Lessons Learned from an Operational Smart Grid Through the Example of a Local Government in Hungary

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Summary

The steadily growing global demand for electricity, sustainability expectations, the global Covid epidemic and the Russian-Ukrainian war are also affecting the electricity supply chain. In our study we will focus on the smart grid, the modern smart electricity network of the near future, from a Hungarian perspective, with management approach. Hungary's newest and most complex smart grid is analysed using the case study method. We investigated the actors of the smart grid and were interested in how the cooperation between the parties was, what learning processes they experienced, and what risks they saw and see now. Our results show that customers and contractors are mutually satisfied; in addition to the numerical benefits, each party also values the learning processes in different areas. The risks identified stem from modern technology, complexity, novel solutions and operational mechanisms, but geopolitical, global economic uncertainties and shortages also have an impact.

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In 2021, Marybel Batjer, the president of California Public Utilities Commission announced her resignation (Hoeven, 2021), as California experienced its first statewide blackout in 20 years in August 2020; a sweltering heat wave and other factors put California's power system at risk. „*We have been unable to predict and prevent these power outages, and this is simply unacceptable*" – California Governor Gavin Newsom said[1]. In 2021, California's system operator issued eight state alerts urging customers to voluntarily reduce their energy use when the system is exposed to the greatest utilisation, which is between 4 and 9 p.m.

According to the latest 2021 Global Energy Trends report, the electricity consumption of the members of the G20 increased by 0.9% from 2018 to 2019, decreased by 2.3% a year later, and increased by 5.3% by the end of 2021[2]. The decline in 2020 was caused by the global Covid- pandemic, as mentioned by the authors (for more details on the economic effects of the pandemic, see Czeczeli et al., 2020). The demand for electricity is constantly increasing both from industry and households. The question is how the supply side can react to this. Unfortunately, the topicality of the issue is made even more obvious by the energy crisis caused by the Russia-Ukraine war, which hits Europe even harder. The EU's leading politicians are no longer worried about high energy prices, but primarily about the quantity of gas[3]. Therefore, in our study, we briefly present the key characteristic features of the current and future supply chains of electricity. In connection with smart grids, we mention some ideas found in literature related to innovation and innovation networks. With this, we prepare the way for our empirical research, in which we analysed the intelligent network in Békéscsaba from the aspect of management and in a network approach, using the methodology of a case study.

Our research questions were as follows:

- What were the motivations of the participants of the smart grid?
- How did the network of contributors work during the development and the operation of the smart grid?
- Has a learning process occurred or is it occurring in the actors of the intelligent network? If so, how and what is the end result?
- What operational risk did they expect or can they see or experience (in terms of trust, technology, relationship/network, behavioural, other)?

Our research represents a novel approach in several ways. Studying operational smart grids from an economic and management point of view is still relatively rare even at the international level. To the best of our knowledge, only one or two scientific studies have been published so far on operational Hungarian smart grids from economic and social perspectives (e.g., Piricz, 2021). We consider it important to take a network approach and examine the topic at a network level.

LITERATURE REVIEW

From business networks to smart grids

According to the so-called network perspective formulated by *Hakanson and Snehota* (1995), a company must accept that it is not independent, but interdependent and embedded in its environment, and this will limit its ability to think and act independently. In their approach, the business network is therefore a system of interconnected business relationships. As a large group of business networks, 'the supply chain encompasses every effort involved in producing and delivering a final product, from the supplier's supplier to the customer's customer.' (*Szegedi et al.*

(2017) cite the definition of the US Supply Chain Council from 1997.) The management of the supply chain includes tasks and functions related to the coordination of the above processes at network level, which covers a kind of end-to-end approach (Mangan et al., 2008).

The traditional supply chain of electricity operates as a pull system, with no option for a significant storage of the final product. Power plants and other generators produce the necessary electricity from moment to moment (in a real just-in-time system). Otherwise, the system will lose its balance, the service will be interrupted, generating a high balancing cost and huge restart costs (Bajor, 2007).

A smart grid is an electricity network that can cost-effectively integrate the behaviour and activities of all connected users – producers, consumers – in order to provide an economically efficient and sustainable energy system with low losses and high energy levels (The European Union Commission Task Force for Smart Grids). These intelligent networks (smart grids) are self-healing and resilient (for more details, e.g. Halmai, 2021) systems that include consumers; tolerate attacks; ensure the power quality required for 21st century users; apply a wide range of supply and demand; and they are fully enabled and supported by competitive markets (Amin and Giacomoni, 2012).

As you can see in *Table 1*, stakeholder tasks will change or increase in smart grids. For example, not only traditional power plants are engaged in electricity production, but also renewable power plants of (organizational or private) consumers; therefore, these end consumers are also producers, or prosumers (combining the words producer and consumer). So, it is an important difference that production and consumption are

Table 1

COMPARISON OF TRADITIONAL ELECTRICITY SUPPLY CHAIN AND SMART GRID ACCORDING TO MAIN ACTIVITIES

	Traditional supply chain of electricity	Smart grid
Power generation	• mainly traditional power plants • centralized generation	• traditional power plants (mass production) • power plants using renewable energy • distributed/shared production (V2G, G2V)
Wholesale trade	• free market operations	• free market operations • growing role of international trade between countries
Transport, warehousing	• natural monopoly	• natural monopoly? • new roles of V2G and G2V
Distribution and metering	• natural monopoly	• natural monopoly? • new roles of V2G and G2V
Retail trade	• free market operations	• free market operations • new role of energy communities

Source: Piricz, 2020; 395

separated in traditional systems, but not in smart grids; therefore, these activities must be optimized.

In recent decades, energy supply has shown strengthening market characteristics (Verbong et al. 2013). This trend is likely to continue in smart grids as well. In addition to a growing trend in international energy trade, we can observe that individual users tend to form energy cooperatives and energy communities.

Smart grids in Hungary

In Hungary, the issue of smart grids came up in the early 2000s, and many different networks operate by now. (There is no official aggregate data on their number yet. Although the Lechner Knowledge Center's Sample Database tries to collect all projects and information related to sustainability, smart environment and smart economy, in many cases these cannot be considered a smart grid.) According to experts, Hungary's electricity network is well-planned, but this extensive network is outdated,[4] for which a possible solution is the spreading of smart grids. This direction is strengthened by ever-increasing expectations regarding sustainability and a reduction in carbon dioxide emissions, or by an EU decision according to which only electric vehicles can be placed on the market as new cars from 2035.[5]

One of the funding sources for Hungarian smart grids currently is the Modern Cities Programme, although its target system is much broader and changes according to local needs.[6] We will now focus only on a few implemented smart grid elements, omitting any projects that are in the phases of collecting ideas, defining goals, statement of intent, or planning.

We do not want to confuse the concepts of smart city and smart grid, but want to note that they are closely related. Budapest has long competed with big cities of the world on the list of smart cities, which is calculated based on a specific, so-called Smart City Index. In the latest Smart City Index 2021 list, Budapest ranks 99th (it was 77th in 2020).[7] Supported under the programme called New Széchenyi Plan – Digital City, Miskolc has developed a dispatching centre and implemented a license plate recognition system.[8]

Along with Budapest and Miskolc, Pécs was included in the European Commission's Climate-Neutral and Smart Cities Mission, which must establish "climate city contracts".[9] Pécs has also joined the Sustainable Energy and Climate Action Plan, under which they undertake to reduce the share of energy consumption and carbon dioxide emissions. Together with Magyar Telekom, Szolnok develops the so-called T-City, which aims to test the most modern telecommunications, IT and content services.[10]

After the above cities, we present additional types of smart grids through Hungarian examples. The Liveable Future Park is located in the Equestrian Therapy Centre of the International Children's Safety Service, primarily serving the needs of the Equestrian Therapy Centre (Piricz, 2021). The prosumer in the Liveable Future Park has taken up an increased role unintentionally due to special circumstances, as it has taken over many tasks from the end user (Piricz, 2021).

The production capacities of the operating BÜKK-MAK, the Hungarian Virtual Micro-Networks Balance Group Cluster (MAVIRKA), consist of in-house, small and medium-sized production units and their own management system. The medium- and high-voltage network has its own coordination and supervision centre, and its own production and consumption system serves residents, entrepreneurs, municipalities and local citizens in 44 settlements in Northern Hungary. This network will revolutionize the current electricity management system by bringing the "inconvenient little ones" together without "tugging" the national grid.[11]

The Alternative Energy Sources Research Centre (Óbuda University) includes solar cells, a reservoir hydropower model, wind turbines and a heat pump.[12] All this also serves research and energy optimization purposes. Infoware Zrt., which is among the world leaders in battery energy storage, uses its own production hall and the equipment of its electrical laboratory as a manufacturer.[13]

The Danube InGrid (Danube Intelligent Grid) project aimed at deeper cross-border integration of energy markets has been launched by the European Commission (with a planned budget of EUR 291 million between 2020 and 2025).[14] The purpose of the Danube InGrid project is to promote network integration by using smart technologies for the growth of renewable electricity production, as well as to guarantee the security of supply by building and operating a smart grid,[15] and as part of this project, the distribution network will be renewed in Northern Transdanubia and Western Slovakia.

Innovation network and electricity network innovation

Nowadays, technological achievements are made less and less as achievements of single market players. In most cases, connecting actors in a heterogeneous composition (Corsaro et al., 2012) can lead to successful innovation (Csizmadia, 2004). As technological development progresses, most companies turn to external "sources of knowledge", capitalising on the advantages arising from the unique skills and special knowledge of the actors cooperating in the network. The resulting networks aimed at joint development are called innovation networks, where resources owned by different network members are used for a common goal (Corsaro et al., 2012). The interaction between the parties plays a key role in the acquisition of knowledge and resources (Mandják et al. 2021) In accordance with the evolutionary economics approach (Pyka, 2002), the actors strive to cooperate with other actors with heterogeneous competences, because in the accelerated competitive situation, they can thus acquire the knowledge necessary for development in the most efficient way.

The riskiness of innovation processes has already been presented in detail by many authors (e.g. Cantù et al. 2013, Weiss and Dale 1998). The use of new technology, the selection of new partners or the targeting of new markets also involve risks, to mention only the most common ones. Our study deals with a special area of innovation: the range of innovations related to sustainability and the use of renewable energy sources, in which case the "double externality" effect (Ramkumar et al. 2022) is a serious risk. This may be an obstacle to the development of innovations of this kind, since knowledge and environmental externalities also arise in the case of eco-innovations. While a company creates social value through innovation, this is accompanied by the production of knowledge-based externalities that enable competitors to learn about implementation difficulties and thus make it easier for them to take over the innovation. In addition, development with sustainability in mind also results in a positive environmental externality at the company's expense, which puts the company in an advantageous position compared to its polluting competitors.

METHODOLOGY

The objective of qualitative methodology is to understand the underlying reasons and motivations fundamentally, and we seek answers to the how and why. The methodology works with a small number of cases (not representative), but it is suitable for exploring and learning about problems (Miles, 1994), therefore, it is a very common research methodology when investigating B2B problems, for example. The qualitative methodology provides an excellent opportunity to present roles played in a network (Yeung et al., 1995), or situations, and solutions. As Yin (2018) put it, a case study is an empirical method that examines a contemporary phenomenon (the "case") in depth when the boundaries between the phenomenon and the context are not clear. He adds that a case study can cope with a technically specific situation in which there may be far more variables than data points, and one of its advantages is that data collection and analysis are based on multiple sources of evidence. In the case of the case study, the "sample" does not mean the "case" or the case study, but rather the experience, the complex picture that emerges, and accordingly the conclusions are drawn from the totality of the understood processes/circumstances/characteristics (Lauckner et al. 2012).

The (classical) case study consisting of one case has the disadvantage of "having to put all eggs in one basket" (Yin, 2018:108); however, the process of the analysis is basically the same as for the case study that includes several cases. We decided to choose a single case because the Smart Grid of Békéscsaba meets the definitions of a smart grid in all respects, it does not operate on a temporary, experimental basis, but continuously, and, according to experts, it is the most technically complex, operational smart grid in Hungary today.

Our case study is, on the one hand, a so-called exploratory case study, as our goal is to understand the operation of smart grids, based on which we may be able to formulate recommendations and appropriate questions for further investigations and information materials. On the other hand, our research is a so-called revelatory case (Yin, 2018); this situation exists when a researcher has the opportunity to observe and analyse a phenomenon that was previously unavailable to investigation by social science.

For checking qualitative data, triangulation is one of the recommended solutions. The term comes from the dictionary of marine navigation and refers to the precise determination of a position based on measurements from three different directions (Denzin, 1978). During in-depth interviews related to the case study, we used the so-called method triangulation, i.e. we asked the same questions in several approaches. In addition, we used personal triangulation, since several experienced researchers participated in conducting in-depth interviews, and we constantly shared our experiences.

The four rules of data collection (Patton, 2015):

❶ Using multiple sources of evidence that we check. This includes the applied method or person triangulation.

❷ A case study – creating a database. (Details of this related to our research are provided in the next paragraph.)

❸ Maintaining the chain of evidence: The process of the case study should be logical, and the "evidence" used in earlier stages (e.g., research questions, experiences, results) should reflect concepts found in later stages (e.g., findings).

❹ Care must be taken when using data from social media sources. (This is not relevant in our case.)

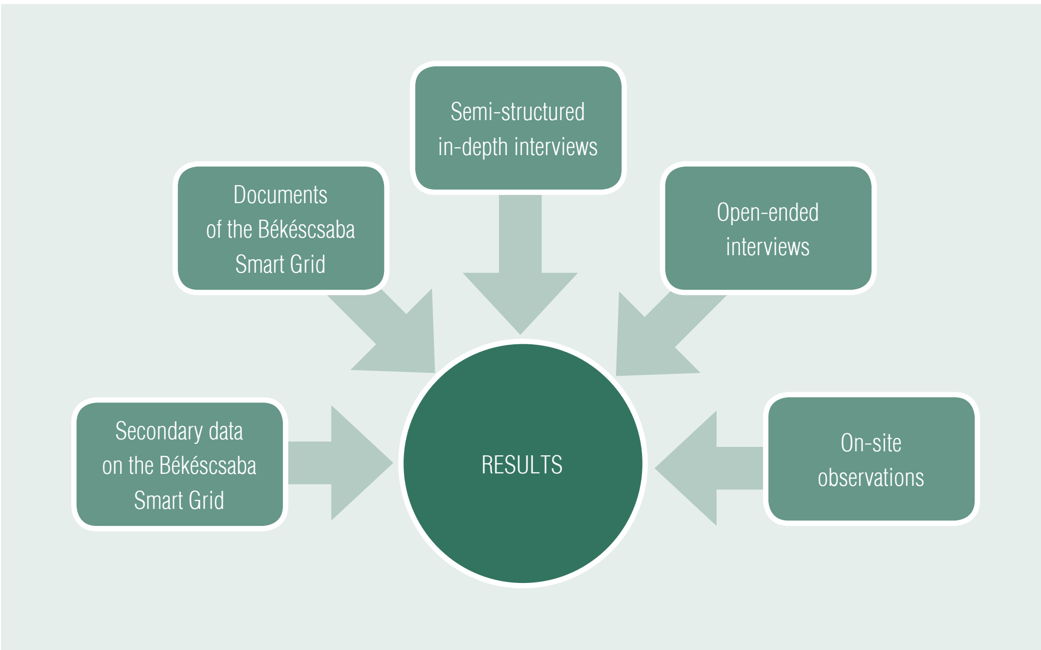
"The course of research is progressive focusing" – Szokolszky (2004) writes about qualitative research, and we have also experienced this. Using the methodology of a relevant Danish research (Ma et al., 2018), we started to conduct in-depth interviews with Hungarian smart grid experts about the management side of the smart grid and the participants' cooperation experiences. In this phase of data collection, we noticed that several people were talking about the Békéscsaba Smart Grid. It was then that we decided to analyse this new project in the form of a case study, keeping and supplementing the outline of the semi-structured in-depth interview. When we talked again with the most important actors, we clarified some topics and, additionally, we managed to obtain much more information about the operational experiences of the past period. Overall, we conducted in-depth expert interviews in two rounds (with external experts, general contractor, owners and users), made a site visit, and used both primary and secondary sources about the given smart grid (see *Figure 1*).

The three classic tasks of data analysis are: data reduction, data display, and drawing and validating conclusions. All in-depth interviews conducted by us were recorded and then we listened to them several times. As part of this process, we developed a general picture of the relevant topics, and we entered the most typical – or very special – phrases and sentences into a detailed Excel table. Thus, full documentation and transparency were achieved. Ideas grouped into categories, as well as specific data and information related to the smart grid (data reduction) were depicted in figures for the purpose of a qualitative understanding of the problems and phenomena (data display).

During data processing, we used a so-called "ground up" (Yin, 2018) strategy, i.e. we did not examine a pre-formed concept, but, on the contrary, we made analyses using the relevant

Figure 1

CONVERGENCE OF EVIDENCE DURING OUR SPECIFIC CASE STUDY



Source: own editing

models with the full knowledge of data and after gaining a deeper understanding.

So we followed the usual methodological process of a case study:

❶ we limited the case study: the examination of the Békéscsaba Smart Grid from the perspective of participants and experts,

❷ we present the "case" in the next section;

❸ we checked our data in the ways described above;

❹ we discuss our analysis in the "Results" and "Conclusions" sections.

PRESENTATION OF THE CASE STUDY

The energy development investment, which is the subject of our investigation and is unique in Hungary, can be realized with support from the Modern Cities Programme. The leadership of the city with county rights dreamed up a complex programme that makes the operation of certain facilities of the city sustainable in the long term. What's more, it can even support the development of an electric public transport system with the possibility of receiving electricity from a solar farm. *"Energy developments are aimed at enforcing the aspects of sustainability and energy efficiency more strongly in the city through initiatives such as the SMART GRID system; building energy investments; utilization of geothermal heat; SMART public lighting system; and the implementation of intelligent traffic control and environmentally friendly public transport systems."*[16]

Among the five development areas listed, the development of the smart grid stands out, as it plays a central connecting role in the programme by ensuring the energy supply of the other areas. Another special feature of the development of the smart grid system is that in Hungary you cannot yet find an energy production and storage system of this size, designed as a sub-grid and optimized to serve direct users within the grid. The components of the system include a solar power plant with a capacity of 1.364 MWp; the battery electricity storage with a capacity of 2.4 MWh; consumers connected to it equipped with smart network endpoint devices; and the smart grid centre (data acquisition and control system) for the optimum operation of the system.

Actors of the innovation network

In the course of our research, we examined the organizations contributing to the development project and the functions performed by them. The innovation process can be divided into three stages concerning the project. In the phase of initiation, the project was planned. In this period, the intention of the city's leadership to develop the settlement with a view to long-term sustainability and economic goals was key and, as a result of this intention, they formed a project management team with the necessary skills and knowledge to implement the programme. In addition, due to the renewable energy sources especially, it was essential that the settlement should have the appropriate natural features (number of hours of sunshine, availability of geothermal energy) and a source of funding, which the city planned to secure in the form of a state subsidy under the Modern Cities Programme.

During the implementation period, the key role was given to the contractor responsible for technological implementation and their subcontractors. The primary task of the project management team during this period was to ensure compliance with the requirements of the funding source, as well as to prepare for the operating phase, in addition to asserting the interests of the settlement. The roles played by the Hungarian Energy and Public Utility Regulatory Authority (Energy Office) and the organization that operates the electricity network and buys the electricity, as well as the utility service company that enables the sale of the produced energy became prominent in the implementation phase in establishing the conditions necessary for the operation of the system and entering into operating agreements.

Although the examined smart grid system was officially under test operation during the period of the last data collection and the contractual and organizational conditions of operation were not yet finalised, the range of actors and operational functions could already be identified. A summary of the innovation partners that contributed to the project as well as their functions are included in *Figure 2*.

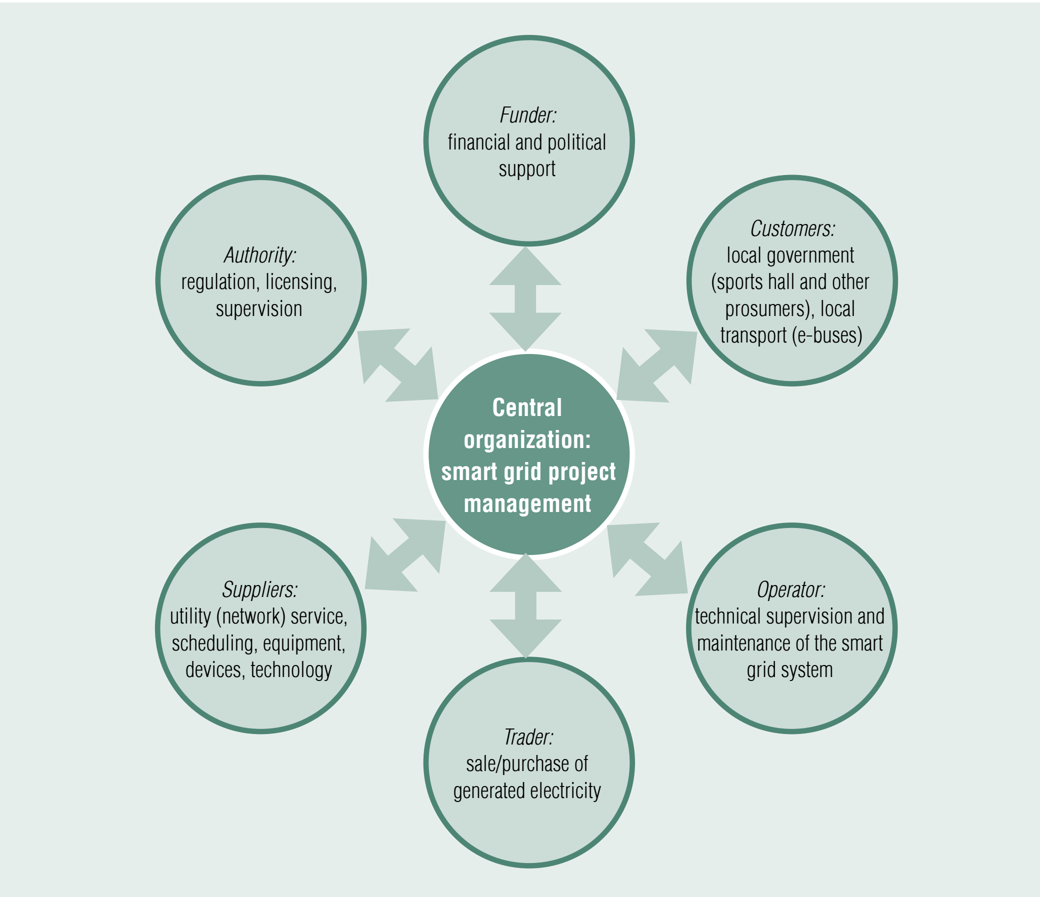
THE RESULTS

Motivations

The implementation of the smart grid system in Békéscsaba is of particular importance from the settlement's point of view. Although

Figure 2

INNOVATION PARTNERS AND THEIR FUNCTIONS IN THE SMART GRID



Source: own editing based on Csizmadia 2004, p. 26

today's drastic rise in energy prices was not yet foreseeable during the planning period of the project, one of the dominant motivations already in the original concept was the optimization of electricity costs. As one of the project management team members put it: *"One of the goals of the city of Békéscsaba is to realize long-term cost reductions, to make savings in city management, and to ensure energy supply for the planned new sports hall and competition swimming pool."* At the start of the project, both the cost-benefit analysis and the net present value calculated for the entire lifetime supported the fact that the investment was justified economically; however "… *NPV and IRR calculations were radically rewritten by the current energy crisis*". Unpredictable changes in the prices of energy on the world market may represent serious difficulties in planning such an investment with a useful life of 15-20 years. Early on in the planning process, the local government expected to achieve electricity cost savings of at least tens of millions of forints per annum through the new electricity supply for their sports facilities; however, changes in energy prices since then will have an impact on this. Any savings realized in this way may be utilised by the leadership of the city in the implementation of other tasks of theirs in accordance with the needs of the population.

Another important goal was to reduce the level of carbon dioxide emissions associated with the settlement, which could be realized by relying on the smart grid system developed based on renewable energy sources. *"The project will be developed as part of a complex programme serving sustainability purposes, where electric buses will be purchased to improve local public transport, a geothermal system will be installed for supplying hot water and heating to city facilities, and a solar smart grid system will be developed to ensure power supply, which will be supplemented by the improvement of the energy efficiency of the city's public buildings and the modernization of public lighting, as well as the development of a smart city management system."* (a member of the project management team).

Thirdly, the PR value of the project should also be mentioned, since innovativeness, keeping sustainability goals in mind, as well as responsible management are virtues that make highly valuable news items about the local government.

Of course, the economic goal (profit) can be regarded as the primary motivation for the general contractor Infoware Zrt. as well, but the project represented additional motivations, such as the value of the project as a novelty and the acquisition of the knowledge derived from its being a novelty; the learning through experiences from the previously inexperienced complexity inherent in the project; and, last but not least, the acquisition of a unique reference as a final result. Professional curiosity as a motivation was also perceptible on the part of the utility service provider as they were aware that the knowledge acquired here can be utilised in other settlements and in future projects.

In overall terms, all actors directly involved in the project found motivation not only in achieving economic and financial gain, but also learning and creating PR value. It is important to note that on markets of organizations, not only organisational-level motivations are present or constitute exciting fields for research. All individuals who contribute to projects implemented by organizations have individual goals and motivations in relation to projects. In the present research, however, we do not address these individual motivations.

Learning processes

This complex, innovative project contains many learning opportunities and learning constraints, for which participating organizations had to prepare in advance. Such a complex investment project had never occurred the practice of the general contractor Infoware, either. Even the design/licensing process was new. It was a novelty not only for the general contractor or the customer – the city of Békéscsaba –, but also for the authorities and public utilities involved in providing electricity services that a power plant generating electricity has storage units and consumer groups connected to it, and that in the longer-term vision, the operator should directly sell the produced energy to other consumers as well. The experience of the project management team was summarized briefly by one of the team members: *"there is no form of this kind to fill out..."*.

Since it is not possible to store the produced electricity in the grid, it is particularly important to ensure the power balance of the electricity system, which is supervised by the transmission system operator in relation to the national electricity grid. Currently not forming part of the national electricity system, the project in Békéscsaba is not directly involved in regulating the voltage of the grid, an activity carried out by the Hungarian Transmission System Operator Private Limited Company (MAVIR). The internal balance of the system is managed by artificial intelligence, striving to maintain the schedule created after negotiations in two rounds, and taking into account consumption forecasts and variables of the state of the system. This results in another learning process on the part of the operator, consumers served by the system, and MVM alike. Moreover, the city is also gaining important experiences, learning in the fields of technology and management alike. As a result of the project, the city will learn how an electric power plant can be integrated into a municipal system. *"Both operate according to strict rules, you have to learn how the power plant can sell electricity to local government actors and businesses maintained by the local government (at what price: free, at universal service price or market price)..." "We learned a lot from this about how the electricity industry works, what our power plant can do, what our storage equipment can do, and according to what procedures we can maintain this schedule," said one of the project management team members.*

Risks

On the operator's side, price changes resulting from the energy crisis are seen as the greatest risk, which may even be a possibility in the future, since, at the current level of consumption, the city has an energy surplus, which may be sold at market prices in the future, so it may be advisable to examine the possibility offered by energy communities. According to the energy law, energy communities may exist in Hungary, but the implementing decree regulating their establishment and operation has not yet been developed. The MNB's Competitiveness Programme (2019) treats it as a priority that the role of renewable energy sources is increased in Hungary and that high-capacity electricity storage facilities are added to the electricity grid, and the specific implementation of these goals could be facilitated by the development of energy communities and the spread of smart grid solutions.

Due to the novelty of the project, it is a risk that neither the regulatory environment, nor the procedures of authorities and utility service providers have been fully developed and tested for the operation of a system of this size and complexity. From the point of view of the learning process, it is an important opportunity for all stakeholders to develop the 2nd phase of the investment project in joint effort with MVM. However, the importance of communication between partners and that of handling perceived risks is well illustrated by the fact that even after several years of negotiations, it was not possible to agree on the terms of the joint R&D project, which was otherwise considered important by both parties (the city and the MVM).

The construction investment content of the project entails an additional risk. Green energy production also has direct environmental effects, for example, the costs of cutting trees due to the construction or the re-design work to avoid their cutting will amount to millions of forints. Technological risks include the replacement of devices in the event of possible failures; the evolution of the situation in world trade (changes in the chip and raw material markets have an impact here as well); and that the future replacement of the battery park and the planned 2nd phase of the smart grid may be implemented by using a possible new battery (brand or even technology), which raises compatibility issues. Moreover, the use of batteries is not only a financial issue, but

Figure 3

INNOVATION PROCESSES AND STRUCTURES IN THE SMART GRID OF BÉKÉSCSABA

ENVIRONMENTAL, EXTERNAL CONDITIONS

- the availability of solar energy production and storage technology
- geological characteristics: the number of hours of sunshine is high
- the project owner is the operator of several facilities; own consumption
- support from the Modern Cities Programme
- public procurement procedure
- technical and administrative preparation of the network operator
- deficiencies in regulations on and procedures for energy communities

NETWORK HISTORY, LIFE CYCLES

- new cooperation, built on new foundations
- early phase

NETWORK STRUCTURE

- cooperation between for-profit and non-profit actors
- interests: acquisition of knowledge, market, profit, public good, sustainability
- institutional embeddedness: formal, informal
- the actors' knowledge base: scientific, technological, engineering, management, financial, marketing
- keeping in contact in person and online

NETWORK DYNAMICS

- supporting mechanisms: state of development of technology/complexity, Modern Cities Programme, reputation
- construction mechanisms: personal motivations, political will, international situation
- internal selection: principle of complementarity, prior experiences, government approval

Source: own editing, based on Csizmadia, Figure 1.9., p. 42

also entails environmental risks. In the short term, the increased fire hazard of batteries is also a serious risk.

In the initial phase of the project, the risk before the investment project was that they did not know the general contractor. No one in Hungary had any reference work of this volume and complexity, but in the end they are basically satisfied with the general contractor. During the operating period, it will represent a problem that it is unusual for consumers (institutions) planned to be connected to the smart grid that they will be required to predict their energy needs in advance. *Figure 3* summarizes the factors underlying the successful implementation of innovation processes during the Békéscsaba smart grid project.

CONCLUSIONS

The generally accepted human attitude of being resistant to change was not (anymore) experienced in the relevant stakeholders of the presented smart grid at the time of data collection, instead openness and interest in what to be gained from this opportunity was observed in them. All of this was accompanied by flexibility, which was necessary when managing unexpected cost increases or technological, legal, or management processes. Those directly or indirectly participating in this project included the city municipality, institutions (sports facilities) operated by it, profit-oriented organizations (such as contractors, those involved in operation/maintenance and electricity traders), as well as various (licensing) authorities. Due to their different operating and decision-making mechanisms, these organizations of different kinds themselves represent a risk factor during such a close and long-term cooperation.

A few years ago, when the project started, the social, geopolitical and economic situation was completely different. What seemed advantageous in the eyes of the municipality as customer at the time – a long-term, environmentally friendly reduction in electricity costs – is increasingly so today. Each interviewed party is of the view that their expectations have been met; not only financial benefits, but also less quantifiable ones, such as the complex integration and application of technologies, the unique reference, and PR. This is organically linked to a multifaceted learning process, which obviously differs from organization to organization, but is valuable in the long run.

The municipality considers changes in prices resulting from the energy crisis, as well as a shortage of spare parts arising as an after-effect of the pandemic and resulting from the unavailability of chips to be the biggest risk factors. But they are already thinking about the future replacement of batteries and the challenges of phase 2. One of the main contractors can see risks in the following areas or for the following reasons:

- changes in the commercial environment and energy prices;
- the (large) grid is still needed, as it provides stability;
- new regulations at EU- and national level;
- the demand for electricity increases significantly;
- global uncertainty in logistics;
- raw material and electronic component prices will soar;
- shortage of spare parts and raw materials.

For an organization, these are external impacts beyond its control, but it can prepare for them to some extent.

The presented smart grid is considered successful because it has achieved the goals set and it is expected to attain them in future, too. All this takes place in an extremely volatile environment, with the participation and even cooperation of Hungarian actors. An innovation in itself contains risks, a situation becoming even more complicated in a network application. This innovation network involved organizations as contributors, who were able to employ and entrust suitable specialists as needed. However, it is a question how motivation, learning, direct and indirect benefits or the interpretation and handling of limited circumstances will work when individual actors and households are actively involved. We assume that adequate information should be provided about smart grids and citizens should be "prepared" for them. ■

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Notes

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