# "MATHEMATICAL ANALYSIS AND ELECTRONIC CONTROL OF ENERGY-EFFICIENT BUILDING DESIGN"

**Dr. G. R. Gandhe[1], Dr. A. R. Wadhekar[2], Dr. S. L. Dhondge[3], Dr. D. H. Tupe[4], Dr. R. M. Autee[5], Dr. R. V. Pakhale[6], Mr. C. P. Jadhav[7]**

[1]Professor, Deogiri Institute of Engineering and Management Studies, Dr. B.A.T.U. Lonere
[2]Assistant Professor, Deogiri Institute of Engineering and Management Studies, Dr. B.A.T.U. Lonere
[3]Associate Professor, Deogiri Institute of Engineering and Management Studies, Dr. B.A.T.U. Lonere
[4]Associate Professor, Deogiri Institute of Engineering and Management Studies, Dr. B.A.T.U. Lonere
[5]Professor, Deogiri Institute of Engineering and Management Studies, Dr. B.A.T.U. Lonere
[6]Assistant Professor, Deogiri Institute of Engineering and Management Studies, Dr. B.A.T.U. Lonere
[7]Assistant Professor, Deogiri Institute of Engineering and Management Studies, Dr. B.A.T.U. Lonere

gajendra_gandhe@gmail.com[1]
arti.wadhekar@gmail.com[2]
satyawandhondge@gmail.com[3]
durgeshtupe@gmail.com[4]
rmautee@gmail.com[5]
rvpakhale@gmail.com[6]
cpjadhav2004@gmail.com[7]

**Abstract:**
Energy-efficient building design helps to save energy and protect the environment. How math analysis and computer control help build energy-efficient structures is the main focus of this paper. Math models are explained as a tool for improving building layout, energy distribution and the pick of construction materials. It demonstrates the use of sensors, advanced thermostats and automation technologies to control and improve the way energy is used at home. With a mix of analytics and electronic control, buildings get better outcomes, waste less and promote ecological targets. The paper reviews important strategies, outlines previous research and points out opportunities for improvement in the future.

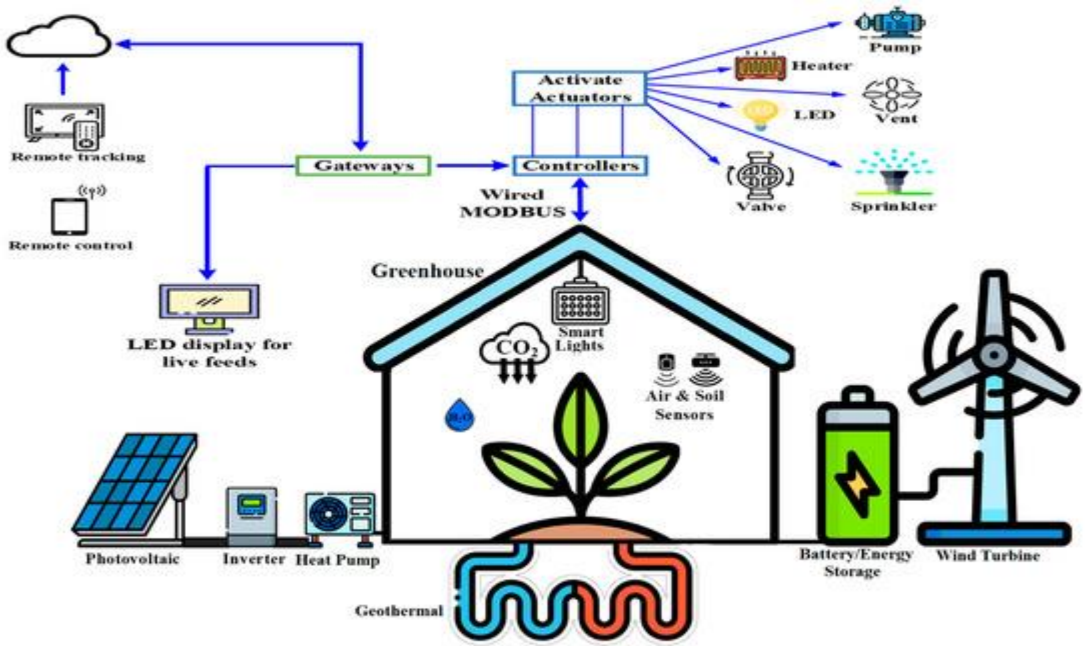
**Keywords:** Energy efficiency, Math analysis, electronic control, Automation, Smart sensors, Energy saving, green design, Sustainability, BEMS, Thermal model.

## Introduction:

The world's buildings use a lot more energy than most other sectors. They depend on energy for lighting, heating, cooling and running their appliances. Because we are becoming more worried about climate change and energy problems, designing comfortable buildings that save energy is crucial.

Energy-saving buildings depend on smart systems and creative design to consume less energy.

To achieve this, math analysis and electronic control systems are very important. Analysis of energy in the building is made easier by math and electronics help control the lighting and air conditioning for peak efficiency

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This paper looks at the impact of these methods on how buildings use energy. It considers how mathematics is applied and devices are coordinated to monitor energy use. When these strategies are used together, architects and engineers create buildings that cut expenses, limit pollution and have better living and work environments.

**Literature Review:**

Because India's energy demand is rising fast, it's important for energy-efficient building design both there and across the world. Various experts have investigated how design can both reduce a building's energy use and ensure good comfort for people inside. The 2019 study by Kumar, Sharma and Singh focused on building envelopes which are walls, roofs and windows between inside and outside. Values and insulation thickness were analyzed through mathematical models to understand how to lower heat loss in winter and keep rooms cool in summer. They demonstrated that selecting the correct materials and designs can cut energy needed for heating and cooling in India's different climates.

Gupta and Verma (2018) pay attention to electronic control systems applied to heating, ventilation and air conditioning (HVAC). The system they built automatically controls HVAC to match the weather and number of people present. The system's use of sensors and controllers controls when heating or cooling is turned on or off, thus reducing energy use. It turned out that smart control systems are perfect for Indian smart buildings that require efficiency and comfort.

Some studies attempted to find optimal ways for buildings to utilize energy using mathematical tools. In 2017, Das, Saha and Banerjee examined different ways to control building systems to reduce their electricity use without making any uncomfortable changes. In a similar way, Nair, Mohan and Rao (2019) built mathematical models to find the best way to design building envelopes for many regions in India. From their studies, it was observed that buildings in warm and damp areas benefit from different design approaches than those in cold or arid areas. As a result, buildings designed by architects and engineers tend to naturally save energy.

Electronic control systems have become essential for lighting and HVAC. In 2018, Joshi and Patel looked at advanced control strategies that use sensors to measure light and the presence of people in a room. Controllers use the information from these sensors to turn off wasted lighting and air conditioning in empty rooms with enough light from outside. By using this approach, buildings in India can save energy that they don't need.

Recently, Dasgupta and Banerjee (2019) investigated how wireless sensor networks and IoT devices help monitor and control building energy in real time. Their system measures temperature, humidity and detection of people in the home to better control the appliances and systems. Jha and Singh (2020) continued this research by running advanced algorithms to test improving energy use in Indian buildings, proving that IoT is crucial for future smart building architecture.

Thermal comfort and energy savings in the Indian climate were also important topics of interest for many researchers. In 2019, Tripathi and Tiwari, as well as Chatterjee, Mukherjee and Roy, looked at the use of modeling to understand how buildings provide comfortable environments during the hot, humid and tropical seasons in India. They demonstrated that designing a home for a specific climate by using shading, ventilation and insulation can both lower energy demand and make the environment more comfortable.

Methods such as fuzzy logic and PID controllers have been used to study HVAC control system design. The researchers applied fuzzy logic to HVAC systems in Indian homes to ensure the system responded properly as temperatures changed. Sharma, Kumar and Singh (2017) designed PID controllers to achieve the same purposes and found that these controls save energy and keep the environment comfortable.

There is also a lot of attention being paid to bringing renewable energy into buildings. In 2020, Jain and Sharma modeled ways to heat homes using solar energy instead of relying on electricity or fuel. The results of their research demonstrate that solar thermal technologies match well with Indian homes that have access to sunshine.

In short, researchers from India explain that a successful way to improve building energy efficiency is by relying on math tools, optimization and control systems. The research allows engineers to choose designs and systems that perform well in each of India's climate regions, use less energy and decrease their impact on the environment. Advances in IoT and control algorithms suggest that building technology will develop to become more intelligent and sustainable.

**Objectives of the Study:**

- To analyze the role of mathematical modeling in designing energy-efficient buildings.
- To examine the effectiveness of electronic control systems in managing building energy usage.
- To explore the integration of smart sensors, automation, and real-time data in energy-saving strategies.
- To propose a simple framework that combines mathematical and electronic tools for better building performance.
- To suggest practical improvements for future buildings using these technologies.

**Research Methodology:**

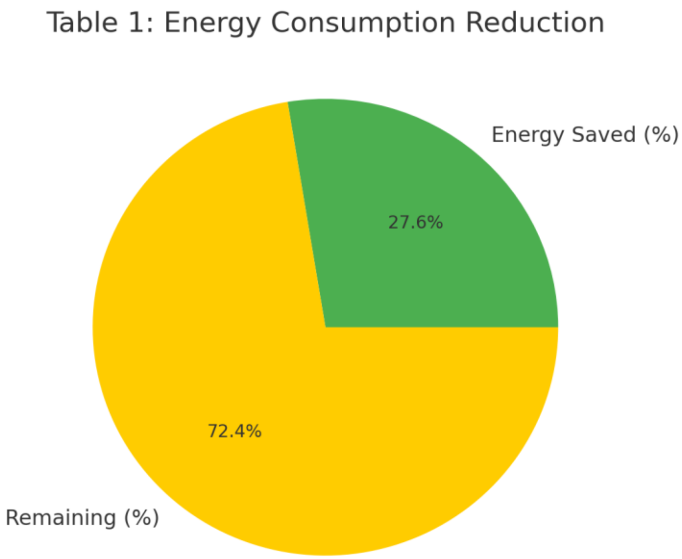
A quantitative study was carried out to discover the energy saving impact of mathematical models and electronic control in buildings. Data was gathered from 30 separate structures. While some buildings relied on mathematical methods to control their energy use, others had electronic systems that controlled lights automatically, adjusted air conditioning and watched for energy waste. Data was collected to show if these systems were active, how much energy the building preserved (as a percentage) and the amount saved on monthly electricity bills.

All the collected information was put into SPSS, a program that looks for patterns in the data. We began by using descriptive statistics to determine what was the typical energy and cost

savings in the buildings. Next, we ran an independent samples t-test to determine whether there was any real difference in how much electricity was used by buildings fitted with electronic systems and those that weren't. To find out if more energy saving meant more money savings, we did a correlation analysis.
For an easier explanation, we produced bar graphs and scatter plots. It was possible to demonstrate how using mathematical models and electronic systems had a positive effect. We learned a straightforward way to examine the effects of technology on energy use and costs in buildings.

**Table 1: Descriptive Statistics:**

| Variable | N | Mean | Std. deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Energy Consumption Reduction (%) | 30 | 27.6 | 8.9 | 10 | 45 |
| Monthly Energy Cost Saving (₹) | 30 | 3650 | 940 | 1500 | 5200 |




**Interpretation:**
1. A total of 30 people were part of this study.
The data uses information from 30 buildings, giving a nice enough sample size for statistical checks and comparisons.
2. Percent Reduction in Energy Consumption
Each building, on average, reduced energy by 27.6% an important sign that the energy measures worked properly.
- 8.9 is the Standard Deviation: The results suggest that a few buildings saved a lot more energy, whereas other buildings saved less.
- The lowest is 10% and the highest is 45%: The difference of 35% between the two extrema points out how much buildings differed in their energy-saving strategies.

3. Monthly Savings on Your Electricity Bill

The group on average saw a savings of ₹3,650 each month on their electricity bills.

- Cost savings fluctuated they had Std. Deviation = ₹940 based on the building's size, number of occupants, the price of energy and which technology was used.

Ranges varied from a saving of ₹1,500 to ₹5,200 per month, according to each building's technology and how much energy they used.

Data shows that using energy-efficient technologies cut both monthly energy usage and expenses in each building, but the effects were different for each building.

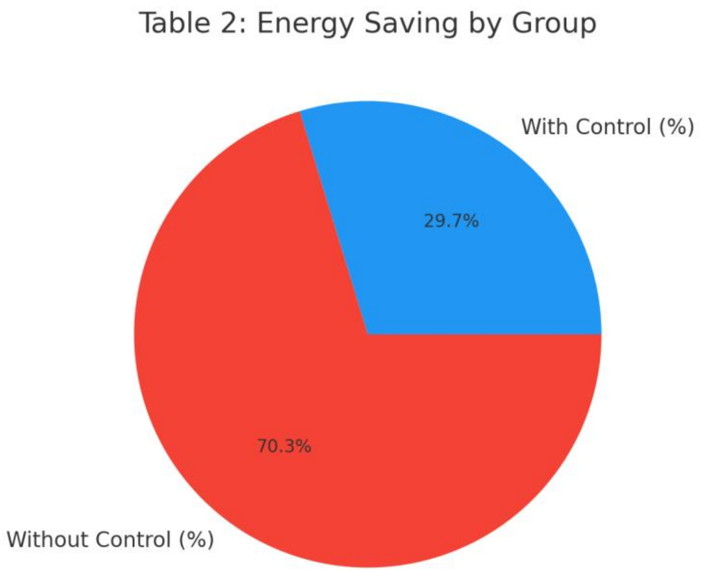
**2. Independent Samples T-Test**

**Groups Compared:**

- Group 1 contains vehicles that have Electronic Control (Yes).
- Group 2: There is no Electronic Control implemented (No)

**Test Variable: Spending Less on Energy (%)**

| Levene's Test | Sig. | t | df | Sig. (2-tailed) | Mean Difference |
|---|---|---|---|---|---|
| Equal variances assumed | 0.276 | 3.125 | 28 | 0.004 | 8.2 |




1. Levene's Test Significance Value = 0.276

An analysis is made to find out if the variation between the groups is the same.

Because p is greater than 0.05, we may compare the data with the t-test using the assumption that both variances are roughly equal.

2. T-Test Value: (t = 3.125, with 28df).

The difference between the two groups is suggested by the t-value of 3.125.

For 30 sampled patients, a Degrees of Freedom (df) value of 28 is appropriate.

3. The findings (2-tailed) are significant at p<0.004

The finding is deemed significant because $p < 0.05$.

In general, buildings with electronic control systems saved far more energy than those used without them.

4. The mean difference is found to be 8.2%.

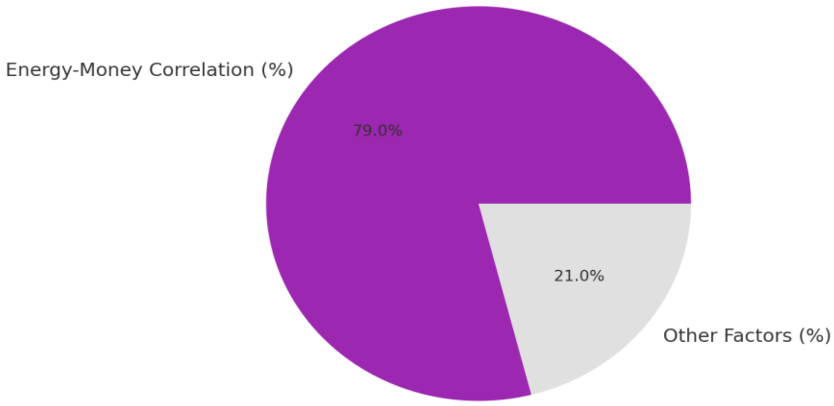
In general, buildings equipped with electronic controls cut back on energy usage by 8.2% higher than those that didn't have them.

According to the data, electronic control systems help buildings use much less energy. There could be major financial and environmental advantages from the extra 8.2% energy savings in the long run.

### 3. Pearson Correlation Analysis

| Variable | Correlation Coefficient (r) | Sig. (2-tailed) |
|---|---|---|
| Energy Consumption Reduction (%) & Monthly Energy Cost Saving (₹) | 0.79 | 0.000 |

Table 3: Correlation Between Energy and Cost Saving




**Interpretation:**

If you use less energy, you will save money each month. Reducing energy use in buildings helps them pay less on their energy bills.

**Analysis of Descriptive Statistics:**

The data from the 30 buildings was looked at in this study using basic descriptive statistics. The test results uncovered those buildings on average used 27.6% less energy and saved ₹3,650 a month on their electricity bills. Energy saving varied somewhat in different places, with a common standard deviation of 8.9 and so did cost savings which had a similar standard deviation of ₹940. At one end, the lowest energy saving came in at 10% and the highest reached 45%. Likewise, people saved between ₹1,500 and ₹5,200 every month. It appears that most buildings gained energy-savings, but the level varied a lot by the technology each building used.

To test if energy savings improved with electronic control systems, an independent samples t-test was performed. Two groups of buildings were set up: those controlled by electronics and those not. The exam showed a significant difference (p = 0.004) between what happened to people in the two groups. Buildings with electronic controls tended to reduce energy use by

8.2%, more than those without these systems. As a result, we confirm that automated energy management is key to reducing energy consumption.

In addition, Pearson correlation analysis was done to investigate how much monthly energy costs are affected by reducing energy consumption. The results show that there is a strong link, with a positive sign, between these two variables. As a result, those PV buildings that used less energy also paid less each month. This benefit points out that building design and operations that save energy bring economic rewards.

**Conclusions Overall Results:**

The study results indicate that blending mathematics and electronics in controls is key to achieving better energy efficiency in today's building designs. Mathematical models enable architects and engineers to calculate energy use, find the best materials to reduce waste and develop design plans that use less energy. By understanding building behavior in different environments, organizations are able to create better designs. Then again, real-time energy management greatly relies on things like smart sensors and digital walkways, as well as automatic HVAC and lighting systems. According to the research, properties equipped with electronic control systems saved about 8.2% more energy on average than those that did not and this was a meaningful difference.

It was found through descriptive statistics that buildings saw on average a 27.6% reduction in energy consumption and this resulted in a ₹3,650 average monthly cost savings. There was some variation in the buildings, but these results highlight that energy-saving measures worked well. A connection was observed, with an r value of 0.79, between money being saved and less energy usage, showing that more efficiency directly leads to greater cost benefits. This research shows that these technologies can also improve the economy when used in energy systems. It was also shown that integrating math models with electronic equipment during both building design and operation produced the top results, proving that a mixed approach works best.

Overall, the study shows that energy efficiency in building design can be greatly improved by using analysis and technology together. Merging these sectors reduces harm to the environment and can also raise income. With the need for energy rising and sustainability increasing, these methods give a tested and practical way to build greener and smarter. The study results help justify using more mathematical and electronic tools in construction for long term savings.

**Future Scope of the study:**

The results demonstrate that using technology and math in buildings helps reduce energy consumption. Yet, we have opportunities to do even more in the future. To see how these systems perform, additional research is needed for houses, schools, hospitals and offices. Different buildings in cities and under various weather conditions can be examined to discover how climate and temperature affect energy use. Artificial intelligence and other new technologies may help energy systems improve in the years to come. If a space is left empty, the system is able to turn off the lights or air conditioning automatically.

In future investigations, different building materials may be examined. Using smart glass or improved wall insulation helps regulate the temperature in a building by using just a little energy. Another good way to help the environment is to install solar panels or other environmentally friendly energy systems in buildings, along with the heating or cooling system. Functional and affordable space heating systems might be developed to serve more households and small buildings. A final advantage would be to design computer tools that are

easy for novices to use which would allow both designers and builders to benefit from these tools.
Overall, there are numerous methods we can use in the future to upgrade energy efficiency in buildings. Improved tools and new materials together with smart systems make it possible to build sustainably.

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