Prospects for using “Smart House” technology in Africa

F Tangning Jiogap¹ and A Abdryashitova²

¹ Vladimir State University named after Alexander and Nikolay Stoletovs, 87 Gorky St., Vladimir, 600000, Russia
² Vladimir branch of Russian Presidential Academy of National Economy and Public Administration, 59a Gorky St., Vladimir, 600017, Russia

E-mail: tajifirmin2@yahoo.com

Abstract. This study aims to present / illustrate that thanks to the growth of new technologies, the effective use of natural resources can be an important factor for the economic development of several African regions. Africa is a continent with the lowest share of “Smart House” construction technology usage. From this study, the minimum requirements for a “Smart House” were determined depending on the level of income of a person in Africa. The parameters of mobile communications for controlling the elements of a “Smart House” were presented. An algorithm of the “Smart House” element power supply system and its various accessories was formed. The use of a “Smart House” construction technology in Africa will reduce financial costs, improve living conditions and increase the population welfare. The technologies implemented will significantly reduce the daily and monthly costs of running a home in African countries. A general analysis of approaches to data transmission over the Internet is also presented, as this is a very important factor in the control and security of “Smart Houses” in remote access mode via mobile phones or computers. Of course, an indispensable condition is the access to this digital technology.

1. Introduction

With the development of information and communication technology and, more concretely, the evolution of the Internet in the world, specialists in the field have begun to study the extent to which human beings can use the advantages of this new technology in order to improve the living conditions of the population of a given region. These new forms of technology are being applied much more in the following sectors: urbanization and smart city building; construction or renewal of hospitals with medical teleconsultation services; education with distance learning courses; buildings with “Smart Houses” and etc.

As far as smart cities [1; 2] are concerned, we have seen surveillance cameras, intelligent traffic light systems, robotic reception and sales services and many others. In medicine, the traditional relationship that existed between the doctor and the sick improved due to this technology, the queue almost lost its popularity. Distance learning has improved with the possibility of direct and visual communication in real time between the learner and the tutor. With “Smart Houses”, there have been some anomalies [3-5] that suggest that the policy adopted in developed countries cannot be adopted in poor or developing countries. In principle, it should be noted that the introduction of new technologies is intended not only to promote the development of regions and strengthen the security of property in
the home, but also to promote the reduction of spending on services for the maintenance or consumption of a house.

Originally, the “Smart House” concept derives from the concept “Passive House” or “Zero House” (ZeroEnergyBuilding). The concept of a “Passive House” [3] was first proposed by Dr. Wolfgang Feist (Germany) and Professor Bo Adamson (Sweden) in 1988. At that time, this meant houses that did not require significant expenditure of thermal energy for heating. The main task that is set in the construction of a “Passive House” is to preserve heat. This goal is also relevant for the existing structures, as well as for more modern “Smart Houses.” Measurements carried out after the construction of the first “Passive House” showed a real reduction in energy consumption for household needs by up to 80% (compared to ordinary houses). Up to this point, the relevance of ensuring resource saving and energy efficiency in the construction of smart houses remains, while digitally controlled elements are being added. The modern legislation promotes energy-efficient technologies around the world. European standard EN 15232 (“Energy Characteristics of Buildings. The Meaning of Automation, Management and Control of Buildings”) [6] was developed and implemented in conjunction with the European Directive on energy performance of buildings 2002/91/EC. The standard describes a method for evaluating the impact of automation and control systems on the energy consumption of buildings [7]. For this purpose, four performance classes are introduced, from A to D.

The question we can ask ourselves today is what is the definition of a “Smart House” as will be described in our manuscript and what is its purpose? Most Western definitions [8] agree that a “Smart House” is a set of technologies that allows you to connect various home systems, providing them with an ability to interact and remotely control life-support systems, with energy and resource-saving characteristics. Our definition is more specific; let's say that in principle, it is a set of hardware complexes that have smart properties due to the smart software that transmits comfort to the owners using artificial intelligence technology adapted to the natural resources of the region. Hence, a “Smart House” [2] will be a dynamically functioning object, that is, it should be adapted to the standard of living of citizens and make decisions individually according to the following main scenarios: change of state of the object after an event, change of state of the object according to a schedule and change of state by personal will.

So, do “Smart Houses” in developed countries fit this definition? How can African houses adapt to this definition? Can solar energy, which is an abundant and sufficient resource in Africa, promote the development of “Smart Houses”? What technology should be used to facilitate everyday life with “Smart Houses” in Africa? These are all questions which will contribute to our research in this manuscript.

2. Materials and Methods
The article uses methods of analysis, synthesis and comparison to identify some of the requirements necessary to build “Smart Houses” with minimal costs. Also an algorithmic approach is used to the organization of power supply systems of the smart house.

2.1. Development problems, solutions and some requirements
According to analysts' calculations, the spread of “Smart Houses” in the global market in 2017 amounted to 14.7 billion of the US dollars.

At the same time, experts predict that in global terms, 10% of households will have smart houses by 2025. In advanced economies, the spread rate will be significantly higher: 60.7% of households are expected to have smart devices in by 2021, compared to 32.5% in 2017. What about Africa?

In many European countries, the state applies tax incentives for the construction of houses with “green” technologies, which are related to the concept of “Smart House”, thereby helping to minimize the cost of supplying equipment and resources. Thus, in Italy, the cost of electricity for buildings certified for high energy consumption class (A-class) is reduced by half.
It is worth noting that the problem of developing smart houses is also reflected in official strategic, systematic and forecast documents. For example, in the forecast for scientific and technological development of the Russian Federation for the period up to 2030 among the promising markets and product groups, compact energy sources for long-term power supply of mass-use digital devices and smart house systems are identified, characterized by “digitalization of household devices, combining them into a single network capable of both automatic maintenance of optimal parameters and of change by remote control”. In addition, there are robot assistants that move freely and interact with people, as well as personalized services that are linked to the consumer needs. All these areas are connected in one way or another with the development of “Smart House”, the meaning of which is currently taking on new outlines in the context of the digital economy development.

Note that a “Smart House” is not always supposed to be very beautiful and expensive. The main feature is that it should have the following artificial intelligence properties namely; automatism and decision making without the input of the human being. All this in order to make life easy for the owner (inhabitant) of the House. Can life be made easy, if the expenses incurred are greater than the results obtained [9]? Our answer to this question will be negative and the information received from this link [2] will give us a very specific case example. Since the mobile phone is no longer a luxury device in almost every corner of the world, it would also be very useful to have a Smartphone in order to give the user, the power to control certain events remotely. In this case, the sine qua non condition would be to have a more or less considerable internet [10] speed in the region (see Table 2).

Although a good external structure of buildings can promote the proper functioning of a “Smart House”, if we wait for the modernization and total transformation of houses or the construction of new cities in Africa, with the high percentage of poverty in this continent, it will never be able to develop and compete with other continents. For this reason, we propose to use natural resources like solar energy [9-13] in order to improve the daily lives of people in general with a minimum of expenditure. The more the population has a balanced spending curve in all sectors, the more profitable it makes savings and thus improves its standard of living.

2.2. World experience in using a “Smart House” construction technology

The program “Digital economy” [10] specifies the need to create an environment for the development of smart cities. In this case, a “Smart House” can be considered as a structural unit of a smart city.

Despite all the advantages of using “Smart House” technologies and concepts, there are examples that prove that these formats need to be approached carefully. So in 2002, 25 kilometers from Seoul, the construction of “SongDo” [9] – “the city of the future,” which was supposed to change the rich residents’ idea of a daily life in a modern metropolis of the capital of South Korea. The construction of the first smart city cost 40 billion dollars. Residents were offered a new eco-friendly environment with a large number of parks and green areas, as well as everything you need within walking distance – shops, entertainment, hospitals and schools. The city was built with the use of advanced smart house technologies. As a result, the investors were not able to fill the city with people, despite all the advantages and technologies of such dwellings. The cost of apartments in “SongDo” was quite high and potential customers did not dare to make such a purchase.

Today, the concept of a “Smart House” is used for the economy of resources (e.g. Austria, Germany and Switzerland) and for intelligent housing, which allows the advance a home comfort level (e.g. the USA, UAE, Japan, Malaysia, Singapore and South Korea).

The most undervalued continent, in terms of implementing “Smart House” technologies, is Africa. Many people in Africa do not have access to grid electricity, but the continent is rich in inexhaustible natural resources, such as solar energy [13]. Individual solar energy is a way to safely and efficiently equip your household. Solar lamps, sockets and phone chargers are among the most popular products.

Another resource [15] in Africa is wind, which can also be used as a base for providing energy to individual households.

3. Results and Discussion
3.1. The ratio of a person's income to the requirements for “Smart House” technology

From the definition given in the introduction of this manuscript, we can say that for a house to be smart, it should have the minimum requirements presented in Table 1.

Let us consider S as a system that represents the different riches that a person living in the African continent can have. Let us form an interval in the form \( R_i \leq R_i \leq R_i^+ \), where \( R_i^+ \) will be the minimum limit and \( R_i^- \) the upper limit for an indeterminate factor \( i \) (the different riches one can have).

The inequality above means that \( R_i \) can take any value from the interval. We can also determine that any type \( R_i \) belongs to a class \( K_J \) (1):

\[
K_J = <K_{1J}, K_{2J}, ..., K_{nJ}>,
\]

where \( K_J \) – type of house or dwelling: “low”, “average”, “high”.

To be even more precise, it will be necessary to use the fuzzy logic that relies on the mathematical theory of fuzzy sets in order to be able to determine the degree of belonging \( \mu \in [0, 1] \) to the class \( K_J \) (J – the index of the Class K). The formalization of such a description with the help of the linguistic variable \( <(\text{number of wealth of a person})_{RP}, K_J, [R_i^-, R_i^+]> \), where \( K_J \) – will vary depending on the type of resource used (\( RP \) – type of resource (financial, material, etc.)). Thus it will be possible to determine the belonging of a person to one of the 3 classes.

**Table 1. Minimum requirements of a “Smart House”**

| Device or Parameters | House Type | House of a person with a low income | House of a person with an average income | House of a person with a high income |
|----------------------|------------|-------------------------------------|------------------------------------------|-------------------------------------|
| Energy source        | Exist (solar) | Constantly (solar or other source) | Constantly (solar and other) |
| The power of the energy supplied | 3–5V: for sensors, detectors; 110–230V for other devices | 3–5V: for sensors, detectors; 110–230V for other devices | 3–5V: for sensors, detectors; 110–230V for other devices |
| Internet Network     | Not required if it is expensive | obligatory | obligatory + high bandwidth |
| Devices (components) required | Smart sockets | Device Control Center | Device Control Center |
| Minimum of devices   | 2 | 4–5 | Not less than 6 |
| Knowledge of the population | Minimum knowledge required | Average knowledge required | Average knowledge required |
| The average characteristics of the Internet speed | Inbound connection: 10 Mbps. Outbound connection: 10 Mbps. | Inbound connection: 25 Mbps. Outbound connection: 30 Mbps. | Inbound connection: 30 Mbps. Outbound connection: 40 Mbps. |
| Type of data to process | Sound signal and text | Text and video messages | Text and video messages |

3.2. Mobile communication requirements for managing a “Smart House”

Based on the following Table 2, we can have an idea [16] of a mobile technology type to use in order to control the house remotely.
Table 2. Types of mobile technology with its different parameters

| Parameters                     | Technology | Network mode (mobile standard) | Parameters       | Internet speed          | Ratio of data transfer between different technologies | Delay while listening to the sound | The number of connected devices per meter | Viewing online video HD (from 720p) (buffering) |
|--------------------------------|------------|--------------------------------|------------------|--------------------------|------------------------------------------------------|------------------------------------|------------------------------------------|-----------------------------------------------|
|                                |            | GSM                            | 2G               | From 53.6 KB/s to 220 KB/s | Y/100                                                | Up to 1s                           | X/130                                    | 4000s                                        |
|                                |            | EDGE                           | 3G               | From 384 KB/s to 42 MB/s  | Y/10                                                  | 0,01                               | X/25                                     | 300s                                         |
|                                |            | GPRS                           | 4G               | From 100 MB/s to 1 Gbit/s | 20Y                                                   | 0                                  | X/1000                                   | 30s                                          |
|                                |            | UMTS                           | 5G               | Up to 20 Gbit/s           |                                                       | 0                                  |                                         | 0,1-1s                                       |
|                                |            | UMTS+ HSDPA, HSDPA+            |                  |                          |                                                       |                                    |                                         |                                               |
|                                |            | LTE                            |                  |                          |                                                       |                                    |                                         |                                               |
|                                |            | WiMAX IMT-Advanced             |                  |                          |                                                       |                                    |                                         |                                               |
|                                |            | There is no accepted standard  |                  |                          |                                                       |                                    |                                         |                                               |

3.3. The main components for the realization of “Smart Houses” in developing countries

After our analysis, we found that there are many electronic devices that have been created to facilitate the construction of “Smart House”. Table 3 lists the main components used to add artificial intelligence properties to these homes. Prices may vary depending on the brand and quality of the product.

Table 3. The main components for the realization of a “Smart Houses” in developing countries

| The name of the device | Role |  |
|------------------------|------|---|
| 1 The control center of your “Smart House” + remote control | Connects all sensors into one for control |  |
| 2 Wireless motion sensor | Detects the movement of any object |  |
| 3 Sensor for detecting the opening or closing of an object | Allows one to detect the state of the object (door / window): open or closed |  |
| 4 Water leak sensor | Detect water leaks from a pipe |  |
| 5 Warning signal | Sets a siren off after a certain action |  |
| 6 Sensor climate control | Controls and regulates the climate (temperature) in the house. Among other things, it can determine the chemical composition of air and carbon dioxide; it examines humidity |  |
| 7 Light sensor | Allows you to turn the light on and off; sets the brightness level of the lighting |  |
| 8 Sun protection sensor | Responds to external factors to control curtains, blinds, etc. (protects the room from the sun) |  |
| 9 Sensor for water supply | Supplies the garden (flowers) with water |  |
| 10 Smart sockets | Control electrical appliances. Remotely enabling and disabling equipment |  |
| 11 IP video camera | Provides remote access video surveillance: motion detector |   |
Several companies (INSYTE, SMARTHOF, SMARTTHINGS, INSTEON, EZVIZ, XIAOMI, etc.) located in different locations around the world sell these products and install them at exorbitant prices, especially in luxury homes. This means that only people with sufficient financial support can afford such comfort.

As for these devices, one should be careful about their use in African regions, since there are some natural challenges in most African countries, the most important being the high temperatures. Apart from this, there are many other elements (the presence of dust in the air, etc.) that can also damage or adversely affect their operation. That said, it is necessary to know that the wrong choice of devices will lead to the incorrect operation of the home automation system. To adapt to these conditions, it will be necessary to: carefully study the operation of these devices; know their main features; collect (evaluate) the pros and cons on the use of devices in the region, taking into account the climatic conditions of the terrain.

The minimum prices of the devices in Table 3 range from 35 to 40 US dollars; the charging voltage (energy) is 5V, with the exception of the control center, which uses 230V. This minimum price range was set on the Russian market in March.

3.4. The organization of the power supply system of the elements of a “Smart House”

The algorithm that we propose in figure 2 considers beforehand that at the beginning of the procedure of energy supply in smart homes, the choice is focused on the use of renewable energy, which is the sun. It is preferred over other types for the following reasons: the resource is inexhaustible; it does not pollute the atmosphere; it is more economical; the devices used for its transformation are mostly made up of recyclable elements.

Each type of energy in one way or another is likely to make reserves to ensure its consumption without interruption. Based on our analysis, we found that the minimum costs of installation and purchase of materials can vary between 730 and 1000 US dollars. They can be used for a minimum period of 20 years (warranty periods) [17] without any difficulty or major problem in general, since the actual life of a solar plate is beyond this period.

Figure 1 shows the period at which the consumer of public energy will reach and exceed the peak of the consumer of solar energy in terms of expenditures.

![Figure 1. The economic efficiency of using solar energy in “Smart Houses”](image-url)

As we said in the beginning, the construction of smart houses in Africa requires the establishment of an unusual plan resembling that of Figure 2. Permutation of energy resources at the scheme level is possible if, and only if, certain conditions are met. In order to switch from one energy source to
another, it will be necessary that the expenses of the new energy source should be reduced compared to the other.

Based on the analyses carried out, we found that the system used in the developed countries could not be fully copied or adapted in most African countries due to the following reasons: the presence of tropical climate; the existence of different technologies during the construction of buildings; the delay in the use of new information and communication technologies; the inadequacy of electrical energy in many regions; poor stewardship of state institutions and many others.

Figure 2. System of power supply and interaction between the main elements of a “Smart House”
Figure 2 shows how to organize the interactions between different important elements for the effective construction of a smart house. There is the source of energy that feeds the control element of all devices, which, through the Internet network, can give us an opportunity to remotely control the house operation online.

4. Conclusion
To conclude, it will be said that the use of Natural Resources, preferably solar energy is a very important factor for the development [18] and construction of “Smart Houses” in Africa. It only suffices to adapt this resource to existing technologies such as information and communication. In recent times, we are witnessing a decline in solar energy production, which is not an important aspect to promote the development of “Smart Houses” in Africa. The higher the demand for components (devices that promote the automation of buildings), the lower the cost of production and thus the purchase price of materials on the market will decrease.

The question of the use of solar energy is a bit complex in the sense that there is competition in the world market with the “Black Gold” that is oil [19]. Several developed countries do not have an interest in encouraging investment in this area, since their exploitation and financial source are mainly based on oil. To make life more comfortable in most African regions, it would be necessary to make understand the negative consequences to a number of countries, the problem of global warming. More than 35% of the population in Africa does not have constant electricity. To have “Smart Houses” will require a constant and low-cost source of energy [20]. Among the advantages of “Smart Houses” include: environmental protection; energy saving used; high safety to its users; comfort; adaptation and cost-effectiveness of energy consumption; the use of intelligence on power grids; the development and introduction of new technologies; effective control of the balance between production and consumption; the facility of the population census; automation of the decision-making process.

When we look at developed countries now, we see that in order to have a “Smart House”, you have to be rich and invest a lot of money [21]. This allows you to introduce a large number of sensors and detectors into your home. Given the problems that Africa faces, despite its present renewable resources, it is necessary to create a new methodology to make it easier to build “Smart Houses” in Africa. To do this, it will be necessary to allow the entire population to have access to the energy that is considered the essential basis for powering the various components (devices) used to create a “Smart House”. Note that the more and the number of components is used, the more abundant the House has properties that will turn it into a “Smart House”.

References
[1] Abu-Matar M and Mizouni R 2019 Variability Modeling for Smart City Reference Architectures 2018 IEEE Int. Smart Cities Conf. ISC2 2018
[2] Okai E, Feng X and Sant P 2018 Smart Cities Survey IEEE 20th Int. Conf. High Perform. Comput. Commun. IEEE 16th Int. Conf. Smart City; IEEE 4th Int. Conf. Data Sci. Syst. 1726–30
[3] Tataru A C, Tataru D and Stanci A 2018 Possibility to implement the concept of passivhaus in russia 18th Int. Multidiscip. Sci. GeoConference SGEM 2018, 02-08 July, 2018 723–30
[4] Lytvyn V, Vysotska V, Mykhailyshyn V, Peleshchak I, Peleshchak R and Kohut I 2019 Intelligent system of a smart house 2019 3rd Int. Conf. Adv. Inf. Commun. Technol. AICT 2019 - Proc. 282–7
[5] Arauz J 2019 Smart Cities and the Dire Need for a Course Correction IEEE Int. Smart Cities Conf. ISC2 2018
[6] Mariotti F 2016 Overview of EN 15232 standard on impact of Building Automation, Controls, and Building Management | Build Up
[7] Mehdi L, Ouallou Y, Mohamed O and Hayar A 2018 New smart home’s energy management system design and implementation for frugal smart cities 2018 Int. Conf. Sel. Top. Mob. Wirel. Networking, MoWNeT 2018 149–53
[8] Adeyeye K, Ntagwirumugara E, Colton J and Ijumba N 2018 Integrating Photovoltaic Technologies in Smart Homes 2018 Int. Conf. Adv. Big Data, Comput. Data Commun. Syst. icABCD 2018

[9] Garfield L 2018 Songdo, South Korea has an eco-friendly design - Business Insider Bus. Insid.1–15

[10] Tangning Jiogap F 2020 The Role of Internet for Digital Economics in Developing Regions Lect. Notes Networks Syst. 87 278–90

[11] Ebhota W S, Eloka-Eboka A C and Inambao F L 2014 Energy sustainability through domestication of energy technologies in third world countries in Africa Proc. Conf. Ind. Commer. Use Energy, ICUE 1–7

[12] Mludi S and Davidson I E 2017 Dynamic analysis of Southern Africa power pool (SAPP) network Proc. - 2017 IEEE PES-IAS PowerAfrica Conf. Harnessing Energy, Inf. Commun. Technol. Afford. Electrif. Africa, PowerAfrica 2017 109–14

[13] Zhang H, He B, Guan Y, Ma M, Li Y and Song S 2017 Assessing the potential for global solar energy utilization Int. Geosci. Remote Sens. Symp. 2017-July 1618–21

[14] Chidzonga R F and Nleya B 2019 Energy Optimization for a Smart Home with Renewable Generation 2019 IEEE PES/IAS PowerAfrica 694–9

[15] Botma J, Hancke G P and Ramotsoela T D 2017 Solar home energy management system 2017 IEEE AFRICON Sci. Technol. Innov. Africa, AFRICON 2017 1575–80

[16] Risteska Stojkoska B L and Trivodaliev K V. 2017 A review of Internet of Things for smart home: Challenges and solutions J. Clean. Prod. 140 1454–64

[17] Razongles G 2012 Study of photovoltaic modules after 20 years of Operation Association Hespul ed G Razongles, L Sicot, F Barruel and L Clavelier (France)

[18] Acone M, Romano R, Piccolo A, Siano P, Loia F, Ippolito M G and Zizzo G 2015 Designing an energy management system for smart houses 2015 IEEE 15th Int. Conf. Environ. Electr. Eng. EEEIC 2015 - Conf. Proc. 1677–82

[19] Mulaudzi S K and Bull S 2016 An assessment of the potential of solar photovoltaic (PV) application in South Africa 2016 7th International Renewable Energy Congress (IREC) (Hammamet, Tunisia: IEEE) pp 1–6

[20] Tazoe T, Matsumoto J, Ishi D, Okamoto S and Yamanaka N 2012 Novel scheduling method to reduce energy cost by cooperative control of smart houses 2012 IEEE Int. Conf. Power Syst. Technol. POWERCON 2012

[21] Mtshali P and Khubia F 2019 A smart home energy management system using smart plugs 2019 Conf. Inf. Commun. Technol. Soc. ICTAS 2019 1–5