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The Effect of Energy Framework in Smart Building Integration into a Smart City

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Abstract

Numerous energy frameworks have been established to assess the criteria for smart buildings. However, most of these frameworks fail to account for the specific standards and needs of individual cities. This study aims to address the gap that exists in many energy frameworks used for evaluating buildings. One of these frameworks, known as the Information and Communication Technology (ICT) Framework, has been explored to bridge the gap and establish connections between the domains of buildings and the unique contexts of the cities in which these buildings are situated. As part of this investigation, a case study was conducted on the Arfa Tower in Vilnius, Lithuania. Additionally, a survey study was undertaken to evaluate energy performance in Jordanian buildings, using a questionnaire that encompasses the key aspects of the ICT-Framework. The results of the study revealed significant progress in the areas of smart energy and smart environment. However, there are challenges in the smart data field, primarily due to the absence of data management technology in buildings. In the Jordanian context, the study found that 30% of the participants do not utilize insulation materials, and 43% do not have insulated windows. This implies an increased rate of heat transfer in these buildings. On the other hand, 61% of homes use Light Emitting Diode (LED) lighting systems, while 81% still rely on traditional lighting control systems. This suggests a lack of modern technologies like sensors for lighting control. Notably, 51% of the surveyed population had heard about smart building technology techniques; however, they did not fully grasp their significance. This highlights the need for energy associations and government agencies to raise awareness about the importance of modern technology in buildings and to activate energy auditing programs for buildings in Jordan.

Keywords: Smart Building, Smart city, Framework .

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تأثير إطار الطاقة في تكامل المباني الذكية داخل المدينة ذكية

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ملخص

يوجد هنالك وفرة من أطر الطاقة والتي تم وضعها لدراسة معايير المباني الذكية. ولكن معظم هذه الأطر لم تأخذ في عين الاعتبار معايير المدن نفسها الموجودة هذه المباني داخلها. ان هذه الدراسة تهدف إلى استكشاف الفجوة في غالبية أطر الطاقة التي يتم من خلالها تقييم مثل هذه المباني. حيث تمت اعتبار أحد هذه الأطر والمعروف باسم إطار عمل تكنولوجيا المعلومات والاتصالات، وللوصول الى النتائج المرجوة وسد الفجوة وربط مجالات المباني بمجالات المدن التي تقع فيها هذه المباني. تم أخذ عينة دراسة لاحد المباني (ARFA) والموجود في ليتوانيا في مدينة فيلنيوس. حيث تم إجراء دراسة مسحية لتقييم أداء الطاقة في المباني الأردنية باستخدام استبيان يتضمن المحاور الرئيسية لإطار عمل تكنولوجيا المعلومات والاتصالات. وأظهر التحليل الذي تم الحصول عليه لمبنى ARFA أنه حصل على نتيجة تقييم بنسبة 77.5٪. كما أظهرت النتائج التطور الكبير في قسم الطاقة الذكية والبيئة الذكية، على عكس مجال البيانات الذكية بسبب غياب تقنية إدارة البيانات في المبنى. أظهرت نتائج الدراسة التي تمت على المباني في الأردن أن 30٪ من المشاركين لا يستخدمون أنظمة العزل وأن 43٪ منهم يستخدمون النوافذ التقليدية. هذا يعني أن هناك زيادة في معدلات انتقال الحرارة. وكذلك فان 61٪ من المنازل تستخدم أنظمة LED للإضاءة والتي تعطي مؤشراً جيداً، ولكن 81٪ منهم ما زالوا يستخدمون نظام الإنارة التقليدي الذي يعطي الانطباع بغياب التكنولوجيا الحديثة مثل أجهزة الاستشعار التي تتحكم في أنظمة الإضاءة. اضافة الى ذلك فان 51٪ من السكان قد سمع عن تقنيات البناء الذكية ولكنهم لا يدركون أهميتها مما يكشف عن غياب دور جمعيات الطاقة والحكومة في عملية التوعية بضرورة التكنولوجيا الحديثة في المباني والذي بدوره يعني ضرورة تفعيل برنامج تدقيق الطاقة للمباني في الأردن.

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Introduction:

The world urbanization prospects report issued by UN (2018) states that currently the world population is increasing dramatically and it is expected that 68% of the population will live in the urban areas within the coming 30 years. Figure 1 represents the dramatic rise in the world population. Projections and estimates of the international urban and rural populations and their main urban settlements should be studied and updated. This was issued by the UN’s population division, the Department on Economic and Social Affairs (2018). These reliable numbers play a huge role in the data needed for the growth, sustainable development and policies planning of urban cities. Data collection involves many sources such as health information systems and the use of remote-sensing strategy and satellite images. Evidence-based studies and results on urbanization can help in creating a systematic track with levels and trends in international expansion. Cities, for example, only occupy 3% of the earth’s land, yet they account for around 60-80% of energy consumption and 75% of carbon emissions (UN, 2015). Air pollution indications, on the other hand, are worryingly high in number. Cities, constructions and factories emit high number of greenhouse gases that worsen global warming and increase the risk of natural disasters. The human, social, and economic losses could be prevented by smart building urban areas. Such impact can have a negative consequences on everyone’s life including health and productivity. For instance, the high risk of natural disaster that would destroy homes and economies. Figure 2 shows the effect of population increase with respect to energy consumption.

All cities around the world face a major constrains to create a viable environment and a standard of living. Taking into account the population increase, critical infrastructure, shortage in land’s resources, waste management and the development of required essential services (Fokaides, 2017). In 1989, the Intelligent Building Institute of the United States first described the smart building as an ideal efficient environment that structures application stages, systems, services and management. Recently, the effect on the operational efficiency, influence of its occupants, the engagement of data collection and communication technologies were adopted (Albino & Berardi, 2015). Furthermore, there is a lack of implementation of using new materials or new technologies in the smart cities projects. For that reason, investigating the features of the policy and construction material, which will be adapted in future buildings to be a digital platform in smart cities, is essential. There is a pre-requisite to identify the integration requirements for construction projects that have to be met in order to be consistent with the overall context of a smart city. The digital platform, compliance of the buildings with the city's ecosystem, adaptability to the environment, information collection and transmission have all become obstacles in the smart building and cities development (Camero & Alba, 2019). There was a serious consideration to the process of improvement for new approaches based on the arrangement of many individual fields to explain the obligatory conditions in smart building incorporation into a smart city. The author clearly defines the essential parameters that must be considered to be in a smart city (Lombardi & Giordano, 2012).

The smart cities were classified into three types as "three distinct phases of how cities have embraced technology and development, moving technology approaches-driven, to the city government council and the civilian concern."

> Smart Cities 1.0 (Technology-driven): single-stand with different technologies solutions for city control without analyzing the overall application impact on citizen well-being.
> Smart Cities 2.0 (Technology Availability): execution of smart technologies and other new innovations lead to industry growth and higher quality of public services for citizens and visitors
> Smart Cities 3.0 (Civilian Co-Creation): this model can create attention of people to work together with the municipality. This can be done by applying the profit for central digital platforms and technologies via transforming the city into a platform of information, projects, services, businesses and sectors.

The rapid expansion of new technologies is defining the future of smart cities. The substitution in the technologies was recently defined by accepting the internet of things (IoT), 5G technologies, and sensors as well as the geographic information systems (GIS) and global positioning system (GPS). Moreover, artificial intelligence, robotics, virtual reality and blockchain technology can be added to the list. It is essential to recognize and be familiar with the specific technologies included in the smart buildings in order to attain the final purpose of urban conversion into the truly smart cities of the future" (Fourtané, 2009). The full integrations of smart buildings into the smart city platform were included. Globally, buildings consume about 40% of the energy, 25% of the water and 40% of the land resources while buildings produce about 33% of Greenhouse Gas (GHG) emissions (UNEP, 2016).. On the other hand, 60% of the world's electricity is consumed by commercial and residential buildings consume

(UNEP, 2016). Figure 3 exhibits the percent of energy consumption in building sectors worldwide.

Several theoretical energy frameworks of smart buildings integrations into smart cities were developed lately by researchers which led to creating full definitions for smart buildings. This was usually mixed with zero energy or stand-alone buildings. The differences start at an early stage (design stage). During developing the digital model, the efficiency of the energy for the future building is analyzed and simulated taking into account the direction and the location. The facilities of the urban infrastructure along with other environmental circumstances use the newest and maximum effective technological solutions of the materials used in building and products based on ICT. This is done also with building services and construction processes. The following relevant energy frameworks in smart building integrations were created by researchers and energy associations:

1. The evaluation framework for smart buildings: the researcher has presented the focal assessment criteria that include the intelligent policy, automation system, management system, sensors, smart materials, BIM design technologies, and renewable resources. Those are in addition to other minor factors for the selection of intelligent materials from the designer's point-of-view. Furthermore, major quality condition components were specified as the main criteria besides the features of environment and energy, room flexibility, cost-efficacy, customer luxury, working efficacy, safety, culture, and technology. The work features allow the project team to ensure energy efficiency while providing ultimate worth living values (Omar, O, 2018).
2. The building intelligent quotient: this is an online framework that was created in 2005, it is containing more than 300 questions related to the rating of the intelligence level index for buildings, which was presented by the Continental Automated Buildings Association.
3. The below issues are considered while choosing the intelligent components appropriate to link the network automation. Those issues are designed by BiQ guiding. (Welcome to the Building Intelligence Quotient (building-iq.com)):

    A. Systems and structure

    B. Communication

    C. Facility management applications

4. Honeywell Smart Building Score (HSBS) was initiated in 2015 where the main criteria should be implemented worldwide for smart buildings assessment. It depends on Fifteen (15) technology aspects with three (3) main impact criteria: Safety, green, and productivity (Ernst & Young, 2015). Table 1 presented the Honeywell smart building components.

The smart city assessment categories: the researcher determined that there are different concepts that have been selected for smart city assessment as there is no agreement on the smart city definition. As well as in the priorities of the developers and the needs of the end-users (Sharifi, 2020). The main problem of this study was that all of the energy frameworks currently used considered only the domains of buildings to meet the required conditions without taking into account the domains of the cities in which these buildings are located. Therefore, this study deals with one of these frameworks, known as ICT-Framework to link the domains of buildings with the domains of the cities in which these buildings are located. Thus the final evaluation is expected to be more realistic. This will provide the consumers and clients with further realistic and personalized solutions which result in easier life in terms of eco-system, environmental-system. Based on the varying lifestyle conditions inside or outside of the building. When the smart buildings are organized into a smart city network platform.

So the purpose of this research is to fill the gap between the smart building integrations and the digital platform for the external world smart city by creating a standard platform for the owners, the developers, and the contractors. This can be achieved when the target group builds future intelligent buildings in smart cities. Additionally, to know the ability to expand smart building integration into a smart city by smart building performance forecasting based on the digital building and digital city modeling by receiving and sharing the data with smart central building inside the city. And finally, to develop plans of the smart city by enabling different building services to interact with each other such as eco-friendly construction materials, sharing best practices between ICT, energy efficiency

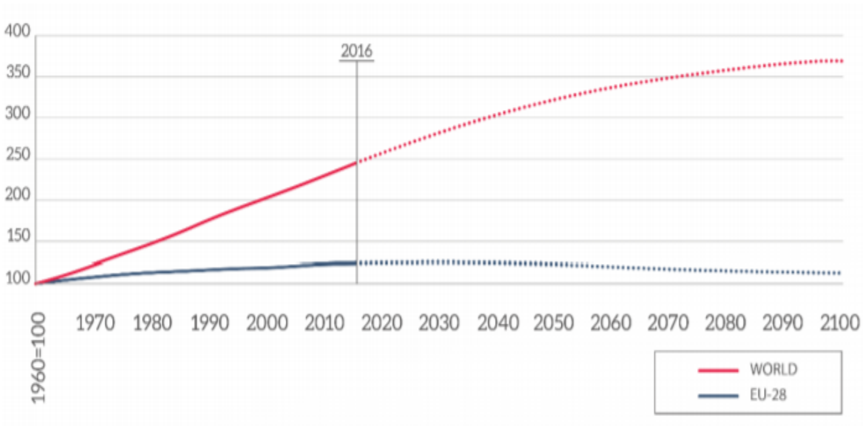

Figure (1) Population growth by 2050 in world countries (David, E, 2019)

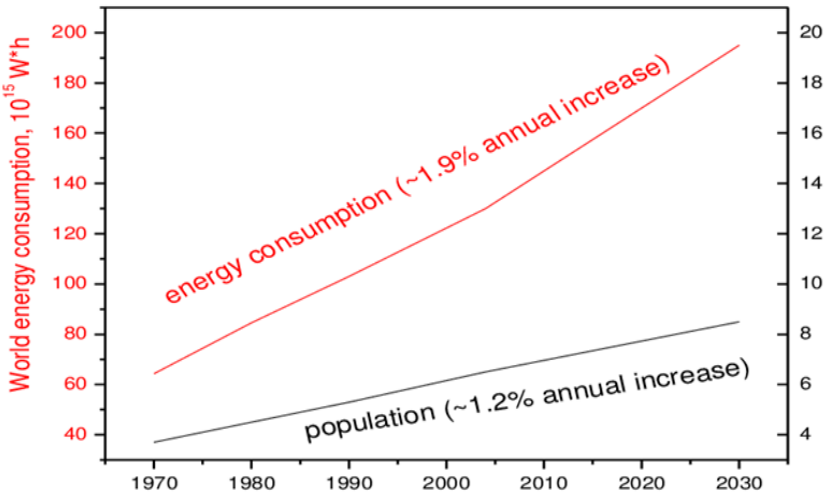

Figure (2) The relation between population and energy consumption (Oleg, F. 2013)

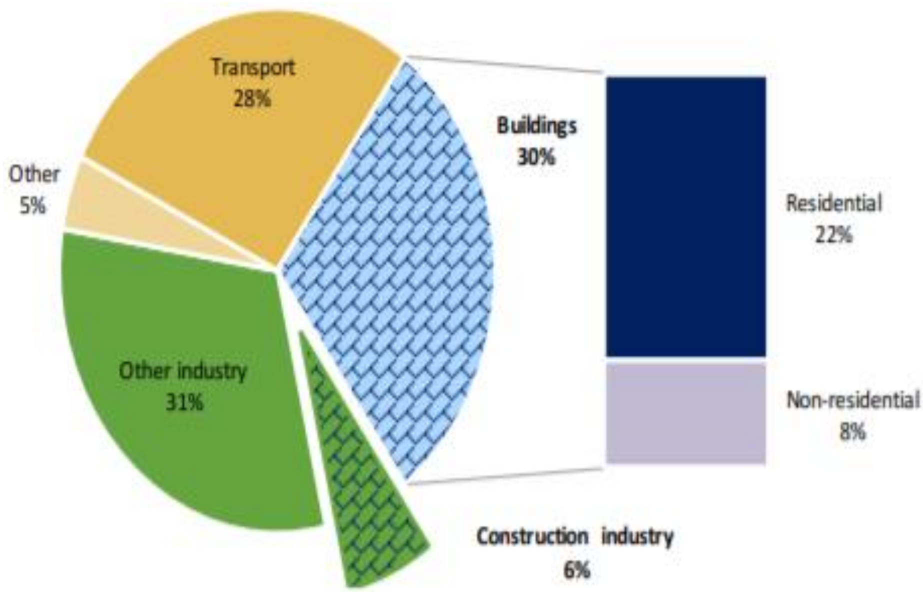

Figure (3) Global energy consumption in building's sector (UN, 2017)

Table (1) The Honeywell smart building aspects

Green	Safety	Productivity
Sources of Energy	Security, vehicle, material	Indoor air and water quality
Utility sources	Fire safety	Circulation, vehicle, material
Management of temperature	Gas safety	Personalization
Management of Electricity	Worker safety	Connectivity
Utility management	Disaster reaction	Energy quality

System Description:

For the purpose of achieving the objectives of this study, it is always important to have a systematic approach for the framework of research implementation. The research data will be gathered from various resources: project websites, books, journals, online databases and project analyses. By studying scientific literature and the existing international project example, the features of smart buildings that are expected to be assumed in smart cities will be recognized. Additionally, a comparison of these scientific papers with the current framework information communication technology framework (ICT- Framework) will be conducted. Such frameworks are used currently by some cities around the world to create a full picture about the advantages and disadvantages. Moreover, a smart building located in Lithuania named, Arfa building, and an online questionnaire were adopted to study the behavior of residents and clients in the field of smart building's integration's in Jordan while comparing the results with smart countries worldwide. This will give a full understanding of the topic and establish a probable platform to investigate the factors of the framework parameters that affect in extensive details of smart buildings as well as in smart cities. So, in order to clarify the concept of energy framework in smart building integrations into a smart city, table 2 contains the main domains of the current information communication technology framework ICT that used recently by cities worldwide and the description for each of them. All of these domains can be observed and managed very efficiently if all construction elements inside the city are interconnected into one ICT network. This will lead to creating a performance baseline for smart building integration by achieving the description for each domain.

Bernstein (2016) presented the process of evaluation based on the ICT framework. This indicates how the selected smart building integrations have a systematic level linked with the description of smart city domains. The highest score is eight (8) points for each domain while the smart building integration has a value equal to one (1) point and all levels are presented in priority order. In order to achieve a higher level, the domain's description on ICT framework lower has to fulfill all lower levels. Built on the required features inside the city, some domains might require more development than others. This means that the total improvement of the project does not achieve the highest scale of eight (8) in every domain. Table 3 shows the integration levels assumed from the research study (Bernstein, R, 2016).

Table (2) Smart cities domain & description based on ICT framework (Ahuja, A. 2016)

Smart city domain	Description
Smart Energy	Response to the power changes when connected to the grids. Information gathering, study, comparison and recollect from previous developments: editing decision-making and control to ensure the mainly effective performance.
Smart Mobility	gaining information’s from surrounding participants about their mobility and needs, link to the networks facilitates efficient logistics and infrastructure, consider past problems, addressing them in accordance with practical trends and development strategies.
Smart Life	Disaster reaction, security, health, comfort, and indoor life quality assurance, with automatic store, analyze, compare data, and make informed decisions.
Smart Environment	inspection, analysis, and adjustment to the external atmosphere and the ability to receive information from significant actors and institutions. Online comparison and management of renewable resources, eco-friendly materials, waste, and validation of decisions based on previous reports.
Smart Data	arrangement of collected data by analysis, comparison and justification. Reports and communication of collective data to different actors responsible by remote control.

Table(3) Smart building integration levels based on ICT framework (Bernstein, R, 2016)

Smart building integration levels	Level Description
Network level	Connection to a wired or wireless network.
Information level	Response to any change in the environment or grip of the amount of a given data stream.
Collect information level	Collection of information with the potential to share
Process information level	Analysis of information received for the suitable actions.
Make decisions level	Evaluation of the resulting analysis and report on changes.
Reference baseline level	Conclusion based on analysis from time to time.
Validate over time level	opening to trends, technological development, continuous and reliable improvement.
Control and monitoring level	independent decision-making and remote control.

Arfa building (Case Study)

In order to know what is the technical data included in the Arfa project and how the final rating will be calculated based on ICT framework criteria. Arfa project is a high-rise building in Lithuania located at Vilnius city was built in 2018 with 43,000 $m2$ area with height of 100 m and 29 floors the final cost of the project was 56 million$. Arfa project representing a group of government buildings and has been designed according to the latest architectural trends. The building has been achieved the Building Research Establishment Environmental Assessment (BREEAM) standards as a very good rating certificate. The geothermal heating system is used in building, intelligent ventilation and lighting systems, special walls insulation properties, harvesting rainwater-saving roofs system and other smart energy-saving technologies. Arfa became the first newly built business center in the Baltics to receive a BREEAM certificate. Firstly, we should study a smart city Vilnius itself and analyze deeply the achieved criteria according to the main five domains mentioned previously for both, project and the city. Table 4 shows the results of analyzing Vilnius city based on the ICT domains for smart cities which were mentioned in the previous section. Table 5 shows the analyzing for the Arfa project which is located in Vilnius city in Lithuania and links between the three major integrations in smart building and the domains for smart cities, in order to analyze the achieved points and be more reliable with eight levels of ICT framework that mentioned previously.

Table (4) Achieved Domains In Vilnius City
(https://lithuaniatribune.com/**)**

Domains	Achieved description
Smart Energy	60% of energy from biofuel and biomass. High efficiency LED street lighting reduced 70% of power consumption
Smart Mobility	The city support car sharing and public transport: redesigned public transport routes, state bus lines. Traffic monitoring and control system joined into one centrally managed network. Mobile applications: city used m.Ticket and m.Parking. m.Ticket allows purchasing transport tickets by phone and monitoring the movement of buses and the schedule of trips. m.Parking is a solution for purchase a parking by smart phone. Mobile platform “Trafi” access to traffic data and schedule the public transportation, parking location and correct price.
Smart Life	Smart management - internet platforms for communication between city administration with the citizens and company in term of decision-making. Mobile application “Tvarkau Miesta”, enables the residents to report overflowing directly with municipality.
Smart Environment	The city provides one of the fastest public Wi-Fi internet connection system in the world, excellence life, hygienic water and fresh air. IoT technology is already used to monitor these systems: lighting, traffic, air pollution, agriculture, healthcare, market

Domains	Achieved description
	trading. Fast growth in smart technologies inside the city: financial technology, cyber security, data collection, biotechnology, electronics and optical systems
Smart Data	The city use LoRa wireless technology which supports low data rate communications over long distances by sensors and actuators for M2M concepts and Internet of Things (IoT) applications. The city municipality provides free access to financial, public administrations, real estate, transport systems and other open data.

Table (5) Analysis of ARFA Building in Vilnius City. (https://galio.lt/lt/)

Domains	Smart Construction	Smart Building Materials	Smart Building Services
Smart Energy	Energy Performance Certificate. BREEAM	large applications of renewable energy sources: 10% of electricity from solar panels. Water system in the building is connected with solar panels. Building are centrally heated by air heat pumps. art engineering systems such as building management system.	composite heating cooling system consists of air-water heat pumps, chillers, variable refrigerant volume (VRV) systems, solar collectors and city heating networks.
Smart Mobility	New street sections, bicycle road was connected to the existing infrastructure and new three level of parking underground. New pedestrian designed and connected in roads. Smart traffic lights installed.	A classic elevator design. Both panoramic and goods elevators were adapted as interior solutions of the building.	Elevators designed with a focus on serviceability their straight up speed meet the highest standards. Electrical stations for car charging.

Domains	Smart Construction	Smart Building Materials	Smart Building Services
Smart Life	Office places are easy to redesign to meet the business needs. The compound also includes social seats and services: meeting room, gym, games room and library.	Four glass layers tinted with external louvers installed to shield the extreme heat and glare. External screen controlled automatically.	Digital room reservation system, flexible contact and easy change of internal divisions and redesign of desired spaces. PC tablets.
Smart Environment	BREEAM certificate (Excellent). The combined square of the buildings form public spaces and attractive environment for city people and visitors. Natural light is possible for every workstation lighting. Facilities for waste sorting.	85% of the construction waste was recycled or used again. The white colour used in roof help to save energy for cooling.	BMS engineering systems contain: security alarm, access control, video supervision system. Automatic lighting, humidity control. Water-saving technology rainwater and tanks utilization.
Smart Data	Smart central platform to collect and monitor construction defects with robotic plan enabled 12% more efficient results.		Ventilation control based on CO2 concentration.

Jordanian Building's (Case Study)

Based on the previous literature review, it was concluded that a personal questionnaire survey is the most appropriate tool for the research to understand the effect of energy framework in smart building integration into Jordanian buildings. Furthermore, the survey needed to include statistical analysis to be more reliable at the resident's behaviors to the topics of smart building integration's into Jordanian's building's. According to the last report from Ministry of Energy & Mineral Resources (MEMR), Jordan is one of the poorest countries in the main energy sources not only in the region but also in the world, dissimilar neighbor countries in the Arabic Gulf area. This makes Jordan look for clean, sustainable, and cheap energy sources and standard energy framework serious need. Another objective of engineers and researchers is to reach the optimal way of energy utilization. One of the measures that show the bad energy condition in Jordan is the massive amount of imported energy sources which represents approximately 97% of the country's needs. In 2017, the electrical consumption in the residential buildings based on the annual report from the ministry of energy & mineral resources was 5885 GWh which represents 43% of the total electrical consumption for all sectors in Jordan (https://memr.gov.jo/ebv4.0 /root_storage/ar/eb_list_page/ householdsurveyp.pdf).

The survey was conducted during February and April of 2021 in Jordan, where the residential buildings were categorized into either public or private housing in this country with a total number of (684718) units based on the last report from the department of statistics (www.dosweb.dos.gov.jo). With random selection of participants, such as designers, engineers and researchers. Therefore, the specific goals of this survey were as the following:

1. To test if the residents in different buildings types have significant differences in terms of their smart energy preferences.
2. To collect data on objective six main factors and investigate the relationship between these factors and residents' satisfaction with smart building's integration's.
3. To identify in detail how personal behavior influence the new technologies in the smart building's field.

The sample size was calculated based on Cochran's formula:

$$n_0 = \frac{Z^2 pq}{e^2}$$

Where the confidence level = 95%, p = 50% (Estimated proportion of population houses), α or e= 0.05 (margin error), q = 1- P = 0.5, Z-value =1.96 for (Confidence level=0.95 and α = 0.05), N = 385 (sample size). The invitation was sent by e-mail taken into account the variety of respondents, 135 engineers, 87 employers from governmental sectors and 163 respondents from energy sectors in Jordan. The data was collected based on participants answers, taking into account the variables for the topics of smart buildings integrations such as, general information's (home type, year of build) and independent variables such as structural information's, air conditioning system, heating and cooling system, lighting system, security system and technology aspects need to be studied at the same time then we will check the reliability of the answers by giving a weighting to the answers to avoid bias due to imperfections in the random sample.

The Statistical Package for the Social Sciences (SPSS) software was used after the response rate was achieved. The data was analyzed for the demographic characteristics of the participants by giving a weight for answers to avoid a bias in participant's answers. The data was also being coded into a single variable. This can take on one of five values based on the Likert scale, depending upon the respondent's choices. The numbers 1-5 used to code the data are given labels as (Extremely important, Very important, Moderately Important, Not important). This analysis process will lead to achieving the mentioned specific goals and transfer the text responses to a quantitative approach. The summary of the questionnaire is shown in figure 4. The first part included the general information about buildings. Part 2 involved parameters of the building's structure such as the wall insulation and windows type, etc. Part 3 contains energy systems which were adopted as heating system, air-conditioning system, etc. Part 4 includes smart technologies in buildings and how residents are comfortable with new technologies.

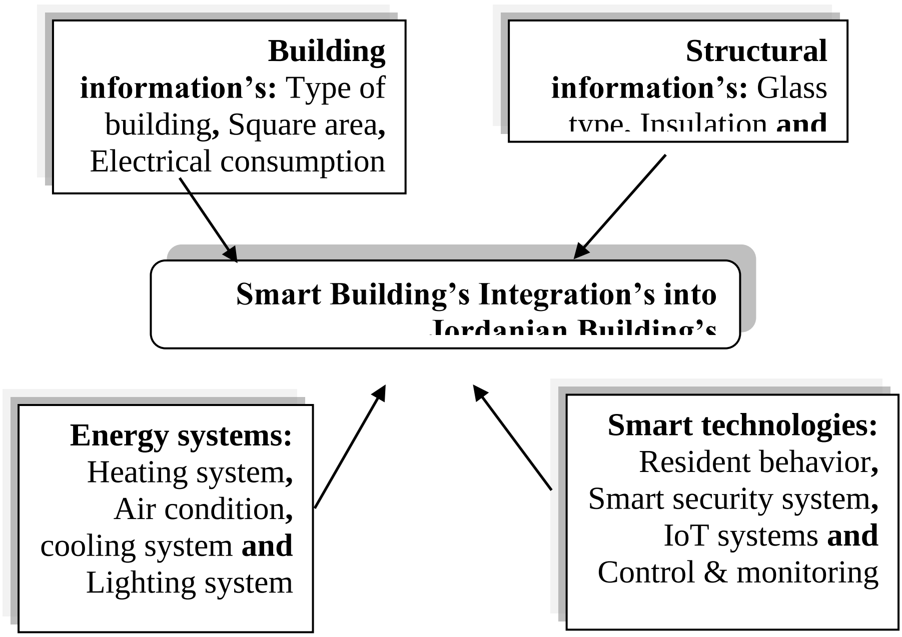

Figure 4 Contents of the Questionnaire

Result's & Discussion's

ARFA Building

For the Arfa project, there was a difference in integrations profile between the city itself and the smart project. This difference in smart city domains especially appears in the field of smart life and smart energy levels. This doesn't mean that every smart building has the smart environment to achieve the maximum level for any domain. Hence, if the city has a higher level of ICT, the functionality might be used until the building fulfills the missing levels. We can see the effect of the energy framework (ICT-framework) to perform the primacy list of the domains of the smart city which is contributed by smart buildings for the analyzed project (Arfa). As shown in figure 5, the high results demonstrated by the smart energy (8-levels) and smart environment (8-levels) domains are related to the recent tendencies of strategic priority in energy sectors and the awareness of the environment in addition to the assessment of the building's sustainability. The high result of the domain of the smart life represents the new technology of the based lifestyle which is supported by sophisticated building automation and management systems. Such systems are stimulated by the 4th revolution of the industry as the current scenarios of the development of smart cities are oriented toward these directions. The domains of both smart mobility and data are so far inside the smart building projects. However, and due to the Artificial Intelligence (AI) and Virtual Reality (VR) applications, the potential of the mentioned domains are supposed to be improved in the near future.

Jordanian Buildings

The data was analyzed based on the Likert scale and Alpha-Cronbach's test to check the reliability of the questionnaire contents with a 99% rate of response and sample(N)=385 the result was 0.751 which indicate that the contents of the questionnaire are quite reliable and within range. A summary of the survey based on the previous results of applying the main domains of ICT- energy framework in Jordanian building's that:

- The majority of the sample (57%) live in single-family homes while 35% live in apartments or duplexes, 5% live in villas and 3% have other sorts of accommodations (Fig. 6)
- 36% of them described their energy consumption as high, which means there is no smart energy systems in most of the Jordanian buildings (Fig. 7). Nevertheless, about 30% of the houses have poor walls insulation (0-5 cm) and the majority of them are either used single panes glass type for windows (43%) and the houses are described by their owners in terms of air leakage, 29% were leaky and 8% were very leaky (Figures 8&9). This means that the heat is transferred easily to and from the outside of the buildings. Thus, will result in additional costs for heating and cooling during summer and winter.
- In the section that describes the heating systems attributes in the houses, figure 10 presents that the least used (17%) heating system was the oil boiler or burner. 23% and 24% of the houses use electric furnaces and gas space heaters, respectively. While the majority (36%) still use traditional heating systems. Figure 11 shows that 45% of the houses use a central electric A/C system, 12% use central gas A/C, and 22% use electric windows or wall units. About one fifth of the houses (21%) use no cooling system

- In terms of household lighting systems, it's noteworthy that the majority (61%) of homes employ energy-efficient LED lighting technology, which is a positive sign. However, there are certain concerning statistics: 42% of these households leave their light bulbs on for more than 8 hours, and 81% of them rely on manual control methods for their lighting systems. These figures suggest the lack of smart sensor technologies in controlling lighting systems, which, in turn, contributes to higher energy consumption within the lighting infrastructure..
- In terms of smart buildings technologies, 22% to 51% have heard about it. However, they do not understand the exact meaning of smart buildings technology. Therefore, this requires great awareness efforts from the government and energy associations in Jordan for the necessity of moving towards smart energy technologies. The study also indicates that 47% of residents are extremely like to live in the smart home during the coming years. Thus, creating new investments in this field and lead to create a job opportunity within flexible loans program supported by the government to encourage residents to reduce energy consumption, greenhouse gases and to live within high-quality indoor environment.

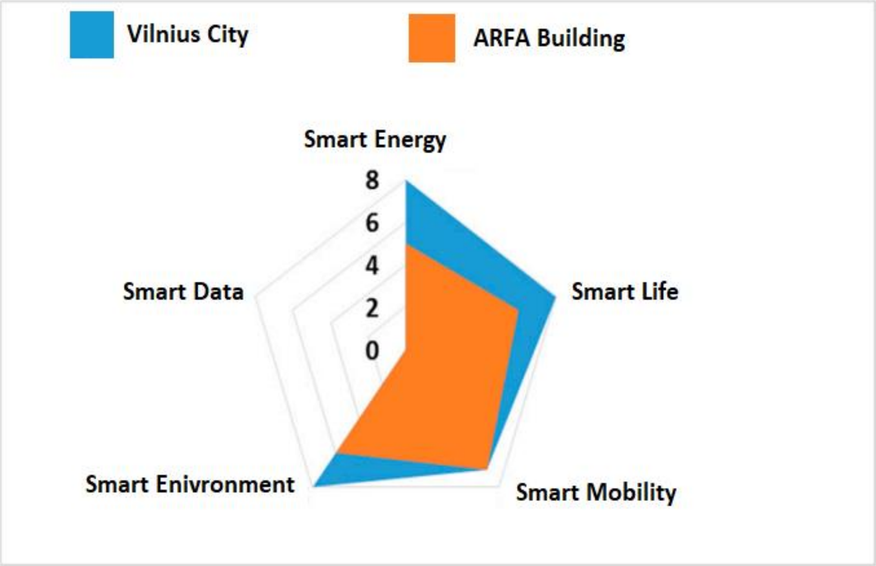

Figure 5 Analysis of ARFA Project

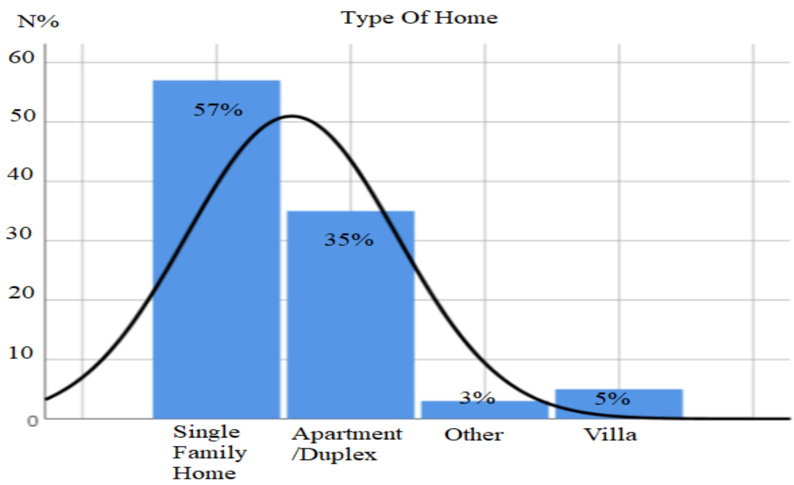

Figure (6) Building's type based on responses

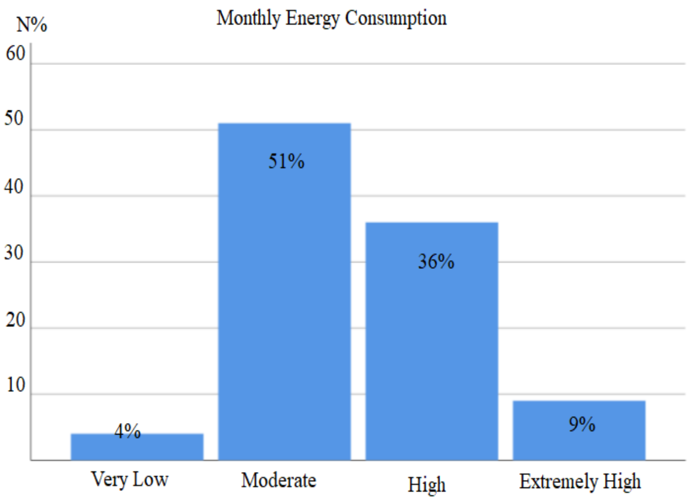

Figure (7) The energy consumption analysis

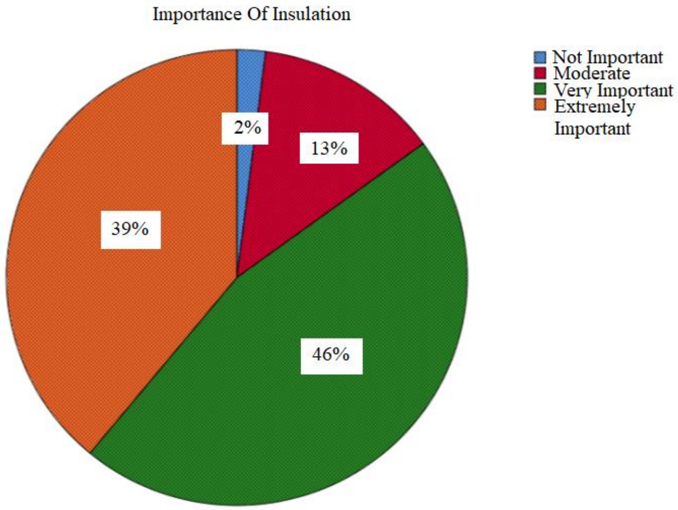

Figure (8) The importance of insulation based on responses

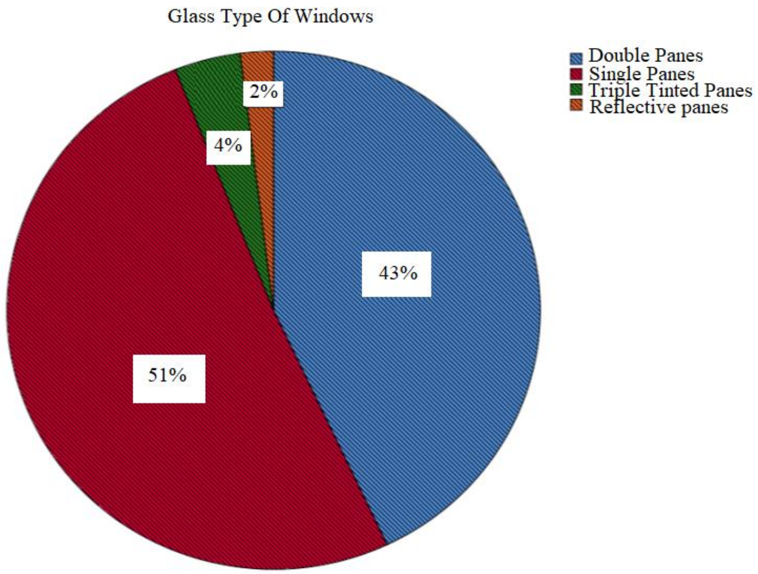

Figure (9) Type of glass for windows

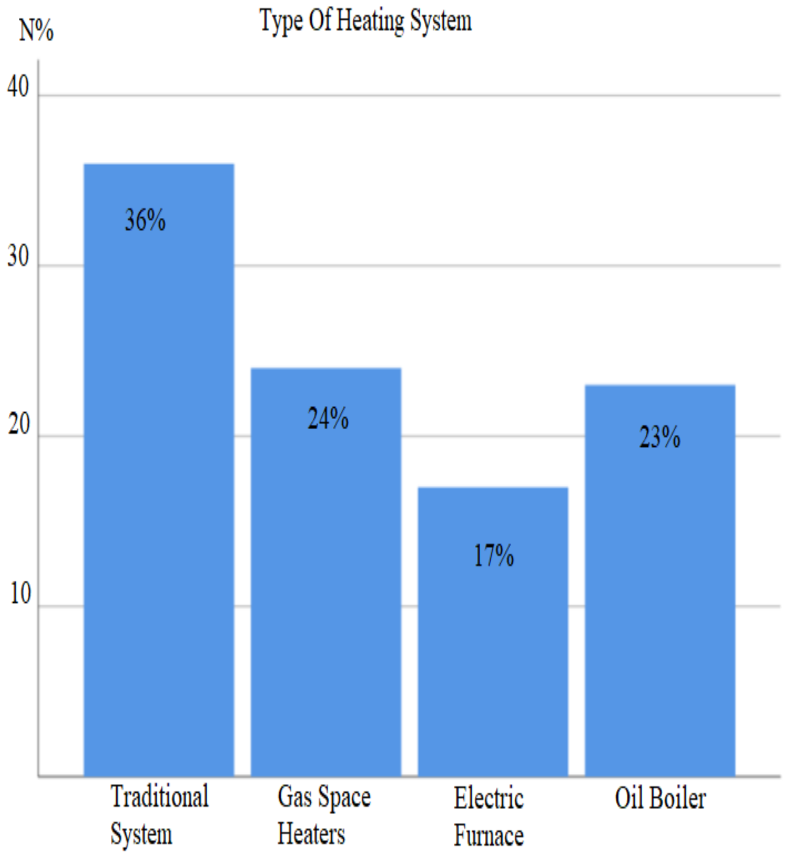

Figure (10) Heating system types

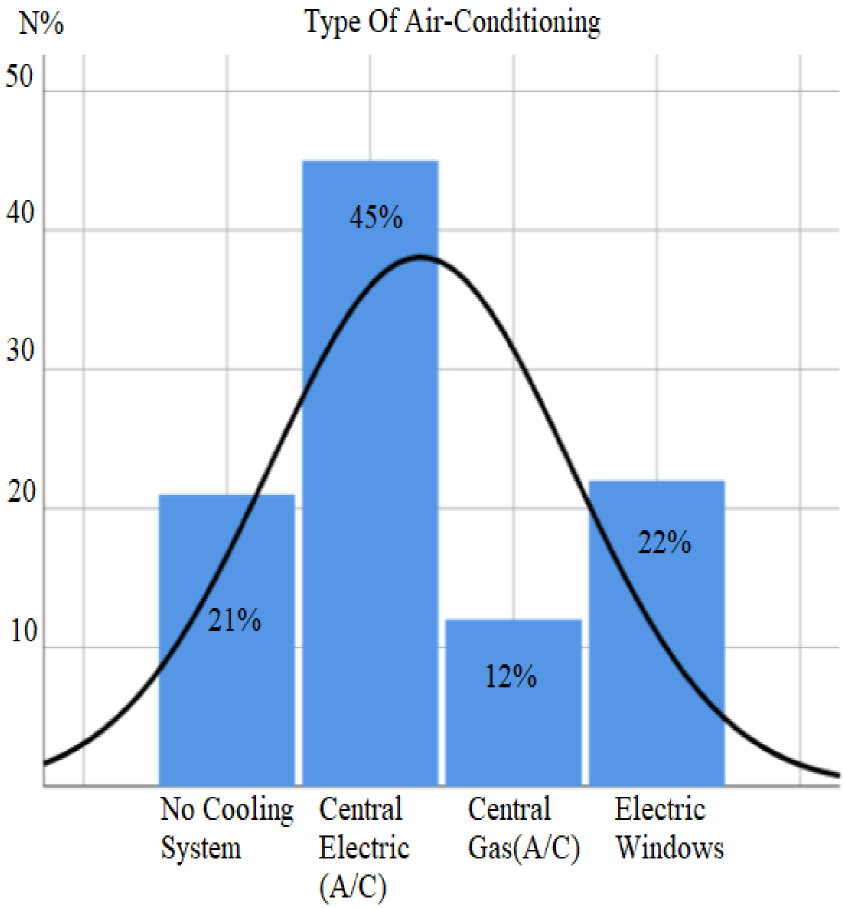

Figure (11) The percent of cooling systems in houses

Conclusion

The energy framework (ICT-Domains) is an inclusive evaluation plan for smart energy policy, linking the criteria of buildings and the city from the design stage to the building's operational stage. The effectiveness of this framework relies on the presence of sensor systems, IoT devices, smart data management, and intelligent construction management. This leads to the continuous assessment of strengths and weaknesses within building systems, with data sent regularly to central information centers. As a result, it reduces effort, costs less, enhances sustainability, and provides better control over energy losses. This adaptability makes the energy ICT-Framework suitable for all conditions and cities worldwide. The Arfa project's criteria in the realm of smart data did not align with or fulfill the framework's domains due to a lack of data management technology and artificial intelligence. The ICT-Framework's criteria and domains have demonstrated their capability to evaluate buildings and cities together by establishing common links between these domains. This sets it apart from previous energy frameworks that typically examined building determinants in isolation from the broader city context.

In the case of Jordan, it is evident that there is a need for a more proactive approach to integrating smart energy technologies into their construction codes. To achieve this, it is imperative to foster fresh investments in this sector, ultimately leading to the creation of employment opportunities. This can be facilitated through a government-backed flexible loan program designed to incentivize residents to reduce energy consumption, minimize greenhouse gas emissions, and ensure high-quality indoor environments. Moreover, it is highly advisable to channel scientific research efforts towards areas such as data management systems, building information management (BIM), and artificial intelligence technology. Sending researchers abroad to gain valuable international experiences in these domains would be beneficial. Additionally, authorities responsible for Jordan's energy sector should consider the establishment of an "Energy Auditing" program, particularly focused on buildings. This program can serve to promote awareness of smart energy technologies among citizens. To further support these efforts, interest-free loans should be made available to assist residents in performing essential maintenance and upgrades.

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