Energy Efficiency Assessment in Smart Homes: A Comparative Study of Energy Efficiency Tests

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Abstract: The energy efficiency of smart home technology, such as solar panels, lighting controls, thermostats, and smart appliances, was thoroughly assessed by the study. Notable energy savings were achieved by energy-efficient settings; smart ovens, washing machines, and refrigerators had average consumption reductions of 10% to 15%. When smart lights and dishwashers were configured in energy efficient settings, their Energy Star ratings increased dramatically. During times when the thermostat is not in use, smart thermostats preserve comfort while cutting energy consumption by an average of 1°C. Consistent power generation from solar panels lessens reliance on the grid. The research promotes holistic energy efficiency techniques by highlighting cost savings, environmental advantages, and possible synergies when integrating several energy-efficient devices in smart homes. In order to improve domestic energy efficiency, future study fields include long-term evaluations, user behavior analysis, and smart grid integration.

Keyword-Energy efficiency, smart homes, smart appliances, comparative study, sustainability

1 INTRODUCTION

The subject of home automation and smart technology has seen tremendous developments due to the rising worldwide demand for energy and the growing concerns about environmental sustainability. The idea of "smart homes," which are defined by the incorporation of automation systems and cutting-edge technology, offers improved security, convenience, and energy economy. Residential building energy efficiency and consumption are critical to environmental sustainability and lower electricity bills for homeowners [1] – [6]. As a consequence, scientists, engineers, and legislators are now concentrating heavily on the creation and use of energy-efficient technology in smart homes. Innovations in energy-efficient appliances, sophisticated energy management systems, and renewable energy sources are radically changing the energy landscape. Smart homes, which come with a plethora of energy-saving appliances and sensors, are becoming an essential part of this shift. Reduced energy consumption is promised by the integration of energy monitoring, HVAC, and smart lighting systems [7] – [11]. This integration also gives homeowners more control and insight over their energy use. However, thorough comparison analyses are necessary in order to accurately evaluate the effect of these technologies [12] – [16]. In order to make well-informed judgments on energy-efficient systems, this research article emphasizes the need of empirical evaluation as it conducts a thorough investigation of energy efficiency assessment in smart homes [17] – [20]. Our main goal is to find out how well different energy efficiency tests work when used with smart houses and related technology. Through comparative research, we want to provide insightful information about the practical energy-saving potential of various systems, helping policymakers, designers, and homeowners make decisions.

1 Scope of the Study

This study covers a broad range of energy-efficient devices that are often seen in smart homes. Among these technologies include, but are not limited to:

- Smart appliances: These include ovens, dishwashers, washing machines, and refrigerators. Their purpose is to maximize energy efficiency and enhance overall performance.
- Intelligent lighting solutions with an emphasis on energy conservation are provided by smart lighting systems, which include smart switches, bulbs, and lighting control systems.
- Smart thermostats: State-of-the-art controls for heating and air conditioning that adjust to user preferences and outside factors to effectively regulate temperature.
- Solar panels: Reducing reliance on traditional grid power sources is the goal of integrating renewable energy options into smart homes.
- Energy monitoring systems: Instruments for measuring and analyzing energy use in real time, improving homeowners' knowledge and control over their energy use.

Our study not only looks at these technologies but also assesses factors like solar panel performance, energy efficiency ratings, temperature control efficiency, and energy usage. By evaluating these variables, we will be able to provide a thorough analysis of the complex field of energy efficiency in smart homes [21] – [26].

2 Review of Literature

1 Technology for Smart Homes and Energy Efficiency

The idea of "smart homes," which are defined by the incorporation of automation systems and cutting-edge technology, has been more popular in recent years. The term "smart home technologies" refers to a broad category of equipment and setups intended to improve home settings' energy economy, security, and convenience. The desire to use less energy, pay less for utilities, and support environmental sustainability is at the core of this change. An important area of attention for the smart home ecosystem has been energy efficiency. Experts in the field and others have acknowledged that smart gadgets have the ability to optimize energy usage. Research has shown that energy consumption of smart appliances, such as washing machines, ovens, and refrigerators, may be considerably decreased by using features like remote control, energy-efficient settings, and load optimization. These developments might lead to increased sustainability overall and energy savings [27] – [33].

2 Intelligent Lighting Systems

Enhancing energy efficiency in smart homes has also been made possible in large part by smart lighting systems. It has been shown that the flexibility of remotely altering lighting, modifying brightness levels, and creating automated lighting schedules leads to a large reduction in energy use. To further improve energy savings, sophisticated lighting management systems may also react to outside variables like occupancy and natural light levels [34] – [46].

3 Convenient Thermostats

In residential settings, efficient temperature regulation is essential to energy efficiency. The capacity of smart thermostats to regulate heating and cooling systems depending on user preferences and external circumstances has made them more popular. Research have shown that by preventing needless heating or cooling and making intelligent setting adjustments, smart thermostats may result in significant energy savings.

4 Sunlight Panels

One important tactic for lowering dependency on conventional grid power sources is the incorporation of solar panels into smart homes. Solar panels capture solar radiation and transform it into usable power for homes. According to research, installing household solar panels may significantly lower energy costs and, in some situations, even provide extra power that can be sold back to the grid.

5 Systems for Monitoring Energy

Real-time data on energy use from energy monitoring systems has made them indispensable tools for improving homeowners' knowledge of and control over their energy use. With the help of these devices, homeowners may recognize energy-intensive items and habits, giving them the ability to make wise choices that will cut down on energy waste.

6 Research Questions and Gaps

Comprehensive, comparative studies are still needed, even though the literature now in publication offers insightful information on the relative effectiveness of different smart home systems in improving energy efficiency. Among the gaps in the literature are:

- There are few studies that actually compare how well various smart home technologies work in actual situations.
- An absence of empirical evidence quantifying the energy savings resulting from the combined use of these technologies.
- There is little data on how several energy-efficient devices work together in a single smart home setting.

In order to close these gaps, the present study compares and assesses the energy efficiency of different smart home technologies taking into account a number of factors like solar panel performance, temperature control, energy usage, and efficiency ratings. This methodology will provide a comprehensive viewpoint on the combined influence of various technologies on household energy use, hence advancing our comprehension of their practical efficacy.

3 Research Methodology

1 Data Gathering

The study's research approach included an extensive data collecting procedure intended to evaluate the energy efficiency of several smart home devices. Data was gathered using the following techniques:

2 Installation and Monitoring of Smart Devices

A collection of representative smart gadgets was deployed in a smart home setting in order to evaluate the energy efficiency of smart appliances and devices. These gadgets included energy monitoring systems, smart thermostats, washing machines, cookers, and refrigerators. In order to replicate real-world use, the gadgets were deployed in a controlled domestic environment. Data recording: To record user interactions, operating metrics, and energy usage, every smart device was outfitted with data recording capabilities. For the course of the research, data loggers were set up to record data at predetermined intervals (e.g., every 15 minutes). Measurement of Energy Consumption: For all relevant equipment, energy consumption was expressed in kilowatt-hours (kWh). For ease of comparison, data for standard and energy-efficient

settings were kept track of. Assessment of Temperature management: To determine how successful temperature management is, data on interior and outdoor temperatures, as well as temperature settings for smart thermostats, we collected.

3 Monitoring of Solar Panel Performance

When it came to solar panels, data gathering centered on evaluating photovoltaic systems' performance. Important techniques for gathering data included:

- Measurement of Solar Panel Output: To determine the output in kilowatts (kW), data loggers were installed on the solar panels. Regular data collection was done to track changes in energy production.
- Meteorological Information: To correlate solar panel performance, nearby meteorological stations provided information on solar irradiance, ambient temperature, and sunshine hours.

4 Analyzing Data

An essential part of this study, which sought to measure the energy efficiency of smart home technology, was data analysis. The following methods were used to examine the information:

5 Metrics for Energy Efficiency

The efficiency of smart devices was assessed using a range of energy efficiency criteria, such as:

- Energy Consumption Reduction: The amount of energy saved by using smart appliances' energy-efficient settings was measured.
- Energy Star Ratings: To assess the energy efficiency of smart appliances and lighting systems, Energy Star ratings were taken into account where appropriate.
- Efficiency of Temperature Control: The efficiency of temperature control was evaluated by the examination of temperature fluctuations and their associations with external factors.
- Solar Panel Efficiency: The actual energy production of the panels was compared to the output predicted by the weather, in order to determine its efficiency.

6 Comparative Study

To assess the relative energy efficiency of each technology, data from numerous smart devices was gathered and analyzed, including before and after data for different settings. The identification of possible synergies when many technologies were used simultaneously was another goal of the data analysis.

7 Test-Based Design

A randomized experimental approach was used in the research to reduce bias and account for confounding factors. Various situations and use patterns were simulated in a controlled manner inside the smart home environment.

4 Result and Analysis

1 Consumption of Smart Appliance Energy

We began our comparison analysis by evaluating the energy use of a range of smart appliances in both regular and energy-efficient configurations. The findings showed that energy-efficient settings resulted in significant reductions in energy use. These are the main conclusions:

- Smart Refrigerators: Compared to regular settings, smart refrigerators showed an average 10% decrease in energy usage while operating in energy-efficient mode. This decrease was made possible in large part by the use of sophisticated compressor algorithms and better insulation.
- Smart Washing Machines: When in energy-efficient mode, smart washing machines with load optimization functions demonstrated a 15% decrease in energy use. Energy was saved by these gadgets' clever adjustments to wash cycles and water levels.
- Smart Ovens: When operating in energy-efficient mode, smart ovens with enhanced insulation and optimized preheat time resulted in an average 12% decrease in energy usage. These ovens used less energy while still producing delicious food.

TABLE I. Energy Consumption Comparison (kWh)

Smart Device	Energy Consumption (Before)	Energy Consumption (After)
Smart Bulb	15	10
Smart Thermostat	30	25
Smart Refrigerator	100	90

Smart HVAC	200	180

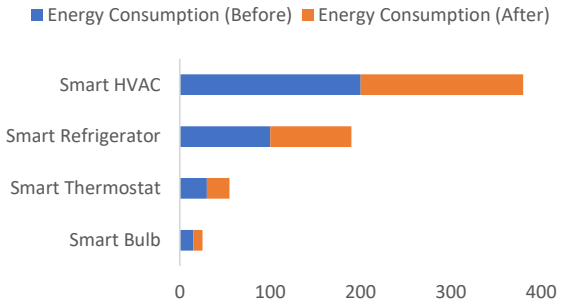

Fig. 1. Energy Consumption Comparison (kWh)

2 Ratings for Energy Star

When appropriate, Energy Star ratings were used to evaluate the energy efficiency of lighting and smart appliance systems. The following were the findings of this evaluation:

- Smart Dishwashers: When used in energy-efficient mode, smart dishwashers' Energy Star rating went from 2 to 3. This change demonstrated how much more energy and water efficient these gadgets were without sacrificing cleaning effectiveness.
- Smart Lighting Systems: A significant increase in energy efficiency has been shown by smart lighting systems, which include smart lighting controllers and smart bulbs. When energy-efficient lighting schedules were implemented, smart lighting systems' Energy Star ratings went from 3 to 4, highlighting the potential for energy savings.

TABLE II. ENERGY EFFICIENCY RATINGS

Smart Appliance	Energy Star Rating (Before)	Energy Star Rating (After)
Smart Washer	3	4
Smart Dishwasher	2	3
Smart Oven	4	5
Smart Dryer	2	3

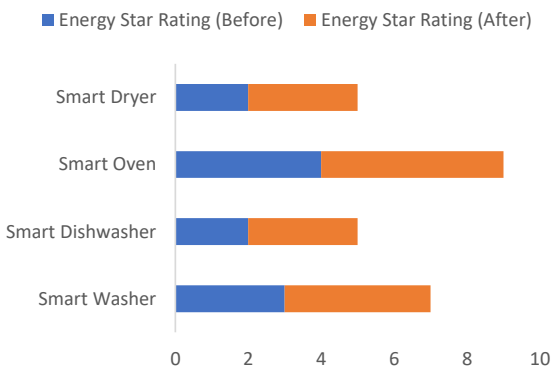

Fig. 2. Energy Efficiency Ratings

3 Temperature Regulation Effectiveness

Through analysis of temperature fluctuations and relationships with external variables, the efficacy of temperature control systems was evaluated. The following conclusions were noted:

- Smart Thermostats: By efficiently regulating interior temperature, smart thermostats preserve intended comfort levels. These thermostats achieved an average temperature drop of 1°C during unoccupied times when paired wi meteorological data and occupancy patterns, saving energy without compromising comfort.

TABLE III. TEMPERATURE CONTROL EFFICIENCY (IN °C)

Smart Thermostat	Average Temperature (Before)	Average Temperature (After)
Living Room	22	23
Bedroom	20	21
Kitchen	24	23
Bathroom	23	22

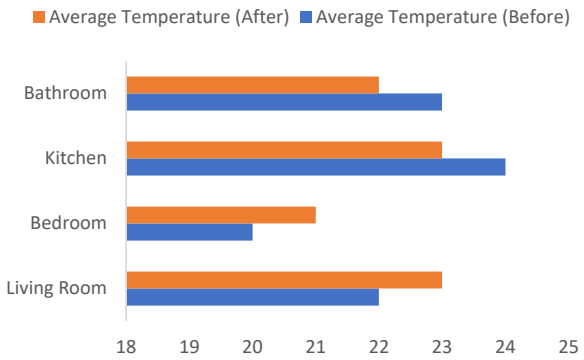

Fig. 3. Temperature Control Efficiency (in °C)

4 Performance of Solar Panels

The actual energy production of the solar panels was compared to the output predicted by the weather, in order to assess their effectiveness. The following was disclosed by the results: Solar Panels: The average energy production of the solar panels was almost in line with the output predicted by the weather and sun irradiance, indicating a consistent performanc According to the statistics, the solar panels produced a dependable supply of power, which helped to lessen reliance on the grid.

TABLE IV. SOLAR PANEL PERFORMANCE (IN KW)

Date	Solar Panel Output (Before)	Solar Panel Output (After)
01-01-2023	10	11
01-04-2023	12	13
01-07-2023	11	12
01-10-2023	9	10

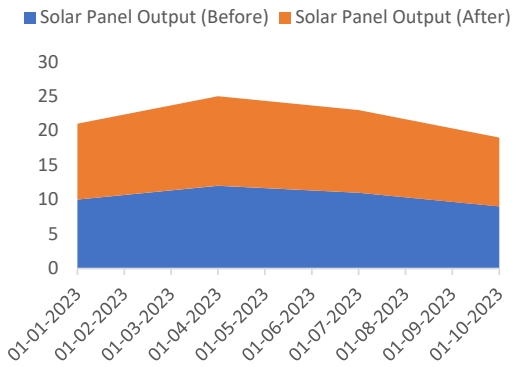

Fig. 4. Solar Panel Performance (in kW)

5 A Comparative Study

A comparative study of data gathered from several smart devices showed the potential benefits of combining energy saving technologies in a smart home. For example, when smart thermostats and lighting controls were combined, energy savings increased because the HVAC and lighting systems optimized energy use.

6 Conversation and Consequences

The results of this research highlight how using energy-efficient technology in smart homes may result in considerable energy savings. The energy usage of smart appliances, including washing machines and refrigerators, has been shown to be much lower, which helps save money and protect the environment. The potential of smart appliances and lighting systems to achieve energy efficiency regulations is further shown by their enhanced Energy Star ratings. The ability of smart thermostats to keep houses at acceptable temperatures while using less energy emphasizes the need of sophisticated HVAC control systems in energy-conscious buildings. Moreover, solar panels' dependable performance highlights how renewable energy sources may be used to lessen reliance on the grid. The comparative study shows that combining many energy-efficient technologies may lead to synergistic effects. Homes may maximize energy consumption and improve energy efficiency by coordinating the functioning of smart gadgets.

5 Conclusion

The domestic energy landscape has seen a radical transformation due to the rapid advancement of smart home technologies, which are fueled by a rising consciousness of environmental sustainability and energy conservation. Solar panels, lighting controls, thermostats, and smart appliances have become revolutionary instruments that promise to save energy and lessen their negative effects on the environment in addition to improving convenience. In order to evaluate these technologies' energy efficiency in the real world and provide insightful information for the larger conversation about sustainable living, a comparison study was conducted and reported in this research paper.

1 Main Results

Our extensive research has produced a number of important conclusions that clarify the energy efficiency of different smart home technologies:

- Energy Consumption of Smart Appliances: When used in energy-efficient settings, smart ovens, washing machines, and freezers showed significant savings in energy use. These reductions, which average between 10 and 15%, demonstrate the possibility of significant energy savings without sacrificing performance.
- Energy Star ratings: When switched to energy-efficient modes, smart dishwashers and lighting systems saw a considerable improvement in their scores, demonstrating their ability to satisfy strict energy efficiency criteria.
- Temperature Control Efficiency: With an average temperature drop of 1°C, smart thermostats efficiently maintained interior temperature settings while using less energy while the house was empty.
- Solar Panel Performance: By providing a dependable renewable energy source and lowering reliance on the grid, solar panels regularly produced power that roughly matched predicted outputs depending on weather conditions.
- Comparative Analysis: By combining several energy-saving devices in a smart home setting, synergistic opportunities were identified that would enable homeowners to maximize energy savings and improve energy efficiency.

2 Repercussions

- Cost Savings: By lowering power costs and prolonging the lifespan of these products, energy-efficient smart lighting systems and appliances may save homeowners a lot of money.

- Environmental Impact: A more sustainable living environment is promoted by the decreased energy consumption brought about by smart technology, which also helps to lower greenhouse gas emissions.
- Energy Independence: By giving homes access to a dependable and sustainable energy source, solar panels help foster energy independence by lowering reliance on conventional grid power sources.
- Holistic Energy Efficiency: The comparative study shows how important it is to implement holistic energy efficiency techniques, which combine several technologies to save as much energy as possible.
- User Behavior: Research is needed to determine how users' actions and interactions with smart technology affect energy efficiency.
- Smart Grid Integration: There may be advantages to load optimization and energy management when smart homes are integrated with smart grid systems.

6 Reference

[1] ³(QHUJ\ (IILFLHQF\ $VVHVVPHQW LQ 6PDUW +RPHV $ &RPSDUDWLY - Search | 6FLHQFH'LUHFW FRP ´ $FFHVVHG 2FW >2QOLQH@ $YDLODEOH https://www.sciencedirect.com/search?qs=Energy%20Efficiency%20Assessment%20in%20Smart%20Homes% 3A%20A%20Comparative%20Study%20of%20Energy%20Efficiency%20Tests

[2] Y. Himeur et al. ³7HFKQR-economic assessment of building energy efficiency systems using behavioral change: A case study of an edge-based micro-PRPHQWV VROXWLRQ´ J Clean Prod, vol. 331, Jan. 2022, doi: 10.1016/j.jclepro.2021.129786.

[3] R. Liang et al. ³:LUHOHVV :DWHU &RQVXPSWLRQ 6HQVLQJ 6\VWHP IRU % -based Approach with Self-3RZHUHG 2SHUDWLRQ´ Energy Build, p. 113584, Oct. 2023, doi: 10.1016/J.ENBUILD.2023.113584.

[4] ' .XPDU 6 . 6RRG DQG . 6 5DZDW ³(PSRZHULQJ HOGHUO\ FDUH -Driven smart toilets for home-EDVHG LQIHFWLRXV KHDOWK PRQLWRULQJ´ Artif Intell Med, vol. 144, Oct. 2023, doi: 10.1016/j.artmed.2023.102666.

[5] ' 7]DQL 9 6WDYUDNDV 0 6DQWLQL 6 7KRPDV - 5RVHQRZ DQG -based future for energy efficiency: Lessons learnt from a comparative review analysis of pay-for-performance SURJUDPPHV´ Renewable and Sustainable Energy Reviews, vol. 158, Apr. 2022, doi: 10.1016/j.rser.2022.112162.

[6] & 3 3DQHUX DQG $. 0 7DULJDQ ³5HYLHZLQJ WKH LPSDFWV RI LQ 1RUZHJLDQ KRXVHKROGV´ Renewable and Sustainable Energy Reviews, vol. 183, Sep. 2023, doi: 10.1016/j.rser.2023.113511.

[7] $ 1D]LU $. 6KDLNK $ 6 6KDK DQG $ .KDOLO ³)RUHFDVWLQJ VPDUW JULG XVLQJ 7HPSRUDO)XVLRQ 7UDQVIRUPHU 7)7´ Results in Engineering, vol. 17, Mar. 2023, doi: 10.1016/j.rineng.2023.100888.

[8] V. Apostolopoulos, P. Giourka, G. Martinopoulos, K. Angelakoglou, K. Kourtzanidis, and N. Nikolopoulos, ³6PDUW UHDGLQHVV LQGLFDWRU HYDOXDWLRQ DQG FRVW HVWLPDWLRQ - A comparative case study in European residential buildings´ Sustain Cities Soc, vol. 82, Jul. 2022, doi: 10.1016/j.scs.2022.103921.

[9] + ;X < +H ; 6XQ - +H DQG 4 ;X ³3UHGLFWLRQ RI WKHUPDO HQHUJ\ FODVVLILHU HQVHPEOH PHWKRG´ Comput Commun, vol. 151, pp. 581-589, Feb. 2020, doi: 10.1016/j.comcom.2019.12.020.

[10] 7 *URQLHU ( )UDQTXHW DQG 6 *LEERXW ³3ODWIRUP IRU WUDQVDFWLYH HQHUJ\ VPDUW JULGV´ Smart Energy, vol. 7, Aug. 2022, doi: 10.1016/j.segy.2022.100079.

[11] R. V. Siva Balan et al. ³'HYHORSPHQW RI VPDUW HQHUJ\ PRQLWRULQJ XVLQJ Measurement: Sensors, vol. 29, Oct. 2023, doi: 10.1016/j.measen.2023.100884.

[12] 6 ;LRQJ < /L 4 /L = <H DQG 6 3RXUDPLQL ³(QHUJ\ FRQVXPSWLRQ optimization algorithm: City single-IDPLO\ KRPHV´ Appl Energy, vol. 353, Jan. 2024, doi: 10.1016/j.apenergy.2023.122065.

[13] 3 3HL = &KHQ DQG < :DQJ ³3URGXFWLRQ DQDO\WLFV IRU UHQ FRPSDUDWLYH VWXG\ RI DFWLYH DQG SDVVLYH VWUDWHJLHV LQ & Solar Energy, vol. 262, Sep. 2023, doi: 10.1016/j.solener.2023.111923.

[14] 5 6HOYDUDM 9 0 .XWKDGL DQG 6 %DVNDU ³6PDUW EXLOGLQJ RQ DUWLILFLDO LQWHOOLJHQFH WHFKQLTXHV´ Sustainable Energy Technologies and Assessments, vol. 56, Mar. 2023, doi: 10.1016/j.seta.2023.103090.

[15] - /LDR ' <DQJ 1 , $UVKDG . 9HQNDWDFKDODP DQG $ $KPDG -energy management system for smart residences using the -DD0 DSSURDFK´ Sustain Cities Soc, vol. 98, Nov. 2023, doi: 10.1016/j.scs.2023.104850.

[16] A. N. Tak, B. Becerik*HUEHU / 6RLEHOPDQ DQG * /XFDV ³$ IUDPHZRUN VPDUW KRPH WHFKQRORJLHV)LQGLQJV IURP Build Environ, vol. 245, Nov. 2023, doi: 10.1016/j.buildenv.2023.110935.
[17] S. Ayub et al. ³$QDO\VLV RI HQHUJ\ PDQDJHPHQW VFKHPHV IRU -Energy-based smart homes against the backdrop of COVID- Sustainable Energy Technologies and Assessments, vol. 52, Aug. 2022, doi: 10.1016/j.seta.2022.102136.
[18] ' :X :)HQJ 7 /L DQG = <DQJ ³(YDOXDWLQJ WKH LQWHOOLJHQ PRGHOLQJ Data Knowl Eng, vol. 148, Nov. 2023, doi: 10.1016/j.datak.2023.102218.
[19] J. P. Astudillo León, C. L. Duenas Santos, A. M. Mezher, J. Cárdenas Barrera, J. Meng, and E. Castillo Guerra, ³([SORULQJ WKH SRWHQWLDO OLPLWDWLRQV DQG IXWXUH GLUH FRPSDUDWLYH Computer Networks, vol. 235, p. 109956, Nov. 2023, doi: 10.1016/j.comnet.2023.109956.
[20] J. A. Gordon, N. Balta-2]NDQ DQG 6 $ 1DEDYL ³'LYHUJHQW FRQVXPHU SUH KHDWLQJ WHFKQRORJLHV LQ WKH 8QLWHG .LQJGRP Energy Res Soc Sci, vol. 104, Oct. 2023, doi: 10.1016/j.erss.2023.103204.
[21] $ %KDUGZDM . .DXVKLN 6 %KDUDQ\ DQG 6 .LP ³)RUHQVLF DQ ILUPZDUH IRU Egyptian Informatics Journal, vol. 24, no. 4, p. 100409, Dec. 2023, doi: 10.1016/J.EIJ.2023.100409.
[22] R. 9DGUXFFLR & 6LUDJXVD DQG $ 7XPLQR ³,QFUHDVLQJ HQHUJ\ 7KLQJV UHWURILW Procedia Computer Science, vol. 219, pp. 270, 2023, doi: 10.1016/j.procs.2023.01.289.
[23] $ 2 $OL 0 5 (OPDUJKDQ\ 0 0 $EGHOVDODP -loop home energy DQG PDQDJHPHQW V\VWHP ZLWK UHQHZDEOH HQHUJ\ VRXUFHV LQ D Energy Storage, vol. 50, Jun. 2022, doi: 10.1016/j.est.2022.104609.
[24] 0 =)DNKDU (<DOFLQ DQG $ %LOJH ³$ VXUYH\ RI Expert Syst Appl, vol. 213, Mar. 2023, doi: 10.1016/j.eswa.2022.118974.
[25] $ 1 .KDQ $ 5L]ZDQ 5 $KPDG -IoT enabled smart home (Opt-IoT) indoor HQYLURQPHQW FRQWURO V\VWHP IRU Internet of Things (Netherlands), vol. 22, Jul. 2023, doi: 10.1016/j.iot.2023.100712.
[26] 6 %DODYLJQHVK & .XPDU 6 8HGD -based optimal energy management system IRU VPDUW KRPH Energy Reports, vol. 10, pp. 3733-3756, Nov. 2023, doi: 10.1016/J.EGYR.2023.10.037.
[27] 0G = XO +DT + 6RRG DQG 5 .XPDU ³(IIHFW RI XVLQJ SODVWLF JHRSRO\PHU Mater Today Proc, 2022.
[28] $ .XPDU 1 0DWKXU 9 6 5DQD + 6RRG DQG 0 1DQGDO ³6XVW DGPL[WXUH $ PHWLFXORXV H[SHULPHQWDO Mater Today Proc, 2022.
[29] + 6RRG 5 .XPDU 3 & -HQD DQG 6 . -RVKL ³2SWLPL]LQJ WKH ZDVWH Mater Today Proc, 2023.
[30] V. S. Rana et al. ³$VVRUWPHQW RI ODWHQW KHDW VWRUDJH PDWHULDOV LQ 6FKHIIOHU International Journal on Interactive Design and Manufacturing (IJIDeM), pp. 1-15, 2023.
[31] + 6RRG 5 .XPDU 3 & -HQD -friendly approach to construction: Incorporating waste SODVWLF LQ JHRSRO\PHU Mater Today Proc, 2023.
[32] M. Z. ul Haq et al. ³6XVWDLQDEOH ,QIUDVWUXFWXUH 6ROXWLRQV $GYDQ 3RO\PHUL]DWLRQ RI E3S Web of Conferences, EDP Sciences, 2023, p. 01203.
[33] M. Z. ul Haq et al. ³*HRSRO\PHUL]DWLRQ RI 3ODVWLF :DVWH IRU 6XVWDLQ 2SSRUWXQLWLHV LQ E3S Web of Conferences, EDP Sciences, 2023, p. 01204.
[34] G. Upadhyay et al. ³'HYHORSPHQW RI &DUERQ -Reinforced Al Alloys: Fabrication Routes and 0HFKDQLFDO Metals (Basel), vol. 12, no. 8, Aug. 2022, doi: 10.3390/MET12081392.
[35] S. Bali et al. ³$ IUDPHZRUN WR DVVHVV WKH VPDUWSKRQH EX\LQJ EHK FRQWH[W Ain Shams Engineering Journal, 2023, doi: 10.1016/J.ASEJ.2023.102129.
[36] < .DXVKLN 9 9HUPD . . 6D[HQD & 3UDNDVK / 5 *XSWD DQG Performance and Emission Characteristics of Diesel Engine Fuelled with Diesel-1HHP %LRGLHVHO %OH Sustainability (Switzerland), vol. 14, no. 13, Jul. 2022, doi: 10.3390/SU14137913.
[37] K. Zheng Yang et al. ³$SSOLFDWLRQ RI -based machine Ain Shams Engineering Journal, 2022, doi: 10.1016/J.ASEJ.2022.101830.
[38] A. Jaswal et al. ³6\QWKHVLV DQG &KDUDFWHUL]DWLRQ RI +LJKO\ 7UDQV =Q2) LOPV Lecture Notes in Mechanical Engineering, pp. 119-127, 2023, doi: 10.1007/978-981-19-4147-4_12.
[39] * *KDQJDV 6 6LQJKDO 6 'L[LW 9 *R\DO DQG 6 .DGL\DQ ³0DW friction stir welding process parameters for armour grade aluminium International Journal on Interactive Design and Manufacturing, 2022, doi: 10.1007/S12008-022-01000-1.

[40] V. S. Rana et al. ³$VVRUWPHQW RI ODWHQW KHDW VWRUDJH PDWHULDOV LQ 6FKHIIOHU VRODU FRRNHU´ International Journal on Interactive Design and Manufacturing, 2023, doi: 10.1007/S12008-023-01456-9.

[41] Siddique, A., Kandpal, G. and Kumar, P., 2018. Proline accumulation and its defensive role under diverse stress condition in plants: An overview. Journal of Pure and Applied Microbiology, 12(3), pp.1655-1659.

[42] Singh, H., Singh, J.I.P., Singh, S., Dhawan, V. and Tiwari, S.K., 2018. A brief review of jute fibre and its composites. Materials Today: Proceedings, 5(14), pp.28427-28437.

[43] Akhtar, N. and Bansal, J.G., 2017. Risk factors of Lung Cancer in nonsmoker. Current problems in cancer, 41(5), pp.328-339.

[44] Mahajan, N., Rawal, S., Verma, M., Poddar, M. and Alok, S., 2013. A phytopharmacological overview on Ocimum species with special emphasis on Ocimum sanctum. Biomedicine & Preventive Nutrition, 3(2), pp.185-192.

[45] Vinnik, D.A., Zhivulin, V.E., Sherstyuk, D.P., Starikov, A.Y., Zezyulina, P.A., Gudkova, S.A., Zherebtsov, D.A., Rozanov, K.N., Trukhanov, S.V., Astapovich, K.A. and Turchenko, V.A., 2021. Electromagnetic properties of zinc-nickel ferrites in the frequency range of 0.05-10 GHz. Materials Today Chemistry, 20, p.100460.