Energy Storage in the new Electricity Market Design – leveling the playing field and improving the Security of Electricity Supply

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The Clean Energy Package reformed the electricity market design with hopes for adapting the electricity system to the challenges of the future. Especially important was to create an efficient electricity market that could improve cross-border trading and the possibilities for energy technologies. This paper aims at identifying the new regulatory framework for energy storage systems. In addition, the electricity market design’s impact on security of electricity supply is assessed.

The method used is a literature review based on EU official documents regarding the electricity market design. In addition, scientific articles provide understanding on the economic and technical possibilities of energy storage systems in the new electricity market design. The impact on security of electricity supply is based on the technical and legal capabilities that are assessed in relation to the needs of the electricity system.

As illustrated in this paper, the new regulatory framework improves significantly the case for energy storage systems. The reforms are divided into the core rules, rules regarding access, market reforms and including energy storage in long-term network planning. These reforms indicate the expectations that policy makers have for energy storage. In addition, by reforming the framework for energy storage, the security of electricity supply will improve as a result of removing the need for capacity mechanisms, creating a favorable environment for renewable energy production and improving the affordability of electricity.

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energy storage – electricity market design – security of electricity supply

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Table of Contents

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1. Introduction

1.1 Electricity Market Design

The vision is to build a "continent-wide energy system, where energy flows freely across borders, based on competition and the best possible resources".[1] As a result, EU energy consumers would benefit from secure, sustainable, competitive and affordable energy. However, there are several regulatory barriers hindering the implementation of an internal energy market. Thus, the establishment of the Energy Union Strategy, which includes fifteen action points for achieving this vision.

The biggest threats towards the vision of an Energy Union is the regulatory fragmentation, as a result of 28 national regulatory frameworks and energy islands[2], the inefficient functioning of the retail market and the ageing energy infrastructure. The regulatory fragmentations and energy islands result as barriers to efficient cross-border markets. Efficient cross-border trading could increase competition and security of supply. Similarly, efficient cross-border trading requires functioning markets with cost-based price signals. In addition, the infrastructure must be renewed to handle intermittent renewable energy and increasing volumes of electricity.

To answer these challenges, the European Union introduced the Clean Energy for all Europeans Package ("Clean Energy Package"), which consists of eight legislative acts creating new rules for a clean energy transition.[3] The legislative acts cover energy efficiency, renewable energy, the design of the electricity market, security of supply and governance rules.[4] Most importantly, the recast of the Electricity Directive[5] and the new Electricity Regulation[6] create the new electricity market design.

[1] A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, Energy Union Package, European Commission, COM(2015) 80, 25.2.2015, p. 2
[2] Isolated energy systems, Council Directive 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) [2019] OJ L 158/125, Recital 7
[3] Clean Energy for All Europeans, European Commission, COM(2016) 860, 30.11.2016, p. 2
[4] Ibid. p. 3
[5] Council Directive 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) [2019] OJ L 158/125
[6] Council Regulation 2019/943 of 5 June 2019 on the internal market for electricity (recast) [2019] OJ L 158/54

The Commission highlighted the need to organize electricity markets in a more flexible manner and to integrate all market players, such as energy storage service providers.[7] The development in energy storage technology may be of great assistance in transforming the electricity infrastructure into a sustainable, low-carbon energy system. As stated by the Commission, "[i]ntegrating storage in the electricity market would further increase the necessary flexibility: electricity should be stored when there is a surplus and prices are low; it should be released when generation is scarce and prices are high, smoothing out variable power production".[8] This highlights the expectations for energy storage and its role in the new electricity market environment.

Another theme of this paper is security of electricity supply. "The European Union's prosperity and security hinges on a stable and abundant supply of energy".[9] The relationship between the new electricity market design and security of electricity supply is clear. Throughout the official documents regarding the internal electricity market, the contribution towards security of supply is repeated.[10] In contrast, whether there is a correlation between promoting energy storage and security of supply is unclear. The correlation between the aforementioned is not directly stated. However, the electricity market design claims to promote security of supply and, on the other hand, new technologies such as energy storage. Therefore, to assess and identify energy storage's impact on security of electricity supply is an objective of this paper.

1.2 Important Terminology

In order to understand the new electricity market design, there is terminology that the reader is required to know. This section introduces important terminology of electricity markets and the different operators in the electricity sector. By comprehending the following, it is easier to follow the assessment of new electricity market rules.

[7] Council Directive 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) [2019] OJ L 158/125, Recital 6
[8] Launching the public consultation process on a new energy market design, The Commission, COM(2015) 340, 15.7.2015, p. 5
[9] European Energy Security Strategy, European Commission, COM(2014) 330, 28.5.2014, p. 2
[10] For example the Electricity Directive 2019/944, Recital 2

First of all, the electricity market sector can be divided into four different operations. Electricity generation consists of producing electricity or in other words, power plants. Electricity transmission consists of transmitting electricity over long distances from generators to local distribution networks. The transmission networks is managed by Transmission System Operators (TSOs), which are regulated entities that are responsible of ensuring the maintenance and performance of the transmission network. Distribution System Operators (DSOs) are the local distributors for electricity. As TSOs, also DSOs are heavily regulated. They maintain the regional distribution network, which distributes electricity to businesses and end-users. Electricity suppliers are operators in the wholesale market. They buy electricity from generators and sell them to end-users. The transmission and distribution of electricity consists of only providing the infrastructure for connecting generators and suppliers.

As explained further in section 2, system operators must balance electricity supply and demand at all times. Therefore, important terminology that is related to the system operator's measures for ensuring the equilibrium between supply and demand. Balancing is the overall term for all "actions and processes, on all timelines, through which Transmission System Operators ensure, in a continuous way the maintenance of system frequency within a predefined stability range".[11] Balancing measures differ depending on timeframe and way. For example, capacity mechanisms are important for balancing. The idea is that electricity generators are remunerated for having the capability of providing electricity. If system operators suddenly need more electricity, capacity providers are obligated to supply electricity. In turn, the day-ahead markets consist of market customers buying and selling electricity for the next 24 hours. System operators govern the overall grid reliability according to market activity.

Another important terminology is congestion, which means "a situation in which an interconnection linking national transmission networks cannot accommodate all physical flows resulting from international trade requested by market participants, because of a lack of capacity of the interconnectors and/or the national transmission systems concerned".[12] Congestion results from physical constraints regarding the electricity grid. Congestion is the primary reason for the need for new investments into electricity infrastructure. Congestion

[11] Council Regulation 2017/2195 of 23 November 2017 on establishing guidelines on electricity balancing [2017] OJ L 312/6, Article 2 (1)
[12] Council Regulation 714/2009 of July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003 [2009] OJ L 211/15, Article 2 (c)

management consists of the actions and processes of reacting to congestion. In comparison to balancing, congestion management pinpoints the reason of unbalance between demand and supply to the physical capacity of the electricity grid.

1.3 Scope, Method and Content

This paper focuses on the new electricity market design from energy storage's point of view. The term energy storage is technologically neutral and considers all alternative electricity storage systems. In addition to focusing on the new electricity market design, the security of electricity supply, which is at the heart of the energy transformation, is assessed. It is important to note that the scope of this paper is EU regulation and will not focus on national regulatory frameworks. The focus is strictly on electricity market rules. As a result, environmental rules, licensing rules and national health and safety rules are ignored.

This paper has two objectives. These objectives consist of systemizing overall harmonized regulatory framework for energy storage and the impact that this regulatory framework has on the security of electricity supply. Thus, there is an assessment for identifying and systemizing the changes that affect energy storage framework. Considering the public support for energy storage technologies and the potential benefits in furthering the development of energy storage systems, it is important to understand the regulatory framework. The focus is on the harmonized electricity market regulation. However, the basic principles of the electricity sector in general are introduced.

Secondly, after systemizing the new electricity market design for energy storage, the impact of these aforementioned reforms in regards to the security of electricity supply is assessed. When looking into the European Security Strategy, improving energy technologies is listed as one area of focus. Another are of focus is building an integrated energy market. Since energy storage is energy technology and has the ability to improve market integration, there is a correlation between improving energy storage and security of electricity supply. Therefore, the objective is to identify the relationship between improving the market framework for energy storage and security of electricity supply.

The methodology for this research is a literature review. The findings of this paper are primarily based on EU official documents, which describe the objectives of the new electricity market design. In order to gain deeper understanding about the reforms, scientific papers are used as sources to add perspective. In addition to purely legal research, studies of the technical and economic impact of energy storage are used. Whereas the official documents provide the insights from a public view, interest groups and scholars provide different views on energy storage and the electricity market design.

An EU literature reviews do not answer directly all the research questions of this paper. Especially the relationship between energy storage and security of electricity supply is not discussed in detail. Moreover, it is presumed by no further argumentation. Thus, the need for an assessment that thoroughly evaluates the impact. The impact is determined by the technical capabilities of energy storage systems and the needs of the electricity system. The structure of this paper is the following.

First, the present state of energy storage technologies and the drivers for energy storage are introduced in section 2. The objective is to familiarize the reader with the present state of energy storage systems. Also, the underlying drivers for energy storage systems are introduced. Especially the electrification of society and the growing share of intermittent renewable electricity drive the need for energy storage systems. As a result, the drivers for energy storage fundamentally drive the need for a new electricity market design.

Section 3 focuses on the new electricity market design and pinpoints, how the regulatory framework has changed for energy storage as an electricity market operator. Energy storage can operate independently in the electricity markets or be ancillary services for other electricity operators. However, the rules are based on the electricity market design. The electricity market design is extensive and includes lots of rules that change the regulatory framework in general. However, if there is no impact on energy storage these rules are ignored. The new electricity design is divided into four categories that highlight the fundamental impact on energy storage. These categories are the core changes for energy storage, rules regarding access, market reforms and including energy storage in long-term planning. The categories are systemized based on the fundamental nature of the rules.

After introducing the regulatory framework, section 4 includes an overview on the EU security of supply doctrine and includes an assessment on energy storage's impact on the security of electricity supply. The security of electricity supply doctrine was reformed and harmonized as part of the Clean Energy Package. Consequently, the new legislative act focusing on security of electricity supply is introduced. In addition to the main rules, other legislative acts of the Clean Energy Package impact indirectly the security of electricity supply. Therefore, the other legislative acts are introduced briefly. Most importantly, the assessment between the new regulatory framework and security of electricity supply is located in section 4.3. The assessment approaches the question from three different angles. These being removing market inefficiencies, improving renewable energy production and finally, the overall on electricity prices. Having answered both objectives of this paper, the final section concludes the findings of this paper.

2. Energy Storage Solutions

2.1 Characteristics of Energy Storage Systems

2.1.1 Drivers for Energy Storage

In order to understand the regulatory framework for energy storage systems, it is important to familiarize with the present state of storage technologies. Section 2.2 includes a brief introduction into five significant energy storage systems. This helps the reader grasp the object of this paper. After all, the subject of this research is energy storage in the new electricity market design. Before introducing the energy storage systems, the recent trend of electrification and renewable energy generation are discussed. These are the most important drivers for storage technology. After this, electricity has certain characteristics, which makes it an challenging commodity to store, sell and transmit. Electricity's characteristics, in turn, affect directly the electricity system. Therefore, the basics our electricity system are explained. The objective of this chapter is to illustrate the technical and physical challenges that have created our present electricity system.

The trend in electricity demand is expected to grow over upcoming years. EU has believes that the overall electricity demand will grow over 5 percent during the next 10 years.[13] Other long-term estimations expect the world-wide electricity demand to double by 2050.[14] This can be attributed to the overall electrification of society. This does not only create worries, but also possibilities for the EU. In 2016, the Commission stated that they will "engage in industry-led initiatives that aim at supporting the EU's global leadership role in the renewables and clean technologies in general".[15]

Electricity impacts a growing share of life. Growth in electricity demand is especially strong because of the electrification of transportation and heating. This requires EU to prepare for the electricity transformation. This can be seen also in the electricity market design. For example, one reason for the Electricity Directive to encourage Member States to introduce

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[13] Table 1, Impact assessment, European Commission, SWD(2016) 410, 30.11.2016, p. 39
[14] Electricity demand will double until 2050, McKinsey's outlook on global energy perspectives' Axpo Magazine (July 11, 2019)<https://www.axpo.com/ch/en/magazine/international-business/electricity-demand-will-double-until-2050.html>
[15] Clean Energy for all Europeans, The Commission, COM(2016) 860, p. 7

network development plans for DSOs is the electrification of the transport sector.[16] In addition, by becoming a leader in energy storage technologies and speeding electrification of transport, EU can decrease oil dependency and decarbonize transport.[17] Moreover, "[h]eating and cooling is the largest single source of energy demand in Europe".[18] Therefore, new storage technologies are capable of increasing energy efficiency and providing flexibility to the energy system with demand-response and thermal energy storage.[19]

Electricity efficiency is a big area of focus for EU.[20] Especially considering that electricity demand is projected to rise, the electricity produced presently, must be used as efficiently as possible. Energy storage systems have the potential to improve electricity efficiency as direct operators of the electricity grid. Efficiency would increase as a result of improved grid reliability. Consequently, reliability correlates with "less costly interruptions, deferred capital spending on costly transmission and generation assets, and increased efficiency of power delivery due to lower distribution losses".[21] In addition to system operation, energy storage can increase electricity efficiency by improving industrial processes by storing heat and reusing it for heating buildings.

In addition to the overall increase in electricity demand and need for improvement in electricity efficiency, the transition from fossil-fuels to renewable energy generation is possibly the most significant driver for energy storage systems. The present electricity system was based on nuclear and fossil-fuel power plants.[22] Therefore, electricity has been generated simply according to demand. However, renewable energy is intermittent, and creates significant challenges to the electricity grid. Energy storage is the key for integrating renewable energy into the present energy system.

[16] Council Directive 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) [2019] OJ L 158/125, Recital 61
[17] A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, Energy Union Package, European Commission, COM(2015) 80, 25.2.2015, p. 14
[18] Ibid. p. 12
[19] An EU Strategy on Heating and Cooling, European Commission, COM(2016) 51, 16.2.2016, p. 2
[20] A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, Energy Union Package, European Commission, COM(2015) 80, 25.2.2015, p. 2
[21] Zame, Kenneth K., et al. "Smart grid and energy storage: Policy recommendations." Renewable and Sustainable Energy Reviews 82 (2018): 1646-1654. p. 1651
[22] Council Regulation 2019/943 of 5 June 2019 on the internal market for electricity (recast) [2019] OJ L 158/54, Recital 2

2.1.2 The Basics of Energy Storage

To understand the novelty of modern energy storage technologies, it is important to understand that electricity is typically considered non-storable efficiently in large utility-scale use. Thus, electricity as a commodity is unique: "[e]nergy is a real time product which must be consumed when produced because it cannot be easily stored".[23] Rafal Weron described the characteristics of electricity as a special commodity that is not economically storable and the power system requires constant balance between production and consumption. In addition, electricity demand is affected by factors such as weather and the intensity of business and every-day activities (difference between weekdays and weekends).[24] Thus, the governance of the electricity system is very challenging and unpredictable.

Typically, balancing the power network has consisted of supply demand. This means that unbalances resulted as system operators increasing or decreasing electricity generation. System operators have therefore, dispatched energy between loaders and generators. Thus, system operators use capacity mechanisms and other mechanisms to ensure system reliability. Now however, upcoming technology is turning the trend towards demand-response. This would allow electricity consumers to adjust consumption depending on electricity prices. In addition, electricity could be generated excessively and stored into energy storage systems.

Energy storage can be approached from several different perspectives because of the varying abilities and benefits of storage technologies. EU, for example, approaches energy storage from several different points of view depending on the objective of energy storage. The Commissions' working staff document discusses storage within the electricity system. This is a general view, which consists of energy storage as a direct electricity market participant. Depending on market, the fundamental task consists of electricity price arbitrage and as a result, alleviating grid stress. This is the most typical application considered for energy storage.[25] Another important segment is sectorial integration. Abilities, such as producing hydrogen, which can be used as industrial feedstock, are seen as very important steps towards

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[23] Berrada, Asmae, Khalid Loudiyi, and Izeddine Zorkani. "Valuation of energy storage in energy and regulation markets." Energy 115 (2016): 1109-1118. p. 1109

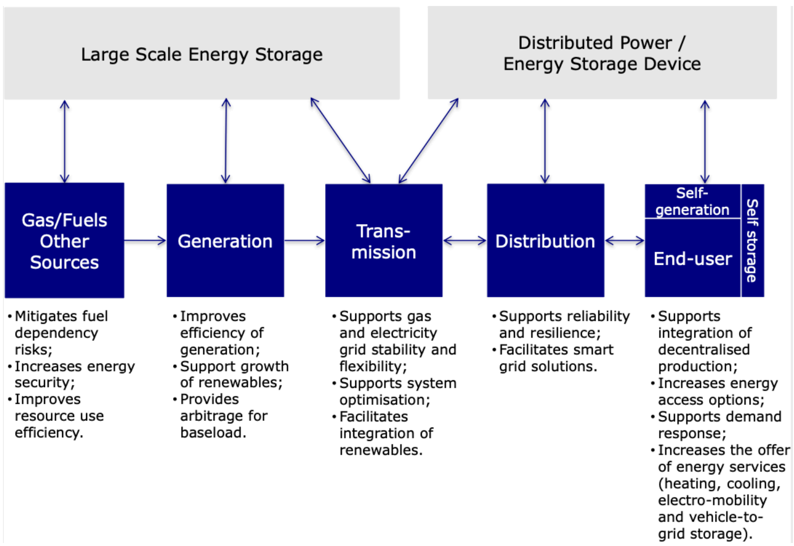
[24] Weron, Rafał. "Electricity price forecasting: A review of the state-of-the-art with a look into the future." International journal of forecasting 30.4 (2014): 1030-1081. p. 1031

[25] Zucker, Andreas, Timothée Hinchliffe, and Amanda Spisto. "Assessing storage value in electricity markets, a literature review." JRC Scientific and Policy reports (2013). p. 29

a decarbonized Europe. This is a consequence of finding alternative uses for electricity generated from renewable sources and replacing unnecessary processes. For example, "[l]arge amounts of fossil fuels are used to produce industrial feedstock like hydrogen".[26]

The aforementioned highlights one important aspect of energy storage. Not only can energy storage defer the time between electricity generation and consumption, energy storage can transform energy forms. As later illustrated in section 2.2, the transformation of the energy form is fundamental for certain electricity storage systems. However, especially industries that are heavily dependent on hydrogen, such as steel production, can benefit from additional supply routes. However, the focus on this paper is in the electricity market design and therefore energy storage will be assessed within the electricity network.

The electricity system consist of electricity generation, transmission, distribution and finally, wholesale market for end-users. The energy storage main services at generation level are load shifting, balancing services and price arbitrage. The services at transmission and distribution level consist of back-up power, increased system reliability and alternatives to expensive infrastructure investments. End-users can benefit from becoming active participants of the electricity market by demand response.[27] The figure below presents the examples of



Source: Energy Storage: Which Market Designs and Regulatory Incentives Are Needed? Study of the ITRE Committee, 2015, p. 17

[26] Energy storage – the role of electricity, Commission Staff Working Document, European Commission, SWD(2017) 61, 1.2.2017, p. 18

[27] Tejada-Arango, Diego A., et al. "A Review of Energy Storage System Legislation in the US and the European Union." Current Sustainable/Renewable Energy Reports 6.1 (2019): 22-28. , p. 23

valuable services in all parts of the energy markets, including the relationship to other competitive energy sources.

The following section consists of an overview of five significant energy storage systems. The different system are introduced briefly in order to create intuition about different energy storage system's differences, advantages and disadvantages. From a functional perspective, the most important characteristics of energy storage systems are power, capacity and response time.[28] In addition, round-trip efficiency indicates the energy "losses measured during charge, discharge and standby phases".[29]

2.2 Different Energy Storage Systems

2.2.1 Pumped Hydro Storage (PHS)

Historically, the most significant energy storage system has been PHS. Therefore, it is also the most common energy storage solution. PHS is based on utilizing two water reservoirs, which are at different heights. "When there is electricity excess, water is pumped into the higher reservoir. Conversely, when electricity is needed, water can be released back into the lower reservoir. While moving down, water powers turbine units to generate electricity".[30] This fairly simple procedure is used as the primary energy storage solution worldwide. In 2017, more than 170 GW of PHS was in operation.[31] In comparison, other energy storage solutions added up only to around 6,5 GW worldwide in 2017.[32] Therefore, PHS accounts for approximately 96 percent of the energy storage systems worldwide. Simultaneously, it represents the novelty of the other energy storage solutions.

PHS, in terms of energy storage abilities, is capable of large-scale applications. In addition, the expected lifespan of a PHS facility is 40-60 years.[33] The round-trip efficiency is around

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[28] Energy storage – the role of electricity, Commission Staff Working Document, European Commission, SWD(2017) 61, 1.2.2017, p. 8

[29] Komarnicki, Przemyslaw, Pio Lombardi, and Zbigniew Styczynski. Electric energy storage systems: flexibility options for smart grids. Springer, 2017. p. 132

[30] Azzuni, Abdelrahman, and Christian Breyer. "Energy security and energy storage technologies." Energy Procedia 155 (2018): 237-258. p. 242

[31] Komarnicki, Przemyslaw, Pio Lombardi, and Zbigniew Styczynski. Electric energy storage systems: flexibility options for smart grids. Springer, 2017. p. 134

[32] Distribution of energy storage capacity worldwide in 2017 by technology, Statista, June 2018, https://www.statista.com/statistics/870011/global-share-of-energy-storage-capacity-by-technology/

[33] Akinyele, D. O., and R. K. Rayudu. "Review of energy storage technologies for sustainable power networks." Sustainable Energy Technologies and Assessments 8 (2014): 74-91. p. 81

70-85 percent.[34] Disadvantages of PHS include two factors. First of all, PHS requires a geographically challenging location, because it has to have two water reservoirs with a competitive height difference. The requirement for water is a result of the basic functioning of PHS-plants. In addition, performance is largely based on the height difference between the reservoirs in order to increase energy storage efficiency.[35] Secondly, PHS requires substantial capital expenditures.[36]

The aforementioned characteristics make PHS a reliable energy storage system for long-term electricity storage. Especially considering the efficiency and long lifespan, PHS is great for ensuring long-term electricity security. However, PHS is challenging in comparison to other energy storage solutions because of locational requirements, which are non-flexible.

2.2.2 Thermal Energy Storage (TES)

The method in TES solutions is to convert excess electricity into heat, which is stored in specific materials. The heat is stored in storage mediums within tanks. Reconversion happens by transforming heat into steam, which rotates turbines that generate electricity.[37] The most common form of TES is Sensible Heat Storage, which raises or lowers the temperature of a storage medium that stores thermal energy. The storage medium can be either liquid or solid such as water or molten salt.[38]

In addition to converting electricity into heat, it is remarkably important that TES systems can store heat.[39] As a result, TES systems may be able to solve several different problems with its many applications. Enabling waste heat recovery in industrial processes and increas-

[34] Komarnicki, Przemyslaw, Pio Lombardi, and Zbigniew Styczynski. Electric energy storage systems: flexibility options for smart grids. Springer, 2017. p. 134
[35] Azzuni, Abdelrahman, and Christian Breyer. "Energy security and energy storage technologies." Energy Procedia 155 (2018): 237-258. p. 242
[36] Akinyele, D. O., and R. K. Rayudu. "Review of energy storage technologies for sustainable power networks." Sustainable Energy Technologies and Assessments 8 (2014): 74-91. p. 82
[37] Energy storage – the role of electricity, Commission Staff Working Document, European Commission, SWD(2017) 61, 1.2.2017, p. 10
[38] European Energy Storage Technology Development Roadmap Towards 2030, European Association for Storage of Energy & European Energy Research Alliance, p. 86
[39] Azzuni, Abdelrahman, and Christian Breyer. "Energy security and energy storage technologies." Energy Procedia 155 (2018): 237-258. p. 244

ing energy efficiency in buildings are among the most prominent expectations of TES systems.[40] When taking into consideration the amount of electricity used for heating in the EU, the potential impact TES systems can have on energy efficiency is massive.

TES systems, at the moment, can be attributed as flexible systems. This is a result of the scalability, relatively low capital expenditures and overall availability.[41] TES systems are available for consumers and electricity market operators because of no locational requirements such as the ones for PHS systems. In addition, the technology does not require special substances. As mentioned, the simplest TES system can consist of the converting technology and water as the storage medium.

However, certain concerns for the overall efficiency of TES systems have been expressed.[42] Especially the transformation from heat to electricity is inefficient. Also, there is a daily loss of heat energy that is fairly high. At the moment, the use of new materials are researched and developed to improve the efficiency of TES systems.[43]

2.2.3 Adiabatic Compressed Air Energy Storage (A-CAES)

One considerable form of mechanical storage technologies is A-CAES. Mechanical storage means that energy is stored in different physical forms. A-CAES can be described as the following, air is compressed using electricity which is then stored into high-pressure vessels. Reconversion in turn, happens by expanding the compressed air through turbines to generate electricity.[44]

An important factor regarding A-CAES is that when air is compressed, it heats up. Consequently, there a beneficial synergies between TES systems and A-CAES systems. The adiabatic prefix in A-CAES refers to the process, where no heat is gained or lost. Whereas before, CAES systems were diabatic. At the moment, technology is capable of storing the heat. In project ADELE, the German electric utility company RWE managed to increase the round-

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[40] European Energy Storage Technology Development Roadmap Towards 2030, European Association for Storage of Energy & European Energy Research Alliance, p. 86
[41] Azzuni, Abdelrahman, and Christian Breyer. "Energy security and energy storage technologies." Energy Procedia 155 (2018): 237-258. p. 245
[42] Ibid. p. 245
[43] Ibid.
[44] Energy storage – the role of electricity, Commission Staff Working Document, European Commission, SWD(2017) 61, 1.2.2017, p. 10

trip efficiency of A-CAES to 60-70 percent by linking A-CAES with a TES system.[45] In contrast, CAES systems without the ability of storing the heat have the efficiency of merely 40 percent.[46]

The benefits of A-CAES are based on the abundance of air, which is the main component of A-CAES. However, costs are based largely on the location. Since the location has certain limitations, such as the requirement of a geographical location suitable for facilitating the underground caverns of compressed air. In summary, A-CAES is fundamentally transforming energy storage solutions regarding the CAES technique by storing heat, which is a natural part of the process. However, the A-CAES is still in an early technological stage.

2.2.4 Battery Systems

Debatably, the most prominent and important energy storage solution consists of batteries.[47] An indication of this is EU's Strategic Action Plan for Batteries, which aims at improving the "whole value chain for the batteries ecosystem".[48] This includes secure access to raw materials, research and development of battery technologies and ensuring consistent regulatory framework.[49] In addition, the Commission approved 3.2 billion euro public support to further the objectives of the Strategic Action Plan for Batteries.[50]

Batteries consist of two electrodes and an electrolyte. Batteries function by producing electro-chemical reactions between the electrodes, or more specifically the anodes and cathodes, that either charge of discharge the battery. Different batteries use different raw materials, such as Sodium Sulphur or Lead-acid, which affect the physical attributes of different batteries. The fastest growing battery technology is lithium-ion batteries, which refers to the material of the cathode.[51] The benefits of batteries as energy storage systems include the fast

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[45] Komarnicki, Przemyslaw, Pio Lombardi, and Zbigniew Styczynski. Electric energy storage systems: flexibility options for smart grids. Springer, 2017. p. 154
[46] Azzuni, Abdelrahman, and Christian Breyer. "Energy security and energy storage technologies." Energy Procedia 155 (2018): 237-258. p. 250
[47] Komarnicki, Przemyslaw, Pio Lombardi, and Zbigniew Styczynski. Electric energy storage systems: flexibility options for smart grids. Springer, 2017. p. 140
[48] Europe of the Move – Sustainable Mobility for Europe: Safe, connected and clean, Annex 2, European Commission, COM(2018) 293, 17.5.2018, p. 2
[49] Ibid. p. 3
[50] State aid: Commission approves €3.2 billion public support by seven Member States for a pan-European research and innovation project in all segments of the battery value chain, European Commission, Press release, 9 December 2019
[51] Energy storage – the role of electricity, Commission Staff Working Document, European Commission, SWD(2017) 61, 1.2.2017, p. 11

response time, high efficiency and flexibility.[52] Flexibility is a consequence of battery storage facilities requiring no geographical location and variety of applications, including small scale residential use to utility-scale grid enforcement.

Depending on battery technology, there are worries about issues such as raw material availability and overall lifecycle. Especially reliance on lithium and cobalt require strategic preparation for securing future supply.[53] However, the rapid development of battery technologies result as lowering costs and attributes that make battery the number one choice. By 2030, the round-trip efficiency is expected to be 90 percent and durability is expected to grow significantly.[54]

2.2.5 Hydrogen Storage

One of the most straight-forward energy storage systems consists of chemical storage. Hydrogen storage, also known as power-to-gas, refers to converting electricity into hydrogen. This process uses an electrolyzer, which similarly to batteries, has anodes and cathodes that separate oxygen and hydrogen from water. Furthermore, the hydrogen can be stored as methane. As a result, the gas can be stored in pressure vessels. When additional electricity is needed, stored gas can be used as fuel for a gas turbine.

Whereas the overall efficiency is relatively low, the biggest benefits for hydrogen storage is environmental and economic. "A power-to-gas system burns hydrogen or methane in a carbon-free process, when the gas is produced from renewable energy sources. The primary economic advantage is the elimination of notable capital expenditure by utilizing the existing natural-gas infrastructure". For example, Europe has over 200 000 kilometers of natural gas transmission pipelines and over 200 caverns in operation.[55] Hydrogen storage differs from the previous energy storage systems introduced since its characteristics are favorable for

[52] Ibid.
[53] Azzuni, Abdelrahman, and Christian Breyer. "Energy security and energy storage technologies." Energy Procedia 155 (2018): 237-258. p. 248
[54] Komarnicki, Przemyslaw, Pio Lombardi, and Zbigniew Styczynski. Electric energy storage systems: flexibility options for smart grids. Springer, 2017. p. 142
[55] Komarnicki, Przemyslaw, Pio Lombardi, and Zbigniew Styczynski. Electric energy storage systems: flexibility options for smart grids. Springer, 2017. p. 149

storing electricity in a longer time-frame. Hydrogen storage as a method is primarily used for long-term strategic reserves, which adds security of supply.[56]

Hydrogen storage is not a new energy storage solution. However, by developing the end-products, such as biofuels, and processes in general, the possibility to decrease the role of natural gas by utilizing the natural gas infrastructure makes hydrogen storage an interesting field of energy storage systems.

[56] Azzuni, Abdelrahman, and Christian Breyer. "Energy security and energy storage technologies." Energy Procedia 155 (2018): 237-258. p. 254

3. Electricity Market Design

3.1 Introduction

The new electricity market design is a reaction to the fundamental changes in the electricity sector. Most importantly, the share of electricity produced from renewable energy sources has increased. As a consequence, market and grid operation rules must become more flexible. Moreover, uncoordinated state interventions into electricity markets have created negative market distortions.[57] Therefore, "[t]he Impact Assessment endorsed an enhancement of current market rules in order to create a level-playing field among all generation technologies and resources removing existing market distortions".[58] Market distortions not only affect electricity prices for end-users, but also "reduce the attractiveness of the energy sector for new investment".[59] The electricity market design is based primarily on the Electricity Directive and Electricity Regulation. Together, these two legislative acts implement the fundamental reform of the electricity sector and electricity markets.

The new Electricity Directive emphasizes on consumers and internal market principles.[60] It addresses the legal uncertainty regarding energy storage by updating definitions and the core rules for the electricity sector. The Electricity Regulation focuses on the market structure of the new electricity market design. In addition, it aims at preparing the electricity market for a fundamental change with emphasis on market-based procedures, technology-neutrality and cross-border trading. Rather than look into the overall market design, the reforms which effect primarily the environment for energy storage are introduced. Therefore, the way specific reforms affect the energy storage framework is illustrated.

This section is divided into four segments, which approach the electricity market design from a certain perspective. The electricity sector regulation is very detailed and extensive. Therefore, in order to grasp the big picture, the reforms are divided into the core rules, access to market, market reforms and including energy storage into long-term planning. The core rules include the basic rules, which are the basis for all interaction in the electricity sector.

[57] Proposal for a Directive of a European Parliament and Council on common rules for the internal market in electricity, European Commission, COM(2016) 864, 30.11.2016, p. 3
[58] Ibid. p. 15
[59] Ibid. p. 4
[60] Ibid. p. 19

Access to market rules are a set of rules that either guarantee access or otherwise benefit the case for energy storage. Market reforms focus on specific electricity markets, that directly or indirectly affect energy storage. Long-term planning is a legal obligation for regulatory authorities and system operates. Network investment planning affects directly all electricity market operators. After illustrating the reforms, the final chapter summarizes the thoughts presented in this section.

3.2 Core Rules for Energy Storage

3.2.1 The definition of Energy Storage

The new electricity market design establishes the legal definition for energy storage and energy storage facilities. Energy storage is defined as "deferring the final use of electricity, to a moment later than when it was generated, or the conversion of electrical energy into a form of energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electrical energy or use as another energy carrier".[61] Energy storage facilities are facilities where energy storage occurs.[62]

The establishment of a legal definition for energy storage is of great importance since the lack of a definition for energy storage has resulted as a significant barrier. This was a result of uncertainty about how to legally categorize energy storage and therefore, how rules such as unbundling requirements are to be interpreted for energy storage operators. As an example, energy storage was treated as electricity generation in the UK since the Electricity Order 2001 defines generation assets as technology that generates or is capable of generating electricity.[63] Because energy storage technically generates electricity after deferring the final use of electricity, it was regarded as an electricity generation asset. Thus, energy storage was prohibited from system operators. However, the fundamental benefit of energy storage is to defer the final use of electricity, not generate electricity. In contrast, Italian law allowed Terna, a system operator, to deploy 40.9 MW of battery storage since 2013.[64] This highlights

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[61] Council Directive 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) [2019] OJ L 158/125, Article 2 (59)
[62] Ibid. Article 2 (60)
[63] The Electricity Order 2001, Article 2 (2) (d) (i)
[64] Nigel Backaby 'Collaboration Essential for the European Storage Opportunity' Blue & Green Tomorrow (November 10 2016) <https://blueandgreentomorrow.com/news/collaboration-essential-european-storage-opportunity>

the fragmentation of electricity market regulation and simultaneously, the need for EU-wide harmonization.

The definition of energy storage was altered several times during the electricity market design process. Initially, the Commission proposed the following definition: “in the electricity system, deferring an amount of the electricity that was generated to the moment of use, either as final energy or converted into another energy carrier”.[65] However, the Committee on Industry, Research and Energy (“ITRE”), a committee of the European Parliament, proposed an amendment to the definition by proposing the following definition: “[e]nergy storage means, in the electricity system, deferring the use of electricity to a later moment than when it was generated or the conversion of electrical energy into a form of energy which can be stored, the storing of that energy, and the subsequent reconversion of that energy back into electrical energy or another carrier”.[66]

When comparing the two proposed definitions with the final definition, the following observations can be made. The original definition is very simplistic and focuses on deferring an amount of electricity. ITRE’s proposal added more substance to the definition and is significantly more closer to the final definition. It especially focuses on energy storage deferring the time of use, rather than amount, as initially proposed. In addition, not only did ITRE add the ability convert electricity into a storable energy form, but to also reconvert it back to electrical energy or other energy carriers. The only difference between ITRE’s proposal and the final definition is the final definition acknowledging the possibility of using energy that is converted into a storable energy form, for example heat, without reconverting it back to electricity. When considering the different proposals and amendments, the process illustrated the challenges in defining energy storage in a way that truly captures the fundamental nature of energy storage in a technology-neutral way.

Another noteworthy factor in the new definition for energy storage is the ability to use other forms of energy. Especially considering hydrogen storage, which consists of transforming

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[65] Proposal for a Directive of a European Parliament and Council on common rules for the internal market in electricity, European Commission, COM(2016) 864, 30.11.2016, Article 2 (48)

[66] Report on the proposal for a directive of the European Parliament and of the Council on common rules for the internal market in electricity, Committee on Industry, Research and Energy, (COM(2016)0864 – C8-0495/2016 – 2016/0380(COD)), Amendment 30

electricity into hydrogen, energy storage can consist of being the mediator for creating industry feedstock products. At the moment, this is not viable due to cost-efficiency. In the future however, this may become a part of energy storage's services.[67] As a result, the nature of energy storage would change. In comparison to EU's overall objectives, this would not have negative impacts since the use of hydrogen is significantly better for the climate than natural gas. However, it may require law-makers to assess the definition of energy storage in the future.

3.2.2 Unbundling requirements for Energy Storage

Unbundling rules aim at removing the conflict of interest between the different functions of the electricity market. The conflict of interest results as less investments into the transmission network, restricting third-party access and anticompetitive behavior.[68] The less investments are made into the expansion of the network and updating the current network, the less capacity is available and therefore, affecting negatively on security of supply. Restricting third party access consequently leads to less competition, which hinders the dynamics of energy prices. Anticompetitive behavior has the same effects as restricting third-party access, but rise when undertakings collude for example by exchanging commercially important information.

The present unbundling rules were originally introduced in the Electricity Directive 2009/72/EC[69]. It is based on implementing one of three distinctive models, which aim at unbundling system operating from electricity supply and generation. The revised Electricity Directive did not alter the main substantive rules in comparison to the Third Energy Package.[70] However, the new Electricity Directive addresses directly unbundling rules in relation to energy storage.

Prior to the new Electricity Directive, a major issue for energy storage operations were the unbundling requirements. This resulted from energy storage, in some Member States, being

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[67] Hydrogen: A Renewable Energy Perspective, Report prepared for the 2nd Hydrogen Energy Meeting, IRENA, September 2019, p. 34

[68] DC Competition Report on Energy Sector Inquiry, European Commission, SEC(2006) 1724, 10 January 2007, section 542, p. 162

[69] Council Directive of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC [2009] OJ L 211/55

[70] Proposal for a Directive of a European Parliament and Council on common rules for the internal market in electricity, European Commission, COM(2016) 864, 30.11.2016, p. 20

legally treated as electricity generation. This in turn prohibited system operator ownership and usage of energy storage. Therefore, TSOs and DSOs, whom could arguably benefit the most due to the information flow between real time supply and demand in the network, were not allowed to utilize energy storage.[71] During and after the implementation of the new electricity market design, an ongoing debate on whether and to what extent, should network operators use energy storage has taken place.[72]

The rules for energy storage ownership are fundamentally the same for TSOs and DSOs. The unbundling rules are located in the Electricity Directive, respectively, in Article 36 for DSOs and Article 54 for TSOs. Primarily network operators are prohibited from owning, developing, managing or operating energy storage facilities. The objective is to adapt energy storage as balancing and ancillary services, which would be procured by market-based and competitive procedures. This consequently, prevents cross-subsidization between energy storage and regulated functions, which assures the efficient use of energy storage facilities.[73] However, the possibility for a derogation to unbundling rules was left to Member States. Based on two alternative options, system operators may own and operate energy storage facilities.

Member States may allow network operators to own, develop, manage or operate energy storage facilities, where they are fully integrated network components and the regulatory authority has granted its approval.[74] Energy storage facilities are fully integrated network components when they are integrated into the transmission or distribution system and is used only for ensuring secure and reliable operation of the transmission or distribution network.[75] In other words, energy storage facilities are integrated network components when they are used for reliable grid operation and not for balancing or for congestion management.[76] This definition for integrated network components is fairly open-ended because the difference between reliable grid operation and balancing is small. The goal is to allow energy storage

[71] Market and regulatory barriers to electrical energy storage innovation, Giorgio Castagneto Gissey et al. Renewable and Sustainable Energy Review 82 (2018), p. 784
[72] See further in this section.
[73] Council Directive 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) [2019] OJ L 158/125, Recital 62
[74] Ibid. Article 36 (2) for DSOs and Article 54 (2) for TSOs
[75] Ibid. Article 2 (51)
[76] Ibid. Recital 63

management without participating in market procedures. After all, electricity supply is a function that unbundling rules require to be separated from system operations.

In addition to being interpreted as an integrated network component, by complying with the following three cumulative conditions, system operators may own, develop, manage or operate energy storage facilities. First of all, there must be an open, transparent and non-discriminatory tendering procedure and other parties have not been awarded the right to own, develop, manage or operate these storage facilities or alternatively, the other parties could not deliver those services at a reasonable cost and in a timely manner. This tendering procedure is subject to review and approval of regulatory authorities. Secondly, energy storage facilities are necessary for the system operator to fulfill their obligations of the Electricity Directive for the efficient, secure and reliable operation of the transmission or respectively, the distribution system, and the facilities are not used to buy or sell electricity in the electricity markets. Thirdly, the regulatory authority has assessed the necessity for the derogation and approved the tendering procedure after a careful assessment.[77] In addition, in case of the derogation being granted to a TSO, the derogation must be notified to the Commission and ACER.

The core substance of these rules clearly support the removal of conflict between functions of managing networks and operating in the electricity market as a supplier or generator. The clearest indicator for this is the definition for fully integrated network components and the second condition for derogation. Since energy storage can only be an integrated network component if it is not used for balancing or congestion management. The conditions for a derogation indicate policymakers understanding the potential of energy storage in every function of the electricity system and therefore, allowing under strict conditions and the supervision of regulatory authorities to utilize storage technologies.

Eurelectric, an electricity industry association, argued that storage is a key part of DSO's "toolkit" which can provide value in bringing flexibility. However, a "mandatory tendering procedure could be both costly and time consuming and not appropriate for every situation".[78] In contrast, the European Federation of Energy Traders ("EFET"), an association

[77] Ibid. Article 36 (2) & Article 54 (2)
[78] DSO Storage ownership & operation, Eurelectric, Publications, 23 May 2017, p. 1

promoting competition, transparency and open access in the European energy sector, published a position paper on the ownership and operation of storage assets in relation to the new electricity market design. In this paper, EFET expressed serious concern regarding the operation of energy storage facility by a system operator. The concern is based on the negative effects on electricity markets since electricity flowing in and out of storage assets affect balancing parameters of electricity market participants. Therefore, the regulatory possibility for system operators to own energy storage assets should be very strict and minimized. As the final outcome of the directive is based on the way Member States transpose the Directive into national law, ETEF stress the need for respect towards market-based procedures and the unbundling principle.[79] This highlights the different interests regarding electricity markets and functions, and therefore, the different output in regards to unbundling requirements for energy storage facilities.

3.3 Rules Regarding Access

3.3.1 Technology-neutral Rules

A major part of the new electricity market design is the objective of opening up competition in the electricity markets.[80] Increasing competition in electricity markets consists of two factors. Firstly, removing barriers for cross-border trade, which increases the amount of regional operators within an electricity market. Secondly, removing technical barriers and therefore, introducing new market entrants such as energy storage operators and demand response services. This section will focus on how the electricity market design removes barriers of entry and ensures access to electricity markets.

As acknowledged by the ITRE in 2015, energy storage should receive equal access to flexibility markets and capacity mechanisms in order to compete with flexible fossil-fuel based generation units.[81] Such barriers may be a result of national licensing or capacity rules having technical specifications, which prevent access for energy storage. For example, the Office of Gas and Electricity Markets ("OFGEM"), UK's energy regulatory authority, learned

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[79] ETEF position paper on the ownership and operation of storage assets – A guidance proposal for the implementation of the recast Electricity Directive (2019/944), European Federation for Energy Traders, 13 September 2019, p. 4
[80] Delivering a New Deal for Energy Consumers, European Commission, COM(2015) 339, 15.7.2015, p. 2
[81] Energy Storage: Which Market Designs and Regulatory Incentives are Needed? Study of the ITRE Committee, 2015 p. 71

from a public consultation that network connection rules acted as a barrier for energy storage and therefore, the UK is in the middle of clarifying the connection process.[82]

Article 3 of the Electricity Regulation establishes the basic principles for the electricity markets. Article 3 (1) (n) requires that market rules allow entry and exit of electricity generation, storage and supply undertakings. In addition, section (q) states that "market participants shall have the right to obtain access to the transmission networks and distribution networks on objective, transparent and non-discriminatory terms". This rule lays down the basic principles for access into markets and access to network infrastructure.

In addition to the general principle, non-discriminatory access is stated several times as a prerequisite for organizing specific markets. Electricity Regulation Article 6, which lays down the rules for balancing markets, requires that all participants, including energy storage, has access to the market.[83] Similarly, all capacity mechanisms must be open to all service providers with the ability to provide required technical performance, including energy storage.[84] In summary, the Electricity Regulation, which is directly applicable, ensures that no market system can have unnecessary distortive qualifications for entering market.

3.3.2 Cross-border Access

Whereas the previous section illustrated how the non-discrimination of new technologies is ensured within markets and infrastructure, this section illustrates the rules promoting cross-border access. In this section, cross-border access refers to the ability to access markets in other Member States. The general principle for non-discrimination between regional operators in established in the Electricity Directive. However, rules for cross-border participation in capacity mechanisms and other electricity markets are in the Electricity Regulation.

In order to foster competition and ensure the supply of electricity at the most competitive price, Member States and regulatory authorities should facilitate cross-border access.[85] Therefore, the principle of promoting cross-border trade is based on Article 3 (1) of the

[82] Upgrading Our Energy System – Smart Systems and Flexibility Plan, OFGEM, July 2017, p. 23
[83] Council Regulation 2019/943 of 5 June 2019 on the internal market for electricity (recast) [2019] OJ L 158/54, Article 6 (1) (c)
[84] Ibid. Article 22 (1) (h)
[85] Council Directive 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) [2019] OJ L 158/125, Recital 13

Electricity Directive, which states that national law cannot act as a barrier for cross-border trade in electricity. This principle should mirror throughout the new electricity market design. However, the aforementioned rule is only a general principle with little practical use aside from guiding national policymakers. In contrast, the cross-border participation in capacity mechanisms is a fundamental reform.

Article 26 of the Electricity Regulation lays down the rules for cross-border participation in capacity mechanisms. This is welcomed regulatory reform. In the sector inquiry for capacity mechanisms, the Commission outlined that "[c]apacity mechanisms often provide subsidies only for national capacity providers, ignoring the value of imports and distorting investment signals".[86] Now, capacity mechanisms and strategic reserves are open to direct cross-border participation for foreign capacity providers. Member States may require foreign capacity providers to have a direct network connection as qualification for participation.[87] Strategic reserves differ from capacity mechanisms by their nature. Strategic reserves are passive reserves that are only activated if balancing is not sufficient with market-based capacity mechanisms.[88] Capacity providers may also participate in more than one capacity mechanism, but are required to make non-availability payments when capacity is not available. In addition, cross-border participation rules activate foreign TSOs and require them to establish the technical capability of capacity providers, carry out availability checks and share information regarding capacity providers.[89]

Besides ensuring cross-border participation, the electricity market design ensures interconnectivity between Member States and restricts TSOs' actions in congestion management. Article 16 (8) states that TSOs may not limit the volume of interconnection capacity as a mean of solving congestion. In other words, TSOs must adapt to increasing interconnection by solving congestions in other ways than limiting interconnectivity. TSOs comply with this requirement if 70 percent of capacity is available for cross-zonal capacity.[90] Fundamentally,

[86] Final report of the Sector Inquiry on Capacity Mechanisms, European Commission, COM(2016) 752, 30.11.2016, p. 2
[87] Council Regulation 2019/943 of 5 June 2019 on the internal market for electricity (recast) [2019] OJ L 158/54, Article 26 (2)
[88] Framework for cross-border participation in capacity mechanisms – Final Report, European Commission, 2014, p. 7
[89] Council Regulation 2019/943 of 5 June 2019 on the internal market for electricity (recast) [2019] OJ L 158/54, Article 26 (10)
[90] Ibid. Article 16 (8) (a) & (b)

this rule promotes cross-border electricity trade by prohibiting TSOs to restrict cross-border capacity services on the basis of congestion management.

Not only do the aforementioned regulatory instruments of the electricity market design promote cross-border trade, in addition, the Article 4 (d) (1) of the Governance Regulation[91] indicates the target of at least 15 percent electricity interconnection for Member States by 2030. The interconnection rate means that Member States should have electricity infrastructure capable of transporting at least 15 percent of electricity generated to its neighboring countries.[92] The tools for promoting interconnections is based on providing a clear electricity market framework, publicly financing important projects and promoting cooperation between regional electricity market operators and authorities.[93]

Fundamentally, the effect on energy storage is two-folded. The promotion of cross-border trading requires attributes from the electricity system, that energy storage systems are capable of providing. Primarily, energy storage systems can reduce the residual load of the grid and increase flexibility. As a consequence, energy storage systems can alleviate the need for investments into the electricity grid. In contrast, cross-border trade provides similar positive effects to the electricity system that energy storage can. Therefore, cross-border participation in may decrease the need of certain energy storage services in the long-term.

A study used energy trading strategies over a 5-year period across European power markets to assess the value of arbitrage for energy storage. The results indicated that "as European markets integrate and become more efficient, the value of arbitrage for energy storage is reduced".[94] This conclusion was based on the notion that the more interconnected the electricity market was, the lower the yield since the price spreads decrease as interconnection grows. For example, the Greek electricity market proved to be an good market for arbitrage. The reason for this was seen as less competition, the use of indigenous energy reserves and

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[91] Council Regulation 2018/1999 of 11 December 2018 on the Governance of the Energy Union and Climate Action [2018] L 328/1

[92] Connecting power markets to deliver security of supply, market integration and the large-scale uptake of renewables, The Commission, Memo, 25 February 2015

[93] A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, Energy Union Package, European Commission, COM(2015) 80, 25.2.2015, p. 9-10

[94] Zafirakis, Dimitrios, et al. "The value of arbitrage for energy storage: Evidence from European electricity markets." Applied energy 184 (2016): 971-986. p. 984

large share of energy imports.[95] This highlights that the promotion of cross-border trading may decrease the need for energy storage systems.

Considering the efforts put into increasing cross-border trading, the short-term needs of the electricity system promote the case for energy storage. In the long-term, energy storage's role may change more into an auxiliary activity. However, rather than see cross-border trading as a competitive force for energy storage systems, it is important to emphasize that energy storage is a product capable of providing services throughout the power system. Therefore, price arbitrage is only one of many services that energy storage systems are designed to do and capable of providing.

3.3.3 Network Charges

A major issue for energy storage has been the excessive network charges, which partly, are a result of the absence of a legal definition. In some Member States, energy storage operators, as a result of being treated as electricity generators and customers, have had to pay double grid fees in some Member States.[96] Rules regarding network charges are very important because of their impact on the electricity markets. "A precondition for effective competition in the internal market for electricity is non-discriminatory, transparent and adequate charges for network use including interconnecting lines in the transmission system".[97]

Article 18 of the Electricity Regulation lays down the rules for network charges. As of now, charges relating to the access, use or connection to the electricity network must be cost-reflective, transparent, take into account network security and flexibility, and reflect actual costs.[98] This reform is very welcomed from energy storage operators since a major barrier has been specifically unfair network charges, which have negatively affected the business case for energy storage investments. Regardless of past situations, rather than aim at improving specifically energy storage's situation, Article 18 (1) states that "network charges shall not discriminate either positively or negatively against energy storage".

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[95] Ibid. p. 984

[96] Energy storage – the role of electricity, Commission Staff Working Document, European Commission, SWD(2017) 61, 1.2.2017, p. 16

[97] Council Regulation 2019/943 of 5 June 2019 on the internal market for electricity (recast) [2019] OJ L 158/54, Recital 26

[98] Ibid. Article 18 (1)

Article 18 (9) states that the European Union Agency for the Cooperation of Energy Regulators ("ACER") must publish a best practice report on transmission and distribution tariffs. The report must be updated every two years. It aims at mitigating market fragmentation, which is seen as a barrier for achieving the internal electricity market. ACER published its latest report on transmission tariff methodologies in Europe on the 23rd of December 2019. It summarizes effectively the present state of energy storage and network charges. First of all, out of 29 Member States, 14 jurisdiction apply injection charges.[99] Injection charges are simply network charges for injecting, in contrast to withdrawing, electricity into the network.[100] Out of the 14 jurisdiction with injection charges, only 7 apply injection charges to transmissions-connected energy storage facilities.[101] In addition, there are a few jurisdiction, which apply tariff exemptions for energy storage facilities in order to promote and support technology.[102] The challenge is a result network connected energy storage facilities not only injecting electricity after storing it, but also originally withdraw it in. Therefore, the risk of unfair network charges rises.

The overall state of the network charges for energy storage is fragmented, as the ACER's latest report indicates. Especially worrying is that there are still jurisdictions where energy storage facilities are not identified as network groups. Therefore, the electricity market design and the Electricity Regulation especially provides an important foundation for improving network charges towards a more harmonized, cost-based and non-discriminatory direction.

3.3.4 Active Customers

An important component of the electricity market design was the role of electricity customers. As mentioned in EU's vision of the future Energy Union, "with citizens at its core, where citizens take ownership of the energy transition".[103] The driver of this transformation is the development of efficient electricity markets. Before the new market design, consumers were

[99] ACER Practice report on transmission tariff methodologies in Europe, Agency for the Cooperation of Energy Regulators, 23 December 2019, section 33
[100] Ibid. Section 30
[101] Ibid. Section 38
[102] Ibid. Section 54
[103] A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, Energy Union Package, European Commission, COM(2015) 80, 25.2.2015, p. 2

passive and prices inflexible. However now the objective is to create a market, were customers are enabled full participation to markets and are "empowered to manage their energy consumption".[104]

The fundamental idea is based on the transformation from supply-response to demand-response. Therefore, Article 15 of the Electricity Directive ensures the rights of 'Active Customers', which are customers who purchase electricity for their own use. In addition, active customers as individuals or groups consume or store electricity generated within their own premises.[105] The fundamental idea is to let consumers to adjust consumption according to market signals.[106]

The Electricity Directive Article 15 ensures the rights of active customers. Especially important is section 5, which lays down rules for active customers that own an energy storage facility. Active customers, who own energy storage facilities, have the right to a grid connection, are not subject to double grid fees, are not subject to disproportionate licensing requirements and are allowed to provide several services simultaneously. At the moment, only a proportion of electricity customers are capable of generating electricity themselves. However, with the development of technology, companies and buildings may be able to become active customers with combining renewable energy and energy storage facilities.

A typical combination suitable for residential buildings is generating photovoltaic energy with solar panels and having battery storage installations to store the electricity. A recent study from Australia concluded that apartment buildings with the solar panels and batteries of 2-3 kWh per apartment could increase self-consumption with 19 percent, increase self-sufficiency up to 12 percent and decrease overall demand up to 30 percent.[107] With smart systems reacting to market prices, the overall efficiency and affordability may improve, which would benefit consumers in general.

[104] Council Regulation 2019/943 of 5 June 2019 on the internal market for electricity (recast) [2019] OJ L 158/54, Recital 7
[105] Council Directive 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) [2019] OJ L 158/125, Article 2 (8)
[106] Ibid. Recital 37
[107] Roberts, Mike B., Anna Bruce, and Iain MacGill. "Impact of shared battery energy storage systems on photovoltaic self-consumption and electricity bills in apartment buildings." Applied energy 245 (2019): 78-95. p. 78

The electricity market design ensures the access into electricity infrastructure for all operators and active customers, whom have the technical capability. The objective is that consumers could adjust electricity use depending on market signals. The fundamental impact active customer rules have on energy storage is opening a new market segment. Now in addition to electricity market operators, by empowering consumers, energy storage can be used by and sold to consumers. This makes the market of potential energy storage system purchasers very large.

3.4 Market Reforms

3.4.1 Bidding Zone Review

Bidding zones are the "largest geographical area within which market participants are able to exchange energy without capacity allocation".[108] In other words, bidding zones are the physical areas, where certain electricity markets and the products of this particular market affect. For example, Nord Pool, the power exchange for 15 European countries, is divided into several different zones. Nord Pool's day-ahead market has Finland as one bidding zone, while Sweden is divided into four different bidding zones.[109]

The Electricity Regulation requires Member States to execute a bidding zone review. "In order to ensure an optimal configuration of bidding zones, a bidding zone review shall be carried out".[110] The objective is to address congestions by configurating bidding zones in a way that would not contain structural congestions.[111] The term 'structural congestion' is defined as "congestion in the transmission system that is capable of being unambiguously defined, is predictable, is geographically stable over time, and frequently reoccurs under normal electricity system conditions".[112]

This is an important factor for the functioning of the markets since the bidding zones are a "cornerstone of market-based electricity trading".[113] During the review, bidding zones are

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[108] Council Regulation 543/2013 of 14 June 2013 on submission and publication of data in electricity markets and amending Annex 1 to Regulation (EC) No 714/2009 of the European Parliament and of the Council [2013] L 163/1 Article 2 (3)
[109] Bidding areas, NordPool, https://www.nordpoolgroup.com/the-power-market/Bidding-areas/
[110] Council Regulation 2019/943 of 5 June 2019 on the internal market for electricity (recast) [2019] OJ L 158/54, Article 14 (3)
[111] Ibid. Article 14 (1)
[112] Ibid. Article 2 (6)
[113] Ibid. Recital 19

assessed "on the basis of their ability to create a reliable market environment, including for flexible generation and load capacity".[114] This is a general reform, which primarily focuses on transforming the electricity markets to being capable of handling fluent cross-border flows. Configurating the bidding zones with flexible generation in mind, the benefits for energy storage are a consequence of the positive correlation between the need of energy storage and flexible electricity generation. The correlation between flexible electricity generation and energy storage systems is discussed in detail in chapter 4.3.3.

3.4.2 Short term markets

The Electricity Regulation focuses on the short-term markets and scarcity pricing. "Short-term markets improve liquidity and competition by enabling more resources to participate fully in the market, especially those resources that are more flexible. Effective scarcity pricing will encourage market participants to react to market signals and to be available when the market most needs them and ensures that they can recover their costs in the wholesale markets".[115] Short-term markets, namely day-ahead and intraday markets, must be non-discriminatory, maximize opportunities for all market participants in cross-zonal trade and ensure prices reflect market fundamentals.[116] Especially important is Article 8, which includes specific rules for the imbalance settlement period and the requirement of creating trading products for small size service providers.

The imbalance settlement period is the time unit for which imbalance is calculated.[117] Article 8 (4) states that the imbalance settlement period must be 15 minutes in all scheduling areas by 1 January 2021. The shorter the settlement period, the more accurately the prices will reflect supply and demand.[118] This can be seen beneficial for energy storage since energy storage attributes include fast reaction times. In addition, Article 8 (3) requires nominated electricity market operators must provide products in the short-term markets, that are targeted for smaller operators, 500 kW or less. This makes the participation of smaller undertakings, such as demand-side response and energy storage operators, capable of effectively participating in short-term electricity markets.

[114] Ibid. Article 14 (3)
[115] Ibid. Recital 24
[116] Ibid. Article 7 (2)
[117] Article 2 (15)
[118] Simultaneous transition to 15-minute imbalance settlement in the Nordic countries, Päivi Leinonen, FINGRID, Publications, 6.3.2019

The aforementioned reforms affect not only energy storage operators, but in general all electricity market operators. However, the Electricity Regulation provides a steady and reliable market framework for energy storage operators. The new market design is changing electricity markets into a direction that is beneficial for energy storage. "Improved cross-border trading and shorter trading timeframes will better reward the flexibility provided by storage".[119] The market reforms do not necessarily directly promote energy storage, but in turn, gives energy storage a chance to compete. At the moment, the electricity markets are designed to reflect more accurately cost-base and therefore, create an operating environment for energy storage to compete with other services purely on prices. Therefore, it is up to the energy storage operators to become efficient enough to reap the benefits of the new electricity market design.

3.4.3 Flexibility Service Procurement

A barrier for energy storage operators has been the unfunctional flexibility market design, which have resulted as barriers for energy storage participation.[120] Flexibility markets consist of balancing markets and ancillary markets. Balancing includes "all the actions and processes, in all timelines, through which transmission system operators ensure in an ongoing manner, maintenance of the system frequency within a predefined stability range".[121] Ancillary markets are the markets for services, which are necessary for the operation of a transmission or distribution system, excluding congestion management.[122]

Article 32 of the Electricity Directive states that "Member States shall provide the necessary regulatory framework to allow and provide incentives to distribution system operators to procure flexibility services… in order to improve efficiencies in the operation and development of the distribution system".[123] The fundamental idea is to remove barriers from DSOs utilizing flexibility services and to ensure participation of new technologies to deliver more

[119] Ibid. p. 17
[120] Gissey, Giorgio Castagneto, Paul E. Dodds, and Jonathan Radcliffe. "Market and regulatory barriers to electrical energy storage innovation." Renewable and Sustainable Energy Reviews 82 (2018): 781-790. p. 784
[121] Council Directive 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) [2019] OJ L 158/125, Article 2 (11)
[122] Ibid. Article 2 (48)
[123] Ibid. Article 32 (1)

affordability, security and efficiency to the whole power system.[124] Especially important are services capable of mitigating need for increasing capacity investments and ability to alleviate stress on system. Particularly important is that the electricity market design ensures the ability for DSOs to procure flexibility services with transparent, non-discriminatory and market-based procedures.[125]

In addition to facilitating the framework, national regulatory authorities must establish or approve specifications for the flexibility services procured and where appropriate, create standardized market products at national level.[126] An identical obligation is also for TSOs based on Article 40 (6), which lays down the general tasks of TSOs. Similarly, the establishment of standardized market products at least at national level are required.[127] Standardized market products are products with harmonized rules. By creating standard market products, the markets will be more accessible and the risk of discrimination is lower since prices, rather than any other characteristics, determine the service provider.

In addition to rules regarding procurements, a fundamental reform is the increased responsibility of DSOs over their system. Whereas the before, the TSO was mainly responsible of overall system security, the DSOs are now responsible of acting as a "neutral market facilitator in procuring the energy it uses to cover energy losses in its system".[128] In addition, the Electricity Regulation Article 5 states that "[a]ll market participants shall be responsible for the imbalances they cause in the system". The new principle is referred to as 'balance responsibility'.

The Electricity Directive requires Member States to open up flexibility markets for all technologies capable of providing the necessary services. The opening of flexibility markets together with balance responsibility aims at activating system operators to at least consider energy storage solutions. This creates a great opportunity for energy storage technologies to participate in flexibility markets and indicates the multifaceted possibilities of energy storage services.

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[124] Flexibility Use at Distribution Level, A CEER Consultation Paper, Council of European Energy Regulators, Ref: C18-DS-42-04, 17 July 2018, p. 9
[125] Council Directive 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) [2019] OJ L 158/125, Article 32 (1)
[126] Ibid. Article 32 (2)
[127] Ibid. Article 40 (6)
[128] Ibid. Article 31 (5)

As an example of recent flexibility procurements, UK Power Networks, a DSO covering South East England, opened a new flexibility tender in July 2019. In the official invitation to tender, UK Power Networks invited undertakings to apply for providing services capable of "shaving or shifting peak demand – importing less or exporting more power to the distribution network as an additional amount relative to its baseline operations – to support UK Power Networks in delivering a safe, secure, efficient distribution network".[129] Contracts were awarded in 7 different bidding zones with a flexibility capacity of 18.1 MW out of which 7.6 MW was awarded to operators using battery technology.[130] This illustrates, already at this stage of the technology, how strongly energy storage can infiltrate into flexibility markets.

3.5 Including Energy Storage in long-term plans

Chapter VI of the Electricity Regulation establishes a new entity called the European entity for distribution system operators ("EU DSO"), which aims at promoting optimal management and coordinated operation of distribution and transmission systems. Article 55 lays down the tasks of EU DSO, which are among other tasks, promoting operation and planning of distribution networks, facilitating demand side flexibility and facilitating the integration of renewable energy sources and other resources embedded into in the distribution network such as energy storage.[131]

It is important to understand that the core mission for EU DSO is to increase the communication between TSOs and DSOs through this new entity.[132] However, the tasks of EU DSO also include facilitating the integration of resources embedded in the distribution network such as energy storage. This highlights the strong desire from policymakers to activate system operators in regards of new storage opportunities. Even though the effect on energy storage is indirect, it is unexpected that energy storage is the only example of "other resources" that is mentioned. Basically, the Electricity Regulation establishes a new entity, which is required, among other tasks, to promote energy storage.

[129] Flexibility Services Invitation to Tender – 2019, UK Power Networks, PE1-0029-2019 Flexibility Services, August 2019, Section 4.1.1
[130] Market Report – 2018/19 Flexibility Tender, UK Power Networks
[131] Council Regulation 2019/943 of 5 June 2019 on the internal market for electricity (recast) [2019] OJ L 158/54, Article 55 (1) (b)
[132] Ibid. Recital 60

However, it is not unprecedented that European entities wish to promote energy storage since already in 2016 four different European associations representing distribution system operators, automotive and industrial batteries published a joint statement on battery-based storage. The statement called upon EU institutions to "deliver a clear regulatory framework incorporating storage as a key instrument towards achieving the Energy Union".[133] Nevertheless, the statement was issued by different interest groups. EU DSO is an expert entity working for the common interest and does not represent particular interest or seek to influence the decision-making process.[134] Therefore, this can be seen as a positive regulatory reform for energy storage operations.

In addition to establishing the EU DSO, the new Electricity Directive requires system operators in general to include energy storage into network planning. Both, DSOs and TSOs, are required to publish and submit to regulatory authorities a network development plan every two years. Article 32 (3) describes what a DSO network development plan consists of. At least it must provide transparency on the medium to long-term flexibility services needed. Particularly important is to publish the upcoming plans regarding the main distribution infrastructure. In addition, the plan must include the use of other resources, such as energy storage, that the DSO is to use as an alternative to system expansion. Similarly, Article 51 regulates the content of the TSOs ten-year network development plan, which is most importantly the upcoming investments into main infrastructure. Article 51 (3) requires TSOs to "fully take into account the potential use of demand response, energy storage facilities and other resources".

Including energy storage in the mandatory long-term networks plans is a strong indicator of public support for energy storage. Since it is specifically stated that other resources must be taken into account, it seems like not procuring or investing into energy storage would require specific justification.

[133] Joint statement on battery-based storage; EDSO, CEDEC, GEODE, EUROBAT; Publications; 7 November 2016; p. 1
[134] Council Regulation 2019/943 of 5 June 2019 on the internal market for electricity (recast) [2019] OJ L 158/54, Article 52 (2)

3.6 Summary

As stated by the Commission in 2017, the proposed electricity market design allows energy storage operators to provide multiple services, such as congestion management for DSOs, balancing services for TSOs and other commercial services, such as price arbitrage.[135] Furthermore, the guiding principles for the market design was to allow energy storage to fully participate in the energy markets. The core changes consisted of the definition of energy storage and the unbundling rules in relation to energy storage.

Major insecurity regarding the legal status of energy storage resulted as barriers for market participation and cut down investments into energy storage research and development.[136] At the moment, the Electricity Directive provides a coherent definition, which is technology-neutral and focuses on the fundamental purpose of energy storage. This being the ability to defer the final use of generated electricity. At the moment, the definition improves energy storage's status as an independent legal object. In the long-term, the relationship between deferring the consumption of generated electricity and using electricity for transforming energy forms for other purposes may arise.

Another major issue, which the Electricity Directive clarified were the unbundling requirements for energy storage. Even though the new unbundling rules are very restrictive for system operators managing energy storage facilities, there are two alternative derogations as illustrated. However, the principle rule is prohibiting the management and ownership of energy storage facilities. This is straightforward and respects the unbundling principle.

Another principle supporting the market development for energy storage includes the integration of new market participants. As ITRE summarized, "[e]nergy storage should be allowed to participate fully in electricity markets".[137] Thus, EU established new rules regarding access. Access, in this paper, consists of several different factors from non-discrimination to a new segment of active customers. The basic principle for non-discrimination was based on the Electricity Directive. Most importantly, the rules for the electricity markets

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135 Energy storage – the role of electricity, Commission Staff Working Document, European Commission, SWD(2017) 61, 1.2.2017, p. 17

136 Energy Storage: Which Market Designs and Regulatory Incentives Are Needed? Study of the ITRE Committee, 2015, p. 71

137 Ibid. p. 23

were transformed into technology-neutral. In addition, energy storage specifically was mentioned throughout the electricity market design to ensure access. Not only are new operators ensured access, but also the huge emphasis on cross-border trading. The consequences of the cross-border rules were briefly discussed. In summary, in a fully integrated European electricity market, cross-border trading could replace the need for some of the energy storage services. At the moment, aside from EEX[138] and Nord Pool, the European electricity markets are not interconnected. Therefore, this line of thought is long-term. In addition, energy storage systems cannot be seen as only mechanisms for price arbitrage. Section 2 illustrated the wide range of business cases for energy storage.

The third focus of this section were the market reforms that included several favorable changes for energy storage systems. Especially focus on short term markets with efficient price signals and standardized market products, also for smaller operators, increase the possibilities for energy storage investments. Also flexibility markets are guided towards market-based procedures that incentivize energy storage use cases.

The final segment, which was integrating energy storage into long-term network planning indicates the public support for energy storage. This opens up direct support for energy storage in the long-term. As a result of all four segments, including the numerous detailed reforms, the overall climate for energy storage technology is bright and optimistic.

[138] European Energy Exchange, a central European power market that operates in Germany, France, Austria and Switzerland

4. Security of Electricity Supply

4.1 Introduction

In 2009, Europe was shaken when Russia decreased their natural gas supplies piped through Ukraine. The reason for decreasing supply was a price dispute between Gazprom PJSC, the company responsible for delivering almost 37 percent of Europe's gas market, and Naftogaz JSC, the Ukrainian national oil and gas company. Because of natural gas's important role in EU electricity generation, this dangered the security of electricity supply. As a result, factories were closed and power was cut in Eastern Europe for several days during the winter.[139] This showed Europe how dependent neighboring countries were on other Member States energy policy. Therefore, EU-wide coordination on the security of supply is necessary.[140]

At the moment, EU imports 53 percent of the energy it consumes. The biggest concern consists of being reliable on one single external supplier. The reliance on a single supplier is more extreme in gas, but also electricity.[141] As a result, the EU has taken policy action. In addition to several revisions to EU regulation, the European Commission published the European Security Strategy outlining the objectives and following steps for increasing energy security.

The European Security Strategy sets out eight distinctive areas of focus, which promote closer cooperation with benefits for all Member States.[142] Especially important in regard of energy storage is moderating energy demand, a well-functioning internal market and increasing energy production in the European Union. Member States are responsible for ensuring the security of supply within their territories, while the responsibility for security of supply is also shared among the Commission and other Union actors, such as TSOs.[143]

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[139] Dina Khrennikova , Anna Shiryaevskaya , and Daryna Krasnolutska, 'Why the Russia-Ukraine Gas Dispute Worries Europe' Bloomberg (December 6, 2019) <https://www.bloomberg.com/news/articles/2019-12-06/why-the-russia-ukraine-gas-dispute-worries-europe-quickta>
[140] Council Regulation 2019/941 of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC [2019] OJ L 158/1, 2019/941, Recital 3
[141] European Energy Security Strategy, European Commission, COM(2014) 330, 28.5.2014, p. 2
[142] Ibid. p. 3
[143] Council Regulation 2019/941 of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC [2019] OJ L 158/1, 2019/941, Recital 10

This section includes an introduction into EU's security of supply doctrine, including the overall objectives and legislation. However, the scope of the review focuses on the security of electricity supply. Therefore, legislation focusing solely on the security of gas supplies is ignored. In addition, legislative acts which impact indirectly security of supply, such as the Electricity Efficiency Directive and the Renewable Energy Directive are introduced. After illustrating the principle of security of supply and the EU framework for improving it, an assessment on the impact the new electricity market regime has on security of supply, by reforming the rules for energy storage operations. In other words, how does the market environment for energy storage impact the security of electricity supply.

4.2 European Framework for Security of Supply

4.2.1 Definitions

Security of supply, or energy security, is one of the three pillars of European Union's energy policy in addition to sustainability and competitiveness.[144] The concept seems rather blurred since it consists of a mixture of secure supply, economic efficiencies and sustainable energy.[145] Security of electricity supply is defined as "the ability of an electricity system to guarantee the supply of electricity to customers with a clearly established level of performance, as determined by Member States concerned".[146]

The fundamental idea of energy security is the continuity of energy supply.[147] Another important term when discussing security of supply is electricity crisis, which means "a present or imminent situation in which there is a significant electricity shortage, as determined by the Member States and described in their risk-preparedness plans, or in which it is impossible to supply electricity to customers".[148] The core principle of energy security is to guarantee a sufficient amount of energy to EU consumers at all times. However, energy security has been used as an political umbrella term to drive different policy goals. As Paul Joskow put it, "[t]here is one thing that has not changed since the early 1970s. If you cannot think of a

[144] A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, Energy Union Package, European Commission, COM(2015) 80, 25.2.2015, p. 4
[145] Winzer, Christian. "Conceptualizing energy security." Energy policy 46 (2012): 36-48. p. 36
[146] Council Regulation 2019/941 of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC [2019] OJ L 158/1, 2019/941, Article 2 (1)
[147] Winzer, Christian. "Conceptualizing energy security." Energy policy 46 (2012): 36-48. p. 41
[148] Council Regulation 2019/941 of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC [2019] OJ L 158/1, 2019/941, Article 2 (9)

reasoned rationale for some policy based on standard economic reasoning then argue that the policy is necessary to promote energy security”.[149]

The Essent Case shows how the European Court of Justice (“ECJ”) viewed unbundling rules in light of EU and European Human rights. The ECJ had to determine whether objectives aiming at combating vertically integrated undertakings constitute as purely economic interests or reasons in the public interest.[150] Since the objectives were interpreted to fundamentally aim for sufficient security of supply, the ECJ concluded that they are in the public interest and therefore, justify restrictions on the fundamental rights.[151] Without further commenting on the legal substance of the Essent Case, the mere objective of energy security was enough for justifying restrictive unbundling rules. This illustrates how serious energy security is in EU policy and law.

This section provided the definition and fundamental objective of security of supply. In the next section, EU rules for security of supply, mainly the Regulation on risk-preparedness in the electricity sector[152] (“Regulation on risk-preparedness”) is introduced. In addition to the Regulation for risk-preparedness, the Clean Energy Package includes EU legislation, which has an effect on the security of supply, mainly the Energy Efficiency Directive and the Renewable Energy Directive. Therefore, these directives are introduced briefly, but the focus remains in security of electricity supply.

4.2.3 The Risk-preparedness regulation

In contrast to the other legislative acts of the Clean Energy Package, the Regulation on risk-preparedness focuses solely on the security of supply. It’s core consists of electricity crisis prevention and management, which includes rules for risk assessments, risk-preparedness plans and managing electricity plans.

[149] Winzer, Christian. “Conceptualizing energy security.” Energy policy 46 (2012): 36-48. p. 36 Original reference: Joskow, Paul L. “The US energy sector: Prospects and challenges, 1972-2009.” Dialogue 17.2 (2009): 7-11. Dialogue 17 (2)

[150] Judgment of 22 October 2013, Essent and Others, joined case C-105/12 and C-107/12, EU:C:2013:677, paragraph 49

[151] Ibid. paragraph 51

[152] Council Regulation 2019/941 of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC [2019] OJ L 158/1

The rules for risk assessments are located in Chapter II of the Regulation for risk-preparedness and Chapter IV of the Electricity Regulation. Chapter IV of the Electricity Regulation dictates the use of capacity mechanisms, which are discussed later in this paper, and covers rules for resource adequacy. A important energy policy objective was to streamline the way Member States approach security of supply since a problem identified was the outdated and inconsistent approaches for assessing electricity supply throughout the European Union. Therefore, a EU-wide fact-based approach is seen necessary.[153]

Risk assessments are primarily assessments for resource adequacy, which is defined as "the ability of the electricity system to offer sufficient generation and flexibility to ensure reliable electricity supply at all times".[154] Rather than state details regarding the risk assessments, the Regulation for risk-preparedness grants the European Network of Transmission System Operators of Electricity ("ENTSO-E") the right to develop a common methodology for identifying the crisis scenarios.[155] As an example to illustrate the methodology, ENTSO-E states that the identification of regional electricity crisis scenarios is comprised of three main parts: collection and aggregation of national electricity crisis scenarios, a gap analysis where missing national electricity crisis scenarios are identified and the preparation of a final set of regional electricity crisis scenarios.[156]

Risk assessments are divided into regional electricity crisis scenarios[157], national crisis scenarios[158] and short-term and seasonal adequacy assessments[159]. While ENTSO-E is responsible for creating the methodology for identifying crisis scenarios and submitting regional electricity crisis scenarios, Member States and their competent authority are responsible for assessing national crisis scenarios. Interestingly, Member States are also responsible also for assessing "risks in relation to the ownership of infrastructure relevant for security of supply".[160] In terms of short-term and seasonal adequacy assessments, they can be made on

[153] A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, Energy Union Package, European Commission, COM(2015) 80, 25.2.2015, p. 6

[154] Capacity mechanisms for electricity, Briefing, European Parliament, 22.5.2017, p. 2

[155] Council Regulation 2019/941 of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC [2019] OJ L 158/1, 2019/941, Article 5

[156] Methodology to Identify Regional Electricity Crisis Scenarios in accordance with Article 5 of the Regulation of Risk-preparedness, Article 8

[157] Council Regulation 2019/941 of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC [2019] OJ L 158/1, 2019/941, Article 6

[158] Ibid. Article 7

[159] Ibid. Article 9

[160] Ibid. Article 7 (4)

national, regional or on Union level. However, ENTSO-E is responsible for carrying out seasonal assessments for summer and winter each year. As an example, ENTSO-E in the 2019/2020 Winter Outlook observed that an adequacy risk is observed in Belgium and France in January 2020, if the daily average temperature in that region drops to -5 degrees Celsius, resulting possibly to out-of-market measures and regional cooperation because of heavy reliance on electricity imports.[161]

In addition to identifying hypothetical risks associated with electricity supply, the Regulation for risk-preparedness requires the establishment of risk-preparedness plans by the competent authority of each Member State.[162] These risk-preparedness plans consist of national and bilateral measures that are planned or taken to prevent, prepare for and mitigate electricity crisis.[163] National measures include for example roles and responsibilities of the competent authorities, mechanisms used to inform the public, the designation of a national crisis coordinator and identifying the contribution of market-based measures. Then again, regional and bilateral measures "ensure that electricity crisis with a cross-border impact are properly prevented or managed".[164] After notifying the Commission by the risk-preparedness plan, the Commission reviews the plan and issues a non-binding opinion, which focuses on the effectivity, inconsistency with risk assessments, compliance with EU regulation and effect on competition.[165]

The third reform of the Regulation for risk-preparedness consists of Chapter IV, which is titled "managing electricity crisis". Managing electricity crisis includes early waring and the declaration of an electricity crisis, cooperation and assistance, and compliance with market rules. In case of evidence occurring of an upcoming electricity crisis, the competent authority of the Member State is responsible for issuing an early warning for the Commission, Member States within same region and Member States directly connected to the country in electricity crises. Then again when confronted with an electricity crisis, the competent authority is responsible for declaring an electricity crisis.[166]

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[161] Winter Outlook 2019 / 2020 Summer Review 2019, ENTSO-E, 27 November 2019, p. 4
[162] Council Regulation 2019/941 of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC [2019] OJ L 158/1, 2019/941,. Article 10
[163] Ibid. Article 11 (1)
[164] Ibid. Article 12 (1)
[165] Ibid. Article 13
[166] Ibid. Article 14 (2)

Article 15 of the Regulation for risk-preparedness introduces a new principle within the scope of security of supply by stating that "Member States shall act and cooperate in a spirit of solidarity in order to prevent or manage electricity crisis".[167] Emphasis is on the risk-preparedness plans preparing for such crisis situations and regional or bilateral measures agreed beforehand. However, in case Member States have not agreed on coordinated measures and technical, legal and financial arrangements, the spirit of solidarity requires that other Member States are responsible for providing assistance.[168] However, measures taken during electricity crisis must comply with rules governing the internal electricity market and system operation.[169] Non-market-based measures can be used only as the last resort and must be necessary, proportionate, non-discriminatory and temporary.

In summary, EU regulates the responsibility to prepare, prevent ja mitigate energy crisis. The primary focus is on increasing preparedness for electricity crisis situations. Another reform of this Regulation is to include spirit of solidarity principle to the risk-preparedness regime. Spirit of solidarity is being used in rather many different EU documents.[170] The EU General Court recently examined the principle of energy solidarity and elaborated the substance of the term. Even though the OPAL case concerned a dispute concerning gas supply, it is relevant for understanding the substance of the spirit of solidarity.

The OPAL case was concerning a dispute between the European Commission and Poland on whether the European Commission's decision to exempt the capacities for cross-border transmission of the planned gas pipeline Ostseepipeline-Anbindungsleitung (hence, the name OPAL) from the application of the rules on third party access was against the spirit of solidarity.[171] To summarize, in the context of energy policy the principle of solidarity implies the obligation for mutual assistance in the event of, for example, natural disasters.[172] In addition, it also implies the obligation to the European Union and Member States to exercise their competences in energy policy to take account the interest of other stakeholders.[173] However, it does not mean that EU energy policy can never have negative impacts on a particular

[167] Ibid. Article 15
[168] Ibid. Recital 29
[169] Ibid. Article 16 (1)
[170] E.g. Article 194 of the Treaty of the Functioning of the European Union & European Energy Security Strategy, European Commission, COM(2014) 330, 28.5.2014, p. 3
[171] Judgement of 10 September 2019, Republic of Poland v European Commission, case T-883/16, EU:T:2019:567, paragraph 5
[172] Ibid. paragraph 71
[173] Ibid. paragraph 72

Member State. Therefore, it consists of a balance of different interests, when there is a conflict.[174]

The Regulation for risk-preparedness also activates several different actors to monitor, prepare and assess the adequacy of electricity at any given time. As illustrated, even the methodology for assessing regional electricity crisis starts by gathering the national risk-assessments, which were the responsibility of the competent authority of Member States. In addition, regional and bilateral measures for risk-preparedness are always agreed between Member States. This fundamentally exhibits the division of competences between the EU and Member States in energy policy since Member States are seemingly reluctant to give away control on energy policy.[175] Based on article 194 of TFEU, energy is part of shared competency between the EU and Member States. Member States have the right to determine their choice between different energy sources and the general structure of their energy supply. However, EU has the right to determine policy aiming at ensuring security of energy supply in the Union.[176] As a consequence, it can be challenging to find a reasonable balance between Member State sovereignty and efficient governance. In this particular matter, the balance consists of EU actors deciding on the methodology for assessing risks, monitoring and following the overall consistency between regions. Then again, Member States have the right to choose and agree on measures in risk-preparedness plans. However, EU principles, such as the spirit of solidarity might restrict the competence of Member States.

4.2.4 Renewable Energy and Security of Supply

In this section, the revised Renewable Energy Directive 2018/2001 ("RES-directive") is introduced. The intention is to present the RES-directive in light of security of electricity supply. However, before finding out the correlation between these two, the content of this Directive is introduced. The revised RES-directive is a response to the need for new ambitious renewable energy targets. The goal is to increase the share of renewable energy in the Union's final energy consumption. The main reasons for increasing the share are the obligations from the Paris Agreement and the possibilities enabled by recent renewable technology cost

[174] Ibid. paragraph 77
[175] Veum, Karina, and Dierk Bauknecht. "How to reach the EU renewables target by 2030? An analysis of the governance framework." Energy policy 127 (2019): 299-307. p. 300
[176] Article 194 TFEU (1) (b)

reductions.[177] Member States are collectively obligated to reach at least a 32 percent share of renewable energy in the Union's final energy consumption by 2030.[178] The RES-directive stipulates rules for financial support for energy from renewable sources. Article 4 is titled "Support schemes for energy from renewable sources", which lays down principles for support schemes aiming at incentivizing renewable energy production.

Basically, the impact RES-directive has on security of electricity supply is decreasing dependency on energy imports and therefore, increasing security of supply. As mentioned in the European Energy Security Strategy, "a fuel-switch to indigenous renewable heating sources can displace significant amounts of imported fuel".[179] The RES-directive emphasizes the role of energy from renewable sources as part of promoting energy security.[180]

In a paper titled "Security aspects of future renewable energy systems – A short overview"[181] by Bengt Johansson, the correlations between renewable energy systems and energy security is assessed. The important aspects is the change in dependency from energy flows, rather than energy resources, short-term difficulties in variable renewable energy production and decreasing concentration as a result of the fact that factors necessary for renewable energy generation are less concentrated to certain countries. The first benefit from increasing renewable energy generation for security of supply is that renewable energy is generated based on energy flow. In contrast, fossil fuels are based on resources, which in the long term are depletable. Secondly, a short term concern are the difficulties of balancing supply and demand as a result of the variable nature of renewable energy. This has a negative impact on security of supply since it makes the balance of the electricity grid more unpredictable. The third aspect consists of the fact, that renewable energy resources are available, to some extent, in all countries and therefore, decreasing the dependency of supply on certain countries.[182]

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[177] Council Directive 2018/2001 of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) [2018] L 328/82, Recital 6
[178] Ibid. Article 3
[179] European Energy Security Strategy, European Commission, COM(2014) 330, 28.5.2014, p. 12
[180] Council Directive 2018/2001 of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) [2018] L 328/82, Recital 3
[181] Johansson, Bengt. "Security aspects of future renewable energy systems–A short overview." Energy 61 (2013): 598-605.
[182] Ibid. p. 602

In summary, the RES-directive aims at increasing the share of renewable energy in the European Union. This results as increasing security of supply in the long term. This being true with the exception of possible short-term difficulties with balancing the electricity supply and demand.

4.2.5 Electricity Efficiency and Security of Supply

In addition to increasing risk-preparedness and renewable energy production, there are other legislative acts that aim to increase security of electricity supply by focusing on electricity efficiency. "Moderating energy demand is one of the most effective tools to reduce the EU's external energy dependency" and therefore, the Clean Energy Package introduced two new directives focusing specifically on energy efficiency. The two aforementioned legislative acts are the Energy Efficiency Directive 2018/2002[183] and the Energy Performance of Buildings Directive 2018/844[184]. With the careful and timely implementation of these directives, the targeted energy savings are possible to achieve.[185]

The core of the Energy Efficiency Directive consists of the new energy efficiency obligation schemes, rules for energy metering and action to make energy billing more transparent. Article 1 states the new electricity efficiency target of 32,5 percent by 2030. The target is expressed in final energy consumption, which is an decrease in comparison to projected final energy consumption. In 2007, one projection was 1887 Mtoe for 2030 and therefore, the target is achieved if final consumption is 1273 Mtoe in 2030.[186] The primary instruments for increasing energy efficiency are energy efficiency obligation schemes, which requires every year a 1,5 percent decrease of annual energy sales to final customers. Article 9 (b) requires individual meters for measuring the consumption of heating, cooling or domestic hot water for each building unit. In addition, billing information for electricity and gas should be free and include the possibility for final customers to access personal consumption information.[187] These reforms indicate the strong desire to empower and activate energy customers.

[183] Council Directive 2018/2002 of 11 December 2018 amending Directive 2012/27/EC on energy efficiency [2018] OJ L 328/210
[184] Council Directive 2018/844 of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency [2018] OJ L 156/75
[185] European Energy Security Strategy, European Commission, COM(2014) 330, 28.5.2014, p. 7
[186] Council Directive 2018/2002 of 11 December 2018 amending Directive 2012/27/EC on energy efficiency [2018] OJ L 328/210, Recital 6
[187] Ibid. Article 10a

Energy efficiency improvements in buildings save money for consumers.[188] In addition, the energy efficiency of buildings have huge potential since 40 percent of EU's energy consumption come from buildings.[189] The framework for buildings in terms of energy efficiency consists of long-term renovation strategies[190], minimum energy performance requirements for new buildings[191] and regular inspections for heating and air-conditioning systems[192]. The implementation of electricity efficiency rules for buildings has been slow.[193] Problems rise from issues such as private ownership not leading to willingness to upgrade buildings energy efficiency and the Member State's will to keep jurisdiction for construction standards to themselves.[194]

In summary, energy efficiency is pivotal for decreasing energy consumption. It has a positive impact on energy security since ideally this would result as a decrease in imported energy. However, the primary focus of electricity efficiency is to improve factors, such as buildings, which have a major impact on energy consumption. Especially considering the increasing demand of electricity, the emphasize on technological improvement is pivotal for maintaining security of electricity supply.

4.3 Energy Storage and Security of Electricity Supply

4.3.1 Introduction

The European Energy Security Strategy lists as the sixth pillar "Further Developing Energy Technologies". By developing new energy technologies, reductions in energy demand, diversification of supply options and optimization of the energy network infrastructure become available.[195] This section consists of an assessment regarding the impact energy storage has

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[188] Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy, Communication from the Commission to the European Parliament and the Council, European Commission, COM(2014) 520, p. 6
[189] Ibid. p. 12
[190] Council Directive 2018/844 of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency [2018] OJ L 156/75, Article 2a
[191] Ibid. Article 6
[192] Ibid. Article 14 & 15
[193] Energy efficiency in buildings – A nearly zero-energy future? European Parliament, Briefing, May 2016, p. 1
[194] Ibid. p. 5
[195] European Energy Security Strategy, European Commission, COM(2014) 330, 28.5.2014, p. 14

on the security of electricity supply. In addition to identifying the impact in general, the way energy storage improves security of supply is illustrated.

The reason for conducting this assessment is to understand the potential of energy storage. The role of energy storage is mentioned in several official documents and has strong public support. As an example, the Commission approved 3.2 billion euro public support for a pan-European research and innovation project focusing at all segments of the battery value chain.[196] In order for the project to be compliant with EU state aid rules, it must fulfill cumulative rules for being a project of common European interest. The second rule requires the project to contribute to the Union's objectives, such as the European Energy Security Strategy.[197] However, the fundamental impact is mostly over-simplified and therefore, the true method for increasing the security of electricity supply is unclear. Thus, the following inquiry.

As this chapter points out, the impact is indirect. The reforms of the electricity market design have improved significantly energy storage's ability to participate in the electricity markets. Therefore, the focus on this section is to identify the benefits of energy storage as a market participant. The section is divided into three parts, depending on the way energy storage impacts security of electricity supply. The first section examines energy storage in relation to capacity mechanisms and the impact of energy storage as an alternative to capacity mechanisms. Secondly, the impact energy storage has on renewable energy generation. This includes the way energy storage can assist in increasing the share of renewable energy in the EU. Thirdly, the correlation between affordability and security of supply. The objective is to understand the relation between energy storage and decrease electricity prices, which consequently improves the security of electricity supply.

4.3.2 Energy Storage and Capacity Mechanisms

In this section, the impact energy storage has on security of electricity supply is assessed. However, in terms of energy security, energy storage has only one meaningful marketplace,

[196] State aid: Commission approves €3.2 billion public support by seven Member States for a pan-European research and innovation project in all segments of the battery value chain, European Commission, press release, 9 December 2019
[197] Communication from the Commission on Criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest [2014] OJ C 188/4 , Chapter 15

where it can impact security of supply as a direct market participant. This marketplace is through capacity mechanisms. In other parts of the electricity markets, energy storage has a positive impact on electricity market undertakings but not necessarily the whole market. The findings of this chapter are based on scientific articles, which have assessed the correlations between capacity markets and security of supply, and energy storage and capacity markets. Before introducing the findings it is necessary to briefly introduce capacity mechanisms and their core function towards security of electricity supply.

Capacity mechanisms aim at protecting the security of supply, by remunerating electricity generators and capacity providers for being available in case of electricity shortage.[198] The mechanisms typically "offer additional rewards to capacity providers, on top of income obtained by selling electricity on the market, in return for maintaining existing capacity or investing in new capacity needed to guarantee security of electricity supplies".[199] The essence of capacity mechanisms is the guaranteed availability of electricity. Commonly, the TSO's which are responsible for balancing the demand and supply of the electricity transmission grid tender capacity from electricity generators.

The Commission identified 35 capacity mechanisms in eleven different Member States.[200] Therefore, it is unnecessary to go into detail of the different forms of capacity mechanisms. More importantly, it is important to understand that the majority of capacity mechanisms are national and regional and therefore, conflict with objectives of the Energy Union. The framework strategy states that "[t]he Commission will ensure that all regional initiatives evolve in a coherent way and lead towards a fully integrated Single Energy Market".[201] However, capacity mechanisms potentially distort the electricity market in both the Member State responsible for the mechanism and possibly also cross-border electricity markets since they alter price signals and affects investment incentives.[202] Therefore, capacity mechanisms have

[198] Final report of the Sector Inquiry on Capacity Mechanisms, European Commission, COM(2016) 752, 30.11.2016, p. 2
[199] Hawker, Graeme, Keith Bell, and Simon Gill. "Electricity security in the European Union—the conflict between national capacity mechanisms and the single market." Energy Research & Social Science 24 (2017): 51-58. p. 53
[200] Final report of the Sector Inquiry on Capacity Mechanisms, European Commission, COM(2016) 752, 30.11.2016, p. 9
[201] A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, Energy Union Package, European Commission, COM(2015) 80, 25.2.2015, p. 11
[202] Ibid. p. 15

a negative impact on cross-border trading. As a result, state aid rules affect capacity mechanisms. However, more important for capacity mechanism design is the market structure.[203]

The Electricity Regulation lays down the general rules for capacity mechanisms.[204] As discussed earlier, the electricity market design ensures access to capacity mechanisms by technology-neutral rules that allow cross-border participation. This is an important reform for energy storage operators since capacity mechanisms have had technical barriers restraining energy storage operators from participating in capacity tenders.[205]

A study which aimed at analyzing the change of need for capacity mechanisms if demand-response and energy storage were available showed results that indicated the capacity obligation can be reduced significantly, which in turn decreases the consumer cost. However, increasing electricity storage facilities does not eradicate the need for capacity mechanisms.[206] The added value brought by energy storage is not an alternative, but rather a by-product, which can decrease the need of capacity markets, and therefore, the distortions to the electricity market. The method how energy storage decreases capacity mechanisms, is simply the ability to smoothen fluctuations and decrease the residual load of the grid.[207]

In summary, none of the studies showed a strong correlation between energy storage and energy security directly. The main reason seemed to be the premature state of technology and the efficiency of capacity mechanisms. However, considering the overall objectives of EU energy policy, energy storage may be capable of reducing the need of capacity mechanisms and therefore, decreasing the distortions to cross-border trading. In other words, energy storage does not improve energy security as it is but it is able to reduce the need for present distortive mechanisms upholding security of electricity supply.

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[203] Hancher, Leigh, Adrien de Houteclocque, and Malgorzata Sadowska, eds. Capacity mechanisms in the EU energy market: law, policy, and economics. Oxford University Press, USA, 2015. p. 183

[204] Council Regulation 2019/943 of 5 June 2019 on the internal market for electricity (recast) [2019] OJ L 158/54, Recital 48

[205] Gissey, Giorgio Castagneto, Paul E. Dodds, and Jonathan Radcliffe. “Market and regulatory barriers to electrical energy storage innovation.” Renewable and Sustainable Energy Reviews 82 (2018): 781-790. p. 786

[206] Khan, Agha Salman M., et al. “How do demand response and electrical energy storage affect (the need for) a capacity market?.” Applied Energy 214 (2018): 39-62. p. 54

[207] Ausfelder, Florian, et al. “Energy storage as part of a secure energy supply.” ChemBioEng Reviews 4.3 (2017): 144-210. p. 155

4.3.3 Ability to Increase the Share of Renewable Rnergy

In this section, the role of energy storage in security of electricity supply is assessed from a renewable energy point of view. EU's Security of Supply Strategy expects increasing the production of renewable energy to increase security of supply. In addition to significant cost-effects, increased production of renewable energy reduces dependency on oil imports and potentially has a massive impact on energy security.[208] This being said, concerns regarding the cost and impact on the internal energy market, due to increased renewable energy production, have arised. This is a consequence of two reasons. First of all, the production of renewable energy is still subsidized by support schemes, which are based on the rules of the RES-directive. Secondly, the intermittent nature of renewable energy may cause severe peaks to the grid. Energy storage technologies cannot effect the price of renewable energy production. However, energy storage can impact the efficient integration of intermittent renewable energy into the electricity system.

The principle concern regarding renewable energy is the intermittent nature of it and the consequences to the electricity grid. The primary renewable energy sources are hydro, biomass, wind and solar, which grew 127 times in terms of generation during 2004-2014.[209] The biggest obstacles are a result of unpredictability. For example, solar energy generation "has a well-established daily cycle, with a peak around noon and low generation over the darker part of the day". However, "varying cloud coverage can cause significant changes in the electricity generation even over the course of minutes, which presents a specific challenge to the grid".[210]

At the moment, electricity production must equal electricity consumption at all times. System operators plan ahead but deviations occur constantly. To react, system operators procure reserves from market operators, which either increase or decrease their electricity generation or consumption according to the need of the network.[211] The added value energy storage provides lies in the effective operation of the grid and fast reaction times in case of rapid

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[208] European Energy Security Strategy, European Commission, COM(2014) 330, 28.5.2014, p. 12

[209] Shivakumar, Abhishek, et al. "Drivers of renewable energy deployment in the EU: An analysis of past trends and projections." Energy Strategy Reviews 26 (2019): 100402. p. 1

[210] Energy storage - Role of electricity, European Commission, SWD(2017) 61, 1.2.2017, p. 6

[211] Reserves and balancing power, Fingrid, https://www.fingrid.fi/en/electricity-market/reserves_and_balancing/

power drops of surges.[212] The simple idea is that "[e]nergy storage is used to time-shift the delivery of power".[213] Therefore since renewable energy is intermittent, by using energy storage the electricity from renewable sources can be delivered when needed in contrast to when generated.

In addition, energy storage location yields a significant advantage. Since most energy storage technologies, especially battery storage facilities, do not require specific geographical locations, energy storage has the ability to link various grid elements together and therefore, add flexibility. In addition, well located energy storage facilities empower "non-network solutions", which have the potential of replacing and deferring grid enforcements by meeting Distribution Network Operator's demand locally.[214]

The Electricity Directive has an obligation for both Distribution Transmission Operators ("DSOs") and Transmission System Operators ("TSOs") to consider energy storage in network planning. Article 32 has an obligation for Member States to create a regulatory framework, which incentivizes DSOs for including demand response or energy storage solutions in network planning, when such services "alleviate the need to upgrade or replace electricity capacity".[215] Also TSOs must take into account demand response and energy storage alternatives when submitting mandatory ten-year network development plans.[216] The fundamental idea for the regulatory obligation of considering alternatives to network enhancement is to support a market framework, which aims at providing services for the overall benefit of the power system.[217]

Similarly to capacity markets, energy storage does not directly impact security of supply with its attributes towards renewable energy production. However, it cannot be understated how energy storage can improve the electricity infrastructure towards a favorable operating

[212] Energy storage - Role of electricity, European Commission, SWD(2017) 61, 1.2.2017, p. 6
[213] Lund, Peter D., et al. "Review of energy system flexibility measures to enable high levels of variable renewable electricity." Renewable and Sustainable Energy Reviews 45 (2015): 785-807. p. 793
[214] Poudineh, Rahmatallah, and Tooraj Jamasb. "Distributed generation, storage, demand response and energy efficiency as alternatives to grid capacity enhancement." Energy Policy 67 (2014): 222-231. p. 222
[215] Council Directive 2019/944 of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) [2019] OJ L 158/125, Article 32 (1)
[216] Ibid. Article 51
[217] Towards smarter grids: Developing TSO and DSO roles and interactions for the benefit of consumers, ENTSO-E, 4.11.2016

environment for an increasing share of renewable energy. Since the correlation between renewable energy production and energy security is expressed as an official pillar in the security of supply strategy, it is clear how energy storage indirectly impacts the security of electricity supply.

4.3.4 Affordable Electricity and Energy Storage

In addition to the actual availability of electricity, the affordability of energy is an important component of security of electricity supply. Typically, energy security studies recognize affordability as one component of security of supply. One framework for the concept of security of supply consists of four As (availability, accessibility, affordability and acceptability).[218] In addition, the EU mentions affordable energy as one the goals of the Energy Union.[219] This section consists of an overview of energy storage's impact on affordable electricity.

Before assessing the correlation between energy storage and affordable electricity, it is necessary to understand how affordable electricity affects security of electricity supply. Earlier in this paper, security of electricity supply was described as the continuity of electricity supply. However, an optional definition has been the "uninterrupted availability at an affordable price while respecting environmental concerns".[220] Nevertheless, Aleh Charp and Jessica Jewell see that the traditional four A's is not good enough to conceptualize security of supply. Especially problematic is the unclarity resulting from the question whom should the energy be affordable for.[221] This is argued by the different possible participants who can benefit from affordable energy. For example, it can be governments by examining their subsidies and import/export balances, energy companies and investors by looking into their energy investment profitability or end-users, namely households and businesses, who could benefit from low energy expenses.

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[218] Cherp, Aleh, and Jessica Jewell. "The concept of energy security: Beyond the four As." Energy policy 75 (2014): 415-421. p. 415

[219] A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy, Energy Union Package, European Commission, COM(2015) 80, 25.2.2015, p. 2

[220] Talus, Kim, and Thomas Wälde. "Electricity interconnectors in EU law: energy security, long term infrastructure contracts and competition law." European law review 32.1 (2007): 125-137. p. 136

[221] Cherp, Aleh, and Jessica Jewell. "The concept of energy security: Beyond the four As." Energy policy 75 (2014): 415-421. p. 417

EU emphasizes the need for both investments into electricity infrastructure and research and development. However, the Commission published a report on energy prices and costs in Europe. The report presents data and trends of energy prices for households, industry, Member States and EU as a whole.[222] Based on the way EU collects energy price data and analyzes the impact of affordable energy, the focus is on end-users and the European Union as a whole. Therefore, in terms of affordable electricity, the profitability of investments, and the benefits of profitable investments, is a separate subject. However, the profitability of energy investments is important to ensure adequate financing towards energy technology and infrastructure investments. Nonetheless, affordability in this section means cheaper electricity bills for end-users and mitigating overall EU energy expenses.

Affordable electricity correlates with security of supply since when electricity is affordable, price is not a barrier for ensuring continuity of supply. However, lower prices can be a consequence of two factors. Firstly, assuming electricity markets work efficiently, prices become affordable when the supply is abundant in relation to demand. Secondly, removing market inefficiencies may result as lower electricity prices. Removing market inefficiencies can include decreasing the use of capacity mechanisms and increasing cross-border trading. Therefore, affordable electricity can be seen as a consequence of energy policy. The objective is to identify, how energy storage can effect affordability, which in turn affects electricity security.

EU has the view that decarbonization correlates positively to affordability. As mentioned in the energy price report, "Prices rises underline the strong economic rationale for decarbonizing the EU and increase the economic benefits of decarbonization".[223] The relation between renewable electricity production and energy storage was examined in section 4.3.3. The conclusion was that energy storage has the ability to create a favorable environment for increasing the share of renewable energy production. Regardless of energy storage implementation, the electricity production in the European Union is projected to increase.[224] However, the benefits of energy storage in relation to increasing electricity generation from renewable sources in the EU relate in particular to the overall governance of the electricity system. This being a result of decreasing grid stress and storing intermittent electricity from

[222] Energy prices and costs in Europe, The Commission, COM(2019) 1, 9.1.2019, p. 1
[223] Ibid. p. 1
[224] Table 1, Impact assessment, European Commission, SWD(2016) 410, 30.11.2016, p. 39

renewable sources. Since energy storage is important for renewable electricity generation, energy storage can impact the affordability of electricity.

The second factor for lowering electricity prices was removing market inefficiencies. The efficiency of a market is a broad subject and cannot be attributed to only certain factors. However, from a policy perspective the rules regarding access to markets and overall market reforms aim at building an efficient and competitive electricity market. The reforms of the electricity market design were discussed in section 3. Most importantly, the framework allows energy storage systems to participate in all areas of the market. Especially the participation in capacity mechanisms is important for decreasing the distortions in prices and market mechanisms. This was discussed in detail in section 4.3.2. The impact energy storage has on market efficiencies is in increasing competition, decreasing the use of distortive capacity mechanisms and assisting the overall efficiency of the electricity system.

Affordability can also include protection from volatility. Similarly to affordability, stability can be seen as a component for security of electricity supply. This creates predictability. However, as discussed in section 3.2.2, cross-border trade can provide stability in the long-term. Before efficient cross-border trading, energy storage systems can provide protection from volatility with price arbitrage, which is the most common application for energy storage.[225] When efficient markets allow energy storage to buy electricity when it is cheap and sell it when expensive, the overall price spreads will decrease. Predictability allows long term planning for businesses and protection to households from sudden price increases.

At the moment, EU focuses on the cost of energy to households and businesses. Electricity prices should be low in relation to household incomes and operating margins of businesses. This ensures that electricity prices do not become barriers for the use and thus, the demand of electricity. In 2015 the poorest ten percent of European households spent 9.8 % of their total expenditures on energy.[226] This naturally affects the overall living standards of Europeans.

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[225] Zucker, Andreas, Timothée Hinchliffe, and Amanda Spisto. "Assessing storage value in electricity markets, a literature review." JRC Scientific and Policy reports (2013). p. 29
[226] Energy prices and costs in Europe, The Commission, COM(2019) 1, 9.1.2019, p. 7

In summary, energy storage can improve the overall electricity system and market efficiency. By stabilizing the electricity prices and deferring the time of electricity use, electricity prices hopefully will become more affordable. Energy storage's impact towards electricity affordability is primarily indirect. It consists of removing market inefficiencies and supporting the increasing share of intermittent renewable electricity. However, it can directly, through price arbitrage, stabilize volatility and thus, create affordability.

4.4 Discussion

There is a clear growing interest in energy storage technology within the electricity markets. There are two indicators for the interest. First of all, the way official EU energy policy documents emphasize the potential of energy storage. Secondly, the recently active acquisitions of energy storage companies. For example Softbank, the Japanese conglomerate, invested in 2019 110 million dollars into Energy Vault, an energy storage start-up.[227] Another example is EDF Group, one of the world's largest producers of electricity largely owned by the French government, which acquired Pivot Power, a British energy storage start-up.[228]

At the moment, the drivers for energy storage are the increasing penetration of intermittent renewable energy, need for electricity efficiency and policy pursuing an internal European electricity market. This raises issues in regard the security of supply since Member States are at the moment not immune to electricity blackouts. On the 9th of August 2019, UK suffered its first wide-scale blackout in more than a decade. As a result, 1.1 million electricity customers were without electricity between 15-45 minutes. To highlight the severity, Ipswich hospital and Newcastle airport were among the electricity customers without electricity. The blackout was a consequence of a lightning strike and a sudden loss of power.[229] This highlights how vulnerable the electricity system is still today. Therefore, EU has ensured new policy aiming at increasing security of supply.

[227] Leslie Hook, 'SoftBank to invest $110m in brick tower energy storage start-up' Financial Times (August 15, 2019) <https://www.ft.com/content/5b06a392-be9b-11e9-89e2-41e555e96722>
[228] EDF Group accelerates its development of battery storage and electric vehicle (EV) charging infrastructure by acquiring Pivot Power' EDF Publications (November 4, 2019) <https://www.edf.fr/en/edf/united-kingdom-edf-group-accelerates-its-development-of-bat>
[229] Technical Report on the events of 9 August 2019, OFGEM, Press releases, 10 September 2019, p. 4-5

The framework regarding security of supply after the Clean Energy Package consists primarily on the Regulation for risk-preparedness. The core reforms consist on increasing preparedness with uniting the methodology for assessing risks. In addition, risk-preparedness plans and the principle of spirit of solidarity is introduced. Furthermore, other legislative acts aim at increasing security of supply with other means. The Renewable Energy Directive aims at increasing energy production within the European Union with setting collective mandatory energy production targets. Another important factor for increasing security of supply is focusing on electricity efficiency. Therefore, as part of the Clean Energy Package, the Electricity Efficiency Directive and the Energy Performance in Buildings Directive set targets for efficiency and rules for planning the long-term improvement of energy efficiency, by for example setting standards for efficiency in new buildings.

In section 4.3 the impact that energy storage has on security of supply was assessed. The results concluded that the impact was indirect but significant. Energy storage may be able to reduce the need for capacity mechanisms. Capacity mechanisms are established to assure security of supply, but have a negative impact on cross-border electricity trading. Therefore, energy storage, by reducing the need for capacity mechanisms, increases indirectly security of supply since cross-border trading enhances competition and as a result, cost efficiency.[230] Another important factor is energy storages effect on renewable energy production. Energy storage having the ability to create flexibility, by location and by time-shifting energy delivery, and improve the environment for increasing renewable energy production is significantly more favorable.

An important theme of this paper is also the reforms of the electricity market design. As the framework allows energy storage to participate in every aspect of the electricity eco-system, from active customers to system operators, one goal is to lower prices. Lower prices are, potentially, a result of several different policy actions that independently and together make markets and the governance of the electricity system more efficient. Efficiency tends to result as lower prices for end-users. In this case, and as discussed in section 3, the policies which could make electricity more affordable by empowering energy storage are, above all,

[230] Meyer, Roland, and Olga Gore. "Cross-border effects of capacity mechanisms: Do uncoordinated market design changes contradict the goals of the European market integration?." Energy economics 51 (2015): 9-20. p. 9

the increased competition in retail markets, short-term market improvements and a steady framework, which hopefully attracts investments into emerging storage technologies.

As stated of energy storage, “[t]he existing technologies satisfy the demand in the current state of the energy system, but are not sufficient to meet the future challenge for several reasons”.[231] For now, the expectations for energy storage are partly hypothetical and depend heavily on technological development. As presented in this section, the impact energy storage could have is clear and straight-forward.

[231] Ausfelder, Florian, et al. "Energy storage as part of a secure energy supply." *ChemBioEng Reviews* 4.3 (2017): 144-210. p. 206

5. Conclusions

This paper introduced the new electricity market design. The focus of this review was energy storage systems in the new electricity market design. The electricity market design focuses on updating the electricity market regulatory framework to a new environment, which consists of pressure for decarbonizing the EU, overall electrification of society, increase of renewable electricity production and the need for investments to prepare electricity infrastructure for an integrated European electricity market. In addition, the security of electricity supply framework was assessed in light of energy storage. The reason is that security of electricity supply's role in the new electricity market design increases as a result of the challenges that electricity systems encounter as electricity markets are transformed.

The electricity market design consists of four different categories. The first being the core rules for energy storage. This consisted of the Electricity Directive establishing the legal definition of energy storage and clarifying the unbundling requirements for energy storage. The unbundling rules respect the unbundling principle but simultaneously, acknowledge the several alternative applications for different operators in the electricity system. Therefore, system operators can under strict rules own, manage and operate energy storage facilities.

Considering the definition for energy storage, it captures the fundamental nature of storing electricity. However, it is interesting that the definition allows for energy storage to act as an energy form transformer. Since energy storage can be the conversion of electrical energy into a form of energy which can be stored and the use of this energy as another energy carrier. Even though the definition emphasizes the storing electrical energy, it is interesting how the definition would be applied to a following hypothetical scenario. A company with an energy storage system practices price arbitrage. However, rather than sell electricity back to the market when prices rise, the company would be in the business of hydrogen generation. It is true that this would still fundamentally consist of storing energy into different forms. However, the point is that the business is different. Rather than act as an short term grid relief, it would be closer to what oil refineries represent to the oil industry. This in turn, changes slightly the nature of the operations.

This type of operations do not necessarily have negative consequences on EU objectives. However, it may create new business models that might involve regulatory needs in the long-term. At the moment, the aforementioned scenario is not viable because of cost-efficiency factors. However, this type of business cases for energy storage systems have been considered.[232] With a combination of low-cost electricity and a decrease in electrolyzer costs, it could be viable. In Germany, electricity from renewable energy sources have already been negative at times.[233] This has been a consequence of oversupply. Therefore, this line of thought may become relevant in the future. In summary, the core changes are overall positive for energy storage. It guarantees energy storage fair legal treatment in the electricity sector.

The second category consisted of developing rules regarding the access in the electricity sector. The Electricity Directive created a new segment called active customers, which could potentially be a significant target group for energy storage facilities and services. The Electricity Regulation in turn, focused on harmonizing electricity market rules. The main focus was on ensuring technology-neutrality in markets, promoting cross-border access and harmonizing network charges, which have previously acted as barriers for energy storage access to markets.[234] The overall state of market changes are very positive for new technologies, including other parties such as demand response service providers.

Market reforms, similarly to the rules regarding access, focus on the overall state of the electricity markets. However, the reforms are particularly beneficial for energy storage operators. This is a result on focusing on short term markets and creating standardized market products for smaller service providers. Considering that energy storage systems are attributed for fast response times but also smaller capacities than other market players, the reforms support energy storage participate in the markets. However, as illustrated in section 3.3.2, the short term markets are most profitable for energy storage when cross-border trading is not sufficient.

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[232] Hydrogen: A Renewable Energy Perspective, Report prepared for the 2nd Hydrogen Energy Meeting, IRENA, September 2019, p. 26

[233] Stanley Reed, 'Power Prices Go Negative in Germany, a Positive for Energy Users' The New York Times (December 25, 2017) <https://www.nytimes.com/2017/12/25/business/energy-environment/germany-electricity-negative-prices.html>

[234] Market and regulatory barriers to electrical energy storage innovation, Giorgio Castagneto Gissey et al. Renewable and Sustainable Energy Review 82 (2018), p. 784

Including energy storage into long-term network planning, which is a legal obligation for system operators, highlights the overall public attitude towards energy storage. In addition, the establishment of EU DSO, which is obligated to consider and promote energy storage solutions between regional distribution operators, increases the support towards energy storage technologies.

Another important theme of this paper was the security of electricity supply. The electricity market design was validated by the improvement of security of supply. Since the electricity market design has an overall positive impact on energy storage, the relationship between energy storage and security of electricity supply was assessed. The findings are divided into three categories: decreasing market distortions, developing an electricity system favorable for renewable energy and ensuring affordable electricity. This was a result of decreasing the need for capacity mechanisms and therefore, market distortions. Secondly, the technical capabilities of energy storage compliment the negative consequences of increasing intermittent renewable energy. Therefore, by decreasing system stress energy storage enables electricity generation in the EU, which in turn decreases energy imports. Thirdly, energy storage indirectly may have a beneficial impact on security of electricity supply by increasing competition, making markets more efficient with price arbitrage and defer expensive network investments.

In conclusion, the regulatory framework has improved significantly. Energy storage has the ability to become an independent electricity market operator or an ancillary product. Considering that on 10 February 2020 the day-ahead electricity prices in Finland dropped negative for the first time ever, the ability to store electricity is topical and necessary to improve the balance between electricity supply and demand.[235] In addition, the new framework improves the security of electricity supply. However, it must be emphasized that the technology is still premature and thus, it is not a solution for all network and energy policy issues. In 2017, EU imported fossil fuels worth 266 billion euros.[236] This highlights how energy storage is only a fracture of EU's future energy policy. Nonetheless, considering the legal barriers prior to the Clean Energy Package and the overall objectives of the electricity market design, the framework for energy storage is competitive. This is step towards public support

[235] Nordpool Market Data, Day-ahead prices, Finland, < https://www.nordpoolgroup.com/Market-data1/Dayahead/Area-Prices/FI/Hourly/?view=table>

[236] Energy prices and costs in Europe, The Commission, COM(2019) 1, 9.1.2019, p. 7

for new technology may create great opportunities for EU as an energy consumer and as a global expert in energy technology.