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Does the hatchery work?

Evaluating the effectiveness of the natural gas balancing regulatory regimes in gas markets which are at the initial stage of market opening

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Ph.D. Dissertation

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I. INTRODUCTION

The past twenty years of the European natural gas market liberalization was the intellectual playground for the practical application of economic theories. 'Market building' in this area is literally true. European regulators have set as a goal competitive markets in the place of the vertically integrated monopolies and have been gradually transforming the sector from the starting point towards the goal through a series of regulatory cycles. In this transformation, the economic theories – especially regulatory economics, industrial organizations, and new institutional economics – as well as the European (and world) discourse about these theories of academic, consultancy, and public administration institutions, have constantly shaped the regulatory direction and the tools used.

One of the peculiarities of the natural gas market is balancing: keeping the physical quantity of natural gas injected into and withdrawn from the system in balance within a short time interval. With the opening of the market balancing has emerged from a simple intra-corporate physical problem into a commercial and physical regulatory task requiring complex coordination.

The experience of the market development paths of the now mature Western European natural gas markets shows that the well formation of the balancing rules is the cornerstone of gas market regulation. A malformed system could mean a serious barrier to market opening, while, if the details are well set, it may be a hatchery for the wholesale gas market: market-based balancing rules can give the boost to the spot markets that they really need in their way towards becoming a liquid market.

Another important experience of the last twenty years of market opening is that fully market-based operation cannot be introduced overnight. Balancing regulation, like the rest of gas market regulation, means the cautious, continuous adjustment of the rules tailored to the structure, possibilities, and regulatory goals of the market. Fully market-based operation can be achieved gradually through the cycles of continuous monitoring of the effects of the rules introduced and the regulatory adjustments delivered based on the results of these evaluations. During this transitional period, regulation is a very sensitive balancing with market capabilities, so it is particularly important for the regulator to deeply understand the functioning of the market and to continuously analyze the impact of the new rules introduced.

This thesis, on the one hand, prepares a comprehensive inventory of the balancing regulatory instruments applicable during the transitional period, and as such summarizes, synthesizes, and deepens the results of academic literature and practice-based professional papers. When presenting the inventory, I present the regulatory tools per each area, the variants of the tools and their effect according to the development level of the market. The inventory is summarised by a balancing regulation development path that illustrates the constellations of regulatory tool variants that constitute the balancing regulatory system's various phases between the initial integrated monopoly structure and the final fully market-based balancing regime.

The dissertation, on the other hand, expands the literature on the evaluation of the effectiveness of balancing regulations, it introduces new analytical tools and builds up a comprehensive analytical methodology. The methodology examines areas – for example, whether there is fundamental potential to introduce market-based balancing or the issue of Internal Adjustment opportunities – which have not been studied in the literature so far – and it also provides a different and more comprehensive approach for the areas already examined by the previous literature. For this I define new indicators that most importantly are based on publicly available data so that they can be used by everyone and, in contrast to the analyses of previous literatures, are also methods that can be applied to the key period when the balancing regime can greatly support market development, when there is no liquid marketplace yet. The methodology is illustrated on three country-cases – Croatian, Polish, Czech.

Because of the key role of balancing, European regulation has now harmonized the balancing regulation of European Member States by a separate regulation. This Pan-European Balancing Network Code (BAL NC[1]) is mandatory for all Member States, even with all the various types of exemptions practically all Member States must implement it by April 2019 at the latest. It places the balancing regime on a fully market-based basis and its stated goal is to generate liquidity and launch the spot wholesale markets.

[1] The Regulation referred to as BAL NC: Commission Regulation (EU) No 312/2014 of 26 March 2014 establishing a Network Code on Gas Balancing of Transmission Networks.

For some Member States[2] the transposition of BAL NC poses a serious challenge which in return means that the balancing regulation can therefore actively shape the wholesale spot markets in these cases. Thus, knowing what kind of balancing regulatory tools are available for transition steps, which tool can be used at which maturity stage, and the evaluation whether the implemented tool is effective is of particular importance for this group of countries. In addition to the European Member States, natural gas market opening is also current in neighboring countries. For example, countries that have signed the Energy Community Treaty[3] have undertaken to introduce EU energy market regulation in their own gas markets. Thus, in our region, for many countries it is a current issue how to setup and regulate the balancing regulatory regime.

My dissertation provides academic support for this regulatory challenge by providing a coherent overview and a list of the regulatory tools that can be used in different stages of development and provides a comprehensive methodology for evaluating and monitoring the effectiveness of implemented regulation.

I started to study about regulatory issues and market analysis of the energy market during my university years. From 2004 I worked as a scholarship student at the Regional Centre for Energy Policy Research of the Corvinus University of Budapest (REKK). One of the results of my studies here was the article on the green model of public transport prepared for the Scientific Students' Conference (TDK), for which I received first prize at the Corvinus University of Budapest in the Environmental Economics section in 2005. As a result of my professional and community activities I was awarded the University's Pro Universitate Prize at the time of graduation.

After graduation, in order to study the energy sector at an academic level I applied to the Doctoral School of Business and Management at the Corvinus University of

[2] This country group requested an extension of the deadline of 1 October 2015 until April 2019: Slovakia, Sweden, Romania, Poland, Northern Ireland, Ireland, Greece and Lithuania.

[3] The Signatories of the Energy Community Treaty are: Albania, Montenegro, Macedonia, Serbia, Ukraine, Moldova, Kosovo, Bosnia and Herzegovina. Of these, Ukraine and Serbia have a natural gas sector of such size where these regulations can be interpreted.

Budapest. My studies in the PhD programme were complemented with the research and lecturing activities that I conducted at REKK.

During the eight years spent in REKK I could follow the transformation of the Hungarian gas market from market opening to today's multi-player, competitive market, based on common European rules. I could see how regulatory goals were shaped by discussions with industry players and by the EU frameworks, and then analyzed the impact of the implemented rules on market players, whether the original purpose of regulation was achieved or not. The results of the analyzes suggested how to adjust the regulation to bring the market closer to the target. During my work I could have an insight also in the development of European regulations, for example, I could participate in an international project that provided the European Commission with an overview of the natural gas balancing regimes of the Member States. With my colleagues I conducted several analyzes on the Hungarian gas market, such as on the flexibility market, the gas and contract release auctions following the opening of the market, and on the security of supply risks.

During this time, I prepared many publications and conference presentations that I mostly made as co-authors with my colleagues. In addition, I have been teaching about the regulation of the gas market at the Corvinus University of Budapest and at the events of international organizations.

My interest in the practical side of the gas market has led me to temporarily interrupt my research activities in 2012 to join the newly established Hungarian gas exchange, CEEGEX, where I was able to utilize my market analysis experience in the field of market surveillance. During my work, by participating in international working groups, I became acquainted how the energy exchanges of other Member States and the European organizations think about market surveillance.

Later, I worked for MVM Partner, a major player in the Hungarian natural gas trading, on strategy and market analysis issues. Here I could also get to know the viewpoints of the key players of natural gas market liberalization, the gas market traders'.

Today, one of the main trends in the energy sector is digitization. With market opening, the number of players multiplied as well as the interactions between them and the expected speed of these interaction and the amount of data to be processed. This

demand requires complex IT solutions. Currently, I am working at a software developer company that has developed the IT system of the Hungarian gas market transmission system operator, including the Hungarian balancing system, and provides IT solutions for several other domestic and foreign natural gas market players, traders, and storage operators as well. During my business analyst work here I have been able to expand my previously gained theoretical and practical knowledge with the understanding of the operational processes of the natural gas market. Among other things, this new knowledge dimension and the experience gained at a trading company and at the stock exchange, allowed me to have been able to develop novel indicators to assess the balancing systems compared to the indicators applied in the literature so far.

I continued my research activity in the PhD programme focusing on the regulation of the balancing of the gas market and the evaluation of the effectiveness of the regulatory measures. In May 2017 I submitted a summary of my research results to the Regulatory Research Award call organized annually by the Energy Regulators Regional Association (ERRA).[4] The submitted papers are judged by an international professional committee, and in 2017 I won the award. In the notification Märt Ots, President of ERRA, Chairman of the Estonian Regulatory Authority, wrote the following justification:

„*The Award Committee believes that this very well-structured paper has an important theoretical and practical value and could be useful for energy regulators dealing with the liberalisation of natural gas markets*."

The methodology developed in this dissertation for the analysis of the effectiveness of the balancing systems builds on this paper, further develops, and complements it.

The dissertation consists of four main chapters. The first introduces the theoretical background of the topic of the dissertation and the relevant literature, it also places the new scientific findings of the dissertation within the literature on gas market

[4] Further information on the award can be found here: http://erranet.org/knowledge-base/erra-regulatory-research-award/

regulation. The second expands the literature of balancing regulation by making a comprehensive inventory. The third chapter introduces a methodology for measuring the effectiveness of balancing system regulations, and finally the fourth shows the empirical application of this methodology in three countries.

The structure of the dissertation is accordingly the following.

Chapter II summarizes the theoretical background of the topic. What is gas market opening, why is it happening and what is its purpose? What were the economic considerations that guided this process and how were economic disciplines affected by the experiences of market opening? I present the focuses and main issues of this regulation-led market-building process. The main goal of market opening and the regulatory process that creates it is to increase the efficiency of the natural gas sector. To be successful in regulation and to be able to evaluate the effectiveness and success of regulation, we need to be aware of what is meant by efficiency. In this chapter, I describe the need to explicitly define this targeted efficiency, and then show how the definitions developed, and the problems that evolved around it. Then I summarize the methods used to evaluate the effectiveness of regulation.

The chapter ends with a summary of the literature relevant to the dissertation. As the dissertation examines a practical question, the relevant literature is formed by various types of works: besides academic articles I also consider the materials of professional organizations that are often prepared on an academic level quality. In addition, I present and place my previous works on the subject.

The main content of Chapter III is a summary of the regulatory toolkit. For this I first outline the balancing problem and its dimensions, the tasks, and implications of the various actors. An important complement to this chapter is Appendix I. and II. that discuss the development of the gas market, the supply chain, and the flexibility market. These provide a summary of the basics of natural gas market that are necessary for understanding the dissertation's topic, the balancing problem.

The balancing problem becomes a complex multi-player coordination task with market opening. This is handled by the balancing regime, a multilayer regulatory package. I prepare a comprehensive inventory of this regime: I present the operating framework of the balancing regulation and the three pillars of balancing regulation within this framework. Within the pillars, I describe the regulatory tools and their possible

variants, which types of tools can be used in the different development states of the market.

As a summary of this, I outline a possible development path of balancing regulation, where I describe the sets of tools that can be applied to different stages of development.

After the theory of regulation, I turn to its practical implementation: how the regulation of the European gas market, and in particular the regulation of balancing, evolved, how it reached to the pan-European network codes that prescribe harmonized rules down to the operational level, and what is the content of the one covering balancing, BAL NC. A very important complement to this section is Appendix IV that describes in more detail the development of European natural gas regulation.

In Chapter IV I lay down the methodology for assessing the efficiency of the balancing systems. First, I discuss the questions that I intend to answer with the methodology. One question is whether there is fundamental basis for introducing market-based balancing or not. For this, I suggest the analysis of the daily flexibility market. I propose how to analyze the flexibility market and how to evaluate the results. On the example of the Croatian natural gas market I illustrate how this methodology can be applied.

The second question is the efficiency of the balancing system itself. First, referring to the lessons learnt from the theoretical chapter, I define what I mean by the efficiency of the balancing system. From the definition I deduce the directions of the analysis. To define the indicators necessary for the analysis, I first present and evaluate the recommendations of the previous literature on such indicators. Compared to these I develop new metrics that on the one hand are based on publicly available data, and thus can be produced by anyone, and on the other hand are more directly related to the evaluation of the efficiency of the balancing system.

The way of evaluation is an important part of the methodology, so in Chapter V I illustrate the application of this methodology in three country-cases.

Finally, by presenting the shortcomings and limitations of the methodology, I designate possible future directions for further development.

II. THE THEORETICAL BACKGROUND OF NATURAL GAS MARKET REGULATION AND MARKET ANALYSIS, SUMMARY OF THE RELEVANT LITERATURE

II.1. The background of regulating gas markets

Regulatory economics provides the theoretical background of my topic – the regulation of natural gas markets and the balancing systems within those. Regulatory economics is an applied branch of economics that focuses on the markets of public services (mainly telecommunications, energy, water, transport) (Kiss, 2008). Its foundations were laid down in the United States in connection to court cases initiated by consumers against privately owned monopolies providing public services in market power abuse cases (Kiss, 2008). Thus, for a long time the focus of regulatory economics was the regulation of monopolies. Since in Europe these public services were carried out by state-owned monopolies – also in case of the gas markets (IGU, 2006) – the problems encountered by these companies were subject to state administrative procedures and thus in Europe there was no need for regulatory economics until the opening of the markets in the 1980s (Kiss, 2008).

II.1.1. The evolution of the concepts of regulation

Basic definitions

Regulation is when the state restricts the behavior of companies or individuals by exercising its power mostly in the name of the common good (Viscusi et al., 2000). The market regulation that is in the focus of this thesis *"aims at preventing or remedying market failure, i.e. making those markets efficient that would function imperfectly without regulation"* (Kiss, 2008, p. 14). The regulator aims at achieving the efficient state of competition on the imperfect markets, through – in the beginnings

– by direct imposition of this final state (e.g. cost-based price), later as the theory and experience evolved, by creating a motivating environment imitating competition (e.g. incentive regulation).

It is important to mention the division of responsibilities within the regulatory framework. The introduction of ex ante rules to prevent abuse of market power in particular should be applied in cases where without regulation abuse is expected to be systematic. In comparison, if there is no potential for systematic abuse in the system, by setting the limits of competition (e.g., banning collusion, deception, etc.), competition should be left freely on its own and, if there is an anti-competitive abuse, i.e. the rules of the competition are violated, it should be solved by ex post regulatory intervention. This ex post regulation is covered by competition policy, while the former ex ante intervention is a sector-specific regulation. This dissertation focuses on the **sector-specific ex-ante regulation** and will only address competition policy to the extent necessary.

The first period of Regulatory Economics: the natural monopoly

Initially – as explained above – regulatory economics focused on the case of monopolies. The 'natural monopoly' was the centerpiece, which according to its definition by microeconomics is formed because in the given industry the production technology is such that a single company can supply consumers more efficiently, cheaper than if there were more companies supplying (subadditive cost function). Thus, the monopoly is naturally created as the most effective form of supply. In case of regulating the natural monopoly, price and revenue control is the main focus in order to prevent monopolistic profits.

The Austrian school provided an important alternative view – which had significant impact on the following period of regulatory economics that focused on imperfect competition. The Austrian school abandoned the negative judgment of the profit and incorporated the importance of innovation into the discourse, highlighting that the profit that a company gains through innovation because it sells better products than anyone or because it sells it more efficiently is a very constructive profit for the market, it motivates companies to develop, so the profit's removal by regulation may be detrimental. Another important aspect that the Austrian school has introduced is that

the state of the market is always dynamic, the competitive situation can change completely with each innovation.[5]

In the evolution of regulatory economics, the theory of contestable markets introduced by Baumol and its colleagues[6] in the 1980's was an important step away from the natural monopoly towards potential 'competition' (Bender et al., 2011). It raised the possibility that, even though there is only one company on the market, still there could be a competitive pressure on it. The essence of the theory is that if it is easy to enter into a market (there are no high fixed, sunk costs) then if the monopoly would set a monopoly price, it would be worthwhile for others to enter the market and lower prices, so the monopoly would lose its market. Therefore, because of the possibility of entry, the monopoly will not set a monopoly price, it will set a lower price (at around the level of the competitors') that is low enough so that entering will not worth it to the others (the specific level depends on the sunk costs of entry). In this case the price regulation of the monopoly is less justified.

The emergence of public choice theory has brought a new turn (also) in thinking about regulation. (Kiss, 2008) This new approach has drawn attention to the imperfection of the ideologized regulation. According to this view regulation also has a cost, the regulator is not perfect there is no complete information, the intervention could be harmful, so it is only worthwhile to regulate if efficiency gains can be achieved overall. It also draws attention to the fact that every actor act in their own interest, and regulation is also a result of the battle of interest groups, and it is naïve to think that the rules that are established support the public good (Hertog, 2010).

During the 1970s and 1980s a new view emerged. According to that, among the public service industries which due to technological conditions were treated as natural monopolies so far, in some segments real competitive environment could be created instead of the 'imitated competition results' prescribed by the regulation through administrative tools. This was supported by on one hand the dissatisfaction with the low quality and – despite the regulation – expensiveness of the monopolies' services and on the other hand by technological developments in various industries, such as the telecommunications and the power sector. These technological innovations raised the possibility that some segments of the supply chain would no longer be characterized

[5] Two outstanding works from the Austrian school: Schumpeter (1942) and Hayek (1948)
[6] The theory is introduced in Baumol et al. (1982).

by subadditive cost functions (Haase, 2008). For example, in the power sector among the gas fueled power plants a new type, the so-called combined cycle technology emerged, which significantly reduced the time and cost of a new power plant investment, and thus entry to the market became easier (Stoft, 2002).

As regulatory economics emerged through telecommunications cases, the introduction of competition and the corresponding revolution of the regulatory theory also started out from the telecommunications sector (Kiss, 2008). It is particularly interesting that a few years later the same market opening and accompanying regulatory issues also commenced in the natural gas sector even though there was no such kind of technological innovation in this sector that launched the thinking about the introduction of competition in the telecoms and power sectors earlier. (For this reason, many still have serious doubts about the justification and feasibility of opening the gas market and consider it only to be forcing a trendy theory on the industry ignoring the specificities of the area. This view is still being heard in many conferences, an illustration for example: Slabá, 2009.)

Market opening, challenges of the transitional period

The introduction of competition is not a one-day event. In case of the natural gas sector the European market opening is ongoing in the last 20 years. This transition period characterized by the gradual introduction of competition, has brought new challenges to regulatory economics, which until then only knew the two extremes: perfect competition and the monopoly. An extremely intense thinking commenced about regulating imperfect markets. Only the starting point (monopoly) and the ultimate goal (competitive market) were covered with regulatory tools, while there was a need for regulation that would bring the industry from the starting point to the goal (Kiss, 2008).

Game theory provided the response to this new challenge and it filled the gap on the theoretical space between the neoclassical monopoly and the infinite static perfect competition by focusing on the reactions of few major players to one-another. It concentrated on the circumstances and the changing relationships between the actors, rather than the static state, and thus it could describe a much wider range of market situations. The works laid down by Lafont, Tirole and their colleagues in analyzing markets in such a dynamic framework to solve regulatory questions coming mainly

from the telecom sector remained lasting[7] and resulted in a new discipline, industrial organization (Industrial Organization - Tirole, 1988).

The game theory approach changed a lot even on the attitude of regulation. The relationship between the regulator and the regulated company was considered in the principal-agent context. Regulation was converted to an incentivization task instead of the one-way administrative instruction (Kiss, 2008). The recognition of the importance of information asymmetry between the regulator and the regulated company has brought to life incentive regulation. In doing so, the regulator transforms the company's circumstances so that the company's private interest, that is, the profit maximizing decision, coincides with the socially desired state.[8] In the natural gas sector, for example, the price cap (or revenue cap) regulatory system has become a complex incentive-based system.

Focal Points

In the beginning of market opening regulation focused on creating the possibility of entering the market and enabling equal opportunities for those already on the market.

Market power has become one of the main concepts. A market player with market power, usually the incumbent (the commercial branch of the company that was a monopoly before opening the market) could distort the market for its own benefit, therefore it should be regulated to limit its market power. One of the main tools to do this is the prescription of selling on a regulated price in a transparent manner. A significant literature was developed on price cap regulation.[9] Another tool, for example, is the gas- and contract release programs used mainly in the natural gas sector, through which the incumbent was obliged to offer its long-term contract portfolio for the newcomers for sale.[10] It is important to note that this type of ex ante regulatory intervention concentrates on the market player with a persistent market

[7] Tirole's 2014 Nobel Prize for Economics also acknowledged that his work and the emerging new discipline, industrial organizations, helped to clarify *"how to understand and regulate industries with a few powerful firms"* (Nobelprize, 2014). A summary of the topics and results of this period and of Tirole's work can be found in e.g. Fudenberg, 2015.

[8] Laffont and Tirole were also innovative in this area: Laffont - Tirole, 1986, Laffont - Tirole, 1988.

[9] Littlechild (2011) for example provides a concise summary of the practical application and forms of price caps in network industries.

[10] With my colleagues we prepared a summary about the gas- and contract release programs conducted in the Hungarian natural gas market. (Szolnoki et al., 2008a)

power, thus on the way towards the competitive market as the market powers of the players become more balanced this regulation should be withdrawn.

The other main concept around which a serious regulatory toolbox has been built is the **concept of essential facilities**. This is basically about the way natural monopolies remain on the competitive markets. In those industries where market opening commenced there was usually a segment (e.g. the network) that still had a subadditive cost structure and therefore it was still reasonable to maintain the monopoly structure. However, as the use of these facilities is indispensable for carrying out the players' activities in the industry's competitive segments, i.e. without the use of it the competitive service could not be provided, therefore regulation must ensure equal access to the essential facilities to all players in the competitive segment. Providing this access requires a very extensive regulatory system on the gas market, ranging from regulating the unbundling of the activity of the essential facility from the competitive activities, through the regulation of access tariffs (price cap is also present here) and the access model, to natural gas balancing regulation. Ex ante regulation of access to essential facilities is necessary until the facility is essential for the provision of the service on the competitive market segment. This also means that even if on the segment opened in the market opening process the competition goal is achieved this ex ante regulation remains until the facility's essentialness is present.

During the discussion of the regulation of the gas market, it will be shown how the regulation treated these two focal points (market power and essential facility) in practice. Due to the special situation of balancing, it is affected by both areas.

II.1.2. Disputed points in regulation in the transitional period

Out of the much-discussed points that emerged during the transitional period regarding the sector-specific ex ante regulation I find two particularly important from the point of view of this dissertation. One is about what exactly are those competitive outcomes that are intended to be replicated by regulation. The other discourse focused on the assessment of the maturity of the market: how transitional this sector-specific

regulation-need really is, when can it be withdrawn, and the market be left to ex post competition regulation and when this continuous ex-ante regulation is to be maintained. Below I will discuss these two points in detail.

Aim: effective competition

The regulatory intervention's aim is thus to imitate the results of effective competition in imperfect markets. For such market regulation to be successful, the regulator must have a clear idea of what exact results competition has, i.e. what are the characteristics of effective competition.

During the "market-making" period following market opening the question has been raised several times whether the objective of market opening is correctly defined in practice. Criticism has emerged many times that increasing the number of market participants in itself is not the goal. If this is not associated with effective competition, then the market is only pretended. As Shuttleworth puts it when assessing the first steps in the opening of the European gas and electricity market: *"the promotion of competition should be synonymous with promoting efficiency and not (for example) with promoting the existence of (potentially inefficient) competitors… Unless a reform creates an environment that promotes more efficient choices, it cannot be said to promote competition."* (Shuttleworth, 2000 p. 1).

This was the key issue of the nearly 20-year history of the European gas market opening: is it possible to generate effective competition with the given industry specificities by the artificial restructuring, market opening, and liberalization reform packages dictated from above, or we just make the industry vulnerable to a „fake-competition" by these?

It is important that Shuttleworth (2000) also made it clear that it is not right to evaluate the evolution of competition solely on the basis of price decreases. Instead, the right question to ask is whether the experienced price decrease was due to a real cost reduction (due to efficiency gains), i.e. whether the competition created on the place of the former inefficient monopoly did really inspire the newcomers for innovation, efficiency? If the decline in prices would only be a result of a shift of surplus from the

supplier to the consumers, this result could in itself also be achieved by the monopoly's profit regulation thus to reach this result market opening would not be necessary.

These ideas are particularly relevant to the topic of this dissertation as they have important implications on the indicators used to assess the impact of regulatory instruments applied on the market. Market analysis indicators are often limited to the evaluation of the number of players, market shares and price developments. Shuttleworth's (2000) article points out that when assessing regulatory intervention instead of these indicators or rather in addition to these indicators the "efficiency gain" should be assessed.

For this reason, the concept of effective competition is described in more detail below, summarizing what kind of approaches were of effective competition in the regulatory economics thinking.

What exactly is effective competition?

To date, in the academic discourse of network regulation, "effective competition" is the "sought" key word. As Bender and his colleagues point out, *"Establishing effective competition is a core objective of European regulatory policy for network industries"*, yet there is no clear, objective definition of effective competition to date (Bender et al., 2011 p. 4).

This absence is problematic not only because assessing whether there is effective competition on the market is a necessary input for evaluating the effectiveness of regulatory interventions but also because knowing the degree of effective competition on the market is also necessary to judge whether the transitional period – when market imperfections require continuous ex ante regulation – has ended or not. How can it be determined when the market can be left on its own to work i.e. specific ex ante sectoral regulation can be phased out and the industry can be left to purely ex post competition?

Despite the absence of objective definition of effective competition, the concept of effective competition has already been incorporated into the practical regulatory discourse and the legal environment (Bender et al., 2011).

The evolution of theories on effective competition

What competitive results do we want to imitate in the imperfectly competitive markets through regulatory interventions?

Neoclassical economics evaluated the tools of welfare economics by comparing their results to the theoretical results of static perfect competition. In this simplified model, cost and demand curves are given there is no possibility for efficiency gain in time and in the competition of infinite number of sellers and buyers the price is simply the marginal cost. In the simplest form, fixed costs do not exist, so the price equals the average cost, there is no profit (Pápai, 2011).

The perfect competition model describes a static equilibrium state in ideal conditions and there is no description about the process of competition – how we got to this state. Schumpeter (1942) and Hayek (1948) – from the previously mentioned Austrian school – compared to this static concept point out the importance of rivalry, which on one hand is independent of the number of competitors, that is, it does not require many actors for the competition to be effective and, on the other hand it places competition into a dynamic environment. Through competition, players are encouraged to innovate, produce products more efficiently, cheaper (cost curve shifts) or with higher quality (shift in demand curve) over time. The incentive is provided by the possibility of profit making, so in this approach, even a market where profits are present can be effectively competitive and the presence of profits is not negative on its own.

The origin of the concept of effective competition – according to the literature (e.g. Khemani-Shapiro, 1993) – originates from Clark's „**workable competition**", which was first elaborated in his article published in 1940 (Clark, 1940) and later further developed in the *Competition is a dynamic process* (Clark, 1961). Clark has formulated workable competition as an alternative to the neoclassical perfect competition, as perfect competition does not exist in practice, and the policy objective that is reachable by regulation must instead be in practice a "workable" competition.

Littlechild defines effective competition along three main characteristics (Littlechild, 2011):

- A: the elimination of excess profits
- B: discovery of more efficient methods of production

- C: discovering the needs of consumers

As Littlechild points out, neoclassical economics focuses on property A of competition, the Austrian concept of competition and the concept of workable competition besides property A, explicitly focuses on properties B and C.

Looking at the evolution of gas market regulation, it is easy to trace how the definition of effective competition has evolved, and thus the target state that the regulator wants to imitate in the imperfect markets. In the '60s and ’70s in their energy sector the British applied the neoclassical economics’ static approach. (Littlechild, 2011) Focusing on the pricing of state-owned integrated companies assuming static demand and cost curves. At the same time the real problem was dynamic: lack of incentives for efficient operation, excessive costs, inefficient investments, and little innovation characterized these state-owned companies. (Littlechild, 2011)

In the 1980s, the British energy sector responded to these dynamic issues with privatization and by introducing competition in the potentially competitive segments of the value chain. In addition, the concept of "incentive price regulation" appeared in the areas left to be regulated. In this method which is used even today in both, the price regulation of the networks and in the method of price regulation of wholesale and retail prices, the price cap is expanded with an incentive factor X. (Littlechild, 2011) The essence of this is that companies do not automatically get their costs back by price regulation. They must constantly strive to lower their cost level and to provide more efficient supply. The way how it is reached is left for the company’s decision – this is the justified solution in game theory in case of information asymmetry – and only the degree of improvement is subscribed by the regulation.

To sum up, both, **when formulating regulation and when assessing it, it is important what kind of vision we have on effective competition and its results.** In this respect, Littlechild's synthesis is in my opinion a very good guide.

Persistent or temporary regulation need?

In addition to effective competition, another important discourse – not fully independent of the interpretation of effective competition – was when the ex-ante regulation could be phased out i.e. when does the transitional period end.

As I have mentioned earlier, for a long time, the need to regulate network industries and its economic foundation were common in the rail, natural gas, electricity, and telecommunications sectors. However, by the end of the 1990s this consensus was challenged. In telecommunications, where like in the energy sector, the network was considered a natural monopoly, new entrants started building competing networks. In addition, with the convergence of telecom, IT and broadcasting, new competing media have entered the telecoms market, that is, intramodal competition and intermodal competition began simultaneously. These two processes have put a real competitive pressure on incumbent network companies. As competition enhanced and monopoly elements eroded the role of sector-specific regulation was questioned (Knieps, 2011). In 1999 an EU review was launched for the phasing out of ex-ante regulation in telecommunications which was followed by a Framework Directive[11] and an Access Directive[12] in 2002. The directives were already formed in the spirit of minimizing sector-specific regulation but afterwards it may be seen as a start of a slow process as today it is still ongoing.

This development has also raised the question in the energy sector regulation: whether a permanent sector-specific regulatory system must be set up, or this is only a transitional period. (Shuttleworth, 2000)

In the last 15 years, the former was verified. The energy sector differs from the telecommunications sector in some important respects, which justify permanent sector-specific regulation.

[11] Directive 2002/21/EC of the European Parliament and of the Council of 7 March 2002 on a common regulatory framework for electronic communications networks and services (Framework Directive)
[12] Directive 2002/19/EC of the European Parliament and of the Council of 7 March 2002 on access to, and interconnection of, electronic communications networks and associated facilities (Access Directive)

To analyze this, Shuttleworth (2000, p. 9.) quotes Newberry (2000), who in the case of the natural monopoly besides the subadditive cost function definition outlined the following further characteristics that justify ex ante regulation:

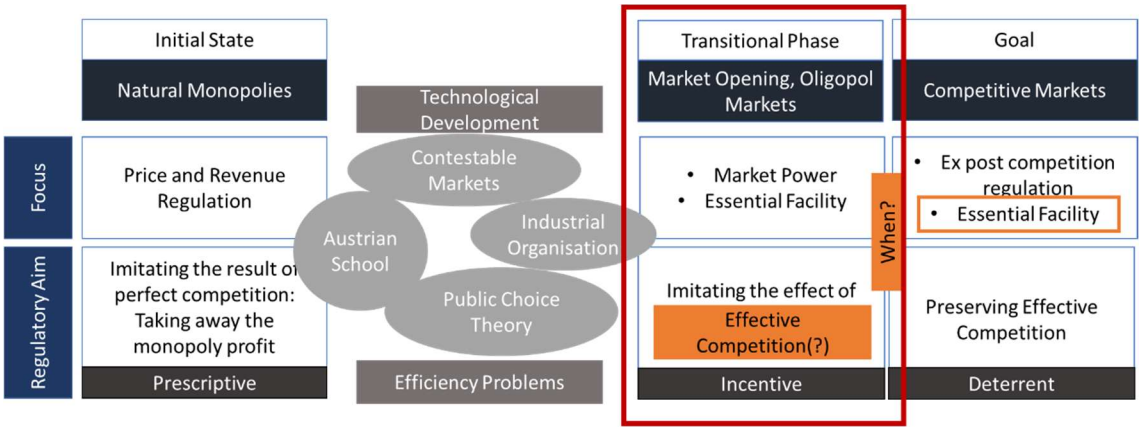
- „Network investments are durable (so rents persist);
- Capital investment in the network is large and irreversible (or "asset-specific", to use the correct economic jargon); and
- Networks are connected directly to large numbers of consumers (which increases transactions costs)."

Thus, after the transitional period as the ex-ante regulation of the player with market power is phased out in the competitive market segment the main topic of ex ante regulation will be the network access regulation.

As the balancing system is an element of the network access system its ex ante regulation therefore will be necessary even after reaching the competitive market goal. Nevertheless, market building (will) also take place within balancing. Within this context, the same process of transition from monopoly to competitive market will develop. Therefore, in case of balancing, during the transitional phase, ex ante regulatory measures for preventing market abuse will also be needed.

The following figure summarizes the evolution of market regulation discussed in this section, the main focuses, and questions.

Figure 1: Summary of the evolution of market regulation



Source: Own figure

II.2. Evaluation of the effectiveness of regulatory instruments

The European gas market regulation in brief

Several national natural gas sectors in Europe are still in the transitional phase. The level of development of natural gas markets in different countries varies, for example, in the case of Eastern European countries, we can speak of much younger markets than in Western European countries where mostly mature competitive markets are present. Their pace of development is usually also different.

Initially, European regulation focused, like in the other sectors, on facilitating and creating opportunity for market entry and ensuring non-discriminatory network access. The European gas market regulation started with softer instruments in the first phase, with Member States having a large margin of discretion, and then, in the second phase due to the slow progress, it switched to a stricter binding legislation mandatory for all the Member States. The main theme of the latter is the comprehensive regulation and harmonization of processes related to the provision of network access. The Pan-European balancing network code, the BAL NC, that covers balancing regulation up to the operational level was also established within this context.

In the first phase of the European natural gas market regulation balancing was considered as an element of the network access regime that can be solved by administrative regulation which only sets the guiding principles. The emphasis was on setting cost reflective balancing prices and providing equal conditions. As more and more experience has accumulated in this area, it has become apparent that, on the one hand, it can significantly distort the wholesale market competition if the balancing regime is not set up properly and, on the other hand, its proper design would best be the market-based setting. The reason for this is that it is so closely tied to the wholesale market (in fact it is its real-time continuation) that if it is not market-based but instead is based on administratively set rules, the result will not be efficient. Alongside this, the lesson learned from the case of the evolution of now mature gas markets has shown that organizing balancing on a market basis and involving as much as possible the market players in the balancing activity can have a beneficial effect on the wholesale market competition, it could drive further liquidity to the spot market during the initial phase of market opening and thus the balancing regime functions as kind of a hatchery

for the spot market. (ACER, 2016) This latter effect is already stated as an explicit aim in the latest European regulation of balancing, BAL NC.[13] The organization of the balancing regime is therefore a complex challenge for regulation, which, if properly designed, can boost the whole process of market opening towards the competitive market target.

It is also important to mention that besides the competitive market target the European gas market regulation's other main target was from the beginning to create an integrated common European gas market (so-called Internal market). The way towards this, on the one hand, is market opening in the individual Member States, and on the other hand, the dismantling of trade barriers between Member States, the harmonization of rules and the increasing of the interconnectedness of these markets through infrastructure developments, which is further supported by the EU's regulatory framework for the efficient use of the infrastructure.

The cyclical nature of regulatory activity

The regulation of the transitional period is a sequential process. Regulation always challenges the market a bit, which then adapts to the new circumstances and thus new opportunities, i.e. develops. If the pace would be too large for the market, chaos would evolve with a great chance. If we introduce full competition in a market where, it is likely that for a long time only a single player will have a chance to have a portfolio that can supply certain consumer segments, then we surely will not realize the efficiency enhancing effects of competition. In this transitional period, regulation is in fact a very sensitive balancing with market capabilities, so it is particularly important for the regulator to deeply understand the market's capabilities and to continuously analyze and evaluate the impact of the new rules introduced.

In addition, it is important to mention that not all effects can be seen in advance, not all can be handled in advance. After the introductions following the consultations, issues can still emerge in practice that need to be remedied quickly.

The regulation is therefore a cyclical process, in practice its elements are planning, consultation, implementation, and afterwards evaluation of the effects attained on the

[13] For example in Preambulum (3) and (5).

market. The lessons learned from the evaluation and the answers to them form the basis for the next regulatory cycle.

Analyzing the impact of the rules introduced on the market is also an important part of today's European regulation. One of the main tasks of the Agency for the Cooperation of Energy Regulators (ACER) is market monitoring, conducting impact assessments and evaluation of the implementations of European regulations.[14]

In this capacity, ACER performs two monitoring activities annually. One is a preparation of an annual market monitoring report that evaluates the progress made in the gas market in the given year towards the ultimate goal of the competitive internal gas market. The other task is the monitoring of the transposition of pan-European network codes in the national markets and analyzing the impact of the regulatory instruments introduced. In this relation ACER prepares an annual report per network code, so it also performs a European-level evaluation regarding the implementation of the BAL NC each year.

In addition, BAL NC requires those Member States which opted for a delayed implementation by April 2019 with the use of interim measures, to prepare an annual report on the development and liquidity of the short-term gas market, the interim regulatory instruments planned to be applied and their intended effects (Article 46 of the BAL NC).

The task is therefore given: assess the impact of regulatory instruments on the gas market to determine whether they are helping to achieve the ultimate goal of internal competitive market or not. (I will call this in the following efficiency analysis.) How can this be measured?

Efficiency Analysis

The framework for efficiency analysis is market analysis. Industrial Organizations is the discipline that provides the theoretical bases for market analysis. (Carlton - Perloff, 2000)

[14] „The Agency shall monitor and analyse the implementation of the network codes and the Guidelines adopted by the Commission … and their effect on the harmonisation of applicable rules aimed at facilitating market integration as well as on non-discrimination, effective competition and the efficient functioning of the market, and report to the Commission." Article 9 (1) 715/2009/EC

In case of imperfect markets, the first and still one of the most significant theories that was prepared based on empirical studies to evaluate the efficiency of competition is the Structure-Conduct-Performance, SCP paradigm. According to this, the separate examination of the structure, the behavior of the market players, and the results, and then the examination of how these three relate to each other provides a comprehensive picture about the nature of the competition (Carlton-Perloff, 2000).

Compared to this, in practice, it is often seen that when assessing market competition, the analyzes focus only on the structure: the number of players on the supply and demand side, their market shares, the concentration of the market. The main reason for this is that these indicators can be measured well in an (near) objective way and the data can be relatively easily accessed (Pápai, 2011). Probably this is why we find that in practice regulatory measures are linked to structural thresholds. For example, the general rule of thumb for identifying a dominant player is that above 40% share it is very likely and above 50% share it is considered sure that market dominance is present (Pápai, 2011).

However, this narrow assessment based solely on the market structure is also deficient on the basis of the SCP and can lead to erroneous results. The structure does not clearly show the performance of the market, the result depends on the industry's characteristics and the behavior of the players. Market structure depends on industry technology, institutional frameworks, and consumer preferences. Exactly in the case of network industries, the technological and institutional characteristics result in a small number of actors, so in these sectors, the structural analysis itself would always indicate a competitive problem (e.g. high concentration). It can be seen, therefore, that relying solely on structural indicators we cannot fully reveal the effectiveness of competition, and as Pápai (2011) shows it is easy to make mistakes with the regulatory measures associated with such simplistic descriptive indicators.

Including the analysis of market performance is thus necessary. However, as Kahn (2006), Bender et al. (2011), Shuttleworth (2000), the Austrian school and many others point out its assessment is not nearly as simple and objective as the structural analyses are. As I have just summarized, there is no generally accepted benchmark for evaluating the results, the result of perfect competition, i.e. marginal or average cost-based prices, alone cannot form the basis of regulatory purposes. Effective competition does not have a general theoretical model that can be used for comparing it with the

market results. Prices higher than cost, profit, alone cannot mean that competition is distorted: it may even mean that competition is just doing its job and encouraged a player to innovate and the market just rewarded this player.

The latter also highlights the importance to concentrate on the dynamic process when assessing the quality of competition, no matter whether the structure or the performance is in focus the changes through time should be analyzed.

Finally, the examination of the central element of the triad of the SCP, the behavior of the players and the motivations that can be inferred from them, provide very important information about the nature of the competition. They complement the picture outlined by the structural and performance indicators. During the analysis the task is to search for rivalry. Efficient competition may include, for example, the emergence of new package offers in the natural gas market, high supplier-switching rates, excess demand, and hence regular auctions on valuable network points.

Overall, based on the theory we can conclude that in case of the indicators to be developed for efficiency evaluation we should not stop at the structural indicators, even though they produce a rapid result. In case of performance metrics, it is important to set in advance what we are considering as an ideal result, what is the efficiency we are looking for and what reflects it, for example do the absence of profit or cost-based prices really capture efficiency. Therefore, it is especially important to examine the dynamics of the market, how the indicator values changed over time, whether real, lasting efficiency gains could be seen on the market. The latter leads to the analysis of the behavior of actors, the observation of which is perhaps the most difficult but most compelling of whether competition really did drive the players to improve efficiency.

Below I present the literature on natural gas market regulation and balancing regulation and the literature on market analyzes evaluating the effectiveness of implemented regulations. I also discuss the place of this dissertation in relation to the presented literature.

II.3. Literature review

European gas market regulation is governed by European regulatory institutions. Alongside them – most often at their request, involvement, or to their criticism – the academic sector, consultancy companies and the energy companies and their associations form active discourse about the regulatory issues.

From the academic sphere, five European research centers are important to mention. These are particularly involved with gas market regulation issues, the analysis of the development of the European gas markets and the Internal market. One of them is the Florence School of Regulation (FSR) based at the European University Institute in Florence, their work on the modeling of balancing zone mergers deserves special attention, as well as their synthesizing materials that summarize the results of natural gas market opening. The other is the KU Leuven Energy Institute, located in the Leuven University, which focuses in most detail on the balancing topic and also addresses its technical aspects. The third is the Oxford Institute for Energy Studies (OIES), which performs in depth analyses of the gas markets. The fourth is the Center for Research on Energy and Environmental Economics and Policy (IEFE) at the Bocconi University, Italy, their significant works that will be discussed later focus on the evolution of balancing markets and its relation to the development of the wholesale market. Finally, the fifth is the Regional Centre for Energy Policy Research (REKK), which focuses among others on the special characteristics of the natural gas markets of the Eastern European countries, it is located at the Corvinus University of Budapest. As a former researcher of REKK, I was fortunate to follow closely the development of gas market regulation in this region and to take an active part in the discourse between research centers, industrial players, and regulators.

Among the consultants, the active and often academic-quality work on the natural gas market and specifically on balancing regulation of the KEMA-DNV and NERA international consultancy companies should be given special attention.

Below, in addition to the summary of the materials of the European institutions the most important works of these centers will be presented.

From the aspect of this thesis one of the relevant field of the literature is the analysis of gas markets and within this topic the impact assessment of gas market regulations. The second important field is the literature on balancing regulation. Finally, the third field is the combination of the first two: the studies that analyze the balancing systems, the effectiveness of the regulatory instruments introduced in balancing.

II.3.1. Gas market analyzes

Market power indicators

The regulation of the gas market and the electricity market, as well as the literature about it is often similar, many times coincide. The comprehensive article by Newberry et al. (2005) on how to analyze power markets and detect whether a player has significant market power is also one of the basic literature even in the field of gas market analyzes. Newberry and his colleagues recommend indicators for each of the three elements of the SCP model and analyze in detail how it is meaningful to produce and then interpret the given indicator in the power market environment. The article also includes practical suggestions for setting up a market monitoring system. This article, by adopting indicators that are already well-known in the market analysis literature specifically for the analysis of the electricity market in a meaningful and comprehensive way has had a large impact on the subsequent energy sector analyses. This is also illustrated by the fact that in 2009 the article was republished (Newberry et al., 2009).

Part of the market analysis toolkit proposed by Newberry et al. can be also adapted to the gas market. These indicators are useful and thought-provoking for the efficiency analysis as well, for example, the CEPA (2015) study, which will be discussed later in detail, also uses this article as a source.

Market power is explored in a wider dimension by Kaderják (2014), who developed a so-called "bargaining power" indicator and an associated bargaining power function for analyzing the market power of the Russian party that exports gas to Europe; this

structural indicator shows whether a given supplier has a market power in supplying the country and can thus influence its price or not.

Market maturity indicators

The focus of Newberry and his co-authors beyond the general market analysis was to detect market power. Another common focus of articles on the analysis of gas markets is the analysis of the level of maturity of the markets. These articles – according to my findings – typically simplify the question to a spot market liquidity indicator, and either analyze the evolution of the value of this indicator over time looking at whether there is progress on the given market or perform a cross-sectional comparison of several markets to determine how they relate to each other in terms of maturity. The latter also relates to the assessment of the evolution of the Internal market, providing information on the convergence of the Member States' markets' maturity (and price) towards one common market.

Liquidity in the SCP model can be considered as a performance indicator. It can also be used for efficiency analysis as it well captures the aim of market opening: an efficient competitive market is sure to be a liquid market. It is thus suitable to be used as one of the indicators in efficiency analyses. Therefore, it is worth reviewing how liquidity is measured in the literature on gas market development.

OIES provides the most systematic and comprehensive assessments of the development of the European gas markets' liquidity. They conduct such specifically targeted analyses since 2010. Heather (2012, 2015), for example, prepared comprehensive liquidity analyzes for hubs (marketplaces that emerge on main transit routes). The five indicators examined by her intend to capture the maturity level of the hubs: the number of market participants, the number of products, the trading volume, the trading index (which provides a combined indicator for the spread between bid and offer) and the churn rate (which is the ratio of the traded natural gas and the natural gas physically supplied). This analysis was also carried out by OIES in 2017, and they compared how the values of the indicators changed over time (OIES, 2017b).

Another type of example for measuring the market's maturity level is provided in a study by two former directors of OIES, Jonathan Stern and Howard Rogers (2014). In

this they analyze what factors influence hub prices: still the oil-indexation of long term contracts determines the wholesale gas market prices, or an own pricing of the gas hubs evolved which is determined as a result of natural gas demand and supply fundamentals. The more this latter can be experienced in the prices, the more we can talk about the presence of gas market competition. Stern and Rogers do not create a new indicator, rather they analyze price changes for given periods and link them to changes in the global gas market fundamentals.

It is important to point out that these analyzes and indicators were only conducted for transparent markets and are based on market price indices and trading data. That is, these types of studies do not give any guidance as to how to look at the development of liquidity in emerging markets that are in the beginning of the market opening process and where therefore there is no such transparent market.

Market convergence

One of the possible ways of assessing the convergence of markets, namely the assessment of progress towards a common European Internal market, is the mentioned cross-sectional analysis of European hubs. One of the main research directions of OIES is the in-depth analysis of the correlation between hub and OTC prices, an assessment prepared regularly by Petrovich (2013, 2014, 2015, 2016).

Another direction of analyzing convergence is modeling. Several research centers have developed a Europe-wide gas market model based on Member State level data to analyze, for example, the impact of an infrastructure element (expansion of storage or interconnection capacity or construction of a new one or closing of storage facilities) on the development of the Internal market and the level of the European security of supply or the effect of the applied tariffs at the interconnection points and the effect of other access regulations on cross-border trade and market integration.

One of such models used for this purpose, TIGER, was developed by the Institute of Energy Economics (EWI) at the University of Cologne. Recently it was used in joint research with OIES to investigate whether the occasional disconnections in the hub prices are caused by fundamental reasons, that is, infrastructure settings, or they are

due to inefficient use of the infrastructure, that is to say, they are due to a trade distorting factor or possibly abuse of market power (Hecking et al., 2016).

The other such model was commissioned by the Energy Community and the European Council for analyzing the possible impacts of energy policies. The European Gas Market Model (EGMM) is being continuously developed by REKK since 2010. In the preparation of the first comprehensive study where the EGMM was applied – The role of infrastructure development in the gas market integration, analyzes with the Danube Region Gas Market Model (Kaderják et al., 2013) – I also participated in. Since then, with the continuous development of this model REKK has conducted several analyzes of our region, for the Energy Community Member States, and for the entire European Internal market. The analyzed topics relate mainly to the effect of infrastructure elements and their regulation (e.g. tariffs) on market integration and on security of supply.[15]

These models are suitable for analyzing the development of trade between Member States, for examining market integration. They illustrate how the effects of regulatory policies for the development of the internal gas market can be assessed. Modeling is a performance-based analyzes tool in the SCP categorization. Modeled scenarios give us an idea of what results should come out if competition would be effective and we can compare those with the actual state.

Hungarian efficiency analysis literature

Studies on the effects of the implemented regulatory measures have also been conducted for the Hungarian energy markets. Out of these I will present briefly the articles written by me and my colleagues from REKK.

To predict the impact of the household retail electricity market opening with my colleague, András Tóth, we prepared a modeling for the Hungarian household electricity market (Szolnoki - Tóth, 2008). In 2008 the Hungarian household consumers also became eligible to choose freely among the suppliers. With András Tóth, we created a theoretical model for the Hungarian three-player power supply oligopoly market where the heterogeneity of residential consumers was represented by

[15] See for example: REKK et al., (2013), REKK (2014), REKK (2016)

a switching function. For the expected result of the three market players' competition for household customers we calculated a so-called ’undercut-proof’ equilibrium. According to the modeling results if price regulation would have been completely abolished on the household market, i.e. if the option for household consumers to choose regulated priced universal service would have been withdrawn, then due to the switching costs and the low level of contestability of the market a significant increase would have occurred in the prices.[16] Our analysis thus showed that the competition in power markets at that time was not sufficiently intensive enough to allow that the ex-ante price control be completely phased out for the household consumer group, the fully competing electricity market has not yet evolved.

In case of the natural gas markets an example for an analysis about the impact of source-freeing regulatory measures implemented in the early years of market opening is the impact assessment we conducted with my colleagues at REKK for the Competition Culture Center of the Hungarian Competition Authority on gas and contract release programs which were prescribed as a condition for authorizing the MOL-E.ON transaction by the European Directorate-General for Competition (Szolnoki et al., 2008a). In this article we analyzed the development of the natural gas market in the early years of market opening, we evaluated the structural changes, and examined the impact of the gas- and contract release programs on this market. This analysis contained qualitative and quantitative elements, the quantitative indicators were mainly structural indicators related to the players and the liberalized consumer group and to the analysis of prices. The study found that the programs had a vitalizing effect on competition between the suppliers, but this was largely the result of the positive turnaround in the international gas market processes, which made it possible to import natural gas from Western Europe for a price that is comparable with the Russian import.

An example for flexibility market analysis – that will also be discussed later in this dissertation – is the assessment of the Hungarian storage market competition which I prepared also with my colleagues in REKK (Szolnoki et al., 2008b). In this paper we defined the supply side of the Hungarian natural gas flexibility market, we calculated the shares of the different flexibility instruments by different owners and according to

[16] Our article was published in Verseny és szabályozás 2008 and we also presented it at the Spring Meeting of Young Economists Conference.

different scenarios, and we assessed the concentration of the market by the HHI index. We used the structural analysis of the supply side of the flexibility market to assess whether the flexibility market was sufficiently competitive in order to enable the regulator to allow that the access tariff for storage be determined under the storage owner's discretion instead of being set as a regulated tariff (negotiated vs. regulated access).

As it can be seen, in the begining we also were mainly relying on structural indicators to determine the level of competition on the market.

An example of an assessment of an infrastructural investment created by a new regulation is my cost-benefit analysis made regarding the Hungarian strategic storage facility. (Szolnoki, 2011) In this article I calculated cost curves for the losses and natural gas consumption curtailment probabilities and curtailed quantities. This quantitative analysis aimed at assessing the utility of security of supply provided by a storage facility that is also a player on the flexibility market. Security of supply is another important focus of natural gas market regulation. The dissertation does not cover this wide-ranging topic, but it has to be mentioned that of the balancing task the provision of security of supply is an inherent part.

To sum up, the analyses of the effects of natural gas market regulations are wide-ranging, both the applied methodologies and the analyzed regulatory instruments can be very diverse. The studies described above focused on the gas market, while the problem of balancing was not analyzed at all or only very indirectly. These were considered to be relevant literature for this dissertation because they illustrated what kind of indicators and analytical tools are used by researchers to analyze efficiency and development and convergence on the gas markets. In case of the balancing segment, the same type of efficiency analysis is the task just now it is focused on one special part of the natural gas market instead of the entire market. Thus, the tools presented above provide a good basis for the analysis of balancing as well.

Below I summarize the literature on balancing.

II.3.2. Studies prepared by industry players and academic articles related to balancing regulation

In the beginning of the European gas market opening balancing did not receive any special attention. In the European legislation only general principles were laid down regarding the operation of the balancing system, it was considered as just one of the elements of the network access regime. Until the appearance of the Third package[17] in 2009, balancing was mostly handled as a physical problem in most of the Member States, there was administrative settlement where settlement prices were not determined on a market basis.

Regulatory proposals

Later, experiences of market opening started to attract attention to the importance of well-designed balancing regimes. First, the Council of European Energy Regulators (CEER) and then the European Regulators Group for Electricity and Gas (ERGEG) published guidelines on how it would be worthwhile to set up a balancing regime that supports the European gas market objectives (CEER, 2003) (ERGEG, 2006). The industry side – mainly the organization of the TSOs the Gas Transmission Europe (GTE, 2001, 2005) and the traders, the European Federation of Energy Traders (EFET) – also started to work on proposals that reflected their positions.

In addition to this, consultant companies (e.g., Brattle group, 2002, Nera - TPA Solutions, 2005) also prepared papers on the request of European organizations, which mapped the highly heterogeneous balancing regulatory regimes in the Member States and proposed proposals for balancing regulatory setups that promote market competition and the development of the Internal market and also suggested which areas should be harmonized. Consultancy materials prepared for the European

[17] The elements of the third EU regulatory package for the natural gas market:2009/73/EC, 713/2009/EC, and 715/2009/EC

authorities synthesized the developed discourse and formulated the possible options for the next regulatory steps.

The comprehensive – one-and-a-half year long – Sectoral Inquiry conducted by the European Commission's Directorate-General for Competition, is of outstanding importance in the European balancing regulation. Its summarizing report (ECDGC, 2007) declared balancing as a priority area, detailly listed the present shortcomings and formulated new regulatory proposals for the area. These proposals formed the basis of the comprehensive balancing regulation laid down in the BAL NC – prescribed by the 2009 Third package – published in March 2014, which forms the main subject of the present dissertation.

The announcement of the results of the Sectoral Inquiry and the proposals based on it was followed by an active discourse between the industry organizations, the regulatory authority, the academy, and the consultants. The European Commission's Directorate-General for Energy (DG TREN) announced a consultancy tender for a comprehensive examination of the Member States' gas transmission tariff systems and balancing regimes, the tender was awarded to the consortium of KEMA and REKK (KEMA - REKK, 2009). In addition to creating a comprehensive overview those differences had to be identified in the national regulations of transmission tariffs and balancing that were most obstructing the development of the Internal market, i.e. those regulatory items that the harmonization of which is of paramount importance. I also participated in this research from the part of REKK. The results about the balancing regimes of this study were consistent with the direction outlined by the Sector Inquiry: the size of the balancing zones should be increased by merging the current zones, the system operator's residual balancing activity and the accompanying imbalance settlement process should be placed on market basis as much as possible, and the TSO procurement should be conducted by the buying and selling of short term standard products. (KEMA - REKK, 2009)

Attention should also be paid from this period to a comprehensive study ordered by DG TREN conducted by KEMA and COWI (2013) on the Entry-Exit Transmission Systems of the European Member States.[18] Here, similarly, the main question was how the national Entry-Exit systems inhibit new entrants and cross-border trade. In

[18] The Entry-Exit system is discussed in detail in Appendix III.

addition, three case studies have been carried out on the merging of balancing zones. Many of the findings of the study, such as the need to establish a virtual point in an E-E system, the restrictiveness of the requirement that nominations should be in balance[19], the inadequacy of current information provision, and the importance of non-discriminatory settlement rules later have been all incorporated into BAL NC.

The publishing of BAL NC has given a big boost to thinking about the assessment of the effectiveness of balancing rules. The Third package requires that the European organizations established by it, ACER and the European Network of Transmission System Operators for Gas (ENTSOG), regularly evaluate the implementation and effectiveness of pan-European network codes (NCs). ACER hired an external consultant to lay down the theoretical foundation of this efficiency analysis and determine the range of analytical tools to be used. The comprehensive work of the Cambridge Economic Policy Associates (CEPA) consultant was completed by October 2015 (CEPA, 2015), comprising the recommended indicators to be used per NCs, including the ones for the BAL NC implementation evaluation.

The CEPA study is a major step forward in starting to think about developing indicators for evaluating the balancing systems that can be applied universally to all Member States' systems. However, the indicators presented in the paper are only theoretically defined indicators, their practical application was not performed by CEPA.

These consultant studies and the materials of industry organizations were based not only on practical experiences but also on proposals from the academic sector. However, it is important to note that although balancing is increasingly recognized by the industry as one of the key points to the operation of the gas market and the success of market opening, as Keyaerts (2012) points out, there are relatively few academic articles on this subject.

[19] See point III.2.1.

Academic articles on balancing

In the beginning, one of the widely discussed areas was the choice between the network access models. (As I show it in Appendix III. the network access model is one of the determinative elements of the wider operative framework of balancing.) At the time of market opening the Member States showed a heterogeneous picture in this area. As the discourse developed, the opinions began to converge towards the Entry-Exit system. The advantages and disadvantages of the Entry-Exit system were summarized in detail by Paul Hunt (2008) of OIES. Finally, the Third energy package made the Entry-Exit system mandatory for all Member States, so the wider framework of balancing became harmonized around the EU.

The article of the Energy Institute's colleagues at Leuven University (Meeus et al., 2008) summarized – for the first time – at an academic level the framework and elements of the balancing regime. They distinguished between physical and commercial balancing and paid a special attention to linepack-flexibility a very important but often neglected part of balancing. This study has thus synthesized the knowledge and view that emerged during the discussions between the industry players, regulatory organizations, and consultant companies on the balancing regime. In this dissertation, similarly to the paper of Meus et al. (2018) I prepare a synthesis on the balancing regulatory system also including the lessons learned from the period since the Meeus et al study's publication and thus create a much more detailed discussion of it including the set of regulatory instruments and their possible variants, and also discussing which regulatory instrument variants are suitable for which development phase.

A former associate of the University of Leuven, Nico Keyaerts, currently a researcher at the FSR, has contributed in several ways to understanding the effects of the choices between the elements of the balancing regime. With his colleague, by simulating shippers' decisions he analyzed the market implications of the different lengths of the balancing period (the time interval within which shippers must balance their inputs and offtakes). Their article illustrates the potential distortions in case interconnected systems of neighboring countries apply a different balancing period (Keyaerts - D'Haeseleer, 2014). The practical relevance of this article is significant. For example, Hungary and Austria apply a different balancing period: in Austria, hourly settlement

is applied while in Hungary there is a daily system. In the European regulatory discourse, the harmonization of the balancing period and whether there is a common optimum interval for everyone has long been a matter. For the time being, BAL NC's consensus is that daily settlement is mandatory in the Member States, but additional rules within the day can be introduced as well.

The intent for merging balancing zones has already been formulated as a conclusion of the Sectoral Inquiry. However, merging the zones is not just an administrative task, the merger can be done in several ways. The academic level review of the various possible modes was performed by the colleagues of FSR and their director Jean-Michel Glachant (Glachant et al., 2013).

The problem of the lack of regulatory focus on linepack-flexibility in balancing and the problem of its differing regulations between countries was also summarized by Keyaerts and FSR researchers (Keyaerts et al., 2011). They illustrated the cases with hypothetical examples.

Mulder and Van Dinther's (2013) article on the evaluation of the performance of the newly introduced Dutch market-based balancing system provides an example for an impact assessment of a particular balancing system. They performed a cost-benefit analysis using the balancing reserve and balancing platform offers and based on their results suggested changes to the system.

The pivotal role of the balancing regime in the success of gas market opening was explicitly diagnosed by Creti and Pontoni (2016) as a conclusion of their summary of recent articles. The most important articles on this subject and from the point of view of the dissertation were those written by the researchers of IEFE at Bocconi University. Leen Dickx, Caterina Miriello and Michele Polo (2014) formulated an analytical framework to demonstrate how the balancing problem is changing with market opening, they defined Aggregate Imbalance and Internal Adjustment the latter reflecting the part of balancing requirement that can be resolved by the trading between balancing parties, i.e. a purely commercial balancing requirement. In addition, they incorporated into one single framework the development phases of the gas market. In their frame, the first form of the wholesale market is the market-based balancing, i.e. the balancing system functions as a hatchery for the wholesale market. From this develops a wholesale market that becomes more and more a hub that can serve shippers

as a procurement source in managing their portfolios. With the further increase of the level of liquidity the hub becomes increasingly capable to assist shippers in covering their risks as well and financial products emerge. In this article, after the presentation of the theoretical model, the authors have analyzed the liquidity of today's advanced Western European hubs with similar indicators as the OIES articles already outlined. The first balancing phase was only described in textual summaries, no quantitative assessment was made. The Aggregate Imbalance and Internal Adjustment breakdown of the balancing requirement presented in their model were not transposed into indicators that can be used in market analysis and they did not conduct such analysis on actual data.

The further development of this article is an extraordinary study by Miriello and Polo (2015) in which the authors with the help of the theoretical model of the Dickx et al (2014) article show, that even if only a small proportion of the Internal Adjustment needs are traded on the transparent platform, in most cases, the formed market price may be a fundamental price signal, i.e. market-based balancing can really be a hatchery for the wholesale market. Another important finding of the article is that although based on this result in most Member States a balancing-based wholesale hub can be set up where the price reflects the fundamentals well, but financial markets will not emerge in every case. This is due to the economies of scale of financial markets.

Background

Inspired by the articles of the IEFE researchers in May 2017 I applied for the Regulatory Research Award competition announced by ERRA. In my study, I used the Aggregate Imbalance and Internal Adjustment division of balancing requirement defined by Dickx et al (2014) to define indicators that can be used to perform efficiency analysis of regulatory instruments on those markets where the market-based balancing design is just being implemented. I wanted to analyze whether the theoretically expected positive effect of these regulatory measures can be detected or not.

I have not found such an efficiency analysis in the earlier works. As can be seen from the literature review, the articles only analyzed the data of mature markets (hubs) even in cases when the balancing systems were in focus. But the introduction of the market-based balancing rules prescribed by BAL NC is not affecting significantly such mature

markets. My question was therefore, that in markets where the introduction of BAL NC is a major challenge – on immature markets – and thus where there is still no transparent marketplace how to analyze market efficiency and the efficiency of the balancing system.

The CEPA indicators did not provide a solution for this problem either because they are based on data that is not publicly available, and what more, the collection of the defined data need is also causing a challenge for European organizations (while some of these data are simply unavailable). For this reason, I defined new types of indicators and I presented the practical application of my indicators on the Croatian natural gas market data. My analysis has shown by the indicators I have defined that the balancing rules introduced in Croatia have had a positive impact on both the efficiency of the balancing system and the efficiency of the wholesale market.

With my article I won the first prize in the ERRA competition

Later in 2017, in June ENTSOG and then in November ACER released their Second BAL NC monitoring reports. (ACER, 2017; ENTSOG, 2017) These, for the first time contained some balancing system analyzes for different Member States. I provide a detailed review of the reports in Chapter IV. the methodological chapter. Despite the significant advances, the main weaknesses of these analyzes – in my opinion – are that these indicators were defined along one-one part of the BAL NC requirements and not from a general balancing system efficiency definition. Because of this, they do not provide a comprehensive view of the system and the interpretation of the indices' values are cumbersome.

In addition, the indicators used are largely based on data only available to ACER and ENTSOG, not publicly available, so others, such as the academic sector cannot analyze them. Furthermore, important indicators, such as the total balancing requirement, are missing even from these reports because of their complicated data need. Finally, to my opinion it is a significant constraint of these analyzes that they are carried out only for a one-year-interval, and only for the period after the introduction of the BAL NC, this way these are not capable to reflect the effects of the introduction of BAL NC.

II.3.3. The place of the dissertation in the academic literature

The dissertation synthesizes and extends the previously presented literature on natural gas balancing in two main directions:

On the one hand, in the topic of **balancing regulation**, I summarize the basic problem of balancing and its regulation, I provide a comprehensive overview of the regulatory instruments and on the case of the evolution of the European balancing regulation I show the practical implementation of balancing regulations. The main contribution of this part to the literature is a comprehensive systematization of the regulatory toolkit, and as a summary of this, I outline a possible balancing regulatory development path, what regulatory instruments can be used to govern the natural gas market from the vertically integrated one-company sector to the fully market-based balancing system and competitive wholesale market. This part of the dissertation can be considered as a more detailed and comprehensive elaboration of the topic of the synthetizing article written by Meeus and his colleagues (2008), the dissertation also extends it with the alignment of regulatory tools to the different market development stages.

The other part of the thesis complements the literature on the **efficiency analysis of balancing regulation**. This part elaborates my article written for the ERRA award competition. Its aim is to set up a comprehensive methodology for the evaluation of the efficiency of balancing systems for markets of any type of maturity, thus to extend the existing literature, where the defined indicators only reflect parts of the system and mostly only analyze mature markets. To establish this, I create a definition of the efficient balancing system by elaborating on the theoretical framework of Dickx et al (2014). Based on this definition I identify the areas to be analyzed and I also develop indicators that are able to measure the efficiency of the balancing systems also in those countries that do not yet have a mature wholesale market yet. By the theoretical grounding the evaluation of the indicator values become more established, more robust, and the analysis framework provides a more comprehensive picture of the efficiency of balancing systems. My dissertation is also a step forward in the sense that it contains not only the formulas of the indices but also their practical adaptation on market data on several-year-long time series. The methodology provides indicators

that can be calculated from publicly available data, thus making it more usable than those of the previously presented literature.

III. THE BALANCING SYSTEM AND ITS REGULATION

The purpose of this chapter is to provide a comprehensive overview of the balancing problem and its regulatory issues, as well as to provide a description of the balancing regulation toolkit and a summary of the implementation of balancing regulation in practice in Europe.

In the followings, after the presentation of the balancing problem along its main dimensions, I outline the framework of balancing and the elements of the balancing system within it. I show what are the main parts of balancing regulation and the alternatives within those parts and how the different alternatives can affect the operation of the system. This way I outline a regulatory toolkit, from which the alternatives of the different parts have to be selected in such a way that it fits the current development level of the gas market and the balancing system while in the same time it also induces the further development of these.

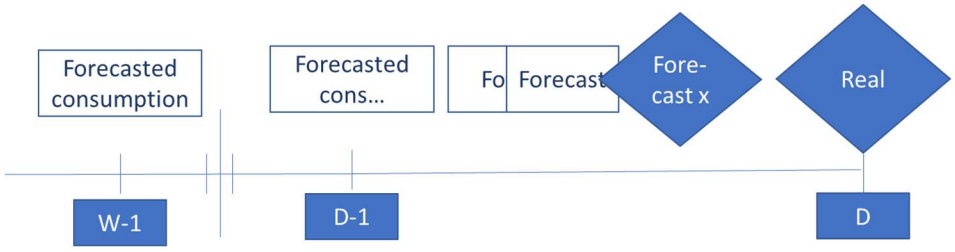
After the description of the regulatory instruments, I will present how balancing regulation is implemented in practice using the case of the European balancing regulation. The present state of this is the BAL NC, its efficiency assessment is laid down in the next chapter and forms the other main theme of this dissertation.

Balancing is the central element of the gas market. To understand its role in the natural gas market, **it is necessary to know the setup of the supply chain of the gas market, the regulatory issues surrounding the structure of the sector, and the flexibility segment of the gas market**. Since these areas are not the main subject of the dissertation, however, the knowledge of the concepts is necessary to understand the balancing problem, therefore all **these topics are presented in detail in Appendix I. and II**. In the following discussion I presume the knowledge of these topics.

III.1. The balancing problem

Natural gas consumption fluctuates considerably: it fluctuates annually, quarterly, monthly, daily, and even within a day. In addition, one of the key features of natural gas is that its consumption – especially among small consumers – cannot be controlled in real time individually only at a larger consumer group level and only for emergency situations. That is, in real time the consumer consumes how she likes, the gas comes from the pipeline, in addition her consumption is stochastic, it cannot be estimated perfectly in advance. This kind of consumption has to be predicted by the supplier and be covered by sources. As the time of consumption approaches, these predictions are becoming more accurate as more and more factors become known about the conditions of consumption. The supplier consequently tends to fine-tune her portfolio to cover the expected consumption: in the short term, she buys and sells natural gas on the wholesale market or uses other flexibility services (such as storage). Both, under- and over-planning is costly for the supplier, as it has to settle the realized imbalances with the system operator. This is the commercial side of the balancing task.

Figure 2: The commercial side of the balancing problem



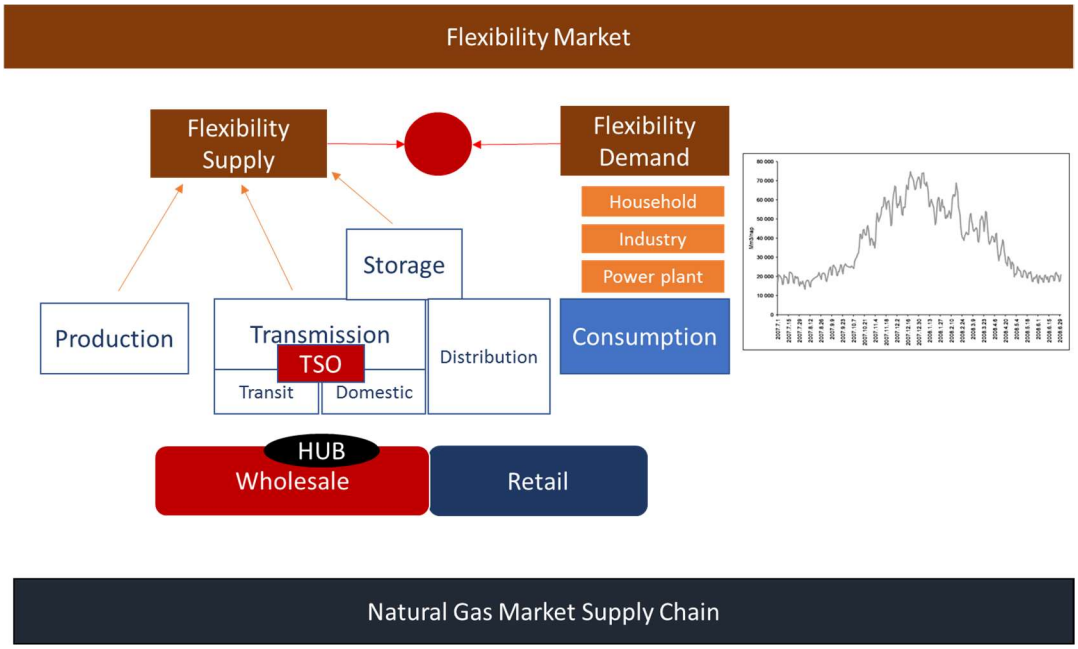
Source: Own figure; where D: the day of physical delivery, D-1: the day previous the physical delivery,
W-1: the week preceding the physical delivery

Another important feature of the gas sector is the pipeline network necessary for the transportation of gas and the related task of system balancing. The transmission network forms the physical backbone of the gas market. It delivers the sources to the large consumers and to the low-pressure pipeline systems for small consumers (distribution network). Basically, transport activity means controlling the pressure in the pipeline system, operating with pressure differences. The transmission system

operator's task is to control the pressure in the pipeline system, to keep it within the limits of safe operation.[20] Physical imbalances affect the pressure level. When more natural gas is injected into the system than it is withdrawn, the pressure increases and accordingly when more is withdrawn than injected, the pressure drops. Balancing the system, i.e. balancing inputs and offtakes, is always necessary to maintain network integrity. The physical side of balancing is therefore the safe management of changes in the consumption and supply of natural gas in the short term at system level.

To supply the fluctuating consumption and to keep the system in balance, the need for flexibility arises practically over the entire supply chain. Short-term flexibility tools are needed to cover daily and within-day consumption changes. The broader framework for balancing is the short-term flexibility market which is comprised of the short-term flexibility need of natural gas supply and the supply of the tools capable of providing such flexibility service. The following figure shows a simplified summary of the relation of the supply chain and the flexibility market. A detailed description of the flexibility market is given in Appendix II.

Figure 3: The relationship between the natural gas market supply chain and the flexibility market



Source: Own figure

[20] For a description of the Hungarian transmission system's operation and the task of the system operator, see, for example, the dissertation of János Zsuga PhD who was the head of the Hungarian TSO for a long time (Zsuga, 2002).

In the short-term flexibility market demand is mainly due to the (temperature dependent) fluctuations in household consumption and the fluctuating power market driven power plant consumption, while unexpected losses may also occur, which also result in a need for flexibility.

On the supply side, depending on the endowments of the system a variety of combinations of the infrastructural elements – storage, production, LNG, import, transmission pipeline – could provide for supplying the flexibility need. Besides the physical capabilities, contractual conditions also affect the supply of flexibility.

Below, I elaborate more on the balancing problem embedded in this flexibility market.

III.1.1. Main dimensions of the balancing problem

The TSO's balancing task

Natural gas transmission – to put it plainly – is formed of pipeline systems and compressor stations. With the management of these, natural gas can be transported, and also temporarily stored – which is an especially important aspect for this dissertation.

The linepack is the sum of natural gas present in the pipeline system. For transportation it is necessary that some quantity of natural gas is always in the pipeline system, i.e. there is a minimum mandatory level for the linepack. Natural gas can be compressed, in the same volumetric capacity by increasing the pressure more natural gas can be 'stored'. Imbalances in natural gas inputs and offtakes change the pressure and thereby change the 'stored' amount of natural gas, that is, the amount of linepack in the pipeline system. As Keyaerts (2012) points out, it is important to distinguish between linepack and linepack-flexibility. Linepack-flexibility is the part of linepack that can flexibly be increased or decreased while keeping the operating pressure within the safe minimum and maximum levels.

The equation of system equilibrium, taking into account linepack-flexibility:

$$\dot{m}_{in} - \dot{m}_{off} = \frac{\partial(\rho V_{geo})_{store}}{\partial t}$$

where $\dot{m}_{in}$ is injection, $\dot{m}_{off}$ is offtake, V_{geo} is the volume of the pipeline (m^3), ρ is the density of gas (kg/m^3) Source: Keyaerts, 2012, p. 18.

Thus, within a given period, the balance of the inputs and offtakes of natural gas is equal to the change in the natural gas mass stored in the pipeline, i.e. with the change of linepack, that is linepack-flexibility. This equation shows well that with linepack-flexibility, balancing natural gas inputs and offtakes becomes an intertemporal problem (Keyaerts, 2012). (Unlike in the case of electricity), there is no need for an all-time equilibrium of inputs and offtakes, the two can differ to the extent of the linepack-flexibility, and it is only necessary to maintain balance in the system throughout a longer period of time. The task of the system operator is to keep the system in balance. For this it primarily uses linepack-flexibility and when the imbalance is so large that it cannot be safely handled with linepack-flexibility, it also applies external physical flexibility resources. (e.g.: Meeus et al., 2008)

This system balancing supervised and performed by the system operator – maintaining system integrity – is a real-time physical balancing activity. Compared to this, as I show below, shippers are doing an ex ante commercial balancing activity and then – ex-post – settle their imbalances with the system operator also on a commercial basis.

Balancing task of the traders

In a liberalized natural gas market traders are the main actors. They conclude supply contracts with consumers and then contract sources for the fulfillment of these supply needs, in addition to physically transport these sources to the consumers they contract for transport services with the transmission system operator and (in case smaller consumers are also supplied) with the distribution system operator. To align the fluctuating consumption with the inflexible sources, the trader also needs to contract flexibility services. These can be classified into two groups. Ex-ante, the trader may buy a storage service, a specific wholesale flexibility contract or obtain flexibility

simply by trading on the spot market. If it fails to balance itself before real time, the system operator, besides performing the physical balancing of the system also provides a balancing service to the individual system users, which can be considered as an ex post balancing, the imbalance settlement between the system operator and the trader is done after the gas day.

It is important to distinguish the predictable flexibility need from the unexpected balancing requirement. Traders make predictions on the expected consumption of their consumer portfolio on a daily basis. Based on their best estimate, if they are sufficiently motivated to be in balance, they put together a supply portfolio to cover the estimated consumption, which may already include flexibility tools, e.g. storage injection/withdrawal. After that, real-time consumption may be different from the planned, because at the end of the network, the consumer is not limited in her consumption and therefore consumes as much or as few as she wants, and not the amount the trader planned.

(This uncontrolled demand differentiates the gas and electricity market from the market for simpler products. Among others this is why a system operator, a central (monopoly) coordinator is needed on the gas and power markets who due to the uncertainty of consumption must coordinate the imbalances (Stoft, 2002).

The balancing task originates from the part of final consumption that was unpredicted by traders. It can be resolved also by the flexibility tools. If regulation provides the trader the possibility to adjust her portfolio near the real-time, the trader, based on her improving consumption forecast upgrades (for example as getting close to real time she knows better the pertaining temperature and thus can better predict the natural gas consumption) can refine ex-ante her portfolio and thus can reduce the balancing need before real time. As a result, the remained balancing task to the TSO is also reduced and the ex post balancing settlement volume between the trader and the TSO also decreases.

With this, we arrived at the next important dimension, the division of responsibilities between the parties.

Division of responsibilities

The division of responsibilities between the traders and the system operator in resolving the imbalance can happen in a variety of ways. The division weights depend on two things. On the one hand, the rule on within what interval the trader is required to balance her inputs and offtakes (balancing period), and on the other hand, on how close to real time the trader is enabled to adjust her portfolio to balance it.

These two very important regulatory elements will be explained in detail in the next section and in Appendix III; in this point I would just like to point out that the division of balancing responsibilities can be very different and depends mostly on the timing rules. If, for example, a trader only has to balance the amount of natural gas injected and withdrawn from the system by her at a monthly level, the day-to-day balancing is entirely left on the TSO. In comparison, in a system with a one-hour balancing period, traders are required to balance their inputs and offtakes at an hourly level, so the system operator 'only' needs to intervene in case of serious system problems within the hours.

Similarly, if traders can adjust their portfolios only until noon day ahead, any change in consumption that was not known until that time but was known afterwards is already left for the TSO to balance. Compared to that, if adjustment for traders is possible until night day ahead or even within-day, the trader can handle these new developments with her own contracted flexibility tools ex ante and thus less remains on the system operator.

Commercial and residual balancing

The system operator is responsible for keeping the entire system in balance. Before the market was opened, the whole system was in one hand, so balancing the system and balancing the one commercial portfolio coincided. With the opening of the market, with the introduction of market competition between many traders, supply became fragmented into smaller portfolios. The system's imbalance is the resultant of the imbalances in these portfolios. This is why the task of the TSO is called residual balancing in the European regulatory discourse. The imbalances of traders' portfolios can balance each other, the system's imbalance is smaller than the sum of the (absolute value of) imbalances.

That is why commercial balance and physical (residual) balance are distinct. Commercial balancing provides incentives for traders to be in balance. Traders are ex post settling their imbalances with the system operator at their portfolio level. It can occur that while the system operator sells to one trader in the same time it buys from another in this ex post settlement process, even though these two imbalances would have been canceled out to the extent of the smaller size imbalance and only the residual imbalance could actually have occurred physically. During physical balancing, this residual imbalance of the system is solved by the TSO. Depending on the regulation of commercial and residual balancing, the two may abut in the imbalance settlement price setting. European regulation for example imposes that the imbalance settlement price should reflect the cost of residual balancing.

The analysis of the relationship between commercial and residual imbalances reveals the effectiveness of the regulatory elements. In Chapter IV. when discussing the methodology for efficiency analysis of balancing regulation I will discuss this in more detail.

Above, I discussed the main dimensions of the balancing problem. It became apparent that the balancing task before market opening, when a single vertically integrated player had fulfilled all the functions of the supply chain, was merely a physical balancing of the system, however with the opening of the market the balancing task became a multi-player coordination problem. The division of tasks and responsibilities is outlined in the balancing regime, a multifaceted, complex set of rules.

Figure 4: Balancing becomes a complex coordination problem

Source: Own figure

III.2. The balancing regulatory regime

Below, I discuss the elements of the balancing regulatory regime. As I have shown, in the literature there are only a few academic articles on the balancing regulatory tools, Meeus et al. (2008) is the main one. Instead of the physical and commercial balancing division they use in their description, I discuss the set of regulatory tools in a three-pillar frame that reflects the timeliness of the balancing activity. This structure is closer to mapping the traders' and system operators' daily operational processes and as such – in my opinion – it supports more the analysis of their behavior. The first ACER report on monitoring the BAL NC implementations (ACER, 2016) also used a similar structure to examine the balancing market regulation in the Member States.

Within each pillar, by summarizing the literature (academic, consultancy and regulatory materials), I discuss the regulatory tools and their possible variants and their expected impact.

Appendix III is an important complementary of this section, it describes the wider framework of the operation of the balancing system: the network access model, the balancing zone, and the balancing period. In Appendix III I also discuss the possible alternatives of these and the consequences of choosing between them. The following description of the regulatory elements presumes the knowledge of these.

Below, I discuss the elements of the balancing system along the three pillars, reflecting the balancing activities' timeliness. This way the decision-making situations of the players are more visible, and it also **provides a good basis for** the later examination of their behavior, for example, in **defining the indicators in the methodological chapters** of this dissertation.

The first pillar of the three pillars includes the tools that affect traders' ex ante balancing activities, the second pillar contains the regulatory tools regarding the real-time balancing conducted by the system operator and the third pillar covers the elements of the ex post imbalance settlement between the system operator and the traders.

III.2.1. Regulatory tools that affect traders' ex ante balancing

The extent to which traders are involved in balancing, how well they are able to balance themselves before real time, depends on how close to real time traders are enabled to adjust their own portfolios. This depends on the nomination and re-nomination rules, what kind of information they have about their portfolio's consumption and the balance of the system, and finally, the ex-ante balancing ability of traders is influenced by the availability of flexibility tools and trading opportunities. Below I will discuss these.

Nomination, re-nomination[21]

In practice, traders use the transmission network through the delivery instructions they give to the system operator. This delivery scheduling is called the nomination procedure. During nomination, the trader tells the TSO, (usually) by hour, what input and offtake plans/orders she has on the Entry-Exit points of the system for the given gas day. At an Entry-Exit point it is only possible to nominate up to the amount of capacity that was previously booked by the trader, so that the trader at the point can only deliver (to the extent) of the capacity right the trader has based on the preceding capacity bookings. Nomination for a gas day in an hourly breakdown is the most common, but on less developed markets monthly nomination with daily brake down is also apparent.

The nominations thus represent the gas flow planned by the traders. The aggregation of nominations shows the system operator what gas flow is expected per Entry-Exit point. The system operator verifies these plans after a hydraulic analysis. If it considers it physically safe for the system, it confirms the nominations of the traders. However, if based on the hydraulic analysis, the given flow plans are unsafe, the TSO sends this information back to the trader and asks for re-nomination. Prior to confirming

[21] The rules on nomination and re-nomination are contained in the transmission network codes (NC). In this section I summarize the general rules of nomination and re-nomination based on my experiances in the previous years studying different national NCs, for example the Hungarian NC (Szabályzati Bizottság, 2017) and its previous versions.

nominations, the system operator also consults with the concerned system operators (storage, production, neighboring TSO), and compare the nominations with them. This process is called matching.

The nomination process has a first deadline, typically around the middle of the day before the gas day. Prior to standardization, in the European countries the nomination deadlines for example were varying between 12:00 and 16:00 p.m. day ahead (ECDGC, 2007). This nomination is the trader's next-day delivery plan. It sums up the trader's forecast of the expected consumptions on the different consumption Exit points within her portfolio and shows what sources the trader contracted for the supply of this consumption (Entry nominations). This nomination is therefore the 'best' estimate for the delivery based on the knowledge available day ahead. In many countries, it is still the element of balancing regulation that this nomination must be in balance. That is, the sum of planned inputs and offtakes must be equal in the balancing period (on a gas day or per hour in case of an hourly system). This rule requires that the trader should not plan imbalance beforehand, she is obliged to strive for a balanced portfolio.

The TSO evaluates the nominations and confirms those by the deadline (which is up to 2 hours after the receipt of the nomination in the harmonized European rules – BAL NC) to the traders. Subsequently, the nomination can be modified through the so-called renomination process. Renomination is a very important opportunity for traders. By renomination, new information about expected consumption (such as weather changes, unexpected outages, etc.) can be incorporated into the delivery plan and can therefore be balanced by the trader before real time. If there is no renomination option, then although the trader has updated information on her consumption after the nomination deadline she cannot adjust her portfolio and has to accept that this new imbalance is eventually handled by the TSO and she has to settle it through the ex-post imbalance settlement system, while if there is renomination possibility she would solve it ex-ante. The latter is more advantageous for both traders and the system.

Initially, the renomination possibility was very restricted in the European countries.[22] On the one hand, in many countries renomination was only possible until midnight the day ahead, and on the other hand in many cases the renomination was restricted by

[22] In Hungary, for example the within-day nomination possibility without restrictions was introduces by 1 October 2015 as one of the steps of compliance with BAL NC. Earlier, only on the system operator's request was possible to renominate within day. The relevant NC: Szabályzati Bizottság (2015)

quantitative limits, for example, the renominated value could only deviate from the original nomination by a small percentage. These restrictions in the case of interconnection points have now been abolished by BAL NC[23] in all European Member States (only Bulgaria applies still a quantitative limit for renomination, ACER (2017)) and the renomination system has become so flexible that even within day traders can submit renominations regarding gas flows up to three hours before real time.

As this system provides significant room for ex ante balancing, by BAL NC the European regulation has now phased out the balanced nomination requirement.[24] The reason of this amendment is that if a trader knows she cannot be in balance, she does not have to submit balanced values which would mislead the system operator. It is not the requirement of balanced nomination that motivates traders to be in balance, but the ex-post settlement system, so with a well-designed imbalance settlement system the balanced nomination requirement is only an information loss.

It is also important to note that the introduction of renomination opportunities goes together with the acceleration of TSO's renomination-confirmation deadlines.

Thus, renomination gives traders the opportunity to correct their portfolios. For this to really happen and so the ex-ante balancing become effective – so that traders are increasingly involved in balancing and by this reduce the balancing task of the TSO – two more things are needed for the traders:

- Regular and up-to-date information on the balance of the system and their own portfolio.
- Accessibility of short-term flexibility instruments, for example through liquid short-term markets, storage capacity bookings, access to cross-border points.

Information provision

After nomination traders can receive new information about their portfolio's expected consumption either from their own consumers or from their internal forecasting

[23] Chapter IV of BAL NC.
[24] Chapter V of BAL NC.

systems. Since after the gas day they settle their imbalance with the system operator, therefore for them it is a key information in ex ante balancing how the system operator sees their portfolio's balance. Furthermore, to see the relationship between the market and the trader's portfolio, information on the entire system is also supporting traders.

Therefore, besides introducing the renomination opportunities, it is also important to provide as frequently updated information as possible to the traders so that they perform the ex-ante balancing right, in the interest of the system as much as possible.

In Europe, the information provision of TSOs has greatly been unified by BAL NC.[25] Briefly summarizing the European system:

- TSOs send to traders the pre-allocated values, part of which are based on forecasts, once the day preceding the delivery (day ahead: D-1 day), and then the updated values are sent to the traders twice within-day (D day), this way providing them the opportunity for even within-day correction. The ex post allocation values – which form the basis of the settlement – are received by system users on the day after the gas day (D + 1), which is usually followed by a month-end correction, that already includes corrections of measurement errors and new measurement data received on less frequently measured consumers.

Allocation[26]

The system operator sends information about the allocated values. This allocated value is the basis of imbalance settlement. The allocated quantity is the officially certified injection and offtake volume. There is a need for allocation mostly because only a few of the consumption points is remotely metered on hourly basis. For household customers, for example, in most countries, there is only one annual reading. Thus, for many consumers their daily/hourly consumption which is needed for the daily/hourly settlement, is estimated with approximating procedures, using the so-called profiles. The methodology for establishing certified allocation quantities on the other hand is

[25] Chapter VIII of BAL NC.

[26] Similarly to nomination/renomination, allocation is also handled in the NCs. In this section I provide again a general description based on my previous experience of studying NCs.

also needed because the flow of natural gas cannot always perfectly mimic the ordered transportation task. Based on the measurement technology and the arrangements between the adjacent system operators, the allocation procedures applied at the different Entry-Exit points of the natural gas network can differ. It can also differ country by country which procedures are used for allocation at the Entry-Exit points. The allocation rules are defined per Entry-Exit points in the network codes.

A typical allocation scheme is, for example, where the interconnection points, the storage points, the production points, and the virtual trading point are allocated as nominated, while for the consumption Exit points, in case of those directly connected to the transmission network the measured value is the allocated and in case of distribution Exit points the quantity measured by the TSO is allocated by the DSO to traders according to the type of measurement.

To sum up, the system operator based on an allocation rule prepares for all system user the allocation values per Entry-Exit points based on the received nominations from system users, the measurement data and the allocation values coming from the adjacent system operators. **These allocation data form the basis of imbalance settlement, the system operator calculates the trader portfolios' balance on the system as the difference of the aggregated allocated inputs and the aggregated allocated offtakes.**

Spot flexibility procurement possibilities for ex ante balancing

The question of the available sources of flexibility is linked to the 'eternal' question: can liquid markets really be created on the European gas market. In this dissertation I will touch upon this issue many times, so here I only draw attention to some important aspects. Activity in short-term markets is similar to a chicken-egg question. One of the main arguments of the BAL NC is, for example, that by assigning traders to be primary responsible of balancing, and for this providing them the renomination opportunities and the necessary information, much of the balancing activity is transferred to the spot market, and this way it contributes to the liquidity of the spot market. (ACER, 2016) So, on the one hand, we can look at the question as whether traders are able to ex-ante balance themselves on the spot market if there is not enough liquidity there, and on the

other hand we can look at it as that by directing the day ahead and within-day ex ante balancing demand to the spot market we can contribute to the liquidity of the spot market. European regulation believes in this latter view and expects that by the expansion of ex ante balancing activity it can significantly contribute to the development of European spot markets. This view is based on the experience of now mature countries such as the UK case. (ACER, 2016)

Prescribing the establishment of transparent marketplaces is an example of a tool with which the regulator can help that the ex-ante balancing needs match on the market, and that trading activity expands. Miriello and Polo (2015) illustrate that the trading of ex ante balancing needs in a marketplace can easily lead to a more developed marketplace where the price reflects real fundamentals, even if only a fraction of balancing needs is present on the platform.

A further measure of trade facilitation is the speeding-up of the TSO's administering of the title transfer (change of ownership of the gas), i.e. speeding up the so-called trade notification process.

And finally, another way of expanding available spot flexibility resources is introducing short-term capacity products on the transmission system. If traders can contract capacity for the next day or even within-day on the interconnection and storage points they have a greater scope for portfolio correction. This option for traders was already established by European regulation by another pan-European network code implemented prior to BAL NC, the so-called CAM NC[27].

To sum up the above, the greater the role regulation prescribes for traders' ex ante balancing and the more supportive tools it provides for this, the larger fraction of balancing need appears on the spot market and thus the more it contributes to the expansion of the spot market's liquidity. Finally, as illustrated by the theoretical model of Miriello and Polo (2015), this process can lead to the emergence of a mature hub. **This is one of the reasons why the market-based balancing system can be considered as a hatchery for the short-term wholesale market.**

[27] Commission Regulation establishing a Network Code on Capacity Allocation Mechanisms in Gas Transmission Systems (984/2013/EU)

For this, it is necessary to provide traders with the opportunity of adjusting their portfolio close to real time as much as possible, by the nomination and renomination rules, by providing detailed and regular information, and by providing tools that support short term trading, such as transparent marketplaces and short-term infrastructure capacity products.

III.2.2. The regulation of TSO's residual balancing activity

The system operator is responsible for the real-time physical balance of the system. For this it uses flexibility products. Prior to market opening in the vertically integrated company that covered the entire sector this physical balancing was conducted through coordination between the company's departments. With market opening and restructuring the system operator has to perform explicit balancing activity with procuring flexibility products from other players on the market. Based on the experience of European gas markets, the following development path of the TSO's balancing activity can be synthesized:[28]

Solutions in the initial stage of market opening:

- The system operator concludes a long-term (multi-year) framework contract with the incumbent trading company that is typically in the same holding as the TSO for the provision of flexibility services. The reason behind this is usually that there is no other player at the early stage of market opening that is reliably available to provide flexibility. The price and other parameters of this contract are often not transparent.; OR

[28] I synthesized the development path based mainly on the country studies of the following articles:
• Dickx et al. (2014) briefly summarizes the development of the British, Dutch, German, Belgian, French, Italian, Austrian and Spanish systems.
• ACER (2016) and ACER (2017): These contain summaries of the structure of the balancing systems of the European Member States of 2015 and 2016.
• KEMA - REKK (2009): A summary of how TSOs in different Member States were procuring for residual balancing at that time.
• KEMA - COWI (2013): A very brief summary of residual balancing procurement in the Member States.
• ECDGC (2007): The Sector Inquiry also contains a summary.
In addition, I have also studied the system of a few countries on my own, for example, I have followed the evolution of the Hungarian system over the years, and I also follow recently the operation of the Croatian and Ukrainian systems.

- The system operator has at its disposable storage capacity and stores gas for balancing. That is, it takes care for itself, maintains a gas inventory and in case of system shortage it withdraws from it and in case of surplus it stores it.

Solutions in the transitional phase:

- As more and more players are active in the market, the regulatory authority conducts regular market analysis. If it finds that a player has a market power – typically the former incumbent – it may oblige it to offer an annual balancing service to the system operator at a price regulated by the regulatory authority. This framework contract is now transparent and may include provisions that promote market based balancing procurement, for example by requiring the designated company to submit a market maker bid on a daily basis to the (recently set up) balancing platform.
- If the market becomes even more competitive, the contracting with the designated company could be replaced by the competitive tendering for the provision of the balancing service. This is the so-called reserve market. Reserve tenders typically refer to a shorter time period, for weekly or daily availability.[29] For the winners, if during the given period they were really available the system operator pays the availability fee that was the result of the tender. The procurement of reserves can insure the system operator that during the real-time it will not have such problem that due to the low liquidity flexibility services are not available and that it will not become vulnerable to any single player.
- Establishing a Balancing Platform: the setting up of a transparent marketplace by the TSO for the purchasing of balancing products is an effective interim measure also recognized by BAL NC[30]. On the balancing platform traders can offer bids for balancing products at the request of the system operator. The system operator is always on one side of the transactions. On the balancing platform the products are defined according to the system operator's needs, i.e. the product range may deviate from a standard stock exchange's. For example,

[29] Such a reserve market was operated for example in the Dutch system (Van Dinther - Mulder, 2013), and in Hungary, The HEGO option product was actually a one-day availability product (FGSZ, 2010)
[30] Chapter X of BAL NC.

a balancing platform offers the option of running also a reserve market, but it can also be a tool for acquiring other special products, such as a specific quality service or a specific hourly service.

- A further step in the development is the phasing out of the special products of the balancing platform and the shift in the system operator's procurement towards products with a shorter time duration – daily and within-day products. Likewise, the shortening of the time period of the reserve market procurements is also a way forward, while the final step in case of sufficient liquidity is the complete termination of the reserve procurement.
- In many cases, the balancing platform is expanded with a new section where traders can trade between each other, so the balancing platform also assists the ex-ante balancing of traders. This section is the trading platform, which is more like an exchange. For a while, the balancing and trading platform operates side by side.

Fully Market Based Operation:

- As the trading platform becomes more liquid the TSO can procure its entire residual balancing need from the trading platform (exchange), interim tools can be phased out.

As the TSO’s procurement is performed increasingly on market-bases, for the traders it becomes more and more a possibility to trade with the TSO flexibility products on the spot market, and this way the system operator contributes increasingly to the liquidity of the spot market. In the case of full market-based operation, the system's residual imbalance might entirely appear on the wholesale spot market. **This is the other reason a market-based balancing system can be considered as a hatchery for the short-term wholesale market.**

If the development path outlined above is introduced inaccurately, for example not transparently and not accessible to everyone, the balancing system can be a serious barrier to market development instead of supporting it. The already mentioned Sectoral Inquiry prepared by the Commission's Directorate-General for Competition (DG

ECDGC, 2007) produced a comprehensive overview on the potential problems, which I summarize in detail in Appendix IV.

III.2.3. Imbalance settlement regulation

The third pillar of balancing regulation is the incentivizing imbalance settlement system. When designing this, attention needs to be paid on not to leave opportunities for arbitrage, the settlement price should always be set in relation to the spot market price that it would not worth for traders to maintain an unbalanced portfolio. On the other hand, it is also important that this incentive penalty for imbalance should not be unreasonably high, as this may result in a serious barrier to entry. (ECDGC, 2007) There is a significant portfolio effect in balancing, meaning that a smaller portfolio is more likely to become imbalanced, while in a larger portfolio, the imbalances in consumption partly offset each other. Thus, balancing means a larger problem in proportion to the market entrants with small portfolios than to large players such as the incumbent. (ECDGC, 2007) As I outline below, there are opportunities in the settlement system to compensate for this fundamental disadvantage of new entrants and thus the balancing system does not become a barrier to market development.

Settlement quantity

In imbalance settlement the system user settles with the TSO ex post the balance of her allocated amounts of inputs and offtakes aggregated during the balancing period on the Entry-Exit points of the transmission system.

$$ImbQ_t = \sum_{Entry\ points} Q_t - \sum_{Exit\ points} Q_t$$

Tolerances

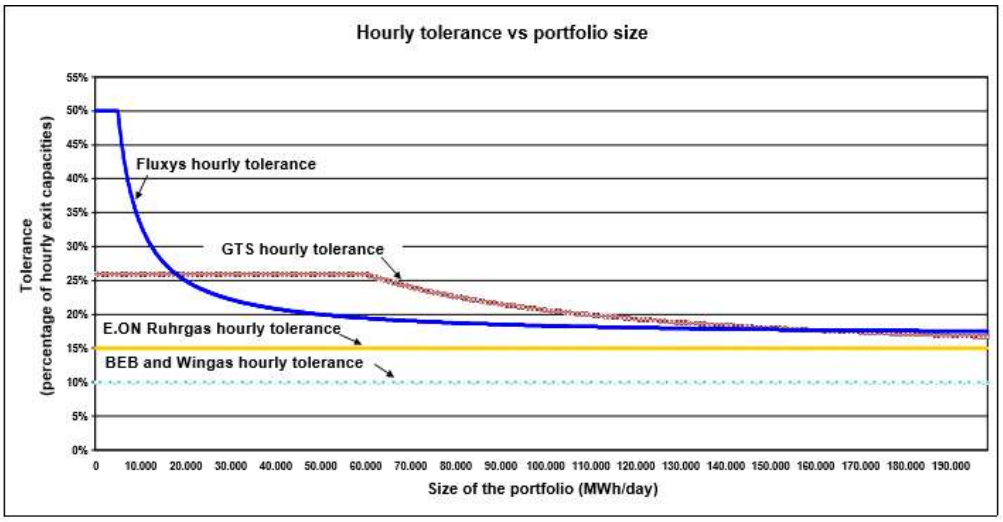
The imbalance settlement system may include tolerance bands to provide sufficient incentives. The usual practice is that the part of imbalance that is under the tolerance band is settled with a settlement price reflecting the average cost of balancing, while

the part over the tolerance band, is settled with a higher price, either applying a penalty surcharge or using the highest marginal cost of the residual balancing procurement.

Tolerance bands can be defined in several ways. It may be related to the imbalance of the whole system, for example, if cumulative imbalance within the day (and hence the linepack-flexibility) reaches a critical level, then the causers are subject to surcharges. But tolerance bands may also be linked to the system user's portfolio. In this case, the simplest solution is when the tolerance band is defined as a ratio of the system user's imbalance and her total offtakes. For example, in Hungary, if the imbalance of a system user (who does not have a trading platform membership) exceeds 2% of its total daily withdrawal, then (by rule) an increased settlement price has to be applied to the imbalance quantity above this level. (Szabályzati Bizottság, 2017)

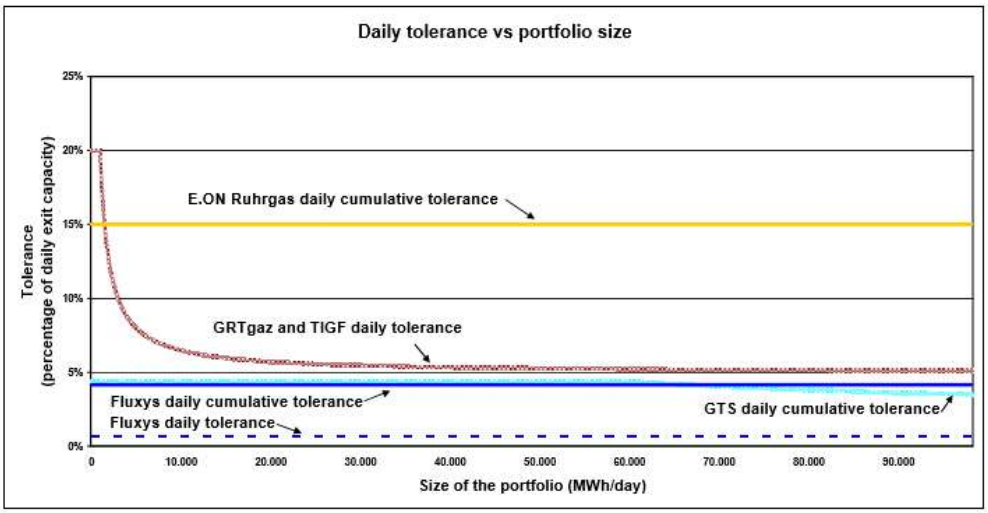
Tolerance rules also provide opportunity to favor the new entrants and traders with small portfolios that due to the portfolio-effect of balancing are in a disadvantage by nature. Many countries employed a portfolio size tolerance band where small-scale users could enjoy exemption from the surcharge up to 50% of their offtakes in the hourly system, while up to 20% in the daily system. The charts below (Figure 5 and Figure 6) are from the aforementioned Sector Inquiry (ECDGC, 2007) and illustrate the tolerance band systems used by the system operators in hourly and daily settlement systems during the initial and more advanced phases of market opening.

Figure 5: Portfolio-size-dependent hourly tolerance bands in the Belgian (Fluxys), Dutch (GTS) and German (E.ON, BEB and Wingas) systems



Source: ECDGC (2007) p. 251.

Figure 6: Portfolio-size-dependent daily tolerances in the Belgian (Fluxys), Dutch (GTS), German (E.ON) and French (GRTgaz and TIGF) systems



Source: ECDGC (2007) p. 251.

The examples also show that the balancing period – discussed in detail in Appendix III – is closely related to the issue of tolerances. In the simplest daily settlement systems, the tolerance band is projected to the daily imbalance. In hourly systems, the hourly imbalance must be balanced so the tolerance bands refer to hourly imbalances. Between these two, there are intermediate systems where the daily settlement system is extended with within-day obligations, for example if within a day the system's imbalance reaches a critical value that exceeds the tolerance band, then besides the daily imbalance settlement there is also a within-day settlement for the critical period. Intermediate systems can be defined in various ways. By studying the systems presented in the ACER report (ACER, 2016), I have identified the following design dimensions:

- Hourly Tolerance Band
- Cumulative Tolerance Band
- One band or multi-band penalty system
- Symmetry: shortage and surplus are symmetrically or differently treated
- Activation of the bands: depends solely on the system user's portfolio, i.e. activation is independent of the overall system state or is activated only when the entire system reaches a predefined imbalance level

For the imbalance settlement system to achieve its ultimate purpose, i.e. to incentivize traders to maintain a balanced portfolio and thus to prevent physical imbalances that threaten the security of the system, it is very important that the tolerances and related penalties are not set arbitrarily but reflect real system fundaments. If the tolerance bands and related penalties are unjustifiably severe, imbalance settlement would rather result in unreasonable punishment of system users instead of the original incentive goal. To avoid this temptation for severe penalties, in many cases the revenue from these penalties are automatically taken away from the system operator and are used for reducing the transmission tariff. However, it has to be highlighted that this is a second-best solution, since that player who benefits most from the reduction of the transmission tariff is the one who contracts the most capacities, but this player does not necessarily coincide with the one paying the imbalance punishment. The Commission has also pointed out in the Sectoral Inquiry that this solution could even lead to the cross-subsidization of the incumbent. (ECDGC, 2007) Therefore, the first best solution is recommended, when only the technologically justified bands and penalties are included in the balancing regime.

Settlement price

According to the conclusion of the Sector Inquiry, to avoid distortions two rules are important to consider in the settlement price formation (ECDGC, 2007):

- It should reflect the costs of the physical balancing. This way the cross financing of balancing activity and transmission activity can be avoided.
- It should reflect market conditions. For example, if the imbalance settlement price is lower than the spot price, traders will use the balancing system as a source for supplying their portfolio. In this case, the balancing system would distort the wholesale market, and the TSO instead of the quantity necessary for the optimal residual balancing would have to procure a much larger amount due to the trader's arbitrage activity and thus residual balancing would be also

distorted. On the other hand, settlement prices far above market prices would place an unreasonable burden on the players.

These two aims can best be combined if the procurement for residual balancing of the TSO is performed on a liquid spot market. In that case, purchasing costs also reflect market conditions, so settlement prices based on the average or the marginal cost of the TSO's purchasing fulfill the two conditions.

If, however, the market is not that mature that the TSO could reliably procure from a liquid spot platform, then it will have to rely on the alternative procurement methods discussed in Point III.2.2. In such cases, the dual aim of reflecting costs and market conditions is not necessarily met. The following options are available:

- Linking the imbalance settlement price to a liquid spot market index that is relevant to the given market. For example, if there is a liquid spot market in a neighboring zone that has an interconnection with the given zone, then a price linked to that zone's market price index can form the bases of the imbalance settlement price. In this case, the price of the cross-border capacity, i.e. the transport price, should also be considered in formulating the settlement price. Croatia for example applies such solution, i.e. the price of the neighboring liquid Austrian hub, CEGH, is the basis of the imbalance settlement price where the shortages are settled with an imbalance settlement price formulated as the price of CEGH and an additional surcharge (multiplier) while surpluses are settled with the price of CEGH and a discount. (HERA, 2017)
    - This solution is although not a directly cost-based approach, but it approximates market conditions as traders can import natural gas from the liquid spot market, so that market price is very likely to be influential on the domestic wholesale market as well. The price on the domestic wholesale market would only differ from the neighboring liquid marktet's price significantly if access to the interconnection point capacities would be limited, and other sources would also be limitedly available for traders. In such case, the incumbent can significantly raise the domestic wholesale price above the neighboring zone's price. In this situation, however, the linking of the settlement price to the

neighboring market's price is no more advisable, because that indexed price no longer reflects domestic market conditions and would result in distorted incentives towards traders. As I discussed it above, due to the systematically lower imbalance settlement prices than spot prices traders would buy the gas needed to supply their portfolio from the balancing system instead from the wholesale market.

- Administrative price setting. If there is no such spot market in the neighborhood or its accessibility is limited, then imbalance settlement price has to be determined on an administrative basis. In this case, the TSO's procurement costs (tender results, storage costs) form the basis of the administrative price. This solution satisfies the cost-reflecting requirement, but it is very complicated and difficult to implement without simplifications. In this case, market conditions are not really reflected, therefore the regulator has to continuously monitor whether the behavior of traders suggests the presence of distortive incentives on the market.

As can be seen, the way how the imbalance settlement price is determined is closely linked to the way the TSO procures its balancing need for residual balancing. This relationship, as demonstrated by the KEMA-COWI (2013) study, is also well reflected in the balancing regimes in the European Member States.

Single-price - dual-price systems

In imbalance settlement, TSO buys the traders' surplus and sells to the traders in shortage. There are various ways for defining the purchase and sale price used by the TSO deriving it from the basic settlement price specified in the previous section. There are two main directions, single-price and dual-price systems. In single-price systems, the sale and purchase price are the same. In case of dual-price systems, the selling price is set higher than the base price, the purchase price is set lower than the base price, typically by predefined multipliers or linked to the marginal purchase and sale costs of the TSO's residual balancing procurement. The imbalance settlement price model can be further sophisticated. The selling and buying price may take different values according to the state of the whole system in the given balancing period. For example, if there is a shortage in the overall system, then the selling price may be higher than

when it is in excess, this way in case of shortage those who caused the shortage are punished more.

Penalty surcharges

Penalty surcharges are applied to imbalances beyond the tolerance band and are set to incentivize traders to keep their imbalances within a safe level. For the penalty surcharge, the main question is how to determine the 'justified' level. New entrants are more likely to be imbalanced due to the portfolio-effect, and moreover in an immature market there are fewer flexibility tools available for them to adjust, so even if the tolerance bands are favorably created, new entrants are more likely to exceed the tolerance band. So, when determining the amount of surcharge attention has to be paid that the security of the system should be supported without hindering market entry.

The diversity of the imbalance settlement price setting options is well illustrated by the KEMA-REKK (2009) study that summarized the prevailing imbalance settlement price-formations in the Member States at that time.

Figure 7: Categorization of the imbalance settlement pricing systems of EU Member States

	Pricing basis			
	Administrated	Indexed	Market based	
			Average cost	Marginal cost
1 price	IT	IE*, NL	AT, BG*, FR*, SE*	-
2 prices	ES, GR, SI	BE, CZ, DE DK, FR*, LU*, SK	-	GB*, (SE*)
Penalties and other charges	CZ, GR, LT, RO, SI	AT*, BE, NL, PT, SK*	N/A	

Source: KEMA - REKK (2009) p. 46.

III.2.4. Balancing regime development path

Above, I have discussed the elements of the balancing regulatory system, their variants, and what effect these variants can have on the market, in what stage of development they are recommended to be applied. Due to the market supporting or distorting effects of balancing, it is especially important for the regulator to understand which tools are appropriate in the different stages of market development. Organizing balancing on a market basis is virtually another market building within the market-building that started with the opening of the gas market. Thus, from a vertically integrated company to a market-based balancing, a regulatory-path has to be defined that adaptively develops together with the market. Below, as a summary of the above, I outline a such possible evolutionary path along the three pillars.[31]

The development path (Table 1) shows how the variables of the elements within the three pillars form a constellation of regulatory instruments per level of development.

The path also illustrates how the regulation of the balancing system adapts to the development of the market, but also implicitly describes how the introduction of a balancing regulatory element such as renomination opportunities or a balancing platform effect market development.

[31] The first version of the development path was presented in Appendix II. of my paper submitted for the ERRA Regulatory Research Award (Szolnoki, 2017).

Table 1: Balancing regulation development path

Vertically integrated industry	Beginning: market opening, few new entrants, dominant incumbent that is still integrated with network branches: restructuring and unbundling is in an immature phase	During the transitional period, market opening proceeds along further restructuring and through increasingly stringent unbundling rules. The number of players is increasing, the incumbent's share and its integration with other segments are decreasing.			Fully market-based balancing system
		Transisitional Period: Phase I.	Transitional Period: Phase II	Transitional Period: Phase III	
-	Daily (weekly, monthly) nomination, there is no or very limited renomination possibility. Trading is done through bilateral contracts, flexibility bands are pre-fixed in the contracts, limited sources can be procured on a daily basis.	A restricted renomination possibility is introduced. Virtual trading point is set up that simplifies and supports trading, and the accompanying trade notification and title transfer service of the TSO is introduced. Bilateral trading becomes more vivid. Shorter term contracts emerge.	Within-day renomination possibility; by the setting up of a Balancing Platform the traders can directly offer short term and smaller balancing products to the TSO, this way they can take part in the system's balancing and they can even trade their imbalances with the TSO ex ante. On the trading section of the platform they now can trade with other traders not just bilaterally. More and more possibilities emerge for the covering of the daily flexibility need.	Renomination is possible up to 3 hours before the physical flow. Detailed, high-quality information is provided several times within day to traders. Traders use actively the Trading Platform and OTC possibilities for the adjustments of their portfolios even within-day. Traders also provide offers for the TSO on the Balancing Platform.	Renomination is possible up to 3 hours before the physical flow. Detailed, high-quality information is provided several times within day to traders. Traders use actively the Trading Platform and OTC possibilities for the adjustments of their portfolios even within-day. Traders also trade with the TSO on the Trading Platform.
Balancing is an intra-corporate coordination activity, the focus is on physical balancing	The system operator either contracts a long term balancing contract with the largest player (it is typically the incumbent which is in the joint holding with the TSO) or performs balancing with own gas stored in the storage and it is accompanied with a long-term privlidged storage capacity contract.	The TSO procures the balancing service through annual tender or the regulator prescribes that the dominant incumbent company shall provide balancing service to the TSO on regulated terms.	By the renominations of traders the unresolved balancing need left to the TSO is decreasing. The TSO diversifies its procurement, it buys balancing service on annual tenders and complements it with the procurement of daily short term products from the Balancing Platform	By the renominations of traders the unresolved balancing need left to the TSO is decreasing. The TSO procures all its balancing need on the Balancing Platform.	By the renominations of traders the unresolved balancing need left to the TSO is decreasing. The TSO procures all its balancing need on the Trading Platform.
-	Daily (weekly or monthly) balancing period. Settlement is either on administratively set prices or performed in kind, for example at the end of the month the shortage or excess is transfered in the storage to the TSO.	Daily imbalance settlement on administrative prices. Application of tolerances.	Daily imbalance settlemen. The settlement price is based on a mixed formula: mainly administrative, frequently it is linked to a liquid marketplace in a neighboring country, but the linking to the prices of the Balancing Platform could also emerge as an option in this phase. Application of tolerances.	Daily imbalance settlement based on the marginal or average prices of the Balancing Platform. The use of tolerances decreases.	Daily imbalance settlement, the settlement price is based on the marginal or average prices of the Trading Platform. Tolerances are not applied.

Source: Szolnoki (2017) Appendix II Table 1. modified

III.3. Regulation of the natural gas sector and of balancing in the EU

After the theoretical description of balancing regulation, I turn to its practical implementation. The section summarizes the evolution and current state of the EU balancing regulation.

In this section, I provide a brief overview of what steps taken by European gas market regulation lead to the recent BAL NC regulation and then describe BAL NC in detail.

Since the detailed discussion of the development of the entire European gas market regulation is not the main focus of the dissertation, but it is an important aspect for understanding this topic, therefore I provide a detailed discussion of it in Appendix IV. The following brief summary only provides a comprehensive picture of the European balancing regulation if it is complemented with Appendix IV, therefore I suggest that this section should be read together with Appendix IV.

III.3.1. Development of the European gas market regulation and balancing regulation

The European energy market reform is governed by two main objectives: the establishment of the Internal market and the setting up of a competitive gas market.[32] From the beginning to the present day European gas regulations contain rules aiming at achieving these two goals, becoming more and more detailed and going down to more and more operational levels, in a more and more legally binding form leaving less and less room for the Member States in implementation.[33]

From the examination of European legislation, it can be seen, that the European regulatory thinking has identified as the main means for the development of a **competitive market** the enabling and supporting of market entry: competition can arise if new entrants have the opportunity to make a competitive offer compared to the (integrated) incumbent company. For this, access rules along the following three dimensions have to be set up:

[32] These goals have been included in all European gas regulatory documents since the First Directive. For example, Preamble (1) and (3) of 1998/30 / EC, Preamble (2) and (5) of 2003/55 / EC but practically throughout the entire Directive.

[33] In addition to the two main objectives, overall EU objectives are to increase efficiency, reduce prices, improve the quality of service and increase competition, which are actually the consequences of the emergence of a competitive internal market.

- access should be enabled to new entrants to **sources** (production, import),
- to **networks** to be able to deliver natural gas to the consumer (this is the already mentioned third-party network access),
- and access to **consumers**, so that new entrants be able to make an offer at all to someone.

To create the **Internal market**, the most important factor is to alleviate the barriers to cross-border trade, reducing transaction costs. One of the means for that is the harmonization of the rules on trade. In addition, a common market can develop if there are no bottlenecks, thus the multidirectional building and expansion of interconnection capacities between Member States is necessary.

To date, the European gas market regulation is moving along these directions: **ensuring non-discriminatory access and harmonization**. Regarding the way of regulation, ex ante sector-specific regulation was continuously complemented and supported by ex post competition regulation.

First phase

European gas industry legislation started initially with softer legal instruments. In the beginning there was a consensus on the view that complete harmonization of the Member States' regulation would be harmful because national markets differ in their structural features (market size, diversification of supply sources, network connectivity, domestic production) and therefore they also differ in their markets' maturity (long-term contractual obligations, spot market intensity) therefore, the same regulatory tools can have completely different effects on different markets (IGU, 2006). That is why, at first, the main legal instrument of the European market liberalization reform was the Directive. This form obliges the Member States to reach the prescribed results, but in what way they achieve it, is mostly under the competence of the Member States. Thus, when transposing the European targets into domestic law, they can formulate a regulatory regime that considers the national specificities of the Member States' gas market.

The main legislations of this initial period were the First[34] and Second[35] Directives and Regulation 1775/2005[36].

European legislation initially did not deal with balancing explicitly, it only mentions it in the Second Directive. By then, Member States started to set up their own balancing systems and the Second Directive laid down the main principles that these national specific rules have to meet, namely that balancing mechanisms should be **non-discriminatory and cost-reflective** and *"as soon as the gas market is sufficiently liquid, this should be achieved through the setting up of* ***transparent market-based mechanisms*** *for the supply and purchase of gas needed in the framework of balancing requirements."* (2003/55 / EC, paragraph 15). Thus, here already appeared the point that, depending on the maturity of the market, if liquidity is low, regulatory intervention is needed in determining the imbalance settlement price so that these non-discrimination and cost-reflectivity principles can be met, if liquidity is sufficiently high, then the imbalance settlement price mechanism should be entrusted to the market mechanism. Finally, the Second Directive underlines that, in addition to the establishment of a cost-based system, it is important that this balancing rule also incentivize the network users to be in balance.

Regulation No 1775/2005 dealt with balancing in more detail than the Second Directive, but it did not go much further in the specifics.

Sector Inquiry

The end of the first phase of European gas market regulation can be marked with the Energy Sector Inquiry launched by the European Commission's Directorate-General for Competition in June 2005, lasting one and a half years. The summary report of its results was published on 10 January 2007. (ECDGC, 2007).

The main conclusion to the Commission was that although competition started on the European market the pace of progress was insufficient, therefore to move forward stronger legal instruments would have to be deployed than the Directives and European

[34] Directive 98/30/EC of the European Parliament and of the Council concerning common rules for the internal market in natural gas
[35] Directive 2003/55/EC of the European Parliament and of the Council concerning common rules for the internal market in natural gas
[36] Regulation (EC) No 1775/2005 of the European Parliament and of the Council on conditions for access to the natural gas transmission networks

regulation should aim at a deeper harmonization including even the operational level. Further progress in access provision should be needed at all three areas – sources, networks, consumers.

The Commission summarized its conclusions and recommendations for the next steps of the European natural gas (and electricity) regulation in its Communication (EC, 2007), published the same day as the Sector Inquiry. This paved the way for the Third Energy Package launching the second phase of European natural gas legislation.

Second phase

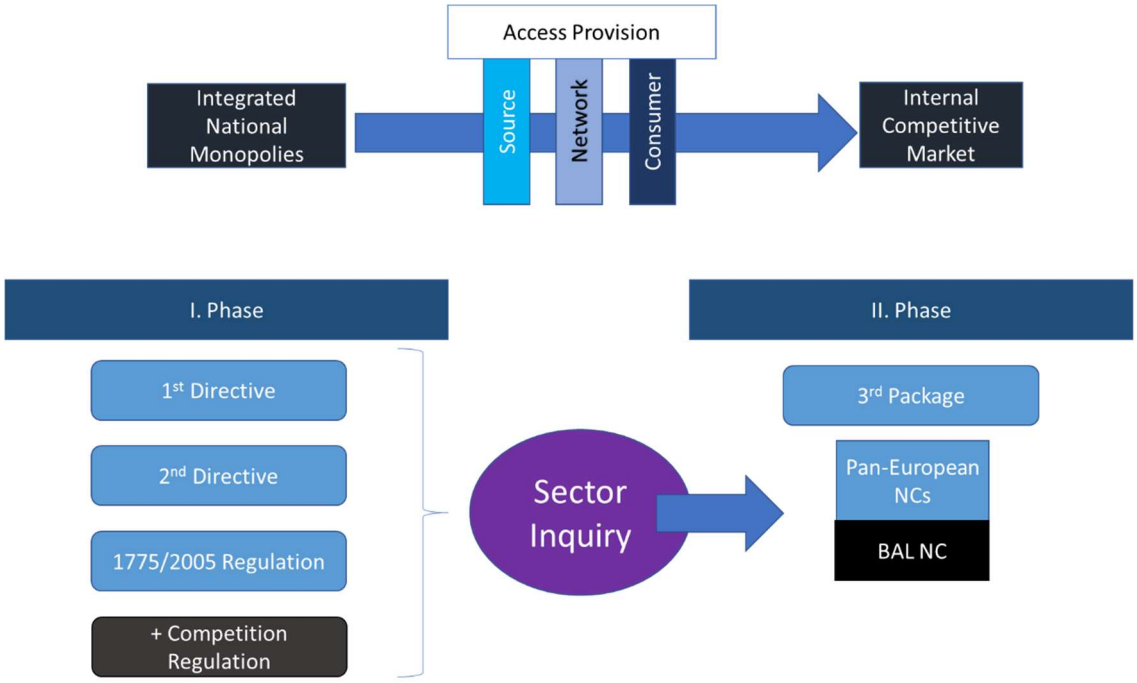
The Third Energy Package for the gas market contained a new directive[37] repealing the Second Directive and a new regulation[38] repealing the previous Regulation. In addition, the Third Package also established a European energy regulatory authority (ACER) with another regulation[39]. Regarding this dissertation the most important point of the third package is the one prescribing the development of European-wide network codes: The Third Package provides for the establishment of 12 mandatory pan-European transmission system Network Codes. This step is the strongest change compared to the previous directive-based legislation. Because contrary to the directives, NCs do not only lay down principles and goals, but also provide for the way in which they should be implemented, going down to in depth operational detail, regulating natural gas market activity in the form of a European Commission's Regulation. Member States have no room in the transposition, just as much as the NCs themselves offer as an option. The main competence of the NCs is cross-border points and processes affecting cross-border trade. The Third Package published in 2009 already foresaw the 12 topics that should be regulated by NCs. This list revealed that European regulation declared balancing as a key area and therefore seeks to regulate it in the context of a pan-European Network Code.

[37] Directive 2009/73/EC of the European Parliament and of the Council concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC
[38] Regulation (EC) No 715/2009 of the European Parliament and of the Council on conditions for access to the natural gas transmission networks and repealing Regulation (EC) No 1775/2005
[39] Regulation (EC) No 713/2009 of the European Parliament and of the Council establishing an Agency for the Cooperation of Energy Regulators

In March 2014, the Balancing Network Code, abbreviated as BAL NC, was published, officially: European Commission Regulation 312/2014 establishing a Network Code on Gas Balancing of Transmission Networks.

The following figure summarizes the main areas of the European natural gas regulation and the legislative steps with which it has reached the present state. Regarding balancing its peak is BAL NC.

Figure 8: Simplified summary of the development of the European gas market regulation



Source: Own figure

III.3.2. BAL NC

The main aim of BAL NC is the EU-wide setting-up of a market-based balancing system. That is, the uniform introduction of such balancing rules on the European Member States' gas markets which formed the end-point of the balancing regulation development path presented in Section III.2.

In the market-based system, it is no longer the TSO, but the traders (system users) are the primary responsible of maintaining the system balance, that is, the aim is to achieve balance by the improving balancing activity of traders, and only a residual role should remain to the system operator. The procurement activity associated with the residual role should also be conducted on a market-based premises by the system operator.

The active involvement of TSO decreases, but it plays a significant role in assisting the balancing activity of system users: providing regularly detailed and timely information and providing flexible system services: renomination and title transfer for traders.

By focusing on system users' ex ante balancing and its support, balancing needs are shifted to day ahead and within-day markets. This is further supported by the direction of the remainder balancing need that remained to the TSO for physical balancing also to a short-term market platform. In this way, in the case of gas markets in the early stage of market opening the balancing system could function as a "hatchery" of the spot market.

Overall, BAL NC supports the emergence of a competitive Internal European gas market in three main ways. On the one hand, through harmonized rules it facilitates trade across Member States by reducing the transaction costs resulting from the differences between the systems. On the other hand, while so far transparency and non-discrimination has been only prescribed as principles, they are now explicitly enforced in the operational level rules[40] and thus market distortion problems identified in the Sector Inquiry are more effectively addressed. And thirdly, BAL NC also promotes the competitive Internal European gas market through the aforementioned spot market liquidity supporting function, i.e. the hatchery function.

Implementation of BAL NC

In case of a harmonized market-based balancing system provided by the BAL NC it is a question whether it is possible to adapt such system in any type of market, whether even the balancing systems of immature markets can be transformed into fully market-based

[40] These principles have been transposed explicitly through for example the neutrality rule, information provision rules, but in all other areas as well, such as TSO procurement, imbalance settlement pricing, and tolerance bands.

systems or whether there is any maturity / liquidity level below which it is not recommended.

European legislators left this liquidity question to the decision of Member States i.e. whether they consider their market mature enough to introduce a fully-market-based system right away or need some time for further development before its implementation. Accordingly, BAL NC offered three options for the timing of the implementation of the full market-based balancing system between which the Member States could choose: the first cluster, including Hungary, chose the deadline of 1st October 2015, the second 1st October 2016, and finally the third, the so-called interim group is obliged to introduce the BAL NC-type full market-based system from 1st April 2019.[41]

This different timing also reveals the different levels of development of the Member States. For Member States in the 2015 cluster the introduction of BAL NC virtually has not caused any problem because their markets mostly had already reached this stage of development. For the second cluster the implementation of the information provision rules meant the major challenge. (ACER - ENTSOG, 2015) On the other hand, most of the countries in the third cluster are either only starting market opening or are stuck at an early stage of market opening having an almost fully administrative balancing system. In these countries, there is typically no transparent marketplace or hub either. (ACER, 2016)

Therefore, today the implementation of BAL NC is a great challenge for this interim group. Their task is to develop their market and balancing system by the spring of 2019 to such a level as to be able to introduce market-based balancing. These countries are at various stages of the balancing regulation development path presented in Section III.2. With the help of interim regulatory tools, they can move forward towards the goal set by BAL NC. BAL NC itself also proposes interim regulatory measures that these countries could implement for support before launching market-based operation. The three interim measures mentioned in Chapter X:

1. Use of tolerance bands;
2. Setting up a balancing platform for TSO procurement for residual system balancing activities. Or if liquidity is insufficient, then procurement of balancing services through tenders.

[41] Cluster 2015: Austria, Belux market, Germany, Denmark, France, Hungary, The Netherlands, Slovenia, Great Britain. Cluster 2016: Czech Republic, Croatia, Spain, Italy, Portugal. Cluster 2019: Greece, Ireland, Lithuania, Northern Ireland, Poland, Romania, Sweden, Slovakia (ACER, 2016)

3. Administrative formation of the imbalance settlement price.

Member States have the freedom to choose from these tools as well as to choose any other interim measure that is consistent with the general principles of BAL NC. The aim is to develop their system by the Spring of 2019 to a level when market-based balancing can be introduced, and all interim measures can be phased out. The interim cluster should prepare a report annually on the development of their wholesale market and on the effectiveness of the interim measures used and the timing of their phasing out.

The specific elements of BAL NC

The BAL NC consists of several small sub-regulations, in the following I summarize these. The discussion will not follow the order of the legislation's text, but instead, for the better interpretation I present it along the three pillars. This summary is complemented by a more detailed one in Appendix V.

First Pillar: Regulatory measures of BAL NC concerning ex ante balancing

The rules of BAL NC prescribe an extensive supporting role for the TSO. At the same time, the areas for own decision-making of the system operator is more limited, which makes the system more predictable and transparent:

- The system operator is required to respond (approve or reject) to the system users' requests ((re)nomination, trade notification) at the latest within a specified period, the reasons for rejection are also set by the regulation, and it also specifies the specific content of the communication between the system users and the TSO.
- By laying down the timing and timeframe of the nomination and renomination cycles in the BAL NC, the daily interaction between system users and TSOs on the interconnection points become standardized and harmonized across the EU. A very flexible system is introduced where the system user can modify her nominations until three hours prior to the actual gas delivery hour. That is, the system really offers traders the opportunity to ex ante balance their portfolio up to almost last minute.

- Lastly, the activities of network users are also supported by the possibility to submit imbalanced nominations, and by providing access to title transfer services at the virtual point by the TSO to even those players that do not have a separate transmission contract with the system operator. By this the regulation supports the emergence of financial traders on the gas market, in hope for liquidity expansion.

Second Pillar: Requirements of BAL NC regarding residual balancing of TSO

BAL NC lays down in which cases the system operators should perform and how they should perform their residual balancing activity. The main principles are non-discrimination, economical functioning, and transparency. Residual balancing should be as far as possible performed by means of short-term standardized products and only in the absence of sufficient liquidity can balancing services be contracted. Market-based procurement is mandatory for both modes. Short-term standardized products should be procured on a transparent trading platform and the merit order to be followed by the TSO in accepting the bids is also set by BAL NC. On the one hand, the more shorter-term products should be preferred, and on the other hand, standard title products should be preferred compared to more restricted products e.g. locational or temporal products. If no trading platform exists or on the trading platform products that are necessary for the TSO are not available, a balancing platform should be set up as an interim measure. Balancing services must also be procured through a transparent, non-discriminatory, public tender for a maximum of one year. In exceptional cases, these rules can be discarded, but the goal is to conduct TSO's balancing through standard trading platform products as soon as possible, so the need for balancing services must be revised annually. Costs and quantities of TSO's procurements shall be published annually.

Third Pillar: Imbalance settlement regulation

The principles set out in the Sectoral Inquiry are reflected in the imbalance settlement system prescribed by BAL NC: cost reflection and incentivizing for keeping a balanced portfolio at the same time.

Settlement must be completely financial, in-kind settlements are no longer allowed.

BAL NC introduces a dual-price imbalance settlement system. Accordingly, the daily marginal sell / buy price is the lower / higher out of the following two:

- the lowest / highest price of the system operator's sales / purchases of title products in respect of the gas day, or
- the weighted average price of gas in respect of that gas day minus / plus a small adjustment (which may be within the range of 0-10%, the choice is left for the Member States)

As can be seen, a penalty surcharge can be applied, which may be up to 10% of the average price.

However, the use of tolerance bands providing exemption from this surcharge is not supported by BAL NC, it should only be used as an interim measure and should be phased out as soon as possible.

It should also be emphasized that BAL NC prescribes a daily balancing period as a default, but in addition it leaves room for Member States to apply within day obligations, although they must provide a detailed justification for this which has to be underpinned by analyzes.

Finally, there is one more further important element of BAL NC, the neutrality principle which strongly relates to the second and third pillars. To ensure that the system operator in its balancing activities and its supporting activities toward system users is not biased – so that it performs it in the interest of the system and not for its own benefit – the BAL NC requires that in its balancing-related activities the TSO should be financially neutral, and to ensure this it has to maintain a separate neutrality account and charge a monthly neutrality fee.

Monitoring activity related to BAL NC

Activities of European organizations

Articles 8 and 9 of the Third Energy Package's 715/2009 Regulation provide for ENTSOG and ACER to regularly assess the impact of European regulations. In this context both ACER and ENTSOG are required to examine the introduction of BAL NC and analyze its impact.

Although the first implementation deadline for the code was 1st October 2015, ACER has already started to assess Member States' early implementation' status with ENTSOG in 2014. Following the publication of BAL NC in March 2014 the 25th Madrid Forum on 6-7 May requested a joint ACER ENTSOG report (ACER - ENTSOG, 2014). It was a status report about to what extent the Member States had already implemented the BAL NC requirements and what are the main obstacles. The second report (ACER - ENTSOG, 2015) was published on 5th November 2015, although it was published after the first implementation deadline of 1st October 2015 it referred to the previous period's preparedness.

After the implementations ACER and ENTSOG published their BAL NC monitoring reports separately. The contents of these reports are described in detail in the following methodological chapter.

Assessment task of Member States

Article 46 of the BAL NC also provides that Member States of the interim cluster shall annually submit a report on the state of development and liquidity of the short-term wholesale market, which shall include at least the specifically listed indicators in the Article. In addition, the report needs to show what interim measures the Member State intends to apply to facilitate the introduction of market-based balancing system by Spring 2019, and why the proposed interim measures are needed and how those would improve market development, and finally how will the measures be phased out.

Thus, these countries need to have a well-established concept and plans on their balancing system regulation, they need to deeply understand at what stage their markets are and what effects the introduced regulatory tools could have on their market.

I wish to contribute to both the assessment task of these Member States and to the monitoring tasks of the European organizations by the elaboration of a balancing system analysis framework introduced in the following chapter.

IV. EFFICIENCY ANALYSIS: METHODOLOGY FOR ANALYSING NATURAL GAS BALANCING SYSTEMS

In the previous part of the dissertation I described the regulatory instruments of the gas market with particular emphasis on the regulatory issues and tools of balancing. European gas market regulatory measures aim at creating an effective Internal gas market. The regulation of the transitional period between the vertically integrated sector and the competitive market is a sequential process. Regulation challenges the market, the market adapts to the new conditions and thus develops. During this transitional period, it is particularly important for the regulator to deeply understand the limits of the market and to continuously monitor the impact of the new rules introduced. Market analysis is therefore an important element of market regulation, an indispensable part of the regulatory activity.

Also, when regulating the balancing system, it is necessary to know the performance of the current balancing regime and to evaluate the impact of the new rules introduced. In practice this means that market analyses should be conducted: calculating and interpreting indicators derived from theoretical considerations.

The analysis of the impact of the rules introduced on the market also plays an important role in the European regulation. Concerning BAL NC, as presented at the end of the previous chapter, both the European level organizations – ACER and ENTSOG – and the Member States that choose the interim measures cluster have an impact assessment and market monitoring obligation. This work can be supported by a comprehensive analytical methodology that can be applied flexibly to balancing regimes of any level of development.

In this chapter I aim to develop such a methodology. I describe the methods that so far have been applied to the analysis of the balancing systems, and then present my new research findings. In these I further develop the current analysis methods, but I also define and calculate new indicators as well. I place the analysis of the balancing system on theoretical foundations and set up a comprehensive analytical framework with theoretical grounding and empirical tool-set.

IV.1. The structure of the methodology

Background

Unfortunately, the literature of analyzing the functioning of balancing systems is rather modest, and it usually focuses on only one-one subfield and on only mature markets. For example, the article of Mulder and Van Dinther (2013) assesses the performance of the new Dutch market-based balancing system, but the analysis only focuses on the balancing reserves and balancing platform offers. In their article, Dickx et al. (2014), although they analyze the balancing system of eight countries, but those are already developed advanced gas markets and specific analyzes are only carried out for the wholesale marketplaces, hubs, and not for the concrete balancing activities.

The first comprehensive study on how to analyze the impact of the introduced balancing regulations on markets is the consultancy work that ACER has commissioned from the Cambridge Economic Policy Associates (CEPA) for the economic grounding of ACER's monitoring task related to the NCs (CEPA, 2015). In this paper CEPA defines indicators, inter alia, to measure the impact of the implementation of BAL NC. ACER started out from these indicators in its balancing system analyzes presented in the 2017 BAL NC monitoring report (ACER, 2017). In the analysis framework set up in the report, probably due to data shortages ACER modified some of the CEPA indicators and defined additional indicators. In addition, ENTSOG has also begun to analyze balancing systems in its latest report (ENTSOG, 2016) and defined its own indicators. These metrics usually overlap, or only slightly differ from the ACER indices.

So, to the initiation of ACER, a thinking began about a general analysis framework that could be used to analyze the balancing system of all the Member States and not just that of countries with advanced market-based balancing systems and liquid wholesale marketplaces.

In the following, when elaborating my proposal for such methodology, I present and evaluate this analysis framework of ACER and extend it in both, horizontal and vertical directions.

The building blocks of the methodology

I suggest that the setting up of a comprehensive methodology should start with laying down what analysis questions should be answered by the methodology. ACER, regarding its analysis framework only says that the purpose of its analysis framework is to assess the effectiveness of the balancing systems in the Member States (ACER, 2017). Thereafter, the indicators themselves follow, which capture one-one segment of the balancing system's operation. I suggest extending this framework with further questions.

When transforming a balancing system to a market-based balancing regime, I think **one of the starting questions of regulation should be that considering the current physical endowments and commercial settings of the natural gas sector is there a theoretical possibility or obstacle to organize balancing in a fully market-based setup?** This kind of consideration of fundamentals is also included in BAL NC, the possibility of an interim measures group is just about it, not everywhere can a BAL NC type market based balancing system be introduced overnight, moreover, in some markets it might be the case that some non-market-based instruments will always be needed. Thus, first subquestion is, whether the physical features of the system are a limit, the second subquestion is whether the current market structure can hinder the introduction of market-based rules. While the presence of physical constraints prevents the introduction of market-based balancing, commercial barriers can be solved by regulatory measures (the regulatory tools for transitional phases).

Only after these analyses I turn to the area also analyzed by ACER, **the evaluation of the effectiveness of the current balancing system**. To answer this question, as initiated by also ACER, a comprehensive analytical methodology is needed. My suggestion is that such a methodology needs to be **grounded by a theoretical model**: it is necessary to define what is meant by an effective balancing system in order to know what we are looking for and how to evaluate what we find. As I discussed it in Chapter II. of this dissertation, the first and most important goal of market opening is the creation of effective markets – in this case effective balancing – but its measurement is unclear. Among others, Littlechild (2011) and Shuttleworth (2000) have pointed out the importance of the ex-ante definition of the 'sought after' efficiency: the analysis of indicators alone, such as the number of market participants and price developments, cannot provide a clear answer on the market's effectiveness. They provide an ad hoc

picture merely from one particular area, their assessment, if we do not know what is meant by efficiency, is not certain as there is no benchmark. Therefore, instead of the indicator based analytical framework of ACER, **I create a methodological framework for analyzing the balancing system's efficiency based on a theoretical model, I derive the areas of analysis based on the model and I define indicators for the assessment of these areas.**

To sum up, the methodological framework that I propose for the analysis of the balancing system is structured as follows:

I. Is there a theoretical possibility or obstacle to organize balancing in a fully market-based setup?
   a. Analysis of physical fundamentals
   b. Analysis of the commercial setting

II. Evaluation of the efficiency of the balancing system
   a. Definition of efficiency based on a theoretical model, and identification of the areas to be analyzed.
   b. Definition of indicators based on publicly available data for analyzing the areas indicated by the theoretical model.

Below I present the methodology along this structure and I will also touch upon the results of the previous literature at each point and will also evaluate those. As the methodology is about a practical analytical task, on the case of three natural gas markets I will also illustrate the application of the methodology, how it could be used.

IV.2. Is there a theoretical possibility or obstacle to organize balancing in a fully market-based setup?

First, the market's fundamental capabilities are assessed. This is particularly important for those Member States that are in the early stages of market opening and therefore have chosen to be in the interim measures BAL NC implementation cluster. For the assessment of this basic question neither academics, nor ACER and its consultants have elaborated a method, this question was omitted. The most explicit proposition in this regard can be found in BAL NC itself: Article 46 defines four indicators that Member States selecting the interim measures cluster should analyze in their annual report to assess the level of liquidity of the short-term wholesale market. The four indicators:

- „the number of transactions concluded at the virtual trading point and the number of transactions in general;
- the bid/offer spreads and the volumes of bids and offers;
- the number of participants having access to the short-term wholesale gas market;
- the number of participants having been active on the short-term wholesale gas market during a given period;"

As can be seen, these indicators are suitable for assessing the activity on the short-term wholesale market, while the purpose of their survey is to find out whether the balancing system is suitable for implementing market-based rules or not. Interestingly, the fundamentals of the balancing market itself are not covered by the indicators. I think that the number of short-term wholesale transactions is rather a consequence of the fundamentals of the balancing system, so to answer the question I suggest to follow the following methodology instead.

Proposal: analyzing the daily flexibility market

To assess the fundamentals of the balancing market, I suggest looking at the broader frame of balancing: the market for flexibility. By looking at the demand and supply of the daily flexibility market, it can be seen to what extent there are available flexible sources for the balancing of the commercial portfolios and the physical balancing of the system,

and what the maximum demand for balancing could be, since the balancing demand is part of the flexibility demand. So therefore, **I suggest, that the analysis of the balancing system should be started by analyzing the daily flexibility market.**

The analysis of the flexibility market usually occurs in the literature of storage price regulation, examining whether the given storage facility can be considered to be an essential facility in the market or not. In the case of storage, seasonal and short-term flexibility markets are also relevant. Such a flexibility market analysis was conducted for example by the British competition authority in a 2003 M&A case (Competition Commission, 2003) and in 2007 by the British energy regulatory authority (Office of Gas and Electricity Market - OFGEM) in a case of an exemption from price regulation for a newly established storage facility (OFGEM, 2007). Later, based on these analyzes, me and my colleagues in REKK we also used the flexibility market's analysis to assess the possibilities of gas storage competition to develop in Hungary (Szolnoki, 2008b). The Austrian regulatory authority (E-Control) also used flexibility market analysis in 2015 to evaluate the market position of storages in the case of introducing regulated access prices (E-Control, 2015).

Below, based on these analyzes and including my own suggestions, I summarize the methodology for analyzing the daily flexibility market: the main elements of the demand and supply side analysis and possible calculation methods, and the forms of evaluation of the results.

IV.2.1. Daily flexibility supply potential

Physical potential

Theoretically, besides linepack, daily flexibility can be provided by storage, domestic production, imports at the cross-border points, LNG, and the largest consumers. The theoretical supply of the daily flexibility market is the technical capacity of these resources, such as maximum capacity for storage withdrawal, production capacity, technological import capacity, etc. However, in practice only a portion of these maximum physical capacities are available on the daily market, as the majority is already in use

through other long-term commitments. Therefore, in analyzing the daily supply of flexibility, the task is actually estimating the **'available flexibility capacity'**.

In the previous literature different indicators were used to determine the available flexibility capacity. These are summarized in Table 2 below.

Table 2: The calculation of available daily flexibility potential in the different studies

Competition Commission	OFGEM	REKK	E-Control
The difference of the Daily Maximum Capacity and the Average Usage	The difference of the average usage of the 10 largest usage day and the average usage of the 10 smallest usage day divided by the average usage of the 10 largest usage day	Based on OFGEM, but the maximum usage is replaced by the technically available maximum capacity	It only considers storage working gas capacity
Max - Average	(Average(10 max) - Average(10 min))/Average(10 max)	(max technical - average(10 min))/ average(10 max)	Technical mobil gas capacity

Source: Competition Commission (2003), Ofgem (2007), REKK: Szolnoki (2008b), E-Control (2015)

These methods are broadly similar: for the determination of physical daily flexibility the range of the maximum and the mean or the maximum and the minimum is applied. While in general this definition is appropriate, in the case of the different supply infrastructures, I suggest the customization of these general formulae according to the circumstances as follows:

- **In the case of storage**, for example, it is not advisable to apply the max-min formula annually, as there is injection in the summer and withdrawal in the winter. It is preferable to examine the winter / summer season separately and to consider the maximum technical withdrawal / injection potential instead of the maximum values of past utilization, since in case of storage the technical capacities are actually available for use. Furthermore, I think it is better to look at the range of maximum potential compared to the average usage, instead of the minimum, either at a weekly, or at a monthly level, or for the full season, as there is a continuous withdrawal / injection level associated with seasonal storage activity. This seasonal storage activity uses a significant part of the storage capacity so only the remaining part can be used for daily flexibility provision. To estimate this seasonal flexibility part, I recommend the average usage rate as I think it reflects it better than the minimum in the max-min formula. In case of the minimum usage I think it is more likely that some capacity will be wrongly

accounted as available for daily flexibility that is actually in use to provide seasonal flexibility.

- **In case of domestic production**, as the flexibility of the production of the fields is technology-dependent, it is worth to analyze the flexibility potential of production along this technology aspect. In case of flexibly producible fields, the part between the technological minimum and maximum can really be considered as available flexibility. Compared to this, in the case of technologically inflexible production, fluctuations experienced in the past are mostly caused by technical problems rather than being reactions to commercial flexibility needs. Changing the level of production of these fields is not really a commercial decision. Therefore, taking account of past minimum production levels might distort the picture: e.g. we would draw conclusions on commercial flexibility potential from technical outages. For this, in case of these inflexible fields I suggest that instead of the minimum usage level, the average usage level (weekly / monthly / year) should be compared with the maximum production flow.
- **In the case of interconnection capacities**, similarly to the storage case, it may also be possible that a part of the technical capacity is used to supply seasonal flexibility and thus is no longer available to satisfy the daily flexibility need. Therefore, the difference between the maximum technical capacity and the average usage of the season can be a more realistic measure.
- As **LNG** shipments typically arrive under long-term contracts, for daily flexibility only the excess capacity is considered accessible, so again the difference between the maximum withdrawal capacity and the average usage rate for the period is recommended.
- **Interruptible consumers** are a special case compared to the previous categories. Typically, based on technological conditions, the daily interruptible capacity is contractually stipulated, which may, however, differ from the actual interruptible rate. The assessment of this supply source of flexibility requires individual examinations, it is not uniform in the markets, and therefore some of the literature do not consider them to be taken into account. Estimations that leave this category out are therefore considered to be conservative estimations for the supply of daily flexibility.

Commercial potential

The above methods can be used to estimate the physical daily flexibility potential of a gas system. They provide a frame for the **commercial potential** of daily flexibility. By examining commercial potential, by looking at contractual relationships and opportunities, we can now get an idea of the level of competition on the supply side of the flexibility market. In this case, the previously established daily flexibility capacities are grouped according to which players have control over them.

- **In the case of storage facilities and LNG**, the question is whether someone has a long-term contract over the capacities or in the form of regulated third-party access anyone can bid for these capacities – in this latter case, this capacity is considered as competitive.
- **In the case of an import interconnection**, similarly, capacity rights should be considered, whether there are privileged rights or that everyone has equal access to the capacity. In addition, it is also necessary to analyze separately whether neighboring markets via the cross-border line are available for purchasing daily natural gas, that is, is there a liquid spot market available, from which daily flexibility can be imported. If it is not possible and import is accessible only under a long-term contract, the import capacities are in practice under the control of the player who has a long-term contract and import flexibility is only available to the degree provided by that long-term contract, i.e. not the physical capacity is the effective limit.
- **In the case of production**, the way in which a production is sold determines the commercial setting of its related flexibility: if it is sold through an auction, it can be regarded as competitive, in the context of a long-term contract, the contract holder has also the control over the production's flexibility.

Based on the above, the market shares of the major players and the competitive part can be determined and by simply analyzing the supply side a first view on the concentratedness of the market can be gained. Its main tool, as described in the article by Newberry et al. (2005) which summarizes the basics of energy market analysis, is the

examination of the market shares of the largest players and the calculation of the HHI index measuring the concentration of the entire market.

However, the supply side analysis is not enough to evaluate the physical and commercial potential, it is also necessary to assess the demand for daily flexibility.

IV.2.2. Demand for daily flexibility

The storage market analysis literature does not examine in detail the demand for flexibility. There is an analysis in a Frontier Economics study prepared for the Danish energy regulatory authority (DTe) where they analyze the wholesale flexibility market, and for the demand side of the flexibility market they define indicators similar to those described previously for the supply-side: the range of maximum and minimum consumption and the range of maximum and average consumption (Frontier Economics 2005 and 2008).

Compared to this, here I suggest a different method. To define a suitable indicator, it should be considered where the need for flexibility really comes from. Demand for daily flexibility is mainly due to the fact that natural gas consumption differs from day to day. Therefore, the daily requirement for flexibility is clearly dependent on the previous day's consumption level. For assessing the demand for daily flexibility, in my opinion, the change in the consumption of natural gas from day to day is a better description than the difference between the minimum and maximum annual consumption. Furthermore, if we are thinking about the portfolio management activity of traders, daily demand for flexibility may also be reflected in the difference between the average weekly consumption and daily consumption, as traders refine their products with their longer-term contracts with weekly products: they plan average consumption for a week, correction is done on a daily basis, with the use of daily flexibility tools. Therefore, I propose to estimate the demand for daily flexibility by the following two indicators:

- Daily consumption change and its distribution over a year
- Difference between the daily consumption and weekly average and its distribution over a year

IV.2.3. Answer to the first question

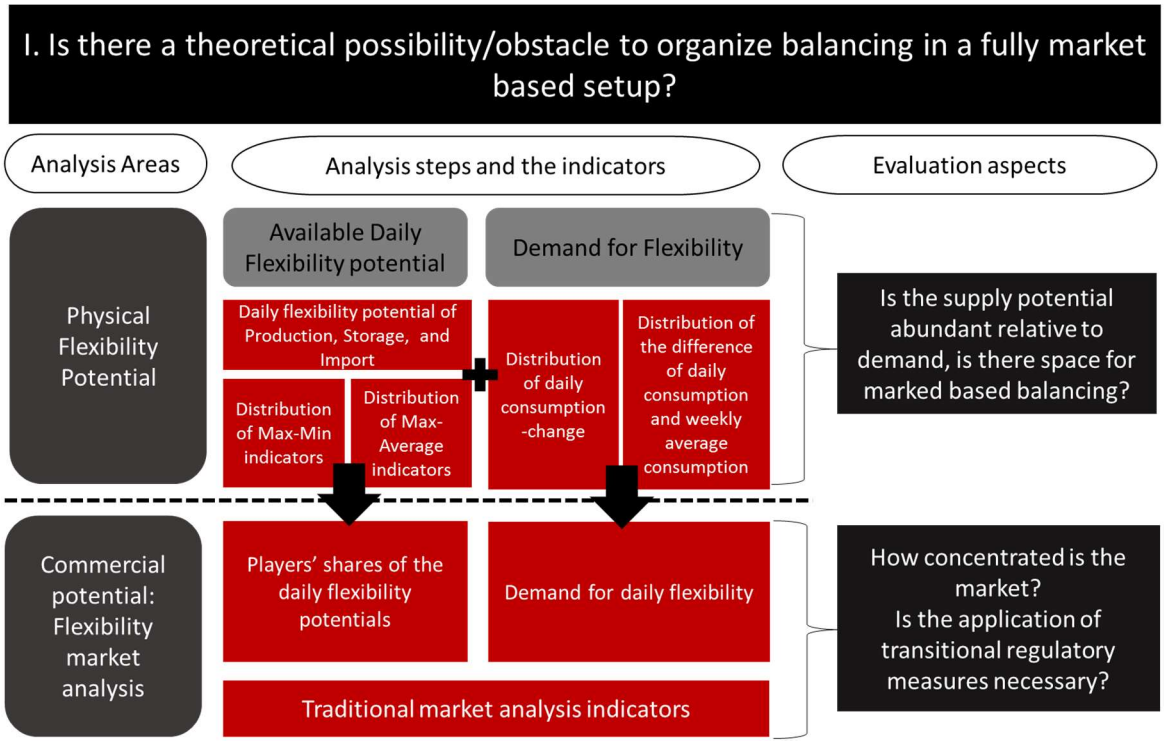
The starting point is whether there is a physical or commercial fundamental obstacle to the introduction of a market-based balancing system. To answer the **first subquestion**, I proposed examining the flexibility market. **If the demand for daily flexibility is well below the physical system's daily flexibility supply potential, then in theory there is a possibility for introducing a market-based balancing system.** If supply only exceeds demand with a minimum amount, the likelihood that a market-based balancing system could well function is low also in the long run.

The **second subquestion** concerns commercial fundamentals, i.e. **whether under the current market structure can market based balancing be introduced**. To answer this question, I have suggested to examine the **market structure of the daily supply potential**, whether there are players with exclusive rights over part of the capacities and, if so, how concentrated is the distribution of the flexibility capacities between these players. This needs to be looked at also in consideration of the demand side, by looking at whether there are any players without which the supply of the daily flexibility need is impossible, whether there are players with significant market power. Since this analysis is quite similar to a general market analysis, I do not discuss here the practical way of performing such analysis, Newberry's (2005) article covers this in a comprehensive manner, while it is not in the focus of this dissertation.

If based on the analysis of physical fundamentals there is room for market-based balancing, however, according to the results of the commercial analysis – i.e. the flexibility market analysis – significant market power is present and new entrants still need support, then the elements of the transitional balancing market regulatory tools outlined in Section III.2. should be applied and tailored to the given situation. By using these transitional regulatory tools, the system must be guided through towards the market-based balancing system.

Figure 9 below summarizes the procedure of the analysis of the first question of the methodology: the fields of analysis, the method of analysis including the indicators and, finally, the aspects of evaluation.

Figure 9: The first part of the balancing system analysis methodology



Source: Own figure

IV.2.4. Practical application of the methodology

The practical applicability of the analysis of physical flexibility potential presented above is illustrated by the daily flexibility market analysis of the Croatian gas market.[42] Due to the constraints on the length of this dissertation the details of the analysis are provided in Appendix VI.

Based on daily Entry-Exit transmission point data I have calculated the indicators presented above on time series of several years. As a result of this analysis, the supply potential and the demand distribution of the Croatian natural gas daily flexibility market were generated. By comparing the two, it is possible to see how much the Croatian market is scarce or how much it is abundant in respect of daily flexibility. As shown in Table 3 below, interconnection points have a key role in winter when storage capacities are used extensively. The daily flexibility market itself is, however, abundant: on the one hand,

[42] The Croatian flexibility potential analysis is based on the analysis presented in Appendix IV-VI of my paper submitted for the ERRA Regulatory Research Award (Szolnoki, 2017), its content has been slightly modified.

the minimum potential is sufficient to serve the maximum flexibility need; on the other hand, flexibility requirements can be covered 10-fold in the two-thirds of cases with the available flexibility tools. That is, due to the interconnection capacities and the storage, there is no scarcity on the daily flexibility market, and **Croatia has good fundamentals to introduce market-based balancing**.

Table 3: The comparison of supply and demand for daily flexibility

Distribution of the Daily Flexibility Supply Potential, MWh						Distribution of Daily Flexibility Demand, MWh	
	Withdrawal /Injection	Production	HU>CR	SI>CR	Total		
min	16570 / 15686	68	46 943	718	63 416 / 64 300	min	3
D10	36577 / 17371	168	64 770	5 948		D10	514
Q1	45490 / 22731	258	67 044	10 224	100 258 / 123 017	Q1	1 328
Median	54646 / 32526	385	67 909	16 787		Median	3 124
Average	50336 / 29904	816	66 814	16 837		Average	5 086
Q3	58515 / 37675	700	69 113	23 416		Q3	7 073
D90	63772 / 38719	1 696	69 120	27 713		D90	11 741
max	63772 / 38719	9 403	69 120	33 596		max	61 407

Source: Own calculations based on transmission Entry-Exit point data from Plinacro (2017)

By this, for the case of Croatia we received the answer to the first subquestion of the methodology. Regardless of the current balancing regulation in Croatia, based on the relationship between the need for daily flexibility and the physical supply potential of daily flexibility, it can be concluded that there is no fundamental obstacle to implement a market based balancing system.

The second step, the examination of what market structure is present on this daily flexibility market, is not analyzed in practice here, as the general market analysis is not the main focus of this dissertation. Instead, in the next section, I turn to the second stage of the methodology, the efficiency analysis of the balancing systems.

IV.3. Definition of the efficiency of the balancing system

The building of a methodology for assessing the efficiency of the balancing system – in my opinion – should be started by defining what we mean under an effective balancing system. Then it becomes possible to deduce from the definition which areas to analyze and then choose which indicators may be useful for measuring efficiency and how it is sensible to evaluate the values of the indicators.

The overall aim of gas market regulation is to achieve effective gas market competition. In Section II.1. I discussed the definition difficulties of this effective competition objective. From the solutions of the literature, I found the proposal of Littlechild (2011) – elimination of excess profits, discovering more efficient methods of production, and the exploration of consumers' needs – to be a good guideline. This definition cannot be directly transposed to the balancing system, but to its analogy in the following I use a theoretical model to define what can be considered as an effective balancing regime.

In the literature so far, the explicit definition of an effective balancing system has not been given. From the academic articles, Dickx (2014) and his co-authors setup a theoretical example that the co-authors, Miriello and Polo (2015) later used to illustrate how a liquid hub can evolve from the balancing platform.

I will use Dickx et al.'s example in another dimension, I will use it for the definition of the effective balancing system, and as will be seen, starting out from this example even the efficiency of the short-term wholesale market can be assessed, which can be an important contribution to the current wholesale market liquidity analyzes literature as well.

Theoretical example[43]

In the example, Dickxs presents the problem of balancing in a simplified market where four identical consumers are supplied through four separate retail contracts. Behind the retail contracts, there are upstream agreements. The authors demonstrate the effects of the

[43] This part contains the II.2.1. point of my article prepared for the ERRA Regulatory Research Award (Szolnoki, 2017) with minor modifications.

market structure on the balancing task through the shocks in consumption. Consequently, consumption demand (D) is described by a predictable (d) and an unpredictable random shock component (Ɛ):

$$D_i = d + \varepsilon_i$$

The shock is a variable with uniform distribution and zero mean (iid). The standard error is $\sigma_\varepsilon = \varepsilon/4$. The upstream supply is contracted to cover the planned part (d) of consumption, so up front the offtakes (i.e. consumption) and inputs (the upstream supply side) are in balance, there is no balancing task. Compared to this, shocks (both positive and negative) result in imbalances for the different consumers. A few possible examples of shock distributions among the consumers are presented in Table 4. As can be seen, if the consumers' imbalances are in the opposite direction, they can partially offset one another, i.e. the overall imbalance of the system will be less than the sum of the absolute value of imbalances of consumers, except for extreme cases. Thus, the part that is in the opposite direction, by the matching of these imbalances – called Internal Adjustment by the authors – can be solved without having to call for additional upstream services into the system. Aggregate Imbalance is the part of the imbalance that cannot be solved by Internal Adjustment, which requires the involvement of upstream service providers.

Table 4: Possible distribution of shocks among consumers and the division of balancing need

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

The phenomenon of Internal Adjustment has a significant role in the liquidity-enhancing effect of transferring balancing activity to the wholesale market. This is illustrated by the following example: If three of the four hypothetical consumers consume less than the projected, with -ε / 4 each, and one consumer on the contrary consumes more with ε / 4 then using the Internal Adjustment possibilities – only -ε/2 extra flexibility are needed from the upstream side to balance the system. If Internal Adjustment does not work, the coordination among retailers is poor, despite that it could be solved within the system, the fourth consumer will still have to buy extra sources from the upstream to solve its individual imbalance.

The simple example of Dickx and his co-authors points out **how important role coordination plays in the balancing process**. However, the nature of the coordination depends largely on the structure of the market. In case of a vertically integrated, monopoly provider before liberalization, for example, all four consumers are supplied by the same company, so individual imbalances add up at organizational level, Internal Adjustment happens through the rearrangement within the portfolio and the company only faces the Aggregate Imbalance need.

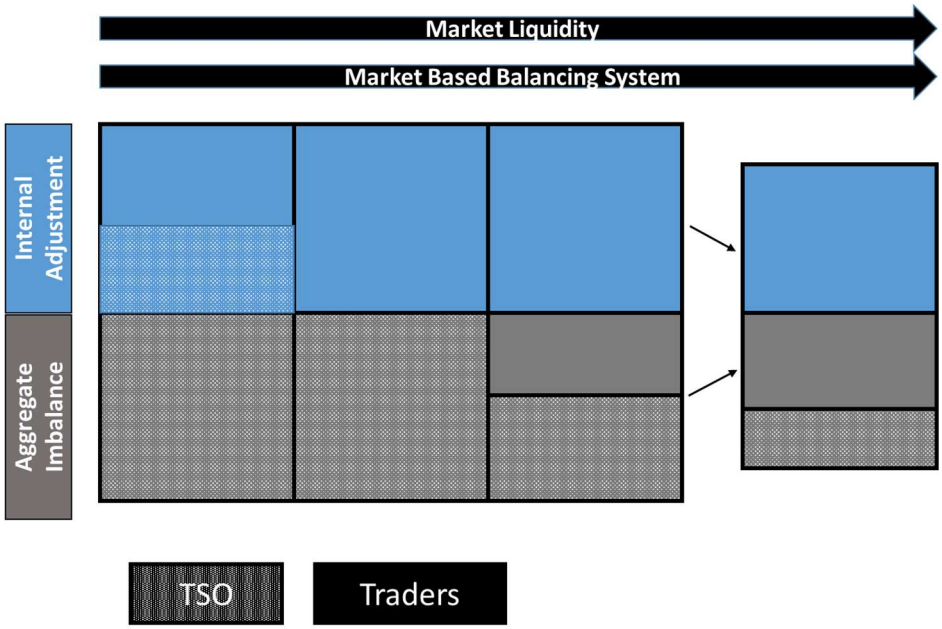
In the case of a liberalized market, however, every consumer contract with different suppliers, so the Internal Adjustment process is realized through commercial transactions. **In a competitive market, therefore, the means of coordinating imbalances that can be resolved through Internal Adjustment can be the spot market. Market efficiency can be interpreted here as the more liquid the market, the better it coordinates the opposite sign imbalances that can be resolved through the Internal Adjustment and the less the traders will use upstream services beyond the Aggregate Imbalance.** Managing Aggregate Imbalance is mainly the task of the system operator. However, if the spot market is not effective, part of the Internal Adjustment will remain to the system operator to be solved, which then settles these otherwise ex-ante solvable amounts with the traders, purchases the surpluses and sells it to those in shortage. In fact, the system operator only uses external sources for balancing to the extent of the Aggregate Imbalance, but the ex post coordination of the Internal Adjustment and settlement with the traders remains.

Defining efficiency[44]

Dickx et al. did not use their example for concrete analyzes, instead applied it only for the theoretical discussion of the coordination task of balancing.

In the following, I use this Internal Adjustment and Aggregate Imbalance division to describe the development path of the balancing system: how a recently opened, immature market develops into a fully market-based balancing system. By this I define what can be meant by an effective balancing system, what is the goal that European regulation wants to achieve.

Figure 10: Development of the balancing systems



Source: Own figure, Szolnoki (2017), p. 7.

- In the initial phase of market development, the lack of transparency and scarcity of trading opportunities leads to that some of the Internal Adjustment possibilities, which could be adjusted between traders, remains for the system operator. In addition, the Aggregate Imbalance is settled exclusively by the TSO.
- With the development of spot markets, trading platforms evolve that are able to coordinate Internal Adjustments, so less and less Internal Adjustments are left to the TSO to be solved, and its main task is to handle Aggregate Imbalance.

[44] This part contains the II.2.2. point of my article prepared for the ERRA Regulatory Research Award (Szolnoki, 2017) with modifications.

- The organization of balancing on market bases and the associated additional services, such as renomination opportunities and information provision, the possibilities of traders increase and thus they not only coordinate Internal Adjustment, but the traders themselves become the primary responsible for balancing and they also resolve part of the Aggregate Imbalance. This minimizes the task of the system operator in the balancing process, and what more the TSO in its residual balancing activity also purchases from the traders in the spot market.
- Finally, by involving traders more in the balancing process, and by providing them better quality information more frequently, the market-based incentive system encourages them to better planning and more effective solutions, this way the overall balancing need of the system decreases.

The model demonstrates the development of the efficiency of the balancing system through the transposition of the responsibilities and engagement in the resolving of the Internal Adjustment and the Aggregate Imbalance between the TSO and system users. To sum up, the definition I propose for the effective balancing system is the following:

In an efficient balancing system, the Internal Adjustment options that are left unsolved by traders are decreasing, while some of the Aggregate Imbalances are also resolved through the ex-ante balancing of traders, so the residual imbalance that remains to the TSO is also decreasing. In addition, through the efficient operation of the incentive mechanism (the imbalance settlement system) and the high-quality information provided by the system operator, the portfolio planning of traders also improves, so the initial Aggregate Imbalance and Internal Adjustment amounts are also reduced.

Additionally, the success / failure of matching opposite sign imbalances (i.e. potential Internal Adjustments) between traders reflects also the effectiveness of the short-term wholesale market as it shows how successful is the market in its main role: in coordinating matching needs.

Directions for analysis derived from the efficiency definition

From the above definition of efficiency now we can deduce which areas to look at and how. My suggestion is that for the analysis of the level of development of the balancing system we should focus on examining the Internal Adjustment and the Aggregate Imbalance and the distribution of the resolving of these between the TSO and traders.

To determine how a balancing system has developed as a result of the introduced regulatory measures and how effective it is today, I suggest the analysis of the followings:

- **The evolution of the balancing need (is there a downward trend)**
    - **Total Balancing Requirement**
    - **Aggregate Imbalance**
- **The degree of imbalance resolved by traders (is there an upward trend):**
    - **Compared to total imbalance**
    - **Within the Aggregate Imbalance**
- **The evolution of the Internal Adjustment unresolved by traders (is there a downward trend).**

IV.4. Indicators of the efficiency of the balancing system

Now, to the analysis areas derived from the efficiency definition specific indicators have to be assigned. Defining indicators is a special task: it needs to be determined which data can really describe the area of investigation. As I will show below, in many cases this is not so evident.

Below I will first introduce and evaluate the indicators that have emerged in the literature so far, and then define my own indicators related to the analysis areas derived from the efficiency definition.

IV.4.1. Indicators of previous literature

The CEPA study

In the already mentioned consultancy study prepared by CEPA for ACER, CEPA, on the one hand, discusses how to measure the impact of the introduction of pan-European network codes on general objectives of the European regulation (the so-called "high-level objectives" such as market integration, non-discrimination, effective competition, and effective market operation), and the second dimension is how to measure the progress in the specific areas targeted by the NCs.

To measure the achievement of high level public policy goals, CEPA also translated these goals into concrete phenomena, namely, what exactly the realization of these goals means in the natural gas market. Then, in the examination of the concrete NCs, they linked how the NC intends to achieve the given high-level goal, and then also ranked the area-specific goals.

According to CEPA's recommendations, the following indicators should be used to measure the efficiency of the BAL NC both in achieving high-level goals and achieving area-specific goals (Table 5):

Table 5: The indicators proposed by the CEPA study to measure the effects of BAL NC's introduction

Aims		Indicators
High-level policy goals	Transparent and non-discriminatory balancing mechanism	Publication frequency towards shippers
		Total balancing procured by TSO via market-based mechanisms as a % of total balancing requirement
		Market participant surveys on their perception with respect to: Transparency in the development of balancing charges; Transparency and non-discrimination in the balancing mechanism; Incentives for TSOs to balance through market
	Effective competition and effective operation: Increased liquidity and competitiveness	Total volume of trades involving TSO and all other non-TSO participants
		Number of registered participants
		Number of independent participants (i.e., not in the same holding)
		Number of active participants (i.e. those who have conducted at least one trade in the last 12 m
		Churn rate: volumes traded relative to the final consumption
		Quantity traded (in absolute terms, relative to local demand, and relative to local demand + transit flows)
		Order book volume (total of bids and offers at a given point in time)
		Increase in within-day cross-border flows (year-on-year % increase)
BAL NC specific goals	TSO performs residual balancing	Total balancing procured by the TSO as % of total daily balancing requirement (TSO balancing actions + shipper-procured balancing on Trading Platform and OTC + exercise of physical flexibility)
		Neutrality charge for balancing for each TSO (daily, short- and long-term) broken down into constituent parts
	Shippers perform primary balancing	Total balancing procured by non-TSO participants as a % of total balancing requirement
		Total balancing procured by non-TSO participants to manage within day obligations
	TSO contracts on a short term	Total balancing services procured by the TSO under long-term contracts as % of total balancing volume procured by the TSO

Source: BAL NC related part of the CEPA (2015) Table 5.7., with minor abbreviations, and the first column is own addition the second column is complemented in some of the rows

CEPA indicators for BAL NC

First, focusing on area-specific indicators, CEPA's proposal was to examine the following indicators:

- BAL.1: Proportion of TSO balancing through short-term standardized products vs. balancing services contracts
- BAL.2: TSO's share of total balancing
- BAL.3: Day-on-day changes of linepack
- BAL.4: Neutrality analysis: the TSO's revenues and expenses from the imbalance settlement, and the balance of the revenues and expenses of the residual activity.

As can be seen, CEPA indicators are designed to assess the implementation of one-one specific requirement of BAL NC rather than to assess directly the efficiency of the balancing system.

- The **BAL.1** indicator is to check the achievement of the BAL NC requirement that the TSO should acquire its purchases as much as possible through short-term standardized products and on trading platforms.
    - To calculate the indicator, on the one hand, data on the TSO's framework balancing service contracts and the calls within it should be provided – CEPA recommends that ACER should ask for these from each Member State – and on the other hand, the TSO's platform purchases have to be separated from the traders' platform transactions. The latter is simpler if the TSO acquires only on a balancing platform, but once it has begun to pursue the final goal of the BAL NC and trades through a trading platform, the CEPA study suggests that these trades must be individually sorted out from the other trading platform transactions. In principle, all trading data are available to ACER throughout Europe in the REMIT database, the setting up of which and the related data provision rules were mandated by the transparency regulation for the energy sector.[45] However, it is still quite complicated to produce this indicator. In summary, certain data is not available even to ACER for this indicator, and others are complex to produce, furthermore to actors other than ACER, such as national regulatory authorities and researchers, the basic data needed to compute this indicator are unavailable.
- The **BAL.2** indicator addresses the question – that I also identified as an area to be analyzed – whether traders are really starting to take greater part in balancing as required by BAL NC.
    - The main challenge for calculating the indicator is the identification of balancing trades. How can you find out about any trading transaction whether it was with a balancing purpose or not? CEPA proposes the following definition for balancing trading:
        - the delivery is on a given gas day D,
        - the transaction takes place after 13:00 D-1, i.e. after the nomination deadline
        - physical settlement

[45] Regulation (EU) No 1227/2011 of the European Parliament and of the Council of 25 October 2011 on wholesale energy market integrity and transparency.

- CEPA recommends that ACER collects from the REMIT database all trade transactions with such characteristics by balancing zone. Additionally, the TSO procurement data already discussed at the previous indicator are also required for the calculation of this index.

As can be seen, these CEPA indicators in theory are well-defined, with them the concrete requirements set by the BAL NC – so not directly the efficiency of the system – could be measured in theory, but in practice, as we will see, the production of these indices is cumbersome or even impossible in the form defined by CEPA.

- The **BAL.3** indicator calculates the daily change of the linepack. It is related to the BAL NC requirement, that linepack should be used only to the extent necessary by the system operator, balancing the system is primarily the task of traders by balancing their own portfolio. Therefore, according to CEPA, if the value of the linepack does not differ significantly every day measured at the same time, the BAL NC goal is met. This, in my opinion, is a correct view. If the linepack does not change at the end of the day compared to the previous day's level, then in the daily balancing system this means that traders through the imbalance settlement system pay and settle their imbalances.
    - Unfortunately, the availability of linepack data is also limited, there is no mandatory requirement for its publication, and only some system operators publish them voluntarily. CEPA also notes that these data should be requested individually from the system operators.
- Finally, **BAL.4** indicator checks the compliance with the BAL NC requirement that the TSO must not have financial interest in conducting its balancing activity and the imbalance settlement system does not include distortive incentives for traders. This indicator is important, it enables to check if there are any distortions in the imbalance settlement, but this indicator also does not say more about the efficiency of the balancing system.

CEPA's indicators to measure the achievement of high-level policy goals

Among the indicators on achieving high-level goals (Table 5), the indicators of transparency and non-discrimination also refer to the check of the fulfillment of the specific requirements, i.e. how often information is provided, how much TSO acquires the products needed to balance the system on a transparent platform (also in BAL.1), how the system users themselves find the system transparent and non-discriminative. The measurement of these is relatively straightforward, but these do not directly measure the effectiveness of the system, but their success is at the end integrated into the efficiency of market operation and the efficiency of competition.

For the latter, CEPA suggests structural indicators (such as the measurement of the number of participants in various ways) and performance indicators (such as liquidity measurement indicators, e.g. trading volumes, churn rates) (see Table 5). These indicators were all discussed in the literature review of this dissertation in Section II.3. The problem with these indicators is that publicly it can be calculated for only a few countries, and with limited content. Another problem is that since these are general gas market indicators it is not possible to separate the impact of the change in the balancing system from the impact of other changes on the gas market. The indicators are not linked to balancing.

After the criticism, it is important to point out that the CEPA study was a very important step in the literature on efficiency analysis of energy market regulation.

The ACER Analysis Framework

The ACER 2016 report (ACER, 2016) did not yet publish any balancing system analysis, just referred to the CEPA study, mentioning that for the time being the necessary data is being acquired and it will publish a comprehensive impact analysis in the next year's report (ACER, 2016 p. 14).

In the second ACER report released on 16 November 2017 (ACER, 2017), the analysis of the impacts of BAL NC implementation has really started. The Agency has begun to set up a balancing analytical framework specifically with a view to evaluating and periodically reviewing the efficiency of the balancing regimes of each Member State. As

they emphasize, the goal is to setup such analytical framework that is flexible enough to be applicable to the balancing system of all Member States and can therefore be used for cross-country comparisons as well. In this report ACER has launched this framework by defining some of the indicators.

The current analysis framework focuses on four areas. (It is interesting that there is no reference to the CEPA study in this report.) The examined areas and the indicators used are the following (ACER, 2017):

Residual balancing activity of the TSO

- The daily volumes of TSO's buy and sell activity for system balancing, and its statistics:
    - On how many days was the TSO buying / selling
    - Average, maximum and yearly total volumes per direction
    - Yearly average price per direction
    - The ratio of the yearly sum quantities of the two directions
    - The ratio of the annual volume and the total Entry gas flow per direction

These indicators are useful for detecting distortions, for example, that balancing of the system is always necessary only in one direction or whether, for example, the balancing activity of the TSO is relatively high in relation to the overall natural gas flow (so it can be considered as a distant proxy estimate for that the TSO's activity is really residual or not). ACER has drawn such type of conclusions when evaluating these indicators in the Member States.

Data of the Imbalance Settlement System

- The imbalance quantities of the system users aggregated per direction and its statistics:
    - Average, minimum, maximum, and yearly totals per direction
    - Yearly average imbalance settlement price per direction
    - The ratio of the aggregated quantities of the two directions
    - The ratio of the annual volume and the total Entry gas flow per direction
- As ACER says, this analysis can be used to identify the pattern of system users' imbalances. Thus, this analysis is also for identifying the distortions.

Neutrality analysis

This analysis coincides with CEPA BAL.4. One of the key points of BAL NC is the requirement of neutrality, i.e. that the TSO cannot be financially interested in balancing activities and does not distort the system for its own benefit. The main tool for realizing neutrality is the neutrality account, where it should be accounted for separately on monthly level the balance of sales and purchase transactions related to the residual balancing of the TSO and the balance of its buying and selling activity during imbalance settlement.

In its analysis ACER examines the neutrality account, compares revenues and expenses, and examines their evolution in time. This method is again suitable for the identifying of distortions.

Comparison of the changes in linepack and the overall commercial imbalance

This indicator can be considered as a further development of CEPA's BAL.3 indicator, which only analyzed the changes in the linepack level. The indicator is based on the assumption that the sum of the net imbalance of system users and the net balancing activity of the TSO, i.e. the total commercial imbalance, must coincide with the daily physical linepack change. Therefore, these two indicators are compared at a daily level. If there is no match, then it could be due to one of the elements of the balancing regime (for example, because of the estimation and allocation model for non-daily metered consumers), while in the worst case it indicates a distortion in the balancing system.

As it can be seen, ACER revised the CEPA indicators, it modified some, and there are some that ACER did not include in its analysis framework at all. The primary reason behind this is probably that the CEPA indicators required such data, for example all short-term market transactions, that are not even available to ACER. Thus, the BAL.1 indicator, which compares the short-term purchases of the TSO to its full procurement, and the BAL.2 indicator, which compares the balancing activity of TSO with all (including system users') balancing activities, are not included in the analysis framework. Instead, ACER looks at TSO's daily procurement, its symmetry, distribution, and magnitude compared to the total Entry gas flow, which can be considered as a very distant proxy of BAL.2. It does not examine the ex-ante balancing activity of system users, instead, it

analyzes the system users' aggregate ex post imbalances, again symmetry, distribution, and its ratio in relation to the entire market. The neutrality analysis, however, is exactly the same as that of CEPA BAL.4, while the comparison of linepack change and commercial imbalance is a reconsideration of the BAL.3 indicator.

ACER has thus started to analyze the balancing systems in practice. It is not only looking at whether Member States have complied with the different requirements of BAL NC any more, but it aims to analyze the efficiency of the balancing systems as a whole.

The framework defined by ACER lays down some new indicators, but these are mostly suitable for detecting distortions in the balancing system. There is no theoretical framework and the comprehensive assessment of effectiveness is not carried out.

The lack of data may be a reason why there is no deeper evaluation, however, as I will show it in the following sections, the same imbalance settlement data that ACER used can be utilized to calculate indicators (Internal Adjustment and Aggregate Imbalance) that reveal more about the efficiency of the system than the analysis ACER prepared based on these same data.

In my opinion, the other main reason why it is hard to derive conclusions from ACER's analyses regarding the efficiency of the Member States' balancing systems and also regarding the compliance with BAL NC requirements is that the Agency has investigated too short time series. It analyzed the markets from October 1, 2015 the BAL NC implementation deadline for the first cluster till September 30, 2016. I think this is a false approach. The changes caused by the regulation can be evaluated on a longer time interval: the pre-introduction values, their multi-year tendencies, should be compared with those experienced after the introduction. Examining the extent of TSO balancing in relation to market Entry volume only tells us something about the efficiency development when we see how this ratio has changed over time. Its annual value does not tell this, nor the one-year time series of the daily values.

ENTSOG indicators

ENTSOG in its second monitoring report (ENTSOG, 2016) also produced indicators and gave them a similar name as the CEPA study, but as shown below, the content of some is different than of those of CEPA:

- BAL.1: The ratio of TSO's purchases through short-term products compared to its total purchases for residual balancing
- BAL.2: Ratio of the daily balancing activity of the TSO and the daily Entry gas flow in the system (as a market volume indicator)
- BAL.3: Ratio of the net value of the daily balancing activity of the TSO and the daily Entry gas flow
- BAL.4: Ratio of net imbalance settlement quantity of the system users and the daily Entry gas flow

As can be seen, BAL.1 is practically the same as CEPA's BAL.1, unlike ACER, according to this, ENTSOG possesses the necessary data from their member TSOs to calculate this indicator. BAL.2 is different from the CEPA BAL.2 indicator. ENTSOG's BAL.2 can also be found among the ACER indicators and, as I have already mentioned, it is likely to be used as a distant proxy for CEPA's BAL.2, i.e. they try to approximate the ratio of TSO’s balancing activity within total balancing with an indicator of the TSO’s balancing activity compared to the total daily market volume (Entry gas flow). However, since they are approximating the total balancing demand with the entire market volume, this is a far approximation of this topic I think.

The BAL.3 and BAL.4 indicators are completely different from the CEPA indicators. BAL.3 compares the daily net TSO balancing volume to the entire market volume, as a second proxy for the CEPA BAL.2 indicator. The BAL.4 indicator relates the daily netting of network users’ imbalance settlement quantities also to the total daily market volume. The latter indicator is examined by ENTSOG only when compared to the BAL.3 indicator, whether the system's commercial imbalance and the direction of the TSO interventions are the same or whether there is any distortion. It also investigates whether these ratios are sufficiently low, but what can be considered low, is not defined.

ENTSOG's analysis is thus even more restricted to indicators, it is not a comprehensive framework. In addition, the problem here is also that it only examines the period from October 2015 to September 2016, which again makes it difficult to evaluate the values of the indicators and to draw conclusions on the systems. It is not possible to know what can be considered low and why, when can we say that efficiency improved because of the regulation.

Summary of the Balancing System Analysis literature

The indicators of the three studies presented above and the overlapping of the indicators between the studies are illustrated in Appendix VII.

Overall, these analyses focus on checking whether the Member States' balancing systems comply with the requirements of the BAL NC or not, the indicators are defined accordingly. The CEPA indicators fully met this goal, however, data are not available for the most important indicators – for the balancing need calculation and the one about the relationship between the system operator's balancing and system users' balancing – so in practice ACER and ENTSOG have calculated distant proxies for these.

The four indicators defined by the ENTSOG were also focusing on the fulfillment of the BAL NC requirements and not the overall efficiency of the system. Here, mostly the balancing activity of the TSO was analyzed, its size compared to the system: is it really residual or not. However, since they were not able to estimate what the system's total balancing need was, this question could not be answered clearly. And – in my opinion – there is a further problem with the interpretation of the data: the time series was too short, so it was not possible to look at trends and compare the values before the introduction of the regulation with the post-implementation values. ENTSOG did not strive to analyze the effectiveness of the full balancing system, it only calculated and interpreted the four indicators, compared their values in the different countries. No comprehensive picture and conclusion emerged from the study.

ACER has been striving to build an analytical framework, and the stated goal here was not just to check the compliance with BAL NC requirements, but to perform a time series and cross-country assessment of the efficiency of the balancing systems. They wanted to lay down a methodology applicable to all the Member States. The published analysis

framework, however, is still more of a set of indicators grouped into analyzed areas, than a comprehensive assessment of the balancing system. And again, due to the shortness of the data series, the evaluation of the indicator values is unclear. ACER itself states that this analysis framework is only a first initiative, and in the future it would like to further develop this.

In my opinion, the main shortcoming of these analyses is the absence of theoretical background, the definition of efficiency that we are looking for. Therefore, the evaluation of the indicator values seemed also to be ad hoc, meaningless.

In the previous section, I showed how I define the efficiency of the balancing system and what areas of examinations follow from this definition. Comparing these areas with the areas of analysis proposed by CEPA-ACER-ENTSOG, the share of balancing between the TSO and system users is common, however for this only very remote proxy indicators were calculated by the previous literature, and the Aggregate Imbalance that I intend to analyze coincides with ENTSOG's BAL.4 but I use this indicator differently, and it will have a larger role in my analysis.

I really missed the analysis of the total balancing need mentioned in the CEPA study (only as a denominator in one indicator) from both, the ENTSOG and the ACER indicators. The reason for this absence is most likely that CEPA has defined this with data content that, although theoretically covers the balancing need, is in fact based on data that is not available to neither of the two European organizations (all transactions with physical delivery after 13:00 D-1 for day D). Below I propose an alternative definition for the total balancing need and I suggest analyzing it on its own as an indicator (and not just as a denominator like in the CEPA report).

In addition to these indicators, I also suggest new types of indicators: the Internal Adjustment and Aggregate Imbalance indicators.

Overall, the advantage of my indices, on the one hand, is that these are based on publicly available data and thus anyone can calculate them, on the other hand, they are not only useful for the direct check of compliance with the BAL NC implementation requirements but put altogether these also provide a general picture of the efficiency and development of the balancing system.

Finally, by Internal Adjustment, I propose an indicator that relates balancing with the efficiency of the wholesale gas market, it provides information on its liquidity, and compared to CEPA's market efficiency indicators it can also be used for countries with no transparent market place. And as it relates to the main task of the market, its coordination capability, it provides a more direct insight on the market's effectiveness compared to the structural CEPA indicators.

IV.4.2. Defining new efficiency analysis indicators[46]

In the following, thus based on the theoretical model I define indicators for the subsequent examination areas:

- The evolution of the balancing need (is there a downward trend)
    - Total Balancing Requirement
    - Aggregate Imbalance
- The degree of imbalance resolved by traders (is there an upward trend):
    - Compared to total imbalance
    - Within the Aggregate Imbalance
- The evolution of the Internal Adjustment unresolved by traders (is there a downward trend).

Balancing need

The first step is to define the balancing need (also referred to as balancing requirement).

(The CEPA study used it as the denominator of BAL.2 and defined it as the sum of all short-term transactions for day D that take place after 13:00 D-1 and are physically settled and the balancing service procurement for day D by the TSO). However, this indicator was not calculated possibly because the necessary data was not available to either ACER or ENTSOG, the two organizations approximated the denominator with the total daily

[46] This part contains the III.2. section of my article prepared for the ERRA Regulatory Research Award (Szolnoki, 2017) with modifications.

Entry gas flow, i.e. they approximated the total balancing demand with the total market volume of that gas day.)

In comparison, based on publicly available data, I suggest a closer proxy definition of the balancing need:

Since the balancing problem is mainly related to the stochastic nature of consumption, therefore, I concentrate on consumption data, specifically to the transmission system's consumption Exit points' data, and define the balancing need as the difference between the nominated values of the consumption points and the actual gas flow on these points.

So, I define the balancing need related to a given Exit point as follows:

$$q_{balancing\ need} = q_{gas\ flow} - q_{nomination}$$

This method can provide a good approximation for the balancing need because transactions that take place after the nomination deadline are really very likely to be balancing transactions, traders' portfolio refinements, adjusting those based on new information. It is important to note that this balancing need does not include ex-ante balancing of traders related for that gas day, that took place earlier than the day ahead nomination, thus it captures a part of the total theoretical balancing need.[47]

Separation of TSO's and network users' balancing activities

CEPA's BAL.2 indicator aimed at comparing the balancing performed by the TSO with the balancing activity performed by traders: whether it can be identified that the balancing activity of the TSO begins to decrease, and traders become the primary responsible for balancing. ENTSOG and ACER however were unable to produce this separation.

I suggest the following solution for this. By allowing traders to renominate up to three hours prior to the physical gas flow, that is, they can adjust their portfolios within day, they will take care of some of the above defined balancing need and they will solve it prior to real time. Therefore, I consider the change between nomination and renomination

[47] The CEPA study also focuses on this balancing need part by focusing on trading after 13:00, i.e. it also considers only those transactions that were made after the nomination deadline.

to be the ex-ante balancing activity of traders while the difference between the real consumption gas flow and the renomination values to be the balancing activity of the system operator.

So, per consumption Exit points I define the part of balancing need resolved by traders and the part left for the system operators as follows:

$$q_{trader\ ex\ ante\ balancing} = q_{renomination} - q_{nomination}$$

$$q_{TSO\ balancing} = q_{gas\ flow} - q_{renomination}$$

In summary, from the transmission system's consumption Exit points' nomination, renomination, and gas flow data I create a balancing need indicator, and I separate it into traders' balancing and into TSO's balancing parts.

By the indicators of balancing need now it is possible to see whether the process aimed by regulation has started or not, that traders become increasingly involved in balancing and whether efficiency gains have been achieved, i.e. the total balancing need is reduced or not.

Internal Adjustment and Aggregate Imbalance

Ideally, the calculation of the Internal Adjustment would be based on the changes in the forecasts of traders as the time is approaching real time. However, such data does not exist on the predicted imbalances of traders in different time intervals, there is only ex post imbalance data.

Below I suggest two different proxy indicators for Internal Adjustment:

- **A:** After the end of the gas day the TSO settles the imbalances with each trader. In some countries these settlement data are publicly available in an aggregated form per direction. ENTSOG and ACER also used these data in their analyses. Using ex-post trader imbalance data as a proxy I define Internal Adjustment as part of the daily aggregate shortages and surpluses that overlap, i.e. the part that could have been prevented if traders would have been efficient in exchanging these opposite sign imbalances between each other. Both ACER and ENTSOG could have calculated this indicator from the data available to them.

By method A I define the daily Internal Adjustment with the following formula:

$$q_{Internal\ Adjustment} = \min(\sum_{pos\ imb\ settlement} q\ ;\ |\sum_{neg\ imb\ settlement} q|)$$

- **B:** For countries where the imbalance settlement data are not publicly available I propose another proxy indicator. Above I defined the balancing need based on nomination and gas flow data. The consumption Exit point data are usually available separately for different consumer groups, for example DSO consumers, power plant data, industrial consumer data. By calculating the balancing need separately for these consumer groups and then comparing them with taking into account their directions, the part that overlaps can be an approximation for the Internal Adjustment possibilities.

By Method B, I define the daily Internal Adjustment as follows:

If the balancing need of the two consumption groups has a different direction:

$$q_{Internal\ Adjustment} = \min(\left|q^{Exit\ point_i}_{Balancing\ need}\right|;\ \left|q^{Exit\ point_j}_{Balancing\ need}\right|)$$

If the direction of the balancing need of the two consumption groups is the same: 0

These Internal Adjustment indicators, as shown in the theoretical example, also provide a picture of the liquidity of the spot market: the fewer Internal Adjustment options remain unresolved in the system, the more effectively coordinates the spot wholesale market.

The Aggregate Imbalance indicator can be derived from the above two indicators: while Internal Adjustment represents the overlapping imbalances that could be avoided by simple trading of opposite sign imbalances, the Aggregate Imbalance is the part of imbalances that are beyond that, i.e. that do not overlap.

For method A, I define the daily Aggregate Imbalance as follows:

$$q_{Aggregate\ Imbalance} = \sum_{positive\ imbalance\ settlement} q + \sum_{negative\ imbalance\ settlement} q$$

For method B, I define the daily Aggregate Imbalance as follows:

$$q_{Aggregate\ Imbalance} = q^{Exit\ point_i}_{Balancing\ need} + q^{Exit\ point_j}_{Balancing\ need}$$

In summary, I elaborated my indicators from the nomination/renomination data of system users and actual gas flow data. These indicators that are based on the behavior of traders – as I show below – offer a lot of insight about the balancing activity and the efficiency of the wholesale market. Market analysis performance indicators can be well complemented and in cases when there is no available data for the calculation of the performance indicators (for example, because there is no transparent wholesale platform, etc.) these could be used as second-best solutions to measure the wholesale market's efficiency.

To illustrate how these indicators can be used to assess the efficiency of the balancing system and possibly evaluate the efficiency of the wholesale market, I will perform the calculation of the indicators and the evaluation of the results in the following chapter on three country-cases.

V. EMPIRICAL APPLICATION OF THE METHODOLOGY

In this chapter based on publicly available data of different countries I illustrate how the introduced methodology for analyzing the effectiveness of the balancing system works in practice.

With this empirical chapter I would like to show what insight can this methodology provide on a balancing system.

I find it particularly important to demonstrate how the values of the indicators can be interpreted because I use not only completely new indices but in some cases I use the same data group that the previous literature used, but I define other indicators based on them, and in some cases I even use the same indicators but with another approach, with other interpretations of the values.

First, I will analyze the Croatian balancing system. The analysis of the Croatian daily flexibility market is presented in Appendix VI and was summarized in this dissertation in point IV.2.4. As a result of the analysis I have found that the Croatian balancing system has good fundamentals to the introduction of market-based balancing. I now turn to the evaluation of the performance of the balancing system itself.

After that, I illustrate on Polish market data how the balancing need and the traders' participation in balancing can be analyzed.

Finally, I use Czech data to demonstrate the calculation of Internal Adjustment and Aggregate Imbalance. I show how method **A** of the Internal Adjustment calculation works, while method **B** is illustrated in the Croatian example.

V.1. Efficiency analysis of the Croatian balancing system[48]

Balancing need

First, I look at the evolution of the total balancing need. In order to identify trends, I analyze the time series of the absolute value of balancing need. There are similar trends in the evolution of the daily total balancing need as in the case of the daily flexibility demand were. The balancing need for DSO consumption is about twice as big as the demand for balancing by Largeconsumers.[49] As the nominal consumption of Largeconsumers is only slightly above the consumption of DSO consumers, it also follows that the supply of DSO consumers requires twice as much balancing need as that of Largeconsumers. For DSO consumers the balancing need accounts for ~ 10% of the total gas consumption, while in case of Largeconsumer it is ~5%.

Table 6: Distribution of the absolute value of Croatian daily balancing need, MWh

	Balancing need, MWh		
	DSO consumers	Largeconsumers	Total
min	0	1	3
D10	194	134	253
Q1	503	358	722
Median	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

Source: Own calculation based on End User Exit and DSO Exit nomination and gas flow data for the period January 2014.01-2017.01, from Plinacro (2017)

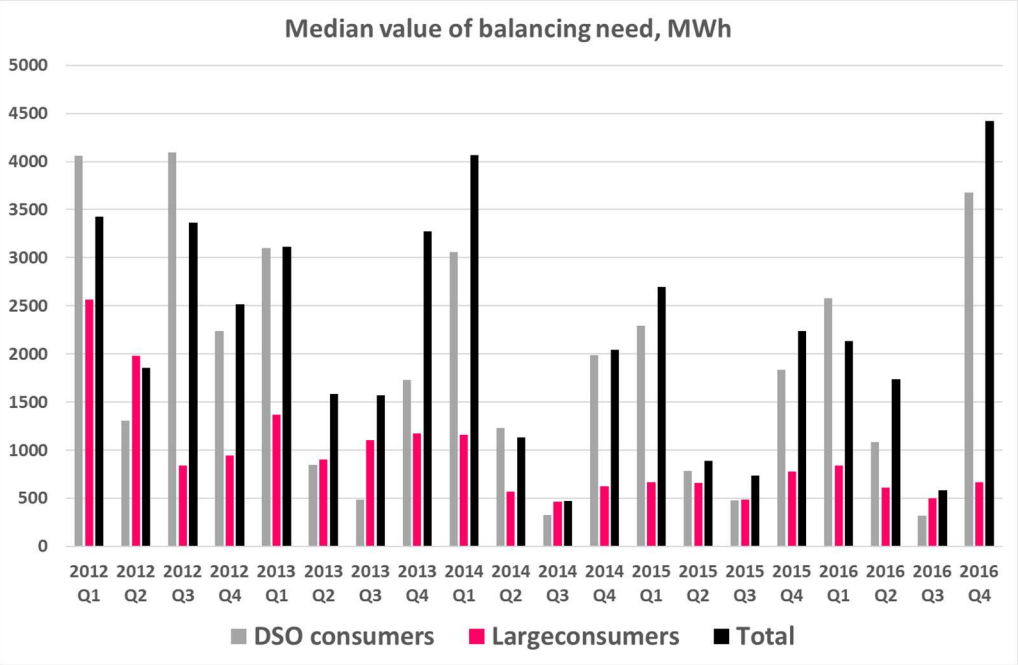
The time series of Figure 11 shows the evolution of the absolute balancing need by its quarterly median values. It can be seen that apart from some extreme periods there are clear trends:

[48] This section contains the III.2. section of my article prepared for the ERRA Regulatory Research Award (Szolnoki, 2017) with minor modifications.

[49] As on the Croatian market the consumption exit point data is broken down into two consumer categories: 1. the consumers with direct connection to the transmission system, and 2. the consumers connected to the DSO networks, I perform my analyzis in this kind of breakdown. Throughout the analysis I refer to the former group as Largeconsumers and the latter as DSO consumers.

- The Largeconsumers' balancing need has decreased over time. According to my efficiency definition I consider this as an efficiency improvement. It could be the result of improved information provision, better forecasting, or the joint outcome of the two.
- In the case of DSO consumers, the downward trend is not that clear. As can be seen, temperature does not only affect consumption, but also the balancing need. From the fact that the balancing needs are bigger in winter it can be concluded that for traders it is harder to predict the small consumers' consumption changes that result from temperature changes than the practically temperature-independent consumption changes in the summer. Overall, efficiency improvement for the time being is not reflected in the evolution of the balancing need of the DSO consumer group. Additional regulatory "support", such as wider roll out of remote metering, increasing the frequency and quality of data provision, etc. may be necessary for achieving improvement.

Figure 11: Evolution of the median absolute balancing need in case of total consumption and different consumer categories, MWh

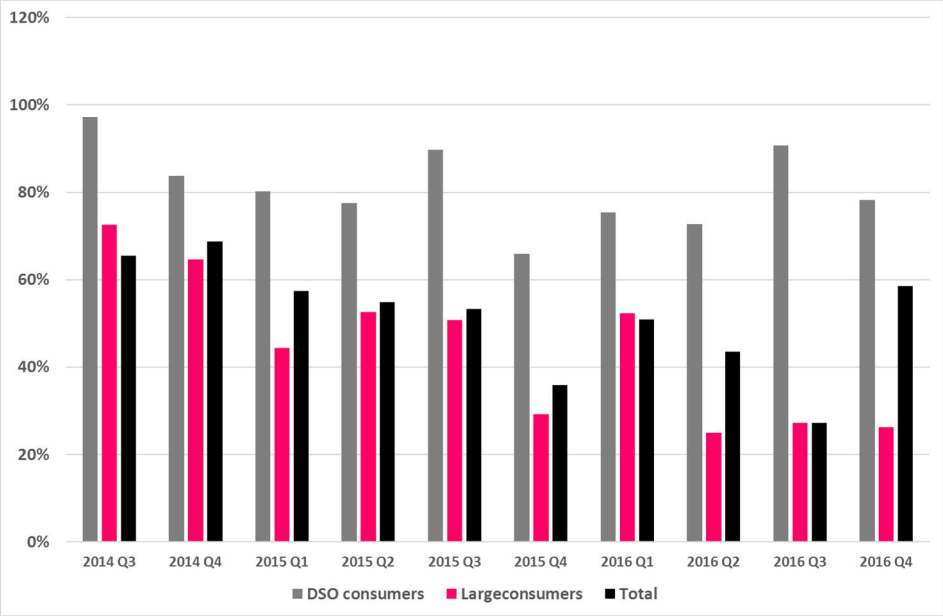


Source: own calculations based on End User Exit and DSO Exit nomination and gas flow data from Plinacro (2017)

Traders' Balancing

Using the separation method introduced in point IV.4.2. that the part of the balancing need that is resolved during renomination is considered as balancing by traders, I will examine below how the traders' participation in the Croatian balancing system evolved over time. Since also in this case I am looking at trends, I worked with absolute values during the calculation.[50]

Figure 12: Ratio of balancing need left to the TSO and the total balancing need



Source: Own calculation based on End User Exit and DSO Exit nomination, renomination and gas flow data from Plinacro (2017)

Figure 12 shows that the ratio of the balancing need left to the TSO in case of the Largeconsumers group has gradually declined and is currently around 30%. On the contrary, DSO consumption does not have this downward trend, the ratio of balancing left to the TSO has remained around 70-80%, which may indicate that this hectic consumption is still difficult for traders to track. Thus, overall, it can be seen that in the case of Largeconsumers the tendency (aimed for by the BAL NC) has started, less and less of the balancing need remains to the TSO as traders ex ante solve the balancing

[50] From the total balancing need I deducted the balancing resolved by the traders during renomination and calculated the ratio of the remaining balancing need left to the TSO and the total balancing need.

problem. In comparison, for DSO consumption it seems that renomination opportunities and the supporting services so far are insufficient for traders to be able to balance this consumer category ex ante. As I have suggested above, the more frequent provision of data with better quality and the broader introduction of remote metering may improve this situation.

Consequently, the following can be stated: in the case of Largeconsumers there was a significant improvement in the efficiency of balancing, the regulatory tools introduced so far were effective. On the one hand, the overall balancing need in this category decreased, on the other hand, traders took the lead in balancing, a smaller and smaller part of the balancing task remains to the system operator. In the case of DSO consumers, however, it seems that there is a need for further 'support' beyond the current instruments.

Finally, it can be said that presumably as traders solve ex ante larger and larger part of the balancing need it has a beneficial effect on the spot wholesale market as well.

By this, I will turn to the examination of the alternative spot market liquidity indicator, the Internal Adjustment.

Internal Adjustment

I calculate the value of Internal Adjustment according to method **B** introduced in point IV.4.2. According to this method Internal Adjustment is the part of the balancing need of the Largeconsumers and DSO consumers that offset one another, i.e. opposite sign of imbalances, and thus, could have been resolved by simple trading. Accordingly, I define Aggregate Imbalance with the excess part, so with the part that would not have been resolved by such a trade.[51]

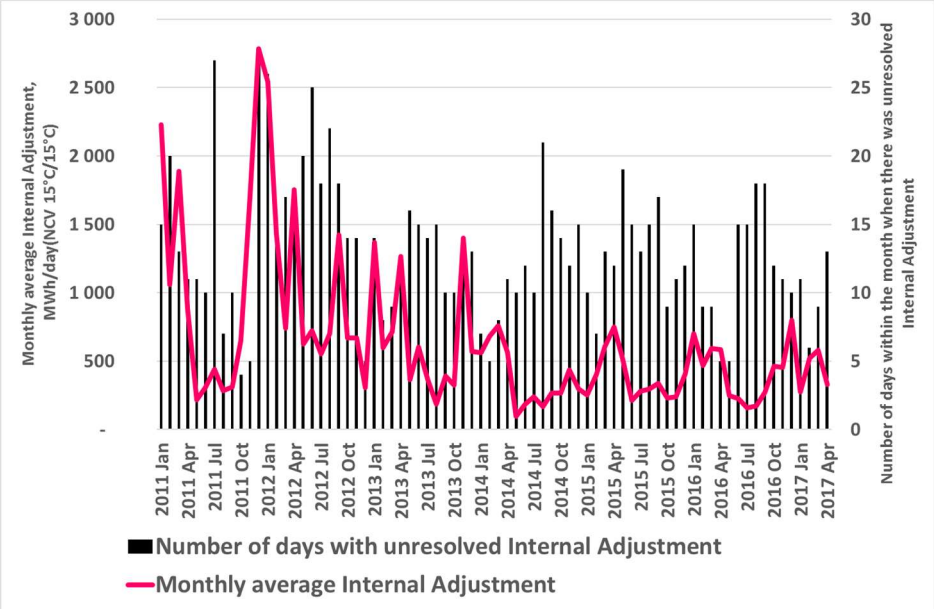
The following Figure 13 thus shows the evolution of the unresolved, i.e. untraded, Internal Adjustment values in two ways: on the one hand, the monthly average[52] Internal Adjustment values (line) and, on the other hand, the number of days within the month

[51] Unfortunately, daily imbalance settlement data is not publicly available for the Croatian market per direction, so for this market I can only calculate this B proxy version of Internal Adjustment.
[52] Monthly median values were 0 in many cases, therefor those would not have been useful to analyse tendencies, therefore, as an exception, I used the arithmetic average here instead of the median.

when there was unresolved Internal Adjustment possibility in the system. Both indicators show a clear trend:

- The unresolved Internal Adjustment options have decreased over time on the Croatian market:
    - The number of days when there was unresolved Internal Adjustment decreased, and
    - The size of the unresolved Internal Adjustments has also decreased, which means that traders were getting better and better in solving these trading possibilities.

Figure 13: The evolution of unresolved Internal Adjustment possibilities

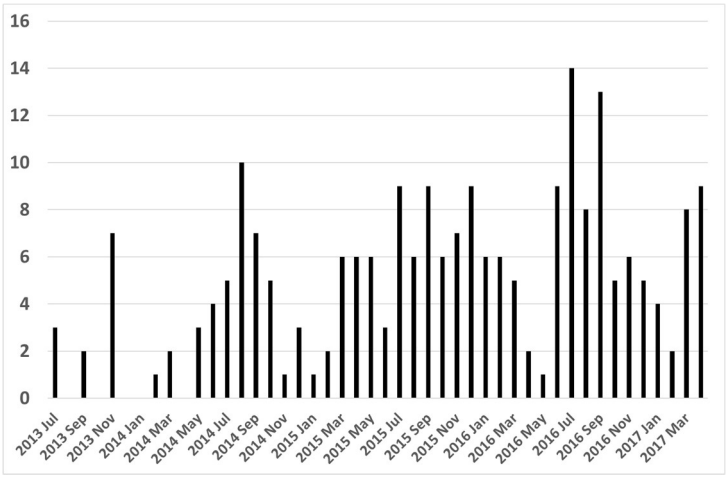


Source: Own calculation based on End User Exit and DSO Exit nomination and gas flow data from Plinacro (2017)

Based on the decrease of unresolved Internal Adjustments it can be said that the co-ordination between traders is getting better, and since the form of this co-ordination is spot trading, therefore the Internal Adjustment reduction experienced on the Croatian market suggests that the spot market is operating increasingly efficiently. From the balancing system data, we can see that the effectiveness of the wholesale market increased.

Further, on this line, it could also be analyzed whether these unresolved Internal Adjustment opportunities have decreased or not during renomination, i.e. whether traders were able to exchange between each other on the intraday market their opposite sign imbalances as they could see their imbalances better closer to real time. For this, I have examined how the number of days in a month evolved when this Internal Adjustment decreased through renomination. As shown in Figure 14, an increasing tendency can be observed. This also indicates the efficiency improvement of the Croatian within-day market.

Figure 14: Number of days in the month when renomination reduced the unresolved Internal Adjustment

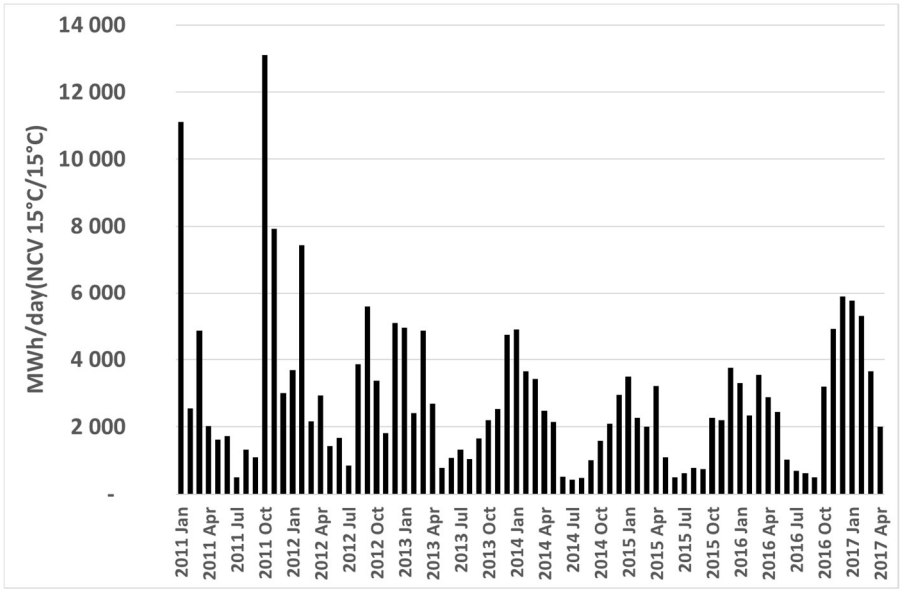


Source: own calculation based on End User Exit and DSO Exit Based on nomination, renomination and gas flow data from Plinacro (2017)

Aggregate Imbalance

Finally, I examine the evolution of Aggregate Imbalance. Aggregate Imbalance shows the physical imbalance of the system. It also reflects how well traders have planned ahead and covered their portfolios. As from the monthly mean values of the absolute value of daily Aggregate Imbalance can be seen, Aggregate Imbalance decreased over time. However, there is a strong temperature dependence, the Aggregate Imbalance is always higher in winter. Overall, the experienced downward trend in Aggregate Imbalance may indicate that traders' forecasting and planning activities have become more and more effective over time.

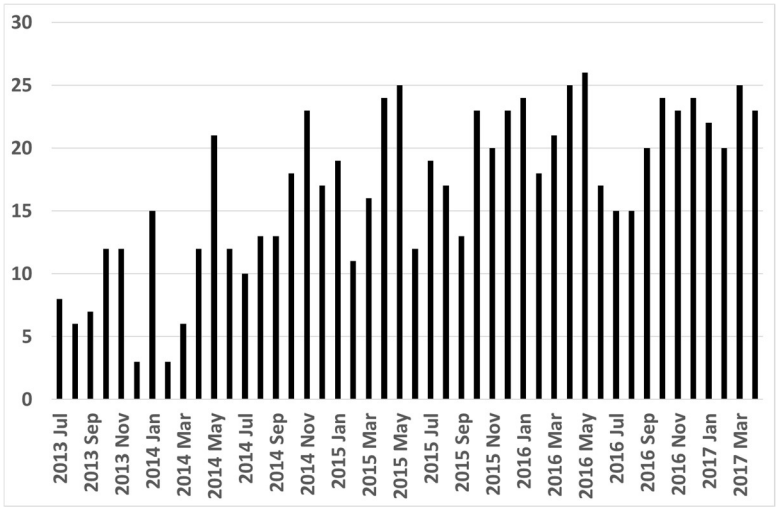
Figure 15: Monthly median value of daily absolute Aggregate Imbalance



Source: Own calculation based on End User Exit and DSO Exit nomination and gas flow data from Plinacro (2017)

Also, in the case of Aggregate Imbalance it can be examined whether traders have taken part during renomination in resolving the physical imbalance of the system (i.e. not just the exchangeable commercial imbalance – Internal Adjustments). From the figure it can be seen that by today, on most days traders during the renomination process through upstream adjustments improve the physical imbalance of the system as well.

Figure 16: Number of days in the month when Aggregate Imbalance was reduced during renomination



Source: own calculation based on End User Exit and DSO Exit nomination, renomination and gas flow data from Plinacro (2017)

Summary of the analysis of the Croatian balancing system

The analysis presented on the Croatian market illustrates how to apply the balancing system efficiency analysis methodology that I have proposed, how can a balancing system's development and efficiency be assessed using publicly available data. I conducted the analysis on two levels, first analyzing the fundamentals of the daily flexibility market (Appendix VI), and then examining how the Croatian balancing system developed in practice and how its effectiveness changed over time.

Based on the analysis of the flexibility market, it can be said that Croatia has good fundamentals for the introduction of a market-based balancing system, and the supply of daily flexibility can abundantly meet the flexibility needs of the market.

Regarding the efficiency of the balancing system:

Evolution of the balancing need:

- The overall balancing need in the case of Largeconsumers had a decreasing trend, which means that traders supplying this group of consumers are more and more improving in planning the next day supply portfolio.
    - This may be the result of many things: for exapmle maybe the incentive system effectively encourages traders to improve portfolio planning and / or traders may work with better quality information, and / or maybe traders can better adjust their portfolio on the day ahead wholesale marketplace.
- There is no such strong downward trend in the case of DSO consumers, it seems that the planning of this consumer group is more difficult, supporting services so far not yet sufficed, additional regulatory support, such as improved data provision and the wider introduction of remote metering can be the next step.

Trader engagement in balancing:

- In case of Largeconsumers traders take significant part in balancing, they actively and well use the opportunity of renomination, by now only 30% of balancing need remains on the TSO to be solved.

- In the case of the balancing of DSO consumers, traders also started to engage through renominations within the day, but by today much less was achieved, still ~80% of the DSO consumers' balancing need is left to the TSO.

Aggregate Imbalance:

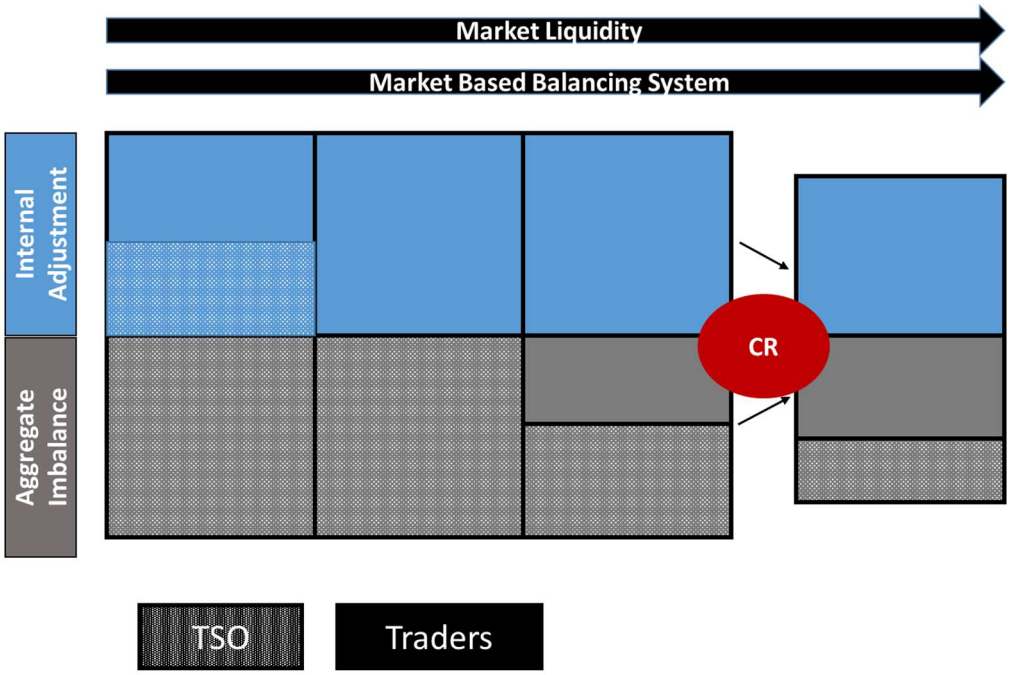
- Aggregate Imbalance shows a decreasing tendency, i.e. the physical imbalance of the system has decreased more and more.
- In addition, the degree of Aggregate Imbalance continued to decline during traders' renominations, i.e. traders have already begun to take part in the physical balancing of the system as well.

Internal Adjustment:

- In the system traders are increasingly coordinating internal adjustment options, the degree of unresolved Internal Adjustments has declined in recent years. In addition, the renomination opportunities are increasingly being used by traders for the matching of opposite sign imbalances.
- This also suggests that the day ahead and within-day wholesale market is becoming more and more efficient.

By using the methodology, I have proposed for the analysis of the efficiency of balancing systems we gained a detailed insight into the performance of the Croatian balancing system. Accordingly, the Croatian balancing system on the development path introduced in Section III.2. has reached the state marked with red circle. Its efficiency is improving more and more, and in order to continue developing, regulation in the future should implement further measures that support traders who supply DSO consumers.

Figure 17: Based on the analysis, positioning the Croatian balancing system on the development path



Source: Own figure, Szolnoki (2017) modified

V.2. Polish example

In Poland there are two separate natural gas systems, the high-methane content NTSHM balancing zone and the NTSN balancing zone built on domestic nitrogen-rich gas. The latter system does not have any connections with other systems, either within the country or outside the country, it was specifically built on domestic production. The high-methane content system is the main system, in 2016 there was 537.8 TWh gas flow in it, while the size of the NTSN system with 7.8 TWh was negligible compared to it (URE, 2017, table 11, p. 52).

For the consumer group that is directly connected to the transmission system – I called this group in case of Croatia the Largeconsumers group – the nomination renomination and gas flow data is publicly available for both zones. It is thus possible to examine the evolution of the balancing need and to what extent have the traders been involved in resolving this balancing need of the Largeconsumer group.

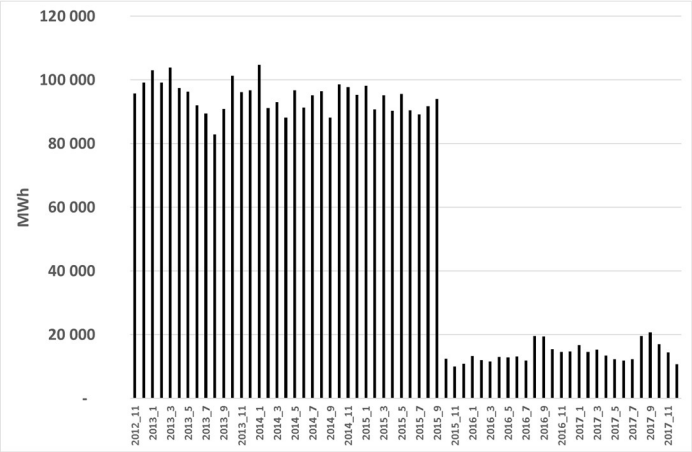
The balancing need and the TSO's and system users' roles in resolving it

NTSN zone

Poland chose to be in the interim measures cluster regarding the implementation of BAL NC, and so it has to introduce the market based balancing system setup by April 2019. As an interim measure, in the small NTSN system a balancing platform was set up and the imbalance settlement price is formed administratively (URE, 2017). The main reason for this is probably that it is too small, and since it is not connected to any other systems, fundamentally there is probably little balancing supply potential.

Figure 18 below shows the monthly gas consumption of the Largeconsumers group. It can be seen that the size of the system has changed significantly since October 2015: it dropped to the level of about one-fifth of the previous period's consumption.

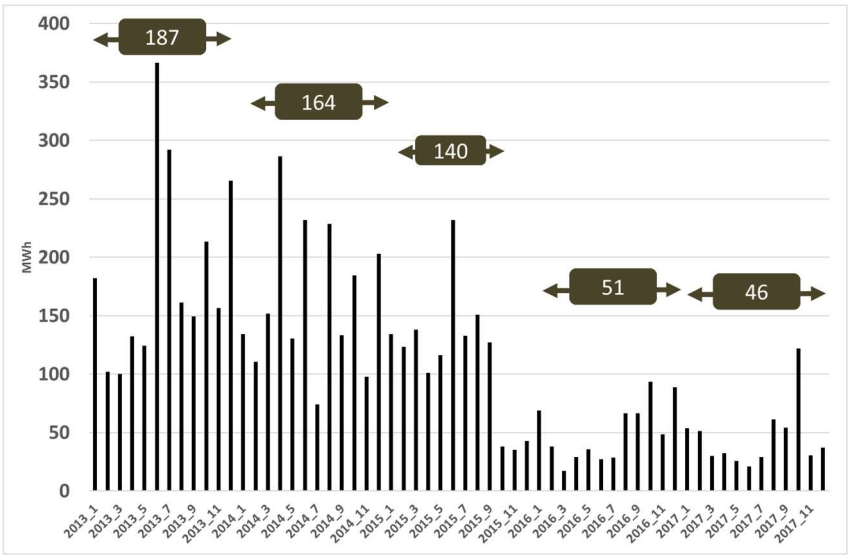
Figure 18: Monthly Consumption of Largeconsumers on the NTSN System, MWh



Source: GAZ System (2018): 909028 Lw / Exit point gas flow data

Figure 19 shows how the balancing need of the Largeconsumer portfolio has developed according to the proxy indicator defined previously. In the period prior to the significant change in consumption gas flow in October 2015, a decreasing trend can be identified in the monthly median value of the absolute value of daily balancing need (and in their annual – in case of 2015 the period Jan-Sept – average value) which could refer to an efficiency improvement. Of course, the significant decline in consumption in October 2015 resulted in a decrease in the balancing need's nominal value as well. In the successive period, as there are no clear trends, no real change in effectiveness can be detected.

Figure 19: The monthly median balancing need of the Largeconsumers on the NTSN system and the (annual) average of the median values, MWh

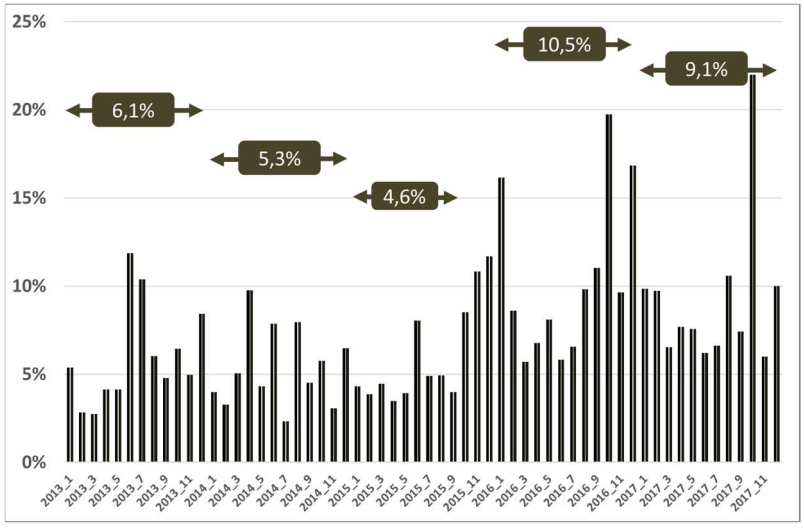


Source: Own calculation based on GAZ System (2018): 909028 Lw / Exit point nomination and gas flow data

The question is how to separate the effects of a significant decrease in gas consumption from the decrease in balancing need. To answer this, I examined the ratio of daily balancing need to daily gas consumption. The figure below shows the monthly median values of the daily ratios. As it can be seen, the balancing need has risen in proportion after the significant drop in gas consumption in October 2015. The decline in gas consumption means a drop in the size of the traders' portfolios, so the portfolio effect of balancing also deteriorates: smaller portfolios have relatively higher balancing need. Presumably, this deterioration in portfolio effect is responsible for an increase in the balancing need relative to consumption on the Polish NTSN system after October 2015. For the period before October 2015, the decreasing tendency identified in the previous figure is also confirmed by this indicator (see the average of the median values), the ratio of balancing need to gas consumption decreased during this period. In the post-break period after October 2015, the rate increased compared to the pre-October period (this is presumably due to the portfolio-effect) but there has been a slight downward trend since then, although this is a short time line to drive conclusions.

Overall, about the period prior to October 2015, it can be assumed that traders became more and more efficient in the planning of the portfolios of the Largeconsumers group directly connected to the NTSN network, since the day ahead nominations were approaching more and more the actual gas flow. In the event of the break in October 2015, however, by the shrinkage of the consumption to one-fifth, the balancing need increased relatively in comparison to the size of consumption. This is probably due to the portfolio effect of balancing. Since then a small efficiency improvement can be inferred, although this is uncertain due to the shortage of the time series.

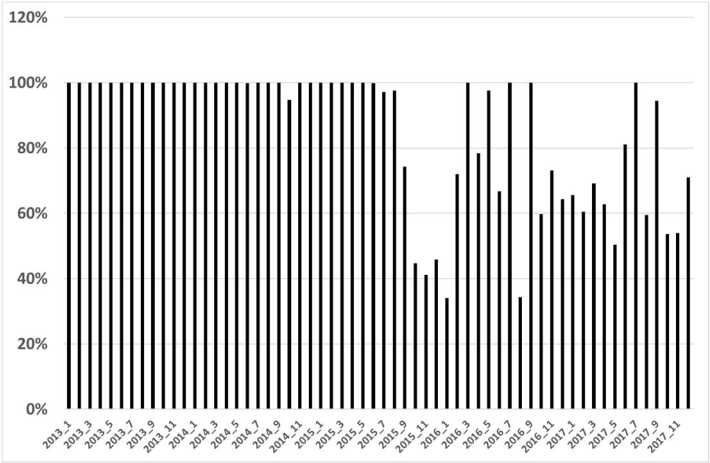
Figure 20: The ratio of balancing need and gas consumption of the Largeconsumers on the NTSN system, monthly median, and their periodic average



Source: Own calculation based on GAZ System (2018): 909028 Lw / Exit point nomination and gas flow data

The next question is the extent to which the role of traders has begun to resolve balancing needs in this system. Figure 21 below shows what percentage of balancing need was left to the TSO after traders' renominations. As can be seen, the monthly median value of the daily rates averaged around 60% in recent years, in other words, **despite that after the consumption drop the portfolio effect led to deterioration of the balancing need's size compared to consumption, traders due to the incentive system and flexible renomination opportunities started to play a significant role in balancing: by now ~40% of the imbalance need is resolved by them during the renomination period.**

Figure 21: The part of balancing need of the Largeconsumer group left for the TSO in the NTSN system, monthly median value



Source: Own calculation based on GAZ System (2018): 909028 Lw / Exit point nomination, renomination, and gas flow data

NTSHM zone

In the high-methane gas zone, which by now accounts for 98.5% of the Polish natural gas market (URE, 2017, table 11, p. 52) the implementation of the fully market based balancing system is also due by April 2019. The following interim measures are applied in this zone: tolerances in the imbalance settlement and balancing platform for the procurement of special locational balancing products for the TSO. (URE, 2017) In this zone, a part of the TSO procurement is performed by standard short term products, and the imbalance settlement price is also formed market based, thus this zone is more ahead in the development path towards the market-based balancing system than the NTSM zone. Due to the size of the market and its interconnections with neighboring systems, it is presumably a much more liquid system than the domestic nitrogen gas system.

Since I perform the same analysis for the NTSHM zone than I did for the previous NTSN zone, and the size of the dissertation is limited, the detailed analysis can be found in **Appendix VIII.** Below I will only summarize the results.

Summary of the Polish results

In Poland, there are publicly available nomination, renomination and gas flow data for the Largeconsumers group of the two separate gas systems. Based on these, although the efficiency of the whole Polish balancing system can only be partially evaluated, but with the indicators I defined, we can still have a significant insight into the evolution of balancing of this Largeconsumer portfolio over the past five years:

- **On the NTSN system:**
    - The decrease in consumption to one-fifth led to also a decrease in the nominal level of balancing need, but due to the portfolio effect of balancing, the ratio of balancing need to consumption increased, i.e. balancing became a greater burden (and cost) for traders.
    - Despite this, traders' portfolio planning improved over time, day ahead nomination values were approaching the actual consumption values more and more, so the total balancing need fell, and the efficiency of the system improved. And this trend was not broken by even the consumption drop.

- Trader engagement in balancing has also begun, already ~ 40% of the balancing need of this consumer group is resolved by traders during the renomination period.

- **On the NTSHM system:**
  - Consumption in this zone, although by a smaller proportion, but also decreased substantially by the middle of the period – to around its half, although at the end of the period there was an increase.
  - The balancing need despite the drop in consumption has risen even in its nominal values, and so also in its proportion to consumption. Portfolio effect deterioration could thus be very significant in this case.
  - There is no clear downward or increasing trend in balancing, which suggests that during this period the quality and efficiency of traders' portfolio planning did not change significantly.
  - On the other hand, there is a significant improvement in the system regarding that traders have been increasingly taken over the main role in resolving the balancing need of this Largeconsumer category during the renomination period, and now ~ 70-80% is resolved by them, and the system operator has really only a residual amount to take care for.
  - This ratio is twice as big as that in the small NTSN system, which is likely due to the higher liquidity in the short-term market of the NTSHM zone.

To sum up, the balancing of the Largeconsumer group of the NTSN zone has become more and more efficient, the balancing need decreased, and traders have begun to take part in balancing. In the latter, however, there seems to be room for improvement, the regulator for example could support more the traders in improving their access to flexibility tools and promoting the further development of the within-day information provision.

In balancing the Largeconsumers in the NTSHM zone, traders have taken the primary role decisively, i.e. renomination possibilities, within-day information provision, and the wholesale market altogether are likely to support traders well in this activity. However, there was no improvement in the size of the balancing need, what more, it has even increased. The regulator in the future should therefore concentrate more on supporting the portfolio planning activities of the traders.

V.3. Czech example

I proposed two different ways for calculating Internal Adjustment and Aggregate Imbalance. Method **B** is based on a comparison of the imbalances at different consumer Exit points, I calculated the evolution of unresolved Internal Adjustments for Croatia previously according to this method. Method **A** is based on the comparison of the network users' daily imbalance settlement quantities aggregated according to the direction of the imbalance. Some countries publish the data needed to calculate this indicator, and this data have also been available to ACER and ENTSOG in their annual reports.

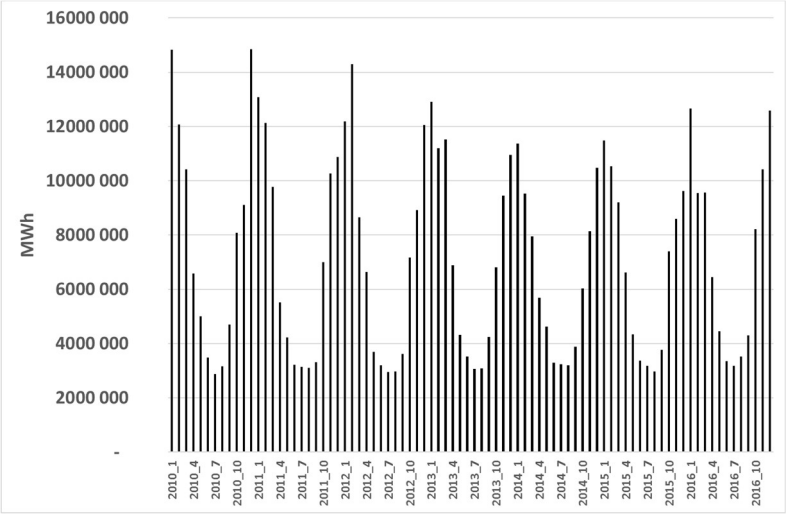
The calculation of the Internal Adjustment indicator is particularly important because, as I have discussed it, it reveals information not only about the efficiency of the balancing system, but also about the short-term wholesale market.

Below, based on the daily imbalance settlement quantities published by the Czech system operator, OTE, I show how this indicator can be calculated and evaluated.

Basic data

As a first step I look at the evolution of the Czech gas consumption. As it can be seen from Figure 22 showing the monthly consumptions and Table 7 summarizing the annual consumption values, the Czech consumption decreased considerably between 2010 and 2014, and after that it started to increase again.

Figure 22: Czech monthly natural gas consumption, MWh



Source: ERU - OTE (2012-2017)

Table 7: Czech annual gas consumption, MWh

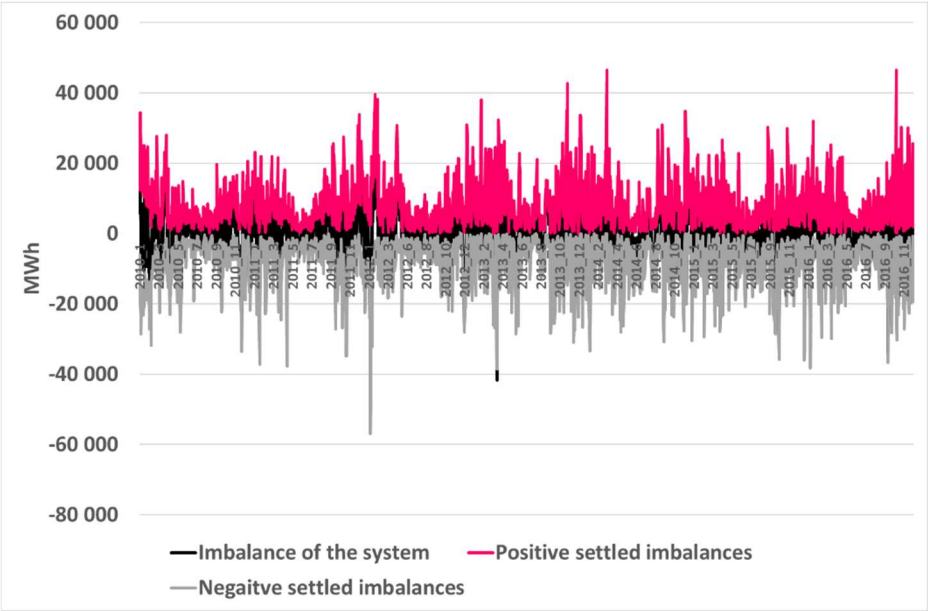
	2010	2011	2012	2013	2014	2015	2016
Éves fogyasztás, MWh	95 138 600	85 645 500	86 325 700	87 968 500	77 409 200	81 067 200	88 243 200

Source: ERU - OTE (2012-2017)

OTE's annual reports include the daily negative and positive imbalance settlement quantities. It publishes the daily values retroactively until 2010. First, I prepared the indicators that ACER proposed for describing the functioning of imbalance settlement in its report (ACER, 2017 p. 28) with the difference that as the full Entry gas flow data was unavailable publicly I substituted it with annual consumption and that I used median values for description instead of arithmetic average as used by ACER. This latter change is made because, in my opinion, for variables with a distribution that contains extremes, and balancing need data is such, the median is more appropriate to describe the tendencies than the arithmetic average which can be deterred more by one-one outlier. In addition, the ACER calculated the indicators for one year, I analyzed them annually between 2010 and 2017 (in 2017 for the first six months).

Figure 23 and Table 8 below illustrate the evolution of imbalance settlement quantities. As can be seen, settled imbalances can be said to be relatively symmetrical. There is no clear trend in the evolution over time. The ratio of settled imbalances to consumption in both directions was in the range of ~ 3% to ~ 4%. (With these indicators, by and large this is all that can be learned about the Czech balancing system.)

Figure 23: In the Czech natural gas system the daily imbalance settlement quantities aggregated per direction, and the imbalance of the system.



Source: OTE (2010-2017) Annual Report

Table 8: Statistics of the Czech positive and negative imbalance settlement quantities

	positive imb. aggregated, MWh	negative imb. aggregated, MWh	Median Pozitive imb., MWh	Median Negative imb., MWh	Minimum Pozitive imb., MWh	Minimum negative imb., MWh	Maximum pozitive imb., MWh	Maximum negative imb., MWh	Ratio of annual pozitive imb. / annual consumption %	Ratio of annual negative imb. / annual consumption, %
2010	2 826 506	-3 046 674	5 890	- 6 349	115	-317	34 410	-33 578	2.97%	-3.20%
2011	2 816 745	-2 683 708	6 335	- 5 334	241	-105	33 794	-37 750	3.29%	-3.13%
2012	2 969 592	-2 820 095	6 067	- 6 300	126	-82	39 495	-56 975	3.44%	-3.27%
2013	3 332 201	-2 552 655	7 208	- 4 844	0	-11	42 675	-38 626	3.79%	-2.90%
2014	2 713 709	-3 030 519	5 351	- 6 425	101	-3	46 397	-33 326	3.51%	-3.91%
2015	2 590 883	-3 032 400	5 534	- 6 924	118	-78	30 234	-35 783	3.20%	-3.74%
2016	2 752 902	-2 890 654	5 576	- 6 081	69	-106	46 496	-38 256	3.12%	-3.28%
2017_1-6	1 992 690	-1 905 133	8 152	- 8 172	546	-63	62 916	-40 097		

Source: OTE (2010-2017) Annual Report

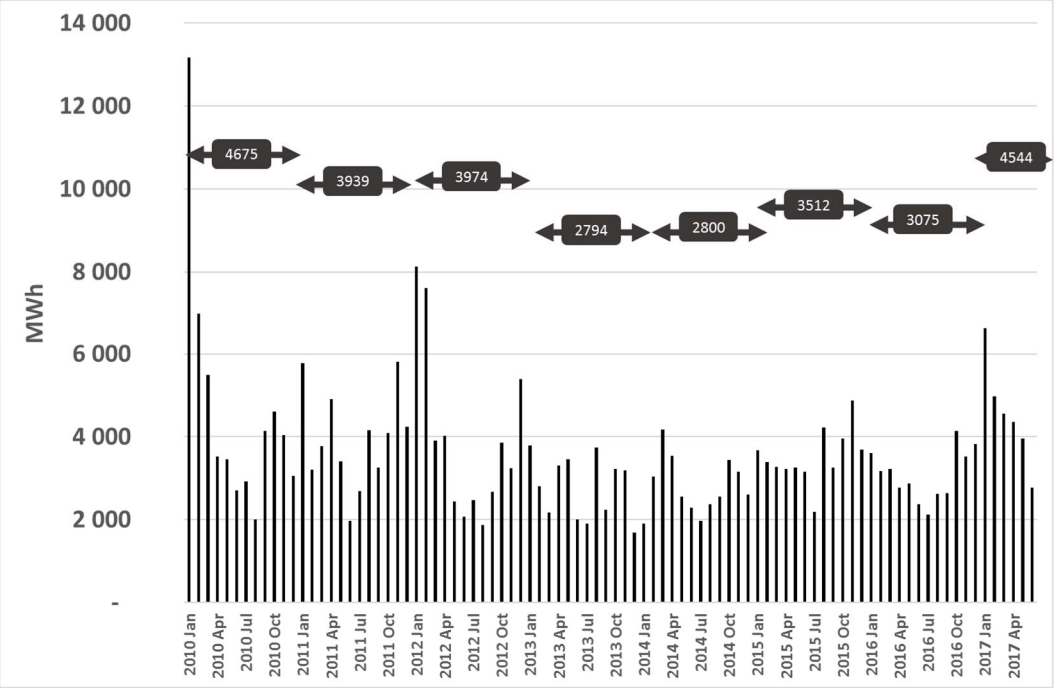
Below, based on these same data I perform further analysis, I calculate the Internal Adjustment and Aggregate Imbalance indices to see whether more information than this could be revealed about the efficiency of the Czech balancing system.

Internal Adjustment

By using these daily imbalance quantity data, according to Method **A** I proposed in Section IV.4.2., I calculated the overlapping part, i.e. the opposite sign imbalances that

could have been exchanged during the day if information provision and the short-term wholesale market were efficient enough. Figure 24. below shows the trend of the monthly median values of the daily Internal Adjustments and their annual average (arrows). As you can see, similarly to consumption, the level of unresolved Internal Adjustment options decreased until 2014, and then it had diverse values, while the 2017 level returned close to the 2010 starting level.

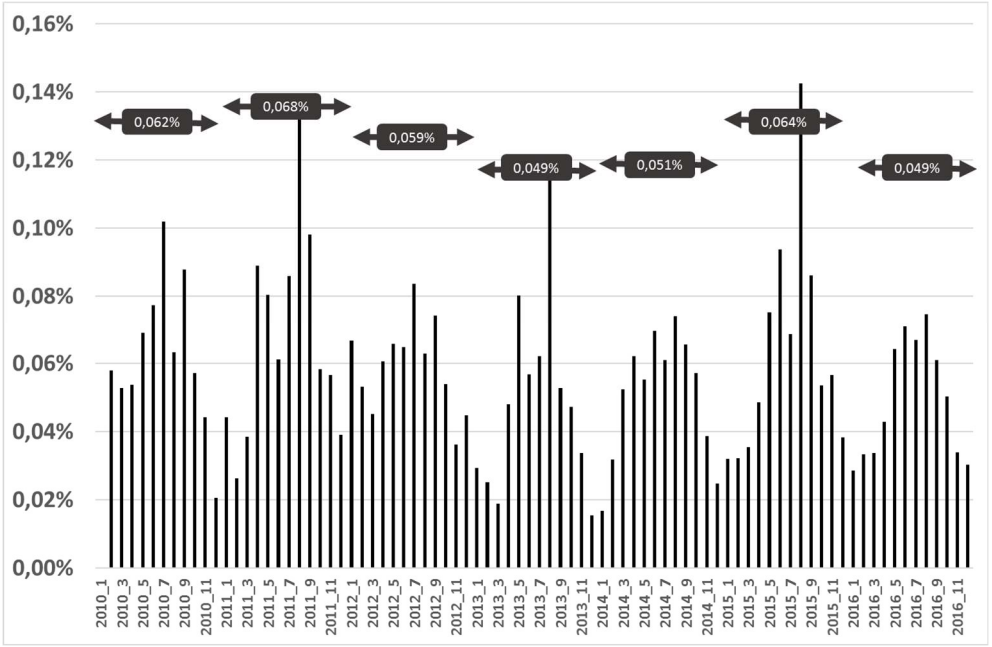
Figure 24: Monthly median values of the Czech daily unresolved Internal Adjustment possibilities, MWh



Source: Own calculation based on daily positive and negative imbalance settlement quantities from OTE (2010-2017) Annual Report

If we compare the Internal Adjustment with consumption (Figure 25), we see that the proportion of the two shows that the Internal Adjustment has decreased more than the consumption decreased in the first half of the period, thus the downward tendency in unresolved Internal Adjustment detected from the above figure for the period until 2014 can be evaluated as an efficiency improvement. Traders could better and better exchange their portfolios' opposite sign imbalances on the Czech market, the short-term wholesale gas market coordinated these trade intentions increasingly better. As for the period after 2014 no clear trend could be detected.

Figure 25: The ratio of the monthly median unresolved Internal Adjustment and the monthly consumption of the Czech market, and its annual average



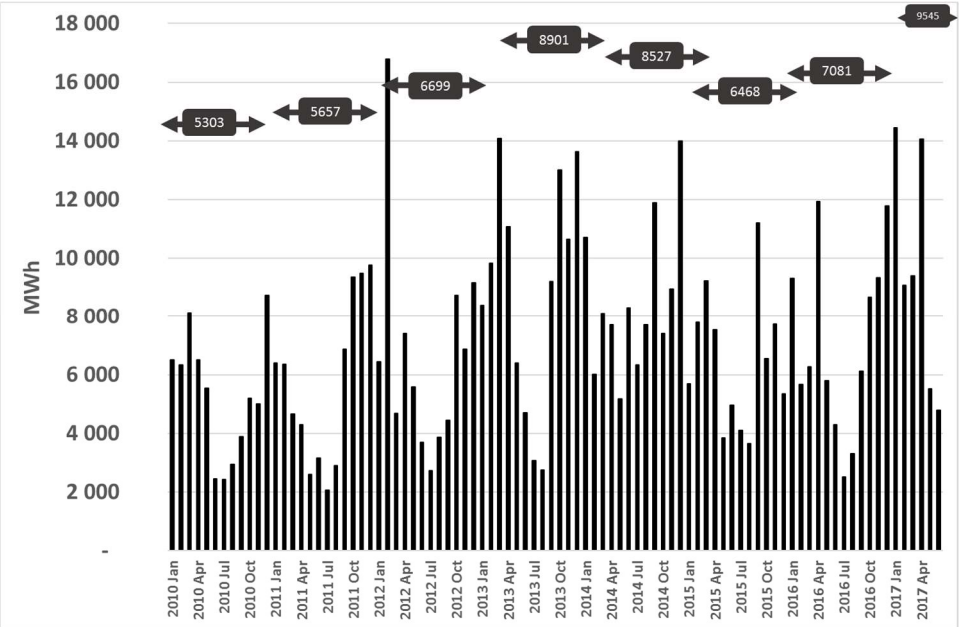
Source: Internal Adjustment: Own calculation based on daily positive and negative imbalance settlement quantities from OTE (2010-2017) Annual Report;

Monthly Consumption: ERU - OTE (2012-2017): Annual Report on the Operation of the Czech Gas System 2011-2016

Aggregate Imbalance

Next, I examine the Aggregate Imbalance which provides a picture about the physical imbalance of the system. For the calculation I follow Method **A** that I proposed in Section IV.4.2. According to this, Aggregate Imbalance is calculated as the resultant of the daily imbalance settlement quantities, i.e. the part that is not offset when comparing the positive and negative sign imbalances. As shown in Figure 26, the absolute value of Aggregate Imbalances had an opposite trend than consumption and Internal Adjustment, in the first half of the period Aggregate Imbalance increased, after that it had various values. Seasonality can be identified: imbalance is smaller during summer.

Figure 26: Monthly median value of absolute value of Czech Aggregate Imbalances and their annual average, MWh



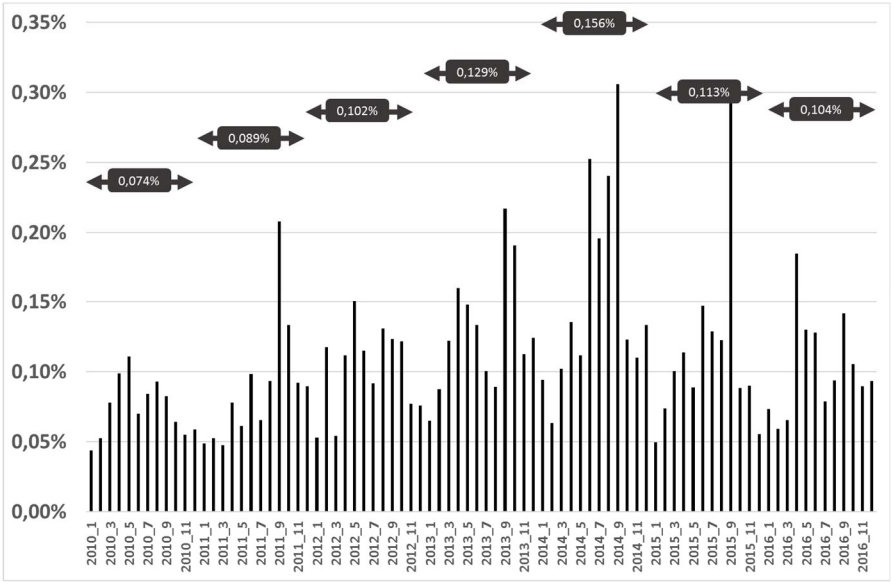
Source: Own calculation from daily positive and negative imbalance settlement quantities from OTE (2010-2017) Annual Report

If we control for consumption (Figure 27), the increase in Aggregate Imbalance is even more pronounced in the first half of the year: by 2015, the 2010 level of Aggregate Imbalance has doubled in proportion to consumption. After that, it has declined significantly but has not yet reached the 2010 level. This suggests that the planning of trader portfolios has become worse relative to 2010. This can be the result of many things, for example, more and more traders entered the market and supply consumers, this results in more number of supply portfolios, which however also means more fragmented, smaller portfolios that might result in the beginning in less effectiveness in balancing. It is interesting that, while traders were becoming more and more efficient in resolving Internal Adjustments in this period, Aggregate Imbalances were increasing, so portfolio planning became worse in the same period while the correction of opposite sign imbalances improved.

For further analysis of this issue, I examined the extent of the Internal Adjustment compared to Aggregate Imbalance. (Figure 28) As you can see, the improvement in resolving Internal Adjustments in the first period is even more apparent. While Aggregate Imbalance, i.e. the physical imbalance of the system, became worse, the situation in

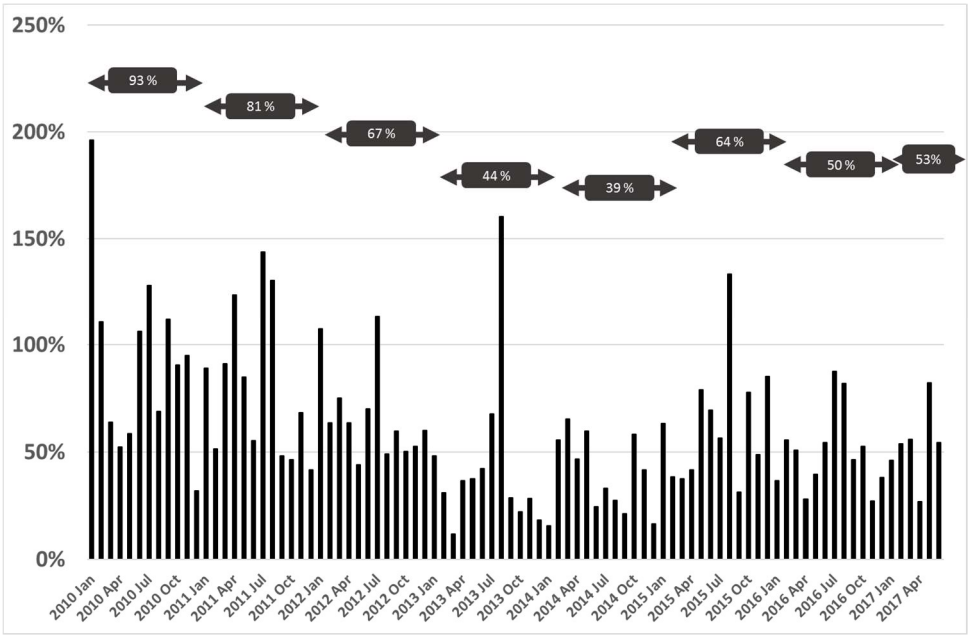
resolving Internal Adjustments, i.e. resolving the mere commercial imbalances, improved.

Figure 27: Ratio of monthly median value of the absolute value of Aggregate Imbalance and monthly consumption



Source: Aggregate Imbalance: Own calculation based on positive and negative imbalance quantities from OTE (2010-2017) Annual Report
Monthly Consumption: ERU - OTE (2012-2017): Annual Report on operation of the Czech gas system 2011-2016

Figure 28: The ratio of the absolute value of Internal Adjustment and Aggregate Imbalance



Source: Own calculation based on daily positive and negative imbalance settlement quantities from OTE (2010-2017) Annual Report

Summary of the Czech case

Above, I examined a part of the Czech balancing system using publicly available daily imbalance settlement quantity data. It can be said that in the Czech balancing system the level of physical imbalance grew until 2014, compared to the consumption, its share doubled. This indicates a clear decline in efficiency of the portfolio planning. Behind this, there could be other reasons than the merely worsening planning of traders. For example, maybe the number of suppliers doubled on the market, which in itself is an improvement on a market, however, the more fragmented portfolios could result in a negative effect on balancing.

Considering the deterioration of the physical balancing need, it is particularly interesting that the resolving of the merely commercial imbalances has improved during this period. This suggests that the wholesale market more and more effectively coordinated these counter-portfolio imbalances between traders. This can be justified by the previously mentioned possible explanation for the increase in aggregate imbalance – that is, more and more active traders are present on the spot market. In this case, more traders intend to exchange on the spot market and thus the market becomes more efficient. Of course, this is just a hypothesis that should be tested by regulators as part of such an analysis.

There is no clear trend over the post-2015 period.

It is worth investigating more in detail what could be the reasons for the tendencies. The explanations I proposed are just suggestions. With these examples, I just want to illustrate how the proposed indicators and the methodological framework works in practice, the dissertation does not aim at examining individual markets in such a detail.

V.4. Summary of country cases

In this chapter I have illustrated the operation of the methodology I proposed on the data of three countries. In the Croatian case, a relatively wide range of data was available publicly, so I could calculate most of the indicators of the methodology and provide a comprehensive picture of the performance of the Croatian balancing system.

In the Czech and Polish examples, I illustrated the analysis of one-one part of the balancing system, how one-one indicator functions in practice.

It is an important result of these three cases that the indicators do not produce the same results everywhere, and thus, not the indicator itself determines the result.

It was also important to show that there are no such clear trends everywhere, as it was in the case of the Croatian Largeconsumers. The interpretation of the indicators works even when there are no such clear improvements, the identification of deteriorating or stagnating tendencies also has a significant role, these also provide an important message for the regulator.

The Polish and Czech cases were special in the sense that both countries experienced a significant drop in consumption during the analyzed period, so the portfolio effect of balancing was also visible. In addition, the effect of this fundamental change on balancing had to be controlled during the examinations.

Another interesting feature of the Czech case was the fact that I performed my analysis on exactly the same data group that ACER also used for examining the imbalance settlement system of some Member States. (ACER, 2017). So, I had the opportunity to demonstrate how much deeper insight can be obtained on the performance of the balancing system with the methodology I proposed than with the analyzes suggested by ACER using the same data.

Overall, we can say that the indicators provided a comprehensive picture of the Croatian balancing system, and even in the case of the Czech and Polish cases that only partially covered the balancing system, the indicators provided an insight into the performance of the balancing system over the past period.

V.5. Summary of the balancing system analysis methodology, its shortcomings, and the possible steps forward

In these two chapters I presented my new research results. I proposed a balancing system analysis methodology. I have defined the two main questions that the methodology must answer, and I derived the areas to be analyzed from a theoretical model. For the analysis I built on the indicators of the previous literature and I have also defined new metrics. Finally, on country examples I illustrated how the methodology works and how to evaluate the results. My aim was to use the analytical methodology built on publicly available data to provide – compared to the results of the previous literature – a more comprehensive picture of the efficiency of the balancing systems. A summary of this methodology is shown in the figure below.

Figure 29: Methodology for analyzing the efficiency of the balancing system

I assessed the previous balancing system analyzes in detail, discussed also their limitations and shortcomings. Of course, the methodology I've developed is not perfect and complete either.

The methodology should be complemented with the other indicators already used by ACER such as the neutrality analysis, and the examination of the relationship between the linepack and commercial imbalance. Also, it should be complemented by the indicator used by ENTSOG for the TSO's procurement activities, showing the ratio of short-term purchases of the system operator to its total procurement. These data are not publicly available, so I could not work with them, but as it can be seen, for ACER and ENTSOG these are available and some of it are also available probably to national regulatory authorities. These indicators are designed to check the compliance with one or more points of the BAL NC, but, at the same time, these could also complement my efficiency indicators and help detecting the causes of the identified trends.

The methodology is limited in the sense that the results do not provide straightforward information on the underlying causes. During the country cases I gave some examples of what could be the cause of the identified efficiency improvement or deterioration, but these were just hypotheses. The methodology must in any case be supplemented by deep knowledge of the country's gas market and balancing system, the regulation of these and, in particular, the changes that took place on the market and in the regulation, in order to detect the causes. It is best to use the methodology the following way: after one year later of implementing a new rule see with the help of the indicators whether there are such changes in the time series that could be related to the implemented new regulation.

There are also limitations in case of the individual indicators. I called the balancing need indicator based on nomination, renomination and gas flow data a proxy indicator because it captures only the balancing demand from the consumption side. Although the balancing problem is predominantly related to consumption, there may be unexpected outages at supply points, which need to be balanced, but these are not included in this indicator. For the Entry points, the same indicator does not work because the allocation process is different and also because from these points network users may provide flexibility services as well, so the difference between the nomination and the gas flow value would no longer reflect just the balancing need of the point.

Another limit of this indicator is that Exit point data aggregates consumers too much, so we can only estimate imbalances in traders' portfolios by an imbalance of a much more aggregated portfolio. One step forward in this area could be if we compare the results of this indicator with the data of the imbalance settlement by portfolio, which, unfortunately, is not publicly available data, but may be requested for ACER and ENTSOG. Another option is to examine the Exit point data in a less aggregated breakdown, for example the DSO consumption per distribution company, and Largeconsumers separately by industrial and power plant groups.

The Largeconsumers group is a particularly important group in case of this indicator, because in some countries, some of the Largeconsumers also provide flexibility services. If such a consumer is in the Exit point examined, then unfortunately the indicators of balancing need and the TSO-trader division for that point are distorted, since the renominations and the gas flows are not only reflecting the traders' portfolio corrections but also the provided flexibility services.

For the Internal Adjustment indicator, it would be a step forward if the results of the Internal Adjustment indicator could be compared with the transactions on the short-term wholesale market, to test the hypothesis derived from the theory that the decrease of the Internal Adjustment indicator means more coordination, and more exchanges between traders.

A further step forward is to define in a more exact way the improvements, that is to say, not just the direction of improvement / deterioration but also the degree of improvement. Prerequisite for this is the availability of more and similar structure data sources.

Finally, it would be a significant step forward in the methodology to extend the study to more countries and countries with the same data type and the same time series (at least 5 years) and thus to enhance the analysis with cross-sectional comparisons and evaluation forms. As data sets with the same structure are available for more than one country, the comparability of calculated indicators increases, they can also function as a benchmark for the level of development of the flexibility markets and the balancing systems. In this case, it would be possible to combine the indicators with the development levels outlined in the efficiency definition, which could lead to a better classification of market development.

I think the methodology could be improved in the future mainly along these dimensions.

VI. SUMMARY

My dissertation was about the theory and practice of balancing regulation on the gas market. By now, both European regulation and the academic sector consider the balancing system as one of the key points to the success of gas market liberalization. The balancing regime is a multipart regulatory package, selection from its toolset should be made carefully: considering the development level of the market and knowing the effects of the tools. The effect of the selected tool should be measured, and the forthcoming regulatory cycle should reflect the results of this evaluation. This cyclical process is thus progresses towards until the introduction of a full market-based balancing regime. After that, the focus is shifted to market analysis and to the detection of possible distortions.

At present, a significant number of EU Member States are still in this cyclical regulatory period. Member States will have to identify the interim measures to be introduced to achieve a market-based balancing regime and will also have to assess the effectiveness of these measures. Regarding the evaluation methodology a European-wide discourse is developing.

In my dissertation, I contribute to this task. On the one hand, based on the academic literature, the reports of European organizations and papers on country cases, I provide a comprehensive overview of the regulatory toolkit. I discuss what kind of variants of the regulatory measures are recommended at certain development levels, what kind of effects could be expected and what disadvantages they may have.

On the other hand, I extend the currently used methods for measuring balancing regulations' efficiency in several directions. I include in the examination the question whether there is a physical and commercial fundamental potential for the introduction of market-based balancing on a given gas market. The proposed methodology is described in detail and its application is illustrated on market data: I use indicators calculated based on the multi-annual data series of the Entry and Exit points of the Croatian gas market to evaluate the demand side and supply potential of the daily flexibility market. Comparing the supply and demand indicators with each other, I evaluate the physical flexibility

potential of the Croatian natural gas market. In the specific case, I concluded that the Croatian natural gas market has very good physical fundamentals to introduce a market-based balancing system.

For the methodological foundation of the efficiency analysis of the balancing system, I first defined what I mean by an efficient balancing system. This is necessary because without this we do not know exactly what the purpose of regulation is and what we are actually looking for during the measurement, but the previous literature has so far not set up a definition of efficiency. With the help of the definition, I identified the directions of investigation and I proposed indicators for the analysis of these directions. Some similar analyses and indicators already exist in the literature, I provided a detailed discussion and evaluation of these in the dissertation. My main criticism is the following: On the one hand, some of the indicators proposed in the previous literature exist only in theory, because they are defined by data requirements that are not yet accessible to even to the European regulatory agency. Some of the other indicators are also based on data that are not accessible publicly therefore are unavailable for academic research and only available for EU institutions. Finally, the main problem of the other indicators and analyzes, in my opinion, is that they do not form a comprehensive analysis, they only look at the fulfillment of one-one requirement, one-one part of the system rather than assessing the efficiency of the whole system. The further inadequacies of these analyses, is that these are based on short time series, merely only one year.

Because of the above, I define new metrics. One of the main indicators that could not be calculated due to the complicated data needs even by European organizations is the balancing need. I proposed to use the daily operational data instead of the previous definition that was based on the daily trading transaction data. Daily nomination, renomination, and gas flow data are actually the technical footprints of trading, so I use these for my balancing need indicator. The approximate nature of the indicator alone does not reduce its value because not the nominal level of balancing need is what is really interesting, but its change in time, for example, to see whether there is an improving trend or not. With this indicator I do not only give a proxy estimate of the balancing need, but also, I contribute to my other indicator that measures the share of traders' and the system operator's participation in resolving balancing need. This is an important issue not only according to my balancing system efficiency definition, but also it is a special highlighted field of study in the EU, as one of the main objectives of common European regulation is

that traders be the primary responsible for balancing. Further advantage of my indicators that they are based on publicly available data.

These indicators provided an alternative solution for analyzing fields that have already been raised in the previous literature.

In addition to these, based on my efficiency definition I defined further new metrics. One is the Internal Adjustment indicator for the calculation of which I proposed two types of solutions. An additional advantage of this indicator is that it not only provides information on the balancing system but also on the efficiency of the wholesale market. This can be particularly valuable in the analysis of markets in Member States that do not yet have a transparent marketplace and therefore, indicators of the degree of market development used in the previous literature cannot be used. The pair of the Internal Adjustment indicator is Aggregate Imbalance, which expresses the physical imbalance of the system. Measuring physical imbalance and examining the tendency of values over time gives a direct picture of the evolution of the efficiency of the balancing activity.

I have illustrated the functioning of my indicators and the methodology on three country-cases. In Croatia, an extensive set of data is publicly available thus I could apply the complete methodology and could evaluate the development of the Croatian balancing market. Based on my results, it can be stated that significant developments have been made in balancing the consumption portfolio of the Largeconsumers (consumers directly connected to the transmission system). Suppliers of this group plan their portfolios more and more accurately leaving less and less balancing need. In addition, a significant part of the balancing need is resolved by traders during renominations within day, so the system operator has a really residual role. Finally, the wholesale market – both day ahead and within day – is coordinating the opposite sign of imbalances between traders more and more efficiently.

These positive processes are much more moderate in the case of the smaller DSO consumers (connected to the distribution network), so I suggest that regulation should focus more on this segment in the future, and support it's balancing with additional regulatory tools such as information provision improving rules.

I have also analyzed the trends in the balancing need and trader/system operator engagement in resolving imbalances in the case of the Largeconsumers of the two Polish balancing zones. Here I found trends in efficiency improvement in balancing need in the

smaller balancing zone, while in the larger balancing zone the balancing requirement did not decrease, but traders have significantly engaged in resolving this balancing need during the renomination process. I proposed several hypotheses for the reasons behind these phenomena.

Finally, on Czech data, I made an analysis of the Internal Adjustment and its counterpart the Aggregate Imbalance indicators. Based on the results, the Czech gas market became more and more efficient, however the balancing need itself increased during the period.

The specialty of the Czech example was the fact that I made my analysis based on the same data range that ACER also used to analyze the imbalance settlement system of the Member States (daily imbalance settlement quantities by directions). So, I had the opportunity to compare the two methods and to show how deeper and more complex insight can be gained on the balancing system's performance with the indicators I proposed.

With my country examples I have shown that the indicators I proposed can also be applied to natural gas markets for which very detailed performance and behavioral data are unavailable, and I also demonstrated that these indicators provide a deeper insight into the balancing system of a country compared to the results of previous literature.

Finally, I closed my dissertation with the critique of my methodology and with the possibilities for its further development.

Of these, the most significant progress in the methodology would be, in my opinion, if the analysis could cover many countries with the same data type and same time series this way the analysis could include cross-sectional comparisons and evaluation forms, benchmarks could be defined for the development levels. In this case, it would also be possible to combine the indicators with the development levels outlined in the efficiency definition, so that it would be possible to classify the development of the markets.

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Appendix I: The Natural Gas Market Supply Chain

I.1. Development of the natural gas sector

The beginning: long-term contracts and the formation of national monopolies

Although the so-called 'urban gas' already was used by the industry and households since the 1880s, the history of the current European gas industry only commenced in 1959 by the exploitation of the Dutch Groningen field– the production of which is currently being drastically reduced due to the frequent earthquakes it causes (OIES, 2017a). The Groningen field besides directly supplying the neighboring countries with natural gas, also had an indirect impact on the commercial structure of gas supply contracts related to imports from distant countries of Europe, such as the former Soviet Union, Algeria, i.e. the foundations of long-term contracts were laid down here (Stern-Rogers, 2014).

Due to the "cleanness" and "convenience" of natural gas compared to coal and oil, it became quickly popular and rapidly grew to become a determinant primary source of energy. National gas sectors have emerged and since only the United Kingdom, the Netherlands, Denmark, and Norway possessed sufficient amount of natural gas reserves that could serve domestic demand and also provide other countries with supply (Stern-Rogers, 2014), in many cases national natural gas industries relied heavily on remote import sources, resulting in the transporting of gas often by transiting through other European countries. In most European countries, therefore, major infrastructure investments were needed to supply consumers. The building of the production infrastructure, transit pipelines and domestic transportation and distribution pipeline systems to supply the consumers required long-term and irreversible financial commitments. On one side of the transaction were the producing parties (countries) which usually also built the infrastructure (transport pipelines and storage) necessary to reach the consumption site, while on the other side there were the integrated companies (countries) serving domestic consumption and building the necessary domestic transportation infrastructure for that.

The risk that companies undertake with this infrastructure investment is significant. The producer is risking that the other side will not take over the natural gas, and she will not be able to deliver it anywhere except to where the pipeline is built. The recipient is also in a vulnerable position, as she also enters into a sunk investment by building a domestic infrastructure to supply consumption (Szolnoki et al., 2008c). If the two actors were within one country, the simplest solution to this risk would be vertical integration, the risk of both sides would be internalized (Joskow, 2005). But most of the production, from which European consumers were supplied were non-domestic sources but came from other countries and most of it were non-EU countries. For such case, the economic theory to minimize risks suggests a long-term contract set up with mandatory rules. With long-term contracts, both the buyer and the seller assume a long-term monopoly obligation (Szolnoki et al., 2008c).

As the recipient companies undertook a long-term contract to take over the natural gas from the producer, they also have had to make sure that this volume would be bought from them in the domestic market in the next 25 to 30 years. In addition, the significant irreversible investment that was necessary for the building of the domestic infrastructure system is also a long-term commitment, so in case of the European importing countries the industry-wide solution for minimizing the risks regarding these long-term commitments was the already mentioned vertically integrated monopoly company setup, which enjoyed a monopoly right over the entire domestic value chain including the supply of consumers. Moreover, the decades-long commitments were unacceptable for private players, so these vertically integrated companies usually were state owned monopolies.

Market opening, liberalization, and restructuring

In the 1980s, a new economic view of the energy markets and the role of the state in the market became popular. Dissatisfaction with inefficient state monopolies has increasingly raised the need to try out competition and its beneficial effects. With the lead of the Anglo-Saxon countries, the opening of energy markets, including the opening of gas markets, began. Restructuring and liberalization started.

By market opening, in some segments of the value chain (production, wholesale, retail), the incumbent which until the opening had monopoly rights on both the downstream (consumer supply) and upstream (import and production) segments now had to compete

in a competitive environment with the new entrants. As I have shown, only in case of those activities that according to the economic theory are considered as natural monopolies, have remained the view that a single operator can perform this task more efficiently and safely in case of the rest of the activities competition was considered as a superior solution.

Market opening was accompanied by restructuring, under which the competitive activities were separated from monopoly network activities. Since access to resources and the supply of consumers are not possible without the use of the network, that is, the commercial activity itself, the conditions under which different competitors can use the network has a great impact on competition in the wholesale and retail markets. One of the key elements of market opening therefore is the non-discriminatory provision of network access. One of its main tools is effective unbundling, i.e. making the network company independent from the incumbent company or from any trading company at a level so that the network company is not encouraged to favor the trading company that is in the same holding compared to the other traders, rather it is committed to a network operation that is optimal for the competitive market. The more and more stricter models of unbundling have been gradually prescribed on the natural gas markets of the European Member States.

Restructuring also involved changes in ownership structure. In areas that were already competitive, the presence of the state was less and less justified, and the advent of the competition meant the entry of new players. Thus, private capital appeared on the gas market. In addition, in our Central and Eastern European region, the shortage of money after the political transition in the beginning of the 1990's and the significant investment need in network maintenance and expansion resulted in the privatization of network companies (mainly distribution networks). As the result of the privatization process, the networks were usually in the hands of foreign companies, which were domestically regarded as private capital, but it is important to mention that these companies were often state-owned companies (e.g. E.ON, GDF, ENI).

Market opening models

Market opening and reaching market competition does not happen overnight. The transition phases also take several years. Thus, market-opening has gradual models. The first possible step is the unbundling of the production activities (in countries where there is significant domestic production potential) from the other vertically integrated segments and the admission of competition to this segment that differs most from the rest of the supply chain.

A next step is the opening of the wholesale market. In this case, the procurement constraints from import and production are abolished, anyone can access these sources and develop a competitive supply portfolio. To do this, non-discriminatory access to the transmission network is indispensable. On the consumer side the largest consumers are granted the freedom to choose supplier thus new entrants have the possibility to build up a consumer portfolio.

The remaining mass of consumers is supplied by a designated supplier (mostly the incumbent) and the price and other terms of supply are regulated. This is the so-called single buyer model. Small consumers are not exposed to the risk that they may not be served by the competitive market players or become vulnerable on the non-liquid market to the profit-oriented suppliers. This designated supplier procures the sources needed for the supply of this consumption portfolio usually by tendering the wholesale market players (hence single buyer) (Szolnoki et al., 2008c).

The opening of the retail market happens, in fact, by the continuous reduction of this single buyer portfolio, the protected consumer group, and simultaneously directing the newly eligible consumers to the competitive market segment. For the new entrants to be able to supply smaller consumers, the distribution network must also be accessible in a non-discriminative manner for all players.

At the final stage of market opening there are no consumers bounded in a regulated supply setting, all are free to choose a supplier, but at the same time the smallest consumers are usually left with a so-called universal service option which they can choose, where designated suppliers offer supply for a regulated tariff. The aim is that also these smallest consumers be targeted by suppliers on the competitive market by competitive bids, but these consumers be assured that regardless of the state of competition they would always

have at least one offer to choose from, the universal service supply. But in order that suppliers compete for small consumers, of course, it is also necessary that the price of universal service not be a politically subsidized price, but a cost-based price that can be competed by more efficient suppliers.

I.2. The natural gas supply chain

Natural gas as a primary energy fuel is used in industrial processes, in electricity generation and by households as well. Its significance is shown by the fact that it has the second highest share within the primary energy fuels after oil in the European Union (~ 25%). In 2016 the EU natural gas consumption was 430 billion m^3, which has broken the downward/stagnant consumption trend of the past 10 years and resulted in a 7% increase compared to 2015 (BP, 2017a).

For the supply of this significant consumption need a complex industry had been built up.

I.2.1. Production

The production segment covers activities from research through drilling and extraction to processing and gathering natural gas. The gas fields can be geologically different, there are both on- and offshore fields. Among the onshore sites there are formations that contain mainly natural gas, but there are some where natural gas extraction takes place as a by-product of oil extraction. In addition to the traditional well drilling exploitation of the gas fields, in the United States, in the 2000s a big innovation of natural gas production was discovered, the production of shale gas. Previously, the extraction of natural gas in shale rocks was not cost effective. With the new fracturing technology these formations have also become economically viable, resulting in a large increase in the amount of natural gas available on the market.

Different fields can be produced with different flexibility, there are those that can be produced with only a fixed, steady speed, in case of fields associated with oil, the rate of natural gas production is driven by the oil extraction, and finally there are fields whose production speed can be flexibly adjusted within certain limits (ECDGC, 2007). These

latter fields can also provide flexibility services, which is an important asset in the natural gas market.

Countries with large natural gas production potential and countries with high consumption demand are usually located in a geographically different area in the World. The range of producing countries is much more concentrated than the group of importing countries. The main producing countries are Russia, Norway, Canada, Iran, Algeria. The United States' shale gas revolution has slightly changed this relatively stable structure, and now America is also an exporting country, but Europe for example still has a significant import-dependency (around 70%) which is projected to further increase in the future (Eurostat, 2017a). The table below shows Europe's main import partners and their shares.

Table A1: Extra-EU natural gas imports, shares of main trading partners

Partner country	Share, %
Russia	39.7
Norway	34.1
Algeria	15.2
Qatar	5.1
Nigeria	2.1
Libya	1.4
Others	2.4

Source: Eurostat, 2017a, Table 2b

Europe's largest import source is Russia, although its share in the European import has been volatile in the previous decade and there were periods with large drops, but its share has now returned to its 2005 level (Eurostat, 2017b). Norway is the second most important source and Algeria is the third, which delivers natural gas to Europe not only in pipelines but also in a liquefied form. With this we can now turn to the question of transport.

I.2.2. Transportation

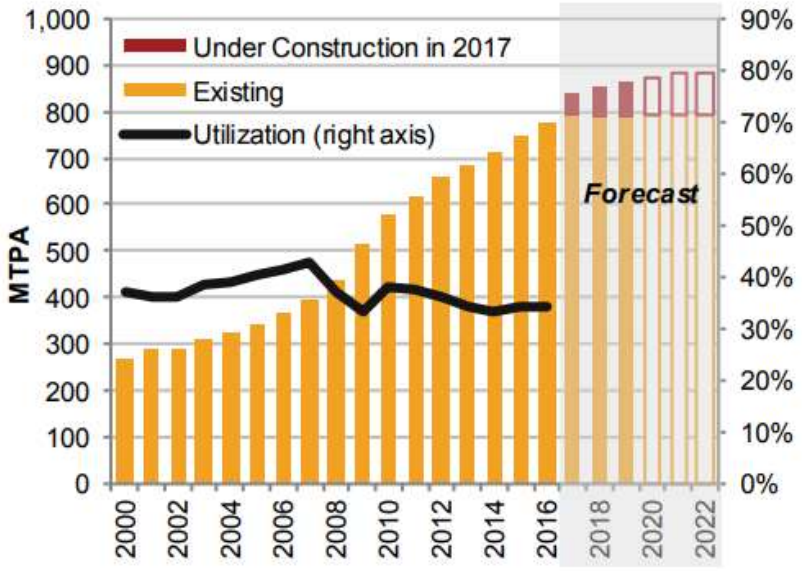
Transit

Natural gas is transported from production centers to consumption points mainly through pipelines. The import of Europe is also mainly supplied by the so-called transit pipelines. This transportation constraint for a long time has largely restricted the scope of the gas markets, and so for many years we talked about regional markets of natural gas and not a global market. Because of this setup, in the different consumption regions (such as Asia, North America and Europe) quite different prices could emerge without affecting each other's markets.

Another way of transporting natural gas is to transport it in a liquefied form (liquefied natural gas - LNG). This mode also requires a specific infrastructure investment that cannot be used for anything else: the liquefaction plants at the producing countries, then special containers and ships, and finally regasification plants in the consumer countries. However, an LNG investment still provides greater freedom than the transit pipeline, because the route is not fix, ships can be diverted elsewhere if there are sufficient regasification capacities built in the world, and vice versa, LNG shipments can be received from any production site.

The choice between LNG and pipeline transportation modes is an economic question. Above a certain distance and with certain environmental conditions LNG is the more cost-effective solution, while in the other cases the pipeline mode is the optimal solution. With technological development the costs of LNG transportation are also decreasing, and this form is becoming increasingly available. In addition, because LNG provides the opportunity for source-diversification next to the imports coming via gas transit pipelines, therefore, as the figure below shows, several LNG receiving terminals have been built recently on both economic and security of supply considerations in the world and in Europe.

Figure A1: The capacity of LNG receiving terminals in the World, 2000-2022 (from 2017 it is a forecast)

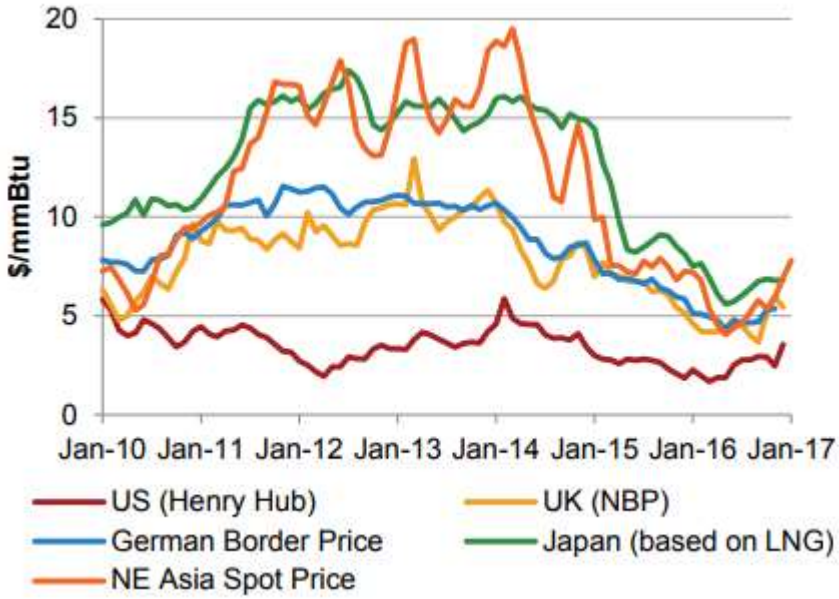


Source: IGU, 2017: World LNG Report. Figure 6.2.

With the spread of LNG, regional markets are becoming increasingly connected and a global market is forming on the place of the regional markets.

This is best demonstrated by the convergence of regional prices (IGU, 2017).

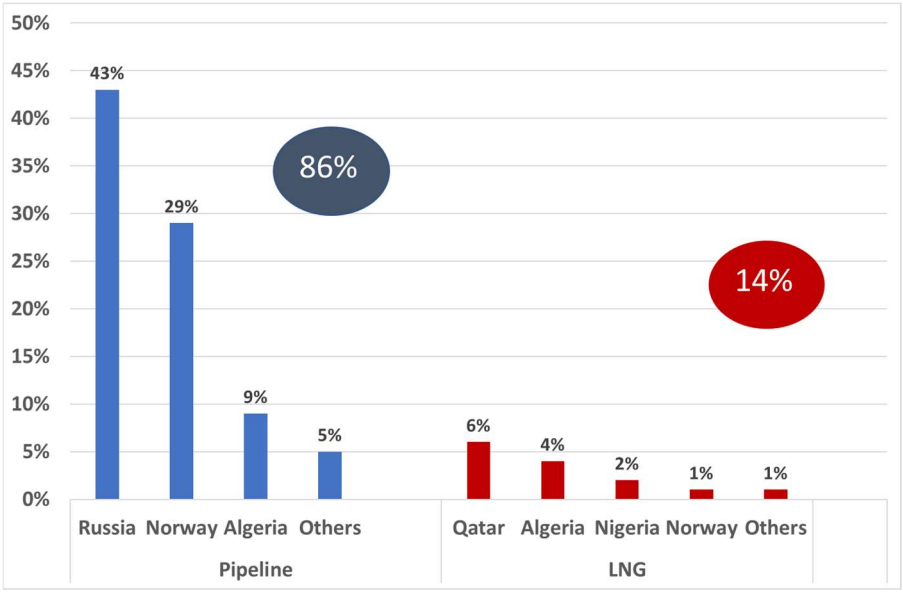
Figure A2: Monthly average regional prices, 2010 - 2017 January



Source: IGU, 2017: 2017 World LNG report. Figure 3.15

Europe's import supply for the time being is mainly served through pipeline, but with LNG new import sources could be involved, this year the United States also became one of the suppliers of Europe this way.

Figure A3: The source of European import and its transportation mode, 2016



Source of data: BP 2017b, p. 34.

Domestic pipeline system

In the consumer countries natural gas is transported from the production to consumer points also via pipelines. The domestic network has two levels. The so-called transmission network transports between the interconnection, producer, storage, distribution, and large end user points. This high-pressure pipeline system provides the backbone of domestic transportation. The operator of the transmission system coordinates with adjacent system operators and most importantly the system operation is responsible for ensuring the physically safe operation of the domestic system. In addition, the commercial balancing of network users is also managed by the transmission system operator (TSO). As it has already been discussed, the transmission network points are the gateways to accessing resources. For example, if someone cannot buy transmission system capacity at the import point, she cannot import even if she has procured the natural gas in the neighboring country. Therefore, the efficiency of wholesale trading requires equal, non-discriminatory access to the transmission network.

From the transmission system to the smallest consumers, natural gas is transported via the low-pressure pipeline network, the distribution system. In most countries, the distribution network company also performs the measurement of consumption and the operation of gas meters. The provision of non-discriminatory access is also essential in case of the distribution network as retail market players can easily be blocked to make a competitive offer to consumers if they do not receive a right to transport.

Compared to other primary energy sources, the transport costs of natural gas are significant in relation to the price of the product. This characteristic distinguishes natural gas from other primary energy sources, and this is why the sector is classified in the so-called „networked industries" group. I described the economic theory relevance of network industries in Chapter II of this dissertation.

I.2.3. Storage

Natural gas consumption is greatly volatile. As I have discussed it due to the geological, technological, and economic aspects production usually cannot be flexibly modified within short time periods. In addition, it is not economical to build the long-distance transit pipelines with the size of the peak winter consumption, if then throughout most of the year its utilization rate would be only at ~60% or lower. Consequently, the economic optimization of the transit infrastructure also suggests a constant base load supply, it is advisable to build the transit pipelines to the size of the average consumption level and not to the peak consumption level. Thus, domestic production and import sources can only be moderately flexible. The coordination of fluctuating consumption and inflexible resources is supported by so-called flexibility tools. The most important of these is the storage facility.

Three kinds of formations can be used for storing natural gas. Depleted gas fields, salt caverns, and aquifers can be converted into natural gas storage facilities.

As it can be seen a gas storage facility cannot be built up at any place, specific geological conditions are necessary. So just as there are producing countries, there are also 'big storage countries'. Hungary, for example, has significant storage capacities in Europe: our storage capacity is the sixth in the EU ranking. (GSE, 2017)

The storage facilities have different capabilities depending on the formation. Salt caverns typically are called as peak-shavers. They have a relatively small storage capacity, but they are able to inject and withdraw at a high speed by rotating countless storage cycles within a year. The depleted fields and aquifers, on the other hand, are able to operate relatively large storage capacity but cycling it at a very slow speed, injections is through summer and withdrawal is through winter, i.e. only one cycle per year.

In many cases, storages are essential facilities in a given gas market, i.e. the supply of consumers is virtually impossible without the access to storage services. Therefore, this infrastructure is often subject to separate regulation. However, in contrast to the transportation network, storages cannot be considered as a natural monopoly as they compete with other flexibility services on the Flexibility market (described in Appendix II below), and in addition if the geological conditions are present there could even be competition between storage facilities in a country.

I.2.4. Trading

Infrastructure transports natural gas from production to consumers. The way this transport is organized and how much the supply will cost in the end is the result of the commercial activity conducted within the infrastructural 'constraints'.

Like on other markets, in case of the natural gas market it is also advisable to discuss separately the wholesale market and the retail market where the direct supply of consumers is organized. The two are separated also along the physical infrastructure.

Wholesale market

As a consequence of the way the gas market evolved, the commercial activity for a long time was limited to long-term contracts, on a pre-defined route and with a ban on resale (destination clause), one player provided natural gas to the single supplier of that country, integrating all consumers in one portfolio. With market opening and infrastructure development commercial activity involves more and more players. Today, we are talking

more and more about competitive markets, and as Figure A2 shows the region's prices have begun to converge, a world market is emerging.[53]

In the wholesale level, import sources, domestic production, and flexibility tools are continuously exchanged on the market among traders. The trading period ranges from 30-year-long contracts to within day-hourly products. Spot Market refers to the day ahead trading. The products can be completely unique but can also be standard homogeneous products. The physical area of wholesale trading is the transmission network. Natural gas is exchanged between the traders at the Entry-Exit points of the transmission system. In addition to the specific physical points there are also virtual points which can be a simple virtual merging of multiple physical points, e.g. to a single production point, but they can also be fully virtual points created specifically for trading without any physical location, virtual trading points (VTPs). Commercial transactions can take place bilaterally, between the traders directly, but in most cases a broker facilitates the matching of supply and demand. The use of brokers is very common in the gas market. In addition, there are transparent platforms, exchanges as well. The exchange is the most developed market organization form in the natural gas market. It provides a completely transparent and anonymous matching of bid and ask offers for the standard homogeneous products. In most cases clearing houses complement exchanges and step in the middle of the concluded transactions: the buyer buys from the clearing house, while the seller sells also to the clearing house. This service provides a solution for dealing with counterparty risks, which is important in case of anonymous trading.

In Europe, at the conjuncture of the main transit routes, hubs are formed. These are commercial nodes where at a physical or virtual point, in addition to brokerage and exchange services, storage services are usually also available.

The development level of the wholesale markets is measured by the intensity of the commercial activity on the hubs, its liquidity. The current state of development of the European hubs was assessed by the already mentioned OIES 2017 Survey (OIES, 2017b). Their following table lists the European hubs according to their level of development. To measure the level of development, they used Heather's indicators from the 2012 and 2015 studies:

[53] See Miriello and Polo (2015) for a summary of the history of the development of now mature Western European wholesale gas markets.

- number of active participants,
- number of traded products,
- quantity traded,
- trading index, which is the spread between bid and offer, and
- the churn rate, which shows the ratio of the quantity traded and the quantity physically delivered.

As it can be seen, the British (NBP), German (NCG and GPL), Dutch (TTF) markets are the most advanced in Europe. The closest hub to Hungary is the Austrian VTP (CEGH), whose prices are often used as reference prices in the region. The Croatian regulator, for example, indexes the imbalance settlement price of the Croatian market to CEGH (HERA, 2017).

Table A2: Development assessment of Europe's hubs

2016	5 KEY ELEMENTS					
HUB	Active Market Participants	Traded Products*	Traded Volumes	Tradability Index (Q4)	Churn Rate	Score /15**
TTF	>40	53	22230	20	57.1	15
NBP	>40	47	20045	19	22.1	15
NCG	30	29	2080	16	4.0	10
GPL	30	23	1110	15	2.5	9
PSV	18	23	885	15	1.2	7
ZEE+ZTP	15	17	780	10	4.1	7
PEG Nord	15	18	550	14	1.7	7
VTP	15	14	530	10	5.7	7
VOB	<10	6	105	8	1.1	5
PEG TRS	<10	13	100	7	0.6	5
PVB	<10	9	30	0	0.1	5

* Score /64 derived from the OTC and Exchange product categories in the Traded Products Table.
** Score based on each of the Key Elements scoring zero for Grey; 1 point for Red; 2 points for Amber; 3 points for Green.

Source: OIES, 2017b p. 12.

According to the model of Miriello and Polo (2015) which describes the evolutionary process of wholesale gas markets, the last stage of development is when financial products that are not linked to any physical delivery appear. At this stage, in addition to the appearance of such products, the purely financial investors (like investment banks) that have no industry fundamental assets, like infrastructures and consumer portfolios also emerge.

The spot wholesale gas markets have often started out from balancing. (ACER, 2016). One of Europe's most advanced hubs, the British NBP (found in the second row in the above table), has also grown from a balancing platform (Miriello - Polo, 2015). This market-support role of balancing, as I have already mentioned, is also considered particularly important by the EU regulation, one of the main mission of the BAL NC is to organize balancing on a market basis and thus to support the liquidity of spot markets.

The source of retail trade, i.e. the supply of consumers, is the wholesale market. If the wholesale market is not liquid enough, there could be no effective competition on the retail market either. Therefore, while regulators are aimed at improving the prices and services experienced by consumers, this cannot be achieved without an efficient wholesale market. Thus, one of the main directions of regulation is the elimination of distortions of competition in the wholesale market, the promotion of competition.

Retail

For the supply of consumers suppliers create a portfolio of the sources. There are suppliers that specialize to a specific type of consumer, e.g. office buildings, industrial consumers, etc., but there are also bigger suppliers who are striving for a highly diversified portfolio so that they can realize synergies that derive from the diversity of their consumers.

The main challenge in retail is the stochastic nature of consumption. Therefore, forecasting consumption is a key task, and the measurement of consumption is a key area. Consumers, depending on their size, are usually measured at different frequency. On the largest consumers hourly measurement data is available through remote metering and the supplier knows this consumer groups' consumption almost real time. There is a consumer category that is measured once per day and there are the consumers that are measured less frequently, monthly, or annually. For the consumers measured monthly or annually the distribution company and might also the suppliers calculate a consumption profile that is determined by sampling measurements and characteristic features of consumer groups. In case of this consumer group these profiles are the main tools of consumption forecasting. In case of large consumers, such as industrial consumers, the situation is much easier. Typically, the trader asks for an updated daily plan of consumption from her

customer, and the deviation from this plan may be subject to a penalty charge set out in the supply contract.

To sum up, retailers buy their resources from the wholesale market and the success of retail competition depends on the liquidity and transparency of this procurement market. There are a variety of trader roles, there are some that deal only with wholesale, there are companies that do both, and there are companies that specialize in only retail supply. A good example for this latter are such new entrants that already have a marketing channel built up in another industry (T- Mobile was such in Hungary for example).

Appendix II: The broader context of balancing: The Flexibility Market

The broader frame of balancing is the flexibility need of natural gas supply and the supply of flexibility tools. In the natural gas market, the market for flexibility services can be presented and analyzed along its demand and supply, just as in the case of any other markets.

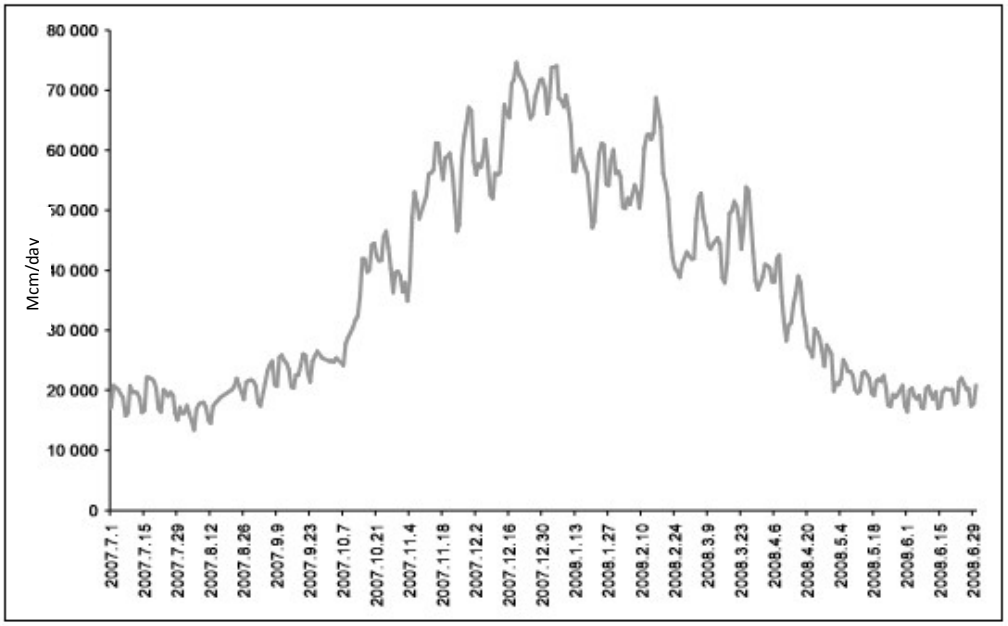
II.1. Demand for flexibility

Natural gas consumption is volatile on an annual, quarterly, monthly, daily, and within-day levels. The figures below show the Hungarian characteristics of gas consumption for different time periods and consumer groups.

Figure A4 shows the daily domestic gas consumption during the 2007/2008 gas year. (The gas year does not coincide with the calendar year, at that time it was from 1 July to 1 July of the following calendar year.) Both winter-summer seasonality and weekly cycles can be detected on the figure. There is almost a fourfold difference between the winter peak days and the consumption of summer days. That is, if the size of the import pipeline would have been adjusted to winter peak consumption, then throughout half of the year it would only be used at a 25-30% usage level. Therefore, tools that can provide seasonal flexibility (most notably storage, but some gas fields, such as Groningen are also capable) are very valuable to the overall system. The beneficial effect of storage on the transmission investments is also recognized by the latest Pan-European NC referring to the transmission tariff setting process (TAR NC)[54]. The TAR NC prescribes a minimum discount of 50% of the transmission tariff on the storage Entry and Exit points.

[54] Commission Regulation (EU) 2017/460 establishing a network code on harmonised transmission tariff structures for gas.

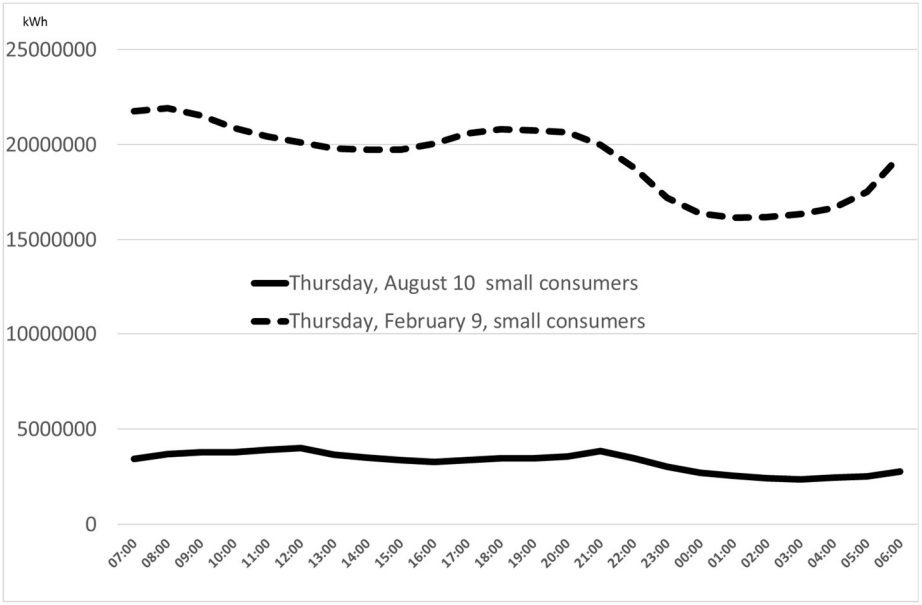
Figure A4: Hungarian daily natural gas consumption, gas year 2007/2008 m^3/day



Source: Data from FGSZ data publication, 2008.

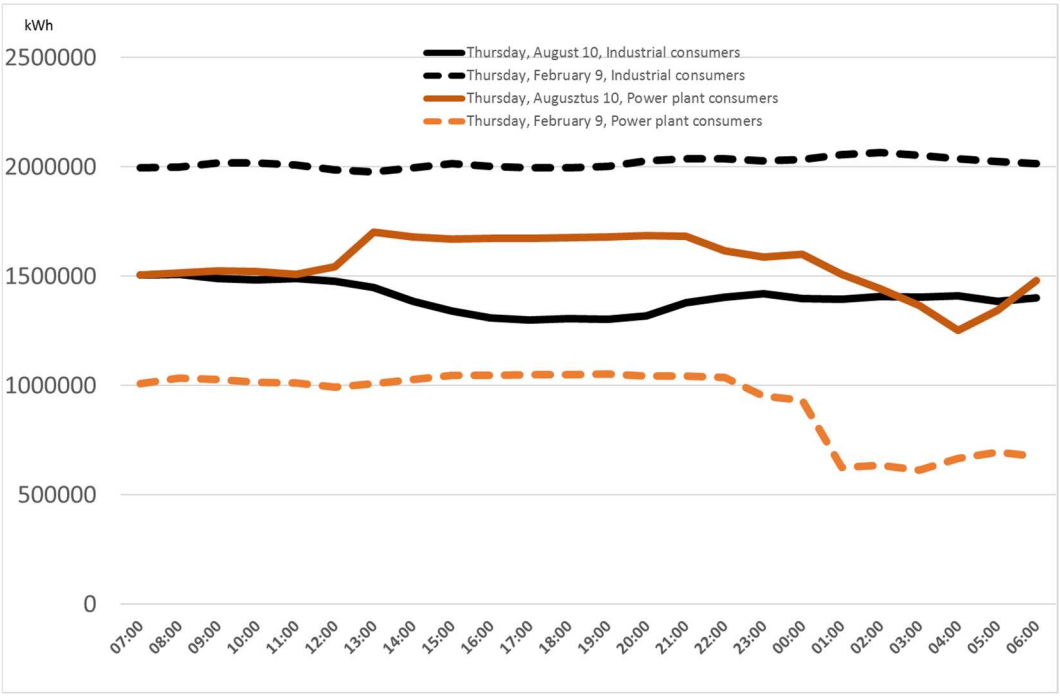
The following two figures illustrate on Hungarian consumption data how natural gas consumption fluctuates within day. For different consumer groups, this fluctuation is different, and its degree also depends on the season. In case of small consumers this within-day fluctuation is significant (Figure A5) and from the figure it also can be seen that small consumers are the ones causing mostly the winter-summer difference in consumption due to their heating demand. The consumption of the industrial consumers (Figure A6) is the most stable, on the one hand the difference between winter-summer consumption is the smallest in this consumption group, and on the other hand they have a close to base load consumption within day in winter – industrial production is running in three shifts – and even in summer there is only a moderate within-day fluctuation. The consumption of power consumers is the most unpredictable: on the days chosen in the example the summer consumption is for example higher than the winter consumption. This is due to the fact that natural gas-fired power plants produce electricity according to the needs of the electricity market and thus consume natural gas accordingly, so the activation of air conditioners in the summer heat generate considerable natural gas demand. The within day consumption of power plants is also hectic, as the natural gas power plants are so called „peak" power plants, the power market's intraday fluctuation is reflected in the gas consumption of the power plant.

Figure A5: Fluctuations in the consumption of small consumers within the day in winter and summer, examples of Hungarian consumption data



Source: Data from FGSZ (2017) Data publication: DSO Exit point hourly data

Figure A6: The fluctuation of consumption of industrial consumers and power plants within the day in the winter and summer, with examples of Hungarian consumption data



Source: Data from FGSZ (2017) Data publication, in case of industrial consumers Industry Direct Exit point gas flow data, in case of power plants, Powerplant Direct Exit point gas flow data

From the above it can be seen that the flexibility need of the gas market depends on what the different consumer groups use natural gas for and on the size of the consumer groups' consumption compared to total natural gas consumption, i.e. the composition of consumption.

- If large share of households uses natural gas for heating, then temperature changes within a short time period can have a significant impact on the balancing market. Temperature changes also play a significant role if heating is mostly supplied by gas-based district heating plants.
- The fuel composition of power plant production (most importantly that of the balancing plants) can also significantly determine the demand for natural gas flexibility, if electricity market balancing is performed mainly by gas-fired power plants it will result in significant within-day fluctuation on the natural gas market.
- The stable consumption of industrial consumers does not cause a balancing need in normal operation, it can be predicted, but an unexpected loss can also cause complications here.
- Similarly, technical problems, unexpected outages on infrastructure elements (e.g. mining, pipeline) may also impose need for flexibility.

To sum up, (temperature-dependent) daily fluctuations in household consumption and the power market dependent natural gas consumption of power plants are the two main factors that can regularly cause demand for daily and within day flexibility on the natural gas market. In addition, in exceptional cases, unexpected losses may also occur, which also affect the flexibility market.

II.2. Supply of flexibility

The range of tools available to provide flexibility depends primarily on the physical infrastructure in the given zone (country). The main tools are:

Linepack- flexibility: The transmission pipeline itself can also provide temporary storage. This is the first tool that is used to handle balancing needs, however it has limited storage capacity and can only be used temporarily, within the day, and it is necessary to restore daily they linepack level.

Storage: Storages are the main flexibility tools of the system. They are designed specifically for this purpose. Geological endowments determine the storage potential of the zone.

LNG: The operation of LNG infrastructure is most economical if it is fully utilized, but if it is not utilized at the maximum level, it is also suitable for temporary storage and thus to provide flexibility.

Production: In the description of the supply chain, I have shown that natural gas fields may (also) differ in the aspect of how much flexibility they can provide. In Hungary, and in the neighboring countries, domestic production is typically inflexible. But for example, the Dutch Groningen field, for a long time, was one of the main suppliers of flexibility to the Western European region.

Importing flexibility: Flexibility can be purchased from neighboring markets. In this case, the unused import capacity available on the interconnection point constitutes the limit of flexibility import. However, since this solution is a waste compared to the optimal utilization level of the transmission infrastructure, it is only advisable to rely greatly on flexibility import if there is no possibility to build storage facilities. It is also important to mention that in addition to the physical constraint imposed by the interconnection point's available capacity, there could also be a further commercial limit to importing flexibility. The commercial flexibility potential depends on the import agreements of the country, or whether there is a liquid spot market beyond the borders. If the country receives supplies from a single supplier and there is no liquid spot market in the neighborhood, then the import of flexibility depends first of all on the flexibility of the import contract and not on the freely available cross-border capacities.

Appendix III: The broader framework of the balancing system

III.1. Access model

The balancing system is partly determined by the transmission network access model. The access model, among others, lays down how natural gas can be traded within the system. There are three main models known in the literature,[55] the variants of these can be found in practice. These models apply a different solution on the division of rights and obligations between TSOs and network users, lay down three different types of contracts between the parties.

In the Postage Stamp model, the trader can transport gas from any point in the system to any other point for a unified charge which is usually paid at the offtake and is based on the amount of natural gas withdrawn. That is, it is an ex post type charge, payable based on usage and is a commodity charge, based on the delivered m^3 or MWh. (The term postage stamp refers to that the trader can deliver its gas to anywhere within the system for a fixed m^3 or MWh fee.)

The Point-to-Point system works as if independent pipelines were to form the system, traders contract specific routes, i.e. they purchase the right to use the system along specified Entry-Exit pairs and pay the usage fees accordingly. This system is capacity-based, the right to use the system is obtained by booking capacity on the system, and the charge is based on this contracted capacity (units of measure: m^3/h, m^3/day, or MWh/h, etc.). Based on the actual usage only a small amount of commodity charge is collected, if collected at all.

Finally, in the Entry-Exit system, traders book the Entry and Exit points of the system separately. There is no route limit, any Entry point can be used by the trader for the supply for any Exit points, and charges for capacity booking at the different points may differ (unlike in the case of Postage Stamp system) and each point has to be booked separately. This system is also capacity-based. A very important element of the Entry-Exit system is

[55] Most of the literature presented in Section II.3. mentions the three access models, a detailed discussion is provided in Keyaerts (2012).

the so-called " virtual trade point (VTP)" a physically non-existent settlement point through which the wholesale trades can be conducted without specific geographical location. VTP typically hosts stock exchanges and other platform-based trades as well as the imbalance settlement.

The Postage Stamp system, as it is seen, is the simplest but due to its simplicity it cannot reflect the complexity of the system, the incoming payments and the cost centers are totally delinked. The Postage Stamp system is usually applied on transmission systems at the beginning of the market opening, in the immature phase of the gas market,[56] while on the distribution networks this is the most typical access model.

The Point-to-Point system is common in the United States, where instead of centralized, systems, transport is based on individual pipelines, and these pipelines compete. The Entry-Exit system is the opposite of this, it connects the points of the system in a spider-web like way. Compared to the Postage Stamp model, with the possibility to price each point differently this model is capable to indicate the cost centers of the infrastructure. The Entry-Exit system is in fact similar to the power grid model.

The three systems set different circumstances for balancing. In the Point-to-Point system traders choose in advance from the flexibility packages the operator of the given pipeline offers, i.e. there is no ex-post balancing in such a system. But even other players (connected storages, wholesalers, etc.) may also offer a flexibility service for that pipeline. In this system, the flexibility agreement is ex ante, and competitive markets emerge for the transportation and flexibility services (Keyaerts, 2012).

The zone-based approach of the Entry-Exit system eliminates competition between routes, as gas can be injected and withdrawn at anywhere on the system. It provides geographical flexibility and by applying the linepack-flexibility for the system as a whole, it also provides time flexibility (Keyaerts, 2012). In this system, balancing is a standard, homogeneous service available to every system user, its parameters are set in the Network Code. It is provided by a single monopoly provider, the system operator, and the service is settled ex post.

The Postage Stamp system provides similar framework for balancing then the Entry-Exit system, but the Entry-Exit system by the virtual trading point provides a much stronger

[56] This is well illustrated in Figure 26 of the KEMA study (KEMA, 2013): In 2013 in the EU Postage Stamp system as a transmission network access model was only applied in the least developed markets (Latvia, Lithuania, Estonia, Finland, Sweden, Bulgaria, Luxembourg).

support to both, the ex-ante balancing of traders, and the TSO's procurement for residual balancing, thus the emergence of a wholesale spot market in general. The Entry-Exit model also promotes secondary capacity trading, which further increases the geographic flexibility of the system and the flexibility opportunities for traders.

Since the application of the Entry-Exit system is now mandatory in the EU Member States, throughout this dissertation I consider this model as the core transmission system model.

III.2. Balancing Responsible Party

The Balancing Responsible Party (BRP) is the legal entity that has concluded the balancing service contract with the system operator. The simplest case, which occurs for example in Hungary, is that each system user is also a BRP for balancing her portfolio and settles the imbalances with the TSO. In comparison, there are systems – such as in Austria, Germany – where multiple system users can form together a BRP. In this case, the transportation services are contracted individually between the system user and the TSO while the TSO only contracts the balancing service with the BRP and only the aggregate imbalance of the BRP portfolio is settled with the system operator. The BRP formation is motivated by the fact that the unexpected imbalances of the intra-group members – if the portfolio is put together well – could offset each other and thus the BRP settles a smaller amount of imbalance with the TSO than the sum of the individual imbalances of the BRP members. Such grouping is therefore expected in systems where balancing expenses are relatively large for system users (as we will see, for example in the hourly settlement systems) and can therefore offset the additional administrative costs associated with group formation.

III.3. Balancing zones

The geographical boundaries of the physical balancing problem and the system users' obligation is marked by the balancing zone. Traders should balance their portfolio within the balancing zone and the system operator is responsible for the system balance within

that zone. Balancing zones often coincide with the Member States, but there are some Member States where there is more than one balancing zone, and there are also cases when more than one Member States form one common balancing zone.

Small zones

At the beginning of market opening, as the Sector Inquiry prepared by the Commission's Directorate-General for Competition (ECDGC, 2007) identified it, one of the main difficulties for the new entrants in trading was that there were too many balancing zones, which were individually small and most of these operated under a different regulatory system. There was even a case when a single pipeline formed a separate balancing zone. The reasons for the multi-zone system within the Member States were various, for example different quality of gas (Germany, Belgium), administrative reasons, such as the different ownership backgrounds of transmission systems (Germany, France). (ECDGC, 2007) Smaller zones are a bigger balancing burden for traders as they can only build smaller portfolios in the zone, and thus the portfolio effect – that imbalances within the portfolio can offset each other – is less effective. Thus, in smaller zones, the risk of imbalance of traders is higher (KEMA-REKK, 2009). Moreover, the availability of balancing tools in a small zone are also more limited, so TSO's system balancing can also be more expensive. Finally, a further disadvantage of small zones is that it makes trading across zones, so the trading on the common Internal European market, more expensive, on the one hand, by having to conduct the full nomination procedure and balancing obligation in each zone, and second, that traders have to adapt to many different systems as these zones generally have different balancing rules. Finally, trading across zones requires capacity booking on each affected interconnection point, which further increases both the administrative and the explicit costs. Thus, it is not surprising that one of the main suggestions of the EU study was the merging of zones, the creation of larger balancing zones (ECDGC, 2007).

Multi-country balancing zones

By today, the merging of balancing zones within the countries has taken place in the EU and only in very justified cases (e.g. due to different gas quality) remained more than one

zone within a Member State. Regarding the balancing zones there are two main directions for the development of an Internal gas market, the barrier-free inter-country trade in Europe: the harmonization of the balancing rules of the zones and the merging of national zones, i.e. the establishment of multi-country balancing zones. The former process started with BAL NC, while the latter process started with some pioneer country groups.

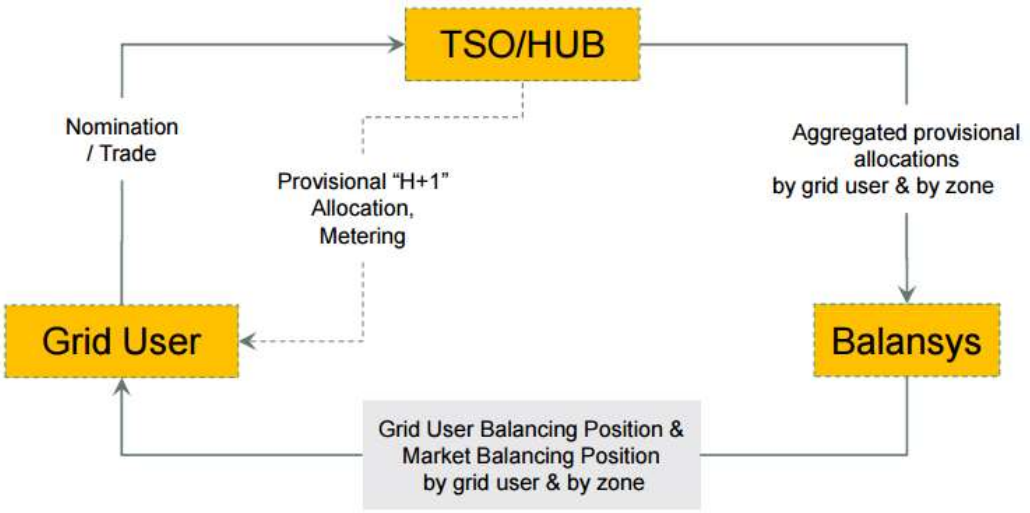
The development of multi-country zones has been analyzed by several consultants for the Commission. For example, with a collaboration of several academic researchers, a 2013 study on quantifying the impacts of integration, calculated also an integration scenario in which the European Union's natural gas market would be integrated into a single balancing zone. Results have shown that the merging would have a beneficial impact on natural gas prices worth EUR 30 billion a year for the EU27 (Booz & Company et al., 2013).

Academic thinking about the methodological possibilities of mergers has also begun. The most important papers in this topic are written by the Florence School of Regulation, a research center focusing on network industries' regulation, already introduced in the literature review part of this dissertation. One of the merging alternatives that they have summarized in their MECOMs model is the full merging that they named as the Market Area Model (MAM), the other alternative, the Trading Region Model is a partial merger where the market is merged, but balancing remains partially national (Glachant et al., 2013).

By today, the Belgian and Luxembourg gas markets are merged into a single zone under the MAM model (Fluxys, 2017). Further MAM merging processes started on the Danish-Swedish market (Energinet.dk, 2017) and in the three Baltic States, Estonia, Latvia, and Lithuania (Amber Grid, 2016). Trading region model is being consulted with the Czech-Austrian market participants (ERU et al., 2016) and have not yet decided on the precise method of consolidation, but there has long been a consultation on merging in the Iberian market (Spain and Portugal) (CNMC-ACER-ERSE, 2014). The box below presents briefly the operation of the MAM model.

The day-to-day operation of the MAM model is illustrated by the following diagram describing the planned information exchange process of the BELUX market. As it can be seen, the national TSOs remain. They receive the nominations and they judge whether the system can fulfill the delivery orders the system users' nominations contain or not. Based on the confirmed nominations and the forecasts, the TSO calculates the allocations per system users per network points. These aggregated values are then sent to the market area operator (MAO) above the TSOs, which is called Balansys in the BELUX system. MAO monitors traders' positions at the entire zone level and determines their imbalances. The MAO regulary informs the system users about the balance status of their portfolio, and then prepares the final imbalance settlement after the gas day. Traders settle their imbalance with the MAO. In addition, MAO is responsible for the balance of the zone, it performs the procurement for the residual balancing of the zone on the basis of the system users' data and the requests sent by the TSOs. And finally, the MAO also operates the virtual trading point of the zone, the place of imabalance settlement, which is also the main place of trading in the entire aggregate market. These three activities: the operating of the imbalance settlement system, the performing of the residual balancing of the system, and the operation of the virtual trading point is the main task of the MAOs.

Illustration of the operation of the MAM model by the example of the BELUX market



Source: Fluxys (2015) p. 45.

III.4. Balancing period

One of the key determining points of the operation of the balancing system is the balancing period, i.e. within what time interval do traders have to balance the amount of gas that they have injected into and withdrawn from the system. The choice of the balancing period also affects the division of responsibilities between TSOs and traders. Within the balancing period, the system operator is responsible for balancing the system while the trader is only responsible for balancing its aggregated inputs and aggregate purchases over the period. This is illustrated by the example below.

Division of responsibilities

Example: The within-day supply of a power plant's consumption

To illustrate how the division of responsibility between the TSO and the system user is affected by the choice of balancing period, based on Keyaerts's (2012) example I use the case of a hypothetical power plant customer below.

Let's assume that the balancing period is a gas day, as in the Hungarian balancing system. In this case, traders are not responsible for imbalances within the day. It is enough to reach the balance of the aggregate values at the end of the day.

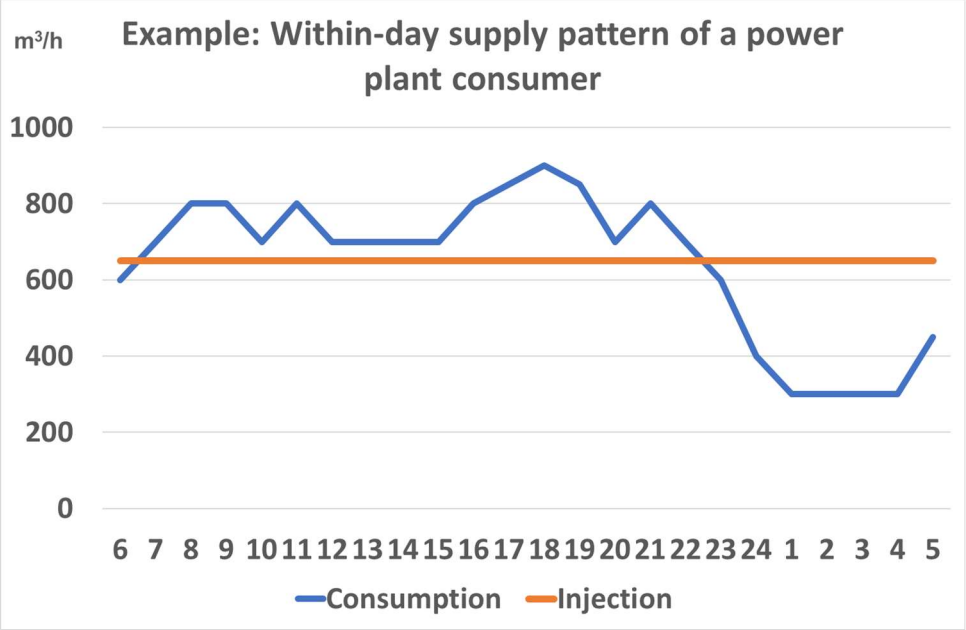
The natural gas consumption of the power plant can be extremely volatile within day, as gas-based power plants typically play a balancing and peak supplier role on the electricity market, i.e. with their power production they cover the intraday fluctuations of electricity consumption. The following Figure A7 shows the natural gas consumption curve of such a hypothetical natural gas-based power plant during the day (blue). (The gas day starts at 6:00 AM and lasts until the next day 6:00 AM) The natural gas trader who supplies the power plant with natural gas is only obliged to supply the total natural gas consumed by the power plant by the end of the day. That is, an optimum choice for the trader could be if it supplies the power plant's production during the day as a base load product (a fix flow during the entire day). In my opinion, it is a good solution for the trader for several reasons:

- The price of a base load natural gas product, which is uniformly delivered per hour, is cheaper than the procurement of a fluctuating profile within a day. The

main reasons for this are due to the properties of the production technology and import transport costs.

- By transporting a daily average amount on the transmission system instead of a fluctuating amount with peaks the trader can save also on the capacity booking fee of the Entry point.

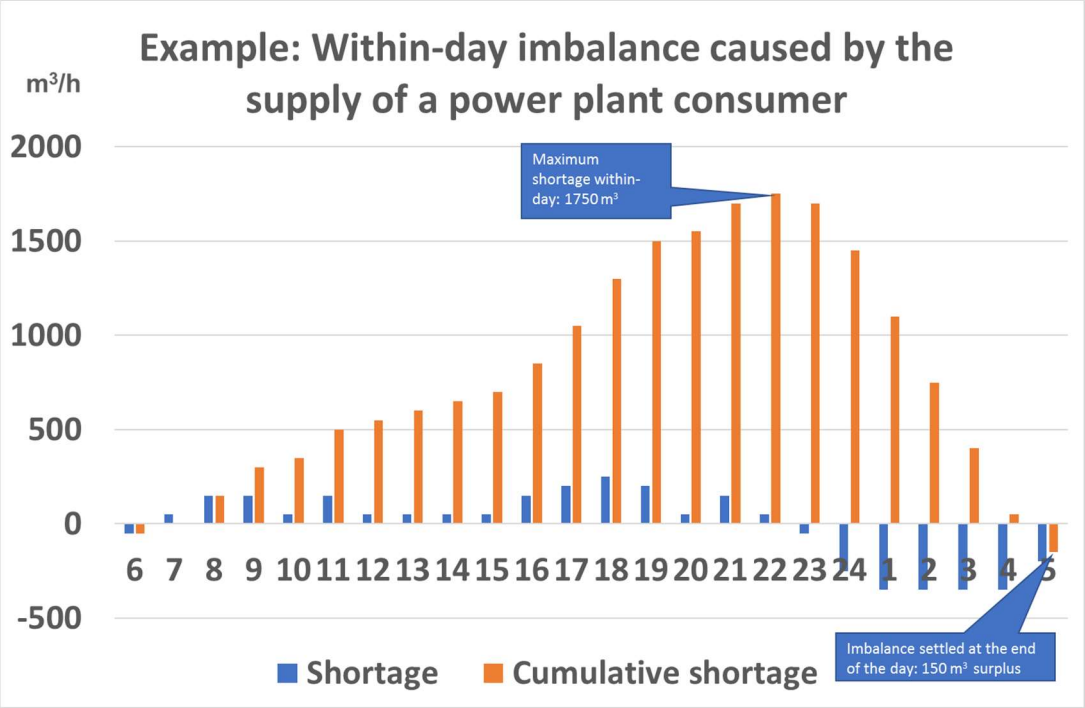
Figure A7: Example: Within day natural gas consumption curve, and its supply of a power plant consumer



Source: Own figure, based on Keyaerts (2012)

With such a supply the trader fulfills her balancing responsibility by the end of the day (in the example with a slight surplus: 150 m^3), while, as Figure A8 illustrates, with this supply and consumption pattern the trader caused significant imbalances in the system during the day, and the peak cumulative shortage rose up to 1,750 m^3. It can be seen, therefore, that in the daily balancing system while the trader has to settle only the surplus of 150 m^3 with the TSO, it does not have to face the deficit of 1750 m^3 it caused within the day. In such a system the TSO is the sole responsible for the within day balancing.

Figure A8: Example: Within day cumulative imbalance of a power plant consumer



Source: own example based on Keyaerts (2012)

The shortages and surpluses within the day are handled by the TSO primarily with the linepack-flexibility, however, if the cumulative imbalance is so large that it cannot be solved with linepack-flexibility safely alone, the TSO procures external balancing tools. Both linepack-flexibility and external flexibility tools are costly. The direct cost of linepack-flexibility – the associated compression activity – is included in the overall cost of the transmission system and thus it is paid by all network users through the transmission tariff. (Keyaerts et al., 2011) The cost of external purchases is born by those traders that are in imbalance at the end of the day. In the example for example, it is not the power plant supplier who will pay the possibly emerging cost of applying an external balancing tool to handle the large within day cumulative shortage, as the trader at the end of the day was in slight surplus. In summary, it can be seen that in the daily balancing system the responsibility of within day balancing is entirely lies on the TSO and its costs are only accidentally born by the causers. It is very likely, that traders who supply consumers with flatter profiles (causing fewer within day cumulative imbalances) are often cross-subsidizing those suppliers who supply consumers with more fluctuating consumption profiles. (Keyaerts, 2012)

Other timeframes

If the balancing period is even longer, such as the monthly balancing period still applied in Ukraine in 2017 (Zachmann, 2017) then these problems and the TSO's responsibility would be even greater. By reducing the length of the balancing period, these distortions can be reduced. In some countries, such as Austria and Germany, there is an hourly balancing system. In case of an hourly system, the injected and withdrawn amounts must be in balance on an hourly level, so much of the balancing responsibility is transferred to the trader, and the costs are borne by the causers. In an hourly system traders ex ante provide for the availability of flexibility tools that they can access within day.

However, an hourly system may also have disadvantages. In the daily system it was apparent that the end of the day balancing is cost-effective for the trader, as it can optimize its capacity bookings (it contracts the average and not the peak consumption level on the Entry point) and it can supply its consumer with a cheaper base load product. This capacity booking optimization can be beneficial for the system as well as in this case it is not necessary to build the entry side capacities as large as the peak consumption, it is enough to build it to the average consumption level, thus by extensively utilizing the linepack-flexibility investment costs can be saved. In an hourly system, the trader cannot do this capacity booking and supply optimization, she has to adjust her purchase bookings to the daily peak consumption. And at the system level, the entry capacities should be built to the hourly peak consumption level while the linepack-flexibility is not used extensively. It can be considered as a waste. Thus, in my opinion, an hourly system should only be introduced if there is already an excess of Entry capacities either due to a drop in consumption or for any other reasons. In this case, too, it should be noted that, due to the underutilization of linepack-flexibility, traders and therefore consumers will have additional costs due to more expensive profiled supply within the day and the associated higher capacity booking obligations.

Distortion of the flexibility market

By the fact that in a daily system the trader is not responsible for imbalances within the day, she needs fewer flexibility services within-day, ex ante she will contract less such services to be available for her. Also, the TSO will only use these flexibility services after

the exploitation of the linepack-flexibility. Thus, it can be seen that the choice of the balancing period also affects the market for flexibility services. If traders would have to meet an hourly balancing obligation, they would contract more storage and other flexibility services ex ante and much less physical balancing task would be left for the TSO. This would also result in the TSO making less use of linepack-flexibility. Of course, then the optimal solution would be Keyaerts et al.'s (2011) suggestion that linepack-flexibility should be available to traders as an ex ante contractable service, just like other ex-ante flexibility tools. Some countries, such as the Czech Republic, France, and the Netherlands (Acer, 2016) are experimenting with this.

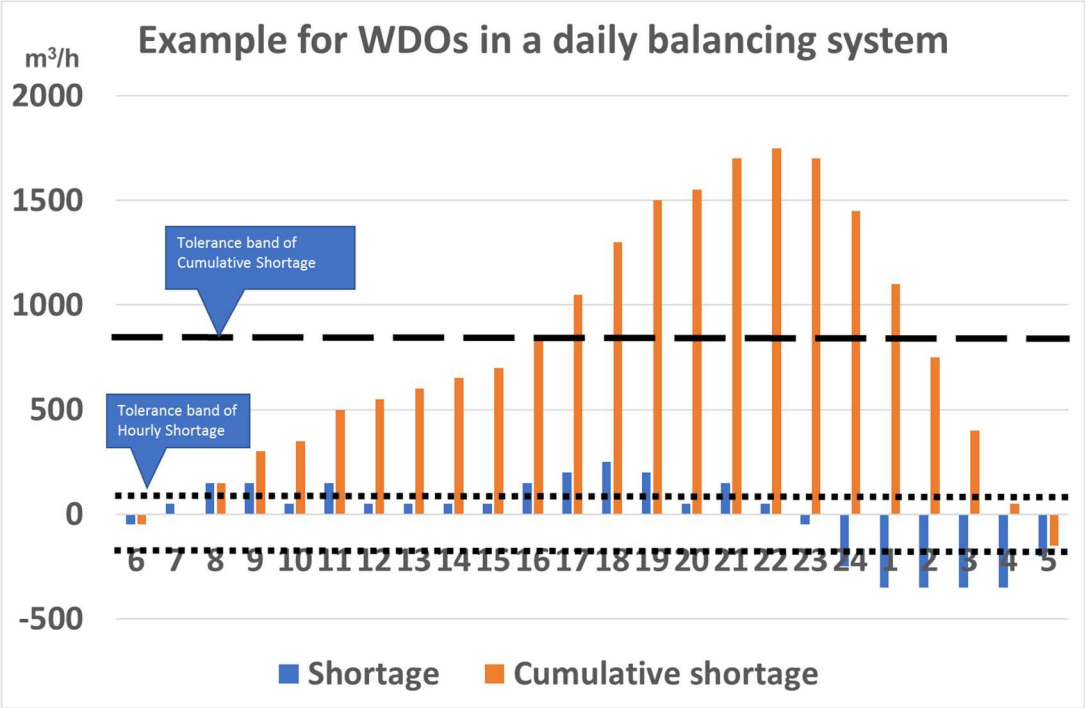
Thus, to sum up, in a daily balancing system storage and other flexibility services are less needed by traders than in an hourly system. Additionally, during the physical balancing of the TSO the extensive use of linepack-flexibility also displaces the other flexibility tools. Thus, the short-term flexibility market is also heavily influenced by the length of the balancing period.

Intermediate systems

Between the daily and hourly systems intermediate systems can be defined that alleviate the problems of the daily system, while avoiding the efficiency losses of the hourly system. For example, such an intermediate solution could be if in a daily system a further threshold would be introduced for the within-day cumulative imbalance, or for the hourly imbalance, and an imbalance settlement charge would be payable for those that go beyond this within day threshold. It is advisable to determine the threshold level according the available linepack-flexibility. The amount that can be safely handled by linepack-flexibility is left for free, and above that level the causers have to pay. This way the imbalance settlement system better reflects the costs associated with the physical balancing of the system. It punishes those that caused large within day imbalances.

In the case of the power plant example, the following Figure A9 illustrates how such an intermediate system can work. In many cases such systems are defined asymmetrically, the surplus is less punished than the shortage.

Figure A9: Example: Intermediate balancing systems: WDOs



Source: Own example based on Keyaerts (2012)

Harmonizing the balancing period with neighboring countries

Keyaerts and D'Haeseleer (2014) have shown that when adjacent connected systems operate different balancing systems, traders will optimize their imbalances between the two systems. In their example they showed the case of an hourly and a daily adjacent balancing system. Although they used hypothetical numbers, they compared the two systems to the English and the Belgian hourly systems (but their theory can be applied also for the Hungarian daily and the Austrian hourly system). In their model they showed that traders who supply consumers in both countries, thus their offtakes are stochastic, cannot be estimated perfectly, compared to the autarch state when there is no interconnection between the two zones, when the systems are interconnected traders begin to optimize their imbalances between the two systems. Their within day imbalances are redirected to the less strict daily system. Keyaerts and D'Haeseleer call this phenomenon Forum Shopping. As they explain it, this term was originally used by the legal literature for the case when the legal entities choose the legal system for the court

trial according where the outcome would be more favorable for them. In this case, with the Forum Shopping term the authors refer to the shopping-like choice of traders between the different balancing systems, they direct their imbalances to the more favorable system.

Although this solution is optimal for the traders, Keyaerts and D'Haeseleer draw attention to the fact that it is not necessarily optimal from the point of view of the systems. It may be that in the daily balancing zone the flexibility tools besides the linepack-flexibility are more expensive than in the other system. Due to Forum Shopping however the within day cumulative imbalance in this daily system will increase which enhances the likelihood that flexibility tools besides linepack-flexibility will have to be applied. This way the more expensive system will be used more. Harmonization of balancing regimes is therefore also important and economically justified in the case of the balancing period.

Appendix IV: The development of the European natural gas market regulation

IV.1. Single Internal Market for Energy

The history of the development of the European natural gas sector for long had been defined by the integrated monopolies, which were the optimal structural solutions needed when the sector was formed. After the initial period, however, the expansions of the European pipeline network resulted in the connecting of the formerly quazi-isolated national markets, and in addition some of the long-term contracts that were made at the beginning and which foreclosed the national markets started to phase out. That is, the physical and economic barriers that separated the national markets began to dissolve.

Following the adoption of the Single European Market initiative in 1985, due to the mentioned developments the European Commission found it possible to also include the natural gas market (Stern-Rogers, 2014). At the end of the 1980s, European legislation embarked on the necessary legal and regulatory steps to achieve the internal liberalized pan-European gas (and electricity) market goal.

Some of the European Member States were more initiative with gas market opening. The United Kingdom was the leader (and outside of the Union Norway was). In these leading Member States, reforms were often deeper and more comprehensive than the EU packages, so in their case, EU legislation had little impact (Haase, 2008). However, to most of the Member States the main drive for the natural gas market reforms was coming from the EU institutions' „pushings", and it is so even today. These countries differ in the depth of transposition of EU requirements. For some countries, their legislative changes have provided for liberalization rules that go beyond EU requirements, while many countries have achieved the EU level, and there are also some other countries that have not met all EU requirements.

In Europe, the United Kingdom has played a pioneering role in the thinking about the gas market opening and its practical implementation. The UK reforms in many aspects functioned as a model for the European energy market reforms.

IV.2. First phase

First Gas Market Directive

The First EU gas Directive[57] published in 1998 had to be transposed by the old Member States by 10 August 2000 (Haase, 2008).[58] In the case of directives Member States have to transpose – in their own way – the principles and objectives set out in the directives. Therefore, besides the specific requirements I will also discuss the general principles and objectives and the area specific principles and objectives set out in the directives.

The principles of the First Directive on the natural gas market were objectivity, non-discrimination, transparency, efficiency, security, and economics. These principles have to govern the natural gas industry's operation also in its details.

As far as the specific requirements are concerned, the First Directive proceeded along the mentioned access provision (to sources, to networks, to consumers) directions:

- In providing access to the networks, it stipulated the principles that third parties should have homogeneous, non-discriminatory, and transparent access to the networks (TPA). Member States had the choice between negotiated and regulated access. In both modes, access should be granted to everyone under the same conditions, no discrimination is possible, however, negotiated access gives more opportunities to the network operator to determine tariffs and conditions. On the other hand, regulated access is more stringent, more transparent for network users, making access subject to conditions and tariffs set by the regulatory authority.
    - To ensure cost-based and transparent pricing of transportation services, the First Directive stipulated the accounting unbundling of the transmission activity from other activities within the integrated (incumbent) company. The purpose of this is to make the cost of the transmission service more visible and so service tariffs for new entrants could be set in a cost-based manner. This is an important element in avoiding the incumbent company to increase transmission tariffs to levels

[57] Directive 98/30/EC of the European Parliament and of the Council concerning common rules for the internal market in natural gas.
[58] Finland, Greece and Portugal have been granted derogation.

higher than real costs and thus cross-financing its other activities (such as the now competing commercial activities), i.e. to distort competition to its own benefit through the transmission tariff setting.

- Providing access to consumers: Regarding legal market opening, the First Directive has divided the Member States into 'advanced' and 'beginners' groups and stipulated a different market opening path for the two groups. The Member States had to meet market opening targets to predefined dates regarding the share of the consumption that had to be made eligible to choose a supplier – for example, for the beginner group at least 28% by 2003, at least 33% by 2008. In addition, it stipulated that consumers with a consumption above 25 million m^3/year and all power plant consumers should also be made eligible to choose freely their supplier.
- Finally, as a first step towards ensuring access to sources, as a consequence of non-discriminatory network access, the First Directive abolished the import restriction, in other words the monopolization of import rights, thus anyone had the right to import (if it could).

Second Directive

The Second Directive[59], which was adopted in June 2003, went along the path set out by the First Directive but it stipulated more stringent standards in practically all areas. It has complemented the principles with fair prices, consumer protection, cost-reflectiveness and environmentally friendliness. As for the specific areas:

- Providing access to networks (and other infrastructures):
    - The Second Directive in the network TPA regulation made the regulated third-party access system compulsory (overwriting the First Directive's option for negotiated access). In addition, it established more detailed requirements for the method and conditions of third-party access and imposed more detailed transparency rules.

[59] Directive 2003/55/EC of the European Parliament and of the Council concerning common rules for the internal market in natural gas and repealing Directive 98/30/EC.

- Another important step of the Second Directive – which was particularly important from the perspective of the flexibility market – was the obligation to provide third party access to storage infrastructure (option between the regulated and negotiated access was given).
- Regarding the unbundling of activities, the Second Directive prescribed in the place of accounting unbundling the more stringent legal unbundling i.e. the network activity had to be organized in a separate company. By this requirement it was expected that in a separate company, even if it was part of the incumbent's holding, network activity can become more independent, it would be less subordinated to the incumbent business division. In addition, the Second Directive required management-level unbundling as well, i.e. that the decision-making body of the network subsidiary should also be separated in person from the rest of the holding's personnel, thereby further strengthening the independence of the network activity. (At the distribution level, networks supplying less than 100,000 consumers were exempted from the legal unbundling obligation.)

- Regarding the provision of access to consumers, i.e. legal market opening, the Second Directive has significantly shortened the previously set market opening path: it required that from 2004 for all business customers and from 2007 for all consumers, including households, the right to freely choose their natural gas supplier should be provided.
- Finally, it was an important step in the strengthening and enforcement of the new rules, that the Second Directive provided for the establishment of independent national regulatory authorities for the consolidation of sector-specific (ex-ante) regulations.

The regulation of balancing

The separation of transmission from the commercial activities and the opening of the market has transformed the relatively simple, within-company centralized coordination of gas flow and balancing into a decentralized multiparty system. To coordinate this decentralized system, as I have shown it previously it is necessary to set up a regulatory regime defining the tasks and responsibilities of the system operator and the traders.

The EU regulation only addressed the balancing issue explicitly for the first time in the Second Directive, where it laid down the main principles that should govern the balancing of Member States. These are **non-discrimination, cost-reflectivity, transparency, incentivizing, and, as much as possible, market-based operation**.[60]

1775/2005 Regulation

The third and final point of the first regulatory phase was Regulation No 1775/200561, which regulated in detail the conditions for capacity allocation and congestion management. In the EU legislation, the regulation is a legal form that, starting from its adoption at EU level becomes immediately applicable to all Member States, thus it is a more stringent EU regulatory tool than the previous Directives, leaves less authority for the national legislators. By this 1775/2005 regulation the process has begun that European regulation after starting with softer legislation tools that leave room for national specifics shifts to more specific and EU-wide binding legislation. Despite that this 1775/2005 Regulation already had a direct application from 1st July 2006, it is still considered to be part of the first softer phase of the EU natural gas regulatory history because it does not contain specific requirements (like for example methodologies for network access provision, such as for the method of capacity allocation, the contracting periods, the application of congestion management procedure, etc.) but instead, just as in the case of the previous Directives, it still leaves the details to the Member States and is rather a supplement to the Directives than the deepening of those (Haase, 2008).

[60] The egzact paragraph: "*In order to ensure effective market access for all market players including new entrants, non discriminatory and cost-reflective balancing mechanisms are necessary. As soon as the gas market is sufficiently liquid, this should be achieved through the setting up of transparent market-based mechanisms for the supply and purchase of gas needed in the framework of balancing requirements. In the absence of such a liquid market, national regulatory authorities should play an active role to ensure that balancing tariffs are non-discriminatory and cost-reflective. At the same time, appropriate incentives should be provided to balance in-put and off-take of gas and not to endanger the system."* (2003/55/EC, Preambulum 15.)

[61] Regulation (EC) No 1775/2005 of the European Parliament and of the Council on conditions for access to the natural gas transmission networks

The main provisions of Regulation 1775/2005:

- A step forward in the ensuring of non-discriminatory network access was that the Regulation raised the issue of the establishment of national transmission network codes (NCs). With this solution, the access rule system becomes more transparent and thus ensures that everyone has access to the same services along the same rules.
- To improve the availability of transmission capacities, the regulation required the application of congestion management procedures. Congestion management procedures are designed to make better use of existing network capacities by making available contracted, but unused, capacities to all system users. This could prevent incumbents from foreclosing the market from potential new competitors by privileged rights to the transmission system capacities. In this spirit, the Regulation required that, in the case of new or renegotiated capacity contracts, where there is a contractual congestion, the system operator shall offer unused capacities as a freely available capacity to the market at least on a day ahead premises (use it or lose it - UIOLI).

The regulation of balancing in Regulation 1775/2005

This legislation was the most specific so far regarding balancing. However, as shown below, it does not go much deeper into the prescription of concrete proceedings than the Second Directive. In Article 7 of the Regulation:

- It reiterates that balancing should be governed along non-discriminatory and transparent criteria, and it complements this with the prescription of fairness and that it should reflect real system needs.
- Similarly, when **determining tolerance bands**, those should reflect the real system needs taking into account the resources available to the system operator.
- In case of **imbalance settlement**, prices should be cost-reflective and incentivizing for network users to strive for a balanced portfolio. The imbalance settlement price-system should not result in cross-subsidization between system users, and it should not hinder the entry of new entrants into the market.

- In addition to cost-based settlement fees, **surcharges** may also be imposed on imbalances, which should also provide incentives for striving for balance and the surcharge should be approved by the competent authority.
- For system users to be able to balance their portfolio, i.e. to be able to adjust in time, the system operator shall *"provide sufficient, well-timed and reliable on-line based information on the balancing status of network users. The level of information provided shall reflect the level of information available to the transmission system operator."* The system operator may charge a fee for the provision of information, which the regulatory authority must approve.
- Finally, *"Member States shall ensure that transmission system operators endeavour to harmonise balancing regimes and streamline structures and levels of balancing charges in order to facilitate gas trade."*

As can be seen, although regulation 1775/2005 is already more detailed regarding balancing, as it mentions areas such as tolerances, surcharges, information provision, but concrete tools, methodologies and processes (such as timing of information provision) are not prescribed, it is still like a Directive, it 'only' stipulates principles and goals to be followed but the way in which these should be reached is left for the Member States' decision.

Additional tools

It is important to mention that Community legislation is supported by other mandatory and non-binding instruments as well, such as the voluntary guidelines developed by the Madrid Forum (European Gas Regulatory Forum) and ERGEG (founded by Commission decision), and the technical standards set up by EASEE-gas (European Association for the Streamlining of Energy Exchanges).

Access to sources

In this thesis I emphasized the need for the three-type of access provisions for achieving the Internal European gas market competition objective. As I have shown, in the first phase, European gas market regulation by the two Directives and the Regulation has

explicitly addressed two of these, the provision of access to the networks and the access to the consumers. The provision of access to sources, as it required the opening of a foreclosed system with concrete (virtually 100% long-term) contracts, was only limitedly achievable at European level.[62] Nevertheless, this first phase still showed some success in this area, which is mainly due to European competition regulation. That is, in the natural gas market, market opening was largely promoted besides the ex-ante sector-specific regulation, also by ex post competition regulation, relaxing long-term contract terms that hampered the opening of markets. The main achievements were:

- **Elimination of destination clauses:** One of the main foreclosure elements of long-term contracts was the destination clause. This provision prohibited the buyer of the long-term contract from reselling the purchased gas, to sell its potential surplus to other countries. European competition law prohibits the use of destination clauses. The banning the trade of certain sources is also contradicts with the common European gas market goal. The Commission has therefore acted against contracts in breach of such European rules and against the related vendor side. The greatest attention was given to the Commission's successful negotiations with Gazprom, as a result the destination clause was eliminated from the contracts of Gazprom made with the largest European incumbents, the Italian ENI, Austrian OMV and German E.ON. (Talus, 2011) E.ON's contract – as E.ON acquired the Hungarian incumbent wholesaler – also affected the Hungarian market. In addition to Gazprom, the Commission has successfully negotiated also in the case of other similar contracts: with the Norwegian Statoil and Norsk Hydro and with the main LNG supplier companies the Nigerian NLNG and Algerian Sonatrach. (Talus, 2011)
- **Gas- and Contract Release Programs:** Although there was no European legislatory requirement for conducting such programs, national regulations or at the level of individual cases European pressure required that incumbent companies sell part of their sources they have acquired through long-term contracts to third parties. These are the so-called gas release programs. The first gas release program was organized in the pioneering Great Britain in 1991, and in

[62] It should be noted that, in most cases, to these supply contracts also capacity contracts were secured for an equally long-term, which was entirely justified in the beginning state of the the European gas supply. These contracts also hindered network access to a large extent. The specification of UIOLI type congestion management procedures at European level was therefore an important step.

the second half of 2000, this access provision method to sources was used in two-thirds of the first-round European Member States (Haase, 2008). In Hungary, there was also a gas- and contract release program organized due to European pressure. The European Commission's Directorate-General for Competition in its Decision in a merger case prescribed that half of the long-term contract amount that the incumbent contracted from the domestic production should be tendered and handed over to a new entrant with the best offer and in addition 1 bcm out of the long term import contract should be auctioned annually for new entrants. The detailed description and evaluation of the Hungarian gas- and contract release program is contained in a study written by me and my colleagues at REKK (Szolnoki et al., 2008a).

- **Accessing new sources:** Lastly, ensuring access to sources can be done through besides providing access to the existing contracts also by creating the opportunity to access completely new sources. The extension of the interconnection capacities between Member States, by the abolishment of destination clauses, has made it possible to exchange sources from different import contracts between countries, so even Norwegian gas could have been traded in Austria. On the other hand, the construction of new infrastructures (mainly LNG terminals) that enable the arrivals of completely new source to Europe further contributed to the expansion of sources available for new entrants.

IV.3. Sector Inquiry

The first phase was closed by a one-and-a-half year long investigation, the Sector Inquiry performed by the European Union's Directorate-General for Competition, its summary report was published on 10 January 2007 (ECDGC, 2007).

The launch of the Sector Inquiry was explained by the findings that *"market opening has significantly changed the functioning of the markets, provided new market opportunities, led to the introduction of new products and services. Competition initially lowered energy prices in Europe in line with market fundamentals… while progress has been made, the objectives of market opening have not yet been achieved... barriers to free competition remain. Significant rises in gas and electricity wholesale prices that cannot be fully explained by"* market fundamentals, consumers' choice of supplier is limited, and new entrants complain about persistent entry barriers. (ECDGC, 2007 p.4.).

In the report, the Commission states that it is still convinced that the liberalization process has no alternative and is committed to it. It is therefore of the utmost importance that Member States fully and effectively transpose the Directives into national markets – to enforce this infringement proceedings were launched against several Member States – but the Commission also states that there is a need for more, i.e. further regulatory steps are necessary to achieve the European goals.

Main findings and suggestions of the investigation[63]

- **Market concentration:** the incumbents still dominate the national markets to a very large extent (90%), their market power is significant. It is difficult for new entrants to compete with these incumbents when to carry out their activity they need to rely on services (e.g. transmission, storage, balancing) that are provided by the affiliates of the incumbent.
- **Vertical foreclosure:** the legal unbundling of networks is not enough. As networks remain in the integrated holding clearly has a negative impact on market functioning and network expansion ambitions. New entrants do not receive effective network access, network operators seem to prefer the partner company

[63] Here I summarize the Sector Inquiry (2007)

in the holding, they are discriminating against other players. Presumably, network development plans are not made according the optimal functioning of the network and the market, but instead plans are created according to the commercial interests of the incumbent company.

- **Market integration:** Cross-border trade does not cause serious competition challenge in national markets for the time being. Incumbents rarely enter the markets of other countries. In addition, cross-border capacity bookings linked to long-term import contracts concluded prior to liberalization limit the available cross-border capacity to new entrants, which this way do not have access to key source routes, and the congestion management procedures that could alleviate this situation do not work effectively. In addition, even in the case of network extensions new entrants were not able to secure interconnection point capacities for themselves. And finally, these network extensions did not follow the needs of the market and the new entrants but were designed in the interests of integrated incumbents.
- **Transparency:** There is a lack of reliable and regular market data provision that would be equally accessible to everyone. System users find the data provision requirements imposed by EU so far as inadequate. At present, there is serious information asymmetry between incumbents and new entrants.
- **Price formation:** Users do not trust the pricing methodologies. Indexing natural gas to oil prices in long-term contracts will divert the wholesale price from natural gas market fundamentals, demand and supply. Infrastructure access tariffs often raise the suspicion of cross-subsidization.
- **Downstream markets:** At the retail level, competition even less exists than at wholesale level. Long-term supply contracts, with renewal clauses greatly limit the opportunities for new entrants.

Based on these analyzes (along with the specific analysis of balancing markets presented below), the Sector Inquiry found fundamental weakness on the gas market in four main areas:

- Structural conflict of interest: the legal separation of the network companies from the incumbents is not sufficient, with the common ownership systematic conflict of interest remains.

- Holes in the regulatory environment: There is a regulatory gap in cross-border issues, regulatory powers are open-ended, and in some cases they do not meet, there are uncovered areas.
- Chronic liquidity shortages in wholesale markets: the market power of pre-liberalization monopolies has remained strong with little free space for others.
- General lack of transparency in market operation.

In addressing the problems, the Commission has foreseen the coordinated, active contribution of the two, the ex-ante sector regulation and the ex-post competition regulation. For the ex-ante sector regulation, the following steps were identified by the Inquiry:

- Ownership unbundling: Both, the experience so far and economic theory as well shows that ownership unbundling is the only effective way for the separation of network companies from the trading activities. It also states that no significant synergy effect was found by the investigation, which would justify vertical integration, rather they even found that where ownership unbundling took place, the two companies, the network and the trading company, were also successful on their own.
- Strengthening regulatory authorities and improving co-ordination between Member States. In this respect, the following main directions were identified by the Commission:
    - Strengthen the competences of national independent regulatory authorities.
    - Strengthen coordination between national regulatory authorities.
    - Strengthen co-ordination between TSOs.
    - Establish more consistency in the regulation of cross-border cases.
- On the chronic lack of liquidity problem ownership unbundling and the strengthening of regulatory authorities can already help, and national regulatory authorities may impose thresholds on the market shares and prescribe mandatory sales (e.g. gas release programs) to prevent market abuse. Merging the zones can also improve liquidity and the potential liquidity enhancing effect of balancing is already reflected in the thinking in the Inquiry: the summary report calls for a

more open and transparent TSO residual balancing procurement to increase the liquidity of the wholesale market. Finally, infrastructure development, expansion of import capacities and congestion management procedures for more efficient use of existing infrastructure, the strict application of UIOLI can all be effective tools according to the Commission for improving liquidity.

- The Commission's proposal for improving transparency is the publication of all relevant information on a timely basis, constantly updated.

In addition to the ex-ante sector regulation, the Commission listed the following ex post competition regulation instruments as suitable measures to address the problems identified in the gas market:

- The requirement of gas release programs and other mandatory sales procedures as a condition in merger cases to alleviate market concentration. (Hungarian gas release and contract release programs were also prescribed this way.)
- Action against vertical market foreclosure. Cases like the contractual exclusions and blocking access to the network, and even the blocking of network extensions due to the interests of the incumbents are all such cases against which the competition rules can be applied.

Balancing

Thus, although market opening has begun, the targeted competitive Internal market has not yet been achieved. In the field of balancing, the Commission also carried out a detailed analysis, analyzing balancing regimes and their impact on achieving European gas market goals. The main findings were:[64]

- Balancing regulation often favors the incumbents against new entrants. This is partly a natural consequence of the portfolio effect, that is, the incumbent has a much larger and more diversified portfolio of consumers than new entrants.
- There are many small balancing zones that make the market fragmented. The size of the zones is also very different. The difference in size between the smallest and

[64] Summary of the balancing section of the Sector Inquiry report ECDGC (2007).

the largest balancing zones is 1 to 278. The small size of the zones makes the trading portfolios even more fragmented, and smaller portfolios are more exposed to imbalance because of the mentioned portfolio effect.

- The zones operate under different balancing rules. This greatly complicates the trading across zones for traders. It implies significant administrative costs to manage various balancing processes on a daily basis, furthermore capacity booking is necessary on the interconnections between zones which further increases the costs and complexity. Small and divergent rule-based zones thus clearly have a negative impact on the Internal market.
- Another critical point is the length of the balancing periods. In many zones, retailers are obliged to balance at hourly level. This for new entrants, also because of the portfolio effect, is far more burdensome than for incumbents. Trade across the zones is further complicated by the fact that the different zones work according to different balancing periods.
- Regarding the elements of the balancing regime, there have also been complaints about the lack of transparency and the suspicion that balancing rules favor incumbents and hinder new entrants. According to the Commission, the only effective solution for this problem – just as in the case of any other network services – is effective unbundling. I summarize the problems identified by the Inquiry regarding the balancing regime along the three-pillars introduced in Chapter III:
    - Opportunities for ex ante balancing for traders:
        - There was no problem mentioned with respect to nomination rules. Regarding the technical implementation of the nomination, i.e. communication and data exchange between the traders and the TSO, it was identified as a limiting factor that the different zones applied different IT systems, and traders incurred additional IT development costs to meet the various requirements.
        - Spot flexibility purchasing opportunities for ex ante balancing are limited. There are only few marketplaces and not many of them liquid. Furthermore, the smaller the balancing zone, the fewer the tools available for ex ante balancing, the spot market is more likely to be illiquid.

- Regarding the TSO information provisions, the Commission's investigation found lack of transparency and regular timely reporting.

- Physical (residual) balancing by the TSO:
  - In the case of purchasing balancing instruments used for residual balancing in many cases due to the insufficient liquidity of the spot market, the incumbent is the only one that can provide the system operator flexibility reliably. However, this procurement is usually not performed transparently, so the suspicion arises that the TSO cross-finances the incumbent company through the balancing procurement as the costs of its balancing activity is spread among all system users – including new entrants. The smaller the zone, the more likely that the incumbent is the only player who can provide flexibility to the system operator on a reliable level.
- Imbalance settlement:
  - Tolerance bands: Most of the countries apply tolerance bands in their imbalance settlement system. The imbalance within the tolerance band is settled by the system operator at the average price, while the deviation exceeding the tolerance level is subject to a surcharge. Many countries employ a portfolio-size tolerance system, in which the players with small portfolio, who due to the portfolio effect would be in disadvantage in balancing, are treated with more favorable tolerance rules than the system users with larger portfolios. This is also supported by the Commission. The problem is that in most cases the way in which tolerance bands are defined is not transparent, it is unclear whether the system's capabilities are reflected in it or not. If technologically unjustifiably stringent tolerance bands are imposed, balancing regulation for system users could result in an unreasonable additional burden.
  - Imbalance settlement fees: Even though the Second Directive and the Regulation have stated that settlement prices should be cost-reflective, due to the lack of transparency system users could not determine whether this was true for the fees they paid or not: the

purchases of the system operators' physical balancing (residual balancing) are usually not published, so settlement prices that are theoretically set based on these purchases many times seem arbitrary to system users.

- In case of surcharges imposed for imbalances that exceed the tolerance levels the same applies: due to the lack of transparency system users suspect that the surcharges are exaggerated, they were not determined based on system fundamentals and hence unjustifiably punish system users.

Suggestions for the problems identified in balancing

The Commission has outlined three directions for remedying the above discussed problems. One is defragmentation, which is, on the one hand, the resolving of geographical fragmentation, that is, the merging of zones as far as possible, its final result is the establishment of the common Internal market. On the other hand, is the defragmentation of balancing periods, the Commission explicitly advocates for the elimination of the hourly balancing period and supports the adoption of longer balancing periods.

The second direction is the harmonization of rules and measures. This direction is clear but for its realization the European level cooperation of TSOs and regulatory authorities is necessary. It requires significant co-ordination and commitment from the parties.

Finally, the third direction is the creation of a more favorable – a market-oriented, cost-effective, and liquid market – environment. One of its key elements is (to avoid collusion of the TSO and the incumbent, the already many times mentioned) effective unbundling. For this the Inquiry undoubtedly suggests ownership unbundling. The other is the interference of competition regulation in limiting market power abuse and supporting competition. The third element is the creation of market places and hubs to support liquidity growth. Finally, as a fourth element, also in this case the importance of the close co-operation of regulators and system operators is mentioned.

Communication from the Commission to the Council and the European Parliament on Prospects for the Internal gas and electricity market

Since the First natural gas Directive, annual assessments have been carried out on the transposition of European legislation at Member State level and on their impact on the Member States' gas markets. On this basis, the Commission found that the basic principles and legal framework of the common European market have been achieved and the institutional structure has been established. However, there was no real competition in many Member States and no common internal market across Member States was achieved. To investigate the reasons for this the Commission ordered the Directorate-General for Competition to conduct the above-discussed Sector Inquiry. Along with the Sector Inquiry detailed country reports were also made during 2006.

Because of these, the Commission published a Communication – on the same day with the publication of the Sector Inquiry report – which summarized the main conclusions drawn by the European Commission during the last seven years of European market opening. In addition to drawing lessons, in this Communication the Commission has also set out the next steps of the European gas (and electricity) market regulation, the main directions and measures. *"The Commission believes that it is now time to consider its options for encouraging a further breakthrough which will be the final step towards fully functioning electricity and gas markets at European level"* (EC, 2007, p. 22) in accordance with the points set out in the Communication.

This communication is actually closes the first European gas market regulatory phase. It evaluated the effectiveness of the measures used so far and outlined the new directions for the next steps.

By stating that *"... clearly demonstrates the insufficiencies and shortcomings of the current EC legal framework arising from the directives"* (EC, p. 6, 2007) the Communication is foreseeing the deployment of stronger European legal instruments than directives. The solutions proposed in the subfields, such as stricter unbundling, the co-operation alternatives of the TSOs, and regulatory authorities, all lay down the bases of the Third energy package.

IV.4. Second phase

The Third Energy Package

For the gas market, the Third energy package (as already discussed in this dissertation) consists of a new Directive repealing the previous Directive, a new Regulation repealing the previous Regulation and a separate regulation establishing ACER:

- Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC
- Regulation (EC) No 715/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the natural gas transmission networks and repealing Regulation (EC) No 1775/2005
- Regulation (EC) No 713/2009 of the European Parliament and of the Council of 13 July 2009 establishing an Agency for the Cooperation of Energy Regulators

The third package thus tried to provide effective responses to the shortcomings identified by the investigations. Below I summarize the most important elements relevant for this dissertation:

- Stricter unbundling rules: The third energy package has introduced new unbundling models in relation of the transmission networks as an answer to the revealed problems. Among these models, the European Commission preferred the model of ownership unbundling. Compared to this, the second-best solution suggested is the Independent System Operator (ISO), and the least supported but still accepted compromise solution is the Independent Transmission Operator (ITO) model. In the ISO model, the vertically integrated company maintains the pipeline infrastructure, but the operation of the transmission system is carried out by an independent system operator which is completely separated from the integrated company. In the ITO model, the system operation remains in the vertically integrated company, but in addition to legal unbundling, further strict rules of unbundling apply, ITO has to have broad decision-making powers and independent corporate operations (accounting, IT, law). In addition, the contracts between other elements of the vertically integrated company and the ITO have to

be submitted for approval to the regulatory authority. An additional guarantee element is the development of an internal compliance program. The TSOs in the Member States can choose from the three models and will be given certification if the certification procedure concludes that they meet the criteria of the chosen unbundling model.

- Making the Entry-Exit System compulsory: One of the key elements of the harmonization of European network access rules was the requirement for a unified network access model in the Member States. The Third package explicitly prohibited the point-to-point access system and made it mandatory for all Member States to provide access to the transmission network by an Entry-Exit model.
- Establishing European Network Codes (NCs): The Third package requires the establishment of 12 NCs. These will stipulate the consolidation of the processes of the Member States up to operational level in 12 sub-areas of the gas market, including balancing. This step is the strongest intervention on national gas markets and at the same time the biggest step forward in the European gas market regulation.
- Establishment of ENTSOG: In response to the identified lack of co-ordination between Member States' system operators, the Regulation establishes the European Network of Transmission System Operators for Gas (ENTSOG). *"All transmission system operators shall cooperate at Community level through the ENTSO for Gas, in order to promote the completion and functioning of the internal market in natural gas and cross-border trade and to ensure the optimal management, coordinated operation and sound technical evolution of the natural gas transmission network."* (Article 4, 715/2009). The main task of ENTSOG is to develop NCs.

The Third package had to be implemented by Member States until March 3, 2011. The European regulatory agency, ACER, and the co-operative body of TSOs, ENTSOG were set up. The work started, the development of Network Codes followed.

In addition, on the request of the 2010 Madrid Forum, CEER has elaborated a vision for the European Gas Target Model (GTM). The GTM envisions the dramatical reduction of the number of Entry-Exit zones, the merging of zones by a 2014 deadline (CEER, 2011).

By today 4 NCs have been adopted for the gas market, their legal form is Regulation. In this dissertation I will only present in detail the Balancing Network Code, regarding the other NCs I will only discuss the parts that have impact on the balancing market.

The first NC harmonized the definition and allocation procedure in detail of cross-border capacity products across the EU (Network Code on Capacity Allocation Mechanisms in Gas Transmission Systems - CAM NC[65]). CAM NC, effective from November 1, 2015, by significantly improving non-discriminatory third-party access to cross-border capacities and by promoting the use of short-term capacity products, has also improved the availability of flexibility tools for balancing. Thus, both the possibilities of ex ante balancing by traders and the range of tools available for the TSO's residual balancing were broadened. (The CAM NC has been modified since then, the new version[66] further specifies the capacity allocation mechanisms, i.e. further enhancing the provision of harmonized, non-discriminatory third-party access to the transmission capacities.)

Congestion Management Procedures (CMP) also related to the access to cross-border capacities were governed by the first Annex to Regulation No 715/2009 of the Third Package. Further detail and specification of the rules has been made in this area.[67] The main means of congestion management is to re-market unused (unnominated) capacities, mostly on a day ahead basis. By means of such tools, the availability of short-term capacity for balancing is expanded.

By laying down the detailed rules of CAM NC and CMP, the capacity management and congestion management pillar of the three pillars of the third-party network access has been harmonized at EU level.

The NC on interoperability and data exchange[68] rules has been adopted after the BAL NC. This policy harmonizes the complex technical processes used by TSOs. This

[65] Commission Regulation (EU) No 984/2013 establishing a Network Code on Capacity Allocation Mechanisms in Gas Transmission Systems and supplementing Regulation (EC) No 715/2009 of the European Parliament and of the Council

[66] Commission Regulation (EU) 2017/459 of 16 March 2017 establishing a network code on capacity allocation mechanisms in gas transmission systems and repealing Regulation (EU) No 984/2013)

[67] Commission Decision (EU) 2015/715/EU amending Annex I to Regulation (EC) 715/2009 on conditions for access to the natural gas transmission networks

[68] Commission Regulation (EU) 2015/703 of 30 April 2015 establishing a network code on interoperability and data exchange rules

seemingly market-independent technical code has a serious impact on market processes, including balancing as well. The Sector Inquiry has revealed that in the technical process of nomination in the different zones different IT solutions are used for the communication and data exchange between the traders and the TSO, causing traders an administrative burden and creating additional development costs, thereby limiting trade across the zones and thus the creation of the Internal market. Therefore, this harmonization clearly supports the balancing market.

The most recently adopted Regulation (adopted on 16 March 2017) is the Network Code harmonizing transmission tariff structures (TAR NC)[69]. This Regulation covers the second of the three pillars of network access that has not been regulated so far at European level, the system of access charges. The TAR NC has only indirect effect on balancing. The link is the closest at the – already mentioned – point where it stipulates that a minimum 50% discount should be applied to the reference price, except for certain exceptions, at the Entry and Exit points for the use of the storage. This is because the storage contributes to optimizing the transmission system itself, so its use needs to be supported. With a 100% price the tariff system would actually double the burden on storage. This point thus reduces the costs of using storage, the major tool for flexibility, for balancing.

Finally, the main topic of this dissertation, the balancing Network Code[70] was adopted on 26 March 2014. Thus, by now all three pillars of network access regulation are harmonized at EU level.

[69] Commission Regulation (EU) 2017/460 of 16 March 2017 establishing a network code on harmonised transmission tariff structures for gas

[70] Commission Regulation (EU) No 312/2014 of 26 March 2014 establishing a Network Code on Gas Balancing of Transmission Networks

Appendix V: The specific elements of BAL NC summarized along the three pillars

Ex ante balancing of system users

Information provisions

- The system user shall receive at least the following three information from the TSO regarding a given gas day:
  - The system user's portfolio's balance (allocated values on the EE points)
  - The system's balance
  - The physical balancing activity of the TSO
- This information should be sent by the TSO regarding the gas day D **once on D-1 day and then twice within day D** with the content and the way it is specified in BAL NC. Then the primary allocation in D+1.
- **In case of non daily measured points** the Member State can choose from 3 information models and has to designate the forecasting parties.
- The distribution system operators (DSO) have to provide the data necessary for this information provision with appripriate timing to the forecasting parties, or if the DSOs are the forecasting parties then to the TSO.
- The forecasting parties have to provide the forecasts regarding the non-daily metered points to the TSO.
- Incentive scheme can be introduced to improve the forecasts.
- After 2 years the TSO has to perform a cost-benefit analysis with the content specified in BAL NC.

Nomination, renomination, TSO notifications

Harmonized nomination and renomination rules for the interconnection points:

- Prescription of the kWh/day and kWh/hour measurement units
- The specification of the minimum content of the nomination messages.
- Nominations do not have to be in balance.
- Fixing the nomination and renomination deadlines and time-windows:
  - Nomination on D-1: 13:00 UCT (winter time)
  - Renomination period starts after 13:00 and ends no earlier than 3 hours before the end of gas day D.
  - A renomination cycle starts every hour and is open for 2 hours.
  - The start time of the effective gas flow change has to be at least 2 hours after the start of the renomination cycle.

Nomination and renomination confirmation rules for the interconnection points:

- The TSO within 2 hours from the start of every renomination cycle has to send the information on the confirmed quantities.
- The BAL NC specifies the reasons for nominatin rejection.
- Amendment of the requested quantities (interruption) may only be in exceptional events, and the national regulatory authority has to be informed about it.

Title transfer, trade notificaitons:

- Title transfer between two portfolios is carried out by the submitted and confirmed trade notifications.
- The content and confirmation criteria of trade notifications is specified in BAL NC.
- Network users can have an agreement with the TSO for submitting trade notifications irrespective of whether they have contracted transport capacity or not.
- Trade notifications have to be confirmed or rejected by the TSO within 30 minutes but within 2 hours at most.

TSO's physical balancing activity

General principles
about in what cases should the TSO perform balancing activity and at least which information it should consider in its decisionmaking.

Linepack

- The TSO may provide flexibility service to network users from the linepack
- According to the specified conditions.
- This must not influence the residual balancing activity.
- The national regulatory authority has to approve it.

Incentive scheme can be introduced for the cost-efficient TSO procurement. The considerations are specified in BAL NC.

The residual balancing of the TSO should be:

- Non-discriminatory and cost-efficient
- Performed by the following two alternatives:

Short term standardised products (STSP)

- For every day of the week. Day ahead and within day products. Within day should be prioritized.
- The merit order of the acceptence is the following:
  - Title products as much as possible
  - Locational products if the direction of the gas flow is necessary.
  - Temporal products if the gas flow has to be changed in a given period, and only if it is more economical and efficient than the use of the title products or locational products or those jointly
  - Temporal locational products…
- The STSPs have to be procured from a Trading Platform
  - The Trading Platform characteristics are specified in the BAL NC
  - If there is no such Trading Platform, a Balancing Platform should be founded as an interim measure.
- The costs, frequency and volume of the residual balancing procurement of the TSO has to be published anually.

Balancing services

- Shall be used if the STSPs are not or would likely not be sufficient or in the absence of liquidity to trade STSPs
- Its procurement should be market based, transparent, non-discriminative, through public tender procedure:
  - The duration of the service shall not be longer than one year:
    - In exceptional cases longer term service contract and non-public tendering could be.
- The procurement principles are specified in BAL NC.
- It should be revisited anually whether STSPs could cover the TSO's needs better, could the use of balancing service be decreased.
- The procured balancing services and their costs should be published anually.

Imbalance settlement

Daily imbalance charge

- General principle: Cost-reflective
- Daily imbalance charge calculation methodolgy:
  - Should be approved by the national regulatory authority and it should be published.
  - It should cover the calculation of the daily imbalance quantity and the derivation of the daily imbalance price.
- Marginal sell/buy price is the lower/higher of the two:
  - the lowest/highest price of any sales of title products in which the transmission system operator is involved in respect of the gas day; or
  - the weighted average price of gas in respect of that gas day, minus/plus a small adjustment.
- Small adjustment:
  - It should be applied to incentivize network users to be in balance, but it should not impede market entry and the develpment of markets
  - 10% at most, but there could be exceptions
- Daily imbalance quantity:
  - Formula: Inputs – Off-takes
  - Exceptions are specified in BAL NC
- Daily imbalance charge: daily imbalance quantity * marginal buy/sell price

Balancing period

- **Daily settlement**
- But in view of ensuring the system's integrity and minimising the need to undertake balancing actions the TSO may apply within day obligations (WDO). There could be three types of WDOs:
  - System-wide
  - Balancing portfolio
  - Entry-exit point
- For the different points different WDOs küld be applied.
- The requirements for the application of WDOs are specified in BAL NC
- The TSO has to consult stakeholders regarding the application of WDOs
  - It has to prepare a recommendation document which shall include analyses specified in the BAL NC on why the application of WDOs is necessary.

Interim measures

General principles
Should be applied if the liquidity of the short term wholesale natural gas market is not sufficient. The measures should be such that support the liquidity of the short term market.

Annaul report should be prepared
With the content specified in BAL NC, analysis, reasons for the chosen interim measures, their expected effects, and the steps how they will be withdrawn. A consultation should also be conducted.

Balancing Platform

If on the short term gas wholesale market there is no or there will likely be no sufficient liquidity, and if the necessary temporal and locational products needed for the TSO cannot be procured reasonable from the market:

- It shall be considered whether a joint balancing platform may be implemented for adjacent balancing zones.
- Its use could be continued for five more years after 2019 if the situation has not improved
- If it can be demonstrated that a balancing platform cannot increase the liquidity of the short term wholesale gas market and cannot enable the TSO to undertake efficient balancing actions, it may use an alternative, such as balancing services, subject to the approval by the national regulatory authority.

Interim Imbalance Charge

Price derivation may be based upon an administered price, a proxy for a market price or a price derived from balancing platform trades.
According to the considerations specified in BAL NC, in order to minimize the risk of market manipulation and excessive costs.

Tolerances

It can be used in cases specified in BAL NC:

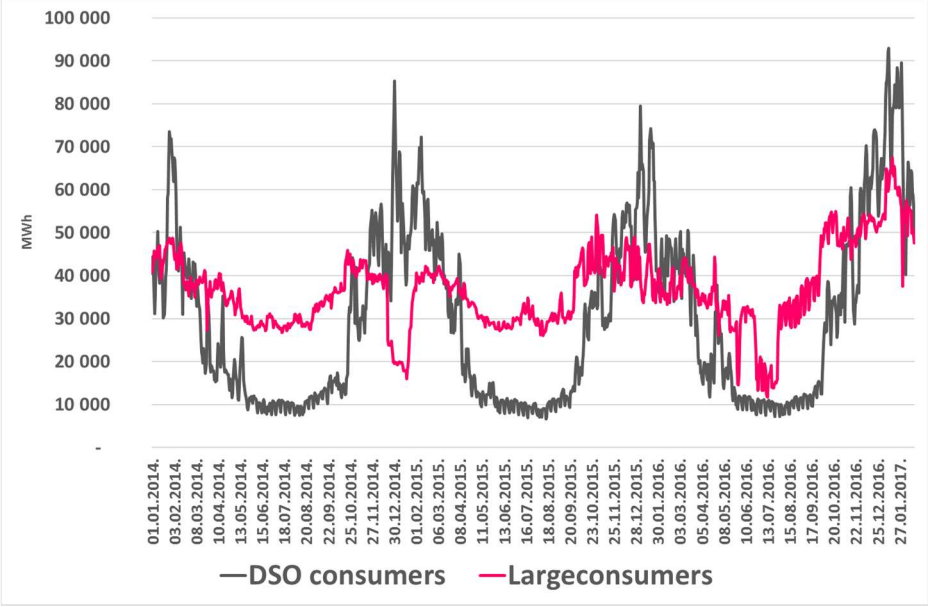
- It should be applied with regard to the network user's daily imbalance quantity
- only to the extent necessary and for the minimum duration required.
- To the imbalance quantity below the tolerance level the weighted average price should be applied, to the quantity above the level the marginal price.
- It should reflect the transmission network's flexibility and network user's needs
- The tolerance level shall not include trades on VTP
- The tolerance level applicable for a non daily metered offtake shall be based upon the difference between the relevant forecast of a network user's non daily metered off-takes and the allocation for non daily metered off-take.

Appendix VI: Analysis of the Croatian Daily Flexibility Market[71]

VI.1. Demand for daily flexibility in the Croatian natural gas market

To explore the demand for flexibility I use the publicly available data of consumption Exit points of the transmission system. Figure A10 shows the aggregated consumption curves of the large consumers that are directly connected to the transmission network (called Largeconsumers from now on) and the small consumers connected to the distribution network (called DSO consumers from now on). As it can be seen, seasonal fluctuations in the consumption of Largeconsumers are more moderate compared to the temperature dependent DSO consumption: the ratio of winter and summer monthly consumption in case of Largeconsumers is 1.5, while for DSO consumers it is almost four times higher, 5.5.

Figure A10: Daily consumption of Croatian consumer groups



Source: Plinacro (2017) TSO Direct Consumer Exit Point and DSO Exit Point Data

[71] This Appendix chapter is based on the Croatian natural gas market analysis published in the Appendix of my article prepared for the ERRA Regulatory Research Award (Szolnoki, 2017) with minor modifications.

According to the discussed methods in Point IV.2.2. of this dissertation I will calculate the short-term flexibility need in two different ways. On the one hand, I analyze the daily change of consumption and, on the other hand, the relationship between daily consumption compared to the weekly average consumption. The results are shown in Table A3 and A4:

Table A3: Defining the daily flexibility need, Version 1: Past distribution of daily fluctuations in consumption, MWh[72]

	Daily change of consumption, MWh			Absolute value of daily change of consumption, MWh		
	DSO consumption	Largeconsumers	Total	DSO consumption	Largeconsumers	Total
min	- 22 402	- 47 572	- 49 460	0	-	2
D10	- 4 025	- 1 881	- 4 774	171	117	268
Q1	- 1 690	- 713	- 1 931	524	314	854
Me	- 147	29	- 125	1 693	746	1 989
Average	- 16	- 35	- 52	2 490	1 338	2 971
Q3	1 693	786	2 020	3 426	1 605	4 143
D90	4 305	1 844	4 959	6 245	3 304	6 834
max	14 529	13 343	14 943	22 402	47 572	49 460

Table A4: Defining the daily flexibility need, Version 2: Past distribution of the difference between daily consumption and weekly average consumption, MWh

	The difference between daily consumption and weekly average consumption, MWh			Absolute value of the difference between daily consumption and weekly average consumption, MWh		
	DSO consumption	Largeconsumers	Total	DSO consumption	Largeconsumers	Total
min	- 31 694	- 51 134	- 61 407	13	0	3
D10	- 7 345	- 3 278	- 8 441	440	245	514
Q1	- 2 235	- 1 371	- 3 080	961	598	1 328
Me	260	56	94	2 192	1 383	3 124
Average	14	- 198	- 122	4 201	2 311	5 086
Q3	2 116	1 387	3 260	6 126	2 826	7 073
D90	7 299	3 215	8 022	10 443	4 796	11 741
max	31 331	12 866	28 359	31 694	51 134	61 407

Source: Own calculation based on TSO Direct Consumer Exit point and DSO Exit point data from Plinacro (2017) for the period between 01/2014 and 01/2017

The results of the two indicators are very similar:

- The changes in negative and positive directions are practically symmetrical except for the extreme values.
- Daily fluctuations among DSO customers are approximately twice as higher than for Largeconsumers, but the largest fluctuation occurred at Largeconsumers. That is, the consumption of small consumers fluctuates more, but the fluctuations in the consumption of Largeconsumers are more extreme.

[72] D10 represents the lower decile, Q1 is the lower quartile, Me is the median, Q3 is the upper quartile, and D90 the upper decile.

With a conservative approach, out of the two indices I choose the one with higher values for the description of flexibility need: the difference between daily consumption and weekly average consumption. Thus, based on historical data, I define the demand for daily flexibility on the Croatian natural gas market by the following distribution:

Table A5: Demand for Daily Flexibility

Distribution of demand for daily flexibility, MWh	
min	3
D10	514
Q1	1 328
Median	3 124
Average	5 086
Q3	7 073
D90	11 741
max	61 407

Source: Plinacro (2017) TSO Direct Consumer Exit point and DSO Exit point data

IV.3.2. Daily flexibility supply potential in the Croatian natural gas market

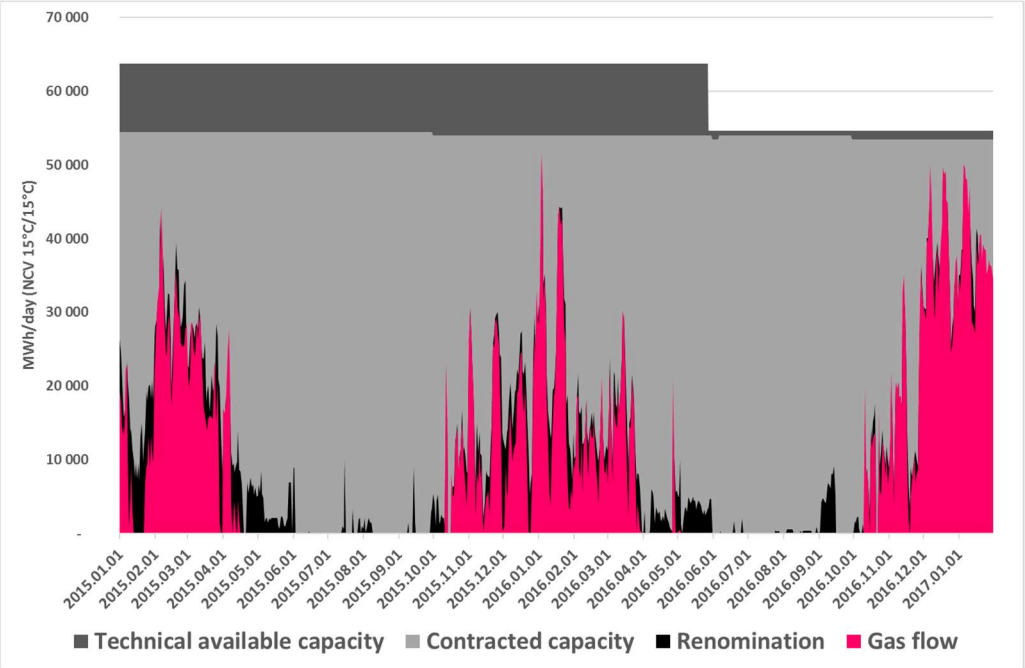
The basic methodology of the analysis is as follows: I compare the technically available capacity and the contracted capacities at a given Entry (and storage Exit) point with the gas flow data showing the actual usage on the point. Based on the examination of these I prepare the indices discussed in Point IV.2.1. of this dissertation to quantify how much daily flexibility a given infrastructure can potentially offer to the market.

Daily flexibility potential of the storage facility

The examination of the Croatian storage Entry and Exit points' data shows that there is a significant capacity contracted for seasonal flexibility provision. To estimate the daily flexibility supply offered by the storage, I use the described indicator, the difference of the technical withdrawal / storage capacity and the average withdrawal / injection level, which I calculate on a monthly basis instead of a yearly due to the seasonality of the storage activity. From the results it can be seen that even on the scarcest days storage

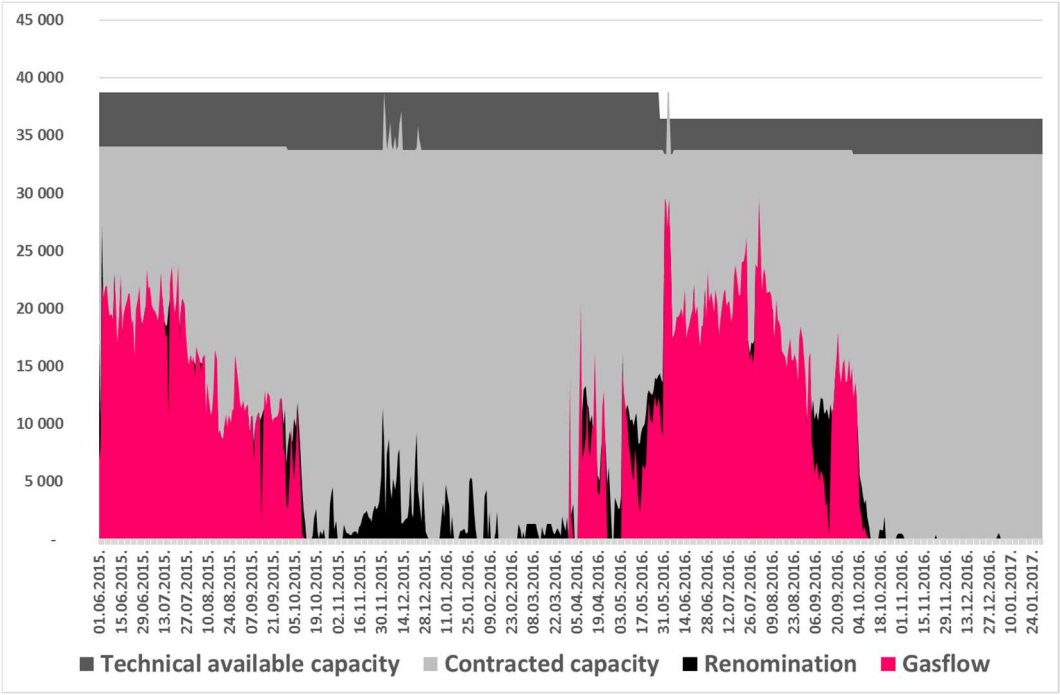
could provide ~16,000 MWh daily flexibility, i.e. alongside the seasonal activity of storage, significant potential remains for serving the daily market of flexibility.

Figure A11: Technical withdrawal capacity and the withdrawal gas flow



Source: Plinacro (2017) Storage Entry point data

Figure A12: Technical injection capacity and the injection gas flow



Source: Plinacro (2017) Storage Exit point data

Table A6: Distribution of Daily Flexibility potential of Storage

Distribution of daily flexibility potential based on monthly averages, MWh		
	Withdrawal	Injection
min	16 570	15 686
D10	36 578	17 371
Q1	45 491	22 731
Median	54 647	32 527
Average	50 337	29 905
Q3	58 515	37 676
D90	63 773	38 719
max	63 773	38 719

Source: Own calculation based on Plinacro (2017) Storage Entry-Exit data for the period 01/2015 - 01/2017

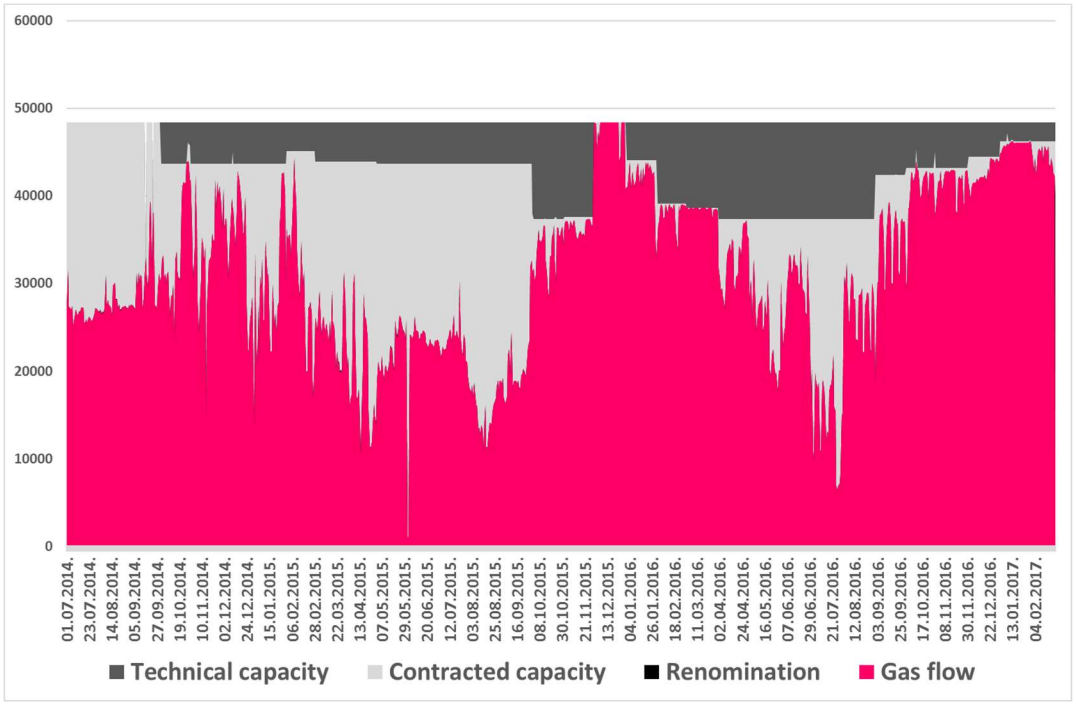
Importable flexibility

As Croatia reaches the most liquid hub of the region via its interconnection with Slovenia, the Austrian VTP, and via its other interconnection with Hungary it also reaches another transparent platform, which although is less liquid than VTP but it is also possible to trade daily products there, consequently there is no commercial barrier to importing daily flexibility to Croatia, we can turn to the physical potential.

In calculating the physical potentials, it can be seen from the figure that in the case of import, like in the case of storage, there is no limit for the daily usage potential beyond the maximum technical capacity, so again in this case I compare the difference between the maximum available technical capacity and the monthly average usage.

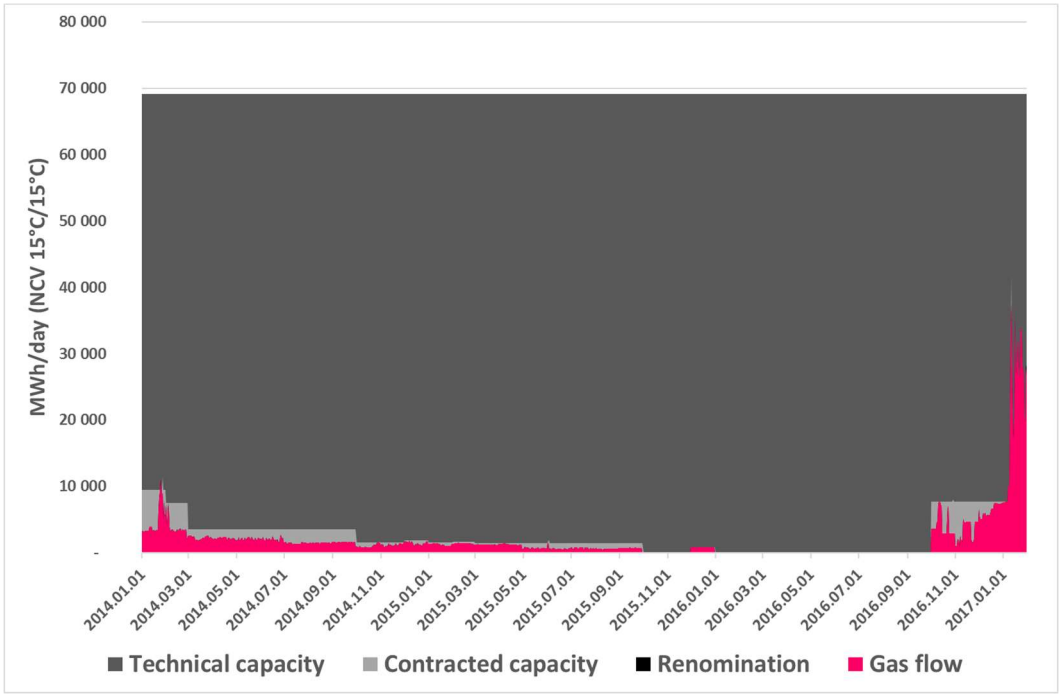
The Slovenian interconnection point has been extensively used in the past, and it can be seen that seasonal flexibility also arrived through this border: in winter gas flow was higher. The Hungarian point, on the contrary, was barely used. (Obviously there are commercial reasons for this, such as transport costs, import contract's routing, etc.).

Figure A13: Rogatec interconnection point capacities and actual gas flow, SI> HR



Source: Plinacro (2017) Rogatec Entry point data

Figure A14: Drávaszerdahely interconnection point capacities and actual gas flow, HU> HR



Source: Plinacro (2017) Drávaszerdahely Entry point data

Based on the analysis of the past cross-border traffic, it can be seen, that beyond the storage potential there is also a significant supply potential of daily flexibility on the Hungarian border, whereas the Slovenian border can be regarded as a daily source of flexibility in a much moderate level in the winter months.

Table A7: The distribution of importable daily flexibility per import points

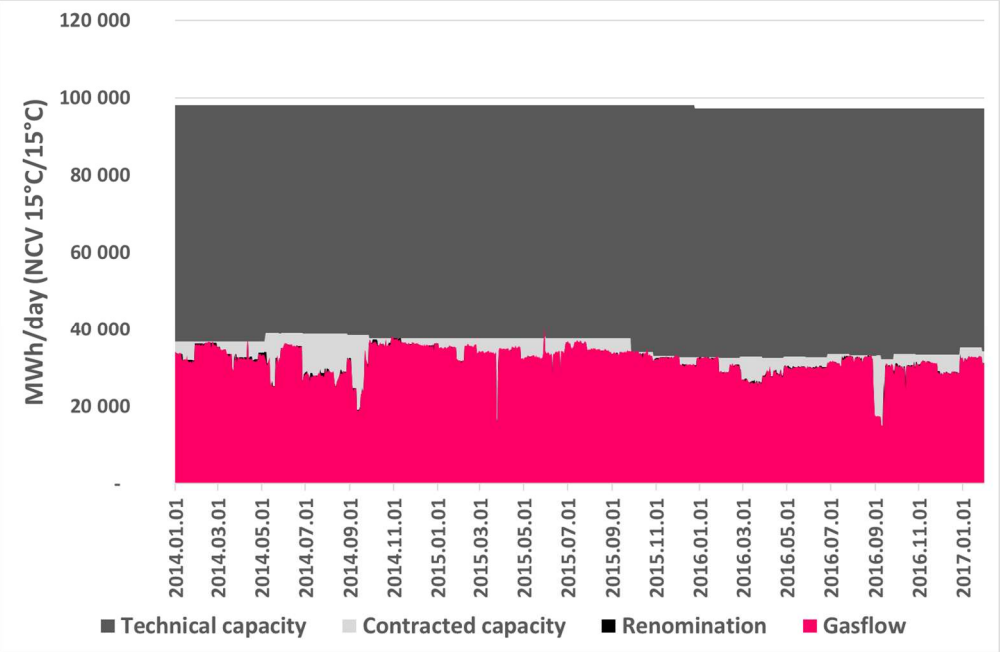
Distribution of daily importable flexibilitiy based on monthly averages, MWh		
	HU>HR	SI>HR
min	46 943	718
D10	64 770	5 948
Q1	67 044	10 224
Me	67 909	16 787
Average	66 814	16 837
Q3	69 113	23 416
D90	69 120	27 713
max	69 120	33 596

Source: Plinacro (2017) Drávaszerdahely and Rogatec Entry point data
For the period 01.2014. and 01.2017. and 07.2014 and 01.2017.

Flexibility of production

There is domestic natural gas production in Croatia. Changing the level of production in theory could provide flexibility to the market. However, if we look at the Croatian production data (specifically, transmission system production Entry data) it can be seen that the daily fluctuation of production is very moderate. It can also be deduced from the graph that significant changes from one day to the next may be linked to a technical problem or planned shutdown rather than to market needs. For this reason, it may be misleading to compare the annual maximum production level with the average production level, technical outages would be included with too much weight, instead, to estimate daily flexibility potential of production I use the same indicator as I used in the case of consumption, the difference between weekly maximum and weekly averages. Based on the data, production can provide daily flexibility on a very moderate level.

Figure A15: Production point capacities and actual production gas flow



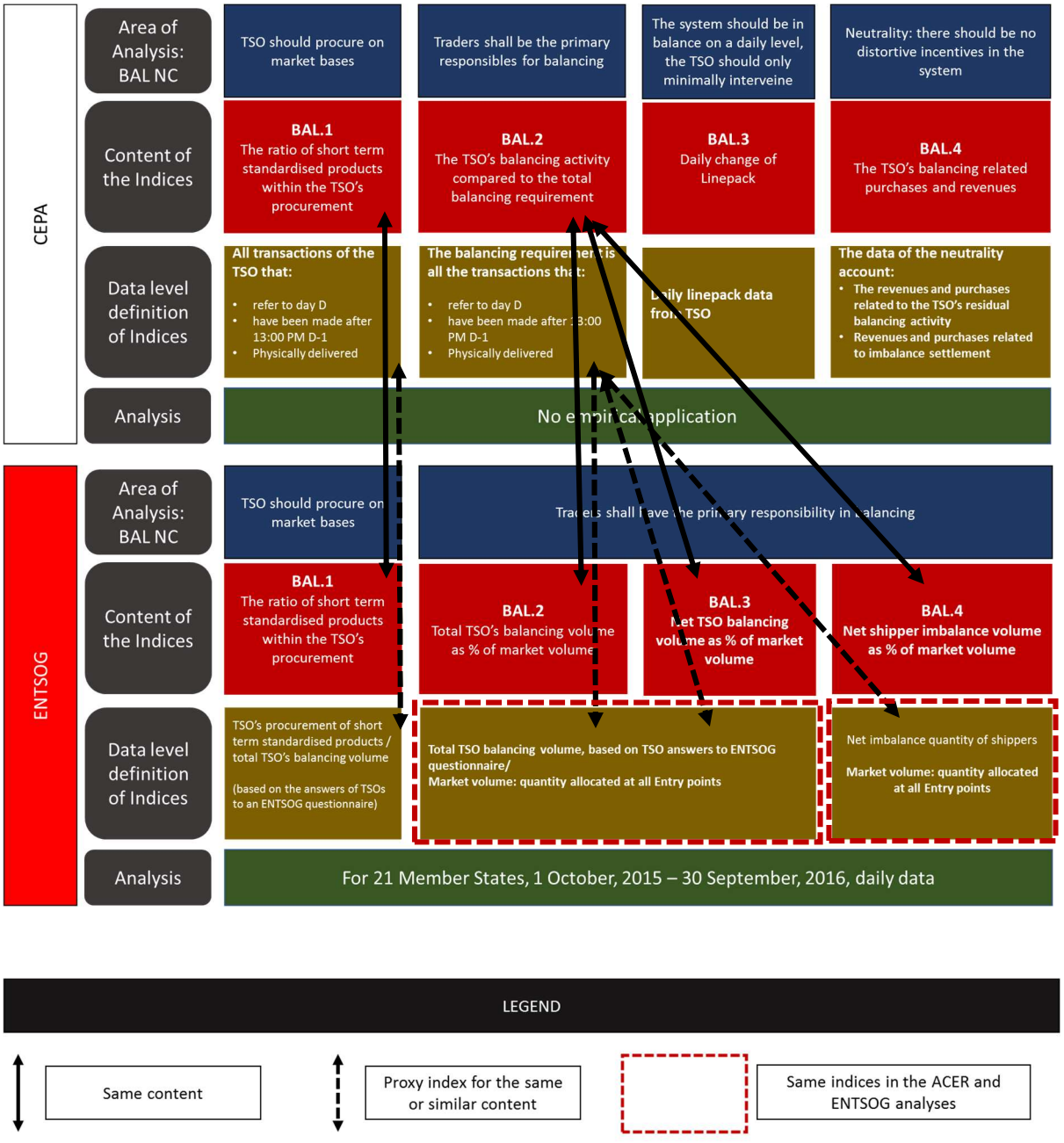
Source: Plinacro (2017) Production Entry point data 01.01.2014 - 01.31.2017.

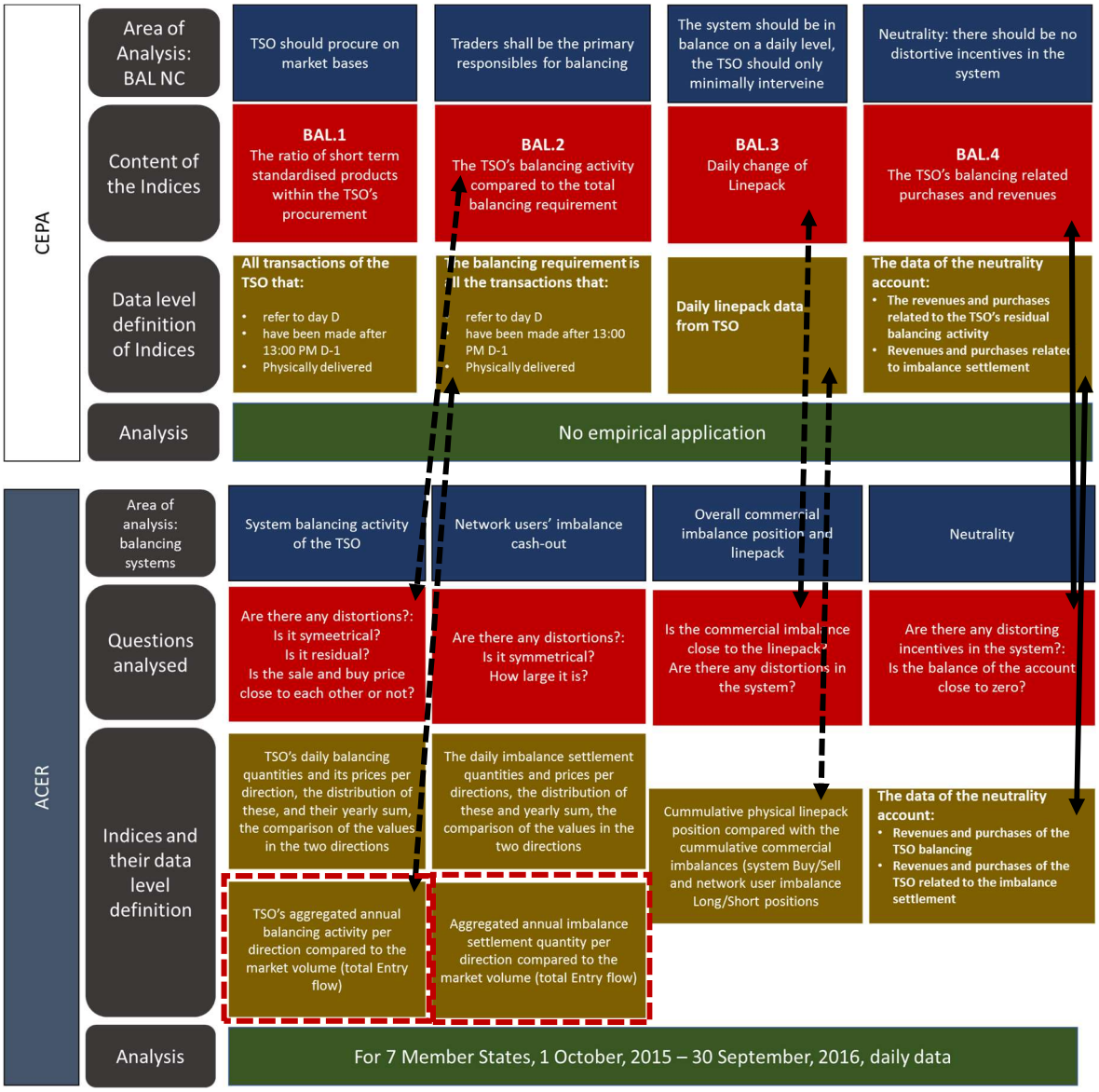
Table A8: Daily flexibility potential of production in recent years, MWh

Daily flexibility potential of production, MWh	
min	68
D10	168
Q1	258
Me	385
Average	816
Q3	700
D90	1 696
max	9 403

Source: Plinacro (2017) Production Entry point data 01.01.2014 - 01.31.2017.

Appendix VII: The CEPA, ACER, and ENTSOG indices and the relations between them

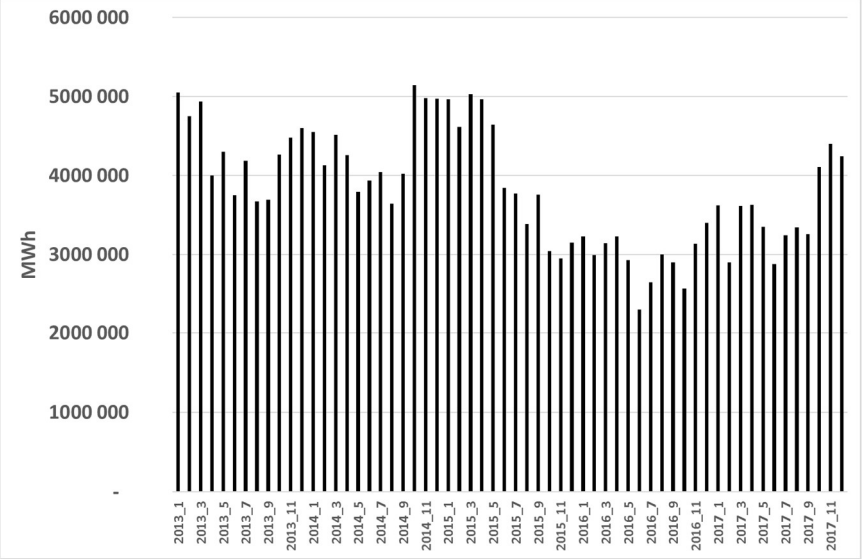



CEPA
Area of Analysis: BAL NC
TSO should procure on market bases
Traders shall be the primary responsibles for balancing
The system should be in balance on a daily level, the TSO should only minimally interveine
Neutrality: there should be no distortive incentives in the system
Content of the Indices
BAL.1
The ratio of short term standardised products within the TSO's procurement
BAL.2
The TSO's balancing activity compared to the total balancing requirement
BAL.3
Daily change of Linepack
BAL.4
The TSO's balancing related purchases and revenues
Data level definition of Indices
All transactions of the TSO that:
refer to day D
have been made after 13:00 PM D-1
Physically delivered
The balancing requirement is all the transactions that:
refer to day D
have been made after 13:00 PM D-1
Physically delivered
Daily linepack data from TSO
The data of the neutrality account:
The revenues and purchases related to the TSO's residual balancing activity
Revenues and purchases related to imbalance settlement
Analysis
No empirical application
ACER
Area of analysis: balancing systems
System balancing activity of the TSO
Network users' imbalance cash-out
Overall commercial imbalance position and linepack
Neutrality
Questions analysed
Are there any distortions?: Is it symeetrical? Is it residual? Is the sale and buy price close to each other or not?
Are there any distortions?: Is it symmetrical? How large it is?
Is the commercial imbalance close to the linepack? Are there any distortions in the system?
Are there any distorting incentives in the system?: Is the balance of the account close to zero?
Indices and their data level definition
TSO's daily balancing quantities and its prices per direction, the distribution of these, and their yearly sum, the comparison of the values in the two directions
The daily imbalance settlement quantities and prices per directions, the distribution of these and yearly sum, the comparison of the values in the two directions
Cummulative physical linepack position compared with the cummulative commercial imbalances (system Buy/Sell and network user imbalance Long/Short positions
The data of the neutrality account:
Revenues and purchases of the TSO balancing
Revenues and purchases of the TSO related to the imbalance settlement
TSO's aggregated annual balancing activity per direction compared to the market volume (total Entry flow)
Aggregated annual imbalance settlement quantity per direction compared to the market volume (total Entry flow)
Analysis
For 7 Member States, 1 October, 2015 – 30 September, 2016, daily data

Appendix VIII: Analysis of the Polish NTSHM zone's balancing system

Figure A16 below shows the evolution of the Largeconsumers Group's natural gas consumption in the last five years in the NTSHM zone. As you can see, there had been also a decline in consumption on this system as well, consumption has fallen by the mid of 2016 to half of the 2013 level, but consumption of Largeconsumers has started to grow again in the past year.

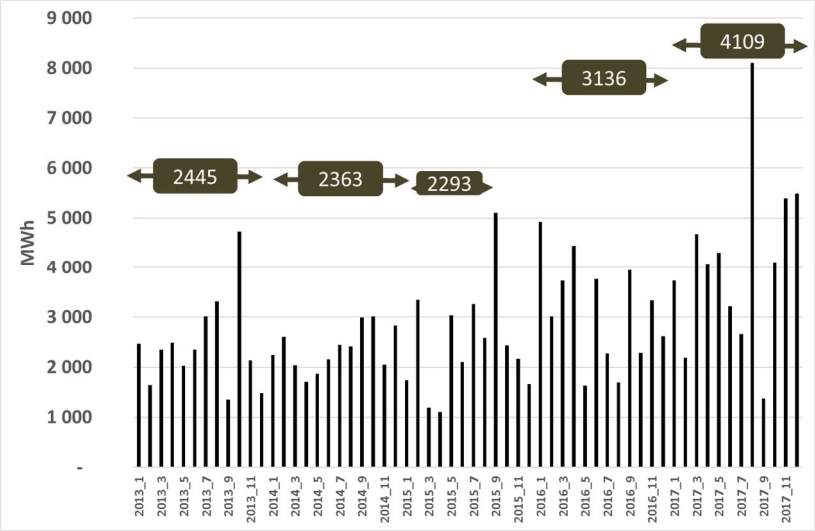
Figure A16: Monthly consumption of Largeconsumers in the NTSHM zone, MWh



Source: Calculated based on data from GAZ System (2018): 909027 E/ Exit point gas flow data

Regarding the demand for balancing, also in this system, there was a break since the middle of 2015, since the consumption of the Largeconsumer group has decreased. Since then the balancing demand is larger. On this system, apart from that break, no further clear increasing or decreasing tendency can be detected (perhaps only from 2016 to 2017, but it is too short to be a tendency). It seems as if the quality of the traders' planning did not change. What is surprising is that the decline in consumption in the middle of 2015, unlike in the case of the NTSN system, did not result in a decrease in the nominal level of balancing, what's more, it even increased in nominal terms. This suggests that the deterioration due to the portfolio effect could be significant.

Figure A17: Balancing need of the Largeconsumer group in the NTSHM zone, monthly median and their average, MWh

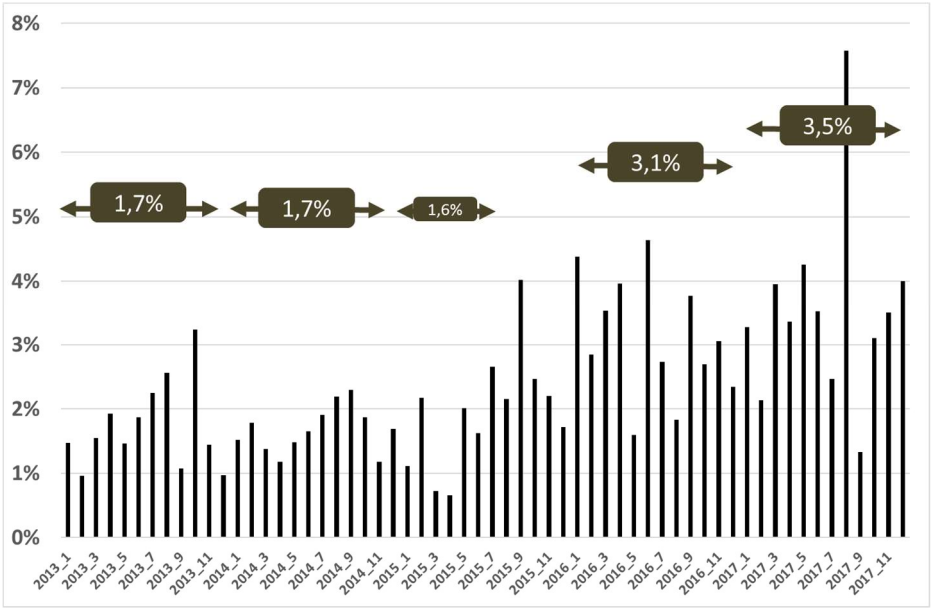


Source: calculated based on data from GAZ System (2018): 909027 E/ Exit point nomination and gas flow data

After that, it is not surprising that the ratio of balancing demand to total consumption also increased by 1.5 - 2 times compared to the level before the break (Figure A18 below). This deterioration due to the portfolio effect was also detected on the NTSN system. Similarly, to the previous figure, there is no clear increasing or decreasing tendency in the period before and after the break in 2015. It still seems as if in this system there was no qualitative change in the forecast of Largeconsumer group consumption portfolios. The only thing that can be said that in the last year the efficiency of balancing deteriorated.

Finally, it is worth mentioning that from the ratio of the balancing demand to consumption the portfolio effect can be detected in one more way: by comparing the ratios of Figure A18 below with the ratios of the significantly smaller NTSN system (Figure 20 in the dissertation) it can be clearly seen that the ratio of balancing demand to consumption on the smaller system is approximately three times bigger than in the larger system.

Figure A18: Ratio of balancing demand and gas consumption for the Largeconsumer group in the NTSHM zone, monthly median value, and its periodic average

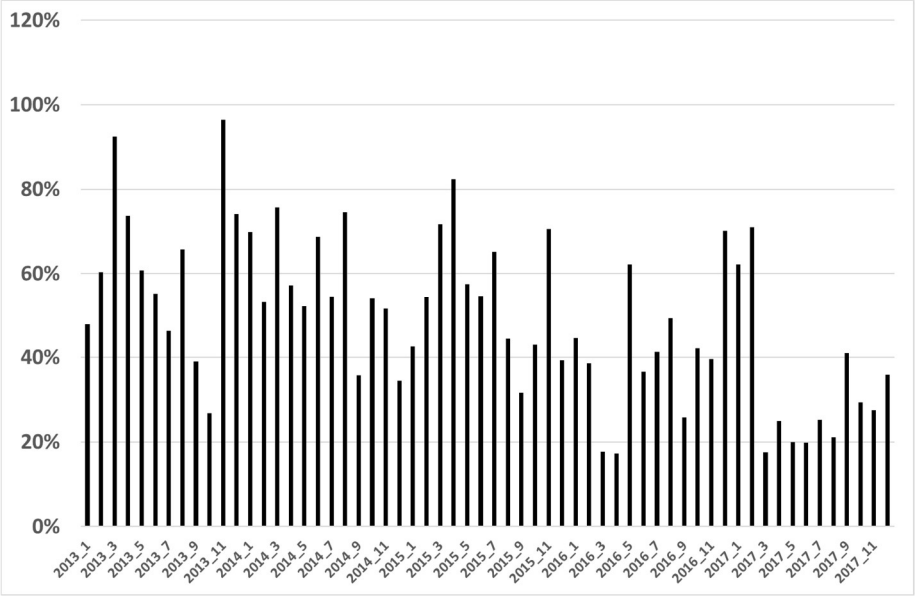


Source: calculated based on data from GAZ System (2018): 909027 E/ Exit point nomination and gas flow data

The next question is whether traders started to take part in resolving balancing need. According to Figure A19 below, yes, significantly: in the NTSHM zone, the Largeconsumer portfolios' imbalance has begun to be resolved by the traders during the renomination procedure, and now that this ratio is around 70-80%, it can be really stated that traders became the primary responsible for balancing this consumption portfolio. This trend is quite similar to that experienced on the Croatian market.

It is particularly worth mentioning that in the NTSHM zone the ratio of trader engagement in balancing is almost twice as much than in the smaller NTSN system. This is probably due to the fact that the NTSHM is a much larger and more liquid system, traders have more option for ex ante balancing.

Figure A19: The ratio of balancing requirement left to the TSO in case of Largeconsumers, in the NTSHM zone, monthly median value



Source: calculated based on data from GAZ System (2018): 909027 E/ Exit point nomination, renomination and gas flow data

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