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Exploring Trade-offs in the Hungarian Renewable Energy Market

PhD Dissertation

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Preface

Perhaps it is not a cliché to say that the topic of my doctoral dissertation was shaped by several personal factors. Both my academic research interest and my professional background are strongly tied to network industries, especially energy markets. My interest in energy policy issues started with my exchange semester at Aarhus University (AU) in Denmark. Besides the excellent academic program at the Aarhus School of Business, I also learned to appreciate the potential of renewables and local energy solutions through examples I saw, for example onshore and offshore wind parks and efficient district heating systems.

The first foundation of the dissertation was laid when I worked at the energy & utilities practice of a Big Four energy consultancy and then at local utility companies on complex projects both in Hungary and in the United States. I am blessed that besides my alma mater, Corvinus University of Budapest (CUB), I also had the chance to study supply chain management at Quinnipiac University (QU) in Hamden (Connecticut) and engineering science focusing on the energy industry on the Hartford (Connecticut) campus of Rensselaer Polytechnic Institute (RPI). I was mesmerized and inspired by the changing landscape of the traditionally stable energy industry: the structure of major natural gas and electric utility providers has been changing and the Hungarian renewables support scheme has also been transforming rapidly.

During my time at CUB, I would particularly like to thank my advisor, Professor Gyula Vastag, who supported me and motivated throughout my studies, gave me useful pieces of advice and gave me the opportunity to learn from his experience, knowledge and skills. During my time in the US, I would like to thank Christopher P. Ball and Christian Sauska for making my wonderful American experience possible.

I am also grateful to my colleagues that I had the opportunity to work closely with on several projects (I am hoping that our cooperation will continue even after my dissertation): Máté Tóth, Márk Laczkó and János Puskás. I owe special thanks to Thomas Richard Mészáros, Csaba Marosvári, János Hajdu, Csaba Sándor and Pál Buday who were not only there to brainstorm with on industry challenges but also turned from co-workers into friends. Many thanks to the participants of the concept

mapping research on renewables, as my industry fellows dedicated significant time and energy (pun intended) to the idea generation, statement review, sorting, evaluation and interpretation of the results, without them concept mapping would have been an empty tool.

Besides my alma mater, I would like to express my special thanks to the Central European Institute at QU that gave me the much needed flexibility, time and resources to conduct my PhD research.

Most of all, I would like to thank my wife Anna and my kids, Aliz and Arnold. Anna has been very supportive throughout my thesis research both in my academic and my professional life, while Aliz and Arnold gave me plenty of energy at the times most needed.

Abstract

Several Directives were issued by the European Union (EU) since the 1990s to promote a non-discriminative, liberalized European single market. As the EU faced new challenges (energy supply security, climate change, technology improvements, etc.), a comprehensive framework was built up incorporating the EU 20-20-20 targets or the concept of the Energy Union. As these EU policies promote renewables and expand the current energy value chains by incorporating new technologies, new trade-offs were introduced. Ultimately, the new trade-offs affect the Hungarian energy market as well.

Currently limited research is available on how different stakeholders perceive critical drivers that enhance or limit the value chains of renewables. Thus, the goal of this dissertation is to present the first comprehensive set of results on the representations and perceptions of Hungarian renewable energy market's trade-offs as perceived by the stakeholders or, rather, energy policy influencers. The research used concept mapping, which is a bottom-up and participatory mixed methods-based approach.

The dissertation addresses the impact of these recent developments on the Hungarian renewables' energy market focusing on, among others, regulatory, pricing and reliability issues by using an interdisciplinary approach to combine the economic, legal, engineering and IT considerations. The research concentrates on and examines the following topics:

- **Research question 1 (RQ1): What are the most important renewable energy sources (RES) related trade-offs in the Hungarian energy market?**
- **Research question 2 (RQ2): How can the crucial RES trade-offs be relaxed in Hungary?**
- **Research question 3 (RQ3): How could the key RES trade-offs be influenced by the new Hungarian Energy Strategy that is under development (with special considerations to the planned Paks 2 project)?**

We discuss the relevant literature, describe the conceptual framework used and the relevance of concept mapping as the chosen methodology. Regarding the increased reliance on renewable energy sources, this dissertation reveals the key country-

specific trade-offs in Hungary. These trade-offs are to be considered when defining energy policy priorities (such as the revision of the Hungarian National Energy Strategy) or designing an efficient supply chain to achieve affordable, environmentally sustainable electricity and to ensure an optimal supply chain performance.

The results include a 2D concept map of 40 actions (statements) grouped into five hierarchical clusters labeled as 1) ‘low level strategy’, 2) ‘high-level strategy’, 3) ‘infrastructure development’, 4) ‘network optimization’ and 5) ‘social aspects’. The concept map provides insights on their interrelatedness and conceptual alignment revealing stakeholders’ ideas and understanding of the trade-offs in the Hungarian renewables’ market. The low- and high-level strategies were given the highest priority by stakeholders, closely followed by infrastructure development and network optimization, while the social aspects were found to be relatively less important compared to the other clusters. Respondents found the most serious issue is the frequently changing Hungarian regulatory environment that has increased business risks and costs. The participants indicated the necessity for a more flexible tariff system to ensure the proper balance between the return on investment and technology trends and the importance to ensure that the hidden costs of the technologies are considered. In addition, the results show that trade-offs are interrelated and should be handled with a complex approach taking into account government policies regarding end-user prices, new cross-border capacities, environmental concerns regarding the different RES technologies, the challenges of innovations and new, potentially game-changer technologies (such as storage solutions).

The relative importance measures for each cluster of drivers were obtained. These measures showed a strong understanding of the energy industry actors but the ladder graphs in almost all of the cases may indicate some potential disagreements between the subgroups. Comparisons were made of industry experience (‘Juniors’, 'Mid-level', ‘Seniors’), type of affiliation (working for ‘State controlled’ or ‘Not state controlled’ entities) and qualification (‘Economics and Management’, ‘JD’). Results are discussed and participant interpretations and remarks on the clusters are provided. Finally, a focused case study is used to demonstrate the role of the energy policy decisions on the energy market and RES developments. In sum, our research results provide additional insights regarding effective policy formulation for enabling an improved, more effective Hungarian energy strategy.

Finally, on the basis of this dissertation we suggest the further research directions i) the RES trade-offs on the high and low strategy levels, ii) the application of concept mapping for relevant energy industry issues and iii) to explore the increased state-ownership effect on RES development.

This research focused on Hungary, the Hungarian renewable energy market and the inherent policy trade-offs related to the dynamically changing desirable energy mix of this country. Our respondents are among the primary influencers of decisions in the Hungarian energy sector; they do know the causal links and the whys behind the actions. Consequently, this study has very high internal validity (the extent to which we can infer that a relationship between two variables is causal), the representations given show valid causal linkages. Additionally, we can argue - in the spirit of Donald T. Campbell's Proximal Similarity Model, which is just a different name for external validity (generalizability to other settings) - that the Hungarian situation is not unique, the neighboring countries, particularly the Czech Republic, Poland and Slovakia (the Visegrád Group), are very much in the same boat with Hungary. These countries face similar challenges regarding energy strategy (e.g., finding the proper RES technology within their energy mix), network development and optimization (e.g., cross border capacities, balancing north-south power loads) and social issues (e.g., controversies of the coal industry). So, the results presented here have external validity and are, to a varying extent, applicable to these countries.

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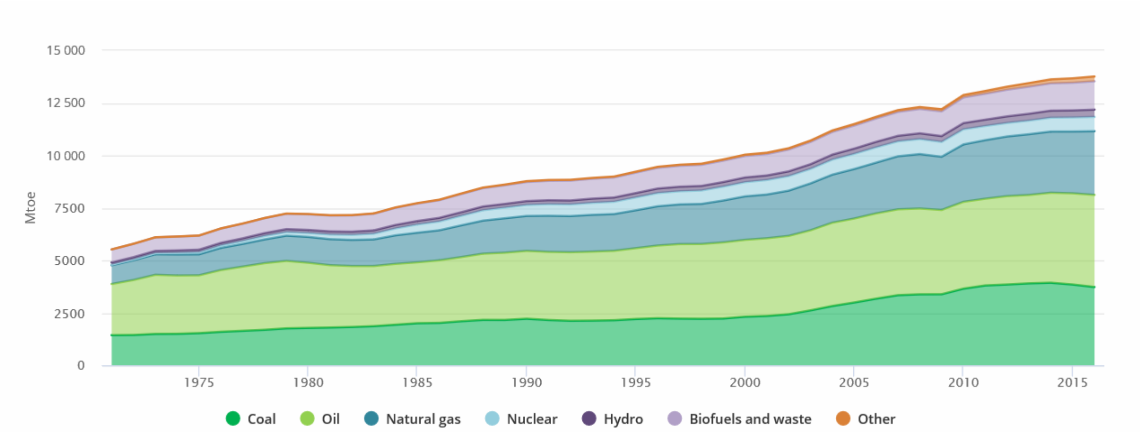
1. General introduction

1.1 Introduction

The access to energy closely relates to the development and economic performance of any given country, such as how energy costs affect competitiveness (EC, 2014, 2015). No wonder that with the global economic growth, the global energy consumption has also been increasing. International Energy Agency (IEA) data shows (figure 1) that while the share of the traditional fossil fuels (like coal, oil and natural gas) is decreasing, their overall utilized amount is still rising.[1]



Notes: i) world includes international aviation and international marine bunkers; ii) peat and oil shale are aggregated with coal; iii) others includes RES including geothermal, solar, wind, tide/wave/ocean, heat and other

Figure 1. World Total Primary Energy Supply (TPES) (1971-2016, Mtoe)

Source: IEA

The exception is the coal in which consumption decreased even in those countries where the coal industry receives strong political support. For example, in the United States of America (USA, U.S.) coal consumption decreased by 1.9% from 2016 to 2017 level, while the U.S. coal production (+6.4%) and the average number of employees at U.S coal mines increased in the same period. However, this increase is more just an interim halt to the tendency that is apparent after 2011 (figure 2), as it has already caused a productivity decrease (EIA, 2018).[2]

[1] Globally, the residential energy market is dominated by traditional biomass (40% of the total) followed by electricity generated from different sources (21%) and natural gas (20%), but the total proportion of fossil fuels has decreased over the past decade (Neyat et al., 2015).

[2] As a result of these tendencies, the U.S. coal mining productivity (as measured by average production per employee hour) decreased by 0.9%. It amounted 6.55 short tons per employee hour as the coal industry had 53,051 employees on average in 2017 (EIA, 2018).

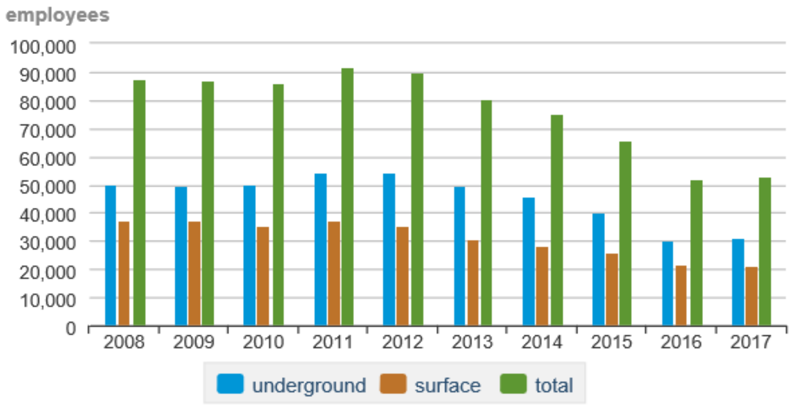


Figure 2. Average number of employees by mine type in the U.S. (2008-2017)

Source: EIA (2018)

We see the following three major factors that will drive coal to lose its share in the energy mix:

- The coal consumption decrease was driven by the electric power sector as it accounted for about 92.8% of the total U.S. coal consumed in 2017. The Renewable Portfolio Standards (RPS)[3] of the different U.S. states – similarly to the EU's renewables related goals (like 20-20-20) – directly ensure the long-term government-support towards renewable energy sources (RES) and indirectly the further decrease of the coal-based power generation in the U.S. electricity mix.
- Innovation may cause other fuel types or technologies to be more profitable: as it happened with the shale gas production in the U.S., or the RES developments in the European Union (EU), especially in Northern European countries.
- Environmental considerations have become more decisive in the past decade and coal is more and more perceived as an unfavorable choice ('dirty coal').

Similar tendencies are apparent in the European Union; however, temporarily existing coal-based power plants could gain momentum in different countries. This has occurred in Germany and Poland, when the shut down and later the nuclear phase out of the German nuclear power plants were initiated.

[3] The U.S. RPS mandated renewables share are varying, but, for example, one of the most ambitious target is the State of California's: 44% by 2024; 52% by 2027; 60% by 2030 and 100% by 2045. The State of Connecticut requires reaching 48% by 2030 from the 17% of 2018. For a summary of U.S. RPS targets please see <http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx>; Last accessed: 15-01-2019

Besides the analysis of the energy consumption, taking a closer look into the types of energy usage also helps to understand the major trends. Based on energy usage three main areas of the global energy consumption can be defined:

- (thermal) energy used for heating and other technological processes,
- liquid fuels used for transport, logistics and other segments (e.g., agriculture),
- the increasing dependence on electricity, which can be considered environmental friendly depending on the site of consumption (from the production and generation standpoint this only applies partially).

The dominance of the fossil fueled based combustion in the case of transportation and energy industries and the reliance on high-temperature (pressurized) steam to drive turbogenerators for the generation of electricity have been global trends since the industry's commercial beginnings[4] (Smil, 2016). In the case of transportation the competition between the different alternative fuel types (including electricity, gaseous, liquid, and solid energy carriers) are still ongoing (Zhao, 2017). While electric vehicles (EV) are gaining momentum (IEDC, 2013), other solutions - like compressed natural gas (CNG) - are following closely. Nonetheless, the role of energy policy is still decisive and regulatory decisions have shaped the decentralized energy markets: Neaimeh et al.(2017) described that regulator support to promote fast-charging is essential for battery electric vehicles (BEVs). Khan (2017) also pointed out how a government-supported road map may be the key to a build sustainable demand for natural gas vehicles (NGVs)[5]. In the case of power generation renewable energy sources are slowly superseding other fuel sources and a gaining competitive advantage. Generally less regulatory support is required as technologies mature; however, grid connection barriers remain major issues. In Europe the best example is Germany, as an early adopter of the RES technologies. Most of the German RES assets are located in the north, while the major

[4] In 1882, Thomas A. Edison completed the world's first two small coal-fired stations in London (at Holborn Viaduct) and in New York (on Pearl Street near the financial district of the City).

[5] In Europe – with the exception of some countries like Italy - there is a lack of widespread use of natural gas as a fuel due to missing infrastructure (Engerer and Horn, 2010). Von Rosenstiel et al. (2015) concluded that in the case of the German NGV market the coordination failure in complementary markets was the most important reason, while an artificially created monopoly of service stations at motorways, imperfect information, bounded consumer rationality, and principle-agent-problems were minor factors.

consumption centers are located in the south.[6] In the past years unplanned power flows caused serious problems at the interconnections of the Central Eastern European (CEE) markets (Schroeder et al., 2013, Singh et al., 2016).

Energy policy continues to play a significant role in system developments and also determines how to promote energy efficiency or to adjust energy consumption within the energy mix. Moreover, policy makers need to consider the strong relationship between the energy mix, energy security and economic growth (Bilgen, 2014). Setting mandatory goals, achievable targets (e.g., net-zero energy buildings), introducing incentives and solutions (such as energy labels) and increasing public awareness (e.g., about consumption patterns or new technologies) are employed within all EU member states. Energy supply security concerns are especially high in the CEE region, as limited access to fossil fuels encourage the countries to look for non-fossil fuel sources: RES or even nuclear energy. Finally, climate policy should be addressed as it has long-term consequences on the logical operation of the industry.

1.2 Climate policy concerns

The global mean surface temperature has risen by 0.9 °C ± 0.2 °C between 1906 and 2005 (IPCC 2013, 2014a, 2014b). NOAA (2018) data shows that in 2016 the global land surface temperatures were the highest since 1850, the instrumental period (figure 3). Blunden et al. (2018) found that 2017 was approximately 0.38 to 0.48°C warmer than the 1981–2010 average. Overall, the years of 2014, 2015, 2016, 2017, 2018 are the five warmest years on record.

[6] North-South Electricity Interconnection in 'Western Europe' (NSI West Electricity) Corridor was established by Regulation (EU) No. 347/2013 (The Energy Infrastructure Regulation). For more details see < http://tyndp.entsoe.eu/insight-reports/north-south-interconnection-western/>

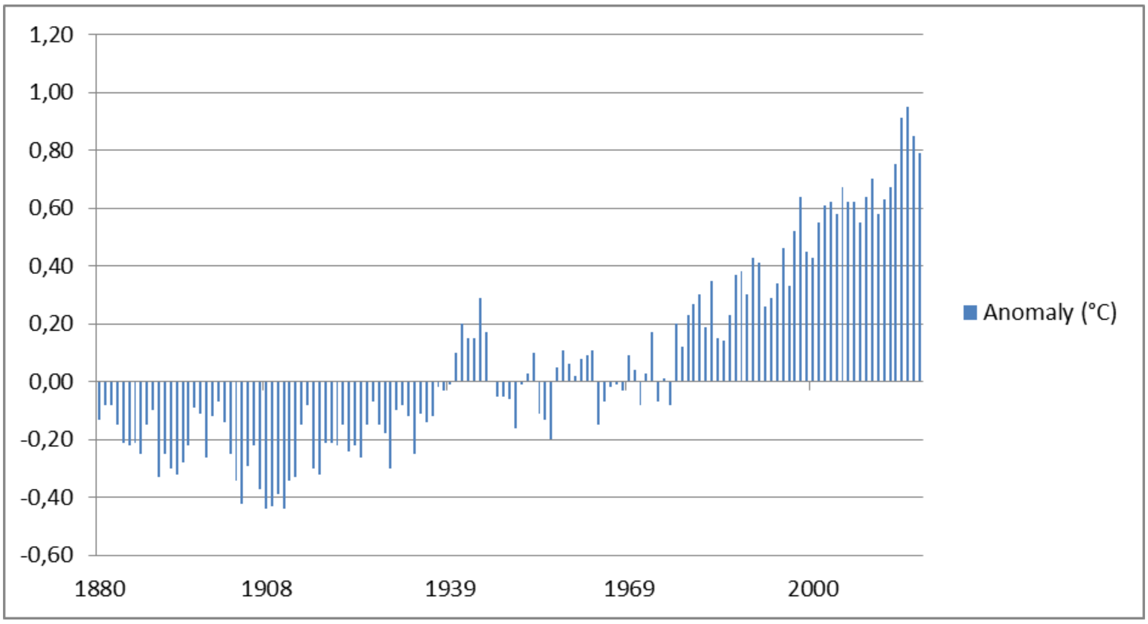


Figure 3. Global Land and Ocean Temperature Anomalies, January-December (1880-2018)

Source: NOAA (2018)

Considering the Arctic's 5.3-year and the Antarctic's 4.5 periodic variations, both reached their minima simultaneously in 2016, which resulted in the minimum in global sea-ice extent and the constant rise of the global see level (estimated between 1.5-3 mm/year depending on the data derived from tide gauges or satellite-derived records[7]) The USGCRP (2014, 2017) reports have several findings that showed man-made factors contributed to the extreme weather (European heatwave of 2003, record heat in Australia in 2013, etc.). The studies concluded that more than half of the global mean temperature increase since 1951 can be linked to human influence. Evidence also shows that even a small change in global temperatures has a significant impact: more powerful heatwaves for longer periods, more intense rain and heavier storms, disappearance of the coral reefs.

Renewables are a valid solution to decrease greenhouse gas emissions, as they represent a viable alternative to the use of polluting fossil fuels, especially coal (Viguier, 2004; Elzen et al., 2018). Therefore, RES investments of the past two decades triggered the energy transition from the fossil fueled based energy industry to a 'cleaner' stage'. While the rapid increase in energy consumption of the 20^{th}

[7] The satellite era started in 1979, from when a wide range of observations are available with nearly global coverage. Satellite and surface observation may be consistently drifting away from each other. For instance in the case of temperature data after 1979 for several years the satellite-based temperatures were often somewhat higher, since 2003 0.1 °C lower than the temperature estimates from the surface stations. (NOAA, 2018)

century relied on fossil energy resources, they cannot sustain further growth for several reasons. Fossil fuels are limited resources with acute negative environmental externalities; therefore, energy policy has become a major geo-political and social-economic concern. As developed countries are using relatively more energy, it also has to be recognized that these must take more responsibility for energy efficiency and mitigating greenhouse gas emissions (Chen et al, 2016).

Nowadays, a large emphasis is placed on stimulating the use of alternative sources of energy that can be sustained in the long run. Ensuring a higher environmental quality by promoting carbonless and/or low-polluting sources with clean energy solutions is necessary. Yet, support for energy policies depends on the customers' acceptance of the type of renewable energy included (Noblet et al., 2015). Since social acceptance is troubled by political, legal, institutional, and procedural frameworks, winning the participation of the stakeholders and communications towards the residents play a key role (Friedl and Reichl, 2016). Understanding stakeholder expectations regarding the RES development, identifying and taking into account their trade-offs[8] should be a priority for policy makers.

1.3 Changing landscape of the energy sector: challenges & opportunities

Every decade the energy industry faces changes: the end of 1990s and the early 2000s was about liberalization and restructuring initiatives (Fox-Penner, 1997). The market-centered ideas regarding deregulation and restructuring were developed originally with physical commodities rather than energy products (electricity, natural gas, etc.) in mind. However, new market designs may lead to suppress supply and price increase, especially if demand factors are also present (Taylor et al., 2015).

In the case of Hungary the restructuring of the 1990s in the energy industry meant privatization (Mihályi, 1999, 2010). The Hungarian Electricity Trust (currently

[8] Our definition: 'a trade-off refers to a situation when one criterion's value gain related to the phenomenon is results in a loss in other aspects (e.g., GHG reduction can be decreased at an increased cost).' Please refer Chapter 1.3.1 for a discussion on its relevant theoretical background.

MVM Group), the vertically integrated state holding was disintegrated in the middle of the 1990s and only some (generation) assets' shares remained within the holding.[9]

Once stable, almost static, energy markets have been changing rapidly since the 2000s due to several factors:

- Competitive energy markets became a standard by the 2010s due to the market liberalization finished in the US, UK, Germany than in the whole EU.[10]
- Energy prices have remained low in the past 5 years. Oil (figure 4) and natural gas were low-priced as shale gas production became economically feasible in the US.

Figure 4. Crude oil prices (WTI, 2012-2019; $/bbl)

Source: FRED, EIA

- The disaster of the Fukushima Daiichi nuclear power plant in Japan (2011) stopped the nuclear renaissance, which started around 2001. Current nuclear capacity developments are mainly initiated by China and India (IAEA, 2018). In the meantime, the transition from nuclear power to renewables is continuing in several countries (Dujardin et al., 2017).
- Maturing technology and government subsidies are promoting economies of scale in the case of RES assets resulting in rapidly shrinking installation costs.
- Therefore, swift expansion of basic forms of Distributed Generation (DG) – in particular photovoltaic deployment - is ongoing. DG in large scale may result in the end of the power sector as we presently know it, as everyone

[9] MVM ownership in the main Hungarian generation assets were at the time: Paks Nuclear Power Plant (99,95%), Vértes Power Plant (42,91%), Mátrai Power Plant (25,49%) and the Dunamenti Power Plant (25%).
[10] Opolska (2017) found that virtual trading point, market-based balancing, market opening, and privatization are the greatest instruments to boost competition.

could become a market player, both to be a producer and consumer at the same time.

- More rigorous emissions standards were introduced that caused traditional fuels to become more expensive (e.g., carbon-capture technology requirements in the case of coal based power generation).
- Technological innovations such as smart metering, the expansion of small-scale energy storage solutions and EVs allowed IT optimization to rise. Traditionally vertically integrated utilities only transacted with customers via meters for simplicity. Yet, as the level of complexity and the size of the data streams have been increasing, the application of the smart solutions to ensure real-time communication becomes dominant allowing better control over system operations (Johnstone et al., 2010)
- Energy supply security concerns in the EU promote the decrease in the high fossil fuel reliance (e.g., increasing liquefied natural gas (LNG) imports, even if more expensive than natural gas from Russia).
- New customer needs constantly arise: for instance the more frequent weather anomalies strengthen the need for additional grid solutions: real-time emergency generators and microgrids.

Without systemic interventions, these changes financially threaten the current utility business models (Castaneda et al., 2017), while technically during the transitional stages they may challenge the reliability of electrical systems and societal welfare. Overall, energy markets – especially the electricity market – have experienced vast changes, resulting in public utilities adjusting their business models and focusing on RES initiatives.

Practically, not only the energy policy forms the energy industry but the changing landscape shapes the energy policy as well.

1.4 Aim and scope of the dissertation

1.4.1 Conceptual model to assess the trade-offs of the Hungarian renewables market

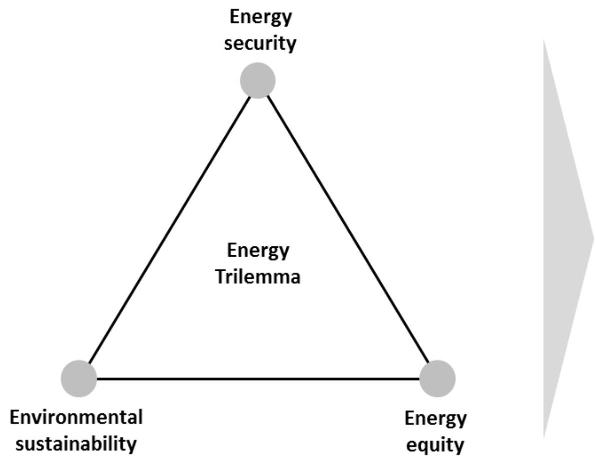
The European Union has promoted since the 1990s a non-discriminative, liberalized European single market. As new challenges (energy supply security, climate change, technology improvements, etc.) appeared, a comprehensive framework built up step-by-step, which incorporates the European Union (EU) 20-20-20 targets or the concept of the Energy Union[11] as well. The interdependencies of the industry require an integral view. A layered approach is applicable to better understand how higher-order changes affecting the supply chain (Osorio et al., 2017).

These changes can be described well through the analysis of trade-offs between competitive priorities, which is one of the core issues in supply chain management[12] (SCM) strategy research (Da Silveira and Slack, 2001; Da Silveira, 2004). WEC (2018) applies the 'Energy Trilemma' analysis[13] to assess the success of competitive priorities of the energy industry and the success of the balance between the three dimensions. Denmark, Switzerland and Sweden ranks at the top with well-balanced energy systems in these countries (figure 5).

[11] The Energy Union is the European Commission's strategy (launched in February 2015) for the integration of EU member states' energy markets to ensure secure, affordable and environmentally sustainable energy. Initiatives include a number of diverse measures: i) regulatory steps, i) market integration, iii) energy efficiency steps, iv) decarbonization and v) investment into research, innovation and competitiveness. Source: European Commission; <https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/building-energy-union>; Last accessed: 15-01-2019

[12] The definition of supply chain varies, for an excellent definition see Hopp (2011) who describes supply chain as a goal-oriented network of processes and stockpoints used to deliver goods and services to customers.

[13] WEC's 'Energy Trilemma Index' tool, ranks countries on their ability to provide sustainable energy through 3 dimensions: 1) energy security, 2) energy equity (accessibility and affordability) and 3) environmental sustainability. If a sustainable mix of policies is achieved then the balance score of the overall ranking highlights how well a country manages the trade-offs. (WEC, 2018)



Ranking	Country
1	Denmark
2	Switzerland
3	Sweden
4	Netherlands
5	United Kingdom
6	Slovenia
7	Germany
8	New Zealand
9	Norway
10	France

Figure 5. 'Energy Trilemma' for trade-offs and the top 10 countries by the Energy Trilemma Index

Source: WEC (2018), author's compilation

However, its acknowledged that maintaining a balance in the context of rapid transition to decentralized, decarbonized and digitalized energy systems is challenging as there are risks of passive trade-offs between equally critical priorities.

SCM in the energy sector was traditionally viewed as a set of trade-offs that had to be made. While in the case of heat generation and electricity large-scale inventories[14] were practically non-existent, (except for some hydropower capacity and pumped storage), and natural gas has some flexibility regarding the available storage capacities. Regardless, even in the case of natural gas the new network codes (NCs) support reduced inventories and improved system responsiveness (Van der Veen and Hakvoort, 2016).[15]

Wacker (2004) developed the theory for 'good' formal conceptual definitions: if 'good' measures of the formal theory are defined then the result is 'good' empirical theory-building. Schmenner and Swink (1998) proposed the basic theory of performance frontiers that is applicable to a broad range of operations management issues.[16] Compared to asset frontiers (structural), operating frontiers (infrastructural) of organizations are more important, since these are unique resources valuable, rare

[14] The lack of sufficient technology is a major limitation on the achievement of 100% renewable supply systems. Currently the most effective storage strategies involve biomass and pumped hydro storage (Trainer, 2017).
[15] These practices can be seen as similar in how manufacturers are applying setup time reduction, kanban, CONWIP (constant work in progress) systems and other supply chain management practices, which now has implications across the entire supply chain (Simchi-Levi et al., 2008).
[16] Schmenner et al. (2009) pointed out the pitfalls of theory application in the case of operation mangement issues.

and specific to a given firm. Since replication of these is difficult, they represent a competitive advantage (Vastag, 2000). In regulated industries such as network industries, these frontiers could be the decisive factors when selecting the preferred RES technologies. Moreover, the approach towards the development of capabilities defines the nature of the trade-offs change: for instance in certain cases trade-offs are possible to avoid, or even enhance another and become 'cumulative' (Ferdows and De Meyer, 1990). As renewable technologies are maturing, the relevant externalities and trade-offs are also receiving more attention. In the context of the Hungarian renewable energy market, we account the asset frontiers as natural constraints and operating frontiers as the current level of exploitation or usage.

We argue that long term supply chain optimization should start by understanding the relevant country-specific trade-offs. Finding the ideal energy mix of the country that should take into account the current performance frontiers (realities) of the Hungarian energy market:

- Hungarian power plant plants are aging rapidly, and its effects are already visible on the Hungarian power system's installed capacity (IC) and available capacity (AC) (figure 6). New investments are needed as the current generation mix will not be able to meet the consumption needs by 2020 (MAVIR, 2018). The largest coal-fired power plants are closed (Vértes PP) or their future is in question (Mátra PP). The development of additional nuclear capacity started (Paks 2 NPP) and one of the latest developments in the case of nuclear power plant licensing was the decision of the European Commission[17] regarding the Paks 2 nuclear power plant financing in Hungary.

[17] Press release of 6 March, 2017 (P/17/464), <http://europa.eu/rapid/press-release_IP-17-464_en.htm>; Last accessed: 15-01-2019

Figure 6. Gross capacity and annual peak load (2007-2017, MW)

Source: MAVIR (2018)

- Adopting a regulatory framework to support small, self-contained energy sources (distributed generation) located near the final point of energy consumption. Distributed generation (DG) sources consist of a wide range of technologies but we consider feasible Hungary solar PV, small-scale wind, geothermal solutions as the main forms but recognize the possibilities in certain instance in the combined heat & power (CHP) and others DG technologies as well (i.e., fuel cells).
- Procurement challenges and supply chain risk[18] regarding the fossil fuels are present in the CEE region. Countries with limited and decreasing production (such as Hungary's oil and natural gas production) are facing constant challenges to ensure a feasible contracting position. We expect that natural gas will remain important in the Hungarian energy mix due to high market penetration[19] and their role for providing flexibility to the grid (e.g., balancing intermittent RES generation, providing black start services). Fortunately, some positive changes have taken place since 2009[20] to

[18] The paper considers risk as the exposure to negative consequences of uncertain events.
[19] In 2017, 3.2 M households were connected to the natural gas network in Hungary. Source: <https://www.nemzetikozmuvek.hu/>, Last accessed: 15-01-2019
[20] In response to the Russian-Ukrainian natural gas crisis; on 16 July 2009, the European Commission (EC) adopted a new regulation to improve security of gas supplies in the framework of the internal gas market. Source: <http://ec.europa.eu/energy/gas_electricity/secure_supply/gas_en.htm>, Last accessed: 15-01-2019

address another Ukrainian crisis in the future. The infrastructure developments (new import pipelines, interconnectors and storage capacities) offer better economic environment for Central Europe and the Balkans, too. However, it is still true that certain restraints may be necessary in the European natural gas consumption if Russian supply will no longer be available.

1.4.2 Motivations of the research

Based on Babbie (2015) the research is exploratory as it explores a specific area of interest which was not presented previously, such as RES related trade-offs of the Hungarian energy market with the accompanying descriptive and explanatory research with sub-objectives. Maxwell (2005) defines research goals for intellectual, practical and personal purposes. Our motivations for the research are the following:

- The intellectual goal is to promote the importance of finding the proper balance when defining the Hungarian energy strategy. The Hungarian economic policy has several priorities such as utilizing EU subsidies, promoting renewable energy sources and sustaining energy supply security. While these are valid and adequate goals the challenge lies within balancing the different perspectives (especially when it comes to safeguarding the return on investment and long-term financing cost with low tariff rates for residents). Nonetheless, the effect of certain trade-offs are still not completely taken into account by the decision makers. The paper aims to support the decision making process by exploring the key issues.
- The practical goal of the dissertation is to develop a framework that integrates the diverse ideas for action to address the RES trade-offs and could be used as a control tool to support regulators and business development to ensure that all aspects are considered in their decisions.
- The author's personal goal is to continue as a researcher and practitioner to promote energy market development.

1.5 Structure of the dissertation

The dissertation comprises six chapters with an introduction and conclusion.

Chapter 1 serves as an introduction to draw up the topic, the key terms and the problem description. Within this chapter the underlined RES related issues give a preview on the topic and describe the context and the scope.

Chapter 2 establishes the theoretical background. As both renewables and trade-offs have extensive and complex literature, the focus of the chapter is on elaborating on those concepts that are utilized by the dissertation. First, the RES and the related energy supply chains are introduced with the characteristics of their products (energy commodities). Then the regulatory framework and the financial support schemes are described that influence the current RES expansion. At that point the chapter provides the fundamentals to the understanding of the RES relevant aspects of the energy market including the regulatory and financial considerations, which are necessary to identify applicable RES trade-offs in the Hungarian market.

Chapter 3 presents the practical research with the rich description and explanation of the concept mapping methodology. As the application of the concept mapping methodology is currently limited in the context of the Hungarian energy industry we go through the six concept mapping steps in great detail. The chapter shows the results regarding the first two research questions, as the RES-related trade-offs of the Hungarian energy market is identified and the strategic actions are suggested. The statements are mapped and categorized into clusters. Evaluation and the analysis of the results are given to establish the basis of the discussion of the findings. We conclude the chapter with some suggestions of utilization.

Chapter 4 builds on the results of Chapter 3 as it explores it from a supply chain management perspective (performance frontiers) in detail regarding the identified issues along the clusters (regulatory, supply chain management, social, etc.). Our main goal is to synthetize the major points as a point of reference to policy makers and as an input to consider for the updated Hungarian National Energy Strategy.

We emphasize that while the energy systems of the EU countries are developing under the same standards (network codes), the financial and political options should be carefully chosen to find the best fit for the Hungarian market. The chapter describes how the regulatory support scheme of Hungary determines the growth potential of the RES market. The chapter also deals with renewables affecting other segments of the energy industry such as the natural gas market and the district heating (DH) sector. At the end the chapter we highlight some special, RES relevant considerations for the planned Paks 2 project – if constructed – as it would affect the Hungarian electricity market with the same magnitude as renewables.

Chapter 5 offers a case study that has shaped the Hungarian energy market, which is the creation of a new, state-owned public utility and the increase of its state-owned assets. While Chapter 3 and 4 discuss the apparent RES-related trade-offs and suggested actions to address the challenges, Chapter 5 sheds light on the lessons learned from these strategic changes in the Hungarian energy market that will influence RES developments as well.

Chapter 6 serves as the conclusion, to summarize the main findings of the dissertation and to define possibilities for future research.

2. Renewables and their role in Hungary

2.1 Renewables

RES is a source of energy or power that has the capacity to replenish itself, providing a clean, 'green' energy. In the EU the following are considered to be the main renewable energy sources: biomass, biofuels, geothermal, hydropower, solar, tidal and wind power. In certain countries regulators consider other forms of power generation as RES, like fuel cells.[21]

While in the 1990s several barriers slowed the penetration of renewable energy (Painuly, 2001), nowadays the built in capacity of the renewables surpassed the coal-based generators and have become the largest source of global electricity capacity. The IEA (2018) estimates that the share of renewables in electricity will reach 28% by 2021; thus they will be responsible for 60% of the global power capacity growth over the next years.

While their share is relatively low currently, the main drivers of the RES increase in electricity production globally are the wind and solar PV. Many of the member states practically 'specialized' themselves in one or two renewable sources, according to local and national geographical conditions. For example Nordic and Alpine countries have focused more on hydropower, while countries with favorable geographical conditions (Denmark, Germany, etc.) have been relying on wind energy to meet their renewable targets. Other forms of RES (especially solar and geothermal resources) have gained popularity in the past years as well.

One of the main concerns that contributes to the increased use of renewable power generation is the widespread environmental disputes (such as global warming and CO_2 emissions) on traditional power generation. Renewables not only reduce CO_2 emissions but other pollution as well, which helps raise public acceptance (Bertsch et al., 2016). Since they utilize only local resources they reduce the independence from foreign (oil, natural gas, etc.) supply sources to support the energy security concerns, while also contributing to creating high-tech innovative jobs and manufacturing capabilities. Long-term RES are expected to be fully integrated and cost-efficient; however, they are still relatively expensive - at least for now – with large CAPEX

[21] The US states have similar practices as well, e.g., Connecticut Renewable Portfolio Standards (RPS): <http://www.ct.gov/pura/cwp/view.asp?a=3354&q=415186>; Last accessed: 15-01-2019

needs, less readily available, and without support schemes most RES forms are still not a viable competitor of non-renewable sources. Currently the most significant EU legislation from the renewables perspective is probably the 20-20-20 targets, which are part of a binding law for all member states to implement. These series of demanding climate and energy targets have to be met by 2020; therefore it requires extensive modeling to understand the impact of any proposed changes and the long-term results. To achieve these targets, the European Council has adopted differentiated mandatory national targets for each of the member states that further encourage member states to find and rely on mechanisms that can produce economically feasible and efficient investments in RES technologies within the liberalized EU single market.

2.2 RES affected energy industry value chains in Hungary

2.2.1 Value chain of electricity

A typical electricity value chain consists of generation, transmission, distribution and the customer itself.[22] The transmission network is operated by one transmission system operator (TSO), MAVIR, which is a state-owned entity[23]. The distribution system is operated by 6 DSOs (1 DSO is part of NKM[24], 2 of them are part of Innogy, while 3 of them part of E.ON).

According the KSH (2018) data the electricity network reaches all settlements of Hungary. The service providers reach 5.606 million customers of which 91% are residential customers. The number of customers has risen steadily: between 2016 and 2017, the number of total customers has increased by 0.5%, and the residential customers by 0.3%. Compared to 2000 the growth was 9.3% and 7.3% respectively. The increase in the number of household customers can be explained by i) the development of the new housing units, ii) the expansion of the electricity grid to the outskirts of the settlements and recreation areas and iii) the new industrial and service facilities.

[22] Microgrids are examples of a small-scale electricity value chains that lack, for instance, transmission network.
[23] MAVIR's major shareholder is MVM Zrt.
[24] former (EDF) DÉMÁSZ

However, the consumption per household consumer declined between 2009 and 2014 (attributed to the economic depression and energy efficiency initiatives), and started once again to grow from 2015 onwards (attributed to the economic upturn and electrification).[25] In 2017, the total amount of electricity supplied was 37,231 GWh, up by 3.3% compared to 2016. Households used 29% (10,972 GWh) of the supplied electricity.

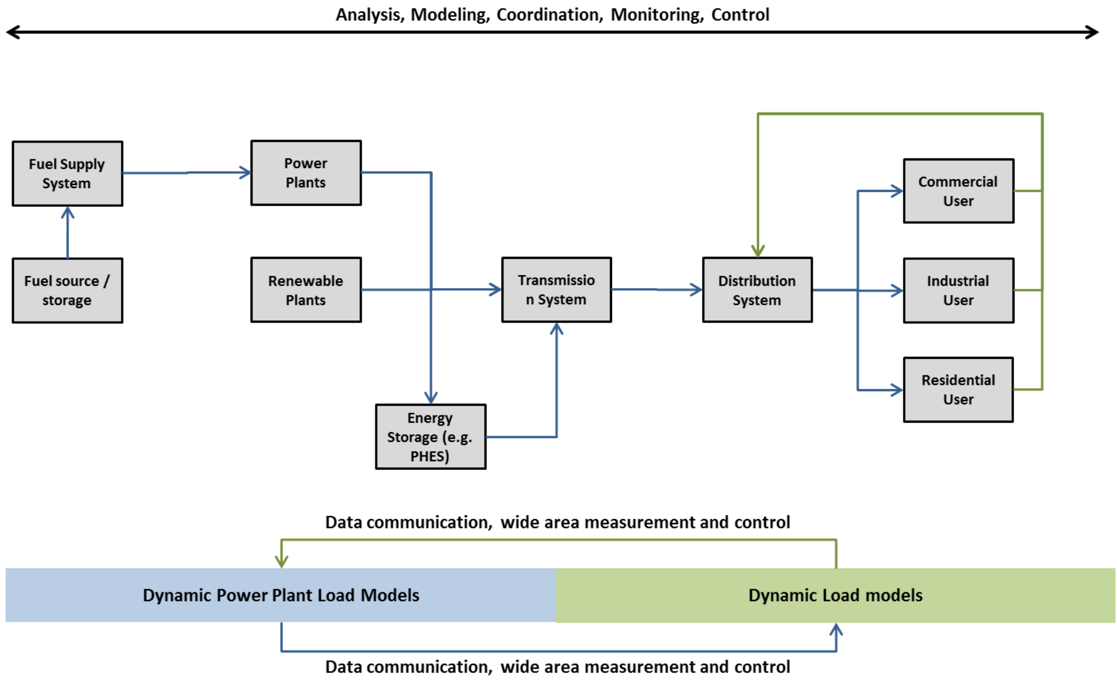


Figure 7. Electricity value chain

Source: MEKH, author's compilation

While the product quality is standard[26] with the liberalization, the physical and the financial aspects of the system have become separated (figure 7). Historically energy flowed in one direction from generators to customers. However, that changed with the expanse of distributed generators. Power flow and data communication is becoming two-way as the electricity system enables the information flow to integrate renewables properly. As the power grid is transforming from a linear value chain to the network of connections the need for complex IT solutions is constantly increasing. As the transition changed the structure of the economy, the Hungarian

[25] In 2017, the specific household electricity consumption was 2.1% higher than in the previous year.
[26] Since 1951, the Union for the Coordination of Production and Transmission of Electricity (UCPTE, later UCTE) had coordinated synchronous operations and specified the expected quality: e.g., 50 Hz UCTE frequency, etc. On 1 July 2009 all operational tasks of the UCTE were transferred to ENTSO-E. <https://www.entsoe.eu/news-events/former-associations/ucte/Pages/default.aspx>; Last accessed: 15-01-2019

electricity market took a new shape in 1995. Back then the majority of large power plants and the distribution system operators with the public utility suppliers were privatized.

To attract foreign investors, to prevent the further increase of generation capacity gaps and to fasten the privatization process, from the middle of the 1990s until 2008, the Hungarian electricity industry has been built around the practice of long-term (typically 15-20 years long) power purchase agreements (PPAs). After the long-term PPA termination domestic power plants continued to sell the majority of their electricity through MVM, which has framework contracts to the universal service providers, bilateral contracts and public capacity auctions were also carried out.

Once again the sector is undergoing major changes, as the ownership structure of the electricity supply chain is altering. Two major forces are the

1) restructuring initiatives of the large incumbents in Europe (Hungarian electricity market was affected by the E.ON-RWE/Innogy[27] acquisitions, French EDF focuses on more profitable markets rather than the CEE region) and the
2) the Hungarian government’s financial and regulatory support to increase ‘domestic’ ownership via acquisitions by:
    a. the ‘national champion’ MVM-NKM (e.g., re-entering the DSO segment with the acquisition of EDF DÉMÁSZ in 2017)
    b. ‘domestic’ private investors (e.g., a majority share acquisition of the Dunamenti Power Plant by MET Power AG in 2014 or the majority share acquisition of Mátra Power Plant by the Opus Group in 2018).

2.2.2 Value chain of natural gas

The structure of the natural gas (NG) in the industry (figure 8) is changing, as in many countries the unconventional sources of natural gas (tight gas, shale gas, coalbed methane shale gas) production has become a feasible option. The Hungarian

[27] Innogy was created as a renewable energy utility on 1 April 2016, by splitting the renewable, network and retail businesses of RWE into a separate entity. In March 2018, the announcement was made that E.ON will acquire Innogy through a complex €43 billion asset swap deal between E.ON, Innogy and RWE. <https://www.eon.com/en/about-us/media/press-release/2018/eon-launches-takeover-offer-for-shares-in-innogy-se.html>; Last accessed: 15-01-2019

domestic production is decreasing, where the MOL Group is the major actor. There are two natural gas TSOs in Hungary: the NG transmission grid is operated predominantly by FGSZ Zrt. (part of the MOL Group) and the HU-SK interconnector is operated by MGT Zrt. The distribution system is operated by 5 large DSOs (2 DSOs are part of NKM[28], 2 of them are part of E.ON, while 1 of them is part of the MET Group) and several smaller ones (e.g., MAGÁZ Zrt.). A major difference between electricity and natural gas is that NG is storable in significant quantities and Hungary has two storage companies: MFGT (with 4 storage facilities) and MMBF (with one facility mostly dedicated to store the national strategic reserve).

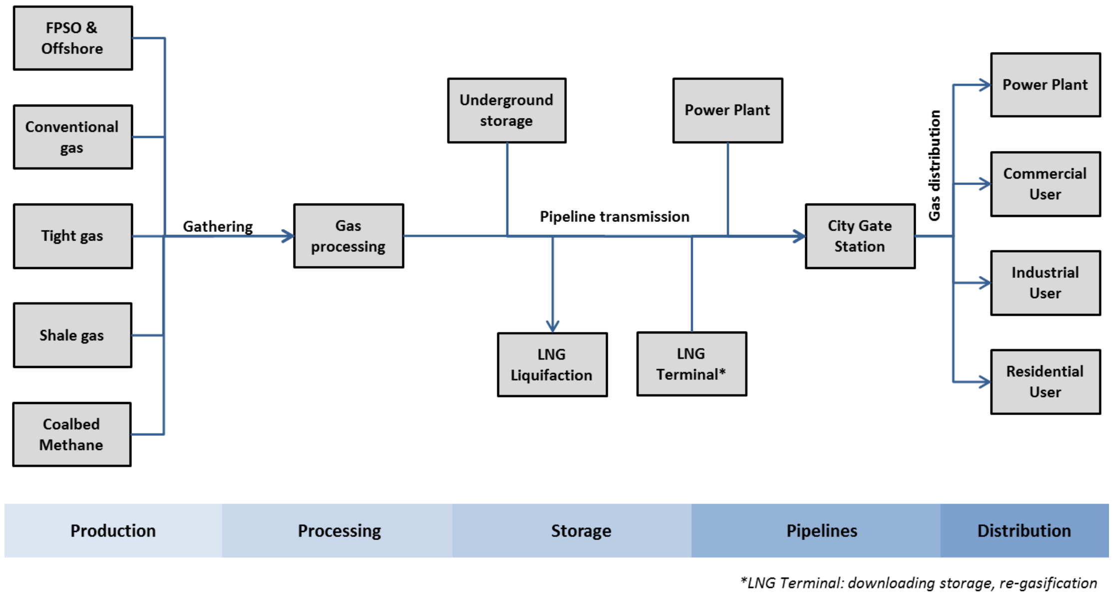


Figure 8. Natural gas value chain

Source: MEKH, author's compilation

According to the KSH (2018) data 2877 Hungarian settlements (~91%) and 73% of all residential households had access to the natural gas distribution network in 2017. The reason for the high household NG penetration has it roots in the former Soviet Union's policy, which was built on its rich resources (including oil and natural gas), as a way to maintain its influence in the CEE region. At the beginning of the 2000s (particularly between 2000 and 2005) the distribution network penetration increased once more from 80% to 91% and has not changed significantly since then. In 2017, 3.469 million customers are connected to the natural gas distribution network and

[28] former (EDF) DÉMÁSZ

88% were households, which are all served by NKM Földgázszolgáltató Zrt., the only remaining NG universal service provider (USP).[29] Nevertheless, only 41% of the consumption is attributed to the residential sector, which was 3.7 billion cubic meters (bcm) in 2017. While that is a 19% increase compared to 2016, there is no clear indication that consumption will increase further or the trend of 2005-2012 would be repeated when the household NG consumption steadily decreased.[30]

There are differences between natural gas pricing logic and the making of the electricity rate. There is only one quality (type) of natural gas defined: 'pipeline quality' and this is determined by the applicable regulation of the given country. Nevertheless, for rate making purposes natural gas service has different classes (Studebaker, 2005, Fazekas, 2014):

- Firm Service
- Interruptible Service
- Flex or Adjustable Rate Service
- Firm Transportation Service of Customer Natural Gas
- Interruptible Transportation Service of Customer Natural Gas
- Local Distribution Company (LDC) Agent Service (commodity purchase by customer) through an LDC affiliated agent (marketing) service

While in the end all types of services provide the same quality of natural gas, costs vary greatly depending on the delivery categories as they represent different quality in shipping construction.

2.2.3 Value chain of district heating

District heating penetration is relatively high in Hungary as according to the KSH (2018) data approximately 650,000[31] housing units (15% of the total housing units) depend on DH service and in most cases these units have no alternate heating solution (except small scale electrical heating). DH service in most cases includes a hot water supply that is available in 89 settlements in 600,000 homes. In 2017 DH

[29] Compatitors left the market due to supply problems (EMFESZ) or after the government lowered the regulated universal service prices in 3 rounds (other USPs, Magyar Telekom). For more details see Chapter 5.

[30] Residential natural gas consumption is mainly influenced by weather conditions but the financial situation and energy-consciousness (e.g., energy efficiency initiatives such as thermal insulation of buildings) also have significant effects.

[31] Data: KSH, <http://www.ksh.hu/thm/1/indi1_4_3.html> Last accessed 15th January 2019

companies delivered 26 PJs of heat of which 72% is used by households. The amount of hot water supplied was 20 million cubic meters (95% of which was used by the public). Household consumption has fallen since 2007 by 21% for domestic hot water and by 16%, for district heating. Besides the modernization of residential buildings (e.g., external thermal insulation, installing controllable heating devices in the older buildings), additional generation options are available for apartments (e.g., solar panels). The reduction in district heating consumption over a longer period of time is due to the modernization of residential buildings with this heating mode (door-to-door replacement, external thermal insulation, modernization of the heating system and making the heating controllable). Regardless, DH has a solid business model, as there are currently no realistic options (at least not without extreme additional costs) for most apartments to chose/switch heating solutions as these apartments were originally designed for district heating.

Most housing units with DH are located in Budapest of which the apartments rely on that service. District heating requires economies of scale; therefore, the largest number and proportion (figure 9) of residential customers connected to the district heating system are in the most populous cities (Szeged, Debrecen, Miskolc, Győr, etc.).

Figure 9. The proportion of residential homes connected to the district heating system in affected settlements (2017)

Source: KSH (2018)

DH penetration has stagnated since 1989 as large state-managed housing construction projects stopped. Yet, in the recent years in several cities several private general construction companies have recognized and chosen DH as a feasible alternate for large privately-funded housing and office building projects. With EU funds, several DH network improvement projects have started. In Budapest the construction of the DH 'ring road' is currently ongoing. The DH service provider of the capital (FŐTÁV) is expecting thousands of new customers after completion. Besides connecting the thermal 'islands' of the capital, the inner parts of the city will be accessible for DH. If the regulator is committed to a chimney-free city center or smog free Budapest it may mandate all public institutions, office buildings and then apartment buildings to join the established single network. Partly due to these infrastructure developments the decreasing trend of DH usage for heating stopped and between 2014 and 2017 household consumption increased by 19%.

When we examine the DH value chain (figure 10) several connections to both renewable energy sources and natural gas should be identified. In the case of the Hungarian district heating market waste, biomass and geothermal energy are considered appropriate RES.

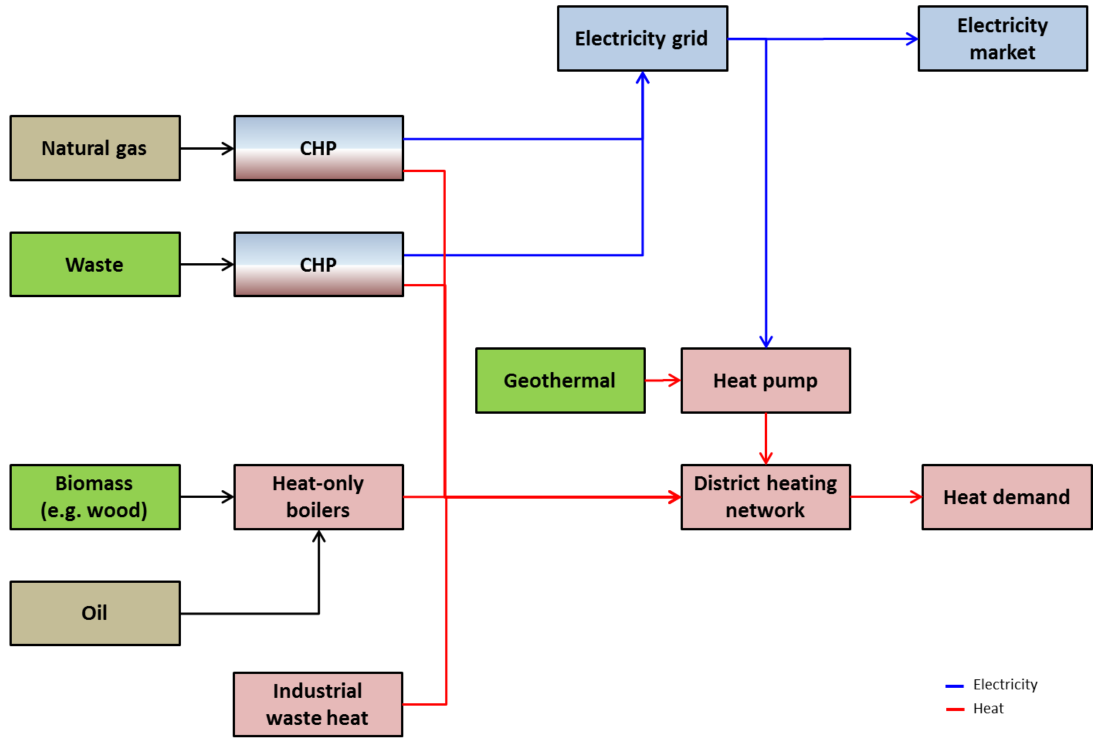


Figure 10. District heating value chain

Source: MATÁSZSZ, author's compilation

Many of the DH generators and DH service providers are owned by the municipalities or private investors. However, the state-owned NKM acquired some assets (e.g., in the town of Kecskemét and Oroszlány) and further expansion is planned.

Overall, when assessing RES challenges, district heating trends should be included. If centralized heat supply structure is continued to be promoted, then with that intention and available resources, DH could speed up the switch to renewable energy sources - biogas, biomass, geothermal and solar energy (Wissner, 2014). For instance certain technologies – such as geothermal energy, mostly heat pumps (Somogyi et al., 2017) – are currently only competitive in the heat segment. Consequently, several cities are utilizing RES in DH (waste-based generation in Budapest, geothermal generation in Miskolc, etc.).

2.3 Special commodities: electricity, natural gas and heat

The reason for the energy industry uniqueness, besides the economic significance, relies within the distinctive physical characteristics (figure 11) that make energy products special commodities (Mileaf, 1977; Newendorp and Schuyler, 2015).

While having similar obligations electricity and natural gas utilities have different characteristics than other public service providers like water supply and district heating companies. While district heating and water supply also have network characteristics, they are limited locally (or at best regionally) with different size, production cost, different opportunities to exploit the economies of scale, and different service obligations (e.g., some district heating companies are obliged to provide heat water).

	Electricity	**Natural gas**	**Heat**
Storage	Non-storable in large quantities (except pumped-storages)	Storable	Non-storable in large quantities
Balancing	Generation and consumption should be in balance all the time (daily and seasonal demand patterns)	Production and consumption should be in balance all the time (daily and seasonal demand patterns)	Generation and consumption should be in balance all the time (daily and seasonal demand patterns)
Role of long-term contracts	Classic long-term PPAs were used in special	Long-term supply contracts are still in	Due to the limited transportability of the

	cases	place although their role has been decreased	commodity, long term arrangements are common between suppliers and operators
Cross border capacities	Well-developed	Well-developed: if the distance between production and consumption is under 2000 km of pipelines, if over that then LNG has the price advantage	Not applicable: local systems with limited distribution network (due to heat loss)
Stage of liberalization	Regional markets	Regional markets	Local market
Elasticity	The product itself is inelastic, the means of production may be changed in the short term	Fuel switch may be possible in certain instances but short term options are limited	Not replaceable in the short term, with additional CAPEX the detachment is possible relatively fast

Figure 11: Comparison of electricity, natural gas and heat

Source: Mileaf (1977), author's compilation

Electricity and natural gas have several characteristics in common; however, understanding why electricity is a special commodity is instrumental for the analysis:

1. Electricity is a set of physical phenomena associated with the presence and flow of electric charge. Power flows according to physical laws and not “touchable”; therefore it can be measured only in meters.
2. Electricity currently non-storable in large quantities (with some exceptions, such as pumped-storage where favorable economic conditions exist). Therefore the generation and the consumption should be in balance all the time (daily and seasonal demand patterns), which differs from natural gas, where storage is an available option for handling short term supply disruption. However, that could change on the longer term with the rising number of battery stations as storage of electricity and with the increasing use of EV’s batteries as storage capacities (e.g., charging EVs in off-peak hours).
3. Due to the lack of storage, the power purchase agreements need to have clauses that are unusual in the case of other commodities. The transfer of good between the generators to the end-customers in the given time requires comprehensive regulatory, engineering and economic background.

4. The network infrastructures are considered to be a natural monopoly. The physical attributes of electricity requires a grid network for transmission and distribution (grid-bound commodity) between generators and customers. Economies of scale apply both in generation and transmission. While the cost of the network is relative smaller than the generation cost, still, the amount is significantly high enough to prevent the establishment of concurrent lines.
5. After the liberalization the physical and the financial deliveries became separated. Uniform power prices do not exist due to the grids limited technical and geographic capabilities. While in the case of the natural gas, transportation between far geographic locations is possible (e.g., LNG), in the case of electricity the constraints only allow to develop regional markets. The price level is determined basically across four parameters[32] (Mazur and Metcalfe, 2012):
    a. accessible local primer energy resources,
    b. the energy mix (power generation portfolio),
    c. available interconnectors between networks and countries (since surplus energy can be sold and energy imports become an option),
    d. regulatory framework of the given regional/local market.
6. Finally, the inelasticity of the commodity should be emphasized.
    a. Electricity is a mean of sustenance, therefore cannot be substituted with another product in the short term. Any change requires the transformation of the consumption structure, which requires significant time and in many cases large investments (see energy efficiency initiatives to reduce power usage). Therefore the bargaining power of the small end-customers (especially households) is very limited and many cases exposed to the service provider.
    b. Besides the customers, other stakeholders of the electricity value chain face inelasticity: traditionally developments have extensive

[32] At present, regulators consider that tje efficiency and reliability are not linear functions of the grid size anymore (Mazur and Metcalfe, 2012) and the design of ancillary service markets will become more sophisticated (Rebours et al., 2007).

resources (capital, time, etc.), needs (high fix cost ratio) and long returns.

Power generation and wholesale activities are unregulated in the EU; however transmission and distribution remains a natural monopoly, similar to other network industries. Additionally these also mean that the interest of the investors and the customers may differ regarding the types of generation and primer energy sources. For example in a turbulent environment investors are minimizing risk by aiming for investments with low fixed cost with fast or high guaranteed returns, while from the customer perspective the minimization of the combined cost of capital and operation is preferred.

2.4 Regulatory background[33]

Electricity and gas markets are regulated under the European Community Law (figure 12), which has special characteristics (Cameron and Heffron, 2016).

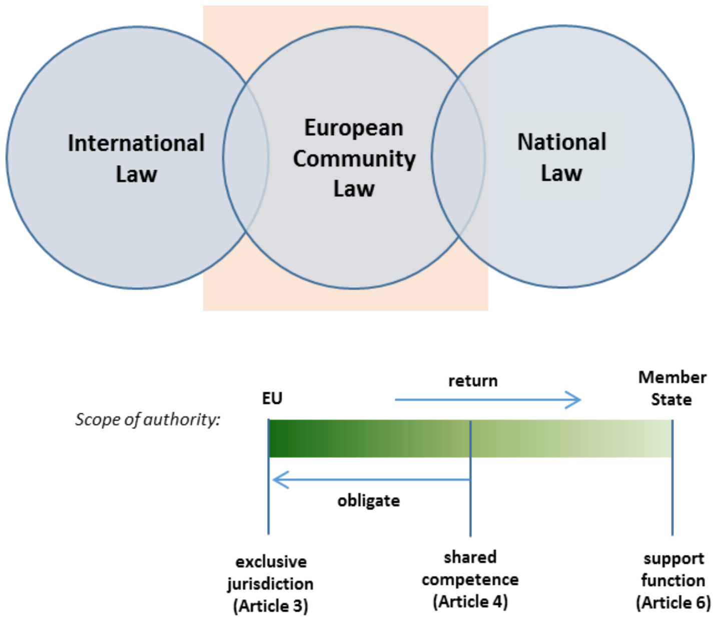


Figure 12. The nature of the EU Law

Source: EUR-lex[34], author's compilation

[33] This chapter based on Herczeg (2015:6-9)

[34] For more information see: Consolidated version of the Treaty on the Functioning of the European Union, <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:12012E/TXT>; Last accessed: 15-01-2019

The European Union issued several directives[35] since the early 1990s with the objective to ensure an electricity (and natural gas) market reform to divide the monopolistic, regulated and competitive parts within the power and natural gas supply chain with deregulation.

- **Transparency Directive - 90/377/EEC (Directive 2008/92/EC)[36]** - aimed to improve the churn rate within the industrial market segment and established the regulatory framework to the Eurostat in which the goal was to improve the transparency of gas and electricity prices.
- **Transit Directive - 90/547/EEC (natural gas: 91/296/EEC)** - aimed to improve the transportation via the high voltage transmission lines (non-discriminatory, fair terms)
- **First Liberalization package – among others Directive 96/92/EC (natural gas: 98/30/EC) -** created a framework for a step-by-step market opening by customer entitling, by addressing the differences in the national legislations and by creating a single European energy legislation framework. Accounting unbundling became a requirement to keep separate accounts for transmission system operator (TSO) and distribution system operator (DSO) activities. The Directives determined the basic principles for the infrastructure access regime: the option to choose between negotiated Third Party Access (nTPA) and regulated TPA (rTPA) was offered. The liberalization package allowed for the single-buyer model. In the case of electricity it was in effect between February 10, 1997 and July 1, 2004 (in the case of natural gas between 10 August, 1998 and July 1, 2004).
- **Second Liberalization package - among others Directive 2003/54/EC (natural gas: 2003/55/EC)** - is also known as the 'Acceleration Directive' since it boosted liberalization by opening up the energy markets for all customers in three steps (in the last stage for households as well, from July 1, 2007) and targeted to achieve an increased level of market integration by recognizing the need to protect vulnerable customers. Functional (independence within the vertically integrated undertaking) and legal

[35] The European Commission prepares the text of a draft directive (since contentious matters usually are subject to the co-decision process) after consultation with its own and national experts. The draft is presented to the European Parliament and the Council (composed of relevant ministers of member governments), initially for evaluation and comment, then subsequently for approval or rejection.
[36] For the specific directives see the References.

unbundling (from other activities not related to transmission and respectively distribution) was introduced for TSOs and DSOs. Also, with the exception of the new infrastructure developments, these companies needed to implement exclusively rTPA regulation (natural gas storage companies could still apply nTPA). The competences of the member states' national energy regulatory authorities were strengthened (e.g., methodology for setting the network tariffs).

- **Third Energy package - among others Directive 2009/72/EC (natural gas: 2009/73/EC) -** was based on the Green Paper of 2006[37] and the comprehensive network industry analysis of 2007[38], which identified that incumbents still had very significant market power due to several reasons. Inefficient implementation of the unbundling principles, the lack of transparency and cross-border capacities, the differing jurisdiction of the national regulatory authorities and the distorting effect of the regulated retail prices were all recognized. After the 2006 Ukrainian-Russian natural gas dispute supply security was in the spotlight once again. Finally, sustainability became a priority. Therefore – among others - the following main changes were introduced:
    - More strict unbundling models with ownership unbundling as a general rule; however in the case of existing transmission operators the ITO/ISO model can be accepted with certain criteria:
        - Independent Transmission System Operator (ITO)
        - Independent System Operator (ISO)
        - Ownership Unbundling (OUSO)
    - Company management guidelines (e.g., conflict of interest, compliance programs)
    - 'Gazprom clause'
    - Enhanced consumer protection
    - Energy efficiency initiatives (e.g., smart metering)

[37] For the Green Papers of the European Commission see <http://ec.europa.eu/green-papers/index_en.htm>; Last accessed: 15-01-2019

[38] For the economic studies on the Single Market see <http://ec.europa.eu/dgs/internal_market/studies/economic-reports_en.htm>; Last accessed: 15-01-2019

    - Strengthening the independence and jurisdiction of the national energy regulatory authorities
    - New organization to coordinate the cooperation between the member states (ACER, ENTSO-E, ENTSO-G)
    - Mandatory 10 year network development plans
    - Regional solidarity mechanism in the case of emergency situations (e.g., natural gas import disruptions)
- **Climate and energy package - among others Directive 2009/29/EC -** addresses climate change (especially CO_2-emission reduction), energy efficiency and renewables. "20-20-20" targets set three key objectives for 2020:
    - a 20% reduction in EU greenhouse gas emissions from 1990 levels
    - raising the share of EU energy consumption produced from renewable resources to 20%
    - a 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency

While all the above EU energy legislation affects the major trends of RES developments and energy supply security[39], the EU has ambitious plans to promote electricity generation from renewable sources (RES) in order to change the European power generation landscape completely. The EU's drastic goals towards renewables burst into the status of the domestic regulation, producing its own – yet unanswered – questions. National regulation and incentives for the electricity generated from RES, though being bounded by the EU expectations and energy policies, produced a number of side effects (trade-offs) and an apparent regulatory deficit as well.

2.5 Support schemes

Support schemes are essential in the case of the renewables, as many of the RES technologies still have a cost disadvantage in comparison to the traditional form of

[39] EU legislation closely follows geopolitical changes to ensure a stable and abundant energy supply by strengthening EU countries' emergency/solidarity mechanisms. For a recent example regarding the 2014 Ukrainian-Russian crisis see <http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1426699551441&uri=URISERV:180101_3>; Last accessed: 15-01-2019

power generation such as natural gas, coal, lignite or even nuclear power. Although pricing for renewable-based or green power remains at a premium, the idea is that as more and more renewable energy applications are invoked, the costs of such technology will go down, while the costs of such traditional resources as coal, oil, and natural gas are expected to continue to climb. The governments throughout Europe, and as well in other parts of the world, embraced that idea and recognized the premium financial need of renewables, and developed support mechanism that compensate these additional costs. Therefore the current governmental support schemes for renewables have a long history. The basis of the current systems can be traced back to the late 1980s and the early 1990s, when most of the EU member states introduced their solutions, starting with Portugal, the Netherlands, Great Britain and Germany (Ringel, 2003, 2006; Woodman and Mitchell, 2011).

Despite that the main goal is the same, regulators in the different countries preferred alternative ways to achieve a larger share of electricity generation from renewable sources. The EU member states are promoting renewables in two common ways: production incentives or investment subsidies (Fazekas, 2011). During the past two decades the following schemes have gained popularity[40]:

1. investment subsidies (for example, equity grants and/or tax exemptions by governmental participation)
2. operating subsidies
    a. guaranteed tariff system (feed-in tariff schemes)
    b. schemes based on a premium system (tenders).
    c. schemes that based on quota obligation (green certificates).

The ***feed-in tariff (FIT)*** guarantees a fix price per kWh of electricity fed into the grid for a given span of years (priority dispatch), with possible tariff degression. The legislator obliges regional or national transmission system operators (TSO) and/or the distribution system operators (DSO) to allow for the full production of green electricity at fixed prices differing according to the various generation sources (wind, hydro, etc.). Then, the TSO/DSO passes on the higher costs for the green electricity to the final consumers in the rates. Although the fundamental principles are the

[40] For a discussion on the green certificate potential of the Hungarian energy market see Herczeg (2012)

same, the feed-in tariff system may vary greatly[41], as they can support additional goals as well, such as to meet certain energy efficiency goals. The most sophisticated feed-in tariff schemes are implemented in Germany, France and Austria. The tariffs are set either as fixed tariffs (above market price) or as bonus tariffs adding to the given actual market price. The goal is to cover the cost disadvantage of the renewable energy sources. Moreover, they could be calculated to grant an investment bonus to the RES producer, too. Indeed, feed-in tariffs – especially if fixed and appropriately high – are boosting the use of renewable energy sources very quickly as they provide the highest degree of predictability for investors.

The ***tender system*** is a volume-driven operating grant providing a premium for potential investors, who apply for new renewable capacities through call for proposals or an open call for tenders. The limit is the available total capacity, which is fulfilled with the bids of the lowest bidders. In general, investors apply for the feed-in price (regulated market) or additional subsidies over market price (liberalized market), which is calculated either as ’pay as you bid’ or the ’strike price’ basis.

Green certificates are part of the quota obligation support scheme. This system is similar to the premium system that price consists of market price; however, the amount of the needed support is determined by market mechanisms. Based on the goals set by the regulator consumers, suppliers or generators have to source some percentage of their electricity from renewable sources. The system is usually based on Tradable Green Certificates (TGCs) or Green Tags. This system has gained significant popularity in the EU during the past decade (e.g., UK, Romania) and widely used in the USA as well, where TGCs are called Renewable Energy Credits (RECs). RECs are non-tangible energy commodities that represent proof that 1 megawatt-hour (MWh) of electricity was generated from an eligible renewable energy resource (renewable electricity). The eligible source defined on a state-by-state basis (for example, fuel cells are an eligible renewable source only in some cases) and the emphasis can be shifted between the sources in terms of the local needs (for example, Solar Renewable Energy Certificates - SRECs). Compliance markets can build up on a mandatory and on a voluntary basis. Voluntary markets

[41] Couture-Gagnon (2010) distinguishes two major FIT schemes: 1) fixed feed-in tariff system and 2) feed-in premium system when the remuneration remains independent from the electricity price. The paper overviews 7 different ways that categorized within the two categories, based on how tariffs are adjusted during the guaranteed purchase period.

exist mainly in US states; however, a special form of voluntary markets can be found in other countries to provide customers the choice to buy renewable power out of a desire to support renewables.

Investment into RES may be profitable without any regulatory remuneration mechanisms; however, cost degression and the development of the merit-order-effect are expected. Zipp (2017) assessed the marketability of variable renewable electricity generation and the results showed a systematic declining trend regarding the average market revenues for wind and PV plants in the period from 2011 to 2016.

In an ideal case, all these support schemes can achieve an optimal distribution of the financial resources. However, as only partial information is available to the regulator many countries are relying on a blend of the support mechanisms (hybrid models). Hungary traditionally relied on FIT, investment grants and investment tax credits.

2.6 Renewables in Hungary

2.6.1 KÁP

EU expectations towards its member states and applicants of the early 2000s were based on two directives:

- **2001/177/EC Directive (Renewable Energy Directive, RED) (currently 2009/28/EC Directive):** incorporates the national targets for renewables and determines support schemes within the EU state aid rules, while provides a guarantee of origin.
- **2004/8/EC Directive (Energy Efficiency Directive, EED) (currently 2012/27/EC Directive):** makes uniform the energy efficiency reference value, provides a guarantee of origin, and guidelines regarding cogeneration.

In Hungary, the first step in setting up the Hungarian renewable support scheme started with the Electricity Act of 2001[42] and the related implementing regulation.[43] The first FIT tariff system was introduced in 2003 and called '**KÁP**'. This FIT system was operating between 2003 and 2007 and universal service providers and

[42] Hungarian Electricity Act of 2011 CX. *('villamos energiáról szóló 2011. évi CX. törvény – régi Vet.')*
[43] GKM Decree 56/2002 *('Az átvételi kötelezettség alá eső villamos energia átvételének szabályairól és árainak megállapításáról szóló 56/2002 GKM rendelet')*

the respective DSOs were obliged to take over and compensate the electricity produced from renewable energy sources. The difference of the wholesale and the takeover price is compensated by the Hungarian State through the KÁP-fee element of the transmission system tariff.

With the EU mandated liberalization of the electricity and natural gas markets it became necessary to implement the relevant EU legislation into the Hungarian legal system. That resulted in significant changes of the KÁP system as well.

2.6.2 KÁT

The new Electricity Act adopted in 2007 (Vet.)[44] and the related government decree (Vhr.)[45] changed the Hungarian subsidy framework of RES (KÁT), in accordance with the EU, to overcome the competitive disadvantage of electricity produced from RES and waste. Under the KÁT system the takeover parameters - purchase price, quantity and duration of the takeover - were determined by the Hungarian Energy Office (MEH) and since 2013 by its successor (the Hungarian Energy and Public Utility Regulatory Office, MEKH). The authority has taken into account the capacity of the network users' load needs, the expected efficiency gains from the development of the technologies and the technologies' impact on the operation of the electricity network. The basis of the mandatory takeover system was provided by the 'KÁT balance group', which was operated by MAVIR Hungarian Electricity Transmission System Operator Ltd. (MAVIR). MAVIR's responsibility has been the coordination of the KÁT system: taking over from generators (sellers), and sold and accounted them to the commercial licensees. If a seller wanted to take advantage on the KÁT support scheme, it was obliged to join the KÁT balance group.

On the basis of the previously submitted production schedule, the responsible operator of the KÁT balance group has taken over the produced energy with the determined FiT tariff (market price plus the KÁT subsidy). The responsible KÁT operator then resold this electricity to those commercial licensees (electricity suppliers), which were the subject of the KÁT takeover, in proportion to their

[44] Electricity Act of 2007 LXXXVI. (A villamos energiáról szóló 2007. évi LXXXVI. törvény)
[45] 273/2007. (X. 19.) Government decree (*'Korm. rendelet', 'Vhr.'*)

respective consumption that was not eligible for 'universal service'[46]. Following the end of the KÁT subsidy period or reaching the quantitative limit (quota), the producer had the opportunity to sell the energy produced according to the general market rules.

The duration of the KÁT grant was determined for new investments and green-field investments (e.g., no second-hand machinery) and it typically ranged between 5 to 25 years[47]. In all other cases, MEKH defined the KÁT eligibility period individually. However, some barriers existed as MAVIR had a system barrier of 330 MW installed capacity established (less than 5% of total installed capacity in the country). Since the feed-in tariffs for wind were high at the time, investors quickly filled the available capacities.

According to the MEKH data, the number of KÁT producers in the first years of the program was approximately 250 but their numbers increased to 350 by 2010. As the majority of these producers were CHP plants (district heating generators), the number of KÁT members decreased to 130 in 2011: i) on 1 January 2011 the requirements for co-generation were changed and ii) the co-generators were

Type of RES	Current installed capacity (2017) (MW)	Prospective installed capacity (2020, MW)
Biogas	40	29
Biomass	315	181
Landfill gas	16	7
Waste	9	7
Solar	41	2150
Wind	315	164
Water	56	56

Figure 13. Prospective RES installed capacity (2017-2020) (MW)

Source: MEKH, author's edit

[46] Universal service tariffs are regulated by MEKH. Universal service is available to small businesses and residential customers.

[47] KÁT entitlement maximums were 5 years for waste-based gas motors, 15 years for biogas with an installed capacity of less than 5MW, 20 years for biomass power plants with an installed capacity of less than 20MW and 25 years for PV plants with less than 2 MW installed capacity. Source: MEKH data <http://www.mekh.hu/>, Last accessed: 15-01-2019

excluded from the KÁT balance group[48]. The number of applications for KÁT licenses rose steeply in 2016 just before the KÁT program was shut down for new entrants (figure 13).[49]

Moreover, in 2016[50] the government practically banned wind developments as no wind turbines were allowed i) within 40 km of a military radar and ii) within 12 km of a built-in area and this includes areas that will be built[51]. While its only theoretical (since they cannot be installed anyway) the regulation limited technology with an installed capacity maximum of 2 MW and a maximum height of 100 meters. These values represent outdated technology (by 5-10 years) and well-below the new wind parks parameters. Actually, these parameters are dwarfed by GE's current prototype development: Haliade-X, which are planned to be manufactured from 2021 with an installed capacity of 12 MW, height of 260 m, and the wind blades itself would be 107m.[52]

2.6.3 METÁR

The operation of KÁT received several criticisms (especially for the over-bureaucratic elements[53]). Additionally, in the summer of 2014, the European Union published a new guideline[54] on the promotion of renewable energy production. The guideline has set several new standards for the member state support schemes from 2016 onwards. From 2017, state aid can only be granted with a clear, transparent and non-discriminatory system of conditions following a competitive bidding procedure. The exceptions are the cases in which i) this procedure would support only one or a limited number of power plants, or ii) the rate of project implementation would decrease to a very low level, or ii) the procedure would increase the level of required

[48] Act of 2011 XXIX. ('*2011. évi XXIX. törvény*')

[49] MEKH received 2428 license applications. Source: <http://enhat.mekh.hu/index.php/2017/06/26/ket-es-felszeresere-novekedhet-a-megujulo-alapu-villamosenergia-termeles/>, Last accessed: 15-01-2019

[50] With the revision of the 253/1997. (XII.20.) Government decree ('*Korm. rendelet'*)

[51] For the relevant map see figure 52 in the Appendix.

[52] Source: GE, <https://www.ge.com/renewableenergy/wind-energy/turbines/haliade-x-offshore-turbine>, Last accessed: 15-01-2019

[53] The administrative impositions (such as the obligation to deliver a production schedule) required for the use of aid have prompted many producers to produce electricity without taking advantage of the subsidies.

[54] 2014/C 200/01 EC Guideline

state aid. Finally, EU member states are not required to follow this procedure in the case of small power plants with <1MW installed capacity or demonstration projects.

To meet these expectation a new Hungarian regulatory framework was introduced from 2017, the ‘Renewable Energy Support System’ (METÁR)[55]. The implementation of the new regulatory environment into the Hungarian legislation took several years.

1) On 1 April 2016 the operating logic of the KÁT balance group has changed. Electricity from RES is no longer sold to the obliged recipients, but the balance group operator can sell it on the Hungarian electricity exchange (HUPX). This change introduced the ‘KÁT financial instrument’, which must be paid to MAVIR by the former obliged recipients to cover the difference in the RES electricity sales.
2) On 1 January 2017, the Renewable Energy Support Scheme (METÁR)[56] was introduced. The new system replaced the former KÁT but existing KÁT contracts are honored, however it is no longer possible to enter the old KÁT.[57]

Under the METÁR regulation:

- the produced RES must be sold directly on the market,
- in principle the financial subsidy is granted in the form of a premium above market price,
- producers should not be encouraged to generate electricity at negative prices,
- many producers have responsibility in network balancing,
- the METÁR support is lessened by the amount of support of the awarded investment aid or loan subsidies,
- METÁR tenders are conducted by the MEKH with a pay-as-bid system.[58]

As part of the METÁR system, there are two support schemes: METÁR KÁT and the premium support system.

[55] 299/2017. (X. 17.) Government decree (*‘Korm. rendelet’*)
[56] 165/2016. (VI. 23.) Government decree (*‘Korm. rendelet’*)
[57] 166/2016. (VI.23.) Government decree (*‘Korm. rendelet’*)
[58] 62/2016. (XII. 28.) NFM decree (*‘NFM rendelet’*)

- New power plants and demonstration projects with a size larger than a household, but lower than 0.5 MW installed capacity (wind-based generation is an exception) could receive subsidies through the METÁR KÁT subsidy system, which has a operational mechanism as its predecessor.
- New, renewables (non-wind) power plants with a nominal capacity of 0.5 MW, but less than 1 MW, could source funds under the premium scheme. The duration of the subsidy and the amount of energy to take over with the premium is set by the MEKH on an administrative basis (administrative premium). The exact amount of the premium depends on several factors.[59] The subsidized price (the reference market price and the subsidy provided) is defined according to the type of RES, the implemented technology, the nominal electricity generation capacity of the power plant and the production zone time (peak, valley and deep valley periods). It should be noted that the subsidy adds up to the major part of the subsidized price, similar to the METÁR KÁT feed-in tariff.[60]
- Wind power plants and power plants with a nominal capacity of 1 MW can only receive support under competitive tendering procedures in accordance with EU guidelines. Electricity producers are competing for the 'green premium' and in all cases the winner of the procedure is entitled to sell electricity at the subsidized price established during the tender. The subsidy may be granted for up to 20 years. The coverage of the 'green premium' is coming from the Premium Fund[61] and the payment falls to the obliged organizations. Accordingly, the system is identical to the financing of the old KÁT system.
- In addition to the 'green premium', Hungary also opted to implement a 'brown premium's system that is available for existing power plants using biomass or a biogas plant and will be threatened with closure in the absence of support. The brown premium is also required to be filed at MEKH and the cost of biomass or biogas-based production (including maintenance and repairs that allow long-term continuous operation) is determined by the

[59] 63/2016 (XII. 28) NFM decree (*'NFM rendelet'*)

[60] 13/2017. (XI. 8.) MEKH decree *('MEKH rendelet'*); METÁR subsidy rates are reviewed every year, by November 1, the most recent one: 10/2018. (XI. 5.) MEKH decree *('MEKH rendelet'*)

[61] *'prémium pénzeszköz'*

subsidized price. The brown premium may not be higher than 50% of the value of the green premium subsidy that is not subject to the tender procedure and is indexed into the subsidized base.

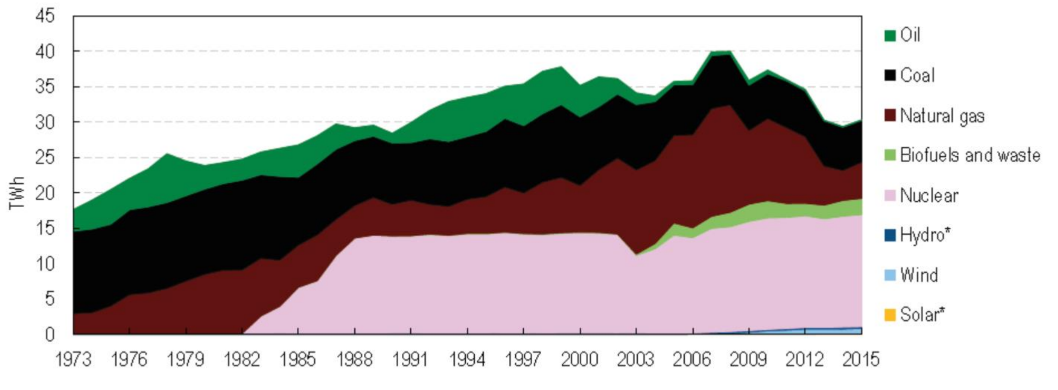
The renewables support scheme will continue to change as the 'Winter Package' of 2016 included 2 proposals:

- Proposal for a new Renewable Directive (RED II)
- Proposal for a new Energy Efficiency Directive (EED II)

On 20 April 2018, the government amended the mandatory takeover of electricity from renewable energy sources, leaving only 5 days for companies planning to build small power plants (under 500 kW) to submit their applications.[62] The extension of the implementation period (3 years instead of 1 year) is possible if the given project is in a reasonable phase or if it classified as a project with national economy priority.

2.6.4 Status of RES development

Hungary has undertaken commitment to increase the share of renewables to 14.65% by 2020.[63] Renewable energy developments in the case of power generation were most apparent between 2005 and 2009 (figure 14). However, by 2013 the new RES capacity developments were drastically slowed down.



*Negligible

Figure 14. Electricity generation by fuel in Hungary (1972-2014, GWh)

Source: IEA (2017)

Sáfián (2014) developed a reference model for assessing different renewable-based scenarios in the Hungarian energy market from an environmental point of view,

[62] 81/2018. (IV. 20.) Government decree ('*Korm. rendelet*')
[63] Many of the EU member states have a much higher RES commitments than the 20% target, mainly due to their natural abilities and economic opportunities. For example Sweden undertook 49%, while Romania 24%, Malta on the other hand has only 10%.

which showed the dominance of biomass. Hartmann et al. (2017) assessed Hungary’s National Renewable Action Plan from the economical aspect and found that by 2020 Hungary will still mostly be using biomass within its renewable portfolio. Currently new wind park development licenses cannot be issued; therefore mainly biomass and PV developments are expected in power generation.

Regardless, the official Hungarian renewable energy target of 13% by 2020 has already been surpassed: the share of renewables in the Hungarian energy mix stood at approximately 14% in 2016. Nonetheless, this target remains far below EU expectations, and the proportion of renewable sources has actually decreased slightly in the past few years.

According to IEA (2018) the Hungarian total primary energy supply (TPES) is predominantly fossil-fuel based in 2017. Natural gas, crude oil and coal account for 65% (almost 2/3) of the energy mix (figure 15).

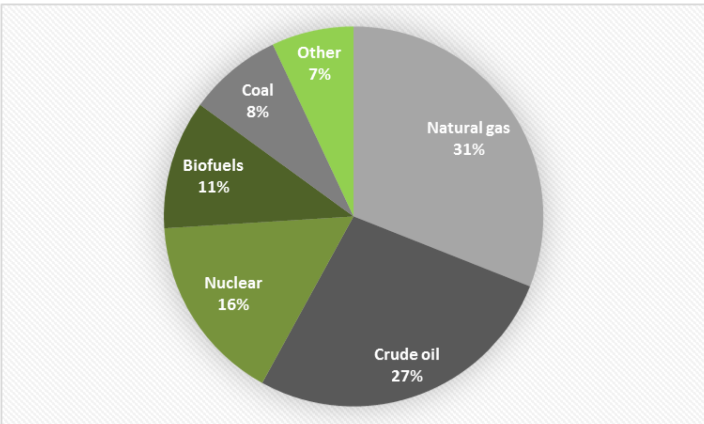


Figure 15. Total Primary Energy Supply (TPES) in Hungary in 2017 (%)

Source: IEA

However, in power generation natural gas and coal only account for 38% (oil is mainly used as a reserve fuel) but nuclear power generation has a 50% share. Other fuel sources, including RES-based generation, account for 12% (figure 16).

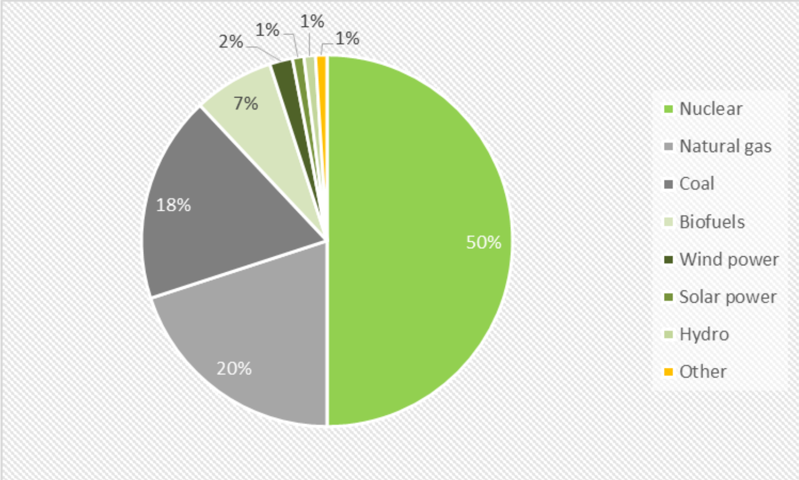


Figure 16. Fuel Shares in Hungarian electricity generation in 2017 (%)

Source: IEA

2.7 The new Hungarian National Energy Strategy: conflicting priorities and trade-offs

The energy strategy documents aim to balance the different goals of the state: ensuring long-term supply security, promoting sustainability and maintaining economic competitiveness. The Hungarian 'National Energy Strategy 2030' of 2012 (NFM, 2012) was a major step towards defining a long-term vision for government policy in the sector. The main objectives of the strategy were formulated along five pillars[64]:

1. Increasing energy efficiency and energy conservation,
2. Increasing the share of renewable energy sources,
3. Promoting the integration of the Central European pipeline network and the construction of the necessary cross-border capacities,
4. Maintaining current nuclear power capacities,
5. Preserving the domestic coal industry by using the domestic coal and lignite in the environmentally friendly production of electricity.

[64] Please note that these goals are resonating to the previously discussed Energy Trilemma (WEC, 2018) trade-offs as the five pillars contain supply security, competitiveness of the Hungarian economy (affordability) and energy efficiency and conservation (environmental sustainability) as well.

The government considered the strengthening of state involvement and the restoration of the previously sold state assets and positions essential elements of the success of that strategy.

Some elements of the NES already materialized in recent years:

- the Hungarian State via state-controlled companies acquired significant assets (DSOs, natural gas storage, largest natural gas trader, etc.);
- new cross-border developments were commissioned (e.g., HU-SK natural gas interconnector) or initiated (e.g., HU-SK high-voltage power line, the increased capacity of the Hungarian-Romanian natural gas interconnector);
- Paks 2 NPP licensing process moved forward.

Other elements, on the other hand, such as energy efficiency and energy conservation initiatives were lagging behind (due to the low energy prices and the lack of the regulatory support) or faced serious challenges (e.g., CO_2 quota price increase), such as the remaining domestic coal industry. These factors ultimately triggered the discussion of the recently (2012-2018) promoted renewables-nuclear-coal energy mix as well. The existing priority conflicts require rethinking the existing strategy to address the current fundamental strategic dilemmas of the Hungarian energy policy (Szőke, 2018), namely:

1) energy import dependence;
2) the role of nuclear energy (in the context of other sources, such as RES or natural gas);
3) the effects of the climate change (including RES developments and the future of the coal industry).

In 2018, as a reaction to the changing landscape of the Hungarian energy industry, the Hungarian Government started the preparation of the renewed (Hungarian) National Energy Strategy (NES) in accordance with the EU mandated National Energy and Climate Policy Action Plan[65]. The government determined the following provisions as foundations to the new NES[66]:

[65] 23/2018. (X. 31.) Parliament resolution (‘*OGY határozat’*) took a decision of the 2nd (Hungarian) National Climate Change Strategy (*’Nemzeti Éghajlatváltozási Stratégia’*), which will provide an

1) to take measures to increase the flexibility of the Hungarian electricity system in order to integrate the - dynamically growing - renewable energy capacity with the lowest possible cost increase:

    a) to examine whether the energy production capacity could meet future domestic energy needs based on the expected market trends and regulatory framework or additional incentives should be introduced,

    b) to elaborate a regulatory framework that promotes innovative technology solutions to stimulate transmission and distribution network flexibility,

    c) to form or improve the programs and regulations for consumer demand-side management and the adaptation of innovative technologies, in particular to stimulate policies to promote the use and integration of battery power storage.

2) to revise the different customer categories and services of the natural gas and universal service for electricity:

    a) to keep customer rates acceptable and relatively steady for customers[67],

    b) to create a differentiated product and service portfolio that supports the national energy efficiency efforts,

    c) to ensure that justified costs of universal service for electricity and natural gas are addressed properly in the long-term.

3) to assess and to shape the residential heating landscape in accordance with the EED directive:

    a) to provide the most favorable heating and energy infrastructure solutions based on total cost for society,

    b) to start the gradual phase out of individual less-favored parallel infrastructures,

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outlook for the period from 2018-2030 to 2050, which is mandated by the United Nations Framework Convention on Climate Change and the Kyoto Protocol.

[66] 1772/2018. (XII. 21.) Government resolution (‘*Korm. határozat’*)

[67] The previous overhead cost decrease was addressed in the government communication ’*rezsicsökkenté*s’, which is currently used with the intention of keeping costs stable, on the same level.

c) to eliminate the limited added-value infrastructure components and duplications (electricity, natural gas and district heating) by taking into account their level of utilization and their role of providing supply security.

4) to prepare a proposal for the elements of the natural gas portfolio supply after 2020 to secure domestic consumption needs

    a) to continue the diversification efforts to access supply from the Black Sea and LNG sources,

    b) to take into account the increased utilization of the domestic natural gas infrastructure,

    c) to develop a program to reduce Hungary's dependence on NG imports (e.g., reducing domestic NG consumption, the increase in the share of domestic NG sources, energy efficiency programs).

5) to revise the current renewables support schemes (FIT and premium system[68]) and the cogeneration regulation[69].

6) to develop a policy program for efficient district heating under the EED directive allowing long-term affordable, environmentally friendly utility service for customers with taking into account the supply security considerations.

7) to propose a regulatory environment that encourages innovation and to develop measures to incentivize the research and development activities.

The update of the NES is planned to be released by the end of August 2019 and the related action plan by December 2019.

Several conflicting priorities and trade-offs could be observed in the 1772/2018. (XII. 21.) Government resolution regarding the different energy value chains. Many of these conflicts may be managed or relaxed; however on many occasions the decision maker needs to carefully weigh the impact of the negative externalities. An example based on the NG network is: higher transmission system utilization could be even with (possibly reduced) NG domestic consumption if the diversification

[68] Revision of the 299/2017. (X. 17.) Government decree (‘*Korm. rendelet’*)
[69] Revision of the 389/2007. (XII. 23.) Government decree (‘*Korm. rendelet’*)

initiatives were successful (e.g., transiting the Black Sea offshore NG production to Austria). On the other hand, increasing the utilization of an already built distribution network is less feasible economically when the domestic consumption decreases.

In the coming chapter, our research aims to collect the major RES trade-offs, which also support the ongoing discussions on the conflicting priorities.

3. Concept mapping of the Hungarian renewables market: a supply chain management perspective

3.1 Concept mapping

Several specific methodologies share the ‘concept mapping’ name. Regardless, significant differences exist both in the applied methods and the reliability of the results. Popular forms of concept mapping is the word based, code based and mixed approaches. Conceição et al. (2017) carried out a literature review, which focused on peer reviewed English language journal articles published between the years 1999–2015 and met the criteria that the empirical study used concept maps as a tool for conducting research (data collection, analysis, or presentation phases). Their concept map (figure 17) organized the papers based on the three approaches (word frequency, relational and cluster) and found that 34% of the articles utilized the cluster approach that is based on Trochim’s methodology.

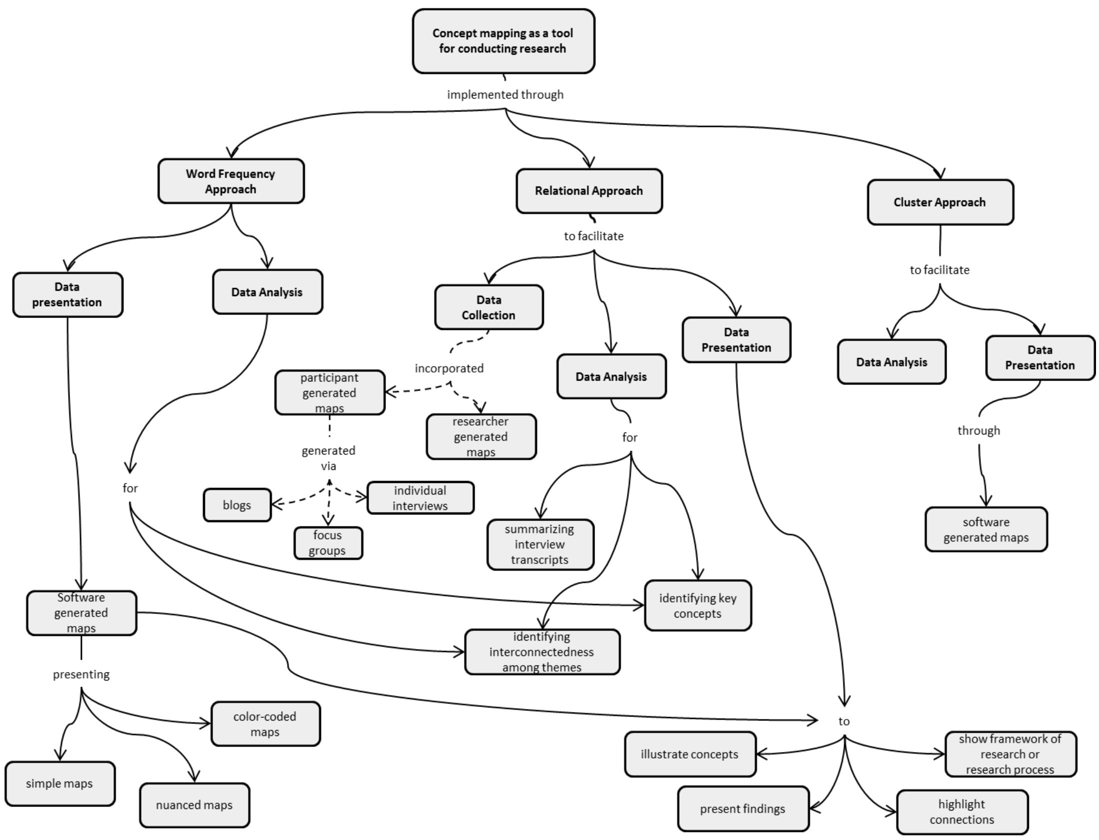

Figure 17. The grouping of concept mapping methodologies

Source: Conceição et al. (2017)

In certain cases, informal processes are chosen, such as in education when individuals (students) draw a picture of all the ideas related to some general theme or question and they show how these are related (Novak and Cañas, 2007)[70]. A more formal group process is preferred when more robust results are needed and include a sequence of structured group activities and a series of statistical and mapping steps.

Also, thematic and word-mapping approaches have their own strengths and weaknesses; therefore the most beneficial is to utilize an integrated approach to the research. We apply a specific type of structured conceptualization process, the "concept mapping" (Trochim and Linton, 1986; Trochim, 1989a; 1989b), which is a mixed method approach to inquiry that enables a defined group of people to articulate thoughts and ideas on a specific topic that are represented in some objective form. Considered relevant outcomes, for example, are conceptualized through the evaluation. Therefore, this cluster approach to concept mapping is described as *"a quantitative approach to the analysis of qualitative data"* (Brown, 2007:1237). As an integration of qualitative (group process, brainstorming, unstructured sorting, interpretation) and quantitative (multidimensional scaling, hierarchical cluster analysis) methods, concept mapping provides the opportunity to combine the strengths of different research approaches while minimizing some of their weaknesses (Jackson and Trochim, 2002).[71]

Concept mapping uses a picture or map to represent the ideas. The described and generated ideas plus the clearly articulated interrelationship enable the construction of a comprehensive idea set. Multidimensional scaling and cluster analysis are then utilized to process this information so the results could be depicted in map form. Both the content and the structure of the map is dependent and determined by the respondents, the role of the researchers during that phase of the process is facilitation. The initial ideas are the output of the participants' brainstorming, and respondents also provide information about how the generated ideas are related. Moreover, they also interpret the results of the analysis and later decide how the map is to be utilized. Concept mapping is ideal for groups (Vastag and Melnyk, 2002) because it is:

[70] Figure 48 in the Appendix shows the graph coordinates in two dimensions

[71] Fine and Elsbach (2000) demonstrated the flexibility and synergies of combining qualitative and quantitative data.

1) participant-oriented, allowing all of the participants to have a say in the final product;
2) bottom-up (inductive) methodology, building on the everyday concrete ideas that people are familiar with and moving gradually to more general abstract ideas;
3) structured, having definite beginning, middle and end point that prevents endless meetings or discussions;
4) simple and intuitive, requiring that participants be able to brainstorm, sort, and rate all fairly common and familiar activities.

Concept mapping is applied in many different areas but originally some of the popular fields were strategic planning, product development, market analysis or decision making (Silva et al., 2013). The usage of this conceptualization method has evolved (Conceição et al., 2017) and continued to increase both geographically and institutionally and has been applied in a wide variety of disciplines and specialties (Trochim, 2017). The popularity of concept mapping is expected to grow even further as concept mapping proved to be a creative and effective solution for clarifying complex topics (Nabitz et al., 2017, McLinden, 2017), and applicable for evaluation projects as well (Goldman and Kane, 2014). Moreover, Rosas and Kane (2012)[72] results suggested that concept mapping consistently yields strong internal representational validity and very strong sorting and rating reliability estimates despite variation in participation and task completion percentages across data collection modes.

3.2 Applying concept mapping for the renewables industry

In the recent years concept mapping was introduced and incorporated to renewables and energy market related research. Martin and Rice (2017) used concept analysis and mapping to analyze renewable energy Feed-In Tariff (FiT) policies in the state of Victoria, Australia. FiT designs enabled the identification of combinations of

[72] Rosas and Kane (2012) conducted a pooled analysis of 69 concept mapping studies. They generated specific indicators of validity and reliability and examined the relationship between select study characteristics and quality indicators.

discrete elements[73] and the authors showed that the government has the means to change the combinations of these design elements in order to accommodate significant shifts in public policies (such as introducing other ancillary policy instruments and regulatory mechanisms). Guerra (2018) aimed to do a systematic analysis that focused on the global governors of the emerging offshore renewable energy (ORE) industries with emphasis on the EU. Berg et al. (2018) focused on the largest European RES market to present the first comprehensive set of results about the collective representations and perceptions of novel biomass-based value chain drivers held by German stakeholders.

When determining the proper tool for our research, several factors were considered.

- Due to the complexity of the topic, interested stakeholders and subject matter expert were scattered across the value chains. As renewables affect directly, in the most significant way, the electricity value chain, the focus of the research concentrated on that.
- However, the RES trade-offs also influence other value chains, mainly the natural gas and district heating, and also the relevant manufacturing (e.g., PV production) operations as well. Therefore, during data gathering relevant stakeholders needed to be considered from these industries as well.
- The Hungarian energy industry is concentrated[74], which should be taken into account when a comprehensive research is carried out. A greater level of anonymity was required in comparison to several research tools (such as interviews, focus groups, open-ended survey questions), which could promote more honest responses and allow respondents to describe market reality with their ‘own’ words.
- Compared to close-ended surveys, we needed to capture the diverse responses that made possible to understand alternative explanations and to record the rich description of the respondents’ reality and experience of the Hungarian RES market.

[73] The main identified elements were fixed and variable: payment rates, differing levels of market regulation and competition, varying tariff operating periods, and eligibility rules for renewable energy system sizes, development sites and low emissions technologies.
[74] Largest companies (based on sales revenues and regulated assets) in the Hungarian energy market include MOL Group, MVM Group, MET Group, E.On, ELMŰ-ÉMÁSZ (part of Innogy).

- On the other hand, we needed to keep the respondent's focus on the given topic compared to interviews, focus groups or open-ended survey questions. The energy markets are facing several challenges and since our research questions are exploratory in nature we needed to aim for scale or interview question development, and/or developing conceptual coding schemes.
- Finally, the research tool should allow us to validate results effectively.

To sum up we needed a coherent conceptual framework or model (a research tool) that is designed to enable a particular large but diverse group of people to articulate and depict graphically their ideas regarding the RES trade-offs and any connected topic or issue of interest. As described above, concept mapping methodology was chosen: it combines the qualitative approach (based on interviews, focus groups or even plant visits and practically could be perceived as a case study) and quantitative methods (relying on computer intensive statistics and data-driven mapping methods).

3.3 Steps of concept mapping

The concept mapping process consists of six steps (figure 18).

Number of step	Name of the step	Description
Step 1	**Preparation**	Identifying the relevant participants and the specific topic focus for idea generation
Step 2	**Statement Generation**	Participants generate ideas to the brainstorming prompt in the form of statements or responses
Step 3	**Structuring and Sorting of Statements**	Sorting and rating of statements to clearly articulate interrelationships and perceived importance
Step 4	**Representation**	The represented statements (point maps) are clustered and mapped
Step 5	**Interpretation**	Clusters are labeled
Step 6	**Utilization**	Determining the further usage of the concept map to developments and improvements

Figure 18. The steps of Trochim's concept mapping research methodology

Source: Trochim, 1989a, 1989b

We followed these steps during our research. All computations were carried out by SYSTAT 13.2.01, the 2D point and cluster maps were created by JMP® Pro 14.2.0 (by SAS).

3.3.1 Step 1: Preparation

In this stage participants were selected and the focus for the conceptualization domain was determined.

m: number of participants

When selecting participants (m=42) several factors were considered. For example, the participants' professional background should represent:

- the different segments of the energy supply chains (mainly electricity, but natural gas and district heating as well);
- large (number of employees>5000), small (number of employees<50) and mid-sized companies, governmental bodies (both national and local level), authorities and regulators, financial institutions, consulting companies and law firms;
- different roles within the supply chain (production, transportation, supplier, trading, retail, functional areas and customer side);
- diverse qualifications (business, economics, engineering, legal);
- different organizational roles (technical leader, professional leader, management leader);
- varying levels of relevant energy industry related experience (from junior level to senior covering from two to 38 years of energy industry experience).

Our participant pool was very heterogeneous (in the complex issues that is preferred by concept mapping to make sure that the research topic is exclusively covered), which also means that after the participant selection basic introductions are required (e.g., Who are we? What kind of background do we have regarding the RES? What is the goal of this research?) and also assurances were communicated by the researchers (no right and wrong answers, no publication without their approval). Then, from the participants' standpoint, most of the concept mapping can be done online or it can be accomplished in two meetings.

3.3.2 Step 2: Statement Generation

Focus for brainstorming: creating the units of analysis

First informal background discussions with the relevant participant group (subject matter experts, managers, leaders, consultants) were carried out. In this stage, the aim was that during the brainstorming session several aspects of the RES could be discussed and a finalized prompt was accepted. During the prompt development two objectives were considered:

1) To identify the crucial trade-offs that are presented in the Hungarian RES market to reflect to our first topic.

   Research question 1 (RQ1): What are the most important renewable energy sources (RES) related trade-offs in the Hungarian energy market?

2) Since there were participants who are familiar with the trade-offs of the Hungarian RES market, we asked them to address and reflect upon our second topic.

   Research question 2 (RQ2): How can the crucial RES trade-offs be relaxed in Hungary?

After the initial discussions, the following prompt was used, since respondents felt that it was reasonable to record the trade-offs together with the appropriate actions. This ensured a common understanding on both elements before grouping and sorting.

> *"Currently, the most pressing issues (that potentially indicate trade-off)*[75] in the Hungarian RES (renewable energy sources) market is: (...)"*

Participants were asked to complete the sentence with an applicable statement that starts with the prompt above. It was emphasized to the participants that the objective

[75] (*) The "trade-off' was defined in our lists as follows: *'a trade-off refers to a situation when one criterion's value gain related to the phenomenon is resulting a loss in other aspects (e.g., GHG reduction can be decreased at an increased cost).'*

is to list as many statements as they can think of. Also, each observation, however insignificant it may seem, is important and counts. Statement generation can be done by emailing each participant separately and collecting his/her suggestions or it can be done in a group meeting.

The statements were generated via e-mail and personal meetings and some of the statements came up in small group discussions. E-mail answers to the open prompt question were mainly a short paragraph of one to five sentences with different ideas. During the group discussions each participant wrote down 3-10 statements. After they finished, we collected the lists as facilitators. After some preparation time the statements were displayed to the participants (e.g., entering them in a Word file and projecting the file). When all statements were on the list, the obvious mistakes (spelling and grammar, for example) were corrected but the statements were not changed in any other way.

The generated statements described the impacts (positive or negative) of the RES development projects on the Hungarian energy market and the actions they thought to be relevant to address regarding the given trade-off (figure 19).

Prompt (please complete the sentence with an applicable statement that starts with the following prompt): ***Currently, the most pressing issues (that potentially indicate trade-off)* in the Hungarian RES (renewable energy sources) market is: (…)***	
(…) ***statement (=action)***	***Example of the trade-off behind the statement***
Addressing employment issues (such as mitigating the negative effect on the existing jobs in the energy and related industries)	RES require different skills than the conventional power plants which can result in unemployment and increased re-training needs. For instance affected jobs include the workers at Vértes Power Plant and Mátra Power Plant (e.g. coal miners).

(*) Definition of "trade-off": A trade-off refers to a situation when one criterion's value gain related to the phenomenon is resulting a loss in other aspects (e.g. GHG reduction can be decreased at an increased cost)

Figure 19. Example of a received statement (with the relevant trade-off illustration)

Source: concept mapping, author's compilation

The open-ended survey question allowed us to create the “units of analysis” in a list-like format. In this case the unit of analysis consisted of a sentence or phrase that contained only one concept. In most cases separate unitizing decisions were not necessary (sentences were left intact), as respondents tended to express one idea for each concern they listed with an underlying trade-off consideration. If a sentence needed a unitizing decision, a small group of respondents was asked to work together to create units by breaking sentences into single concept phrases (actions), while also keeping them distinct from other units.[76] For example, one response was: *"(...) RES expansion increases pressure on the existing electricity grid, therefore new domestic transmission developments, improved crossed border connections and large scale energy storage options are needed"*. This response was broken down into three separate statements: (a) (…) new domestic transmission developments are necessary, (b) (...) improved crossed border connections are required, (c) (…) large scale energy storage options needed. Consequently, the context of each concept is retained and is readily available for participants to sort. This was done for the entire data set. No trade-off decisions had to be made concerning the amount of access to respondents[77]; therefore relevant respondents were involved in the unitizing decisions, the sorting and cluster-solution stages of the analysis over the unitizing process.

Statement purification: creating the units of analysis

The draft ideas were collected in a list, the 'original list of statements'. Next the obvious mistakes (e.g., spelling) were corrected then the individual response lists were combined and randomized. To ensure that each statement (unit of analysis) would be considered independently later by all respondents, each statement was given a random number generated by a random number function. Subsequently all other identifiers were removed and the original list of statements was sent back to all participants to check for overlaps and wordings to ensure that participants have all their ideas included and to address any clarification that might be needed regarding the statements. Typically, after several iterations (via e-mail and phone discussions) the group reached a consensus on the list of statements.

After review by the respondents the 'reduced list of statements' was accepted by everyone. The final list comprised 40 statements. These statements (*n* number of

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[76] As an alternative method at least two researchers may make unitizing decisions together (if only one researcher unitizing the statements separately, then an inter-rater reliability check should be performed).

[77] E.g., involving participants only into sorting or clustering over unitizing due to lack of spare time (e.g., C-level executives), limited access (e.g., permission only to sort and evaluate) or contamination of a follow-up survey (e.g., discussing issues that might be later measured against).

statements) describe the conceptual domain for RES improvement options (actions) (*figure 20*) with the relevant trade-offs (*figure 21*) at the unit of analysis.

Respondents identified the following as the most pressing issues (this also indicates trade-offs) in the Hungarian RES market:

No.	(…) statement (action)
1	Addressing employment issues (such as mitigating the negative effect on the existing jobs in the energy and related industries)
2	Developing social awareness towards renewables with transparent communication
3	Ensuring a steadier regulatory environment (licensing process, tax burdens, etc.)
4	Promoting renewables technologies that rely on resources available within Hungary or the EU
5	Developing a more flexible tariff system to ensure the proper balance between the return on investment and technology trends
6	Minimizing subsidies in the RES related tariff schemes
7	Improving cross-border connections and TSO mechanisms to balance the intermittent generation of RES on the regional level
8	Developing the large- and/or utility-scale energy storage options
9	Minimizing environmental damages by preferring brown-field investments (e.g., developing PV farms at closed power plants or mine sites)
10	Eliminating cross-subsidies in the electricity and the district heating service and finding synergies (biomass power stations for district heating)
11	Estimating the total cost of renewables production (lifetime cost)
12	Taking into account the greenhouse gas (GHG) emissions caused by renewables
13	Defining fair tariffs that comply with industry standards ("used and useful" principle; user should pay fix delivery charge if the system is used as a "safety net")
14	Ensuring strict environmental, health and safety regulations
15	Addressing the increased distribution network development needs and preparing to manage the changing physical energy flow
16	Channeling investment (e.g., with capacity fees) to create the feasible amount of rapid start-up (even black start) installed power generation capacity
17	Ensuring that European and global trends are followed
18	Limiting the expanding, regulatory environment with increasing complexity, which is less and less transparent from the investor’s and customer’s point of view
19	Identifying and mitigating the resource constraints
20	Funds should also channeled to other form of power generation investments
21	Maintaining the existing, domestic industrial knowledge (knowledge management)
22	Addressing the increased transmission network development needs
23	Handling the risk of voltage level and quality fluctuations
24	Preventing the negative effect on quality of life and biodiversity
25	Revision of the national energy strategy and finding the right mix of (RES) technologies according to local or regional circumstances
26	Addressing the conversion loss during the generation process
27	Optimizing the current and the planned (MAVIR's 10 year plan) installed generation capacity
28	Education of customers on RES technologies
29	More transparent, market-based tariff scheme is needed (a social tariff could be incorporated for "protected customers")
30	Promoting renewables R&D development by strengthening the cooperation between higher education and industry to reduce the cost of the technology

31	Ensuring the financial sources for the further decommissioning of the RES, e.g., setting up RES Decommissioning Fund similar to the Central Nuclear Financial Fund (KNPA)
32	Preparation of the system operators to handle the effect of detachments
33	Raising end-consumers' awareness and level of information about the advantages of renewables and incentivizing them to install own renewable generation capacity through a state program
34	State funds to promote utility-scale RES programs
35	Transparent estimation of the long-term effect of the renewables in the energy prices (domestic and regional, comparisons such as installation of the renewables plus balancing capacities vs. installing the usual ones)
36	Revising the regulation to reflect on the changing market segment
37	Maintaining affordable price levels for both residential and industrial end-users
38	Preparing power exchanges for new types of challenges
39	Incentivizing system operators (DSO) to streamline their processes to integrate more RES generation capacities into their network
40	Eliminating the discriminative renewable subsidy lawmaking

Please note that statement numbers were randomly generated.

Figure 20. The final 'reduced list of statement': Actions

Source: Source: concept mapping, author's compilation

The following Hungarian RES market related trade-offs were listed with the statements:

No.	Example of the trade-off behind the statement
1	RES require different skills than the conventional power plants, which can result in unemployment and increased re-training needs. For instance affected jobs include the workers at Vértes Power Plant and Mátra Power Plant (e.g., coal miners).
2	Deployed RES solutions (e.g., large wind turbines) and the related infrastructure developments (e.g., new power lines) can raise public opposition. Renewables may create visual intrusion of the landscape that may trigger a "not in my backyard" (NIMBY), "build absolutely nothing anywhere near anyone" BANANA attitude with concerned, affected residents.
3	The Hungarian - both national and local - regulatory environment (relevant for the renewables energy market) has changed more frequently than the EU average, which results in higher business risk and increased costs.
4	The rising scarce raw material need of the RES technologies - for instance during the manufacturing of wind turbine blades - can result in shortages, longer lead times and price increase; especially in the case of rare earth elements and metals such as copper, and, for roof-mounted PV, aluminum.
5	Most of the RES developments rely on significant subsidies to ensure long-term financing and investment returns; however, this financial stability on the other hand sets back the adoption of more efficient RES innovations.
6	The current Hungarian tariff system can over-subsidize certain RES types, which ultimately increases customer/tax payer burdens.
7	In the past years both hydro plants in Serbia and intermittent PV/wind generation in south Hungary affected market efficiency and the TSOs incomes as both of the Hungarian (MAVIR) and Serbian (Elektromreža Srbije) TSOs needed to reserve a significant part of their respective cross-border capacity to be able to handle the voltage level and quality fluctuation.
8	Intermittent RES generation created a high demand for storage solutions. While constructing a large-scale pumped-storage for hydroelectricity is less realistic in Hungary, utility-scale storage solutions or other feasible technologies (e.g., power-to-gas) should be deployed.
9	While RES construction is perceived as environment friendly; yet, damages are present when green-field renewables sites are developed: enormous land, new roads, lines, water supply,

	etc. are required
10	Current Hungarian energy strategy treats geothermal as a preferred RES; however, currently there is an inaccessibility of acceptable geothermal sources for power generation in Hungary (pilot projects exist but were not successful, as of yet), but due to the incentives the relatively expensive geothermal sources have gained popularity in district heating.
11	By using ethanol to substitute gasoline several negative externalities can arise (e.g., soil erosion, fuel usage during production, pollutant emission during combustion such as nitrogen oxides or formaldehydes, ethical issues such as possible food production).
12	While RES have no direct GHG emission after commissioning; regardless, they can contribute to GHG emissions in several other ways (e.g., directly due the manufacturing process of wind blades, PV panels or indirectly due to the need of flexibility that comes from natural gas, coal-fired power plants).
13	Currently the rate plans for small-scale RES plants which does not allow for the DSO to recover certain "balance of the system" (BOS) costs (related the cost to handle the two-directional flows within the electricity system)
14	While geothermal energy development is considered a safe technology; yet it can cause certain geological damages (landslides, subsistence, fractures).
15	While investors are financing the small-sized RES power plants these developments create an investment strain on the DSO side as well (connections, transformers).
16	Supporting RES also means that other, indispensable types of generations forms are losing competitiveness, as without proper schemes investors are preferring RES over other forms of power generation investments
17	RES technologies are improving fast and new innovations penetrate the European energy market within years (previously the speed of change was not years but decades).
18	The stakeholder has complex interests regarding RES technology, which is also delayed by years, the acceptance of the newest support scheme: Renewable Energy Support Scheme (METÁR)
19	While RES developments are not relying on fossil fuels, yet they could face resource constraints: e.g., water use in the case of PV, CSP plants could be an issue in the coming decade in the south and south-east (dryer climate) of Hungary
20	RES subsidies are decreasing the competitiveness of the conventional power plants; however, growing RES installed capacity increases the importance of the conventional sources through balancing. Overall, customers directly pay for the RES through the subsidies than through the balancing services.
21	RES expansion create a brain transfer within the industry, which threatens the accumulated practical knowledge and the supply of subject matter experts (nuclear engineering) that would be needed in future projects (Paks 2)
22	Large-scale RES developments provide scale efficiency but also require new connecting lines and transformers within the network (only in the case of biomass is evident to use already existing ones - e.g., in the proximity of the closed power plants).
23	The increasing proportion of the RES generation also means more nodes and quick start reserve capacities are needed to handle fluctuations.
24	While RES does not contribute to global warming, several negative externalities can be identified regarding residents (e.g., whirring wind turbine blades) and wildlife mortality (e.g., bats, birds, insects). For instance 1) birds avoid the windmill turbines, therefore the population of rodents are increasing in the surrounding fields or 2) insect population reduction takes place as the polarized reflection on PV panels seems to occur in the place of reproduction for insects, like the water surface.
25	While nuclear and coal-based generation are still the major generator sources, the challenges of the Mátra Power Plant (coal supply, commissioning) and the RES developments require a revision of the current national energy strategy's coal-nuclear-renewables mix.
26	Despite the intermittent generation feature, RES is perceived as highly efficient generation solutions; yet conversion loss is still high: in the case of PVs: sunlight to direct current (~84%) and direct current to alternate current (~10%)
27	The renewables are affecting the energy supply security as 1) the sum of the base load power plant's installed generation capacity is decreasing and further aging, plus 2) the need for quick

	start reserves are increasing.
28	The RES technologies are "game changer'-s and have shaken the previously stable utility service; yet, residents are not aware why RES are important and how their everyday lives are affected (e.g., burning waste).
29	As residential energy prices diverted from market prices, the return on investment on RES technology became less transparent and longer payback period characterizes the majority of the RES investment even when market conditions would be advantageous for them (e.g., high electricity prices).
30	Without government subsidies renewable energy investments are commercially less viable than traditional energy investments.
31	The increased number of renewable power plants will require a feasible solution to handle dangerous waste at their decommissioning (e.g., PV panels).
32	While scale efficiency promotes a centralized grid; RES expansion allows users to opt for further grid decentralization and with a proper storage solution detachment from the grid.
33	Due to the large upfront costs household-sized RES developments are financed by wealthy customers, while other end-users with suitable property but low purchasing power have no means to take advantage on the technology.
34	The solar boom helped developers to secure bank financing for mid-sized utility-scale renewable power plants; however, as the fund depleted very fast (several banks have run out of their Hungarian renewables budget), new constructions may slow down.
35	While investors can currently calculate with a fairly high selling price for the generated RES-based electricity, as more and more subsidized RES installed capacities are added to the market, the greater challenge is to estimate the long-term effect of the renewables in the energy prices (domestic and regional) and account for the balance of the system costs on the TSO level and also on the balancing group level.
36	RES (on <1 MW level) can create a new segment in short-term, which should be handled by the market participants (mainly trade companies).
37	While RES are contributing the GHG reduction, they also contributed to the rising electricity prices. Industrial users' competitiveness is deteriorating as more expensive green energy costs increase the price of the end product.
38	RES development boom increased the number of new players (sellers) on the generation side but local and regional power exchange markets are currently not well-prepared (enough) for traders.
39	While from the investor side many RES developments were initiated, the approval and integration process - including the status of the DSO connections - are slower than expected.
40	RES expansion addressed the direct, visible and controlled environmental concerns (e.g., GHG emission) but raised unforeseen, uncontrolled environmental concerns (e.g., wind turbines add to global warming), and ultimately resulted in targeted, discriminative RES law making (e.g., practical ban of Hungarian wind developments).

Please note that statement numbers were randomly generated.

Figure 21. The final ‘reduced list of statement’: Trade-offs

Source: Source: concept mapping, author’s compilation

3.3.3 Step 3: Structuring of Statements (Sorting)

The next step in the concept mapping process is structuring the statements by a group of sorters[78] into piles of similar statements. We relied on the original respondents to do the sorting, which on the one hand minimized the potential for

[78] Jackson and Trochim (2002) suggest that at least 10 sorters are necessary for viable research results.

misunderstandings and on the other hand provided maximum representativeness of the structure that emerged later from the multidimensional scaling (MDS). While in certain cases that may not be an option, reliability greatly improves if the sorters have different experiences or backgrounds than the original respondents and misinterpretations are less likely to happen.

To reveal how the statements are related to each other, we applied the unstructured card sorting procedure (Rosenberg and Kim, 1975; Weller and Romney, 1988) that requires each participant to receive a complete set of statement cards, and respondents had to assign each one to one pile (but the number of piles cannot be 1 or the total of the number of statements). We asked the 42 participants to arrange the statements into groups in a way that made sense to them.[79] As 40 statements were defined, the number of groups had to be more than 1 and less than 40. The participants could place the statements in only one group. This limitation was necessary to prevent the creation of 'miscellaneous' pile and ensured that if a statement was not judged to be similar to any other statement, then it has to remain alone in its own pile. Overall, this maintained the quality of the data by averting the possible formation of a 'junk' cluster in the final analysis stage. The majority of the participants allocated the RES-related trade-off statements into 4-6 groups.

At the very end, the participants gave each pile a name they thought most accurately represented the statements in it. The statements were allocated by different approaches during the grouping process, for example:

- soft and hard measurements,
- (RES) technologies,
- strategy levels,
- responsibility.

Some of the most often used key words for grouping included (in alphabetical order):

> *Cooperation, Cross-border (regional), Education, Employment, Environmental, Financing, Funding, Infrastructure, Innovation, Investment, Legal, Local, Marketing, Network (DSO/TSO), Operation, Optimization, PR,*

[79] The instruction was the following: *'Please arrange the statements into groups 'in a way that makes sense to you.' (Each statement can be placed in only one group and the number of groups had to be more than one and less than 40.)'*

Regulatory, Resources, Social, Stakeholder, Strategy, Synergies, Tariff, Technology

Rating of statements

Following the sorting, the participants were asked to evaluate each statement in a questionnaire form.[80] We asked the respondents to rate each item on a 5-point Likert scale in terms of how important they found the statements, where:

1 = relatively unimportant (compared with the rest of the statements)

2 = somewhat important

3 = moderately important

4 = very important

5 = extremely important

Participants were asked to bear in mind that none of the 40 statements are totally unimportant, so their rating should be considered a relative judgment of the importance of each item to all other statements.

3.3.4 Step 4: Representation

Multidimensional Scaling of the Sorting Results

To aggregate individual understanding in the form of similarity judgments we coded the data from the responses in two steps:

1. During this step, as a starting point a matrix was created for each respondent (sorter). In our case a symmetrical 40 × 40 binary matrix (rows and columns represent statements) was created for each sorter. Cell values could take two values: whether (1) or not (0) a pair of statements was sorted by the respondent into the same pile.

Binary symmetric matrix of similarities (figure 22):

[80] The instruction was the following: *'Please rate each statement on a 5-point scale in terms of how important the statement you think is, where 1=relatively unimportant (compared with the rest of the statements), 2=somewhat important; 3=moderately important; 4=very important; 5=extremely important. Please keep in mind that none of these 40 statements are totally unimportant, so this rating should be considered a relative judgment of the importance of each item to all other statements.'*

$X^k_{ij} = 1$, if statements i and j were placed in the same pile by participant k, 0 otherwise (i, j=1, 2, . . . m; k=1, 2, . . . n).

Statement no. >>>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
3	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
4	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
5	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
6	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
10	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
12	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0
13	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0
14	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0
16	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
18	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
19	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
20	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
21	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0
22	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0
23	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0
24	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
26	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0
28	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0
30	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
32	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0
33	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
35	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
36	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
38	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
39	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0
40	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1

Figure 22. Binary symmetric matrix of similarities (*m*=1)

Source: Source: concept mapping, author's compilation

2. In the second step we aggregated the similarity of judgments of the respondents by adding all 42 of the individual matrices together.

Total similarity matrix (figure 23):

$$T_{ij} = \sum_{k=1}^{k=n} X_{ij}^{k} \; (i, j = 1, \ldots, m)$$

where the cell value indicates the number of people who placed the (i, j) pair in the same pile.

Statement no. >>>

Statement no. >>>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	42	14	1	11	2	3	3	2	9	1	5	5	4	5	3	4	3	1	5	3	12	4	2	9	4	4	1	16	2	10	3	5	12	6	4	1	4	4	2	2
2	14	42	2	11	2	3	2	0	11	1	5	4	3	6	1	0	5	3	3	4	15	1	0	10	2	3	2	28	2	15	0	1	28	5	3	2	5	1	0	3
3	1	2	42	5	26	28	3	4	4	25	3	9	24	21	5	8	9	35	3	5	2	7	2	7	24	1	11	3	23	7	12	7	1	8	17	36	19	9	15	31
4	11	11	5	42	7	7	6	6	11	7	8	11	9	8	8	11	9	7	18	12	6	10	6	10	5	9	3	5	8	16	12	6	9	17	8	6	9	8	6	8
5	2	2	26	7	42	36	7	2	5	27	10	8	37	12	6	13	5	25	5	16	3	7	4	4	15	3	8	1	34	4	22	4	2	19	23	24	26	9	13	20
6	3	3	28	7	36	42	5	3	4	27	11	7	32	13	5	12	7	23	4	14	3	7	3	5	17	3	8	3	31	7	20	4	2	17	24	24	23	10	13	19
7	3	2	3	6	7	5	42	27	6	8	3	3	5	2	28	13	6	4	8	8	5	22	24	3	6	15	13	3	4	4	5	24	4	6	5	5	4	18	15	5
8	2	0	4	6	2	3	27	42	3	8	4	1	3	3	27	13	10	3	11	5	6	25	24	4	7	20	14	3	4	7	6	21	2	3	3	3	2	15	20	3
9	9	11	4	11	5	4	6	3	42	5	12	23	3	18	4	5	3	6	11	7	10	5	4	25	7	4	3	8	2	8	11	3	10	5	4	6	6	5	3	9
10	1	1	25	7	27	27	8	8	5	42	9	10	24	15	8	11	9	24	8	9	3	11	7	5	22	6	14	0	21	4	18	8	2	13	19	24	17	12	17	21
11	5	5	3	8	10	11	3	4	12	9	42	20	13	11	4	12	8	5	10	17	2	4	3	16	7	7	5	1	11	7	17	4	3	16	15	3	10	9	4	7
12	5	4	9	11	8	7	3	1	23	10	20	42	8	19	3	4	9	10	15	6	7	5	4	22	11	3	8	2	6	6	11	3	5	6	9	9	11	3	5	13
13	4	3	24	9	37	32	5	3	3	24	13	8	42	12	7	12	6	23	5	16	2	7	3	4	16	5	10	0	34	5	20	5	0	21	21	22	27	9	15	19
14	5	6	21	8	12	13	2	3	18	15	11	19	12	42	3	3	11	21	7	2	4	4	0	23	16	5	9	6	10	8	5	3	3	5	13	20	16	5	11	22
15	3	1	5	8	6	5	28	27	4	8	4	3	7	3	42	16	6	5	8	10	4	32	28	3	8	15	18	3	7	6	6	25	1	8	7	6	5	17	20	5
16	4	0	8	11	13	12	13	13	5	11	12	4	12	3	16	42	3	7	7	25	4	15	14	3	7	8	8	1	11	9	20	10	4	18	14	9	8	12	12	7
17	3	5	9	9	5	7	6	10	3	9	8	9	6	11	6	3	42	9	16	5	9	8	8	8	12	10	11	7	6	10	5	7	5	3	11	9	12	10	13	10
18	1	3	35	7	25	23	4	3	6	24	5	10	23	21	5	7	9	42	6	7	3	6	2	6	26	3	12	2	22	4	14	7	3	9	18	35	20	10	16	33
19	5	3	3	18	5	4	8	11	11	8	10	15	5	7	8	7	16	6	42	9	9	9	11	13	10	14	7	1	5	10	11	8	4	7	6	3	6	10	6	8
20	3	4	5	12	16	14	8	5	7	9	17	6	16	2	10	25	5	7	9	42	7	9	7	5	8	6	10	3	16	9	24	5	7	28	17	5	13	13	8	9
21	12	15	2	6	3	3	5	6	10	3	2	7	2	4	4	4	9	3	9	7	42	5	7	4	4	5	6	20	5	9	3	7	18	3	3	4	5	4	6	3
22	4	1	7	10	7	7	22	25	5	11	4	5	7	4	32	15	8	6	9	9	5	42	28	3	10	17	15	1	8	5	8	21	1	6	7	4	6	18	21	4
23	2	0	2	6	4	3	24	24	4	7	3	4	3	0	28	14	8	2	11	7	7	28	42	1	4	20	18	1	7	4	7	26	1	4	2	4	2	16	17	2
24	9	10	7	10	4	5	3	4	25	5	16	22	4	23	3	3	8	6	13	5	4	3	1	42	9	5	6	9	4	12	9	4	8	4	6	5	6	5	5	11
25	4	2	24	5	15	17	6	7	7	22	7	11	16	16	8	7	12	26	10	8	4	10	4	9	42	7	15	2	14	9	12	6	6	8	14	23	14	12	16	22
26	4	3	1	9	3	3	15	20	4	6	7	3	5	5	15	8	10	3	14	6	5	17	20	5	7	42	10	1	5	9	4	14	3	5	4	1	5	10	14	2
27	1	2	11	3	8	8	13	14	3	14	5	8	10	9	18	8	11	12	7	10	6	15	18	6	15	10	42	3	13	3	7	16	3	4	8	11	9	15	23	11
28	16	28	3	5	1	3	3	3	8	0	1	2	0	6	3	1	7	2	1	3	20	1	1	9	2	1	3	42	2	17	0	2	30	2	3	3	4	2	2	2
29	2	2	23	8	34	31	4	4	2	21	11	6	34	10	7	11	6	22	5	16	5	8	7	4	14	5	13	2	42	7	19	6	2	16	18	21	24	10	14	15
30	10	15	7	16	4	7	4	7	8	4	7	6	5	8	6	9	10	4	10	9	9	5	4	12	9	9	3	17	7	42	8	6	18	11	8	6	5	6	4	6
31	3	0	12	12	22	20	5	6	11	18	17	11	20	5	6	20	5	14	11	24	3	8	7	9	12	4	7	0	19	8	42	7	3	25	19	12	15	13	10	15
32	5	1	7	6	4	4	24	21	3	8	4	3	5	3	25	10	7	7	8	5	7	21	26	4	6	14	16	2	6	6	7	42	1	3	6	10	3	21	24	8
33	12	28	1	9	2	2	4	2	10	2	3	5	0	3	1	4	5	3	4	7	18	1	1	8	6	3	3	30	2	18	3	1	42	4	5	2	4	2	1	1
34	6	5	8	17	19	17	6	3	5	13	16	6	21	5	8	18	3	9	7	28	3	6	4	4	8	5	4	2	16	11	25	3	4	42	18	9	15	9	4	12
35	4	3	17	8	23	24	5	3	4	19	15	9	21	13	7	14	11	18	6	17	3	7	2	6	14	4	8	3	18	8	19	6	5	18	42	17	22	9	14	16
36	1	2	36	6	24	24	5	3	6	24	3	9	22	20	6	9	9	35	3	5	4	4	4	5	23	1	11	3	21	6	12	10	2	9	17	42	19	8	14	31
37	4	5	19	9	26	23	4	2	6	17	10	11	27	16	5	8	12	20	6	13	5	6	2	6	14	5	9	4	24	5	15	3	4	15	22	19	42	7	13	18
38	4	1	9	8	9	10	18	15	5	12	9	3	9	5	17	12	10	10	10	13	4	18	16	5	12	10	15	2	10	6	13	21	2	9	9	8	7	42	15	10
39	2	0	15	6	13	13	15	20	3	17	4	5	15	11	20	12	13	16	6	8	6	21	17	5	16	14	23	2	14	4	10	24	1	4	14	14	13	15	42	12
40	2	3	31	8	20	19	5	3	9	21	7	13	19	22	5	7	10	33	8	9	3	4	2	11	22	2	11	2	15	6	15	8	1	12	16	31	18	10	12	42

Figure 23. Total similarity matrix of responses (*m*=42)

Source: Source: concept mapping, author's compilation

The higher a value is, the more similar the participants think the two impact statements are. The total similarity matrix is the input into a two- dimensional nonmetric MDS (multi-dimensional scaling).

Mapping

Trochim (1989a) argued, referring to Kruskal and Wish (1978) that *"Since it is generally easier to work with two-dimensional configurations, ease of use considerations are also important for decisions about dimensionality. For example, when an MDS configuration is desired primarily as the foundation on which to display clustering results, then a two-dimensional configuration is far more useful* *than one involving three or more dimensions."* (Kruskal and Wish, 1978: 58). Therefore, using the aggregated total similarity matrix, MDS created coordinate estimates and a two-dimensional map of distances between the statements based on the aggregate sorts of the 42 coders, as shown in figure 24 (The two-dimensional MDS plot of statements).[81] The graph was prepared using JMP® Pro 14.2.0.

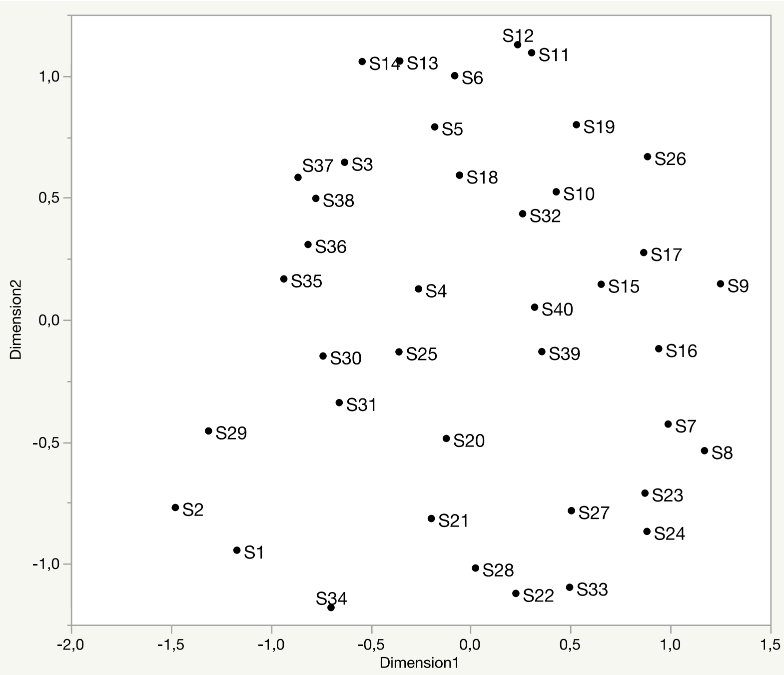


Figure 24. MDS 2D graph with the statements

Source: Source: concept mapping, author's compilation

MDS estimates are shown through the distance between the points that show how similar the statements are judged to be by the respondents. The further a point is, the less often they were sorted together with those points that are closer together. It should be noted that the distance or spatial relationship between the points are important but not the position of the points itself on the map (e.g., right, left, top, bottom).

Goodness of fit of the two-dimensional configuration to the original similarity matrix is called the stress value, which is the common statistic in the MDS analyses. Stress function (value) measures the degree to which the distances on the map (in two dimensions) are discrepant from the value in the input similarity matrix. A high stress value indicates that there is more complexity in the similarity matrix that can be represented well in two dimensions, that there was considerable variability or

[81] Figure 48 in the Appendix

noise in the way people grouped the statements, or both. Trochim (1993) reported that the average stress value across 33 concept mapping projects was 0.285 with a range from 0.155 to 0.352. Donelly (2017) found based on the review of 104 completed doctoral dissertations that the mean multidimensional scaling analysis stress value for 96 concept maps was 0.26 with a standard deviation of 0.05.[82] In our case the MDS results are as follows:

> The stress value was 0.314 and the variation explained 42.4%[83], which makes sense, as our respondent group was rather large and diverse. However, if the stress value would have been greater than 0.35 it may have been difficult to interpret the map sensibly.

3.3.5 Step 5: Interpretation (labeling the clusters)

Hierarchical Cluster Analysis

The last step of the concept mapping is to determine the appropriate number of clusters that represent the final solution for the coded data. Individual statements on the map are grouped into clusters of statements reflecting similar concepts (Anderberg, 1973, Everitt et al., 2011). In our case hierarchical agglomerative cluster analysis using Ward's algorithm on (X, Y) coordinates of MDS statements was applied to determine how the statements cluster together based on similarity. In general, theory-based decisions are difficult or impossible to make in advance about the best clustering fitting procedure or the number of clusters chosen, thus we relied on previous empirical studies. When the structure of categories is not already known, then Trochim (1989a) found that Ward's algorithm is the most useful type of cluster analysis to identify the categories. The Ward's algorithm generally gave more sensible and interpretable solutions than other approaches (e.g., single linkage or centroid method) and minimizes the within-cluster sum of squares to the between-cluster sum of squares at each level of joining (Milligan, 1980, 1981; Rondinelli and Vastag, 2000). Deciding on the number of clusters is not simple and straightforward; it requires significant input from the users, who are the "problem-owners."

[82] Donelly (2017) did a comprehensive search on those doctoral dissertations that applied to Trochim's concept mapping methodology between 1985 and 2014 at different universities in the US and Canada. A set of 108 eligible dissertations in a wide variety of topic areas were identified and these studies were coded on 77 variables.

[83] For more details see figure 49 in the Appendix

Typically, several cluster solutions are generated and the participants reach consensus on the "best" one. The final cluster solution is chosen when all of the cluster solution within a certain range is examined to determine how appropriate are the statement groups' merging and splitting. When selecting the cluster number, we relied on the iterative process that allowed us input from the respondent group.

We asked the individual respondents to take a closer look into the clustering solutions. The name of the cluster solutions are as follows (just to clarify: cluster 9 refers to a solution where the statements were grouped into nine hierarchical clusters):

cluster 1, cluster 3, cluster 4 … cluster 9

Participants considered the solutions of *cluster 4, cluster 5, and cluster 6*. Most of the discussion was spent on whether the output of *cluster 5* or *cluster 6* (a five or a six cluster solution) could be more appropriate and reasonable for the participants.

		No. of clusters (*) >>>								
Statements no.		1	2	3	4	5	6	7	8	9
V	1	1	1	1	1	1	1	1	1	1
V	2	1	1	1	1	1	1	1	1	1
V	3	1	1	1	1	2	2	2	2	2
	4	1	1	1	1	2	2	3	3	3
	5	1	2	2	2	3	3	4	4	4
	6	1	2	2	2	3	3	4	4	5
	7	1	2	3	3	4	4	5	5	6
	8	1	2	3	3	4	4	5	5	6
	9	1	2	2	4	5	5	6	6	7
	10	1	2	2	4	5	5	6	7	8
	11	1	2	2	2	3	3	4	4	5
	12	1	2	2	2	3	3	4	4	5
	13	1	2	2	2	3	3	4	4	4
	14	1	2	2	2	3	3	4	4	4
	15	1	2	2	4	5	5	6	6	7
	16	1	2	3	3	4	4	5	5	6
	17	1	2	2	4	5	5	6	6	7
	18	1	2	2	2	3	3	4	4	4
	19	1	2	2	4	5	5	6	6	7
	20	1	2	3	3	4	6	7	8	9
	21	1	2	3	3	4	6	7	8	9
	22	1	2	3	3	4	6	7	8	9
	23	1	2	3	3	4	4	5	5	6
	24	1	2	3	3	4	4	5	5	6
	25	1	1	1	1	2	2	3	3	3
	26	1	2	2	4	5	5	6	6	7

27	1	2	3	3	4	6	7	8	9
28	1	2	3	3	4	6	7	8	9
29	1	1	1	1	1	1	1	1	1
30	1	1	1	1	2	2	3	3	3
31	1	1	1	1	2	2	3	3	3
32	1	2	2	4	5	5	6	7	8
33	1	2	3	3	4	6	7	8	9
34	1	1	1	1	1	1	1	1	1
35	1	1	1	1	2	2	2	2	2
36	1	1	1	1	2	2	2	2	2
37	1	1	1	1	2	2	2	2	2
38	1	1	1	1	2	2	2	2	2
39	1	2	2	4	5	5	6	7	8
40	1	2	2	4	5	5	6	7	8

**Colors reflect to the particular cluster, where the given statement belongs.*

Figure 25. Comparison of *Cluster5* and *Cluster6*

Source: Source: concept mapping, author's compilation

Respondents were asked to base their decision on the close examination of the statements within the relevant clusters of these solutions (figure 25) and the respondents discussed whether it made sense for them or not.

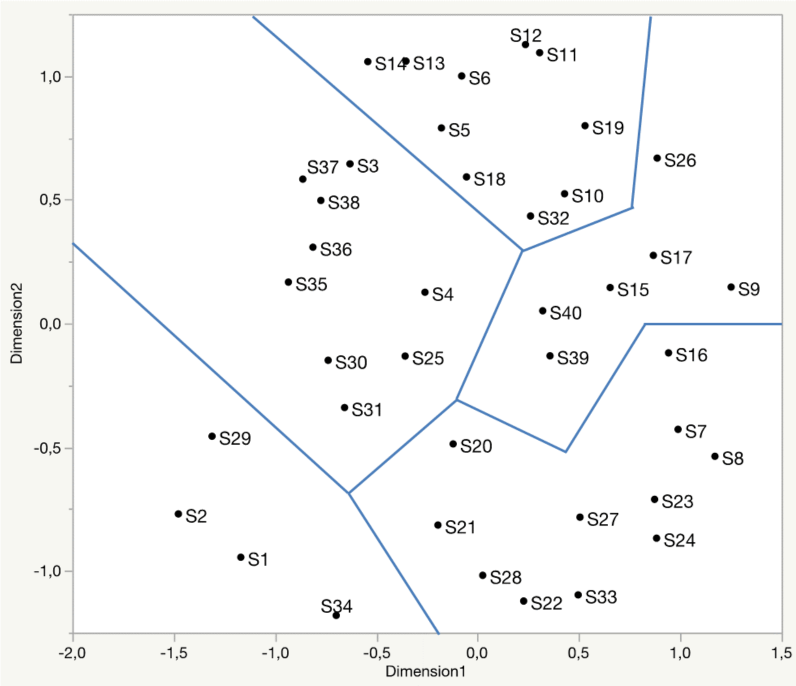


Figure 26. MDS 2D graph with the five clusters

Source: Source: concept mapping, author's compilation

Cluster 5 was chosen as it reflected better to the infrastructure development as a whole (figure 26). C*luster 6* provided no clear differentiation between the technology, PR and the environmental aspects of the infrastructure development but rather mixed these elements. That clearly demonstrates how concept mapping is incorporating human judgment to the more objective mathematical algorithm of cluster analysis.

The five clusters were labeled with the help of respondents (figure 27).

Cluster No.	Cluster name
1	**Social aspects** (stakeholder impact)
2	**High level strategy** (regulatory, tariff system, cooperation)
3	**Low level strategy** (regulations, pricing, complexity management)
4	**Infrastructure development** (technology, PR)
5	**Network optimization** (network operation, resource management)

Please note that 'Cluster No.' does not reflect the importance of the cluster.

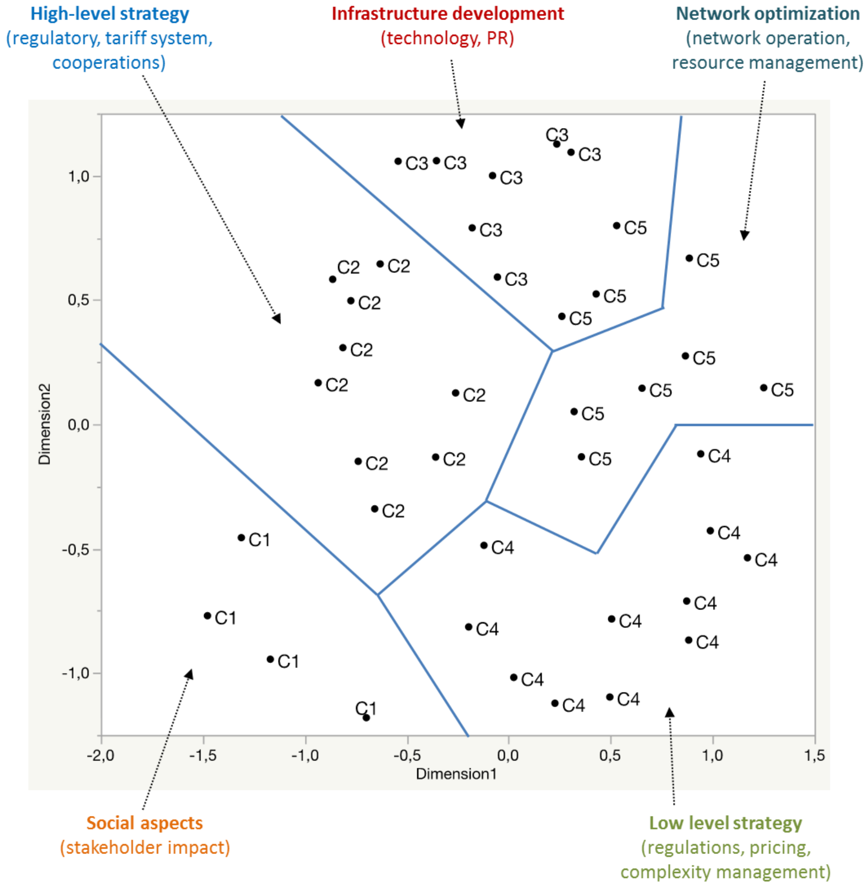
Figure 27. Labels of the 5 clusters

Source: Source: concept mapping, author's compilation

Respondents' noted that the statements and the clusters are focusing on the following major topics:

1) Strategy (clusters of '*High level strategy*' and '*Low level strategy*')
2) Network (clusters of '*Infrastructure development*' and '*Network optimization*')
3) Social (cluster of '*Social aspects*')

After labeling the finalized map concluded the Hierarchical Cluster Analysis process (figure 28).



Please note that 'Cluster No.' does not reflect the importance of the cluster.

Figure 28. The labeled five clusters

Source: Source: concept mapping, author's compilation

Comparison of rating evaluations

After cluster labeling, based on the rating of the statements, the cluster ratings were calculated (figure 29):

Rank	Cluster name	Rating	Original Cluster No.
1	**Low level strategy** (regulations, pricing, complexity management)	3,35	3
2	**High-level strategy** (regulatory, tariff system, cooperations)	3,29	2
3	**Infrastructure development** (technology, PR)	3,19	4
4	**Network optimization** (network operation, resource management)	3,11	5
5	**Social aspects** (stakeholder impact)	2,20	1

Figure 29. Ranking of the 5 clusters (based on the rating of all respondents')

Source: Source: concept mapping, author's compilation

The low- and high-level strategies were given the highest priority by stakeholders, closely followed by infrastructure development, and not far behind network optimization, while social aspects were found to be relatively less important compared to the other clusters.

The next step was to compare the different subgroups of the respondents.[84]

When ‘Seniors’ and ‘Juniors’ are compared (figure 30), we define them as follows:

a) *‘Seniors’ are defined as having more than 14 years of relevant experience.*
b) *‘Juniors’ are defined as having less than 5 years of relevant experience. Please note that people with 5 or more years of experience are not included in this group.*

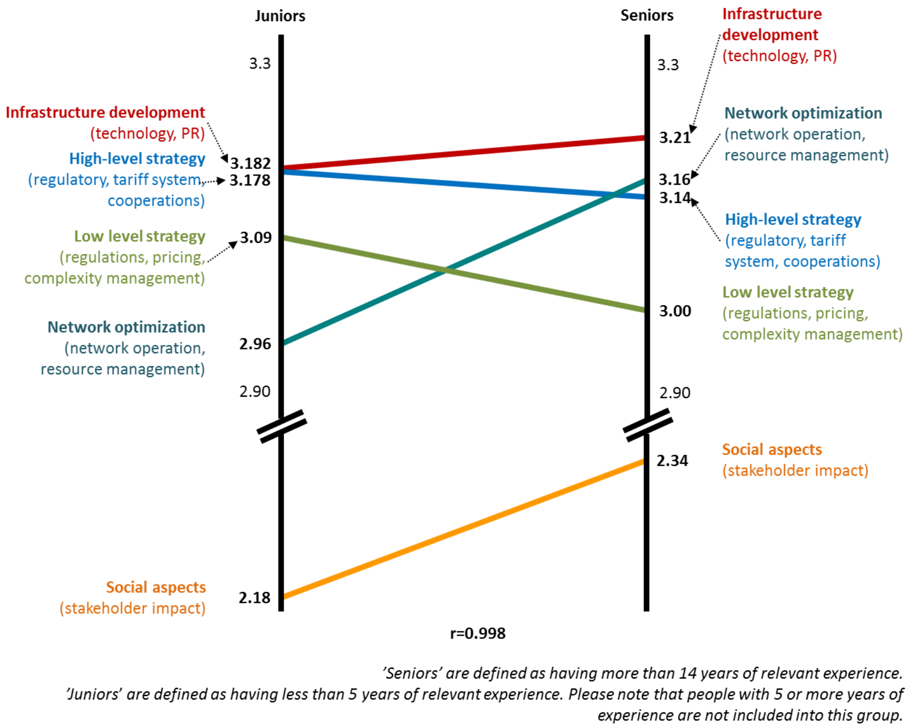


Figure 30. The comparison of ’Juniors’ and ’Seniors’

Source: Source: concept mapping, author’s compilation

The ladder shows only one crossing and the correlation coefficient is r=0.998. That means that the views of the juniors and seniors are very similar, as the correlation between the views is extremely strong.

[84] For more details see figure 51 in the Appendix (respondents' characteristics used for the analysis)

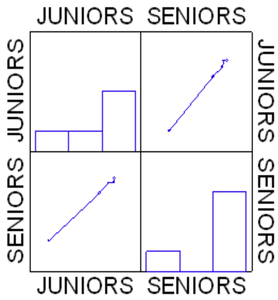


Figure 31. Junior-Senior scatterplot matrix with the LOESS robust smoother

Source: Source: concept mapping, author's compilation

Figure 31 shows the 'Junior-Senior' scatterplot matrix with the LOESS robust smoother for illustrative purposes, and confirms the linear fit as appropriate.

When 'Seniors' and 'Other' are compared (figure 32), we define 'Other' as follows:

a) The 'Other' group has less than 14 years of experience (please note that nobody has 14 years of experience).

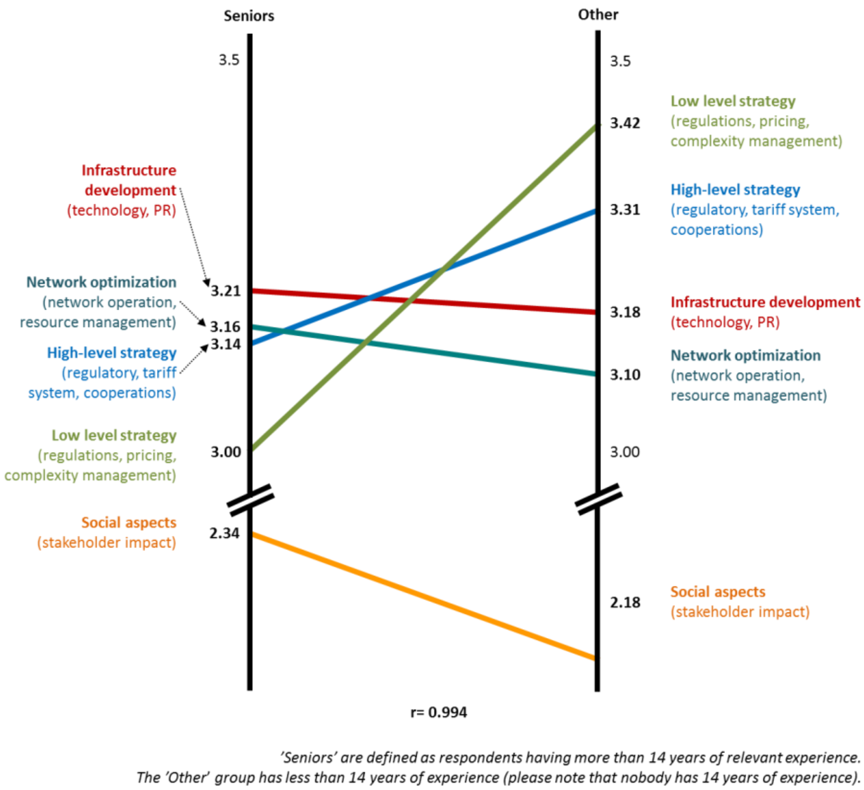


Figure 32. The comparison of 'Seniors' and 'Others'

Source: Source: concept mapping, author's compilation

The ladder shows more crossings than in the case of (Juniors-Seniors) but the correlation coefficient only has a little bit less than in the previous case, r=0.994.

However, if we would exclude the ‘Juniors’ from the ‘Other’ group (we called it ‘Mid-level’[85]) the correlation coefficient would decrease to r= 0.961.

When ‘State-controlled’ and ‘Not state-controlled’ are compared (figure 33), we define them as follows:

a) *‘State-controlled’ is defined as respondents affiliated with state-controlled institutions.*
b) *The ‘Not state-controlled’ is defined as respondents affiliated with not state-controlled institutions (please note that companies with a minority state ownership are within that category).*

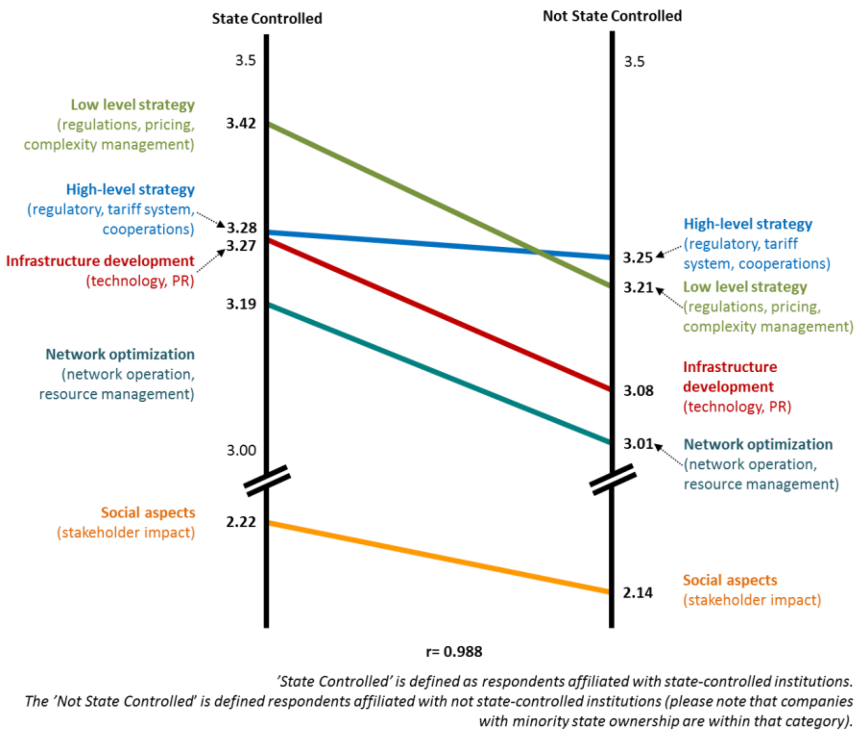


Figure 33. The comparison of respondents affiliated with ‘State-Controlled’ and ‘Not State-Controlled’ institutions

Source: Source: concept mapping, author’s compilation

The ladder shows more crossings and the correlation coefficient is r=0.988.

When ‘Economics and Management’ and ‘JD’ are compared (figure 34), we define them as follows:

[85] ‘Mid-level’ are defined as having at least 5 years of relevant experience but less than 14 years of relevant experience. Please note that nobody has 14 years of experience.

a) *'Economics and Management' is defined as respondents having an Economics and/or Management degree.*
b) *The 'JD' is defined as respondents having JD (Law) degree.*

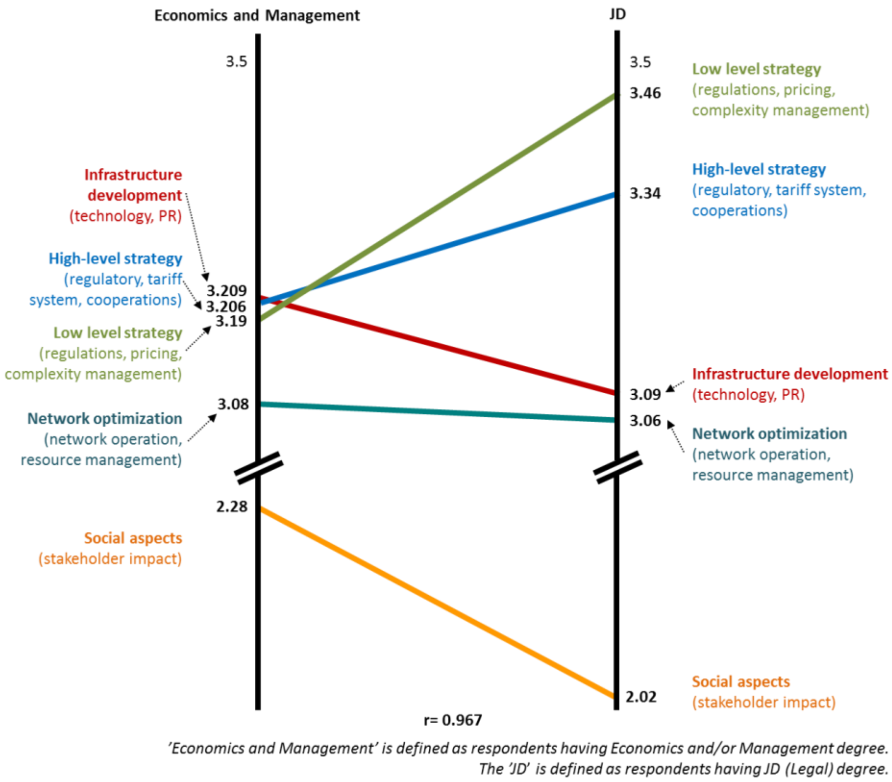


Figure 34. The comparison of 'Economics and Management' and 'JD'

Source: Source: concept mapping, author's compilation

The ladder shows more crossings and the correlation coefficient is r=0.967.

To summarize, the numbers for the values of the linear correlation coefficient (r) between the various subgroups should be emphasized.

- r(Seniors; Mid-level) = 0.961
- r(Seniors; Others) = 0.994
- r(Seniors; Juniors) = 0.998
- r(State Controlled Institutions; Not State Controlled) = 0.988
- r(Economics and Management; JD) = 0.967

These are very high numbers but we have to keep in mind that there are only five aggregate values on each side of the ladder. Overall the respondent group has a strong agreement on the importance of the factors and the trend is the same in all cases. For instance practically nobody assigned great importance - perhaps rightfully - about the social aspects. However, the ladder graphs may, in almost all cases, indicate some potential disagreements between these subgroups.

Based on respondents' feedback we reason that the source of these disagreements may come from the following:

- **'Juniors' - 'Seniors':**
    - *Limited industry experience:* juniors have limited industry experience and their first impressions come from the senior colleagues in most cases. On the other hand limited industry experience in many cases does not equal with limited experience. In the case of the 'infrastructure development' and 'network optimization' clusters there were no significant differences between juniors and seniors. However, respondents with less than 5 years of overall experience (both junior and total experience is less than 5 years) significantly rated less the 'social aspects'.
    - *Copy behavior:* in the traditionally stable energy industry, copy behavior is presented as a way to adjust to the 'best' practices.
    - *Peer pressure:* similar to other industries, juniors are faced with peer pressure as the organization accepts those newcomers faster who are able to quickly adapt to the existing operation.
    - *Value system:* the new generation of employees in the industry is taught by the older generations (e.g., energy and nuclear engineers), which can result in a converged value system.
- **'Senior' - 'Mid-level'**
    - *Adjust or leave:* while long-term employment attracts employees, it also implies slower changes compared to other industries. At the 'mid-level' the more senior employees could find themselves in the situation where seniors are resistant to their ideas. The highest level of disagreement arose here, as mid-level employees either adjust or leave.

- **'State controlled' – 'Not state controlled'**
    - *Informal control:* in the case of state-controlled entities in many cases management is moving between similar companies within the industry (MVM Group, former ENKSZ / NKM, Paks 2, etc.) or to other state-controlled entities (ministries, MVM Group, MFB Zrt., NÚSZ Zrt., etc.). Therefore state control takes on informal forms through the migration of managers from state controlled companies to others.
- **'Economics and Management' – 'JD'**
    - *Prejudice towards the field of interest:* JDs perceive those clusters with a regulatory focus and regulations more critical than other clusters. Respondents with economics and business backgrounds see these clusters important as well (e.g., due to the financial and tariff considerations, complexity of management). They also perceive infrastructure development similarly or with higher importance than any other group (mainly due to the investment requirements and management issues such as public relations and environmental management).

3.3.6 Step 6: Utilization

Based on the respondents' feedback we noted the following major areas for utilization:

- the concept mapping results allow for a more formalized, in-depth discussion on the challenges (and trade-offs) of the Hungarian RES market from a new perspective (Chapter 5).
- the results are inputs for relevant stakeholders in the governmental sector to be able to prioritize between RES technologies that promote state goals while minimizing their negative externalities (e.g., social aspects may be less pressing).
- the actions with the respective trade-offs represent a guide for in-house strategy and decision-making and give industry experts as a 'check list' when RES-related complex technical-, legal- and economic problems are analyzed.

- the results serve as a summary and point of reference for industry actors and for external stakeholders (knowledge management).

In regards to the author’s professional level the research and its results:

- provide an opportunity to promote concept mapping as an excellent tool for qualitative and quantitative research for both energy industry and non-energy industry problems.

- allow for a foundation for further research (see Chapter 6).

4. Addressing the trade-offs regarding the RES expansion on the Hungarian energy market

In chapter 3 with the concept mapping methodology we identified the most important renewable energy sources (RES) related trade-offs in the Hungarian energy market as of January 2019. Our respondent group suggested the main issues and given ideas of how the crucial RES trade-offs could be relaxed in Hungary. The chapter discusses the results of the concept mapping along the five clusters[86] and highlights those aspects that during the concept mapping session were addressed by the participants as relevant for a renewed Hungarian Energy Strategy. Our focus was on the renewables market due its magnitude and financial impact so we will highlight RES relevant issues regarding the largest ongoing Hungarian power plant construction project.

- **Research question 3 (RQ3): How could the key RES trade-offs be influenced by the new Hungarian Energy Strategy that is under development (with special considerations to the planned Paks 2 project)?**

The chapter uses the concept map's grouping categories. In the case of statement discussions, certain elements (e.g., licensing, tariff) could be listed under more points but firstly we will address them under their particular cluster that ranked higher.

4.1 Cluster 1: Low level strategy (regulations, pricing, complexity management)

Figure 35 lists the statements (with rating and ranking) under the cluster label *'Low level strategy (regulations, pricing, complexity management)'* that was ranked 1st among the clusters. The cluster is comprised of 7 statements (17.5%) of the total 40.

Original statement no.	Avg. Rating (1-5)	Statement ranking (1-40)	(…) statement (action)	Example of the trade-off behind the statement
5	3,79	2	Developing a more flexible tariff system to ensure the proper balance between the return on investment and technology trends	Most of the RES developments rely on significant subsidies to ensure long-term financing and investment returns; however, this financial stability sets back the adoption of more efficient RES innovations.

[86] First, cluster no. 3 is discussed, it was ranked the most important by the repsondents in discussions.

13	3,76	3	Defining fair tariffs that complies with industry standards ("used and useful" principle; user should pay fix delivery charge if the system is used as a "safety net")	Currently Hungarian renewables tariff scheme offers reduced rate plans for small-scale RES plants which does not allows for the DSO to recover certain "balance of the system" (BOS) costs (related the costs of handling the two-directional flows within the electricity system)
18	3,43	14-15	Limiting the expanding, regulatory environment with increasing complexity, which is less and less transparent from the investor's and customer's point of view	The stakeholder has complex interests regarding RES technology, which is also delayed by years with the acceptance of the newest support scheme: Renewable Energy Support Scheme (METÁR)
14	3,36	17	Ensuring strict environmental, health and safety regulation	While geothermal energy development is considered a safe technology; it can cause certain geological damage (landslides, subsidence, fractures).
11	3,29	18	Estimating the total cost of renewables production (lifetime cost)	By using ethanol to substitute gasoline several negative externalities can arise (e.g., soil erosion, fuel usage during production, pollutant emission during combustion such as nitrogen oxides or formaldehydes, ethical issues such as possible food production).
6	2,95	23-25	Minimizing subsidies in the RES related tariff schemes	The current Hungarian tariff system can over-subsidize certain RES types, which ultimately increases customer/tax payer burdens.
12	2,88	30-31	Taking into account the greenhouse gas (GHG) emissions caused by renewables	While RES have no direct GHG emissions after commissioning, regardless they can contribute to GHG emissions in several other ways (e.g., directly due the manufacturing process of wind blades, PV panels or indirectly due to the need of flexibility that comes from natural gas, coal-fired power plants).

Figure 35. The statements under the label '*Low level strategy (regulations, pricing, complexity management)*'

Source: concept mapping, author's compilation

The cluster could be divided into two subgroups:

1) Several statements incorporate actions on the tariff design (*No. 2*, *No.* ., *No. 14*, *No. 6*) that influences financial decision making on the corporate level. Respondents pointed out the need for a more flexible tariff system to ensure the proper balance between the return on investment and technology trends. All aspects (flexibility, new tariff solutions and innovation) are specifically included into the government degree on the new NES.

2) The other statements (*No. 14, No. 11, No.12*) focus on the hidden costs of the technologies, including:
    a. Environmental, health and safety (EHS) regulation and management (both from the standpoint of people and the technology).
    b. Total cost of renewables production (lifetime cost): the trade-off example describes the biofuel production due the possibility of having several externalities (soil, water, fuel use) but other RES technologies are also affected. Many of the large PV plants in Hungary are deployed on plough fields, which means that it prevents alternate utilization (agriculture), while a PV plant could require a significant amount of water for operation (e.g., for panel cleaning).
    c. Greenhouse gas (GHG) emissions of RES: while respondents evaluated GHG emission risks lower than other statements within this cluster, it shows the importance of climate considerations.

The two subgroups perfectly describe that the balance of financial trade-offs among competing goals are one of the most important tasks of energy and environmental policies (Costa-Campi et al., 2017). With the highly ambitious renewable energy plan ('Energiewende'), Germany targeted to reduce 80% of its greenhouse gas emissions between 1990 and 2050. However, rising German electricity prices could slow down the energy transition (Finon and Perez, 2008). Any growth renewables that have a share in the Hungarian energy mix may result in a price increase in the long term.

4.2 Cluster 2: High-level strategy (regulatory, tariff system, cooperations)

Figure 36 lists the statements (with rating and ranking) under the cluster label *'High-level strategy (regulatory, tariff system, cooperations)'* that was ranked 2nd among the clusters. The cluster is comprised of 9 statements (22.5%) of the total 40.

Original statement no.	Avg. Rating (1-5)	Statement ranking (1-40)	(…) statement (action)	Example of the trade-off behind the statement
3	4,36	1	Ensuring a steadier regulatory environment (licensing process, tax burdens, etc.)	The Hungarian - both national and local - regulatory environment (relevant for the renewables energy market) has changed more frequently than the EU average, which results in higher business risk and

				increased costs.
25	3,60	7	Revision of the national energy strategy and finding the right mix of (RES) technologies according to local or regional circumstances	While nuclear and coal-based generation are still the major sources of generation, the challenges of the Mátra Power Plant (coal supply, commissioning) and the RES developments require a revision of the current national energy strategy's coal-nuclear-renewables mix.
35	3,45	12-13	Transparent estimation of the long-term effect of the renewables in the energy prices (domestic and regional, comparisons such as installation of the renewables plus balancing capacities vs. installing the usual ones)	While investors can currently calculate with a fairly high selling price for the generated RES-based electricity, as more and more subsidized RES installed capacities are added to the market, the greater challenge is to estimate the long-term effect of the renewables in the energy prices (domestic and regional) and account for the balance of the system costs on the TSO level and also on the balancing group level.
36	3,40	16	Revising the regulation to reflect on the changing market segment	RES (on <1 MW level) can create a new segment in the short-term, which should be handled by the market participants (mainly trade companies).
37	3,26	19	Maintaining affordable price levels for both residential and industrial end-users	While RES are contributing to GHG reduction, they contributed to the rising electricity prices. Industrial users' competitiveness is deteriorating as more expensive green energy costs increase the price of the end product.
30	3,14	21	Promoting renewables R&D development by strengthening the cooperation between higher education and industry to reduce the cost of the technology	Without government subsidies, renewable energy investments are commercially less viable than traditional energy investments.
31	2,93	26-27	Ensuring the financial sources for the further decommissioning of the RES, e.g., setting up the RES Decommissioning Fund similar to the Central Nuclear Financial Fund	The increased number of renewable power plants will require a feasible solution to handle dangerous waste when decommissioning (e.g., PV panels).

			(KNPA)	
4	2,71	36-37	Promoting renewables technologies that rely on resources available within Hungary or the EU	The rising scarce raw material need of the RES technologies - for instance during the manufacturing of wind turbine blades - can result in shortages, longer lead times and price increase; especially in the case of rare earth elements and metals such as copper, and for roof-mounted PV, aluminum.
38	2,71	36-37	Preparing power exchanges for the new type of challenges	RES development boom increased the number of new players (sellers) on the generation side but local and regional power exchange markets are currently not well-prepared (enough) for traders.

Figure 36. The statements (with rating and ranking) under the cluster label *'High-level strategy (regulatory, tariff system, cooperations'*

Source: concept mapping, author's compilation

The cluster incorporates several statements regarding the role of the regulator and regulatory environment *(No. 3, No. 25, No. 36).* The most important statement (*No.3* with a rating of 4.36/5.00) is also within this subgroup regarding the frequently changing Hungarian regulatory environment. The importance of the steadier regulatory environment could prevent regulatory-driven, unintended investment cycles, higher business risk and increased costs.

A recent example is that in 2016 an extremely large number of applications for KÁT licenses were received by MEKH[87] just before a major regulatory framework change (it was known that from 2017 the period of constructing a power plant, that is part of the FIT scheme, would be reduced from 25 to 13 years). According to the MEKH data, the authority issued a record number of (approximately 2,000) permits for the construction of PV plants with a size of 500 kW and below. And while we are not expecting that all of these capacities (figure 37) would be built, the number of PV plants under construction will be increased. [88]

[87] For more information on the issued KÁT licences: <http://www.mekh.hu/kotelezo-atvetellel-kapcsolatos-kerelem>, Last accessed: 15-01-2019

[88] Several large energy industry actors started to invest into PV projects in the recent years. (MVM, MET, Mátra PP, etc.). Source: MVM (2018): The MVM Group has delivered Hungary's largest solar power plant, 2018-11-26; <http://mvm.hu/uncategorized/the-mvm-group-has-delivered-hungarys-largest-solar-power-plant/?lang=en>, Last accessed: 15-01-2019

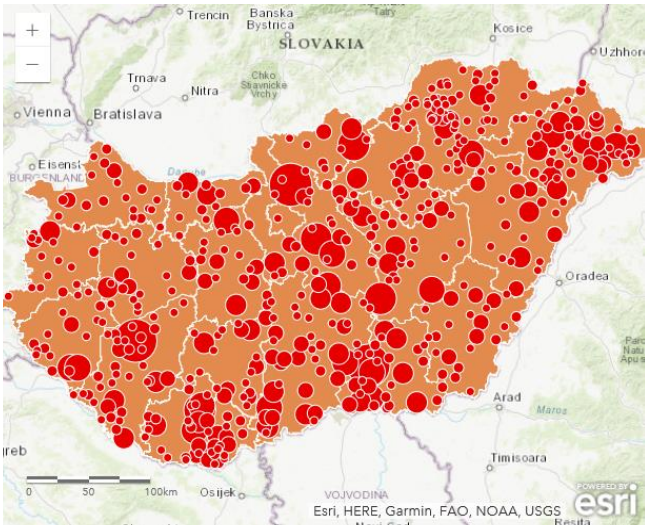


Figure 37. Published PV projects in Hungary (2018)

Source: energiaklub.hu[89] based on MEKH data

The highlighted issue shows that the promotion of the renewables requires a new set of competence for energy regulators as well. RES regulation has a limited regulatory history compared to the traditional rate making process (e.g., rate cases) and the RES itself is the growth phase (traditional fossil fuels are either in the maturity or the decline phase) of its lifecycle; therefore considerable regulatory knowledge (on RES certification, licensing and market monitoring) and human capital are still under development. The regulator must be prepared to give fast feedback of market information into the rulemaking process to prevent similar situations.[90] Respondents emphasized that they greatly appreciate it when the regulator consults with them (as stakeholders).

Under the Hungarian RES regimes (*Chapter 2.6*) the licensing requirements changed frequently. Statement *No. 34* indicates a market need for a more streamlined permission and licensing process. From the investors' point of view, simplicity, lead time and cost of licensing are the critical factors in that aspect. The permission and licensing procedure typically involves several main authorities (e.g., MKEH, MEKH, etc.) but if needed, as in the case of an environmental protection permission procedure, additional specialized authorities may be included.

[89] Source: Energia Klub (2018), the map was created by ArcGis; <https://energiaklub.hu/hirek/hol-epulnek-naperomuvek-magyarorszagon-interaktiv-terkep-4580>, Last accessed: 15-01-2019

[90] Other countries faced similar problems and 'energy bubbles'. For example, further PV promotion in the Czech Republic has stopped in 2013, due to the cost-efficiency considerations caused by the regulatory-driven PV boom. Additionally, retroactive taxation of RES electricity was introduced ('solar tax': 28% on revenues) (Wimmer, 2015).

Public presentations and the media mention 20 to 40 'authorities' in relation to the licensing procedures (Energiaklub, 2009). A typical PV project in Hungary requires 9 licenses for implementation and operation (figure 38).

Name of the permission		Type of the permission
Construction Permit	>	Establishment
Network Connection License	>	Establishment
Consolidated Small Power Plant License	>	Establishment
Power Production Cable Line Establishment License	>	Establishment
Power Plant Commissioning License	>	Commissioning
Network Access Permission	>	Commissioning
Operational Agreement	>	Commissioning
Balancing Group Agreement	>	Commissioning
Power Production Cable Line Operating License	>	Operational

Figure 38. Licenses required for PV construction and operation

Source: MKEH, author's compilation

To limit the time and cost of administrative procedures the number of involved authorities in the RES-based generation licensing should be reduced and similar to the national public utility model, where all services (electricity, NG, district heating) have a one-stop-shop, which would assist in obtaining all licenses needed. Good examples for one-stop-shop authorities are Denmark and Germany (Ropenus and Klinge Jacobsen, 2015).

The energy mix was a major consideration of the respondent group (*statement No. 25*) and they pointed out that while on the company level businesses may decide regarding their own mix, their choice is dependent on the technology preferred by the regulator and the financing opportunities. Governments may influence even liberalized energy markets into the continued investment in fossil fuel technologies while making low-carbon investment riskier (Owen, 2014). While the EU supports RES development, the member states have the right to define their own preferred energy mix and have the tools to support their goals. Statement *No.25* addresses the issue that the energy mix should be clearly defined in the governmental energy policy (NES). The NES of 2012 highlighted the RES-nuclear-coal energy mix and the Hungarian government communicated regarding in addition to the new RES a NG consumption decrease is preferred. However, in the case of electricity generation the respondents expected a strengthening position of NG along with a stagnation or decrease in the total energy usage mainly due to the energy efficiency initiatives.

Smith (2013) analyzed twenty-three projections of EU member states' natural gas demand and concluded that even in a pessimistic scenario gas demand is unlikely to rise before 2020, and may remain close to current levels up to 2030.

4.3 Cluster 3: Infrastructure development (technology, PR)

Figure 39 lists the statements (with rating and ranking) under the cluster label *'Infrastructure development (technology, PR)'* that was ranked 3rd among the clusters. The cluster is comprised of 11 statements (27.5%) of the total 40.

Original statement no.	Avg. Rating (1-5)	Statement ranking (1-40)	(…) statement (action)	Example of the trade-off behind the statement
22	3,71	4	Addressing the increased transmission network development needs	Large-scale RES developments provide scale efficiency but also require new connecting lines and transformers within the network (only in the case of biomass is it evident to use already existing ones - e.g., in the proximity of the close power plants).
8	3,64	6	Developing the large- and/or utility-scale energy storage options	Intermittent RES generation created high demand for storage solutions. While constructing a large-scale pumped-storage hydroelectricity is less realistic in Hungary, utility-scale storage solutions or other feasible technologies (e.g., power-to-gas) should be deployed.
23	3,55	8-9	Handling the risk of voltage level and quality fluctuations	The increasing proportion of the RES generation also means more nodes and quick start reserve capacities that are needed to handle fluctuations.
7	3,45	12-13	Improving cross-border connections and TSO mechanisms to balance the intermittent generation of RES on the regional level	In the past years both hydro plants in Serbia and intermittent PV/wind generation in South Hungary affected market efficiency and the TSOs incomes as both the Hungarian (MAVIR) and Serbian (Elektromreža Srbije) TSOs needed to reserve significant part of the respective cross-border capacity to be able to handle the voltage level and quality fluctuation.
27	3,43	14-15	Optimizing the current and the planned (MAVIR's 10 year plan) installed generation capacity	The renewables are affecting the energy supply security as 1) the sum of the base load power plant's installed generation capacity decreasing and further aging, plus 2) the need for quick start reserves are increasing.
16	3,19	20	Channeling investment (e.g., with capacity fees) to create a feasible amount of rapid start-up	Supporting RES also means that other, indispensable types of generations forms are losing competitiveness as without proper schemes investors

			(even black start) installed power generation capacity	prefer RES over other forms of power generation investments
21	2,90	28-29	Maintaining the existing, domestic industrial knowledge (knowledge management)	RES expansion creates a brain transfer within the industry which threatens the accumulated practical knowledge and the supply of subject matter experts (nuclear engineering) that would be needed in future projects (Paks 2)
28	2,90	28-29	Education of customers on RES technologies	The RES technologies are "game changer'-s and shake up the previously stable utility service; yet, residents are not aware why RES are important and how their everyday lives are affected (e.g., burning waste).
33	2,88	30-31	Raising end-consumers' awareness and level of information about the advantages of renewables and incentivizing them to install their own renewable generation capacity through a state program	Due to the large upfront costs household-sized RES developments are financed by wealthy customers, while other end-users with suitable property but low purchasing power have no means to take advantage of the technology.
24	2,74	35	Preventing the negative effect on quality of life and biodiversity	While RES do not contribute to global warming; several negative externalities can be identified regarding residents (e.g., whirring wind turbine blades) and wildlife mortality (e.g., bats, birds, insects). For instance 1) birds are avoiding the windmill turbines, therefore the population of rodents are increasing in the surrounding fields or 2) insect population reduction takes place as the polarized reflection on PV panels seems to occur in the place of reproduction for insects like the water surface.
20	2,67	38	Funds should also channeled to other forms of power generation investments	RES subsidies are decreasing the competitiveness of the conventional power plants; however, growing RES installed capacity increases the importance of the conventional sources through balancing. Overall, customers directly pay for the RES through the subsidies rather than through balancing services.

Figure 39. The statements (with rating and ranking) under the cluster label *'Infrastructure development (technology, PR)'*

Source: concept mapping, author's compilation

The EU target of creating a single, integrated European energy market became the driving force of the regional market coupling initiatives. These smaller-scale integrations ensure the preparation for the European Price Coupling and will ultimately lead to the creation of the European Internal Energy Market by standardizing the systems and promoting cooperation between the given countries. The first pioneer of these models was the CZ-SK-HU-RO Market Coupling and it was successfully launched on 19 November 2014, integrating the Czech, Slovak, Hungarian and Romanian day-ahead electricity markets and replacing it with the CZ-SK-HU Market Coupling.[91] Market coupling requires a close collaboration by the transmission system operators (TSOs)[92] of each country together with power exchanges[93] supported by national energy regulators[94] in order to develop and implement all necessary solutions that ensure technical and procedural compatibility with the target European solution[95], which is already implemented in other coupled European regions. The most recent development is the proposed launch of the DE-AT-PL-4M MC Project initiated by the respective regulatory authorities[96] on 21 December 2018. Overall, we expect that market coupling allows higher efficiency of trading and capacity allocation, which should lead to higher security of supply, higher liquidity and lower price volatility.

No. 28 reflects the education of customer, which is especially critical in the construction stage. RES developers need to consider the NIMBY (Not In My Back Yard) and the BANANA (Build Absolutely Nothing Anywhere Near Anything or Anyone) expectations (Hartung and Kiss, 2014, Brennan and Van Rensburg, 2016, Zaunbrecher and Ziefle, 2016). Ek and Persson (2014) determined five critical attributes that are important for higher acceptance:

i. type of landscape,
ii. type of ownership,
iii. the degree of local participation in the planning process,
iv. the choice to transfer revenue to the society in a pre-specified way and

[91]Source: <http://www.mavir.hu/documents/10262/199492726/20141911_PRess+Release_succesful+go-live.pdf/92fdcaff-1196-47af-947a-23077588ab55>; Last accessed: 15-01-2019

[92] CZ, SK, HU, RO electricity TSOs: ČEPS, SEPS, MAVIR and Transelectrica

[93] CZ, SK, HU, RO power exchanges: OTE, OKTE, HUPX and OPCOM

[94] CZ, SK, HU, RO power exchanges: ERÚ, ÚRSO, MEKH and ANRE

[95] Price Coupling of Regions (PCR) is the initiative of the European power exchanges, to develop a single price coupling solution to be used to calculate electricity prices across Europe, and allocate cross border capacity on a day-ahead basis. Source: <https://www.epexspot.com/en/market-coupling/pcr>, Last accessed: 15-01-2019

[96] The authorities are: ANRE (Romania), BnetzA (Germany), E-Control (Austria), ERU (Czech Republic), MEKH (Hungary), URE (Poland), URSO (Slovakia)

v. a monetary cost in terms of an additional electricity certificate fee.

Technology remains the key to achieve economies powered solely by alternative energy. The most optimistic scenarios found (Jacobson and Delucchi, 2011a, 2011b) that with today's technology energy generation is possible within 20-40 years for all types, from wind, water and solar resources, with a limited footprint (the solar footprint would reach 0.4 percent of the world's land and the wind footprint would consume another 0.6 percent to meet wind-turbine spacing requirement). As PV and wind energy remain the most dynamically growing industries (GWEC, 2016), they would require fundamental changes in land-use policy (Håkansson et al., 2005). Noise and bird collision problems also exist (Kikuchi, 2008; Kosenius and Ollikainen, 2012; Masden and Cook, 2016) and the damages should be accounted for in RES calculations. (*No.24.*)

As there are several bottlenecks both in the case of power grid (north-south interconnection) and natural gas pipeline system, forecasting remain crucial for optimization purposes (*No.7., No.27., No.16.).*

Forecasting components based on Bowersox et al. (2012):

- *Base demand* is the long-term average demand that has no seasonality, trend, cyclic or promotional components.
- *Seasonal component* is an annually recurring upward and downward movement in demand. Demand for electricity may peak in the winter or in the summer.
- *Trend component* is the long-range shift in periodic sales – new technologies – such as renewables that may increase the supplemental source's supply – e.g., natural gas.
- *Cyclic component* is periodic shifts in demand lasting more than a year. The demand for energy, for example, heavy industry is typically tied to this business cycle. After the 2008 financial crisis the natural gas demand of Hungary steadily declined until 2013, which affected infrastructure investments.

- *Promotional components* characterizes demand swings initiated by a firm's marketing activities, such as advertising, deals or promotions. After the promotion the sales usually declined in the case of energy commodities due to the inventory purchased (e.g., natural gas).
- *Irregular component* includes the random or unpredictable quantities that do not fit within the other categories. The goal is to minimize the magnitude of the random component by tracking and predicting the other components.

Source and route diversification opportunities should be considered (Canes and Norman, 1985). In an optimal case (assuming that European countries have enough cross-border capacities within the integrated market), the offset of the European (including) consumption can be met in different ways:

1) increasing indigenous production growth,
2) amplifying natural gas imports of non-Russian origin via the north and the south pipelines,
3) intensification of LNG imports and
4) cutting off of the consumption (e.g., larger reliance on power plants that are not using natural gas as a fuel).

The seasonality and the temporary inequalities could be balanced using storage capacities only in the case of natural gas (figure 40). As small-scale electricity storage developments started in Hungary, it is reasonable to suggest that temporary inequalities may be better addressed in the coming years regarding the power grid as well.

$$\boldsymbol{Consumption_{Europe}} = Production_{\mathrm{Europe}} + Import_{pipeline} + Import_{LNG} - Export +/- Changes\ in\ stocks$$

$$\boldsymbol{Import_{pipelines}} = Import_{Russia} + Import_{\mathrm{North\ Sea}} + Import_{Algeria} + Import_{other\ pipelines}$$

$$\boldsymbol{Import_{LNG}} = Import_{Qatar} + Import_{USA} + Import_{other\ LNG\ sources}$$

Figure 40. Natural gas consumption and import possibilities

Source: author's compilation

However, due to the inadequate cross-border capacities, countries with cross-border capacity bottlenecks (like Hungary) are paying a premium in high demand periods (e.g., winter peaks).[97] The crucial challenge is that in disadvantageous market conditions when the pipelines usage are pushed to the limits (for instance during a cold winter), the existing European cross-border capacities (Figure 41) will not be enough to transport the natural gas from the west-east and the north-south direction (Krzykowski and Krzykowska, 2017).

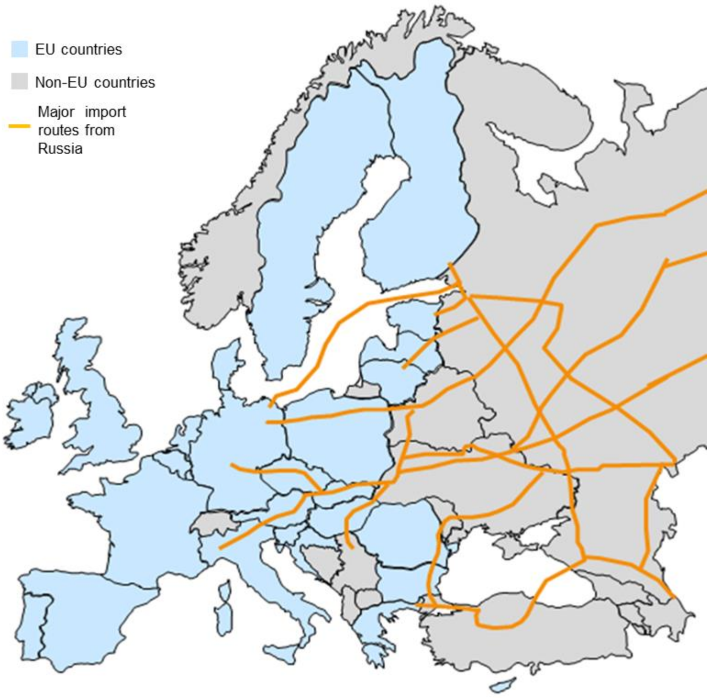


Figure 41. Major natural gas import routes from Russia

Source: EC, author's edit

An additional challenge is that procurement costs differ greatly (Coop, 2006) and without an integrated European cost sharing mechanism, the economic burden of the more expensive alternate sources would hit the Central Eastern and the Southeastern countries, which were the most vulnerable in 2009 as well. While the infrastructure is more developed and the integration of the European market is at a considerably higher level than ever before, during a cold winter period, the lack of a Russian source can still cause anomalies in the system (Talus, 2007).

[97] NG prices in traded markets asserted to be more volatile compared to crude oil (Alterman, 2012).

4.4 Cluster 4: Network optimization (network operation, resource management)

Figure 42 lists the statements (with rating and ranking) under the cluster label *'Network optimization (network operation, resource management)'* that was ranked 4th among the clusters. The cluster is comprised of 9 statements (22.5%) of the total 40.

Original statement no.	Avg. Rating (1-5)	Statement ranking (1-40)	(...) statement (action)	Example of the trade-off behind the statement
15	3,69	5	Addressing the increased distribution network development needs and preparing to manage the changing physical energy flow	Investors are financing the small-sized RES power plants but these developments create an investment strain on the DSO side as well (connections, transformers).
39	3,52	10	Incentivizing system operators (DSO) to streamline their processes to integrate more RES generation capacities into their network	While from the investor side many RES developments were initiated, the approval and integration process - including the status of the DSO connections - are slower than expected.
40	3,50	11	Eliminating the discriminative renewable subsidy lawmaking	RES expansion addressed the direct, visible and controlled environmental concerns (e.g., GHG emissions) but raised unforeseen, uncontrolled environmental concerns (e.g., wind turbines add to the global warming), and ultimately resulted in a targeted, discriminative RES lawmaking (e.g., a practical ban of Hungarian wind developments).
17	2,95	23-25	Ensuring European and global trends are followed	RES technologies are improving fast and new innovations penetrate the European energy market within years (previously the speed of change was not years but decades).
19	2,95	23-25	Identifying and mitigating the resource constraints	While RES developments do not rely on fossil fuels, they could face resource constraints: e.g., water use in the case of PV, CSP plants could be an issue in the coming decade in the south and south-east (dryer climate) of Hungary
9	2,93	26-27	Minimizing environmental damages by preferring brown-field investments (e.g., developing PV farms at closed power plants or mine sites)	While RES construction is perceived as environment friendly, damages are present when green-field renewables sites are developed: enormous land, new roads, lines, water supply, etc., are required

32	2,86	32	Preparation of the system operators to handle the effect of detachments	While scale efficiency promotes a centralized grid; RES expansion allows users to opt for further grid decentralization and with proper storage solution, a detachment from the grid.
10	2,83	33	Eliminating cross-subsidies in the electricity and the district heating service and finding synergies (biomass power stations for district heating)	Current Hungarian energy strategy treats geothermal as a preferred RES; however, currently there is an inaccessibility of acceptable geothermal sources for power generation in Hungary (pilot projects exist but were not successful, as of yet), but due to the incentives the relatively expensive geothermal sources have gained popularity in district heating.
26	2,79	34	Addressing the conversion loss during the generation process	Despite the intermittent generation feature, RES is perceived as a highly efficient generation solutions; yet conversion loss is still high: in the case of PVs: sunlight to direct current (~84%) and direct current to alternate current (~10%)

Figure 42. The statements (with rating and ranking) under the cluster label '*Network optimization (network operation, resource management)*'

Source: concept mapping, author's compilation

To successfully integrate sufficient intermittent RES (e.g., PV, wind) resources, the regulation has to find the balance of the risk exposure. Risk exposure itself is only an approach (for example, it is the highest in the UK and lowest in Germany and both countries renewables market are well-functioning); however, from a policy maker's perspective, there is a trade-off between "high risk" and "low risk". When innovation, flexibility and more opportunities for newcomers are present, then it translates into an expected increase of the current low risk environment. On the other hand the regulator should prevent the market from reaching a very high risk factor, as it may force market players to demand a much higher return, which would be disadvantageous in the current economic situation.

The grid system forecasts are essential to maintain reliable power services, since electricity storage options are very limited and the availability for the renewables are periodical and yet not aligned with the demand patterns. The improvement of the forecasting processes is a permanently a top priority for the TSOs.[98] Models have become more sophisticated in the past years and include more input factors than ever before; however the application of intelligent (learning), modern mathematical models are still dropping behind. While economic-engineering models started to keep up with the improved data obtaining processes, renewables (wind or PV) planning and operation remain to have a more frequent data supply need in long-term weather conditions. Optimization efforts could address RES –developments on the asset (e.g. wind turbine) or on the aggregate (e.g. wind farm) levels (Kusiak and Zheng, 2010). Reliable power service requires predictability and grid/pipeline flexibility. Besides variability handling routines (capacity, storage, etc.), energy supply chains also face risks from events beyond normal levels of variability in the short term (e.g., weather anomalies), medium term (e.g., currency crises when importing primer energy sources) or long term (e.g., technological breakthroughs like shale gas production, PV expansion, etc.). Some of these are predictable surprises that should have been anticipated, prioritized and responded to (but were not) by the stakeholders[99] (Hopp, 2011). It is anticipated that energy needs and energy production/generation is fluctuating with the weather. In the case of electricity the added variability and limited storage options require smart integration to manage the output to the grid, which should promote a supportive regulation. Besides the application of legacy standards and the available voluntary demand restriction resources (e.g., real-time emergency generation resources, real time demand response assets), more obligatory restrictive rules (with proper compensation options) are also needed to manage risks. The RES integration has already revealed several challenges:

1) The ongoing change impacts substantially both existing market players (including the large incumbents) and new entrants in the short and medium term as well. Long-term investment decisions can be challenging

[98] Refer to the TSOs 10-year development plans. The many types and sizes of power plants can be broadly grouped into central-station, local, or dispersed applications. Installing more renewables means more pressure on grids; nonetheless, with a well-selected generation mix, the gravity can be minimized.

[99] If a contingency plan would have been prepared and executed then the events could have been handled in the most effective, proactive contingency planning way rather than a reactive crisis management way. Bazerman and Watkins (2004) classify the Enron collapse and even the 2003 blackout of the northeastern U.S. as predictable surprises. The argument follows: 1) sufficient information existed to anticipate the events and 2) consequences were substantial enough to warrant developing a contingency plan.

particularly, as the regional prices are most likely going to differ after the integration from the current ones.

2) The location of capacities (especially the renewable ones) requires additional grid development projects, which causes congestion at present. Under current network management methods this factor can be challenging to properly taken into account, and we expect that the problem will exist at least until the internal energy market is completed with a more developed capacity planning process. Insufficient network capacity and the congestion could create new flow patterns (Neuhoff et al., 2015).
3) The subsidy mechanism of the renewables (feed-in tariffs, green certificates, etc.) in a given country – such as Germany – may have a long-lasting effect on smaller markets (e.g., Central European countries). The political support of one technology (e.g., large scale wind or solar) may prompt investors to delay much needed investments into other capacities.

Statement *No. 40* and *No. 10* refer to discriminative renewable regulatory practices (subsidies, cross-subsidies). The pricing of the technologies highly depends on the market conditions. Gaining favor from governments remains key in the expansion / exchanging of a particular technology:

- After the World War II, nuclear power was promoted by governments due to the expectation for economic growth coming from urbanization and greater electrification (Phillips, 1993). The support allowed utility companies to include the capital cost of the nuclear developments in the rate base, which means that ultimately consumers are bearing the risk while investment amortization was ensured. Deregulated energy markets introduced competition in the case of generators and risk shifted back from customers to companies and its shareholders.
- State subsidies are still major issues in the EU[100] due its economic (e.g., supply security) and social considerations (e.g., re-employment issues). Subsidization of coal (so called 'szénfillér') totals €74 million in Hungary as well, which aims to prevent losses coming from the industry restructuring but ultimately sponsors company losses (Whitley et al., 2017).

[100] Mainly Czechia, France, Germany, Greece, Hungary, Italy, Netherlands, Poland, Spain, United Kingdom

- Most of the rapidly evolving RES technologies still rely on subsidy mechanisms (Chapter 3) that should be taken into account when system development and the optimal energy mix is assessed.

Finally addressing the conversion loss during the generation process (*No. 26*) is crucial both in the case of generation and network operation. The regulatory authority has the authority to set minimum efficiency standards for new generation units entering the market. Before July 2011, the Hungarian regulation required a 75% minimum joint efficiency in fuel conversion for cogenerating units to become eligible for KÁT support. On the other hand legislation could define parameters that actually is impossible to meet, such as in most of the cases of new wind developments (Chapter 2.6.). The transportation of energy also leads to losses (at the distribution level it might account for 10-20 percent), accordingly regulators should incentivize network operators (primarily distribution network operators) to be engaged in loss reduction (via commercial, maintenance and investment actions). The regulator should set well-justified network loss expectations based on benchmarking, which allows the network operator to earn part of the savings from loss reduction.

4.5 Cluster 5: Social aspects (stakeholder impact)

Figure 43 lists the statements (with rating and ranking) under the cluster label *'Social aspects (stakeholder impact)'* that was ranked 5th among clusters. The cluster is comprised of 4 statements (10%) of the total 40.

Original statement no.	Avg. Rating (1-5)	Statement ranking (1-40)	(…) statement (action)	Example of the trade-off behind the statement
29	3,55	8-9	More transparent, market-based tariff scheme is needed (a social tariff could be incorporated for "protected customers"	As residential energy prices diverted from market prices, the return on investment on RES technology has become less transparent and a longer payback period characterizes the majority of the RES investments even when market conditions would be advantageous for them (e.g., high electricity prices).

34	3,00	22	State funds to promote utility-scale RES programs	The solar boom helped developers to secure bank financing for mid-sized utility-scale renewable power plants; however, as the fund depleted very fast (several banks have run out of their Hungarian renewables budget), new constructions may slow down.
2	2,43	39	Developing social awareness towards renewables with transparent communication	Deployed RES solutions (e.g., large wind turbines) and the related infrastructure developments (e.g., new power lines) can raise public opposition. Renewables may create visual intrusion on the landscape that may trigger a "not in my backyard" (NIMBY), "build absolutely nothing anywhere near anyone" BANANA attitude with concerned, affected residents.
1	2,05	40	Addressing employment issues (such as mitigating the negative effect on the existing jobs in the energy and related industries)	RES requires different skills than the conventional power plants, which can result in unemployment and increased re-training needs. For instance affected jobs include the workers at Vértes Power Plant and Mátra Power Plant (e.g., coal miners).

Figure 43. The statements (with rating and ranking) under the cluster label *'Social aspects (stakeholder impact)'*

Source: concept mapping, author's compilation

In Cluster 5 the smallest from the five and its most important statement is *No. 29*, which suggested a more transparent, market-based tariff scheme. The Hungarian government sees this as one of its priorities in order to maintain affordable price levels that are predictable for citizens even at the 'cost' of diverting residential energy prices from market prices. When residential energy prices are lower and the industry is not compensated directly for the loss, the return on investment of RES developments becomes less transparent and investors are calculating with a longer payback period even when market conditions would be advantageous for them (e.g., high electricity prices). Additionally, subsidized energy prices are influencing residential energy conservations decisions and result in the wasteful use of energy resources. At the end, separate tariffs (that applies to vulnerable, 'protected' customer tariffs and electricity from RES as well) and support schemes (*No. 34*) should be applied for public service obligations.

Statement *No. 1* was ranked the lowest by the respondents regardless that the traditional Hungarian energy industry has faced large job losses in certain parts of the value chain. Coal production and generation were hit the hardest after 1989 and currently only one coal-fired power plant is operational (Mátra PP). One of the reason why coal-based generation was included into the National Energy Strategy in 2012 was to save the existing jobs and to prevent another depressed area in Northern Hungary. Nevertheless, there was a consensus within the respondent group that unemployment and retraining needs are currently less crucial. The reasoning mentioned several elements:

i. the formulation of the energy strategy of 2012 started in 2010, just when the 2008 financial crisis, and the decision makers aimed to prevent the deepening of its distress. However, by 2019 the global and the Hungarian economy is in a growth period therefore unemployment is not as pressing as it was around 2010.

ii. While existing jobs may be lost due to the RES expansion, new ones are created, especially in the labor intensive manufacturing but the operation and maintenance require new workers but at a much smaller magnitude. Additionally, most new jobs will generally be created at different geographic locations, as RES developments are not concentrated solely on one central location. An upside though is that brown-field (e.g., recultivation) sites are an ideal placement for PV plants from an environmental standpoint as it utilizes areas that were not used for agriculture or forestry.

iii. Regardless of the market innovations the remaining coal-fired PP plant is close to the end of its life-cycle and significant investments are needed to renew the outdated technology, to maintain continuous fuel supply and to comply with the stricter standards (e.g., Carbon Capture and Storage solutions).

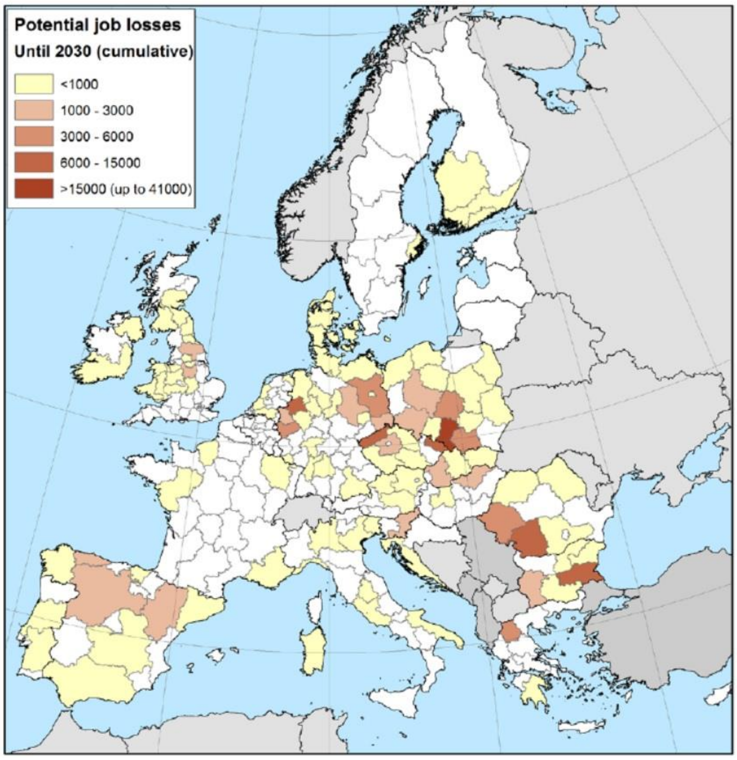


Figure 44. Potential job losses until 2030 in the European coal industry

Source: EC JRC (2018)

EC JRC (2018) forecasted that by 2030 both the remaining workers of the Vértes PP (currently this site is under recultivation) and the Mátra PP employees will not work in the coal industry (figure 44).

4.6 RES and nuclear: any trade-offs?

As indicated in Chapter 2.6 nuclear power plays a key role in the Hungarian power generation portfolio. Currently one nuclear power plant is in operation with four VVER-440 units (Paks NPP) that have been operating since the 1980s.[101] Due to the lifetime extension projects all four units were granted a license-extension for 20 additional years; thus, the units are planned to be decommissioned between 2032 and 2037. As nuclear power plant construction is a tremendously lengthy process, the debates over the replacement of units started at the end of 2000s. In 2009, the Hungarian Parliament passed a decree[102] on the construction of the new units. In

[101] The blocks started commercial operation between 1982-1987. <http://www.atomeromu.hu/en/Lapok/default.aspx >; Last accessed: 15-01-2019

[102] 25/2009. (IV. 2.) Parliament resolution (‘*OGY határozat*’)

2014, the Hungarian government signed an intergovernmental agreement[103] with Russia. The agreement defines two new blocks at Paks with a total capacity of 2,400 megawatts (MW) to be constructed by Rosatom with an estimated cost of EUR 12.5 billion and of which 80% would be financed via Russian credit.

Nuclear power plant development is a tricky topic as nuclear related studies are strongly influenced by sponsors (Figure 45). Stakeholder perception is even more critical than in the case of fossil fuels or renewables.

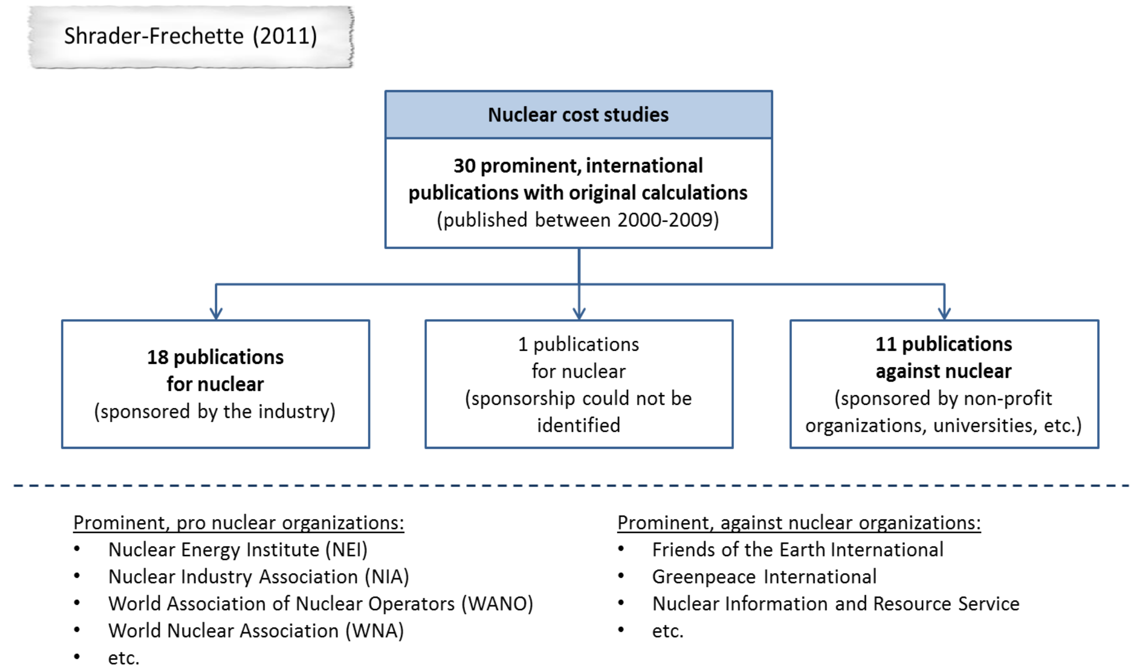


Figure 45. Examined nuclear cost studies by Shrader-Frechette (2011)

Source: Shrader-Frechette (2011), author's compilation

While the assessment regarding the Paks 2 project is outside the scope of the research, nevertheless, nuclear generation is currently the largest source of electricity in Hungary. Excluding and abandoning nuclear power from the generation mix can also upset prices and change the energy mix towards increasing CO_2 emissions (due to the growth of coal-based generation output), as currently renewables cannot replace traditional base load generation forms completely. On the other hand nuclear power requires a long term commitment, which may be not be beneficial when technologies are rapidly changing. Once again we refer back to the example of wind

[103] Source: Paks 2: Contracts signed on the implementation of new reactor units at the Paks Nuclear Power Plant; <http://www.paks2.hu/en/media/lapok/Details.aspx?NewsID=34>; Last accessed: 15-01-2019

turbine efficiency and how technologies older than 5 years are already obsolete. And PV manufacturing follows the same trend.

Neverthless, the 2013 Hinkley Point C[104] and Paks 2 decisions[105] rather show a turn in EU's approach towards power purchasing agreement (PPA)-kind of structures (Manuel, 1996; Nam et al., 2006; Hauteclocque and Glachant, 2009). A power purchasing agreement (PPA) is a bilateral legal contract between (a) the seller, who generates the electricity and the buyer, who is looking to purchase electricity. The conditions and terms of the contract are defined by both parties and can include other parties. The seller type in the case of the traditional PPAs are large power plants (e.g., coal, nuclear, etc.), but also included are large renewable generation plants (e.g., hydro, tidal power generation). The buyers are typically utility companies or large end customers. In the case of the electricity sector the LTCs (long-term PPAs) the main goal is to prevent blackouts and meet with the expectation of continuous supply and environmental sustainability.

The Hinkley Point C structure is something like a feed-in tariff ensuring that the Hinkley Point nuclear plant operator would get stable revenue (like the Hungarian generators did through the PPA-capacity fee) for a period of 35 years despite the expected volatility of the wholesale electricity market price; thus shielding the plant operator from market effects through a long-term contract to this effect. This will be granted through the so-called "contract for difference" ("CfD") structure, meaning that when the market price of the electricity is lower than the strike price established, the state will pay the difference between and the market price and the strike price. Conversely, when the market price is higher than the strike price, the power plant operator will be obliged to pay the difference to the state, meaning that the plant operator will ultimately receive in either case a fixed level of revenue benefitting from a state guarantee covering the debt of the operator in funding the construction of the plant itself.[106]

PPAs are applicable in the case of RES generators as well. However, the expansion of renewables promoted several changes: for instance many of the renewable PPAs

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[104] SA.34947 Support to Hinkley Point C Nuclear Power Station, Brussels, 18.12.2013 C(2013) 9073 final

[105] Source: EC press release, March 6, 2017; <http://europa.eu/rapid/press-release_IP-17-464_en.htm>; Last accessed: 15-01-2019

[106] For a deatiled discussion on Long term contract (LTC) and PPAs, their pros and cons, 2008 termination of the Hungarian PPAs and their effect see Herczeg (2015b).

(e.g., solar) are not standardized due to the diversity of the contracting parties and the parameter (e.g., location, installed technology) differences.

RES expansion is providing an advantageous market environment for natural gas power plants as they could provide flexibility with a relatively low CAPEX; however, for base load generators – such as nuclear power plants – the effect is the opposite. As the price of electricity fell significantly since 2008, nuclear reactors faced substantial financial difficulties. 2/3 of the U.S. 102 GW nuclear capacity is unprofitable, and 1/5 of them is likely to retire early (Haratyk, 2017).

The nuclear industry faced similar pressures before: when in 1973 and 1984 the increase in the price of oil from near $4.00 per barrel to over $30.00 per barrel made utilities change their energy generation dependency on imported oil. Taking an example of a smaller utility: in the given period 92% of The United Illuminating Company (UI)'s [107] energy was generated in power plants that relied on import oil, but by 1985 that was cut by half with the conversion to coal and receipt of hydro-power from Hydro-Quebec (Fassett, 1991). That period was a great example of how rapid changes negatively effect given segments, such as nuclear power. The construction of Seabrook Station (which was originally owned by more than ten separate utility companies serving five New England states) was triggered by the oil crisis. However - due to regulatory issues, protests by the public and poor construction management - the plant was completed ten years later than expected, with serious cost overruns.[108]

In the 2000s the energy industry stakeholders (including policymakers, utility executives and construction companies) expected that the clean energy future will be powered by a new generation of cheap, safe nuclear reactors (Gutierrez and Polonsky, 2007). The expansion of the existing nuclear plants in South Carolina and Georgia were on track, and which were described as the start of the 'nuclear renaissance'. The political change (change in laws and regulations, Fukushima costs) and the economic environment (cybersecurity, physical security upgrades) triggered

[107] The United Illuminating Company (UI) is a regional electric distribution company in Connecticut, USA. Since December 2015 UI became a subsidiary of AVANGRID, Inc. (formerly Iberdola USA).
[108] Regarding the cost approaching $7 billion the Nuclear Regulatory Commission (NRC) found the regulatory and decision making processes fragmented and uncoordinated. Before completion, in 1988 the project caused the bankruptcy of Seabrook's major utility owner, Public Service Company of New Hampshire (Kaen and Tehranian, 1990).

the decision to abandon construction of the two new V.C. Summer Nuclear Station Westinghouse AP-1000 units[109], effective July 31, 2017. The units owners (SCE&G and Santee Cooper) have evaluated future options that were: (1) continue with construction of both units, (2) focus on construction of one unit and delay construction of the other, (3) continue with construction of one unit and abandon the other, and seek recovery of the costs of the abandoned unit under the Base Load Review Act (BLRA). However, they failed to get a federal grant totaling at least $1 billion and as much as $3 billion from the Trump administration[110]

As the government of Hungary engages to construct Paks 2, the decision makers need to consider that until the nuclear plant is not connected to the grid, all investments may end up as sunk costs if licensing and project management issues hinder the construction. Decommissioning a nuclear plant is also expensive, Giacchino and Lesser (2011) estimated its costs $300-$500 million per plant. Therefore, if Paks 2 project is moving forward, the current Hungarian nuclear decommissioning fund (KNPA) should be extended significantly to collect sufficient funds by the end of the plant's lifecycle or when its operating license expires, so no additional amount would be required from ratepayers or taxpayers. Additionally, there is a risk that in the case of cost overruns, future possible Paks 2 financial contributions to the KNPA could be used up ahead of time of the decommissioning of Paks 1.

[109] Under the Base Load Review Act (BLRA) the project plan was approved in the 2008 proceeding with a cost forecast of $6.3 billion. That amount represented South Carolina Electric & Gas Company's (SCE&G) 55 percent share of the costs in future dollars. The utility negotiated with the Westinghouse Consortium to make approximately 52 percent of the costs of the construction contract fixed, but inflation or escalation was applied. After Fukushima, in 2011, a new agreement was reached with Westinghouse to fix approximately 67 percent of the costs of the units. In 2015 a further option with Westinghouse was negotiated to fix 100 percent of the unit cots at an estimate of approximately $7.7 billion and got Commission approval as well. On March 29, 2017, Westinghouse field bankruptcy for the stated purpose of separating the nuclear construction businesses from the losses it would have to incur in fulfilling fixed-price commitments it made to SCE&G and to the Southern Company for its Vogtle project. Bankruptcy allows Westinghouse to reject these commitments.

[110] 8/1/2017 South Carolina Public Service Commission hearing, Columbia, SC (Proceeding #17-11621)

5. Case study: the creation of the national utility and the consequences of the RES market

5.1 Case study approach

During our discussion with the participants one-on-one and during the group session as well, several major topics were mentioned in different contexts and we found after the evaluation sessions that some of the related concerns were present across clusters. This was related to the creation of a centralized national utility company (ENKSZ/NKM), which is currently merging into the MVM Group. MVM with the assets of NKM is now present in all segments of the electricity value chain and further strengthened its position in the natural gas and the district heating markets.

We used the case study approach to describe NKM (national public utility service provider) and its background. Through the case study methodology interesting, unusual or particularly revealing set of circumstances can be shown, and the history of companies following the ENKSZ > NKM > MVM line provides exactly that.[111] If the case selection would have been based on representativeness the particular insights could be overlooked. This research method involves an up-close, detailed examination of the subject of study, the case, clarifies the history (foundation of ENKSZ and the transition to NKM then to MVM) and the related contextual conditions. The case offers a unique chance to shed light on the turbulent Hungarian energy market and demonstrates its potential effect on RES expansion and on the trade-offs discussed in Chapter 4 and 5. Additionally, the case study demonstrates how the government-influenced strategy and regulatory framework could shake the Hungarian energy markets, which is also applicable for RES developments as well.

5.2 Background

While the national utility provider was established only in February 2015, its short history is already full with twist and turns. In 2019, most likely it will merge into MVM, into the company where it is all started from. The history of the past five years is essential to provide a indication of the Hungarian regulatory environment and the surrounding environment of the RES developments.

[111] Johansson (2003) gives an excellent summary of the case study method.

5.2.1 Beginnings

When overhead costs are rapidly rising (‘rezsi’) then they immediately become a main focus of governments. As developing countries with less purchasing power, the energy costs are especially critical issues, which results in governments subsidies. Due to the large burden placed on the Hungarian central budget the natural gas subsidy system was restructured after the 2008 financial crisis. Regardless, after the 2010 election the government introduced rate freezes and then other regulatory measures to prevent price increases. In 2013, electricity, gas, and district heating costs were cut in three rounds (by 10 percent on January 1, 2013, an additional 10% on November 1, 2013, and between 3.3% and 6.5% in 2014.[112] The household energy price cuts proved to be politically very popular; therefore there were cuts in other utility segments as well (water industry) and in the case of garbage removal and chimney inspection fees, too.

At the time the Hungarian government planned to nationalize the oldest gas supplier in Hungary (FŐGÁZ) and the capital’s water works company (Fővárosi Vízművek) and turn them into non-profits.

With the restructuring of the regulatory environment and the state-owned Hungarian Electricity Works (MVM) entering the natural gas market in 2011, MVM became a dominant player on September 30, 2013 when they acquired the natural gas storage and natural gas wholesale companies of E.ON in Hungary, and thus the Hungarian Gas Storage Ltd.[113] (MFGT, previously E.ON Földgáz Storage Zrt.[114]) and the Hungarian Gas Trade Ltd.[115] (MFGK, previously E.ON Földgáz Trade Zrt.) were established.

Continuing the expansion and fulfilling the Hungarian government’s intention MVM signed a contract on December 18, 2013 to purchase Germany-based RWE Gas International’s 49.83% stake in FŐGÁZ for HUF 41 billion.[116] FŐGÁZ is one of the

[112] The price of natural gas was cut by 6.5 percent from 1st April, 2014, electricity by 5.7 percent from 1st September, 2014 and district heating by 3.3 percent from 1st October, 2014.

[113] MFGT has 4 facilities (Zsana, Hajdúszoboszló, Pusztaederics, Kardoskút) in Hungary with a total annual working gas storage capacity of 4.43 billion cubic meters.

[114] The Hungarian Government signed an agreement with E.ON AG in which the German company offers pre-emption rights if the E.ON Földgáz Storage shares are offered for sale (Mihályi, 2015).

[115] MFGK is the Hungarian party in the long term Russian natural gas supply contract.

[116] 14/2014. (I.29.) Government decree (‘*Korm. rendelet’*) declared the transaction of ‘national strategic importance’

dominant players in the domestic market and the company's distribution system consists of the natural gas pipeline system of Budapest and some of the capital's suburbs.

In August 2014 the Government announced the necessary measures for a holding-based public service system[117] and the forming of a national public utility provider.[118]

On December 13, 2014 the Budapest Municipal Council's 50%-plus-one-share stake in regional gas-distributor FŐGÁZ[119] was purchased by the MFB Group[120]. In 2015, all the shares were consolidated under MFB[121] and MVM was not among the shareholders anymore. With a just recently passed law enacted in the 2014[122], by the end of 2015 MFB was able to buy out the small shareholders (~0,17% of the shares) and became the 100% owner of FŐGÁZ Zrt.

5.2.2 Establishment of the integrated national public utility

'ENKSZ Első Nemzeti Közműszolgáltató Zrt.' (ENKSZ) was established on February 13, 2015[123] to oversee and expand FŐGÁZ operations and to become the holding to enter into the electricity and the district heating utility business.[124] ENKSZ was formed based on MVM's human capital[125]. At the time ENKSZ did not have ownership in FŐGÁZ but was the representative of the MFB and exercised voting rights and managed the asset based on contractual agreement ('quasi' operated as a holding).[126]

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[117] 1465/2014. (VIII. 15.) Government resolution ('*Korm. határozat'*)

[118] 1484/2014. (VIII. 27.) Government resolution ('*Korm. határozat'*)

[119] 1545/2014. (IX. 29.) Government resolution ('*Korm. határozat'*)

[120] At the closing of the transactions the MFB Zrt. owned 81.6% + 1 shares, while thr MFB Invest Zrt. (MFB Invest Zrt. is a fully owned subsidiary of MFB Zrt.) owned 18.23% of the shares.

[121] 1586/2014. (X. 21.) Government resolution ('*Korm. határozat'*)

[122] Act of 2009 CXXII. was amended on 14 December 2014. The amendment created the possibility to mandatory buy out the minority shareholders of the state controlled entities – at the time for example MVM, Vértes Power Plant, Paks Nucklear Power Plant.

[123] 1027/2015. (I. 29.) Government resolution ('*Korm. határozat'*)

[124] 1545/2014. (IX. 29.) Government resolution ('*Korm. határozat'*), 7/2015. (II. 18.) Ministry of National Development resolution (*'NFM rendelet'*), 1568/2015. (IX. 4.) Government resolution ('*Korm. határozat'*)

[125] The first CEO of ENKSZ was appointed from MVM, where - before arriving to ENKSZ - he was a (co-)CEO responsible for the natural gas operations.

[126] On 16 April 2015, MFB Zrt. and MFB Invest Zrt. entered into a voting agreement with ENKSZ in respect of Főgáz Zrt. Based on the agreement, ENKSZ Zrt. exercised voting rights and asset management related to the 100% shareholding in MFB Zrt. Source: ENKSZ Zrt. 2015 Annual Report

On April 1, 2015 the FŐGÁZ received a natural gas universal service license for the whole territory of Hungary, which triggered a complete consolidation of the universal service portfolios. Besides the original 800,000 customers at FŐGÁZ, the company acquired on 1st August 2015 60,000 customers from Magyar Telekom and on 29th September 2015 from the GDF SUEZ[127] natural gas universal service portfolio in Hungary[128]. After the remaining natural gas universal service providers indicated their wish to pass their respective licenses, the resolutions of the Hungarian regulatory authority (MEKH) appointed FŐGÁZ to take over both E.ON's (1st January 2016) and ENI's (1st October 2016) universal service portfolio in Hungary. Therefore FŐGÁZ became responsible for supplying approximately 3,400,000 universal service customers.

In 2015 H2, the negotiations with the German majority shareholders (RWE, ENBW) of ELMŰ Plc. and ÉMÁSZ Plc. were intensified. By December 2015, the parties agreed on the planned transactions parameters, bounded to the owners' approval. For the purpose of the transaction, ELMŰ and ÉMÁSZ united their respective universal service portfolio into 'ELMŰ-ÉMÁSZ Energiaszolgáltató Zrt.' and ENKSZ established a subsidiary, the 'ENKSZ Északi Áramhálózati Vagyonkezelő Zrt.' (ENKSZ ÉÁV) on December 16, 2015 which was registered on the next day.[129] On December 21, 2015, the General Meetings of ELMŰ and ÉMÁSZ approved the sale. However, the Hungarian State unexpectedly halted the transaction indefinitely.

In 2015, ENKSZ was selected to prepare the state to enter the district heating service market. The company was responsible for carrying out the District Heating Audit Project[130]. In 2016, the assessment of the largest Hungarian district heating operators was finished based on their operating model, including the areas of property, finance, engineering-technological, regulatory and cost-efficiency. In 2016 H1, ENKSZ entered into negotiations with the City of Hódmezővásárhely and the City of Szeged[131] for the purchase of the cities' district heating service providers. Due diligence was carried out but no purchase was agreed on.

[127] GDF SUEZ is rebranded as ENGIE on 24th April 2015.
[128] GDF SUEZ Energia Magyarország Zrt. (GSEM) was renamed to ENKSZ Észak-Dél Regionális Földgázszolgáltató Zrt., then merged into FŐGÁZ on 30th December 2016.
[129] ENKSZ ÉÁV 2015 Annual report
[130] 1794/2015. (XI. 10.) Government resolution ('*Korm. határozat*')
[131] Source: <https://www.nemzetikozmuvek.hu/Hirek/2016/05-06>; Last accessed: 15-01-2019

On December 7, 2015, ENKSZ signed a share purchase agreement (SPA) with MFB Zrt. for the purchase of 'MFB Földgázkereskedő Zrt.' (MFBF)[132]. Following regulatory approval,[133] the transaction was closed on February 19, 2016. On April 5, 2016, due to the respective regulations, MEKH withdrew the restricted natural gas trading license of MFBF.[134]

5.2.3 From a public utility towards a 'home solution provider'

Political changes triggered the modification of the managements of NKM and MVM. Once again, MVM stepped in to provide the financial basis for further expansion. With the capital injection[135] and with the parent company lending MVM, ENKSZ completed its acquisition of EDF DÉMÁSZ[136], a regional electricity distributor, from France's EDF International on January 31, 2017. The MFB approved its shares into ENKSZ.[137] To facilitate the process, the government declared these transactions of 'national strategic importance' as well. The ownership structure of NKM is 100% state-owned and at the time the owners were: 50%: MVM[138], 44%: MFB, 6%: Hungarian State.[139] With the transaction NKM increased its activity in the district heating segment and through its subsidiaries NKM became the minority owner of one of the largest district heating service provider.[140]

Démász received the national universal service provider license from MEKH, which gives the company access to all residential customers from June 1, 2017. Magyar Telekom left the Hungarian electricity market on October 31, 2017 and on November 1, 2017 the majority of customers previously contracted by Magyar Telekom have become the customers of NKM.[141]

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132 MFBF was established by MFB with natural gas trading as its main activity. MFBF was registered on September 2, 2014 and received its restricted natural gas trading license on November 3, 2014. Source: MFBF 2016 Annual report

133 195/2016 MEKH resolution ('*MEKH határozat*')

134; MFBF 2016 Annual Report

135 455/2016. (XII. 19.) Government decree ('*Korm. rendelet*')

136 434/2016. (XII. 15.) Government decree ('*Korm. rendelet*')

137 146/2017. (VI. 12.) Government decree ('*Korm. rendelet*')

138 Both MVM and MFB are 100% state-owned.

139 1342/2016. (VII. 5.) Government decree Government decree ('*Korm. rendelet*')

140 A local district heating provider's (KECSKEMÉTI TERMOSTAR Hőszolgáltató Kft.) share (34.09%) was owned through NKM Áramszolgáltató Zrt. (former DÉMÁSZ Zrt.), while the share (51%) of a heating plant in Budapest (Zugló-Therm Energiaszolgáltató Kft) was owned through NKM Földgázszolgáltaót Zrt. (former FŐGÁZ Zrt.).

141 Source: <https://www.nemzetikozmuvek.hu/Hirek/2017/10-31>, Last accessed: 15-01-2019

In Q3 2017, ENKSZ adopted the strategy of the ‘home service provider’ and just after 2 years a re-branding took place and it continued its operation under the new name of NKM National Utilities. As part of the new strategy several changes took place.

- Goals were defined for MFBF: as a first step it was sold to ENKSZ ÉÁV on March, 2017, then on April 5, 2017, the name of the company was changed to ‘NKM Plusz Zrt.’[142] The scope of the activity has been defined as the sale of third party services (e.g., insurance, financial products) and the organization and management of NKM Group loyalty programs (with a special focus on residential customers). Practically the company forwarded NKM partners’ business offers to end users.
- On 5 July 2017, the name of the ENKSZ ÉÁV was changed to ‘NKM Optimum Zrt.’ This subsidiary is responsible for the development, marketing and lifecycle management of the non-core activities of the NKM Group (electricity, NG, DH sales and network services).[143]
- Former ‘FŐGÁZ CNG Kft.’ was rebranded to ‘NKM Mobilitás Kft.’[144] and became a 100% subsidiary of NKM Optimum Zrt. Originally the company’s mission was to supply customers with CNG fueled vehicles customers with compressed natural gas.
- On August 1, 2018, the ‘NKM Ügyfélkapcsolati Kft.’ started its operation after customer service was reorganized into that subsidiary.

Nevertheless, the cost of service remained a major consideration for the government. Winter utility cost reduction (‘*téli rezsicsökkentés*’)[145] took place in 2018, which gave compensation (e.g., residential customers received HUF 12,000 credit to their balance) from the ‘regulatory account’ and this was sent to the accounts of each of the universal service customers.

On January 11, 2018, NKM acquired ‘Égáz-Dégáz Földgázelosztó Zrt.’ (Égáz-Dégáz), which name changed from May 2, 2018 to ‘NKM Észak-Dél

[142] NKM Plusz Zrt. 2017 Annual Report
[143] NKM Optimum Zrt. 2017 Annual Report
[144] NKM Mobilitás Kft. 2017 Annual Report
[145] 37/2018. (III.8.) Government decree (‘*Korm. rendelet*’)

Földgázhálózati Zrt.'[146] With the transaction the (electricity and natural gas) distribution network of NKM increased to over 60,000 km.[147]

On April 24, 2018, NKM and the City of Ororszlány signed a share purchase agreement for the acquisition of Ororszlényi Szolgáltató Zrt. (OSZ). The transaction was successfully completed on July 31, 2018 following authorities' approval and the new name of the company became 'NKM Oroszlányi Szolgáltató Zrt.' (OSZ), which was the first fully owned district heating service company in portfolio of NKM. From October 2018, a cooperation between NKM and FŐTÁV was launched with a customer service.

By the summer of MVM and NKM were directly under the same Ministry, NVTNM.[148] Once again management changes were underway. The stated goal of the government is to finish the MVM-NKM merge by the end of 2019.

5.3 State-owned public utility and RES

Originally, the plans were for ENKSZ/NKM to remain a non-profit public utility.[149] Mejía-Dugand et al. (2017) found that despite public ownership, administrative autonomous companies may remain competitive in a liberalized market but economic autarky with the liberalization conditions may create a blurry line between private and public domains. While a non-profit public utility could have been a feasible choice, ultimately this expectation changed with time for the following reasons:

1) the regulated universal service tariff sends disadvantageous price signals and hinders CAPEX intense investments (e.g., renewables developments) and the profit of NKM can be allocated to make up for the reduced network investments.
2) the EU pressured Hungary to fulfill its obligation regarding the energy related directives and investor protection treaties (e.g., to determine fair tariff rates for the natural gas DSOs).

Thus, the governmental focus shifted towards acquisitions and further strengthening the state-owned public utility. Moreover, NKM started to concentrate on developing

[146] Source: <https://www.nemzetikozmuvek.hu/Hirek/2018/05-02>, Last accessed: 15-01-2019
[147] Source: <https://www.nemzetikozmuvek.hu/Hirek/2017/2018-01-11>, Last accessed: 15-01-2019
[148] 3/2018. (VIII.1.) NVTNM decree ('*NVTNM rendelet')*
[149] For a detailed discussion on utility models see Bálint et al., (2014, 2015).

complex service solutions and building on its unique ability to reach almost all residential end-user in the country.

From the RES standpoint, the national public utilities tariff environment (Lowell, 2006) should be considered. As energy prices started to increase, the government could prevent the increase of the regulated price assigning a tariff-keeper role to MVM (as the parent company of NKM) as in the recent years it became the 3rd largest Hungarian companies based on revenue. MVM (NKM was not fully consolidated in 2017, yet) was the 3rd largest company from the electricity industry (figure 46).

Ranking	Name of company
1	Mol Magyar Olaj- és Gázipari Nyrt.
2	Audi Hungaria Zrt.
3	MVM Magyar Villamos Művek Zrt.
4	Mercedes-Benz Manufacturing Hungary Kft.
5	GE Infrastructure Hungary Holding Kft.
6	Samsung Electronics Magyar Zrt
7	Magyar Suzuki Zrt.
8	Magyar Telekom Távközlési Nyrt.
9	Robert Bosch Elektronika Kft.
10	Ventas Coffee Hungary Kft.

Figure 46. Largest Hungarian companies by revenue (2017)

Source: HVG (2018), author's edit

Artificially low energy prices could hinder the transition to sustainable energy generation forms: both large RES development and small scale distributed energy resources (DER).

Overall, the national utility provider and the government also recognized the potential of new products and customer focused service. While still a long shot, theoretically with proper management MVM and its subsidiary NKM could become an innovation driven company making available affordable RES solutions and new technologies[150] for its customers.

[150] In Spring 2019, the NKM Áramhálózati Kft. plans to finish the development of its first energy storage units at two locations (Kecel, Zsombó). Source: <https://www.nemzetikozmuvek.hu/Hirek/2018/12-05>, Last accessed: 15-01-2019

5.4 Further growth and RES related considerations

Owner (state) expectations will determine the key elements of the national public utility in the future as well:

- Responsibility for the national climate and energy policy goals (including major contribution to the achievement of the goals set in the new National Energy Strategy and the National Energy and Climate Plan).
- Affordable energy service (utility operational efficiency) for residents and economy actors to contribute to the long-term competitiveness of the economy.
- Ensuring security of supply (addressing market and technological challenges).
- Increasing the value of the national energy assets (continuous development).
- Customer-oriented innovative national champion (innovation leader in Hungary).
- Meeting customers' needs by providing comprehensive solutions.
- Modern energy utility suitable for international competition and capital market introduction

These goals themselves are conflicting priorities with several trade-offs.

Besides high-level expectations, respondents mentioned several concrete short-term expectations during the concept mapping discussions regarding the national utility provider:

- Ramping up the transportation – EV, CNG – promotion (NKM Mobilitás), energy efficiency, small-scale RES development initiatives (NKM Optimum), and third-party, value-added customer solutions (NKM Optimum).
- Consolidation of MVM and NKM subsidiaries:
    - merger of the natural gas and electricity business lines.
    - elimination of duplications (e.g., e-mobility, retail and wholesale activities).

On the electricity market:

- Further (DSO) acquisition on the basis of the former DÉMÁSZ. For example E.ON-RWE-Innogy merger approvals may trigger certain EU requirements, such as the sale of the CEE assets of Inoggy. That could revitalize the previously halted ELMŰ-ÉMÁSZ transaction).
- Further expansion on the residential market, as NKM is the only USP with an electricity (and natural gas) USP license valid for the whole country.

On the natural gas market:

- Acquisitions of the smaller Hungarian natural gas DSOs (Turulgáz, MAGÁZ etc.) and their integration into the state-owned utilities' network subsidiaries.
- Locking alternate energy supplies (currently undergoing BRUA and Krk LNG negotiations) to ease the dependency on Russian NG.

District heating

- Speed-up of the district heating expansion both in DH generation (e.g., biomass projects) and in DH service (shared customer service offices with local DH service providers).

To sum up, from a RES perspective, the state is shifting towards an understanding and reflecting on more different ways to meet its residents' needs. Energy costs are important but many of the customers have other considerations as well, which are reflected. We highlight that our concept map actions suggest the usage of a broader definition of the energy industry's supply chain compared to the traditional definitions. A broader but more valid definition should be kept in mind by the industry actors: "*supply chain consist of all parties involved directly or indirectly, in fulfilling a customer request"* (Chopra and Meindl, 2016). The implications for energy policy are clear:

1) to understand the real depth of the supply chains and the stakeholders.
2) to have customer focus and to meet customer requests (e.g., continuous, convenient access to affordable energy that comes from a source without biasing the quality of the life and environment) should be a priority for regulation, technology choices, tariff system, etc. Moreover, from a customer perspective - as real competition on the Hungarian residential

energy market is practically non-existent at present [151] - the national public utility has a greater responsible to identify and actively engage to meet residential customer needs.

Applying the framework of Treacy and Wiersema (1997), the public utilities in the Hungarian energy industry fell into the 'Operational excellence' category (figure 47) with narrow product lines (electricity with a strictly defined quality, heat, etc.), high expertise in chosen areas of focus and with a slow pace of change. The major goals were to keep cost down with efficient generation with high volumes. While in the case of electricity the volumes once again started to increase, the fix costs were rising steadily (e.g., expanding network, decrease of fixed fee element in tariffs, stricter regulations, etc.). Overall, it is more and more challenging to strive for low costs. In our expanded model the aggregate cluster of '*Network*' is comparable to the '*Operational excellence*' category of the original framework.

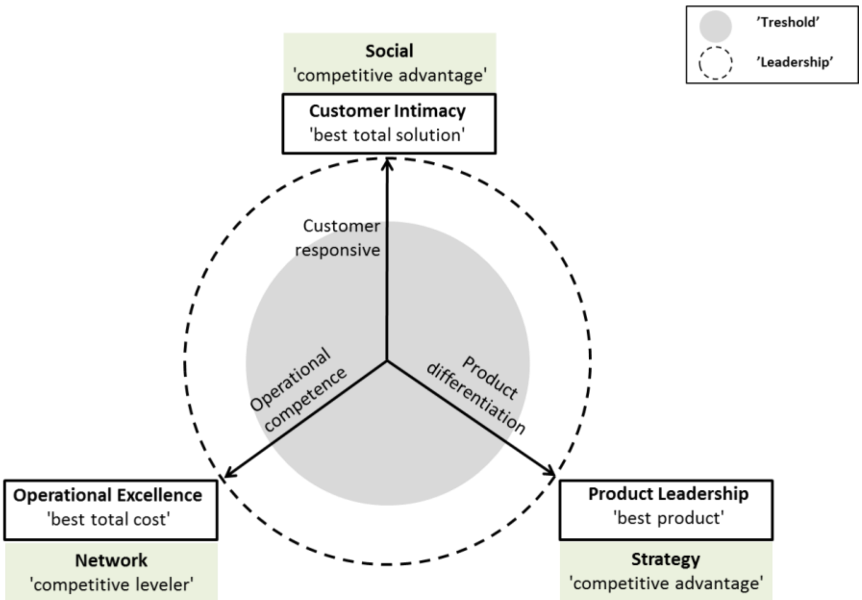

Figure 47. The Three Disciplines in the context of the three-aggregate clusters of the Hungarian RES trade-offs

Source: Treacy and Wiersma (1997), author's compilation

New products (household-scale generation, smart homes, etc.) and new markets (EV, CNG, etc.) became available while new entrants (e.g., telecommunication

[151] At present, there are going to be no alternative offers for Hungarian residential customers. After February 28, 2019, E.ON Energiakereskedelmi Kft. will no longer offer non-USP offers for residential customers (its tariffs have more favorable pricing than the USP tariffs). <https://www.eon.hu/hu/rolunk/vallalatcsoport/eon-energiakereskedelmi-kft.html>, Last accessed: 15-01-2019

companies) entered into the traditional business lines. In our expanded model these reflect to the aggregate cluster of '*Strategy*', which is comparable to the '*Product leadership*' category.

Customer relationships need more focus and resources, as not only the regulator, but also the owner (state-owned utility) expects to provide residents (voters) quality service (e.g., one-stop-shop to run electricity, NG and DH business). Therefore the national public utility faces the dilemma to focus on 'customer intimacy' as the best total solution' or find the 'best product' to maintain profitability and compensate for the increasing total costs. In our expanded model these reflect to the aggregate cluster of '*Social*', which is comparable to the '*Customer intimacy*' category.

Based on Chapter 5 we are firmly deducing that:

1) NKM is not yet five years old but it already has a 'long' and thought-provoking history.
2) the national public utility service provider was created by increasing market concentration at a state-owned entity. Economies of scale and lack of competition allowed NKM to start to change its strategy from cost leadership to product differentiation (Porter, 1985)[152] including the support of RES technologies and electric vehicles.
3) the strategic focus of NKM is turning towards 'customer intimacy' and even 'product leadership' and these could promote RES solutions or ease many of the pressing trade-offs. From the customer point of view the change in value discipline could be beneficial, the state expectation of affordable energy (thus of 'operational excellence') is present. Therefore in our view a potential strategic and supply chain risk is present, as companies cannot master all three categories at the same time.

[152] Figure 53 in Appendix

6. Conclusion

6.1 Closing thoughts on the Hungarian RES industry

Currently, the renewables are changing the energy industry landscape and the signs of turmoil greatly affect Hungary as well. The changes in the industry circumstances, consumer needs and new technological, economic and regulatory practices trigger the transformation of energy policies in Hungary as well. The industry is changing, therefore the question is not that if it should, but rather in which direction, and especially how to address the uncertainties without (or at least with as few as possible) major missteps.

1. The technology of renewables and the expansion of the distributed generation solution have created a great interdependence between the consumers and grid operators. That interdependence created new incentives, and new kinds of rates. Regardless fair and effective rules for ratemaking are still the subject of the state's energy policies.
2. While METÁR finally came out and renewable developments may again pick up a faster pace, still, a more consistent and transparent Hungarian energy policy is needed with a 'real' green energy strategy that targets renewables and energy efficiency.
3. Moreover, to ensure the expansion of wind (and solar as well) developments, investment in storage solutions (EV, pump storage) are needed; even if the costs have to incorporated into the renewables development financing. Without these developments, further optimizations will be challenging; even, in the long-term grid stability will become much more sensitive to planning and modeling errors. In the end, renewable developments must align with the ultimate goals of the European (and Hungarian) regulations - to ensure the continuous modernization of the power industry following the principles of sustainability, competitiveness and supply security.

6.2 Summary of the research

With the utilization of the concept mapping methodology we determined the most pressing RES related trade-offs of the Hungarian energy market and suggested improvement actions that could be considered both on the state and the company level, and most of all they could be a valuable input for decision makers for the Hungarian Energy Strategy that is currently under update. For that reason, the dissertation attempted:

1) to be focused on a particular ‘hot’ topic (RES trade-offs of the Hungarian market as of early 2019) (Chapter 1),
2) to provide a comprehensive literature review to prepare the discussion on the RES-related trade-offs (Chapter 2)
3) to ensure that the methodology is robust but able to catch the very diverse ideas in a structured, quantitative way (utilizing concept mapping to apply all aspects of the RES developments) (Chapter 3),
4) to warrant that the respondent group is knowledgeable, competent and mutually exclusive[153], so in practice we could be sure that their opinion could be treated as their aggregate opinion of the ‘industry’ (42 respondents, whose age, qualification, industry experience and affiliated institution reflected the complete value chain)
5) to draw up the relevant issues in a comprehensive and transparent framework due to the complexity of the topic (iterative process with MDS) (Chapter 3),
6) to summarize the topic to the actors of the RES and related energy markets and everyone else that is interested in the topic (five clusters with detailed evaluation results of the statements with utilization suggestions) (Chapter 4),
7) to present the trade-offs and the suggested actions by the respondents in an-easy-to understand way to decision makers, since they are looking at the industry from a ‘bird’s eye view’ and
8) to support the ideas with the structured opinions of a focus group and with a mini case study, so the relations and the arguments could be easily be placed in context for those stakeholders that are less familiar with the challenges of the RES industry (Chapter 4 and 5).

[153] We strongly emphasize that no single actor is able to reflect all aspects of the Hungarian RES market, at least not without consulting a diverse, experienced group like we had the opportunity to work with during this research.

Besides these direct results, we trust that we raised awareness for some of the exciting problems of our field (energy markets and RES developments in particular) and we introduced concept mapping as an excellent methodology to incorporate both qualitative and quantitative research techniques.

6.3 Summary of the research results

While there are several research projects on the Hungarian renewables market, until now only partial aspects of the RES-related trade-offs of the Hungarian energy market have been recognized. Due to the size and the diversity of the industry, the research has focused on one particular problem set (e.g., technology, value chain, strategy, regulatory) and had only a glimpse of some of the trade-offs. To develop **the comprehensive list of the relevant RES trade-offs in Hungary** we aimed to **reach a common understanding across the industry actors**.

Hence, we used concept mapping as a mixed method and relied on the inputs of 42 respondents, who were stakeholders in the energy value chains. In the iterative process 40 statements became part of the 'reduced list of statements' that consisted of the actions and the trade-offs. The statements were then evaluated by the participants. With hierarchical cluster analysis the **five-cluster solution was identified as the best fit** and then their labeling was discussed by the respondents. The five labeled and ranked clusters were:

1) **Low level strategy** (regulations, pricing, complexity management) (3.35/5)
2) **High-level strategy** (regulatory, tariff system, cooperations) (3.29/5)
3) **Infrastructure development** (technology, PR) (3.19/5)
4) **Network optimization** (network operation, resource management) (3.11/5)
5) **Social aspects** (stakeholder impact) (2.20/5)

The linear correlation coefficients between the various subgroups were very high. Comparisons were made of industry experience ('Juniors', 'Mid-level', 'Seniors'), type of affiliation (working for 'State controlled' or 'Not state controlled' entities) and qualification ('Economics and Management', 'JD'). Overall the respondent group had a s**trong agreement on the importance of the factors with a same**

trend in all cases. With the ladder graphs in almost all cases **some potential disagreements** could be identified.

The **suggested utilization of the results:**

1) Inputs for relevant stakeholders to **prioritize between RES technologies** (e.g., National Energy Strategy).
2) **Guide for in-house strategy and decision-making, a practical 'check list' for industry experts** when RES-related complex technical-, legal- and economic problems are analyzed.
3) A **formalized, in-depth discussion framework** on the challenges (and trade-offs) of the Hungarian RES market for further research.

With the case study methodology, we found that:

1) the national public utility service provider (former ENKSZ / current **NKM**) is not even five years old but already **has a ‘long’ and thought-provoking history**.
2) NKM was created with strong state support and by increasing market concentration. Economies of scale and lack of competition allows **NKM to start to change its strategy from cost leadership to product differentiation** including the support of RES technologies and electric vehicles.
3) **the strategic focus shift of NKM towards ‘customer intimacy’ and even ‘product leadership’ could promote RES solutions or ease many of the pressing trade-offs**. From the customer’s point of view the change in value discipline could be beneficial. However, the state’s expectation for affordable energy (‘operational excellence’) is present, which is a potentially strategic issue with many elements of supply chain risk present.

This research focused on Hungary, the Hungarian renewable energy market and the inherent policy trade-offs related to the dynamically changing desirable energy mix of this country. **Our respondents are among the primary influencers of decisions in the Hungarian energy secto**r; they do know the causal links and the whys behind the actions. Consequently, **this study has very high internal validity** (the extent to which we can infer that a relationship between two variables is causal), the representations given show valid causal linkages. Additionally, we can argue—in the spirit of Donald T. Campbell's Proximal Similarity Model, which is just a different name for external validity (generalizability to other settings) - that **the Hungarian situation is not unique, the neighboring countries, particularly the Czech Republic, Poland and Slovakia (the Visegrád Group), are very much in the same boat with Hungary**. These countries face similar challenges regarding energy strategy (e.g., finding the proper RES technology within their energy mix), network development and optimization (e.g., cross border capacities, balancing north-south power loads) and social issues (e.g., controversies of the coal industry). So, the results presented here have external validity and are, to a varying extent, applicable to these countries.

6.4 Suggested future research

The aim of the dissertation was to explore the trade-offs of the Hungarian RES market. We see **three major directions regarding future research**:

1) In the case of RES trade-offs further research suggested:
    a. On a larger scale, the possible role of a more integrated resource planning (similar to the recent energy supply security initiatives for natural gas) at the EU level within the competitive market constraints to promote renewable optimization.
    b. On a smaller scale, challenges and trade-offs of the Hungarian grid decentralization should be further explored, for instance household-sized generators are gaining popularity due to the provided flexibility and increased reliability. This is regardless that they make the overall system more expensive if the customer is connected to the bulk system as well. Connected issues (e.g., microgrid, EVs as storage) may be explored.
2) Further utilization of concept mapping to explore 'hot' topics of the Hungarian energy industry with limited previous research available. Additionally, the use of social network analysis (SNA)[154] could be useful

[154] Social network analysis (SNA) is a widely used technique to study relationships and flows between people, organizations, or other information/knowledge centers. The given network's nodes

when examining the disagreements of the subgroups, as it helps to map and interlock relations between the distant members of the energy systems (Galadigma and Gan, 2007).

3) The mini case study, the example of the national utility provider, could and should be developed into a more comprehensive case study that reflects its significance in the energy industry in other aspects as well, which were outside the scope of this dissertation. Since 2013, the Hungarian State greatly influenced the energy value chains (electricity, NG, DH). We expect that the major acquisitions could slow down with the ongoing NKM-MVM merger (which should be closed by the end of 2019), and the consolidation period provides a good opportunity for us to evaluate and summarize the results of the national utility's past 5 years.

are the people or groups and the links are the relationships or flows between these actors. SNA is capable of visualizing these relations with detailed mathematical description.

7. Acronyms and terminology

The following glossary is a collection of acronyms and terms used throughout this paper:

Acronyms:

Acronym	Full Term
AC	Available Capacity
ACER	Agency for the Cooperation of Energy Regulators
APICS	American Production and Inventory Control Society
BANANA	Build Absolutely Nothing Anywhere Near Anything or Anyone
BATEA	Best Available Technology Economically Achievable
BCM or bcm	Billion Cubic Meters
BEV	Battery Electric Vehicle
BTU or Btu	British Thermal Unit
CAA	Clean Air Act (USA)
CAAA	Clean Air Act Amendments (1977, 1978, 1990) (USA)
CBM	Coalbed Methane
CEE	Central Eastern Europe
CCGT	Combines Cycle Gas Turbine
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power (CHP)
CNG	Compressed Natural Gas
CONWIP	Constant Work in Progress
CWA	Clean Water Act (1977, 1987)
DÉMÁSZ	South Hungarian Power Company (previously EDF DÉMÁSZ, Dél-magyarországi Áramszolgáltató Zrt.)
DH	District Heating
EED	Energy Efficiency Directive
EHS	Environment, Health and Safety
EIA	U.S. Energy Information Administration (USA)
ENKSZ	First National Public Utility Ltd. (Első Nemzeti Közműszolgáltató Zrt.), currently NKM Zrt. (Hungary)
ENKSZ ÉÁV	ENKSZ Northern Power Network Property Management Ltd. (ENKSZ Északi Áramhálózati Vagyonkezelő Zrt.) (Hungary)
ENTSO-E	The European Network of Transmission System Operators for Electricity
EPA	Environmental Protection Agency (USA)
EPR	Energy Payback Ratio
ERGEG	European Regulators' Group for Electricity and Gas
EU	European Union
EV	Electric Vehicles
Égáz-Dégáz	Égáz-Dégáz Natural Gas Distribution Zrt. (Égáz-Dégáz Földgázelosztó Zrt.), currently NKM North-South Natural Gas Public Utility Zrt. (NKM Észak-Dél Földgázhálózati Zrt.)
FGSZ	FGSZ Natural Gas Transmission Ltd. (FGSZ Földgázszállító Zrt.) (Hungary)
FID	Final Investment Decision
FIT	Feed-in Tariff
FŐGÁZ	Metropolitan Gas Works (Fővárosi Gázművek Zrt.) (Hungary)
FŐTÁV	Budapest District Heating Works (Budapesti Távhőszolgáltató Zrt.) (Hungary)
GHG	Greenhouse Gas
GSEM	GDF SUEZ Energy Hungary Ltd. (GDF SUEZ Energia Magyarország Zrt.) (Hungary)
GVH	Hungarian Competition Authority (Gazdasági Verseny Hivatal)
GWH	Gigawatt Hours
HUPX	HUPX Hungarian Power Exchange Company Ltd. (HUPX Magyar Szervezett Villamosenergia-piac Zrt.) (Hungary)
IC	Installed Capacity

ICSID	International Centre for Settlement of Investment Disputes
IEA	International Energy Agency
IAEA	International Atomic Energy Agency
IRENA	International Renewable Energy Agency
ISO	Independent System Operator
ITO	Independent Transmission Operator
KÁP	Feed-in Financial Instrument (Kötelező Átvételi Pénzeszköz) (Hungary)
KÁT	Feed-in Tariff Scheme (Kötelező Átvételi Rendszer) (Hungary)
KNPA	Central Nuclear Financial Fund (Központi Nukleáris Pénzügyi Alap) (Hungary)
KSH	Hungarian Central Statistical Office (Központi Statisztikai Hivatal) (Hungary)
LDC	Local Distribution Company
LNG	Liquefied Natural Gas
LTC	Long Term Contract
MATÁSZSZ	Association of Hungarian District Heating Enterprises (Magyar Távhőszolgáltatók Szakmai Szövetsége) (Hungary)
MAVIR	MAVIR Hungarian Independent Transmission Operator Company Ltd. (Magyar Villamosenergia-ipari Rendszerirányító Zrt.) (Hungary)
MCDA	Multiple-Criteria Decision Analysis
MEKH	Hungarian Energy and Public Utility Regulatory Authority (Magyar Energetikai és Közmű-szabályozási Hivatal) (Hungary)
METÁR	Renewable Energy Support Scheme (Megújuló Támogatási Rendszer) (Hungary)
MKEH	Hungarian Trade Licensing Office (Magyar Kereskedelmi Engedélyezési Hivatal) (Hungary)
MFB	Hungarian Development Bank Ltd. (Magyar Fejlesztési Bank Zrt.) (Hungary)
MFBF	MFB Natural Gas Trading Ltd. (MFB Földgázkereskedő Zrt.) (Hungary)
MFGK	Hungarian Gas Trade Ltd. (Magyar Földgázkereskedő Zrt.) (Hungary)
MFGT	Hungarian Gas Storage Ltd. (Magyar Földgáztároló Zrt.) (Hungary)
MGT	Hungarian Gas Transit Ltd. (Magyar Gáz Tranzit Zrt.) (Hungary)
MMBF	MMBF Natural Gas Storage Ltd. (MMBF Földgáztároló Zrt.) (Hungary)
MTOE	Million Tonnes of Oil Equivalent
MVM	Hungarian Electricity Works / Hungarian Electricity Ltd. (Magyar Villamos Művek Zrt.) (Hungary)
NES	National Energy Strategy (Hungary)
NG	Natural Gas
NGV	Natural Gas Vehicles
NKM	National Public Utilities (Nemzeti Közművek Zrt.), former ENKSZ (Hungary)
NIMBY	Not In My Back Yard
NOAA	National Oceanic and Atmospheric Administration (USA)
NPP	Nuclear Power Plant
ORE	Offshore Renewable Energy
OSZ	District Service Provider of Oroszlány (Oroszlányi Szolgáltató Zrt.) (Hungary)
PHES / PSH	Pumped Hydroelectric Energy Storage
PP	Power Plant
PPA	Power Purchase Agreement
PSHN	Public Service Company of New Hampshire (USA)
PV	Photovoltaics
REC	Renewable Energy Credit (USA)
RED	Renewable Energy Directive
RES	Renewable Energy Source
RPS	Renewable Portfolio Standard (USA)
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference (SCOR)
SNA	Social Network Analysis
SPA	Share Purchase Agreement
TGC	Tradable Green Certificate
TPES	Total Primary Energy Supply (TPES)

UI	The United Illuminating Company (USA)
USP	Universal Service Provider
V4	Visegrád Four / Visegrád Group (the Czech Republic, Hungary, Poland, Slovakia)
WEC	World Energy Council
WTI	West Texas Intermediate (USA)

Terms:

Term	**Definition**
'20-20-20' targets (EU)	The 20-20-20 targets of the EU represent an integrated approach to climate and energy policy that aims to combat climate change, increase the EU's energy security and strengthen its competitiveness.
Agency for the Cooperation of Energy Regulators (ACER)	ACER complements and coordinates the work of national regulatory authorities by monitoring, reporting and advising on developments in the European energy markets and participating in the creation of European network rules.
Base Load Review Act (BLRA)	Base Load Review Act is a law in the US state of South Carolina (SC) enacted in 2006. The bill intended to enable utility companies to build large energy generation facilities while saving money by having the consumers pay the cost of financing the construction as the facility was being built. Practically the act promoted nuclear energy.
Benchmarking	A standard to measure against.
Blockchain	Blockchain is a distributed, digital transaction technology. It permits a secure but peer-witnessed execution of smart contracts over peer-to-peer networks independently from a central authority such as banks, trading platforms or energy companies and utilities. The transactions are stored permanently on a digital ledger — the blockchain — which is duplicated by every computer on the network.
Carbon Capture and Storage (CCS)	Set of technologies that allow the capturing of CO_2, from large point sources (typically from fossil fuel and biomass power plants), its transportation to the storage site and depositing, in order to reduce GHG emissions
City Gate	A point or measuring station at which a distributing gas utility receives gas from a natural gas pipeline company or transmission system.
Compressed Natural Gas (CNG)	CNG is methane stored at high pressure. The fuel is used in place of gasoline (petrol), diesel fuel and propane/LPG. CNG combustion produces fewer undesirable gases than those substituted.
Concept mapping	Concept mapping is specific type of structured conceptualization process, which is a mixed method approach to inquiry that enable a defined group of people to articulate thoughts and ideas on a specific topic that are represented in some objective form.
Distributed Energy Resources (DER)	DER consists of demand- and supply-side resources that are deployed in the electric distribution system to meet energy and reliability needs of a given customer. DER can be installed either on the customer side or the utility side of the meter.
Directive (EU)	A directive is a legal act of the European Union, which requires member states to achieve a particular result without dictating the means of achieving that result.
Distribution System Operator (DSO)	A DSO is an entity entrusted with transporting energy (electrical power or natural gas) in a given area and, where applicable, its interconnections with other systems and for ensuring the long term ability of the system to meet reasonable demands for the distribution of electricity or gas.
Energy Payback Ratio (EPR)	EPR is a ratio of 1) the total energy produced during a given system's normal lifespan, which is divided by 2) the energy required to build, maintain and fuel the system. High ratio indicates better environmental performance. If the system has an EPR close to 1, then it consumes as much energy as it generates (development should have not happened).

European Union Greenhouse Gas Emission Trading Scheme (EU ETS)	EU ETS is an international system for trading greenhouse gas emission allowances. The EU ETS is a cornerstone of the EU's energy policy to combat climate change and its key tool for reducing industrial greenhouse gas emissions cost-effectively.
Integrated Resource Plan (IRP)	IRO looks at the present and future demands for electricity in a comprehensive way, to plan for meeting those demands.
International Renewable Energy Agency (IRENA)	IRENA is an intergovernmental organization supporting countries in their transition to a sustainable energy future.
KÁT, METÁR	KÁT and METÁR are both renewable support schemes in Hungary, based on the feed-in tariff logic.
Liquefied Natural Gas (LNG)	Natural gas (primarily methane) that has been liquefied for ease and safety by reducing its temperature to -162°C (-260°F) at atmospheric pressure. LNG only takes up about 1/600th the volume of natural gas in the gaseous state.
Likert scale	A Likert(-type) scale is the most widely used approach to scaling responses in survey research. The Likert scale incorporates the sum of responses on more (Likert) items that exhibit both 'symmetry' and 'balance'.
Multidimensional scaling (MDS)	Multidimensional scaling (MDS) is a means of mapping the level of similarity of individual cases of a dataset while also preserving distances.
Price Coupling of Regions (PCR)	PCR is a project of European Power Exchanges to harmonize the European electricity markets. The initiative aims to develop a single price coupling solution to be used to calculate electricity prices across Europe, and allocate cross border capacity on a day-ahead basis. PCR is based on three main principles: a single algorithm, robust operation and individual Power Exchange accountability.
Renewable Portfolio Standard (RPS)	A Renewable Portfolio Standard (RPS) is a regulation that requires electric providers to obtain a specified percentage or amount of energy they generate or sell from renewable sources. The regulation promotes renewable energy projects by ensuring a market and financial incentive (steady stream of revenue for renewable generators).
The European Network of Transmission System Operators for Electricity (ENTSO-E)	ENTSO-E is an association of Europe's transmission system operators (TSOs) for electricity. It is a successor of ETSO, the association of European transmission system operators founded in 1999 in response to the emergence of the internal electricity market within the European Union.
Trade-off	A trade-off refers to a situation when one criterion's value gain related to the phenomenon is resulting in a loss in other aspects (e.g., GHG reduction can be decreased at an increased cost).'
Transmission System Operator (TSO)	A TSO is an entity entrusted with transporting energy (electrical power or natural gas) on a national or regional level, using fixed infrastructure.
Universal service (in Hungary)	Customers eligible for universal service are 1) household customers and 2) other customers defined by the respective laws (e.g., in the case of natural gas other customers with purchased capacity below 20 m^3/hour, and the local governments that supply customers living in the rented apartments of the local government are entitled for universal service).

8. Appendix

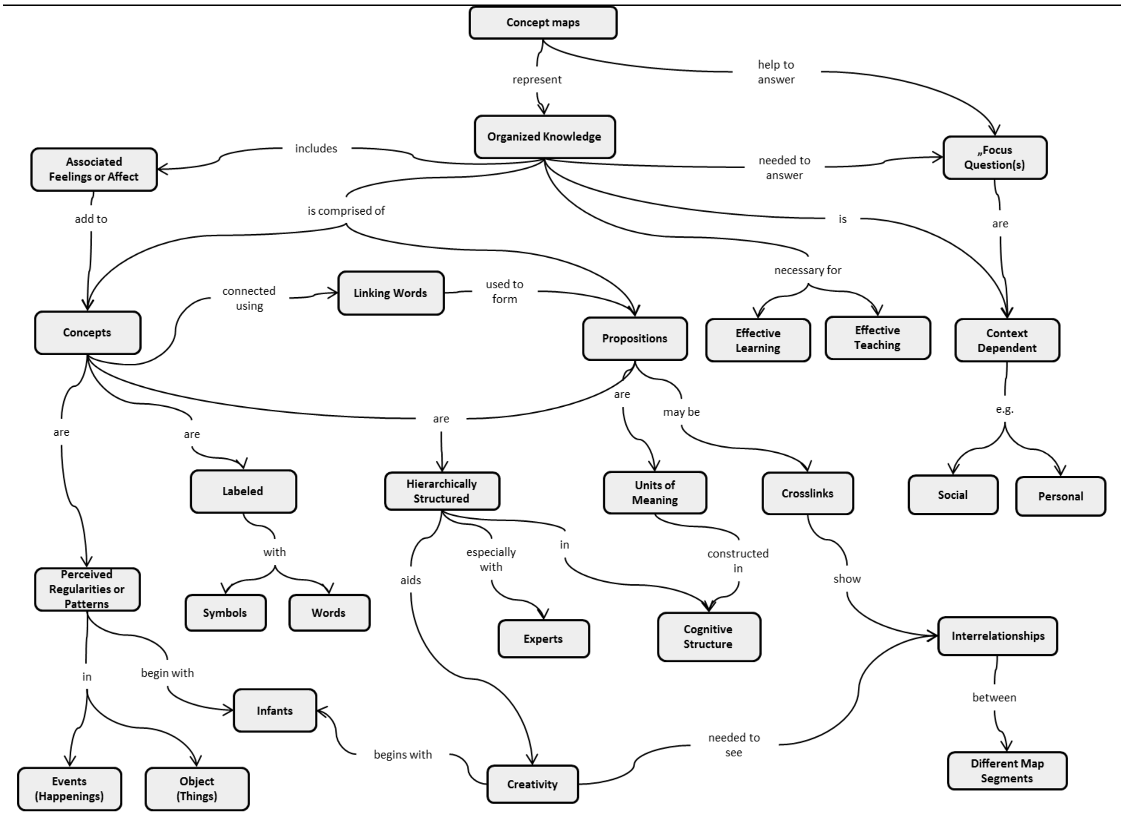

Figure 48. Concept map of concept mapping

Source: Novak and Cañas (2007), author's edit

Multidimensional Scaling

Monotonic Multidimensional Scaling
Kruskal Method
The data are analyzed as similarities
Minimizing Kruskal STRESS (form 1) in 2 dimensions

Iteration History	
Iteration	STRESS
0	0.351
1	0.335
2	0.328
3	0.324
4	0.322
5	0.321
6	0.320
7	0.319
8	0.319
9	0.318
10	0.317
11	0.317

12	0.316
13	0.316
14	0.315
15	0.315
16	0.314
17	0.314
18	0.314
19	0.313

Stress of Final Configuration : 0.313
Proportion of Variance (RSQ) : 0.424

Figure 49. Results of Multidimensional Scaling (MDS): stress value and variance

Source: concept mapping, author's compilation)

Coordinates in 2 Dimensions		
Variable	Dimension	
	1	2
C1	1.027	-1.109
C2	1.353	-0.962
C3	0.740	0.587
C4	0.319	0.066
C5	0.280	0.773
C6	0.169	1.040
C7	-1.097	-0.217
C8	-1.245	-0.376
C9	-1.229	0.284
C10	-0.310	0.567
C11	-0.167	1.112
C12	-0.079	1.111
C13	0.482	0.988
C14	0.619	1.027
C15	-0.676	0.407
C16	-0.853	-0.112
C17	-0.740	0.172
C18	0.181	0.571
C19	-0.443	0.862
C20	0.059	-0.497
C21	0.079	-0.812
C22	-0.374	-1.083
C23	-0.980	-0.576
C24	-0.980	-0.770
C25	0.301	-0.150
C26	-0.805	0.774
C27	-0.635	-0.684
C28	-0.156	-1.003
C29	1.212	-0.665
C30	0.722	-0.218
C31	0.600	-0.426

C32	-0.166	0.385
C33	-0.623	-1.033
C34	0.547	-1.269
C35	0.956	0.040
C36	0.863	0.202
C37	0.934	0.477
C38	0.828	0.391
C39	-0.354	-0.063
C40	-0.359	0.188

Figure 50. Graph coordinates in two dimensions

Source: concept mapping, author's compilation

Respondent no.	**Industry experience** (classification)	**Qualification** (primary degree)*	**Affiliation with state-controlled entities** (yes/no)
1	Mid-level	Other	no
2	Senior	Economics/Business	yes
3	Mid-level	JD	no
4	Mid-level	Economics/Business	yes
5	Junior	Economics/Business	yes
6	Mid-level	Economics/Business	no
7	Mid-level	Other	yes
8	Senior	Economics/Business	no
9	Senior	Economics/Business	no
10	Senior	Economics/Business	yes
11	Mid-level	Economics/Business	no
12	Junior	JD	yes
13	Junior	Economics/Business	yes
14	Mid-level	JD	no
15	Mid-level	Economics/Business	no
16	Junior	Economics/Business	yes
17	Mid-level	Economics/Business	no
18	Senior	Other	yes
19	Mid-level	Economics/Business	yes
20	Mid-level	Other	yes
21	Mid-level	Economics/Business	no
22	Mid-level	Other	yes
23	Junior	JD	no
24	Mid-level	Economics/Business	yes
25	Mid-level	Other	yes
26	Mid-level	Economics/Business	yes
27	Senior	Other	yes
28	Senior	JD	yes

29	Mid-level	Economics/Business	no
30	Mid-level	Other	yes
31	Mid-level	JD	yes
32	Mid-level	Other	yes
33	Mid-level	Other	yes
34	Mid-level	Other	yes
35	Mid-level	JD	no
36	Mid-level	Other	yes
37	Mid-level	Economics/Business	no
38	Mid-level	JD	yes
39	Mid-level	Economics/Business	yes
40	Mid-level	JD	no
41	Mid-level	JD	no
42	Mid-level	Economics/Business	no

**"Other" defined as "other primary qualification than JD/Economics/Business"*

Figure 51. Respondents' characteristics used for the analysis (for step 5 of "concept mapping": interpretation)

Source: concept mapping, author's compilation)

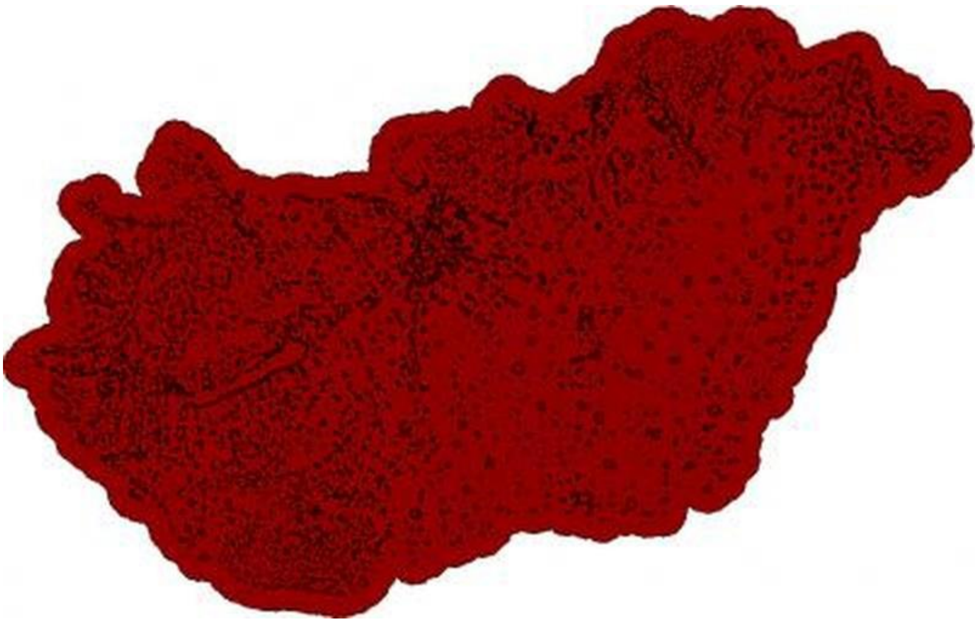

Figure 52. Possible wind development sites in Hungary (red: not allowed, white: allowed)

Source: ELTE TTK Institute of Geography,, energiaklub.hu

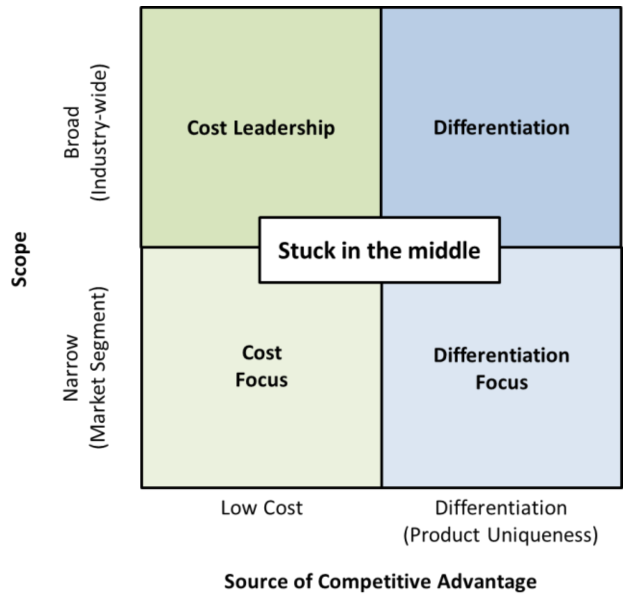

Figure 53: Porter's Model of Generic Strategies

Source: Porter (1985)

9. List of figures

List of figures:

10. References

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[192] Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003; http://eur-lex.europa.eu/legal-content/EN/TXT/?&uri=CELEX:32009R0714
[193] Regulation (EC) No 715/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the natural gas transmission networks and repealing Regulation (EC) No 1775/2005; http://eur-lex.europa.eu/legal-content/EN/TXT/?&uri=CELEX:32009R0715

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[194] Directive 2009/29/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community; http://eur-lex.europa.eu/legal-content/EN/TXT/?q&uri=CELEX:32009L0029
[195] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC; http://eur-lex.europa.eu/legal-content/EN/TXT/?&uri=CELEX:32009L0028
[196] Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006; http://eur-lex.europa.eu/legal-content/EN/TXT/?&uri=CELEX:32009L0031
[197] Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC; http://eur-lex.europa.eu/legal-content/EN/TXT/?&uri=CELEX:32009L0030
[198] Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO 2 emissions from light-duty vehicles; http://eur-lex.europa.eu/legal-content/EN/TXT/?&uri=CELEX:32009R0443
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Other relevant EU legislation

[200] Council Directive 90/377/EEC of 29 June 1990 concerning a Community procedure to improve the transparency of gas and electricity prices charged to industrial end-users; http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31990L0377
[201] Council Directive 90/547/EEC of 29 October 1990 on the transit of electricity through transmission grids; http://eur-lex.europa.eu/legal-content/EN/TXT/?q&uri=CELEX:31990L0547
[202] Council Directive 91/296/EEC of 31 May 1991 on the transit of natural gas through grids; http://eur-lex.europa.eu/legal-content/EN/TXT/?&uri=CELEX:31991L0296

[203] Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market; http://eur-lex.europa.eu/legal-content/EN/TXT/?&uri=CELEX:32001L0077

[204] Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC; http://eur-lex.europa.eu/legal-content/EN/TXT/?&uri=CELEX:32004L0008

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[207] Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection; http://eur-lex.europa.eu/legal-content/EN/TXT/?&uri=CELEX:32008L0114

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