Motivation towards energy saving by means of IoT personal energy manager platform

Y Zhukovskiy¹, D Batueva¹, A Buldysko¹, M Shabalov¹

¹St. Petersburg Mining University, 2, 21 Line of Vasilyevsky Island, St. Petersburg, 199106, Russian Federation

E-mail: zhukovskiy_YuL@pers.spmi.ru; dasha-batueva4@rambler.ru; buldysa@gmail.com, Shabalov_MYu@pers.spmi.ru

Abstract. The article presents a study of implementations of information technologies for energy saving. The study provides an analysis of cloud platforms used in the energy sector. Most platforms are used to increase equipment load factors, diagnose it, or integrate the energy infrastructure of individual systems into large systems. The article discusses the role of man in the process of improving energy efficiency. As a result of the research, it is found that the user’s connection to energy saving will act as a significant motivation. The proposed cloud platform focused on the personalization of energy actions will create the prerequisites for the formation of a smart consumer. The article describes the structure and functionality of the system. As a result of the platform implementation, the user will be able not only to reduce his bills for energy, but to see the real effect of his actions in the overall balance.

1. Introduction
In the next 12 years, the energy sector of various regions and countries must cope with the issues of ensuring energy security and become the guarantee of "sustainable development" as the basis for satisfaction of future generations needs. The increase in the world population, urbanization and exponential increase in information amount will require stricter requirements for energy security, environmental friendliness, energy efficiency and adaptability of the energy infrastructure [1]. The consumption of all types of primary energy resources is growing (as a function of GDP growth) and despite the increase in energy efficiency, the physical deterioration of energy infrastructure is still growing at an accelerated pace [2]. The role of intellectual energy therefore is crucial for the whole world due to the growing limitation of the traditional energy resource base [3]. A qualitative change in the nature of global and local energy systems based on digital and information technologies will allow to integrate electricity, heat, cold and gas supply systems and to combine them with the means of distributed generation. Issues of energy saving and efficiency remain the most significant for the Russian Federation, which mean that the peculiar attitude of consumers to the use of resources should be changed, and not by increasing tariffs but by educational shifts.

The interweaving of information and digital technologies and their introduction into the economic and social spheres in the foreseeable future will unite the real and virtual world, which in turn will generate many new markets, services, business strategies and qualitatively transform energy markets [4,5]. However, at the moment, the emerging fourth industrial revolution leads to a very high uncertainty regarding the success of various technological areas that are the basis for the transition from the existing
energy paradigm to integrated intelligent systems of electricity, heat and gas supply (energy "system of systems" or "Energy SoS ").

Integration of various energy resources and means of distributed energy generation will allow to create a flexible democratic infrastructure of free energy exchange. Only the transition to Energy SoS will allow the energy sector to become a guarantee of sustainable development during the transition to a new technological order. Expansion of functionality based on integration is impossible without a unified information and communication platform providing control, management, observability of energy exchange and energy trading services. Accordingly, the economic collaboration and integration of regulators can level many barriers in the energy transition and form a unified legislative, regulatory, social system of rules that form a safe, affordable, high-quality energy supply to all participants [6-8].

All this can be linked with the Internet of Things concept into a unified system. The literature mentions a lot about the possibilities of Internet of Things application both for the production environment and for consumers, not only in the energy segment, but also in any other.

2. Required background

Access to energy and sustainable development of the fuel and energy sector are still considered a big problem. It is known that today one of the main strategic goals of Schneider Electric, Siemens, ABB, General Electric, Honeywell, and others is a transition to policy of energy saving and the introduction of information technologies that can enhance the interaction between the consumer and the power system.

Energy saving is an important trend both at production sites and at residential consumers. The literature discusses many options for cost savings through the introduction of energy-efficient technologies. In article [9], literature review and empirical data (expert interviews, sources available on the Internet) are used as a basis for a topic that is relevant for enterprise managers. Unlike traditional decision-making principles, this document presents the opposite approach to guiding the process of energy saving: starting with the most important question ("What advantages do I want to achieve?"). The paper emphasizes what practices will have to be in place and what data is required for methods and tools to be implemented and run in manufacturing processes. The goal is to show how operational and tactical decision-making processes can use data to improve energy efficiency and, therefore, the competitiveness of manufacturing companies. Products or technologies used by most thermal power plants mainly focus on monitoring and analyzing performance, optimizing operating parameters, and not many functions exist to optimize the operating modes of power plants and assess energy savings, while the latter is of great importance and has a potential for energy savings and consumption reduction.

Based on the energy management platform, the system described in [10] can monitor performance, analyze energy consumption, optimize performance, optimize load distribution, information statistics, quickly evaluate energy conservation upgrades, and comprehensively analyze power plant. The structure of the system includes a data collection layer, a data analysis layer and a data display layer. The system adopts an open, standard and distributed structure, supports remote monitoring and data management, as well as remote updating and maintenance of the system.

But there are many problems associated primarily with the transformation of all the data that the system can collect into a single network for further work with them. Problems and challenges arising from the development of various types of platforms are described in [11]. Internet of things (IOT) data have characteristics of intensive velocity, high volume and enormous variety. In article [12] authors studied middleware that can integrate different IOT data and integrate various data formats into a single format.

It is also important to understand that maximum energy saving and the introduction of an energy-efficient lifestyle concept are impossible without the interaction of all market participants. The author of the article [13] offers the platform “The Energy Synchronization Platform". This is a product for the information exchange between all participants in the electricity market and it allows them to synchronize the demand for electricity and its supply. The platform can be divided into two types of logical platforms - market platform (MaP) and company platform (CoP), connected via a simplified service-oriented
connection interface (CnI). The platform allows the industry to actively participate in the energy market both as a consumer and as a supplier.

Real-time IoT applications allow manufacturers to continuously analyze data and determine or predict a maintenance schedule for a device or promptly replace faulty equipment. Those kind of IoT applications reveal the benefits of the “smart home” data analysis and their architecture is described in detail in [14]. While such data provide valuable insights into the dynamics and behavior of smart homes and their inhabitants, it also poses tremendous challenges in terms of data management, storage and analysis. To ensure that users do not get lost in available data, they need systems that can manage, analyze, and transform this amount of data into useful ideas for smart city applications that require quick actions with strict requirements. These systems also need to meet scalability requirements because of increasing data volume and time specification in the decision-making process, whether offline or in real time.

Article [15] presents a new platform that allows innovative analytics based on data obtained from the Internet of things, in particular, smart homes. It is proposed to use mist nodes and the cloud system to provide data-driven services and solve problems associated with the complexity and resource requirements to process, store, and classify data online and offline. Mist computing nodes are resource efficient because they are equipped with virtual machine technologies that can continuously process fresh IoT data streams and transfer the processed data to the cloud for further processing. Cloud computing offers many benefits, such as infrastructure as a service (IaaS): providing access to unlimited storage space; platform as a service (PaaS): the potential to run demanding applications; software as a service (SaaS): simplifies software access and service. In general, the platform can assist in efficient and timely decision making for individual homeowners by facilitating various home-level energy management programs.

There are several platforms in the IoT ecosystem that provide support from the sensory stage to the stage of managing and storing data in various forms. Household energy management and data analysis is a complex operation that requires the continuous integration of several sources into a general processing system with easy access to data. One of the most ambitious solutions is the FIWARE platform, a key initiative of the future public-private partnership on the Internet (PPP) (Europe), aimed at creating a clear set of open ways for receiving, processing, contextualizing and publishing IoT data about “smart” cities ranging from citywide information to specific data about houses.

In the article [16], the authors designed, developed and approved the IoT Energy Platform (IoTEP). The main advantage of IoTEP is that (as it is claimed by authors) this is the first comprehensive solution for large-scale energy data management in buildings from IoT. In this area, there are not enough platforms aimed at households and at supporting data analysis. The result is the IoT Energy Platform (IoTEP), which covers the two above-mentioned needs, following an open approach based on FIWARE support.

3. Energy efficient life style

Energy saving, which can be achieved by tracking many indicators of connected devices, is not able to push a human, that is, an important energy consumer, to become part of an energy saving program.

A lot of research is being done in various countries about people's attitude towards modern energy management technologies. For example, a study was conducted among the Israeli population about their attitudes towards dynamic pricing and flexible systems through Smart House Technology (SHT) [17].

It turns out that the more people know about SHT, the more willing they are to implement these systems at home, despite different criteria such as cybersecurity systems [18,19]. It is not particularly important for people that apart from them, housing and communal services also receive positive effects. Systems must meet high user expectations — be comfortable and reliable. In addition, the “seamless” quality of technology implementation plays a huge role - the more imperceptible and smoother it is, the more convenient the user is.

Public utilities must examine their consumer and their needs. It is necessary to pursue a policy at the international level to ensure technological reliability, creating uniform standards for ensuring quality,
safety and compatibility of technologies. Policies at the national level should provide a fair, transparent and reliable integration market for home automation and trade in flexible systems [20].

Proceeding from the above, it becomes necessary to introduce such measures that will be able to motivate the consumer, because there will be a demand for SHT platforms when consumers understand why they need it and what benefits it will bring.

Creating an “energy efficient society” in Russia is not a task for a year or two, it is a task for decades. You can use energy-saving equipment, energy-efficient mechanisms, create innovative enterprises, but they will work under the guidance of “non-energy-efficient people”, therefore, the proper effect will not be achieved. Lean attitude to energy consumption, both in the enterprise and in living conditions, must be educated, starting from the earliest years of human life. Promotion of energy conservation should be country-wide and affect all sectors of society [21]. Energy conservation is necessary for all segments of the population, even those not related to energy, since it is energy-efficient thinking that ultimately can lead to the release of huge amounts of energy [22].

The introduction of the PerPower virtual platform concept will help to cope with this problem.

4. «PerPower» project (Personal Power)
The aim of the project is to ensure the interaction of each consumer personal energy costs with its production by traditional means and by energy saving.

Project tasks:
- Informing about current consumption, consumption over the past months, and payment costs by building online load schedules.
- Payment of bills for electricity through the application online.
- Recommendations on options for possible savings during the day by changing the time and place of electric vehicles charging.
- Organization of the electric vehicles distribution to charging stations in the city.
- Informing about the possibility of using an electric vehicle as a generator in energy-deficient areas.
- Informing about power outages in homes in advance through notifications in the app.
- Informing about changes in the power system: accidents, overloads, failures, tariff changes, installation, meter checks, etc. - news feed.
- Tips and recommendations for energy saving and energy efficient lifestyle (Smart Home).

5. Short description of scientific project «PerPower»
“PerPower” is a personal energy account with a point-based cumulative reward system, tied to a specific person, providing information to the consumer about his personal effect, about his global participation in energy saving; infographics about the share of consumers already connected to “Personal Power”, about the created capacity and NegWatt generation (unit of energy conservation) by their actions in the field of energy-efficient lifestyle: for installing energy-efficient equipment, reducing the load of receivers during peak hours (such actions will gradually be included in habit), for young people - for participating in events, contests, conferences, case-championships, then the opportunity to spend the accumulated points in payment for electricity, to pay for utilities, to pay in partner companies and to have a priority when applying for an energy specialization in secondary and higher education institutions.

The implementation of the consumer informing concept is based on the development of a mobile platform with the possibility of universal function integration. Collection of information about receivers and consumption can be entered in to the application manually and automatically: using sensors installed at sockets, automatic collection from smart devices, control devices and other applications that can be used in smart homes (the concept is shown in Figure 1).

The application finds the brand of equipment on the network, determines the nominal parameters, if necessary, connects to it via the IoT platform and establishes the exchange of information in order to add it to PerPower or to get it banned. Electric vehicles and any other personal devices involved in
consumption, demand management, the creation of energy services and the generation of energy can be tied to the bill [23,24].

The platform structure consists of the following components:

- **Smart Home components** - sensors, equipment, devices and measuring systems, conditionally divided into three levels: cyber physics, communication and contextual support. The cyber-physical layer consists of intelligent devices, measurement systems, sensor systems, instruments and energy management systems. These elements are responsible for all the actual operations of the smart home. They interact with the outside world through the three levels – communication [25, 26]. Communication protocols allow these devices to communicate with each other and with the cloud system via an IoT gateway. The communication level is responsible for outgoing and incoming communication with Smart Home, which includes direct interaction with consumers via mobile or web applications. The context level provides real information on Smart Home. The context-based layer includes user rules and policies for managing interaction and services. This level allows you to configure privacy and security based on a context that satisfies the interests of the tenants.

- **IoT management and integration services** - a subsystem that is responsible for processing requests for IoT services from several Smart Home applications to the cloud system. It plays a vital role in providing authentication services for these requests and ensures that admission rules comply with pre-configured policies. Services that require access to Smart Home data must register with the IoT control broker before using any data from the cloud system. The operation of the IoT management services is independent of the protocol and is responsible for maintaining continuity and flexibility for the entire IoT ecosystem. The integration service provides security since external applications will not be able to directly access the analytical engine. All this allows the use of data for various user applications, including mobile and desktop; provide interoperability for various transmission technologies (Wi-Fi, Bluetooth, ZigBee, LPWAN, etc.) and data transmission protocols M2M, MQTT, CoAP (Constrained Application Protocol), etc [27,28].

- **Fog computing nodes** provide additional resources and computing services to support various time-sensitive applications for Smart Home, provide tools to speed up analytic services, while providing enhanced response speed of the cloud infrastructure. It consists of several functions, including data pre-processing, analysis, classification, forecasting and visualization. The fog node performs all short-term analytics at the edge of the cloud system. The data entering the mist node is not structured and does not have a predefined model. At the preprocessing stage, all flows are filtered, analyzed and converted into a single data structure for further analysis. When using the frequent pattern analysis method, these repeating patterns are searched in a given data set to determine associations and correlations between the patterns of interest. Predictive analytics is responsible for predicting consumer activity or the use of certain devices [29]. Visualization provides an interactive environment for the user with a report on the analyzed data for understanding consumer actions and learning decision-making processes. Finally, the results of the above steps are sent to the cloud system, in which there are many resources for tasks that require a large amount of computation.

- **The cloud system** is responsible for providing essential services for Smart Home applications, which include historical data analysis, enhanced storage capabilities, and basic management infrastructure. Cloud services include tracking, configuration, analysis, reporting, device authentication and authorization services. These functions provide users with an additional service to control and manage their smart homes using various means (for example, web applications and mobile applications), as well as to interact with third-party providers.
6. Expected results of the research

- Optimization of electricity costs for households.
- Reduction of energy costs for consumers.
- Reduction of peak electricity consumption and, therefore, there will be no need to switch on additional generators at power plants, which will lead to a reduction in the cost of electricity.
- Enhanced control of energy companies over electrical load schedules.
- The ability to interact with the consumer through interactive tools will help simplify the management of the entire system.
- Formation and improvement of energy saving culture and consumption culture, energy efficient thinking, informational interest in energy saving, energy efficient habits.

7. Conclusions

The world is entering the period of, perhaps, the largest technological transition in its history, when the availability of natural resources and cheap labor are no longer the main growth factors. However, the country's energy infrastructure will still provide the fundamental means for the development of society and economic growth.

It is obvious that for energy transition and for distributed energy resources (as well as for centralized energy systems) integration it is necessary to stimulate general ecosystems for the development of digital and information technologies, which will become vital for design ways and equipment of power, heat and gas supply intelligent systems. This will allow the power industry to monitor and control parts of the system at any time range from high-frequency switching devices in the microsecond range, energy quality correction devices in the millisecond interval to hourly prediction of energy production for weather-dependent sources, daily redistribution of production capacity and annual planning of hydrocarbon emissions and energy consumption [30-32].

The emergence of services at each hierarchy level and time periods will change the energy markets and the daily lives of consumers. The measures proposed in the work will provide for a net inflow of capital to the private sector and boost the level of population economic activity, and the PerPower platform will create prerequisites for the emergence of a smart, active consumer. Revitalization of innovation activity will increase the proportion of organizations implementing technological
innovations, which will favorably affect the economic performance of the Russian Federation. At the same time, it is necessary to correctly set the direction of scientific and technological development, since it determines ways of further progression for the region, the country and the world as a whole. However, the unpreparedness of state regulators and infrastructure organizations of the electric power industry to the emergence of active consumers can become a brake on large-scale changes and the sustainable development of the Russian economy.

As a result, both in Russia and in other countries, the question arises of identifying organizations that can put the project into reality and who should provide funding from both the state and the private sector. At the moment, in order to conduct an effective energy policy in the Russian Federation, it is necessary to primarily carry out financial and legislative support to the areas of energy, covering sectors of digital and information technologies, energy storage, and also technologies of distributed and renewable energy.

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