Corvinus University of Budapest

Doctoral School of Information and Communication Technologies

DISSERTATION SUMMARY

András Herczeg:

Exploring Trade-offs in the Hungarian Renewable Energy Market

Ph.D. Dissertation
Summary

Advisor:

Dr. Gyula Vastag, DSc.
Professor

Budapest, 2019

Department of Computer Science

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Table of contents

1. Research background

1.1 Research questions

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)?

1.2 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. Methodology

2.1 Concept mapping

We applied concept mapping, 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. Concept mapping 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).

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 concept mapping process consists of six steps (figure 1):

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 1. 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). 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.

2.2 Case study

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. 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 to demonstrate its potential effect on RES expansion and on the trade-offs discussed. 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.

3. Results of the research

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) had only a glimpse of some of the trade-offs. To develop a 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. The participants' professional background represented:

- 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 heterogeneous and the 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. A prompt was developed and respondents felt reasonable to record the trade-offs together with the appropriate actions (figure 2).

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

Source: concept mapping, author's compilation

In the iterative process of 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 (figure 3).

Original statement no.	Avg. Rating (1-5)	Statement ranking (1-40)	(…) statement (=action)	Example of the trade-off behind the statement
1	2,05	40	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).
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 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	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.
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.
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 on the other hand sets back the adoption of more efficient RES innovations.
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.

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 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	3,64	6	Developing the large- and/or utility-scale energy storage options	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	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; yet, damages are present when green-field renewables sites are developed: enormous land, new roads, lines, water supply, etc. are required
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.
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).
12	2,88	30-31	Taking into account the greenhouse gas (GHG) emissions caused by renewables	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	3,76	3	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")	Currently the Hungarian renewables tariff scheme offers reduced 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	3,36	17	Ensuring strict environmental, health and safety regulations	While geothermal energy development is considered a safe technology; yet it can cause certain geological damages (landslides, subsistence, fractures).
15	3,69	5	Addressing the increased distribution network development needs and preparing to manage the changing physical energy flow	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	3,19	20	Channeling investment (e.g., with capacity fees) to create the feasible amount of rapid start-up (even black start) installed power generation capacity	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	2,95	23-25	Ensuring that 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).
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, the acceptance of the newest support scheme: Renewable Energy Support Scheme (METÁR)
19	2,95	23-25	Identifying and mitigating the resource constraints	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	2,67	38	Funds should also channeled to other form 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 than through the balancing services.
21	2,90	28-29	Maintaining the existing, domestic industrial knowledge (knowledge management)	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	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 evident to use already existing ones - e.g., in the proximity of the closed power plants).
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 are needed to handle fluctuations.
24	2,74	35	Preventing the negative effect on quality of life and biodiversity	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	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 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	2,79	34	Addressing the conversion loss during the generation process	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	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 is decreasing and further aging, plus 2) the need for quick start reserves are increasing.

28	2,90	28-29	Education of customers on RES technologies	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	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 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	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 RES Decommissioning Fund similar to the Central Nuclear Financial Fund (KNPA)	The increased number of renewable power plants will require a feasible solution to handle dangerous waste at their decommissioning (e.g., PV panels).
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 a proper storage solution detachment from the grid.
33	2,88	30-31	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	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	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.

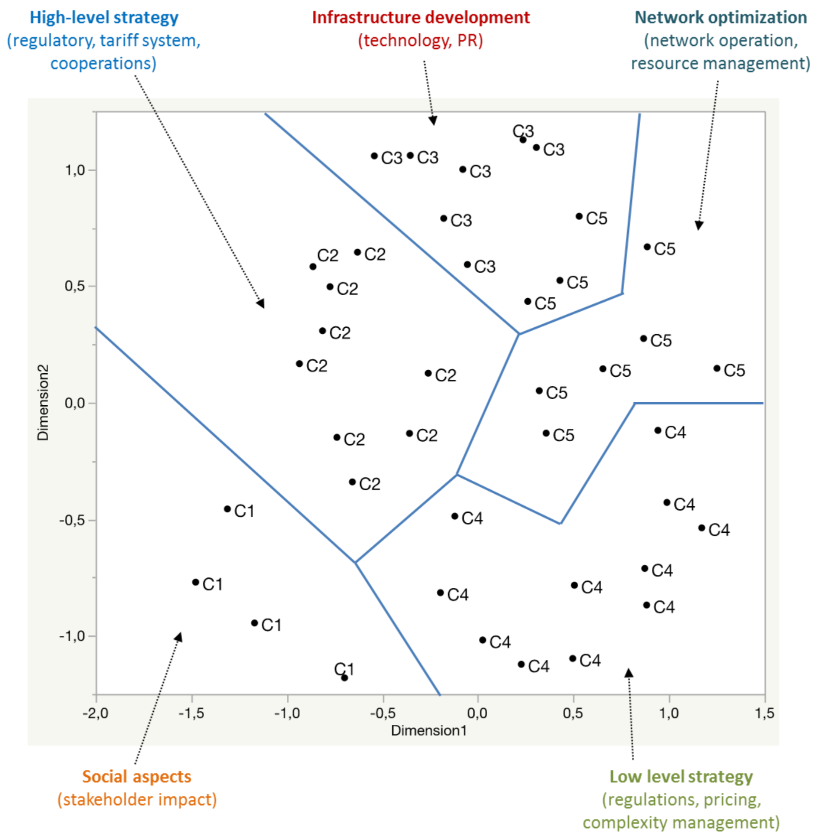
35	3,45	12-13	Transparent estimation of the long-term effect of the renewables in the energy prices (domestic and regional, comparisons such as installation of the renewables plus balancing capacities vs. installing the usual ones)	While investors can currently calculate with a fairly high selling price 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 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 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	2,71	36-37	Preparing power exchanges for new types 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.
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 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 3. The reduced list of statements with the evaluation

Source: Source: concept mapping, author's compilation

With hierarchical cluster analysis the five-cluster solution was identified as the best fit and then their labeling was discussed by the respondents (figure 4).



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

Figure 4. The labeled five clusters

Source: concept mapping, author's compilation

The five labeled and ranked clusters were (average importance rating of clusters on a five-point scale):

1) Low level strategy (regulations, pricing, complexity management) (3.35/5)
2) High-level strategy (regulatory, tariff system, cooperation) (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 ('State controlled', 'Not state controlled') and qualification ('Economics and Management', 'JD') (figure 5).

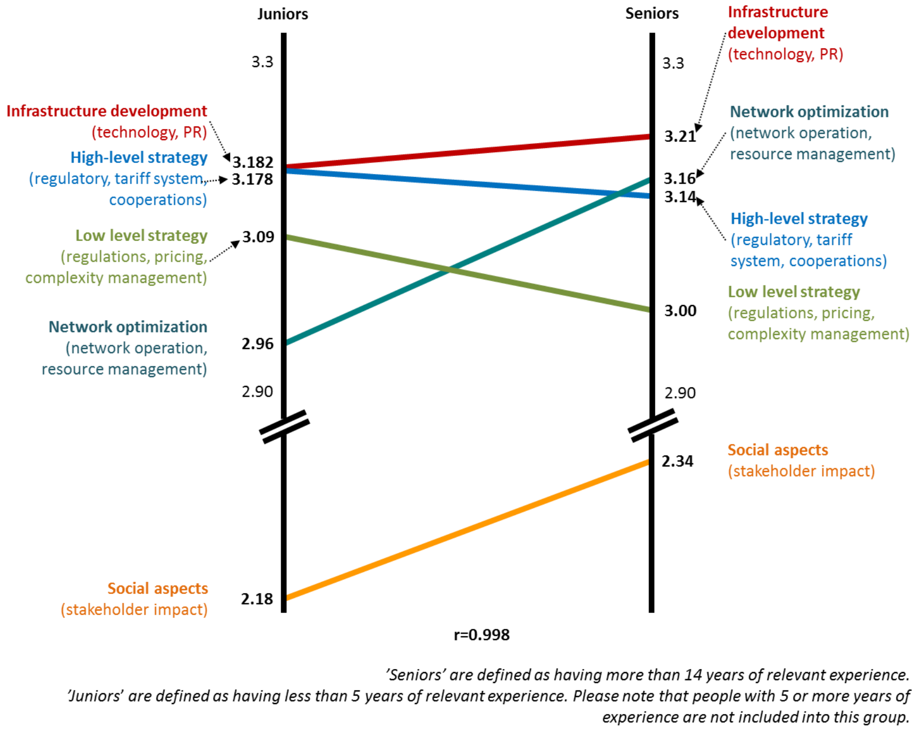


Figure 5. Example of comparison ('Juniors' and 'Seniors')

Source: Source: concept mapping, author's compilation

Overall the respondent group has a strong agreement on the importance of the factors with a same trend in all cases. With the ladder graphs in almost all of the 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.

The 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, 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.

4. Summary and future research

4.1 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, 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).

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.

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.

Applying the framework of Treacy and Wiersema (1997), the public utilities in the Hungarian energy industry fell into the 'Operational excellence' category (figure 6) 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.

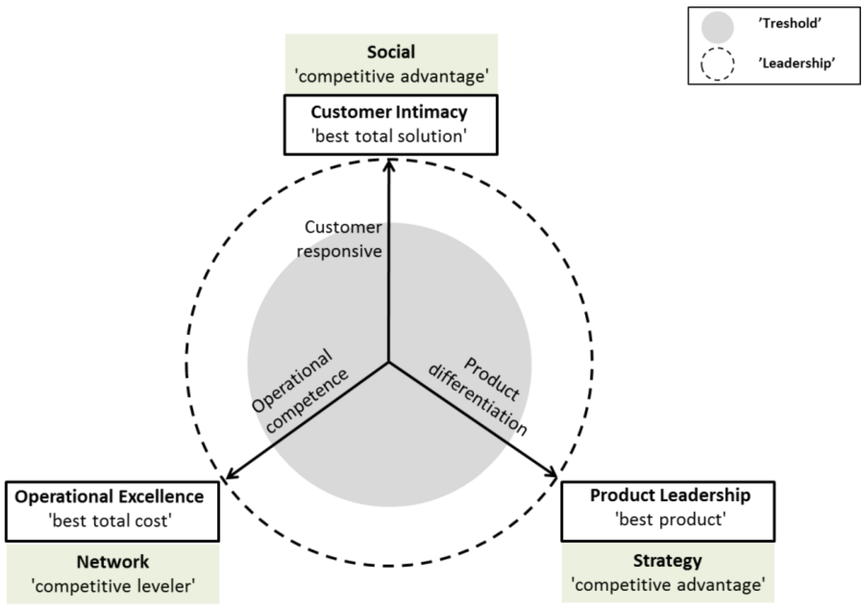


Figure 6. The Three Disciplines in the context of the three-aggregate clusters of the Hungarian RES trade-offs

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 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.

4.2 Suggested future research

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) could be useful when examining the disagreements of the subgroups, as it helps to map and interlock relations between the distant members of the energy systems.

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.

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