Journal of
Refrigeration, Air Conditioning, Heating and Ventilation

ISSN: 2394-1952
Volume 12, Issue 3, 2025
September–December
DOI (Journal): 10.37591/JoRACHV

https://journals.stmjournals.com/jorachv

Review JoRACHV

Advanced Energy-Efficient Technologies, Role of Artificial Intelligence and IoT in Energy Conservation

Gopinath Thirunavukarasu[1], Yash Sanjay Gandhi[2], Shailendra Kumar Shukla[3,*]

Abstract

One of the key elements in the development of every nation's economy is energy. Due to their enormous investment requirements to meet their rising energy needs, developing nations place a high priority on the energy industry. Utilize energy management, auditing, and conservation for cost reduction and boost efficiency. Achieving and maintaining optimal energy procurement and use across the organization is the goal of energy management in order to reduce energy expenditures and waste without compromising output or quality. to lessen the impact on the environment. The first step in a methodical approach to energy management decision-making is an energy audit. It identifies the entire energy stream in premises and makes an effort to balance the facility's overall energy inputs and uses. This paper explores cutting-edge innovations that optimize energy consumption across industrial, commercial, and residential sectors. Special emphasis is placed on the transformative role of Artificial Intelligence (AI) and the Internet of Things (IoT), which together enable intelligent monitoring, predictive analytics, automated control, and real-time optimization of energy systems. AI-driven algorithms enhance demand forecasting, fault detection, and adaptive energy management, while IoT networks integrate sensors, smart meters, and connected devices to create seamless, responsive energy ecosystems. By combining these technologies, organizations and smart cities can significantly reduce energy waste, lower operational costs, and improve environmental performance. The paper concludes that AI- and IoT-enabled energy-efficient solutions represent a pivotal pathway toward global energy conservation, driving the transition to smarter, cleaner, and more sustainable energy infrastructures.

Keywords: Energy conservation, renewable energy, commercial energy, CHP systems, waste heat recovery

***Author for Correspondence**
Shailendra Kumar Shukla
E-mail: skshukla.mec@iitbhu.ac.in

[1]Assistant Professor, Department of Mechanical Engineering, Dr. Vishwanath Karad MIT World Peace University, Pune, Maharashtra, India
[2]Student, Department of Computer Engineering, Vishwakarma Institute of Technology, Pune, Maharashtra, India
[3]Professor, Department of Mechanical Engineering, Indian Institute of Technology (BHU), Varanasi, Uttar Pradesh, India

Received Date: December 03, 2025
Accepted Date: December 08, 2025
Published Date: December 24, 2025

Citation: Gopinath Thirunavukarasu, Yash Sanjay Gandhi, Shailendra Kumar Shukla. Advanced Energy-Efficient Technologies, Role of Artificial Intelligence and IoT in Energy Conservation. Journal of Refrigeration, Air Conditioning, Heating and Ventilation. 2025; 12(3): 51–64p.

INTRODUCTION

Energy Conservation

Work is the conversion of energy from one form to another, and energy is the capacity to perform work. Different types of energy exist, including thermal energy, radiant energy, mechanical, chemical, electrical, and nuclear energy. The supply of coal as well as other petroleum-based fuels, which took nearly three million years to produce, will probably run out shortly. We have used up 60% of all resources in the last 200 years. We must take action to improve energy efficiency if we want sustainable development. Today, non-renewable and fossil sources (coal, oil, etc.) account for 85% of all primary energy. Due to rising use, these reserves are constantly being depleted and will be gone for future generations. We study energy efficiency and conservation in this chapter by learning how to reduce energy demand to a reasonable minimum cost, recover and reuse heat whenever possible, and study the use of energy-efficient equipment to supply the remaining energy demand. We also learn about energy and the environment, as well as how to conduct an energy audit [1,2].

Energy Scenario and Energy Sources

Based on the following criteria, different forms of energy can be classified [1].

- Primary and Secondary sources of energy
- Commercial and Noncommercial energy
- Renewable and Non-Renewable energy

The primary sources of energy are those that can be discovered in nature or are stored there. The most common sources of energy are biomass (such as wood), natural gas, coal, and oil. Other main energy sources that are accessible are potential energy from gravity, thermal power stored in the interior of the earth, and nuclear power from radioactive materials.

Primary energy sources, such as coal, oil, and gases, provide ***secondary sources of energy***, such as steam and electricity, which are used for distribution, control, and transportation.

The term "***commercial energy***" refers to sources of energy that are offered for sale in the market at a set price. Modern industrial, agricultural, transportation, and commercial development are all predicated on the use of commercial energy.

Non-commercial energy is defined as sources of energy that are not offered for sale in the commercial market. For instance, in rural areas, firewood, agricultural waste, solar, animal, and wind energy.

Renewable energy sources, such as hydroelectric power, geothermal energy, wind power, solar energy, and tidal power, are practically limitless.

Conventional fossil fuels like coal, oil, and gas are examples of ***non-renewable energy*** since they are likely to run out over time [3].

ENERGY CONSERVATION AND EFFICIENCY

Energy Conservation

Energy cannot be created or destroyed; rather, it can only be transformed from one form into another through effort. Energy can be described as the capacity to perform work. Any action that leads to a reduction in energy use is included.

As an example, Keep the water from running and turn off the lights. Recycling (including glass, cans, bottles, and papers) either stroll or cycle, instead of using the air conditioner in the heat, open a window and take public transportation.

Energy Efficiency

It refers to utilizing technology that uses less energy to do the same task. Energy efficiency can be shown in a compact fluorescent light bulb, which consumes less energy to provide the equal quantity of illumination as an incandescent light bulb. One way to conserve energy is to choose a compact fluorescent lightbulb instead of an incandescent one. An example of energy economy is driving the same distance in a car with a higher mileage [4-6].

Need of Energy Conservation

The years-long formation of fossil fuels such as coal and oil is about to end. We have used up 60% of the available resources in the last 200 years. Energy efficiency strategies are necessary for sustainable development. Fossil and non-renewable energy sources account for 85% of the primary sources of energy today. These reserves are growing in quantity and will last for upcoming generations. The Ministry of Power's 1992 energy survey revealed the need for increased energy generating efficiency, improved energy transmission (transmission & distribution networks), and increased use end equipment performance efficiency. The study of "Energy strategies for Future" led to the development of two concepts: the use of renewable energy and efficient, energy-saving techniques. The first and least expensive alternative turns out to be energy conservation [7].

AREA OF APPLICATION OF ENERGY CONSERVATION

An electrical system comprises a network where power is produced through conventional means from non-renewable sources, and it is then delivered at high voltage across greater distances to load centers for usage in different energy conversion processes. Power generating stations, transmission and distribution networks, and energy consumers are the three main subsets of the end user sector [1]. Customers can also be divided into three categories: industrial, commercial, and domestic.

EC in Power Generating Station

The cost of 4.5 to 5.25 cores of power generation and Rs. 2 cores of T&D are required to produce 1MW of power. It is noteworthy that the cost of saved electricity amounts to Rs. 1 crore per megawatt-hour. Additionally, it takes 5 years to set up a power plant, 1 year to set up a transmission line, and just 1 month to plan energy conservation. Less EC is available in the generating area, but we can still increase the efficiency of generator performance by optimizing load, distributing load among various units optimally, performing routine maintenance, and expanding capacity through the use of advanced technology and renewable energy sources [8].

Remedies to overcome the challenges associated in EC at Power generating stage

At the generation stage, energy conservation entails streamlining the electrical production process to cut down on waste and boost productivity. The principles of thermodynamics mean that some energy loss is unavoidable, however there are a number of techniques and tools available to reduce energy loss during the production of electricity:

i. *Transition to Renewable Energy*

   Solar Power: Invest in photovoltaic solar panels to capture solar energy and turn it directly into electrical power.

   Wind Power: Create wind farms where there are reliable, strong wind patterns to provide renewable energy [9].

   Hydropower: Use hydroelectric power plants or dams to harness the energy of falling or flowing water to produce electricity.

   Geothermal Energy: Utilize the natural heat of the Earth to create steam and electricity, a dependable and sustainable energy source.

ii. *Combined Heat and Power (CHP) Systems*

   Cogeneration: Install CHP systems to increase overall efficiency and decrease waste by simultaneously producing power and useful heat from the specific energy source.

iii. *Energy Efficiency in Fossil Fuel Plants*

   High-Efficiency Combined Cycle Plants: Utilizing high-efficiency combined cycle technology, design and run natural gas power plants to extract more energy from the same quantity of fuel.

   Advanced Turbines: Employ modern gas turbine technology to boost efficiency by operating at higher pressures and temperatures.

   Carbon Capture and Storage (CCS): Use carbon capture and storage (CCS) technologies to reduce carbon dioxide emissions from power plants powered by fossil fuels and improve their environmental impact [10].

iv. *Waste Heat Recovery*
Cogeneration and Trigeneration: Gather waste heat from the production of energy and utilize it to cool or heat adjacent buildings or industrial activities.

v. *Smart Grid Integration*
Demand Response: In order to lessen the need for additional generating during peak periods, implement demand response schemes that modify electricity usage depending on supply and demand.

Grid Optimization: Modernize the electrical infrastructure to reduce transmission losses and maximize electricity distribution, guaranteeing that produced energy is effectively consumed by users [11].

Nuclear Energy Efficiency:
Advanced Reactor Designs: Investigate and make investments in modern nuclear reactor designs that use nuclear energy as a low-carbon source of energy and are intrinsically safer and more efficient.

vi. *Research and Development*
Funding for Innovation: Provide funding for energy generation research and development in order to identify and apply new technologies that improve energy efficiency.

vii. *Energy Storage Solutions*
Battery Technology: Invest in modern battery technology to maximize energy output by storing extra energy produced during times of low demand and making it available during moments of peak demand.

viii. *Grid Modernization*
Decentralized Generation: Small-scale renewable energy solutions can promote decentralized generation and mitigate the transmission and distribution losses linked to centralized power plants.

Microgrids: Establish microgrids that can function both alone and in tandem with the main grid to improve energy resiliency and lower transmission losses [12].

By concentrating on these strategies, energy conservation at the generation stage can be accomplished, resulting in a system of energy production that is more efficient and sustainable.

EC in Transmission & Distribution

State grids, regional grids, and distribution networks make up India's three-tiered power transmission as well as distribution (T&D) system. Electrical networks are connected by INTRA-REGIONAL LINK in order to meet the demand for electricity. At the end of 2007, India's interregional power transmission capacity was at 14,000 MW [13-15]. Statistics from 2005–06 show that the T&D system in India has significant losses of roughly 34.54%, compared with 10-15% in wealthy nations. There are two types of power losses in a T&D system: technical losses and commercial losses.

Technical Losses In T&D System

Technical losses are power losses in the T&D sector that result from flaws in the technical part that can lead to a loss in investment in this industry. Inadequate system planning, incorrect voltage, low power factor, and other issues are responsible for these technical losses.

Commercial Losses

The financial losses incurred in the system of transmission and distribution are the ones that directly cause waste. These losses are a result of poor maintenance, ineffective management, etc. Another major factor for the commercial losses is corruption. Metering losses include money lost as a result of improper invoicing, incorrect metering, misuse, malfunctioning meters, and outright theft. A large number of household energy meters fail due to inferior equipment [16].

Remedies to Overcome the Challenges Associated in EC at Transmission & Distribution

In order to minimize energy losses, guarantee a steady supply of energy, and advance sustainability, energy conservation is essential in the transmission and distribution phases of the electrical supply chain. Here are a few methods to save energy throughout these phases.

Transmission Stage

i. *High-Voltage Direct Current (HVDC) Transmission*
Install HVDC transmission lines instead of conventional alternating current (AC) lines, which offer lower energy losses over long distances.

ii. *Efficient Transformers and Conductors:*
To reduce losses when transforming voltage, use high-efficiency transformers.
Use high-conductivity conductors in transmission lines, like aluminum, to lower resistive losses [17].

iii. *Reducing Line Resistance*
Investigate and put into use superconducting wires, which completely eliminate transmission losses and have zero electrical resistance.
To minimize traffic jams and maximize energy flow, dynamic line rating systems are used to determine the transmission lines' real-time capacity based on meteorological conditions.

iv. *Grid Expansion and Optimization*
Modernize the electrical grid to ensure effective energy flow by reducing transmission losses and optimizing the distribution of power.

To uniformly divide the demand for power over several transmission lines, avoid overloading, and minimize losses, load balancing can be achieved by utilizing advanced technologies.

Distribution Stage

i. *High-Efficiency Transformers*
At substations, use high-efficiency transformers to reduce energy losses when converting high-voltage electricity to low-voltage electricity [18].

ii. *Underground Cables:*
Invest in underground cables, especially in heavily populated urban areas, as they have fewer transmission losses than above lines.

iii. *Voltage Regulation:*
Use voltage stabilization tools to reduce losses from voltage variations, such as static VAR compensators and synchronous condensers, by stabilizing voltage levels.

iv. *Grid Modernization*
Use smart grid technologies to lower losses, improve load balancing, and monitor in real time.
To reduce downtime and losses, use distribution automation systems to identify and address defects.

v. *Demand Response Programs*
To lower peak demand, encourage customers to take part in demand response programs, which allow them to modify their electricity usage in response to supply and demand signals [19].

vi. *Energy Storage Solutions*
Utilize distributed energy storage devices, such as batteries, to store extra energy locally and utilize it during moments of high demand, therefore mitigating grid stress.

vii. *Regular Maintenance and Upkeep:*
To guarantee the system runs effectively, inspect distribution lines and substations on a regular basis. This will help you find problems and fix them quickly.
Use predictive maintenance strategies to foresee probable malfunctions and save energy losses from unplanned outages.

viii. *Public Awareness and Education:*
Encourage responsible energy use by educating consumers about the value of energy conservation during the transmission and distribution phases.

ix. *Regulatory Measures and Incentives:*
Enforce laws requiring utilities to reduce transmission and distribution losses in order to incentivize them to make investments in energy-efficient practices and technologies.

At the distribution level, offer utilities and consumers that invest in energy-efficient devices financial incentives, tax exemptions, or refunds.

The conservation of energy at the transmission and distribution phases can be accomplished by putting these techniques into practice, creating a more effective and long-lasting energy distribution system.

EC at Utilization Stage

The term "energy loss at the utilization stage" describes the energy wasted by end users when they use power. At this point, a number of things, including as inefficiencies in machinery, appliances, and procedures, contribute to energy losses. Inefficient appliances and equipment, inadequate insulation and building envelope, inadequate lighting, improper HVAC systems, inefficient industrial processes, wasteful behaviors, phantom loads, inefficient transportation, a lack of energy management systems, outdated equipment and technologies, etc. are some common causes of energy loss during the utilization stage.

Remedies to Overcome the Challenges Associated in EC at transmission & Distribution

At the utilization stage, energy conservation entails reducing the amount of energy utilized in residences, workplaces, factories, and other areas. Here are some particular tactics for energy conservation throughout the use phase:

i. *Energy-Efficient Appliances and Equipment*
Energy Star Rating: Select devices and appliances bearing the Energy Star logo, which denotes that they fulfill stringent energy conservation requirements.

LED Lighting: LED lights use less energy, last longer, and generate less heat than incandescent bulbs [20].

HVAC Systems with Programmable Thermostats: To maximize energy economy, install HVAC systems with programmable thermostats that are high-efficiency.

ii. *Energy-Efficient Water Heaters:* To save energy, use tankless or on-demand water heaters or insulate the tank of conventional water heaters.

Smart Appliances: Make an investment in remotely controlled, sleep-mode-programmable, and other intelligent appliances.

iii. *Home and Building Insulation*
Appropriate Insulation: Make sure that homes and businesses are adequately insulated to minimize the need for heating and cooling systems and to prevent energy loss via the walls, roofs, and floors.

Sealing Leaks: To stop drafts and save energy, seal gaps, cracks, and leaks in doors, windows, and ducts.

iv. *Energy-Efficient Practices*
Switch Off and Unplug: When not in use, switch off lights, appliances, and devices. Devices and chargers should be unplugged because they still use electricity when plugged in.

Natural Ventilation: To lessen the demand for air conditioning, use natural ventilation strategies like opening windows and hanging ceiling fans.

Energy-Efficient Cooking: When cooking, use appliances that consume less energy, such as microwave ovens, slow cookers, or pressure cookers.

Cold Water Laundry: Instead of using electricity to heat water, wash clothing in cold water to conserve energy.

Energy-Efficient Landscaping: To reduce the demand for air cooling, plant trees and shrubs in strategic locations around buildings to create shade.

v. *Industrial and Commercial Energy Conservation*

Energy Audits: To find places where energy is wasted in commercial and industrial establishments, conduct routine energy audits.

Process Optimization: Reduce energy use in industrial processes without sacrificing output by optimizing them.

Variable Speed Drives: To match energy consumption with demand and save energy during partial load operation, install variable speed drives (VSDs) in motors and pumps.

Waste Heat Recovery: To lessen the need for extra energy, recover and repurpose waste heat produced during the production of electricity and industrial activities.

vi. *Transportation*

Public Transportation: To cut down on the amount of energy used for personal transportation, take public transportation, carpool, bike, or walk.

Electric or hybrid vehicles: Make the switch to electric or hybrid cars, which are more ecologically and energy-efficient.

Appropriate Vehicle Maintenance: Make sure your car is well-maintained so it runs more smoothly and uses less gasoline.

vii. *Education and Awareness:*

Public Awareness Campaigns: Launch educational initiatives to spread knowledge about energy-saving measures and motivate people and companies to embrace energy-efficient practices.

viii. *Incentives and Regulations*

Government Incentives: Offer tax breaks, rebates, and monetary incentives to people and companies who invest in energy-saving devices.

Energy Efficiency Standards: To encourage the use of energy-efficient goods and procedures, enforce energy efficiency standards and laws for buildings, cars, and appliances.

Individuals, companies, and industries can all greatly reduce energy consumption during the utilization stage by putting these strategies into practice, which will help ensure a future with more sustainable energy sources.

REQUIREMENTS

- To reduce energy/fuel shortage
- To reduce peak demand shortage
- To save fuel, natural resources and money
- To reduce environmental pollution
- Only 1 % of natural resources available in India, while population is 16% of the world
- Provides Energy security

VARIOUS ADVANCE TECHNOLOGIES TO BE ADOPTED IN ENERGY CONSERVATION

The development of new technologies is essential to the fight against energy waste. The following advanced technologies are either being implemented or have the potential to make a major impact on energy conservation [3]:

Smart Grids: Smart grids increase the grid's efficiency, adaptability, and dependability by utilizing digital technology. They make it possible to optimize energy distribution, cut waste, and control energy supply and demand more effectively.

Renewable Energy Sources: As solar, wind, and hydroelectric technology continue to progress, renewable energy sources become increasingly economical and efficient. These renewable energy sources lessen reliance on fossil fuels and produce sustainable energy.

Energy Storage Systems: Modern energy storage technologies, such as pumped hydro storage and grid-scale batteries, assist in storing extra energy produced during peak hours. During times of heavy demand, this stored energy can be used, guaranteeing a steady supply of electricity and cutting down on waste.

Demand Response Systems: Based on real-time price or demand indications, these systems let users modify how much energy they use. During periods of peak demand, energy usage can be automatically reduced by IoT devices and smart appliances.

Home Energy Management Systems (HEMS): HEMS monitor and manage lights, HVAC, and appliances in the home using smart technologies. By optimizing energy usage patterns depending on user behavior, machine learning algorithms lower total consumption.

Energy-Efficient HVAC Systems: State-of-the-art HVAC systems with sensors and intelligent controls minimize energy use by regulating airflow and temperature in response to occupancy and outside weather.

IoT-integrated LED lighting: LED lighting is energy-efficient by design. They can significantly reduce energy use by adjusting brightness based on occupancy and natural light levels when integrated with IoT sensors.

Systems for managing building energy (BEMS): Commercial buildings' energy usage is optimized, controlled, and monitored by BEMS. They use automation, data analytics, and sensors to cut down on energy waste and boost productivity.

Energy-Efficient Appliances and gadgets: As home appliances and electronic gadgets continue to evolve, more energy-efficient goods are produced. Greener appliance production is a result of manufacturers being driven by Energy Star ratings and strict energy efficiency criteria.

Blockchain in Energy Trading: Peer-to-peer energy trading is made possible by blockchain technology. By eliminating the need for middlemen, producers of renewable energy can sell extra energy to customers directly, encouraging the usage of clean, locally produced energy.

Advanced Sensors and Predictive Analytics: Real-time data on energy usage patterns is gathered by sensors and Internet of Things devices. By using machine learning algorithms to analyze this data, energy systems may be optimized, predictive maintenance can be performed, and energy waste can be avoided.

Nanotechnology: To improve the efficiency of current technologies, researchers are examining nanomaterials and nanodevices for energy storage, solar cells, and energy-efficient coatings.

Carbon Capture and Storage (CCS): By capturing carbon dioxide emissions from factories and power plants, CCS systems stop the gas from getting into the environment. By lowering greenhouse gas emissions, this technique encourages the creation of cleaner energy.

Tidal and Wave Energy: Developments in the utilization of tidal and wave energy present consistent and dependable renewable energy sources. Significant amounts of electricity could be produced by these methods, particularly in coastal areas.

Countries and communities may make a major contribution to energy conservation efforts, lower carbon emissions, and move toward a more sustainable energy future by investing in and implementing these modern technologies.

ROLE OF IOT AND AI IN ENERGY CONSERVATION

Artificial intelligence (AI) and the Internet of Things (IoT) are becoming more and more important components of energy-saving initiatives. They make it possible to gather, analyze, and understand enormous amounts of data, which facilitates automation and more intelligent decision-making across a range of energy production, distribution, and consumption aspects. This is how AI and the Internet of Things help save electricity [4,5]:

IoT (Internet of Things)

Smart Grids and Metering: Internet of Things (IoT) devices allow for real-time tracking of grid functioning and electricity use. With the help of smart meters' comprehensive use data, customers can make well-informed decisions about how much energy they use.

Home automation and smart buildings: Internet of things (IoT) sensors in buildings can track temperature, lighting, occupancy, and other variables. In order to cut down on wasteful energy use, smart appliances, lighting controls, and thermostats can automatically change settings in response to user preferences and occupancy.

Industrial IoT (IIoT): Businesses utilize IoT sensors to keep an eye on machinery and optimize workflows. IoT-enabled predictive maintenance makes sure that equipment runs well, cutting downtime and energy use.

Smart Street illumination: Internet of Things (IoT)-enabled streetlights can conserve energy when high-intensity illumination is not required by adjusting brightness in response to ambient light levels and movement.

Energy-Efficient Transportation: Internet of Things (IoT) devices installed in infrastructure and cars can help improve traffic flow, lessen traffic jams, and enable effective routing.

Precision Agriculture: IoT sensors in agriculture facilitate precision agriculture by tracking crop health, monitoring soil conditions, and optimizing irrigation. The efficient use of resources in farming, such as energy and water, is guaranteed by this data-driven methodology.

AI (Artificial Intelligence)

Predictive analytics: To forecast patterns in energy consumption, AI algorithms examine data from Internet of Things devices. Then, in order to prevent wasteful energy production, utilities can modify their energy generation and distribution in real-time.

Energy Management Systems: To optimize energy use in buildings and industrial processes, AI-driven energy management systems learn from past data and user behavior. By forecasting peak usage periods, they are able to modify energy consumption.

Optimized Energy Distribution: Artificial intelligence (AI) algorithms make sure that energy reaches consumers more effectively by minimizing transmission losses and optimizing the distribution of energy in the grid.

Demand Response: AI is capable of identifying demand trends and launching systems to meet them. AI contributes to grid balancing by reducing energy consumption at peak hours and preventing overloading, therefore conserving energy resources.

Energy-Efficient HVAC Systems: AI algorithms are able to optimize HVAC systems by using real-time data to make sure that the systems run as efficiently as possible and use less energy.

Smart Devices and Appliances: AI makes it possible for appliances to recognize usage trends and adjust their operation to maximize energy efficiency. Dishwashers and washing machines, for example, can set their cycles to operate later in the day, during off-peak hours, when electricity costs are lower.

Microgrids and electricity Trading: AI makes it easier for microgrids to trade electricity in real time. By maximizing the exchange of energy between producers and consumers, it guarantees the effective use of energy in nearby communities.

Energy conservation initiatives become more focused, effective, and responsive to needs in real time by fusing AI's analytical powers with IoT's data collection capabilities. These innovations are essential to the shift to a future that is more energy-efficient and sustainable.

ADOPTION OF IOT AND AI IN ENERGY CONSERVATION

The system is employed as an Internet of Things architecture. Actuators collaborate with a number of sensors to complete the design. The architecture's software component includes a module with two monitoring and control functions for continuous humidity and ambient temperature data. The home owner receives authority. Since all information is kept online, users may examine their bills and make monthly payments for the full amount paid. With the user's consent, data analysis may be performed. Users can interact with the server and make requests to the database [6].

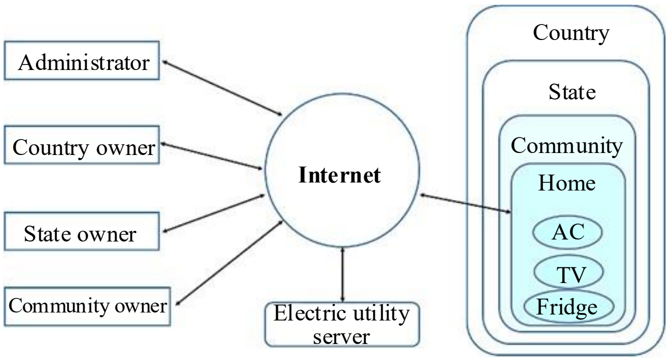

Figure 1. System architecture.

The system is designed with IoT and platform of Big data for analytical and scalable storage for a smart way of building user's privilege. An administrator, country owner, state owner, community owner communicates with appliances such as AC, TV, Fridge in-home through the internet. All data is stored on an electric utility server which connected with the internet as shown in Figure 1. The devices were monitor and control with remote access. Through mobile users can get an online bill that generates using this system with accuracy.

A microgrid controls energy distribution resources and loads for different areas within the confines of the electrical environment. The system offers the best strategic control element due to its durability as an energy storage system. The utilization expense associated with power from the grid with low robust activity is updated with its assistance. The worst-case economy will now cost more due to this method. Through an interface similar to RESTful API, external servers and microgrids can communicate with the database. Prediction modules and the best control modules are used to acquire data in real time [7].

The system's architecture is based on Internet of Things apps that look into mobility-aware networks to maximize lifespan. It computes in real time while adhering to quality-of-service requirements. It is a quick and easy method to save energy [8].

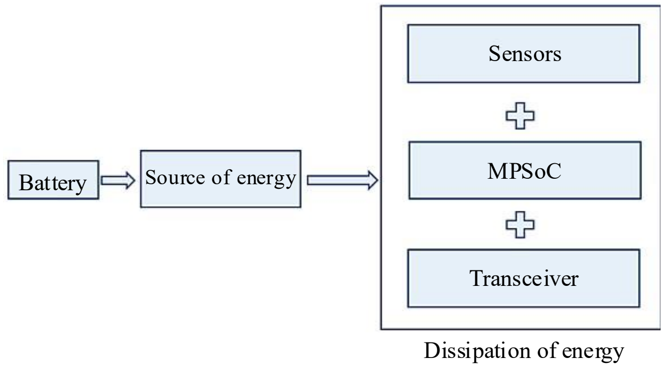

Figure 2. Communication with devices.

Energy supplies, sensors, an MPSoC, and a transceiver make up the system. For the purpose of acquiring energy, the energy source reacts to the dissipation of energy module. Assisting with task performance, the sensor may detect tangible items and gather additional input data. As illustrated in Figure 2, Multiprocessor System-On-Chip (MPSoC) is helpful for task execution and transceiver to accomplish communicating between the IoT device and the gateway.

System projections based on daily, seasonal, and annual at the microgrids are derived from load demand and the availability of energy resources. It integrates regular and forecasted data to control microgrid connections. An environment that is long-term is necessary for scheduling maintenance. ANN is a useful tool for real-time applications. The system's construction describes the mechanism of activation mechanism and simulator. It highlights the significance of putting the newest unit into practice to increase load demand [9].

Infrastructural three-level structures are utilized for communication. The technology makes it possible for real implementation to take place in a more consistent, cost-effective setting. The primary hub for gathering load data that affects cost analysis and storage is the smart grid [10].

The three-layer hierarchical structure of the network's communications infrastructure is made up of WAN, NAN, and HAN. In the smart grid, cognitive radio technology ensures a more effective, dependable, and cost-effective communication infrastructure.

Adoption of AI to Smart and Energy-Efficient Buildings

It is feasible to develop solutions to complicated issues that call for intellectual input by applying AI as a science. AI takes many different shapes in contemporary society. Algorithms are used to examine data since machines are designed to recognize specific patterns in datasets. AI uses learning based on experience to offer reinforcement. Moreover, artificial intelligence (AI) plays a key role in the Internet of Things (IoT), which facilitates essential network applications that connect mobile phones, houses, cars, offices, appliances, and pertinent service providers. These days, artificial intelligence (AI) is widely applied in the financial industry, healthcare, energy and transportation, smart towns and cities, security, educational institutions, and food chains [11-13]. AI is being utilized in city planning and transportation infrastructure to reduce traffic jams, accidents, and obstructions by real-time analysis of driving behaviors [14, 15].

The potential and uses of AI in society are greatly impacted by the quick advancements in technology. Although it is true that people's fear and mistrust of AI systems have increased as a result of the perceived risks of losing control, the benefits of AI systems are astounding and well worth the time and effort needed to investigate the possibilities and reduce the risks [16]. The goal of augmenting human capabilities is at the core of AI advancements. This is what motivates all of the inventions and research in this area.

An example of a contemporary infrastructure concept is the smart building. It optimizes the building's performance and occupants' degree of comfort through automated control systems and data utilization [17]. It offers a cyber-physical system (CPS) that unifies the physical world—which consists of different electric appliances and electronic gadgets—with the cyber world. It also incorporates sensing devices, controllers, and metering components.

The idea of smart buildings is predicated on the right assumption that benefits result from unrestricted interactions between the two worlds. Artificial intelligence (AI) technologies are increasingly prevalent in smart buildings as technology progresses. Simultaneous advancements in hardware and software technologies and the creation of ever-smaller, greater energy-efficiency sensors and communication protocols provide up more straightforward options for assessing, monitoring, and interacting with the environment [18, 19]. Lower operational and maintenance expenses, less energy consumption, and concurrent improvements in the degree of comfort and safety for building occupants all contribute to efficiency's continuous improvement [20]. The building management system (BMS) concept suggests that artificial intelligence (AI) may play a significant role in the future in improving not just the functionality of buildings but also the quality of life they provide.

EFFORTS MADE BY GOVT OF INDIA AGAINST EC

To encourage energy saving and sustainable development, India implemented number of laws and guidelines. For the most up-to-date information, please check with official government sources or pertinent authorities as rules and regulations may have changed since then. Here are some important laws and programs pertaining to energy saving in India as of 2021:

Bureau of Energy Efficiency (BEE)

Energy Conservation Act (2001): The Bureau of Energy Efficiency (BEE) was founded in India by the Energy Conservation Act. The main goal of BEE is to encourage energy conservation and efficiency.

Standards and Labeling Program: BEE has established labeling programs for equipment and appliances to show their degrees of energy efficiency, enabling customers to make knowledgeable decisions.

Perform, Achieve, and Trade (PAT) Scheme: This program promotes energy-intensive enterprises to meet predetermined goals for energy efficiency. The resulting energy savings can be traded as tradable instruments by industries that surpass their targets.

Building Codes

Energy Conservation Building Code (ECBC): Energy-efficient building design and construction are standardized by ECBC. Its goal is to encourage energy conservation in business buildings.

Appliances and Equipment

Star Rating Program: To indicate the energy efficiency levels of different appliances, such as refrigerators, air conditioners, and LED lights, BEE has put in place star rating schemes.

Industrial Sector

National Mission for Enhanced Energy Efficiency (NMEEE): Programs like Perform, Achieve, and Trade (PAT) and Market Transformation for Energy Efficiency (MTEE) are part of NMEEE and are aimed at increasing energy efficiency in businesses and industries.

Agricultural Sector

Agricultural Demand Side Management (AgDSM) Program: encourages the adoption of energy-saving techniques in the agriculture industry, such as the use of energy-saving pumps and machinery.

Transportation Sector

Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) Scheme: Encourages the adoption of electric and hybrid vehicles, reducing reliance on conventional fuel.

Rural Electrification

Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY): focuses on rural electrification and incorporates plans for distribution infrastructure that utilizes less energy.

Public Awareness

National Awareness Campaigns: National awareness programs are held on a regular basis to inform the public about energy-saving techniques.

Financial Incentives

Financial Assistance and Subsidies: The adoption of energy-efficient technologies and practices is encouraged by a number of financial incentives, subsidies, and loans.

For the latest and greatest details about energy conservation laws and regulations in India, please visit official government websites, such as those run by the Ministry of Power and the Bureau of Energy Efficiency.

CONCLUSION

This concentrated on a number of strategies that have been shown to be beneficial for energy conservation. This article also examines the application of energy harvesting systems with modern technologies like ANN and IoT. The goal was to acquire implementations of specific linked use cases in addition to modern technology.

REFERENCES

1. Deshmukh, S. C., & Patil, V. A. (2013). Energy conservation and audit. International Journal of Scientific and Research Publications, 3(8), 1–5.
2. Fakhar, M. Z., Yalcin, E., & Bilge, A. (2023). A survey of smart home energy conservation techniques. Expert Systems with Applications, 213, 118974.
3. Ribeiro, P. F., Johnson, B. K., Crow, M. L., Arsoy, A., & Liu, Y. (2001). Energy storage systems for advanced power applications. Proceedings of the IEEE, 89(12), 1744–1756.
4. Kaur, Navroop, and Sandeep K. Sood. "An energy-efficient architecture for the Internet of Things (IoT)." IEEE Systems Journal 11, no. 2 (2015): 796–805.
5. Dounis, A. I. (2010). Artificial intelligence for energy conservation in buildings. Advances in Building Energy Research, 4(1), 267–299.
6. Al-Ali, A. R., Zualkernan, I. A., Rashid, M., Gupta, R., & AliKarar, M. (2017). A smart home energy management system using IoT and big data analytics approach. IEEE Transactions on Consumer Electronics, 63(4), 426–434.
7. Choi, J., Shin, Y., Choi, M., Park, W. K., & Lee, I. W. (2018). Robust control of a microgrid energy storage system using various approaches. IEEE Transactions on Smart Grid, 10(3), 2702–2712.
8. Cao, K., Xu, G., Zhou, J., Wei, T., Chen, M., & Hu, S. (2018). QoS-adaptive approximate real-time computation for mobility-aware IoT lifetime optimization. IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, 38(10), 1799–1810.
9. Barge, M. D., & Surve, A. R. (2020). A Review on Energy Conservation System with IoT Oriented Technique. International Research Journal of Engineering and Technology, 07 (07), 1683–1686.

10. Wang, K., Li, H., Maharjan, S., Zhang, Y., & Guo, S. (2018). Green energy scheduling for demand side management in the smart grid. IEEE Transactions on Green Communications and Networking, 2(2), 596–611.
11. Chen, W., Zhao, L., Kang, Q., & Di, F. (2020). Systematizing heterogeneous expert knowledge, scenarios and goals via a goal-reasoning artificial intelligence agent for democratic urban land use planning. Cities, 101, 102703.
12. Olayode, O. I., Tartibu, L. K., & Okwu, M. O. (2020). Application of Artificial Intelligence in Traffic Control System of Non-autonomous Vehicles at Signalized Road Intersection. Procedia CIRP, 91, 194–200.
13. Camarena, S. (2020). Artificial intelligence in the design of the transitions to sustainable food systems. Journal of Cleaner Production, 271, 122574.
14. Pau, G., Campisi, T., Canale, A., Severino, A., Collotta, M., & Tesoriere, G. (2018). Smart pedestrian crossing management at traffic light junctions through a fuzzy-based approach. Future Internet, 10(2), 15.
15. Boukerche, A., Tao, Y., & Sun, P. (2020). Artificial intelligence-based vehicular traffic flow prediction methods for supporting intelligent transportation systems. Computer networks, 182, 107484.
16. Farzaneh, H., Malehmirchegini, L., Bejan, A., Afolabi, T., Mulumba, A., & Daka, P. P. (2021). Artificial intelligence evolution in smart buildings for energy efficiency. Applied Sciences, 11(2), 763.
17. Al Dakheel, J., Del Pero, C., Aste, N., & Leonforte, F. (2020). Smart buildings features and key performance indicators: A review. Sustainable Cities and Society, 61, 102328.
18. Sembroiz, D., Careglio, D., Ricciardi, S., & Fiore, U. (2019). Planning and operational energy optimization solutions for smart buildings. Information Sciences, 476, 439–452.
19. Rivera, W. (Ed.). (2017). Sustainable cloud and energy services: Principles and practice. Springer.
20. Panchalingam, R., & Chan, K. C. (2021). A state-of-the-art review on artificial intelligence for Smart Buildings. Intelligent Buildings International, 13(4), 203–226.

