

Awada, Emad A.; Abed, Amal; Radwan, Eyad et al.

## Article

Energy conservation as a sustainable strategy for smart home buildings in Amman, Jordan with improving indoor built environment features and key performance

International Journal of Energy Economics and Policy

## Provided in Cooperation with:

International Journal of Energy Economics and Policy (IJEEP)

*Reference:* Awada, Emad A./Abed, Amal et. al. (2021). Energy conservation as a sustainable strategy for smart home buildings in Amman, Jordan with improving indoor built environment features and key performance. In: International Journal of Energy Economics and Policy 11 (6), S. 408 - 417.  
<https://www.econjournals.com/index.php/ijEEP/article/download/11717/6144>.  
doi:10.32479/ijEEP.11717.

This Version is available at:  
<http://hdl.handle.net/11159/7904>

## Kontakt/Contact

ZBW – Leibniz-Informationszentrum Wirtschaft/Leibniz Information Centre for Economics  
Düsternbrooker Weg 120  
24105 Kiel (Germany)  
E-Mail: [rights\[at\]zbw.eu](mailto:rights[at]zbw.eu)  
<https://www.zbw.eu/>

## Standard-Nutzungsbedingungen:

Dieses Dokument darf zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden. Sie dürfen dieses Dokument nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, aufführen, vertreiben oder anderweitig nutzen. Sofern für das Dokument eine Open-Content-Lizenz verwendet wurde, so gelten abweichend von diesen Nutzungsbedingungen die in der Lizenz gewährten Nutzungsrechte. Alle auf diesem Vorblatt angegebenen Informationen einschließlich der Rechteinformationen (z.B. Nennung einer Creative Commons Lizenz) wurden automatisch generiert und müssen durch Nutzer:innen vor einer Nachnutzung sorgfältig überprüft werden. Die Lizenzangaben stammen aus Publikationsmetadaten und können Fehler oder Ungenauigkeiten enthalten.

## Terms of use:

*This document may be saved and copied for your personal and scholarly purposes. You are not to copy it for public or commercial purposes, to exhibit the document in public, to perform, distribute or otherwise use the document in public. If the document is made available under a Creative Commons Licence you may exercise further usage rights as specified in the licence. All information provided on this publication cover sheet, including copyright details (e.g. indication of a Creative Commons licence), was automatically generated and must be carefully reviewed by users prior to reuse. The license information is derived from publication metadata and may contain errors or inaccuracies.*



<https://savearchive.zbw.eu/terms-of-use>



# Energy Conservation as a Sustainable Strategy for Smart Home Buildings in Amman, Jordan with Improving Indoor Built Environment Features and Key Performance

Emad A. Awada<sup>1\*</sup>, Amal Abed<sup>2</sup>, Eyad Radwan<sup>3</sup>, Aws Al-Qaisi<sup>1</sup>, Ayman Y. Al-Rawashdeh<sup>1</sup>

<sup>1</sup>Department of Electrical Engineering, Al-Balqa Applied University, Amman, Jordan, <sup>2</sup>Jordan University of Science and Technology, Faculty of Architecture and Design, Irbid, Jordan, <sup>3</sup>Department of Electrical Engineering, Applied Science Private University, Amman, Jordan. \*Email: [emad.awada@bau.edu.jo](mailto:emad.awada@bau.edu.jo)

Received: 08 June 2021

Accepted: 25 September 2021

DOI: <https://doi.org/10.32479/ijeep.11717>

## ABSTRACT

As an ingenious efficient environment, smart buildings can be considered as essential constituents for energy conservation. That is, in today's energy demands upsurges and energy sources degradation, the idea of the smart home building has a major implication on improving the living environment along with cutting down on energy consumptions. Therefore, this study investigates the energy conservation theme in Amman, Jordan in terms of opportunities and challenges vs. renewable energy technology. This study was based on interviews with the expert (academics, professionals architects, and electrical engineers, in addition to employees in Electrical companies) aiming to identify the problematic gap in designing theoretical analysis of a smart automated building based on collaboration work between Electrical and Architectural Engineering. From an Electrical Engineering point of view, automated control building systems can provide efficient means of comfort, sustainable habitat environment, and energy conservation as a building advantage. Such a scheme can be accomplished through automated control software (LabView), sensors, network infrastructure, logic design, and mechanical actuators. Meanwhile, from an architecture point of view, passive design strategies can reduce energy consumption along with public awareness for building users. This was implemented through simulation for base case building showing the integration between architectural and electrical systems through using a hybrid system. As a result, this new building automation design will help reducing energy consumption by controlling light fixtures, air-condition, water pumps, and many more appliances. The design guidelines, once formulated and enacted, will guarantee energy conservation qualitatively which will serve as a proposed guideline for enhancing buildings' regulation and codes.

**Keywords:** Energy Conservation, Sustainable Strategy, Smart Building, Indoor Built Environment.

**JEL Classifications:** Q2, Q3, Q4

## 1. INTRODUCTION

The indoor environment has a significant contribution effect on human wellbeing since they spend most of their time indoors. Some studies have shown that most of the human population spend their daily time indoors whether at home, work, or even entertainment. To make matters worse, children and the elderly spend most of their time in closed doors (homes, daycare, and

senior homes) due to today's lifestyle, which has significantly impacted through quarantine of COVID-19. As a result, this may explain the growing attention towards better indoor environment quality and its influence on users' wellbeing. That is, human wellbeing is connected with senses related to comfort level at thermal, visual/lighting, sound, ergonomics, and air quality dimensions De Dear et al. (2013). However, achieving these comfort parameters can be done through two methods.

**Active design:** A system that uses or produces energy to meet a specific standard.

**Passive design:** Related strategies used to minimize the needed energy based on architectural design elements as in Mainasara and Alibaba (2019).

In the last decade, comfort was connected with human dependence on active design systems, which puts more pressure on energy resources, leads to the continuous growth of energy costs, and is reflected directly on utility bills globally and locally. This fact can be noticed clearly according to Jiang and Liu, 2010, where 40% of worldwide energy consumption claimed by buildings in developed countries and 25% in developing countries. In the year 2007, 198 quadrillions Btu out of 495 quadrillions Btu was consumed by the buildings sector only. In the annual report of national electrical power company, the total building electrical energy consumption for 2013 was shown as 43.02% of the total energy, while in 2019, 45.12% of total energy was consumed by building for 2018 (NEPCO, 2013; NEPCO, 2019). The significance of energy consumption can be clarified by the continuous growth for demand, which has doubled in the last 40 years and affects negatively energy source supplies. Assessments show with the current usage rate, fossil fuel will only have supplies for the next 200 years as in Europe's Energy Portal. (2010), and Intergovernmental Panel on Climate Change (2007). Yet, more than half of the electrical energy was used for heating, cooling, and lighting as in Jaber et al., 2015. Therefore, as a result of today's fast striving energy consumption, a major issue was created due to lack of energy availability, environmental catastrophe, and overpriced energy bill which makes people fall back into passive design techniques as building shape, orientation, and Window-to-Wall Ratio (WWR), thermal mass, and shading devices. In general, since energy is used to optimize individuals' task performance and enhance comfort level over different daily life activities, it was a priority to investigate and study techniques to save energy without compromising the comfort level for indoor living spaces. As a result, most countries have used the following strategies to improve their energy load factor:

1. Energy conservation is related to reduce energy consumption and maximum demand, which reduce dependence on finite resources (such as fossil fuel)
2. Energy production from renewable resources such as solar thermal systems, PV panels, and windmills to help buildings' owners produce their renewable energy.

However, in this research, the focus will be on the first strategy since the need for energy is expected to grow exponentially due to the digital lifestyle and obstacles facing the expansion of renewable energy production. In term of buildings, several studies have shown that the active and passive elements can be simulated successfully for informed, rational decision-making as in Al-Hindi and Al-Sallami (2017). Therefore, many types of research have been done in this field to overcome this problem with the best solutions. Some researchers have focused on an active system by finding a new clean source of renewable energy by employing ecological materials and natural resources such as wind energy, solar radiation, and others to enable the building to produce adequate power for its operations. Yet, this approach has

obstacles due to immature technology (still under development), lack of properties (a large amount of land needed for such process), intermittent availability, and level of availability is dissimilar from one part to another based on building location. Meanwhile, other researchers have invested in finding means of saving energy by adjusting building materials, designs, and implementing new technology based on smart communications among building systems, according to Chen and Chang (2010), to identify major energy consumption systems, control energy consumption without compromising comfort level, and set new regulation for energy consumption rating.

In this work, the focus will concentrate on the implementation of an active smart building system for energy conservation with the highest level of indoor comfort in terms of thermal (heating and cooling for air and water), visual (lighting fixtures control), air ventilation, and many other electrical/mechanical systems. While Smart home venture goes back to the 1980s by the National Association of Home Builders (NAHB), a study was done by Li et al. (2009), 20 houses were set as a prototype research experiment by research groups such as MIT, Cisco, Siemens, and others to set smart appliance, network, and artificial intelligence protocols. In, Cetina et al. (2009), Autonomic Computing was proposed as administrative computer systems of smart homes with the intention of self-healing, and self-organizing. However, an interruption may lead to reset the system without overriding. Meanwhile, in Cetina et al. (2009), a study of the smart home was performed based on tenant comforts and quality of service (QoS) to include a level of convenience and security. However, in this work, knowing the tenant's centric requirements of comfort and security, in addition to their point of view on energy saving, the scoop of this work will intend to implant the intelligence concept of automation as in Markovic et al. (2012), and Ding et al. (2011) with energy-saving and architectural design to optimize the comfort and convenience level of building design.

In the past, smart houses or spaces were often suggested as an advanced design for future communications as shown in Li et al. (2009), Han and Lim (2010), Cetina et al. (2009), Marco et al., 2010, and Sanchez and Tercero (2010). However, in this work, an automation process based on communication among parts will be performed by designing LabView algorithms (as advanced automation, control software). Such an algorithm will allow interaction between building systems and their inhabitants to increase building energy conservation by adjusting conventional energy consumption.

The significance of this new proposed active/automated system will be designed and evaluated by a collaboration of architects and electrical engineering. Such collaboration will enhance the indoor building environment and energy conservation in terms of planning, energy-efficient solutions, automation, and building management software (LabView) as smart building. In addition, in this work-study, tariff and legislative issues will be discussed as energy consumption in Jordan is significantly escalate in the last two decades due to population increase, refuge effect, and major life modernization changes in terms of variety of electronics equipment's which is not covered by legislative energy efficiency requirements.

This Journal is licensed under a Creative Commons Attribution 4.0 International License.

## 2. SIGNIFICANCE OF ENERGY CONSERVATION VERSUS RENEWABLE ENERGY

Provide Energy conservation has a significant positive impact on environmental and economic dimensions that will improve life quality and well-being for individuals. At environmental aspect, less energy reduces the pollution level (resulted from burning fossil fuel) and enhance air quality, which reduces the rate of serious medical problems related to respiratory systems such as lung cancer and asthma for human and protecting wildlife in general. Moreover, less consumption reduces natural disasters because it will reduce the negative impact of global warming and other serious harmful incidents related to extraction projects, spills, coal mining, and nuclear power. At the economic dimension, energy conservation leads to decrease demands and reduction in utility fees, rise building resale value, and reduce building owner's liability. In the same matter, this will decrease pressure on the city's infrastructure and allow to spend capital on enhancing other fields rather than expanding the grid system capacity as in Pleasant et al. (2004) and Optimal Energy and Synapse Energy (2011). In general, energy is used to optimize individuals' task performance and enhance comfort level over different daily life activities according to Liu et al. (2019).

Several techniques were implemented throughout the world. In the European Union, there was a saving potential of 20–50% by the refurbishment of existing buildings along with stringent regulations for new buildings as shown in Eichhammer (2009). In the United State, while 15% of existing Federal buildings were mandated to new energy efficiency standards by 2015 and 100% of all new Federal buildings to comply with zero-net-energy by 2030 as of Executive Order 13514, the state of Maryland initiate a proposal to drop its energy usage 15% by 2015 according to Mansoori et al. (2016).

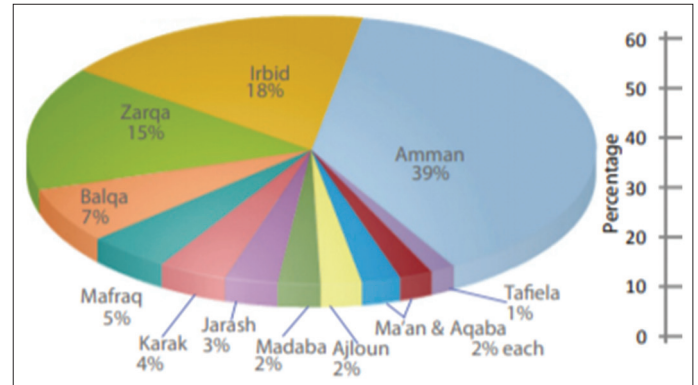
Despite the success of energy conservation at a global level, the Jordan energy field has shown many problematic issues such as high utility bills, technical issues causing blackout more often (latest in May 2021), and severe deficiency in infrastructure.

On one hand, the use of proper renewable energy technology must be carefully selected based on site characteristics, building features and orientation, feasibility, and other environmental issues as in Jiang and Liu (2010). For example, solar radiation panels could be used in dwell units. However, these application has many problematic issues tied in with the characteristics of global location. For example, According to the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) as in OCHA(2012), most populations are centralized in the capital city of Amman wherein in 2012, 39% of the population reside in Amman as shown in Figure 1.

Meanwhile, in Worldometer (2020), Jordan demographic has shown a significant population escalation in the last few decades as shown in Figure 2.

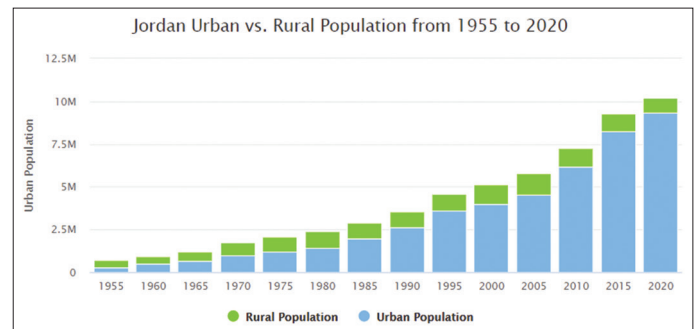
In addition, As a topography, Amman consists of 7 mountains which makes this geography implies a hard train of multi-leveling among buildings as shown in Figure 3. Such a topography and high density of population have negatively affected the sun path chart of solar radiation and reduce the Maximum Power Point Tracker (MPPT) as a result due to shade effect among adjacent

**Figure 1:** Population distribution in Jordan demographic areas



Source: <https://reliefweb.int/sites/reliefweb.int/files/resources/Jordan.pdf>

**Figure 2:** Population density increase in Jordan urban Vs. rural areas from 1955 to 2020



Source: <https://www.worldometers.info/demographics/jordan-demographics>

**Figure 3:** Amman city view of buildings and houses



Source: <https://depositphotos.com/44072183/stock-photo-amman-buildings-view-in-the.html>



buildings. Also, due to high properties value and very limited land spaces, most buildings consist of a minimum of 4 floors with 8 apartment units or more. Which make it impossible for each homestead to take advantage of solar panel in the very limited common functional roof area.

Furthermore, one of the major issues associated with solar panel renewable energy is the initial installation cost versus type of tariff applied by the national electrical company and government stimulus. As shown in Figure 4, most dwell units fall in the 1<sup>st</sup> and the 2<sup>nd</sup> categories of charges (0.33 JD up to 160 kWh and 0.72 JD from 161 up to 160 kWh per month). That is, and based on questioner surveys, the average of common light bills is around 20 JD a month, which make it unfeasible to install solar radiation panel with a long time for the return of investment.

Yet, in Jordan, there is a very limited effort in mapping problems and proposing strategies. Therefore, this research aims to understand the paradox of energy conservation in the Jordan context to facilitate proposing comprehensive strategies, hoping this will be developed as a policy that encourages stakeholders to move towards implementation.

### 3. STRATEGIES FOR ENERGY CONSERVATION

Due to interdisciplinary energy conservation strategies, implementation needs to be applied at several dimensions as follow:

1. Smart active technology: The main idea of a smart building is to provide the highest level of comfort and efficacy by automating and controlling building systems, as shown in Hosein et al. (2013), Al-Ali et al. (2011), Hoseini et al. (2011), Elangovan et al. 2018, and Chao-Lin and Li-Chen (2012), and integrating systems to optimize comfort and energy saving. This optimization can be attained by computerize monitoring and compiling data based on periodic iterative data collection. Systems such as Air-conditioning (HVAC), lighting, window and door operations, multi-media, safety, security, and many other systems.

**Figure 4: Jordan Electrical Tariff Structure**

Domestic tariff	
33	From 1-160 kWh per month (Fils / kWh) (
72	From 161-300 kWh per month (Fils / kWh)(
86	From 301 - 500 kWh per month (Fils / kWh)(
114	From 501 to 600 kWh per month (Fils / kWh)(
158	From 601 - 750 kWh per month (Fils / kWh)(
188	1000-750) kWh per month (Fils / kWh(
265	More than 1000 kilowatt hours per month (Fils / kWh)(

Source: [http://www.nepco.com.jo/store/docs/web/2019\\_en.pdf](http://www.nepco.com.jo/store/docs/web/2019_en.pdf)

It can be said that smart buildings aim to achieve sustainability based on developing intelligent design through controlling energy performance while enhancing the life quality of users. Also, this vision is upgraded through trials to achieve the nearly Zero Energy Building target and be able to respond to external dynamic conditions such as the weather and the grid. This ensures the importance of understanding the potentials of an “intellectual” building based upon the circumstances of control strategies, and automation approaches such as LabView to be harmonized with sustainability principles according to Chao-Lin and Li-Chen (2012), and Barghi et al. (2014). This can be implemented on several systems such as (a) Intelligent Lighting where building’s lighting makes a significant difference in energy consumption Liu et al. 2019, as in Barghi et al. (2014), the US Department of Energy and Climate Change had stated home sector energy consumption increased by 1.7% over the period between 1970 and 2013 making residential utility 900-kilowatt hours per a month per household. That is and according to Higuera et al. (2014), 40% of energy consumption corresponds to lighting. Therefore, intelligent lighting control is necessary to provide energy conservation and comfort zone with adequate luminance. Especially with the wide variety of LED technology that can provide efficient, long-lasting replacements to conventional lamps, as shown in Nacer et al. (2017) and a 20-30% decrease in electricity bills according to Higuera et al. (2014).

(b) Climate Control was one of the smart build-essential controlled systems, HVAC has been always the main target in energy-saving and habitat comfort Liu et al., 2019. In Higuera et al. (2014), around 60% of residential energy consumption alone corresponds to cooling, heating. In a traditional building, one thermostat will control a major area based on a built-in heat sensor.

2. Passive design: It utilizes natural sources of heating/cooling, and ventilation to create comfortable conditions inside buildings by achieving a lifetime of thermal comfort, low energy bills, and low greenhouse gas emissions. Several strategies were used as follows: (a) Building envelope related to the integrated design of building form and materials as a total system to achieve optimum comfort and energy savings; (b) Orientation related to the building’s allocation for climatic features. Therefore, it needs to be analyzed at three levels: whole building, building zones, and glazed areas; (c) Insulation that provides a barrier to heat flow and is essential to be installed correctly to avoid leakage; (d) Fenestration that related to window wall ratio (WWR), and the characteristics of glazing in terms of position, size, and material; and (e) Other passive strategies include thermal mass, shading devices, and landscape as in Mainasara and Alibaba (2019), and Janssen (2004). While passive design should create buildings that consume less energy and enhance the life quality of the indoor environment, they do not always achieve the target (comfort level). Therefore, it will be a necessity to optimize it by using smart technological systems with embedded sensors to increase the efficiency of such design.

Public awareness seeks to link formal learning with daily life to enhance awareness of how individuals use energy in everyday

practices and illustrate how changing behaviors affect energy use. Also, it helps to draw attention to the economic advantages of lower energy costs, as well as the environmental impacts that are associated with the continuously growing energy use. This can be achieved through (a) Awareness programs on energy conservation by training people of behaviors that help in reducing energy consumption; (b) Tours for successful buildings with design and occupancy compliance; (c) Public hearing to spread benefits, and practices of energy savings by using local language and expression through social media, shows, posters, and many more as shown in Baharum et al. (2016), and Twumasi et al. (2017). In general, it can be said that public awareness about energy issues is a vital strategy to improve energy-saving behavior as well as empower activities to promote its efficiency. Therefore, it has a key role in adaptation and adjustment to the way of living.

#### 4. LABVIEW MANAGEMENT FOR SMART BUILDING

Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is an automated and control design and development software based on a Graphical User Interface (GUI) platform programming language. The automation and controlling of instruments can be done through remote programming of PXI with a specific address for each instrument as shown by Akujuobi and Awada (2008), and Hamed (2012), Ethernet, Bluetooth, RF, ZigBee, RFID, WiFi, etc. In addition to LabView's great benefit of interfacing with the users, LabView offers a great advantage by being great compiling software, parallel programming, large libraries of VIs, and many more advantages.

In this project, as shown in Figure 5, LabView as a controller (Central Unit), will play a major role in making a decision based on rubrics and occurrence. As a controller, LabView will receive data through PXI Multifunction I/O Module for sensors to process and command based on pre-set rules. For example, in the summertime, if the inside temperature exceeds 22 degrees while the outside temperature is below 22 degrees, LabView will command a window actuator to open the window. Yet, if the outside temperature is 22 degrees or more, and other building adjacent spaces are less than 22 degrees, a command will be sent by LabView to open a damper to permit air exchange between rooms. However, if none of these conditions occurred, LabView will command the HVAC to run after insuring all the proper conditions (window closed) to drop the temperature below 22 degrees. As a result, to have a full completed system, the Central Unit need to be interacting with sensors (to monitor, detect, and measure the sounding such as humidity sensors, heat sensors, movement sensors, etc), and actuators (mechanical devices to perform the physical commands such as window, door, curtain opening, and light switch relays).

#### 5. RESEARCH METHODOLOGY

A mixed-method approach was adopted to understand the significance, opportunities as well as challenges of energy conservation aiming to propose strategies and guidelines.

This was achieved through the following steps:

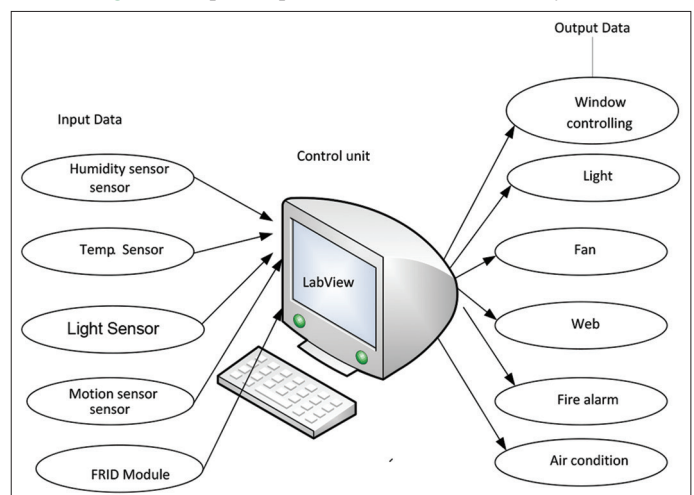
1. Delphi's technique relied on feedback from experts using face-to-face interviews aiming to involve academics and professionals. Academics (Master and Ph.D. holders), faculty members in different Jordanian universities, who are interested in the energy field; professionals include electrical engineers and architects who have been working in building design for more than 10 years and employees in governmental agencies concerning energy. Three iterative online workshops were held using the online video conference technique

The first meeting was held with professionals and academics as separated groups. This workshop focused on the level of interest and familiarity of energy conservation techniques (benefits and challenges) along with the willingness to be involved with projects focused on energy conservation; and recommendations for developing guidelines to facilitate the implementation of strategies for energy conservation.

Data were conducted from September 10<sup>th</sup> to November 25, 2019. The workshops lasted between 2 h and a half to three hours depending on the participants' collaboration and involvement. A total of 112 respondents agreed to participate, were distributed as follows: 30 employees from National Electric Power Company at various branches, 20 Architects, 40 Electrical Engineers, and 22 Academics Faculties. Generally, the first workshop was a brainstorming technique that used trying to get various points of view about good practice. The collected data from the first round used for the 2<sup>nd</sup> and 3<sup>rd</sup> workshops, which were held for both academics and professionals together trying to get feedback about the best strategies for practice along with their opinion and evaluation of the proposed model that was suggested by researchers.

2. Smart Active Building management using the software as an experimental platform for smart home building analysis and evaluation, algorithms were designed to improve the indoor environment based on computing parameters and enhancing the quality of living. This approach of combining hardware (PXI Multifunction I/O Module) and software (LabView)

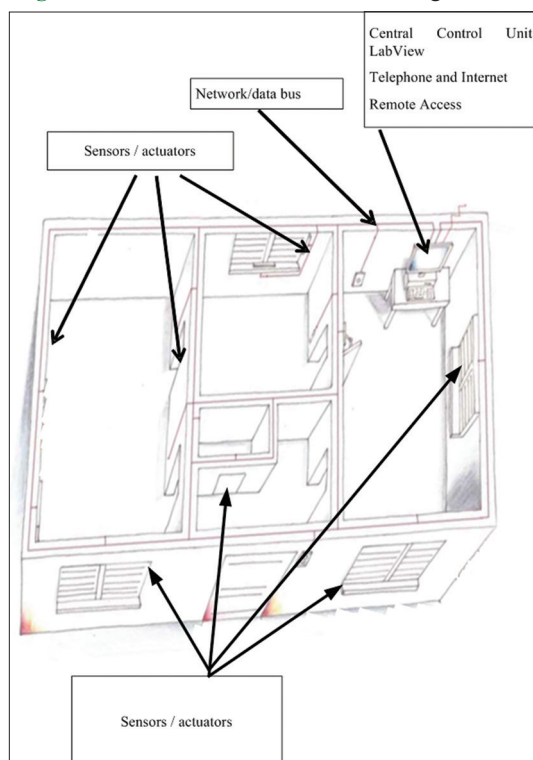
Figure 5: Input-output control and automation system



technologies has enabled a smart active environment system. Analog sensors, actuators, networks, and controlling software were combined as a modernized sensor- embedded with various integrated systems, able to communicate with each other, and controlled by Integrated Circuit as shown in Han and Lim (2010), Cetina et al. (2009), and Marco et al. (2010), and arrange for appropriate comfort occupants building environments as in Li et al. (2009), Choi et al. (2005).

A smart algorithm was designed to command and adjust lighting brightness and operation as needed based on pre-set parameters. This integration among the lighting system of LED, motion sensors, light sensors, and LabView control and automation will allow developing live interaction between building tenants and the lighting system to dim, turn off and on the lights as occupants enter and leave a space. In addition, to adjust lighting based on outside sunlight. In addition, as shown in Figure 6, a set of thermostats, heat sensors, actuators, motors, and network communication are tied in together through LabView VIs, as a detection system to improve energy efficiency, lessen heating and cooling demands, and prevent expensive exposure to harmful UV rays. The temperature setting will be allowed in a specific area or throughout the entire floor where the compiling automated software (LabView and PXI Multifunction I/O Module) will control the level of the blinds to open and close based on temperature and light setting. Control dampers between adjacent spaces as the temperature required, control window opening based on inside and outside temperature, and control HVAC operation as an outcome of all controlled guidelines.

Figure 6: Smart house structure and sensing elements



## 6. BUILDING ENERGY CONSERVATION PROJECT SETUP

In this work, the focus to reduce energy consumption and maintain a low level of utility bills was through the use of smart home building applications impeded into LabView and passive techniques through a small two-bedroom apartment (120 m<sup>2</sup>). The algorithm was developed to collect data, analyze, and make a suitable function decision based on pre-set parameters, state machines, and flow chart commands. In a general aspect, a finite state machine organizes a sequential logic technique.

With a set of complex rules and conditions, an output state will be determined based on the current state and input state as shown in Figure 7. Such a model can be very helpful in designing systems with sequence order.

However, creating such a smart system needs to be based on the logic flow of data measurements and match with pre-set roles. For example, the temperature and lighting algorithms are designed to compare all adjacent spaces temperature, outside temperature, and motion Sensor before a proper action as shown in the flowing flow charts Figure 8 for one room temperature control as an illustration model.

Figure 7: System state machin

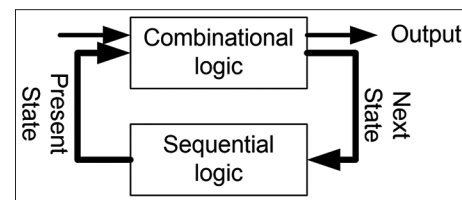
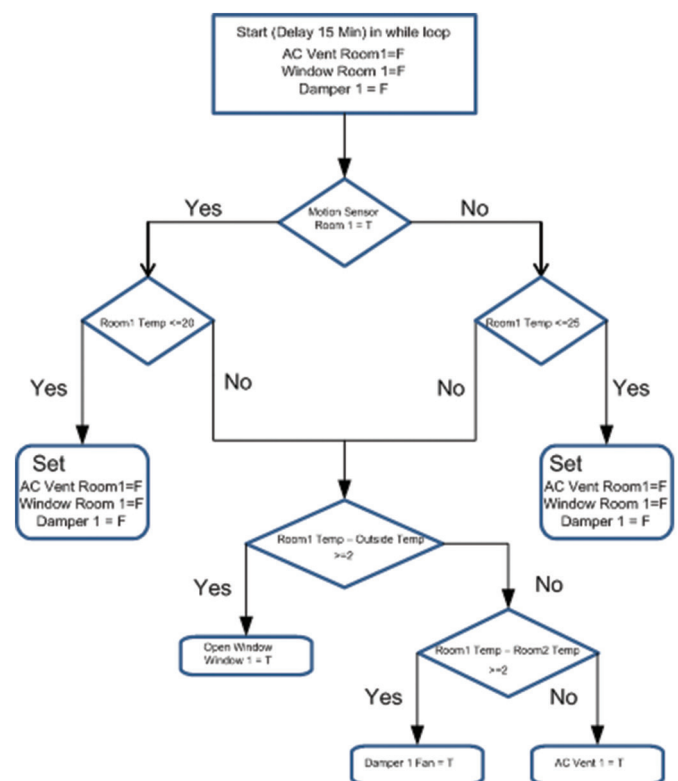


Figure 8: Room cooling control flow chart





As an easy user interface, LabView provides the GUI panel where users can monitor, override, and set parameters as shown in Figure 9 for space temperature, light controlling, and fire detection applications.

Meanwhile, LabView VIs will allow a developer to write their program based on a block diagram to cluster all functions and overlap as needed as shown in Figures 10 and 11 for VIs and sub-VIs.

From Figures 10 and 11, it clear that the user can override the AC1 controller output to run Air Condition as needed regardless of the system state, in addition to changing the cooling and heating operation automatically based on system state.

In Figure 12, Entrance Lights was controlled to turn on at night only in case of movement.

Garden lights and Street lights are also designed to turn on at night-based light sensors of exterior illumination below 1000 lumen.

## 7. RESULTS AND DISCUSSION

The collected data from participated respondents showed that the stakeholders are aware of energy conservation significance, as well as are passionate and willing to cooperate with

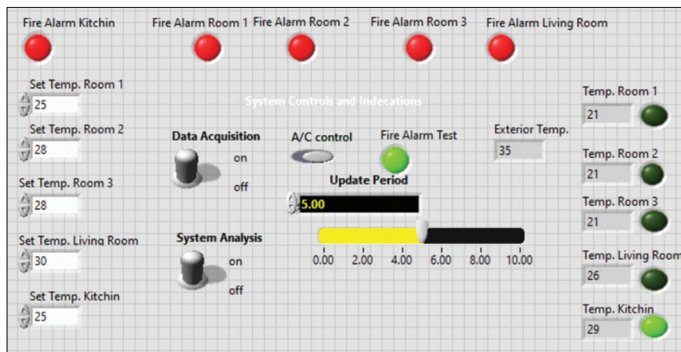
governmental institutions to propose strategies and regulations to facilitate practice. Based on respondents' feedback, about 90% of practitioners agreed that buildings in Jordan are still built in traditional methods due to a shortage of skillful and knowledgeable laborers in this field as well as a higher initial cost. In addition, about 70% of the sample referred to energy conservation policy as an urgent issue, where the governmental institutions have to respond rapidly. Especially, the continuous growth of energy consumption affects negatively on stability of electric current. This was noticed clearly through COVID-19 in Jordan where people stay home longer hours and using more energy which leads to blackout in terms of time and zone and then leads to being dropped out of work, study, or any activities involved. The academics and electrical engineers highlighted opportunities for implementing different techniques that would reduce energy consumption such as installing a programmable thermostat, replacing traditional light bulbs with the new technology of LED, an embedded sensor for smart control, using energy-efficient appliances, and smart power strips.

Additional strategies from the architectural side were implemented through a selection case study such as the building orientation preferably facing east-west for long axis and seal any air leakage through windows that have single glazing. However, unfortunately, a limited effort was done towards the building's envelope since the residents have inadequate information about the insulation system.

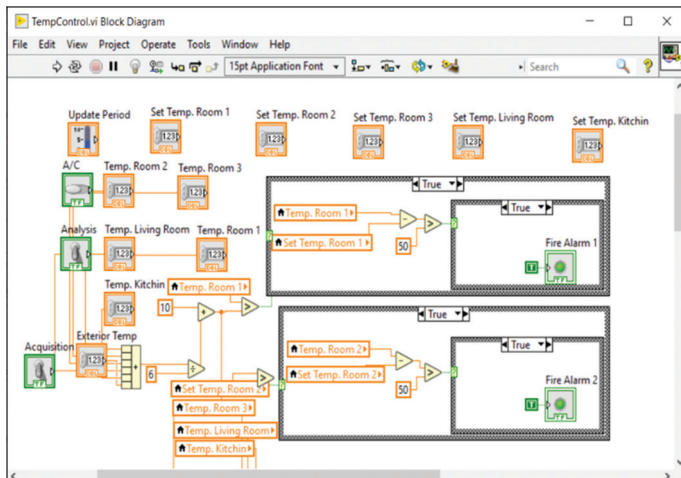
These strategies were associated with awareness and education for residents of how to manage energy usage such as:

1. Setup appliances (preferred setup for energy efficiency)
2. Consumer behavior that includes strategies for using washing machines, ironing, dishwashing, etc

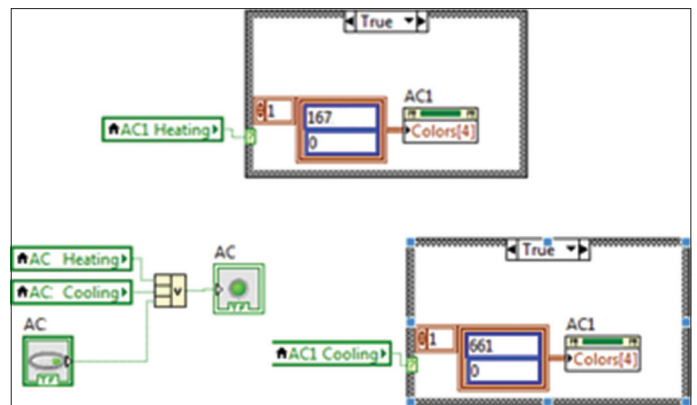
**Figure 9:** LabView front panel for user interface (control, monitor, and override)



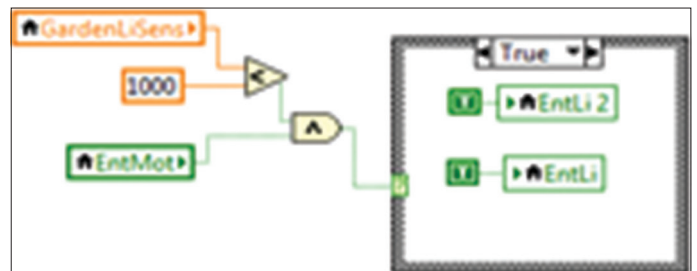
**Figure 10:** LabView temperatures and fire control codes



**Figure 11:** LabView HVAC control codes per room

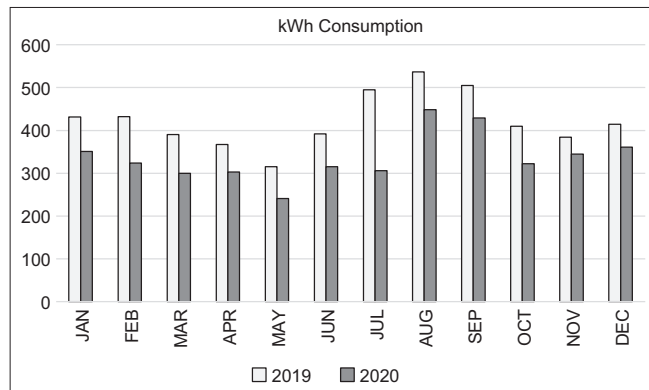


**Figure 12:** LabVIEW external light control





**Figure 13:** Electrical energy saving between 2019 and 2020 due to proposed modification



**Table 1: Total monthly electrical energy consumption in kWh and cost for 2019 without proposed modification**

Month	Price	kWh
January	26.65	431
February	26.74	432
March	23.19	390
April	21.16	367
May	20.46	315
June	27.49	319
July	31.42	495
August	36.79	536
September	33.2	505
October	24.88	410
November	22.62	384
December	25.23	414

**Table 2: Total monthly electrical energy consumption in kWh and cost for 2020 with proposed modification**

Month	Price	kWh
January	19.83	351
February	17.52	324
March	15.38	300
April	15.65	303
May	14.42	241
June	20.4	315
July	25.87	306
August	28.13	448
September	26.47	429
October	17.28	322
November	19.29	345
December	20.62	361

**Table 3: Total monthly electrical energy saving in kWh and cost for 2020 with proposed modification**

Month	Saving
January	25.6%
February	34.5%
March	33.7%
April	26.04%
May	29.5%
June	25.8%
July	17.7%
August	23.5%
September	20.3%
October	30.5%
November	14.7%
December	18.3%

3. Fenestrations management like opening windows for cross ventilation to improve air quality inside the residence, controlling shutters to balance between the amount of natural lighting and gained heating from sun's radiation; and
4. Management for space layout where spacious/less crowded zone (without unused furniture) helps to reduce used energy for heating and cooling space.

From Tables 1 and 2, the above strategies achieved conservation in power consumption for a two bedrooms apartment (prototype case study) ranging from 14.7% to 34.5% over 1 year as shown in Table 3 and Figure 13.

These strategies can achieve better results in terms of energy saving for new buildings and remodeled structures as well which consider the following guidelines:

1. Building orientation should be the east-west axis for longer side
2. Well-sealed insulated building envelope along with using double or triple glazing for fenestrations
3. Evergreen landscape for south and west sides of buildings
4. Using cross ventilation systems to circulate air inside the building
5. Facilitating building's setback and distances between buildings
6. Providing furniture layout for spaces' layout to avoid crowdedness; and
7. Manual showing the best behavior for using the facility in terms of energy conservation.

These guidelines need to be implemented on a simulation model testing energy conservation before real-life testing.

The above guidelines can be considered as the first step in energy conservation in the Jordan context especially there is no regulation or policy at the country level discussing energy conservation except a few initiatives and proposals originated by academics and small businesses. This can be considered as an individualistic mission and fragmented effort with little practical attention which is mainly ineffective. On the other hand, at the international level, there are several programs, guidelines, regulations initiated to stimulate energy conservation.

## 8. CONCLUSION

A sustainability theme was proposed in terms of smart building energy conservation with the ability to adjust itself based on the surrounding environment to create a sustainable better living condition. Yet, energy and smart building have been tied up together in many types of research due to the positive impact of smart building on energy usage and production.

This was supported by several views, conducted by academics and professional experts in both Architectural and Electrical Engineering fields, emphasized the need for a comprehensive strategy to bridge the gap and encourage harmonious collaboration.

Such recommendations were considered seriously in this study aiming to optimize the design of smart buildings in the housing sector. This can be achieved clearly through using LabView (software automation) to design a comfortable space with power saving, automated adjustment, and continuous monitoring for early detection and proper actions.

As technologies embedded in smart building, a new era of energy conservation, well living environment, and a high level of comfort can be obtained. Nevertheless, this work-study had discussed energy consumption in Jordan, where the majority of consumers were centralized in the buildings sector.

Based on professional feedback surveys and technology implementation, the notion of smart buildings is required to create sustainable living environments with higher quality and less energy.

Therefore, promoting such technology and implementing it into the newly constructed building must be an important approach by local regulation and building codes towards zero energy buildings.

In general, buildings' efficiency needs to be designed in a holistic approach starting from building envelope, orientation, layout, openings as well as all details that include appliances, lighting features, and other technological systems. All these techniques will not be productive if not joined with users' behaviors which will be improved through public education and awareness.

## REFERENCES

- Akujuobi, C., Awada, E. (2008), Wavelet-based ADC testing automation using labview. *International Review of Electrical Engineering*, 3, 922-930.
- Al-Ali, A., El-Hag, A., Dhaouadi, R., Zainaldain, A. (2011), Smart home gateway for smart grid. *International Conference on Innovations in Information Technology*, 2011, 90-93.
- Al-Hindi, I., Al-Sallami, H. (2017), Potentials and barriers of energy saving in Jordan's residential sector through thermal insulation. *Jordan Journal of Mechanical and Industrial Engineering*, 11(3), 141-145.
- Baharum, F., Bin Zainon, M., Ee Ling, Y., Nawi, M. (2016), The evaluation of building occupants' public awareness on energy efficiency: The study case of government office building. *Revista de la Facultad de Ingeniería U.C.V.*, 31, 22-33.
- Barghi, A., Kosari, A., Shokri, M., Sheikhaei, S. (2014), Intelligent Lighting Control with LEDs for Smart Home. United States: IEEE Smart Grid Conference. p1-5.
- Cetina, C., Giner, P., Fons, J., Pelechano, V. (2009), Using Feature Models for Developing Self-Configuring Smart Homes. United States: 5<sup>th</sup> International Conference on Autonomic and Autonomous Systems. p179-188.
- Chao-Lin, W., Li-Chen, F. (2012), Design and realization of a framework for human-system interaction in smart homes. *IEEE Transaction on Systems, Man, and Cybernetics Part A: Systems and Humans*, 42(1), 15-31.
- Chen, S., Chang, Y. (2010), The Computer-aided Design Software for Smart Home Device Based on Cloud Computing Service. United States: 2<sup>nd</sup> WRI World Congress on Software Engineering. p273-278.
- Choi, J., Shin, D., Shin, D. (2005), Research on Design and Implementation of the Artificial Intelligent Agent for Smart Home Based on Support Vector Machine. United States: ICNC. p1185-1188.
- De Dear, R., Akimoto, T., Arens, E., Brager, G., Candido, C., Cheong, K., Baizhan, L., Nishihara, N., Sekhar, C., Tanabe, S., Toftum, J., Zhang, H., Zhu, Y. (2013), Progress in thermal comfort research over the last twenty years. *Indoor Air*, 23(6), 442-461.
- Ding, D., Cooper, A., Pasquina, F., Fici-Pasquina, L. (2011), Sensor technology for smart homes. *Maturitas*, 69(2), 131-136.
- Eichhammer, W. (2009), Study on the Energy Savings Potentials in EU Member States, Candidate Countries, and EEA Countries. Germany: Fraunhofer-Institute for System and Innovation Research.
- Elangovan, R., Santhannakrishnan, N., Rozario, R., Arjuman, A. (2018), Tomen: A plant monitoring and smart gardening system using IoT. *International Journal of Pure and Applied Mathematics*, 119, 703-709.
- Europe's Energy Portal. (2010), Available from: <http://www.energy.eu>. [Last accessed on 2020 Feb 16].
- Hamed, B. (2012), Design and implementation of smart house control using LabVIEW. *International Journal of Soft Computing and Engineering*, 1, 98-106.
- Han, D., Lim, J. (2010), Smart home energy management system using IEEE 802.15.4 and ZigBee. *IEEE Transactions on Consumer Electronics*, 56(3), 1403-1410.
- Higuera, J., Hertog, W., Perálvarez, M., Carreras, J. (2014), Hybrid Smart Lighting and Climate Control System for Buildings. London, United Kingdom: IEEE Conference on Future Intelligent Cities, IET. p1-5.
- Hosein, A., Hoseini, G., Dahlan, N., Berardi, U., Makaremi, N. (2013), The essence of future smart houses: From embedding ICT to adapting to sustainability principles. *Renewable and Sustainable Energy Reviews*, 24, 593-607.
- Hoseini, A., Ibrahim, R., Baharuddin, M., Hoseini, A. (2011), Creating green culturally responsive intelligent buildings: Socio-cultural and environmental influences. *Intelligent Buildings International*, 3(1), 5-23.
- Intergovernmental Panel on Climate Change. (2007), 6<sup>th</sup> Assessment Report on Climate Change: Synthesis Report United Nations. Available from: <https://www.ipcc.ch>. [Last accessed on 2020 Jan 13].
- Jaber, J., Elkarmi, F., Alesis, E., Kostas, A. (2015), Employment of renewable energy in Jordan: Current status, SWOT and problem analysis. *Renewable and Sustainable Energy Reviews*, 49, 490-499.
- Janssen, R. (2004), Towards Energy Efficient Buildings in Europe. London: The European Alliance of Companies for Energy Efficiency in Buildings. p1-74.
- Jiang, Y., Liu, X. (2010), Building energy conservation and technology. *Frontiers in Energy*, 4(3), 10-25.
- Li, B., Hathaipontaluk, P., Luo, S. (2009), Intelligent oven in smart home environment. *International Conference on Research Challenges in Computer Science*, 42, 247-250.
- Liu, Z., Li, H., Li, G. (2019), Special issue for building energy conservation and renewable energy integration. *Journal of Thermal Science*, 28(6), 1103-1103.
- Mainasara, A., Alibaba, H. (2019), Enhancing energy efficiency through passive design principals in hot-humid climate. *International Journal of Engineering Research and Reviews*, 7(4), 8-17.
- Mansoori, G., Enayati, N., Agyarko, L. (2016), Energy: Sources, utilization, legislation, sustainability, illinois as model state. *Energy Sources, Part B: Economics, Planning, and Policy*, 12, 96.
- Marco, J., Marc, J., Christian, P., Pramudianto, F., Al-Akkad, A., Reinert, R. (2010), The Energy Aware Smart Home. United States: IEEE 5<sup>th</sup> International Conference on Future Information Technology. p1-8.
- Markovic, D., Cvetkovic, D., Zivkovic, D., Popovic, R. (2012), Challenges of information and communication technology in energy-

- efficient smart homes. *Renewable and Sustainable Energy Reviews*, 16(2), 1210-1216.
- Nacer, A., Laurent, D., Bruno, M. (2017), *Smart Home, Smart HEMS, Smart heating: An Overview of the Latest Products and Trends*. New York: 6<sup>th</sup> International Conference on Systems and Control. p1-5.
- NEPCO. (2013), *Annual Report-2013*. Available from: [http://www.nepco.com.jo/store/docs/web/2013\\_en.pdf](http://www.nepco.com.jo/store/docs/web/2013_en.pdf). [Last accessed on 2021 Feb 10].
- NEPCO. (2019), *Annual Report-2019*. Available from: [http://www.nepco.com.jo/store/docs/web/2019\\_en.pdf](http://www.nepco.com.jo/store/docs/web/2019_en.pdf). [Last accessed on 2021 Feb 10].
- Optimal Energy and Synapse Energy. (2011), *Economic Impacts of Energy Efficiency Investments in Vermont, Final Report*. Available from: [https://www.publicservice.vermont.gov/sites/dps/files/documents/Energy\\_Efficiency/EVT\\_Performance\\_Eval/Economic%20Impacts%20of%20EE%20Investments\\_2011.pdf](https://www.publicservice.vermont.gov/sites/dps/files/documents/Energy_Efficiency/EVT_Performance_Eval/Economic%20Impacts%20of%20EE%20Investments_2011.pdf). [Last accessed on 2020 May 07].
- Pleasant, P., Gaudioso, J., Chae, N., Lassiter, Y., Schiavoni, A., Jackson, L., Eaton, A. (2004), *US energy conservation and efficiency: Benefits and costs*. *Environment Development and Sustainability*, 6, 279-305.
- Sanchez, A., Tercero, R. (2010), *Smart Home Technologies: Uses and Abuses*. Pachuca, Mexico: 9<sup>th</sup> Mexican International Conference on Artificial Intelligence. p97-102.
- Twumasi, E., Frimpon, E., Appiah, D., Okyere, P. (2017), *Energy Efficiency Awareness and Preparedness among Students*. United States: IEEE Conference PES/IAS PowerAfrica. p456-461.
- United Nations Office for the Coordination of Humanitarian Affairs (OCHA). (2012), Available from: <https://www.reliefweb.int/sites/reliefweb.int/files/resources/Jordan.pdf>. [Last accessed on 2020 Dec 20].
- Worldometer. (2020), *Jordan Population*. Available from: <https://www.worldometers.info/demographics/jordan-demographics>. [Last accessed on 2020 Oct 23].