Monitoring Natural Gas Balancing Markets

A practical guide for regulators on how the performance of the implemented balancing mechanisms can be assessed

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Abstract

Gas market liberalization is an ongoing process in many ERRA countries. By now it has turned out to be an iterative development process instead of a one-time transition as it took as long as 20 years for numerous, now mature EU countries. The experience of these markets has also shown that balancing mechanisms had pivotal role in this market transition process. The designing of the balancing mechanism is thus a crucial regulatory task which shapes current and future functioning of gas markets. Balancing regulation can be perceived as a continuous, adaptive designing process: matching the rules to the market's structure, its capabilities, and the regulatory aims. Consequently, regulators should closely monitor and assess the effects of implemented balancing measures on the market. Despite such importance of analyzing the effect of the implemented balancing schemes, little explicit guidance is available either from EU institutions or from academic literature. Furthermore, most of these focus on the analysis of liquidity on the developed trading hubs, which does not provide a solution for most ERRA countries which either lack a centralized trading platform or it is still underdeveloped.

This paper aims to contribute to the work of regulators by providing an example on how such balancing-focused market analysis could be conducted in practice. We build a theoretical framework for the analysis and based on that we define indicators that can describe the various aspects of the balancing market. Our method is also applicable to markets where the majority of short term trades is not organized through a transparent trading platform, and thus there is no available straightforward indicator to assess the short term market liquidity. We demonstrate our tools and analytical framework on the Croatian market to show how a specific assessment could be conducted.

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I. Introduction

Gas market liberalization is an ongoing process in many ERRA countries. By now it is evident that it is not a one-time transition, rather it is a long process which took for many by-now mature EU countries as long as 20 years. The experience of these markets has also shown how pivotal role balancing mechanisms have in this market transition process. (Creti, 2016) Market based balancing regimes can provide the support of the short term markets that they essentially need in their infancy to be able to thrive towards becoming a well-functioning liquid wholesale market. What's more, some academics argue that the first phase in the development of wholesale gas market entails balancing as the primary objective of traders. While only a second phase – which develops on this first phase - entails gas provision as a second sourcing for shippers to supplement long term contracts. (Miriello-Polo, 2015) The designing of the balancing mechanism is thus a crucial regulatory task with high impact on the current functioning and also on the future performance of the gas market. It is no wonder that the EU regulation also placed high importance on harmonizing the balancing rules within the Union and to push Member States towards the implementation of full market based balancing mechanisms.[2]

Balancing regulation can be considered as a continuous adjustment of rules to the market's structure, its capabilities, and the regulatory aims. It starts out from a rather technical oriented prescription for the vertically integrated monopoly; follows with the gradual implementation of market based tools after market opening (transition period); and 'ends' with the implementation of a full market based regime. During the transition period – which most ERRA countries are currently at – regulation could be perceived as a very delicate balancing with the market's capabilities. If implemented measures are 'too-market based' compared to what the actual industry can handle the regulation can result in inefficiencies, price distortions and even supply disruptions instead of the expected positive and strengthening outcome. Therefore, regulators during the transition period need to have a profound understanding of the market's ability and should continuously monitor the effect of the implemented new balancing rules on the market.

The EU Balancing Network Code (BAL NC) which effects many ERRA countries either as being Member States or either as Signatories to the Energy Community Treaty also considers this adaptive approach for those countries which are in such transition phase. Specifically, BAL NC provided the possibility that "in the absence of sufficient liquidity of the short term wholesale gas market, suitable interim measures… shall be implemented by the transmission system operators." (BAL NC – Article 45) In this group the TSOs shall prepare annually a report which shall assess the current state of the short term market, the proposed interim measures and how those support market liquidity and the proposed timeline of the removal of those.[3]

Furthermore, the Third Energy Package[4] also established the high level market monitoring responsibility of the Agency for the Cooperation of Energy Regulators (ACER) which includes the monitoring of the implementation of the Network Codes and the assessment of the implementation of the NCs on the markets. Thus, market assessments of the readiness of the short term markets for implementing BAL NC's market based requirements and also assessments of market effects after the implementation of market based balancing will be made in the near future in the EU on national level and on a Union level as well.

To summarize, regulators after market opening need to carefully and adaptively design the balancing mechanism and adjust it along the development path so that balancing would fulfill its dedicated role of being a key driver of short term market trade and thus liquidity. For this it is necessary that regulators

[2] European Network Code for Balancing (Regulation (EU) No 312/2014) - BAL NC

[3] For this interim measures group the deadline of the full implementation of the Code is no later than five years as from the entry into force of the Regulation, i.e. April 2019.

[4] Mainly the Gas Regulation: Regulation (EC) No 715/2009

continuously monitor and assess the effects of implemented balancing measures on the market. EU regulations also prescribe such regular market assessments.

Despite such importance of this 'balancing-focused' market analyses at current state only little explicit guidance is available either from EU institutions either in academic literature on how these analyses could be/should be performed in practice. Furthermore, these mostly focus on the analysis of market hub indicators, which is not an applicable solution for most countries in the transition phase. This paper aims to contribute to the work of the regulators by providing an example on how a market analysis could be performed on an exact country-case. Our methods could also provide solutions for analyzing short term market liquidity developments on markets with no developed hubs.

In Section II we will first describe the theoretical framework of the analysis then in Section III based on the theoretical framework we define quantitative indices to assess the development of the balancing market. We apply our tools for the case of Croatia. In Section IV we conclude.

II. Theoretical Framework

In this Section we describe the theoretical framework for our analysis of the development of balancing markets. We will first describe the relationship between the short term flexibility market and balancing. Then to describe the balancing process we will use a theoretical model built by (Dickx et al, 2014) and extend it to construe the evolutionary process of balancing from the vertically integrated monopoly to the mature market with full market based balancing mechanism.

Due to the maximum length requirement of the Call[5] basic descriptions on the elements of a balancing mechanism - including the description of the applied balancing regime in Croatia - and the elements of a flexibility market can be found in Appendix I and Appendix II.

II.1. Flexibility and balancing

Balancing needs of a natural gas system and the sources to supply them can be analysed in the context of the daily flexibility market. The available physical flexibility sources besides providing flexibility in the supply portfolios are also the tools for keeping the system in balance. The more various these sources and the larger their potential size compared to the daily flexibility demand, the more likely is that the short term market for balancing the shippers would become liquid and competitive. For this, in a balancing market assessment it is a primary task to analyse the physical flexibility market, comparing the potential supply and possible demand.

The availability of physical flexibility tools is a precondition for balancing the system, however as Dicx et al. (2014) points out commercial flexibility is also necessary to balance the system. Available physical flexibility tools, like free interconnection capacities can only be considered as potential balancing tools if contractual conditions and market settings allow to call for additional supply of gas through the border in case the system needs it.

[5] ERRA Regulatory Research Award – Call for Paper: the maximum length requirement: -6000 words

To illustrate both the necessity of various flexibility sources and the importance of commercial flexibility we draw here the finding of Miriello-Polo (2015) in their cross-country analyses: short term market liquidity increases more rapidly in countries endowed with significant domestic gas production, and less so when the main source of supply and thus also flexibility is a long term import contract.

As a consequence, contractual conditions behind the physical tools should also be analysed when assessing the ability of a natural gas system to adapt to market based balancing conditions.

To summarize, a balancing market assessment should start with the assessment of physical and commercial flexibility. In our analysis performed for the Croatian market we will first define quantitative indices and then with the help of these we will compare the size of the physical flexibility supply sources to the potential flexibility demand to assess the market's ability to adapt to market based balancing conditions. Briefly we will also consider commercial flexibility aspects.

II.2. Analysing the development of Balancing

We now describe the theoretical framework for the analysis of developments in balancing.

II.2.1. A simplified example for the description of the balancing problem

Dickx et al (2014) illustrate the balancing problem on the case of a simplified market with four identical consumers who are supplied by four retail contracts. These retail contracts are backed up by corresponding wholesale contracts. To illustrate the effect of market structure on the balancing task they consider a simple case of a shock in final consumption: i.e. the final conusmers' demand has a predictable and a random shock component:

$$D_i = d + \varepsilon_i$$

Where the shock is an iid, zero mean and a standard error $\sigma_\varepsilon = \varepsilon/4$. The upstream contract is signed for d: injection and withdrawal in the transmission system this way is ex ante balanced. Shocks - positive and negative – result in an imbalance for the different consumers. Some possible distribution of shocks among the four supply contracts is described in Table 1. A part of the individual imbalances could be closed with Internal Adjustments by matching the positive and negative imbalances of the different consumers. This part can be managed without the further need of inflow to or outflow from the system, i.e. without adjustments to the upstream provisions. Aggregate Imbalance of the system is the part that cannot be solved internally, adjustments by upstream providers is necessary.

Table 1: The possible distribution of shocks and the decomposition of market imbalance

Shocks	Aggregate imbalance	Internal adjustment
(-ε/4,-ε/4,-ε/4,-ε/4)	-ε	0
(-ε/4, -ε/4, -ε/4, ε/4)	-ε/2	ε/4
(-ε/4, -ε/4, ε/4, -ε/4)		
(-ε/4, ε/4, -ε/4, -ε/4)		
(ε/4, -ε/4, -ε/4, -ε/4)		
(-ε/4, -ε/4, ε/4, ε/4)	0	ε/2
(-ε/4, ε/4, -ε/4, ε/4)		
(-ε/4, ε/4, ε/4, -ε/4)		
(ε/4, ε/4, -ε/4, -ε/4)		
(ε/4, -ε/4, ε/4, -ε/4)		
(ε/4, -ε/4, -ε/4, ε/4)		
(-ε/4, ε/4, ε/4, ε/4)	ε/2	ε/4
(ε/4, -ε/4, ε/4, ε/4)		
(ε/4, ε/4, -ε/4, ε/4)		
(ε/4, ε/4, ε/4, -ε/4)		
(ε/4, ε/4, ε/4, ε/4)	ε	0

Source: Dickx et al. (2014) p. 13.

Internal Adjustments are a key issue in our analyses. If for example three consumers have a consumption shock of ε/4 while the fourth consumer has a positive consumption shock of -ε/4, through Internal Adjustments only -ε/2 additional amount of outflow is necessary from upstream sources. However, if coordination is imperfect, it could lead to inefficiencies that the fourth consumer buys additional gas to manage its imbalance from outside.

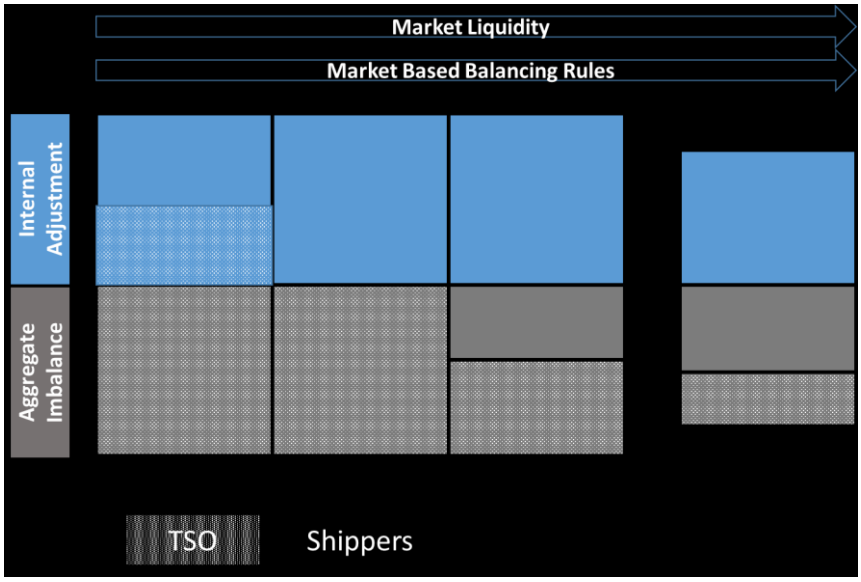
This simple example of Dickx et al. (2014) shows the **crucial importance of coordination in balancing**. The method of coordination however greatly depends on the market structure. In case of the pre-liberalization world a vertically integrated monopolist supplies all the four trades of the example. Internal Adjustments of positive and negative individual shocks are coordinated on an organizational level, adjusting flows within its portfolio of contracts, the company faces only the Aggregate Imbalance.

In case of restructured liberalized markets as all consumers of the example are supplied by different shippers the management of Internal Adjustments also leads to commercial adjustments. In this case the short term market is the tool to coordinate internal imbalances. If the market is efficient, e.g. liquid enough all Internal Adjustments could be managed and upstream provisions would only take place to the extent of Aggregate Imbalance. This letter would be managed by the transmission system operator. If however this Internal Adjustment is inefficient then the transmission system operator has to intervene, and buy the excess and sell it to those who are in shortage, thus a part of the Internal Adjustment is left to the TSO. As a whole, the TSO will only buy balancing service from outside the system to the extent of the Aggregate Imbalance, however will take an administrative coordinator role for Internal Adjustments, supplementing the market as a coordinator.

II.2.2. Framework

We now use this Internal Adjustment - Aggregate Imbalance division to build a framework for analyzing the evolution of balancing systems from the beginning of market opening with immature markets to the full market based balancing regimes.[6]

Figure 1: Analytical framework of the evolution of balancing



[6] The evolutionary phasis of Balancing Regimes is described in Appendix II.

Figure 1 summarizes our framework:

- In the beginning of market opening lack of transparency and lack of trading possibilities result in a situation that part of the imbalance that could be adjusted between shippers – Internal Adjustment - is nevertheless left to the TSO to be solved. While TSO is the sole organizer of managing the system's Aggregate Imbalance as well.
- As the short term market develops, trading platforms emerge, coordination between shippers to trade their opposite sign imbalances improves up to the level that TSO only has to manage the Aggregate Imbalance amount.
- As market based balancing rules are implemented, and shippers are given more possibilities – through flexible renomination possibilities, information provision, imbalance settlement incentives – to take part in balancing, they not only coordinate between themselves the Internal Adjustments but also become the primary responsible for balancing and solve part of the Aggregate Imbalance of the system themselves, leaving residual part to the TSO. Furthermore, the TSO itself bases its procurement on shippers' offers on the short term market.
- Finally, as shippers become more involved in balancing and are endowed with better information during the planning and throughout the day coupled with proper incentives by the market based imbalance settlement the overall imbalances in the system can be reduced.[7]

We will use this analytical framework to perform a quantitative assessment of the development of balancing in Croatia. We will make the following analysis:

- The evolution of the size of imbalances, including Aggregate Imbalances.
- The evolution of the share of overall imbalance solved by shippers during the renomination process.
- The evolution of Internal Adjustments unsolved by shippers
- The evolution of the share of TSO balancing performed on short term platforms, e.g. upstream adjustments are delivered by shippers.

The index of the evolution of Internal Adjustment unsolved by shippers before the day ahead nomination has a primary importance, as **it actually provides an insight on how liquid is the day ahead short term market.** The less Internal Adjustments are left unsolved by the shippers the more efficient the day ahead market is in coordinating the trading of these opposite sign imbalances. Thus, this indicator can be used to assess day ahead market efficiency/liquidity also in those countries where hub indices are not applicable.

[7]The theoretical model of Dickx et al. (2014) focuses on the coordination problem and on its own could have an interpretation that balancing under the vertical monopoly market setup before market opening was more efficient. Therefore, it needs to be added that in such settings efficiency considerations (especially cost-efficiency) played a minor role in turn, the market based balancing mechanisms in liberalized markets with many players theoretically provide a more allocative efficient solution by giving incentives decentralized to individual players to react to gas inflows and outflows. (Van Dinther et al., 2013) This is implemented in our framework through the reduction of the balancing need in this last phase of mature short term market, which could be considered as a total cost indicator, not just a volume indicator.

III. Analysing the evolution of balancing in Croatia

As we summarize it in Appendix III in the current literature there are some suggestions available for indices to be used for balancing market assessment, however the data necessary to calculate them is in most cases not publicly available, sometimes need very complex transformations, many are not applicable for markets without hubs, while even with the availability of indices it is hard to have a straightforward interpretation about the liquidity status and potential further steps that could be introduced on the balancing market. Furthermore, most of these are only suggestions, not practical samples.

In the following we make an attempt to deliver such a country analysis using publicly available data on the case of the Croatian balancing market. For this assessment we will define our own specific indicators and suggest a possible interpretation of the actual outcome values and trends.

Based on Transparency data published by the TSO Plinacro (Plinacro 2017) and the Market Operator Hrote we describe how balancing in the Croatian market evolved. Our analysis is limited by the unavailability of detailed individual data, but the analysis we perform still can provide interesting insights that if is supplemented by individual imbalance and trade data - which is available to regulators - could provide a complete picture on the market and support regulatory decisions on balancing mechanism implementations.

First, we will analyse the potentials of the short term flexibility market as it is the frame in which the daily and within day balancing activity is embedded. Then we analyse the evolution of the balancing activities from many perspectives to assess the effectiveness of the introduced balancing regulations on the Croatian market.

III.1. The short term flexibility market

When analyzing the flexibility market our main question is whether the short term physical flexibility potentials of the Croatian natural gas system provide enough supply opportunities compared to the flexibility need of the market to allow for a full implementation of a market based balancing system.

To assess the demand side of the flexibility market we analyse how the daily consumption varied compared to the previous day and also compared to a weekly average. We decided to define the index for demand for flexibility as the absolute value of daily consumption deviation from its weekly average. We use the distribution of its historical values to describe the Croatian short term flexibility market's demand side. The detailed analysis and calculations can be found in Appendix IV.

To assess the supply side of the flexibility market we compared the technical capacities to contracted capacities and to actual usage data for the production, storage, and the interconnection points. When analyzing the capacity and flow patterns on the supply sources we deduct those capacities that are used in the majority of times and only consider 'usually available' capacities as potential sources of supply of flexibility. The detailed analysis and calculations can be found in Appendix V.

III.1.1. Comparing potential demand and supply of daily flexibility

By comparing the demand for flexibility and the possible supply of it, we can have a descriptive view on the level of scarcity/abundancy of the Croatian flexibility market. As we can see, interconnection points play a

crucial role in case of high storage usage. Furthermore in 90% of the flexibility of demand cases it could be supplied tenfold. **Thus, we can say that with the interconnection availabilities the daily flexibility market is not tight at all. I.e. Croatia has good foundations for implementing market based balancing as it has large supply potentials compared to the potential size of the demand for flexibility.**

Table 2: Comparing the distribution of demand for flexibility with the supply potentials, kWh

Demand for short term flexibility

The distribution of the absolut value of daily consumption changes							
max	D90	Q3	Average	Median	Q1	D10	Min
61 407 291	11 741 416	7 072 625	5 086 007	3 124 454	1 328 170	514 221	2 910

Supply of short term flexibility

	Available IP (SI->CR) capacity	Available IP (HU->CR) capacity	**Available withdrawal capacity**	**Production level's daily change**
min	- 6 336 818	13 796 362	4 609 700	273
D10	4 702 861	59 390 723	26 688 627	37 711
Q1	9 402 206	64 091 770	43 901 466	95 238
Me	17 490 710	67 177 166	54 662 400	226 333
Average	16 864 878	65 153 729	50 754 412	654 153
Q3	23 835 847	68 345 034	63 772 800	485 457
D90	29 429 554	69 120 000	63 772 800	1 280 590
max	47 333 569	69 120 000	63 772 800	17 526 195

III.2. Analysis of the balancing market

In this Section we assess the Croatian balancing markets evolution. Our analysis is limited by the non-availability of detailed balancing data therefore first we will have to define alternative indicators compared to the suggested ones by ACER and other organizations described in Appendix III.

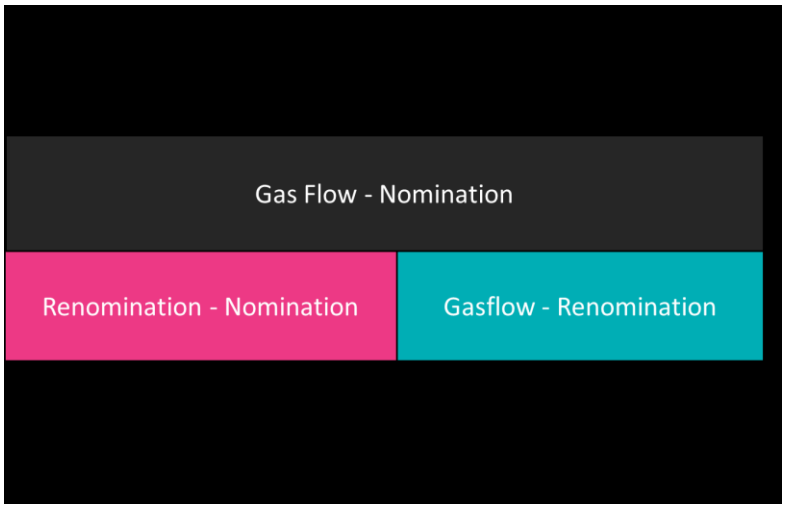
First, we will assess the balancing activity performed by shippers then we will analyse how the TSO's residual balancing activity evolved over time.

III.2.1. Defining the balancing needs of the market

We suggest to define the total balancing need of the market for covering consumption deviations by looking at the difference between nominated values and actual flows on the consumption exit points. This indicator is a good proxy of the balancing need because trades after nomination deadline are adjustments made by shippers to balance their portfolio in reaction to new information on the expectations about the real-time values. This balancing need does not show the balancing need that the shippers faced day ahead, it reflects only part of it, namely the balancing need they face after the nomination deadline. By providing shippers renomination possibilities, shippers take over (primary) part of the balancing responsibility. Therefore, the differences between nomination and renomination values can be considered as the shippers' balancing activities, while the differences between renomination and actual flows is the part of deviation that is left to the TSO to balance, i.e. residual balancing. (By this assumption, we can calculate in

an alternative way the indicator defined in the CEPA study: the share of TSO balancing as % of total balancing requirement.) A simplified illustration of this decomposition is illustrated by the figure below.[8]

Figure 2: Illustration of the calculation of total balancing need, and its decomposition



Balancing needs also occur when unexpected outages happen on one of the entry points, we do not include these possibilities in our calculation as we are looking for overall trends in this case and not the extreme security of supply situations.

III.2.2. The evolution of total balancing need

First looking at the total balancing need/imbalance we can see similar tendencies as in the case of the daily change of consumption, which we used for an approximation of the demand for daily flexibility. Again, DSO level consumption has a ~2 times higher balancing need than TSO level consumption. Since on aggregate level TSO level consumption is a bit higher than DSO level consumption this shows that supplying DSO level consumers has more than 2 times higher balancing needs. On the DSO level the deviation on average is 10% of the actual flow, while on the TSO level it is its half: 5%.

By comparing the combined balancing need with the two separate levels' consumption we can see that on aggregate level the deviations to some extent cancel each other out. These missed Internal Adjustment possibilities will be further analysed in Section III.2.4.

[8] Unfortunately it can happen that during renomination shippers adjust their portfolio towards the wrong direction, and thus the residual balancing left on the market operator is even higher than the balancing need after the initial nomination. This situation happened in 8-20% of the days analysed depending on the consumption level. For TSO level consumers shippers adjusted better, while for DSO consumers shippers adjusted towards the wrong direction more frequently. We correct for this phenomenon during our calculations of the share of residual balancing, in these cases we calculate the indicator of share of residual balancing of total balancing need to be 100%.

Table 3: The distribution of balancing need values, MWh

	Balancing need, MWh		
	DSO level	TSO level	Total
min	0	1	3
D10	194	134	253
Q1	503	358	722
Me	1 398	776	1 870
Average	2 748	1 924	3 742
Q3	3 698	1 617	4 266
D90	6 547	3 161	8 168
max	36 557	52 792	65 108

Data is calculated for the period 01.2014 – 01.2017.

From the time series, we can see that there were some extreme periods, but also there are clear trends:

- TSO level consumption's balancing need decreased over time, this could reflect better forecasting of shippers due to better available information, and also better possibilities to cover short term needs on the market.
- DSO level consumption had a slightly decreasing trend, however its level is decisively dependent on temperature. It is usually large in winter. This balancing need could possibly be reduced in the future by improving the quality of information available for shippers day ahead on the DSO level consumers, e.g. by implementation of interval metering for larger consumer categories.

Figure 3: Balancing need on the TSO End user and the DSO exit points and their total, kWh

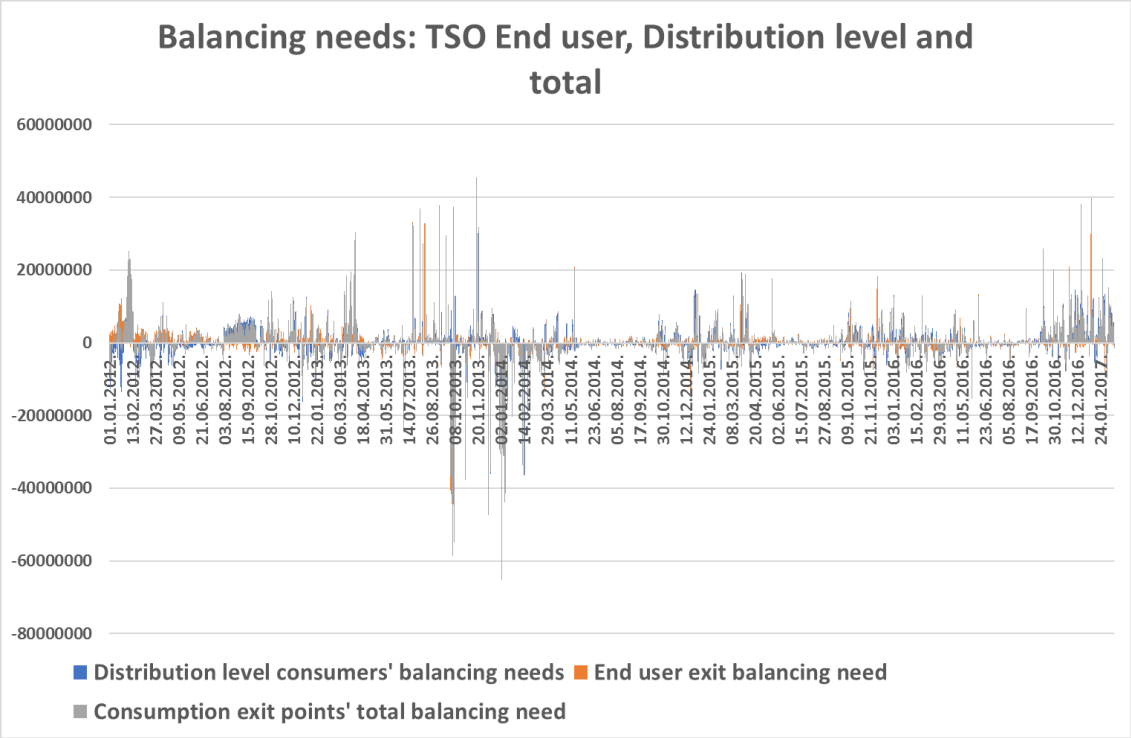
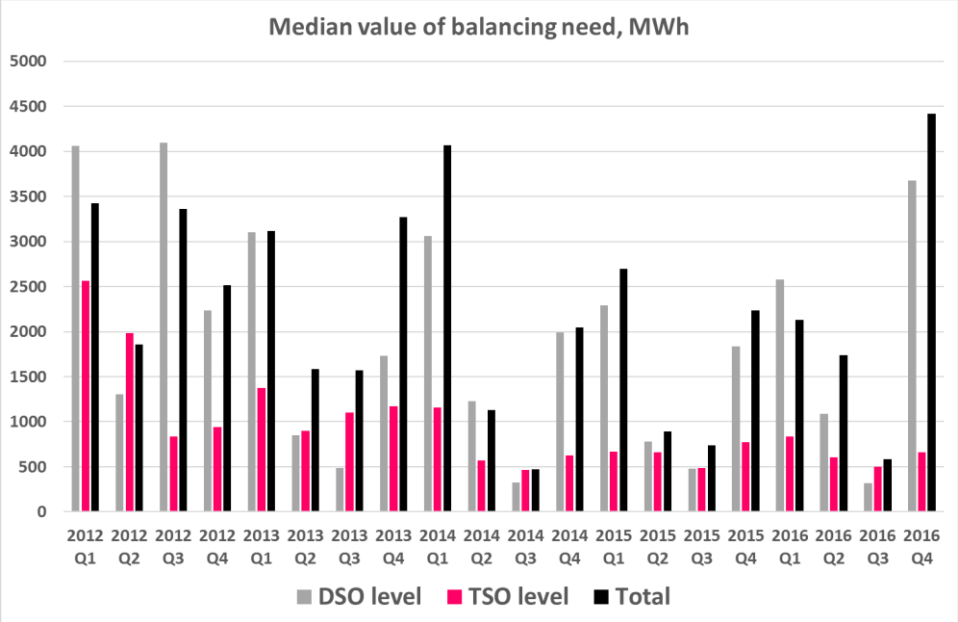


Figure 4: The evolution of the median balancing need value over time for the different consumption levels

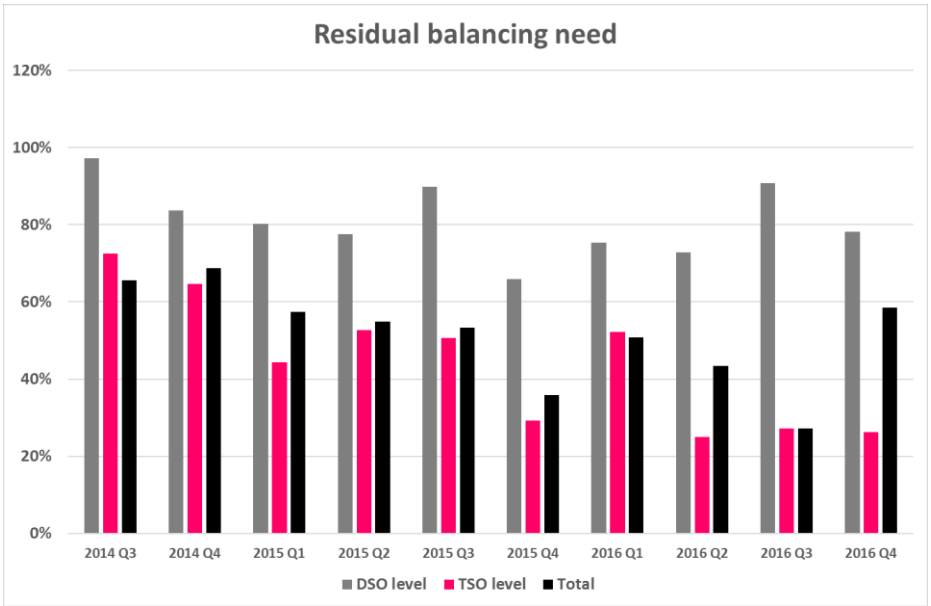


III.2.3. Shipper balancing

When looking at what share of this balancing need is solved by shippers and what share is left as residual balancing to the market operator, we can see the following:

- After the introduction of renomination possibilities in the summer 2013 traders started to take their part out of balancing. In 2013 there were very high balancing needs and these were mainly solved by shipper adjustments. After 2014 - when overall balancing needs stabilized in a lower level compared to the previous peaks - a decreasing trend can be observed in the share of residual balancing for the TSO level consumption, it is now around 30%, while in case of DSO level consumption it remains in a range of 70-80% indicating that this type of consumption is still hard to balance by shippers. Thus TSO level consumption is already mainly balanced by shippers. DSO level consumption is in major part still balanced by the TSO, the renomination possibilities and better market conditions are not enough for shippers to significantly take part, this could be improved in the future again by the introduction of interval metering on the DSO level, and thus by the provision of better quality information towards the shippers.

Figure 5: The percentage of the balancing need left for the market operator



Thus, we can already state that on the Croatian market shippers started to take part in balancing the system. Residual balancing left for the market operator to organize has a decreasing trend.

To what extent this shipper portfolio adjustment activity has a direct liquidity increasing effect on the short term market is not straightforward. Renominations could result simply from change in storage use and not actual trade. Unfortunately, information on the actual number or quantity of short term trades is not available, therefore we can only suggest that there should be some positive effect of this identified shipper short term balancing adjustments to the number of short term trades and thus short term market liquidity.

The next analysis provides a bit more insight on how efficiently shippers might trade on the short term market to solve their imbalances or put it around how efficient is the Croatian short term market in supporting the coordination between shippers to trade their opposite side imbalances.

III.2.4. Internal Adjustment – Aggregate Imbalance

In the previous analyses we already saw that sometimes there are overlaps between the imbalances of the two consumption categories. We now use the analytical framework descirbed in Section II to assess the efficiency of the Croatian short term market. Dickx at al. (2014) did not actually use the Internal Adjustment – Aggregate Imbalance analytical framework to make quantitative assessment of the markets, and so they did not define quantitative indicators that reflect the two theoretical parts of balancing need. In the following we make a first attempt to define specific indicators that correspond to the two theoretical concepts, and use those for actual market assessment.

Internal Adjustment is the part of balancing needs which overlap in the shipper portfolios. An ideal indicator of Internal Adjustment would be if we would have data on each shipper's day ahead forecasts when they determine based on new information what kind of procurement would be necessary to balance themselves. This forecast on imbalance and then the actual trades would be the ideal source for calculating the indicator for Internal Adjustment. However first, there is no data on anticipated imbalances, only ex post imbalance is known for the settlement, and second, this latter data is not available publicly on a shipper level. Therefore, we have to make compromise and use the proxy for ex post imbalance the balancing need defined in the previous section, i.e. the consumption exit point's flow-nomination

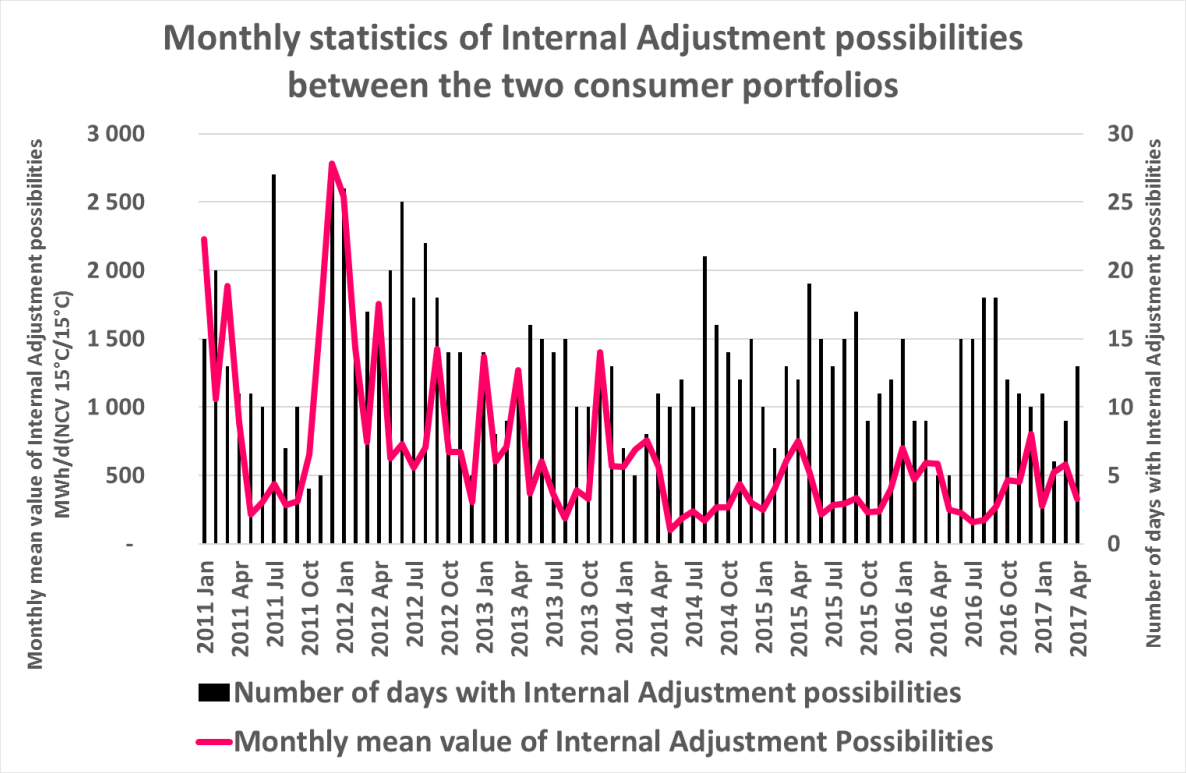
(renomination) indicator, and instead of calculating this per shipper we will use the only available portfolio breakdown: the consumption on the TSO-DSO level. Thus, due to lack of detailed data we simplify the market as if there were two large shipper portfolios, one which supplies large consumers connected to the transmission pipeline and one which supplies DSO level consumers. We therefore define our Internal Adjustment indicator as the overlap of the balancing needs of the TSO level consumers and the DSO level consumers. Correspondingly we define Aggregate Imbalance as the sum of the TSO level consumers' balancing need and the DSO level consumers' balancing need.

The evolution of Internal Adjustment possibilities

Our indicator shows the imbalances of the two type of consumer portfolios that due to their opposite sign - from an ex-post perspective - could have been traded day ahead between the traders without further upstream sourcing however were not, thus these are missed out Internal Adjustment possibilities. Figure 6 illustrates the evolution of these missed Internal Adjustments from two perspectives. First, it shows how the median Internal Adjustment possibility value developed, second it shows on how many days of a month were there missed Internal Adjustment possibilities at all. Both indicators show a clear trend that:

- Missed Internal Adjustment possibilities decreased on the Croatian market, both:
    - The number of days decreased when Internal Adjustment possibilities were missed.
    - And the size of these missed Internal Adjustments also decreased.

Figure 6: The evolution of the Internal Adjustment possibilities missed by shippers day ahead

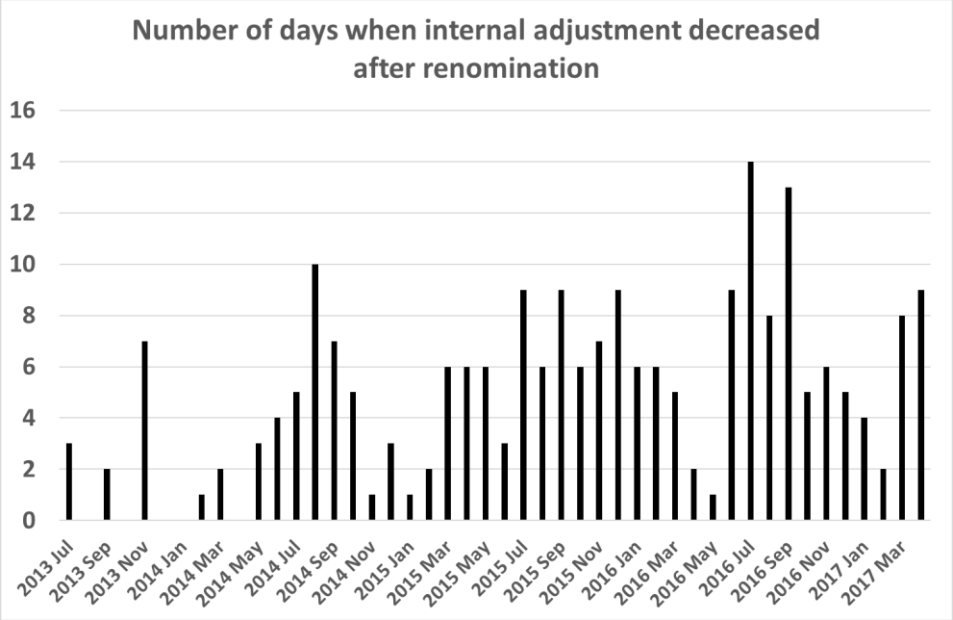


Since our indicator shows the missed out trading opportunities up until the nomination deadline these results clearly reflect the state of the day ahead short term trading possibilities on the Croatian market. **As less and less internal adjustment possibilities were left out by traders before the day ahead nomination**

deadline this shows that the Croatian day ahead market became more and more efficient in supporting shippers' day ahead balancing.

We can also look at how the renomination possibilities and thus intraday trading were used by shippers to solve the Internal Adjustment possibilities left out day ahead. For this we compared the Internal Adjustment possibilities related to the nomination deadline to that related to the renomination deadline. Figure 7 illustrates how the number of days when Internal Adjustment possibilities were further reduced during the renomination process increased over time. Thus ,besides the day ahead market the within day market is also improving in providing efficient support for traders.

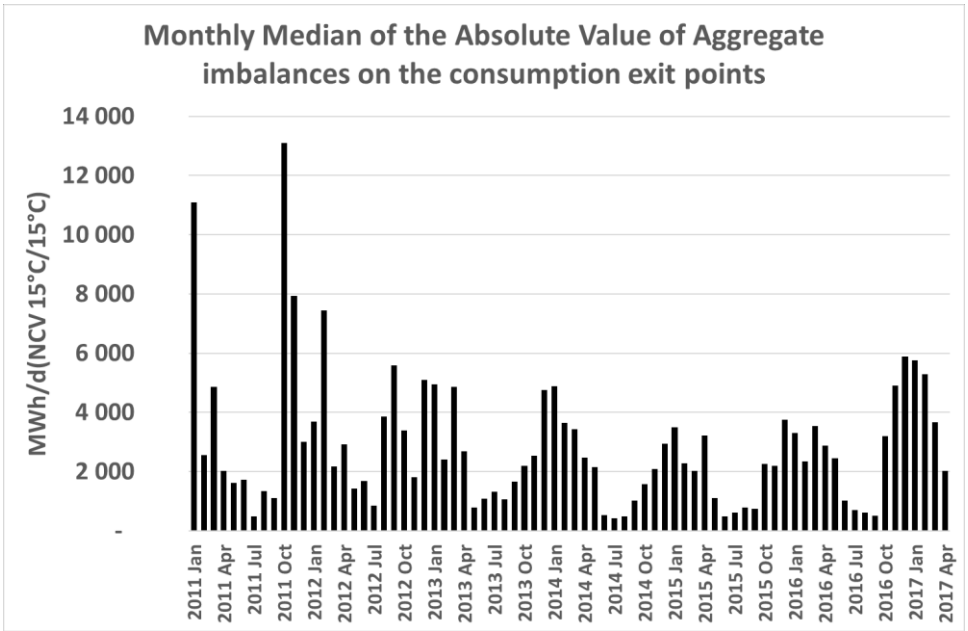
Figure 7: The evolution of the number of days in a month when renominations solved part of the Internal Adjustment possibilities



The evolution of the Aggregate Imbalance

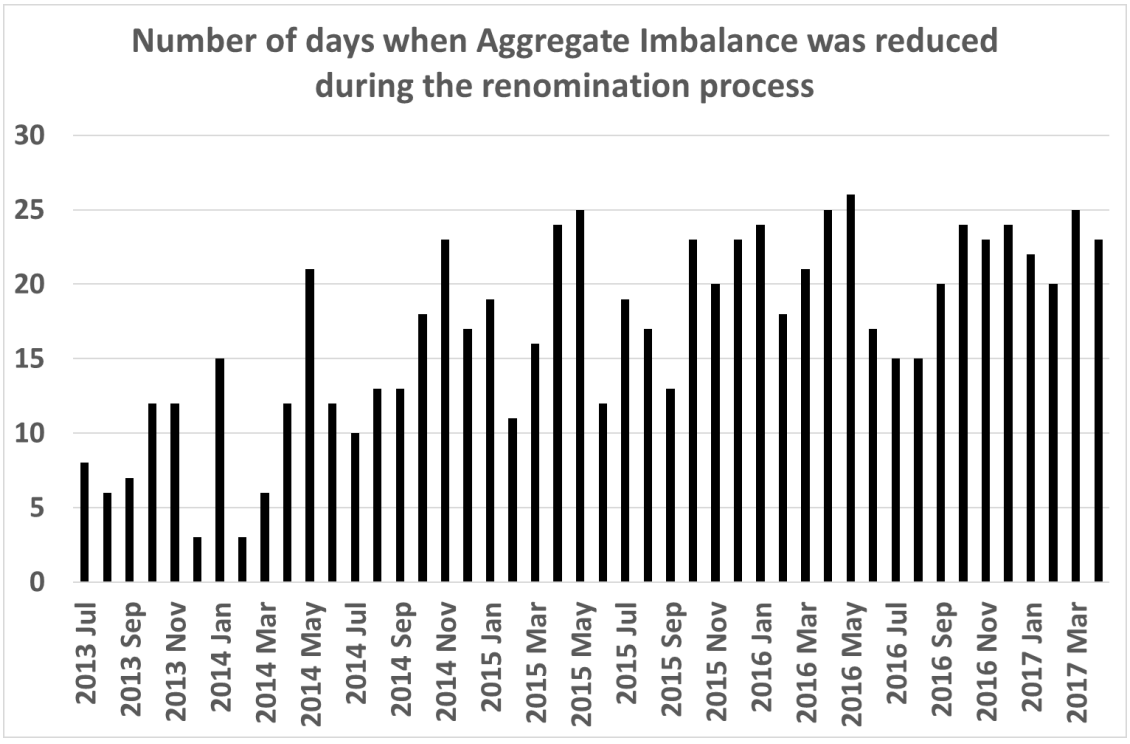
Aggregate Imbalance shows the physical state of the system. It also reflects how well the shippers predicted in advance their portfolios' consumption, and how well they were able to cover that on the day ahead market, but there will always be a part which cannot be solved day ahead. As we can see Aggregate Imbalance decreased over time, however it can also be seen that it has a strong weather dependent part, and thus in colder winters its level is usually higher. **Thus we could draw a conclusion that some part of the Aggregate Imbalance had been reduced by shippers' better predictions and trading**.

Figure 8: The evolution of the absolute value of the Aggregate Imbalance



If again, we look at how the renomination possibilities were used to decrease the Aggregate Imbalance we can see that by now in most of the days within day adjustments also include the involvement of upstream sourcing by shippers.

Figure 9: The evolution of the number of days in a month when a renominations reduced the Aggregate Imbalance

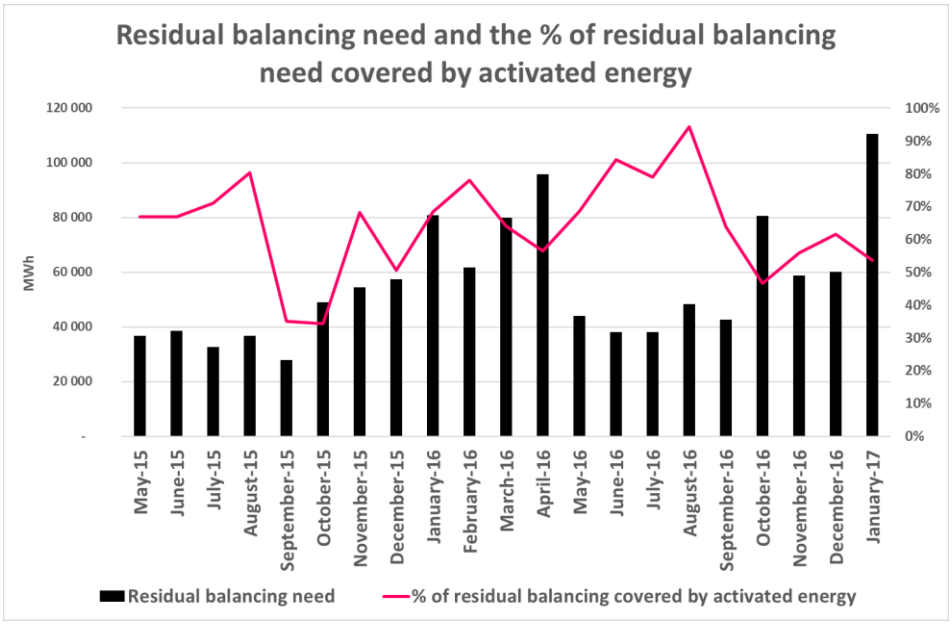


III.3. Residual balancing

Finally, we analyze how the system balancing performed by the TSO evolved over time. By analyzing the data published by the market operator Hrote (Hrote 2017) about the activated calls on the balancing platform we can see the following:

The activated shipper bids on HROTE's balancing platform represent a significant share from the used energy for balancing the system. In summer months with relatively low residual balancing need 70-90% of system balancing is covered by the activated bids, while in winter months 50-60%. **Thus, in the majority of times residual balancing is performed through activating transparent daily bids on the balancing platform.**

Figure 10: Monthly residual balancing need and the share covered by activated bids on the balancing platform



III.4. Evaluation

A detailed summary of our results for the Croatian market can be found in Appendix VI.

Based on the above and referring back to our framework described in Section II and Figure 1 we can state that the Croatian market is a good candidate for the complete introduction of market based balancing mechanisms. The introduced balancing mechanism already contributed to the efficiency of the day ahead and within day market. Traders are taking role in balancing. They solve major part of the Internal Adjustment possibilities and they also solve some part of the Aggregate Imbalance. In addition, by participating in the Balancing platform, they also take part in a large share of the residual balancing of the TSO. Furthermore, regarding the TSO level consumers category the efficiency effects of the decentralized

balancing and market based incentives of shippers already can be seen by the reduction of the level of overall balancing need in supplying this consumer group.

IV. Conclusions

With this paper we aim to contribute to the regulatory task of the monitoring of the balancing market to assess the effectiveness of the introduced balancing rules and the market's potential to introduce further market based mechanisms.

We set up the theoretical framework and based on that defined quantitative indicators that could be calculated on publicly available data. On the case of Croatia we calculated these indicators and analysed their trends. Based on the quantitative analysis and the guidance of the theoretical framework we evaluated the Croatian market. The Croatian market showed a positive development both in the shippers' increasing role in balancing, and in the increasing role of the balancing platform in supplying residual balancing. Furthermore, the balancing system also seems to have positive effects on the liquidity and efficiency of the day ahead market. And finally, the decentralization of balancing and the proper incentives already had a reducing effect on the level of imbalances in the supply of the TSO level consumers.

The methods we proposed in this paper could provide as a sample for regulators during their monitoring and balancing mechanism planning tasks.

References

ACER 2016: ACER Report on the implementation of the Balancing Network Code. 07/11/2016.

BAL NC: Regulation (EU) No 312/2014

CEPA 2015: Implementation monitoring and evaluation of the impact of the gas network codes and guidelines on the Internal Market. Final Report ACER/OP/DIR/08/2013/LOT 2/SC06

Creti A., Pontoni F. (2016): Natural gas balancing, storage and flexibility in Europe: assessing the recent literature. Current Sustainable/REnewable Energy Reports. 2016 3:18-22. DOI 10.1007/s40518-016-0046-0

Dickx L, Miriello C., Polo M (2014): Balancing Systems and Flexibility Tools in European Gas Markets. Research Report Series – Centre for Research on Energy and Environmental Economics and policy IEFE -ISSN 2036-1785. February 2014

Hrote 2017:

http://www.hrote.hr/energija-uravnotezenja-109

Plinacro 2017: Transparency data:

https://www.sukap.plinacro.hr/wps/portal/Home/SukapPublishing/!ut/p/b1/04_Sj9CPykssy0xPLMnMz0vMAfGjzOI9fLzcHN08jAwM_ANdDDzDAvx9fcwDjAzczYAKIoEKDHAARwNC-sP1o8BKnN0dPUzMfQwMLEwtDA08HT1Czc2CXYwMHI2hCvBY4eeRn5uqX5AbYZBl4qgIAD7Iks0!/dl4/d5/L2dBISEvZ0FBIS9nQSEh/

Miriello C., Polo M. (2015): The development of gas hubs in Europe. Energy Policy, 2015;84 pp 177-90. DOI: 10.1016/j.enpol.2015.05.003

Van Dinther A., Mulder M. (2013): The allocative efficiency of the Dutch gas balancing market. Competition and Regulation in Network Industries 2013; 14(1): 47-72. DOI: 10.1177/178359171301400103

Appendix

I. The demand and supply of flexibility

Demand for flexibility

The flexibility needs of a natural gas market depends on what natural gas is used for in the given market and the share, i.e. composition of these usages.

For example, if natural gas is used in a large share by domestic households for heating, then temperature variations within a short period effect greatly the natural gas balancing market. Temperature variations also play a great role if district heating is primarily based on natural gas fired plants.

The fuel-composition of electricity production, especially that of the electricity balancing market effects natural gas balancing needs as well. If electricity balancing is provided mainly by gas fired power plants, then the fuel off-take of gas-fired plants could be subject to considerable fluctuations during the day.

Unexpected outages of major consumers, e.g. industrial customers can also effect natural gas balancing needs, however this is expected to be an exceptional case and not a regular issue like in the case of natural gas fueled regulating power plants.

And finally, unexpected outages on the supply side, e.g. in natural gas production or on import capacities also result in demand for flexibility.

Supply sources of flexibility

The physical products that can be used to balance the system depend on the infrastructural capability of the country. In practice the combination of these flexibility sources is used.

Line pack: The transmission pipeline itself can provide for a short period a buffer for the system storing gas within the pressure levels required for safety operation. While line pack is available without delay, it is available for a limited volume.

Storage: Natural gas can be stored in depleted natural gas fields, salt caverns, aquifers, or for a limited amount in LNG plants. In these cases a dedicated asset is built to assist the system to satisfy the seasonal, monthly, …, and daily flexibility needs.

Production: The modulation of gas production capacities can be an available tool in countries with natural gas production however, this source is usually limited. Gas fields have a relatively low flexibility.

Cross border exchange of flexibility: Flexibility can be bought and imported from other systems. In this case the availability of free, accessible interconnection capacities determines the imported flexibility possibilities. As we discussed it above this flexibility opportunity is also dependent on the type of import supply contracts and the availability of neighboring short term markets. If the country is supplied only through one contract, and no short term markets are available, then the import supply flexibility depends on the contractual terms and not the size of available import capacity.

II. Balancing mechanisms

In this Appendix we describe the balancing mechanisms that can be applied by the regulators to the markets, i.e. the tools they can choose from. We describe the building components of a balancing regime and a scheme for how these could evolve from a non-market based setup towards the full market-based solution, we also describe here what the European Balancing Network Code, the BAL NC prescribes for the Member States.

The components of a balancing regime

Balancing regimes can be described along three main components:

I. The rules that provide possibilities for shippers to balance their portfolio ex-ante. These include the renomination possibilities, the available trading venues, the information they are provided by the system operators, etc.
II. The system balancing performed by the TSO or market operator. This includes the way TSO procures the balancing services, the time-frame and the platforms used, information provision of the used tools and the system's status, etc.
III. Imbalance settlement. This includes the settlement time period, the way of calculation of shipper imbalances, e.g. the application of tolerances, the determination of the imbalance charge, etc.

System balancing

TSOs in Europe rely on different sources with different procurement methods for system balancing. The way of procurement greatly depends on the given market's structure and maturity. The development of procurement in the European countries usually followed the following path: before market opening it was solved in-house with the coordination of two-three departments' work in the vertically integrated company that covered the whole industry. After market opening the unbundled TSO used non-market based mechanisms, such as regulated access or direct contracts for underground storage, or contracting with the incumbent wholesaler (usually having at its disposal the majority -80-90% - of supply sources) for long term to provide these services. As markets became more competitive the procurement time-frame shortened and became more and more market based, from the use of public yearly or shorter term tenders for balancing services, through the use of daily balancing platforms, to the procurement of standardized short term products on exchanges. This trend can be clearly observed in the history of by-now mature natural gas markets.

The Balancing Network Code ordains Member States' TSOs to conduct their procurement in a market-based manner and should preferably rely on short term (within day and day ahead) standardized products procured on trading platforms. While this setup can be easily met by MSs with mature natural gas markets, for newly opened markets with low supply diversity these provisions do not fit naturally into their current daily operations.

The BAL NC acknowledges that in case of lack of liquidity these markets need some time to develop and use of interim measures could help reach a maturity level when these provisions can be beneficially implemented. For that MSs are offered to choose the setting up of a balancing platform where TSOs ask for balancing energy bids and take always one side of the deal. Furthermore BAL NC also provides possibility for TSOs to contract through tenders longer term products with a duration of maximum one year. However an yearly review should assess whether the short term products would better meet the TSO needs, and balancing services should only be used where standardized product trades would be insufficient to keep the system within the accepted operational limits.

Possibilities for ex-ante balancing of shippers' portfolios

An incentive scheme is designed to motivate shippers to balance their portfolio's and thus only a residual system imbalance would be left to the TSO to be solved in real time. In order for shippers to well balance their portfolios rules are necessary that enable them to perform adjustments close to real time, and be able to trade, while also information from the system operator on the portfolio's balance is also important. BAL NC introduced within day renomination possibilities with a 2 hours lead time before real time, reduced the time for the TSO to process trade notifications and imposed intensive information provision rules. This way providing the possibility for near real time adjustments and the necessary information for shippers.

Imbalance settlement

The primary incentive for shippers to be balanced is the ex-post imbalance settlement, where imbalances are calculated and are charged for. This settlement in an early phase of market development could be only a monthly aggregation of daily imbalances and in kind settlement of the differences between the TSO and the shippers. BAL NC requires full cash out of daily imbalances. There are systems where even within day obligations are imposed. Regarding the penalized quantities, in case when shippers do not have sufficient and/or equal possibilities for balancing their portfolio tolerances could be introduced, e.g. for those who do not participate on the daily balancing market an imbalance below 2% of the nominated quantity could be charged by a lower imbalance charge or could be not charged at all. BAL NC acknowledges that tolerances could be useful in less mature markets, however it only sees it as an interim measure and it should be withdrawn as soon as possible. The determination way of the imbalance charge is closely linked to the TSO's procurement process. If procurement is fully performed on a daily platform, marginal prices could be readily used as the imbalance settlement charge, just as it is prescribed by BAL NC. However, if the majority of balancing services procurement is not daily market based administrative price determination is a usual solution - considered also by BAL NC as an interim measure - either based on the regulator's cost revision activity or a linking to the nearest liquid short term market in the region.

Looking at the experiences of now mature Western markets and also the evolution of the Hungarian balancing regime the following phases can be identified in a path from an integrated market to a fully market based balancing regime.

Table 1.: The evolution of balancing regimes from non-market based to fully market based design

	Vertically integrated holding	Base case: recent market opening, few new entrants, large incumbent, premature restructuring and unbundling	Interim period, characterised by further market opening, restructuring, increasing number of players decreasing market share of the incumbent.			Fully market based (BAL NC compliant) balancing system
			Interim step I.	Interim step II.	Interim step III.	
Balancing possibilities of shippers	No shippers	Daily nomination (weekly, monthly), no within day renomination possibility. Trading is carried out through bilater negotiations.	Renomination possibility is introduced. VTP for title transfer is in place. Bilateral trades between market players.	Within day renomination is possible. A balancing platform is introduced where shippers can offer balancing services to the TSO on a daily basis. And they can exchange between themselves either bilaterally or through a trading platform as well.	Renomination possible with 2 hours lead time. Shippers use extensively the trading platforms and OTC trades for adjusting and balancing their portfolios. They also provide bids for the TSO's balancing market. Extensive and timely information is provided by the TSO to the traders.	Renomination possible with 2 hours lead time. Shippers use extensively the trading platforms and OTC trades for adjusting and balancing their portfolios. They also provide bids for the TSO on the trading platform. Extensive and timely information is provided by the TSO to the traders.
System balancing by TSO balancing	Balancing is managed by coordination within the company.	Primary way of balancing. The TSO contracts for long term either with the major supplier for balancing services or/and has direct storage access. Linepack is extensively used.	TSO conducts yearly tender for procuring balancing service. Or the large incumbent is nominated by the regulator to offer balancing services to the TSO. Linepack is used.	Residual balancing: After shippers' renomination the balancing need of the system from the part of the TSO is lessened. TSO procures from both: yearly tender for balancing services and daily balancing platform. Linepack is also used.	Residual balancing. The TSO procures all its system balancing needs from the balancing platform.	Residual balancing. The TSO procures all system balancing needs from the trading platform.
Imbalance settlement	-	Account settlement daily (weekly, monthly). Settlement price is administratively set, or in kind settlement e.g. at the end of the month only for the monthly aggregated imbalance.	Daily imbalance settlement with administrative imbalance prices. Tolerances are used.	Daily imbalance settlement with imbalance charge with a mixed formula. Some indexation to the balancing platform, but primarily set administratively, usually linked to a neighboring country's liquid short term market's index. Tolerances are used, but in a smaller extent.	Daily imbalance settlement with imbalance charges derived from the marginal balancing platform prices. Tolerances are withdrawn.	Daily imbalance settlement with imbalance charges derived from the trading platform. No tolerances.

The Croatian Balancing Regime

Croatia started to implement market based balancing mechanisms gradually. Renomination was first possible in the summer of 2013. Since then continuous refinements of renomination rules, imbalance settlement and the residual balancing of the TSO were made. Croatia opted for the deferred implementation of BAL NC regulation, i.e. by October 2016 BAL NC rules should have been in place. These BAL NC compliant measures were introduced in April this year. Therefore, its effects cannot yet be analysed on the currently available data. The balancing regime that was in force for preceding this current implementation is most similar to the Interim Step II phase described in Table 1 above. Network users already had the ability to renominate on the interconnection points with a 2 hours lead time before real time. A balancing platform - which by the new regulation is replaced by a trading platform - was implemented where market players could provide bids to the market operator, there were four active traders participating in the platform, while there are 16 balancing responsible parties on the Croatian market. However, on the Croatian market there is one dominant player with public supply obligations, and attached to that privileges for storage capacities. To overcome the problems that could emerge due to this market concentration, the market operator Hrote besides using the balancing platform, also conducted yearly procurement for contracting balancing services. The public services provider, as the player that is endowed with extensive flexibility capacities was assigned to contract with Hrote. (From April 1st the TSO Plinacro tenders and contracts with the public service provider instead of Hrote.) Traders were already incentivized to balance their portfolio through the balancing group system. Daily imbalance settlement was put in place, where the settlement charge was administratively set, its value was derived from the nearest liquid short term market's (CEGH) daily index. In the new system, this imbalance charge - in line with BAL NC - is based on the daily marginal sell and buy prices.

The quantitative analysis we perform in Section III shows the impact of the implementation of this system.

III. Assessment of balancing markets – summary of guidances

As we described in the Introduction, ACER and the EU Member States have monitoring and evaluation responsibilities regarding the Member States' balancing market developments and the effect of the implemented measures on it. The results of the assessments have important effects: e.g. interim measures could be abolished or should be maintained, further rules should be imposed, etc.

For the assessment, the following guidance is available:

- BAL NC Article 46 (a): This section describes what an annual report should contain prepared by countries applying interim measures. For the "description of the state of development and the liquidity of the short term wholesale gas market" the report should contain the following indices:
    - (i) the number of transactions concluded at the virtual trading point and the number of transactions in general;
    - (ii) the bid/offer spreads and the volumes of bids and offers;
    - (iii) the number of participants having access to the short term wholesale gas market;
    - (iv) the number of participants having been active on the short term wholesale gas market during a given period of time;

  Unfortunately, this data is not available publicly. Furthermore, there is no guidance on how to evaluate these indices and for example what could be a threshold value for these or the combination of these, that below of which interim measures should be maintained and above which going forward towards market based solutions should be.

- CEPA Final Report: CEPA prepared a study for ACER on monitoring and evaluating the impacts of gas network codes and guidelines on the internal market. (CEPA 2015) The study reviews the literature and collects the best practices used for such an assessment and based on these describes the potential way the effects of the network codes could be assessed, indicators are recommended. For the evaluation of the BAL NC implementation effects the report proposes the following indicators to be used:
    - Share of TSO balancing through short-term standardized products vs. balancing services contracts.
    - TSO balancing as % of total balancing requirement
    - Physical linepack day-on-day changes
    - Balancing net neutrality analysis

  Again, data needed for the CEPA indicators is not publicly available, and still these indicators do not provide clear interpretations and threshold. The study highlights that the "indicator values may need to be interpreted with caution. They may for example, reflect the TSO's inability, rather than the unwillingness to balance through the market." Low values of for example the index of the share of TSO trade through short term standardized products could be the result of that the trading platform is insufficiently liquid to meet the TSOs balancing requirements, etc. "Increased TSO trading through markets should help increase liquidity but also increased liquidity should permit the TSO to conduct its trades in the marketplace." (CEPA 2015, p. 109)

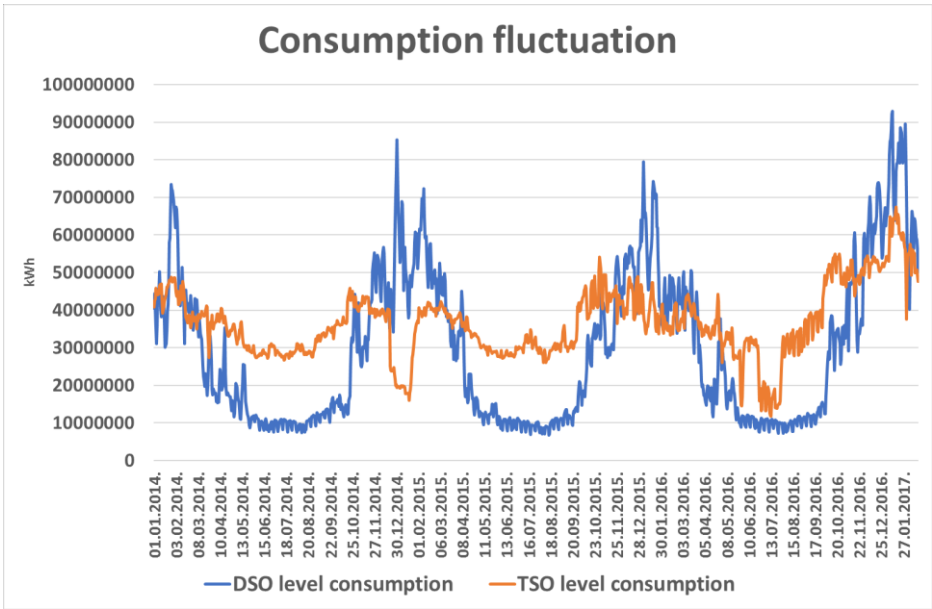
To summarize there are suggestions for indices to be used for such an assessment, however the data necessary to calculate them is in most cases not publicly available, while even with the availability of indices it is hard to have a straightforward interpretation about the liquidity status and potential further steps that could be introduced on the balancing market. Furthermore, these are only suggestions, so far such specific country assessment by the Authorities was not performed, currently there is no such sample available.

IV. Analyzing demand for short term flexibility on the Croatian market

In Appendix I. we described what sources form the demand side of the flexibility market. Out of these sources we only consider here the demand for flexibility related to the consumption points as we consider this to be the dominant source and we are looking at trends, not exceptional cases.

Looking at the consumption pattern of gas flow on the TSO End User exit points and DSO exit points of the transmission system we can see how the large consumers' consumption vary over time compared to the small consumers' consumption. Large consumers have less seasonal fluctuation, while the definitive effect of temperature variation of DSO level consumption can be clearly seen on Figure below. The ratio of winter and summer monthly consumption is around 1.5 for TSO level consumption, while for the DSO level consumers it is almost 4 times more: 5.5.

Figure 1: Daily consumption gas flows on the TSO End User and DSO Exit points



If we look at daily fluctuations of consumption which is relevant for short term (including the balancing) market, we can describe it by the consumption change from day to day, and also by for example the deviation of the daily consumption from a weekly average level, as short term markets are mainly the place for adjusting a portfolio planned for average circumstances in the given timeframe. We summarize the results for the two consumer groups in Table below.

Table 1: Distribution of the daily consumption change values on the different consumption levels

	Daily change of consumption, kWh			Absolut value of daily change of consumption, kWh		
	DSO level	TSO level	Total	DSO level	TSO level	Total
min	- 22 402 463	- 47 571 778	- 49 459 736	305	-	1 586
D10	- 4 025 477	- 1 881 264	- 4 773 953	171 201	116 805	267 606
Q1	- 1 690 410	- 712 569	- 1 931 285	524 396	313 587	854 007
Me	- 147 033	29 269	- 124 558	1 692 966	746 262	1 988 928
Average	- 16 305	- 35 497	- 51 802	2 490 453	1 337 793	2 971 461
Q3	1 693 122	785 949	2 019 580	3 425 594	1 604 847	4 142 868
D90	4 304 854	1 843 588	4 958 633	6 244 738	3 303 760	6 833 591
max	14 529 246	13 342 836	14 942 927	22 402 463	47 571 778	49 459 736

Data is calculated for the period 01.2014. – 01.2017.

From the daily changes we can see the followings:

- Deviation in the negative and positive directions are fairly symmetric.
- The value of daily fluctuations are around 2 times higher on the DSO level than on the TSO level, however the maximum deviation is attributed to the TSO level consumers.
- The median daily deviation value is 1,700 MWh on the DSO level and 750 MWh on the TSO level, and 2,000 MWh on the total, while 90% of the deviations of the total consumption are under 6,900 MWh, which represents 11% of the median consumption level.

Table 2: Distribution of the daily deviation from weekly average values on the different consumption levels

	Daily deviation from average of consumption, kWh			Absolut value of daily deviation from average of consumption, kWh		
	DSO level	TSO level	Total	DSO level	TSO level	Total
min	- 31 694 292	- 51 133 647	- 61 407 291	13 284	144	2 910
D10	- 7 345 038	- 3 277 791	- 8 440 694	439 878	244 740	514 221
Q1	- 2 235 169	- 1 371 307	- 3 079 984	960 504	597 832	1 328 170
Me	259 530	56 231	93 621	2 191 539	1 382 617	3 124 454
Average	13 745	- 197 933	- 122 439	4 200 537	2 310 855	5 086 007
Q3	2 115 608	1 386 653	3 259 536	6 126 437	2 825 862	7 072 625
D90	7 299 094	3 215 450	8 021 938	10 442 896	4 796 160	11 741 416
max	31 331 323	12 866 448	28 358 886	31 694 292	51 133 647	61 407 291

Data is calculated for the period 01.2014. – 01.2017.

When we look at the daily deviation from a weekly average value, we also find that the deviation in the negative and positive directions are fairly symmetric, and that there are more than two times higher deviations in the DSO level consumption than in the TSO level consumption. The median deviation of total daily consumption from its weekly average is 5,000 MWh, while 90% of the deviations are under 12,000 MWh, which accounts for 20% of daily median consumption, but the maximum deviation is 5 times this much: 60,000 MWh.

By these we can describe the distribution of demand for short term flexibility in the Croatian market, i.e. we define the index for demand for flexibility as the absolute value of daily consumption deviation from its weekly average. We use the distribution of its historical values to describe the Croatian short term flexibility market's demand side.

Table 3: The distribution of the absolute value of daily consumption changes – i.e. demand for flexibility, kWh

The distribution of the absolut value of daily consumption changes							
max	D90	Q3	Average	Median	Q1	D10	Min
61 407 291	11 741 416	7 072 625	5 086 007	3 124 454	1 328 170	514 221	2 910

V. Analyzing supply sources of short term flexibility on the Croatian market

By analyzing the capacity and flow patterns on the supply sources we can provide an approximation of the supply possibilities of flexibility in the Croatian market.

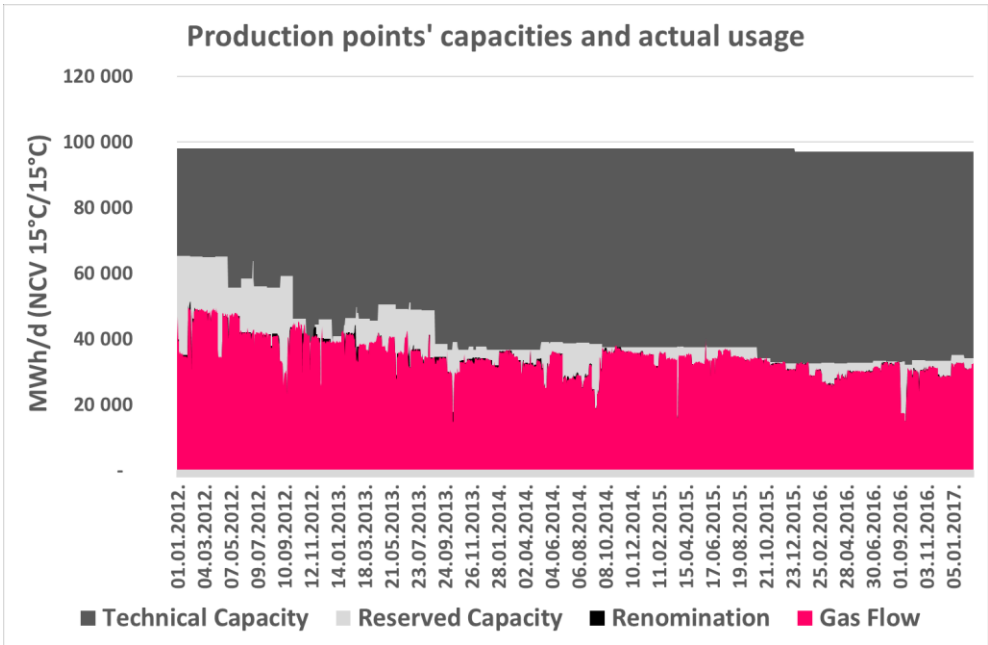
Flexibility of production:

Croatia has indigenous natural gas production. The modulation of gas production capacities could provide flexibility on the short term market, however due to technological and economic characteristics of field depletion it is not frequently used for this role. Looking at the Croatian production gas flow into the transmission system, it can be seen, that although there is a daily fluctuation in its level, it is moderate. The median change is 226 MWh. As large drops in the historical data could be the result of outages we suggest to rule those out when considering normal flexibility opportunity of the production sites therefore a range of 200-400 MWh/d could be assigned to this supply source as available flexibility.

Table 1: Distribution of the daily changes in the gas flow on the production entry point of the transmission system, kWh

	Production level's daily change (MWh)
min	0
D10	38
Q1	95
Me	226
Average	654
Q3	485
D90	1 281
max	17 526

Figure 1: The evolution of daily gas flows compared to the technical and reserved capacities on the production entry point



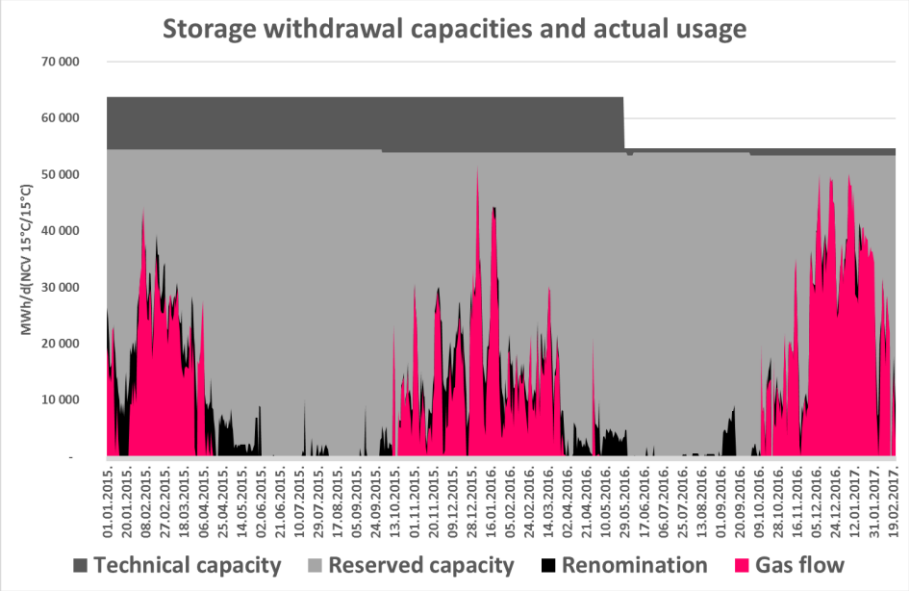
Flexibility of storage

Storage sites are built for providing flexibility therefore in this case total withdrawal/injection capacity could be considered as a flexibility source. However, since storage is used to provide seasonal flexibility, in winter a stable part of storage withdrawal capacity is fixed for a longer term usage, i.e. there is a level that is steadily used throughout the winter months therefore it cannot be considered as a daily flexible part. And this is also true for the injection capacities during summer months. Looking at the historical usage pattern of storage we can see that during the winter and summer months there is a fix level that is used steadily, therefore we use the lower quartile value of available storage capacities to count with as daily flexibility.[9]

Table 2: Distribution of not used injection and withdrawal capacities, kWh

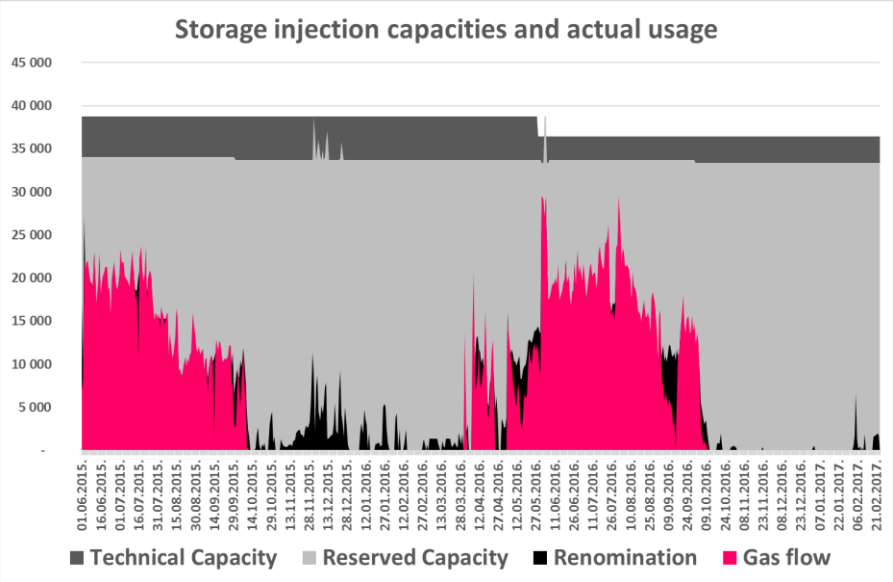
	Available injection capacity	Available withdrawal capacity
min	6 900 795	4 609 700
D10	17 157 109	26 688 627
Q1	22 613 908	43 901 466
Me	36 441 600	54 662 400
Average	30 514 183	50 754 412
Q3	38 719 200	63 772 800
D90	38 719 200	63 772 800
max	38 719 200	63 772 800

Figure 2: The evolution of daily gas flows compared to the technical and reserved capacities on the storage entry point



[9] Naturally, the two directions work in a complementer way, if there is winter and small amount of available withdrawal capacity, then injection capacity (virtually) is abundantly available.

Figure 3: The evolution of daily gas flows compared to the technical and reserved capacities on the storage exit point



Flexibility from the borders

Flexibility could be brought in from other markets through the interconnection points. However as discussed in Section II. contractual flexibility is also a key question in these cases: the availability of liquid short term markets from the neighboring countries. Croatia through its interconnection points can reach either CEGH the nearest liquid gas hub or the Hungarian market, where there are also short term trading platforms available. Therefore, contractual flexibility is provided, the main question is the available capacity for bringing flexibility from abroad.

The Slovenian borders were used extensively in the past, especially during winter. It seems that seasonal flexibility is also provided from this interconnection point. On the other hand the Hungarian entry point is used scarcely. Obviously economic reasons are behind such a usage pattern, e.g. the difference in interconnection capacity charges, the difference in the prices of available markets beyond the borders, the route choice of long term contracts etc.

As we are assessing the potential flexibility supply without the economic aspects, based on the historical usage patterns we consider the majority of the interconnection capacities on the Hungarian border as available for daily flexibility needs, while only a minor part of the capacities on the Slovenian border.

Table 3: Distribution of not used interconnection capacities, kWh

	Available IP (SI->CR) capacity	Available IP (HU->CR) capacity
min	- 6 336 818	13 796 362
D10	4 702 861	59 390 723
Q1	9 402 206	64 091 770
Me	17 490 710	67 177 166
Average	16 864 878	65 153 729
Q3	23 835 847	68 345 034
D90	29 429 554	69 120 000
max	47 333 569	69 120 000

Figure 4: The evolution of daily gas flows compared to the technical and reserved capacities on the Rogatec entry point

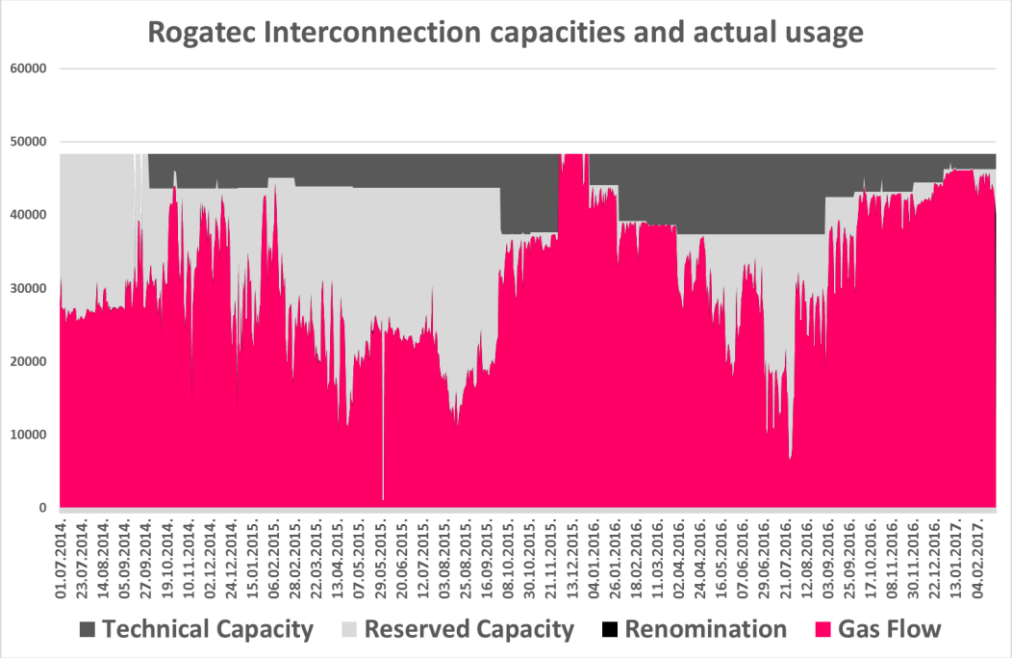
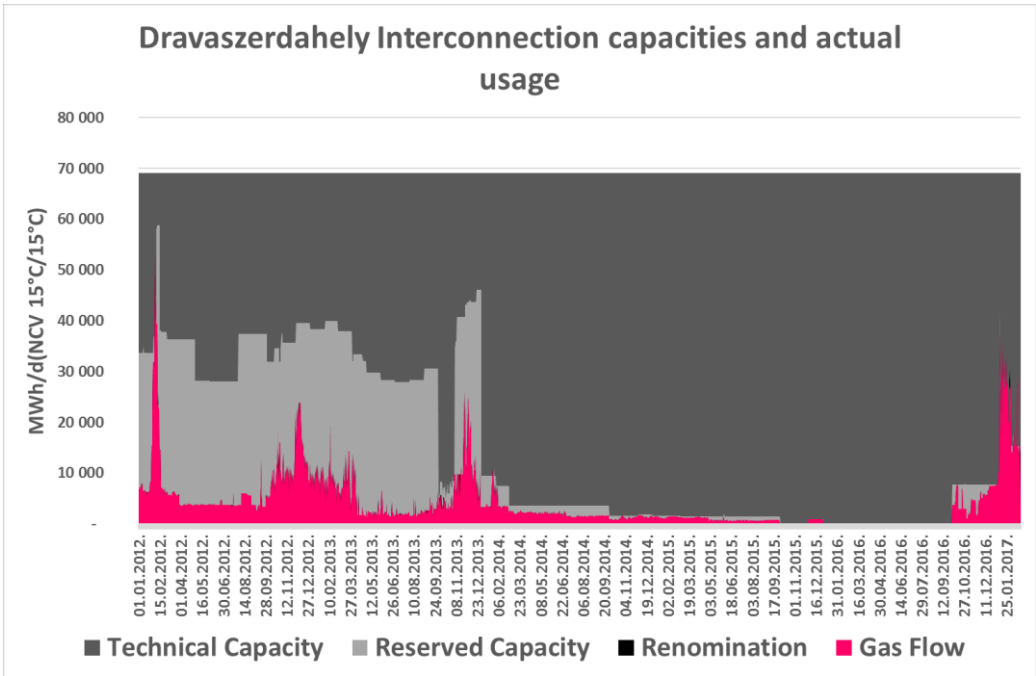


Figure 5: The evolution of daily gas flows compared to the technical and reserved capacities on the Dravaszerdahely entry point



VI. Evaluation of the results

By the detailed analysis of the evolution of the Croatian balancing market we can state the followings:

- Based on the analysis of physical potentials of the short term flexibility market Croatia has good fundaments for implementing market based balancing as it has large supply potentials compared to the potential size of the demand for flexibility.
- Balancing need for supplying DSO consumers is around 2 times higher than for supplying large consumers connected to the transmission system. And while for the latter group this balancing need decreased over time, which could be the result of better planning and forecasting, DSO level consumption's balancing need did not significantly change over time. In the future, however, the introduction of remote metering for smaller consumers could result in lower balancing needs for the DSO level consumption as well, since more and timely information would be available for planning the portfolios.
- After the introduction of renomination possibilities traders started to take their part out of balancing. There is a clear trend: the share of balancing performed by shippers in relation to TSO level end user consumption increased over time, by now only about 30% of the balancing need is left for the market operator for residual balancing. In case of DSO level consumption still 70-80% of balancing need is left for the market operator. Again, this latter could be due to lack of sufficient data to make better adjustments and with the spread of interval metering could also decrease like in the case of TSO level End user consumption.
    - Thus, on the End user consumption level shippers already took over the primary role in balancing, while with the DSO level consumption this could be reached in the future.
- The decreasing trend of the Internal Adjustment possibilities that remain in the system after nomination reflects an increasingly efficient day ahead market. The short term market continuously improves in coordinating shippers in trading their opposite sign of imbalances.
    - Renomination possibilities again provide further field for such trades, traders further decrease the level of Internal Adjustments within day.
- Regarding the market operator's residual balancing activity, we can say, that the balancing platform introduced a transparent and close to market-based procurement system. By now activated bids on the daily platform account for the 50-90% of the energy used for residual balancing depending on the season.