SMART TECHNOLOGIES: DIGITAL SOLUTIONS FOR AN ENERGY-SAVING PRESENT AND FUTURE

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Abstract. *Driving towards a high-tech future, digital technologies contribute to the expansion of economic opportunities, increasing the level of social well-being and environmental protection. The appliance of digital technologies as tools to improve energy efficiency for all economic sectors is aimed at solving the major objectives of sustainable development. Alternative energy production is rapidly gaining popularity around the world and is becoming the preferred source of energy supply for consumers. The effective application of digital technologies to stimulate production and supply growth in demand in developed and developing countries ensures the competitiveness of alternative energy sources. As Tajikistan is a country with rich hydropower resources, around 96% of electricity in the country is generated by hydroelectric power plants. In terms of hydropower potential per capita (87,800 kWh per year/person), Tajikistan shares the first two places in this indicator with Norway, and has the potential to serve the wider region. However, there is a lack of digital technologies, and modern techniques need to be introduced to adequately respond to the needs and consider negative trends in climate warming. Thus, these risks require a search for more effective technologies for the development of the country's energy sector. The smart home concept takes a special role in applying the capability for increasing the efficiency of energy resources' use and energy saving. The smart home concept entails the most outstanding idea for effective house space formation through digitalization. This article presents research results on an autonomous intelligent system within a residential building based on the use of digital and intelligent technologies. The trends in the development of the intelligent smart home system and the barriers that slow the development of this market are identified based on global experience. This integrated automatization project for autonomous homes is developed based on KNX digital and intellectual technologies. The solutions proposed in this article are verified by calculations of economic efficiency and can be recommended for further practical use.*

Keywords: *information technologies, smart home, digital technologies, energy-saving, KNX, efficiency.*

Introduction

Digital technologies are actively being introduced into all spheres of modern society. Pursuant to the challenges and opportunities of the digital economy, implementing the ideas of the smart home and smart city concepts can be considered as one of the directions for changing the life habits of the modern population. These concepts are technologies for integrating the Internet and digital interactive services into various electronic devices (TVs, computers, mobile phones, tablets, household appliances, etc.) for the purpose of forming a single digital space for user convenience. The main principles of the smart home concept are considered to be human-oriented, life quality improving, and ensuring economic efficiency. These principles shall be implemented through the widespread introduction of digital technologies and engineering solutions. The purpose of the smart home is not only limited to the digital transformation and automation of processes, but also a comprehensive increase in energy efficiency within housing space. The human-oriented principle is the main principle of a smart home, such as the principle of providing residents with the opportunity to be involved in energy consumption management by applying digital technologies.

The governments of many countries are developing strategies for sustainable development, the most important areas of which are to ensure energy security and increase energy efficiency. The implementation of energy efficiency and energy saving programs in the energy policy of developed countries and regions, such as the EU, is considered an additional source of energy.

In developing countries, energy conservation and energy efficiency programs tend to focus on eliminating energy poverty and improving the quality of life of the population.
Of particular concern to the global community are climate change trends and the environmental aspect of the problem of energy conservation and energy efficiency. Growth in the consumption of energy resources invariably entails increased environmental pollution.
The prospects for reducing the energy intensity of the global economy and the destructive impact of its development on the environment are associated with the development of the smart home concept. Currently, the strategic priority for the development of megacities in many countries is the creation of a smart city. The problem of implementing intelligent systems for managing the energy consumption of cities is of particular relevance in the context of the predicted growth in the urban population. According to UN estimates, by 2050, 67% of the world's population will live in cities.

The main body of the paper

The current level of intelligent technologies and the emerging trends in their development in the near future enable humanity to increase the efficiency of energy resource use based on the implementation of the concepts of smart home and smart city, and make a significant contribution to improving the environmental situation on our planet. Today, the thesis is undeniable that humanity, by changing its consumption of energy resources, can change the world (Kremlev et al., 2014).
The depletion of fossil fuel reserves, climate change, the aggravation of the environmental state, increases in prices for energy resources followed by growth in consumption, and the rise the significance of energy efficiency and saving increase these problems, and pose challenges for the global community to search for problem-solving mechanisms.
In 2018, global consumption of all energy sources increased by 2.3%. Moreover, the predominant demand was typically for electricity and gas power sources. The highest rate of energy consumption was in China (3.7%). In the USA, in 2018, compared to 2017, the increase in energy resources consumption amounted to 3.5%. According to experts, one of the reasons that led to this increase is climatic conditions such as hot summers and cold winters. At the same time, energy consumption in the EU decreased by 1% within the reviewed period. For example, energy consumption decreased by 3.5% in Germany, resulting from a warm winter period and the effective implementation of an energy-saving policy in the country.

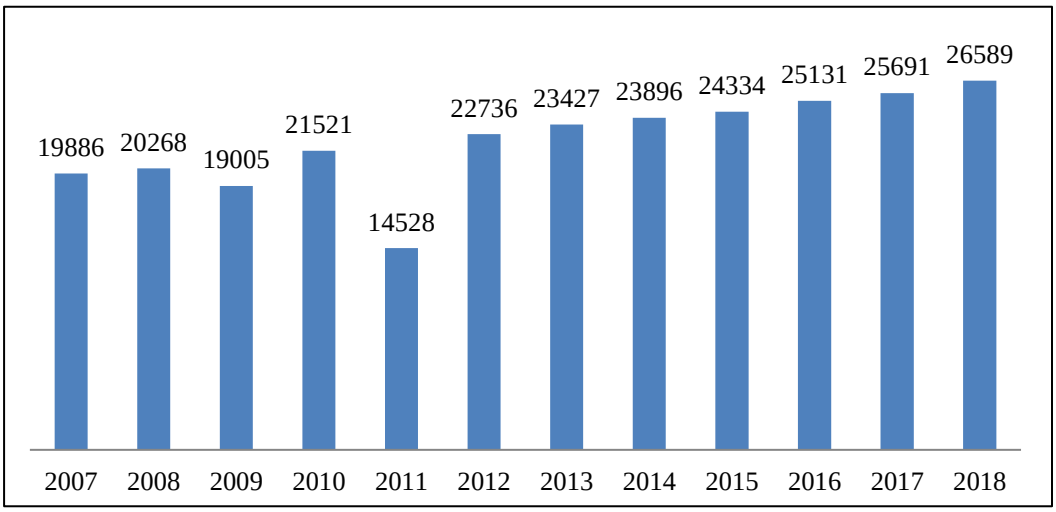

Figure 1. Global electricity consumption dynamics, TWh
Source: Enerdata (2022)

The global electricity consumption dynamics provided in Figure 1 indicate a noticeable growth rate. Global electricity consumption in 2018 increased by 3.5% compared to 2017. Global electricity consumption in 2018 is illustrated in more detail in Figure 2. At the same time, global energy consumption mainly increased due to Asia (around 80% of this increase), where China consumed 60% of the total amount of energy used (Enerdata, 2022). Economic growth and industrial demand have led to an increased demand for electricity in China (Figure 2).

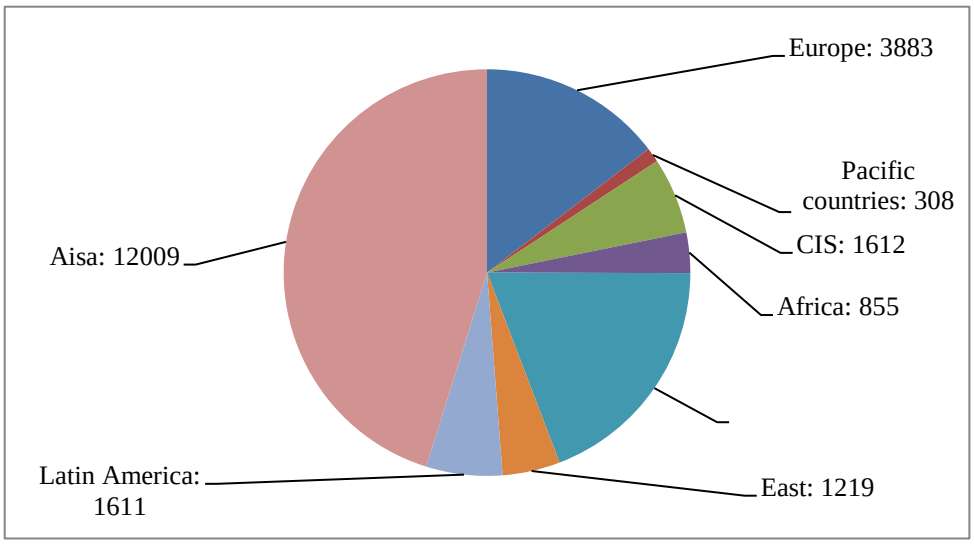

Figure 2. Electricity consumption by regions of the world in 2018, TWh
Source: Enerdata (2022)

Moreover, energy demand increased in Japan, India, Indonesia, and South Korea. Compared to 2017, US electricity consumption increased by 2.2% in 2018. The residential sector had a significant impact on the increase in electricity consumption. The increase in electricity consumption in this economic sector amounted to 6.2%, resulting from the increase in the electricity consumption of household appliances and air conditioning. In the residential sector, the electricity consumed by household appliances is around 50%, while the use of centralized or individual air conditioning systems in the US is almost 90% of electricity consumption.
Economic growth in some countries (e.g., Brazil and Russia) has contributed to the growth in electricity consumption. There is also an increase in electricity consumption in Africa (Egypt and the Middle East). The electricity consumption rate in Europe remained stable throughout 2017 and 2018 overall, as it decreased in Germany, Austria, and France, stabilized in the UK, Italy, and Spain, and increased in Poland, Bulgaria, and the Netherlands (Enerdata, 2022).
The environmental aspect of the problem of energy saving and energy efficiency is of particular interest. Growth in the consumption of energy resources invariably leads to a negative impact on the environment. Energy-related CO_2 emissions increased by 2.1% in 2017 and by 1.9% in 2018. As a result of energy sector activities, CO_2 emissions into the environment increased by 1%–1.5% in 2019, and this was determined by the increase in energy consumption. All countries except those in Europe and Latin America experienced increased energy consumption. Despite the policy of shifting from coal to gas, CO_2 emissions into the environment increased significantly in China, India, and Russia by 3.1%, 4.2%, and 3.9%, respectively. In the USA, CO_2 emissions increased by 3.1%, driven by increased weather-related energy consumption. In the EU, CO_2 emissions decreased by 2.1% due to several reasons such as reduced energy demand (in Germany, for example), an increase in the share of renewable energy sources in electricity generation, and relatively favorable climatic conditions. In Japan since 2016, carbon emission has continued to decrease due to solar and nuclear energy use.

The limited opportunities for implementing the potential for increasing energy efficiency and energy saving that are available to developing countries, including Tajikistan, can be determined by the following reasons:

- low level of motivation to use energy-efficient household electrical appliances, modern intelligent home support systems, and digital technologies in management;
- weak regulatory and legislative framework for energy-saving;
- unfavorable investment climate and, as a result, limited access to investments for the implementation of energy-saving programs.

In this regard, the benefits resulting from the implementation of energy efficiency and energy-saving programs are characterized by different scopes in each country. In developing countries, where a significant part of the population is below the poverty line, these programs are focused on providing access to energy for this part of the population, thus reducing energy poverty.

Currently, the lowest GDP energy intensity indicators in oil equivalent (0.057–0.108) are present in Colombia, the UK, Indonesia, Japan, and Europe. Most countries have high GDP energy intensity (0.112–0.326), including the USA, Brazil, India, China, Argentina, the CIS, and others.

The special significance of the energy saving and energy efficiency problem and the search for mechanisms to solve it in different countries is seen at all levels. At the state level, problems are solved considering the characteristics and different scales of such problems as those noted above. Such solutions include ensuring the energy security of the country, providing the population access to energy, and reducing energy poverty and the negative impact on the environment (X10, 2019).

The increased interest of business in energy-efficient technologies is caused by the following:

- reducing energy costs and increasing the competitiveness of their products;
- improving the company's image from an environmental perspective;
- reducing the cost of technological processes in the use of the building.

The interest of the population in energy efficiency improvement is specified by its particular importance in improving the living comfort in the house, reducing the cost of energy resources, and improving the environmental situation.

A special role in the implementation of energy-saving and energy efficiency improvement programs is given to state authorities. Effective energy-saving state management measures made France form the Energy Saving Agency, Japan the Office for Rational Use of Natural Resources, the UK the Energy Efficiency Committee, etc. The principle of mandatory state expertise on energy saving consists of determining the compliance of the entity's activities with the principles of energy saving, as well as establishing the compliance of project, planning, and other decisions with the requirements of energy saving legislation. The main purpose of this examination is to prevent the production and release of energy-inefficient equipment, technologies, devices, household appliances, etc. Economic incentives for investments to improve energy efficiency are effective measures of state support for the growth of the energy-saving equipment and services market.

The effectiveness of government incentives for energy saving differs in different countries. This can be described by the effectiveness of the implemented measures. For example, tax benefits established by the governments of Canada and the USA have not had a stimulating effect on intensifying investments in energy-saving programs in the industry. In Canada and France, accelerated depreciation based on increased depreciation rates has had a significant impact on stimulating industrial energy-saving programs. The narrowing of the energy efficiency gap between the West and East German economies was ensured by the fact that building owners in East Germany were legally able to invest part of their income tax in energy efficiency improvements.

Programs aimed at producing and promoting energy-efficient equipment, devices, materials, and systems on consumer markets had a significant contribution to the development of energy saving and energy efficiency in a number of countries. These programs provide incentives for manufacturers and dealers to produce and distribute such products. For example, a US electric utilities consortium regularly provides funding to incentivize manufacturers to produce more energy efficient models of energy-consuming equipment and devices.

Besides the American energy companies, large European energy companies such as EdF (France), ENEL (Italy), and a number of companies in the UK have a significant positive experience in the development and implementation of consumer demand management programs for energy. This experience is already being actively used in a number of developing countries.

The experience of establishing energy service companies that offer energy-efficient equipment and technologies for various sectors of the economy also deserves attention. The significant contribution made by these companies to energy efficiency and energy saving served as a prerequisite for the initiation of a project to create an international energy-saving fund for the organization of energy service companies in Eastern Europe and the CIS by the UNECE Committee on Sustainable Development (United Nations, 2015).

At the same time, it should be noted that activities in the area of improving energy saving and energy efficiency can be considered a business direction. Therefore, state policy in this area should also provide incentive measures for development and should reduce risks.

The research results in this paper show that countries' economies, including in the housing sector, have unused potential to reduce their energy intensity. The program of energy saving and energy efficiency improvement in housing and communal services based on the use of intelligent systems can be considered one of the directions of this reduction.

The global market for smart home technologies in 2020 amounted to $78.8 billion; by 2026, it is expected to grow to $207.8 billion. According to existing forecasts, the volume of the global market for smart home devices will reach $207.8 billion by 2026, despite the decrease in the forecast for the market volume in 2021 due to the consequences of the COVID-19 pandemic. The largest is the US market, but changes are predicted in favor of Europe and the rest of the world. The US is the market leader, with an annual revenue of $23.3 billion, the European market is second with $20.1 billion, and China is third with $15 billion. The smart home devices market is conditionally divided into 6 segments depending on the scenarios for using devices: 1) control and communication; 2) smart home appliances; 3) security; 4) home entertainment systems; 5) comfort and lighting; and 6) energy consumption management. The largest of these segments in terms of volume is smart home appliances, which amounted $29.1 billion in 2020. This segment along with the management and digital communication segments are the most future-oriented in terms of growth. Annual growth in these segments is expected to be around 18%–18.5% (Enerdata, 2022).

According to the analytical company IDC, in the EU the volume of the smart home systems market amounted to 88.8 million systems in 2018, and by 2023 the volume of various smart home devices in the European market will increase to 187 million systems. The average annual growth rate (CAGR) in the considered market in the period from 2018 to 2023 will be 16.1%, as shown in Figure 3.

In 2018, video entertainment formed a significant share of smart home equipment in the EU at 61.2%, music speakers 18.1%, home security systems 10.3%, lighting systems 4.8%, and thermostats 2.6% of all smart home technology supplies (Bannikova, 2016).

Products from large companies such as Amazon, Google, ADT, and Samsung have promoted the spread of the smart home system in North America. In Europe, such large companies as Centrica Connected Homes (CCH), Deutsche Telekom (Magenta), eQ-3, and Enco (Toon) dominate. In Asia, the market is represented by such companies as Xiaomi, LG, U+, iTSCOM,

and Panasonic. According to forecasts, by 2023 the smart home market will grow by an average of 10% each year to $155 billion, and the number of customers will grow to 293 million. The best-selling smart home devices are smart lighting systems, smart thermostats, and security and warning systems. Currently, the main market for smart home systems is North America, and this market forms 41% of all smart systems.

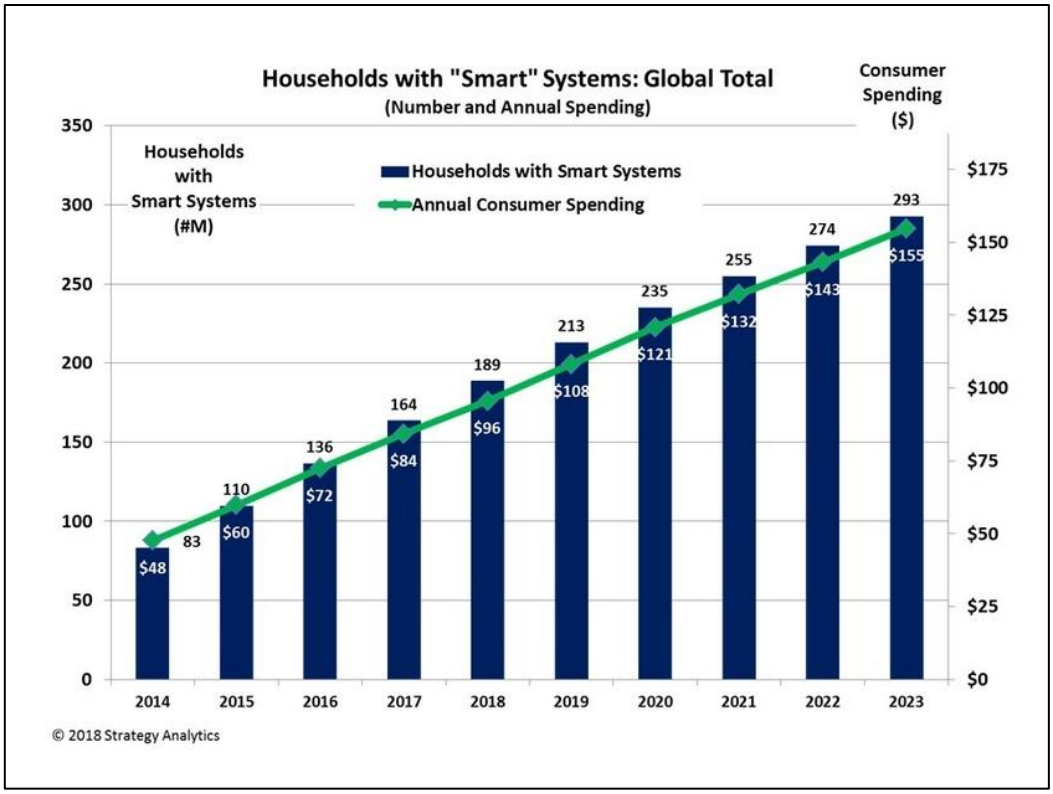

Figure 3. Growth dynamics of the global smart home market
Source: Strategy Analytics (2021)

International statistics, where the smart home concept is a long-standing reality, highlight the benefits of investments made and their rapid payback:

- reduced operating costs by 30%;
- reduced energy consumption by 30%;
- reduced CO_2 emissions into the environment by 30%;
- reduced water consumption by 41% and payment for water accordingly;
- reduced heating bills by 50%.

In addition, there are risk insurance benefits, as risks are reduced by 60% when using smart technologies. The main motivation that encourages customers to invest in a smart home system is the desire to have comfort and safety; at the same time, an important aspect of this choice is the uninterrupted operation of equipment and energy savings.

One of the main obstacles to the spread of digital systems is the problem of smart home device compatibility. The use of different data exchange communication protocols by manufacturers complicates the application of smart home devices and their integration with each other (Chew et al., 2008). The number of companies offering apartment automation services is growing, together with the growing demand for digital smart home technologies.

The amount of consumer spending per capita in the CIS – which, in Tajikistan, is $563, out of which almost 62% is food expenses – is considered a barrier to the development of the market. In Russia, this figure is almost 1.5 times lower than the world average (334,000 rubles against 483,000 rubles in the world). The lack of a necessary level of consumer confidence in smart

home technologies also negatively affects the growth in demand for smart technologies. The low level of digital literacy, observed in 39% of the adult population in Tajikistan, is an additional obstacle to the development of the market.

Considering the importance of the processes of the digitalization of the economy, it should be noted that Tajikistan, more than other countries, needs processes for the development of digital technologies. This is related to the geographical location of the republic and the lack of access to sea routes, and digital technologies are a cheaper way of communication from an economic point of view. Demand for smart home technology in Europe is much higher than in Tajikistan. One of the reasons for this is that the prices of energy products in the domestic market of Tajikistan are relatively low. Therefore, the payback period for smart home technologies based on the use of automated energy management systems in the EU is significantly lower than in Tajikistan. The low solvency of the population leads to the fact that digital solutions to the energy-saving problem are perceived by most buyers as luxury elements (United Nations, 2015).

The underdevelopment of the corresponding segment of the Internet of Things market, which includes the corresponding smart home devices, is considered as a deterrent to the development of intelligent systems in Tajikistan. Experts also point out the barriers associated with the existence of unified standards. For most construction companies, it still remains problematic to obtain practical solutions from developers and suppliers of smart home intelligent systems. When it comes to management companies, such companies, as a rule, do not have the necessary resources to operate intelligent systems, and the low cost of energy products is not an incentive for the population to make decisions on investing in energy saving. Representatives of telecommunications and smart home services also point out the problematic organization of the network model as a barrier, which is very important for guaranteeing the quality of telecom services and smart home services (Kremlev et al., 2014).

Telecommunications operators are also interested in increasing demand for smart home technologies, considering this area as a new sector of the telecommunications services market. Research shows that a number of telecommunications companies consider the automation of the management of housing and communal services a promising area of their activity. The introduction of smart home technologies in only 10% of households would create a huge market. The advantage for Internet providers consists in constant contact with the homeowner, which is difficult for service companies to achieve. As global experience shows, smart home technologies will become mass-produced only when the operator model is applied.

Energy savings from the use of digital systems in the housing sector of Tajikistan, which can be considered as a potential method of release of energy resources in the domestic market and the possibility of increasing their export, is an important advantage of smart home technologies. Today, the market for digital building management systems in Tajikistan is much lower than the Russian market, not to mention the Western market, and this market is not even at the initial stage. Consumers must realize the benefits, both in social terms and in the economic aspect. Only then will there be an increase in demand in the smart home system market, both for individual apartments and rural houses and for the construction of intelligent buildings.

Demand for research into smart technologies in the construction of buildings in Tajikistan shows that the main barriers to the growth are: the limited access to information of potential buyers of housing and office space regarding the benefits of automating systems; the insufficient level of professional capacity of designers and their limited access to standard engineering solutions in the field of designing intelligent premises; and the weak motivation of construction companies to use intelligent technologies. In addition, an important and temporary factor such as relatively low prices and tariffs for energy resources in housing and communal services should be noted. In the near future, the predicted growth in demand for smart homes

will continue to depend on access to the Internet, which shall provide automated management of life supporting systems.

Due to the low solvency of most of the country's population, the demand for intelligent systems for a separate apartment is quite limited. To date, only 1–2 Russian and Chinese companies are represented in the country's intelligent systems market. The low effective demand associated with software and setting up an automated system controlled from a computer remains problematic. The latter is characterized by significant budget costs, limiting the demand of the average homeowner for digital innovative technologies. As a rule, at the initial stage of implementation and proposal, people treat this technology with some prejudice and get used to it over a long period of time. However, given the systematic increase in utility prices, the situation may change quickly. Increasing competition will lead to the widespread and active introduction of intelligent systems at the stage of building construction (Bannikova, 2016).

The problem of implementing digital technologies in urban energy consumption management is of particular relevance in the context of the predicted growth in the urban population. The UN estimates that by 2050, 67% of the world's population will be living in cities. In most countries, the prospects for the application of digital technologies in everyday life form the basis of numerous smart city projects. The level of digital technologies achieved currently and the emerging trends in their development in the near future shall enable humanity to increase the efficient use of energy resources based on the implementation of the smart home and smart city concepts to make a significant contribution to improving the environmental state of our planet. The concept of a smart home is a logical continuation of the ideas embodied in the concept of a smart city.

Currently, due to the complexity of the smart home concept, there are various definitions in the literature. We adhere to the fact that a smart home is a complex digital building management system, including subsystems of its heating, air conditioning, power supply, water supply, ventilation, video surveillance, alarm, security, fire safety, and telecommunications. The list of managed subsystems and the functional characteristics of the integrated automated system as a whole is very diverse and is determined by the user, the level of development of the technology, and digital technologies.

The current level of development of intelligent technologies used in the integrated smart home automation system is characterized by a wide variety of data transmission methods. Electrical wiring and a coaxial cable can be used to transmit information in the automated lighting control subsystem. Twisted pairs, radio signals, or infrared rays can be used in the climate control subsystem and in the control of digital devices. The switching of various methods of data transmission (protocols) is provided for by the conversion of incoming signals using routers or special devices like bridges (data bridges) (Chew et al., 2008).

The number of companies offering services for automating energy consumption management in apartments is systematically increasing in European countries. The market of intelligent systems for smart homes is developing intensively. With the development of mobile technologies and the increasing availability of the Internet, the population highly appreciates the benefits of intelligent automation systems for managing the energy consumption of an apartment (or house). Now, a comprehensive remote-control system for home support systems has become widespread. For example, installing special software on personal computers allows users to control lighting, air conditioning and heating subsystems, i.e., energy consumption at home remotely. This will not only increase the level of comfort, but also reduce energy costs.

However, this market is not yet developed in Tajikistan and may be of interest to European manufacturers of home support automation systems such as BTicino (Italy) or In One by Legrand (France).

Providing an individual apartment in a new residential building with an intelligent system will significantly increase its cost, which, accordingly, limits effective demand. At the same time, it

should be noted that the intensive development of the housing construction market and the growth of competition between construction companies may be an incentive to intensify the use of intelligent systems by construction companies that reduce energy consumption in Tajikistan.

Different conceptual approaches to the use of smart home systems in the post-Soviet space, in Europe, and in the USA should be noted. The priority goal of automating life support systems in houses (apartments) in the EU and the USA consists of energy-saving and energy efficiency improvement. Smart home systems provide owners with significant savings in electricity, heat, and water, and the effective use of family budgets accordingly.

Effective demand for intelligent energy consumption management technologies and various conceptual approaches predetermine the corresponding scale of the spread of smart homes in the CIS countries and developed countries. In Western countries, at the beginning of this century, intelligent technologies were used in the construction of residential apartment buildings in the residential areas of cities, and in the construction of new housing estates with individual houses in the suburbs.

Unfortunately, the widespread use of digital energy consumption management systems and the use of other intelligent systems in the practice of building residential buildings in Tajikistan is limited by insufficient knowledge and information access. Investment and construction companies do not have the opportunity to receive qualified consultations regarding engineering solutions, lack qualified local experts, and suffer an ineffective regulatory framework. They also experience the priority desire of apartment buyers to save financial resources when purchasing real estate by not taking into account the costs associated with its operation and maintenance of engineering systems.

Review of modern smart home technologies.

The smart home system allows people to centrally control and intelligently manage residential, office, and public spaces. Depending on the complexity and desire of the client, the smart home system may consist of several control automation subsystems, which are shown in Figure 4.

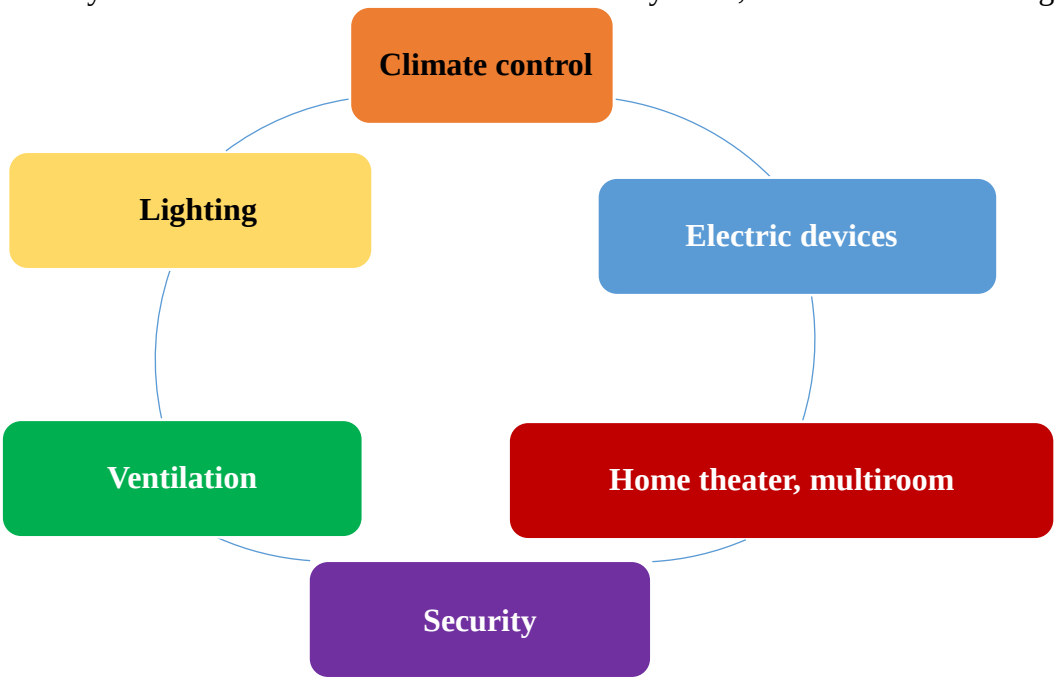

Figure 4. Residential intelligent support systems
Source: KNX (n.d.)

When installing such a system, each user can remotely control a separate subsystem using digital technologies by setting the required air temperature, illumination of individual rooms, sound, resolution of video surveillance cameras and other parameters.
In addition, a smart home may have a multi-tasking operating system and programming tools, and sometimes a web server.
Sensors are placed at certain points in the building, and all sensors are connected by a single network, either directly or through intermediate devices.
The control interfaces control the smart home system. Controlled devices are lamps, air conditioners, home theater components, etc.
Currently, there is a fairly large variety of intelligent technologies for implementing the smart home concept in global practice. Large and small companies are striving for the mass introduction of intelligent technologies in the everyday lives of people. Table 1 shows popular smart home projects from various companies.

Table 1. Smart home projects
Source: KNX (n.d.)

Company	Producing country	Cost	Abilities
Samsung Smart Things	South Korea	$89.99–$249.99 depending on capacity and equipment	Depending on the price, it can connect simple compatible smart devices, or be a more advanced smart home router of different power levels depending on the task and area of the room.
Xiaomi Smart Home Kit	China	$66	It has a remote control, window and door security sensors, can be controlled with smartphones, and can be integrated with other smart devices.
Tron Project	Russia	Starting from $1,740 depending on the complexity of the project	Offers wireless control of the smart home at the same time from several devices that may provide control of light, curtains, security, heat, ventilation, etc.
Little Bits	USA	$249	The client can independently connect devices to the network using password codes. The set includes a CP3 player and 14 modules.
Insteon	USA	$79.99	Connected to the Apple system, control is offered from any Apple device over light control, smooth shutdown, temperature control, video surveillance of the Insteon system, wireless Internet access, and push notifications when sensors are triggered.

Designing stages for a smart home system. Creating an automated digital home control system involves several steps:

- the first stage is the development of proposals, agreement with the owner of the housing, and approval of the smart home project with a detailed list of equipment;
- the second stage commences as soon as the preliminary design is approved, wherein a detailed design is developed and approved with the participation of an architect and a designer;
- the third stage involves the installation of equipment;
- the fourth stage entails the connection of programming and the debugging of equipment.

This stage includes the work of programmers who set up equipment, components and assemblies, and debug. After that, the system is put into operation.
The experience of using digital technologies in the management of house support systems indicates that these technologies provide a reduction in operating costs by 30%, payments for electricity and heating bills by 20% and 25%, respectively, and payments for water by 40%. Modern digital technologies make it possible to create fully automated houses and transfer many house managing functions to automated devices, and in some cases to fully automate

processes when human intervention is not required at all. These systems are considered in more detail below.

Climate control digital system. This allows users to adjust the temperature regime and air quality in the room depending on the temperature inside and outside, and to adjust the parameters of the thermal energy used in the apartment. Underfloor heating control ensures the maintenance of optimal temperature and humidity parameters in each individual room. The climate control system controls temperature, ozonation, humidity, fresh air intake intensity, and the cleaning system, taking into account the area of the apartment and its separate premises (north, south) and the individual requirements of the people living in it.

Digital control system for a complex of multimedia equipment. This involves sound and video control through throughout the apartment remotely. At the same time, automation can provide editing, setting automatic start times, and related settings for viewing – for example, turning on the air conditioner in the room where the home theater is installed, closing the blinds, reducing the intensity of lighting, etc.

Digital lighting control system. This system provides lighting control remotely. The advantage of an automated lighting control system is the ability to set the intensity of lighting and to turn on and off depending on the time of day and the presence of a person in the room by using information from sensor and timer data. This system also provides the possibility of simulating the presence of the apartment owners.

Intelligent autonomous power supply system. This system ensures comfort, safety, and economic efficiency. The avoidance of power supply interruptions when a centralized power supply is turned off is ensured by the automatic activation of backup energy sources such as solar panels, batteries, chargers, and liquid fuel generators installed in the system and integrated through the software.

Digital security system. This system is an integral part of the smart home. This system provides a security and fire alarm and video surveillance, ensuring protection against short circuits in electrical wiring, water and gas leaks. Security is ensured by triggering a smoke detector and turning on fire extinguishing systems, autonomous power supply, alarms, and automatic calls to the relevant services. Intelligent video surveillance based on the use of the Internet and satellite television networks is also an advantage of modern smart home systems.

At the same time, it should be noted that most household appliances included in the smart home system do not need an automation system, since they have the corresponding functions installed by manufacturers. This includes such household appliances as:

- refrigerators, which are fully automated electrical appliances that operate under a set program;
- air conditioners operating under the set parameters of temperature and humidity;
- washing machines with appropriate programs for managing operating modes and switching on and off functions;
- electric stoves, with automated switching on and turning off mode;
- electric water heaters, with programs that allow them to switch on and off;
- lighting systems, with on or off modes controlled by relays with photodiodes that react to the level of illumination.

This list of household equipment can be continued, considering the wide variety of household electrical appliances already in use and the desire of manufacturers to increase demand for such products. However, it should be noted that most people use the most common functions without applying the full functionality of the TV, air conditioner, or water boiler programs, for example.

Based on the foregoing, the following conclusions can be provided regarding the main advantages of using digital technologies for managing home support systems:

- a comfortable microclimate is constantly maintained in each room of the apartment and for each resident. Air temperature, humidity and other parameters are constantly maintained or

adjusted in each room at a certain time;

- the ability to control each system remotely is provided;
- in case of any malfunction, the system will not allow the devices to be turned on, and will send relevant information to the owner which will help to avoid significant damage in case of emergencies.

The global market for system solutions and automation equipment for building support systems is currently quite developed. The market is formed by a large number of companies, including Crestron, AMX, ABB, GIRA, SIEMENS, Schneider-Electric, MARMITEK, etc. (X10, 2019).

The development of algorithms for controlling home support systems by an intelligent room. Smart room control is performed according to a number of scenarios. In this article, we have considered user scenarios that are developed to increase the level of comfort and energy saving. When developing such a scenario, economically advantageous parameters will also be fundamentally considered.

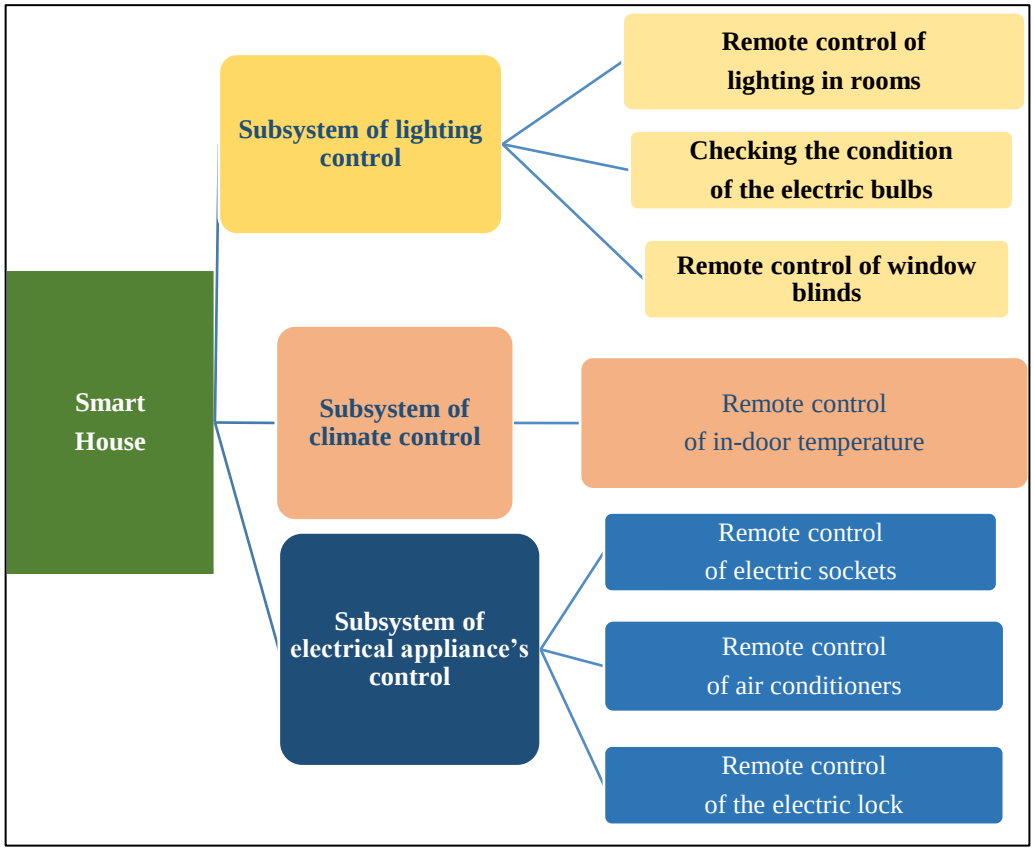

Figure 5. Functional configurations of the smart house system
Source: KNX (n.d.)

The proposed smart room system (Figure 5) monitors three subsystems that perform the relevant functions. The functions of various engineering systems of an object are weakly connected without an automation system, and in an intelligent room they often depend on each other and provide the effective work of initially unrelated tasks. Thus, the components of a digital automation system must be synchronized to work together and, at a certain time interval, provide information exchange between the system components, the dispatching console, and the central controller (if any).

Information exchange is carried out by combining system components through a single data bus or a central controller, which receives digital or analog signals from converters and

modulators that allow receiving information from systems that cannot be included in a single information network for various reasons.

For the most economical and efficient use of system resources, the following automation algorithms should be performed in an intelligent room:

1) algorithm for synchronizing the blinds and lighting system;

2) algorithm of the climate control system;

3) *control subsystem for individual electrical appliances*.

The calculation of economic efficiency for the use of digital technologies in home support systems management. A significant share in maintaining housing cost is occupied by utility bills, including payments for electricity, gas, water, heating, and other components. These costs are determined by tariffs, which are established by legislation. The amount of expenses is calculated if a meter is installed according to the actual consumption of the resource, otherwise as per the established standards. A systematic increase in tariffs predetermines the need to find solutions to reduce costs without reducing the level of comfort of life. As noted above, an effective solution to this problem is the introduction of digital technologies in house support management systems, i.e., intelligent rooms.

It should be noted that people, as a rule, point out the problem of increasing energy tariffs and overlook the types and conditions of the electrical appliances used and the modes of such appliances. The use of energy-efficient electrical appliances is an important energy-saving aspect in a residential area. Calculations point out that, in an apartment, the maximum annual electric power saving when replacing incandescent lamps with LED ones when used for 5 hours a day will be 1,080 kWh. Since artificial lighting is usually used during peak demand, the annual savings in monetary terms in Tajikistan will be from 380 to 550 somoni/year.

Table 2. Unproductive consumption of electrical energy by electrical appliances on standby mode

Source: 1Home (n.d.)

Name of electrical appliances	Unproductive electrical energy consumption, watt-hour	
	Obsolete model	New generation models
Electric stove	6.0	2–4
TV	10	0.1–0.3
Audio System	6–8	3–5
Computer	85	2.1–3.6
Laptop	3	1.5
Cell phone charger	7	0.5–15
Desk phone base	5	0.3–1.1

The ambiguous electricity consumption of old and new generation household appliances in standby mode (not disconnected from the network) should be also noted. Firstly, as can be seen from Table 2, the unproductive consumption of electrical energy by appliances in standby mode is insignificant even for obsolete models. However, when such models are removed from use, significant energy savings can be achieved even in a separate apartment, and even more if residents become in the habit of turning them off from the network.

Table 3 shows the estimated cost of automation equipment for the home support systems of selected residential premises.

Table 3. Estimated cost of automation of home support systems in a residential building

Source: 1Home (n.d.)

#	Item's name	Quantity	Price per unit in TJS	Total amount in TJS
1	Socket S55	16	35	560
2	Switch S55	5	60	300
3	Driver UIO82M	1	970	970

4	Blind actuator Zennio SHUC1C	2	310	620
5	Air conditioning driver Zennio KLIC-TS	3	900	2,700
6	Heating driver ZIO-RQUAD8	1	1,150	1,150
7	Thermometer NTC68	1	150	150
8	Electronic lock Gira Fingerprint	1	1,500	1,500
9	Lighting interface DimInBox	1	2,790	2,790
10	Power supply TDK-Lambda DSP 30-24	1	410	410
		TOTAL	**31**	**10,740**

The available expert assessments on the use of KNX system technology indicate that the annual saving of electrical energy in IR compared to the traditional model is 30%, and the saving of thermal energy is up to 40%. The annual consumption of electrical energy in the considered apartment after automation is set up will decrease by 1,158.6 kWh (Konnex Association, 2004). The use of KNX technology in the digital climate control system allows heat energy consumption savings of up to 40% (Konnex Association, 2004). The decrease in the volume of consumption of electrical and thermal energy is characterized by an increase in the comfort of living conditions, improved health, and a reduction in CO_2 emissions from energy generating sources, i.e., social and environmental performance, which is difficult to quantify. Additionally, with an energy consumption decrease, the energy losses during transmission and distribution are reduced. The payback period for capital investments of the proposed engineering solution is 3.5 years, with a profitability of 28.6%, which indicates the economic efficiency of the proposed integrated solution to the problem.

Conclusion

1. The economies of many countries have an untapped capacity to reduce electrical intensity. However, the measures taken are not enough and most countries still cannot ensure the reduction of inefficient energy costs, although the significance of energy-saving issues is recognized and there is a desire to solve them.
2. The programs aimed at improvements in energy saving and energy efficiency in housing and communal services are considered to be one of the directions for achieving the energy goals of sustainable development (SDG–2030). Untapped energy saving capacity in this area is around 30%, as specified by the energy efficiency barriers outlined in this article.
3. The active development of digital technologies contributes to the intensive development of the smart home concept. Currently, in the global practice, there is a large variety of intelligent technologies for implementing the smart home concept. When a smart home system is installed and used, savings shall amount to up to 25% due to climate control systems and up to 35% due to lighting automation.
4. A comparative analysis of the experience of implementing the smart home concept showed different purposes for its use. However, due to the obvious upward trend in prices for energy resources, the development of mobile technologies, and the increase in Internet access, the interest of the population of most countries in digital intelligent energy management systems for an apartment (or house) is increasing.
5. The advantages of the KNX system, which is applied in this intelligent room creation project, are justified based on a comparative analysis of the advantages and disadvantages of protocols and standards for the main smart home engineering systems.
6. An analysis of actual electrical and thermal energy consumption was performed and the actual invoices for its payment were processed, with the purpose of assessing the economic efficiency of the proposed solutions to the objectives set. The profitability of capital investments in the energy management digitalization system amounted to 28.7%.

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