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Innovation and Knowledge Management in the Energy Sector

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Abstract
We experience significant changes in the energy sector globally. The main trends are related to the sustainability, the growing share of renewables, the demand for decentralized solutions, the use of smart devices and the importance of energy efficiency and energy security. Because of the changing market environment, large energy companies need new organizational solutions and business activities, which can be achieved through innovation according to market trends. However, the rigorous regulation and the rigid institutional context limit opportunities, moreover, the large size of the energy companies, the highly concentrated markets and the dominance of traditional technologies result organizational inertia and path dependency suppressing innovation and organizational change. Our article analyzes the external factors forcing changes, external and internal factors suppressing changes, and finally identifies those management tools that can facilitate the innovation processes and organizational changes.
Keywords: energy sector, environmental changes, organizational changes, change management, innovation management, knowledge management

1. Introduction

1.1 Changes in the energy sector

There are significant changes in the energy sector globally that are related to the growing importance of sustainable solutions and renewable energy, as well as the changing government policies and new technologies (Schaeffer, 2015; Ergüden & Catlioglu, 2016; Bollino & Madlener, 2016; Ruiz-Abellón et al., 2016; Salies, 2010). Schaeffer (2015) identifies general macro environmental factors (for example global economic crises, geopolitical tensions, climate change) and industry-specific phenomena (growing energy demand of emerging countries, the sudden increase of shale oil and shale gas production of the United States, the demise of nuclear energy, the decreasing costs of renewable energy technologies) as the reasons and drivers of changes. On closer examination, five interconnected industry phenomena can be identified, which mean adaptation challenges for the energy companies:

1. **Sustainability.** Corporate activities related to sustainability can derive from inside the company (values of the top managers / the company) or from external pressure (national and international policies, social expectations); consequently, energy companies have started transforming their portfolios in terms of sustainability and investing in renewable energy technologies (Ergüden & Catlioglu, 2016). Høgevold and Svensson (2012) emphasize that corporate sustainability is not an alternative for growing and profit maximization, rather a complementary goal. Hernádi points out that there is a need for considering the resources and business areas from the aspect of sustainability. (Hernádi, 2012)
2. **Renewable energy.** The use of renewable energies is closely related to the actions for sustainability. Many authors have examined the consequences of the growing share of renewables and the electricity market challenges from various aspects (Bollino & Madlener, 2016). The policies, initiatives and agreements significantly influence the marketing and research and development activities of the energy companies, for example the goal of the EU Renewable Energy strategy is to reach the 20% share of renewable energy by 2020 (Parobek et al., 2016). However, not only the goals are defined but also the ways: Ruiz-Abellón et al. (2016) point out that the EU aims electricity market integration, which would mean the possibility to use renewables at a higher volume and with a better allocation in the energy-mix. The renewable energy is a critical topic for energy companies from technological, marketing and regulation aspects as well (Bollino & Madlener, 2016).
3. **Decentralization.** In contrast with the traditional energy sector paradigm - which means centralized energy production and distribution -, due to technological development (the decreasing costs of renewable energy technologies, the appearance of smart devices) and changing customer needs (independency from central energy system, environmental awareness), decentralized solutions are coming into focus. Adil and Ko (2016) identified three components of decentralized energy systems (DES): distributed generation, microgrids and smart microgrids. The phenomenon of decentralization means an infrastructural challenge for energy companies, because decentralized solutions are not completely compatible with the current physical systems; moreover, it means a business challenge too,

because new ownership and operation models are needed: for example, consumer systems, community systems, municipality systems or mixed systems with the assistance of energy companies (Adil & Ko, 2016).

4. **Smart grids.** The need of technological development related to smart grids is connected to the growing energy demand, the need of energy efficiency, the use of renewables and the intermittent changes in power supply and demand, according to the literature (Alagoz & Kaygusuz, 2016, Chen et al, 2016). Luthra et al (2014) point out that growing energy demand and need for energy efficiency can be solved by the optimization of grid operations, which requires the use of smart devices. Besides, Schaeffer (2015) points out that there is also a need for new controlling systems and management strategies owing to the spreading ICT solutions.
5. **Energy efficiency and energy security.** Energy companies must make their research and development focus on the efficiency of energy generation, distribution and storage (decreasing energy loss) and on the system security as well as continuous, safe energy supply (Costa-Campi et al, 2014).

1.2. Necessity of change

The changing external environment and new trends result significant challenges for large energy companies. Following the logic of the contingency theory - situation theory (Lawrence – Lorsch, 1967; Pugh et al., 1969) the new needs and conditions require new organizational solutions and business activities. The device of reform is innovation, whose main content was highlighted also by Fejes (2015) as progress and development after having examined numerous definitions. Chikán (2008) has identified not only the content and types of innovation (new product or service, new technology, new organizational solution) but also its root: the change of market, the development of technology or unintentional invention. The trends listed in the previous chapter mean both business and technological pressure for energy companies to change and innovate.

Creativity, intellectual capital and knowledge are commonly mentioned in the literature as the preconditions of innovation (Fejes, 2015). In the economy of the 21st century, the access to knowledge and the ability of knowledge management means competitive advantage (Lee et al., 2015). According to Girard and Girard (2015), the management of corporate knowledge means the process of creation, share and use of the corporate knowledge and information. Besides, the corporate performance can be also increased by learning inside the company or through cooperation with other companies (Peng et al., 2005; Yeunga et al., 2007). Chen and Wang (2012) distinguish exploratory and exploitative learning. This differentiation can be interpreted not only in the context of corporate learning, but also in the context of innovation focus, because management must find the balance between the maximal exploitation of current solutions and the development of new solutions (Fejes et al., 2014). On a higher level, in the aspect of corporate strategy and structure, this is also a relevant management problem:

1. Nowadays, ambidexterity is a key attribution of the competitive companies, because they can operate in the most effective way possible with their available resources at present, and they are also capable of finding new business opportunities and innovating with focus on the future and ensuring the effective operation in the long term (Duncan, 1976; March, 2012).
2. Stability is needed to operate efficiently, but operating effectively in the long term is only possible with transforming and changing. While strategy and structure is interrelated, being an ambidextrous company is not only a strategic but also a structural challenge: there is a need for a kind of structure that ensures stability but also can handle changes (Csedő, 2006).

2. Key factors influencing change

2.1. The barriers of change in the energy sector

Beyond general management challenges, there are some industry-specific factors that suppress environmental adaptation and innovation:

1. **Rigid external regulation.** Nisar et al. (2016) have examined the organizational structure of large energy companies whether they facilitate the dominant innovation trend, the open innovation or not. The authors point out that organizational openness (and consequently the innovation capability) does not depend only on internal factors. In the most developed countries, the energy sector can be characterized by strict regulation, rigid institutional context, and this results in less open, less cooperative structures because of the inner emergence of the external factors (Nisar et al, 2016).
2. **Ownership.** Nisar et al. (2016) have indicated that the root of this rigid institutional background is that energy has been part of public goods historically; moreover, the controlling of the energy supply has been a critical activity on national level. This is the reason of the previously dominant state-owned model in the energy sector, which has been followed by a privatization trend in the 1990s, while nowadays the public energy sector is increasing again (Cullmann et al., 2016). We should see that the rigid conditions correlate with the state-owned model.

3. **Company size and market concentration.** Costa-Campi et al. (2014) pointed out, based on Cohen's (2010) empirical studies that the large company size is a hampering factor of research and development, mainly because of the long and difficult decision making procedure about the focus and the expected results of innovation activities. Moreover, this phenomenon is even more relevant in the energy sector because of the highly concentrated markets (Costa-Campi et al., 2014).
4. **Prevalent technology and resources.** Anadon et al. (2011) and OECD (2011) found that the dominance of traditional technologies impedes starting innovation processes related to new businesses and technologies as well as the definition of the expected results. Markard and Truffer (2006) and Salies (2010) regard fossil and nuclear energy technologies as the barrier of radical renewable energy innovations. The large company size, the highly concentrated markets and the dominance of traditional technologies lead to organizational inertia and path dependency.

2.2. Innovation and knowledge management

There is a consensus in the literature that more resources are needed to facilitate research and development, and innovation in the energy sector (Costa-Campi et al, 2014). However, innovation is supressed by some industry-specific factors listed previously. Furthermore, large energy companies also must solve general management problems (ambidexterity, balance between stability and change), consequently, innovation management is a serious challenge.

Fejes (2015) highlights five input factors of successful innovation activity: creativity, motivation, capability, money (resources) and supporting environment (structure, culture, leadership style). Expanding this thinking, the list can be broadened with "planning" (as one of the basic management functions) or the more general "management" term, because successful innovation must fit the market needs (strategic planning), and even in a poorly structured innovation process there is a basic need to use resources as efficiently as possible (controlling). Jorgensen and Ulhoi (2010) defines innovation management as the mobilization of innovational capacities and managing the transformational capabilities, while according to Fejes (2013), innovation management is the management of the organizational changes that focus on improving competitiveness and are related to development and progress.

The essence of innovation management can be seen (in several ways) by the definitions of the two part of the term. Synthetizing the previously presented definitions and following the four fundamental functions of management (Antal & Dobák, 2010) we define innovation management as the sum of management activities,

a. which is based on discovering, creating, sharing and using corporate knowledge (knowledge management)
b. which includes
    1. determining the purpose of innovation activities (planning)
    2. organizing innovation processes, the novel combination of the current resources, capabilities and acquiring the missing ones (organizing)
    3. forming a supporting, innovative organizational culture (leading)
    4. controlling the innovation capabilities and the results of innovation processes (controlling).
c. which results in new organizational, technological, business solution through which the created value for costumers and shareholders is increased.

2.3. Management tools facilitating innovation

We summarize the management tools, tasks and changing opportunities that facilitate innovation and transformation. Based on our comprehensive review of the recent literature about innovation in the energy sector, the following tools have been identified as the main drivers of innovation. While these tools might also be used in a lot of industries, we also highlight the related energy sector-specific factors to emphasize their relevance in this context.

1. **Strategic research and development approach.** Salies (2010) examined the innovation suppressing role of traditional, dominant technologies (fossil, nuclear) and also the new topics of the research from the aspect of profitability and time horizon of their potential competitive advantage. In the short term, innovations related to smart metering, smart grids, wind and solar energy mean competitive advantage, while in the long term, the key research and development focus is fuel cell batteries, tidal turbine systems, storage, and biomass gasification (Salies, 2010). Energy companies must find the balance between efficiency-focused developments related to traditional technologies (short term advantage) and investing in new technologies, in order to operate effectively in the long term.
2. **Open innovation.** According to Chesbrough (2003) open innovation is the new form of (mainly technological) innovation processes. Cheng and Huizing (2014) characterized open innovation as the method of innovation based on knowledge transfer, sharing, combination of knowledge from inside and outside the company, moreover as a way of market expansion. In expanded interpretation, open

innovation includes not only the transfer of knowledge but also the transfer of resources and competencies among the actors of the industry or other sectors, realized usually by strategic alliances and targeting to improve research and development and innovation activities (Nickerson & Zenger, 2004; Schumpeter 1942). Nisar et al. (2016) examined structures supporting open innovation in the energy sector and identified four types of openness and related organizational structure:

a. The functional structure is really enclosed, isolated and rigid.
b. The divisional structure is embryonically open, there is some awareness about the need of openness and cooperation.
c. In the matrix structure openness is burgeoning, experimentation and deploying new ideas is possible.
d. The flat, network-based structure is the most open, where cooperation and flexibility is embedded, an organizational routine. (Nisar et al, 2016)

As earlier mentioned, the authors also point out that openness does not depend only on internal factors, furthermore, the more open matrix and network-based structure cannot really be realized in the energy sector because of the high coordination needs of the large company size. This dilemma can be dissolved by the next points.

3. **New organization and outsourcing.** Gassmann et al. (2010) point out that more and more companies are outsourcing their research and development activities in order to reduce costs or to be specialized in a complex technology. In this context, specialization means also the accumulation of knowledge about one research area and the efficient internal knowledge transfer in case of a smaller, flatter, less regulated organization. This model can be realized by strategic alliances (Gassmann et al., 2010) or founding a new organization, as Cullmann et al. (2016) point out, examining the state-owned model and the rigid structure: while the presence of the public sector is increasing, certain activities (for example the development of new business areas, in other words: strategic innovation) are being outsourced to legally independent subsidiaries.
4. **Intrapreneurship.** The term intrapreneurship was firstly stated by Pinchot (1985), which is the abbreviation of intra corporate entrepreneurship, which means that entrepreneuring takes place inside the company. The intrapreneur is characterized by mostly the same attributions as the entrepreneur (creative, innovative, agile, ambitious, has an idea and also motivation and ability to realize it), but he uses the corporate resources and the innovation focus fits into the corporate strategy too (Pinchot, 1985; Åmo & Kolvereid, 2005). Cadar and Badulescu (2015) reviewing the entrepreneurship – intrapreneurship literature point out that large innovative companies have recognized the value and the need of entrepreneurial culture in order to innovate and transform, that is why they are supporting experimentation: they take into account the possibility of failure and employees are not reprimanded for that. Intrapreneurship is a higher level of involvement of employees in innovation processes; the proper conditions, the responsibility and the supporting culture increase the motivation and the engagement, while using the intrapreneurs knowledge and creativity, value is created for the company (Seshadri & Tripathy, 2006). In large and extensive energy companies, the existence of future intrapreneurs and innovators are very likely based on the numbers of the employees, discovering and supporting them is also a way to ease the less innovative, highly regulated, rigid culture.
5. **Integrated IT strategy.** Information technology can facilitate innovation in two ways:
   a. *Knowledge management systems.* As emphasized earlier, the correlation between knowledge management and innovation management is considered to be clear in the literature, moreover, the knowledge management functions and the steps of the innovation process are fitting: for example, knowledge creation – brainstorming or knowledge sharing – networking (Bencsik & Für, 2015). Knowledge management systems are broadly prevalent tools, Nonaka et al. (2014) found that these systems has a crucial role in discovering and exploiting synergies between the information processing capabilities of IT systems and human creativity and innovational capabilities. In the knowledge management model of motivation – opportunity – ability (MOA model) the IT support means opportunity (Kettinger et al, 2015), because it can ensure a transparent, collaborational interface independent from time and location, which is a serious advantage in case of extensive, large, multilocational companies.
   b. *Big data opportunities.* Successful innovations fit market needs, and nowadays, due to smart devices (for example smart meters) more data is available than ever, moreover, the customers' demands can get known and services can be formed more precisely by statistic modeling of big data (Lima et al., 2016). Big data analyses will be really important in the future, because they make it possible to discover new business areas (strategic innovation) and to improve operational efficiency through the analyses of big data generated by smart grids (DOE, 2013). Stimmel (2015) identified four key components of big data analyses related to smart grids: (1) fix operation

mechanism, (2) a constructional standard, (3) a sharing platform and (4) a big data team.
In case of large energy companies with many products and services, a knowledge management system covering the whole company; a central big data unit, which is capable of synthetizing all the company data; and the combination of these two tools can facilitate innovation processes by valuable data and bottom-up ideas.

6. **Corporate venture capital and acquisitions**. Corporate venture capital investments are usually strategic ones and run longer than venture capital investments with simply financial purposes (Ivanov & Masulis, 2008). Furthermore, their motive is to acquire new technology and innovation, the financial return is only indirectly targeted (Katila et al, 2008). In case of corporate venturing, the big company is not only an investor but also a cooperative partner, and this dual relationship facilitates knowledge and resource transfer between the two organizations, redounding innovation processes (Galloway et al, 2017).

3. Conclusion

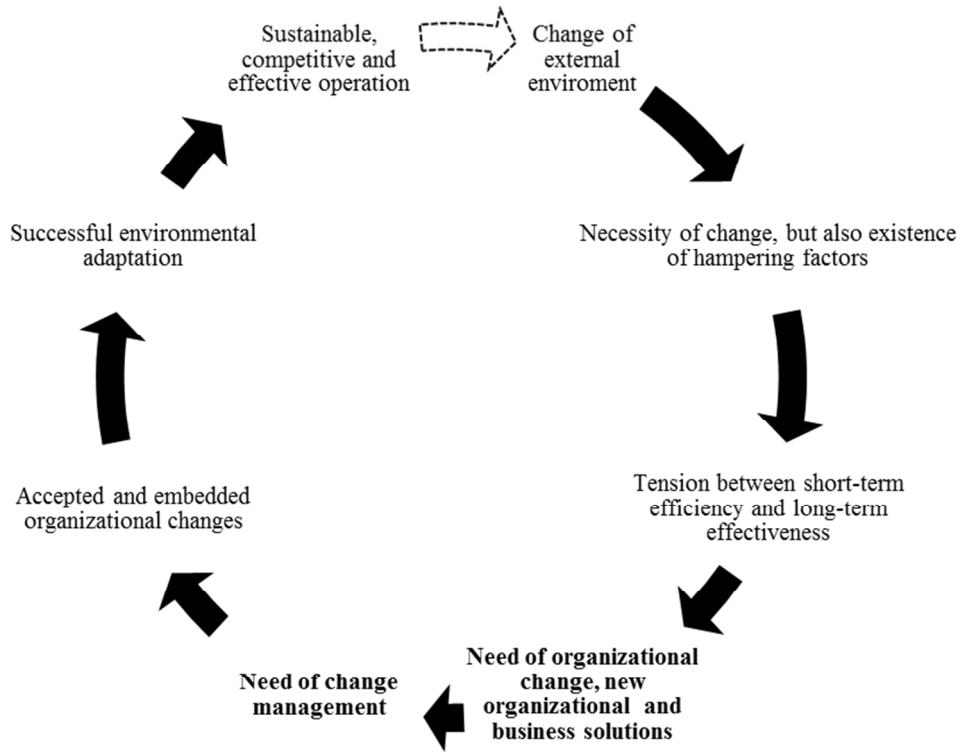
Large energy companies need to transform and innovate because of the changing external environment, but organizational change is suppressed by several external and internal factors. Table 1. summarizes the challenges of innovation management in the energy sector, following the logic of the innovation management functions.
In order to facilitate innovation, large energy companies need to find the balance between efficiency-focused developments of the traditional, currently dominant technologies and research and development investments focusing on renewables, through which effective operations can be realized in the long term. Furthermore, energy companies must ease their closed structures in order to facilitate open innovation, and find new organizational solutions (for example founding new organization) with different inner operation methods so as to develop new business areas. Besides, they need to find future innovators, intrapreneurs, foster their ideas and promote entrepreneurial values. They need a knowledge management system, which subsidizes knowledge sharing, creating and brainstorming and they also need to take advantage of the volume of data generated by smart grids with big data analyses. Finally, corporate venturing and acquisitions are also feasible ways to acquire new technologies and innovations, facilitating environmental adaptation.

Analyzing the situation of the global energy sector and the large energy companies from a more theoretical aspect, we can see that there is a serious tension and implementation difficulty between the goal of continuous, secure, efficient operations on short term and the long-term research and development and innovation strategies and investments. In this challenging situation, organizational change and change management theory can mean a methodological bridge; sustainable, competitive operations can be only ensured by the proper implementation of change management. Figure 1. represents the importance of organizational change and change management in environmental adaptation and efficient operations in the long term.

Table 1. Challenges of innovation management in the energy sector

Innovation management theory	Industry-specific factors suppressing innovation	Management tasks and challenges
Strategy – Orientation and purposes of innovation activities	Strictly regulated environment Rigid institutional context Changing external environment and market needs	Following market trends Forming an ambidextrous organization Finding balance between traditional and new technologies
Organization – Innovation processes, capabilities, resources and knowledge	Large and extensive organization with high coordination needs Closed and rigid structure	Acquiring missing resources and capabilities through strategic alliances Finding new organizational solutions to increase openness and knowledge transfer Capturing, creating, distributing and using corporate knowledge
Culture – Innovative, supporting environment	Large and extensive organization Strict internal regulations	Promote and represent entrepreneurial values Fostering experimentation Finding and supporting innovators and intrapreneurs

Figure 1. The importance of change management based on the situation of the energy sector



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