Dynamic Co-Capabilities in Innovation Management: the Case of Power-To-Gas Technology Development and Implementation

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Abstract
Power-to-gas technology has a great potential to facilitate the integration of renewables into the energy grid, but there are operative and system-level challenges in the development and implementation of this innovative technology. The authors aimed to explore with qualitative methodology the innovation management challenges which emerge during cooperatively performed technology development and implementation tasks by power-to-gas developer startups and established / multinational energy companies. The main findings of our research highlight the importance of complementary capabilities between smaller and larger organizations. The exploitation of these synergies can be hampered, however, by the contradictory organizational characteristics. Our research results conclude that technological and cooperation challenges can be solved by dynamic co-capabilities which help to explore and exploit complementarities between startups and established / multinational energy companies resulting in scaled-up technological innovation and significant steps forward towards an increased level of integration of renewable resources into the energy grid, as well a towards the transformation of the energy sector.
Keywords: power-to-gas technology, innovation management, dynamic capabilities, technology development, technology implementation, renewables, energy sector transformation

1. Introduction
Established, large energy companies, mainly in the electricity sector, face serious renewal challenges because of both external and internal factors (Zavarkó et al., 2017). The need of sustainable and renewable technologies (Bollino – Madlener, 2016; Ergüden – Catlioglu, 2016; Hogevold – Svensson, 2012; Hernádi, 2012; Parobek et al., 2016), the decentralized and digital solutions (Adil – Ko, 2016; Alagoz – Kaygusuz, 2016; Schaeffer, 2015; Luthra et al; 2014) and increasing importance of energy efficiency and security (Costa-Campi et al., 2014) are significant drivers of change. However, the rigorous external and internal regulation (Nisar et al., 2016), the rigid institutional background (Cullmann et al., 2016), the organizational inertia deriving from large company size and market concentration (Costa-Campi et al., 2014) and the dominance of traditional technologies and resources (Anadon et al., 2011; OECD, 2011) hamper organizational renewal and innovation. But the energy sector needs significantly new, innovative solutions, one of which could be the power-to-gas technology (Blanco – Faaij, 2018; Götz et al., 2015). The power-to-gas technology could be a solution for the challenges of the storage of excess renewable energy generated also by volatile weather conditions (Csedő, 2017; Sinóros-Szabó et al., 2018). It converts electricity to gas, which can be efficiently stored and transported through the natural gas system for different uses and applications (Schiebahn et al., 2015). The development of the power-to-gas technology is realized by pilot projects in which power-to-gas technology development focused startups, large energy companies and sometimes research institutions participate (Bailera et al., 2017). The power-to-methane technology, which produces renewable methane from CO_2 and H_2 could also play a crucial role in the future of the energy sector, but industry-level implementation has not happened, yet (Ghaib – Ben-Fares, 2018). Consequently, authors identify the need of research for exploring what innovation management challenges emerge related to power-to-gas technology development and implementation, and how these challenges can be solved in cooperation among smaller and larger organizations, based on strategic adaptation and innovation management theory.

2. Theoretical background
2.1 Strategic adaptation and innovation management theory
As the environment changes, companies need to modify their strategy, structure, behavior, in order to maintain or improve their performance (Burns – Stalker, 1961; Lawrence – Lorsh, 1967; Pugh et al; 1969; Teece, 1986). As Chikán (2008) determined customer-orientation and newness as the main elements of innovation, and Fejes (2015) – after examining several literature definitions – identified progress and development as the main contents of innovation, innovation can be the tool of renewal and adaptation.

Greiner (1792) points out, however, that renewal is often hampered in large organizations because of the expanded regulations and control mechanisms which are needed to operate efficiently. In these situations, renewal can be facilitated through partnerships with other companies (Balaton et al., 2009), which leads to the open innovation concept in which companies share their resources to develop new solutions (Chesbrough, 2003). Besides external connections, internal experiments and autonomous strategic process are needed for renewal, but companies tend to follow exploitative strategies in current business areas even in crisis because of structures, previous experience, cognitive patterns (Burgelman, 1991). This is the challenge of managing strategic ambidexterity, which means that companies need to explore new business areas, but without worsening efficiency in current business areas (March, 1991). The efficiency-effectiveness and the stability-change dilemma is also relevant on the level of innovation because companies need to find the balance between exploiting current solutions (technologies) and developing new ones (Sára et al., 2014). This balance can be ensured by shaping innovation-growth strategies fitting the context: once companies need to make huge effort to implement innovation, while at other times they need a stable period to concentrate on developing innovation capabilities (Dobák – Hortoványi – Szabó, 2012).

Innovation capabilities are related to Teece's (1997, 2016) dynamic capabilities framework, which describes that companies need capabilities by which they can (1) sense the new business opportunities, (2) seize the ordinary capabilities, orchestrate resources to develop new business models and to exploit the opportunities, and (2) transform to operate with efficient processes according to the new activities (Teece, 2016). We can see that the dynamic capabilities framework is about innovation management activities: sensing is similar to strategic choices about innovation goals; seizing deals with creating new solutions or business models, then transforming is often needed for supporting environment and for the implementation of innovation.

Accordingly, innovation management means the management (of a part) of renewal, which interpretation makes clear the need of change management in innovation management, similarly to knowledge management, project management or process management (McDermott, 2002; Sára et al., 2014; Fejes, 2015). So, innovation management is an interdisciplinary activity in the field of management, and literature defines its content from numerous approach (similarly to the innovation term) (Bagno et al., 2017). For example, innovation management can be interpreted as an activity, which is about the management of organizational change in order to improve competitiveness (Fejes, 2013; Sára et al., 2014); or an activity which contains (1) shaping innovation strategy (planning), (2) organizing innovation processes, new combination of the current resources, capabilities and acquiring the missing ones (organizing), (3) forming a supporting, innovative organizational behavior and culture (leading), (4) controlling the innovation capabilities and the performance of innovation processes (controlling) (Zavarkó et al., 2017; Csedő et al.; 2018a). Moreover, some researchers approach innovation management from the view of practical tasks: innovation management can contain innovation strategy planning, using external business intelligence (e.g. benchmarking), idea management, product portfolio management, technology portfolio management, development and launch, post-launch learning, resource, and competence management (Tidd - Thuriaux-Alemán, 2016). Finally, innovation management can also be defined from an external view, considering the digitalization trend. So, Nambisan et al. (2017) introduces the concept of digital innovation management, which should focus on (1) the dynamic pairing of problems and solutions (needs and technologies), (2) the socio-cognitive sensemaking among the actors, (3) the evaluation and the development of the technological infrastructure and (4) orchestrating the listed elements.

Based on the approaches described above, we can see that innovation management is a complex activity, which is related to strategy, organization, capabilities, and behavior. Moreover, innovation management is not only about developing new (technological) solutions, but implementing them into the organization, into the daily operations. This often requires organizational change, mainly, because innovation terminates stability and generates change in the organization (Csedő, 2006; More, 2011). From a strategic perspective, it means that the conflict between exploitation and exploration (Szabó, 2011; Füzes et al., 2017) hampers the implementation of innovation strategy, innovation goals, that is why improving ambidexterity can be the subject of organizational change management (Csedő et al., 2018a). It can be realized by structural separation through which exploitative and explorative activities are placed in different business units (Tushman – O' Reilly, 1996); or by contextual development, which means that organizational context (e.g. processes, culture, leadership) make possible for employees to synchronize these conflicting activities at the same time on individual level (Gibson - Birkinshaw, 2004). So, the organizational change aiming ambidexterity can mean new or modified structures, culture and knowledge basis (Csedő et al., 2018a), or even developing a new business model (Osterwalder – Pigneur, 2010), realizing business model innovation through improving value proposition, transforming operational logic and involving new cost structures and revenue streams (Horváth et al., 2018).

In sum, strategic adaptation and renewal are often hampered because of organizational inertia in large companies, but the exploitative activities can be realized through external partnerships as well. However, as innovation management is a complex activity, dynamic capabilities are needed to sense new opportunities, to seize internal and external resources, and to transform the operation or even the whole business model in line with the implementation of the innovation.

2.2 Power-to-gas technology and its challenges

The essence of the power-to-gas technology is that it converts surplus power into gas which can be injected to the gas grid (Götz et al., 2015). The most prevalent power-to-gas technology is the power-to-hydrogen technology, which can be realized by different types of water electrolysis. Water electrolysis means that water is split to hydrogen and oxygen (Schiebahn et al., 2015). Even though the hydrogen is considered an important energy carrier, hydrogen storage is expensive and requires new infrastructure, consequently, power-to-methane technology come into view (Ikaheimo et al., 2018). The power-to-hydrogen process is the basis of the power-to-methane process (Baleirea et al., 2017), during which the hydrogen deriving from the electrolysis is mixed with carbon-dioxide and they are catalyzed by either a chemical or a biological catalyst (Sinóros-Szabó et al., 2018) producing renewable methane. Unlike hydrogen, the (renewable) methane can be effectively stored and transported in the existing gas grid (Götz et al., 2015).

The literature is not always fully consistent about the operative meaning of "power-to-gas" and "power-to-methane" technology, some studies use these terms interchangeably. However, we can clear the connections with two concrete definitions:

"The production of these chemical energy carriers using electric power during peak power production periods is termed "power-to-gas" (Schiebahn et al., 2015, p. 4286).

While

"Power-to-methane is a concept that converts electrical into chemical energy using CO_2 and H_2O" (Ghaib – Ben-Fares, 2018, p. 433).

Obviously, power-to-methane technology also uses "electric power during peak power production periods" for the water electrolysis, then converts the produced hydrogen and carbon-dioxide to renewable methane. However, based on the analysis of numerous power-to-gas technology-related publications from the last 5 years, we found that research papers often use the power-to-gas term for only methane generating technologies. Because of the complexity of power-to-gas solutions and to ensure correct referencing we also use the larger, power-to-gas term in the following.

Within the current research paper, there are two main topics in the focus of the researchers. First, there are studies which focus on operative technological questions about the improvement of the efficiency of the power-to-gas technology. Second, other studies are considering the role of power-to-gas technology in the energy system, asking and answering conceptual questions. We introduce these topics and subtopics, as follows.

Power-to-gas innovation challenges are related to the different technological solutions regarding hydrogen production, then methane production. Mostly three types of electrolysis and three types of methanation solutions are in the focus of the researchers: alkali electrolysis, PEM electrolysis, and solid-oxide electrolysis; as well as catalytic methanation, biological methanation and biogas upgrading. The most challenging technological innovation areas are the followings:

a) In case of electrolysis, which produces hydrogen as an input of the power-to-methane process, solid-oxide electrolysis (or high-temperature electrolysis) is an emerging research area, which can integrate in a single reactor the H_2O/CO_2 co-electrolysis and methanation reactions, so an efficient one-step power-to-methane process can be undertaken (Lu et al., 2018; Wang et al., 2018). Besides solid-oxide electrolysis, alkali electrolysis and PEM (polymer electrolyte membrane) electrolysis is widely used as a part of the power-to-gas process (Bailera et al., 2017; Ghaib – Ben-Fares, 2018; Götz et al., 2015).
b) Regarding methanation solutions, biogas upgrading is a widely researched area. During biogas upgrading, traditionally the CO_2 is removed from the output gas to increase the methane concentration. Recent studies are focusing on the in-situ hydrogen injection through which higher CH_4 content can be achieved (Mulat et al., 2017; Lovato et al., 2017; Agneessens et al; 2017). The biological hydrogen methanation concept is also important because of the gas-liquid mass transfer, which influences mostly the methanation performance (Lecker et al., 2017).
c) Besides biogas upgrading, the Sabatier process which contains a catalytic methanation is also researched from the aspect of the proper reactor design (Götz et al., 2015), the applicability in case of the flue gas emitted by conventional power plants (Müller et al., 2018), and different catalyst performances (Bacariza et al., 2018).
d) In case of biological methanation, which means that methane production happens directly from CO_2 and H_2 and is done by microorganisms (archea) (Götz et al., 2015), usually the reactor characteristics, nutrients and catalysts are analyzed (Inkeri et al., 2018; Alitalo et al., 2015; Savvas et al., 2018; Stangeland et al., 2017). Even though the gas-liquid mass transfer is a limiting factor in case of biological methanation as well (Inkeri et al., 2018), recent studies show that CH_4 content in the output gas can be increased by a unique Archaea strain, higher mixing energy and pressure level in the bioreactor (Sinóros-Szabó et al., 2018).

Besides the operative technology development challenges, conceptual questions also emerge about the implementation of the innovative power-to-gas technology into the global, national or regional energy sector.

a) On the micro level, some studies highlight the critical factor of the availability, quantity, and location of the CO_2 resources which are needed to the power-to-gas process to be integrated into higher levels to the energy sector (Götz et al., 2015; Blanco – Faaij, 2018; Meylan et al., 2017). Moreover, plant sizing questions also should be answered (Simonis – Newborough, 2017).
b) On regional and industry level, the power grid balancing potential of the power-to-gas technology is analyzed (Zoss et al., 2018; Gaundalini et al., 2015), which might involve also challenges for transmission system operators (Bertalan et al., 2016). This technology might affect other sectors, as well: with the wide application of the power-to-gas technology, new links and interactions could be formed between the gas, electricity, and carbon (CO_2) sector resulting in unforeseen implementation problems (Vandewalle et al., 2015). It also needs to be considered, that power-to-gas technology can be used in other areas as well, for example with wastewater treatment (Patterson et al., 2017) or in the electrochemical industry (Bailera et al., 2017). Furthermore, there are also possibilities in the combination of the power-to-gas and power-to-liquid solutions (Varone – Ferrari, 2015) or synergies between power-to-methane systems and upgrading biogas produced from grass and slurry (Vo et al., 2018).
c) On macro level, power-to-gas technology can play a crucial role in achieving renewable energy-related goals defined by policymakers of different countries or the European Union (Jentsch et al., 2014; Meylan et al., 2017; Blanco – Faaij, 2018; Schiebahn et al., 2015), because this technology supports sustainability and decarbonization initiatives (Csedő et al., 2018b). However, the environmental impact of power-to-hydrogen and power-to-methane technologies should be analyzed based on different technological variations and also regarding societal and economic perspectives (Zhang et al., 2017).

In sum, we can see that there are also operative and system level challenges related to the development and implementation of power-to-gas technology. Based on the overview of power-to-gas technology projects (Bailera et al., 2017), small companies specialized in power-to-gas technology, large energy companies with remarkable resources, and sometimes research institutes with deep scientific knowledge base need to work together to improve the technical performance and to prepare industrial-scale plants. While Ghaib and Ben-Fares (2018) points out, that system level questions are not answered yet, we highlight based on our theoretical background introduced earlier, that innovation management challenges about development and implementation of the power-to-gas technology could be solved with efficient cooperation and later-on some integration between small and large company structures.

3. Methodology

We aim to explore with qualitative approach, what innovation management challenges emerge related to power-to-gas technology development and implementation, and how these challenges could be addressed and also solved within cooperation initiatives between smaller and larger organizations. Based on Yin (2003) work, the qualitative methodology is applicable when the researcher aims to answer "What…?" or "How…?" questions and the researched phenomenon is continuous in the present. The authors chose the qualitative content analysis method for the research because it is focused on the deep understanding of a concrete phenomenon (Cho – Lee, 2014). Moreover, based on the scientific literature background of the power-to-gas technology, there is much more left to explore the power-to-gas market segment from a managerial aspect.

Because of the qualitative approach, there is a need to specify the context on which the authors focus. We chose those small and large firms to research, which participate in the development and implementation of any biological methanation technology project. The reason behind is that biological methanation is the most efficient solution and can produce the largest methane content in the output gas compared to catalytic methanation and biogas upgrading (Blanco – Faaij, 2018). Thus, biological methanation can be considered as the most innovative and impactful technology, so it seems to be proper for innovation management research. Based on Ghaib and Ben-Fares's (2018) study and additional own research, we identified four innovative startups which participate in the development of biological methanation technology: Electrochaea, Power-to-Gas Hungary, MicrobEnergy and Krajete. However, this is only one side of the research, because, based on the scientific literature review, power-to-gas technology development and implementation can be effectively realized through cooperation initiatives between smaller and larger energy companies. So, after long deliberation and pre-analysis, we chose five large energy companies to analyze deeper, which are significant market players in those regional energy sectors in which power-to-gas startups operate and are interested in renewable technologies and biomethanation based on their strategy and previous activities: E.ON, RWE, EDF, MVM (Hungary), CEZ (Czech Republic).

We conducted a qualitative content analysis on more than 250 pages of publicly reachable corporate documents and communication (annual reports, strategies, websites, online communication, and articles) of the listed firms. We followed the method described by Zhang and Wildemuth (2009) during the analysis:

1. Preparing the data: We analyzed publicly reachable written documents, so after the collection and selection, further preparing was not needed.

2. Defining the unit of the analysis: We aimed to identify words, expressions, and sentences which imply the context (e.g. goals, activities, resources) of the innovation management because innovation management is the main topic of the research.
3. Developing coding scheme: We followed inductive coding logic, which means that we defined categories and codes based on the data. Nevertheless, the categories and codes were later fine-tuned according to the theoretical background.
4. First-round coding: We coded the documents of one smaller power-to-gas technology developer company resulting in one main category and five subcategories, based on more than 30 codes.
5. Testing the coding scheme and fine-tuning: After that, we tested this categorization and coding scheme on the documents of one larger energy company and of another smaller power-to-gas technology developer company. We found new emerging categories and codes, moreover, there were some inconsistencies in the coding scheme, that is why we revised and fine-tuned it. As a result, we identified two main categories and ten subcategories.
6. Coding all the documents: Using this coding scheme we coded the all the documents and recoded the previous ones. We found more than 250 codes in the documents.
7. Assessing coding consistency: Among the 250 codes, there were numerous similarities and overlaps, consequently, we needed to terminate redundancy. Finally, we got ca. 50 codes.
8. Draw conclusions from the coded data: During the coding process, we identified clear connections between the two main categories and the codes, and that is why we also separated clearly the codes of smaller and larger companies. The findings were finalized and summarized in two tables presented in the next chapter.

4. Research results

Based on the qualitative content analysis we found complementary activities and capabilities in case of smaller power-to-gas technology developer companies and large, established energy companies. Through these complementarities, power-to-gas technology development and implementation challenges could be solved, but we found significant differences, as well, regarding organizational characteristics, which might hamper the cooperation between these companies. The results are presented in Table 1 and in Table 2.

Regarding complementarities, we found that activities of the startups are obviously narrower, focusing on the operative development and pilot implementation of the power-to-gas technology. In their documents, they usually emphasize that they *"have developed" "disruptive solutions"*, they *"solve one of the most pressing challenges"*, or they *"specialize in process control"*, conduct *"scientific research"*, *"build"* or *"optimize"* something innovative with *"experts from the fields of chemistry, biology, (bio) process engineering and engineering"* resulting in the *"leading method for biological methanation"*. These citations indicate their focused research and development activities and the introduction of the background of their small teams highlight heterogeneity and knowledge-intensity. However, they do not write about serious resources and infrastructure in contrast to large energy companies. Established, large companies highlight their vast financial resources, *"complex portfolio"*, investment activities *"in future profitable growth",* or *"in better future of energy"*. They mention their extensive infrastructure, *"considerable market share"* and role in *"supporting economic growth"*, with delivering *"competitive solutions"* and *"attentive support of customers"* to *"increase market and shareholder value"*. In sum, established, large energy companies focus their public documents and communication on their complex activities, several types of valuable resources and impact on the economic and societal environment.

Regarding differences in organizational characteristics, we found – in line with literature (e.g. Greiner, 1972, Teece, 2016) – that power-to-gas technology developer startups and large energy companies operate with different structural solutions, behavior, control mechanisms and need for external resources. The newness of the findings is the terms, which indicate these differences. Power-to-gas technology developer startups often write about *"research projects"*, *"development teams"*, *"engineering teams"* and *"project groups"* as a part of *"a dynamic early stage company"*, while large energy companies have *"boards"* and *"directorates"* which *"set our strategic course"* and *"define our policies"*. They also have *"committees"*, numerous *"departments"* with functional labels which *"cover the whole energy sector"*, but only *"playing by EU regulations"* and in an *"efficient and responsible"* way. These findings indicate horizontal connections with flexibility in case of startups and hierarchical connections with top-down planning and regulations in case of large energy companies. This also determines the strict control in case of large energy companies and the profit-orientation with *"optimization, cost-effectiveness"* to create *"an attractive dividend for our (their) shareholders"*. In contrast, power-to-gas startups focus on the results of the technology development, such as *"demonstrated the efficiency, productivity, robustness, and responsiveness"*, *"patented biocatalyst"*, *"proprietary process"*, *"patent applications"*. However, while large energy companies rarely write about their *"strategic partnerships with external startups"*, the startups often mention that they work *"in partnership with"* other actors or in a *"network* *of industrial and university partners"* and that they *"received funding"* from investors.

Based on these findings we created the following categories, subcategories, and codes, which were finalized based on the literature background. They characterize the possible cooperation and imply underlying dependencies and dynamics in the power-to-gas technology development and implementation aiming technological innovation or a whole business model innovation.

Table 1. Category 1: Complementary capabilities and activities (relative statements)

	Codes	
Subcategories	**Small power-to-gas technology developer companies (Startups)**	**Large, established energy companies (Incumbents)**
Activities	Technology-focused research and development Technology testing and optimizing Pilot implementation Cooperation with other institutions	Complex and wide range of activities (e.g. energy generation, supply, infrastructure development, satisfying end-customer's needs, investments, digitalization)
Human resources	Low number of employees and heterogenous background (entrepreneurs, business development experts, researchers in natural science, researchers in management, engineers)	High number of employees and immense experience in specific functional areas
Knowledge	Specialized knowledge in renewables and natural science; holistic management knowledge	Wide and deep knowledge related to the traditional energy system; deep and separated functional management knowledge
Material resources and infrastructure	Few: Laboratory and related tools, pilot plants	Many: Financial resources, investment capabilities, large infrastructure, industry-leader experience, and dominance, production level
Main external connections	Universities, research institutes, industrial firms	State, financial investors, startups

Table 2. Category 2: Differences in organizational characteristics (relative statements)

	Codes	
Subcategories	**Small power-to-gas technology developer companies (Startups)**	**Large, established energy companies (Incumbents)**
Strategic goal	Disruptive innovation Competitive advantage Patents, licensable technology New approaches and solutions Scientific results and publications	Profitable growth Creating shareholder value Sustainable and responsible operation Supporting national and regional energy, economic and societal policies Stable and efficient operation International business development
Structure	Project- or team-based	Hierarchical, clearly structured and regulated
Behavior	Flexible and dynamic	Inflexible, top-down planned, strictly controlled
Control	Goal-oriented (efficiency of the technology, project results)	Behavior-oriented and profit-oriented
Need for external knowledge and resources	High (capital, infrastructure, wide market knowledge)	Low (new ideas and innovative solutions)

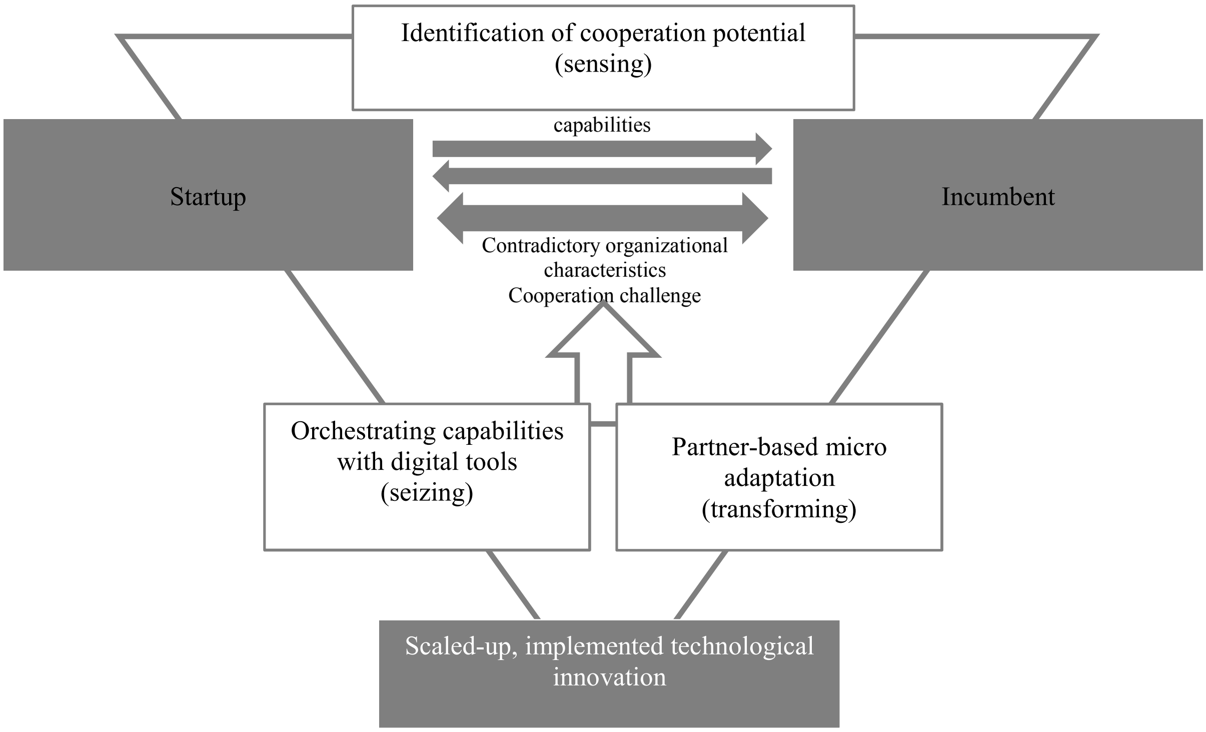
5. Discussion and conclusions

The research aimed to explore what innovation management challenges emerge related to power-to-gas technology development and implementation, and how these challenges can be solved in cooperation between smaller and larger organizations. Based on the qualitative content analysis, we found that there are complementary capabilities and activities, through which power-to-gas technology-related challenges could be solved. But the possible cooperation can be hampered by almost antagonistic organizational characteristics: the flexible, team-oriented and consequently dynamic startup structure and behavior is in contrast with the top-down controlled operations of large, established energy companies, having strictly regulated processes, which usually affect innovation-related projects, as well, within these companies (Nisar et al, 2016; Costa-Campi et al., 2014;). To overcome these difficulties, we built a theoretical model based on strategic adaptation and innovation management theory, which extend Teece's (1997, 2016) dynamic capabilities framework for strategic or project-based partnerships aiming technological innovation.

1. First, the identification of possible cooperation potential is needed. Large, established energy companies tend to exploit their traditional business areas even in crisis (Burgelman, 1991) when exploration would be needed because of the environmental change (March, 1991). The reason for that is the organizational inertia, missing knowledge, inadequate behavior or structures (Csedő et al., 2018a). As Teece (1997) points out, sensing means the identification of new business opportunities, which, in this case, can mean an implementable innovative technology supporting the renewal of a large, established energy company. From the perspective of the startups, this identification is also needed to scale-up the technology and achieve the planned growth or to support an exit by a strategic investor (Katila et al., 2008).
2. Second, there is a challenge during the cooperation because of the contradictory organizational characteristics described above. Regarding the seizing activity, we adopt the concept of Nambisan et al. (2017) about digital innovation management. Based on this concept, companies need focus on the dynamic pairing of problems and solutions, on socio-cognitive sensemaking among the actors with the development of the technological infrastructure (Nambisan et al., 2018). As IT solutions can improve external and internal knowledge flow (Hortoványi – Ferincz, 2015); innovation performance (Trantopoulos et al., 2017; Wu, 2015), organizational flexibility (Ravichdaran, 2018), and competitiveness (Hortoványi, 2016; Zavarkó – Csedő, 2018a), we conclude that using digital solutions, for example customized engineering and project management software (Csedő et al., 2017), knowledge management platform (Zavarkó – Csedő, 2018b) or workflow system (da Silva et al., 2017) during the coordination and orchestration of the complementary capabilities support innovation goals and help to overcome efficiently on the challenges emerging from antagonistic organizational characteristics of startups and large, established energy companies.
3. Third, based on contingency theory, organizational configuration determines performance by the interconnections of strategy, structure, behavior, and control (Burns – Stalker, 1961; Lawrence - Lorsh, 1967; Pugh et al; 1969), we state that using digital solutions is needed but not sufficient to overcome challenges. As on company level, if external environment changes, adaptation is needed (Teece, 1986), so, when the configuration is modified by the involvement of new actors, the other elements of the configuration also need to incrementally or radically be transformed, especially when technology and digitization plays an important role in the operations (Zavarkó – Csedő, 2018c). Realizing micro level adaptation based on the partners' operations can practically mean (1) more regulated and planned daily operations in case of startups and (2) more decentralized decision-making processes in case of large, established energy companies, during cooperatively executed development or implementation tasks. Obviously, every change can generate organizational resistance, which should be handled by change management tools and best practices.

In sum, dynamic co-capabilities in innovation management help to explore and exploit complementarities between organizations with significantly different or antagonistic characteristics.

Figure 1. Dynamic co-capabilities in innovation management



The theoretical contribution of the study is that it applies and extends the interpretation of dynamic capabilities for cooperatively performed innovation management tasks and identifies its possible meanings on a more operative level based on the combination of fundamental and recent theoretical background of strategic adaptation and innovation management. The practical contribution derives from the defined possible dynamic co-capabilities (identification of cooperation potential, orchestrating capabilities with digital tools and partner-based micro adaptation) which can help top managers to recognize the underlying challenges of the exploitation of complementary capabilities and react to them, resulting in the higher adaptation and integration into the grid of renewable resources. However, these conclusions have some limitations as well. First, we conducted qualitative research and focused on the deep understanding of the specific power-to-gas market segment of the complex energy sector. Thus, the conclusions cannot be generalized in a broader sense but can function as a basis of further research following functionalist approach and quantitative methodology. Moreover, this research explored the underlying factors of innovation management based on publicly accessible documents, that is why the credibility of the findings could be increased with future researches containing in-depth interviews or analyzing confidential documents. Finally, future research of the management of power-to-gas technology could also involve other technologies, for example, the power-to-ammonia process (Ikaheimo et al., 2018).

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References

Adil, A. M., Ko, Y. (2016). Socio-technical evolution of Decentralized Energy Systems: A critical review and implications for urban planning and policy. Renewable and Sustainable Energy Reviews, 57, 1025-1037

Agneessens, L. M., Ottosen, L. D. M., Voight, N. V., Nielsen, J. L., De Jonge, N., Fischer, C. H., Kofoed, M. V. W. (2017). In-situ biogas upgrading with pulse H_2 additions: The relevance of methanogen adaption and inorganic carbon level. Bioresource Technology, 233, 256-263

Alagoz, B. B., Kaygusuz, A. (2016). Dynamic energy pricing by closed-loop fractional-order PI control system and energy balancing in smart grid energy markets. Transactions of the Institute of Measurement & Control, 38, 565-578

Alitalo, A., Niskanen, M., Aura, E. (2015). Biocatalytic methanation of hydrogen and carbon dioxide in a fixed bed bioreactor. Bioresource Technology, 196, 600-605

Anadon, L., Bunn, M., Chan, G., Chan, M., Jones, C., Kempener, R., Lee, A., Logar, N.,Narayanamurti, V. (2011). Transforming U.S. energy innovation. Energy Technology Innovation Policy Research Group,

Harvard Kennedy School, Cambridge, In: Costa-Campi, M.T. - Duch-Brown, N. - García-Quevedo, J. (2014): R & D drivers and obstacles to innovation in the energy industry. Energy Economics, 46, 20-30.
Bacariza, M. C., Maleval, M., Graca, I., Lopes, J. M., Henriques, C. (2018). Power-to-methane over Ni/zeolites: Influence of the framework type. Microporous and Mesoporous Materials, 274, 102-112
Bagno, R. B., Salerno, M. S., Da Silva, D. O. (2017). Models with graphical representation for innovation management: a literature review. R&D Management, 47, 637–653
Bailera, M., Espatolero, S., Lisbona, P., Romeo, L. M. (2017). Power to gas-electrochemical industry hybrid systems: A case study. Applied Energy, 202, 435-446
Bailera, M., Lisbona, P., Romeo, L. M., Espatolero, S. (2017). Power to Gas projects review: Lab, pilot and demo plants for storing renewable energy and CO2. Renewable and Sustainable Energy Reviews, 69, 292-312
Balaton, K., Hortoványi, L., Incze, E., Lackzó, M., Szabó, Zs. R., Tari, E. (2009): Startégiai menedzsment. Budapest: Aula Kiadó.
Bertalan, Zs., Nagy, K., Csedő, Z., Tamus, Á (2016). Innovations in Operational Risk Management and Business Continuity Planning Methodologies of Transmission System Operators: Implications of the Operational Security Network Code. Journal of Energy Technologies and Policy, 6, 12-17
Blanco, H., Faaij, A. (2018). A review at the role of storage in energy systems with a focus on Power to Gas and long-term storage. Renewable and Sustainable Energy Reviews, 81, 1049-1086
Bollino, C. A., Madlener, R. (2016). Foreword to the Special Issue on "High Shares of Renewable Energy Sources and Electricity Market Reform". Energy Journal, 37, 1-4
Burgelman, R. A. (1991). Intraorganizational Ecology of Strategy Making and Organizational Adaption: Theory and Field Research. Organizational Science, 1991 (2), 239-262
Burns, T.; Stalker, G. (1961) The Management of Innovation. London: Tavistock.
Chesbrough, H. W. (2003). Open innovation: The new imperative for creating and profiting from technology. Boston, US: HBS Press
Chikán, A. (2008). Vállalatgazdaságtan (Business Economics). Budapest.: Aula Kiadó
Costa-Campi, M.T., Duch-Brown, N., García-Quevedo, J. (2014). R & D drivers and obstacles to innovation in the energy industry. Energy Economics, 46, 20-30
Cho, J. Y., Lee, E. (2014). Reducing Confusion about Grounded Theory and Qualitative Content Analysis: Similarities and Differences. The Qualitative Report, 32, 1-20
Csedő, Z, Zavarkó, M., Sára, Z. (2018a). A vállalati innováció által indukált szervezeti változások a magyar energiaszektorban. Vezetéstudomány / Budapest Management Review, 49, 53-62
Csedő, Z. (2006). Organizational change and change management in term of continuous differentiation and integration: the example of the innovative pharmaceutical industry (Szervezeti változás és változásvezetés a folyamatos differenciálódás és integráció tükrében: az innovatív gyógyszeripar példája). PhD-dissertation. Corvinus University of Budapest.
Csedő, Z. (2017). Power-to-Gas: egy ígéretes lehetőség a megújuló energiaforrások integrációjára (In English: Power-to-Gas: A promising opportunity for the integration of renewebles). Zöld Ipar Magazin, 7, 28-29
Csedő, Z., Sinóros-Szabó, B., Zavarkó, M., Sinóros-Szabó, B. (2018b). Biometánt előállító és hasznosító power-to-gas technológia műszaki és rendszerszintű fejlesztése (In English: Technical and system-level development of a Power-to-Gas technology producing and using biomethane). Hogyan tovább a klímatudatos jövő felé? (In English: What's next for climate-conscious future?) Conference: Innovation and Technology Ministry, Budapest, Hungary, 26.11.2018.
Csedő, Z.; Kovács, K.; Zavarkó, M. (2017): How does Digitalization Affect Change Management: Empirical Research at an Innovative Industrial Group. European Journal of Business and Management, 9, 1-5
Cullmann, A., Nieswand, M., Seifert, S., Stiel, C. (2016). No differences in efficiency between public and private utilities. DIW Economic Bulletin. 5/19/2016, 233-238
Dobák, M., Hortoványi, L., Szabó, Zs. R. (2012). A sikeres növekedés és innováció feltételei. Vezetéstudomány / Budapest Management Review, 18, 40-48
Ergüden, E.; Çatlioglu, E. (2016). Sustainability Reporting Practiceses In Energy Companies With Topsis Method. Journal of Accounting & Finance. Jul 2016, 201-221
Fejes J. (2013). Innovációvezérelt vállalatirányítás: stratégiai megközelítés. Study. Budapest: Corvinus University of Budapest.
Fejes J. (2015). Innovation adventuring from theory to strategy. Vezetéstudomány / Budapest Management Review, 46, 58-69
Füzes, P., Szabó Zs, R., Gódor, Z., (2017). Escaping from the exploitation trap by shaping the digital future: How can an established firm drive industry changes by exploring and exploiting cloud computing? Conference: Euram 2017: Making knowledge work. Glasgow, UK, 2017.06.21-2017.06.24. Paper 2081.
Ghaib, K., Ben-Fares, F. Z. (2018). Power-to-Methane: A state-of-the-art review. Renewable and Sustainable

Energy Reviews, 81, 433-446

Gibson, C. B., Birkinshaw, J. (2004). The Antecedents, Consequences, and Mediing Role of Organization- al Ambidexterity. Academy of Management Journal, 47, 209-226.

Götz, M., Lefebvre, J., Mörs, F., McDaniel Koch, A., Graf, F., Bajohr, S., Reimert, R., Kolb, T. (2016). Renewable Power-to-Gas: A technological and economic review. Renewable Energy, 85, 1371-1390

Greiner, L. E. (1972). Evolution and Revolution as Organizations Grow. Harvard Business Review, 50, 37–46

Guandalini, G., Campanari, S., Romani, M. C. (2015). Power-to-gas plants and gas turbines for improved wind energy dispatchability: Energy and economic assessment. Applied Energy, 117-130

Hernádi Bettina (2012). Green Accounting for Corporate Sustainability. Club of Economics in Miskolc, TMP, 8, 23-30

Høgevold, N. M., Svensson, G. (2012). A business sustainability model: a European case study. Journal of Business & Industrial Marketing, 27, 142-151

Hortoványi, L., Ferincz, A. (2015). The Learning Organization The impact of ICT on learning on-the-job. The Learning Organization, 22, 2–13

Hortoványi, L. (2016). The Dynamic Nature of Competitive Advantage of the Firm. Advances in Economics and Business, 4, 624–629

Horváth, D., Móricz, P., Szabó, Zs. R. (2018). Üzletimodell innováció. Vezetéstudomány / Budapest Management Review, 49, 1-12.

Ikaheimo, J., Kivilouma, J., Wiess, R., Holttinen, H. (2018). Power-to-ammonia in future North European 100 % renewable power and heat system. International Journal of Hydrogen Energy, 43, 17295-17308

Inkeri, E., Tynjälä, T., Laari, A., Hyppänen, T. (2018). Dynamic one-dimensional model for biological methanation in a stirred tank reactor. Applied Energy, 209, 95-107

Jentsch, M., Trost, T., Sterner, M. (2014) Optimal Use of Power-to-Gas Energy Storage Systems in an 85% Renewable Energy Scenario. Energy Procedia, 46, 254-261

Katila, R., Rosenberger, J. D., Eisenhardt, K. M. (2008). Swimming with sharks: Technology ventures, defense mechanisms and corporate relationships. Administrative Science Quarterly, 53, 295–332

Lawrence, P. R.; Lorsch, J. W. (1967). Organization and Environment: Managing Differentiation and lntegration. Boston: Division of Research, Graduate School of Business Administration, Harvard University.

Lecker, B., Illi, L., Lemmer, A., Oechsner, H. (2017) Biological hydrogen methanation – A review. Bioresource Technology, 245, 1220-1228

Lovato, G., Alvarado-Morales, M., Kovalovszki, A., Peprah, M., Kougias, P. G., Rodrigues, J. A. D., Angelikadi, I. (2017). In-situ biogas upgrading process: Modeling and simulations aspects. Bioresource Technology, 245, 332-341

Luo, Y., Shi, Y., Li, W., Cai, N. (2018). Synchronous enhancement of H_2O/CO_2 co-electrolysis and methanation for efficient one-step power-to-methane. Energy Conversion and Management, 165, 127-136

Luthra, S., Kumar, S., Kharb, R., Ansari, Md. F., Shimmi, S. L. (2014). option of smart grid techno- logies: An analysis of intractions among barriers. Rennewable and Sustainable Energy Reviews, 33, 554-565

Mangedari, M., Farzad, S., Görgens J. F. (2018). A new insight into sugarcane biorefineries with fossil fuel co-combustion: Techno-economic analysis and life cycle assessment. Energy Conversion and Management, 165, 76–91

March, J. G. (1991). Exploration and exploitation in organizational learning. Organization Science, 2, 71–87

McDermott, C. (2002). Managing radical innovation: an overview of emergent strategy issues. Journal of Product Innovation Management, 19, 424–438

Meylan, F. D., Piguet, F. P., Erkman, S. (2017). Power-to-gas through CO_2 methanation: Assessment of the carbon balance regarding EU directives. Journal of Energy Storage, 11, 16-24

More, R. (2001). Creating profits from integrated product-service strategies. Ivey Business Journal 65(5): 75-81.

Mulat, D. G., Mosbækm, F., Ward, A. J., Polag, D., Greule, M., Keppler, F., Nielsen, J. L., Feilberg, A. (2017) Exogenous addition of H_2 for an in situ biogas upgrading through biological reduction of carbon dioxide into methane. Waste management, 68, 146-156

Müller, K., Fleige, M., Rachow, F., Schmeißer, D. (2013). Sabatier based CO_2-methanation of flue gas emitted by conventional power plants. Energy Procedia, 40, 240-248

Nambisan, S., Lyytinen, K., Majchrzak, A., Song, M. (2017). Digital Innovation Management: Reinventing Innovation Management in a Digital World. MIS Quaterly, 41, 223 – 238

Nisar, A., Palacios, M., Grijalvo, M. (2016). Open organizational structures: A new framework for the energy industry. Journal of Business Research, 69, 5175-5179

OECD (2011). Fostering Innovation for Green Growth. Organisation for Economic Co-operation and Development, Paris (2011) in: Costa-Campi, M.T.; Duch-Brown, N.; García-Quevedo, J. (2014). R & D drivers and obstacles to innovation in the energy industry. Energy Economics, 46, 20-30.

Osterwalder, A., Pigneur, Y. (2010). Business Modell Generation, John Wiley & Sons, Inc., Hoboken, New Jersey

Parobek, J., Paluš, H., Kalamárová, M., Loučanová, E., Šupín, M., Križanová, A., Štofková, K. R. (2016). Energy Utilization of Renewable Resources in the Europe Union: Cluster Analysis Approach. Bio-Resources, 11, 984-995

Patterson, T., Savvas, S., Chong, A., Law, I., Dinsdale, R., Esteves, S. (2017). Integration of Power to Methane in a waste water treatment plant – A feasibility study. Biosource Technology, 245, 1049-1057

Pugh, D. S.; Hickson, D. J.; Hinings, C. R.; Turner, C. (1969). The Context of Organization Structures. Administrative Science Quarterly, 14, 91-114

Sára, Z., Csedő, Z., Fejes, J., Tóth, T., Pörzse, G. (2014). Innovation management and innovation strategies – the role of corporate knowledge in innovative processes. Vezetéstudomány / Budapest Management Review, 45, 42-48

Savvas, S., Donnelly, J., Patterson, T., Chong, Z. S.; Esteves, S. R. (2018). Methanogenic capacity and robustness of hydrogenotrophic cultures based on closed nutrient recycling via microbial catabolism: Impact of temperature and microbial attachment. Biosource Technology, 257, 164-171

Schaeffer, G. J. (2015). Energy Sector in Transformation, Trends and Prospects. Procedia Computer Science, 52, 866-875

Schiebahn, S., Grube, T., Robinius, M., Tietze, V., Kumar, B., Stolten, D. (2015). Power to gas: Technological overview, systems analysis and economic assessment for a case study in Germany. International Journal of Hydrogen Energy, 40, 4285-4294

Simonis, B., Newborough, M. (2017). Sizing and operating power-to-gas systems to absorb excess renewable electricity. International Journal of Hydrogen Energy, 42, 21635-21647

Sinóros-Szabó, B., Zavarkó, M., Popp, F., Grima, P., Csedő, Z., (2018). Biomethane production monitoring and data analysis based on the practical operation experiences of an innovative power-to-gas benchscale prototype. Journal of Agricultural Sciences, 150, 399-410

Stangeland, K., Kalai, D., Li, H., Yu, Z. (2017). CO_2 methanation: the effect of catalysts and reaction conditions. Energy Procedia, 105, 2022-2027

Szabó, Zs. R. (2011). Strategic adaptation, ambidexterity and competitiveness in Hungary between 1992 and 2010. (Stratégiai adaptáció és kettős (verseny)képesség Magyarország 1992 és 2010 között). PhD-dissertation. Corvinus University of Budapest.

Teece, D. J. (1986). Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Research Policy, 15, 285–305

Teece, D. J., Pisano, G., Schuen, A. (1997). Dynamic capabilities and strategic management. Strategic Management Journal, 18, 509–533

Teece, D. J. (2016). Dynamic cap abilities and entrepreneurial managementin large organizations: Toward a theory of the (entrepreneurial) firm. European Economic Review, 86, 202–216

Tidd, J., Thuriaux-Alemán, B. (2016). Innovation management practices: cross-sectorial adoption, variation, and effectiveness. R&D Management, 46, 1024–1043

Tushman, M. L., O'Reilly, C. A. (1996). Ambidextrous organizatio: Managing evolutionary and revolution- ary change. California Management Review, 38, 8-30

Vandewalle, J., Bruninx, K., D'haeseleer, W. (2015).Effects of large-scale power to gas conversion on the power, gas and carbon sectors and their interactions. Energy Conversion and Management, 94, 28-39

Varone, A., Ferrari, M. (2015). Power to liquid and power to gas: An option for the German Energiewende. Renewable and Sustainable Energy Reviews, 45, 207-2018

Vo, T. T. Q., Rajendran, K., Murphy, J. D. (2018) Can power to methane systems be sustainable and can they improve the carbon intensity of renewable methane when used to upgrade biogas produced from grass and slurry? Applied Energy, 228, 1046-1056

Wang, L., Pérez-Fortes, M., Madi, H., Diethelm, S., Van Herle, J., Maréchal, F. (2018). Optimal design of solid-oxide electrolyzer based power-to-methane systems: A comprehensive comparison between steam electrolysis and co-electrolysis. Applied Energy, 211, 1060-1079

Zavarkó, M., Bertalan, Zs., Sára, Z., Csedő, Z. (2017). Innovation and Knowledge Management in the Energy Sector. Journal of Energy Technologies and Policy, 7, 45-53

Zavarkó, M.; Csedő, Z. (2018a): Increasing competitiveness by digitalization. 2nd EIBA Workshop, Corvinus University of Budapest, Hungary, 7.03.2018.Zavarkó, M.; Csedő, Z. (2018b): Digitalization opportunities of corporate knowledge in order to increase innovation ambitions and operational efficiency. Conference: Digitalization in Management Education and Development: How to create communities of inquiry? Corvinus University of Budapest, Hungary, 27.04.2018.

Zavarkó, M., Csedő Z. (2018c). A digitalizációs stratégiai célok megvalósításának szervezeti változással összefüggő kihívásai az egyedi IT fejlesztési projektek során (In English: Organizational change-related challenges of the implementation of digitization stratategic goals during individual IT development projects). Conference: A stratégiai menedzsment legújabb kihívása: a 4. ipari forradalom (In English: The newest challenge of strategic management: 4. industrial revolution), Corvinus University of Budapest, Hungary, 18.10.2018.

Zhang, X., Bauer, C., Mutel, L. C., Volkart, K. (2017). Life Cycle Assessment of Power-to-Gas: Approaches, system variations and their environmental implications. Applied Energy, 190, 326-338

Zhang, Y., Wildemuth, B.M. (2009): Qualitative analysis of content. Applications of Social Research Methods to Questions in Information and Library Science, pp. 308-319.

Zoss, T., Dace, E., Blumberga, D. (2016). Modeling a power-to-renewable methane system for an assessment of power grid balancing options in the Baltic States' region, Applied Energy, 170, 278-285