicable.

From this high level analysis it is also clear that any full implementation of 15min measurement would carry significant costs and that specific work should be undertaken to establish whether it would be feasible to introduce 15 min measurement across the board as a separate investment. This study does not provide insight into normal end of life replacement type investments, but from initial expert discussions, it is evident that in such a scenario differentiation between 60min and 15min capability will not produce any significant marginal cost difference due to technological advancement.

[12] By economic gain we mean aggregated cost savings for electricity users and additional revenues for producers.

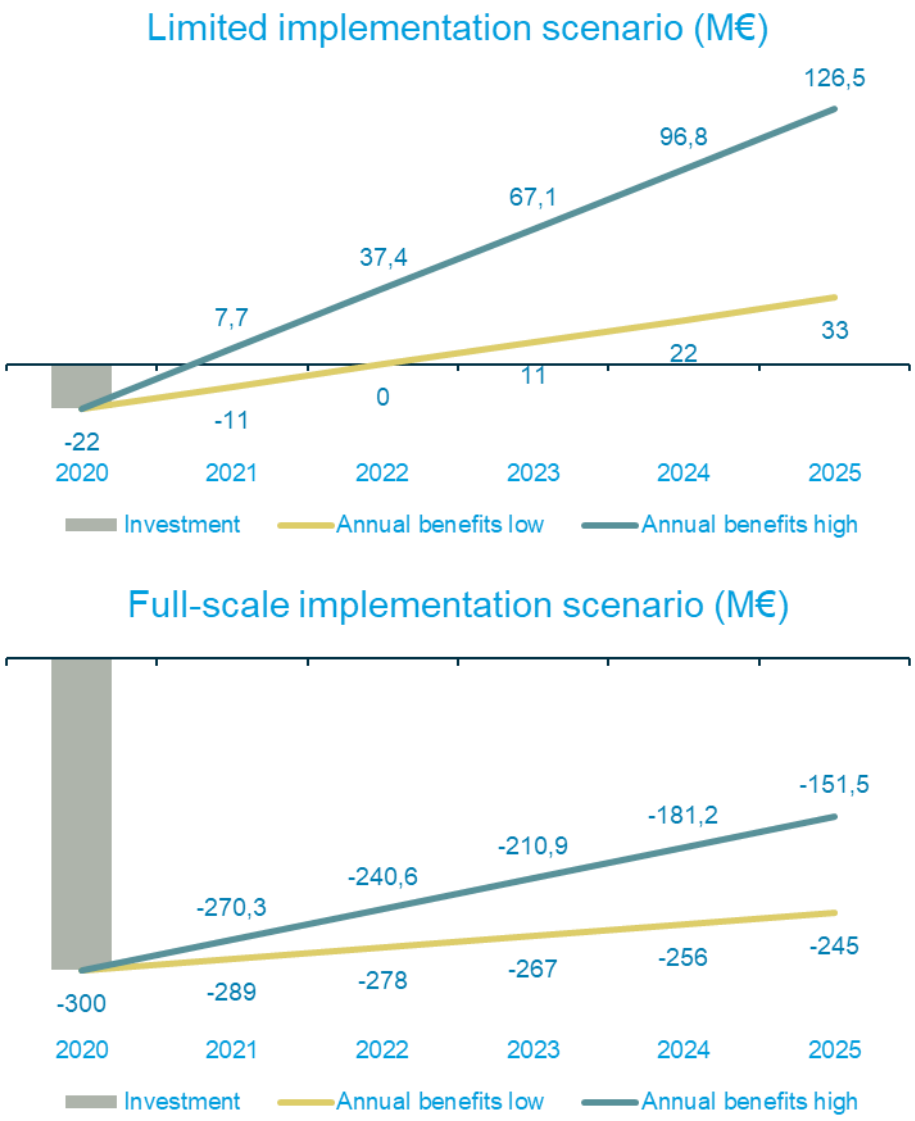

Figure 19. Impacts on overall economic gains and implementation costs with different implementation strategies (combined content of Chapter 3 and Chapter 4 financial evaluations) .

5.7 Overall consequences on the European market integration process

Based on our expert interviews (Joki-Pesola, 2018), it is likely that Sweden and Norway are proceeding with 15 min balance settlement on schedule set by the EU Commission and they are not planning to ask for the derogation. We expect that possible Finnish derogation would not change the decision in Sweden nor in Norway.

Choosing a different implementation date for settlement from Sweden and Norway would not make sense from a Finnish standpoint. The overall European market integration process would not be impacted by Finnish derogation but as discussed earlier, Finnish markets would lag behind the European market integration if derogation is utilised. This would build a market entry barrier for Finnish flexibility in 15 min resolution and correspondingly continue unjust allocation of cost away from Finnish market participants creating these costs by causing imbalance.

6 Recommendations to ensure smooth transition to to 15 min balance settlement

6.1 Recommendations on transition to 15 min balance settlement

We encourage all market participants to recognise the different steps and parts of market design and implementation so that conversation between different stakeholders is focused and to the point and avoid mixing different issues. Figure 20 represents a framework how conversation could be divided into different stages. The earlier stages in the path to the future energy markets are enablers for benefitting from following stages.

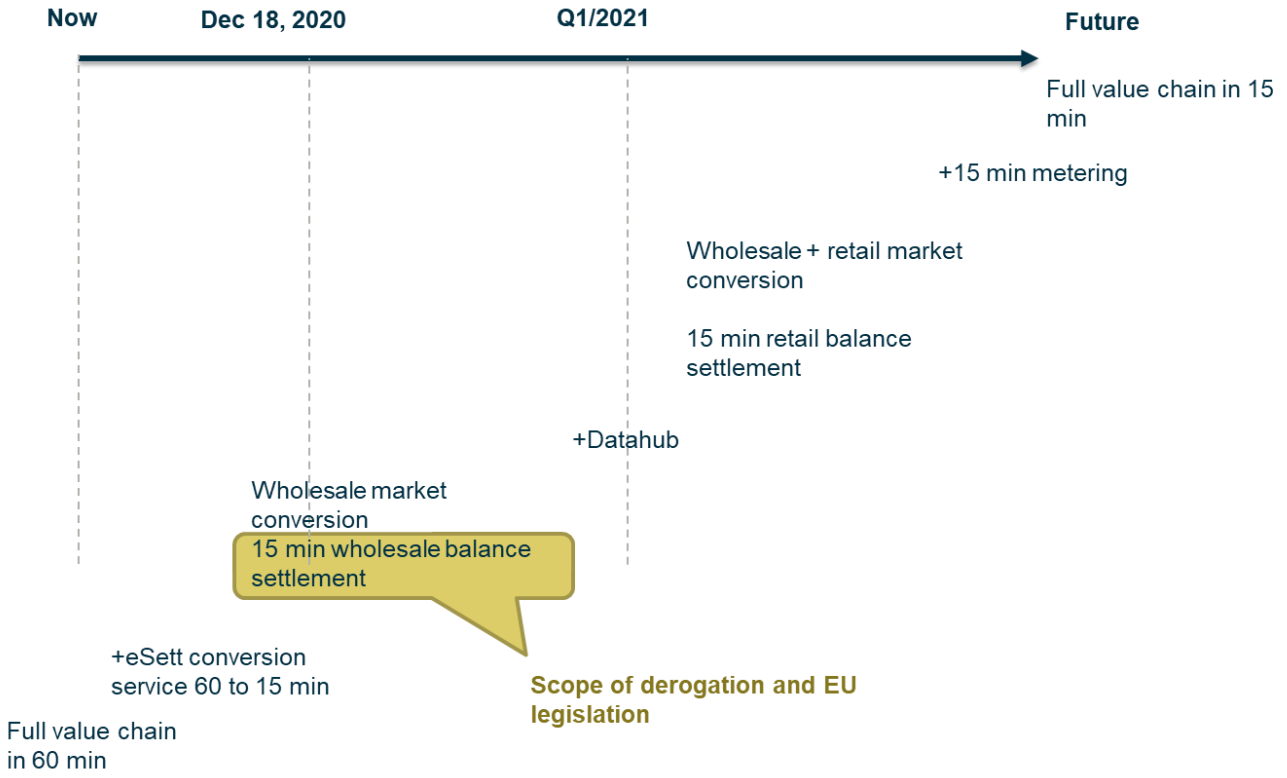

Figure 20. We encourage all market participants to recognise the different steps and parts of market design and implementation so that conversation between different stakeholders is focused and to the point and avoid mixing different issues.

6.2 Recommendations on development of regulation to ensure change benefits

As we see that a market driven approach is likely to produce the most efficient implementation of the 15 min market time period, we highlight the following scopes for change in underlying regulation for incentivising stakeholders in enabling access to the market:

1. The full benefits of the 15 min market period and corresponding settlement will not be achieved until at least the customers mostly responsible for balance errors are equipped and settled in 15 min time periods without any calculated or profiled consumption/generation data. To ensure such coverage of parties in requiring 15 min measurement, a change in existing regulation may be needed (Valtioneuvoston asetus sähköntoimitusten selvityksestä ja mittauksesta, 2009). This change should be made with proper market goal settings in such a way that costs and benefits of balance settlement could be allocated correctly to the affected market participants causing the balance error. Detailed work will be needed to focus the change accordingly.

   In addition, for costs induced by the required update of metering equipment and adjoining capabilities to handle the above mentioned customers, a dedicated metering fee should be considered if measurement is not implemented across the board. This would allow the change cost to be allocated to the specific participants instead of creating an additional shared cost for all system participants. In preparation work, special consideration must be given to establishing baselines and behavioural information from periodic sampling or other methods in order to establish group eligibilities.

   We strongly emphasise that the focus of this study has not been to identify customers or market stakeholders that should be prioritised in introduction of 15 min capable meters. Bearing in mind that meter replacement costs are estimated to be significant, we emphasise the recommendation to study optimal meter implementation strategies in more detail. In doing so, it is crucial that underlying regulation will allow corresponding cost allocation in a way that will incentivise DSOs as retail market enablers to make full use of available technologies in implementing whichever strategy is deemed appropriate in future work.

2. The DSO regulation model should be modified after corresponding legislation concerning 15 minute time period implementation is in place so that it encourages DSOs to provide 15 min data to market participants (i.e. end users and retail/wholesale companies). In case settlement is done in 15min periods over grid exchange points measured in 15 min and part of the customers are in 60 min measurement, but conversion based balance settlement is done in 15 min also for them, it is not possible to separate errors in calculated and actual balances from other network losses. The current DSO regulation model considers network losses a “pass-through” item that DSOs can fully allocate to their customer tariffs. On the other hand, any costs related to implement and execute 15 min measurement are considered “controllable costs” that DSOs are required to reduce.

   The description above means that the existing DSO regulation model does not encourage DSOs to implement 15 min measurement, but rather encourages them to keep up calculated data as long as possible in order to avoid more controllable costs subjected to efficiency requirements. Potential solutions could be to exclude operative costs related to 15 min measurement from the efficiency requirement, or to provide a similar “innovation incentive” as was used for incentivising AMR meter data flow opening for retail markets in 2012-2014.

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