BBEMA: Dashboard for Baltic Balancing Energy Market Analysis

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ABSTRACT

In order to increase the efficiency of the power system balancing process, the Baltic countries launched a common balancing market in 2018. While the new market does have a data dashboard, its visual functionalities and interactivity are limited, which hinders its use for deeper analysis. In this study, a dedicated dashboard for visual analysis has been developed utilizing data from the first three years of the market's operation. The tool can be useful to various market stakeholders such as operators, participants, policy makers and researchers. The paper provides examples on the insights that can be gained from the dashboard.

CCS CONCEPTS

• Human-centered computing→Visualization→Visualization application domains→Visual analytics

KEYWORDS

Baltic balancing market, energy data visualization, dashboard, visual analysis, data analysis, data visualization

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1 Introduction

All electric power systems are characterized by an important and unique feature: electrical energy cannot effortlessly be stored in large amounts. Therefore, at any time instant the energy demand must be met by corresponding production [9]. Nowadays, with energy markets liberalized in many countries, power system equilibrium is mostly achieved via well-functioning markets of different type and scale. Among others, these include wholesale markets (forward, day-ahead, intraday) and also separate markets for reserves or balancing services [11]. Through balancing, transmission system operators (TSOs) continuously ensure that the electricity system frequency is kept within a defined security range. To foster effective competition and enhance efficiency of balancing, the European Commission Regulation on electricity balancing aims at integrating balancing markets and promoting cost-efficient and reliable exchange of balancing services among the European countries [5]. In light of this Regulation, the three Baltic TSOs (Augstsprieguma tīkls AS (Latvia), Elering (Estonia) and Litgrid (Lithuania)) have established a common Baltic balancing market (BBM) to exchange balancing energy and manage the imbalance netting process within a coordinated balancing area, which is operational since 2018 [3]. The Baltic balancing market is just one example of the marketplaces for electricity that have emerged during the last decades as a result of the EU-wide electricity market liberalization, harmonization and integration. Still, the Baltic example is one of the first already implemented regional initiatives aimed at integration of balancing markets specifically [1]. Currently, it is used for manual frequency restoration reserve (mFRR) products [4], whereby the TSO selects balancing energy bids of market participants from a common merit order list and employs marginal pricing.

The focus of this study is development of a dashboard for Baltic energy balancing market analysis (BBEMA) based on historic market data covering the first three years of its operation (2018–2020). The remainder of the paper is organized as follows. After a short of review of the available BBM data and dashboard, the development of BBEMA is presented by introducing the use cases, data employed and providing illustrative visualization examples.

2 Existing solutions

Though the BBM was launched more than three years ago, due to its limited regional scale, to the best of our knowledge, there have been only a few publicly available papers analyzing selected aspects of BBM operation during its first two years [8, 10, 12]. These analyses have been performed by the Latvian TSO, while the raw operational market data is freely available to the market participants and other interested parties on a dedicated website, the Baltic CoBA Balancing Dashboard [15]. It includes most important market indicators, such as the volume of aggregated balancing

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energy bids, activated bids, balancing energy prices and imbalance volumes. The data are available through API and downloadable in several formats, and each individual indicator can also be visualized on the dashboard in a simple line chart for a user-selected time period (Figure 1). While this provides market transparency, a lot of additional effort is required for the user to actually analyze the data from various aspects, cross-relate different quantities and time periods, and evaluate the long-term dynamics. In addition to the dashboard data, the Latvian TSO publishes regular (monthly and annual) overviews of the Latvian electricity market. While this includes also some statistics on BBM, the number of indicators covered is limited, and the visualizations lack interactivity. Moreover, the static charts are available just in the Latvian version [16], while the English publication only includes a few tables [17].

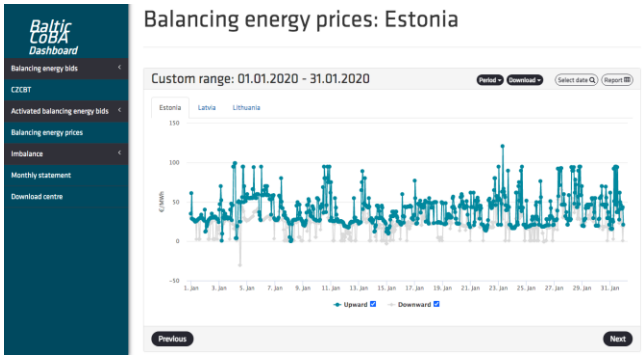

Figure 1: Screenshot of a BBM dashboard chart

3 BBEMA development and results

Although the launch of BBM has already contributed to more efficient system balancing, the Baltic TSOs are still seeking for additional balancing providers to improve market liquidity, increase its cost-efficiency and widen the scope of available balancing resources in preparation for the planned Baltic power system synchronization with the Continental Europe system as of 2025 [8]. To that end, user-friendly tools for analyzing the BBM data could be beneficial in raising awareness and attracting new market participants, including those parties which have not been active in electricity markets before (e.g., demand response (DR) aggregators). Furthermore, independent analysis of BBM operation could inform the further endeavors of the Baltic TSOs in expanding the market to include new products and ensure continuous availability of the required balancing reserves. To provide BBM participants and other stakeholders with an interactive tool for broad balancing market analysis, the development of BBEMA dashboard was started. In the next subsections, potential users and requirements for the dashboard, used datasets, developed visualizations and use cases are presented.

3.1 Potential users and use cases

Potential users of BBEMA can be classified in three main groups: (1) market operators (TSOs); (2) market participants (both existing and prospective); (3) researchers, market analysts and policy-makers. All the groups can benefit from the data analysis facilitated by the BBEMA visualizations, allowing them to observe not only long-term trends but also identify extraordinary events for further analysis. For the purposes of this study, five main use cases have been identified to be supported by BBEMA dashboard so as to provide the users with data analysis tailored for their needs. Based on the use cases, specific data were selected for BBEMA.

Market liquidity can be analyzed based on the **volume of balancing energy bids** submitted by market participants. For the TSOs and policy-makers, it is important to identify market deficiencies, e.g., hours with shortage of balancing energy as this can be critical for the power system stability. Ideally, there should be no hours with zero balancing bids.

Furthermore, the **activated balancing energy bids** would be of interest for a market participant allowing them to assess the volumes of energy ordered by the TSO and, thus, evaluate the market potential for a specific amount of their mFRR resource. These data, along with the total volume of bids, illustrate the probability of bid acceptance for mFRR providers.

Next, **balancing energy price** is an important indicator for all the involved parties as it can have an effect on all the electricity market participants, end-users including. The balancing price determines the income/cost of the balancing energy sold/purchased by the TSO to/from the balance service providers, respectively. Furthermore, it is used for calculating the imbalance settlement price paid by all the balance responsible parties.

Moreover, the resulting **imbalance volume** analysis is crucial for the TSO in order to plan ahead the required balancing energy volume, and the **imbalance price** should be considered by the balance responsible parties when pricing their service provided to other electricity market participants.

Finally, BBEMA allows comparing the market strategy of participants in all three countries, by observing the trends of their balancing energy bids submitted/activated and their bid price range offered to the market. Considering the small size of the Baltic regional balancing market, strategies of individual market participants can also be deduced from BBEMA visualizations. This information is useful also for research purposes, including market modeling.

3.2 Used data sets

To support users with wider data analysis possibilities, BBEMA combines data provided by the Baltic CoBA Dashboard [15] with some data from the Nord Pool day-ahead market [18]. It is necessary because CoBA provides only balancing market data; however, it can be very useful for a market participant to cross-relate balancing prices with day-ahead market prices. This allows comparing the potential profitability from both markets in case a prospective participant needs to select one of the two or devise a profitable strategy for operating in both markets, thus improving their overall financial results. E.g., in case of an inaccurate day-ahead volume forecast (foreseen before the closure of balancing market), the respective surplus/deficit could possibly be compensated in the balancing market for a more beneficial price than the resulting imbalance price. Therefore, to provide a tool for this type of analysis, BBEMA includes not only the balancing

market price but also the respective Nord Pool day-ahead market price and, furthermore, illustrates their difference. As a rule of thumb, the price for upward/downward balancing is usually above/below the day-ahead price, respectively.

To be more precise, the Baltic CoBA Dashboard provides the following indicators with hourly resolution (corresponding to the hourly imbalance settlement period) [15]: (1) balancing energy bids for the standard and specific (emergency reserve) products of mFRR; (2) activated balancing energy bids per type of activation (normal activation, special activation for countertrade and for other purposes); (3) balancing energy prices; (4) imbalance volumes and prices. Also, it has data on cross zonal capacities within the balancing timeframe and monthly statements of Baltic TSOs, but they are not used in this version of BBEMA as they are irrelevant for the selected use cases. All data used are shown in Table 1.

Table 1: Data used in BBEMA

Baltic CoBA dashboard	
Balancing energy bids	Volumes of aggregated balancing energy bids for the standard mFRR product - datetime, country, direction, volume in MWh
	Balancing energy bid price range for the standard product - datetime, country, direction, minimum/maximum price in €/MWh
Activated bal. energy	Activated balancing energy (normal activation) - datetime, country, direction, volume in MWh
Balancing prices	Balancing energy prices - datetime, country, direction, price in €/MWh
Imbalance	Imbalance volumes - datetime, country, volume in MWh
	Imbalance prices - datetime, country, price in €/MWh
Nord Pool day-ahead market	
Day-ahead prices	Day-ahead prices - datetime, country, price in €/MWh

When integrating data from both data providers, the difference of time zones needs to be considered. While Baltic CoBA uses Eastern European Time, Nord Pool employs Central European Time. Moreover, the daylight saving time is represented differently in both databases (while Nord Pool provides correctly the data for all hours of the year, the BBM data does not reflect the shift to/from the daylight saving time accurately, thus eliminating some data).

3.3 Developed dashboard

BBEMA dashboard is implemented in Tableau [19], which is a widely used visual analytics platform. Tableau allows integrating data from various sources, creating interactive visualizations and putting them together into a dashboard. BBEMA is implemented in Tableau Desktop and published on Tableau Public as https://public.tableau.com/views/BBEMA/Balancingbids_1.

Ten interactive charts together with data summaries are used in BBEMA to support analytics needs described before. The charts are organized into six separate dashboards, corresponding to the identified balancing market analysis use cases (Balancing bids, Balancing bid prices, Activated energy, Balancing prices, Imbalance volume, Imbalance price and Additional). A user can navigate between the dashboards using buttons. All dashboards have some degree of interactivity, because it offers the user more extensive analysis options and support for decision making, as it has already been proved in dashboards or visualizations for different domains [2, 7, 13, 14]. The data can be viewed at different levels of aggregation (yearly, monthly, weekly, daily, hourly) or in a user-selected range. A number of screenshots for various dashboards are provided in the Appendix, but two specific use cases are presented below showcasing some of the additional visual analysis tools provided by BBEMA which are unavailable on the existing BBM dashboard.

The barcode (stripe) chart in Figure 2 provides the user with a tool for analyzing potential market shortages. A barcode chart is similar to a rug plot [6], except it shows not only density (a fact represented with a bar) but also the values encoded with color saturation. It illustrates the number of hours per day with no bids submitted by market participants per balancing direction during 2018–2020. Interestingly, in the Baltics overall, there is less market liquidity for the downward balancing compared to the upward direction.

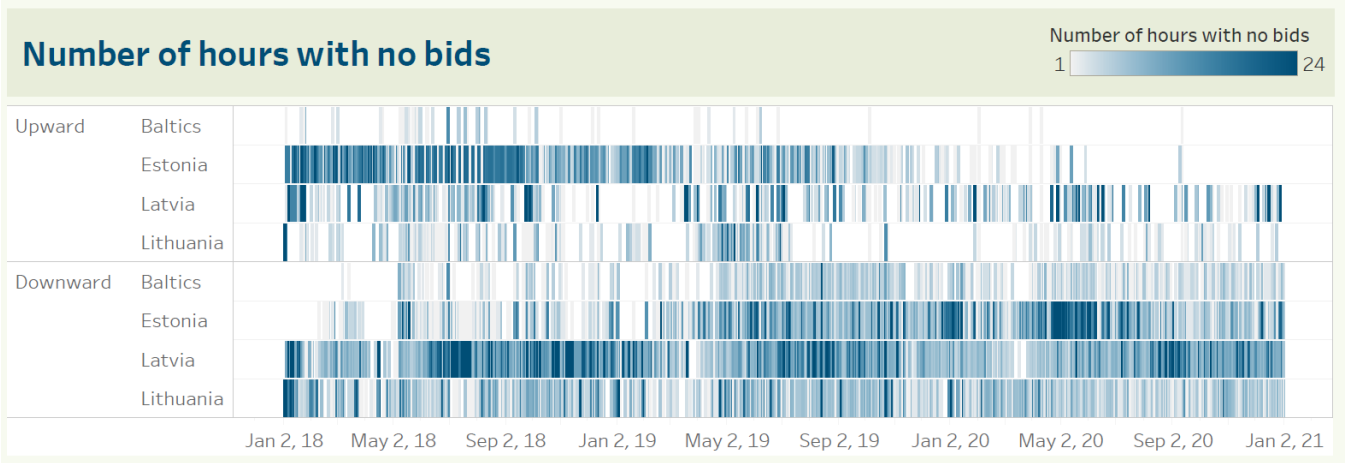

Figure 2: Balancing bid analysis in BBEMA

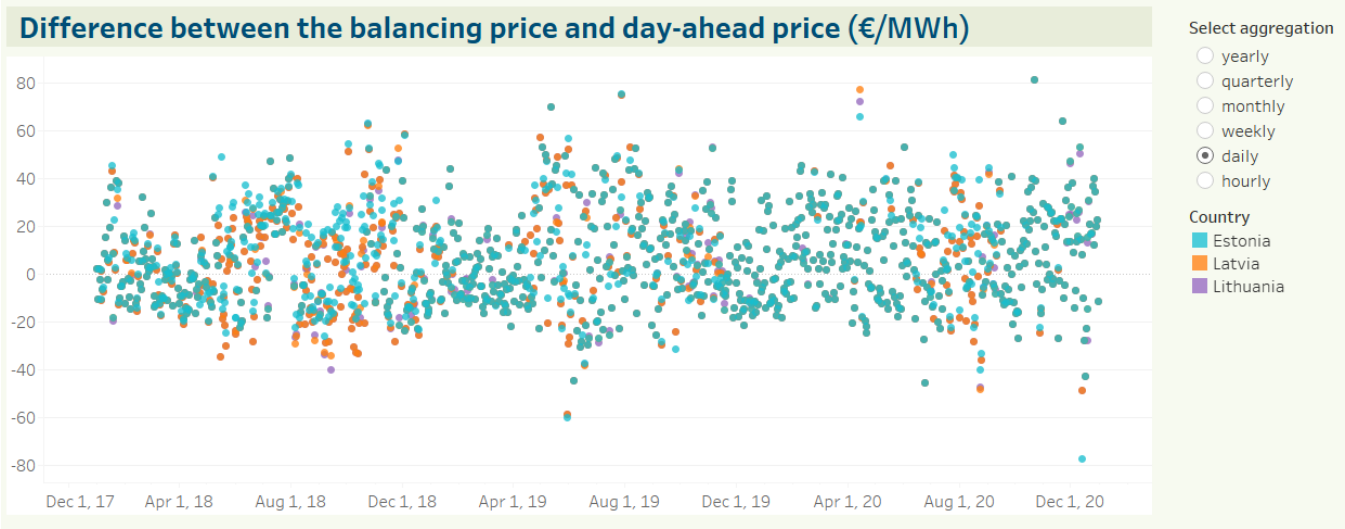

Figure 3: Balancing price analysis in BBEMA with respect to the day-ahead market price

This could be related to the technical capabilities of conventional power generators and the need to have a generator in operation to be able to provide the downward regulation by reducing its output. This can be easily provided by flexible hydropower plants (HPP), hence in Latvia we can observe the least downward balancing shortage around spring each year, which coincides with the spring flood season when HPPs dominate as an abundant energy source. Overall, Lithuania demonstrates the largest bid availability for both directions in Figure 2. This might be partly due to their Kruonis pumped storage HPP, which is able to operate in both directions (gen./cons.) and can be considered the most flexible large-scale generation source in the Baltics. Nevertheless, the chart shows occasionally insufficient availability of balancing bids. This indicates a potential market opportunity for energy storage or emerging DR aggregators in the Baltic countries who could provide upward balancing by reducing the consumption of DR-enabled equipment or smart appliances or even downward balancing, e.g., with thermostatic loads and employing thermal inertia inherent to buildings etc. The barcode chart also allows analyzing market trends during its first three years. E.g., a decreased activity of Estonian participants for downward balancing in 2019–2020 but a continuous increase of bids for the upward direction during the whole 3-year period. While the market activity from participants of different countries can be rather varied, it is obvious that the establishment of the common BBM has been very helpful in providing the Baltic TSOs with the balancing resources at hand compared to sourcing them by each individual TSO in their own country as was the case before [8, 10].

Next, Figure 3 shows the result of integrating data of two markets: Baltic balancing market and Nord Pool day-ahead market for the three Baltic countries. A positive price difference between the balancing and the day-ahead market usually implies upward balancing (selling the deficit energy to the TSO), while a negative difference is common for downward balancing (purchasing the energy surplus from the TSO). For a prospective balancing market participant such as a DR aggregator, this price difference indicates their potential profit from providing balancing services. E.g., if the DR resource reduces their normal consumption the energy for which has been procured in the day-ahead market, and the aggregator sells this non-consumption in the balancing market but still needs to compensate for the electricity purchased in the day-ahead market, then their profit would depend on the positive difference of both prices. In contrast, if there is a DR resource able to shift their consumption, thereby increasing the load and providing downward balancing, the benefit would be established based on the negative price difference.

4 Conclusion and future work

BBEMA dashboard developed in this study provides the various market stakeholders with visualizations for market analysis from a number of perspectives to support different use cases. The dashboard can be employed for a broad research of the first three years of Baltic balancing market operation and can also serve as a valuable tool for identifying extraordinary events in the market for further analysis of the outliers. The future work should be devoted to automation of data updates in BBEMA from the various sources of market data so as to allow the users accessing operational market data close to real time. Moreover, additional market indicators could be included in the next versions of BBEMA such as the expectation of bid acceptance, correlations between different market indicators (e.g., volume of bids or energy activated vs the bid price and balancing price). Finally, additional studies of user experience with BBEMA should be performed to finetune and extend the use cases and identify the user needs for further elaboration of the dashboard visualizations.

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A Additional BBEMA screenshots

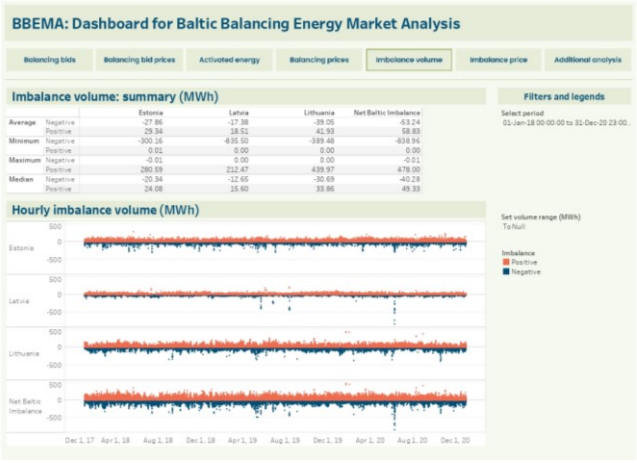

Figure 1A: BBEMA dashboard for imbalance volume analysis

Figure 2A: BBEMA dashboard for analysis of balancing bids

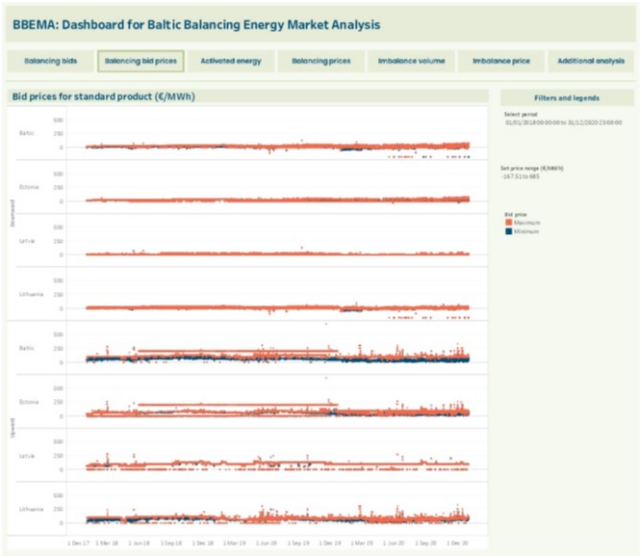

Figure 3A: BBEMA dashboard for analysis of balancing bid prices

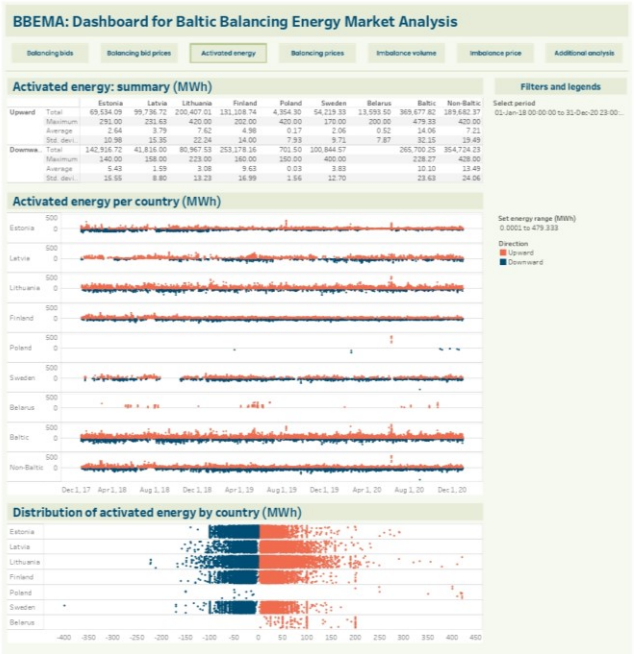

Figure 4A: BBEMA dashboard for activated energy analysis

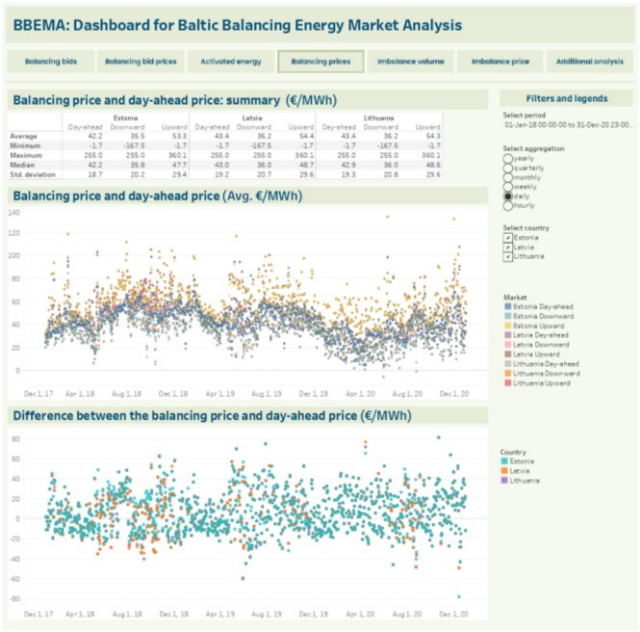

Figure 5A: BBEMA dashboard for analysis of balancing prices

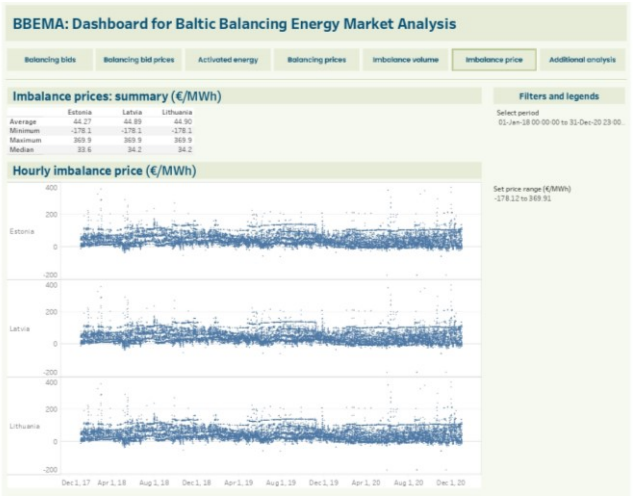

Figure 6A: BBEMA dashboard for imbalance price analysis

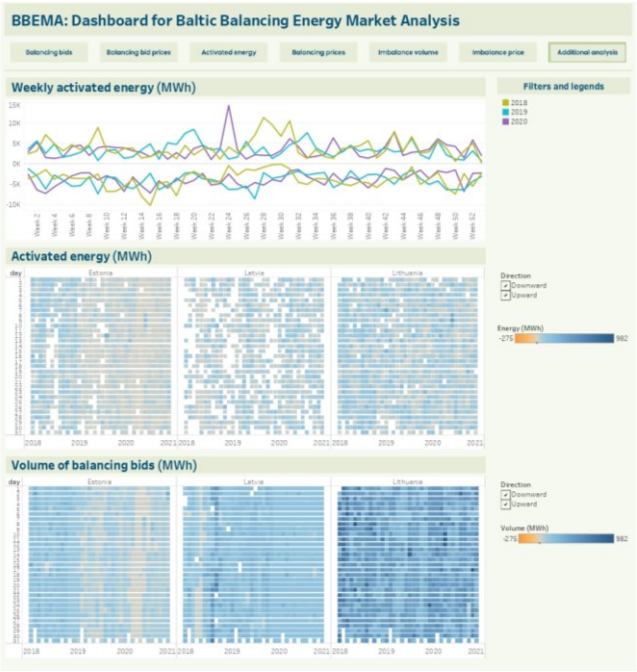

Figure 7A: BBEMA dashboard for additional analysis of activated energy and volume of balancing bids