St. Petersburg University
Graduate School of Management

[Master in Management Program]

FACTORS AFFECTING SMART TECHNOLOGIES DEVELOPMENT IN RUSSIAN ENERGY SECTOR

Master's Thesis by the 2nd year student
Concentration — Management
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ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПОЛНЕНИЯ ВЫПУСКНОЙ КВАЛИФИКАЦИОННОЙ РАБОТЫ

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АННОТАЦИЯ

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Описание цели, задач и основных результатов	Цель данного исследование – выявить факторы, влияющие на развитие «Умных» технологий в сфере производства тепловой энергии. Задачи: - Проанализировать существующую литературу на тему умных технологий в энергетике; - Сформировать группу экспертов для проведения интервью; - Проанализировать информацию, полученную по результатам интервью и сравнить выявленные факторы с выводами обзора литературы; - Сформулировать практическое применение данного исследования. Основные результаты: - Проанализированы работы на тему «умных» технологий в энергетике; - Определены причины внедрения «умных» технологий, преимущества и потенциальные сложности; - Описаны стратегические цели энергетических компаний, связанные с внедрением «умных» технологий - Описаны два примера проектов по внедрению умных технологий; - Проведен сравнительный анализ факторов, выявленных в процессе интервью, с факторами, изученными в существующих исследованиях.
Ключевые слова	Умные технологии, энергетика, производство тепла

ABSTRACT

Master Student's Name	Natalia S. Arkhipova
Master Thesis Title	Factors of smart technologies development in Russian energy sector
Faculty	Graduate School of Management
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Description of the goal, tasks and main results	The goal of the research is to define factors affecting the implementation of the Smart technologies in Russian heat production sector. The main tasks include the following: - Observe and analyze existing research on the specified topic; - Select a sample of experts for interviews; - Synthesize the information obtained during the interview; - Compare the factors mentioned by the experts to those, identifies in the existing researches; - Highlight practical implementations of the results obtained. Main results: - Analysis of existing research, related to the topic of smart technologies in energy sector; - Identified reasons, benefits and challenges of smart technologies implementation in Russian heat production sector; - Specified strategic goals of energy producing companies, related to the development of smart technologies; - Described two examples of the projects of smart heat network implementation in cities Samara and Lisva; - Comparison of the factors, identified during the interviews with those mentioned in existing research; - Mind map of the summarized driving forces, characteristics and functions of smart heating systems.
Keywords	Smart technology, smart city, energy sector

CONTENT

INTRODUCTION

Recent research of the World Bank has shown that the urban population will increase by 50 % by 2045th. Considering the fact, that currently the urban population already accounts for 54% of the global population (Urban Development Overview, 2016), the increasing trend provides a reason to plan, build and develop the cities in a smart and efficient way, bringing the long-term benefits and improving the quality of life. The smart technologies are developed and implemented in different sectors, such as transportation, government, water management and energy production.

Russian energetic sector plays crucial role in the development of the economy. New smart technologies are being implemented to increase the efficiency and effectiveness of electricity and heat production to reduce sharply the energy losses as well as consumers' expenditures. However, implementation of smart technologies is related to specific challenges, which are slowing down the process. One of the challenges is the unawareness of the employees about the benefits of smart technologies, motives of their implementation and strategic view.

Academics and practitioners are currently attempting to develop a systematic knowledge about smart cities. Existing literature covers such aspects of smart technologies implementation as main drivers and challenges, strategic goals, and management perspective. From a theoretical perspective, literature on digital technologies for government and urban innovation can help in understanding what a smart city is and what its main components are or should be. The existing researches are also devoted the recently developed smart technologies, implemented in different industries, discussing challenges, factors, opportunities related. However, there is no unified definition or framework, which brings difficulties while making estimations and forecasts. From a practical perspective, successful stories of cities development give a basis to develop frameworks and models to guide cities in their efforts. They propose a system of smart city's components and tools to assess the multiple capabilities of a city as it attempts to become smarter. When implementing the new technology, there are several factors of its success, such as industry characteristic, historical stage of infrastructure development, corporate culture and norms, innovation friendliness of a particular company – representative of the sector. Moreover, each project of technology implementation is specific due to such differences as legal regulations, infrastructure, and access to investments.

Study on the factors, affecting the implementation of smart technologies for energy sector will not only contribute to the existing theoretical base, but also bring the companies from energy sector the complex understanding of their activities and strategic development goals.

The current research of factors is based on expert interviews with representatives of Russian heat generation companies and IT and technical suppliers, specialized in smart solutions.

The purpose of this case study is to identify the factors affecting the implementation of smart technologies in Russian energy sector. Those are reasons to implement, expected benefits and challenges for energy producing. The results are summaries into two cases, representing the smart technologies implementation in two Russian cities: Lisva and Samara.

Key take-away from the research:

- Identification of a market of smart technologies for Russian energy sector, its opportunities and providers;
- Identification of major market driving factors;
- Identification of the major stakeholders in the sector;
- Insights on ongoing projects of smart technologies implementation in heat production in 2 cities.

The paper is organized into 3 chapters. The first chapter is providing a theoretical background and overview of existing research. The second chapter brings details about the methodological approach used for systematic analysis of factors, affecting smart technologies development in Russian energy sector. The final chapter will bring the results of the empirical study and their practical implementation.

1. OVERVIEW OF THE SMART TECHNOLOGIES DEVELOPMENT IN RUSSIA

1.1. Urbanization as an incentive for Smart technologies development

Cities have always been a source of opportunities and with the recent urbanization growth their number is increasing drastically. Moreover, cities also play an important role in the problem of global climate change, due to their consumption of energy and gas emissions. With the urban growth, their impact on the climate increases. According to the recent research of World Bank on the topic of urban development (Urban Development Overview, 2016), about 54 percent of global population lives in urban areas today and this trend will continue. It is expected, that the number of people living in cities will increase by 1.5 times and reach 6 billion, adding 2 billion more urban residents by 2045. Even now 80% of global GDP is generated in cities, therefore, the process of urbanization will keep its contribution to the global sustainable economical growth. However, the scale of the urbanization brings not only wide opportunities, but also challenges related to smart and efficient management. The problems of productivity, innovations and implementation of new technologies are becoming crucial.

Mentioned trends raise the problem of efficient planning, building and managing of the cities. New systems are introduced to the market, aimed to improve infrastructure, services, and transportation systems to improve the quality of people's life, manage investments to decrease the maintenance costs, build the basis for future sustainable growth. This makes the city a source of tremendous innovation such as smart technologies, to create and implement, opportunities to invent, test and implement new services.

Smart technologies are aimed to address some of the challenges of urbanization by helping to optimize resource consumption and improve services through better management of demand and supply (United Kingdom, 2013). The scope of the possible financial effect is significant. However, there are a lot of factors, affecting the fast and efficient implementation of those technologies. Those are: political and economic situation and stage of the economy's development, industry, scale of the specific city.

There are plenty of definitions of a smart city. Generally it can be described as way of city development and management, which allows improving the quality of life via integration of multiple technology solutions to manage city's assets, such as information systems, transportation systems, hospitals, plants, etc. Information and communication technologies allow building a connection between the community and infrastructure with means of real-time systems, which collect and process the data. Enhanced quality and interactivity of urban services reduced the costs of resources used and facilitates fast reaction to the challenges.

Smart city technologies cover the development of the following urban sectors:

- Government services;

- Transport systems and traffic management;
- Waste management;
- Energy producing and transmitting;
- Health care;
- Water management;
- Smart building;
- Smart security, etc.

The mostly developed technologies used in smart cities use such tools as Internet of things (IoT), smart phones, cloud-based services, and smart meters. The smart solutions are aimed to improve the quality of life by integration of technology with social life. It has been estimated that by 2050 70% of the world's population will be living in urban areas (Urban Development Overview, 2016). Since all cities occupy only 2% of the world's land but consume 75% of energy and discharge almost 80% of carbon dioxide. One of the goals of smart cities development is to provide sustainable ways to develop infrastructure and economic activities, improve people's quality of life. According to B. Singh, "it is a duty of every government to implement sustainable development based on renewable energy and technology" (Singh, 2015, p.50). Other stakeholders, involved in the process of cities development are listed below.

- National/state/municipal leaders;
- Real estate/property developers;
- IT suppliers;
- Utilities service providers;
- Networking and telecommunication companies;
- Building management system providers;
- Grid infrastructure service providers.

1.2. Smart technologies used in energy production: state-of-the-art

The main goal of the Smart energy production is minimizing the losses, which in result solve different problems, such as emission control, cost efficiency, high quality service, provided to the consumers. In the energy sectors there are two main industries: electricity generation and heat generation. Talking about the electricity production, each has the following stages of production: generation, transmitting, distribution, industrial, service and residential (figure 1). The goal of smart technologies is to increase efficiency at each stage.

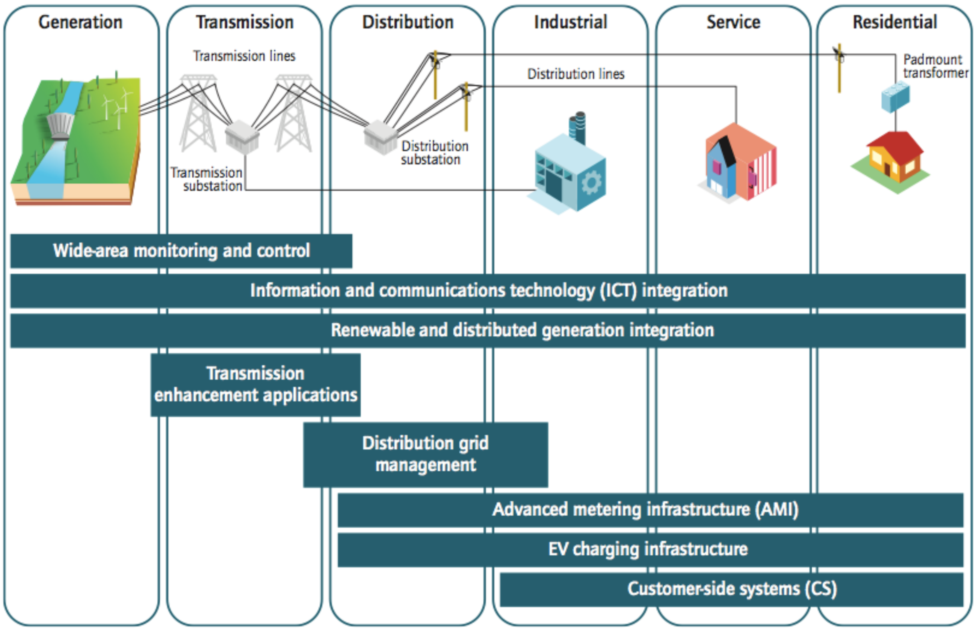

Figure 1. Technology areas of Smart grid

Source: Technology categories and descriptions adapted from NETL, 2010 and NIST, 2010.

The terming “Smart Grid” has recently got popular in the area of energy production and delivery. In general, electric grid presents a network of generation stations, transmission lines, distribution substations and transformers which deliver electricity from the power plant to households. Smart development of such network results in increasing their capacity via digital and computerized equipment that can manage the increasing complexity and electricity needs.

One of the features of the smart grids is the demand-side management. Digital technologies allow two-way communication between the utility and its customers. Computers, controllers, and automation mechanisms respond digitally to the quickly changing electric demand. Smart Grid technology allows moving the energy industry into a new level of reliability, availability, and efficiency, which are main contributors of economic and environmental health. The process of Smart Grid implementation includes testing, technology improvements, education of users and consumers, development of standards, etc.

The **benefits of the Smart Grid** are mostly associated with increased efficiency and reduced costs:

- Increase of electricity transmission efficiency;
- Faster restoration of electricity after power disturbances;
- Reduced peak demand resulting in efficient planning of production and lower electricity costs for consumers;
- Increased level of integration of energy systems;
- Improved security;
- Reduced operational and managerial costs, as a result, lower prime costs for

electricity production.

Smart Grid also helps to prevent and deal with emergencies, which has a significantly impact: a series of failures that can significantly affect operations in different industries. The threats are even more serious during wintertime, when homeowners can be left without heat. A smarter grid makes the electric power System more resilient and better prepared to address emergencies. When a power outage occurs, Smart Grid detects and isolates the outages, containing them before they become large-scale blackouts. The recovery process is also happening faster and in a correct strategic order. It allows addressing energy efficiency, with less harm to the environment.

Smart Grid is not only the utilities and technologies, developed to improve the efficiency of the process of energy distribution and delivery. Smart technologies are aimed to use information in the process of decision-making. Smart Grid is the tool to generate and provide the information to users, which is necessary to make choices about their energy use.

A smarter grid enables a high level of consumer participation, for instance, providing real-time information on consumption and expenditures. In combination with dynamic pricing models this gives opportunity to save money by shortening the consumption during the peak-hours. Mentioned above benefits of smarter grids are widely discussed in terms of economics, national security, and renewable energy goals. Therefore, the Smart Grid has not only the potential to reduce energy production costs, but also the costs of consumption. Those practices, however, are mostly common outside of Russia, while in Russia the development of Smart Grid is in the beginning stage.

The Smart Grid is a complicated system, which consists of millions of components - controllers, computers, power lines, and new technologies and equipment. The implementation process takes time, during which the technologies are tested and equipment is installed. The Smart Grid is evolving, piece-by-piece, over the next decade. As soon as the system is mature, it is forecasted to bring the same transformation that for example, the Internet has already brought to people’s life (What is the Smart Grid?, n.d.).

1.3. Literature review of Smart technologies development

The topic of smart cites is being actively discussed in publications, since the phenomena is not only has wide implications in different spheres of business and life, but also is interesting from the point of views of economic benefits and challenges. Every country is now concerned about its fast growth with efficient investments, and there are plenty of research papers, discussing the best practices, benefits and challenges of the process of making the city smart in relation to specific territory. Another direction for the research is evaluation of the financial result of making a city «smart». There are different ways to estimate the effect from a specific initiative; however, it is hard to scale the effect to the whole economy, due to difference in forecasts and estimations. To sum up, there are following directions of existing researches, covered by the literature review:

- Definition of smart city;
- Smart technologies development for Energy sector;
- Smart grid: technologies, opportunities and challenges;
- Managerial problems, related to Smart Grid implementation.

1.3.1. Definition of a smart city

In order to be able to make the reliable and fair estimations of the effects of smart cities, it is important to understand, what they represent. There are several studies devoted to this field and aimed to give a specific characteristic of this phenomenon.

"Smart cities" is a label used in the academic world, business and government to characterize cities that are progressively constituted of and observed by prevalent and omnipresent computing, and whose economy and administration is being directed by innovation, inventiveness and entrepreneurship, established by smart individuals (Popescu, 2015).

According to Bhopendra Singh, "every economy wants to achieve sustainable developments by means of a smart city, smart economy, smart life, smart tourism and even smart education" (Singh, 2015, p.49). However, there is no unified definition yet, and many different approaches have been used to create one. The approach used by the author can be also called MESH cities (Komninos, 2009). It stands for:

M - Mobile (mobile devices and networks provide the real-time information which can be used to generate knowledge about a city, its users, and its systems),

E - Efficient (sustainability is provided by effective use of resources, monitoring and management systems),

S - Subtle (modern city systems are user-friendly and invisible),

H - Heuristics (continuous improvement, which makes the system self-reflexing, adaptive self-forming and citizen-focused).

Components of a smart city

There are three categories of components of a smart city: technology, people and institution. The cities are considered smart, if the investments into those areas bring sustainable growth and enhanced quality of life. Since the smart city is a common concern, the government of Dubai is not an exception and is developing the following aspects of the smart city concept: e-government, electric cars, smart parking, smart metering and smart grid, cloud computing, smart waste management (Singh, 2015).

The article "What makes a city smart? Identifying core components and proposing an integrative and comprehensive conceptualization", provides opinions of different researchers on what the smart city is. The paper presents a complex summary of "smart city" definitions from previously published papers and comprehensive conceptualization of smart city based on a result of deep comparative analysis. According to the authors, under the formulated conceptualization, and any other comprehensive definition of smart city, many cities are already smart. The main difference of the outcomes is that the most relevant concepts proposed in this paper are the degree and nature of smartness, instead of a dichotomy between "being smart" or "not being smart." The researchers concluded, that smartness should be seen as a continuum in which local government officials, citizens and other stakeholders could think about and implement initiatives that attempt to make a city smarter: "a better place to live and work" (Gil-Garcia et al., 2015).

There are many studies aimed to look at how cities perform in economic, environmental, and social terms, and ranked them accordingly. The results of such studies help understanding the elements, which make the city great: smart, efficient, easy to live in. However, them didn't highlight an important question: what the leaders of those cities do to make them great. Different research centers (Bouton et al., 2013; Stone, 2015) got interested in the topic of smart cities' management and leadership.

Outstanding management is one of a crucial problems investigated by the McKinsey research institute (Bouton et al., 2013). With means of analysis, case studies, and interviews, mentioned research answers the question "what drives the city's performance?" and presents examples of what the leadership of cities does to make their cities better places for life and work. According to the findings, the answer is a successful balance between three areas: first, they secure the best growth opportunities while protecting the environment and ensuring that all citizens enjoy prosperity. Second, they do more with less. Finally, the leaders win support for change by delivering results swiftly.

Other successful stories of big and developed cities are presented in the report (Stone, 2015). It consists of success stories of five successful smart cities with comments of their leaders on how they have got there. Those cities use different approaches defined by criteria, used to evaluate the feasibility of smart technology. Those criteria are:

- The maximum number ideas analyzed. With the approach used in Las Vegas "ready, fire, aim" lots of ideas were analyzed to start the pilot versions of suggested solutions fast. "Try it and if it doesn't work, move on."
- The maximum impact to achieve. In contrast, the approach used to make Albuquerque a smart city takes the possible impact as the main criteria for the consideration. Each initiative is being test for feasibility at every stage of the implementation.
- Benefit for people. The main criteria for technology projects implemented in New

York – its impact on people life.

- Clear goals. The criteria used in Toronto are tangible benefits as an initiative return, such as “Make Toronto a better place to live, work and play. Make it more competitive. Drive economic prosperity and encourage sustainability” (Stone, 2015).

To sum up, the core components of a smart city is the technologies used to increase the efficiency of the existing infrastructure and the government of the city – its strategy and decisions made to improve the quality of life. The smart technologies are constantly developing and being implemented to different sectors.

Launching new technologies

This addresses to the issue of *launching of new technologies*. Introducing technological change into an organization presents a variety of challenges to leaders of the organization. According to the research by D. Leonard-Barton and William A. Kraus, based on the example of multinational corporations (Leonard-Barton et al.,1985), the main challenges are related to the fact, that “the user organization is not willing or not able to take responsibility for the technology at the point in its readiness at which the development group wants to hand it over”. To overcome it, the implementation managers need to combine the opportunities and the demand of both developers and users. The following actions should be made within implementation process:

1. Identify of the fit between a product and user needs, improving it if possible;
2. Prepare the user organization to accept the innovation;
3. Shift the responsibility from developers to users.

Technological advances give city leaders the tools to collect big quantities of data, which when structured in a right way can be analyzed and applied to help to reduce capital and operating expenditures, increase revenues and improve services. There are many examples of cities that are using data to improve efficiency, provided by Bouton. Those are related to transportation, crime prevention and other issues:

- Automatic control of the street lighting based on real-time data on the light conditions is saving up to 30 percent on energy costs and providing residents with safe lighting.
- Cameras installed at intersections to optimize traffic lights and cut transit time allow reducing air pollution and the costs of tackling it.
- There is also an online portal in Singapore that enables government, businesses, organizations, and residents to use geospatial data.

Another implementation, provided by smart technologies, is opportunity to combine the data from different government sources and reveal valuable insights. Cross-departmental data analysis allows improvement of the efficiency of building inspectors. By combining data about economic conditions of a specific neighborhood, like the age of a buildings, reference from neighbors, whether the building was under foreclosure, inspectors were able to detect major safety problems in 80 percent of their site visits, compared with 13 percent before the system was implemented (Bouton et al., 2013).

1.3.2. Examples of smart technologies in urban mobility and energy management

Arup and Qualcomm Technologies, Inc have published a research about Intelligent Connectivity, which is a driver of a complete re-imagining of urban mobility (how people and things move through the cities). Intelligent Connectivity is, according to the authors, “the sum of the systems, services and technologies connecting people, data and infrastructure. Intelligent Connectivity unites a broad range of emerging technologies to enable smarter, healthier, more resilient and economically vibrant urban life. Intelligent Connectivity requires a shift in thinking, towards integration across systems and scales” (Mistry, Schemel, & Newton, 2015).

Why is it important? Effective transport of citizens and goods is a key to a city’s high quality of life (both from economic and social point of view). It also helps to overcome such urban challenges as, for instance, air quality, safety issues and pressure on energy systems.

The main trends affecting the urban mobility, listed by the researches are:

- Urbanization - increase of urban population and number or urban cities;
- changing demographics - life expectance growth with fertility rate decrease;
- climate change - global temperature is getting warmer;
- increased use of energy and resources;
- technological convergence – growth of internet users.

Based on four case studies, the research presents appearing trends, related to the intelligent connectivity. By 2030 the usership will be substituted by ownership with means of mobile applications. Invisible systems will become an extension of our decision-making processes., the rate of digital usage of global devices will also have a growing trend (Lutzenberger et al., 2015). Lutzenberger and Masuch present developed solutions, which consider energy and mobility-related problems jointly.

Correct use of resources is possible with means of an accurate monitoring and management system. L. Parra and S. Sendra prove this statement by the example of water management system: groundwater management with use of sensors can be a good solution to use the recourses efficiently. For example, in the USA, aquifers represent the water source for 50% of the population. Sustainability of groundwater resources is affected by various factors. The issues of their contamination as well as efficient distribution in the cities can be solved by advanced monitor systems, presented in the article (Parra et al., 2015). The sensor is able to measure the electric conductivity of water, which is directly related to the water salinization.

Other papers related to the topic cover the following areas: reduction of emissions of harmful gases in order to achieve sustainability; saving energy and public transport for improving the heat and energy management; a smart grid for water distribution in a smart city and light control methods for smart grids.

1.3.3. Development of smart technologies for Energy sector

There have been undergoing significant changes of the markets for energy generation, distribution and consumption in the last two decades, concerning their overall infrastructure, technical aspects of control and communication mechanisms, legal regulations. Maintaining a high level of energy efficiency in all steps of the chain (production, distribution, consumption, metering, and the development of control mechanisms) will both reduce the environmental impact and costs. Among the currently developed projects aimed to design efficient systems is Intermodal mobility assistance for mega-cities project (IMA) that is providing an open mobility platform with intermodal trip planning, monitoring and trip-assistance functionality. The platform integrates different types of mobility and infrastructure providers, such as car-sharing, bike-sharing, public transportation and traffic surveillance, which can dynamically be included at run-time by using semantic description mechanisms.

Smart technologies for energy sector

The smart technology used for electricity and heat production is Smart Grid – electrical interconnected network for delivering electricity from suppliers to consumers. It includes operational and energy measures: smart meters, renewable energy resources and applications to manage the production and distribution of electricity. Smart technologies for energy networks has been widely discussed in existing literature, mainly from the following aspects: existing frameworks and further improvement of the system, security issue, and challenges during implementation from the point of view of the project managers, opportunities of machine-to-machine communication.

Every economy is now emphasizing on sustainable development by incorporating new technology solutions with minimum resource requirements, non-carbon emissions or refreshing the existing technology with smaller energy demands. This can be achieved via export of energy sources for producing, storing and distribution of energy in smart city or by “modernizing the power system through smart metering system and smart grid infrastructure” (Singh, 2015, p.51).

Initially, the electrical grid has been a ‘broadcast’ grid – system of power stations, which produce electricity to satisfy demand in a country or region, and distribute this electricity to the end users via a large network of cables and transformers. The aging infrastructure, environmental and societal challenges were the incentives for a reform the traditional electrical grids and resulted in increase the system’s efficiency (Metke & Ekl, 2010).

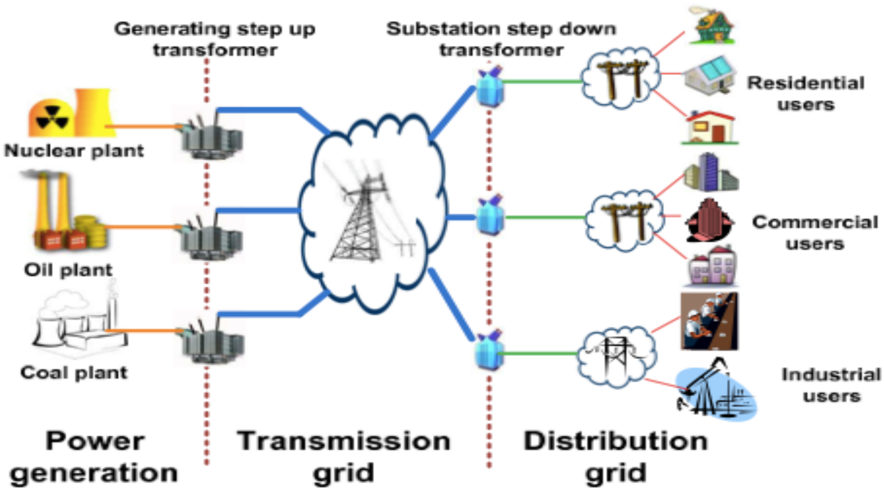

Figure 2. An example of Traditional Power Grid

Source: Fang, Member, Misra, & Xue, n.d.

The comparison of traditional grid and smart grid was made by H. Farhangi, and used in the work of X. Fang. The paper contains overview of the literature on the enabling technologies for the Smart Grid: the smart infrastructure system, the smart management system, and the smart protection system, as well as directions for their future development. In contrast, to the traditional grid, the smart grid uses "two-way flows of electricity and information to create an automated and distributed advanced energy delivery network"(Fang et al., n.d., p.1) The distinction between traditional and smarter network are summarized in the table 1.

Table 1: A Brief Comparison between the Existing Grid and the Smart Grid

Source: Farhangi H., 2010

Existing Grid	Smart Grid
Electromechanical	Digital
One-way communication	Two-way communication
Centralized generation	Distributed generation
Few sensors	Sensors throughout
Manual monitoring	Self-monitoring
Manual restoration	Self-healing
Failures and blackouts	Adaptive and islanding
Limited control	Pervasive control
Few customer choices	Many customer choices

Smart grid is not a final product, but rather a process of development and increasing the efficiency. The main directions for development of the smart grid are:

1) *Digitalization.* Smart grid is a digital and safe platform for fast and reliable sensing, measurement, communication, computation, control, and maintenance of the entire transmission system.

2) *Flexibility.* There are four aspects of smart transmission grid flexibility:

- Opportunities for expansion and future development with implementation of innovative and diverse technologies;
- Adaptability to different geographical locations and climates;
- Multiple strategies for the coordination of decentralized control systems;
- Compatibility with market operation styles and capability to install the upgrades with hardware and software components.

3) *Intelligence.* Combination of the intelligent technologies and human expertise.

4) *Resiliency.* Capability of the network to deliver electricity to customers securely and reliably in the case of any external or internal hazards. On-line analysis allows flexible control and fast solutions in case of emergencies.

5) *Sustainability.* There are three aspects of sustainable smart grid: sufficiency, efficiency, and environment-friendliness. There is a trend of an increasing electricity demand, so the solution is affordable alternative energy resources – will increase the energy savings via technology in the electricity delivery and system operation. Innovative technologies should decrease the pollution or emission, which will also reduce the negative environmental effect and climate changes.

6) *Customization.* In terms of the design, the network should be client-oriented, easy to use and convenient, as well as safe its functionality and interoperability. This will result in a high quality/price ratio of the energy consumed. The quality increase will consist on increased transparency and improving competition for market participants.

Architecture of the Smart Grid network

Apart from recommendations to strengthen the security of Smart grid, the authors A. Metke and R. L. Ekl present two models of Smart Grid architecture: High-Level conceptual model, developed by NIST (National Institute of Standards and Technology, 2010) and detailed logical model. However, it is worth mentioning, that there are other views on the architecture, which differ depending on the purpose of analysis.

High-Level Conceptual Model: the model (Fig. 3) has been developed by NIST and presents a connection of the smart grid and utility industry. There are seven main domains of the smart grid technology interconnected: by information flows and the energy flows. The model identifies interfaces among domains and actors. Those domains are described in Table 2 and shown graphically in Figure 2. It also includes applications requiring exchanges of information, for which interoperability standards are needed.

Table 2: Domains of the Smart Grid

Source: National Institute of Standards and Technology, 2010

Domain	Actors in the Domain
Customers	The end users of electricity. May also generate, store, and manage the use of energy. Traditionally, three customer types are discussed, each with its own domain: residential, commercial, and industrial.
Markets	The operators and participants in electricity markets.
Service Providers	The organizations providing services to electrical customers and utilities.
Operations	The managers of the movement of electricity.
Bulk Generation	The generators of electricity in bulk quantities. May also store energy for later distribution.
Transmission	The carriers of bulk electricity over long distances. May also store and generate electricity.
Distribution	The distributors of electricity to and from customers. May also store and generate electricity.

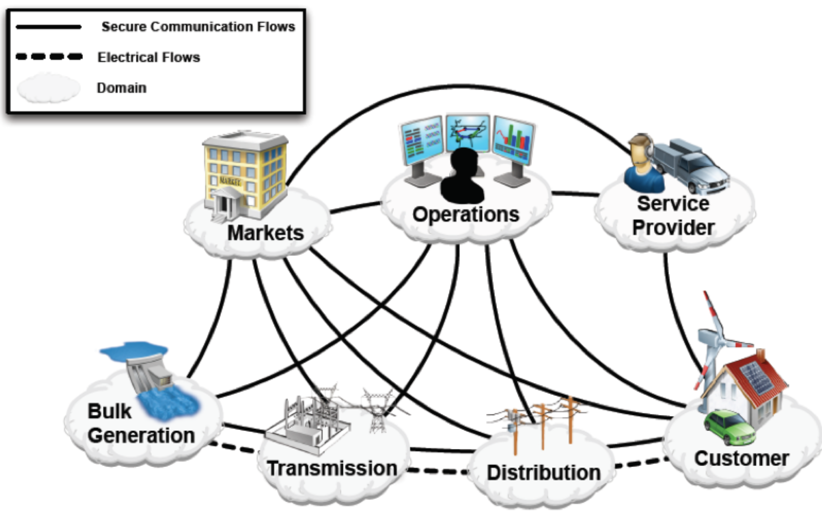

Figure 3. High-Level conceptual model

Source: National Institute of Standards and Technology, 2010

Actors of each domain include devices, systems, and programs, necessary for information exchange and decision-making, based on that information. The examples of devices and systems are smart meters, solar generators, and control systems, while the applications are the tasks performed by one or more actors within a domain. According to the NIST report (National

Institute of Standards and Technology, 2010), actors of the same domain have similar objectives and interact with the actors of other domains. The model, of course, varies depending on the market specialties.

Detailed Logical Model presents interconnection between several key elements: networks (wireless and wired), functional subsystems (SCADA), endpoints (computers in the back offices, controllers), and overlays, for example, distributed security functions and elements (Metke & Ekl, 2010).

Another framework is presented by Fangxing Li*,* Wei Qiao (Li, et al., 2010). It shows the crucial components of the system, as well as drivers, affecting its development: diversified challenges and needs of the environment, customers, and the market, as well as existing infrastructure issues. The main steps of the roadmap for future development of the grid summarized to the following:

- digitalization,
- flexibility,
- intelligence,
- resilience,
- sustainability,
- customization.

From the technical point of view, according to X. Fang, there are 3 components of a Smart Grid network (Fang et al., n.d., p.2): infrastructure, protection and Smart management.

1) Infrastructure

The smart system supports two-way flow of electricity and information, regulating production and consumption of electricity in real time. For example, in the traditional power grid, the electricity is generated by the station and sent to the transmission grid, and with means of distribution grid is delivered to users (fig. 1). In the smart grid the users can manage energy flow. The author divides the smart infrastructure into three subsystems:

- Smart energy subsystem - generation of electricity, delivery, and consumption at technologically advanced level;
- Smart information subsystem - improved metering, monitoring, and management;
- Smart communication subsystem - the network of systems, devices, and applications for information transmission.

L. Cepa, Z. Kocur and Z. Muller presented detailed description of IT networks used in Smart Grids (Cepa, et al., 2012). The authors propose that a sufficiently dimensioned data network is a key factor of an effective management and present an overview of industrial control networks and how the IT technologies are developed in industrial control networks.

2) Protection

Smart protection system is the subsystem, which provides security and privacy services, as well as an advanced grid reliability analysis. Smarter management system is possible to be organized by means of the smart infrastructure. It allows effective and efficient support of failure protection mechanisms, and preserving the data privacy.

One of the key components of a smarter grid is smart metering which causes one of the main challenges, related to the development of the system - security and privacy. A smart meter is an electrical meter, recording consumption in hourly intervals. The information is sent back to the utility for monitoring for billing purposes (Federal Energy Regulatory Commission, 2010). The security issue is actively discussed in existing research (Metke & Ekl, 2010; National Institute of Standards and Technology, 2010; Efthymiou & Kalogridis, 2016). C. Efthymiou and G. Kalogridis stress on the importance of data security as a part of development of smart grid. Moreover the users of new applications, such as smart meters will need to be reassured that their data is secure and present a method for securely anonymizing frequent electrical metering data sent by a smart meter. Smart meters automatically provide accurate readings at requested time intervals. There are two types of data generated:

1. 'High-frequency' metering data is meter readings, transmitted by meters to the utility with high frequency (e.g. every few minutes). It proposes information related with the electrical data user's private life (such as usage patterns).
2. 'Low-frequency' metering data is meter readings, transmitted by smart meter to the utility less often (weekly or monthly). This data is used for account management or billing purposes (Efthymiou & Kalogridis, 2016, p. 239).

Such detailed information about energy consumption describes the daily energy usage patterns of households. The crucial challenge, addressed in the paper (Efthymiou & Kalogridis, 2016) is that high-frequency data received from meters is required for efficient network operations may expose private information. The method proposed my researchers provides a 3rd party mechanism, which allows reading the meters anonymously, so that the readings cannot be associated with a particular smart meter or customer.

Apart from the technical solutions to maintain the security of private data, the issue of privacy has also been studied from the perspective of consumers: concerns about privacy violations can become a barrier for technology to be used. However, studying this topic, A. Ståhlbröst concluded that, based on the results of a survey conducted in Europe, "people have information privacy concerns related to this type of solution on a general level". As soon as consumers get introduced to the technology or solution, they get more positive towards it with no regards on the personal privacy issues. Additionally the study identified principles supporting the design and implementation of smart city solutions, related not only to users, but also perspectives (Ståhlbröst et al., 2015).

Another aspect of security is the system's reliability (Metke & Ekl, 2010). The upgrading of existing technology requires significant dependence on distributed intelligence and broadband communication capabilities. Those cause the necessity of proven security technology for extremely large, wide-area communications networks. The authors discuss key security technologies for a smart grid system using the example of the North American power grid. Among those are public key infrastructure (PKI) technology elements based on industry standards (such as certificate lifecycle management tools, trust anchor security, and attribute certificates), and trusted computing elements.

3) Smart Management

The smart management system is the subsystem in Smart Grid, responsible for management and control functionalities. Smarter infrastructure exposes the functionality with means of developed management applications and services, which can leverage the technology development. The main objectives of smarter management are improvement of energy efficiency, balance of supply and demand, cutting of operational costs and maximization of utility.

The goals of management within the Smart Grid concept are presented in figure 4.

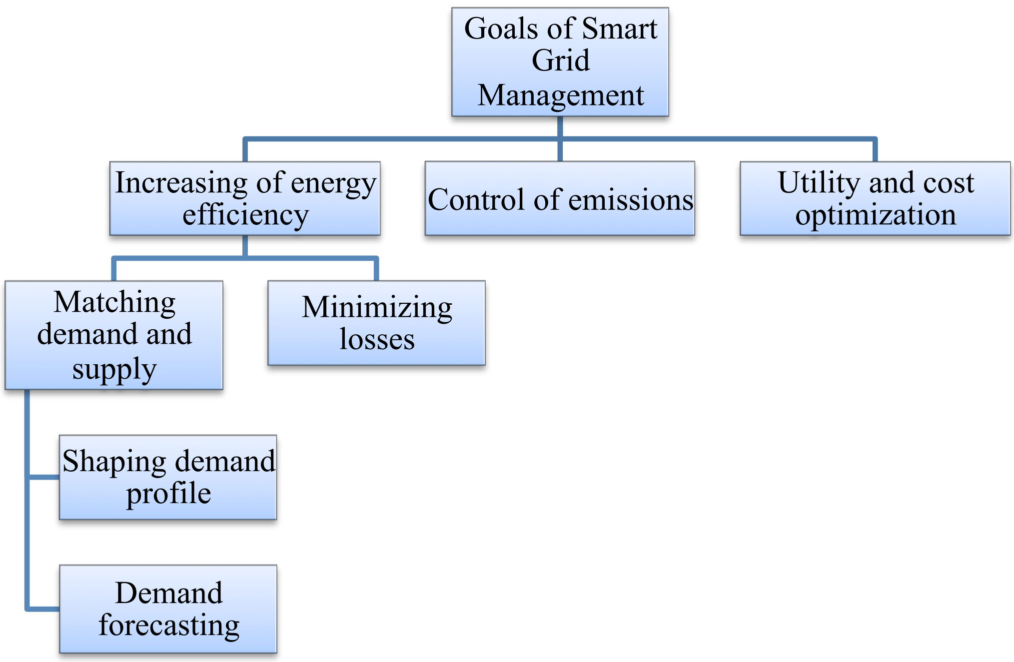

Figure 4. Goals of Smart Grid Management

Energy efficiency

There are two topics discussed by the researchers, related to the energy efficiency: shape of demand profile and minimizing energy loss.

Matching demand and supply

One of the most important concepts of the smart grid is demand response. Two directions of information flow allow managing the energy consumption (for instance, send the energy surplus back to the grid), which is the first step to matching of the supply to the demand for energy.

Since the energy demand is dynamic and changes quickly, the attempts to meet the demand could fail, resulting in brownouts (i.e. a drop in voltage), blackouts (i.e. electrical power outage), and even cascading failures (Fang et al., n.d., p.19). Smart Grid, in contrast, takes into account the demand response and does not need to match the demand with the supply, but rather matches the demand to the available supply with means of control technology. Traditionally, it is made by scheduling or reducing of existing demand in order to reshape (smoothen the peaks) a demand profile (Bakker & Bosman, 2010). In result, the energy consumption can be reduced by turning off non-essential devices during peak time in a way that the peak total demand can be reduced. Smooth demand profile results in reduced costs and increased reliability of the system.

The topic is widely discussed by the researches from different perspectives (Bakker & Bosman, 2010; Caron & Kesidis, 2010; Chen, 2010; Ibars & Navarro, 2010; S. Kishore, 2010; Mohsenian-Rad, 2010; Taneja & Culler, 2010; Saad, et al., 2016).

One of the examples of such algorithms is presented in the paper "A Novel LTE Scheduling Algorithm for Green Technology in Smart Grid". Smart grid applications allow meeting "the demand of increasing power consumption by combining renewable energy resources and electrical grid by means of creating a bidirectional communication channel between the two systems" (Hindia, et al., 2015). M. Hindia studies the suitability of such applications as the distribution automation (DA), distributed energy system storage (DER) and electrical vehicle (EV) for the long term use and proposes the demand scheduling algorithm, allocating available network resources according to the dynamic weighting factors of to quality of service.

In the paper "Demand side load management using a three step optimization methodology" V. Bakker and M. Bosman stress on the issue of energy efficiency and emission control. The solution is introduced three step control and optimization strategy, applied to reshape the energy demand of a large group of buildings. With this new approach the consumers are becoming active players in the optimization process, new technologies allow controlling the load and generation volume, giving the system a potential for optimization. The authors provide a methodology to use this potential by optimizing efficiency of the power plants, supporting renewable sources and optimizing usage of the existing capacity. There are three main steps of the demand control strategy:

1) Prediction of production and consumption for the upcoming day, based on the historical usage pattern of the residents and external factors like the weather.

2) Using of optimization potentials to reach a global objective (compensating the fluctuation of the production of renewable sources). In the result of this step the planning is done daily for each household.

3) A real-time control algorithm, identifying when the appliances are functioning, estimating energy flows (Bakker et al., 2010) .

Shaping demand profile

Another solution to deal with inefficiency is dynamic pricing scheme, making the consumers modify their consumption to flatten their demand by different incentives. It allows reducing the discrepancy between power supply and demand, as a result if the shift of power usage away from peak periods, improving stability and lowering production costs (Caron & Kesidis, 2010; Kim & Poor, 2011).

The mathematical model, presented by C. Gorria, J. Jimeno, is aimed to forecast the flexibility in aggregated electricity demand of a group of domestic consumers signed up to an incentive-based demand management program. Within this program the consumers received the signals, offering financial incentives for limiting their consumption during the peak demand intervals. The authors consider, that adapting the consumption to supply is an effective way to tackle the energy storage problem.

Dynamic electricity pricing models can potentially bring economic and environmental advantages compared to the flat rates, for instance, by reducing electricity expenditures, responding to daily price variations (Mohsenian-Rad & Leon-Garcia, 2010). However, success of the dynamic pricing depends primarily on reaction of the consumer to the varying prices. Since it is impractical and rare for the consumers take an action depending on a price change, full economic benefit is only possible when "power consuming devices are equipped with an automatic price-aware scheduling mechanism that requires minimal action from the consumers"(Kim & Poor, 2011). Based on simulation results, Caron and Kesidis infer, that cooperation between the consumers allows reducing costs and peak-to-average ratio (PAR) of the system significantly. Kishore and Snyder have presented mechanisms to optimize electricity consumption based on an optimization model, with lower electricity rates during off-peak periods within a home and across multiple homes in a neighborhood where the energy management controllers (EMCs) – one of the components of Smarter Grid - are used (Kishore & Snyder, 2010). Additionally, the authors developed a distributed scheduling mechanism to reduce peak demand within a neighborhood of homes. P. Samadi has also studied the Smart Grid and smart pricing methods with use of energy consumption controller (ECC or EMC), connected both to the power grid and a communication infrastructure. The researchers modeled users' preferences and consumption patterns, resulting in a utility function and concluded, that smart pricing is beneficial both to users and utility provider (Samadi, et. al., 2012).

According to A. Mohsenian-Rad, however, the main barriers to the application of the dynamic (real-time) electricity pricing tariffs is lack of awareness among users as well as absence of effective automation systems. Using game theory and linear programming computations, the author came to a conclusion, that adopting pricing tariffs with differentiated energy usage in time and level, the global optimal performance is achieved at a Nash equilibrium of the formulated energy consumption scheduling game. The authors propose an energy consumption scheduling framework, aimed to achieve a trade-off between the expectancy time and electricity price (Mohsenian-Rad & Leon-Garcia, 2010). The simulation results of the study have shown, that the proposed model of energy consumption scheduling and the price predictor filter bring reduction of the peak-to-average ratio for various scenarios. This leads to the conclusion, energy consumption schemes are beneficial for the companies, generating energy, as well as for the customers.

The topic of real-time management of energy consumption and price presents an interest from economical perspective as well (Cui, Wang, Goudarzi, Nazarian, & Pedram, 2012). It was studied from the point of view of consumer behavior and competition among multiple non-cooperative utility companies in an oligopolistic energy market. According to the authors, from the perspective of economic theory, oligopolistic electrical market is effective for decreasing the electricity.

Demand forecasting

As mentioned above, the management objectives are mainly concentrated on the questions of production efficiency: precise match of supply and demand and minimization of production losses, financial stability (dynamic prices and operations management), and environmental impact. Another area, widely investigated is a forecasting of the energy demand. Demand forecasting is a tool for operational decision making, which allows planning and reserving margins and functioning of the electricity networks, as well as capacity expansion.

The problem of precise forecast of the demand is complex, due to various factors affecting the demand profile, such as uncertainties in the generation profile of generation resources, environmental impact and lack of historical data. The main challenge, associated with the energy demand forecasting is a large volume of data about electricity consumption in small time periods provided by the smart meters. It required advanced data processing algorithms to process the information within short time periods (Khodayar & Wu, 2015). In long-term perspective overestimated demand will result in higher investments, while underestimations can lead to inefficient supply (Stremel, 1981). As for the short-term, overestimated demand will increase the system operation cost, whereas underestimations could cause real-time imbalance of energy supply and demand (Nogales et al., 2002). The existing researches can be grouped by term, geography, industry, methods and tools. Moreover, there are two approached for demand forecasting: bottom-up and top-down. Top-down approach focuses on industrial demand and uses macro-variables to predict the demand trends, while bottom-up demand forecasting models are based on aggregated sectorial simulations. Since both approaches have their pitfalls and benefits, the solution, which one to use depends on the context of the question (Khodayar & Wu, 2015). F. Lescaroux proposes an approach, which combines the best of those two approaches: the predicting variable is a two-term decomposition of industrial energy intensity, presented by two indices reflecting the effects of changes in the industrial structure and of efficiency gains or losses at the sectorial level (Lescaroux, 2013).

Demand forecasting plays an important role in the smart grid paradigm. It is applicable to such practices as demand-side management, discussed above, integration of renewable energy, planning of energy storage. Current forecast methods in the power network are based on conventional generation technologies and passive customers, while the smart grid paradigm implies that the framework for demand forecast should take into consideration the awareness on energy consumption and participation of the customers. The main factors, influencing the energy demand are introduced by M. Khodayar (Khodayar & Wu, 2015) and M. Raza (Raza & Khosravi, 2015). Those are weather conditions, time, random behavior of customers, temporary factors as time of day, day of the week, as well as the season, volatility in generation and demand profiles, electricity price and demand response, availability of renewable energy resources and virtual power plants, micro grids and nano grids. The patterns of energy consumption, according to M. Khodayar are formed at three levels:

1) Very short-term load forecasting (from seconds to hours) – plays a crucial role in the control of spinning reserve, evaluation of sales and purchase contracts;

2) Short-term load forecasting (from hours to weeks) – used for efficient maintenance of the power system;

3) Long-term load forecast (from months to years) – used for the long-term power system

(Khodayar & Wu, 2015, p.52).

There is a wide range of works, devoted to the problem of demand forecasting, presenting different approaches and models. According to A. Ghanbari, and S.M.R. Kazemi, all the methods of energy demand forecasting can be categorized into two groups: conventional and intelligent techniques. Relating to the latest, the authors also present ant colony optimization, genetic algorithms and fuzzy logic to construct energy demand forecasting knowledge-based expert systems which can be used as a reliable tool for decision making. Various other demand forecasting models are reviewed by L. Suganthi, and A. Samuel. Among traditional methods they point out regression, time series, ARIMA, soft computing techniques, as neural networks. M. Q. Raza and A. Khosravi also provided the comprehensive and systematic literature review of Artificial Intelligence based short-term load forecasting techniques.

According to M. Khodayar, discussing challenged of the demand forecasting, to achieve the accuracy in the demand forecasts, behavior of the customers should be better understood. Smart meters allow managing the consumption of the energy and sending its surplus back. Therefore, behavior of the customers with smart meters differs significantly and both should be taken into consideration. To be precise, accurate forecasting model should differentiate the type of customers with their respective characteristics (Khodayar & Wu, 2015, p.59).

Minimizing energy loss

Minimizing energy losses is another aspect of energy efficiency, which has also been studied actively. There are several solutions for decreasing the energy loss, based, mainly on the integration of storage units and renewable energy sources. Opportunity of the consumers to store energy or send it back into the grid is the main step toward a large-scale exchange of energy within the grid (Saad, et al., 2016). As a result, integration and exploitation of storage units and consumer-owned renewable sources is an important demand of the future smart grid.

Ochoa and Harrison has presented a methodology for optimal accommodation and operation of distributed generation plants to minimize losses, by using an optimal multi-period alternating current power flow. The methodology (the multi-period AC OPF technique) was applied to a generic U.K. distribution network within a case study. The results proved a significant impact of time-varying characteristics to the energy loss minimization problem (Ochoa & Harrison, 2011). Other researches propose statistical models (Atwa et al., 2010) and optimization algorithms (Aquino-Lugo & Overbye, 2010) to shape demand curve and minimize losses.

Utility and cost optimization

Among the other management objectives, apart from demand profile and minimization of energy loss, there are the following: increasing profit and decreasing costs (Mohsenian-Rad & A. Leon-Garcia, 2010; Mohsenian-Rad et al. 2010) and improving utility (Mohsenian-Rad et al. 2010), control of emissions (Fang et al., n.d.). M. Rayati and A. Sheikhi stressed on their investigation on operational costs. The authors introduced the smart energy hub (SEH) as a new concept. SEH is an energy hub, unit of a smart energy infrastructure, to convert and store energy carriers. It can be used for efficient reduction of electricity and natural gas bills (Rayati, Sheikhi, & Ranjbar, 2014). The solution allows consumers to manage their energy consumption, reducing their electricity bills. To estimate the efficiency, Monte Carlo estimation method for finding a near optimal solution was used. The results showed the possible costs reduction up to 40% while keeping desired comfort levels of the consumers, as well as peak load and CO_2 emission social cost reduction by 17% and 50%, respectively.

The management objectives are intercrossing with each other, for example, effective management of demand profile can result in costs optimization both for consumers and for the energy generation companies. According to the paper "Computational Methods for Residential Energy Cost Optimization in Smart Grids: A Survey" (Alam, et al., 2016) cost-saving opportunities, existing in smart homes is a motivator to involve users in smart grid operations. The survey explores the cost-saving strategies from the users' perspective and concludes that optimization methods, which gained the most popularity in the existing literature, are aimed to create a schedule and power utilization schemes of households, energy storages, renewables, and other energy generation devices. One of the most effective methods for users' costs optimization is trading energy among neighborhoods; however, the methods of consumption prediction (forecasting the energy price, generation, and consumption profiles) are also popular. The authors present an overview of cost optimization methods as well as the mechanisms and reasons for costs reduction, presenting a unified cost optimization framework.

Control of emissions

Control of emissions is an important area of the electric power management, due to its significant influence on the environment. Since the costs of energy generation are not always the lowest, the minimization of emissions is not possible just by minimization of generation costs or maximizing the profit. As a result, according to S. Gormus, the environmental impact of the energy production should be considered as a cost parameter, influencing peak loads (Gormus et al, 2010). Moreover, other researchers have also studied the problem of emission optimization. The three-step control strategy of energy efficiency optimization, introduced by V. Bakker, is aimed to reduce the CO_2 emission caused by electricity generation (Bakker at al., 2010).

Another way to reduce the emissions with means of smarter grid is to encourage renewable energy deployment: integration of more renewable and low carbon electricity into the power grid. However, according to C. Koenigs this aspect is not central in smart grid policy discussions. Development and building of a smart grid is a complicated and complex process. And the path differs according to the context: states and regions are approaching grid modernization in different ways. The authors present a comparative analysis of smart grid development in several U.S. states, depending on the motivators, relation of the technologies to renewable energy (Koenigs, et al., 2013). Obviously, geographic location is an important factor of smart grid development, mostly, because it defines the existing infrastructure and access to other energy sources, like wind and solar.

Value of the smarter grid

There are a lot of stakeholders involved to the process of implementation of smart grid innovations; therefore, the economic aspect of smart grid presents an interest due to its importance for the decision-making. There are several studies, devoted to the estimation of the financial effect and customer value of the smart grid. According to (Shlatz, n.d.), the main challenge, associated with the implementation of smart grid pilots, is the absence of history to demonstrate the cost-effectiveness of the technologies. However, to satisfy the needs of stakeholders, both short- and long-term value should be generated by investments to the technologies.

The common approach does not differ much from evaluating traditional investments: it is required to estimate the value of a particular utility is to define the costs, related and benefits generated over the lifecycle of the implementations. The review of industry publications and vendor websites present a wide range of studies on smart grid evaluation, covering cost, benefits, and integration. They address both qualitative and quantitative benefits. However, some of them are oversimplified by evaluating benefits on a one-time basis. According to E. Shlatz, a proper comparison of the smart grid versus traditional utility system investments brings to the following conclusions: on the one hand, smart grid investments have shorter lifespans, than traditional ones. Also, they might be considered as more risky, due to higher level of uncertainty and commercially immature technologies. However, the case study, organized by E. Shlatz, suggests, that deployment of new smart grid applications will deliver significant benefits to all stakeholders.

Technologies, developing within a smart grid paradigm

Intelligent technologies are embedded in the smart transmission grid. The systems become sufficient, environment-friendly and digital: the smart grid employs a new platform which allows faster and more reliable measurement, connection, security, visualization, and maintenance of the transmission system. Growing electricity demand should be satisfied with the usage of affordable alternative energy resources, increased energy savings via technology of the electricity delivery and system operation. Innovative technologies to be employed should have less pollution or emission, and decarbonize with consideration to the environment and climate changes.

The smart grid is flexible in four aspects:

1) Opportunity to expand for future development;

2) Adaptability to various geographical locations and climates;

3) Several strategies for coordination of decentralized control schemes;

4) Compatibility with different market operation styles and plug-and-play capability to accommodate progressive technology upgrades with hardware and software components (National Institute of Standards and Technology, 2010).

A smart grid is not a ready product, but rather a process of network development aimed to improve efficiency of the system. The technologies developed within the concept are described by Fangxing Li and Wei Qiao (Li, et al., 2010). The main directions for technology development are the following:

1) Application of *new materials and alternative clean energy resources* – which will make the power supply more efficient by reducing energy losses, and lowering construction costs.

2) *Advanced power electronics and devices* will improve the quality of power supply and flexibility of power flow control.

3) *Sensing and measurement* - the basis of information computing, control and intelligence. Advanced metering infrastructure provides more efficient real-time control to balance energy supply and demand through more visible supply and demand patterns. It helps understanding the correlation between the consumption and electricity price, as well as provides an insight into demand response, pricing scheme, and expansion planning (Khodayar & Wu, 2015).

4) *Communication networks' flexibility* will facilitate the work of open-standardized communication protocols on a unique platform. Real-time controlling tools are based on a quick information transfer is enhancing system's reliability and security.

5) *Advanced controlling methodology* is needed for automation of customer-centric power delivery network. It will enable real-time modeling of complex power systems.

6) *Market regulations and policies* is a way to improve the transparency, strengthen interaction between customer and electricity consumption, and create conditions of a fair competition in the power market.

7) *Intelligent technologies* aimed to facilitate the process of the new technology acceptance.

Role of consumers

Smart energy grids are creating wide opportunities for cost saving, giving the consumers power to manage and plan their consumption. Therefore, such fundamental changes of the energy production should be delivered to the consumers in a right way, giving them awareness and opportunity to experience all the benefits of smarter systems. This creates a room for interdisciplinary research of the consumption behavior. The article by Nicole D. Sintov "Unlocking the potential of smart grid technologies with behavioral science" stresses on the necessity of the users to participate in the systems to maximize the impact of smart grid technologies (Sintov & Schultz, 2015). The authors present emerging technologies, related to a smart grid infrastructure, and ways to apply behavioral science to increase the impact on energy savings. The research contributes to the theoretical background of the area, improving the level of understanding theoretical underpinnings of energy use behavior. The paper focuses on consumer adoption and optimal use of smart technologies for energy production. It contains the overview of the models from behavioral science that aid in understanding the adoption and use of smart grid technologies, as well as the overview of strategies that utilize smart grid infrastructure to encourage electricity savings among residential users. Also the authors prove the theoretical knowledge with the specific examples, discuss the underlying behavior change tools at work.

The challenges, related to smarter technologies application and consumers' reaction are also analyzed in paper (Wilson, et al., 2014). Based on a systematic literature review on smart homes and their users, the authors formulate a research framework aimed to identify the presence or absence of crosscutting relationships between different understandings of smart technologies applied in smart homes and their users. The main challenges, related to the spreading of smart technologies, can be grouped into 3 categories: (1) hardware and software, (2) design, (3) domestication. Therefore, apart from necessity to develop high-quality secure smart systems, it is also important to understand the social barriers to the adoption of smart homes, such as loss of control, reliability, privacy, trust, cost and irrelevance.

1.4. Overview of Russian energy industry and the scope of research

Smart cities – a current trend of business and industrial development has a sufficient importance for economy: the world's city population is increasing every year, making cities not only a source of income and production, but also a reason for increased pollution level and other sustainability issues. The way to solve them is building and reorganizing the cities using new technologies which will deliver added value, increase quality of life, help to solve environmental issues.

Development of smart cities in Russian market is currently in process. Global pioneers of this area are cities in Europe (Spain, Germany), Asia (Korea, Taiwan, Japan) and the USA. Companies – the main players of transportation, energy, water supply industries, as well as the government are inspired by foreign success stories of smart cities and financial and non-financial benefits provided. The strategic view of those companies includes the implementation of smart and innovative solutions. However, the main directions of this processes launched by Russian companies and the results are not widely published.

Energy sector has a strategic importance for Russian economy due to availability of the resources: oil and gas, coal, hydro and nuclear energy. The consumption of primary energy resource's in 2013th was 699 billion of tons in oil equivalent: most of them was gas and oil (53,2% and 21,9% respectively), coal (13,4%), hydro energy (5,9%) and nuclear energy (5,6%). The building of heat and hydro-electro stations had a significant importance for soviet economy since 1920-1930th. Later, in the middle of twentieth century, the accent had moved to the development of nuclear energy. Due to the great capacity of the resources Russia is in top 10 of countries, secured by energy resources (EIA, n.d.).

The volume of energy production per capita in Russia reaches the level of such countries as Germany and Denmark, which have lower transportation losses and costs of heating. The consumption of energy is growing year by year and, in 2014th the total production of electricity was 1 064 100 Gw/h.

As for the main consumers of electricity, they are industrial production (36%), energy sector (18%), households (15%). The losses reach the level of 12% (EIA, n.d.). However, the statistics by regions differs according to the population density and natural environment. The development of technologies in the sector of electric energy in Russia is aimed to implement new and efficient technologies to reduce the losses.

Due to the fact, that Smart technologies implementation in heat production are currently in the very beginning stage, it was decided to concentrate the research on this sphere. As a result, during the interview the industry experts provided the industry insights and personal opinions about the main drivers, challenges and benefits of the smart technologies implementation.

1.5. Research problem

Development of smart cities in Russian market is currently in process. Companies – the main players of transportation, energy, water supply industries, as well as the government are inspired by foreign success stories of smart cities and financial and non-financial benefits provided. The strategic view of those companies includes the implementation of smart and innovative solutions to increase business efficiency.

Energy sector management is one of the important issues of Russian economy, both due to enormous costs and its ecological impact. There is a significant difference of Russian energy sector infrastructure in comparison to that in developed economies. Most of production capacities were built tens of years ago, which causes the necessity of their innovations as well as creates the challenges. However, even with the slower pace, the industry players are interested in developing existing capacities: making it more efficient by reduced operational costs and emissions, providing benefits for consumers. However, there are certain challenges, related to making the energy distribution network «smarter», related to legislation, weather conditions, economy and other factors.

The analysis of existing research has shown that Smart technologies implemented in electricity production and distribution has been overviewed from different perspectives during the recent years (see Figure 5).

Smarter Grid is already implemented both in Russia and developed countries. However, there is very limited information about the smart technologies in heat production. Smart technologies in heat production have things in common with those, implemented for more efficient electricity production and distribution, considering the different nature of the energy. Those are smart metering centers, which allow automation of the production, eliminating the human role in operations. Talking about Russia, the lack of research can be explained by the fact, that those technologies are new for the market and still not widely known.

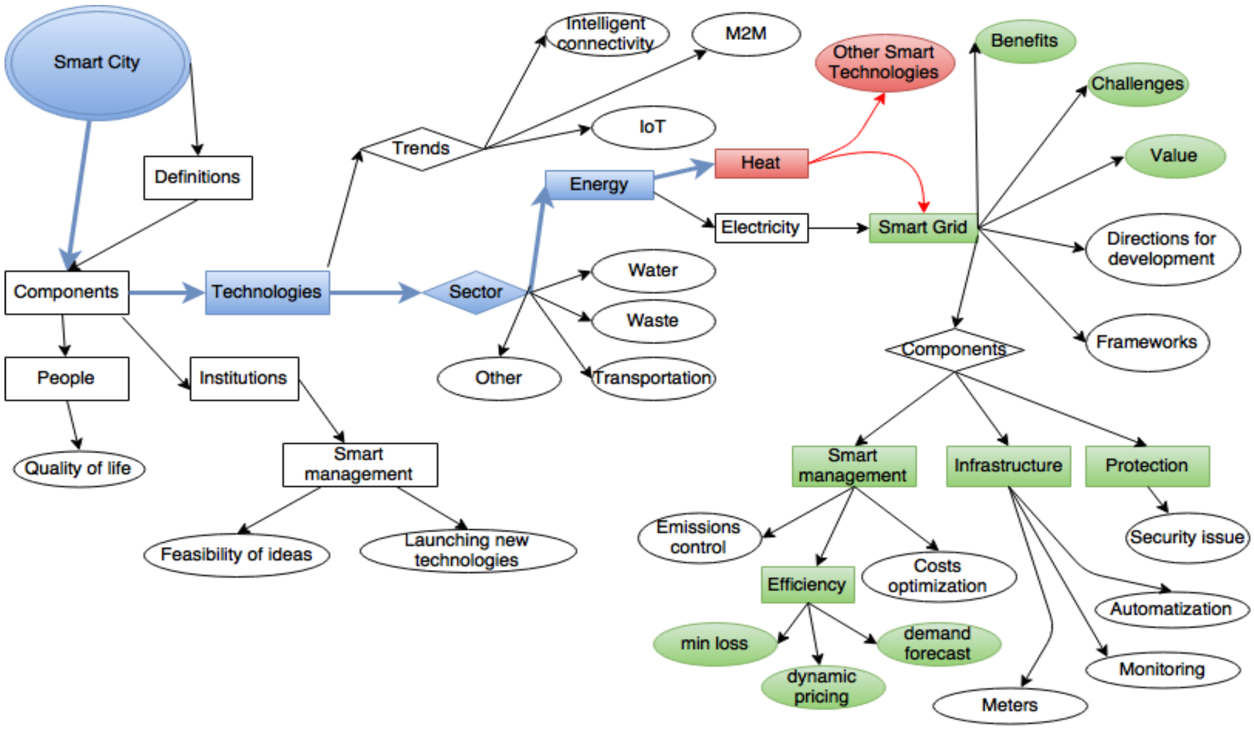

Figure 5. Areas covered by the literature review

Research gap: lack of knowledge about smart technologies for energy sector being implemented in Russia, in particular – in the heating production sector.

Understanding the factors, affective the implementation of a new technology is crusial for efficient management – structured knowledge of this topic among the employees will facilitate the process of smart technologies implementation. Therefore, existing research, aimed to identify those factors contributes both to theoretical and practical background.

The **goal of the study** is to create an overview of smart technologies used in Russian energy sector (on the example of heat production), as well as to identify the factors affecting their implementation.

1.6. Research framework

The research is investigating on the factors, affecting the development of smart technologies. To create an unbiased overview of them, and avoid the risk of limited expert opinions, the research questions and interview questions were formulated based on the framework, developed by F. Li (Li, 2010, p.3), covering the main aspects of the Smart Grid (see Appendix A for the vision of a smart transmission grid). Due to the fact, that production steps of the electricity production and distribution are similar and facilities. The main aspects are the following:

1) Characteristics of the smart grid. The smarter electricity production benefits, according to F. Li, are grouped into six categories. They are intelligence, resiliency, sustainability, customization, digitalization and flexibility. Therefore, the benefits of the smart technologies implementation can be allocated to one of those categories.

2) Components. F. Li defines three components of the smart electricity production: smart transmission networks, smart control center and smart substations. Therefore, technologies and applications can be related to one of them.

3) Functions. Functions of the smarter grid are mainly defined by the components and specified in details in the paper of D. Xenias. Those considered most important are increase of controllability and observability, employment of demand side response technologies and enabling network management (Xenias, et al., 2015, p. 95).

4) Fundamental driving forces. The categories of fundamental driving forces are environmental challenges, customer and market needs, infrastructure challenges and innovative technologies.

Since the smart technologies, used in heat production are based on a similar idea of smart metering installation and avoidance of a manual labor, the framework proposed is considered to be suitable for the analysis. The model presents a vision of a smart grid, combining the characteristics, main components, functions, benefits and challenges, as well as main drivers (fundamental driving forces).

In order to adjust the view presented to the research subject, the following **research questions** were formulated:

Central question:

What is affecting the implementation process of smart technologies in Russian heat production sector?

The central question can be divided into the following sub questions:

1. What are the reasons/drivers for smart technologies development in this sector?
2. What are the benefits/challenges?
3. When the projects are expected to be implemented?

The research questions are to be answered in the result of primary and secondary industry data analysis. The objectives of current research are the following:

1. Analyzing existing literature on the topic;
2. Selecting a sample of experts, ready to share the insights on project information;
3. Analyzing and synthesizing the information to create a complex overview on the research problem;
4. Describing the examples of systems, where the technology is implemented.

1.6. Summary of chapter 1

The rapid growth of the cities is one of the main incentives for their smart development. Technologies, making the usual processes efficient and effective are called smart technologies. Their implementation brings certain benefits as well as correlated to specific challenges.

The chapter is aimed to highlight the importance of studying the factors affecting smart technologies development in Russian energy sector. Being a core sector of Russian economy, it needs to be developed and managed according to the resent world standards.

The review of existing literature has shown the following outcomes:

- Smart technologies in energy sector are aimed to maximize automation level, to reduce human factor in production and distribution processes;
- Important features of smart grids is managing and shaping the energy demand, as well as giving the consumers the power to make the decisions, related to consumption;
- Smarted grids are the combination of innovative IT applications with networks and modern infrastructure;
- Implementation of smart technologies will result in losses level decrease as well as prime costs reduction;
- Environmental impact of smart technologies is undoubted: they allow both to reduce the level of emissions and to use renewable energy sources.
- However, the implementation of smart technologies in energy sector is a complex process and is highly dependent on the context: country, region, legislation and other factors.

The current research is aimed to identify the factors, affecting the development of smart technologies in Russian energy sector, based on the example of heat production. The empirical case study is based on the results of expert interviews with representatives of the industry from different regions, analysis of existing research, companies' internal documentation and online resources.

2. METHODOLOGY OF THE STUDY OF THE KEY FACTORS OF SMART TECHNOLOGIES DEVELOPMENT IN RUSSIAN ENERGY SECTOR

The chapter provides an overview of the research methods used to achieve the thesis' objectives. First, the research approach and methods chosen are described ae well as the choice is augmented. Second, the data collection part contains the description of data, necessary as well as methods of data collection. Finally, reliability of the results and limitations, associated with the research are discussed.

2.1. Problem statement

Smart city development is a popular trend, related to innovation technologies and implementation of new and efficient information systems in every sector of city's development: transportation, energy and water management, government, etc. The concept is widely discussed in the existing sources from several perspectives: challenges and benefits of the new technologies implementation, leadership aspect, future trends, and comparison of the approaches used for different cities. The smart technology (Smart Grid) is already widely used to increase the efficiency of energy in the electricity production, however, in the heat production the project of Smart Grid implementation is only at its beginning stage. Though, the benefits of the technology are undeniable: using of computer-based remote control and automation for system management will significantly increase the quality of life. Within recent years the technology has launched in Russian energy providers. The crucial question is how to estimate the cost efficiency of this technology, possible risks and benefits.

As mentioned above, the objectives of the study are the following:

1. Analyzing existing literature on the topic;
2. Selecting a sample of experts, ready to share the insights on project information;
3. Analyzing and synthesizing the information to create a complex overview on the research problem;
4. Describing the examples of systems, where the technology is implemented.

2.2. Research methodology and organization of the study

2.2.1. Research approach and subject

The research will cover the Russian energy sector in the perspective of smart technologies usage. The industry is represented by several companies – producers and distributors of the energy.

The research conducted is *applied*, meaning, the results can not only complement the existing area of intellectual enquiry, but also has practical implications. For example, “the results can be used by a particular company for facilitation of decision-making process” (Riley, 2000, p.9). Applied research is problem-oriented and aimed to solve a particular puzzle with practical implementation, while, in contrast, pure or basic research is aimed to contribute to the creation of a new knowledge in particular area.

There are a lot of studies on the management objectives within smart grid paradigm, which give an overview on main directions, goals, and challenges. However, Russian case is different from other counties due to specific characteristics of industry. Therefore, the overviewed literature frames the main ideas, related to the topic of Smart Grid. While based on the companies' overview and analysis of primary data, the theories formulated are related to the literature. Therefore, the conducted research can be characterized as *inductive*.

2.2.2. Organization of the study

In order to answer the first research question, deep analysis of the theoretical background is required. Both previous researches and practical tools as indexes must be analyses to give a comparative estimation. The action plan is presented below:

1. Observation of the existing literature related to the research area;
2. Designing the research;
3. Theoretical analysis of the existing frameworks and concepts;
4. Analysis of the chosen industry;
5. Collection of the primary information – searching for companies – energy industry representatives;
6. Conducting interviews;
7. Analysis of the collected information to make outputs.

One of the main and most important phases of the research is interviews with the managers of the companies, which are operating in energy sector. Its purpose is to highlight the most popular ways to increase the productivity and extract value from smart technologies. There can be specific difficulties, related to the small number of companies and limitations of data, which could be provided. The rest of the paper is structured as follows: chapter two describes the approach and presents the methodology and data. Chapter three contains the results obtained. Finally, the concluding section summarizes the paper and presents directions for future investigation.

2.2.3. Justification of a research approach: Case study

Many issues in organizations can be only approached with the context: the understanding of some aspects of operational management, financial estimations or controlling is only possible when taking into account the company's management style and culture, historical development of the industry and other factors. The 'case study' method is an approach which explores this interconnection within the context and highlights the specific features of some organization, affecting certain project. During the case study the following methods of primary data is being collected by conducting interviews, surveys, focus groups and observations. To connect the research and the context the data is connected in multiple areas of an organization. This research method is used, when the research questions are “How?” and “Why?”, rather than “What?”, since it allows to understand particular problem in depth and provide advanced solutions (Cameron & Price, 2009).

Opportunities and limitations of case study

Case study will help to construct a complete picture of the problem, based on a data from different sources, both primary and secondary. The results will be drawn from the synergies between quantitative and qualitative data. Since the case study approach provides an opportunity to view the problem from different perspectives, within a context, it will not be useful, if there is a single theme research question should be answered, or the data required is not relevant to the context of organization or the time-frame of a project is short.

Comparison to other research approaches

Case study is a method that provides a deep understanding of certain phenomena in depth. Alternative to case study research approach is action research.

Action research is an empirical approach, applied to problems, in which researchers and participants, representatives of the situation researched, are involved in a cooperative and participatory way. Action research links researcher and research object, with an intervention line in support of both, in a prescriptive approach. It is applicable for the cases, when the research contains implementation stage and proper planning is required. This approach is characterized by high level of involvement, since a lot of insider information necessary to change the habits, culture or simple processes in the organization. Since this research approach is more suitable for dynamic problems, it is less preferable for the subject of studying. In addition, researchers working with this approach do not deal with hypotheses, but rather with research topics and organizational challenges. The result of this research will be a sequence of events will lead to resolution of a problem. Action research comprises three main phases: preliminary, conduction cycle and metaphase. The conduction cycle comprises six main stages, and each of the six stages contains the metaphase (Cameron & Price, 2009).

2.2.4. Conducting a case study

After research gaps are identified and the research questions are formulated, the most appropriate, useful and effective methods of data collection and analysis should be selected (Saunders et al., 2003). Finally, the work should be carried out with means of necessary methods.

Conducting a case study included the following steps:

First of all, a mapping of the reference literature should was developed. Conducted literature review provided both research gaps and constructs - elements extracted from literature that represent a concept to be verified in the field. These constructs defined the propositions of the work and its objectives.

The second step was defining the number of cases, methods and techniques for data collection and analysis. Data collection included multiple sources of information, for example, interviews, document analysis and company visits to create a complex view of the problem. As soon as the techniques for data collection are chosen, a plan of the research should was developed.

On the third stage the data was collected via expert interviews.

Further step was the data analysis based on the information from the multiple sources of evidence. The final analysis included only the relevant and essential information, closely related to the objectives and constructs.

Finally, all the activities from the previous steps were summarized in a final report, associating practical results and evidence with the theoretical background.

2.3. Data collection methods

2.3.1. Description of data and resources

Both primary and secondary data is used for the research. First, secondary theoretical background is required to understand the energy industry characteristics, the concept of Smart Cities and now these two areas intercross.

Key data from secondary sources

- previously published papers and articles related to the topic of Smart Grid;
- technologies and tools are being used in the smart energy sector;
- Indexes, legislation regulations related to estimation of smart cities;
- Market segmentation and its application;
- Researches by consulting companies and agencies;
- List of ongoing smart technology projects and the details;
- Legislation and regulations related to the technological industry.

Key data from primary sources

The primary data was received from the experts from related industries and companies (electric and heat producers) by interviewing to obtain and verify critical information:

- Description of medium-term strategy, related to the implementation of the Smart Grid technology;
- Companies overview and market size;
- Data related to the regions where the technology is implemented;

- The company's technical tasks on the project;
- Costs of the project;
- Expert estimation of the time schedule, main goals and directions and challenges of the project;
- List of the companies involved and their strategic role.

2.3.2. Methods of data collection

There are following methods were used to complete the research objectives: expert interviews with representatives of the industry; deep analysis of existing information, publications, reports, web-resources.

Method of data collection: interview with experts

Expert interview is one of the most commonly used methods of data collection in qualitative research. It allows to gather information, when only few is known about the study phenomenon or when the researcher is looking for detailed insights from individual participants. The method also allows to avoid a group environment, for example, if a sensitive topic is explored (Gill et al., 2008). The expert interview as a method of qualitative empirical research was developed in early 1990s to explore expert knowledge. Interview with experts, as a an exploratory tool of data collection is more efficient than other methods, such as participatory observation or systematic quantitative surveys. Expert interviews allow shortening time of data gathering processes and its analysis, especially when the insider knowledge is an area of the researcher's interest. Moreover, it is comparatively easy to encourage and motivate experts to participate in the research due to the relevance of the field of expertise, professional curiosity about the topic and field of research or desire to help.

As for the experts' selection and description, according to the pragmatic perspective, the expert status can be ascribed by the researcher itself and purely depends on the researcher's judgement. This possesses a challenge due to the absence of the criteria to distinguish between experts and non-experts. According to A. Bogner, "a person is considered an expert if she or he possesses an institutionalized authority to construct reality". However, it is worth mentioning that not "only professional knowledge is treated as expert knowledge".

The fundamental types of research interviews are:

1) Structured – verbal questionnaires with a list of prepared questions asked. Structured interviews are easy to conduct, quick and used for likely to be used for clarification of the research topic. However, a little variation and small opportunity for follow-up questions eliminates the application of this method to the cases when the 'depth' is necessary.

2) Semi-structured interviews consist on two types of questions. The key questions help to define the areas to be explored and make a guideline for the interview, while additional

questions allow to get detailed responses. The approach is flexible and, therefore, allows discovering and elaborating the information.

3) Unstructured – opposite to structured, these interviews are executed with little organization. They are time-consuming, harder to manage and participate in, since little guidance is provided. The use of unstructured interviews is considered when significant clarifications are required.

The questions for a qualitative interview should be open-ended (require more than a yes/no answer) and understandable (Britten, 1999). It is advised to start with easier questions and proceed to more complicated and sensitive topics to help the respondents to build up confidence and rapport as well as to generate rich data.

Description of the data collection

To provide a full perspective on the research area, the experts were selected according to the following criteria: geographic location, stage of the project, role in the project, availability, area of expertise. The full list of interviewee is presented in the table 3.

The preparation for data collection included making of a preliminary list of the interviewers with assessment of the performance level, as well as selecting the most preferable way to contact the interviewer (face-to-face, telephone or e-mail interview) to avoid the problem of low quality of the results. Before the interview is conducted, respondents were informed about the details of the study.

For the existing research, the interviews were based on a topic-guide to be appropriate for data collection to give the experts an opportunity to unfold their own outlooks and reflections. This allowed making comparisons during the later analysis of the results. The questions for the interview were composed in advance based on the review of the existing literature about factors of smart technologies development, as well as the theoretical study books, related to the case study methodology.

During the preparation phase the guidance for the interview and the **questions** were formulated. They covered the following topics:

1) Role of the expert in smart technologies project implementation.

2) Description of the projects in different regions (according to the information available), scale of the project, time and payback period.

3) Perceived benefits of smarter heat production. (For the main stakeholders: company, city, consumers).

4) Steps of the projects (within the region), future plans.

5) Challenges, associated with the smart technologies development in heat production.

6) Other issues not covered by the expert, for example, sustainability aspect.

2.3.3. Steps of data collection

1) Preliminary unstructured interview to specify the borders of the research.

Duration: 40 min

Topic: smart technologies used in Russian energy sector.

Result: the energy sector consists of electricity and heat sectors. Those involve production, distribution, delivery to the consumer. While the smart grid is being implemented successfully in electricity production sector, the implementation of technology in heating sector is on its' beginning stage. The area of the research was specified to the heating sector.

2) Overview of on-line resources and existing literature.

Goal: description of the current infrastructure conditions, key stakeholders and their roles.

3) 4 semi-structured interviews with the managers of the smart grid implementation projects in different cities and technical specialists.

Duration: 20-45 min

Topic: implementation of smart technologies – goals, reasons, problems.

4) Analysis of data (project documentation) and description of results

5) 3 semi-structured interviews with IT directors of heat producing companies in different regions.

Duration: 30-50 min

Topic: implementation of the smart technologies in Samara and Lisva.

Result: detailed description of project goals, challenges, countable results.

6) Analysis of cases, making the report.

7) Verification of the results with the experts.

2.3.4. Data analysis procedures

Analysis: analysis of data obtained during the interviews with experts

The analysis of data obtained during the interviews was focused on thematic units, predefined by the framework. Therefore, the passages with similar topics were summarized in results. At the same time, the statement within single interviews was highlighted in cases description as a specifics, which created the case difference. The stages of the analysis of data obtained were the following:

1. Transcription of the interviews;
2. Paraphrasing and ordering according to thematic units (blocks of the questions);
3. Thematic comparison;
4. Conceptualization – to identify features shared by the experts and those, different;

5. Theoretical generalization – formulating the outcomes according to the selected framework.

Limitations of the method

The success of the interview-based data collection depends on the several factors, most of them are related to the selection of a valid sample of the experts and results interpretation. First of all, the "quality" of the interviewees plays an important role, since the researcher identifies the expert characteristics. The experts should understand the topic and provide the relative, extensive, complete and detailed responses on the interview questions, as well as the information about their perceptions and motives.

Second, quality of the source (expert) must be taken into consideration not during the data collection stage only, but also during the data analysis. For example, it is important to differentiate the "good" experts from "bad" ones. As well as take into account that "good" expert does not necessarily solves a problem.

Third, during the analysis there is a risk of results misinterpretation. In particular, a prejudice against a group can occur:

- information is shaped by the 'aspiration level' of the interviewee;
- a specific content of work that is due to specific performance levels might have shaped the information;
- differences between performance levels are accompanied by different self-images and valuations
- interviewee's performance level affects reported causalities.

As for the challenges, associated with the method, the first on is managing the dynamics of the situation, which is determined by the mutual perceptions of the participants.

Since some of the interviews were conducted by phone, special approach was required to the preparation and the process in interview conducting. Rather than face-to-face interviews, they require a strongly structured guideline, similar questionnaire with "open questions".

Telephone interviews are in general shorter, due to the fact that it is easier for the expert to get distracted, therefore, are only suitable for interviews with simple question patterns and guidelines for answers. A. Bogner (Bogner, et al., 2009) recommends a three-step procedure:

1) Addressing the potential interview partner to inform about the goals and subject of the project;
2) Sending a letter about the first telephone call some days after the first step with description of the interview – approximate time and content;
3) Conducting an actual telephone interview.

Justification of the preferred method

The method of semi-structured interviews is preferred to others, like focus groups, workshops for the reasons described below. The interviews were conducted in three forms – face-to-face, telephone and via email. First, this allowed to reach the experts on a distance. Second, it provides more flexibility in topic discussion, as well as insight information, indirectly related to the topic. Finally, it is believed, that interviews is the best solution to achieve the research objectives, after the preparation stage is completed.

As for the credibility of the data, obtained during the interviews, considering the sampling criteria and perceived involvement into the topic (based on the interest the experts were showing), it is believed that information and opinions received are relevant and credible. To avoid the biased perception, the interview questions were formulated based on the literature review. After the information was analyzed, the procedure of results verification was done with the help of experts.

2.4. Summary of chapter 2

The second chapter of the thesis is describing the methodology selected. The goal of the research is to define the factors, affecting the implementation of smart technologies in heat production sector. Those technologies are aimed to make the production process automatic and reduce the human participation. The technology is similar to Smart Grid, implemented in electricity production. Since the awareness of the project details is limited, the qualitative approach to research conducting was preferred to the quantitative one.

The sample of the 8 experts for semi-structured interviews consists on the IT directors of heat production companies from different regions, representatives from IT and technical solutions providers, project managers.

Semi-structured interviews as method of data collection allows to get more detailed information from the experts about the specific details of the smart technologies, as well as their personal opinions. Also, this method has proven to be efficient in the existing research.

The framework, specifies the interview questions is based on the works of of D. Xenias (Xenias, et al., 2015) and F. Li (Li, 2010), which investigated on the factors of smart grid development in different countries and regions.

3. EMPIRICAL STUDY OF SMART TECHNOLOGIES DEVELOPMENT IN RUSSIAN ENERGY SECTOR

This section provides an overview of smart technologies implementation in Russian heating sector. The structure of the chapter is the following: first, the historical background is presented, with the current state of the infrastructure, as well as problems summarized. Second, the smart technologies, used for solving those problems are described, followed by the examples. Finally, benefits, challenges and effect is summarized in conclusion.

The chapter is based on the information, obtained during the semi-structured interviews with representatives of the heat producing companies, involved to the process of smart technologies implementation. The full list of interviews participants is presented in Table 3. The information obtained during the interviews is also complemented by the analysis of internal documentation.

Table 3. List of experts

	Expert's position	Company, its role	Region	Role of the expert in smart technologies implementation project	Result from the interview
1	Regional IT director	T+ Group, heat and electricity producer	N.Novgorog	Control of technical solutions implementation in IT area. Development of systems ideology	Strategic view, benefits, challenges
2	Regional IT director	T+ Group, heat and electricity producer	Ivanovo	Control of technical solutions implementation in IT area.	Strategic view, benefits, challenges
3	Regional IT director	T+ Group, heat and electricity producer	Samara	Development of IT solutions, control of technical solutions implementation in IT area.	Details about the project in Samara
4	Regional IT director	T+ Group, heat and electricity producer	Perm	Project management	Details about the project in Lisva
5	Supervisor of heat network	T+ Group, heat and electricity producer	Saratov	Project manager. Cooperation of technical and IT blocks	Strategic view, benefits, challenges
6	Deputy sales director of heat equipment	Danfos, energy systems automatization	Moscow	Equipment supply, approvement and integreation of technical solutions.	Strategic view, benefits, challenges
7	Director	TOES, energy systems automatization	Perm	Building solutions, supply and installment of the equimplemt. Implementation of technologies.	Details about the project in Lisva
8	Managing Director	T+ New Solutions, automatization of Zakamsk heat distribution	Perm	Project management	Strategic view, benefits, challenges

3.1. Sample: main companies

Depending on a region, the heat is generated by the heat or electric stations. However, the research is based on the example of specific regions.

Sample criteria

The experts for the interviews were selected according to the following criteria:

- Industry experience – working in the energy producing company or provider of IT and technical solutions.
- Area of responsibility – different management levels to create an complete view of the research area from perspectives of strategy, technical solutions and issues, management features, external factors.
- Geography – the sample of experts represents projects in different geographic regions – covering the differences in facilities and infrastructure and stage of development.

Overview of the companies

T Plus Group - heat and electricity producer

T Plus Group is the biggest Russian private company, functioning in the sector of electricity generation and heat distribution. It currently owns more than 7% of the estimated capacity of power plants in Russia, operating in 16 regions. Being a leader of the heat production, it represents 10% of the Russian market share. Company's client base accounts for more than 14 bln people and more than 160 thousands entities. T Plus Group's level of annual production is estimated as 60 bln kVt/h of electricity and more than 100 mln Gcal of heat (T Plus, n.d.).

The experts selected for the data collection represent the following regions: Perm, Samara, Saratov, Ivanovo and N. Novgorod.

Danfoss, energy systems automation

Danfoss is a producer of the smart infrastructure. It helps cities to build roads, buildings, and energy systems in effective and efficient way to improve quality of life in developing countries. The equipment, produced by Danfoss is aimed to minimize the losses and enhance efficiency. The company is keeping a leading position in the Russian market of energy-saving technologies, which reduce the operational cost level and contamination of the environment also those technologies enhances the use of renewable energy sources (Danfoss, n.d.).

TOES, energy systems automation

The TOES company provides services of energy production automation system installation and support in Zakamsk and Lisva. During the interview the representative of the company shared the details of project of the smart technologies installation for Lisva.

T+ New Solutions, automation of Zakamsk heat distribution

The subsidiary of T+ Group is in charge of the project of production automation in Lisva. The director of the company shared his view on the benefits and challenges, related to the automation of the system.

Identification of cases

The purpose of this case study was to describe the factors affecting the development of smart technologies in Russian energy sector, based on the evidence from Russian heat companies. The analysis is based on experts' opinions about the factors in general, as well as two cases represent the details about the projects in two different cities.

The cases studied are the projects of smart technologies implementation in different regions. The experts are divided in two groups:

1) Experts who provided information about the factors in general;

2) Experts who have specific knowledge about the regions provide the information about projects in smart technologies implementation in those regions (Samara and Lisva). The results are described below.

The cases were selected by the following criteria:

- Availability of internal information;
- Active stage of project discussion/implementation;
- Readiness of the experts to share the information.

The difference between the projects is defined by the geographical characteristics of the cities: Samara is a regional center with industrial production companies, where T Plus owns nearly 70% of the market. The smart technologies are needed in this region to control the losses level. While Lisva is a smaller city, which main concern is ageing infrastructure needed to be renovated.

3.2. Analysis of specifics of smart technologies development in Russian heat production sector

3.2.1. Description of smart technologies used in Russian heat production sector

Smart heat production is a complex system of technologies, developed to reduce volume of generated energy, save costs, and improve production efficiency level.

Schematically the energy production flow is presented in the figure below. Electricity and heat stations use water to produce the electricity and heat for use of industrial and residential consumers. The distribution and transmission of heat towards the consumers is organized through the distribution units – *central heating stations and individual heating stations*. These, as mentioned by the experts are the main objects of smarter technologies implementation.

Automation of central heat distribution center allows enhancing the quality of production, reducing the risk of failure as well as save human resources. The main stakeholders, benefitting from it are the company-producer itself and the state.

Installation of automatic individual heat distribution centers is made locally (in residential buildings) and allows managing the supply of heat depending on the characteristics of the house. This will not only drastically reduce the prime costs of production and consumers' expenditures, but also improve the quality of the heat supply with more precise planning of the demand. However, installment of such centers is a costly process, requiring time and resources.

Among the other technologies are improvement of control and monitoring of production with means of smart meters, sensors and automatic systems (Fig.6).

Implementation of opportunities to use renewable energy sources is less spread in Russia, however, still possible as the next step of systems' development, according the regional IT director of T Plus subsidiary in Perm.

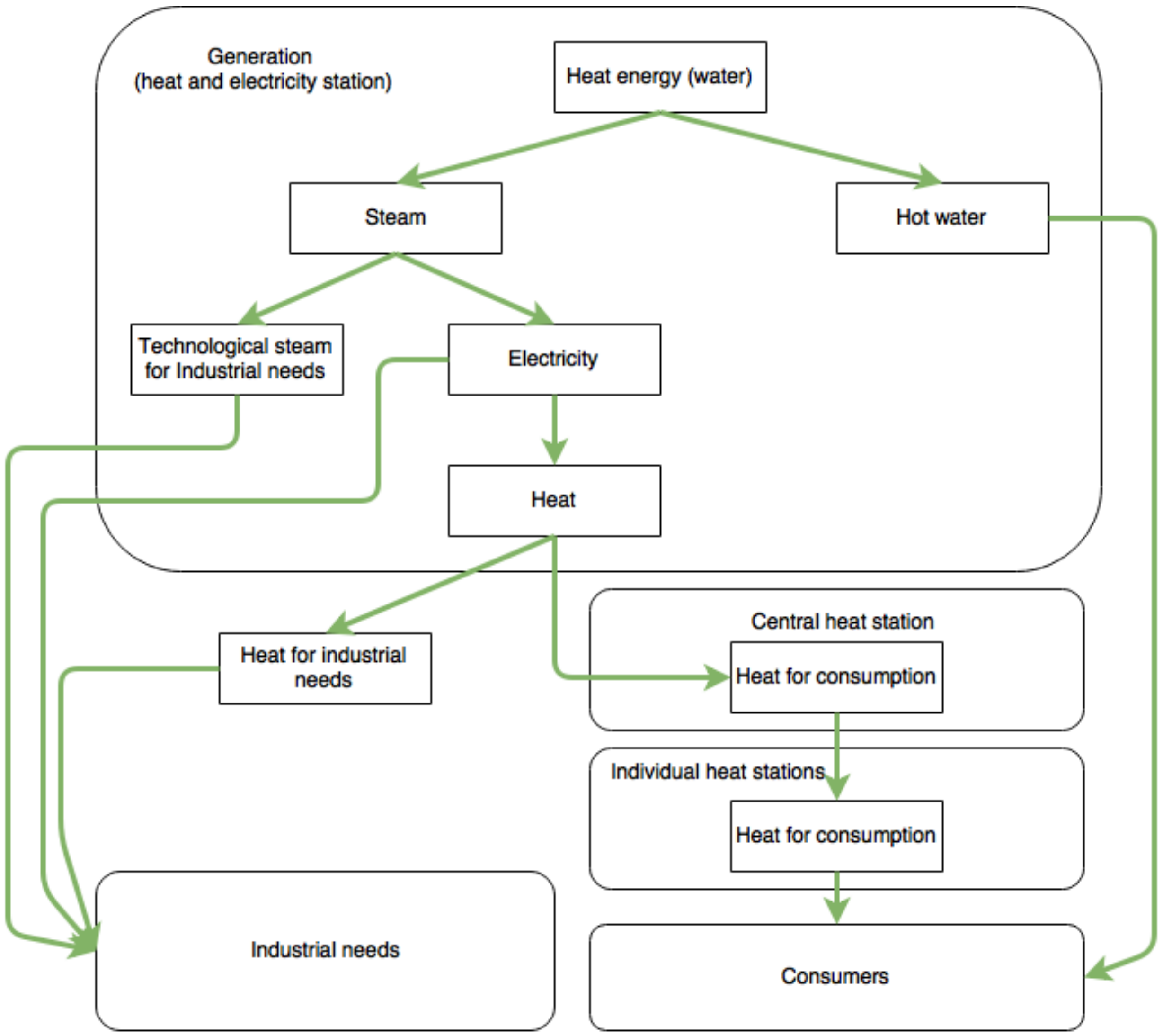

Figure 6. Heat production flow

Even though the specter of smart technologies for energy generation is wide, their implementation in Russia is a slow process, affecting by several groups of factors.

Summarized features of smarter heat production are presented in the table 4 below. The networks become more reliable and flexible, providing opportunity to get and analyse real-time data and make the solutions more user and consumer friendly.

Table 4. Characteristics of Smarter heat production

Intelligence	Resiliency	Sustainability	Customization	Digitalization	Flexibility
Mentioned by the experts as important					
Self-healing	Fast response	Sufficiency	Low prices and efficiency	Measurement	Multiple options for resource operation
Coordination	Robustness	Efficiency	Operator/client-friedly	Communication	Multiple options for Control schemes
	Real time analysis			Protection	
	Protection and restoration			Visualization	
Not mentioned by the experts or commented as minor					
Self-awareness		*Environmenral friendliness*	*Market liberty*		*Multiple options for Expansion*

3.2.2. Functions of smart technologies used in Russian heat production sector

The functions of smart heat production are related to the implementation of the following systems and applications:

1) *Development and implementation of geoinformation system*

According to the Federal law №210 «On the bases of regulation of tariffs of utility complex", the system of heat distribution is considered as a basis for development of the plan of the city and building infrastructure. That is why it is important to digitalize the model of heat production. It will decrease the time for reacting on the changes of the environment and create a unified information platform for managing the production and delivery networks. The experts highlighted the following blocks of such a system as the most important:

- Electronic map of the heat networks;
- Pasportization of the networks – complete description of all the parts of the network;
- Hydraulic modeling of the heat flows – calculation of the system load taking into account the consumer demand and temperature regimes. The system will decrease the negative effect in case of failures.

2) *Calculation of consumers' demand – the subsystem, presenting a tool to calculate the volume of production and balance the production system*

According to the company's internal reports, due to the not accurate planning of production levels, the level of fuel spending exceeds the norm for 30%. Stable supply of the heat will result in technical and economic effects approximately estimated as 5-35% of savings.

3) *Calculation of energy losses*

Calculation of actual and normative heat loss is one of the crucial needs. As mentioned by the expert "the most important issue, related to the losses is to find out the part of the production line, where they are generated". Identifying the losses in different parts of the network will allow prioritizing the investments for network repairing. Currently the losses are calculated according to the methodology, described in the document "Procedure for the calculation and substantiation of technological losses standards of heat transmission", approved by the Russian Ministry of industrial energy by the order №265 from 04.10.2005. Described subsystem aimed to compute the losses of the network in general as well as separated parts within set period of time or within certain month. The system also takes into account the diameters of the pipes and types of isolation material of heating networks.

4) *Archive and analysis of damage*

This tool is aimed to record and process the damages of heat networks. Classification of the damages and their graphical representation will help to identify parts of the network with higher risk of damage.

5) *Operating application*

This subsystem will allow monitoring the implementation of planned and emergency repair work on the heating networks based on the applications.

6) *Unified data base*

Unified data base of different information systems, involved to the heat generation networks will save the cost for bases actualization and eliminate data mismatch.

7) *Reliability of the heating system*

Subsystem calculates quantitative indicators of heat supply reliability (probability of failure), taking into account:

- the service life of the heat pipe network;
- climatic characteristics;
- storage capacity of buildings;
- the allowable temperature drop on the premises;
- the average time of liquidation of damages of thermal networks.

Thus, the subsystem allows defining the so-called "range of heat quality" for each heat source, characterized by the minimum allowable probability of failure of the heat supply system. This, in turn, makes it possible to identify "weak" places in the heating network and to plan measures to improve the reliability of the system as a whole.

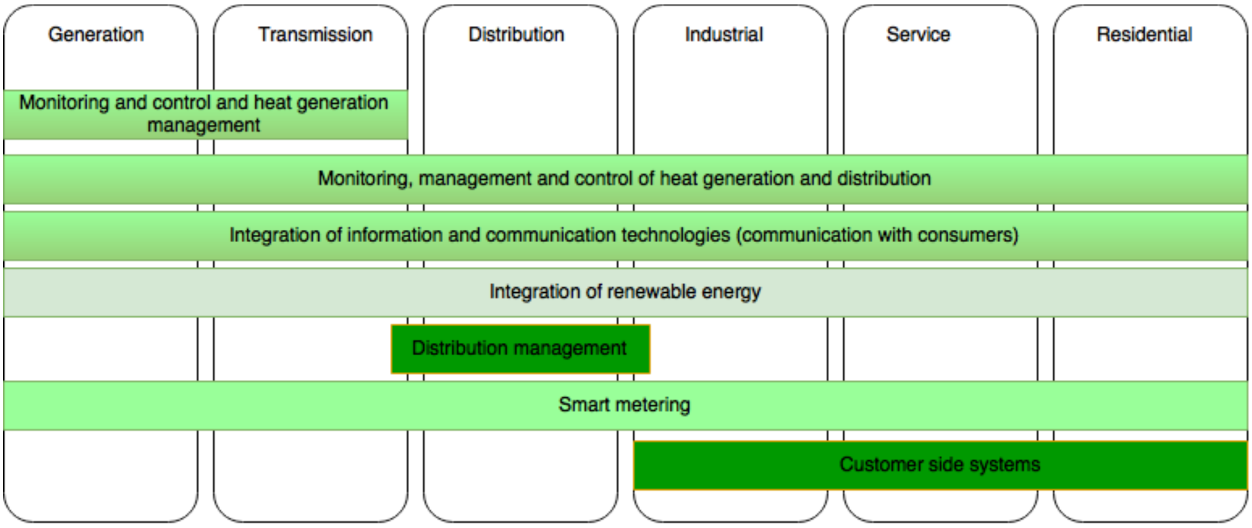

Figure 7. Smart technologies used in different stages of heat production in Russia

As a result from interviews with 8 experts, the current first priority is automation of central heat distribution centers. Several cities are also running the automation of individual heat stations (table 5).

Table 5. Stages of heat production and distribution automation in Russian cities

City	Automation of central heat station	Automation of individual heat stations	Stage	Factors		
Samara	Yes	Yes	Beginning	Decision of management		
Perm	Yes	No	Beginning	Decision of ingeneer	Lack of financing	
Lisva	Yes	Yes	In process	Big losses before modernization		
Zakamsk	Yes	Yes	In process	Big amount of investment	PR	Government support
N. Novgorod	No	No	No	Currentlly lack of investment		

3.2.2. Drivers of smart technologies development in Russian heat production sector

One of the main problems, which the company is currently challenging, is an inefficiency of the production. Due to the fact, that energy consumption per head increases, energy systems, built tens of years ago are getting harder and more expensive to maintain. These factors drive the need to upgrade the existing systems in efficient way. Implementation of smart technologies is the main solution to the problem.

Summary of the drivers, affecting the development of smarter heat production is presented in the table 6. The experts mentioned the following drivers of smart technologies development as the most important:

1) Aging infrastructure.

Most of the existing infrastructure needs to be innovated due to the age and conditions. The outdated transmission assets threat the reliability and stable work of the whole system. However, due to the lack of investments, the renovation plan should prioritize those parts of distribution chain, where the highest level of losses is identified.

2) Increase of efficiency in energy production.

As a result of reduced losses and smarter planning of supply and forecasting of demand, the companies can reduce drastically their operational costs as well as produce less energy. According to the experts, he heat demand in Russia has been decreasing over the last year. However, the heat producers pay fees both for the amount of energy produced and for the capacity they declare. Therefore, the driver "increasing energy efficiency" consists on the following sub-drivers:

- Minimizing energy loss.

The main problem, identified my management of the smart technologies implementation projects is the high level of losses.

- Necessity to identify the spot of the supply chain, where the losses are generated.

Implementation of the sensors on different parts of the distribution line will allow measuring the losses more precisely and solving the problem.

- Necessity to manage the existing capacity.

The companies, which produce energy, own enormous amount of infrastructure, not all of those, however, deliver efficient production results. Necessity to maintain all those objects results in high maintenance costs, which can be avoided.

3) Reduction of human factor in production

Automation of distribution stations allow to eliminate the human factor in the heat system management. Managing director of T+ New Solutions, company, responsible for automation of

Zakamsk heat distribution, mentioned: «human factor plays a crucial role and can cost millions of losses. Automation will allow the system to be managed not basing on the operators' decisions. The system will collect the historical data and with means of mathematical model, forecast demand».

4) Saving costs

There are two ways to save the costs of heat production: automation of load and prediction of energy usage.

Automation project allows to save the salary of operators. In such cities as Perm and Samara average payout period for the project of central heat distribution station is 2 years with cost of 72 mln and 70 mln rub accordingly.

Mathematical models of usage forecast based on the historical data will result in accurate planning of demand and supply, decreasing the level of losses.

5) Following legal regulations

According to the federal law №190-FZ from 27.07.2010, the companies are obliged to use computer modeling for heat production and distribution. This gives the companies opportunity to avoid the manual calculation of tariffs and forecasted demand, according to the standards, used tens of years ago. Also, interest of the state opens the financial resources for such systems development.

Table 6. Drivers of smart technologies implementation Russian in energy sector

Environmental Challenges	**Customer&Market needs**	**Infrastructure challenges**	**Innovative technologies**
Mentioned by the experts as important			
Geographic constraints	Regulations and policies	Aging networks	Computation and control
Emissions	Energy price and production cost	Sufficient investment	Communications
	Energy quality and sufficiency	High level of losses	Power electronics
	Consumer driven services	Economics and reliability	
	Decreasing volumes of heat production		
Commented as minor			
Exhausting natural resourses			
Climat change			

To sum up, the measures proposed are aimed to develop an advanced information system of heat production control, which will

1) Reduce the human factor;
2) Make the processes automatic;

3) Reduce the risks of failure;

4) Make the production transparent in terms of production volume and losses level.

"Smart technologies, when applied in complex, give a maximum synergy effect. Complete reconstruction of heat distribution system can result in economy about 35-45% and resource use reduction up to 50%", stated the representative of Danfoss. Counting for one apartment, economy can reach 1250 rub monthly or 15 000 rub annually.

3.2.3. Challenges of smart technologies development in Russian heat production sector

The main challenges identified during the interviews are related to infrastructure, technologies and market needs (see Table 7).

Ageing infrastructure, being both driver and challenge, results in investment and proper project planning necessity.

Elimination of human factor is the production process and installation of computerized systems stresses on the issue of **data security**, which, according to the expert "results in sufficient investment". Risk of hacker attacks on the sensitive information can lead to emergencies and breakage of the whole system, resulting in losses on a state level.

Slow implementation can be explained by **lack of financing** and experts in this industry, this stresses the importance of studies of smart technologies and employees education.

The main stakeholders of the process are company management and state authorities. **Governmental support** has a sufficient impact in the process of systems modernization, since it provides an access to financing.

Table 7. Challenges of smart technologies implementation Russian in energy sector

Customer&Market needs	**Infrastructure challenges**	**Innovative technologies**
Customer unawareness/resistance	Infrastructure needs	Lack of expertise/innovation capacity
Conflict of interests	Investment and costs	Complexity of solutions
	Data protection/privacy	Unproven/underdeveloped technology
	Poor/slow implementation	

3.2.4. Strategy of smart technologies implementation

During the last year the T Plus Group got concerned about the smart technologies development and implementation in order to maximize the automation level. However, in comparison to the developed European countries, Russian systems are far behind. Within the following years the company is aimed to implement the smart automatic metering systems for 100% of the consumers.

The timeline is presented in the table 4 contains the main steps for further development of heat and electricity production.

Table 8. Development plan for smart technologies in energy sector

Source: interview with T Plus Group representative

Time	Smart system	Characteristics	European benchmark systems	Russian systems
Before 2005th	Off-line metering	Manual data collection Billing accroding to norms No data about real-time consumption	Completed	Completed
2009th-2015th	Smart metering	Automatic metering Two-site communication with consumers Remoted control of meterings Automatization	Completed for 90%	Completed for 10-15%
2010th-2015th	Smart network	Automatic systems of work with consumers Remote network management and control Energy analytics	Completed for 30%	In process
2015th-2020th	Smart city	Smart home devices Automatic self-recovering network On-line metering information access Monitoring and remote control	Completed for 15%	In process

3.3. Case study: Implementation of Smart technologies in Samara

This subsection is aimed to describe on a real example the implementation of the smart technologies in heat production sector in Samara.

Samara is a big cultural and industrial city with 1,5 million of inhabitants. Recent statistics has shown stable population rate over the last years (see Appendix B for the graph of population in Samara). Moreover, the rate of new housing is also stable, which is promising for a demand dynamics (see Appendix B for the diagram of residential market growth). In this region the T Plus Group has the biggest market share (69%) (figure 8) and attractive level of operational costs (within norms). As was mentioned in the interview with the regional IT director, responsible for the development of IT solutions, control of technical solutions implementation in IT area, «the main priority for the company in this region is to maintain stable financial result».

The main challenge, identified, however, it lack of facilities management and excess capacity. Proper system planning and redistribution of the production load within the production units will allow to increase the effectiveness.

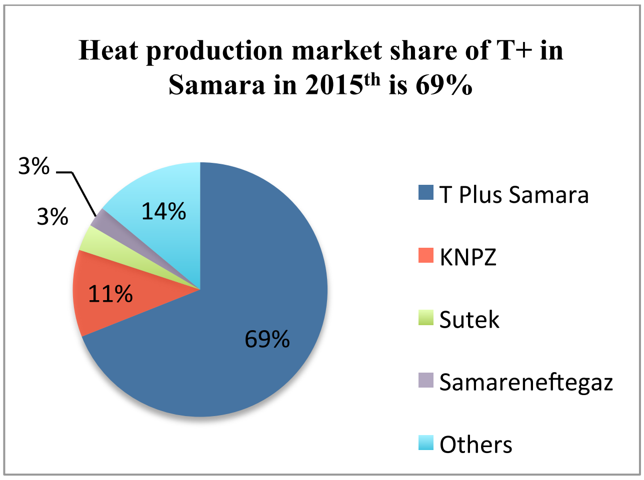

Figure 8. Heat production market share in Samara, 2015

Source: T Plus Samara

Moreover, the volume of the heat production in this region has been decreasing over the last years, while the level of losses got higher (figure 9). Mentioned factors stress on the necessity to renovate the distribution system – by automation of central distribution stations and individual distribution stations. The projects are currently in progress and it is expected to reach the payback within two years. Smart heating production is beneficial from different perspectives. Mainly, the expert mentions, «it allows enhancing efficiency and identifying the weak places of the network and investing into their renovation».

As for the main **challenges** the company is currently struggling with, there are:

1) High level of required investment and administrative support to move from manual collection of metering data;

2) Wide spread (in up to 30% cases) of manual approaches to estimate the amount of resources consumed.

Volume of T Plus heat production and losses in Samara, th. GCal

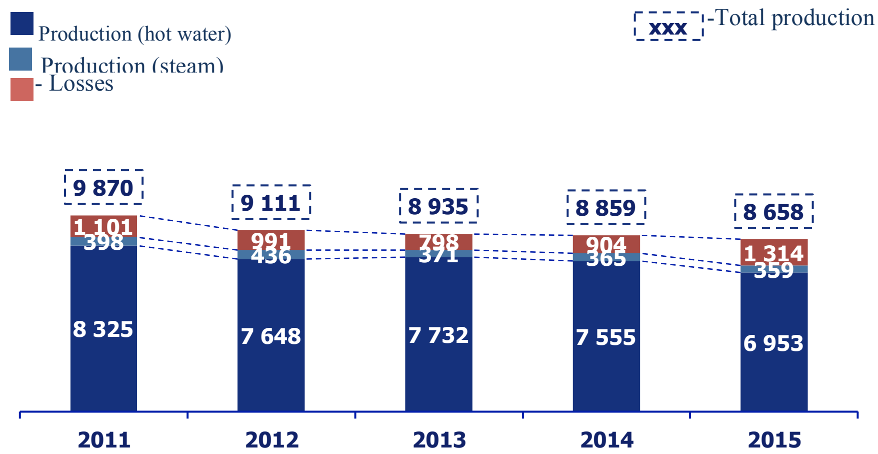

Figure 9. Heat production volume in Samara, 2015

Source: T Plus Samara

Summary

Being a strong player on the market of heat production and distribution in Samara, the company wants to strengthen the position by implementing technologies which will improve the efficiency by reducing the volume of losses. Both central heating distribution stations are being renovated and individual heat distribution stations are being installed.

Apart from information system installment, the project also covers rebuilding of the infrastructure, which required additional investment. Modernization of the heat system will allow reducing personnel costs. Expected payback period is accounting for two years. According to the experts, the project was mainly initiated by the company's management.

3.4. Case study: Implementation of Smart technologies in Lisva

This subsection is aimed to describe on a real example the implementation of the smart technologies in heat production sector in Lisva.

Lisva is an administrative center of the municipal district. It has the status of an urban settlement. Heating in this city is provided by eight boilers, owned by T Plus company. Normative loss of heat energy during transportation, approved by order of the Ministry of Energy, account for 52 552 Gcal per year, which is 12.23% of the volume of the network output. However, according the expert, «the actual amounts of heat energy losses, in our opinion, are much higher, but since there is no data on the actual measurements and testing, the actual losses volume is impossible to detect».

Reasons to renovate the system of heat supply of the city Lisva

The following factors can be attributed to the current problems Lisva city heating system:

1. Misalignment heating system. Absence of the hydraulic heating system model results in its misalignment – heat supply excess or shortage, raise of production costs and transportation losses.

2. "LMZ-Energo" boilers have an opened system of heat generation (see the difference in Appendix C), which causes the problems: quality and temperature of hot water and heat transportation losses. During winter time the water temperature exceeds the normative level, which leads to the system failures and burnings.

3. Ageing infrastructure. Lifetime of the 60% of heat networks exceeds normative – 25 years. This increases the risks of failures. As for the heat isolation systems, thermal insulation for more than 80% of the pipes is worn out. Absence of isolation is a barrier to reduce the level of losses, which is currently 50% higher that the normative.

4. The absence of a unified system of dispatching and automatic regulation of the heating system and hot water. This complicates the operational system management and increases the time to detect emergencies, and does not allow changing the production level in a fast way according to the dynamic demand level.

Measures to improve the efficiency of heat production system in Lisva

The measures to be implemented for system reconstruction are aimed to improve the quality of generated energy, bringing the production volume and level of losses to the normative level. This, in result is expected to lower consumers' expenditures.

Upgrading the information system is not enough, so the aging infrastructure should be repaired and changes as well. This will also result in losses control and matching of heat supply with demand.

According to the experts, the measures proposed – improvement of the infrastructure and implementation of IT solutions will bring the following results:

- Improvement of the quality of the heat produced
- Decrease of the damage and accidents risks
- Increase of pipes run-out time
- Reduce prime costs of the heat production as well as consumers' expenditures.

Modernization of the heat production system consists of the following:

1) Transformation of the open heat distribution system to the closed (see the description in Appendix C) – installing blocks of individual heating units with integrated automatic adjustment according to the heating schedule (based on the temperature change) depending on outside air temperature. The equipment is produced by "Danfoss" (see section 3.1 Sample: main companies).

The expectations from the system's modernization are the following:

- Increased reliability of heat distribution system (maintaining the necessary temperature level despite the weather conditions and heat network parameters);
- Increased the resistance of the heating system: automatic system will not allow the excess heat consumption level;
- Heat energy economy up to 15% due to the adjustment of the temperature according to the current weather conditions;
- Increased lifetime of the heating system pipes in 4-5 times (cleaner water used for heating and prevents the corrosion;
- Decreased prime costs with better quality of production.

1) As the next stage of system renovation there will be repairs of the pipelines. Mainly those, which are older than 25 years. First of all, this will allowing the level of losses reduction up to 40%, according to the estimations, which, in scale of the city, is a drastic level of economy.

2) Creation of a unified control and automation center.

The system allows controlling the work of the subsystems and processes, which are taking place in facilities, change the settings of devices that serve these objects, as well as record the protocols of their work. Gathering and processing of data is carried by programmable controllers that support a variety of data transmission standards. These controllers can operate in two modes: independent, without external control, and dependent, together with a central control panel. Complex and integrated control and monitoring system provides coordinated operation of autonomous systems in the infrastructure, measuring of resource consumption and informing of the departments in case of emergency.

Summary

Process of smart technologies implementation is influenced by wide range of factors. Renovation of the heat distribution system in Lisva included changing of the type of distribution system to the closed one (which allows to save the money for the resources - water), as well as complete automation of central heat distribution station and installment of individual distribution systems. The main challenges of the project are related to the old infrastructure – resulting in high amount of required investments and complexity of the project.

3.5. Limitations and validation

The limitations of the research are based on the following factors:

1) Sample characteristics
2) Industry specifics
3) Changing environment

1) Sample characteristics. The sample of the experts was selected to provide an unbiased opinions on the researched problem. Therefore, the experts are representing different geographic locations, levels of responsibility, managerial levels. However, due to the fact, that knowledge of smart technologies is limited within the personnel of heat production companies, there is a risk of results (identifies factors) being dependent from the perspective of the experts.

2) Industry specifics. The factors, affecting the development of smart technologies in heat production sector are partly coinciding with the factors, mentioned in the existing research about smart grid. However, as stated in (Khodayar & Wu, 2015), each project is specific and should be accessed in context. Therefore, some of the factors are applicable to the industry in general, while others to specific regions.

3) Changing environment. During different stages of smart technology project implementation the importance of the factors differs. This can explain that fact, that some of the opinions of managers from different regions did not match with the others.

The results of the research are considered to be valid since they were logically derived from the research findings. The following strategies, mentioned in (Creswell & Creswell, 2007) were used to provide the reliability of the received outcomes:

- Evidence from different sources – the results were framed based on the information from the experts, companies' documents (projects presentations, reports, and technical tasks) and information, available on-line (news, articles) using the outcomes of the existing research to provide the complex review of the research subject.
- Rich, thick description (describe the participants) – the criteria used to collect the sample of experts allowed to get the perspective from different parties of the smart technologies implementation process.
- External check – as the main part of validity check, the results of the analysis were shown and discussed with 2 of the experts. Corrections were mainly related to the technical description of the production process and participants, as well as interpretation of the factors. The feedback from the experts was taken into account when drawing the conclusions, which proves their reliability and objectivity.

The validity of the research methods is proven by the fact, that expert interviews were widely used in the existing research of smart technologies implementation in energy sector. The next step of the study, the factors identified can be checked via quantitate methods of data collection and analysis, such as survey. However, as mentioned by the experts, even the employees of the heat production companies are poorly aware of the smart technologies, motives and results of their development.

3.6. Practical implementations and discussion

This subsection is devoted to the discussion of the results obtained and their practical usability.

The empirical study of the factors affecting development of smart technologies in heating production system has shown, that main reasons of existing systems modernization and automation are the following:

- increasing efficiency of the production (decrease of losses and costs);
- new mechanisms of demand forecast and supply planning;
- improving the quality of people's life in the cities;
- following the regulations.

Identified reasons for smart technologies development in heating production sector correlate to the reasons, mentioned in the existing research, however the following conclusions are made:

1) the first and second priorities for Russian energy producers are automation and installation of control and monitoring mechanisms, which will solve the crucial problems of production inefficiency.

2) Such an important aspect of smart transmission networks as demand-side management is on the early stage of development. This can be explained by several reasons. First, companies are lacking of investment, so they try to prioritize the projects according to the maximum effect in middle term. Second, awareness about smart technologies is low both within companies and consumers.

3) As the first stage of demand-side management there are initiatives of individual heating stations installation. The main purpose of them – improving the mechanisms of demand volume calculation.

4) In the future, theoretically, consumers will have a chance to manage their consumption, however, the experts mentioned, that this aspect is not considered as important during the project planning.

5) The main challenges, faced by the companies are unawareness about new technologies, necessity to increase security measures, lack of initiative and investment.

6) As a strong incentive to implement the technologies is a federal law, prescribing the energy producers to use smart technologies in heat production.

Growth in cities' role in the economy, fast development of technologies for smart cities and smart life makes the companies think about their long-term development in a smart way: enhancing the efficiency of the processes, reducing costs, improving the quality of products and services, using latest technologies, rescuing environmental impact. Most of the heat distribution networks in Russia were build ages ago, therefore, their renovation demands investment and detailed plan with considering the latest world trends. However, despite the companies are facing the main challenge: lack of knowledge about benefits of smart heat production. Understanding of the factors, affecting the systems' development is important for the following reasons:

1) smart technologies allow identifying the parts of the networks with biggest level of losses and prioritize the investments;

2) Intellectual systems with means of mathematical modeling reduce the human factor and plan supply in relation to the previous system's performance;

3) Individual heat distribution stations are dynamic systems which adjust the production levels according to the changing conditions;

4) Reducing the human participation lowers the risk of human error;

5) Advanced metering infrastructure controls the costs of production;

6) Demand response and consumer energy efficiency is the world trend in energy networks development;

Undeniable benefits of smarter systems highlight the necessity of the smart technologies implementation, which are not clear to the companies yet. However, each city is different and, therefore, some specific factors need to be taken into consideration. Lack of knowledge does not allow to implement technologies in a fast and efficient way. Understanding of the benefits, strategic view, challenges related to smart technologies will fasten the networks development.

3.7. Summary of chapter 3

The third chapter contains results of empirical study of factors, influencing the process of smart technologies implementation. The chapter consists on explanation of the sample of experts, representatives of the heat production company from different regions. Based on the results of the interviews the main features/functions, challenges, benefits of the smart technologies for heat production were identified. Also the steps of strategic development of the companies were highlighted.

The results of the empirical study are summarized in scheme, combining characteristics, components and functions of smart heat generation and transmission and the fundamental driving forces, affecting development of smart technologies (see figure 10 for the overview of the factors). The main drivers for smarter heat production grouped into 4 categories: infrastructure challenges and market needs define the necessity to develop smart solutions for heat production, innovative technologies present at the market allow implementing the solutions. Environmental challenges are considered as minor, since most of the decisions in the sphere are made based on payback and efficiency criteria. So most important drivers, identifies by the experts are state regulation (federal laws) and necessity to improve efficiency – reduce costs and losses. Big proportion of the losses is caused by the aging infrastructure, which results in high amount of investments, required for the renovation. Another driver for the companies is necessity to reduce the risks, related to human factor. Mathematical models, used for forecasting of demand allow using historical data for automatic decision-making.

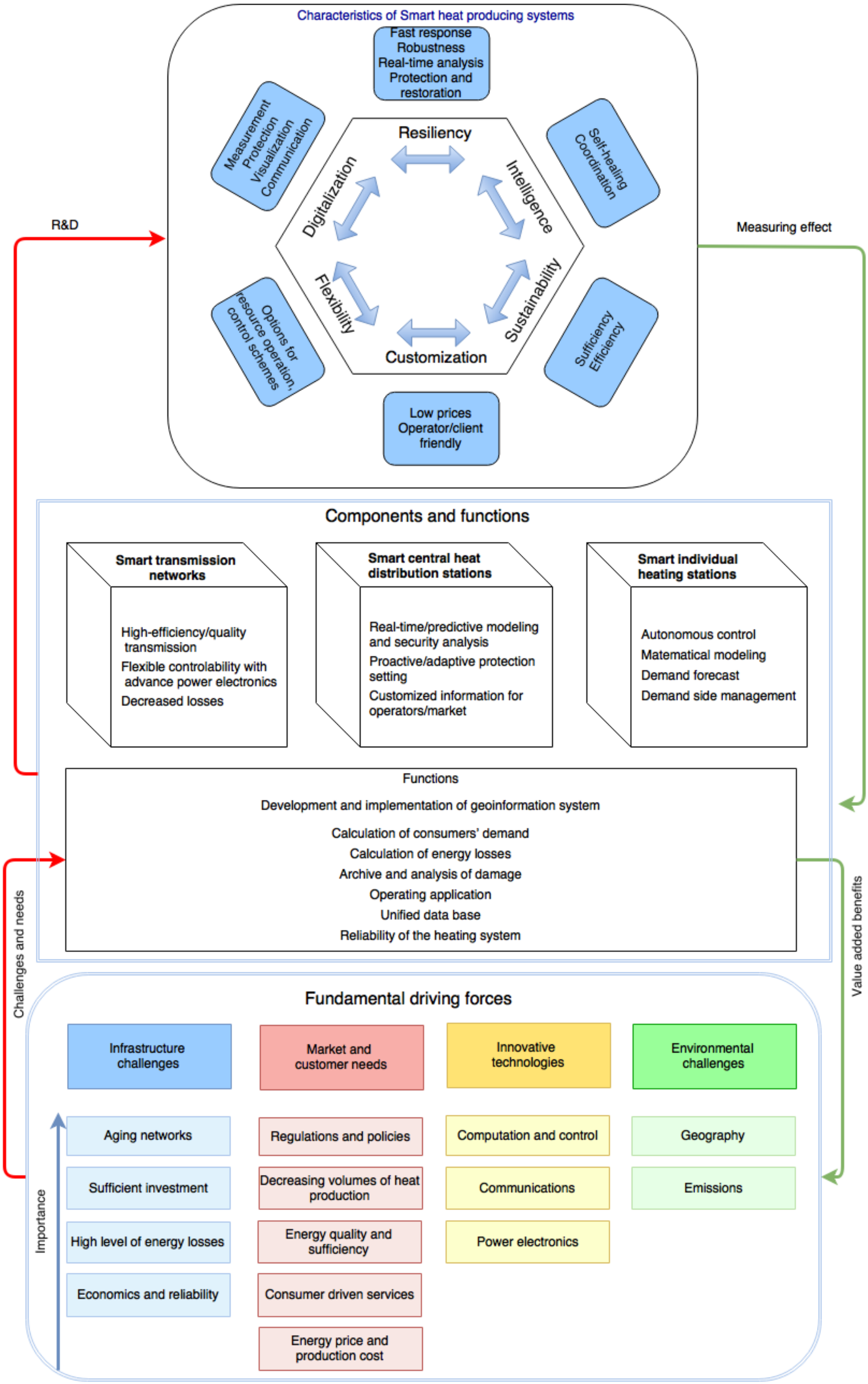

Figure 10. Factors affecting development of smart technologies in Russian heat production

As for the challenges, identified by the experts, they are mainly associated with the lack of experts in the area of smart technologies and poor awareness about them in all levels of the stakeholders. Costs related to the projects are another challenge, resulting in extension of the time, required for technology implementation.

The chapter is concluded by description of two cases of projects implementation in Lisva and Samara to prove the statement, that every project should be viewed from the context (age of infrastructure, type of heating system (open or closed), incentives for management to implement the technologies).

For instance, the project in Lisva is one of the benchmarks in the industry, was supported by state authorities as an example of a component of a smart city. The renovation covered both infrastructure and automation of central heat distribution stations and individual stations installed in residential buildings. The latest allow forecasting the changes in demand, related to weather conditions, network material and other factors, to adjust the generation volumes and lower the losses. However, it should be mentioned, that despite all the benefits of the smart technologies, the process of their implementation is low and challenging. Russia is far behind the Europe in the process of development (see table 8 for the main stages of smart technologies development).

To sum up, the experts mention the big importance of smart technologies, as well as poor awareness of their benefits and components at the company's level. However, this knowledge is crucial for building the long-term strategy of heat producers development.

CONCLUSION

Importance of smart technologies for is undeniable for city development. Over the last years smart technologies have been implemented to different sectors, such as transportation, energy production, waste and water management, allowing to save costs and resources, improving quality of life and reducing environmental impact of industrial production. Federal laws (№ 210 and № 190), regulating the heat production and distribution and tariffs, obliged Russian heat producing and transmitting companies to use smart technologies, such as automation, computer modeling, smart metering infrastructure. According to the law, the cities should be planned and developed considering the renovated heat networks. This as well as the need to renovate the ageing infrastructure (sufficient part of networks is more than 25 years old) has pushed Russian energy companies to adopt smart technologies for efficient heat generation and transmission.

Russian heating production is segmented by the regions, in most of them there is a one company, leading the market by the production volumes. It owns several production facilities (heat and electricity generating companies), and needs to manage the load of the facilities in an efficient way. Understanding of factors, affecting the process of smart technologies implementation presents a crucial importance for the industry.

Existing literature has covered such topics as benefits, challenges, strategic directions for smart grids development (mostly covering the electricity production), however, the heat production industry is poorly investigated. Moreover, every network in every city differs by the type of the heat transmission system, age of the infrastructure, involvement of managers, so the projects of technology implementation should be estimated by the context.

The goal of the existing research was to define the factors, affecting the development of smart technologies in Russian heat production sector. The empirical study was based on 8 expert interviews with representatives of the industry as well as analysis of documentation and on-line resources. In result, the main driving forces of the Russian heat production sector development were formulated (see figure 10 for the overview of the factors).

Smart technologies for Russian heat generation sector are aimed to atomize the process of generation, transmitting and distribution. They represent a combination of technical devises and IT systems. Due to the necessity to repair the existing facilities, management of the heat production companies uses an opportunity improve the efficiency of the networks with means of smart technologies. The systems of monitoring, controlling and management of generation and distribution allow releasing human resources and lowering the risks of emergencies; smart metering set on different parts of the networks allow identifying the losses of heat. This allows the companies improving the quality of the heat sufficiently.

As for the types of the systems, companies see two main smart solutions:

1) Automation systems for central heat distribution center. The systems allow the companies to reduce costs up to 30-40 % within 2 years payback period.

2) Installing individual heat distribution stations allows estimating the demand of particular houses and improves the quality of heat production for consumers. Future development of such stations could give an opportunity to consumers to manage their consumption in real time. However, as mentioned by the experts, the systems are too young so far.

The main benefits of smarter heat production identified are:

- Reduction the human factor and risks of system failure;
- Making the processes fast and efficient;
- Costs saving and loss reduction;
- Improving the quality of a service for consumers;
- Opportunity to launch the demand side services in the future;
- Making the production transparent in terms of production volume and losses level.

The main drivers for smarter heat production grouped into 4 categories: infrastructure challenges and market needs define the necessity to develop smart solutions for heat production, innovative technologies present at the market allow implementing the solutions. Environmental challenges are considered as minor, since most of the decisions in the sphere are made based on payback and efficiency criteria. So most important drivers, identifies by the experts are state regulation (federal laws) and necessity to improve efficiency – reduce costs and losses. Big proportion of the losses is caused by the aging infrastructure, which results in high amount of investments, required for the renovation. Another driver for the companies is necessity to reduce the risks, related to human factor. Mathematical models, used for forecasting of demand allow using historical data for automatic decision-making.

However, there are certain challenges, related to the implementation of smart technologies. Due to the fact, that technologies are relatively young for Russian market, the companies are lacking of experts – engineers and management, who could insist of the development of smart heat networks. Also, the public attention, drawn to a specific project plays crucial role, providing necessary investment. For instance, the project in Lisva is one of the benchmarks in the industry, was supported by state authorities as an example of a component of a smart city. The renovation covered both infrastructure and automation of central heat distribution stations and individual stations installed in residential buildings.

It is worth mentioning, that the first priority for the companies is rather renovation of the infrastructure, so every project requires sufficient investment. For example, estimated costs of automation of central heat distribution station in Perm city is 72 mln rub, with relatively small payback period of two years. Lack of investment results in longer duration of the renovation process.

As for the strategic plans, the government is interested in efficient and smart heat production, but Russia is still behind the European countries. In the future, theoretically, consumers will have a chance to manage their consumption, however, the experts mentioned, that this aspect is not considered as important during the project planning.

Current research contributes to existing theoretical base, giving the perspective on the Russian market, as well as has a practical implementation, describing the factors, important to make managerial decisions, related to building the strategy for middle and long term company and industry development.

To sum up, the benefits of smarter systems highlight the necessity of the smart technologies implementation, which is not clear to the companies yet. Moreover, each city is different and, therefore, some specific factors need to be taken into consideration. Lack of expert knowledge in the industry does not allow implementing technologies in a fast and efficient way. Understanding of the benefits, strategic view, challenges related to smart technologies will fasten the networks development. This creates new opportunities for IT and technological sector development, improve quality life and in perspective reduce level of losses and costs of production.

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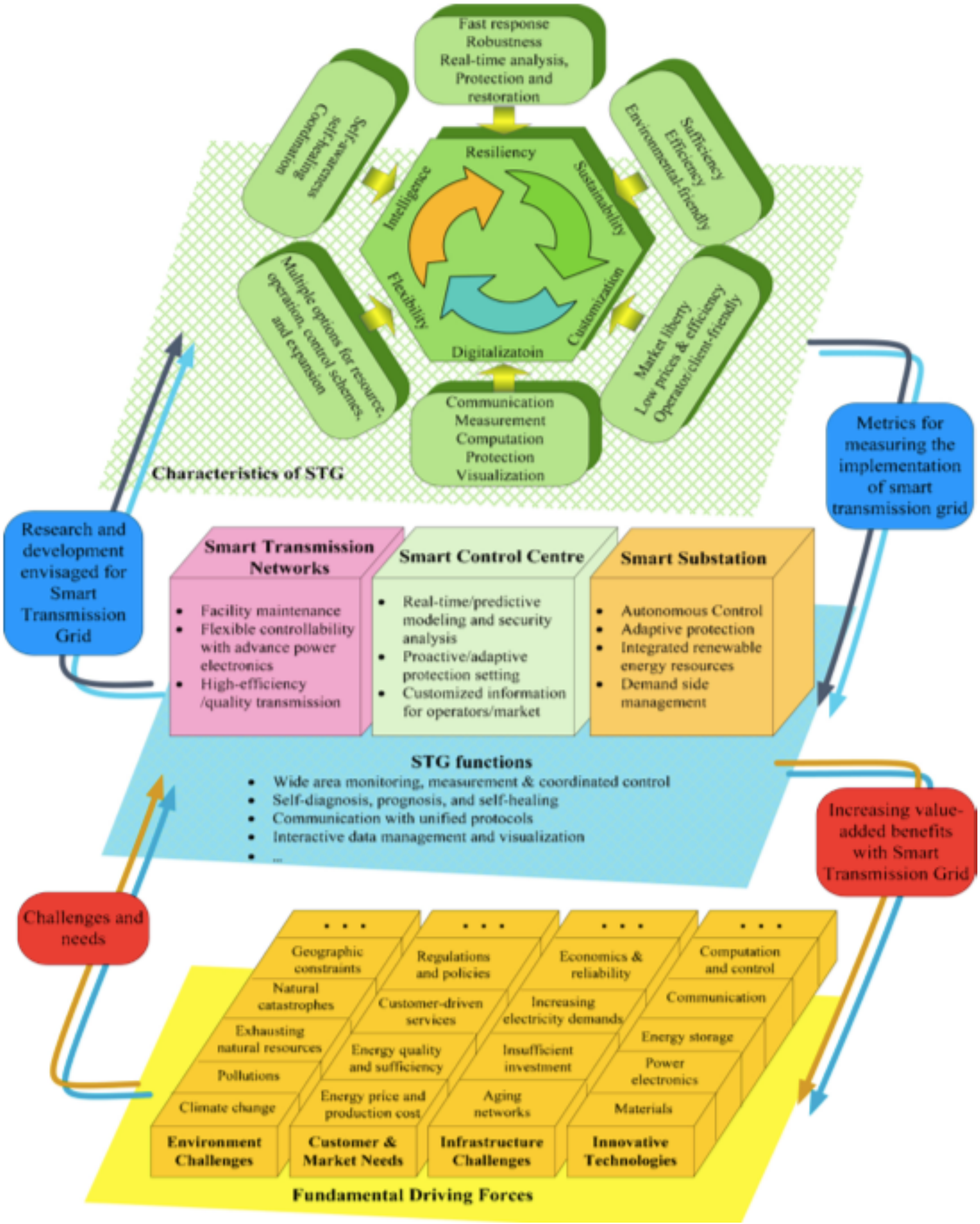
APPENDIX A. VISION OF A SMART TRANSMISSION GRID

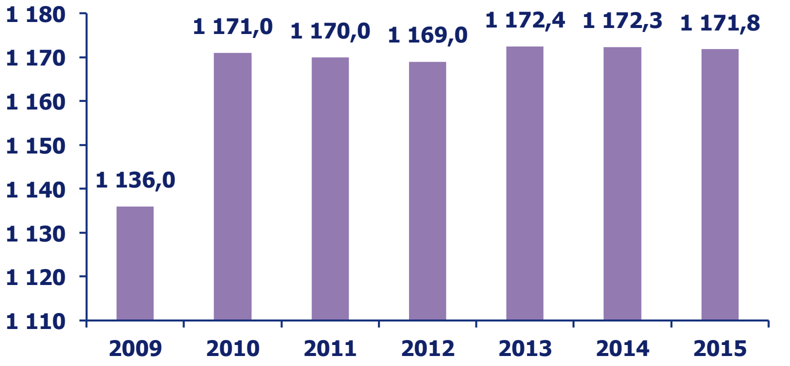
Sourse: Li, 2010



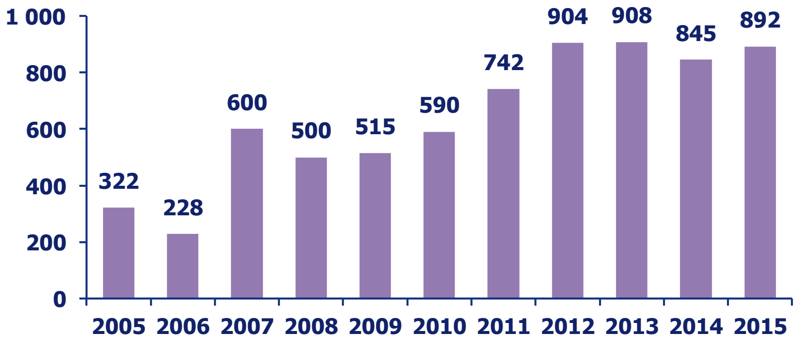
APPENDIX B. POPULATION GROWTH AND HEAT PRODUCTION VOLUME IN SAMARA

Source: T Plus company documentation

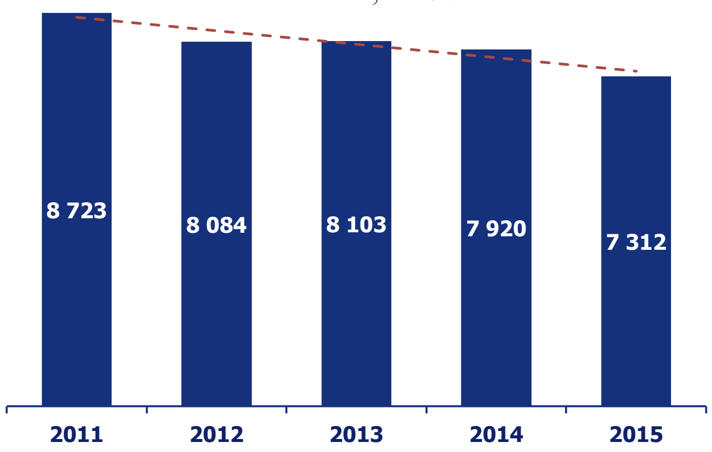
Population of Samara city, th. people



New housing in Samara city, th. square m per year



Volume of heat production by T+ Group in Samara, 2011-2015, th.Gcal



APPENDIX C. DESCRIPTION OF OPEN AND CLOSED HEAT PRODUCTION AND DISTRIBUTION SYSTEMS

Source: Mosbitenergo

Open heating systems

Open heating system - a system in which hot water for consumption is taken directly from the heating system (partly or completely). The rest of the system's hot water is used for heating and ventilation. 50% of the heating systems during the Soviet period were open type. The main advantage of such heating systems is the economic benefits. As for the drawbacks there are low sanitary quality of water. Heaters and water pipe networks color the water, bring the smell and bacteria. To improve the water quality additional costs are required.

Closed heating system

Closed heating system - a system in which the water circulating in the pipeline is only used as the coolant, and not taken from the heating system to provide hot water. The system in this case is completely closed from the environment. Of course, in such a system might be a slight leakage of coolant. Water losses are compensated by a recharge regulator automatically.

The heat supply in a closed heating system is regulated centrally, and the amount of coolant (water) remains unchanged in the system, and the heat flow depends on the temperature of the circulating coolant. Closed heating systems use the heater points.

The advantages of a closed heating system - high quality hot water supply, energy-saving effect. As for the disadvantage, there is a complexity of the water treatment because of the distance between the heating stations.