Energy Sustainable House: A Case study and validation through Revit

Energy Sustainable House: A Case study and validation through Revit

Arjun Malik[1], Ravinder Kumar[2], Rhythm Gupta[1], Varun Vikal[1], Minhan[1], Ujjwal Bhardwaj[1].

[1] Department of Civil Engineering, Amity University, Noida, Uttar Pradesh, India-201303.
[2] Department of Mechanical Engineering, Amity University, Noida, Uttar Pradesh, India-201303.

Abstract: Reducing carbon footprints and adopting green energy sources is the need of modern time. Green sources of energy need to find preference over traditional sources. Unconventional sources of energy like solar, wind are alternatives of traditional energy sources. Lack of awareness, high initial investment and lack of government incentive are few challenges in adoption of green sources of energy in housing sector, especially in developing economies. Construction, design and aesthetics of traditional residential building have a significant effect on energy consumption and environment. Town planners, private housing developers and individual house owners have to become aware and adopt the non-traditional sources of energy like solar energy for meeting their daily need of energy. An energy sustainable house has minimum dependency on traditional sources of energy like coal based thermal power plants. For moving a step closer to energy sustainable building, in this research paper authors have studied the design, energy consumption and transformation of energy dependencies on roof top solar plant of a residential building by situation actor process & learning action performance (SAP-LAP) methodology. Further authors tried to validate the observations and findings of study by energy balance analysis of the same residential building by Autodesk Revit software. Studying the economical aspect of current case authors observed that the case house got 60% saving in monthly electricity bill after installing rooftop solar power plant and payback period of total investment on solar power plant is 6.5 to 7 years only.

Keywords—: Renewable Energy, Energy Sustainable House, SAP-LAP, Sustainability, Solar Energy, Revit

1. Introduction

Buildings contribute to 30% of global greenhouse gas (GHG) emissions and are responsible for the utilization of one-third of the global raw materials, energy and water. Energy sustainable houses are the necessity of modern era because of reduces the greenhouse gases emissions and are cost efficient in long run [1]. Sustainability focuses on social, economic and environmental aspect of any activity. Globally organizations are shifting from traditional practices to green practices. Focus is on reducing carbon footprints by using renewable sources of energy, reuse of products and recycling [2, 3]. Energy sustainable housing can be attained by using renewable energy and encouraging technological innovations. A shift from traditional practices & technologies to use of unconventional sources of energy with latest technologies is required. Renewable sources of energy like solar, wind have tremendous capabilities of meeting energy demands of modern housing with reduced GHG emissions & minimum carbon footprints [1]. Renewable energy has a direct relation with sustainable development through its impact on development of humans and cost efficiency. Renewable sources provide opportunities in energy access, climate change reduction and health impacts.

The main objective of establishing renewable energy in India is to promote economic development, improve access to energy and its security, mitigate climate change and ensure affordable housing. Renewable energy application focuses on how to match the energy supply with the energy demand of buildings and yield system performance [4]. Sustainability is a wider concept that focuses on overall development of a healthy, affordable, productive and a comfortable environment for a long period of time with minimum impact on the environment and society [5-7]. Achieving sustainability is the need of the hour in today's world due to the damaging effects of increasing population, their consumption of non-renewable resources and increased global warming. Thus, sustainable housing should aim at social,

economic and environmental sustainability and at the same time result in the type of housing that is affordable and environment friendly. Utilization of renewable energy into households will help in achieving an affordable house as well as reducing the energy cost. Modern day buildings are highly energy intensive with a significant consumption of energy right from the construction phase to the operation and maintenance. Owing to global energy crisis, suitable strategies need to be developed to address energy conservation in modern buildings [8]. There are various methods to reduce the use of conventional energy generated by fossil fuels and meet the energy requirement for the building. The combination of various solar passive design aspects can easily be integrated in new buildings based on the site, orientation of building and local climatic conditions. Reducing carbon emissions and addressing environmental policies in the construction domain should be intensively explored with solutions ranging from energy efficiency technique, building informatics and other different renewable energy strategies [9]. It is observed that the Cost of energy of solar system in large residential area is lower than the cost of energy in single building or small area. The results translate that the solar energy can be an alternative source of electricity for housing, especially for large residential area and have many environmental benefits [10]. The efforts to bring the benefits of solar to low-income consumers can benefit from the experience of utility energy efficiency programs, as well as from decades of experience in government programs to provide affordable housing reduce harmful emissions [11].

In this research paper authors have studied the design, energy consumption and transformation of energy dependencies on roof top solar plant of a residential building. Section two discusses the methodology. Section three explored the case house building by using SAP-LAP methodology. Section four analyse the case with Revit software. Section five concludes the finding of study.

2. Methodology

In this research paper authors have studies a residential building for its design and energy consumption pattern by using situation actor process and learning action performance (SAP-LAP) methodology. Data is also analysed and validated by Autodesk Revit software for energy analysis. On the basis of observations of case study authors analysed the traditional energy consumption with the roof top solar power plant system. Case study comprises of two parts, one is data collection and another is analysing it with SAP-LAP framework followed by the validation of findings through Autodesk Revit Software.

The SAP-LAP framework is an innovative and holistic framework for case analysis [12, 13].The SAP-LAP methodology consists of two component first one is SAP. SAP framework comprises the “situation”, “actors” and “process” and their interplay. Situation defines the external and internal environment of an organization and its performance in simple term the situation inspect the past present and future trends. The situation is influenced by the actors. The process is the overall transformation process that converts a set of input into outputs to create the situation. The interplay and synthesis of SAP leads to LAP that is learning, action, performance [12] then through analysing the situation actors and process the key issues problem and drawbacks is known depending on the learning the action have to be taken accordingly which will lead to the improve performance.
The findings of the SAP-LAP methodology are then validated through energy analysis of the Residential model with Revit software. The three dimensional model of the building is created using Autodesk Revit software and further for energy analysis of the model Autodesk Insight is used. Autodesk Insight is a cloud based Energy Analysis Program which helps to improve energy and environmental performance through different energy efficient strategies.

3. Case Study

In this section authors have discussed the general description and features of the residential building located in Ghaziabad, Uttar Pradesh. Orientation of the building is in the North-West direction. The plot size is 464.495 Sq.mt and has a ground floor and 2 upper floors. The ground floor is equipped with an entrance lobby, drawing room, puja room, kitchen, lobby/Dining Area and two bedrooms with attached

washroom followed by three bedrooms with washroom, lobby and a sitting area on the first floor and then the terrace. Energy efficiency and carbon emission neutrality in the building was ensured with features like efficient lighting & LED, insulation of roof and wall, overhang sizing, skylight for daylight and orientation optimization. The objective of the design was to make the building self-sufficient and economically viable. To minimize energy consumption, the service core areas are located at South-West ends of the building and allowed natural ventilation and daylight. This minimized the dependency on artificial lighting and ventilation while blocking excessive heat and ensuring maximum sunlight. The building is designed in a way to get improved physical comfort parameters such as visual, thermal and acoustic while maintaining the aesthetics. Table 1 shows the general specifications and the structural details of case building. The building is North-West oriented with appropriate shading and light shelves on the south helps in optimizing building energy performance. The building form helps reduce heat gain or loss. All habitable rooms have admission of air and light with one or more apertures such as windows, glazed doors opening directly to the external air. A total number of 22 windows are used in the building to enhance the ventilation and lighting features. 90% of the spaces, including the core and service areas, receive uniformly distributed daylight throughout the day minimizing the dependency on artificial lighting. Glass is the primary material which is used for both indoor spaces and outdoor enclosures which offers privacy, maintains ambient temperature and adds to the aesthetic value of the building interior and exterior. It reduces the absorption of heat while allowing natural light to penetrate.

Table 1. General & Structure details of Case Building

Utility of Building	Residential Building
Number of Storey	G+1
Type of construction	R.C.C Framed Structure
Orientation	North-West
Grade of concrete	M30
Steel	Fe500
Area Chart	Sq. Mt.
Total Plot Area	30.48×15.24=464.495
Permi. Covered Area on G.Floor	301.920
Open Area Required on G.Floor	162.575
F.A.R. 1.50	696.740
Proposed Covered Area on G.Fl.	252.832
Proposed Covered Area on F.Fl.	252.832
Total Proposed Covered Area All Floors	732.303

3.1 SAP-LAP Analysis

In this section authors has studied the energy requirement, current traditional supplies and final condition after setting up rooftop solar power plant of case building by SAP-LAP methodology.

3.1.1 Situation

In the current situation India is a developing country which is going through an economic transition phase which is marked by increase in energy demand and it is estimated to get double in over a decade since energy is one of the major inputs for the economic development of any country. The ever increasing energy needs requiring huge investment to meet them. About 80 -85% of India's energy generation is from fossil fuels. Delhi NCR the major consumer of India energy. Most of the demand of energy of Delhi NCR is met by burning fossil fuel (Like coal etc). At present different areas of NCR is getting energy at different and higher rates. In Delhi the energy provided at rupees 6.50 for 400 to 800 units and rupees 7 for 800-1200 units, Ghaziabad (Rs 6.20 to 6.50 per unit on 300-600 units and Rs 6.5-7 per unit for more than 500 units). In Faridabad it is Rs 6.30 per unit for 250-500 units and Rs 7.10 per unit for 500-800 units. In this paper the case we are analysing is a residential house with plot area for 464.495 square metre situated in Ghaziabad, Uttar Pradesh. Expected energy requirement of a house

with this much area is generally around 1000-1200 kWh per month depending on the consumption. Figure 1 shows average energy consumption of the house in our case study which comes out to be around 1500-1600kWh per month. The total load of all equipment's and facilities sums up to around 22,250 units annually and the approx. daily energy requirement is around 50-60 kwh.

Figure 1. Electric equipment details of the case house

3.2. Actors

For case house the power is supplied by NTPC, Dadri, Gautam Buddh Nagar, Uttar Pradesh is also taken under observation. Research was done about the power plant. It is a coal fired thermal power plant and gas fired plant. Producing electricity using coal not only release fumes in the environment, it burns a non-renewable resource which does not call being sustainable. After producing electricity, it then transfers the power generated to different power houses to supply that power to residential and commercial buildings under those power houses. During the power transfer, some power gets lost during the export from various sources. Due to line loss, carbon footprint increases which results in depletion of environment and is not a sustainable practice for production and transfer of energy. The laying of transmission line accounts for restricted land use, change in the landscape and impacts on nature and biodiversity. Climatic effect is caused while transmission of electricity in these lines.

3.3. Process

Transmission of power is carried through transmission lines. Transmission over long distances, from power plant to substations, creates power loss. Severe environmental effects occur during the production process of electricity but that does not limit the damages that electricity causes. The transmission of electricity also causes damage to the environment.

3.4. Learning

Focusing on sustainability and affordability of energy, Authors framed learning from SAP part of analysis. One of the factors in an affordable housing is the operational cost of the house or to say the cost at which we are getting the energy. As observing the present situation the rate of energy production and transmission are increasing at a very rapid pace which give rise to the key issue cost inefficiency. To tackle this issue the action that can be taken is to shift from conventional source to non-conventional source or to integrate renewable energy strategy and technology in the house to reduce building energy use and cost. Coal is the major fossil fuel used in the industrial units and power plants for power generation in India. In the present situation the energy in the house is supplied by the NTPC Dadri which is a coal based power plant. In the production process of energy the coal is burned as a result of which the carbon dioxide is emitted as a product which is currently responsible for over 60% of the enhanced greenhouse effect.

3.5. Action

To meet the energy requirement of case building and integrate the renewable energy concepts, authors suggested setup of a rooftop solar power plant. It leads to the benefits such as decreased building operational energy costs, energy consumption and improved the environmental and social comfort. The action of incorporating a renewable energy technology into building operations was taken by installing Solar Panels. Its general description is given in Table 2.

Table 2. General Description of installed Solar Panels

Location	Ghaziabad, Uttar Pradesh
Capacity	17kWp
No. of Panels	68
Area	111.07 sq. mt.
Tilt Angle	12
Orientation	Towards South
Elevation	220m
Annual Average Production	19 MWh

3.6. Performance

In this section, the potential benefits of the case study and its performance evaluation will be discussed. To evaluate the performance of solar power plant on sustainability criteria, performance and project benefits are divided into three aspects; namely economical, environmental and social and community.

3.6.1. Economical Aspect

Cost Savings: The project's main intention is to promote healthy and green environment to the surroundings with financial benefits. One of the greatest advantages of installing solar panels is not only clean source of energy but also cost effectiveness. It continues to serve both nature and the society for a longer time. People who switch to solar energy experience a huge cut in electricity bills, hence saving a lot of money [14]. Figure 2 shows the monthly saving in electricity bill. Approximately 60% savings on cost were achieved after the installation of solar panels.

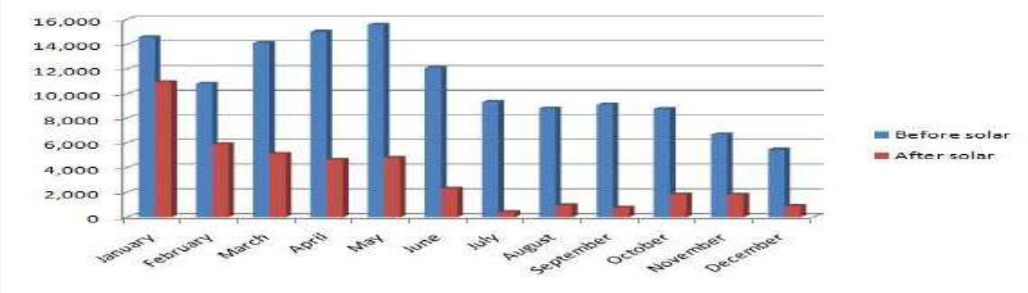

Figure 2. Monthly Bill Savings

Payback Period: It is a calculation that estimates how long it will take for you to "break even" on your solar energy investment. Table 5 shows calculation for the payback period of solar system installed in our case study:

3.6.2. Environmental Aspect

Incorporation of renewable practices in a building translates to better environmental health. Solar power's environmental impact is minimal and the technology produces none of the carbon, methane or particulate emissions that fossil fuels emit, and it does not require large-scale mining or drilling operations [15]. Figure 3 shows different environmental benefits of using solar energy.

Table 3. Payback Period Calculation

Total cost of plant	**Rs 8, 00,000**
Plant capacity	17kw
Generation per day	50kwh approx
Annual generation	50x 365= 18,250kwh approx
Annual saving	18,250x4.5= Rs 82,125
Subsidy	(30/100) x total cost = 0.3x 8,00,000 = Rs 2,40,000
Payback period	(Total cost-subsidy)/Annual saving =(8,00,000- 2,40,000)/82,125 = **6.5 ~ 7 years**

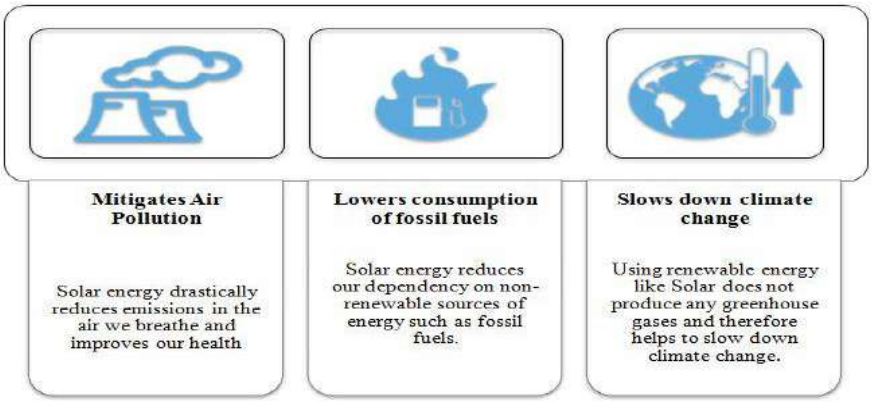

Figure 3. Environmental Benefits

Reduces Carbon Footprint: For every 1 megawatt-hour (MWh) of solar energy produced, 0.5 to 1 ton of carbon dioxide is offset. We found that the carbon emissions by the building were around 12.74t and after the addition of Solar panels the annual carbon savings were about 14t units.

3.6.3. Social Aspect

The low energy residential building analysed in our case study projected improved health, well-being and social outcomes. Health and well-being outcomes included less stress due to relieved pressure on finances and less health impacts from extreme temperatures [16]. In terms of social aspect it affects community individual, lifestyle and the quality of life and makes people realise the importance of renewable energy in achieving affordable housing by motivating them to integrate renewable energy practices in the house operations.

3.7. Energy Balance Validation through Revit

In the operational phase huge amount of energy is consumed by the buildings and they are one of the major sources of carbon discharge throughout their service life. It not only compromises the environment but directly affects global warming as well. Therefore, it is necessary to study the energy consumption of the building and optimize energy use intensity (EUI) as well as energy cost.

The energy analysis of the residential building with the help of Revit software is done to validate results and findings from the SAP-LAP methodology of our case study which includes total energy

consumption and integration of renewable energy technology into building operations in order to offset building energy needs and provide energy efficiency.
The three dimensional model of the building is created using Autodesk Revit software and further for energy analysis of the model Autodesk Insight is used. Autodesk Insight is a cloud based Energy Analysis Program which helps to improve energy and environmental performance through different energy efficient strategies. The main target of the analysis is to provide energy –efficient building by varying different design strategies with respect to energy cost and EUI. The energy stimulation of the residential building through Revit software involved the following steps:

- Collection of the information and drawings about the building to be studied.
- Creating a 3D model using the Autodesk Revit software with the help of the drawings.
- Changing the energy setting like building operating schedule, type of building, type of HVAC system etc. as per the need.
- Locating the building using Internet Mapping Service inbuilt in Autodesk Revit.
- Automatically generating a building energy model using the analyze panel in Revit software
- Optimizing the generated energy and running the results in the Autodesk Insight over the cloud.
- Estimating the energy use of the building.

3.7.1. Analytical Assessment
3D Model of the residential building is shown in the Figure 4.

Figure 4. 3D Model of the building

3.7.2. Energy Model
Energy generated by Revit based on the location, weather and the settings as shown in figure 5.

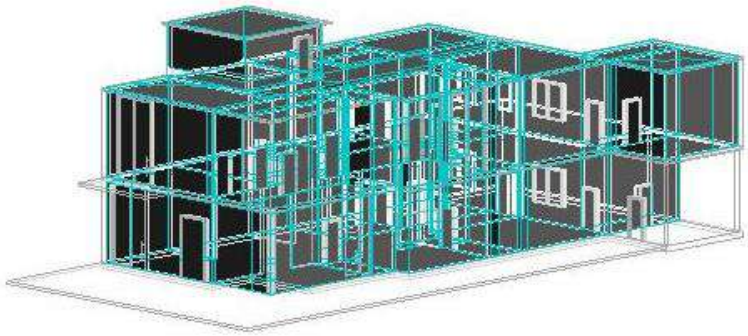

Figure 5. Energy model generated by Revit based on the location, weather and the settings.

3.7.3. Results and Findings

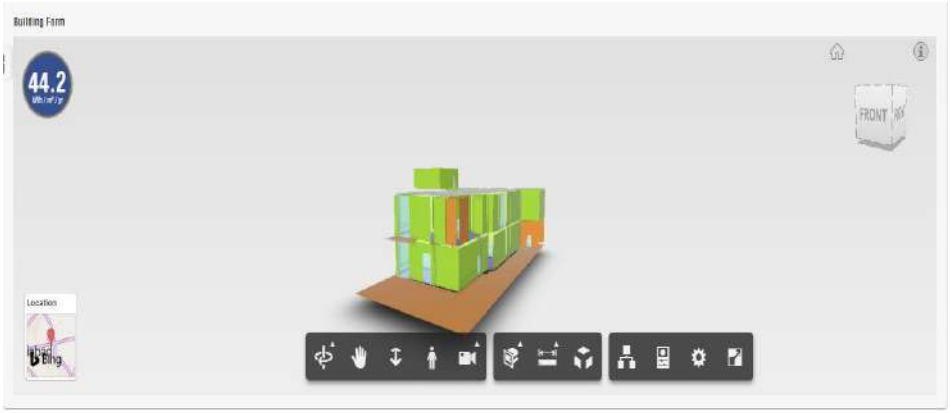

Figure 6. Total Energy Consumption of the building

44.2 kWh/m2/year is the total energy used per unit area in the residential building. The total energy use intensity (EUI) or the energy consumption of the residential building comes out to be around 20-22Mwh after computing with the area of the residential building which is similar to our findings done through SAP-LAP analysis.

3.7.4. PV-Surface Coverage

The PV analysis on the residential building shows how much area on the roof-top can be used for PV panels assuming area for access, system infrastructure and maintenance and in order to reduce the building energy demand as shown in Figure 7 and 8.

Figure 7. PV- Surface Coverage

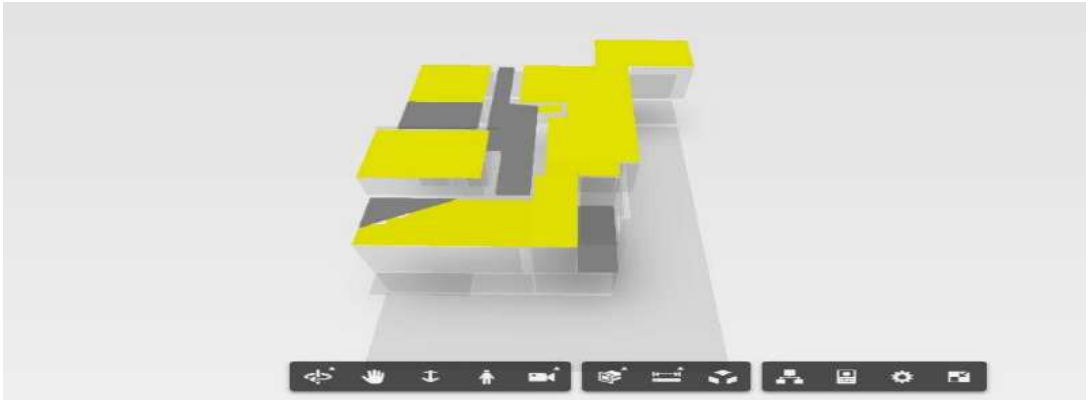

Figure 8. PV-Surface Coverage through Revit of the Residential Building

This validates our finding and learning from the SAP-LAP analysis where a renewable energy technology was integrated on the rooftop and in the building operations in order to minimize the building energy use and maximise the use of renewable energy for achieving sustainable and affordable housing.

4. Observation and Conclusion

Buildings are major contributors to economic and social development of a nation and are also responsible for utilizing a large amount of energy and natural resources that are available. Rapid urbanization has resulted in huge exploitation of the energy resources that are available. Large amount of energy is being consumed by the buildings leading to greenhouse emissions which have created greater impact on our fragile ecosystem. Analysing the energy consumption and the energy use Intensity (EUI) of buildings is important in order to adopt strategies that lead to a more energy efficient facility.

In current research paper authors did a case study of a residential building and analysed it with SAP-LAP methodology. To study the impacts of combining renewable energy technology into the building operations in orders to achieve sustainable and affordable housing and then validated our findings by doing energy balance analysis of the same residential house on Revit software. Learning from the SAP-LAP framework was to integrate a renewable technology into the building operations to maximize energy and cost savings which was achieved by installing solar panels and later validated energy analysis results from Revit software. After analysing the residential model of our case building with Revit Software, it is observed that with minor variations in the design strategies and integration of renewable technology like solar energy large percentage of difference in the energy use of the building can be observed. Authors observed a saving of 60% in energy bills after installing roof top solar plant. Pay back pack period of roof top solar plant comes out to 6.5 to 7 years. It is a very normal period to recover costs in solar system [17].

To maximize energy and CO_2 savings, it is essential to focus on constructing energy efficient buildings as well as understanding the role of renewable energy in sustainable and affordable housing for long term benefits by integrating renewable energy techniques and strategies into building operations to offset the building energy needs and receive financial benefits. Major implications of current study are that by taking one step towards renewable source of energy we can help the environment, ourselves and the society.

References

1. Maurya, A., Kumar, R., Bharadwaj, U., Rawat, P. and Kumar, M. (2021) "Sustainable Building Design: Energy Analysis of a Residential Building using Autodesk Revit," 2021 2nd International Conference on Intelligent Engineering and Management (ICIEM), 2021, pp. 441-446, doi: 10.1109/ICIEM51511.2021.9445376.
2. Kumar, R. (2020a). Sustainable Supply Chain Management in the Era of Digitalization, Issues and Challenges." *Handbook of Research on Social and Organizational Dynamics in the Digital Era.* IGI Global, 2020, ch021. pp. 446-460. Doi: 10.4018/978-1-5225-8933-4.
3. Kumar, R., Singh, R.K. and Dwivedi, Y.K. (2020).Application of industry 4.0 technologies in SMEs for ethical and sustainable operations: Analysis of challenges, Journal of Cleaner Production, Vol. 275, 2020. https://doi.org/10.1016/j.jclepro.2020.124063.
4. Hongwei,T. Lei Yong, Chen Yibo. Renewable Energy Development for Buildings 2016. https://doi.org/10.1016/j.egypro.2016.11.254.(https://www.sciencedirect.com/science/article/pii/S1876610216314643).
5. Kumar, R. (2020b). Sustainable Manufacturing in the era of Industry 4.0: A DEMATEL analysis of Challenges. Handbook of Research on IT Applications for Strategic Competitive Advantage and Decision Making. IGI Global. DOI: 10.4018/978-1-7998-3351-2.
6. Kumar, R. (2020c). Espousal of Industry 4.0 in Indian manufacturing organizations: Analysis of enablers, *Handbook of Research on Engineering Innovations and Technology Management in Organizations,* IGI Global publisher, DOI: 10.4018/978-1-7998-2772-6.

7. Garg, D. Mustaqueem, O.A. and Kumar,R. (2021). Sustainable Circular Manufacturing in the Digital Era: Analysis of Enablers, *Advances in Industrial and Production Engineering*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-981-33-4320-7_48.
8. Chel, A. and Kaushik, G. (2018). Renewable energy technologies for sustainable development of energy efficient building. Alexandria Engineering Journal, 57, 655–669.
9. Petri, I.; Kubicki, S.; Rezgui, Y.; Guerriero, A.; Li, H. Optimizing Energy Efficiency in Operating Built Environment Assets through Building Information Modeling: A Case Study. *Energies* 2017, *10*, 1167. https://doi.org/10.3390/en10081167.
10. Lucianto A. E. and Herdis, H. (2020). The Potential of Solar Panel Implementation towards Sustainable Affordable Housing Development. *IOP Conf. Ser.: Earth Environ. Sci.***519** 012024 International Conference Earth Science & Energy IOP Publishing IOP Conf. https://iopscience.iop.org/article/10.1088/1755-1315/519/1/012024.
11. Paulos, B. (2017). Bringing the Benefits of Solar Energy to Low-Income Consumers. https://www.cesa.org/resource-library/resource/bringing-the-benefits-of-solar-energy-to-low-income-consumers.
12. Sushil (2000), SAP-LAP models of inquiry, Management Decision, 38(5), 347-353.
13. Kumar, R., Singh, R.K. and Shankar, R. (2013), "Study on coordinationissues for flexibility in supply chain of SMEs: a case study", Global Journal of Flexible Systems Management, Vol. 14 No. 2, pp. 81-92.
14. Nushrat Shabrin ,Saad Bin Abul Kashem , (2017) " A Comprehensive Cost Benefit Analysis of Green Building " , International Journal of Advances in Mechanical and Civil Engineering (IJAMCE) , pp. 100-108, Volume-4,Issue-2.
15. Hayter, S and A. Kandt. Renewable Energy Applications for Existing Buildings: Preprint (2011) ,48th AiCARR International Conference Baveno-Lago Maggiore, Italy ,September 22-23, 2011.
16. Moore Trivess, Nicholls Larissa, Strengers Yolande, Maller Cecily, Horne Ralph. Benefits and challenges of energy efficient social housing. International Conference on Improving Residential Energy Efficiency, IREE 2017. (https://www.sciencedirect.com/science/article/pii/S1876610217334859).
17. Kumar. J, C.R., Majid, M.A. Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities. Energy Sustain Soc 10, 2 (2020). https://doi.org/10.1186/s13705-019-0232-1.