Green Energy and Technology

Parul Agarwal
Mamta Mittal
Jawed Ahmed
Sheikh Mohammad Idrees *Editors*

Smart Technologies for Energy and Environmental Sustainability

Springer

Green Energy and Technology

Climate change, environmental impact and the limited natural resources urge scientific research and novel technical solutions. The monograph series Green Energy and Technology serves as a publishing platform for scientific and technological approaches to "green"—i.e. environmentally friendly and sustainable—technologies. While a focus lies on energy and power supply, it also covers "green" solutions in industrial engineering and engineering design. Green Energy and Technology addresses researchers, advanced students, technical consultants as well as decision makers in industries and politics. Hence, the level of presentation spans from instructional to highly technical.
Indexed in Scopus.
Indexed in Ei Compendex.

More information about this series at http://www.springer.com/series/8059

Parul Agarwal • Mamta Mittal • Jawed Ahmed
Sheikh Mohammad Idrees
Editors

Smart Technologies for Energy and Environmental Sustainability

Springer

Editors
Parul Agarwal
Department of Computer Science and Engineering
Jamia Hamdard
New Delhi, India

Mamta Mittal
Department of Computer Science and Engineering
G B Pant Govt Engineering College
New Delhi, Delhi, India

Jawed Ahmed
Department of Computer Science and Engineering
Jamia Hamdard
New Delhi, India

Sheikh Mohammad Idrees
Computer Science
Norwegian University of Science and Technology
Gjøvik, Norway

ISSN 1865-3529 ISSN 1865-3537 (electronic)
Green Energy and Technology
ISBN 978-3-030-80701-6 ISBN 978-3-030-80702-3 (eBook)
https://doi.org/10.1007/978-3-030-80702-3

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The title of the book is ***Smart Technologies for Energy and Environmental Sustainability***, which is published under the book series "Green Energy and Technologies".

Green energy is a type of energy that is generated from natural resources that do not harm the environment by producing greenhouse gases and, therefore, reduce the impact on global warming. Greenhouse gases consist mainly of ozone, carbon dioxide, methane, nitrogen oxide, etc. CO_2, methane, and nitrogen oxide are not efficient enough to stop the solar radiation from entering into the atmosphere; they cannot absorb all these radiations. The rapid rise of carbon footprint, due to several reasons, is a leading factor of increasing levels of carbon dioxide in the environment which, in turn, increases the atmospheric temperature.

With technological advancements, we have acknowledged a series of benefits, but we have also noticed the succession of disasters and catastrophes because of the misuse or selfish use of these technical advancements. Smart technologies are being developed and used to reduce greenhouse gas emission. Smart IoT-based services are producing green benefits. Construction of buildings with net zero carbon emissions and efficient energy usage are on rise. Technologies related to smart agriculture are also helping to make the environment more sustainable.

The entire world is on the verge of a major energy crisis. We are witnessing an era in the global energy environment where global measures using smart and intelligent technologies for the environment have already geared up. This book examines the trends and analyses factors that impact the environment by focusing on efficient energy consumption, storage, and management. Efficient energy management techniques using computation models and techniques in domains like transportation, green buildings, smart homes, and smart cities are much needed. The potentials of IoT and other smart technologies can provide solutions for the same where smart algorithms and techniques can be proposed. This book focuses on exploring these techniques to enhance the performance of energy systems. Methods/models/architectures/algorithms and their results to improve the consumption of energy and using alternative sources of energy for protecting the environment are the prime focus of the book. A well-illustrated book with case studies that support the theory is an important feature of the book.

Book Contents

This book ***comprises 15 chapters***, designed to capture the core ideas of Smart Technologies for Energy and Environmental Sustainability, and is organized as follows:

Chapter 1: Organic Semiconductors: Technology and Environment

Organic semiconductors are based on carbon materials, whereas inorganic semiconductors are composed of non-carbon-based materials such as silicon. These materials are popularly used in compact (in weight and size) and power-efficient light-emitting devices like small digital display units used in many electronic gadgets. In this chapter various aspects related to organic semiconductors have been discussed such as their operation, types, applications, and limitations. This chapter also reviews the conduction mechanisms of organic thin-film transistor and issues associated with it.

Chapter 2: Defining and Visualizing Energy and Environment Related Smart Technologies

Climate change and global warming are global issues. Scientists, experts, and academicians are much concerned over this issue. They are making policies and strategies to minimize its impact on the environment. This chapter sheds light on the need for smart technologies in the area of energy and environment to make our environment safe and smart.

Chapter 3: Energy Minimization in a Sustainably Developed Environment Using Cloud Computing

In a cloud computing environment, data centres are used for processing and storing the data which may cause carbon footprint issues to the environment. Through the concept of green technologies, this issue may be addressed by how to get a sustainable cloud computing system by using various techniques like software optimization, network optimization, and hardware optimization.

Chapter 4: Sensing, Communication with Efficient and Sustainable Energy: An IoT Framework for Smart Cities

Smart cities refer to a network of physical objects connected through sensors. They communicate among themselves to accomplish specific tasks. The basic issue is how to reduce the power consumption of each sensor node. In this chapter, an optimal IoT framework is discussed for a better energy management system to make the entire system more sustainable. Here, for simulating the energy consumption of IoT framework, a simulator named Cooja is used for analysing the energy consumption data.

Chapter 5: Existing Green Computing Techniques: An Insight

Green computing means eco-friendly usage of computing resources and facilities. It is directly or indirectly related to the environment. This chapter aims at green design and manufacturing techniques for reducing the ecological footprints. Green disposal is equally important because of the growing e-waste problem related to health and the environment.

Chapter 6: Smart Home for Efficient Energy Management

One of the aspects of a smart home is to manage the consumption of electrical energy most efficiently. Through intelligent energy management techniques and scheduling techniques for devices, energy consumption may be reduced that will eventually reduce the electricity bill. A metaheuristic algorithm is used for the optimization of energy consumption and to maintain optimal energy consumption with reduced energy cost without compromising supply and quality.

Chapter 7: Solar Energy Radiation Forecasting Method

Among many alternative energy sources, solar energy is the most powerful source. In this chapter, a forecasting methodology known as solar irradiance is discussed considering all important parameters. Combined forecasting methods are also used for the prediction purpose.

Chapter 8: Electric Vehicles for Environmental Sustainability

Transport vehicles, powered by traditional sources of energy, are one of the prominent sources of pollution in the environment. Electric vehicles may reduce this pollution level. This chapter discusses the short, medium, and long-term role of electric vehicles within urban and rural areas. It also discusses the potential market for it.

Chapter 9: Smart Grid: A Survey

Traditional power grid has not been relevant to meet the current demands and challenges efficiently. To solve such problems, different techniques are being used to make the power grid much smarter. This chapter explains about high power converter, advanced transmission system, and automated control system. This chapter also deals with how to minimize its impact on the environment.

Chapter 10: Green Building: Future Ahead

Green building is not to preserve the environment but to restore it. The utilization of solar energy, smart home appliances, cool roof technique, etc. makes the building a zero energy building, which consumes less energy. In this chapter how the concept of green building is related to the concepts of renewable energy, e-waste, minimizing toxicity in indoor air, etc. is shown.

Chapter 11: Reliable and Cost-Effective Smart Water Governing Framework for Industries and Households

Issues related to water leakages during transmission, its consumption tracking, its overflow from water tanks, and water quality check in industries and households are discussed in this chapter. An Internet of Things-based sustainable smart water governing framework is also proposed. Relevant data is collected, analysed, and visualized using analytics tools to make an effective decision.

Chapter 12: Adaptation of Smart Technologies and E-Waste: Risks and Environmental Impact

E-waste is a growing environmental issue. It is mainly due to mercury and lead which are toxic to human beings, air, water, and soil. In this chapter, various problems are discussed related to e-waste and also how to manage it using smart technologies. A model is also proposed for handling e-waste.

Chapter 13: A Comprehensive Study on the Arsenic Contamination in the Groundwater of Assam and West Bengal with a Focus on Normalization of Arsenic-Filled Sludge from Arsenic Filters

The presence of arsenic in consumable water, a poisonous chemical element, is dangerous and harmful to health. It is accumulated in the food chain and thus has cascading effects on each stakeholder of this chain. This chapter proposes technical solutions for providing arsenic-free water for consumption; it also discusses safe deposition and utilization of arsenic-enriched sludge.

Chapter 14: Sustainable Approach for Cloud-Based Framework Using IoT in Healthcare

Technologies in the healthcare domain are an emerging and important area of research to address the issues related to healthcare, particularly in developing countries. In this chapter, two technologies, IoT and cloud services, have been discussed so as to bring better health services even to remote areas of the countries. The concerned technologies with their merits and demerits are also discussed.

Chapter 15: A Case Study on Evaluation of Energy Management System by Implication of Advanced Technology in a Typical Cement Factory in Tamil Nadu, India

Cement factories are considered to be one of the most polluting agents. So, their energy assessments and audits help in the analysis and plan of energy use, specifically for the industrial production process. Several reports and documents are verified pertaining to energy aspects, and the auditor prepares a hierarchical report which helps factory managers to update and make changes and follow the procedures that lead to better environment-friendly alternatives. This chapter carries out extensive research on the same and presents a case study on a typical cement factory located in Tamil Nadu, India.

We hope that you delve deeper into the varied aspects of the book and enjoy reading and learning about various smart technologies that focus on optimal energy usage for a better future.

We dedicate this book to our family members without whose support this would not be possible. The authors form an integral part of this volume. We express our gratitude to the contributions and are also obliged to the reviewers for their comments that helped to improve the quality of the book. Last but not least, thanks to God, for showing us the light to start this project and blessing us to complete it.

New Delhi, Delhi, India — Parul Agarwal
New Delhi, Delhi, India — Mamta Mittal
New Delhi, Delhi, India — Jawed Ahmed
Gjøvik, Norway — Sheikh Mohammad Idrees

Contents

Organic Semiconductors: Technology and Environment

Shikha Jaiswal

1 Introduction to Organic Semiconductors

The organic semiconductors are picking attention due to easy processing with reduced cost, large area and flexible structure. Prospects of flexible unbreakable and lightweight electronics at low cost are very high. Silicon, germanium, gallium arsenide are fairly in use in micro electronic industry for years. Silicon dioxide insulator along with gold, aluminum and copper are backbone of this technology but the inherent limitation of flat and inflexible semiconductor prevents the application over bigger areas and flexible substrate [1].

The alternative to inorganic semiconductors is the organic semiconductors that for applications in electronics where cost, area coverage and flexibility in structure are basic requirements. These materials are just small organic molecules polymers that offer exciting possibilities for basic research and application in electro-optic and electronic devices like organic light emitting diodes (OLED), organic field effect transistors (OFET), lasers, photovoltaics, sensors, detectors etc. [2, 3].

Organic semiconductors are carbon materials like polyaniline (PAn), polyparaphenylene (PPP), polyparaphenylene, vinylene. They are broadly categorised into two. First, the organic molecule semiconductors (OMS) having lower molecular weight and are deposited using thermal evaporation in high vacuum environment and second is polymeric organic molecule having long chain of organic molecules processed from solution. These molecules are generally vacuum deposited thus are not printable but have high conductivity [4, 5].

The organic semiconductors have relatively low charge mobility that is why not competed with Si (inorganic counterparts) in applications that require switching speed. These materials offer new possibilities for applications in different areas of

S. Jaiswal (✉)
Department of Physics, Feroze Gandhi College, Raebareli, Uttar Pradesh, India

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_1

organic light emitting diode (OLED), organic field effect transistor (OFET), photovoltaic, sensors. Organic semiconductors based organic light-emitting diode (OLED) displays are widely used in smart phones. Organic field effect transistors (OFETs) are extremely important as they are the main component of organic electronics. OFETs are integral part of organic electronics. Tsumara et.al introduced OFET in 1986 [6] and Tang et al. in 1987 [7] demonstrated first OLED and after that the successive demonstrations of electroluminescent polymer in 1990 [8] i.e. organic materials. It started with first p-channel (hole-transporting) OFET in 1986 [7] with a mobility of 10^{-5} cm^2/Vs and reached presently to organic single crystals based OFETs with a mobility of up to 15–40 cm^2/Vs [8]. But it is very difficult to fully replace silicon with organic materials due to lower speed and high driving voltage of organic transistors. Thus, the major challenges are stability, mobility and operating voltage.

Organic materials present the possibility of devices organic thin film transistor (OTFT) that can be used with human biological systems promise applications to human health [9]. The device that "uses specific biochemical reactions mediated by isolated enzymes, immunosystem, tissues, organelles or whole cells to detect chemical compounds usually by electrical, thermal or optical signal," is said to be biosensor as defined by Kergoat et al. [10]. Bartic et al. OTFT are well suited for bio sensing applications as they are biocompatible with bio recognition elements (BRE) such as enzyme [11]. The electronic materials used now require high temperature and are non porous thus does not suit to incorporate enzyme [12]. Clark and Lyons review the steady development of biosensors [13]. Yan et.al gave excellent review articles [14, 15].

1.1 Applications

Due to mechanical flexibility of organics the most important application is wearable electronics. Organic materials also present the possibility of devices when used in biological systems can be very helpful in health care application. The organic field-effect transistors are technological interesting as it serves as an integral part of electronics. The first p-channel field effect transistor in 1986 with mobility 10^{-5} cm^2/Vs progressed to present organic single crystal based organic field effect transistor with mobility upto 15–40 cm^2/Vs [16, 17]. Mechanical flexibility of organic semiconductors is an important feature for rollable displays wearable electronics and the paints. The organic semiconductors can be used commercially in e-paper, low end data storage, radio frequency identification tags and sensor array. Devices that can be used with biological systems can be possible. These materials can be used to make artificial skin with tactile sensitivity or add functionality E2 prosthetic limbs [18–20].

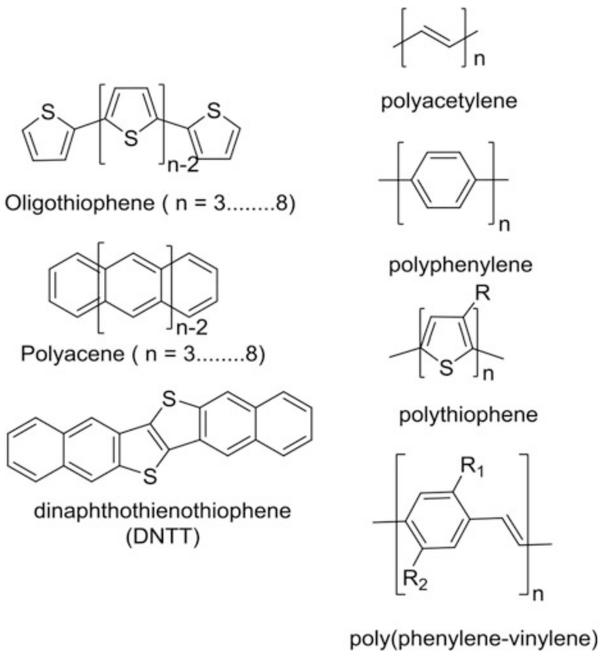
1.2 Limitations

Silicon couldn't be fully replaced with organic materials due to lower speed and high driving voltage. Materials are highly sensitive to environmental conditions like stability, mobility and operating voltage are three major fronts.

2 Types of Organic Semiconductors

Organic semiconductors are basically carbon based materials and have ability to hybridize like conjugated molecules and polymers. They are of two types small π conjugated organic molecular semiconductors and polymeric organic semiconductors. The organic molecular semiconductors are low molecular weight organic molecules and typically deposited by thermal evaporation in high vacuum environment as for example pentacene, teracene, rubrene, copper phtohaloocyanine(CuPc). The polymeric organic semiconductors have long chain of organic molecules and generally process from solution as for example polyaniline (PAni), polyparaphenylene (PPP), polyparaphenylenevinylene (PPV) and polythiophene given in Fig. 1 [21, 22]. The organic semiconductors are joined by alternate single and double bonds due to these alternates bonds they are also called conjugated molecules. Due to their conjugated nature they exhibit semiconducting properties.

Fig. 1 Organic semiconductors: conjugated polymers



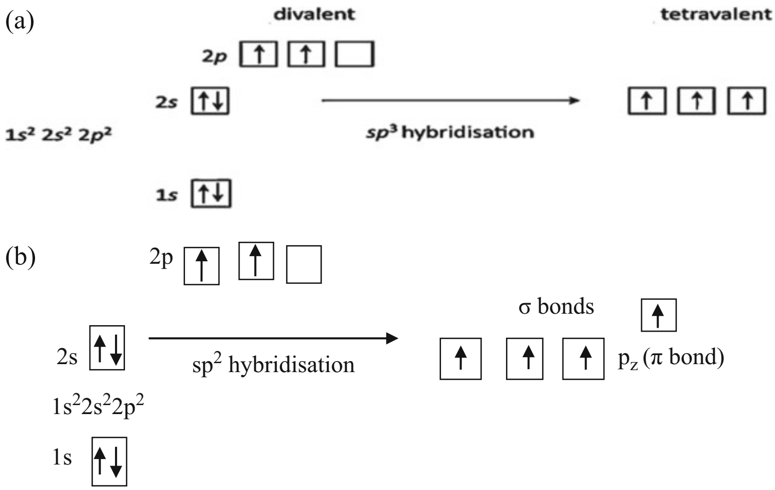


Fig. 2 (**a**) sp^3 hybridisation in carbon atom. (**b**) sp^2 hybridisation in carbon atom

In carbon atom the electrons into a state has 3–4 eV covalent binding energy but required ~4 eV to jump to 2p orbital, the four electrons in n = 2 state can be hybridized in three ways sp, sp^2 and sp^3. Electrons in highest energy state in carbon help in conduction. Though the carbon should be divalent shown in Fig. 2a as its highest energy state has two electrons but it is tetravalent because 2p orbitals hybridize to form four orbitals with equal energy. The hybridization involves one of 2s and three of 2p orbitals i.e. sp^3 and new orbitals form σ bonds shown in Fig. 2b. The sp and sp^2 hybridization are relevant for semiconducting properties. sp^2 has only three electrons 1 in s and 2 in p orbitals participate in hybridization and form sigma bonds. Only one p_z orbital electron is left forming weaker π bond. These weak p_z electrons forms weaker π bond and free to move on molecules and are responsible for most electronic and optical properties [23, 24].

In hybridisation sp^2 (2p orbitals mix with the 2s orbital to form three σ bonds and the third p-orbital keep p character thus form π bond).

The energy level splits into two bonding and antibonding orbitals as shown in Fig. 3a, b; σ bonds are much stronger than π bonds, σ bonding and σ* bonding states formed from the overlap of hybridized sp^2 orbitals and π bonding and π* antibonding states formed from overlap of p_z orbitals. The energy gap between bonding and antibonding sigma levels is much higher than π bonds. The energy gap associated with sp^3orbitals is much larger than sp^2. Most plastics are aliphatic polymers only linked by σ bonds thus electrically insulated due to large energy gap. In contrast the conjugated molecules and polymers have narrow energy gap thus are expected to behave as semiconductors.

The state with highest energy of all occupied orbitals is called highest occupied molecular orbitals (HOMO) and the state with lowest energy of all unoccupied molecular orbitals is called lowest unoccupied molecular orbitals (LUMO). Number

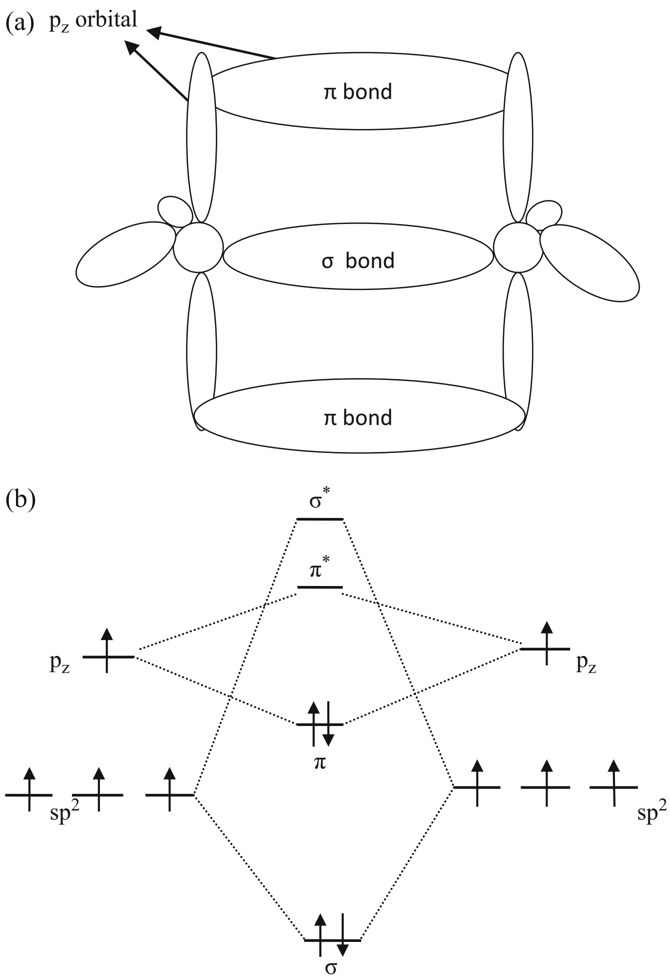


Fig. 3 (**a**) sp^2 hybridized orbital forming a strong sigma bond with its neighbor and p_z orbital forming a weak π bond with its neighbor. (**b**) Overlap of neighboring sp^2 orbitals giving rise to σ bonding state and σ* antibonding states and overlap of neighboring p_z orbitals giving rise to π bonding state and π* antibonding states

of states increases as the number of molecules in organic material increases. The energy bandgap is the HOMO-LUMO gap as given in Fig. 4. HOMO level in organic semiconductors is similar as valence band in inorganic semiconductors and LUMO level in organic semiconductors is similar as conduction band in inorganic semiconductors is the. The electron donor is HOMO, the outermost orbital containing electrons that donate. The electron acceptor is LUMO, the inner most orbital that accept electrons [25, 26].

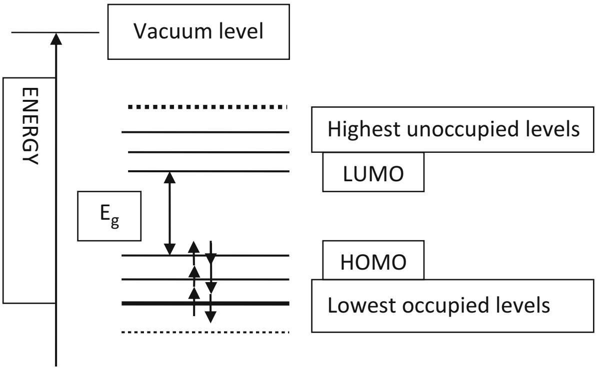


Fig. 4 Organic semiconductors: molecular orbitals and energy levels

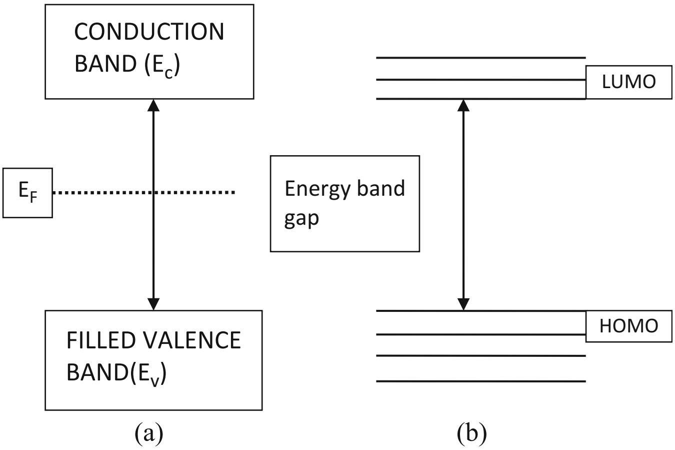


Fig. 5 (**a**) Inorganic semiconductor energy bands (**b**) Organic semiconductor: energy levels

Conjugated molecules and polymers have single and double bond alteration and small HOMO-LUMO gap. The conjugating polymers are also called conducting polymers and behave as semiconductors. The variation in conjugation lengths and in the interaction energies with surrounding molecules give rise to locally varying polarization energies leading to Gaussian density of States for bonding (occupied) and antibonding (unoccupied) orbitals of molecular sites [27].

The conventional semiconductor has strong covalent or ionic bonds thus electronic bands but organic materials have intramolecular covalent bonds and held together by weak intramolecular Vanderwaal's interaction. The diagrammatic comparison is given in Fig. 5a, b with Table 1 [28, 29].

Table 1 Comparison between Organic and Inorganic semiconductors

S. N		Organic	Inorganic
1	Binding energy	Weak (Vanderwaal's)	Strong
2	Mechanical resistance	Weak	Strong
3	Charge carriers	Localised	Delocalised
4	Polarisation	Strong	Weak
5	Charge transport	Hopping	Band
6	Carrier mobility	$-1\ cm^2/Vs$	$-1000\ cm^2/Vs$
7	Exciton	Frenkel	Wannier

3 Localisation of Charge

Mobility in organic semiconductors is low because of localisation of charge carriers. The individual molecules have strong localised electronic wave function but weak intermolecular interaction thus narrow bandwidth responsible for charge conduction. The mobility in crystalline materials is limited by phonon scattering mechanism that is moving electrons are hindered by thermal lattice vibration. Thus, at lower temperature, phonons decrease and mobility of charge carrier increases. The charges in organic semiconductors due to energy disorder localised and charge transport is described by hopping through localized states that is phonon assisted tunneling from site to site. By absorbing a phonon charge career gap has enough energy that career mobility increases with increase in temperature. Localisation can be done in two ways via polarization and disorder [30, 31].

3.1 Localisation via Polarization

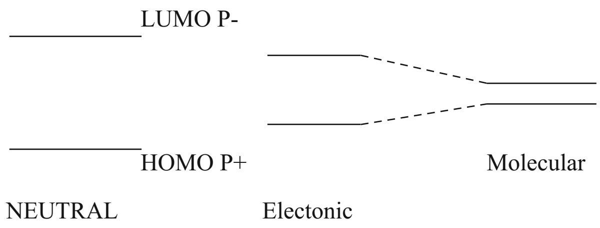
The effect of polarization on charge transport is evaluated by estimating time scale of each state of process i.e. Residence time is the time the charge carrier stay on the molecule before moving to next and polarization time is the time to set the polarization. Residence time is to be associated with the width of HOMO and LUMO. The binding energy in inorganic semiconductor is greater than organic semiconductor thus the residence time is 100 times smaller in inorganic semiconductor than organic as the energy gap in inorganic semiconductor is larger i.e. 10 eV and few tenths of eV for organic semiconductor. Polarization time is associated with energy gap (1 eV) roughly identical in inorganic and organic semiconductors. In inorganic semiconductors, the residence time is so short i.e ten times lower than polarization time thus polarization time is not enough to set the polarization though in organic semiconductor the residence time is ten times longer polarization place is always there. The effect of polarization on organic and inorganic semiconductors is given Table 2.

Polarization is of two types: electronic polarization and molecular polarization. Electronic polarization is always present in organic semiconductors as the residence time is longer. Molecular polarization refers to the movement of nuclei of the

Table 2 Effect of Polarization on inorganic and organic semiconductors

	Inorganic semiconductor			Organic semiconductor		
	Without polarization	Electronic polarization	Molecular polarization	Without polarization	Electronic polarization	Molecular polarization
HOMO-LUMO gap (eV	10	Never	Not applicable	0.1	1	Sometimes
Residence time (s)	10^{-16}			10^{-14}	10^{-15}	

Fig. 6 Effect of polarization on HOMO-LUMO gap



molecules. The characteristic energy is at the vibration of molecule. The residence time and molecular polarization time have the same order of magnitude thus molecular polarization depends on precise nature of organic solid. Polarization shifts HOMO and LUMO towards each other corresponding to polarization energy, an additional shift is induced by molecular polarization. Polarization induces self-localisation of electrons and the self-localized charge is called polaron. Polarization is a direct consequence of weak intermolecular bonding in organic semiconductors. The charge carrier surrounded by the polarization cloud is called a Polaron. The polaron is self-localized. Charge transport takes place through self-localized polarons. As adjacent neutral molecule becomes charged under the effect of thermal energy, the charge transport occurs. Thus the charge transport is not done through delocalized level but due to hopping between adjacent localised states. Delocalised and localised charge carrier transport can be different by temperature dependence of mobility [32] (Fig. 6).

By Drude's Model, The effect of temperature on mobility can be seen from Eq. (1) that shows temperature increases mobility decreases and vice versa.

$$\mu \propto T^{-n} \tag{1}$$

As Polaron hopping is thermally activated so temperature decreases and mobility also decreases.

$$\mu = e^{-E_{act}/KT} \tag{2}$$

where E_{act} is the activation energy.

3.2 *Localisation via Disorder*

ΔV measures the mean value of variation in potential. The disorder leads to localization as given in Fig. 7a. It leads to disturb the translational symmetry in crystal thus no longer the Bloch theorem is followed by ψ but follow the Eq. (3).

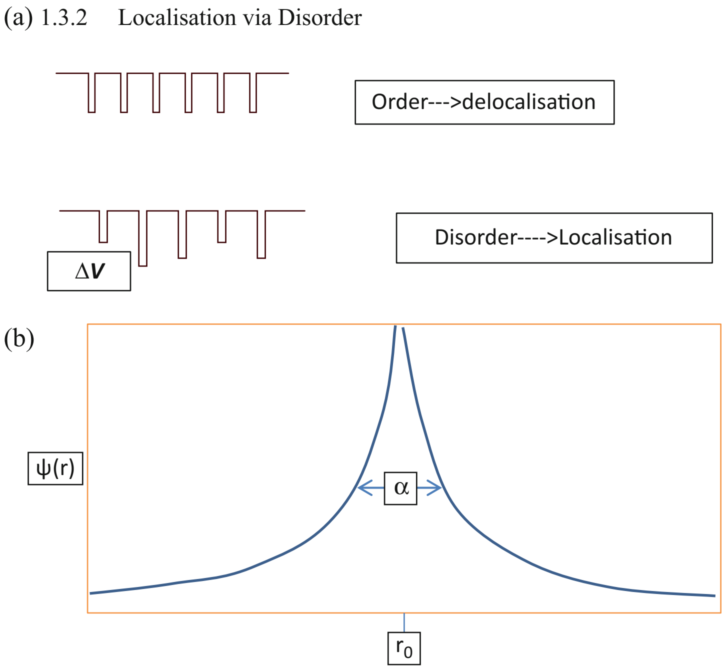


Fig. 7 (**a**) Disorder leads to localization and ΔV is the mean value of variation in potential. (**b**) Localization of wavefunction r_0 = coordinate of the site, α = localisation length

$$\Psi(r) = \exp\left[-2\{r - r_0\}/\alpha\right] \tag{3}$$

r_0 is coordinate of site and α is the localization of length as in Fig. 7b. If $\Delta V/W < 3$, it is the weak localization and when it is $\Delta V/W > 3$, the strong localization is there, where W is the Width of conduction band and valence band. W ~ 10 eV in inorganic semiconductor corresponds to weak localisation and W ~ 0.1 eV in organic semiconductor corresponds to strong localisation as shown in Fig. 8.

4 Charge Transport in Organic Semiconductor

The different models for transport of charge carriers in organic semiconductors are: Vissenberg Matters model: the transport occurs via hopping through localized states located in energy distributed Gaussian density of states (DOS) of HOMO and LUMO and Multiple Trapping and Release model: it is associated with that traps which are localized States in band gap or at the edge of HOMO (or LUMO) produced by impurity or defects in organic semiconductor [32, 33].

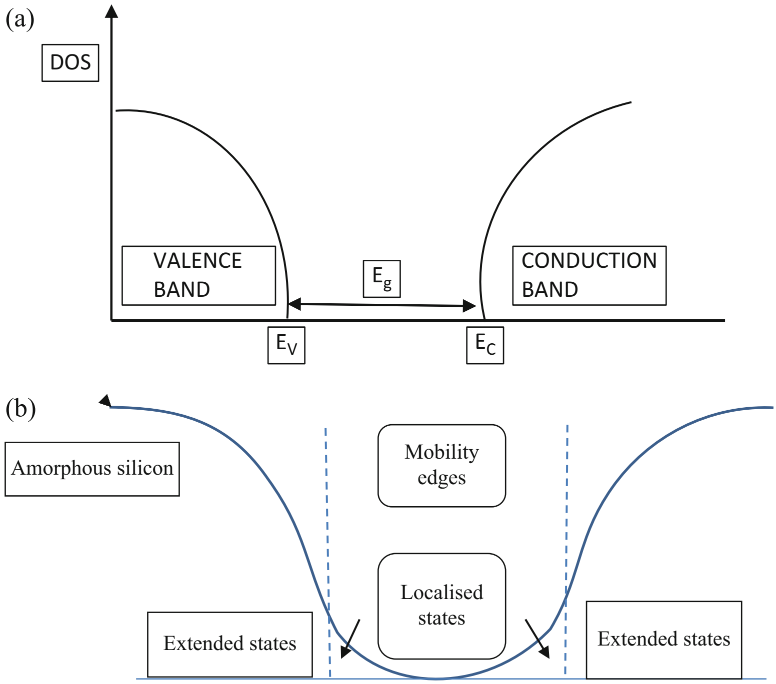


Fig. 8 (**a**) The single crystal has clear gap between conduction and valence band. (**b**) The amorphous silicon has extended states due to localisation

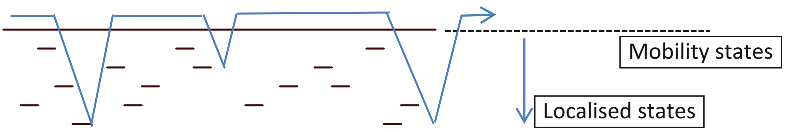


Fig. 9 Multiple Trapping and release model

4.1 Multiple Trapping and Release Model (MTR)

This is the model of choice for charge carrier transfer in weakly disordered semiconductor. MTR model assumes that the charge carriers move in extended states with μ_0. During transfer the carriers are trapped by localized states. As τ_{trap} is greater than τ_{free} thus the mobility decreases. Due to thermal activation the charge carriers are released with activation energy of $E_c - E_t$as given in Fig. 9 and shown by Eq. (4).

$$\mu = \mu_0 \frac{\tau_{free}}{\tau_{trap}} \cong \mu_0 \frac{N_c}{N_t} \exp\left(-\frac{E_c - E_t}{kT}\right) \tag{4}$$

where μ_0 =d mobility in extended states, τ_{trap}=trapping time, τ_{free} =free time N_c = effective density of extended states, N_t = density of localised states (traps), E_c = mobility edge, E_t = effective energy of traps.

4.2 Hopping Model

In most organic semiconductors the transportation of charge is limited by disorder which induces a localisation of energy states. Because of the weak nature of intermolecular bonds, bandwidth is narrow and localisation is strong resulting in Gaussian density of states. In this context, charge carrier transport occurs through hopping between localisation states. Hopping model predicts that mobility of charge carrier depends on both density of charge carriers and electric field.

When all states are localised the charge carrier transport happens by hopping. Hopping to lower energy states is more likely than hopping to higher energy states. Thus, the charge carrier starting from dense states near the maximum of density of states tends to go down to sites with lower energy. However when reaching sites of energy far from center of Gaussian, the density of site decrease a lot, so the mean distance between sites become very high and the first exponential in the hopping rate drastically decreases as given by Eq. (5). So there is a tradeoff between hopping distance and energy difference as shown in Fig. 10. The hopping to a site closer the center of density of states becomes more likely. The transport consists of alteration jump downwards and upwards. All charge carriers localised in deep level will sooner

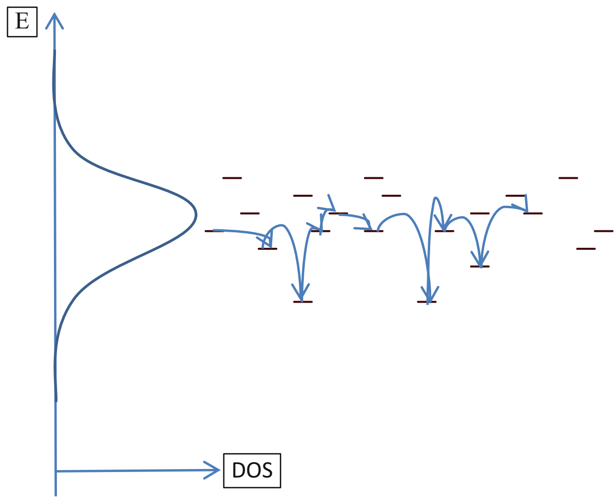


Fig. 10 Transportation of charge in organic semiconductor : Hopping between localized states. (DOS is density of states)

or later jump to a site to an energy close to universal value referred to as transport energy localised slightly lower to the maximum of density of states.

$$\nu_{ij} = \nu_0 \ exp \left(-\frac{2R_{ij}}{a}\right) X \begin{cases} exp\left(-\frac{E_c - E_t}{kT}\right. & for\ E_i < E_j \\ 1 & for \quad E_i > E_j \end{cases} \quad (5)$$

5 Optical Properties of Organic Semiconductors: Excitons

An exciton can be defined as an electrically bound combination of an electron and hole. This is equivalent to lifting an electron from HOMO to the LUMO level. Exciton can emerge either by absorption of a photon (Photoluminescence) or recombination of an electron and hole which correspond to electroluminescence. Electroluminescence is the process in which by light excitation, the organic molecule absorbs photon and it moves from lower energy state to higher energy state. Due to the absorption of a photon, an electron–hole pair is generated [34, 35].

Charged molecules are called Polarons. The hole polaron charged positively and electron polaron charged negatively. The reaction occurs through the transfer of an electron from LUMO of electron polaron to HOMO of hole polaron thus forming excited called exciton. Due to coulombic attraction the HOMO and LUMO levels come closer to each other leads to the formation of an exciton.

6 Energy Level Determination

The difference between energy of electrons in solids and that of vacuum is called work function. This is the energy required to extract electrons from solids. In metals, the highest energy level occupied is Fermi energy and level is called Fermi level. The work function is defined as Fermi level and vacuum level energy difference. In organic semiconductors, the HOMO band is full and the LUMO band is empty, two energy barriers are to be defined, one to extract electron from HOMO called Ionisation Potential and one for capturing electrons in LUMO Level called electron affinity as given in Fig. 11. When metal and organic semiconductor are in contact, to give electrons to LUMO level, the energy required is the difference of metal work function and electron affinity of semiconductor.

Similarly the injection barrier to inject holes in HOMO band equals to the semiconductor's ionization potential and metal's work function difference. The energy level determination is of prime importance in organic semiconductor given by Eqs. (6) and (7) where E_{bn} and E_{bp} are the electron injection barrier and hole

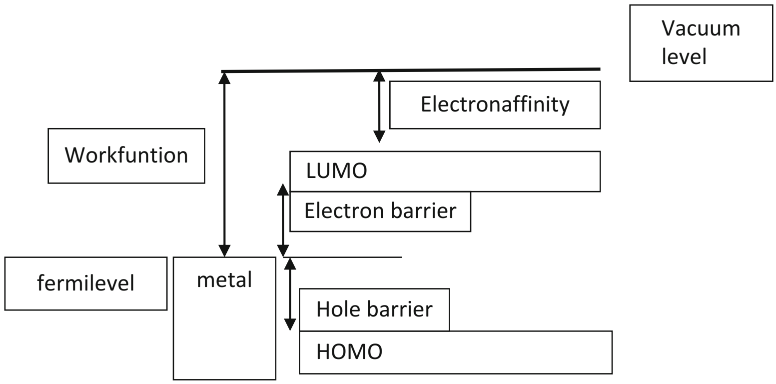


Fig. 11 The different energy levels in organic semiconductor

injection barrier, W_M, EA and IP are work function of metal, electron affinity and ionization potential.

$$E_{bn} = W_M - EA \quad (6)$$

$$E_{bp} = IP - W_M \quad (7)$$

The useful tool for this is photoelectron spectroscopy: UV photoelectron spectroscopy and x-ray photoelectron spectroscopy [36, 37].

The organic molecules can be sorted into two families, on the left side the molecules with deep LUMO level, so electrons are easily inserted due to low electron barrier height while difficult to insert due to high barrier. On the right side, the HOMO level is shallow so holes are easily injected while electrons are difficult to inject as shown in Fig. 12. Semiconductors with easy electron injection is called n-type where n: negative and semiconductors with easy hole injection are called p-type where p: positive. The semiconductor between two extremes has complex situation, these are called ambipolar.

7 Charge Carrier Injection

Unlike inorganic semiconductors, the organic semiconductors have very small density of charge carriers when at equilibrium. Charge carrier injection is therefore the fundamental process in organic semiconductors. In case of disordered solids, the states are localized and randomly distributed, transport occurs by hopping in localized states. The first step is to jump to a state close to metal-semiconductor interface. The first step is thermally activated, the transport occurs against the electric field so the charge carrier can go back and recombine in the metal. The second step can be either ballistic transfer over the barrier i.e. thermionic emission or diffusion of

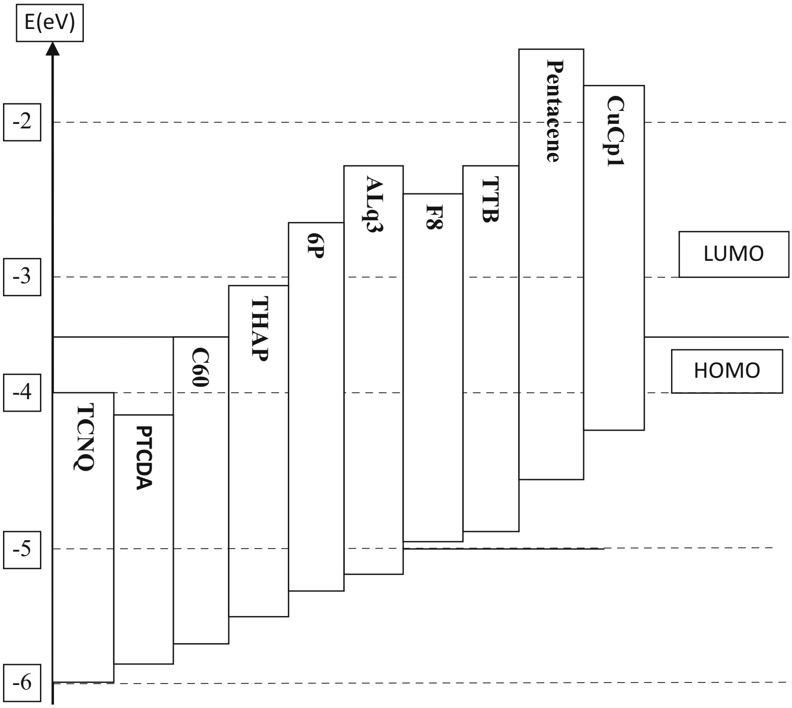


Fig. 12 The molecules are n-type with deep LUMO level are on LHS so electrons can easily be inserted due to low electron barrier while it is difficult to insert holes. The molecules are p-type with shallow HOMO level are on RHS so holes can easily be inserted while holes are difficult to insert. Between these are ambipolar semiconductors

carriers. Diffusion occurs in materials with lower carrier mobility which is the case for most organic semiconductors. The third mechanism is tunneling that takes place at low temperature or for thin barrier, the charge carriers can tunnel through the barrier. Injection strongly depends on width of Gaussian density of states. As the width of Gaussian density of states increases the injection current increases. Qualitatively, the disorder reduces the injection barrier by creating localized levels in the energy gap [38, 39].

8 Types of Organic Semiconductors

The inorganic semiconductors are either p or n type, however the organic semiconductor can be p-type, n-type or can be both p-type and n-type known as ambipolar. p-type organic semiconductor e.g. pentacene teracene, rubrene. n-type organic semiconductors e.g. perfluoropentacene, naphthalene dimide, perylene dimide still lag behind p-type due to low device performance, ambient stability and complex synthesis. Mobility is upto 0.11 cm^2/Vs with on-off ratio 10^5 by introducing cyano halogen or by imide functionalization. They are highly planar and conjugated with tunable electronic properties. Most promising result for n-type polymer is naphthalene based (P(NDI2OD-T2) with mobility greater than 0.1 cm^2/Vs upto 0.85 cm^2/Vs and on-off ratio 10^6 [40].

8.1 Major Challenges

The electrons are injected in LUMO level of semiconductor from a suitable electrode is the major challenge in p-type organic semiconductor. For n-channel devices, the major challenge is to be operated and tested under inert condition due to their susceptibility to water and oxygen in ambient conditions.

8.2 Ambipolar

The complementary approach is superior to unipolar in fabricating integrated circuit. It can be used both as n and p channel thus can be used as inverters. The deposition of two organic materials in controlled amount on substrate increases the complexity and manufacturing cost. They work on both p and n depending on supply voltage though unipolar works on single polarity. In ambipolar transistor, higher power dissipation is due to leakage current and lower switching speed. Two materials show both polarity: amorphous silicon and carbon tubes [41]. The major challenges are efficient injection of both types of carrier and their trapping.

FET based on semiconducting single walled carbon nanotube (S-SWNT) can be tuned to p-type, n-type or ambipolar by using proper injecting electrodes or doping [2]. Mobility is high and greater than 1000 cm^2/Vs. The density of traps in crystalline semiconductor is low as compared to carrier concentration therefore the effect is almost negligible but in disordered organic semiconductor due to high trap density the carrier transport is interrupted by capture and release process. As injected carrier concentration increases, the traps are filled by charge carriers and charge transport improves i.e. the mobility is again thermally activated. In highly purified organic molecular crystals mobility follows inverse power law dependence on temperature, as temperature decreases, the mobility increases [24, 25].

9 Technology and Environment

Organic semiconductor has remarkable advances and applications in displays used in computers, palmtops, mobile phones, and TV sets. Their features of flexibility, transparency, low weight, color scale, brightness, shorter reaction time, wider viewing angle are giving importance to this area. OLEDs are better than traditional illumination systems because of large surface area with higher energy efficiency and minimum heat emission [21]. Currently TFTs based on amorphous Si and organic semiconductors are used.

10 Conclusions

The mobilities of organic semiconductors progressed from 10^{-5} cm^2/Vs for polythiophene to 10 cm^2/Vs for diketopyrroleopyrrole (DPP) based polymers. The factors for high performance organic semiconductors are purity, molecular structure, electronic structure, molecular packing and energy alignment. The mechanical flexibility of organic semiconductors leads to the most important application of wearable electronics. These have the possibility to interface with biological system thus have promising bright future in healthcare applications though silicon couldn't be fully replaced with organic materials due to lower speed and high driving voltage. Organic materials are highly sensitive to environmental conditions i.e. stability, mobility and operating voltage are three major challenges.

References

1. Raúl, J., Martín-Palma, J. M., & Martínez-Duart. (2017). *Nanotechnology for microelectronics and photonics* (2nd ed., pp. 243–263). Elsevier.
2. Thejo Kalyani, N., Swart, H., & Dhoble, S. J. (2017). *Luminescence in organic semiconductors*. Elsevier BV.
3. Li, F. M., Nathan, Y. W., & Ong, B. S. (2011). *Organic thin film transistor integration*. Wiley.
4. Dimitrakopoulos, C. D., & Mascaro, D. J. (2001). Organic thin-film transistors: A review of recent advances. *IBM Journal of Research Development, 45*, 11–27. https://doi.org/10.1147/rd.451.0011
5. Horowitz, G. (1998). Organic field effect transistors. *Advanced Materials, 10*, 365.
6. Tsumura, A., Koezuka, H., & Ando, T. (1986). Macromolecular electronic device: Field-effect transistor with a polythiophene thin film. *Applied Physics Letters, 49*, 1210–1212. https://doi.org/10.1063/1.97417
7. Horowitz, G., Fichou, D., Peng, X., Xu, Z., & Garnier, F. (1989). A field-effect transistor based on conjugated alpha-sexithienyl. *Solid State Communications, 72*, 381–384. https://doi.org/10.1002/jae.3950040505
8. Crone, B., Dodabalapur, A., Lin, Y.-Y., Filas, R. W., Bao, Z., La Duca, A., Sarpeshkar, R., Katz, H. E., & Li, W. (2000). Large-scale complementary integrated circuits based on organic transistors. *Nature, 403*, 521–523. https://doi.org/10.1038/35000530
9. Blom, P. W. M., de Jong, M. J. M., & van Munster, M. G. (1997). Electric Field and temperature dependence of hole mobility in p-phenylene vinylene. *Physical Review B, 55*, R656. https://doi.org/10.1063/1.119692
10. Kergoat, L., Piro, B., & Harowitz, P. (2012). Advances in organic transistor based biosensors from organic electrochemical to electrolyte gated organic field effect transistors. *Analytical and Bioanalytical Chemistry, 402*, 1813–1826. https://doi.org/10.1007/s00216-011-5363-y

11. Bartic, C., Campetelli, A., & Borghs, G. (2003). Field effect detection of chemical species with hybrid organic/inorganic transistors. *Applied Physics Letter, 82*, 475–477. https://doi.org/10.1063/1.1527698
12. Zhou, L., Wanga, A., Wu, S. C., Sun, J., Park, S., & Jackson, T. N. (2006). All-organic active matrix flexible display. *Applied Physics Letters, 88*, 083502. https://doi.org/10.1063/1.2178213
13. Clark, L. C., & Lyons, C. (1962). Electrode system for continuous monitoring in cardiovascular surgery. *Annals of New York Academy of Sciences, 102*, 29–45. https://doi.org/10.1111/j.1749-6632.1962.tb13623.x
14. Liao, C., & Yan, F. (2013). Organic semiconductors in organic thin film transistors based chemical and biological sensors. *Polymer Review, 53*, 352–406. https://doi.org/10.1080/15583724.2013.808665
15. Lin, P., & Yan, F. (2012). Organic thin film transistors for chemical and biological sensing. *Advanced Materials, 24*, 34–51. https://doi.org/10.1002/adma.201103334
16. Katz, H. E., Lovinger, A. J., Johnson, J., Kloc, C., Siegrist, T., Li, W., Lin, Y. Y., & Dodabalapur, A. (2000). A soluble and air-stable organic semiconductor with high electron mobility. *Nature, 404*, 478–481. https://doi.org/10.1038/35006603
17. Salleo, A., Chen, T. W., Volkel, A. R., Wu, Y., Liu, P., Ong, B. S., & Street, R. A. (2004). Intrinsic hole mobility and trapping in regioregular thiophene. *Physical Review B, 70*, 115311. https://doi.org/10.1103/PhysRevB.70.115311
18. Katz, H. E. (2004). Recent advances in semiconductor performance and printing processes for organic transistor-based electronics. *Chemistry of Materials, 16*, 4748–4756. https://doi.org/10.1021/cm049781j
19. Sirringhaus, H. (2005). Device physics of solution-processed organic field-effect transistors. *Advanced Materials, 17*, 2411–2425. https://doi.org/10.1002/adma.200501152
20. Anthopoulos, T. D., Setayesh, S., Smits, E., Cölle, M., Cantatore, E., Boer, B. D., Blom, P. W. M., & Leeuw, D. M. D. (2006). Air-stable complementary-like circuits based on organic ambipolar transistors. *Advanced Materials, 18*, 1900–1904. https://doi.org/10.1002/adma.200502677
21. Koezuka, H., Tsumura, A., & Ando, T. (1986). Field effect transistor with polythiophene thin film. *Applied Physics Letters, 49*, 1210. https://doi.org/10.1063/1.97417
22. Loffler, S., Liberton, B., & Richter-Dahlfors, A. (2015). Organic bioelectronic tools for biomedical applications. *Electronics, 4*, 879–908. https://doi.org/10.3390/electronics4040879
23. Darwis, D., Elkington, D., Ulum, S., Bryant, G., Belcher, W., Dastoor, P., & Zhou, X. (2013). Novel low voltage and solution processable organic thin film transistors based on water dispersed polymer semiconductor nanoparticulates. *Journal of Colloids and Interface Science, 401*, 65–69. https://doi.org/10.1016/j.jcis.2013.03.052
24. Elkington, D., Cooling, N., Belcher, W., Dastoor, P., & Zhou, X. (2014). Organic thin-film transistor (OTFT)-based sensors. *Electronics, 3*, 234–254. https://doi.org/10.3390/electronics3020234
25. Elkington, D., Wasson, M., Belcher, W., Dastoor, P. C., & Zhou, X. (2015). Printable organic thin film transistors for glucose detection incorporating inkjet-printing of the enzyme recognition element. *Applied Physics Letters, 106*, 263301. https://doi.org/10.1063/1.4923397
26. Turner, A. P. (2013). Biosensors: Sense and sensibility. *Chemical Society Reviews, 42*, 3184–3196. https://doi.org/10.1039/C3CS35528D
27. Weng, B., Morrin, A., Shepherd, R., Crowley, K., Killard, A. J., Innis, P. C., & Wallace, G. G. (2014). Wholly printed polypyrrolenano particle-based biosensors on flexible substrate. *Journal of Materials Chemistry, B2*, 793–799. https://doi.org/10.1039/C3TB21378A
28. Sokolov, A. N., Roberts, M. E., & Bao, Z. (2009). Fabrication of low-cost electronic biosensors. *Materials Today, 12*, 12–20. https://doi.org/10.1016/S1369-7021(09)70247-0
29. Feron, K., Lim, R., Sherwood, C., Keynes, A., Brichta, A., & Dastoor, P. C. (2018). Organic bioelectronics: Materials and biocompatibility. *International Journal of Molecular Science, 19*, 2382. https://doi.org/10.3390/ijms19082382

30. Kumar, B., Kaushik, B. K., & Negi, Y. S. (2014). Organic thin film transistors: Structures, models, materials, fabrication, and applications: A review. *Polymer Reviews, 54*, 33–111. https://doi.org/10.1038/srep41171
31. Magliulo, M., Mulla, M. Y., Singh, M., Macchia, E., Tiwari, A., Torsi, L., et al. (2015). Printable and flexible electronics: From TFTs to bioelectronic devices. *Journal of Materials Chemistry C, 3*, 12347–12363. https://doi.org/10.1039/c5tc02737c
32. Coropceanu, V., Cornill, K., Filho, A., Oliver, Y., Silbey, R., & Bredas, J.-L. (2007). Charge transport in organic field-effect transistors. *Chemical Reviews*. https://doi.org/10.1021/cr050140x
33. Kumar, P., Yadav, S., Kumar, N., & Kumar, L. (2021). Effect of organic solvent vapor treatment on transistor performance and contact resistance of copper phthalocyanine based organic field-effect transistors. *Solid-State Electronics*. https://doi.org/10.1016/j.sse.2020.107954
34. Li, M., Mangalore, D. K., Zhao, J., Carpenter, J. H., Yan, H., Ade, H., et al. (2018). Integrated circuits based on conjugated polymer monolayer. *Nature Communications, 9*(1). https://doi.org/10.1038/s41467-017-02805-5
35. Matsui, H., Takeda, Y., & Tokito, S. (2019). Flexible and printed organic transistors: From materials to integrated circuits. *Organic Electronics, 75*, 105432. https://doi.org/10.1016/j.orgel.2019.105432
36. Yuvaraja, S., Nawaz, A., Liu, Q., Dubal, D., Surya, S. G., Salama, K. N., et al. (2020). Organic field effect transistor-based flexible sensors. *Chemical Society Reviews, 49*(11), 3423–3460. https://doi.org/10.1039/c9cs00811j
37. Kweon, O. Y., Lee, M. Y., Park, T., Jang, H., Jeong, A., Um, M.-K., et al. (2019). Highly flexible chemical sensors based on polymer nanofiber field-effect transistors. *Journal of Materials Chemistry C, 7*(6), 1525–1531. https://doi.org/10.1039/c8tc06051g
38. Kotlowski, C., Aspermair, P., Khan, H. U., Reiner-Rozman, C., Breu, J., Szunerits, S., et al. (2018). Electronic biosensing with flexible organic transistor devices. *Flexible and Printed Elect, 3*(3), 034003. https://doi.org/10.1088/2058-8585/aad433
39. Haddon, R. C. (1992). Electronic structure, conductivity and superconductivity of alkali metal doped (C60). *Accounts of Chemical Research, 25*(3), 127–133. https://doi.org/10.1021/ar00015a005
40. Ostroverkhova, O. (2016). Organic optoelectronic materials: Mechanisms and applications. *Chemical Reviews, 116*(22), 13279–13412. https://doi.org/10.1021/acs.chemrev.6b00127
41. Yang, J. P., Busolotti, F., Kera, S., & Ueno, N. (2017). Origin and role of gap states in orgsnic semiconductors studied by UPS: As the nature of organic molecular crystals. *Journal of Physics D Applied Physics, 50*(42). https://doi.org/10.1088/1361-6463/aa840f

Defining and Visualizing Energy and Environment Related Smart Technologies

Manish Kumar Singh and Kamlesh Kumar Raghuvanshi

1 Introduction

Envisaging energy and environment related smart technologies have become key concern in the recent times worldwide. We know that technology grows much faster than we catch it up. It has impacted our lives and work seamlessly with the advent of myriad smart technologies that are sparked by latest apps on our mobile phones and guided by the artificial intelligence to manage and access data. Most importantly, today's technology is evolving to lead us to live a greener and a smarter life.

In this chapter, we are going to put light on defining and visualizing the smart technologies in the areas of energy and environment. In its second section, we will explain how technology is making environment "smart", whereas the third section will cover the relation between smart environment and pervasive computing, the fourth section details the impact of smart technology on environment, the fifth section is devoted to smart technology for energy, while the sixth section provides an account of the future scope of energy and environment related smart technologies, and we will conclude the chapter in the seventh section.

M. K. Singh
Department of Computer Science, Shyama Prasad Mukherji College (University of Delhi), New Delhi, India

K. K. Raghuvanshi (✉)
Department of Computer Science, Ramanujan College (University of Delhi), New Delhi, India

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_2

2 How Technology Is Making Environment "Smart"

Smart environment is the term used famously to correlate human beings and their ability to affiance and interconnect with their surroundings through advance technologies and software based services [1]. It is quite worthy to note that the advancement in technologies has shaped the twenty-first century to fulfill the dream of "smart environment" which is capable enough to perceive technology besides doing fast computational processing [2] (Fig. 1).

2.1 Definition of Smart Environment

According to *(Cook, Diane; Das, Sajal (2005). Smart Environments: Technology, Protocols and Applications. Wiley-Interscience.)*: A smart environment is defined as "an ecosystem built on the edifice of various kinds of smart devices that is supposed to ease one's life" [3]. It aims to felicitate its inhabitants with an environment equipped with automated agents that accompany them to carry out their tasks in safe and easy manner without undergoing intensive or dangerous labor.

2.2 Key Features of Smart Environment

– Devices in a smart environment can be remotely controlled, just like the devices controlled by power line communication systems [4].
– Communicating devices of smart environment are connected through Wireless communication or middleware in order to obtain connected environments in real sense [5].

Fig. 1 Concept of "Smart Environment"

– Smart environment has decision making and predictive capabilities [6].
– It uses sensor networks to acquire or disseminate information [5].
– The intelligent agents of smart environment provide enhance functionalities [7].

3 Smart Environment and Pervasive Computing

Smart environments are considered an improved version of a concept known as pervasive computing. The pervasive computing works on the philosophy of connecting a world through computers and sensors [8] (Fig. 2).

Pervasive computing (widely known as Ubiquitous computing) is a technique where internet is used to connect smart computers in order to carry out every-day functions in an automatic fashion [9, 10]. An Apple Watch, for instance, provides features of not just alerting a person to a phone call but also to complete the call. Other examples of pervasive computing include digitally locked doors, Wi-Fi lighting, smart appliances, like TV, Refrigerator, Air Conditioner etc. The phrase of "ubiquitous computing" was coined by Mark Weiser when he was the Chief Technologist of the Xerox Palo Alto research facility (PARC) in 1988 [11, 12].

The categorization of a "smart environment" can be done into three types with consideration of systems, services and devices: (a) virtual (or distributed) computing environments, (b) physical environments and (c) human environments, or a hybrid combination of those. They can be explained as:

Fig. 2 Smart environment and pervasive computing

– *Virtual computing environments:* They are concerned with making the smart devices capable enough to provide suitable services anytime anywhere [13, 14].
– *Physical environments:* They can be created as well as monitored by smart devices through sensors, tags and controllers which may exist in different versions varying from nano- to micro- or of macro-sized [15].
– *Human environments:* They are sensible environments for devices that can essentially be developed at individual or collective basis by humans. Nevertheless, such environments can have humans (instead of smart devices) dressed with surface-mounted devices (viz. wearable computing) or embedded devices like pacemakers (to cater a heart operation in healthy manner) or AR contact lenses [16].

4 Impact of Smart Technology on Environment

The industrial revolution has fueled immense power among modern technologies. This revolutionized the manufacturing processes of the US as well as Europe between 1760 and1840. Following this, a continued industrialization and further technological advancements were observed round the world (particularly among the developed countries), which led to adverse impacts on the environment including the misuse and damage of our mother earth [17]. They further damaged our world in two main ways—(a) pollution and (b) the reduction of natural resources.

Irrespective of the technology's adverse impacts on environment, the recent concern for climate change at global level has resulted into the event of latest environmental technology development in order to build a sustainable economy with less carbon [18]. Environmental technology, additionally, implies to a 'green' or 'clean' technology which comprises of the state-of-the-art technologies that are meant to the environment conservation and to monitor or to reduce the technology's ill effect on the environment. Moreover, it aims to lessen the human dependence on the non-renewable resources.

The 2016 Paris agreement was signed to bring all the countries of world to adopt steps to deal with the issue of global climate change and to cap the earth's average temperature at 2 °C of pre-industrial levels [17, 19].

Let us check out the definite impacts of technology on the environment in the wake of the given aspects: (a) renewable Energy; (b) Direct Air Capture' (DAC); (c) electric vehicles; and (d) smart technology.

4.1 Renewable Energy

Also known as 'clean energy', renewable energy, in general, implies to the energy gathered from renewable resources which are obtained from nature in the given forms—sunlight, geothermal heat, rain, wind, waves and tides. The latest

Fig. 3 Use of Renewable energy is a smart way to build a “smart” and safe Environment

environmental technology has provided an opportunity to tap this present energy and change it into some pertinent products including electricity or useful energy with the help of devices like solar panels, water turbines and wind, which provides technology’s promising side with respect to the environment.

Renewable sources took over coal and became electricity’s second largest generator since 2015. UK at present produces 20% of its electricity through renewable sources which EU aims to likely extend it to about 30% till 2020. Even though several projects harnessing renewable energy are available on large scale, the technologies mean for renewable energy retrieval are furnishing in developing countries and remote areas since energy plays vital role to human development in these regions (Fig. 3).

The technologies for harnessing renewable energy (for instance, wind turbines or solar panels) cost less and so the many governments are investing huge amount in them. Consequently during the period of 2007–2017, the country like Australia observed an amazing rise in the rooftop solar installations from forty six thousand households to over 1.6 million.

4.2 Direct Air Capture (DAC): Dealing CO_2 in Air

The idea of removing CO_2 from the atmosphere has been a key research topic for years in the area of mitigating climate change (at global level), however it’s only recently been implemented and remains within the early stages of development. The ‘Direct Air Capture’ (DAC) is considered as an environmental technology that converts CO_2 present in the ambient air to produce CO_2 of concentrated stream for further use. The air is then pressed into a filter using several giant fans that help to remove CO_2. It is, however, observed that this technology is not suitable to control

Fig. 4 Removing CO_2 from Atmosphere through DAC

emissions from distributed sources, for instance exhaust emitted from cars. A full scale DAC, on an average, can absorb around 250K cars' annual carbon emissions (Fig. 4).

It is argued by many that DAC is significant for the mitigation of climate change (at global level) which it can help to achieve goals of the Paris Climate Agreement, to lessen the presence of CO_2 in the atmosphere. Nevertheless, the costly DAC is not a good choice on an outsized scale in the present times and a lot more is still to be done to use this technology on wider scale to lessen carbon emissions from the environment.

4.3 Electric Vehicle as a Smart Technology

An electrical vehicle proves to be an environmental friendly technology that employs electric motors to control its operations by utilizing the energy reserved in its batteries which are rechargeable. An amazing rise has been observed since 2008 in the development of electrical vehicles which is attributed to the global concerns of combating air pollution and 'greenhouse effect'.

Governments of many countries worldwide have provided many incentives in the form of tax credits, plug-in vehicles, subsidies to develop, promote and adopt the idea of electrical vehicles as a part of environment technology initiative. Electric vehicles are supposed to fulfill the vision of a greener society and the organizations such as Bloomberg expects electrical vehicles will be available at cheaper rate as compared to petrol or diesel car by 2024. The car manufacturing company, Nissan, has worked for having more charging stations of electrical vehicles in the UK as compared to fuel stations (Fig. 5).

Fig. 5 Smart vehicle under environment technology

Fig. 6 Smart technology for environment

4.4 Smart Technology

It uses tools like sensors and other electrical components to the IoT (i.e. Internet of things) that can be programmed and monitored remotely to enable them to become energy efficient and to reply to the users' requirements.

The IoT uses a mechanism of connecting objects through the Internet which are capable enough to gather data through the technologies of embedded sensors [20]. The IoT devices utilize such gathered data to 'take decisions' autonomously on real time basis. For instance, smart lighting system illuminates desired areas and a smart thermostat maintains the temperature of a house. Both the devices prevent the wastage of energy, time and money.

The IoT enabled technologies are environment friendly that simply need Internet connectivity either through WiFi or Bluetooth to connect objects and their sensors are easy to fit and configure in house buildings and around cities. Many IoT practitioners with the support of their governments are on verge to build 'smart cities' which would be energy efficient and would connect everything from electronic gadgets to household appliances or from vehicles to traffic lights through Internet and sensors. It will ultimately lead to a smart environment [20, 21] (Fig. 6).

5 Smart Technology for Energy

Smart energy solutionscomprise of devices like smart meters and smart grids that are employed to gather relevant data. Conceiving this information, informed decisions can easily be made by an energy provider to conveniently control power flow completely at the three verticals—(a) power generation, (b) its transmission, and (c) its distribution [19].

To suffice the electricity demands of the skyrocketing population across the world, power generation companies and utilities are regularly optimizing their existing methodologies. By advancing the methodologies of working and machineries, the efficiency of the general plant can be improved which eventually enables utilities to provide electricity to large number of people. For an extended duration, PLCs (aka programmable logic controllers) along with SCADA systems have allowed the companies to check the condition and effectiveness of tools and equipment of the power plants owned by them. Nevertheless, SCANDA system faces certain limitations including (a) it has less interoperability, and (b) it also lacks monitoring system that could check the electricity utilization of the consumers [22].

The development in the area of IoT research brought a great revolution in energy sector in the form of smart energy solutions. IoT sensors along with telemetry powered these solutions at a breakthrough level to provide rich serviceability to the facility industry including the monitoring of utilization pattern, optimizations of operations, and controlling asset performance.

Smart meters and smart grids are the key devices in smart energy technology that help to collect important data. The data gathered in smart energy technology are helpful to identify variables associated with the electricity flow. These variables range from the kit performance to the top consumers' utilized energy [23]. Conceiving this information, informed decisions can easily be made by an energy provider to conveniently control power flow completely at the three verticals—(a) power generation, (b) its transmission, and (c) its distribution. The IoT plays a significant role in maintaining the electricity flow through the above mentioned stages that enables the facility companies to easy control the electricity availability during rush hours and cap its dissipation. Let go into the details of benefits that IoT provides during these stages [24] (Fig. 7).

5.1 Generation of Power

To deal with the wastage of electricity, the power plants' components must be effective. Nevertheless, there are certain limitations faced by power plants, including increased inefficiency and unreliability. This may be attributed mainly to: (a) use of old and flaw assets, (b) irregular procedures of operations and maintenance (OM), and (c) wrong way of using assets related historical data.

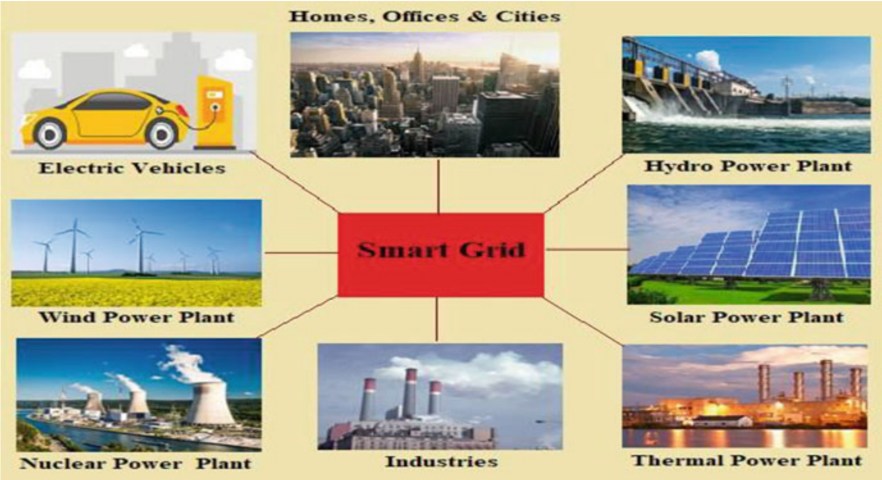


Fig. 7 Smart Grid as A Smart Technology for Energy

The above conditions have negative impacts on the workings of kit and the entire system. IoT provides facilities (that are cost-effective) to companies associated with power generation by advancing their operations and maintenance (OM) related tasks, hence upgrading their assets' lives. By tracking kit's working and performance at constant rate, two key things can be predicted with accuracy—(a) it's failure point, and (b) required maintenance time [22].

1. *Uptime tracking:* Uptime tracking implies to the course of time during which device or system is working. Whilst the system is working, distinctive parameters are computed to determine its condition and performance. These parameters are not sufficient enough to compute the duration of system breakdown or even schedule circumstance, predictive, or threat-based maintenance obligations.
2. *Downtime tracking:* Downtime tracking implies to the course of time during which a system undergoes maintenance or just not working. Suitable repairs and maintenance are generally made by utilizing the gathered historical data through myriad embedded sensors so as to allow the system to do operation.

The kit's supply can be computed by tracking myriad equipment's uptime and downtime simultaneously in a power station. The machines in-standby can then be operated at the time of rush hours to deal the excessive demand. Few other benefits of tracking kit's supply availability include: (a) less cost of maintenance, (b) assets' efficiency and enhanced reliability, (c) speedy analysis and determination of failure's sources.

5.2 Advantages of Smart Grids During Complex Transmission

1. *Catering Renewable energy:* Variable power is the term used for such energy that is produced through renewable resources since such energy results from changes observed in environment conditions. A transmission of sensible kind is able to detect such variations and try to equipoise the facility supply by withdrawing electricity from power plants of traditional kinds.
2. *Less cost of operation:* Smart grids are capable of computing consumption of electricity in various sites through certain distribution systems and attempts to seek period during which rush power consumption is high. Using this knowledge, software can resolve the suitable time to start "peaking plants" (the plants that run during rush hours) to control the supply of power during rush hours. Consequently, the utilization of slow peaking plants becomes less which ultimately lowers the operational costs [25] (Fig. 8).
3. *Catering Asset:* There are several transformers, substations and transmission wires present during a transmission. Due to uninterrupted operation and overloading, chances are high of fault development and further deterioration of these assets and equipment. Eventually, several IoT sensors are employed on many occasions to track myriad asset associated factors to detect safety risks and un-safe asset units. This simply upgrades the tasks associated with up-keeping and improving the life expectancy of the transmission assets.

5.3 Power Distribution

IoT is at its best to improve the services and users' experiences related to smart grids and smart meters. IoT caters to provide important data ranging from a house's

Fig. 8 A home battery of Tesla company

electricity consumption to the service provider through smart meters. The customer can also access this information using internet based application [26].

In short, the smart power distribution has become possible through the smart meters enabled systems which provides many benefits with respect to various fields including [27]:

1. *Restoring and rerouting of power supply:* Systems meant for transmission have the chances of getting their components damaged in case of abrupt and undesirable overload or environmental conditions which may result into the limited electricity flow in specific sites. It would lead to wastage of an appreciable amount of time while fixing the situation of power cut and restore the electricity. This issue can be effectively dealt by using smart grids along with smart meter which altogether is capable enough to determine a distinct path for availing electricity and letting software to change the route of electricity supply to meet the demands of the blackout affected sites [28].
2. *Catering home related energy need:* The home appliances can be smartly built through smart meters that enable them to store, analyze and share data associated to utilization of energy [29]. This data is transmitted to a compact platform by smart meters in order to make data available to television screen for viewing purpose or for further analysis. The consumers can utilize this information to cater their house's electricity need and hence controlling prices of their electricity bills [30].

   Smart technology allows companies and households to use energy more efficiently which will simply lower the need for creating additional power stations. This will ultimately help to prevent pollution caused due to the burning fossil fuels like that of gas or coal by traditional power stations.

6 Smart Technology for Energy and Environment: Future Scope

To achieve the idea of smart energy and smart environment, the utilization of renewable energy sources on an urban scale and thus the introduction of smart mobility plans are supposed to be the major future concerns [31]. There is utmost need for developing, promoting and utilizing smart technologies in the areas of energy and environment that could help to meet environment objectives (decrease of energy utilization and contaminating emanations), financial objectives (lessening of administration costs for citizens and for public organization, development of companies and alarming employment situation) and social objectives (enhancement of the welfare and QoS i.e. quality of services).

M. Casini in his conference paper titled "Green Technology for Smart Cities" put a light on some of the newly adopted techniques in the recent times that are well contributing to the idea of smart energy and smart environment [32]. These techniques are illustrated under Sects. 6.1–6.3.

6.1 Green Buildings

The construction industry is one among the cornerstones of priority effort for the fulfillment of the dream of a "smart, sustainable and inclusive" growth and for a transition to an economy that could support efficient utilization of resources and low carbon emissions. At present, over 40% of the ultimate energy consumption within the EU-27 is done by houses, public and personal offices, shops and other buildings (43% is utilized by households, 44% by industry and remaining 13% from the services) [33] (Figs. 9 and 10).

As far as the goal of achieving green building is concerned, there is a need for promotion of the energy modernization techniques in the already existing as well as public buildings through the following ways [35, 36]:

- by backing the energy sufficiency measures. It is concerned with the means to scale back dissipation through the building envelopes;
- by advocating the usage of cleaner sources of energy. For instance, replacing patrol with natural gas;
- by encouraging the usage of renewable sources of energy. For instance, solar thermal, heat pumps, solar photovoltaic etc.;
- by promoting the production of the clean energy means for the hot domestic water; and
- by incorporating the measures of energy efficiency and checking their emissions.

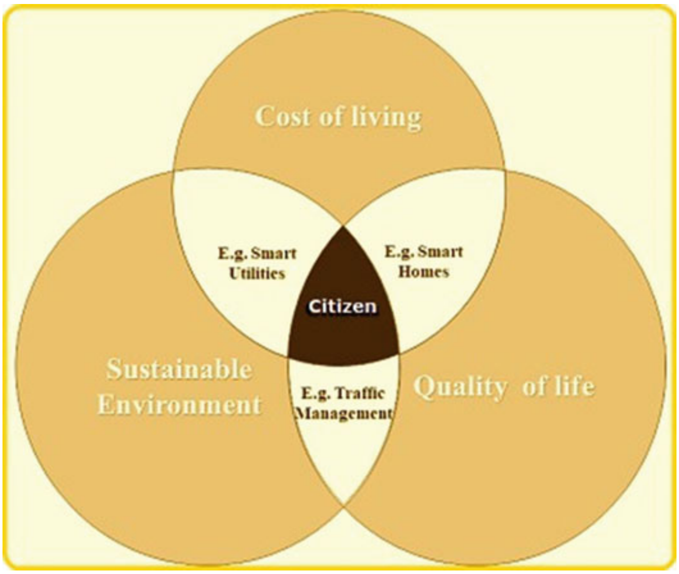


Fig. 9 Future scope of smart technology w.r.t energy and environment

Fig. 10 An example of green building [34]

Several cities of the world have started rewarding condominiums to those adopting efficient energy solutions. MVRDV designed Seoul Sky-garden in South Korea are progressing to be a botanical reference site with over 250 diverse species of trees sorted steady with the Korean letter set. The transformation, which can permit citizens to require an alternate route to go to the rail station, will permit one to travel in 11 min instead of 25, strolling through trees and bushes and looking at the town by 17 feet tallness [37].

6.2 Smart Lighting with Smart Grid

The much effort for lowering the energy utilization on an urban scale is centered mainly on (a) the improvement of the civil power grid to make it a ‘smart grid’, (b) improving the effectiveness of public lighting through the substitution of obsolete lights with traditional LED lamps, (c) the usage of photovoltaic or wind controlled plants, and (d) the utilization of sensors for real-time information discovery.

The power systems of cities are required to be developed as sensible machines that can oversee the reversal of energy flow in real-time, from fringe hubs disseminated inside the region towards the center of the system (dispersed generation), and any surplus of energy due to renewable sources, adjusting request and grant. Keeping this thing in mind, AEEGSI (an Italian Authority for Energy) provided minimum features for brand beating latest smart power counters through its Resolution 87/2016/R/eel (version 2.0) that will progressively take over the output of the

Fig. 11 The Brooklyn Microgrid

essential generation produced since 2001 and whose valuable life of 15 years finished at the best of 2016. The smart counters' latest generation guarantees to be more user-friendly and smart as compared to the past one [22, 38].

Especially focusing the smart grids field are the ventures that are supposed to build microgrids of communities to allow clean energy sharing similar to the one managed by the New York's TransActive Grid(a start-up) in two areas (Park Slope and Gowanus) of Brooklyn [38, 39]. The venture is trying to pursue the conviction of building a trans-active network, means that each person can constitute a hub using this network within his/her house. This requires the person to go through agreements with his/her neighbors for granting or purchasing energy in addition to having physical connection. It naturally differs from the normal supply of energy where an individual purchases energy either from the government or from the company. The other benefits of microgrids of communities include the transaction warranty and security offered by their blockchain powered pc system (Ethereum which is nothing but a bitcoin equivalent) that regulates the microgrids against any kind of tampering [40] (Fig. 11).

EnGoPLANET, a corporate entity, patented and installed one of innovative systems of smart grid in 2016 in the city of Las Vegas which consists of an integrated lighting system with floors tiled with piezoelectric tiles that can transform the pedestrian walks into electric energy. The system further comprises of sensors (which will sense motion to facilitate the illumination), Wireless pads or USB charging devices, video surveillance cameras to check vehicular traffic and additional sensors to determine temperature air quality, precipitations [41].

6.3 Smart Mobility

The measures for achieving a sensible mobility within cities revolve around following concerns:

- encouragement to the development and use of effective systems related to transportation including driverless vehicles, combustion engines with low-emissions, hydrogen or electric motors;
- promoting the idea of (a) using electrical and hybrid vehicles by individuals, (b) installing charging columns (likewise in the European Union), developing more rental services for electric cars, and launching of smart charging systems including vehicle to building and vehicle to grid;
- solar photovoltaic cycle paths shall be developed to support clean smart and clean environment, similar to that developed in Netherlands and France.
- backing the idea of car sharing, bike sharing and policy building of car-pooling;
- instrumenting early caution frameworks for traffic passage, devising parking addressing systems and further promoting the idea of pay parking;
- smart streetlights that allow automated lighting modulation shall be developed with respect to the number of the transit whose data can later be analyzed to build important logistics for public administration;
- the public transport system shall be digitized through smart palettes as well as panels with suitable instructions at traffic stops, and development of info-mobility kiosks that will deliver instructions related to waiting hours, urban lines, atmospheric conditions etc. on the smartphones of the individuals [17];
- encouragement to foot activity policies' building with respect to traffic so as to promote walking indeed through the retraining of the ways, the improvement of lighting and establishing dedicated signage;
- smart traffic lights shall be developed that can count the car flows on the real time basis as presently developed in a few cities inside the US;

7 Conclusion

The rising concerns for climatic change and global warming have caught the attention of academicians, researchers and industry persons to the development of energy and environment related smart technologies at global level. The energy sector with the help of smart technology is predicted to lessen CO_2 emissions by replacing fossil fuels in the power generation industry and the transportation sector. Due to the adverse effect observed during the production of conventional energy and its irreversible nature, the time has come to develop and promote the production of renewable energy based smart technologies [42]. This will not only help us to make our environment smart but also help to make it safe to live.

However, there are certain future concerns related to the smart environment. These concerns are mainly attributed to the use of IoT (Internet of Things), its sensors and components that are utilized to monitor, collect and analyze data of the environment and sharing information obtained from this data with the users for decision making or any related purposes [43, 44]. Won't it make human beings feel under continuous surveillance? Won't it raise privacy issues if data goes in the wrong hands? Will the environment be a safer place in real sense if the technology becomes more autonomous and doesn't require any human intervention at all? There is a need to think over these issues and come out with full-proof solutions to make the idea of a smart environment "safe" in all aspects.

References

1. Joshi, N. (2019). *How IoT And AI can enable environmental sustainability*. https://www.forbes.com/sites/cognitiveworld/2019/09/04/how-iot-and-ai-can-enable-environmental-sustainability/?sh=3b73096e68df
2. *The impact of technology on the environment and how environmental technology could save our planet*. 2019. https://edinburghsensors.com/news-and-events/impact-of-technology-on-the-environment-and-environmental-technology/
3. Cook, D. J., & Das, S. K. (2007). How smart are our environments? An updated look at the state of the art. *Pervasive and Mobile Computing, 3*(2), 53–73.
4. Das, S. K., & Cook, D. J. (2005). Designing smart environments: A paradigm based on learning and prediction. In *International Conference on Pattern Recognition and Machine Intelligence* (pp. 80–90). Springer.
5. Toninelli, A., Pantsar-Syväniemi, S., Bellavista, P., & Ovaska, E. (2009). Supporting context awareness in smart environments: a scalable approach to information interoperability. In *Proceedings of the International Workshop on Middleware for Pervasive Mobile and Embedded Computing* (pp. 1–4). ACM.
6. Misra, A., & Das, S. K. (2005). Location estimation (determination and prediction) techniques in smart environments. In Cook, D. J., & Das, S. K. (Eds.), *Smart environments* (Chap. 8, pp. 193–228). Wiley.
7. Hagras, H., Callaghan, V., Colley, M., Clarke, G., Pounds-Cornish, A., & Duman, H. (2004). Creating an ambient-intelligence environment using embedded agents. *IEEE Intelligent Systems, 19*(6), 12–20.
8. Intille, S. S., Larson, K., Tapia, E. M., Beaudin, J. S., Kaushik, P., Nawyn, J., & Rockinson, R. (2006). Using a live-in laboratory for ubiquitous computing research. In K. P. Fishkin, B. Schiele, P. Nixon, & A. Quigley (Eds.), *PERVASIVE 2006. LNCS* (Vol. 3968, pp. 349–365). Springer.
9. Poslad, S. (2009). *Ubiquitous Computing Smart Devices*. Wiley.
10. Coroama, V., Bohn, J., & Mattern, F. (2004). Living in a smart environment - implications for the coming ubiquitous information society. In *IEEE International Conference on Systems, Man and Cybernetics (IEEE Cat. No.04CH37583)*, The Hague (Vol. 6, pp. 5633–5638). https://doi.org/10.1109/ICSMC.2004.1401091.
11. Weiser, M., Gold, R., & Brown, J. S. (1999). The origins of ubiquitous computing research at PARC in the late 1980s. *IBM Systems Journal, 38*(4), 693–696.
12. Weiser, M. (1991). *The computer for the 21st century : Comprehensive materials processing* (pp. 94–101). Scientific American.
13. Cook, D. J., & Das, S. K. (2005). *Smart environments: Technologies, protocols, and applications*. Wiley.

14. Baccouche, M., Mamalet, F., Wolf, C., Garcia, C., Baskurt, A. (2011). Sequential deep learning for human action recognition. In *International Workshop on Human Behavior Understanding* (pp. 29–39). Springer.
15. Nugent, C. D., McClean, S. I., Cleland, I., & Burns, W. (2014). *Sensor technology for a safe and smart living environment for the aged and infirm at home: Comprehensive materials processing* (pp. 459–472). Elsevier.
16. Swan, W. (2012). Sensor mania! The Internet of Things, wearable computing, objective metrics, and the quantified self 2.0. *Journal of Sensors and Actuator Networks, 1*, 217–253.
17. Yang, J., Han, Y., Wang, Y., Jiang, B., Lv, Z., & Song, H. (2020). Optimization of real-time traffic network assignment based on IoT data using DBN and clustering model in smart city. *Future Generation Computer Systems, 108*, 976–986.
18. Calvillo, C. F., Miralles, A. S., & Villar, J. (2016). Energy management and planning in smart cities. *Renewable and Sustainable Energy Reviews, 55*, 273–287.
19. LalKolhe, M., Labhasetwar, P. K., & Suryawanshi, H. M. (2018). *Smart Technologies for Energy, Environment and Sustainable Development: Select Proceedings of ICSTEESD*.
20. Perera, C., Liu, C. H., Jayawardena, S., & Chen, M. (2014). A survey on Internet of Things from industrial market perspective. *IEEE Access, 2*, 1660–1679.
21. Hashem, A. T., Chang, V., Anuar, N. B., Adewole, K., Yaqoob, I., Gani, A., & Chiroma, H. (2016). The role of big data in smart city. *International Journal of Information Management, 36*(5), 748–758.
22. Wang, J., Li, K., Lv, Q., Zhou, H., & Shang, L. (2010). Hybrid energy storage system integration for vehicles. In *ACM/IEEE International Symposium on Low-Power Electronics and Design (ISLPED)*, Austin (pp. 369–374).
23. Sŭsac, M. Z., Mitrovíc, S., & Has, A. (2021). Machine learning based system for managing energy efficiency of public sector as an approach towards smart cities. *International Journal of Information Management, 58*, 1–12.
24. Talari, S., Shafie-Khah, M., Siano, P., Loia, V., Tommasetti, A., & Catalisã, J. (2017). A review of smart cities based on the internet of things concept. *Energies, 421*, 1–23.
25. Aztiria, A., Izaguirre, A., & Augusto, J. C. (2010). Learning patterns in ambient intelligence environments: A survey. *Artificial Intelligence Review, 34*(1), 35–51.
26. Stenudd, S. (2012). A model for using machine learning in smart environments. In M. Rautiainen et al. (Eds.), *Grid and Pervasive Computing Workshops. GPC 2011. Lecture Notes in Computer Science* (Vol. 7096). Springer.
27. *Market insight: ICT for a low carbon economy - smart electricity distribution networks*. 2009. European Commission and Directorate-General for the Information Society and Media. https://shorturl.at/mtHMZ
28. Czajkowski, K., Fitzgerald, S., Foster, I., & Kesselman, C. (2001). Grid information services for distributed resource sharing. In *10th IEEE International Symposium on High Performance Distributed Computing* (pp. 181–184). IEEE Press.
29. Market insight: The move from the connected home to the intelligent home. Gartner, Inc, Technical Report G00355564. 2018. https://www.gartner.com/en/documents/3876868/market-insight-the-move-from-the-connected-home-to-the-i0
30. Cohen, A.(2020). *Get Smart - AI and the energy sector revolution*. https://www.forbes.com/sites/arielcohen/2020/08/31/get-smart-ai-and-the-energy-sector-revolution/?sh=7ec439d26044
31. Bergman, L. (2019). *6 Things to Know About Using Sustainable Smart Technology*. https://biofriendlyplanet.com/green-alternatives/sustainable/6-things-to-know-about-using-sustainable-smart-technology/
32. Casini, M. (2017). Green technology for smart cities. *IOP Conference Series: Earth and Environmental Science, 83*, 012014.
33. Le Gal, C., Martin, J., Lux, A., & Crowley, J. L. (2001). Smart office: Design of an intelligent environment. *IEEE Intelligent Systems, 16*(4), 60–66.

34. *India: KMC to build green building as admin HQ*. 2014. http://www.asiagreenbuildings.com/8926/india-kmc-build-green-building-admin-hq/#:~:text=The%20proposed%20building%20of%20the,cost%20around%20Rs%2050%20crore
35. Richardson, I., Thomson, M., & Infield, D. (2008). A high-resolution domestic building occupancy model for energy demand simulations. *Energy and Buildings, 40*(8), 1560–1566.
36. *Technology Roadmap: Energy Efficient Building Envelopes*. International Energy Agency 2013. OECD/IEA. https://www.oneplanetnetwork.org/sites/default/files/technology_roadmap_energy_efficient_building_envelopes.pdf
37. Abowd, G. D. (1999). Classroom 2000: An experiment with the instrumentation of a living educational environment. *IBM Systems Journal, 38*(4), 508–530.
38. Rayner, T (2018). *Brooklyn's blockchain power grid: The future of clean, green, community energy?*. https://en.reset.org/blog/brooklyns-blockchain-power-grid-future-clean-green-community-energy
39. Jiao, J. (2020). Application and prospect of artificial intelligence in smart grid. In *4th International Workshop on Renewable Energy and Development (IWRED 2020)*.
40. *How will smart energy solutions fulfill the electricity demands of 7,631,091,040 People?* https://www.biz4intellia.com/blog/smart-energy-solutions/#:~:text=How%20will%20Smart%20Energy%20Solutions%20Fulfill%20the%20Electricity%20Demands%20of%207%2C631%2C091%2C040%20People%3F,-IoT%20in%20Energy&text=Enhancing%20the%20working%20methodologies%20and,provide%20electricity%20to%20more%20people
41. Xu, H., Huang, H., Khalid, R. S., & Yu, H. (2016). Distributed machine learning based smart-grid energy management with occupant cognition. In *2016 IEEE International Conference on Smart Grid Communications (SmartGridComm)*, Sydney (pp. 491–496).
42. Heshmati, A., Abolhosseini, S., & Altmann, J. (2015). Summary and conclusion. In *The development of renewable energy sources and its significance for the environment* (pp. 147–155). Springer.
43. Kang, B.-H. (2007). Ubiquitous computing environment threats and defensive measures. *International Journal of Multimedia and Ubiquitous Engineering, 2*(1), 47–60.
44. Janssen, M., Luthra, S., Mangla, S., Rana, N. P., & Dwivedi, Y. K. (2019). Challenges for adopting and implementing IoT in smart cities. *Internet Research, 29*(6), 1589–1616.

Energy Minimization in a Sustainably Developed Environment Using Cloud Computing

Sanna Mehraj Kak, Parul Agarwal, and M. Afshar Alam

1 Introduction

From the last two decades, hardware and software developers have given sustainability a great deal of significance because of the increased growth in the utilization of energy. Energy utilization and management methods have been kept under close surveillance. Whatsoever, limiting the energy utilization can mainly result in a cost decrease. The complete effect of ICTs on the environment has been studied to improve and increase green developments and sustainability. This can increasingly improve the present weakening situation of the environment and decrease the adverse effect that has been deepened for the last decades. In ICTs, the green attributes of services and products have been seen in concepts related to sustainability like sustainable computing, green computing, green ICTs including ecological and environmental informatics [1, 2]. In addition to high energy costs in data centers, heat discharge increases with a higher power utilization resulting in system dis-functioning. The switching of data from one CSP to another is yet one of the big tasks. QoS-aware resource selection has a vital part to play in cloud computing. Datacenter resources witness a varied performance to the clients. There is an increased variation in the workloads that need to be kept in check and control. Increased energy efficiency can be attained by using better selection and equipment of resources [3]. Thus, the workload policies and the distribution of resources should be consolidated and should be delivered to the provider that can calculate and make sure that the whole computation takes place in an energy-saving mode. Technology has been playing a vast role in sustainable development covering all of its aspects: social, economic, and environmental. Below are a few ways to develop and use

S. M. Kak (✉) · P. Agarwal · M. A. Alam
Department of Computer Science and Engineering, Jamia Hamdard, New Delhi, India
e-mail: pagarwal@jamiahamdard.ac.in; aalam@jamiahamdard.ac.in

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_3

technology for attaining sustainability. The technologies of green cloud computing should implement and use technologies that can be useful in decreasing environmental issues like decreasing the carbon footprint. The appeal of cloud computing has been so huge that in most of cases, its influence on the environment has been neglected by both the CSP and the consumer.

- **Environmental Sustainability**

  Everything one needs for survival relies upon the surrounding natural environment. Environmental sustainability generates and sustains the conditions with which humans and nature can co-exist in a valuable synchronization with one another while still being able to maintain social and economic necessities. Thus, by regularizing ideas and conserving our way of life in such a fashion that it does not exhaust our resources, we are making a promise to the future generations who will also be capable of sustaining themselves. The main goal of green technology is to alternate the methods that deplete or exhaust the natural resources with methods that are sustainable and resourceful. So, consuming renewable sources of energy as an alternative can highly decrease pollution and depleting natural resources [4]. There are quite other forms of green technologies including newly used green building techniques and eGain forecasting. Green buildings or sustainable buildings are concrete constructions that are resource-efficient as well as environmentally responsible. EGain uses weather prediction to estimate how future weather patterns will affect the construction, which can decrease the unnecessary use of heat, energy consumption, and GHG emission.
- **Economic Sustainability**

  Economic sustainability requires various approaches that use resources mostly finely and reliably so that a clear balance can be made between the resources used now and the resources required in the future. Technological advances in health, business, and the environment will provide a chance for the communities in the shape of new jobs and opportunities. Small businesses that use the local produce, employ recycling and green energy should be supported as it is a great way to increase the local economy as well as help in storing the resources at the same time. Partaking in sustainable agriculture and fisheries that do not consume pesticides or hormones or any type of antibiotics on their produce decreases the depletion of natural resources on a large scale as well as delivers products with health benefits and not the reverse.
- **Social Sustainability**

  Social sustainability includes a wholesome area including the basic human rights and corporate governance to something philosophical features of an individual's behavior and his attitude towards sustainability. Economic and environmental sustainability are solely dependent on social sustainability. The difference between a 'desires', what one wants, and 'necessity', what one needs, need to be evaluated by the people for a clear idea. Relatedly, it is hard to manage businesses that employ green energy because they are more expensive. So people prefer going to a more affordable, easier, and available option hence abandoning the very basic concept of sustainability. Since social sustainability is the key to basic

Table 1 Technologies based on various cloud computing services

Cloud computing service	Technology
SaaS	Facebook, You Tube, Google Applications
PaaS	MS Azure, Amazon Simple DS/S3, Google App Engine
IaaS	Amazon EC2, Flexiscale
HaaS	Data centers, Servers, Backup

Table 2 Top 10 CSPs

S. No.	Cloud service providers
1	Microsoft Azure
2	Amazon Web Services (AWS)
3	Google Cloud
4	Alibaba Cloud
5	IBM Cloud
6	Oracle
7	Salesforce
8	SAP
9	Rackspace Cloud
10	VMWare

sustainable habits, the easiest way to encourage and advocate economic and environmental sustainability is through education. By educating ourselves and people, we can have a clear idea of the sustainable alternatives that we have around in our daily lives such as food, clothes, common household items, and building materials [4].

The cloud computing revolution is reshaping and restructuring modern networking, and highly contributing to environmental protection as well as economic and technological advancements. These technologies can potentially enhance energy-efficiency and decrease carbon footprints and e-waste. These features can alter cloud computing into green computing which is the main aim here. Cloud computing comprises of four service models. Table 1 below refers to some technologies for various cloud computing services.

Limiting the energy utilization doesn't diminish the gigantic expense and improves framework quality, yet it helps in ensuring our natural balance and habitat. Therefore, decreasing energy utilization of a cloud computing framework and data centers is a test since information and applications are developing at a rapid speed that needs bigger servers which requires processing them quickly within the necessary slot of time frame. The unexpected expansion of the data centers has been greatly increasing its effect on the environment, the economy, and the services provided by the CSPs. Table 2 gives a list of the top 10 CSPs.

Among these top 10 CSPs; AWS, Azure, and Google Cloud are the main players that offer cloud computing to the world with annual revenue of $33 billion for AWS, $35 billion for Microsoft Azure, and $8 billion for Google Cloud. US government has infused cloud computing in all aspects of their trade and communication. The

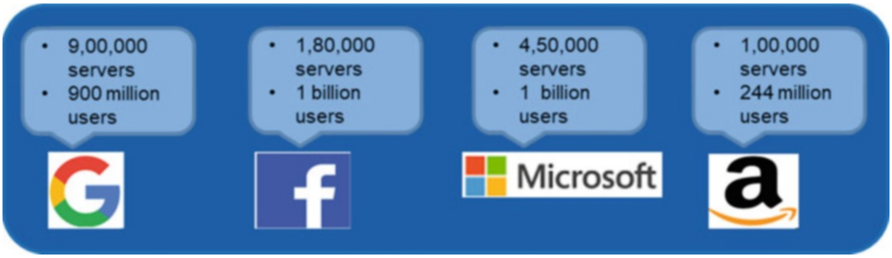


Fig. 1 Largest CSP's around the globe

better services provided by the CSPs result in better security [5]. Various studies have been made by the researchers where they secure the searching and recovering of the client data in a cloud environment. There are usually several distinct interfaces each of which are dealing with a different characteristic of the cloud services. Figure 1 shows the number of servers and the number of users among the largest cloud service providers all over the earth.

1.1 Minimizing the Energy Consumption

One of the most obvious disadvantages of using cloud computing is that we cannot access the data without the internet which could have been easier if we had direct access to the services first hand. Among various struggles of cloud computing, minimization of energy consumption takes a huge area of interest as the service providers have been developing ideas trying to save energy by using renewable sources of energy which shall be our main area of interest in the study. The main energy loss happens in cloud data centers. The present energy-efficient resource management techniques use a lot of energy while executing the tasks. Cloud data centers should provide cloud services with a minimum discharge of heat and carbon footprint as a greenhouse gas which is one of the main concerning issues. Below are the suggested steps that can be used to build energy-saving algorithm:

1. Identifying the resource and the resources available that can be used.
2. Calculating the processing time of each available resource.
3. Calculating the processing time of arriving task size.
4. Calculating the processing time for the total number of tasks.
5. Allocating the processing time to the resources for the whole task.
6. The un-allocated resource saves energy by moving to the idle state.
7. Repeat the steps for accuracy.

2 Literature Survey

In [6], authors focus on the struggles of a CSP to decrease the operational cost by improving the utilization of energy while providing the services to the customers. The paper provided a broad view of the failures that can happen within a cloud system considering the spatial and temporal characteristics of the surroundings. They summarized and measured the total effect of the failures on the task and servers considering energy waste within a properly evaluated trace log. The authors conclude their paper by mentioning that their results are depicting that the re-submissions due to task and server crash failure produce crashing computations resulting in major loss of energy, almost 21%. Their results proved 88% of task failure occurred among the low priority tasks which further produced 13% of energy waste and only 1% of task failure occurred among high priority tasks because of the server failure which accounts for 13% of the total energy loss.

In [7], a survey on cloud computing was made and emphasis was laid on the need of the hour, i.e., decreasing the use of energy in a data center. They included the architectural elements, the models, and services which gave an understanding of energy enhancement. The authors in this paper presented system categorization in cloud computing. They further focused on migration, virtualization, and task scheduling algorithms. They believed that by using scheduling algorithms, they could control and improve the processing time taken for mapping data center servers and the tasks. They presented the main architectural elements of cloud computing, the models, and all the involved elements. They also used different kinds of simulators that were particularly developed for the cloud computing environments. Their future work discussed developing an innovative structure for decreasing the usage of power in a cloud computing environment using a cloud simulator, CloudSim.

In [8], the authors researched various aspects of the cloud computing environment by improving the resources of computing, which is hardware optimization, network optimization, storage optimization, and software optimization. This paper gives an overview of optimized cloud computing energy techniques. This study will further be used to design a fresh data center or to decrease the energy in an already operating data center. The authors concluded the paper by stating the hazardous presence of carbon footprint in the environment and supporting the eco-friendly data center which is more efficient and will help in saving energy. The authors also suggested simulating the designed data center by using energy-aware cloud simulators such as GreenCloud, CloudSim, etc. Their future focus would mainly be on decreasing the consumption of energy in a data center where they may use renewable resources as their main source of power.

In [9], the authors discussed about the role ICT plays which include the ability to gather the data for monitoring purposes, finding alternative ways of working, and controlling the energy supply and control transport. The author also emphasizes on educating people about the conservation of energy and finding the potential alternatives to attain sustainability. The author concludes by considering sustainability as the main and core element of teaching and research in ICT. The author believes that opportunities offered by making ICT sustainable will promote a green IT environment in the future.

In [10], the authors suggested two energy models for interchanging between the operational modes of the servers. The team investigated the power estimation taken at the input of the server's AC, to decide the energy exhausted in the idle state, the sleep state, and the turn off state, to see the impact of interchanging between these states. However, interchanging between these modes is a bit time-consuming and can degrade the performance if there is any sort of hike in the load. In addition, the structure of the servers which take on the load can favorably shift consistently, suggesting short idle states for almost half of the servers used. More power displaying methods have been suggested by a few researchers.

The work suggested in [9] treated a single assignment processing in the cloud as the central unit for summarizing the energy. With this strategy, Chen and her other partners saw that the overall energy utilization of two tasks isn't comparable to the aggregate of individual utilized energy because of scheduling overhead. They introduced a power model for overall energy utilization that centers on storage, calculation, and communication assets. Then again, a few research actions have been additionally made to lower the energy utilization in a cloud environment for the most part on virtualization. This approach utilizes fewer servers offering services to more than one device.

The power utilization model suggested in [11] examined a connection between the usage of energy of the CPU and the workload taking time into consideration. In [12], authors additionally suggested an energy utilization model that studied the relationship between the total system power utilization and the use of the component. In [13], the authors suggested that cloud virtualization can be a prospective method to decrease unnatural weather change and energy utilization. Their methodology uses a smaller number of servers as opposed to utilizing different servers to offer help for various applications. The power demonstrating strategies for the physical foundation data centers suggested in [14] are generally pertinent.

In [15], the authors have discussed various features related to the adoption of cloud computing. They expanded the basic cloud computing components, its advantages, and management services and discussed various limitations of cloud computing. The creativity to clear the basic confusion about the technologies used and implemented in the cloud was carried out in alliance with HP Enterprise Businesses. The main steps that need to be implemented while achieving a successful implementation of cloud is clearly a regular check-up of organizational errors and activity plans, a well-designed strategy for error, consequences of cloud adoption as per the price, and proper calculation of technical interfaces used in the cloud implementation. There have been several pros and cons of cloud computing and its implementation. The user cannot have direct control of the access but as per the cost, the services used by the user are higher than the money he spends on accessing them. But sometimes in a business, the opponent company may be using the same services as us, which can be an issue in the competitive world.

In [16], the authors mainly focused on task scheduling using an algorithm, Clonal Selection also known as TSCSA to improve the energy and processing time. CSA is a distinctive class of immune algorithms that are stimulated by clonal selection theory to provide us with effective methods for search and development. They observed that a multi-objective CSA-based optimization algorithm solved the task scheduling issue in cloud computing surroundings in which the number of data centers and the customer jobs change energetically. Thus, a multi-objective CSA-based algorithm is the most suited algorithm for cloud computing surroundings where this algorithm uses the system resources to decrease energy and makespan. The experimental results proved that the suggested TSCSA was better than several application scheduling algorithms and random scheduling.

In [17], the authors derived an energy-aware task scheduling model (EATS) which schedules and splits big data in the cloud. The main objective of EATS is to decrease the consumption of energy and increase the efficiency of the applications of the core resources. The power usage in a computational server has been measured under various workloads. The experiments showed that the ratio of energy usage to peak performance compared to an idle state is 1.3 which illustrates that resources must be utilized appropriately taking performance into account. Thus, the implementation of such strategies by the CSPs can highly save energy in a cloud data center. The increased cost of power usage in data centers and its parallel environmental failures and threats has exponentially raised the demand for energy-efficient computing. Thus, the amount of energy consumed by the overloaded and underutilized servers is something that needs to be taken into consideration.

3 Enhancing Energy-Efficiency in a Cloud-Computing Environment

Improving energy effectiveness in cloud computing is a necessity. It is suitable to accomplish energy proportionality at the cloud data center levels by dynamically moving tasks between servers and doing server combinations with the goal that the specific state of the power dissipation vs. utilization curve at the server level turns out to be less important, whereas the shape of the power utilization curve at the cloud data center level converts into a line at the starting point which is the origin [18]. Additionally, it has been shown that energy progressive operation can be achieved for delicately used servers with full-system coordinated idle low-control modes [19]. The effects of consuming energy proportional servers in data centers are studied in [20]. The authors revealed that 50% of energy can be decreased by the usage of energy-proportional servers with the idle power of 10% of peak power rather than average servers with 50% idle power utilization. They also proved that expanding the power proficiency of the disk, memory, network cards, and CPU aids in constructing energy-proportional servers. Besides, DPM strategies, for example, DVS and sleep mode for disk and CPU segments, expand the power proportionality of the servers. A high energy ratio in a cloud computing environment might be accomplished by substituting traditional cloud data centers geared with progressively more powerful and energy proficient servers. The servers use more progressed inner cooling frameworks with lesser energy devoured by their fans which makes it significant because the power utilization of the internal server decreases is magnified by reserve funds in the rack and cloud data center power dissemination and cooling structures. System-wide power management is a significant key method for progressive energy effectiveness in cloud figuring situations. Firstly, we have the TCO which is the cost of Ownership for cloud computing environments, which incorporates the power cost of managing a cloud data center. The general power scattering in a cloud data center must be diminished in order to limit the cost. Furthermore, the limit of the power sources for cloud data centers and electrical flow constraints of the energy conveyance system in the cloud data center also exists, which set the farthest point on the peak control at the server level and data center level. Expanding the cooling effectiveness is an additional approach to bring down the power cost of cooling a cloud data center by CRAC which is the compute room air conditioning units and air handling units with request focused, variable frequency drive (VFD) fans within exchanges so as to coordinate variable loads of heat with a variable rate of airflow. Finally, limiting energy utilization would result in a cover cost decrease. Aside from the massive cost of energy, heat discharged increments with complex power utilization, accordingly, thus increasing the load which results in system failure [21].

The development of GCC is highly influenced by the development of green data centers. The whole setup in a green data center is planned to attain maximum energy efficiency with decreased impacts on the environment. Such data centers use substitute energy sources that uses the minimum power resources for both procedures and maintenance of all the gears [22]. Thus usage of GCC would be far easier to implement if all the available data centers used these features. To decrease the energy usage of a server, two main levels of resolutions are recognized [23]:

1. Server Level: Decreasing the power used by a single server
2. Data Center Level: Enhancing the usage of the power of a group of servers

At the server level, precise approaches and procedures have been suggested for decreasing the consumption of energy at the compiler level as well as for operational and application layers [24]. These methods include—decreasing the clock speed of CPUs, turning off parts of the chip, developing methods to run in high-temperature surroundings, improved performance per watt, increased efficiency in managing the workload, and turning off the parts when in an idle state.

At the data center level, the main work is done in developing the methods for virtualization. It further improves resource utilization and provides reliability and flexibility. The consumption and usage of power can highly be developed by using software and hardware techniques [25]. DVFS (Dynamic voltage frequency scaling) and DPM (Dynamic power management) are usually used for hardware optimization. Software techniques for GCC comprise of project strategy to increase the efficiency and to use less space for storage and computing modes like distributed and grid computing and other high-performance computing.

Thus, sustainable energy comprises two modules: energy efficiency and usage of renewable energy. The foremost advantage of GCC is the reduction of carbon footprint. The use of renewable energy decreases the emission of CO_2 into the environment. Garg et al. [26] suggested an architecture that could reduce the carbon footprint in cloud structure entirely in an integrated way established on three constraints: emission rate of CO_2, the efficiency of VM, and power efficiency of the data center. Further, Wadhwa and Verma [27] suggested a technique for the distribution of VM and relocation in two steps. In the first step, the VM was placed with a host that emitted less CO_2 from data center distribution. In the second step, VM was optimized within each data center. Their suggested technique was devoted to geographically distributed clouds. Decreasing the operational costs is another advantage of moving to GCC for the user as well as the provider. For a cloud service, charges reduce as an outcome of decreased expense on energy and the necessity for infrastructure. The employment of energy-saving methods and ideal cooling systems can decrease the cost and maintenance. There have been proofs for having a company server using only 10–30% of the offered computing power and the desktop computers have an average capacity utilization of less than 5%. Lesser the infrastructure, the better as it helps in decreasing the e-wastes that are produced by the consumers using the cloud services.

4 Measures for Reducing Carbon Emissions

Higher performance and higher energy efficiency are hindered by several serious issues. For example, reliability is highly decreased by the excessive use of power. The necessity for decreasing the CO_2 emissions into the atmosphere affects several divisions of the economy like energy creation, transport, construction, manufacturing, cultivation, human settlements, etc. They are explained as follows:

Energy Creation: The accessibility of sufficient power resources is a very essential aspect of the present modern existence. Presently, non-renewable resources like coal, oil, and natural gas offer the main percentage of energy. These resources need to be replaced by renewable resources that are lesser to nil carbon-emitting fuels, such as wind energy, solar energy, and nuclear energy. Even though the generation of nuclear power has definite risks, it will help to escalate the amount of lesser to nil carbon as the higher concentration will be given in intensifying the safeguards. Better emphasis needs to be put on technologies that are being developed for energy generation through renewable resources. In these efforts, the CCS technology plays an essential job. In CCS technology, the CO_2 released by fossil fuels is seized and permanently stored underground. The storage of electricity produced from renewable resources as the supply of energy is irregular is another area for technological advancement.

Transportation: Major improvements have to be made in regions of energy efficiency, enhanced usage and functioning of all automobiles including electronic automobiles, unified urban schemes, improvement of high-speed railway structures, and enhancement in public conveyance systems, etc.

Constructions: Various attempts have to be made for the usage of lower energy building codes, usage of energy proficient appliances, decreased usage of non-renewable electricity, etc.

Manufacturing: It is among the most excessive user of energy. It is essential to start taking extreme measures for enhancement, reconstruction, and distribution of innovative technologies, efficient use of materials, and re-using and recycling of supplies and produces.

Cultivation, Forestry, and Other Land Usage: The main focus in this area needs to be on the management of crops, reforestation, management of grazing, refurbishment of biological soils, etc. Another preference for modification is the decrease in the aggregate of animal agriculture. The Food and Agriculture Organization (FAO) of the UN approximates that 18% of the emissions are produced by animal agriculture. Sixty-five percent of the emission of nitrous oxide which is a GHG is almost 300 times more fatal than CO_2 which is caused by livestock [28]. Livestock also releases methane which is also fatal but not as much as CO_2 and NO_2.

Human Settlements, Infrastructure, and Spatial Planning: New developmental concepts of urban schemes need to be implemented. Improvement in public transportation systems will play a major part.

The revolution of Cloud computing is to redesign the current networking systems and providing favorable ecological fortification visions as well as technological and economic benefits. Such technologies give us the probability to reduce e-wastes as well as carbon footprint and improve the efficiency of energy thus transforming cloud computing into GCC. GCC is not only limited to the usage of energy of the computing devices but involves the energy consumed by networks or various equipment for cooling and ecological issues such as emission of CO_2, consumption of natural resources, and e-waste management. The largest producer of carbon footprints usually arises from generating electricity, around 32% of GHG emissions. In the US, around 70% of the electricity still comes from consuming fossil fuels, mostly coal and natural gas. Transportation is the second major producer of carbon footprints, which sums up for around 28% of GHG. The consumption of fossil fuels in automobiles like cars, trucks, planes, trains, and also ships produces these emissions. Petroleum accounts for almost 90% of all of the transportation fuel.

An efficient resource management system will enhance the performance of cloud computing by decreasing the power usage, its cost, and e-waste. In GCC, management of resources means using diverse resources and geologically distributed resources to meet the requirements of the clients with the least negative effect on the surroundings. Luckily, few factors that are benefitting the cloud computing providers also benefit the environment. For example, decreasing the energy usage will decrease the providers' cost and will also result in decreased emission of CO_2. The benefit of GCC essentially focuses on saving energy and reduction of carbon emissions. From the perception of energy efficiency, cloud providers can achieve greener cloud computing in two ways: by developing the methods for efficient energy in the cloud and by the usage of clean energy. The switching from a highly powered to a lesser-powered device increases the energy efficiency for the cloud users. The approaches for decreasing the consumption of energy ranges from plain and easy techniques like guaranteeing the management of energy for servers in the cloud, just by simple on and off technique or turning them to sleep [29], or comparatively complicated techniques like auto-scaling organizations to construct GCC surroundings or the usage of virtualization techniques for improved management of resources. Climate changes have been progressively encountered universally where the influences are wide and evident [30]. The whole world is presently working on techniques using renewable energy that can substitute the usual extremely polluting and excessive power-consuming routine of non-renewable technologies to reduce CO_2 concentration, making study on renewable energy advancement an emergent matter. All the scientists agree that GHG is the key reason for climate change resulting in global warming.

4.1 Future Prospects of Sustainable Cloud Computing

The increased employment of cloud computing has resulted in the increased number of cloud data centers where all the data is stored, processed, and recovered if needed. To support the idea of sustainability in cloud computing, proper technologies, and deployment models should be implemented by the organizations. The implementation of cloud computing with its influence on sustainability in the future is exceptional. Various technologies are implemented by various industries including the education system, health care, and manufacturing. All these developments are only possible because of the low cost of the cloud and its global access [31]. In the past decade, the area of data centers has been increasingly growing as a result of the shifting of businesses to cloud computing due to the increase in data.

Various developing countries can increase their sustainability by implementing green IT [32]. Global e-Sustainability Initiative and Microsoft showed in their studies that if the services are run over a cloud, it can result to be 95% more efficient than the ones that are not. For maximum efficiency, the CSP needs to have a better understanding of the cooling schemes and power usage of a data center. The CSPs have to decrease the need for electricity used by the cloud and start implementing renewable resources rather than just looking for a solution for decreasing the cost [33]. We have compiled a table (Table 3) comprising of the top 10 data centers as per the square footage all over the world.

The main source of energy inefficiency in cloud computing is the energy non-uniformity server. Additional inefficiency in a cloud computing environment is the energy cost of Cooling and Air Conditioning Units that account for 30% of the total energy cost of cloud environment [34] which can be decreased by using a new cooling method, new server and rack configurations for the cloud computing environment. These standards can also be decreased for a cloud data center that is situated at a geographical place where the cooling is beneficial. Still, cooling energy consumption is yet among the main contributor to energy inefficiency in a cloud

Table 3 Top 10 data centers in the world

S. No.	Data center name	Location	Size
1	The Citadel	Tahoe Reno, Nevada	7.2 million square feet
2	Range International Information Group	Langfang, China	6.3 million square feet
3	Switch SuperNAP	Las Vegas, Nevada	3.5 million square feet
4	DFT Data Center	Ashburn, Virginia	1.6 million square feet
5	Utah Data Center	Bluffdale, Utah	1.5 million square feet
6	Microsoft Data Center	Wes Des Moines, Iowa	1.2 million square feet
7	Lakeside Technology Center	Chicago, Illinois	1.1 million square feet
8	Tulip Data Center	Bangalore, India	1 million square feet
9	QTE Metro Data Center	Atlanta, Georgia	990,000 square feet
10	Next Generation Data Europe	Wales, UK	750,000 square feet

computing environment. The developing technology in the field of IoT is gaining a lot of interest which is giving way to a smarter world [35]. IoT is advancement and development in the field of wireless communication where sharing of information, making collective decisions, and completing jobs in ideal mode is involved. Green IoT has been predicted to be the future of technology.

The global cloud ecosystem is the main concern of the European Union in making it more adaptable for the users. It helps in developing new features for the support of cloud employment. It can also help in overcoming the main issues that include energy efficiency, proficient data management, new programming models, and increased protection of data by increasing security.

5 Conclusion

The growing use of cloud computing has been highly increasing the carbon footprint in the environment which makes one question if cloud computing is green or not. The increased measures for maintaining the GHG that has been emitted into the environment need to be kept in check and within limits. Such measures illustrate the need of making cloud computing sustainable. There also arises the need to handle energy and QoS together to allow energy efficiency and sustainable cloud computing services. The prerequisites for handling and processing of an enormous sum of data and higher performance use a huge amount of energy which raises the problem of handling the energy consumed, QoS and SLAs at the same time. Thus developments need to be made to make energy more efficient and benefit in regulating the content of carbon dioxide into the environment.

References

1. Hilty, M. L., Arnfalk, P., Erdmann, L., Goodman, J., Lehmann, M., & Wager, A. P. (2006). The relevance of information and communication technologies for environmental sustainability—A prospective simulation study. *Environmental Modelling and Software, 21*, 1618–1629.
2. Agarwal, P., & Alam, A. (2018). Use of ICT for sustainable transportation. In *Proceedings of International Conference on Future Environment and Energy* (Vol. 150, No. 1, pp. 1–7).
3. Kalange Pooja, R. (2013). Applications of green cloud computing in energy efficiency and environmental sustainability. *Journal of Computer Engineering, 1*, 25–33.
4. Kolodziej, J., Khan, S. U., Wang, L. Z., Kisiel-Dorohinicki, M., Madani, S. A., Niewiadomska-Szynkiewicz, E., & Xu, C. Z. (2014). Security, energy, and performance-aware resource allocation mechanisms for computational grids. *Future Generation Computer Systems, 31*, 77–92.
5. Mohammad, A., Kak, S. M., & Alam, M. A. (2017). Cloud computing: Issues and security challenges. *International Journal of Advanced Research in Computer Science*, 8(2), 26–28.
6. Uchechukwu, A., Li, K., & Shen, Y. (2014). Energy consumption in cloud computing data centers. *International Journal of Cloud Computing and Service Science (IJ-CLOSER), 3*(3). ISSN 2089-3337.
7. Alshathri, S. I. (2016). Towards an energy optimization framework for cloud computing data centers. In *Proceedings of the Eleventh International Network Conference*
8. Gordin, I., Graur, A., & Balan, D. (2017). Development of eco-friendly cloud computing environments. In *International Conference on Engineering of Modern Electric Systems (EMES)*. IEEE. ISBN: 978-1-5090-6073-3/17.
9. Pattinson, C. (2017). *ICT and green sustainability research and teaching* (pp. 12938–12943). Elsevier.
10. Chen, F., Schneider, J., Yang, Y., Grundy, J., & He, Q. (2012). An energy consumption model and analysis tool for Cloud computing environments. In *Green and Sustainable Software (GREENS), 2012 First International Workshop*, pp 45–50.
11. Rajkumar, B., Anton, B., & Jemal, A. (2010). Energy efficient management of data center resources for cloud computing: A vision architectural elements and open challenges. In *Proceedings of International Conference on Parallel and Distributed Processing Techniques and Applications (PDPTA 2010)*, Las Vegas, USA, July 12–15, 2010.
12. Bohra, A., & Chaudhary, V. (2010). VMeter: Power modelling for virtualized clouds. In *International Symposium on Parallel & Distributed Processing, Workshops and Phd Forum (IPDPSW), 2010 IEEE*, April 19–23, 2010 (pp. 1–8).
13. Yamini, B., & Selvi, D. V. (2010). Cloud virtualization: A potential way to reduce global warming. In *Recent Advances in Space Technology Services and Climate Change (RSTSCC)*, November 13–15, 2010 (pp. 55–57).
14. Pelley, S., Meisner, D., Wenisch, T. F., & VanGilder, J. W. (2009). Understanding and absracting total data center power. In *WEED: Workshop on Energy Efficient Design*.
15. Hurwitz, J., et al. (2010). *Cloud computing for dummies*. Wiley.
16. Jena, R. K. (2017). Energy efficient task scheduling in cloud environment. *Energy Procedia, 141*, 222–227.
17. Ismail, L., & Fardoun, A. (2016). EATS: Energy-aware tasks scheduling in cloud computing systems. *Procedia Computer Science, 83*, 870–877.
18. Seubert, T. (2012). Microsoft builds new data Center in Dublin. Available at: http://facilitygateway.com/news/?p=1937
19. Meisner, D., Gold, B. T., & Wenisch, T. F. (2009). PowerNap: Eliminating server idle power. In *Proceedings of the 14th International Conference on Architectural Support for Programming Languages and Operating Systems (ASPLOS)*, USA.
20. Belady, C., Rawson, A., Pfleuger, J., & Cader, T. (2012). Green grid data center power efficiency metrics: PUE and DCIE. White paper #49, *The Green Grid*, 1-9. [Online] Academia.edu. Available at: http://shorturl.at/wCHU2

21. Feng, W. C., Feng, X., & Rong, C. (2008). Green supercomputing comes of age. *IT Professional, 10*(1), 17–23.
22. Dougherty, B., White, J., & Schnlidt, D. C. (2012). Model-driven auto-scaling of green cloud computing infrastructure. *Future Generation Computer Systems, 28*, 371–378.
23. Itani, W., Ghali, C., Kayssi, A., Chehab, A., & Elhajj, I. (2015). G-route: An energy-aware service routing protocol for green cloud computing. *Cluster Computing, 18*, 889–908.
24. Garg, S. K., Yeo, C. S., Anandasivam, A., & Buyya, R. (2011). Environment-conscious scheduling of HPC applications on distributed cloud-oriented data centers. *Journal of Parallel and Distributed Computing, 71*, 732–749.
25. Hussein, S. R., Alkabani, Y., & Mohamed, H. K. (2014). Green cloud computing: Datacenters power management policies and algorithms. In *Proceedings of the 9th International Conference on Computer Engineering & Systems (ICCES)*, Cairo, Egypt, 22–23 December (pp. 421–426). IEEE.
26. Garg, S. K., Yeo, C. S., & Buyya, R. (2011). Green cloud framework for improving carbon efficiency of clouds. In Jeannot, E., Namyst, R., Roman, J. (Eds.), *Lecture Notes in Computer Science, Proceedings of the European Conference on Parallel Processing*, Bordeaux, France, 29 August–2 September 2011 (pp. 491–502). Springer.
27. Wadhwa, B., & Verma, A. (2014). Energy and carbon efficient VM placement and migration technique for green cloud datacenters. In *Proceedings of the Seventh International Conference on Contemporary Computing (IC3)*, Noida, India, August 7–9, 2014 (pp. 189–193). IEEE.
28. Brath, B., et al. (2015, August) *Climate change and resource sustainability an overview for actuaries*. Document 215068 Ce document est disponible en français © 2015 Canadian Institute of Actuaries.
29. Cao, F., Zhu, M. M., & Wu, C. Q. (2015). Green cloud computing with efficient resource allocation approach in green services engineering. In *Optimization, and modeling in the technological age* (1st ed., pp. 116–148. ISBN 9781466684478.). IGI Global.
30. Cook, G. et al. (2017). Clicking clean: Who is winning the race to build a green internet?, Greenpeace Inc., [Online]. Available at: http://shorturl.at/htEW6
31. Benioff, M. et. al. (2011). Exploring the future of cloud computing: Riding the next wave of technology-driven transformation. *World Economic Forum*. [Online]. Available at: http://shorturl.at/jpLMT
32. Agarwal, P., Chopra, K., Kashif, M., & Kumari, V. (2018). Implementing ALPR for detection of traffic violations: A step towards sustainability, 2018. In *Proceedia: Computer science* (pp. 738–743). Elsevier. ISSN: 1877-0509.
33. Sasikala, P. (2013). Research challenges and potential green technological applications in cloud computing. *International Journal of Cloud Computing, 2*(1), 1–19.
34. Rasmussen, N. (2007). *Calculating total cooling requirements for datacenters*. American Power Conversion, white paper 25.
35. Agarwal, P., Hassan, S. I., Mustafa, S. K., & Ahmad, J. (2020). An effective diagnostic model for personalized healthcare using deep learning techniques. In *Applications of deep learning and big IoT on personalized healthcare services* (pp. 70–88). IGI Global.

Sensing, Communication with Efficient and Sustainable Energy: An IoT Framework for Smart Cities

Omid Mahdi Ebadati E., Seyed Mahdi Sadat Rasoul, Kaebeh Yaeghoobi, and Faezeh Hadadi

1 Introduction

The advent of IoT has made human life different and easier. IoT has opened its way into every category. Recently with the significant progress in communication devices such as radio wave identification, Near Field Communication devices, and embedded sensor nodes; IoT has been highlighted. With the advent of communication devices and services, IoT will become next-generation revolution for the mobile and landline networks. Recent forecast shows that IoT will be a fundamental part in the future of the Internet. According to International Telecommunication Union, ITU 2016, IoT will be a global infrastructure for the information community that provides advanced services through connecting physical and virtual things based on evolutionary of information and communicational technologies [1] IoT integration in smart cities helps its citizens to achieve knowledge regarding their environment and participate in reaching to new data by mobile devices.

IoT leads to wider perspective and awareness of energy consumption and counters in devices. So, the real-time data of energy consumption will be easily gathered and analyzed; which it results in energy improvement decision making [2]. Energy efficiency is one of the crucial issues in massive wireless sensor network's

O. M. Ebadati E. (✉)
Department of Mathematics and Computer Science, Kharazmi University, Tehran, Iran
e-mail: ebadati@khu.ac.ir

S. M. Sadat Rasoul · F. Hadadi
Department of Information Technology Management, Kharazmi University, Tehran, Iran
e-mail: msadatrasoul@khu.ac.ir

K. Yaeghoobi
Department of Computer Engineering, AleTaha Institute of Higher Education, Tehran, Iran
e-mail: yaeghoobi@aletaha.ac.ir

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_4

establishment and IoT application. With the increase in IoT usage, the demand for energy efficiency and service quality guaranty has leveled up [3].

Today, there is an obvious need for creating and developing IoT devices and the possible solutions are increasingly more common; hence, IoT application development still demands a lot of effort due to lack of appropriate tools. Many software components should be initially developed, and the developers should have a deep understanding of the related technologies [4].

Monitoring real time energy consumption data and finding major factors and patterns for various IoT systems, are noticed by researchers. These results could be used to design and run IoT based systems for energy efficiency. In previous surveys, researchers have always suggested companies and organizations to look for ways about energy efficiency, so that it results in economic, social, and environmental cost reduction.

As for increasing demand for energy sources and decreasing fossil resources; environmental health, air pollution reduction, lack of electrification and fuel supply, and consumption management are critical and strategic categories to reach every country's economic excellence and development. Recent prosperity, especially in smart systems field caused huge progress in supervision and management of energy consumption and functional efficiency upgrade. To use the IoT potential, a series of technology is needed. Precise and correct recognition of every technology and its role in IoT eco-system without an architecture-based concept would be difficult and sometimes impossible. By the knowledge in IoT architecture and its available capabilities, it is possible to define a logical business model beside of opportunity and threat recognition.

In this research, with the help of a deep survey in associated IoT and smart energy literature, many factors that could have an effect on these framework improvements have been recognized. In this regard, this chpater is trying to study effective factors in an IoT framework in smart cities with an energy consumption approach, so that finally with the use of obtained results; it would be possible to represent an efficient solution to develop and improve the present IoT frameworks.

The essential goal of this research is to study the effective factors on IoT development in smart cities with optimal energy consumption in each layer of IoT model. In respect to the goal of the research, following sub-objectives are followed:

- Related factors and optimal energy consumption identification for different IoT services
- Represent an optimal energy consumption framework for IoT in smart cities
- Determining the effect of gathering energy data infrastructure on IoT framework development for energy efficiency
- Determining the effect of management systems and energy data saving on IoT framework development for energy efficiency
- Determining the effect of applications and user interface on IoT framework development for energy efficiency

2 Literature Review

2.1 Smart City

Smart city is a city, where ICT has been combined with traditional infrastructures and integrated with new digital technologies. In fact, a smart city is a place, where citizens benefit from sustainable quality of life through technology. Smart city planning is to make efficiency, sustainability, quality of life and equity for the citizens. In recent years, the citizens have changed their communication ways, relationships, habits and life styles, and it is time to imply cities to standards that citizens deserve [5].

A smart city connects the physical, social, business and ICT infrastructures to increase smartness. It is a developed modern city that benefits from ICT and other technologies to improve life quality, competitiveness, and operational effect of urban services [6]. More than six billion people are expected to live in smart cities and surrounding areas till 2050. Consequently, efficiency, automation and city smartness will be crucial in near future. Challenges regarding the city infrastructural abilities are noticed for cover citizen needs for water supply, transportation, health cares, education, security and most importantly energy consumption to maintain and improve economic, social and environmental situation [7].

Authors for sustainable smart cities studied different technologies to control, manage and access remotely with the help of smart devices. They provides a description of smart cities and its related technologies, also, the role of devices in realization of sustainable smart cities ecosystem [8]. In other researches, focus on smart healthcare and reduce energy consumption based on forwarded nodes. The research, considered topology of the sensors and Each source node forwards the data towards the coordinator node. The multi-hop protocol in the research, selects the next forwarder node based on the residual energy of nodes, node's position, distance, and node density. The authors reached to higher performance in their work compare to others [9]. In e-health scenario for smart cities, there are other research that worked on energy efficient real-time routing to send patients data from body sensors to gateways. The research was based on sleep-awake schedule of sensors to manage data communication in energy-efficient method [10].

Main features of a smart city include a high level of IT and comprehensive application of informational resource's fusion. IoT is about sensor installation for anything and connecting them to the Internet via specific protocols to interact with information and communication to obtain a smart knowledge, situation, tracing, monitoring and management. Daily growth of smart cities functionality and IoT brings about many scientific and engineering challenges that make efforts to develop an efficient, scalable and reliable city based on IoT [11].

2.2 Internet of Things (IoT)

The term Internet of Things was mentioned in 1999 when Kevin Ashton brought up a report on Radio-Frequency Identification [12]. IoT is the use of sensors, actuators, physical device made data communication technology that could be known as tracing, coordination, and control in a data network or the Internet [13]. IoT represents fundamental components of smart cities such as information production, information management and investigating usages [6]. IoT is making anything smart via connecting it to the Internet that makes remote control of anything possible [1]. IoT results in wider perspective and knowledge of energy consumption with the help of smart sensors and counters in production and equipment level. So, the real-time data is easily collected from energy consumer device in the production process, and then it is analyzed to end in energy improvement decisions [2].

IoT enables physical things to share information and make coordination decisions by listening, thinking and doing things. Using basic technologies, IoT turns the traditional devices to smart devices. Technologies like, Ubiquitous and Pervasive Computing, Embedded Devices, communicational technologies, sensor networks, the internet protocols and applications [2]. Cisco has estimated that up to the year 2020, 50 billion things would be connected to the internet which probably would be 6.58 times the earth population [12].

Domestic energy consumption is about 30–40% of total energy consumption. IoT is a scientific domain emerging with many practical applications for various types of scopes, such as smart cities, domestic automation, independent transportation devices and health care technologies. IoT could facilitate control and monitoring over energy usage and production [14].

2.3 IoT Framework

IoT framework concept demands a structure in which processes are matched and controlled by various components of IoT. This structure is a set of terms, protocols, and conditions that organizes, the way data is processed and traded between all included parties. This framework should also support running high level IoT applications and decrease the infrastructural protocols' complications. There are multiple methods to make IoT framework that could be followed based on needed conditions and business targets [15]. IoT is based on three technology layer: hardware (include chips and sensors), communications (wired and wireless) and software (include saving data, analysis and applications) [16]. Regarding to another work that proposed an IoT-enabled data acquisition framework that utilizes low-cost computers, sensors modules, developed software agents, and the existing building Wi-Fi network to establish a central facility database. They stablished a whole framework for smart buildings. Choosing the right type of nodes are an important part of their framework to stablish an energy-efficient framework [17].

2.4 Data Center and Its Management System

Data center is a series of data with organized and arranged structure that there is a concept of saving and relations between data sets are possible. These data usually are saved in a format that is not readable or reachable by computers. Access to data inside the data center is usually provided via data center management system. This system is made of integrated set of computer software that lets users communicate with one or many data centers or databases and access their data.

To consider security in the smart cities, a research developed a secure and reliable communication for next generation networks. They used the mobile edge computing solution to enables node collaboration among IoT devices, also, they used a learning method to identify candidates for the service composition and delivery process. The data center management system takes part an important role in their work to manage devices [18].

IoT data management includes data collection, process, saving and analysis. The main goal is that data collection (and data cleaning) should be precise and reliable from various sources and the managing heterogeneous data structure be done [18]. Moreover, high level data should be extracted and summarized from row data so that they are used for decision making [19]. Data management is of great importance in smart cities, because data production, transfer, and extraction make a smart city more efficient and easier than an ordinary city. However, cyber security instability puts a data oriented smart city in a difficult situation. When services and vital infrastructures are connected digitally and data is relied on a smart network, cyber-attacks threat are more serious and more dangerous; so, if a smart city decides to use private cloud services; that organization should support the ordinary standards of private sector. Since privacy and security protection is essential for a smart city, organizations, which manage a smart city's data should be regulated in a way that moves toward this goal. So there should be a precise balance between organization responsibility against security breaks and organization economic risk justification [20].

2.5 Smart Networks

A smart network is a power-control network, which uses modern computers and communicational technologies, so, that it is possible to achieve a network that is able to confront potential failures. In recent years, using a smart network on our lives has become an extensive and comprehensive issue, and smart network systems have changed life styles to some extent. Generally, smart network systems are divided into two main networks: power-control network and communication network. Smart systems have considerably improved energy consumption in recent years. In smart networks, communication network needs power-control network to support energy consumption, when energy stations are controlled by communication networks [21].

Smart infrastructure system includes, smart energy system, smart communications, and smart information systems. Smart energy system is supported by communication and energy mutual flow in three main sectors: production network, transfer network, and distribution network [22].

2.6 Energy Conservation in IoT Wireless Networking

Wireless sensor networks have a considerable potential in our ability to observe and control physical environment, but the energy consumptions in this category of networks have been an important parameter regarding their reliability, and since we need to guarantee specific end to end parameters quality in many wireless sensor network's functions, supporting service quality in these networks is of great importance. One of the most important issues in wireless sensor networks is each network's life span that directly relates to energy consumption balance in these networks. Life span extension is the most challenging need in this kind of networks.

First step to reduce energy costs is a form in which, it could be determined that where, when, and how the energy is used. This almost helps to improve energy efficiency. Combining IoT technology and energy-efficiency management system simplifies achieving data and the related business operation [23]. Resource improvement and energy efficiency would be possible through a structured approach towards WSN and IoT integrity [24].

In this section, extracted result of the studied paper and other suggested frameworks in this category in different IoT levels with concentrating energy consumption optimality is summarized in Table 1.

IoT framework concept requires a structure recognition in which processes are controlled and matched by IoT different components. The structure is a series of rules, protocols, and regulations that organize data process method and exchanges among all engaged parties. It should also support high level IoT applications running and reduce infrastructural protocols complication. There are many approaches to form IoT framework that could be followed according to situations and business targets [15].

In the next section the conceptual model for energy efficient smart cities framework presented and discusses in detail.

3 Conceptual Model

In the recent years, smart city has been really important, because of urbanism all over the world. City operation's performance with the help of ICT has made cities efficient in different concepts. Smart city is a modern developed city that is in different functions with ICT and other technologies to improve citizens' quality of life by decreasing supply and demand conflicts.

Table 1 Extracted factors from literature review

Main section to develop the framework	Subsection of layers	References
IoT infrastructure and sensor devices	Temperature, humidity and daylight sensors	[1, 8, 16, 22, 25]
	Mobile devices	[18, 26]
	Smart meters	[17, 22, 23, 25, 27–29]
Communication technologies	Protocols	[3, 9, 10, 23, 30–32]
	Standards	[14, 32, 33]
Data management and storage system	Cloud computing	[1, 34–36]
	Datacentres	[33, 37]
	Data management	[24, 38–45]
IoT applications	Smart home and smart building	[12, 19, 27, 28, 38, 46–50]
	Smart network	[21, 22, 36, 38, 51–54]
	Smart offices	[55],
	Smart transportation	[13, 36, 51, 56, 57]
	Smart lighting	[58–61]
	Smart environment	[4, 36, 62]
	Smart garbage collection	[63, 64]
Security	Sensor Security	[14, 65]
	Storage Security	[7, 20]
	Secure networking and communication	[66–68]
	Secure protocols	[18, 66, 69]
	Cloud Security	[65, 68, 70]
	Information encryption	[71, 72]
	AAA	[67, 73–75]

IoT improves energy efficiency, which ends in reducing pressure on energy demand. There are many methods through, which IoT would help energy industry, especially in water, power, oil, and gas area. In this chapter, some methods that optimize energy consumptions using IoT are defined. Temporary business world is strictly competent, and any organization or individual is looking for more energy savings. With energy price increasing, businesses are compelled to create new strategies to save energy. These have high concentration on energy consumption and have caused a constant monitoring on it.

The conceptual framework of this research that has been resulted from literature of the research is represented in Fig. 1. It indicates that the successful IoT development in smart cities by energy consumption optimality depends on IT infrastructure factors to gather energy data, management systems, data storage, user interface, and other applications.

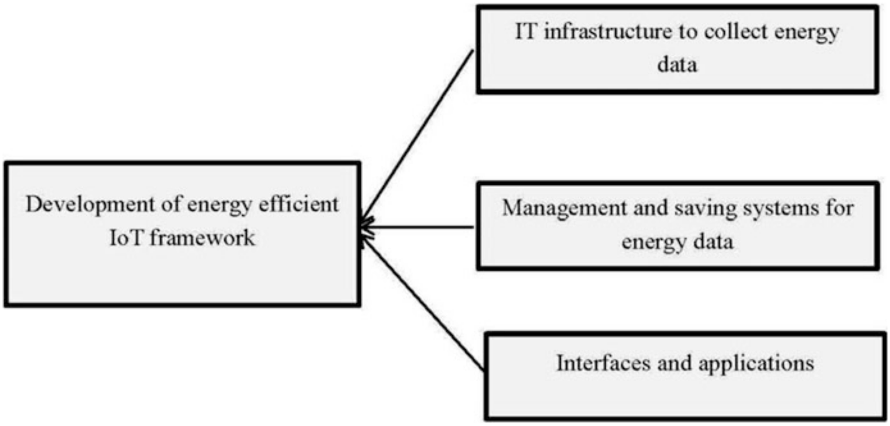


Fig. 1 Research conceptual model

As the IoT functions in smart cities are growing, efficient energy solutions for low consumption devices are evolving. There are some competent energy solutions that would reduce energy consumption or optimize resource consumption. In the following, some smart cities efficient approaches are represented. The model is divided into three sections in the conceptual model, including, IT infrastructures to collect energy data, energy data management systems and storage and user interface and applications.

In this section, after considering literature review and looking into solution's reviews in IoT frameworks, the proposed IoT energy consumption as an optimal framework will be presented. It includes a city information system on sensor levels, data-management network supported structure, and IoT application in smart cities. The main architecture of the proposed framework is shown in Fig. 2.

This framework helps all of the people, organizations, and interest groups in IoT and smart cities to have a better understanding of factors affecting IoT deployment and provides with planning for extreme usage of IT-based models and gained understanding of that. As it can be perceived in the Fig. 2, the optimal framework consists of three original sections and each has their own components. In continue, all of these layers are defined in details:

Multiple technologies are required to have smart energy network, and many of them are being used by now. Some of them are included:

- **Integrated communications and communication technologies:** It is considered to have an integrated communication network that keeps data for online control and exchange. It is used for a possible optimize and reliable network, network efficiency, and security. These technologies are included, PLC, DSL, GSM, WPAN, WIMAX, Zigbee, etc. Table 2 represents a comparison of these technologies concentrating energy consumption.

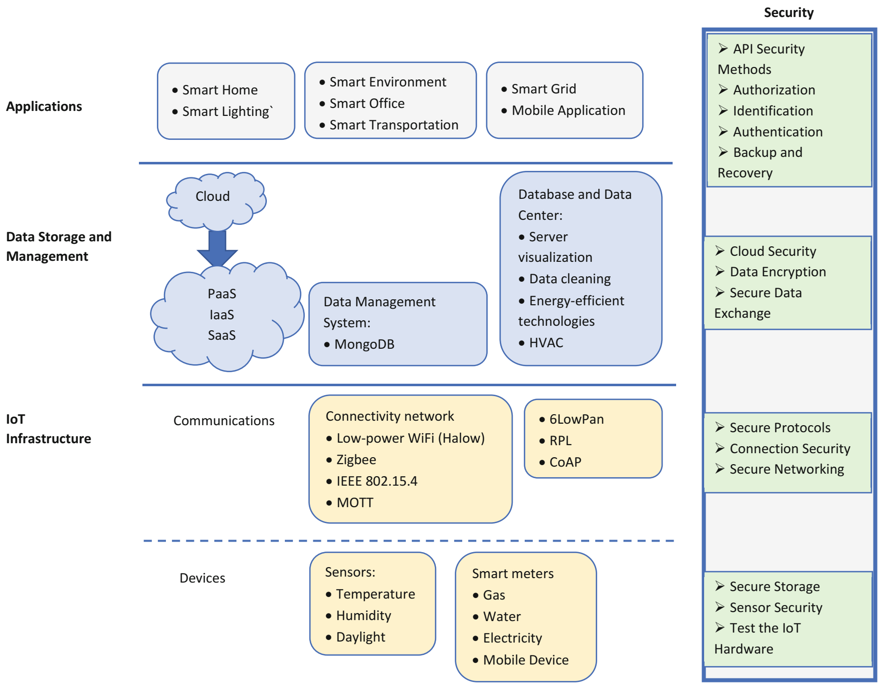


Fig. 2 The proposed IoT framework

Table 2 Smart energy network comparison

Technology	Standards	Data rates	Advantages
GSM	2.5G HSCSD,GPRS	2.5G: 144 kbps	Low energy consumption for indoor equipment
WPAN	IEEE 802.15.4	IEEE 802.15.4:256 kbps	Very low energy consumption Low deployment cost
PLC	BB-PLC: TIA-1113 (HomePlug1.0)	1–10 Mbps	Lower maintenance and operating costs Possibility of physical disconnection based on other networks
Zigbee	Zigbee	250 Kpbs	Compatible with IPv6 based networks

- **Sensors and measuring devices:** such as advanced microprocessor-equipped devices, smart measuring devices, extended monitoring systems, instant pricing tools, etc.
- **Power flow distributed system:** power flow control devices enter the current power control flow to provide the possibility of access more renewable-energy usage via constant and instant energy control all over the network.

- **Smart network stations:** these stations are completely operated based the demand for heavy equipment and human resource. The equipment would include, transformers, switches, capacitor banks, circuit breakers, and a protected relay in the network.

The results of the proposed conceptual model show that multiple infrastructures such as smart power, water and gas counter; smart water sensor, temperature and humidity sensor, light sensor, mobile devices' sensors to collect energy data are effective and count as the main infrastructural components. Communication protocols are one of the most important parts of the infrastructure that could be seen in different layers of the network. The important suggested protocols that control energy consumption are included, Low-power WiFi (Halow), Zigbee, RPL, IEEE 802.15.4, 6LoWPAN, MQTT, and CoAP.

Based on the researches on data management and storage; cloud computing, using NoSQL data centers, and specifically MongoDB was mostly proposed to develop the framework more efficient. This took place after comparing them with a data center management system in relation with type and optimization models.

The results indicate that in IoT function section in smart cities, items that are significantly affected by energy control are very impressive on smart transportation, smart house and domestic automation, smart lighting in streets and roads, smart enterprises and smart network for smart cities development and energy consumption management.

4 IoT Framework Simulation

In this section, the related simulation part of the framework by using Cooja running on contiki 3 operating-system is presented, and accordingly, analyzes of the proposed framework is taking place. Cooja simulator monitors the sensor node energy consumption through Powertrace plugin. The measured parameters, include CPU energy(CPU_ON), low-power mode (LPM), radios transmit energy (TX), and radios listen (RX). To calculate each item's power consumption in Contiki the following items are used:

- CPU Energy: total amount of energy used for calculation process by processor from sensor node.
- LPM Energy: It shows the total used energy when a sensor node is in Low-power mode.
- Radios Transmit and Radios Listen: total amount of energy used by radio devices to send and receive data packages.

The four above-mentioned parameters are received from sink node in cooja simulator and energy consumption could be calculated after studying these parameters.

Simulation results analyzes through mote output in which, it is possible to log running time. All communicational data and signals are engaged in mote output, and the result of analyzes illustrated through various graphs.

In the following sections, the description of each low-power IoT protocol simulation in the simulator and their energy consumption are explained.

4.1 *RPL-UDP Protocol Simulation*

RPL protocol considers network resources limitations and there is a possibility of defining criteria and new limitations to provide service quality as for its different functions.

First Scenario

The UDP-RPL protocol is used to transfer information to multiple computers by Broadcast or Multicast. The mote type in this simulation is a sky mote model that includes these properties:

- MSP430 low power microcontroller with 8 MHz velocity
- 10 KB RAM
- Chipcon wireless receiver with 802.15.4 IEEE, 2.4 GHZ, and 250 Kbps
- Humidity, temperature, and light sensor
- SMA antenna

In Fig. 3, node 1 is a sink type, and the other nodes are the sender type, and these nodes transmit their data packages to node 1. Figure 4 indicates each node's energy

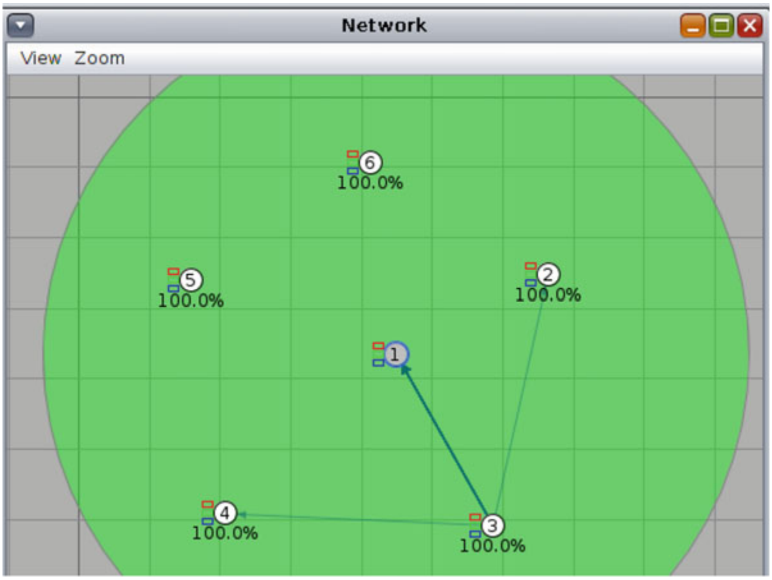


Fig. 3 UDP-RPL protocol simulation scenario

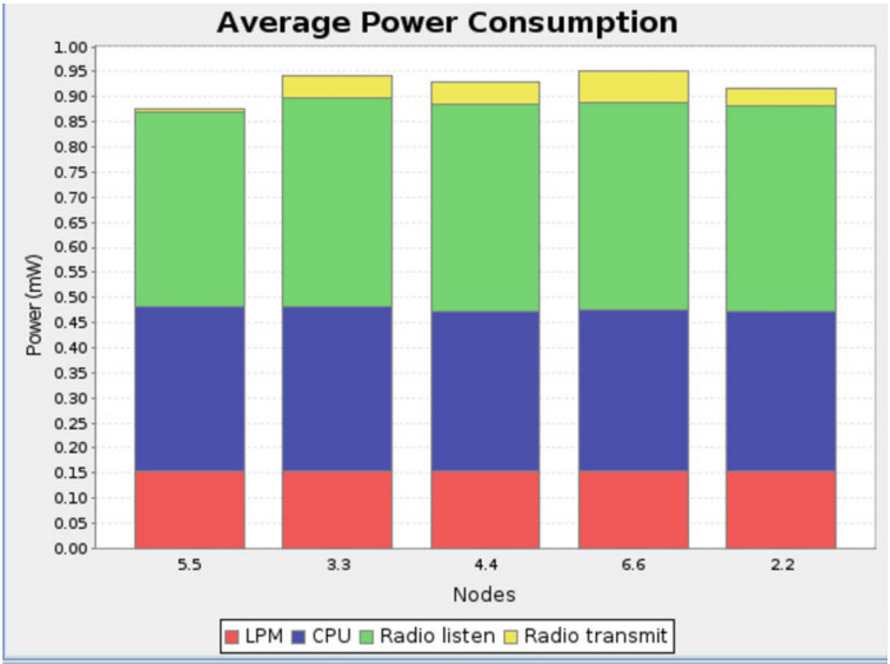
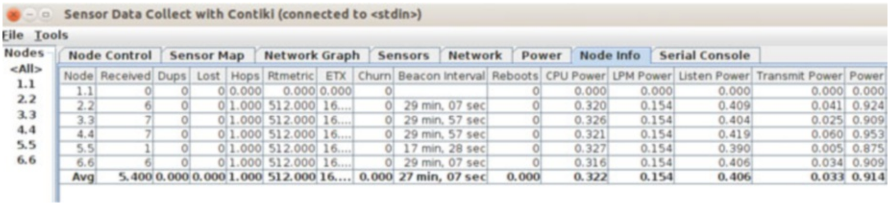


Fig. 4 Average scenario energy consumption


Sensor Data Collect with Contiki (connected to <stdin>)

File Tools

Nodes: <All> 1.1 2.2 3.3 4.4 5.5 6.6

Node Control | Sensor Map | Network Graph | Sensors | Network | Power | Node Info | Serial Console

Node	Received	Dups	Lost	Hops	Rtmetric	ETX	Churn	Beacon Interval	Reboots	CPU Power	LPM Power	Listen Power	Transmit Power	Power
1.1	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000
2.2	6	0	0	1.000	512.000	16....	0	29 min, 07 sec	0	0.320	0.154	0.409	0.041	0.924
3.3	7	0	0	1.000	512.000	16....	0	29 min, 57 sec	0	0.326	0.154	0.404	0.025	0.909
4.4	7	0	0	1.000	512.000	16....	0	29 min, 57 sec	0	0.321	0.154	0.419	0.060	0.953
5.5	1	0	0	1.000	512.000	16....	0	17 min, 28 sec	0	0.327	0.154	0.390	0.005	0.875
6.6	6	0	0	1.000	512.000	16....	0	29 min, 07 sec	0	0.316	0.154	0.406	0.034	0.909
Avg	**5.400**	**0.000**	**0.000**	**1.000**	**512.000**	**16....**	**0.000**	**27 min, 07 sec**	**0.000**	**0.322**	**0.154**	**0.406**	**0.033**	**0.914**

Fig. 5 Data collected from nodes

consumption of data communication in the network. The average of beacon interval is 27 min and 07 s, and the average of packets received by nodes to send data to sink node is around 5.4.

Each sensor node's energy consumption set of collected data and average time have been calculated. In Fig. 5, various results and analysis are shown based on different nodes, and it is possible to deliberate behavior of nodes in data communication individually or in groups.

In the first scenario, for better understanding of behavior of nodes, collected energy consumption information from network data transmission perceived in Table 3, and it should be mentioned that nodes are as sky mote type.

Table 3 First scenario, nodes energy consumption data

Energy consumption (mw)	CPU	LPM	TX	RX	Total
Node 2	0.32	0.154	0.041	0.409	0.924
Node 3	0.326	0.154	0.025	0.404	0.909
Node 4	0.321	0.154	0.06	0.419	0.953
Node 5	0.327	0.154	0.005	0.39	0.875
Node 6	0.316	0.154	0.034	0.406	0.909

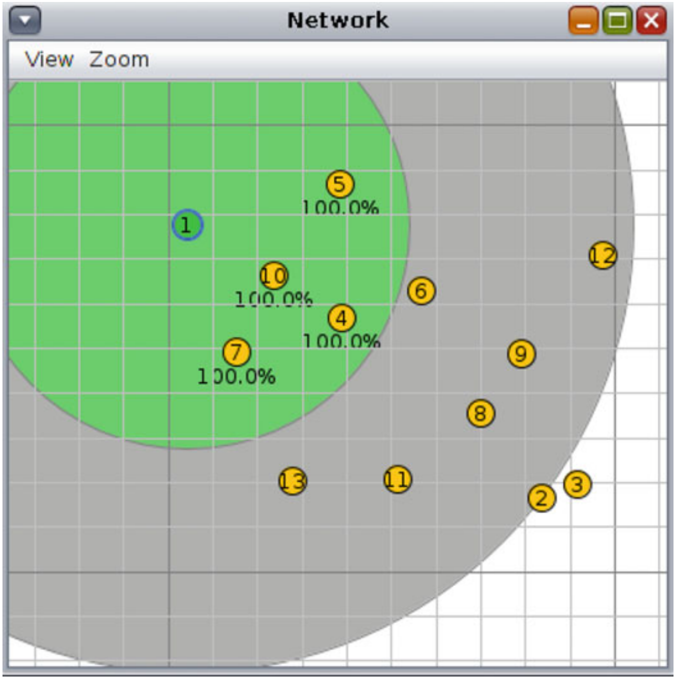


Fig. 6 UDP-RPL protocol simulation, second scenario

Second Scenario

In the next scenario as could be seen in Fig. 6, the number of sender nodes has increased to 12 and their intervals from sink node are different. Mote type in this simulation is also sky mote. Some nodes are completely in sink node radio network, and others are in longer intervals.

Nodes start broadcast, and data transmit after simulation is initiated as in Fig. 7, and after 60 s it would be time to collect data; and send each node's energy consumption chart data according to Fig. 7. As this figure indicates, radio wave frequency is different in each node and any node is in a different interval from the sink node. This affects each node's amount energy consumption for sending data.

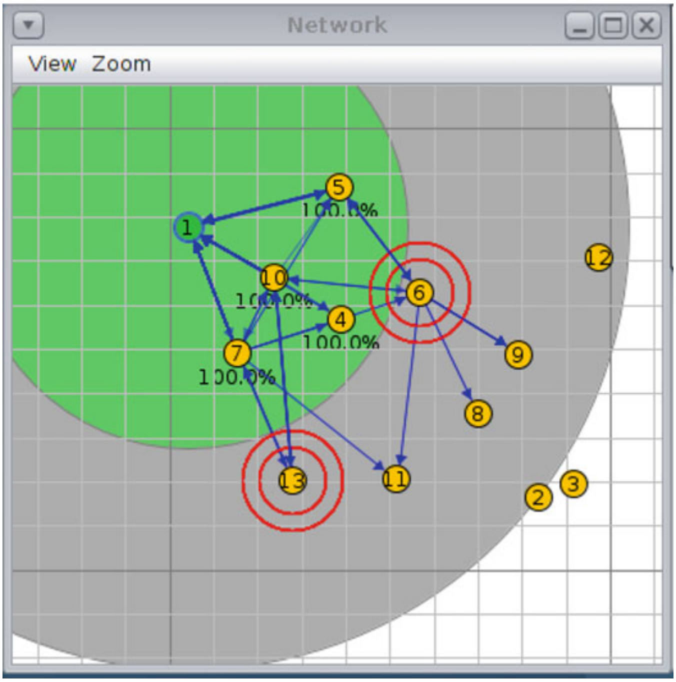


Fig. 7 Send and receive data packages in simulation

In this scenario, nodes 6 and 13 send a data package to other devices connected to the network. Other nodes listen to the line constantly and this communication channel is provided by radio networks, which respond to the sender. In wireless sensor networks, when the data is received by a node in an area that node should send the received data to all adjacent nodes. The more they do so, the more they lose energy and practically; they would stop working as from now onward they have no impact on the network; so, the number of lost data packages in the transfer process affects process quality and more energy consumption. Moreover, many package losses are due to radio wave interference, which is as well as data-transfer quality under the influence of network structure and topology.

Figures 8 and 9 illustrate the average energy consumption of nodes in the second scenario. Nodes 11 compare to node 13 that send a data packet has more energy consumption in data communication, it is due to receiving redundant data from two nodes (6 and 7), because of its location that are in the radar of two nodes.

Figure 10 indicates the detailed information of data transmission of nodes in this scenario that could be used to extract graphs and further analysis. The table shows the number of received data packages for each node during the simulation, number of lost packages, operation time and processor energy factors, energy consumption in low power mode, and the total energy used among the radio wave. Finally, each node power consumption is calculated by adding four interfering factors.

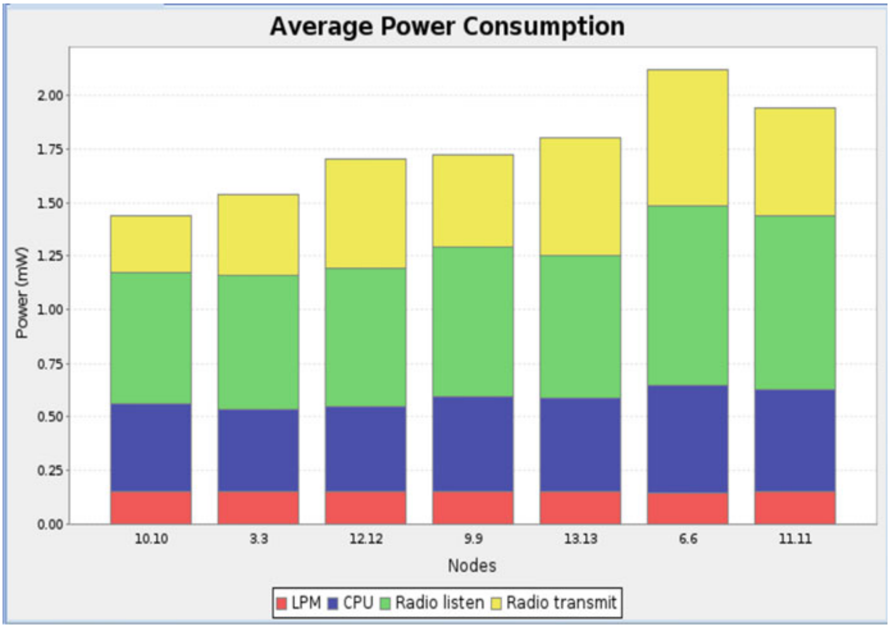


Fig. 8 Second scenario average energy consumption (gray area)

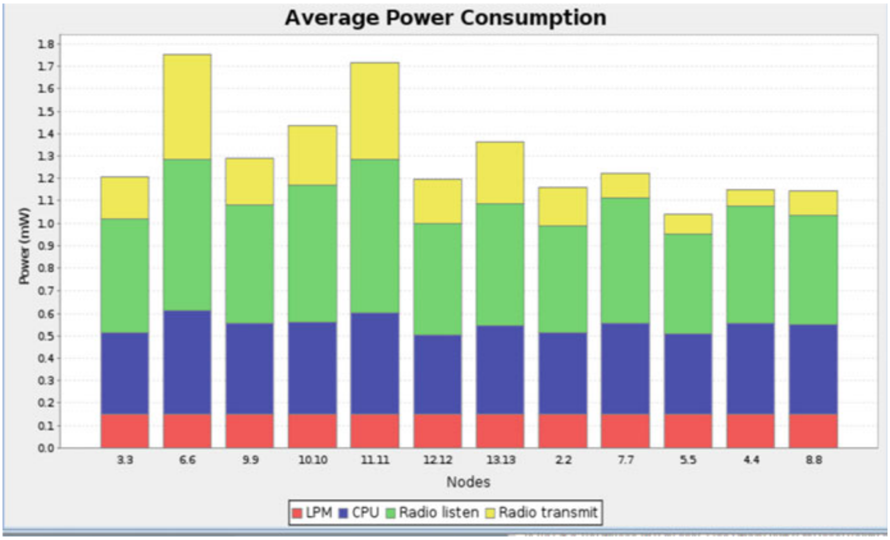
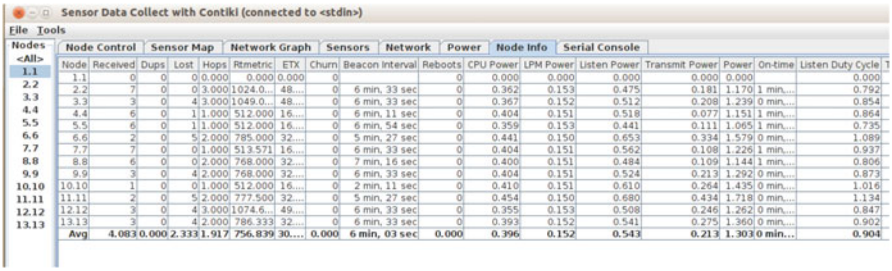


Fig. 9 Second scenario average energy consumption (all nodes)



Node	Received	Dups	Lost	Hops	Rtmetric	ETX	Churn	Beacon Interval	Reboots	CPU Power	LPM Power	Listen Power	Transmit Power	Power	On-time	Listen Duty Cycle
1.1	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000		0.000
2.2	7	0	0	3.000	1024.0...	48....	0	6 min, 33 sec	0	0.362	0.153	0.475	0.181	1.170	1 min,...	0.792
3.3	3	0	4	3.000	1049.0...	48....	0	6 min, 33 sec	0	0.367	0.152	0.512	0.208	1.239	0 min,...	0.854
4.4	6	0	1	1.000	512.000	16....	0	6 min, 11 sec	0	0.404	0.151	0.518	0.077	1.151	1 min,...	0.864
5.5	6	0	1	1.000	512.000	16....	0	6 min, 54 sec	0	0.359	0.153	0.441	0.111	1.065	1 min,...	0.735
6.6	2	0	5	2.000	785.000	32....	0	5 min, 27 sec	0	0.441	0.150	0.653	0.334	1.579	0 min,...	1.089
7.7	7	0	0	1.000	513.571	16....	0	6 min, 33 sec	0	0.404	0.151	0.562	0.108	1.226	1 min,...	0.937
8.8	6	0	0	2.000	768.000	32....	0	7 min, 16 sec	0	0.400	0.151	0.484	0.109	1.144	1 min,...	0.806
9.9	3	0	4	2.000	768.000	32....	0	6 min, 33 sec	0	0.404	0.151	0.524	0.213	1.292	0 min,...	0.873
10.10	1	0	0	1.000	512.000	16....	0	2 min, 11 sec	0	0.410	0.151	0.610	0.264	1.435	0 min,...	1.016
11.11	2	0	5	2.000	777.500	32....	0	5 min, 27 sec	0	0.454	0.150	0.680	0.434	1.718	0 min,...	1.134
12.12	3	0	4	3.000	1074.6...	49....	0	6 min, 33 sec	0	0.355	0.153	0.508	0.246	1.262	0 min,...	0.847
13.13	3	0	4	2.000	786.333	32....	0	6 min, 33 sec	0	0.393	0.152	0.541	0.275	1.360	0 min,...	0.902
Avg	**4.083**	**0.000**	**2.333**	**1.917**	**756.839**	**30....**	**0.000**	**6 min, 03 sec**	**0.000**	**0.396**	**0.152**	**0.543**	**0.213**	**1.303**	**0 min...**	**0.904**

Fig. 10 Data collected after second scenario simulation

Table 4 Second scenario, node energy consumption data

Energy consumption (mw)	CPU	LPM	TX	RX	Total
Node 2	0.362	0.153	0.181	0.475	1.17
Node 3	0.367	0.152	0.208	0.512	1.239
Node 4	0.404	0.151	0.077	0.518	1.151
Node 5	0.359	0.153	0.111	0.441	1.065
Node 6	0.441	0.15	0.334	0.653	1.579
Node 7	0.404	0.151	0.108	0.562	1.226
Node 8	0.4	0.151	0.109	0.484	1.144
Node 9	0.404	0.151	0.213	0.524	1.292
Node 10	0.41	0.151	0.264	0.61	1.435
Node 11	0.454	0.15	0.434	0.68	1.718
Node 12	0.355	0.153	0.245	0.508	1.262
Node 13	0.393	0.152	0.275	0.541	1.36

From information simulation can retrieve the energy consumption of the nodes 2–13 in the network and that summarized and generated in Table 4.

Third Scenario

In the following, to investigate network mode considering the number of nodes in simulation and their energy consumption, the number of sink nodes and sender nodes have increased to 5 and 25 respectively (Fig. 11). Correspondingly, Sensor map graph and information sent to sink node is illustrated in Fig. 12.

Sink nodes receive packages from sender nodes and considering the package reception time and number of packages; their energy consumption would be different. Initially after the simulation starts node 4 receives 4 packages from adjacent nodes. After study of energy consumption data, it is concluded that the time of data reception is varied due to node intervals and radio wave network type; and more energy is used.

In the other round we choose four nodes as the sender nodes, which are nodes number 12, 13, 15 and 17 and the energy consumption information of these nodes are illustrated in Fig. 13.

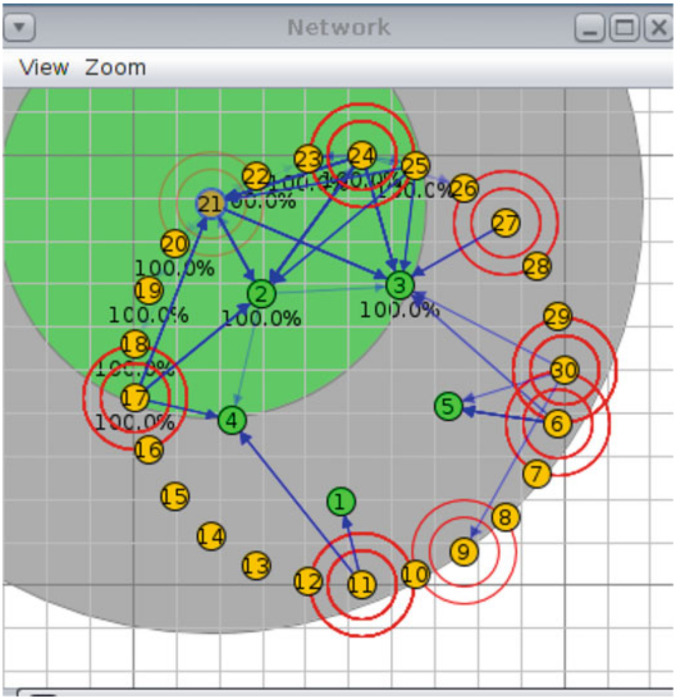


Fig. 11 Third scenario, network with high number of nodes

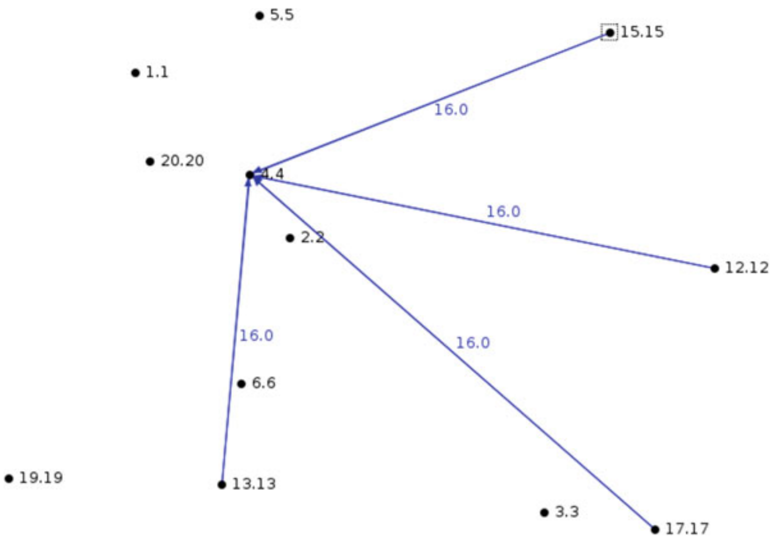


Fig. 12 Sensor map graph

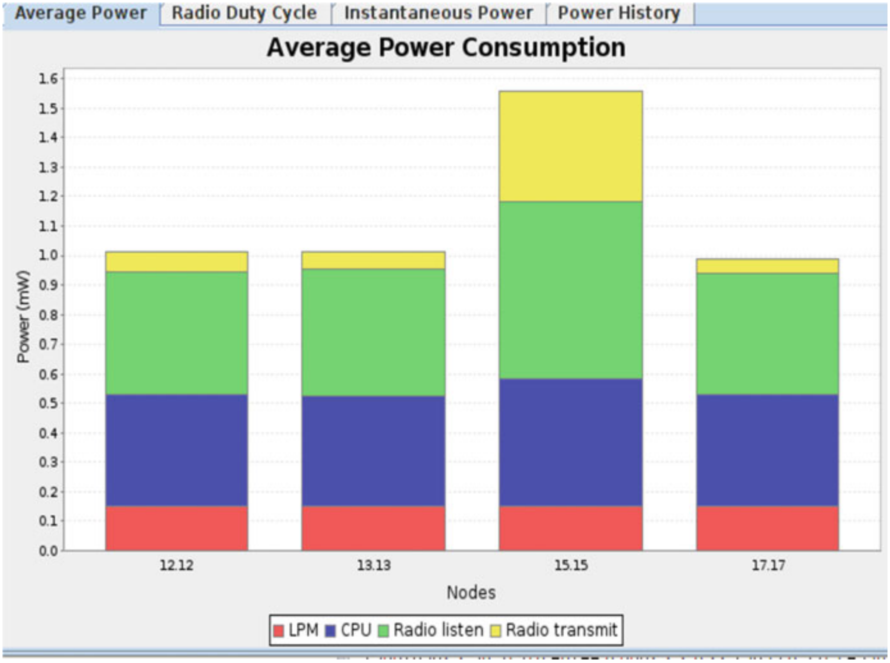
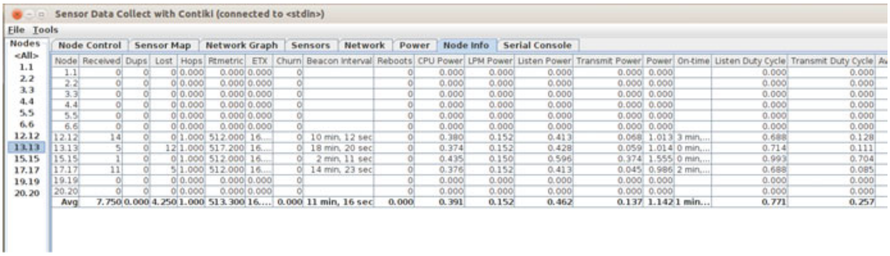


Fig. 13 Third scenario average energy consumption



Node	Received	Dups	Lost	Hops	Rtmetric	ETX	Churn	Beacon Interval	Reboots	CPU Power	LPM Power	Listen Power	Transmit Power	Power	On-time	Listen Duty Cycle	Transmit Duty Cycle
1.1	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000		0.000	0.000
2.2	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000		0.000	0.000
3.3	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000		0.000	0.000
4.4	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000		0.000	0.000
5.5	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000		0.000	0.000
6.6	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000		0.000	0.000
12.12	14	0	0	1.000	512.000	16....	0	10 min, 12 sec	0	0.380	0.152	0.413	0.068	1.013	3 min,...	0.688	0.128
13.13	5	0	12	1.000	517.200	16....	0	18 min, 20 sec	0	0.374	0.152	0.428	0.059	1.014	0 min,...	0.714	0.111
15.15	1	0	0	1.000	512.000	16....	0	2 min, 11 sec	0	0.435	0.150	0.596	0.374	1.555	0 min,...	0.993	0.704
17.17	11	0	5	1.000	512.000	16....	0	14 min, 23 sec	0	0.376	0.152	0.413	0.045	0.986	2 min,...	0.688	0.085
19.19	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000		0.000	0.000
20.20	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000		0.000	0.000
Avg	**7.750**	**0.000**	**4.250**	**1.000**	**513.300**	**16....**	**0.000**	**11 min, 16 sec**	**0.000**	**0.391**	**0.152**	**0.462**	**0.137**	**1.142**	**1 min...**	**0.771**	**0.257**

Fig. 14 Third scenario energy consumption data

The Fig. 14 shows data of energy consumption in third scenario that works with Sky mote sensor. The detail of number of send packets and lost packets with the energy consumption of nodes for CPU, LPM energy, radios transmit and radios listen is listed in the Table 5.

From collected data and information analysis the following outlets can be concluded:

- The total of sending and receiving package energy consumption of the radio device in node 15 have increased and this would cause its total energy for one package be higher than the others and in fact, the amount of energy used to send this package was high.
- High number of sensor nodes are resulted in energy consumption inefficiency.

Table 5 Third scenario energy consumption

Energy consumption (mw)	Number of packets send	Number of packets lost	CPU	LPM	TX	RX	Total
Node 12	14	0	0.32	0.154	0.041	0.409	0.924
Node 13	5	12	0.326	0.154	0.025	0.404	0.909
Node 15	1	0	0.321	0.154	0.06	0.419	0.953
Node 17	11	5	0.327	0.154	0.005	0.39	0.875

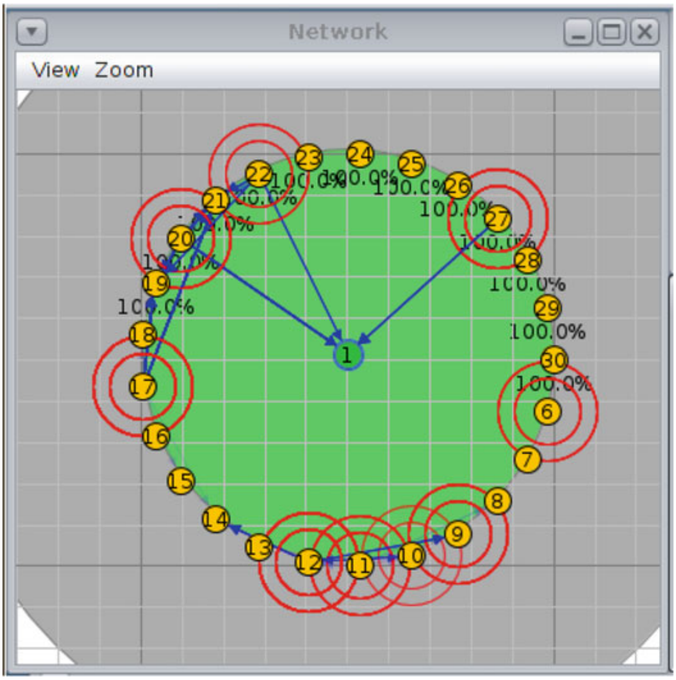


Fig. 15 Data sending by nodes

- The processor's energy consumption in all modes is approximately the same and is not related to the number of packages and distance.
- Increasing the number of sink nodes would severely impress data-transfer operation and raise sending time; this influences the network optimality.
- The more, the number of lost packages, the less network optimality and the more energy consumption.

In the following to check out all node's energy consumptions, a sink node is used, so that the transfer operation is done optimally and orderly. Subsequently, better investigation is done on the received data. When the simulation finishes the received data is shown in the following Fig. 15, and the graph of sensor map and the way that data sent to sink node are presented in Fig. 16.

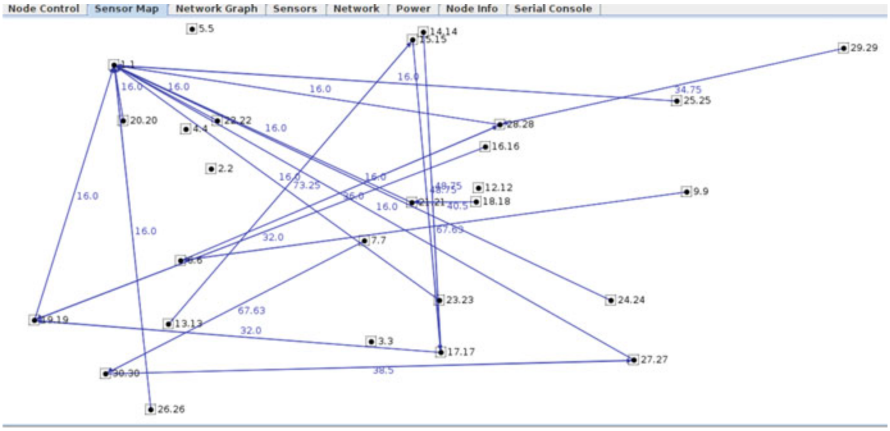
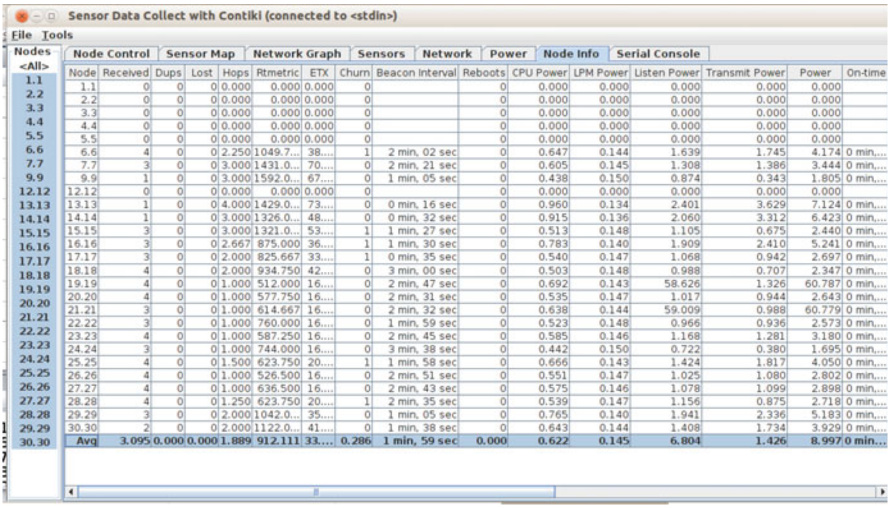


Fig. 16 Sensor map graph



Node	Received	Dups	Lost	Hops	Rtmetric	ETX	Churn	Beacon Interval	Reboots	CPU Power	LPM Power	Listen Power	Transmit Power	Power	On-time
1.1	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000	
2.2	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000	
3.3	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000	
4.4	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000	
5.5	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000	
6.6	4	0	0	2.250	1049.7...	38....	1	2 min, 02 sec	0	0.647	0.144	1.639	1.745	4.174	0 min,...
7.7	3	0	0	3.000	1431.0...	70....	0	2 min, 21 sec	0	0.605	0.145	1.308	1.386	3.444	0 min,...
9.9	1	0	0	3.000	1592.0...	67....	0	1 min, 05 sec	0	0.438	0.150	0.874	0.343	1.805	0 min,...
12.12	0	0	0	0.000	0.000	0.000	0		0	0.000	0.000	0.000	0.000	0.000	
13.13	1	0	0	4.000	1429.0...	73....	0	0 min, 16 sec	0	0.960	0.134	2.401	3.629	7.124	0 min,...
14.14	1	0	0	3.000	1326.0...	48....	0	0 min, 32 sec	0	0.915	0.136	2.060	3.312	6.423	0 min,...
15.15	3	0	0	3.000	1321.0...	53....	1	1 min, 27 sec	0	0.513	0.148	1.105	0.675	2.440	0 min,...
16.16	3	0	0	2.667	875.000	36....	1	1 min, 30 sec	0	0.783	0.140	1.909	2.410	5.241	0 min,...
17.17	3	0	0	2.000	825.667	33....	1	0 min, 35 sec	0	0.540	0.147	1.068	0.942	2.697	0 min,...
18.18	4	0	0	2.000	934.750	42....	0	3 min, 00 sec	0	0.503	0.148	0.988	0.707	2.347	0 min,...
19.19	4	0	0	1.000	512.000	16....	0	2 min, 47 sec	0	0.692	0.143	58.626	1.326	60.787	0 min,...
20.20	4	0	0	1.000	577.750	16....	0	2 min, 31 sec	0	0.535	0.147	1.017	0.944	2.643	0 min,...
21.21	3	0	0	1.000	614.667	16....	0	2 min, 32 sec	0	0.638	0.144	59.009	0.988	60.779	0 min,...
22.22	3	0	0	1.000	760.000	16....	0	1 min, 59 sec	0	0.523	0.148	0.966	0.936	2.573	0 min,...
23.23	4	0	0	1.000	587.250	16....	0	2 min, 45 sec	0	0.585	0.146	1.168	1.281	3.180	0 min,...
24.24	3	0	0	1.000	744.000	16....	0	3 min, 38 sec	0	0.442	0.150	0.722	0.380	1.695	0 min,...
25.25	4	0	0	1.500	623.750	20....	1	1 min, 58 sec	0	0.666	0.143	1.424	1.817	4.050	0 min,...
26.26	4	0	0	1.000	526.500	16....	0	2 min, 51 sec	0	0.551	0.147	1.025	1.080	2.802	0 min,...
27.27	4	0	0	1.000	636.500	16....	0	2 min, 43 sec	0	0.575	0.146	1.078	1.099	2.898	0 min,...
28.28	4	0	0	1.250	623.750	20....	1	2 min, 35 sec	0	0.539	0.147	1.156	0.875	2.718	0 min,...
29.29	3	0	0	2.000	1042.0...	35....	0	1 min, 05 sec	0	0.765	0.140	1.941	2.336	5.183	0 min,...
30.30	2	0	0	2.000	1122.0...	41....	0	1 min, 38 sec	0	0.643	0.144	1.408	1.734	3.929	0 min,...
Avg	**3.095**	**0.000**	**0.000**	**1.889**	**912.111**	**33....**	**0.286**	**1 min, 59 sec**	**0.000**	**0.622**	**0.145**	**6.804**	**1.426**	**8.997**	**0 min...**

Fig. 17 Energy consumption data with high number of nodes

Moreover, the energy consumption of data delivery in dense network with high number of nodes that are in the type of Sky mote is captured and displayed in Fig. 17. The average of beacon interval is 1 min and 59 s, and average packets received by nodes to send are 3. The average of CPU energy consumption for total network communication is 0.622, the average LPM energy, Listen and Transmit energy is 0.145, 6.804 and 1.426 respectively. Information on the average energy consumption of nodes that are sending data is illustrated in Fig. 18.

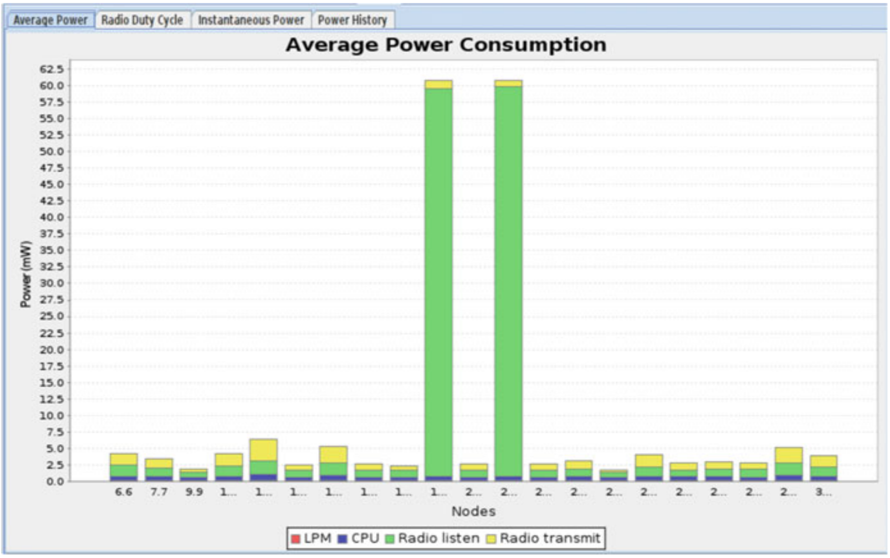


Fig. 18 Sender nodes energy consumption

Simulation Results

Since it has specified in the simulation result as figures, it signifies that the most of the energy consumption in the network is when data are transferring, and for some intermediate nodes for listening to the network communication drain the power, and have in mind that the nodes power supply is limited; so, at the termination point of node it shows that the network life span is decreased. While for adding to the number of nodes in second scenario, the total energy consumption has raised. This is due to: the number of engaged nodes to send and receive data, sensor's temperature, number of received data, number of lost data, network topology structure, communication distance with main station and the distance from sink node, distance among nodes and adjacent nodes, routing distance, and RAM size. Therefore, the following points are reflected:

- Each node energy resource should be planned, so that the total network life span increases.
- High number of sensor nodes result in energy consumption.
- The network should be scalable considering the number of nodes and their dispersal, and it should be able to support different node distribution intensity. In many applications, node distribution is random and in some of them; it is linear.
- Because the nodes are connected wirelessly and each node is connected with nodes, which are within its range, topology management would be different considering network function. Topology management strategies should make it

possible to add new nodes or delete out of service nodes, so that node damages would not impress the total network performance.

- Topology control is to select a series of nodes that should be active for the connection to continue; so, the other nodes would turn to sleep mode and save energy.
- To enhance network life span and lengthen of nodes life, it is required to work reduction of energy consumption.
- The faster each processor is, the more its capability and performance become.
- The faster the processor is, the faster the calculations are and the less energy are wasted; totally network energy consumption becomes more optimal.
- If the processor's velocity and vigor are low, it needs less energy to cool down.
- Networks use radio waves to transfer information, and the power of these waves decreases as the distance increases.

4.2 6lowPAN Protocol Simulation

In this part of simulation, IPv6 is used in the network layer that provides communication among elements, to give accessibility, and user connection via applications. For IPv6 and IEEE 802.15.4 standard connection, a layer is needed to simply adjustment between IPv6 layer requirements and connection layer capabilities. This layer is 6LowPAN and which its communication stacked structure is shown in Fig. 19.

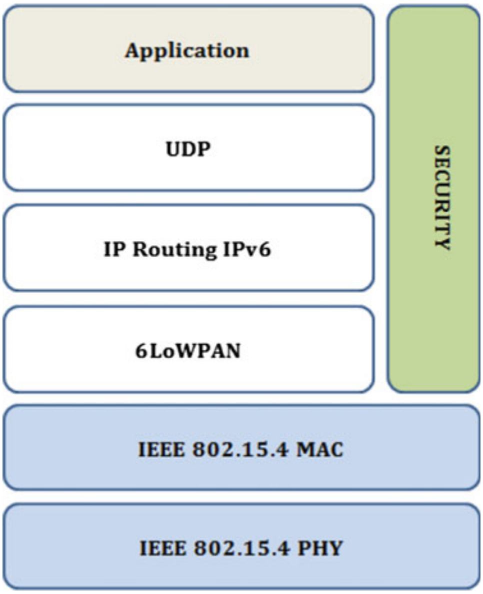


Fig. 19 Communication stack structure of 6LowPAN protocol

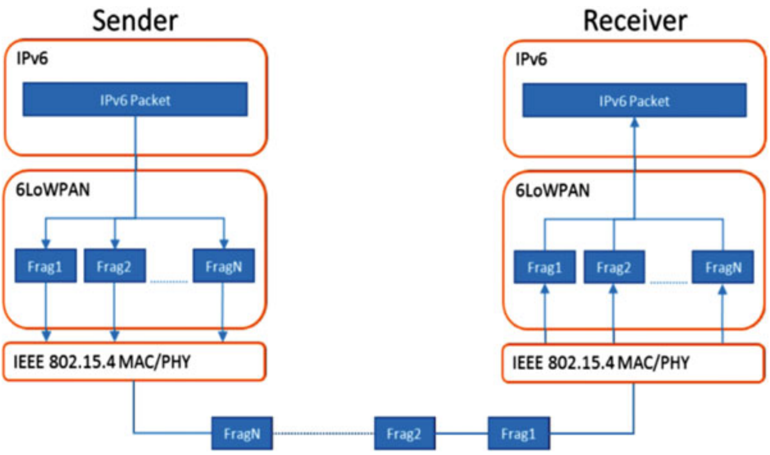
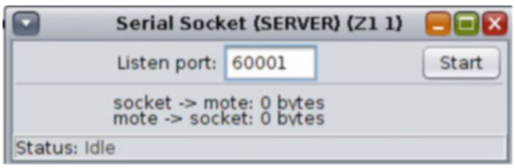


Fig. 20 6LowPAN mechanism of action

Fig. 21 Server port setup



IPv6 packages could be exchanged on IEEE802.15.4 standard based networks. 6LowPAN slices the package in the sender and put it together in the receiver (Fig. 20). So, it consists of a sender and a receiver. Standard mechanisms are presented in this protocol that would result in a personal wireless network optimality with low power. The mechanisms include:

- Partitioning
- Header compression
- IPv6 address automatic configuration

Simulation Structure

To create 6LowPAN infrastructure, it is required a border router to construct the network that is able to connect to tribute from itself. To simulate this protocol and find the efficiency protocol, the Z1 mote is used.

Before Cooja simulation, a bridge between simulation and the real computer socket to have a communication tunnel outward is created. The tunslip6 program available in contiki storage is run. A local configuration of Cooja is required to create the packages tunnel to send 6LowPAN packages. For this purpose, a Serial Socket (SERVER) and a port that listens to it on 60001 is created (Fig. 21).

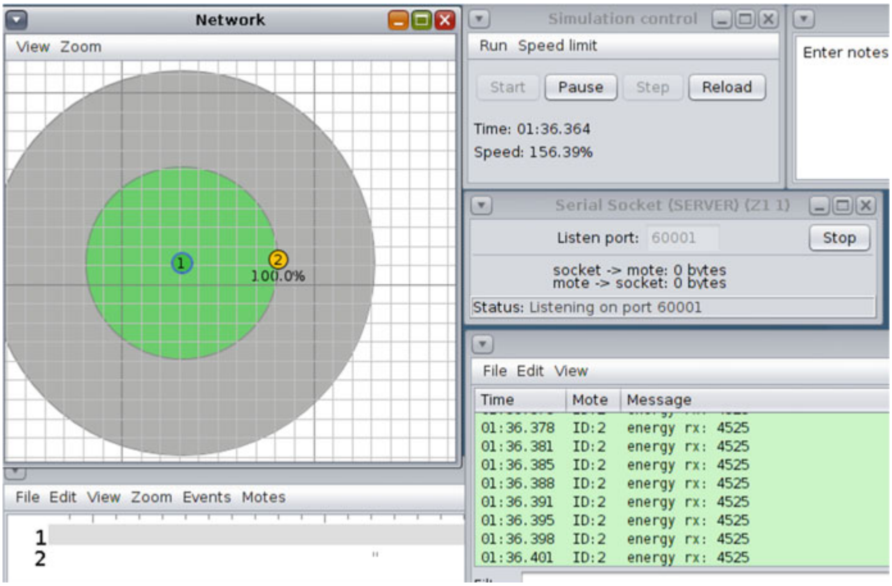


Fig. 22 6LoWPAN simulation scenario

Fig. 23 Browser output

After the simulation starts, a request should be created through the web, which, aaaa::c30c:0:0:1 is entered in the URL bar that belongs to Border-Router in Cooja environment. When a new device is added to the network, its name is also added to the web list (Figs. 22 and 23).

CoAP Protocol Simulation

The CoAP protocol controls the deployed sensors for IoT. It can easily be compiled to HTTP, and it is designed to simple integration with web. In simulation of this protocol in Cooja, there is a router node for tracing and two servers to exchange data. The main CoAP features are listed as bellow:

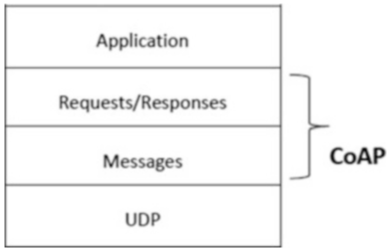


Fig. 24 CoAP protocol

- Asymmetric massages exchange
- UDP connection
- Small overhead and non-complicated analysis
- Saving capabilities and simple proxy
- URL and content type support
- Proxy accessibility to CoAP resources via HTTP
- Datagram Transport layer security (DLTS)

Simulation Scenario

Three motes are used in this scenario; two server nodes and one client node. The mote type is sky mote that is equipped with low power 430 MSP microcontrollers with 8 MHz velocity and have 10 KB RAM, Chipcon wireless receiver with properties such as IEEE802.15.4 standard and 2.4 GHz frequency and 250 Kbps transmission rate; humidity, light and temperature sensor; and SMA antenna.

This protocol practically uses a two-layered approach: a message layer and a request/response bottom layer that works with UDP and asynchronous techniques. While upper layers (Fig. 24) manage to map between requests and responses. The messaging type of CoAP in this scenario is based on compressed message exchange via UDP among nodes by default. Moreover, CoAP can do the transfer via DTLS, TCP, SMS, or SCTP. Messages are shared through requests and responses. Each message has an ID that is used to recognize repetitive messages.

To exchange information with the server, there are DELETE, PUT, GET, and POST methods that their buttons in web page to communicate with the server is used. Their functions include:

- GET: to call a resource
- POST: to create a resource
- PUT: to update a resource
- DELETE: to delete a resource

To connect to CoAP server, its URL and PORT in the browser are entered to be able to use its resources. In this part (CU) copper is used that is a public CoAP based IoT browser. Figure 25 show copper user interface in the web browser.

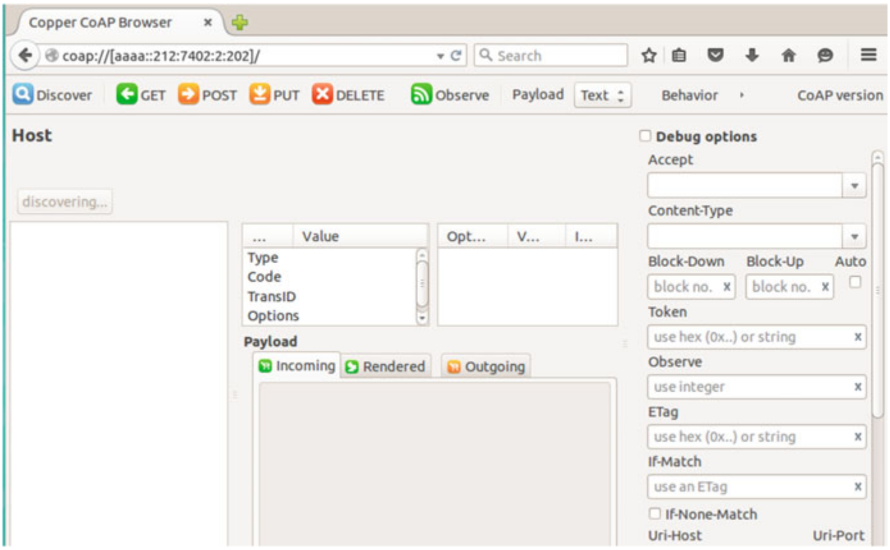


Fig. 25 Copper browser

After running the simulation two nodes, number 2 and 3, power on to exchange data via IPv6 and node number 1 initiates this connection's orientation; in fact, it creates a bridge between the router and the other web nodes. On the other hand, the router opens a socket and listens to port 60001 to receive messages from the servers (Fig. 26).

Simulation Results

IoT sensor devices have limited memory, processor and power resources. An IoT device and other limited devices' energy consumption is a crucial issue for most of the limited energy resources. PowerTrace function that uses CPU time per clock density unit is used in this simulation; the time that the processor is used. This function has 94% accuracy in comparison to real Tool's measurement. Table 6 shows data that are represented by this function in the protocol's simulation. Total simulation time is 100 s, and the amount of consumption is calculated based on every 10 s for the client.

Z1 mote is used instead of sky mote after data structure in the previous simulation condition that is different from sky node, and its hardware properties include:

- Equipped with a low power MSP430F2617 microcontroller
- RISC 16 b CPU
- 16 MHz Clock speed
- 8 KB RAM
- 92 KB flash memory

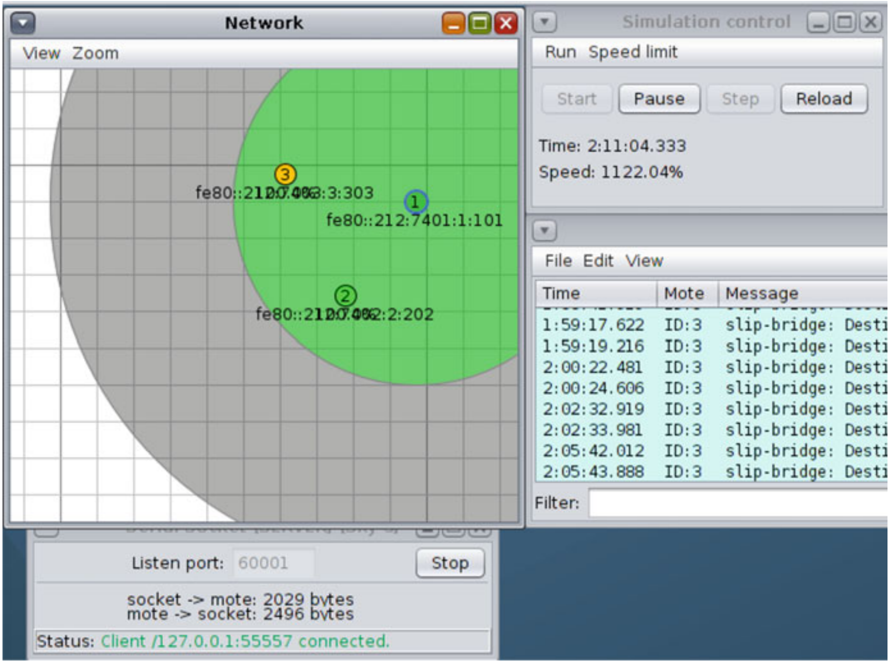


Fig. 26 CoAP protocol simulation scenario

Table 6 CoAP protocol simulation data for sky node

RX	TX	LPM	CPU	Total
0.053608887	0.003120025	0.359862671	1.644598389	2.061189971
0.053808289	0.00311938	0.360021973	1.782810059	2.1997597
0.048055847	0.003138213	0.306177979	1.614821777	1.972193816
0.044137299	0.003151566	0.270175781	1.469208984	1.786673631
0.049623871	0.003133248	0.324656982	1.657335205	2.034749306
0.044892609	0.003149653	0.287698975	1.446833496	1.782574732
0.046131317	0.003144446	0.288017578	1.553891602	1.891184943
0.04487146	0.003150459	0.270016479	1.464217529	1.782255927
0.050784027	0.003128202	0.337241821	1.621534424	2.012688474
0.047013519	0.003141898	0.288017578	1.534958496	1.873131492

- IEEE802.15.4 compatible
- 2.4 GHz velocity with 250 Kbps Data rate
- Maximum efficiency with low energy cost
- A digital programmable accelerometer (ADXL345)
- A digital temperature sensor (TMP102)
- Possibility of energy supply with a 3.3 V battery or 5 V u-USB port

After running the simulation the energy consumption data calculated by PowerTrace for Z1 client node type is as perceived in the following Table 7.

Table 7 CoAP protocol simulation data for node Z1

RX	TX	LPM	CPU	Total
0.02968369	0.00319969	0.16200989	0.9172229	1.11211617
0.03219434	0.00319131	0.17985168	1.01567505	1.23091238
0.03203421	0.0031918	0.18017029	1.03546875	1.25086505
0.03191638	0.00319222	0.18001099	0.9855542	1.20067379
0.03321249	0.00318788	0.17443542	1.02032227	1.23115807
0.03218829	0.0031913	0.18001099	1.04235352	1.25774409
0.02980151	0.00319934	0.16200989	0.90534668	1.10035742
0.03209464	0.00319167	0.18001099	1.01842896	1.23372624
0.0321611	0.00319146	0.18001099	1.05457397	1.26993752
0.03185898	0.00319247	0.18001099	1.02428101	1.23934344

After data analysis and comparison; the conclusion would vary based on the energy consumption differences that are caused by various selected devices and sensors. Energy consumption is observed more in sky type. This difference is insignificant and does not cause a big difference, but when the number of nodes' increases, this little difference becomes significant.

The results from two types of mote's comparison show that as the RAM size increases in nodes, there would be higher-energy consumption and also, according to the simulation results, the powerful and faster processor has the faster calculations, and leads to less energy wasting as well; finally, network energy consumption becomes optimal, accordingly.

5 Conclusion

The goal of this chapter is to study IoT as a practical part of smart cities based on energy consumption in different parts of a smart city in order to achieve an optimal framework, which controls energy consumption and reduces its costs significantly. IoT architecture is simply considered with three layers of sensors, network and function that any of these layers should consider a specific challenge. In any of these layers, all factors that help consumption control and optimization are researched and represented in various parts of the smart cities. Finally, a proper framework is proposed to fulfill all items related to this chapter. Specially to evaluate how cities benefit from IoT in smart city categories: transportation, smart network, houses and apartments, smart lightening, enterprises and garbage collection. Moreover, in all situations and functions, IoT causes questions regarding security and privacy; in this research besides representing a framework; solutions and important security challenges in different layers were introduced. Basically, developing a smart city is not just complicated, but also, expensive. In current situation, technologies are so user friendly that any user can easily provide equipment. Moreover, using IoT equipment has become more affordable than before.

The following Table 8 is concluded from the simulation and analysis of retrieve information.

Table 8 Proposed IoT framework outcome

Main factors	Description and conclusion
Number of engaged nodes in the network to send and receive data	Each node should plan its energy resource in a way that increases the total network life span Numerous sensor nodes end in energy consumption inefficiency The network should be scalable in node's number and their dispersal, and it should support node's different distribution density. In many functions, node distribution is random and, in some functions, it is linear
Sensor temperature	To cool down the environment and the sensors, if the temperature gets high, more energy should be used, and this causes more costs
Number of received packages Number of lost packages	As the number of packages increase, more processes, calculation and navigation are created on the network and energy consumption increases too
Network structure and topology	Due to wireless node connection and that any node is connected to other nodes within its range, topology management should be done accurately that is different according to various network functions. Topology management methods should be in a way that there would be a possibility for adding new nodes and deleting out of work nodes, and damages should not affect total network performance Topology control is the selection of a series of nodes that should remain active to continue connection, so the other nodes turn to sleep mode and save energy In many cases, the network topology is random
Communication distance to main station and sink node interval The interval between the nodes and their adjacent nodes Navigation interval Wireless sensor network range coverage	Networks use radio waves for data transfer and waves strength decreases as the distance increases
RAM size	Energy consumption gets higher as the RAM size increases
CPU power	The more this power is the more CPU capability and performance rate become The more powerful and the faster the CPU is, the quicker calculations are done, and consequently; the network energy consumption is optimal If the CPU power and speed are low, less energy is needed to cool it down
Sensor node size	Each node should be light, small and low-weighted enough beside the necessity that it should have all the needed parts Weight wise, the node should be capable of being suspended in the air and compatible to the environmental circumstances

5.1 Future Work

The primary suggestion is to simulate other suggested optimal protocols in IoT framework of smart cities like MQTT that would be simulated between function and transfer layers and to study their amount of energy consumption in various circumstances and different scenarios of other nodes.

Moreover, framework simulation in NS2, OMnet++ and MATLAB environments and comparing their results with results from Cooja simulator to conclude more accurately could be possible.

Running simulation scenarios with other common sensor devices in the simulator's environment such as MicaZ mote, ESB mote, Wisnote, Eth 1120, etc. that each of them has different CPU power, temperature sensor, and hardware features compared to each other. It is possible to choose intended sensor and configure it and check out their performance in nodes and the amount of energy they use.

References

1. Dehury, C. K., & Sahoo, P. K. (2016). Design and implementation of a novel service management framework for IoT devices in cloud. *Journal of Systems and Software, 119*, 149–161.
2. Shrouf, F., & Miragliotta, G. (2015). Energy management based on Internet of Things: Practices and framework for adoption in production management. *Journal of Cleaner Production, 100*, 235–246.
3. Nguyen, T. D., Khan, J. Y., & Ngo, D. T. (2017). Energy harvested roadside IEEE 802.15.4 wireless sensor networks for IoT applications. *Ad Hoc Networks, 56*, 109–121.
4. Lin, T., Rivano, H., & Mouël, F. L. (2017). A survey of smart parking solutions. *IEEE Transactions on Intelligent Transportation Systems, 18*(12), 3229–3253.
5. Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., Ouzounis, G., & Portugali, Y. (2012). Smart cities of the future. *The European Physical Journal Special Topics, 214*(1), 481–518.
6. Silva, B. N., Khan, M., & Han, K. (2018). Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities. *Sustainable Cities and Society, 38*, 697–713.
7. Bohli, J. M., Skarmeta, A., Moreno, M. V., García, D., & Langendörfer, P. (2015). SMARTIE project: Secure IoT data management for smart cities. In *2015 International Conference on Recent Advances in Internet of Things (RIoT)* (pp. 1–6).
8. Ahad, M. A., Paiva, S., Tripathi, G., & Feroz, N. (2020). Enabling technologies and sustainable smart cities. *Sustainable Cities and Society, 61*, 102301.
9. Qureshi, K. N., Tayyab, M. Q., Rehman, S. U., & Jeon, G. (2020). An interference aware energy efficient data transmission approach for smart cities healthcare systems. *Sustainable Cities and Society, 62*, 102392.
10. Kaebeh Yaeghoobi, S. B., Soni, M. K., & Tyagi, S. S. (2016). Dynamic and real-time sleep schedule protocols for energy efficiency in WSNs. *International Journal of Computer Network and Information Security (IJCNIS), 8*(1), 9–17.
11. Kim, T.-H., Ramos, C., & Mohammed, S. (2017). Smart city and IoT. *Future Generation Computer Systems, 76*, 159–162.

12. Hui, T. K. L., Sherratt, R. S., & Sánchez, D. D. (2017). Major requirements for building smart homes in smart cities based on Internet of Things technologies. *Future Generation Computer Systems, 76*, 358–369.
13. Gohar, M., Muzammal, M., & Ur Rahman, A. (2018). SMART TSS: Defining transportation system behavior using big data analytics in smart cities. *Sustainable Cities and Society, 41*, 114–119.
14. Beligianni, F., Alamaniotis, M., Fevgas, A., Tsompanopoulou, P., Bozanis, P., & Tsoukalas, L. H. (2016). An internet of things architecture for preserving privacy of energy consumption. In *Mediterranean Conference on Power Generation, Transmission, Distribution and Energy Conversion (MedPower 2016)* (pp. 1–7).
15. Ammar, M., Russello, G., & Crispo, B. (2018). Internet of Things: A survey on the security of IoT frameworks. *Journal of Information Security and Applications, 38*, 8–27.
16. Bedi, G., Venayagamoorthy, G. K., & Singh, R. (2016). Internet of Things (IoT) sensors for smart home electric energy usage management. In *2016 IEEE International Conference on Information and Automation for Sustainability (ICIAfS)* (pp. 1–6).
17. Gao, X., Pishdad-Bozorgi, P., Shelden, D. R., & Tang, S. (2021). Internet of things enabled data acquisition framework for smart building applications. *Journal of Construction Engineering and Management, 147*(2), 04020169.
18. Al Ridhawi, I., Otoum, S., Aloqaily, M., Jararweh, Y., & Baker, T. (2020). Providing secure and reliable communication for next generation networks in smart cities. Sustainable cities and. *Society, 56*, 102080.
19. Krishna, M. B., & Verma, A. (2016). A framework of smart homes connected devices using Internet of Things. In *2016 2nd International Conference on Contemporary Computing and Informatics (IC3I)* (pp. 810–815).
20. Braun, T., Fung, B. C. M., Iqbal, F., & Shah, B. (2018). Security and privacy challenges in smart cities. *Sustainable Cities and Society, 39*, 499–507.
21. Peng, H., Kan, Z., Zhao, D., Han, J., Lu, J., & Hu, Z. (2018). Reliability analysis in interdependent smart grid systems. *Physica A: Statistical Mechanics and its Applications, 500*, 50–59.
22. Kabalci, Y. (2016). A survey on smart metering and smart grid communication. *Renewable and Sustainable Energy Reviews, 57*, 302–318.
23. Wang, J., Huang, J., Chen, W., Liu, J., & Xu, D. (2016). Design of IoT-based energy efficiency management system for building ceramics production line. In *2016 IEEE 11th Conference on Industrial Electronics and Applications (ICIEA)* (pp. 912–917).
24. Shu, L., Mukherjee, M., Pecht, M., Crespi, N., & Han, S. N. (2017). Challenges and research issues of data management in IoT for large-scale petrochemical plants. *IEEE Systems Journal*, 1–15.
25. Ahmad, M. W., Mourshed, M., Mundow, D., Sisinni, M., & Rezgui, Y. (2016). Building energy metering and environmental monitoring – A state-of-the-art review and directions for future research. *Energy and Buildings, 120*, 85–102.
26. Alaba, F. A., Othman, M., Hashem, I. A. T., & Alotaibi, F. (2017). Internet of things security: A survey. *Journal of Network and Computer Applications, 88*, 10–28.
27. Ford, R., Pritoni, M., Sanguinetti, A., & Karlin, B. (2017). Categories and functionality of smart home technology for energy management. *Building and Environment, 123*, 543–554.
28. Zhou, B., Li, W., Chan, K. W., Cao, Y., Kuang, Y., Liu, X., & Wang, X. (2016). Smart home energy management systems: Concept, configurations, and scheduling strategies. *Renewable and Sustainable Energy Reviews, 61*, 30–40.
29. Erlinghagen, S., Lichtensteiger, B., & Markard, J. (2015). Smart meter communication standards in Europe – A comparison. *Renewable and Sustainable Energy Reviews, 43*, 1249–1262.
30. Wei, M., Hong, S. H., & Alam, M. (2016). An IoT-based energy-management platform for industrial facilities. *Applied Energy, 164*, 607–619.

31. Ray, P. P. (2018). A survey on Internet of Things architectures. *Journal of King Saud University – Computer and Information Sciences, 30*(3), 291–319. https://doi.org/10.1016/j.jksuci.2016.10.003
32. Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M. (2015). Internet of things: A survey on enabling technologies, protocols, and applications. *IEEE Communications Surveys & Tutorials, 17*(4), 2347–2376.
33. Rault, T., Bouabdallah, A., & Challal, Y. (2014). Energy efficiency in wireless sensor networks: A top-down survey. *Computer Networks, 67*, 104–122.
34. Al-Azez, Z. T., Lawey, A. Q., El-Gorashi, T. E. H., & Elmirghani, J. M. H. (2015). Virtualization framework for energy efficient IoT networks. In *2015 IEEE 4th International Conference on Cloud Networking (CloudNet)* (pp. 74–77).
35. Laubhan, K., Talaat, K., Riehl, S., Aman, M. S., Abdelgawad, A., & Yelamarthi, K. (2016). A low-power IoT framework: From sensors to the cloud. In *2016 IEEE International Conference on Electro Information Technology (EIT)* (pp. 0648–0652).
36. Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems, 29*(7), 1645–1660.
37. Gill, S., & Lee, B. (2015). A framework for distributed cleaning of data streams. *Procedia Computer Science, 52*, 1186–1191.
38. Deakin, M., & Reid, A. (2018). Smart cities: Under-gridding the sustainability of city-districts as energy efficient-low carbon zones. *Journal of Cleaner Production, 173*, 39–48. https://doi.org/10.1016/j.jclepro.2016.12.054
39. Lee, I., & Lee, K. (2015). The Internet of Things (IoT): Applications, investments, and challenges for enterprises. *Business Horizons, 58*(4), 431–440.
40. Ma, M., Wang, P., & Chu, C. H. (2013). Data management for Internet of Things: Challenges, approaches and opportunities. In *2013 IEEE International Conference on Green Computing and Communications and IEEE Internet of Things and IEEE Cyber, Physical and Social Computing* (pp. 1144–1151).
41. Padiya, T., Bhise, M., & Rajkotiya, P. (2015). Data management for Internet of Things. In 2015 *IEEE Region 10 Symposium* (pp. 62–65).
42. Swamy, S. N., & Sowmyarani, C. N. (2018). Repeated data management framework for IoT: A case study on weather monitoring and forecasting. In *2018 4th International Conference on Recent Advances in Information Technology (RAIT)* (pp. 1–7).
43. Fatima, H., & Wasnik, K.. Comparison of SQL, NoSQL and NewSQL databases for internet of things. In *2016 IEEE Bombay Section Symposium (IBSS)* (pp. 1–6).
44. Kang, Y. S., Park, I. H., Rhee, J., & Lee, Y. H. (2016). MongoDB-based repository design for IoT-generated RFID/sensor big data. *IEEE Sensors Journal, 16*(2), 485–497.
45. Paethong, P., Sato, M., & Namiki, M. (2016). Low-power distributed NoSQL database for IoT middleware. In *2016 Fifth ICT International Student Project Conference (ICT-ISPC)* (pp. 158–161).
46. Bellagente, P., Ferrari, P., Flammini, A., & Rinaldi, S. (2015). Adopting IoT framework for Energy Management of Smart Building: A real test-case. In *2015 IEEE 1st International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI)* (pp. 138–143).
47. Kesavan, G., Sanjeevi, P., & Viswanathan, P. (2016). A 24 hour IoT framework for monitoring and managing home automation. In *2016 International Conference on Inventive Computation Technologies (ICICT)* (pp. 1–5).
48. Risteska Stojkoska, B. L., & Trivodaliev, K. V. (2017). A review of Internet of Things for smart home: Challenges and solutions. *Journal of Cleaner Production, 140, Part 3*, 1454–1464.
49. Sembroiz-Ausejo, D., Careglio, D., Ricciardi, S., & Fiore, U. (2019). Planning and operational energy optimization solutions for smart buildings. *Information Sciences, 476*, 439–452.

50. Alaa, M., Zaidan, A. A., Zaidan, B. B., Talal, M., & Kiah, M. L. M. (2017). A review of smart home applications based on internet of things. *Journal of Network and Computer Applications, 97*, 48–65.
51. Lund, H., Østergaard, P. A., Connolly, D., & Mathiesen, B. V. (2017). Smart energy and smart energy systems. *Energy, 137*, 556–565.
52. Gore, R., & Valsan, S. P. (2016). Big Data challenges in smart Grid IoT (WAMS) deployment. In *2016 8th International Conference on Communication Systems and Networks (COMSNETS)* (pp. 1–6).
53. Bayindir, R., Colak, I., Fulli, G., & Demirtas, K. (2016). Smart grid technologies and applications. *Renewable and Sustainable Energy Reviews, 66*, 499–516.
54. Tuballa, M. L., & Abundo, M. L. (2016). A review of the development of smart grid technologies. *Renewable and Sustainable Energy Reviews, 59*, 710–725.
55. Cicirelli, F., Fortino, G., Guerrieri, A., Spezzano, G., & Vinci, A. (2017). Metamodeling of smart environments: From design to implementation. *Advanced Engineering Informatics, 33*, 274–284.
56. Lin, J., Niu, J., Li, H., & Atiquzzaman, M. (2019). A secure and efficient location-based service scheme for smart transportation. *Future Generation Computer Systems, 92*, 694–704. https://doi.org/10.1016/j.future.2017.11.030
57. Sumalee, A., & Ho, H. W. Smarter and more connected: Future intelligent transportation system. *IATSS Research., 42*, 67–71.
58. Kandasamy, N. K., Karunagaran, G., Spanos, C., Tseng, K. J., & Soong, B.-H. (2018). Smart lighting system using ANN-IMC for personalized lighting control and daylight harvesting. *Building and Environment, 139*, 170–180.
59. Chew, I., Karunatilaka, D., Tan, C. P., & Kalavally, V. (2017). Smart lighting: The way forward? Reviewing the past to shape the future. *Energy and Buildings, 149*, 180–191.
60. Jin, D., Hannon, C., Li, Z., Cortes, P., Ramaraju, S., Burgess, P., Buch, N., & Shahidehpour, M. (2016). Smart street lighting system: A platform for innovative smart city applications and a new frontier for cyber-security. *The Electricity Journal, 29*(10), 28–35.
61. Yoshiura, N., Fujii, Y., & Ohta, N. (2013). Smart street light system looking like usual street lights based on sensor networks. https://doi.org/10.1145/2487166.2487202
62. Pham, T. N., Tsai, M. F., Nguyen, D. B., Dow, C. R., & Deng, D. J. (2015). A cloud-based smart-parking system based on Internet-of-Things technologies. *IEEE Access, 3*, 1581–1591.
63. Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of Things for smart cities. *IEEE Internet of Things Journal, 1*(1), 22–32.
64. Medvedev, A., Fedchenkov, P., Zaslavsky, A., Anagnostopoulos, T., & Khoruzhnikov, S. (2015). Waste management as an IoT-enabled service in smart cities. Paper presented at the NEW2ANand 8th conference, ruSMART 2015: Internet of things, smart spaces, and next generation networks and systems. Springer, Cham, Switzerland, pp. 104–115. https://doi.org/10.1007/978-3-319-23126-6_10
65. Zhou, J., Cao, Z., Dong, X., & Vasilakos, A. V. (2017). Security and privacy for cloud-based IoT: challenges. *IEEE Communications Magazine, 55*(1), 26–33.
66. Kamble, A., & Bhutad, S. (2018). Survey on Internet of Things (IoT) security issues & solutions. In *2018 2nd International Conference on Inventive Systems and Control (ICISC)* (pp. 307–312).
67. Unwala, I., Taqvi, Z., & Lu, J. (2018). IoT security: ZWave and thread. In *2018 IEEE Green Technologies Conference (GreenTech)* (pp. 176–182).
68. Wei, W., Yang, A. T., & Shi, W. (2016). Security in Internet of Things: Opportunities and challenges. In *2016 International Conference on Identification, Information and Knowledge in the Internet of Things (IIKI)* (pp. 512–518).
69. Dragomir, D., Gheorghe, L., Costea, S., & Radovici, A. (2016). A survey on secure communication protocols for IoT systems. In *2016 International Workshop on Secure Internet of Things (SIoT)* (pp. 47–62).

70. Choudhury, T., Gupta, A., Pradhan, S., Kumar, P., & Rathore, Y. S. (2017). Privacy and security of cloud-based Internet of Things (IoT). In *2017 3rd International Conference on Computational Intelligence and Networks (CINE)* (pp. 40–45).
71. Mukherjee, B., Wang, S., Lu, W., Neupane, R. L., Dunn, D., Ren, Y., Su, Q., & Calyam, P. (2018). Flexible IoT security middleware for end-to-end cloud–fog communication. *Future Generation Computer Systems, 87*, 688–703.
72. Chandu, Y., Kumar, K. S. R., Prabhukhanolkar, N. V., Anish, A. N., & Rawal, S. (2017). Design and implementation of hybrid encryption for security of IOT data. In *2017 International Conference on Smart Technologies for Smart Nation (SmartTechCon)* (pp. 1228–1231).
73. Bekara, C. (2014). Security issues and challenges for the IoT-based smart grid. *Procedia Computer Science, 34*, 532–537.
74. Tewari, A., & Gupta, B. B. (2018). Security, privacy and trust of different layers in Internet-of-Things (IoTs) framework. *Future Generation Computer Systems, 108*, 909–920.
75. Kolluru, K. K., Paniagua, C., Deventer, J. V., Eliasson, J., Delsing, J, & DeLong, R. J. (2018). An AAA solution for securing industrial IoT devices using next generation access control. In *2018 IEEE Industrial Cyber-Physical Systems (ICPS)* (pp. 737–742).

Existing Green Computing Techniques: An Insight

Nafisur Rahman

1 Introduction

1.1 Green Computing: A Contextual Description of the Concept

With ever-increasing environmental pollution levels, the demands to adopt ways leading to environmental sustainability cannot be overlooked. Computing technology impacts the environment in various ways. Sustainable Development practices are applicable everywhere and computing is no exception. In this context, Green Computing refers to the design and manufacturing of computing devices, their usage to accomplish computing tasks, and the disposal of these devices in such a way that aims at environmental sustainability. It is accomplished by reducing the environmental hazards caused by computing devices and their usage through the promotion of recycling and reuse and through curtailing the carbon footprint on the environment. It includes green design, manufacturing, utilization, and disposal (Fig. 1).

1.2 Green Computing Goals

The goal of Green Computing is to achieve economic viability without compromising with the objectives of environmental sustainability. Green computing aims at cutting down the amount of energy consumed to a minimum, minimizing the use of harmful materials in the manufacturing process, promoting and using biodegradable

N. Rahman (✉)
Department of Computer Science and Engineering, School of Engineering Sciences and Technology, Jamia Hamdard, New Delhi, Delhi, India

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_5

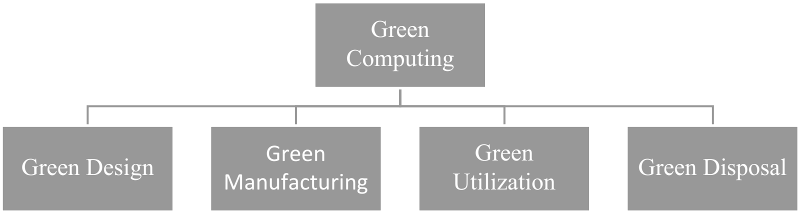


Fig. 1 Green Computing

materials wherever possible, and prolonging the lifespan of the computing devices to the maximum possible extent. To achieve these goals, advanced researches in the areas of energy efficiency, algorithms, and other allied computing technologies have been going on and needs to continue.

1.3 Motivations for Green Computing

Lash and Wellington [1] have demonstrated the risks posed by climate change and global warming. They have identified the needs for computing to go green. Regulatory bodies that govern various domains, including computing, are increasingly being stricter in ensuring environmental sustainability. So, businesses need to employ green techniques to ensure better compliance. In fact, it's not just about regulatory authorities anymore. These days, many big investors also look into the environmental aspects. Therefore, in order to attract potential investments, green techniques have become important. With every passing day, there will be fewer takers for the products or technological solutions that are not environment friendly. So, to keep the customer base intact, companies need to focus more and more on climate-friendly computing technology. Any lack of care about environmental safety and sustainability can also potentially invite litigations and legal troubles due to the alleged environmental harms. Increasing energy costs also require the manufacturers and users to opt for green computing techniques to check the associated costs incurred.

The needs, like those of regulatory compliance, etc. do not necessarily make green computing a disliked necessity. On the contrary, Green Computing, in reality, gives a competitive edge due to the range of benefits that it offers. The tangible benefits include decreased energy consumption and lower costs of production and usage in the long run. In addition, the after-use value also gets increased due to the special focus on recycling and reuse. Other benefits lie in the fact that green computing techniques don't cause as much pollution as caused by conventional techniques. This shows the responsibility towards protecting the environment and, consequently, leads to the strengthening of the brand value too.

Chou et al. [2] have demonstrated how an awareness of the environmental and other issues once translated into understanding leads to Green Computing value which eventually helps ensure a safe and sustainable environment.

2 Green Design Techniques

Goldberg [3] identifies the issues that Green Design deals with. Green Design aims at minimizing the consumption of resources and generation of waste, develops and employs manufacturing processes that are cleaner than their conventional equivalents, reduces power consumption, and focuses on the longevity of the computing devices.

Green Design, as an approach, is now practiced widely. Better design techniques that are in line with the aims and objectives of Green Design are used. Some of them find a mention in the subsequent paragraphs.

Gradual migration from single-core processors to multi-core processors has significantly minimized the power consumption that was otherwise required if the processing capability was increased in the conventional ways. It has also led to a decrease in the heat generated by increasing the frequency of a single-core processor. Murugesan [4] notes that a 15% frequency cut can cut down the power requirements by half. In addition, the multi-core design significantly reduces the fabrication materials needed.

Caches are fragmented into segments that receive the power only on demand and remain unpowered otherwise. This also reduces energy needs. Similarly, migration towards power-efficient architectural designs has also led to a reduction in power demands. Nowadays, a lesser number of hard disks with relatively larger capacities offer better energy-efficiency.

Green Data Center [4] design techniques revolve around lowering power requirements, better cooling, and relying more on renewable energy. Modular Data Center design, evolving from racks to blades to containers, offers better scaling and energy efficiency. For storage, optimum use of a combination of NAS, SAN, and DAS technologies is encouraged to get better performance while consuming lesser energy.

Virtualization techniques have been found effective in reducing resource requirements. Liu et al. [5] have proposed an architectural design that uses Virtual Machine technology, for data centers, to reduce power consumption without disrupting the quality of service. They have demonstrated that their *GreenCloud* architecture can save up to 27% of power. Gupta et al. [6] have discussed a Green Data Center Simulator that helps in finding out how efficient a data center is in terms of energy consumed.

3 Green Manufacturing Techniques

Green Manufacturing involves the production of computing devices and associated components in a way that doesn't harm the environment. This can be achieved by reducing the dependency on hazardous materials, minimizing the use of non-renewable natural resources, and cutting down the power requirements.

Green chip making focuses on lower usage of acids and other chemicals. Conventionally, a lot of coppers used to get wasted in making the Printed Circuit Boards. But now, to save copper, the boards are not copper plated. Instead, copper is added externally only where it is needed. This also reduces the use of the acids needed to clear the copper from the board.

For soldering, better substitutes to toxic lead are used in the form of alloys of copper and tin. This eventually checks the contamination of lead in soil and groundwater from the discarded computing devices.

Energy-efficient filaments, specialized transistors, and flat-panel LCDs have reduced power consumption to a great extent. A computer requiring less energy also produces less heat thereby not warming the environment. Energy efficiency is very important because computing devices consume more energy in cooling for each unit of energy consumed in routine work. A typical Data Center Server requires up to one and a half watts for cooling against each watt consumed otherwise [7, 8].

The use of recycled materials in the manufacturing of computers is also one of the ways that significantly reduce wastage and pollution. Some regulations even require the manufacturers to disclose the amount of recycled materials used in the manufacturing process.

Manufacturing computers using refurbished parts is another simple yet effective technique that utilizes the limited resources, promotes extended use of the components manufactured, and delays the eventual dumping of the devices thereby keeping the pollution in control. Use of the refurbished parts often makes the computers cost-effective and hence encourages the users to prefer them. Many manufacturers also offer the users the end-of-life take-back facility for their products.

Green manufacturing does not stop at merely ensuring environment-friendly production of primary computing and other devices. Instead, it entails the green manufacturing of the associated packaging materials too. The packaging industry is looking forward to the increased use of biodegradable packaging materials [9–11] so as to minimize the harmful effects of non-biodegradable packaging materials on the environment.

Energy star ratings and EPEAT [12, 13] ratings give the users an idea of how environment-friendly is the manufactured product that they are using. Therefore, most manufacturers take care of these ratings nowadays.

4 Green Utilization Techniques

Green utilization refers to the use and reuse of computers and allied devices and components in a way that energy consumption and carbon emission are minimized by virtue of the choices and patterns of usage.

Most personal computers, while turned on but not in active use, account for a big share of the energy consumed. For a single computer, this may not appear significant. But, if we consider the hundreds, or, in many cases, thousands, of computers that are used in an enterprise, the amount of energy consumed by them collectively becomes huge. It calls for the adoption of measures that reduce power consumption.

Turning off the computers, when not in use, is one of the simplest yet powerful techniques that significantly reduce energy consumption. Many users are under a false impression that turning off their computer will cut its life short. In fact, turning it off, by reducing the total usage time, like for most things, prolongs its life.

Power management features of computers can be smartly used to cut down the energy requirements to a great extent. A computer that comes with the option of sleep mode reduces power consumption by up to 70%. An IT enterprise can opt for software-based solutions to enable power management features over the networked computers. Network managers can monitor and manage the power consumption patterns remotely.

Informed use of screen savers also helps in saving the power consumed by the computer. A screen saver that does not contain any image consumes less power than the one that contains images that move. These images require frequent interaction with the processors and hence lead to increased power consumption. A power-conscious user, therefore, opts for screen savers that are blank.

Taking prints only if it is really required and not doing so otherwise is also one of the simple yet smart ways of making computer usage green. Printing less saves, paper, ink, and power. The paperless or less-paper strategy ultimately also saves trees. Also, for the necessary printing, refilling of cartridges and toners promotes long-term usage and reduces the landfill burden too.

The use of thin clients is another strategy that positively impacts the environment by saving energy and reducing the dissipation of heat. Preferring thin clients over desktop PCs reduces the power consumption by up to 80%.

WiFi schedulers and Wake on LANs are used to save energy and enhance security as well. WiFi schedulers allow the wireless network to power on and off automatically by managing and scheduling the active usage hours. Wake on Lan allows the computer to turn on only on the arrival of a network message. Time-based Power over Ethernet is another solution that optimizes the power consumption based on a schedule.

Ensuring software and deployment optimization is also one of the ways to improve resource utilization and minimize energy requirements. It includes efficiency of algorithms, proper allocation of resources, and virtualization.

Green utilization techniques also involve proactive diagnosis of the health of the computing devices. It is analogous to the diagnosis of diseases in humans [14]. Just as humans fall sick and develop diseases, machines also get worn out and develop problems. For example, if a computer's cooling system develops some problems, it will get heated quickly. This can potentially disrupt the performance in addition to giving rise to the level of energy consumed and heat dissipated. Problems, if identified timely can lead to getting them fixed quickly and ensure that the device doesn't get damaged badly. This increases the overall life span of the device.

5 Green Disposal Techniques

Disposal of computers and their components mostly falls in the broader category of the disposal of electronic waste [15]. Kiddee et al. [16] have reviewed various approaches towards electronic waste management.

Direct disposal of computers and their components is extremely hazardous for the environment. Therefore, Green computing gives special emphasis on reuse, refurbishment, and recycling (Fig. 2) so that the discarded computers don't go to landfills.

For every new project undertaken, a new computer is not needed. But many people tend to buy and use new computers even when there is absolutely no need to do so. In such situations, reuse [17] of the existing computers is a wiser strategy if our requirements are met. Else, if our requirements force us to buy a new computer or components, the old ones deserve reuse [18] by someone whose requirements can be fulfilled using them. Such users may not be easily identifiable and, at times, the old computers need to be transported to them. Information and Communication technologies should be used smartly for the identification of such users and for sustainable transportation [19].

Many a time, new computing requirements can be catered to by using the old, used or reused, computer components to come up with a computer that is in line with the requirements. This technique is known as refurbishment [20]. Many enterprises are now selling refurbished computers or procuring them for their use. While it

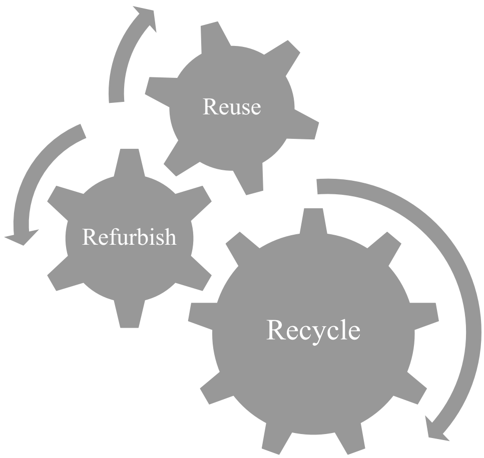
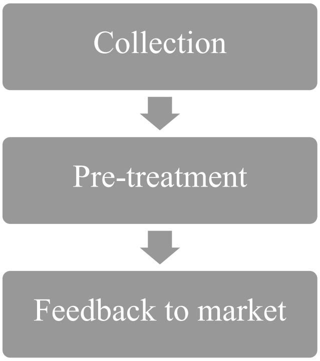


Fig. 2 The Three R's of Green Disposal

Fig. 3 Steps involved in Recycling



protects the environment by minimizing or delaying the eventual dumping of electronic waste, it is cost-effective too.

Computers when reach a stage where their reuse or refurbishment does not remain an option anymore, need to be suitably collected, dismantled, and recycled [21, 22]. Common recyclable computer parts include monitors, plastic parts, CD drives, cathode ray tubes, copper in power cords, metal from circuit boards, cartridges of printers, batteries, etc.

If the electronic waste is not segregated and recycled, it will reach the landfills and pollute the soil and water with toxic chemicals. Even if it is burnt, it will pollute the air with toxic gases. Therefore, electronic waste should be carefully collected, separated, and recycled by detoxification, Shredding, and refining. It can also serve as a secondary source of raw materials.

Teller [23] has discussed various methods for recycling electronic waste. Tanskanen [24] describes the three steps involved in recycling as (1) Collection, (2) Pre-treatment, and (3) Feedback to market (Fig. 3).

The first step involves the take-back of discarded products and their subsequent consolidation. The pre-treatment step involves sorting, separating, dismantling, and upgrading of materials. The Feedback to market involves recycling through refining, incineration, and final disposal of materials that do not get utilized.

6 Conclusions

Based on the observation of various Green Computing techniques, we conclude that Green Computing, as an approach, is the need of the hour. In order to ensure the safety of the environment and to promote sustainable development, Green Computing techniques should be employed widely in the design, manufacturing, utilization, and disposal of computers, their components, and other associated devices. Green Computing is not merely a theoretical proposition or an outlandish idea, rather it has every bit of practicality attached to it and can thrive from a financial perspective as well. While enough techniques have already been proposed and practiced, the sheer importance of the subject calls for still newer techniques to be employed.

References

1. Lash, J., & Wellington, F. (2007). Competitive advantage on a warming planet. *Harvard Business Review, 85*, 95–102.
2. Chou, D. C., & Chou, A. Y. (2012). Awareness of green IT and its value model. *Computer Standards & Interfaces, 34*(5), 447–451. https://doi.org/10.1016/j.csi.2012.03.001
3. Goldberg, L. (1998). The advent of "green" computer design. *Computer, 31*(9), 16–19. https://doi.org/10.1109/2.708445
4. Murugesan, S. (2008). Harnessing green IT: Principles and practices. *IT Professional, 10*(1), 24–33. https://doi.org/10.1109/MITP.2008.10
5. Liu, L., Wang, H., Liu, X., Jin, X., He, W. B., Wang, Q. B., & Chen, Y. (2009). GreenCloud. In *Proceedings of the 6th International Conference Industry Session on autonomic computing and communications industry session—ICAC-INDST '09*. https://doi.org/10.1145/1555312.1555319
6. Gupta, S. K. S., Gilbert, R. R., Banerjee, A., Abbasi, Z., Mukherjee, T., & Varsamopoulos, G. (2011). GDCSim: A tool for analyzing Green Data Center design and resource management techniques. In *2011 International Green Computing Conference and Workshops*. https://doi.org/10.1109/igcc.2011.6008612
7. Lawton, G. (2007). Powering down the computing infrastructure. *Computer, 40*(2), 16–19. https://doi.org/10.1109/MC.2007.69
8. Schmidt, R. R., & Shaukatullah, H. (2002). Computer and telecommunications equipment room cooling: a review of literature. In *ITherm 2002. Eighth Intersociety Conference on thermal and thermomechanical phenomena in electronic systems (Cat. No.02CH37258), San Diego, CA, USA* (pp. 751–766). https://doi.org/10.1109/ITHERM.2002.1012531
9. Jafarzadeh, S., Jafari, S. M., Salehabadi, A., Nafchi, A. M., Uthaya, U. S., & Khalil, H. P. S. A. (2020). Biodegradable green packaging with antimicrobial functions based on the bioactive compounds from tropical plants and their by-products. *Trends in Food Science & Technology, 100*, 262–277. https://doi.org/10.1016/j.tifs.2020.04.017
10. Rabnawaz, M., Wyman, I., Auras, R., & Cheng, S. (2017). A roadmap towards green packaging: The current status and future outlook for polyesters in the packaging industry. *Green Chemistry, 19*(20), 4737–4753. https://doi.org/10.1039/c7gc02521a
11. Ahmed, J., & Varshney, S. K. (2011). Polylactides—Chemistry, properties and green packaging technology: A review. *International Journal of Food Properties, 14*(1), 37–58. https://doi.org/10.1080/10942910903125284
12. Katz, J., Rifer, W., & Wilson, A. R. (2005). EPEAT: Electronic product environmental tool—Development of an environmental rating system of electronic products for governmental/institutional procurement. In *Proceedings of the 2005 IEEE International Symposium on electronics and the environment, 2005, New Orleans, LA, USA* (pp. 1–6). https://doi.org/10.1109/ISEE.2005.1436980
13. Omelchuck, J., Katz, J., Salazar, V., Elwood, H., & Rifer, W. (2006). The implementation of EPEAT: Electronic product environmental assessment tool the implementation of an environmental rating system of electronic products for governmental/institutional procurement. In *Proceedings of the 2006 IEEE International Symposium on electronics and the environment, 2006., Scottsdale, AZ, USA* (pp. 100–105). https://doi.org/10.1109/ISEE.2006.1650042
14. Agarwal, P., Hassan, S. I., Mustafa, S. K., & Ahmad, J. (2020). An effective diagnostic model for personalized healthcare using deep learning techniques. In *Applications of deep learning and big IoT on personalized healthcare services* (pp. 70–88). IGI Global.
15. Jindal, G., & Gupta, M. (2012). Green Computing "Future of Computers". *International Journal of Emerging Research in Management &Technology*, 14–18.
16. Kiddee, P., Naidu, R., & Wong, M. H. (2013). Electronic waste management approaches: An overview. *Waste Management, 33*(5), 1237–1250. https://doi.org/10.1016/j.wasman.2013.01.006

17. Williams, E., Kahhat, R., Allenby, B., Kavazanjian, E., Kim, J., & Xu, M. (2008). Environmental, social, and economic implications of global reuse and recycling of personal computers. *Environmental Science & Technology, 42*(17), 6446–6454. https://doi.org/10.1021/es702255z
18. André, H., Ljunggren Söderman, M., & Nordelöf, A. (2019). Resource and environmental impacts of using second-hand laptop computers: A case study of commercial reuse. *Waste Management, 88*, 268–279. https://doi.org/10.1016/j.wasman.2019.03.050
19. Agarwal, P., & Alam, A. (2018). Use of ICT for sustainable transportation. *Proceedings of International Conference on Future Environment and Energy, 150*(1), 1–7.
20. Ijomah, W. L., & Danis, M. (2012). Refurbishment and reuse of WEEE. In *Waste electrical and electronic equipment (WEEE) handbook* (pp. 145–162). https://doi.org/10.1533/9780857096333.2.145
21. Klatt, S. (2003). Recycling personal computers. In R. Kuehr & E. Williams (Eds.), *Computers and the environment: Understanding and managing their impacts. Eco-efficiency in industry and science* (Vol. 14). Springer. https://doi.org/10.1007/978-94-010-0033-8_11
22. Lee, C., Chang, C., Fan, K., & Chang, T. (2004). An overview of recycling and treatment of scrap computers. *Journal of Hazardous Materials, 114*(1–3), 93–100. https://doi.org/10.1016/j.jhazmat.2004.07.013
23. Teller, M. (2006). Recycling of electronic waste material. In *Eco-efficiency in industry and science* (pp. 563–576). https://doi.org/10.1007/1-4020-4539-5_23
24. Tanskanen, P. (2013). Management and recycling of electronic waste. *Acta Materialia, 61*(3), 1001–1011. https://doi.org/10.1016/j.actamat.2012.11.005

Smart Home for Efficient Energy Management

Shakeel Ahmad Siddiqui, Md Omair Ahmad, and Jawed Ahmed

1 Introduction

A smart home energy management is a well-designed structure enabling to ensure with adequate access of assets, a well-defined communication controls and the proper use of Information technology for instantly enhancing the best quality of life with the increased connectivity and efficient energy management [1]. For decades, the concept of smart home energy management widely acknowledged, but its application could not be made, and very few had seen smart home and the concept of efficient use of energy management earlier.

The concept is now being used and applied on a large scale all over the world. As someone suggested that the common reason of its slow growth, was its exorbitant cost associated with it and the complete absence of information technology advancement or the network-connected appliances [2].

Now, the perception of consumers have hugely underwent a huge change and now they show willingness to incur cost on latest and state of the art technology, and they are much more inclined to use the services of broadband internet connectivity and frequent use of LED TV and cellular phones. The new challenges before the information and communication technology (ICT) is that of monitoring and optimizing the flow of data in the automatic home system (AHS) [3]. An Automatic Home system (AHS) is basically a residence centered technology. However, sometimes in some cases, it can also be applied for gardens or outdoor open spaces too, that remains equipped with sensors and actuators in order to collect data, and thereafter to have controls as per the requirements of the consumers as and when necessitate..

S. A. Siddiqui · M. O. Ahmad (✉) · J. Ahmed
Department of Computer Science and Engineering, Jamia Hamdard, New Delhi, India
e-mail: shakeel@jamiahamdard.ac.in

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_6

Therefore it provides a centralized device for electrical applications. Such device instantly and frequently provide intelligence to the entire home premises that enables excellent and optimum levels of comfort and provides energy savings in almost all places wherever it would be applied. Concerning to this efficient home energy management system, smart sensor technologies as well as advanced metering infrastructure (AMI) home energy storage system(HESS) [4] etc. were studied.

.

It is however, suggested that a Smart Home Energy Management (SHEM) concerns to the application of both supervisory control devices and data acquisition mechanism vis-a-vis efficient energy management and its generation, transmission, and distribution system of electrical networks having concept of smart grid mechanism. The above mentioned concept of efficient home energy management has been unanimously approved for the smooth development of power grids in the future. For the sake of it, SHEM has been considered to be very essentials for residential consumers. SHEM, is efficiently capable of dealing in real time monitoring and can arrange home appliances on the requirements of end users preferences with the support of intelligent ambient system, controlled by human–machine interface in smart houses that enables to cut electricity cost and in a better way, and can manage efficient energy utilization in the premises where it has been commissioned. The main aim to set up SHEM is to monitor home renewable energies also. Now in some of the places due to acute global energy deficiency and environmental emissions, solar panel and turbines are frequently being used along with fast and rapid development in numerous sophisticated power electronics and renewable energy technologies. Recent researches suggest that some intelligent system may be included in SHEM for the best available use of the stored and accumulated energy sources installed at the different residential buildings:

Before SHEM, it is an open challenge in achieving demand response, peak-saving and load shifting that are addressed with an aim to offering solutions to the consumers and network operators. Despite having so many challenges in its different stages, it is well responsive devices and mechanism that equip consumers to have a very positive outcomes in the management of efficient energy management.

1.1 Definition

Home energy management is a scientific and technological mechanism that aims to preserve power resources by supplying efficient home energy to enhance the comforts of the residents by facilitating the household activities in a very scientific manner. It varies with its different types of applications. It is such an application of omnipresent computing technology which can accurately provide the consumers/users with context-aware automated services in the form of ambient intelligence, such as remote control devices of home appliances or automation [5].

SHEM is one of the efficient mechanisms to smartly utilizing devices for providing comfort and saving energy as well as reducing cost incurred on it, that is why the researcher all over the world attracted towards it and applying its available devices to have maximum.

Benefits out of it. The main reason is that it enables cutting the cost enormously, and simultaneously the operational cost also reduces during its whole life cycle. However, the full potentials are yet be achieved due to its complicated nature and heterogeneity in the system. Now, HEMS, are getting popularity exponentially and also technology for that, it is also improving, and small size solar and battery storage are becoming more viable now. As the HEMS technology comprises both hardware and software application protocol, that lets consumers easily monitor the amount of energy consumption or the total usage. It also makes capable to immediately control manually as well in the premises where HEMS has been installed.

2 Hardware

A home energy management system (HEMS) normally has a 'hub' device that transmit communications inside the house, and among the users. Also, sometimes in some cases, in the local utilities or electricity retailers [6]. This type of hub devices installed on the Electrical board panel of the household, may be installed virtually, other necessary components may be included e.g. smart plugs, light and temperature sensor and other smart devices within the household [1].

3 Software

In HEMS, the software used can moderate the incoming as well as outgoing data and communication. That software works as interface that permits access in order to monitoring data control functionality of the systems. That interface is normally based on the form of Apps or web portals. Therefore, that software related to HEMS, keeps the motive to enhance efficient energy of the household, and simply the focus is on controlling devices with a remote distance in order to maintain safety in the premises [7].

3.1 Control Functionality of HEMS

- It enables to turn devices on and off from remote places.
- It enables to set devices to operate on schedules
- It establishes and set up some conditionality in rules for the right functioning of the devices.

- It also establish energy from the installed solar panel, throughout the home or inside or outside of battery.
- It also permits to machine learning to take over it and run the system smoothly

4 HEMS Monitoring and Management

The home energy management system is able to differentiate accordingly to its breadth of its applications. Normally, it comprises four main platform based on home energy areas, where home energy management can be used.

4.1 Electricity

The core functionality of application of home energy management involves the electricity application within and inside the home. A HEMS make capable and confirm the users, the capacity therein can directly monitor whether the devices are properly working or not. That makes users to modify its operations accordingly. Its main consideration is related to include grid electricity rates to ensure whether the solar power or batteries availabilities are there or not.

4.2 Solar PV

In managing efficient energy management, small-scale solar photovoltaic (PV) are very popular in many countries that allows portion of electricity on the scheduled site, providing smart home energy management successfully. Solar battery storage presence make the equation even more complex that makes the home energy management system much more attractive and effective.

4.3 Battery Storage

The role and function of Battery storage is the next areas in the process of home energy management that creates the platform for more and greater energy self-sufficiency and low electricity bill.

4.4 Solar Thermal

Solar thermal is again a next frontier in the way of Smart home efficient energy management. It is much cost effective and most effective mechanism that provides a good amount of power generation at virtually no cost. It is completely based on renewable energy mechanism. Solar thermal is an extremely popular and easily available renewable resources and technology that exploits the power of the SUN to heat water within a home, and through that it makes available power resources of travelling efficient energy management in the whole household premises. This sort of Solar systems always operates independently with the remaining home's electrical devices, however, a smart HEMS with the actual connectivity & proper monitoring functionality can smartly help improve their value even further.

5 HEMS Challenges

The main task of HEMS is to provide energy usage monitoring and control to their users. To do so, HEMS should be able to provide seamless communication among different smart devices and sensors that are running different communication technologies. To design a robust and flexible networking infrastructure, the characteristics, and requirements of each of these technologies must be understood.

For wired communication, IEEE802.3 and Home Plug Green PHY are the leading communication standards. Zig Bee, Z-Wave, and Wi-Fi are the leading technologies for wireless communication. ZigBee is a low-power, low-cost wireless with a low data rate. Z-Wave, the most popular home automation protocol, is another secure and reliable wireless communication protocol [8].

Wi-Fi HaLow is a low-power, high-range, secure wireless communication standard that can be used in devices that incorporate IEEE 802.11ah. Other new communication technologies have been introduced for connected homes, such as Google Thread, which is a simple, secure, and scalable mesh network, developed for connecting devices in a home [9]. In HEMS, various smart devices, appliances, sensors, and smart grid services are connected to one another and communicate large amounts of information [10]. The information and the applications used by these systems need to be protected and secured, and this leads to cyber security challenge of developing it [11].

6 Conclusion

The application of HEMS is growing in the era of smart grids and smart homes. Significant amounts of energy are consumed by dwellings, showing the importance of improving energy efficiency in residential buildings. HEMS are primarily intended to save energy by providing information to users regarding energy consumption and helping them adapt their energy use behavior based on the feedback. They receive from the HEMS. In this review, the desired capabilities and expected challenges for HEMS were identified and discussed. HEMS need to be able to monitor and control devices regardless of their communication protocols. They also need to support DR which requires significant coordination and collaboration between HEMS vendors and utilities. These systems need to include some intelligence to provide feedback to users and help them save money and energy by adapting their energy consumption behavior. HEMS also should keep users' information secure. Because of the tremendous amount of data communicated between devices, HEMS, and smart grid, these systems should be capable of storing and retrieving this data efficiently.

Even though a variety of different energy management systems have been introduced to the market, they are not being used by many homeowners. Open-source HEMS are hard to deploy for most users and the cost associated with proprietary. HEMS doesn't justify the energy saving for most users especially since most management systems do not support any intelligence. Available HEMS are capable of monitoring and controlling certain devices. However, they can support only devices with certain types of communication protocols, and they generally cannot use the information they receive regarding users' energy consumption to save energy. They also lack DR support and sophisticated cyber security. Most available HEMS are not easy to deploy, and some even require extensive installation by an expert.

To have HEMS that can largely be used by homeowners in the smart grid era, there is a need for an open-source energy management system which is easy to deploy and use by any user with any level of technical background. The system should provide support for a wide range of smart devices running through different communication protocols, so users can communicate with any smart device of their choice. Owning to its multi dynamic and smart functionality of SHEM, the research communities all over the world showed keen interest in the SHEM, as according to them it shows much promising results in the saving of energy and making household efficient in the conservation of electrical energy and that make household and its consumers in reducing the cost on energy, spent in the household premises.

Though, full potentials of smart homes could not be achieved owing to its complex structural mechanism and diversity in the system as well as the problems of sub-optimal control system installed in the building premises. Consequently, energy consumption is still costly, and that is why the users are not able to get full comfort in their automated home.

The system should also be able to handle all the information being communicated in a secure fashion. Moreover, for better support DR can reduce the energy cost while satisfying the user comfort level, so intelligence algorithms should be incorporated in the system, Since the system is open-source, if there is a need for supporting a new smart device, a new communication protocol, or a desired capabilities, other developers and vendors can add support for that feature in the system.

References

1. Asare-Bediako, B., Kling, W. L., & Ribeiro, P. F. (2012). Home energy management systems: Evolution, trends and frameworks. In *Proceedings of the Universities Power Engineering Conference*.
2. Aman, S., Simmhan, Y., & Prasanna, V. (2013). Energy management systems: State of the art and emerging trends. *IEEE Communications Magazine, 51*(1), 114–119.
3. Uddin, M., & Nadeem, T. (2012). EnergySniffer: Home energy monitoring system using smart phones. In *IWCMC 2012 - 8th International Wireless Communications and Mobile Computing Conference*.
4. Agarwal, P., & Alam, M. A. (2018). Use of ICT for sustainable transportation. *IOP Conference Series: Earth and Environmental Science, 150*(1), 012032.
5. Bartram, L., Rodgers, J., & Muise, K. (2010). Chasing the negawatt: Visualization for sustainable living. *IEEE Computer Graphics and Applications, 30*(3), 8–14.
6. Batchu, R., & Pindoriya, N. M. (2015). Residential demand response algorithms: State-of-the-art, key issues and challenges. In *Lecture Notes of the Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering, LNICST* (Vol. 154).
7. Agarwal, P., Chopra, K., Kashif, M., & Kumari, V. (2018). Implementing ALPR for detection of traffic violations: A step towards sustainability. *Procedia Computer Science, 132*, 738–743.
8. Kailas, A., Cecchi, V., & Mukherjee, A. (2012). A survey of communications and networking technologies for energy management in buildings and home automation. *Journal of Computer Networks and Communications, 2012*, 932181.
9. Lobaccaro, G., Carlucci, S., & Löfström, E. (2016). A review of systems and technologies for smart homes and smart grids. *Energies, 9*(5), 348.
10. Agarwal, P., Hassan, S. I., Mustafa, S. K., & Ahmad, J. (2020). *An effective diagnostic model for personalized healthcare using deep learning techniques*. IGI-Global.
11. Khamphanchai, W., Pipattanasomporn, M., Kuzlu, M., & Rahman, S. (2016). An agent-based open source platform for building energy management. In *Proceedings of the 2015 IEEE Innovative Smart Grid Technologies - Asia, ISGT ASIA 2015*.

Solar Energy Radiation Forecasting Method

Anuj Gupta, Kapil Gupta, and Sumit Saroha

1 Introduction

Energy demands around the world are expected to have more than double by 2050 and to more than triple by the end of century. Growing improvements in the existing energy grid would not be enough to meet the world's energy demand. Global security, economic growth and the quality of life are closely related to sufficient supplies of clean energy. The most daunting challenges for the world is to find energy resources to meet the rising demands of the planet. Solar prediction is a milestone to these challenges. Solar prediction depend on several factors such as characteristics of solar power plants which convert sun's energy to electric power, scattering process, knowledge of the Sun's path, nature of atmosphere etc. [1]. Solar forecasting information is necessary for the operation and planning for the future. Forecasting information provide grid operators with means to forecast and align electricity production and consumption and set up bilateral contract negotiations between suppliers and customers. Precise prediction methods increase the quality of the energy supplied to the grid and reduce the extra costs associated with ancillary equipment [2]. Based on the input data types and forecasting time horizons requirement various prediction approaches are introduced. For a very short time scale, on-site measurements are sufficient for the time series model. Intra-hour forecast obtained from a ground based sky imager with a high spatial and temporal resolution. Cloud motion vector forecast based on intra-day satellite images shows good

A. Gupta (✉) · K. Gupta
Department of Electronics and Communication Engineering, Maharishi Markandeshwar (Deemed to be University), Mullana-Ambala, India

S. Saroha
Department of Electrical Engineering, Guru Jambheshwar University of Science and Technology, Hisar, India

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_7

results. These forecast based on NWP models. Photovoltaic system integrated with grid required information up to minimum 2 days ahead or even beyond. Different type of solar power systems exist in the solar forecasting such as solar concentrating system and solar non-concentrating system [3]. DNI is highly correlated to a concentrated photovoltaic system. Measurement of DNI is very important for the operation and management of concentrated solar thermal power plants. DNI is highly affected by the number of factors like as dust storms, air pollution, cirrus clouds which degrade the DNI up to 30%. For non-concentrated solar PV systems, the primary element to measure is GHI which is less sensitive to error in DNI.

2 Research Motivation

India is facing Energy crises along with the world. There is a substantial difference in energy demand and supply. As our country progresses towards development day by day, this gap is rising and addressing this situation is very important in order to continue the ascending direction of our country. In order to address this situation, a range of options with a strong emphasis on renewable energy are considered. A lot of researcher and academics are engaged in developing tools, models and algorithms in today solar system. In today's dynamic world forecasting is a critical part of business planning with greater penetration of renewable energy resources and implementation of power deregulation in industry. Forecasting of solar power has become a major issue in power systems. Following needs of the markets, various techniques are used to forecast the solar radiation. As a result, it is anticipated that the thorough analysis would assist potential researchers as well as utility operators in gaining useful insight into the need for solar power output and forecasting models. The knowledge gained can also assist the government and energy market participants in making more efficient and beneficial decisions regarding solar power system implementation.

3 Solar Radiation Component

Three essential and fundamentals component are assessed for measurement of the solar irradiance [4].

3.1 Direct Normal Irradiance

Direct Normal Irradiance can be defined as the total amount of solar radiation obtained in a direct path from the sun at the horizontal earth surface with no atmospheric losses. Such amount of radiation is very important for the concentration of solar thermal system like concentrated solar power and concentrated photo voltaic.

3.2 Diffuse Horizontal Irradiance

Diffuse Horizontal Irradiance can be characterized by as the amount of solar radiation obtained from the sun on an indirect path on the horizontal surface, when it has been spread by air molecules, aerosol particles, cloud particles or other particles [5].

3.3 Global Horizontal Irradiance

Global Horizontal Irradiance is the cumulative amount of radiation received by the surface horizontal to the ground [6]. It consists of both DNI and DHI.

The three fundamental component of solar irradiation can be related to each other using the following equation:

$$GHI = DNI + DHI \times COS(Z) \tag{1}$$

where Z represent the solar zenith angle.

4 Need of Solar Forecasting

The necessity of forecasting is for the operation and planning for the future. However the need of forecasting is given below

- Solar generation is variable in nature
- Necessity for successful bilateral contract negotiations between suppliers and customers
- Operational planning decision which are used to describe the economic location, type and scale of solar power plants
- Solar forecast provide grid operators with means to forecast and align electricity production and consumption
- Decision on expansion and enhancement of transmission, augmentation of generation, planning of distribution and exchange of regional electricity

5 Solar Forecasting Methodologies

The determinant factor for classifying methodologies for solar forecasting is different-2 forecast horizons. Precise forecasting can enable grid operators to create balance between consumption and production [7]. Table 1 shows three forms of horizons: intra-hour, intra-day, and day ahead.

1. For very short time scale various time series models such as an Artificial Neural Network, Autoregressive Integrated Moving Average, and Persistence model used for forecast solar irradiance [8, 9]
2. For short time irradiance forecasting, solar irradiance largely depend on the observation based on the temporal developments of clouds, may be used as a basis
   - For the sub-hour range, cloud data is collected from sky images ground based with high spatial resolution may be used to predict solar irradiance.
   - For 30 min up to 6 h solar irradiance depends on cloud motion vector from satellite photos.
3. For long term horizon, from 4–6 h ahead numerical weather prediction model perform better than the satellite based forecasts [9, 10]
4. There are also integrated techniques to derive an optimized forecast for the different-2 time horizon

6 State of Art for Solar Irradiance Forecast

As Per literature, forecasting methods are categorized into three types: statistical method, physical method and ensemble method.

6.1 Physical Methods

The physical methods are depending on the Total Sky Imagers (TSI), Numerical Weather Prediction (NWP) and physical parameters include temperature, cloudcover and humidity etc [11].

Table 1 Relationship between time horizon, prediction model and related operations

Horizon type	Forecast horizon	Granularity time step	Events	Forecasting models
Intra hour	15 min to 2 h	30 s to minute	Ramping events, variability related operations	Total sky imagers and /or time series modles and NWP models and /or satellite imagery
Intraday	1–6 h	Hourly	Load following forecasting	
Day ahead	1–3 day	Hourly	Unit commitment, transmission scheduling, day ahead markets	

Numerical Weather Prediction

The numerical weather prediction depends on atmospheric physics. For forecasting the future weather state, current observations of the weather are forecast using the assimilation process. NWP model performance is good for the horizons of 1 day to multi days ahead [12]. NWP process as follows:

– Step 1: In the initial stages, satellite and sky images ground based used to collect the current weather condition of an atmosphere. Assimilation process is used for processing the current weather state which is a very critical and complex process.
– Step 2: In the second phase, the most dominant atmospheric equation such as thermodynamic equation, Newton second law for fluids are integrated and solved [3].

Well, a known example of NWP models is worldwide model, regional model and weather research & forecasting model (WRF) model (Table 2). We can differentiate them in term of input parameters and spatial resolution [1].

Cloud Imagery and Satellite Models

The situations of clouds are analyzed by cloud imagery with high spatial resolution. They detect the variability of clouds and predict global irradiance up to 6 h ahead. Solar irradiance is highly affected by cloud cover and cloud optical depth. Information about the clouds helps to predict the solar irradiance using total sky imagers for very short term forecasting. Some researchers develop their own TSIs while other researchers use commercially available TSIs such as TSI-800 [4].

6.2 *Statistical Methods*

Prediction method depends on the previous time series data of solar irradiation as input and does not depend on the internal phase of the model. Persistence model, ARIMA, ANN, Fuzzy logic etc. include in the statistical method.

Table 2 Comparison of various NWP model

	Model	Time step	No. of layers	Resolution (km)	Agency
Mesoscale model	HRRR	15 min	50	3	NOAA
	NAM	6 h	60	12	NCEP
	RAP	1 h	50	13	NOAA
	WRF	Depends on user	Depends on user	1	NCAR
Worldwide model	ECMWF	3 h	91	25	–
	GFS	6 h	64	28	NOAA

Time Series Model

Time series model predicts future value by consider previously observed value. Observation measured over time it may be hourly, daily and weekly. The sequence of data could be random and mainly focus on the pattern of the data. The pattern of the data should be recognizable and predictable for forecasting techniques. Auto-correlation Function (ACF) & Partial Correlation Function (PCF) used to identifying the pattern [5].

Time series is expressed as:

$$y(t) = s(t) + R(t) + T(t) \quad \text{Where } \; t = -1, 0, 1, 2, 3\ldots\ldots\ldots\ldots\ldots \tag{2}$$

$S(t)$ = Seasonal term, $R(t)$ = Random term, $T(t)$ = Trend term Stock market, revenue forecasting, economic forecasting, budgetary analysis, sales forecasting also utilize the application of time series method.

One of the benchmark model in the solar irradiance forecasting is an ARIMA model. Moving Average (MA), Auto Regressive (AR), & Autoregressive Moving Average (ARMA) is the variants of the ARIMA model. First one is moving average and the second one autoregressive. ARIMA is the most commonly used model for evaluating the relationship between real and expected performance. ARIMA model is the statistical tool to analyze the relationship between actual and forecasted output. ARIMA use three main steps for the forecasting: model identification, estimation of parameters and diagnostic checking [6]. There are seasonal and non-seasonal time series models that can be used for forecasting. An ARIMA is describe by three elements: p, d, q. where "p" is for autoregressive term, "q" is for moving average term and d is the number of differencing required to make the time series stationary. Mathematically, Autoregressive AR can be expressed as:

$$\begin{aligned} y_t &= a + \sum_{i=1}^{p} \phi_i y_{t-i} + \varepsilon_t \\ &= a + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \ldots\ldots\ldots\ldots\ldots \phi_p y_{t-p} + \varepsilon_t \end{aligned} \tag{3}$$

y_t represents the actual value, ϕ_i is model parameter and ε_t represent the random error, a and p are the constant term. This equation represents the linear relationship between the predicted value and the past value with some random error and constant term.Whereas the Moving Average equation represent the past value as a dependent variable

$$y_t = \eta + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t = \eta + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \ldots\ldots\ldots\ldots \theta_q \varepsilon_{t-q} + \varepsilon_t \tag{4}$$

θ_j represent the model parameter, η represent the mean of the time series and q is the order of the model.

Combining Eqs. (1) and (2) become ARMA and mathematically can be expressed as

$$y_t = a + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t \tag{5}$$

Here p is for autoregressive and q is for moving average.

ARIMA is very popular for users due to the advantage of statistical expertise, the latest version of MATLAB makes it easier with the "Econometric Modeler app" available in MATLAB 2018 and 2019 [7]. In comparison to ARIMA, this approach requires an additional coefficient differencing operator, i.e. (p, d, q). The ARIMA's mathematical expression is

$$\phi(L)(1 - L)^d y_t = \theta(L)\varepsilon_t \tag{6}$$

ϕ and θ is model parameter, ε_t is random parameter and L denote lag operator and d represent differencing operator.

Persistence Model

It is also known as naïve predictor. Persistence model is very simple as comparison to other forecasting model. It forecast the future value based on previous value [8].

$$x_{t+1} = x_t \tag{7}$$

The performance of persistence model is better when changes in weather pattern are little.

Artificial Neural Network

The working of the neural network is similar to the human brain which takes the decision based on biological neurons. Neurons in the human brain perform the different-2 types of parallel processing, pattern recognition etc. The same phenomenon can be used to solve non-linear math problems in modeling, image analysis, and in other fields [10]. The ANN use different-2 algorithm to predict solar irradiation such as: scaled conjugate gradient, levenberg marquardt algorithm, pola-ribiere conjugate gradient etc. This techniques trained model to map the input and output to obtain the best value. Support vector machine, radial basis network, multilayer perceptron and Hopfield network include under the artificial neural network. ANN process is carried out in three stages: (1) Design phase (2) Training phase

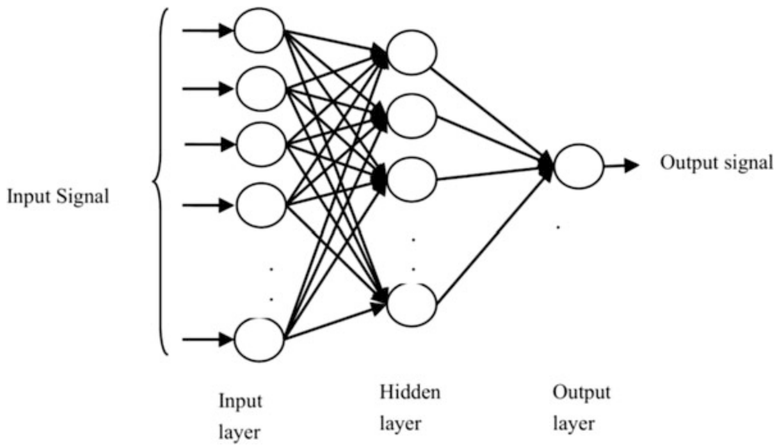


Fig. 1 Basic Architecture of ANN

(3) Validation phase. First stage consists of input parameters, neural network type, hidden neurons, In the training phase weight of the neuron are modified and in validation stage forecasting of solar irradiance based on trained weight [11]. Basic Architecture of artificial neural network is shown in Fig. 1.

The MLP structure is one of the important forms of neural network. This MLP structure consist an input layer, hidden layer and output layer. Hidden layer was characterized as a number of hidden neuron, input and output layer denoted by vector p & q respectively.

$$q = q(p : w) = \sum_{i=0}^{h} \left[w_i f \left(\sum_{j=0}^{d} w_{ij} x_j \right) \right] \tag{8}$$

$_j$ & i represent the weights and biases while vector $_w$ supervises the non-linear mapping. Babak Jahani et al. compared the empirical, artificial neural network and artificial neural network with a genetic algorithm optimization technique to predict the global solar radiation. The Genetic algorithm was used in the model to reduce the error in predictive results [13] Premalatha Neelamegam et al. proposed two artificial neural network model with different combinations of inputs, the accuracy of the model was measured based on MAE,RMSE and R^2 [14]. Voyant et al. presented a review of solar radiation forecasting using machine learning techniques. According to the author standalone models such as: artificial neural network, linear regression, random forest, support vector machine performed well in the forecasting field while hybrid model are viable way to improve the accuracy of prediction model [15].

Support Vector Machine

It is a form of machine learning introduced in 1995 by Cortes and Vapnik with statistical learning. Firstly, this particular approach is developed for pattern recognition and is now enthusiastically used for various technologies such as image retrieval, fault diagnosis, regression computation and forecasting etc. [16]. The time series is used to train a model that is as simple as neural network model and there is no question of over fitting curve, struck to local minima in SVM [17]. Essentially, it uses the mapping function to map the input vector ($x_1 + x_2 + x_3 + \ldots\ldots x_n$) to the output ($y_1 + y_2 + y_3 + \ldots\ldots y_n$). The equation with SVM can be represented as

$$y = \sum_{i=1}^{n} \phi_i k(x, x_i) + b \quad (9)$$

where y is output function and b is bias and the basic architecture of SVM shown in Fig. 2.

Jie shi et al. used SVM model to forecast the solar power. The entire data is dividing into four groups based on all seasons. The categorized data are feed into four SVM developed models. The performances of developed models are evaluated using RMSE and MAE and performance of all developed models outperform bench mark model [18].

Markov Chain

It represents a deterministic cycle that used to forecast wind and solar irrdiance. The procedure of deterministic cycle is essential reliant on the neighboring states i.e. the current state variables are dependent on the former one. Similarly, the next state variables are reliant on the current one [19] as shown in Fig. 3.

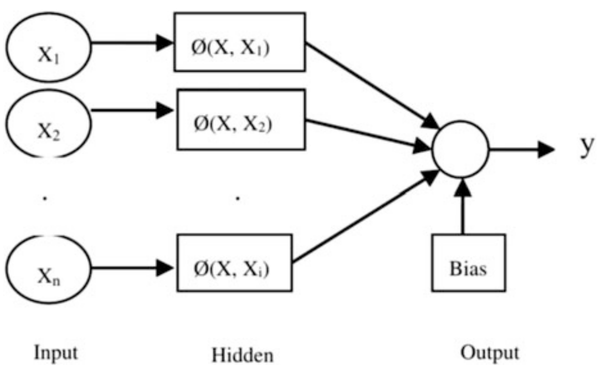


Fig. 2 Architecture of SVM

This procedure is described by a sequence of finite random digit. Let $\{y_n, n=0,1,2.........\}$. The sequence for the current state i at nth time can be shown as

$$y_n = i$$

Whereas the likelihood of next condition in j is P_{ij}. i.e.

$$p\{y_{n+1} = j|y_n = i, y_{n-1} = i_{n-1}, \ldots\ldots\ldots\ldots\ldots, y_1 = i_1, y_0 = i_0\} = P_{ij} \quad (10)$$

This equation shows the next state having the dependency on the present state.

To estimate the power of a photovoltaic device, Sanjari et al. developed a markov chain model. The input parameters were radiant energy and relative humidity. The proposed model outperforms other approaches in terms of MAPE results [20].

7 Empirical Model

Empirical modeling is a genetic term for activities that create model by observation and experiments. Samani and Hargreaves present first empirical model in 1982. Now number of model have evolved by changing the various factor such as altitude, latitude, angular position, tilt angle, air particle dispersion, water vapor content, hours of sunlight, max temp, lowest temperature, cloud cover index etc. Empirical model is a mathematical technique used to forecast solar irradiance by creating a linear or nonlinear connection between climatologically and solar variables [21]. Nadjem Bailek et al. addressed mathematical models for obtaining a accurate diffuse solar radiation. The developed models were dividing into three categories based on sunshine period and clearness index. The performance of all three models were evaluated using MAPE, RMSE and U95 (Uncertainty Factor) and compared with the eight models discussed in the literature [22].

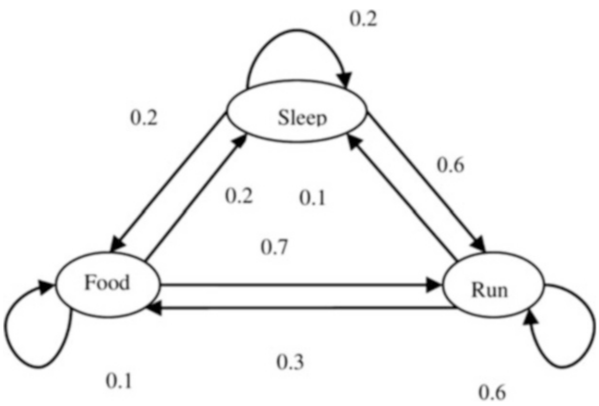


Fig. 3 Markov chain process

8 Deep Learning

This term deep learning introduced in 1986 by Rina Dechter & over the past years, deep learning has become very prevalent. It is also named as deep structured learning, is a branch of machine learning which intern is the subset of artificial intelligence; Machine learning is a technique for achieving artificial intelligence through algorithms trained with data, whereas artificial intelligence is a technique for enabling a machine to act like a person as shown in Fig. 4. On the other hand, Deep learning is a set of statistical machine learning techniques used to learn feature hierarchies which is often based on ANN. Here, learning can be supervised, unsupervised or semi-supervised. The application of deep learning algorithm such as: CNN, RNN and DBN are used in computer vision, image processing, audio recognition, speech recognition etc. [23].

Deep learning is a modern substitute for machine learning; we can have a variety of structured and unstructured data in various forms and aspects from every region of the world. Structural data can be easily drowned out while unstructured data could take decades to provide relevant information. Deep learning is used to deal with a huge amount of data simply known as big data which is taken from various medium such as social medium, online platform i.e. e-commerce, internet engine search so on. This abundance amount of data is smoothly accessible. It can be shared through fintech application such as mobile payment applications etc.

Wang et al. present a forecasted model using deep learning techniques. The author applies pre-processing technique to improve the performance of forecasted model [1]. Melit et al. conducted a review on machine learning techniques. According to the author, deep learning techniques and numerical weather forecast with extracting features use to generate long term photovoltaic power generation and for determine the time dependence information in forecasting the performance of convolution neural network and recurrent neural network were better [24].

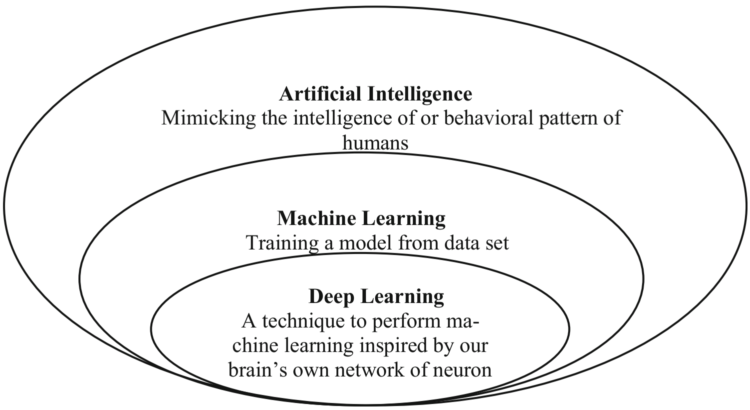


Fig. 4 Deep learning is a subset of machine learning

9 Hybrid Method

These models are used to enhancing the precision of forecasted models. There are many factors that are not considered in the individual model by a model needed to perform more accurately. The hybrid approach is about integrating two or more methods for determining the forecast. Various data decomposition techniques used with forecasted models to increase the accuracy of forecasted models [25] (Table 3).

10 Factors Influencing Solar Radiation Forecasting

There are some other factors/parameters that affect the accuracy of model forecasting directly or indirectly. The solar forecasting depends on forecast horizons, geographical condition, day/night value and normalization, testing period, climatic variability and pre-processing technique.

10.1 Input Parameter Selection

Solar energy is an important aspect of solar radiation forecasting but it is unavailable for many places due to measuring device cost, upkeep and calibration. So, we need input parameters for estimating the solar radiation. The input parameter may be temperature, pressure, humidity, solar zenith angle, precipitation, latitude, longitude, wind direction, wind speed, sunshine duration [48–50].

10.2 Forecast Horizon

The time horizon concept is concerned with the span of time duration which the model is used for prediction. Time duration can range from a few seconds to many hours. As per literature, four type of time horizon exist such as: very short term, short term, mid-term and long term forecasting [48–51].

10.3 Climatic Variability

The variables in the input data may be systemic, endogenous and exogenous. On various combinations of input parameter different model behave differently. The model's efficiency suffers as the number of insignificant meteorological variables used. As a result, the necessary parameters must be chosen to improve a model's efficiency. To predict solar radiation, M.A. Behrang et al. proposed two models using neural network based on various combinations of a climatologically variable [52].

Table 3 Study of solar forecasting techniques

Author (year)	Location	Input value	Prediction method	Time horizon	Evaluation metrics	Forecast variables	Results
A. Koca et al., 2011 [17]	Turkey	Latitude, longitude, month, cloud cover, wind speed	ANN	–	RMSE,R^2	Solar radiation	RMSE = 0.0358 R^2 = 0.9974
F. Wang et al., 2012 [26]	China	Third order difference of SI, T_m day, T_a	ANN	24–72 h ahead	MAPE, RMSE, MABE	Solar radiation	MAPE = 9.09–26.7% RMSE = 42.29–84.65 (W/m^2) MABE = 31.10–64.6 (W/m^2)
R. Hossain et al., 2012 [27]	Australia	Wind speed, wind direction, relative humidity, meteorological variables	ANN	3 h	R	WE,SE	R^2 = 0.96399
S. Bhardwaj et al., 2013 [28]	Gurgaon	AT,RH,AP,WS, WD,SR	HMM + GFM	N/A	MAPE, RMSE	Solar radiation	RMSE = 7.9 MAPE = 3.4
S. X. Chen et al., 2013 [29]	Singapore	T,SKI,SR	Fuzzy+ANN	1-h day	MAPE	PV power output	MAPE = 6.03%–9.65%
I. Colak et al., 2015 [30]	N/A	Time series	ARMA & ARIMA	1–3 step ahead	MAPE	Solar power	MAPE_ARMA = 72.67% MAPE_ARIMA = 33.07%
A. Wibun et al., 2016 [31]	Thailand	Global solar radiation, daily solar radiation, clear sky index	Markov transition matrix	Hourly	RMSE	Global solar radiation	Second order>first order
L. M. Aguiar et al., 2016 [32]	Spain	Meteorological data, NWP, satellite data	Neural network	1–6 h	RMSE	GHI	RMSE = 83.58%–147.88%
N. Kumar et al., 2017 [33]	India	WS, RH, P,SD, T_{max}, T_{min}	ANN + unity feedback RBF + LR	N/A	MAPE	Daily global solar radiation	MAPE = 14.84%–16.32%

(continued)

Table 3 (continued)

Author (year)	Location	Input value	Prediction method	Time horizon	Evaluation metrics	Forecast variables	Results
S. Li et al., 2017 [34]	FortPeck, Montana	Time series data	Discrete Markov chain	Seasonal	% error	TSRY	% Error lies between 10% to 6%
C. R. Chen et al., 2017 [35]	Taiwan	Temp., relative humidity, wind speed, wind direction	Neural network	60 min	MBE, RMSE	GSI	RMSE = 232 (W/m^2) MABE = 32 (W/m^2)
M. Bou-Rabee et al., 2017 [36]	Kuwait	Time series data	GD algorithm, LM algorithm	N/A	MAPE	Solar radiation	MAPE = 86.3%
M.. Guermoui et al., 2018 [37]	NEA, Singapore	Maximum elevation, declination, angle day duration	WGPR-CFA WGPR-PFA	N/A	RMSE,r^2	GHR, DHR	RMSEGHR = 3.18 (MJ/m^2) r^2GHR = 85.85% RMSEDHR = 5.23 (MJ/m^2) r^2DHR = 56.21%
H. Verbois et al., [38] 2018	Singapore	NWP	NWP + PCA	1-day	RMSE, rMSE, MAE, rMAE	SI	RMSE = 169 (W/m^2) rRMSE = 35.7% MAE = 193 (W/m^2) rMAE = 28.1%
L. Benali et al., 2019 [39]	France	Time series data	SP,ANN,RF	1–6 h ahead	Nrmse, MSE, MAE, nMAE	PV power	nRMSE can by improved by 20%
Persson et al., 2017 [40]	Japan	Historical data, NWP data	Gradient boosted regression tress	1-h	nRMSE	Solar power generation	Nrmse = 0.1–0.137 kW
L. Cornejo-Bueno et al., 2019 [41]	Spain	Clear sky, irradiance, CI	ELM	1-h ahead	RMSE	GSR	RMSE = 60.60 W/m^2

A.T. Eseye et al., 2018 [42]	China	Temperature, cloud cover, relative humidity, wind speed	Wavelet-PSO-SVM	1 day	MAPE	Solar PV power	MAPE = 4.22%
K. R. Kumar et al., 2018 [43]	Andhrapradesh, India	Temperature,pressure,wind speed	ANN.ANFIS	–	% error	PV power	ANN > ANFIS
F. Rodriguez et al., 2018 [44]	Euskalmet	Atmospheric pressure, relative humidity, temperature	ANN	N/A	RMSE	Solar irradiation	RMSE = 0.03%
D. Liu et al., 2019 [25]	GEFcom 2014	Meteorological data	Random Forest+ PCA	1–3 step ahead	RMSE, MAE	PV power	RMSE = 8.88–9.82% MAE = 4.76–5.80%
W. Vandeventer et al., 2019 [45]	Australia	Ambient temperature, solar irradiation	GASVM	Hourly	RMSE, MAPE	PV power	RMSE = 11.226WMAPE = 1.7052%
A. Shadab et al., 2019 [46]	New Delhi	Time series	SARIMA	Month	MPE	Solar radiation	MPE = 1.402
S. Ghimire et al., 2019 [23]	Australia	Past global solar radiation	CNN + LSTM	30 min	MAPE, APE, rRMSE	Solar radiation	MAPE = 4.672% APE = 1.233% Rrmse = 1.515%
Y. Liu et al., 2020 [21]	China	Sunshine ration, average temperature, relative humidity	SVM Empirical model	–	RMSE, MABE, MBE,R^2	Solar radiation	SVM > CNQR>empirical model
J. Dong et al., 2020 [47]	Oak Ridge National Laboratory	Past PV	Uncertainty bias +kalman filter	1-50 min	MAPE, nRMSE	Solar radiation PV power	MAPE = 5.72–25.75% Nrmse = 7.43–26.13%

10.4 Night Hour and Normalization

The solar irradiance is not available in the night hours. But energy providers required PV production continuous at all times. The bulk of the test took place during the day time and omitted the night time hours. To avoid the effects of inaccurate readings, the time just after sunrise and just before sunset were also excluded from the data collection [53].

10.5 Preprocessing Techniques

The quality of input data plays crucial role in the enhancement of forecasted model. The data collection from various sites mostly available in raw format and does not have a significant characteristics to provide appropriate accuracy. So, the data has to be process before processing with the model called preprocessing stage. Here, the preprocessing means scale up or down the input measurements, clean up and define the input data accordingly to the specifications. There are number of preprocessing techniques available in the literature such as: wavelet transforms kalman filter, empirical mode decomposition, self organization map, normalization, trend free time series which were used before the model learning [54].

10.6 Training and Testing Period

The training and testing cycle is also one of the factors which affect the accuracy of the model. Various studies have shown that the large collection of training data set enhance the learning capacity and also improve the accuracy. B. Sivaneasan et al. used 4 months data set to train the model and 1 month data set is used to test the model [55] whereas Mohammed Bou-Rabee et al., used 3 years data to train and 1 year data to test the model [36].

10.7 Geographical Location

The behavior of the model varies according the geographical location. The model performance directly affected by the area or locations having certain/uncertain climatic conditions like Leh, India where the cold desert receives the enormous amount of solar radiation may perform better than the area having most of the cloud in the sky [14].

11 Solar Forecasting Evaluation Metrics

Various evaluation metrics have used by researchers to predict solar irradiation value. The aim of the evaluation metrics is to compare the actual observed value with the forecasted value. Different performance metrics have different units; for example, the statistical error of solar radiation is measured in W/m^2, whereas power is measured in KW or MW. The forecast evaluation provides a forecaster with:

- The ability of selecting correct forecasting model so, that the maximum prediction accuracy can be achieved as comparison to others.
- Forecasters analyze forecasting error and utilizing it for improving performance of forecasting model.

Forecasting model accuracy is the primary concern for the forecaster and it can be evaluated by using the following Conventional Statistical Assessment Metrics:

- **Normalized Error:**
  It is indicate by Ne and is used to identify outliers in a set of data used. Mathematically it is represented as [26]

$$nE = \frac{R_{prediction} - R_{real}}{\max\left(R_{prediction}\right)} \tag{11}$$

- **Mean Bias Error:**
  This metric is used to measure the system's or model's average bias [56].

$$MBE = \frac{1}{n}\sum_{i=1}^{n}\left(R_{prediction,i} - R_{real,i}\right) \tag{12}$$

  The MBE positive value indicates that the model is overestimation whereas the negative value represents the underestimation.
- **Mean Absolute Error (MAE):**
  It provides uniform forecasting error. This metric provides a difference between two set of data [57].

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|R_{prediction,i} - R_{real,i}\right| \tag{13}$$

- **Standard Deviation Error (SDE):**
  This metric is used to assess the deviation from the average [42].

$$SDE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(R_{prediction,i} - R_{real,i} - MBE\right)^2} \tag{14}$$

- **Root Mean Square Error (RMSE):**
  It is a metric for determining the largest expected error in the forecasted data [58].

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(R_{prediction,i} - R_{real,i}\right)^2} \tag{15}$$

- **Mean Absolute Percentage Error (MAPE):**
  It is a metric for uniform forecasting error expressed as a percentage [56]

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{R_{prediction,i} - R_{real,i}}{R_{real,i}}\right| \tag{16}$$

- **Mean deviation Absolute Percentage Error (Md-APE):**
  Outliers have less of an effect on this metric than they do on the MAPE [59].

$$MdAPE = median\left(\left|100.\frac{R_{forecast} - R_{real}}{R_{real}}\right|\right) \tag{17}$$

- **Relative root mean square error (Rrmse):**
  It is a metric for determining the largest expected error in the forecasted data set [59]

$$Rrmse = \frac{RMSE}{R_{real}} \times 100 \tag{18}$$

- **Correlation Coefficient**
  This metric is used for representation a connection between two set of data.
  Forecasted Model's ability is better if the value of correlation coefficient is high. The optimal correlation coefficient value is 1 [60]

$$\rho = \frac{\left(Conv\left(R_{real}R_{prediction}\right)\right)^2}{Var} \tag{19}$$

where R_{real} represent real radiation value and $R_{prediction}$ represent predicted radiation value.

- **Determination Coefficient**
  It is used to derive knowledge about the association between predicted and actual values and this metric is denoted by R^2 [61]

$$R^2 = 1 - \frac{\operatorname{var}\left(R_{real} - R_{prediction}\right)}{\operatorname{var}\left(R_{prediction}\right)} \tag{20}$$

- **Clear Sky Index**
  It is defined as the proportion of measure radiation to the clear sky radiation

$$K_t = \frac{R_{real}}{R_{real(CKS)}} \tag{21}$$

11.1 Contemporary Statistical Metrics

The MAPE, MAE and RMSE cannot distinguish the two different data sets with the same mean and standard deviation but having varying consistency or skewness distributions and Kurtosis. However, traditional metrics are required to measure the system but other parameters such as skewness, kurtosis may affect the real time procedure.

- **Kolmogorov-Smirnov test integeral (KSI) and OVER metrics**
  The Kolmogorov-Smirnov test is used to distinguish the relationship between two data sets. The distinction between two CDFs is represented as [62].

$$D = \max\left|F_{(ni)} - \widehat{F}_{(ni)}\right| \tag{22}$$

F represent the actual data set for solar power generations and $\widehat{F}$ represents the predicted solar power generation data set. D statistics define the disparity between one sample and the reference sample is smaller than the target value (V_c). The target value depends on the amount of points in the estimation of the data series, measured at a confidence level of 99% [62].

$$V_c = \frac{1.63}{\sqrt{N}} N \geq 35 \tag{23}$$

The distinction between the two CDFs of real and forecasted energy is specified for each phase

$$D_j = \max\left|F_{ni} - \widehat{F}_{ni}\right| \text{where j} = 1, 2, 3 \ldots\ldots\ldots \text{m} \tag{24}$$

Where $P_i \in [P_{\min} + (j-1)d, p_{\min} + jd]$.

The period difference d is calculated as follows:

$$d = \frac{P_{\max} - P_{\min}}{m} \tag{25}$$

The KSI factor is represent as the distinction between two CDFs calculated as

$$KSI = \int_{x_{\max}}^{x_{\min}} D_n dx \tag{26}$$

The actual value and the predicted value are identical when the KSI is lower [62] D_n represent the distinction between the two CDFs.

- **OVER**

  It is used to define the difference between the cumulative distribution function of real and predicted solar value [59].

$$OVER = \int_{x_{\max}}^{x_{\min}} Tdt \tag{27}$$

Where $x_{\min}$ and $x_{\max}$ represent the minimum and maximum radiation value and t is represented as

$$T = \{T_j - U_c \;\; if \;\; D_j > U_c$$
$$\{0 \quad if \;\; D_j < \mathrm{U_c}$$

$\mathrm{U_c}$ represent the critical value.

- **Skewness and Kurtosis**

  The assessment of incongruity in a probability distribution is skewness [55].

$$\gamma = E\left|\left(\frac{e - \mu_e}{\sigma_e}\right)^2\right| \tag{28}$$

e = difference between the forecast solar power and real solar power μ_e indicate mean error and σ_e represent the standard deviation error.

Kurtosis: It is a metric used for assessing the magnitude of the distribution

$$K = \frac{\mu_4}{{\sigma_e}^4} - 3 \tag{29}$$

K is the kurtosis, μ_e represent the mean and σ_e denote standard deviation error.

- **Uncertainty Quantification**

  Renyi entropy of solar forecast error: The Renyi entropy is used to quantify the degree of uncertainty in solar prediction and expressed as [63, 64]

$$H_a(x) = \frac{1}{1-a} \log_2 \sum_{i=1}^{n} P_i^{\,a} \tag{30}$$

  a represent the scale of Renyi entropy and P_i represent the probability distribution function. Larger Renyi entropy value indicate more ambiguities present in the expected outcome.

- **Metrics for Ramp Characterization**

  The main priority associated with grid operators is to maintain a constant solar power output because a number of fluctuations occurred in the solar output due to variability of weather events. Solar ramps also influenced by different time and geographic factors, they can be up ramp or down ramp. The accurate solar forecasting help to overcome these types of uncertainties [65].

  In case of Ramp Characterization Florita et al. developed a signal compression algorithm in which used to extract ramp interval into a sequence of power cycle by specifying the beginning and finishing point of each ramp [66].

- **Ramp Detection Index (RDI)**

  This metric is used to measure the caliber of a model to predict ramps in a short time frame [67].

$$RDI = \frac{N_{hit}}{N_{hit} + N_{miss}} \tag{31}$$

  Where N_{hit} represent the total number of strike counts

  N_{hit} + N_{miss} represent the cumulative number of times a ramp appears.

- **Ramp Magnitude (RM)**

  It is used to measure the difference between radiation value at current time and after small time with respect to the clear sky radiation value of the current time. Chu et al. study the concept of ramp magnitude in their research paper to explore the caliber to predict ramps [68]

$$RM = \frac{R_h(t) - R_h(t + \Delta t)}{R_{csk}(t)} \tag{32}$$

12 Conclusion

This study conducts on several statistical, physical and ensemble methods. NWP models, satellite based models and cloud Imagery are studied in the case of physical method. These models are used for long-term forecasting horizons ranging from a few hours to several days and are ideal for circumstances where no other information is available. The only downside of the physical approach is that they are suffering from spatial and temporal resolution. Various time series and learning model discussed in the statistical model. In the time series method, the observation is measured over time. AR, MA, ARMA, ARIMA included in the time series model. Learning model include Markov chain, artificial neural network, support vector machine which provide excellent information about the solar irradiance when enough historical data is available. Nowadays, a hybrid method is used to overcome the shortcomings of individual model. These techniques also reduce the forecasting error. For evaluating the performance of prediction model various error metrics are discussed. Solar prediction error assessments allow understanding the model and re-evaluating it in case of high error.

References

1. Kleissl, J. (2013). *Solar energy forecasting and resource assessment*. Academic.
2. Kostylev, V., & Pavlovski, A. (2011). Solar power forecasting performance towards industry standards. In *Proceedings of 1st International Workshop on Integration of solar power into power systems,* Aarhus, Denmark.
3. Mentzer, J. T., & Hoon, M. A. (2004). *Sales forecasting management: a demand management approach*. Sage.
4. Diagne, H. M., David, M., Lauret, P., Bolan, J., & Schmutz, N. (2013). Review of solar irradiance forecasting methods and a proposition for small-scale insular grids. *Renewable and Sustainable Energy Reviews, 27*, 65–76.
5. Mentzer, J. T., & Hoon, M. A. (2004). *Sales forecasting management: a demand management approach*. Sage.
6. Bacher, P., Madsen, H., & Nielsen, H. A. (2009). Onilne short-term solar power forecasting. *Solar Energy, 83*(10), 1772–1783.
7. *Econometric Modeler App Overview-MATLAB & Simulink-MathWorks India*. https://in.mathworks.com/help/econ/econometric-modeler-overview.html.
8. Hunand, R., Hunag, T., Gadh, R., & Li, N. (2012). Solar generation prediction using the ARMA model in a laboratory-level Micro-grid. In *IEEE Third International Conference on Smart Grid Communications (SmartGridComm)*, Tainan (pp. 528–533).
9. Xie, Y. (2011). Values and limitations of statistical models. *Research in Social Stratification and Mobility, 29*(3), 343–349.
10. Haykin, S. (2008). *Neural networks and learning machines*. Prentice Hall.
11. Khosravi, A., Nunes, R. O., Assad, M. E. H., & Machado, L. (2018). Comparison of artificial intelligence methods in estimation of daily global solar radiation. *Journal of Cleaner Production, 194*, 342–358.
12. Koca, A., Oztop, H. F., Varol, Y., & Koca, G. O. (2011). Estimation of solar radiation using artificial neural networks with different input parameters for Mediterranean region of Anatolia in Turkey. *Expert System with Applications, 38*(7), 8756–8762.

13. Jahani, B., & Mohammadi, B. (2019). A Comparison between the application of empirical and artificial neural network methods for estimation of daily global solar radiation in Iran. *Theoretical and Applied Climatology, 137*(1–2), 1257–1269.
14. Premalatha, N., & Arasu, A. V. (2016). Prediction of solar radiation for solar system by using artificial neural network (ANN) models with different back propagation algorithm. *Journal of Applied Research Technology, 14*(3), 206–214.
15. Voyant, C., et al. (2017). Machine learning method for solar radiation forecasting: A review. *Renewable Energy, 105*, 569–582.
16. Zendehboudi, A., Baseer, M. A., & Saidure, R. (2018). Application of support vector machine models for forecasting solar and wind energy resources: A review. *Journal of Cleaner Production, 199*, 272–285.
17. Hargreaves, G. H., & Samani, Z. A. (1982). Estimation potential Evapo-transpiration. *Journal of the Irrigation and Drainage Division, 108*(3), 225–230.
18. Shi, J., Lee, W. J., Liu, Y., Yang, Y., & Wang, P. (2012). Forecasting power output of photovoltaic systems based on weather classification and support vector machine in. *IEEE Transactions on Industry Applications, 48*(3), 1064–1069.
19. Wan, C., Zhao, J., Song, Y., Xu, Z., Lin, J., & Hu, Z. (2016). Photovoltaic and solar forecasting for smart grid energy management. *CSEE Journal of Power and Energy Systems, 1*(4), 38–46.
20. Sanjari, et al. (2017). Probabilistic forecast of PV power generation based on higher order Markov chain. *IEEE Access, 32*, 2942–2952.
21. Liu, Y., Zhou, Y., Chen, Y., Wang, D., Wang, Y., & Zhu, Y. (2020). Comparison of support vector machine and copula-based nonlinear quantile regression for estimating the daily diffuse solar radiation: A case study in China. *Renewable Energy, 146*, 1101–1112.
22. Quansah, E., et al. (2014). Empirical models for estimating global solar radiation over the Ashanti region of Ghana. *Journal of Solar Energy, 14*, 1–6.
23. Ghimire, S., Deo, R. C., Downs, N. J., & Raj, N. (2019). Global solar radiation prediction by ANN integrated with European centre for medium range weather forecast fields in solar rich cities of Queensland Australia. *Journal of Cleaner Production, 216*, 288–310.
24. Melit, A., et al. (2020). Advanced methods for photovoltaic output power forecasting, A review. *Applied Science, 10*, 487.
25. Liu, D., & Sun, K. (2019). Random forest solar power forest based on classification optimization. *Energy, 187*, 115940.
26. Wang, F., Mi, Z., Su, S., & Zhao, H. (2012). Short-term solar irradiance forecasting model based on artificial neural network using statistical feature parameters. *Energies, 5*(5), 1355–1370.
27. Hossain, R., Oo, A. M. T., & Ali, A. B. M. S. (2012). Historical weather data supported hybrid renwable energy forecasting using Artificial Neural Network (ANN). *Energy Procedia, 14*, 1035–1040.
28. Bhardwaj, S., et al. (2013). Estimation of solar radiation using a combinations of Hidden Markov Model and generalized Fuzzy model. *Solar Energy, 93*, 43–54.
29. Chen, S. X., Gooi, H. B., & Wang, M. Q. (2013). Solar radiation forecast based on fuzzy logic and neural networks. *Renewable Energy, 60*, 195–201.
30. Colak, I., Yesilbudak, M., Genc, N., & Bayindir, R. (2016). Multiperiod predictions of solar radiation using ARMA and ARIMA models. In *Proceeding-2015 IEEE 14th International conference on Machine Learning and Applications, ICMLA 2015* (pp. 1045–1049).
31. Wibun, A., & Chaiwiwatworakul, P. (2016). An estimation of Thailand's hourly solar radiation using Markov transition matrix method. *Applied Mechanics and Materials, 839*, 29–33.
32. Aguiar, L. M., Pereira, B., Lauret, P., Diaz, F., & David, M. (2016). Combinning solar irradiance measurements,satellite-derived data and a numerical weather prediction model to improve intra-day solar forecasting. *Renewable Energy, 97*, 599–610.
33. Kumar, N., Sinha, U. K., Sharma, S. P., & Nayak, Y. K. (2017). Prediction of daily global solar radiation using Neural Networks with improved gain factors and RBF Networks. *International Journal of Renewable Energy Research, 7*(3), 1235–1244.

34. Li, S., Ma, H., & Li, W. (2017). Typical solar radiation year construction using k-means clustering and discrete time Markov chain. *Applied Energy, 205*, 720–731.
35. Chen, C. R., & Kartini, U. T. (2017). k-nearest neighbor neural network models for very short term global solar irradiance forecasting based on meteorological data. *Energies, 10*(2), 186.
36. Bou-Rabee, M., Sulaiman, S. A., Saleh, M. S., & Marafi, S. (2017). Using artificial neural networks to estimate solar radiation in Kuwait. *Renewable and Sustainable Energy Reviews, 72*, 434–438.
37. Guermoui, M., Melgani, F., & Danilo, C. (2018). Multi-step ahead forecasting of daily global and direct solar radiation: A review and case study of Ghardaia region. *Journal of Cleaner Production, 201*, 716–734.
38. Verbois, H., Huva, R., Rusydi, A., & Walsh, W. (2018). Solar irradiance forecasting in the tropics using numerical weather prediction and statistical learning. *Solar Energy, 162*, 265–277.
39. Benali, L., Notton, G., Fouilloy, A., Voyant, C., & Dizene, R. (2019). Solar radiation forecasting using artificial neural network and random forest methods: Application to normal beam, horizontal diffuse and global components. *Renewable Energy, 132*, 871–884.
40. Persson, C., Bacher, P., Shiga, T., & Madsen, H. (2017). Multi site solar power forecasting using gradient boosted regression trees. *Solar Energy, 150*, 423–436.
41. Cornejo-Bueno, L., Casanova-Mateo, C., Sanz-Justo, J., & Salcedo-Sanz, S. (2019). Machine learning regressor for solar radiation estimation from satellite data. *Solar Energy, 183*, 768–775.
42. Eseye, A. T., Zhang, J., & Zheng, D. (2018). Short-term photovoltaic solar power forecasting using a hybrid wavelet-PSO-SVM model based on SCADA and meteorological information. *Renewable Energy, 118*, 357–367.
43. Kumar, K. R., & Kalavathi, M. S. (2018). Artificial intelligence based forecast models for prediction solar power generation. *Materials Today: Proceedings, 5*(1), 796–802.
44. Rodriguez, F., Fleetwood, A., Galarza, A., & Fontan, L. (2018). Predicting solar energy generation through artificial neural networks using weather forecasted for microgrid control. *Renewable Energy, 126*, 855–864.
45. Van Deventer, W., et al. (2019). Short-term PV power forecasting using hybrid GASVM technique. *Renewable Energy, 140*, 367–379.
46. Shadab, A., Said, S., & Ahmad, S. (2019). Box-Jenkins multiplicative ARIMA modeling for prediction of solar radiation: A case study. *International Journal of Energy Water Resources*, *3*, 305–318.
47. Dong, J., et al. (2020). Novel stochastic methods to predict short term solar radiation and photovoltaic power. *Renewable Energy, 145*, 333–346.
48. Voyant, C., & Notton, G. (2018). Solar irradiation now casting by stochastic persistence: A new parsimonious simple and efficient forecasting tool. *Renewable and Sustainable Energy Reviews, 92*, 343–352.
49. Jiang, F., et al. (2017). Artificial intelligence in healthcare: Past, present and future. *Stroke and Vascular Neurology, 2*(4), 230–243.
50. Bowing, H., Xiong, J. N., & Yinzhao, C. (2015). The mid-term forecast method of solar radiation index. *Chinese Astronomy and Astrophysics, 39*(2), 198–211.
51. Yang, D. (2019). A guideline to solar forecasting research practice: Reproducible, operational, probabilistic or physically based ensemble and skills (ROPES). *Journal of Renewable and Sustainable Energy, 11*(2), 022701.
52. Behrang, M. A., Assareh, E., Ghanbarzadeg, A., & Noghrehabadi, A. R. (2010). The potential of different artificial neural network techniques in daily global solar radiation modeling based on meteorological data. *Solar Energy, 84*(8), 1468–1480.
53. Paulescu, M., & Paulscu, E. (2019). Short term forecasting of solar irradiance. *Renewable Energy, 143*, 985–994.
54. Monjoly, S., Andre, M., Calif, R., & Soubdhan, T. (2017). Hourly forecasting of global solar radiation based on multiscale decomposition methods: A hybrid approach. *Energy, 119*, 228–298.

55. Sivaneasan, B., Yu, C. Y., & Goh, K. P. (2017). Solar forecasting using artificial neural network with fuzzy logic pre-processing. *Energy Procedia, 143*, 727–732.
56. Willmott, C. J., & Matsuura, K. (2005). Advantage of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance. *Climatic Research, 30* (1), 79–82.
57. Zhang, J., Hodge, B. M., Florita, A., Lu, S., Hamann, H. F., & Banunarayanan, V. (2013). Metrics for evaluating the accuracy of solar power forecasting. In *3rd International Workshops on Integration of Solar Power into Power Systems* (Vol. 17436, pp. 1–10).
58. Lauret, P., Voyant, C., Soubdhan, T., David, M., & Poggi, P. (2015). A benchmarking of machine learning technique for solar radiation forecasting in an insular context. *Solar Energy, 112*, 446–457.
59. Sobri, S., Koohi-Kamali, S., & Rahim, N. A. (2018). Solar photovoltaic generation forecasting methods: A review. In *Energy conversion and management* (Vol. 156, pp. 459–497). Elsevier.
60. Hyndman, R. J., & Koehler, A. B. (2006). Another look at measure of forecast accuracy. *International Journal of Forecasting, 22*(4), 679–688.
61. Bouzgou, H., & Gueymard, C. A. (2019). Fast short term global solar irradiance forecasting with wrapper mutual information. *Renewable Energy, 133*, 1055–1065.
62. Espinar, B., Ramirez, L., Drews, A., Bayer, H. G., Zarzalejo, L. F., Polo, J., & Martin, L. (2009). Analysis of different comparison parameters applied to solar radiation data from satellite and German radiometric stations. *Solar Energy, 83*(1), 118–125.
63. Bessa, R. J., Miranda, V., Botterud, A., & Wang, J. (2011). Good or bad wind power forecast: A relative concept. *International Journal on Wind Energy, 14*(5), 625–636.
64. Hodge, B. M., Orwig, K., & Milligan, M. (2012). Examining information entropy approaches as wind power forecasting performance metrics. In *12th International Conference on Probabilistic Methods Applied to Power Systems*, Istanbul, Turkey (pp. 1–6).
65. Mills, A., & Wiser, R. (2010). *Implications of wide area geographic diversity for short-term variability of solar power*. Report on Environment Energy Technologies Divison, Ernest Orlando Lawrence Berkeley National Laboratory.
66. Florita, A., Hodge, B. M., & Orwig, K. (2013). Identifying wind and solar ramping events. In *IEEE Green Technologies Conference* (pp. 147–152).
67. Caldas, M., & Alonso-Suarez, R. (2019). Very short term solar irradiance forecast using all-sky imaging and real time irradiance measurements. *Renewable Energy, 143*, 1643–1658.
68. Chu, Y., Pedro, H. T. C., Li, M., & Coimbra, C. F. M. (2015). Real-time forecasting of solar irradiance ramps with smart image processing. *Solar Energy, 114*, 91–104.

Electric Vehicles for Environmental Sustainability

Iflah Aijaz and Aijaz Ahmad

1 Introduction

Prior to actually constructing automobiles with an internal combustion engine, the automobiles, fitted with an automatic transmission, were made. In 1830–1840, the first prototypes were manufactured and were sloppy and unstable modules that operated at very low speeds [1]. Transportation, especially the burning of gasoline and diesel in cars, has played an increasingly important role as a cause of national and global air pollution since 1970. More than 95% of road vehicles is dependent on gasoline and contributes for almost 50% of petroleum consumption worldwide [2]. In the Economic Cooperation and Development, for the number of fuel vehicles, the total vehicle ownership statistics are over 450 cars per 1000 people; and in some developing countries there are even more cars per person. In countries such as the United States, this figure is also growing [3]. Fuel use has been growing steadily for the past few years. Growing volumes of automotive use, the rise of heavy duty vehicle use, and a change from private commercial vehicles to private light-duty trucks, buses, and Sport Utility Vehicles have mostly induced this [4]. The demand for diesel engines is constantly escalating internationally. In 2030, small engine diesel vehicles with sophisticated internal combustion motors are projected to win about 6% of the emerging US demand for cars and light trucks [5]. Diesel vehicles and petrol engines are the primary types of motors we have currently. There is a rising issue in fuel usage, especially gas and diesel, as more than 90% of road vehicles use gasoline and diesel engines nowadays. Every type of fuel has its

I. Aijaz (✉)
Department of Computer Science and Engineering, Jamia Hamdard, New Delhi, India

A. Ahmad
Department of Electrical Engineering, National Institute of Technology, Srinagar, India
e-mail: aijaz54@nitsri.net

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_8

advantages and poor implications. Such harmful contaminants have been linked to severe illnesses. Consequences include early mortality, failure of respiration, reduced function of the lungs and heart disease [6]. Carbon Dioxide also has a strong atmospheric influence and leads to global warming. This massive rise of vehicle populations would put tremendous environmental stress in numerous ways on regional and global levels, especially triggering air pollution. Some energy sources have also been developed as the quantity of fossil fuels declines some of which are still very much in new requirement, such as methanol. These alternative energy sources can decrease reliance on fossil fuels, and certain global problems can be minimized by the use of these energy sources, including the use of electric cars without pollutants.

In the early 1990s, the concept smart city was introduced. This concept covers urban planning with recent technological advances, creativity, and modernization that have changed. The main achievement is to the adaptation of the late 1990s smart growth trend. This has encouraged increased spatial planning and the use of enhanced Wi-Fi-enabled equipment. In the modern global knowledge economy, this is vital for development. The management of public utilities and facilities used in houses, infrastructure, power and water delivery, and community security are also combined [7].

At the forefront of next-generation mobility are electric vehicles (EVs). At global panels, this so-called magical approach is widely addressed with a growing emphasis on renewable energy and use on the global level. Eventually, governments and green campaigners are trying to pin great standards on EVs with developing cities on the brink of suffocation [8]. The ability of electric cars to reduce contaminant emissions in the urban environment is a significant explanation for promoting their use in the private car market. This concern encompasses only comparatively to greenhouse gas emissions, and particularly to carbon dioxide. Evidently, given that a significant proportion of electricity is provided by fossil fuel power plants and that the effect of greenhouse gases needs to be viewed internationally, the potential reduction of the overall CO_2 released by the passenger vehicles in the urban world should be calculated [9].

The economist magazine officially appointed the next group disruptor in the business world, that is, climate change and they have a point as the Covid-19 pandemic showed us how difficult it would be to cope with climate change [10]. It has caused economic activity to cease and the carbon dioxide emissions associated with electricity have dropped significantly. But even a substantial reduction in this year's overall carbon dioxide production is projected to only trigger a drop of 4–7%. Nevertheless, in order to meet the target of the 2015 Paris Agreement that restricts global warming well below 2 °C, we will have to reduce our greenhouse gas emissions in the next 30 years by another 90% [11]. The European Union's long-term plan is to become climate stable by 2050. The 2030 climate and energy system is the first step. The new goal is, as part of the European Green Deal, to reduce greenhouse gas emissions by 40% in just 10 years [12]. The European Commission recently suggested that this goal be further increased to a 55% reduction and that the Green Recovery Plan be adopted [13]. It is expected that the Green Recovery Plan will help economic growth in a more sustainable way. But halting the economy is not an alternative, so we need technological improvements to achieve these goals. Each year, a single car can easily release a few tons of carbon dioxide into the atmosphere. Road transport actually accounts for 12% of the world's overall greenhouse gas emissions, so these technological advances could also have an effect on road transport. Such improvements will provide many new problems and many new possibilities to address them and see how telematics will support management by calculation. The 2020 year will be remembered for the pandemic, but this year will also be remembered where fleet electrification has really gained traction in Europe, making it the largest EV market in the world. Europe is already on its journey to surplus China, leading the charge since 2015, with EV sales every month at record high levels [14]. Electric vehicle energy obviously needs to be brought from somewhere. The large bulk of electric energy would have to come from the power grid if battery electric cars are widely adopted, in which most energy generation currently emerges from the combustion of fossil fuels [15]. Only around 10% of the energy used throughout the grid is currently supplied by sustainable energy sources, so that majority of the electricity used to charge electric vehicles would be acquired from the from power plants that burn fossil fuels such as coal, gas, and gasoline [16]. In modern power plants, conversion efficiency for generating electricity from fossil fuels is usually around 45%, far better unlike fuel cars [8]. This must, indeed, be delivered to the customer and the average quality of propagation, together with communication over local and small voltage setups, is about 90%. This suggests that the real performance of translating the chemical fuel oil at the power plant to energy at the electronic connectors of customers is usually around 41%. This would then be transformed to electricity provided by the wheels of the car.

2 Electric Vehicles (EVs)

A vehicle that operates fully or partially on power generation is an electric vehicle. E-vehicles use an electric motor that is operated by a fuel cell or batteries, unlike traditional cars that simply operate on carbon fuels. We may also use the 'e-vehicle' and 'EV' terminology for Electric Vehicle. Generally, the expression 'electric vehicle' (EV) indicates an automobile with an electric drive (motor) power mechanism that can be inserted in to refuel the battery, supplying at least part of the vehicle's power storage room [17]. Electric vehicles would include electric vehicles, electric trains, electric trucks, electric lorries, electric aircraft, electric ships, electric scooters and motorcycles, and electric spacecraft. Sustainable attributes are the greatest benefit of having an electric vehicle. Ultimately, the wider community has awakened attention to the reality that fossil fuel-based cars are one of the world's largest main sources of rising climate change and poisonous gas emissions. This situation is going to get even worse with the growing population and commodification. As a timely response to this growing issue, electric cars have arisen. Although because of its anti-polluting functionality, the innovation has been marketed nation-wide, it does have some drawbacks that have stifled its expanded universal recognition [18]. An electric car is an ultimate platform for you to not only save your expenses, but also aim to lead to a peaceful and reliable world.

The very first formal proposal to promote electric cars was introduced in India in 2010. The cabinet approved an economic motivation for producers of electric vehicles sold in India under the Rs. 95-crore policy sanctioned by the Ministry of New and Renewable Energy (MNRE) [19]. As of November 2010, the scheme contemplated discounts of up to 20% on ex-factory vehicle costs, according to a higher limit. Conversely, in March 2012, the reimbursement system was subsequently discontinued by the MNRE. The 'National Electric Mobility Mission Plan (NEMMP) 2020' was launched by India in 2013 to create a significant change to electric vehicles and to resolve power generation stability, automotive emissions and domestic energy capability development problems. While the plan was supposed to provide grants and build e-vehicle knowledge base, the proposal remained mainly a plan. Then finance minister Arun Jaitley proposed quicker implementation and production of electric vehicles (FAME), with a potential amount of Rs 75 crore, when proposing the Union Budget for 2015–2016 in Parliament. The programme was designed with the goal of offering opportunities for cars with clean energy sources to expand their revenues to up to seven million vehicles by 2020. Transport Minister Nitin Gadkari expressed an opinion in 2017 demonstrating the intention of India to move to 100% electric cars by 2030. The car sector, moreover, has faced doubts regarding the adoption of such a project. Consequently, the government narrowed the scheme from 100 to 30%. A Rs 10,000-crore project under the FAME-II scheme was approved by the Union Cabinet in February 2019. This policy has been in effect since 1 April 2019 [20]. The key goal of the program is to facilitate rapid implementation of electric and hybrid cars by providing early opportunities for the purchase of electric vehicles, as well as by building the required charging facilities for EVs.

The reason that it will not require any gas or diesel to operate has been one of the main benefits of having an EV. Rather, a charging station is required where the car can be charged in and prepared to go. The cost of building up a charging station is very high, but it is not assured of the investment rewards of such projects. The inability of different investors to spend in charging networks continues to be a significant impediment to the development of charging ports. And furthermore, car manufacturers have not been interested in speeding up charging activities around the nation. Other than this, the level of information about the EV charging strategy of the company is very tiny. Not many people understand whether or not one has to receive a permit to set up a charging station. It is worth resolving the uncertainty around charging protocols. It would make absolutely no sense even though you buy an EV if there is no charging station in your proximity. To encourage the increased use of these automobiles, a sufficient number of charging stations must first be built. It is also costly to own an electric car. There are several fossil fuel vehicles available at varying price levels on the market. Nevertheless, hybrid cars have fewer choices to choose from, and the best ones are very costly. Also, the batteries that are used are still expensive, although it is projected that their costs will decline in the coming years.

2.1 Technical Components of Electric Car

Battery is charged by the electricity either when connected to the power grid via a charging station or during braking through kinetic energy recovery system. As its performance can now vary approximately 60–97%, squandering 3–40% of grid energy as heat, the charger is a key element. Based on the load scenario, the motor controller provides the electric motor with variable power. The electric motor transforms electricity into kinetic motion and into torque when used within a powertrain. Central engines were used in the BEV series produced till now, but hub wheel electric motors are also conceivable and will be necessary for large scale manufacturing. Traditional, extremely effective electric motors are built on permanent magnetic components, the hardest of which are alloys comprising neodymium and samarium (REE) rare earth elements. This has generated several apprehensions as REEs are limited and a few countries, mostly China, regulate their exports. Electrical engines for BEV, nevertheless, do not usually produce REE. There are a range of electric motor types, typically separated into categories of alternating current (AC) and direct current (DC). Based on personal usage, there are indeed AC and DC electric machines designed with and without magnetic materials. Traction motors without magnets are very popular in electric vehicles, as they are inexpensive.

2.2 EV Types

Electric vehicles are classified according to the degree of electricity that will be used by these vehicles as energy sources. Mainly they are classified in three categories, such as BEVs or battery electric vehicles, PHEVs or plug in hybrid electric vehicles and HEVs or hybrid electric vehicles. Among the three only BEVs are capable of charging on a level 3 DC fast charge [21].

Battery Electric Vehicles (BEV)

BEVs are more frequently called by the name EVs; these are fully electric vehicles with rechargeable batteries and no gasoline engine. High capacity battery packs are used to store electricity. The battery power is used to run the electric motor and all types of electronic devices on board. These vehicles don't emit any kind of harmful emissions and hazardous gases which are otherwise emitted by the traditional gasoline powered vehicles. Such vehicles are charged externally and each type of charging source is classified as per the speed of charging. The main charging capacities are classified as level 1, level 2, level 3 or Dc fast charging. The level 1 charging facility uses the traditional household outlet and takes up to 8 h to charge an EV which will run almost for 75–80 miles. Level 1 charging can be usually done at home or otherwise such charges have the capability to charge most EVs on the market.

Level 2 charging requires a special type of station which will provide power at 240v. Such charging facilities are more common at workplaces or public charging stations and will consume at least 4 h to charge the battery which will run for almost 75–80 miles.

Level 3 charging or Dc fast charging is currently the fastest charging facility among the three available in market. DC fast chargers are found at dedicated EV charging stations and take up to 30 min to charge a battery which will run up to 90 miles.

Plug-in Hybrid Electric Vehicle (PHEV)

Such electric vehicles have the type of batteries which can be charged either through regenerative braking or plugging into an external source of power. The standard models of such vehicles can only go up to 1–2 miles until the gasoline engine turns on. PHEV models can run for almost 10–40 miles before gas engine is turned on.

Hybrid Electric Vehicles (HEV)

These vehicles are powered by both gasoline and electricity. The electric energy required to run the vehicle can be generated by the braking system of the vehicle, as a result help in recharging the battery of the vehicle. Such kind of braking is called regenerative braking; it is a process where electric motor of the vehicle slows down the vehicle to some extent which in turn helps it to use some of the energy which is normally converted to heat by the brakes.

3 Impact of Electric Cars on the Environment

Production of electric cars seems more appealing in current time as bringing about reduction in carbon releases and greenhouse gasses is a rising alarm all over the world. A number of researches have been conducted on the impact of such cars on environment and mostly the results have revealed that such vehicles are indeed better for environment. Such cars release less smokes through their whole lifespan in comparison to the vehicles powered by petrol and diesel. The results have been the same even after taking into consideration the manufacture process of the vehicle and the production of electricity mandatory to fuel them.

The foremost advantage of electric cars is that they make a healthy contribution in bringing about the improvement in the air quality of towns and cities. Such cars have no tailpipes and produce no carbon dioxide emissions while being driven. This in turn helps us in making our cities and towns greener and better for people to live in them. Over the course of 1 year one electric car can save up to 1.5 million grams of CO_2 which in turn is equivalent of four round-trip flights from London to Barcelona. Further electric cars can also help in reducing noise pollution more so in cities where speeds are commonly on lower side, as such cars are far more quite than the traditional vehicles and thereby forms an additional serene surrounding.

On the other side making such cars consumes a lot of energy as the emission created when such cars are in production process is usually higher than the conventional car, the main cause being manufacture of lithium ion batteries which are an essential part of electric cars. The energy used to manufacture an electric vehicle accounts for more than a third of the car's total CO_2 emissions over its lifespan, however as the technology keeps on improving and better manufacturing techniques are devised, the amount of emission will also be decreased to a great extent in the production process of such cars. At the same time the results from a number of researches have been encouraging as one such research conducted by European energy agency found out that even with emissions emitted in electricity generation of such cars it is still 17–30% lower than what a conventional car emits. The emissions from electricity generation can further be improved if low carbon electricity is used. However, as the EVs become more and more widespread battery recycling which is of concern will become more efficient and reduce the need to extract new materials as such there will be less reliance on mining and production of new batteries. Total impact of electric vehicles is more pronounced when their lifetime is put to comparison with a combustion engine powered vehicle and there seems to be no competition between the two, as EVs are responsible for lower emissions over their lifetime than the usual vehicles, hence make a huge difference to the state of environment.

Keeping existing systems into account, they are striving to address their dependence on fossil fuels and to maximize their renewable energy supply on a regular basis. Electric vehicles, irrespective of the power supply, produce significantly less pollutants over their lifespan, indicating that they are still the vehicle of the next generation. Car companies are also in agreement with the fact that such cars are way less contaminating when compared to conventional vehicles.

4 Advantages and Disadvantages

4.1 Advantages

Smooth, nearly noise—free driving experience

There aren't a lot of moving parts inside the engine in electric vehicles. They have only one moving part, in particular, which would be the electric motor. Within, the petrol engine has a multitude of spinning components. They have to continuously keep scraping and striking against each other in order to generate electricity. The vibrations formed from the interaction between these parts are heard as the engine sound and perceived as fluctuations within the car's interior. While petrol engines today produce substantially less noise relative to what they would release 7 or 8 years earlier, they do have substantial amounts of both. The only driving aspect of an electric vehicle is the motor that revolves and shuffles the wheels throughout. A very modern and almost quiet buzz is the only sound from this phase that can be observed. The same characteristic also leads to a completely noise-free driving environment as well.

Standstill explosive torque accessible-

One of the key disadvantages of the operation of the petrol engine is that it generates maximum torque only at a particular point of RPM. The torque produced by it, as a result of its nature, begins from a really low value, goes up to its absolute peak and then falls again as the RPM increases. Owing to a huge series of various parts used to transfer the torque, petrol engines often suffer output drop. Due to frictional drops, the net performance is decreased by around 20% by the time it hits the wheel. In the case of electric vehicles, right out of the box, they achieve their highest output power. That means you have standstill access to the entire torque output. When you advance into the upper RPM range due to the effect of back EMF, it just continues to decrease. Electric cars only comprise of one integral component, the transmission, between the wheels and the engine. Therefore, they achieve a very high output of torque and at the same time suffer zero output loss.

Simplest procedure for driving

In the world of vehicles, electric vehicles have the easiest driving approach. Commercial electric cars come with a gearbox consisting of only one very long gear. As diesel cars do, they also do not suffer from the issue of instability. To stop that from occurring, it essentially prevents the need to incorporate a clutch function. Because what it ultimately says is that with only the accelerator pedal, brake pedal and steering wheel you can run an electric vehicle. Regenerative braking is another truly valuable function in electric vehicles. The braking mechanism usually results in complete wastefulness of kinetic energy in normal cars that is emitted as frictional heat. Even so, in an electric car, to power the battery, the same electricity is used rather than being exposed as heat. You avoid providing it some accelerator input when you hit the brakes in an electric vehicle. The induction machine that rotates the tires is now starting to act as a tire-rotating engine. The whole circuit is flipped, and now the tires use the same rotational energy to power the batteries. Regenerative braking is configured to be so powerful and efficient in the newest batch of electric cars that you will only have to use the car's real brakes very occasionally or only in emergency.

Zero emissions and pollution

Energy is generated in a petrol car by combustion of fuel inside the motor. Carbon Dioxide, Carbon Monoxide, Sulphur Dioxide and different SPM's (Suspended Particulate Matter) are the residue produced due to this method. All of these are particularly contaminating in nature and, when inhaled does a lot of damage to the human body. They also do a lot of environmental harm at the same time. The amount of these emissions is much greater in the case of a diesel vehicle. Although emissions management equipment is being continually developed throughout time, the total elimination of the emission of toxins is yet to be achieved. On the other side, electric cars do not rely on the method of fuel combustion to generate electricity. They essentially convert a battery's electric energy to spin a motor that rotates the wheels in turn. They thus create zero amounts of any contaminant gas or gaseous pollutants and operate on 100% renewable energy efficiently.

Battery Life and Cost

Batteries are an essential element of an electric car. Most batteries for electric cars are lithium batteries, and their prices are decreasing each year. A lithium-ion battery cell's maximum power should be sufficient for 300–500 cycles. Up to 10 years, a decent battery might last. The value of these batteries is predicted to reduce even further with the improvement of technology.

Low Maintenance

There is no need to rehydrate the engines, nothing similar to the gasoline engine or a number of repair activities that are normally connected with a gas engine. Electric vehicles operate on electrically driven motors.

4.2 Disadvantages

While the promising data has become quite evident, there are also some drawbacks that each person wants to rethink before agreeing to make their next major investment in an electric vehicle. Those explanations are-

Recharge Points

There are also electric fueling facilities in the planning process. Not a couple of areas you drive to on a constant schedule may have electric fueling stations for your car, which ensures that it might be more difficult to locate a charging station if you are on a road drive or wish to see relatives in a rural or suburban area and run out of charge. Maybe you may be trapped where you have been. Nevertheless, once charging points are much more common, ensure you have a map of the charging station where you reside and where you go regularly, so that when you will need, you can recharge your new EV.

Electricity isn't free

If you don't properly give it some thought, electric vehicles can even be an issue for your energy bill. If your investigation into the electric car you intend to buy has not been completed, so you might be proposing an imprudent venture. Electric cars often need a large fee to function effectively, and each month can impact negatively on your energy bill.

Short Driving Range and Speed

Electric cars are constrained by distance and velocity. Many of these vehicles are about 50–100 miles in length and have to be powered up again. As of today, you really can't use them for long trips, but in the meantime that is predicted to progress.

Longer Recharge Time

Although charging the gasoline-powered vehicle requires a couple of minutes, an electric car takes around 4–6 h and occasionally even a day to get charged up. Consequently, as the resources necessary to refill these is very significant, you need dedicated power stations. Therefore, certain individuals are turned off by the expenditure in time and required preparation. There are a few packages that can drastically cut on the charging time. But it is going to be an extra investment.

Minimal Amount of Pollution

Electric cars are not 100% emission-free either; they indirectly generate a slight level of pollutants. Renewable energy sources do not inherently produce the batteries and electricity required for charging. Many authorities do not have measures to enable you to purchase an electric vehicle to save costs. Only because there are a lot of variables don't mean they have got to be daunting. Doing a fair amount of study into multiple versions, and perhaps even combinations, will help you change on with a correct judgment. That being said, an electric vehicle will save our fragile world.

Higher number of options

Today's electric car demand is rising, with no signs of stopping. The fact, though, is that there are limited options for customizing and choosing your EV's designs. At the same time, typical cars have a huge array of customization available. This is bound to improve over time, so it is continuing to be a downside for several individuals.

5 Market Penetration of Electric Vehicles

A wide range of factors will rely on the introduction of electric vehicles. This concerns battery performance and prices, proximity to and reliability of the distribution system, the type of business model introduced to provide the customer with stable batteries and energy, the adoption of different models of cars by the consumer and possible inferred driving behaviors. Such heterogeneity and interconnections between these variables make it highly challenging and impractical for any demand forecast to identify a single electric vehicle penetration scenario. On the above-mentioned elements, many sets of predictions can be made, resulting in numerous projections about the brand recognition of electric cars. It is essential to recognize research in various literatures of which the assessment of consumer expansion is very positive. With regard to charging infrastructure, considering the developments already proposed in different countries, it is anticipated that access to charging facilities will grow significantly. At least, current charging opportunities are now or will be expanded in a very short term, often at home, where parking lots operate. The implementation of charging infrastructure by network destinations to the grid at home and in other places (especially workplaces) helps to provide more car buyers with a wide variety of car choices that can satisfy their needs, not just traditional vehicles, but also electric vehicles. The design of batteries continues to be the driving force of the second order and leads to making electric vehicles more powerful and cost-effective in trying to adapt favorably with their traditional counterparts. The predicted developments in these two perspectives clarify that BEV sales shares continue restricted until 2020 in both situations (0.5–3%). On the opposite, as soon as they are commercially available, PHEVs are easily infiltrated. This stems from the fact that higher limits for BEVs are the battery and charging amenities. The electric car market has grown rapidly since 2008. This market growth is largely attributed to the more widespread use of engineering by automakers, as well as a dramatic reduction in prices. Thanks to the increasing outcry about the environmental harm that greenhouse gas emissions do, the credibility of electric vehicles has also improved. Global warming is already being addressed, but more people all over the world are gradually treating it as a real concern. Some have indicated that as quickly as they are produced, chemical emissions are washing away the forests and oceans. Even so, in January 2017, the United States Environmental Protection Agency released a study revealing this prerogative to be unfounded. Some people oppose claiming that global warming is an ordinary global phenomenon, and the EPA (2017) acknowledges that the process that holds Earth at a sustainable degree is global warming. The excess of pollution that triggered the temperature rise of 1.5° Fahrenheit over the last century, however, is a grave threat [22]. This rise in pollution is credited to increased electricity, population and transportation production and use. From 1990 to 2012, just 22 years ago, greenhouse gas emissions rose globally by 41%. If the rise in carbon persists at this accelerated rate, much higher spikes in temperatures and the more dangerous effects of global climate change will have to be tackled in the near future. The United States probably accounts 4.5% of the global population, but consumes 19.2% of the world's energy; it's the world's second-largest user of energy, well behind China. Efforts have been made by several smaller countries to minimize their pollution and generate electricity by clean energies, but even though 100% of the energy generated was green, the effect would be much smaller than if major energy users had decreased a large proportion of their emissions. The US transport industry accounts for 28% of the nation's greenhouse gas emissions, which implies there is a massive possibility to reduce tailpipe emissions and more electric cars being used. Fully-electric vehicle (FEV) emissions will be evaluated to show that FEVs will substantially decrease greenhouse gas emissions by taking into consideration emissions from oil generation.

The ability of electric vehicles to reduce pollution concentrations in urban areas can be demonstrated as a significant justification for promoting their use in the private car market. Just a portion of this solution applies to greenhouse gases and carbon emissions in particular. Considering that fossil fuels produce a large portion of energy and that the impact of greenhouse gases must be assessed globally, the possible decrease (if any) in the total CO_2 emitted by the car fleet in the metropolitan environment must be measured. To be prepared to do this, it is obvious that an evaluation of the development of the electric automotive sector and its rise in a metropolitan area is needed.

6 Challenges in Introducing Electric Vehicle Fleets

A range of influences can hinder or reduce the introduction of electric cars on a broader level. They can be categorized into factors affecting the appeal of the EV for prospective investors and consequently, the experiential learning of EV consumers, and, on the other hand, the industry's financial incentive in investing in the growth, processing, sales and recharging of EVs. Companies need to provide a mobility systems integration plan that offers insight into preparation, timing, and delivery coupled with data modeling to optimize performance for both customers and EV providers in order to efficiently handle electric fleet vehicles where charging specifications reflect equipment effectiveness [23]. Among several other factors, the priority of the client would be calculated by:

- Purchase price or cost of the lease
- Complete Ownership Expense
- Offers to the market (brands, models, trim levels etc.)
- Experience Driving
- Comfort of re-charging
- Perception of Security
- EV familiarity
- The industry's economic interest would be limited by:
- Possible business size of EV and its volatility.
- Margin on Profit
- Needs for Investment
- Threats from production
- Objection to Danger.

Most analysts believe that, as opposed to older vehicles, technical costs, especially battery costs, render today's EVs unviable for the mass market, even when overall expense of possession is considered. In past years, the problems that EV implementation faces are becoming more manageable, but they are still substantial. The cost of maintenance of BEVs (Battery Electric Vehicles) in the development cycle has dropped significantly; further drops in integrated battery costs below $300 per kWh could lead in the next 5–7 years to substantive comparison with ICEs (Internal Combustion Engines) [1]. Once this main hurdle can be resolved, learning results can be resolved and future encroachment in expertise will pave the way to realistic longer repayment periods for sensible consumers. The cost-effective, reliable implementation of electric vehicles is much more critical for sustainable growth of EV control [24]. Standalone commercial review of various charging options shows that, where available, residential Level 2 charging can be the best choice for most charging needs of an EV owner, and that prices (typically for rapid charging) can minimize the estimated price. The residual value of the vehicle is a significant consideration for the TCO. The total price of EVs is greatly impacted by the batteries' predicted longevity and lifespan. In order to reduce similar consumer issues, adequate warranty programs may help. The higher purchasing prices will stay a blocking influence in the long run, as many commercial consumers do not usually conduct a TCO estimate but rely mostly on the appraised value during their buying decision [25]. In contrast to outmoded cars, the travel range limits of fully electric vehicles are a vital aspect. While this aspect does not perform the topmost part for most automobile consumers today in the cities and suburbs setting, it may discourage prospective buyers from preferring an EV if they are unable to negotiate with existing traditional automobile models [24]. One way of solving this detrimental feature of today's EVs could be rapid charging or battery switching. It is not anticipated that other driving elements such as reduced speed and other traditional features of EV driving can cause substantial adoption challenges for EVs, particularly in the urban and regional environment [26]. Because power transmission networks are widespread, especially in urban and suburban areas, the key problems arise with the actual set-up of recharge locations and the development of uniform recharge frameworks, procedures for communicating between vehicles and grids, as well as processed data and sustainability strategy. To allow accurate EV re-charging for the EV customer, all these issues need to be properly handled. Suitable re-charging options need to be sought in the urban setting for urban residents who have no chance of re-charging their EV at home [27]. The experience of the wider populace with this modern battery technology may be a problem until a wider rollout of EVs is achieved. By concerted publicity and advertising strategies, awareness can be strengthened until a large group of EVs is on the street and brand awareness subsequently improves public interest [28].

7 Conclusion

More than 80% of Europe's population is concentrated in cities. It's a mystery that they need to retain their mobility while still protecting their health and the environment. Several overarching European initiatives in the energy and transport industries are seeking to shift the tension between mobility and the environment.

In the urban world, the electrification of public transport, as well as our approximately thorough dependence in fossil fuels will probably minimize CO_2 emissions (and other pollutants) on the streets of our cities. This is focused on the much better proficiency of rechargeable engines comparison to ICEs, and also the strength to de-carbonize the transport energy sequence and, in specific, well-to-tank paths. BEVs are much more attractive from a CO_2 Well-to-Wheel emission factor of standpoint, and as an intermediate level, PHEVs are a fair alternative. The world is increasingly urbanizing, and creativity is hitting new levels as well. However, we do have a good potential to achieve our target [22].

However, the high cost penalty associated with BEVs and PHEVs would continue to be a concern until 2030, when learning consequences should have lowered the cost forfeit to a degree that would ensure the BEV's reasonable payback periods of less than 6 years and a level equal to the PHEV's other hybrid cost penalties. If replacement rates for parts or insurance rates are advanced and appear to be sophisticated than traditional vehicles, it will be a long time before a modest norm for TCO is reached. As such, a cohesive overall fiscal and regulatory structure would be important both to support the most energy-efficient infrastructure choices and to protect public budgets in line with new revenues from fuel use. In addition, the experience of the general population with this emerging propulsion system must be discussed in order to achieve a greater rollout of EVs. By dedicated publicity and advertising strategies, familiarity can be strengthened until a serious figure of EVs is on the road and a confirmed technology benefit further improves community interest [29].

As a final point, a cautionary note: encouraging the use of electric vehicles just wouldn't, say, result in the implementation of a green transportation infrastructure. It will also help to minimize the environmental footprint of road transport, but it is just one aspect of long-term development. To pursue the sustainability framework in a genuine way, necessary steps to reduce the use of personal transportation (private cars) in place of communal public transportation are unquestionably necessary. This involves moving the decision-making perspective from the point of view of sustainable transport to one of sustainable mobility [30, 31].

References

1. Petrillo, A., Mellino, S., De Felice, F., & Scudo, I. (2018). Design of a sustainable electric pedal-assisted bike: A life cycle assessment application in Italy. In *New frontiers on life cycle assessment-theory and application*. IntechOpen.
2. Woodcock, J., Banister, D., Edwards, P., Prentice, A. M., & Roberts, I. (2007). Energy and transport. *The Lancet, 370*(9592), 1078–1088.
3. Moriarty, P., & Honnery, D. (2008). The prospects for global green car mobility. *Journal of Cleaner Production, 16*(16), 1717–1726.
4. Martin, G. T. (2019). *Sustainability prospects for autonomous vehicles: Environmental, social, and urban*. Routledge.
5. Boden, T. A., Marland, G., & Andres, R. J. (2009). *Global, regional, and national fossil-fuel CO2 emissions*. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy.
6. Karavalakis, G., Hilari, D., Givalou, L., Karonis, D., & Stournas, S. (2011). Storage stability and ageing effect of biodiesel blends treated with different antioxidants. *Energy, 36*(1), 369–374.
7. Telang, S., Chel, A., Nemade, A., & Kaushik, G. (2021). Intelligent transport system for a Smart City. In S. C. Tamane, N. Dey, & A. E. Hassanien (Eds.), *Security and privacy applications for Smart City development. Studies in systems, decision and control* (Vol. 308). Springer. https://doi.org/10.1007/978-3-030-53149-2_9
8. Shanthi.rajan (2019). Are electric vehicles really green if they don't use clean energy? Retrieved from https://inc42.com/features/are-electric-vehicles-really-green-if-they-dont-use-clean-energy/
9. Bebkiewicz, K., Chłopek, Z., Sar, H., & Szczepański, K. (2021). Comparison of pollutant emission associated with the operation of passenger cars with internal combustion engines and passenger cars with electric motors. *International Journal of Energy and Environmental Engineering*, *12*(2), 215–228.

10. The great disrupter. (n.d.). https://www.economist.com/special-report/2020/09/17/the-great-disrupter
11. The Paris Agreement. (n.d.). https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
12. The 2030 climate and energy framework. (2019, December 06). https://www.consilium.europa.eu/en/policies/climate-change/2030-climate-and-energy-framework/
13. Press corner. (n.d.). https://ec.europa.eu/commission/presscorner/detail/en/ip_20_940
14. Kakoulaki, G., Kougias, I., Taylor, N., Dolci, F., Moya, J., & Jäger-Waldau, A. (2021). Green hydrogen in Europe–A regional assessment: Substituting existing production with electrolysis powered by renewables. *Energy Conversion and Management, 228*, 113649.
15. Srivastav, A. (2021). The challenges of energy supply. In *Energy dynamics and climate mitigation* (pp. 77–120). Springer.
16. Gayathri, M. N. (2021). A smart bidirectional power interface between smart grid and electric vehicle. In *Intelligent paradigms for smart grid and renewable energy systems* (pp. 103–137). Springer.
17. Wolbertus, R., Kroesen, M., van den Hoed, R., & Chorus, C. G. (2018). Policy effects on charging behaviour of electric vehicle owners and on purchase intentions of prospective owners: Natural and stated choice experiments. *Transportation Research Part D: Transport and Environment, 62*, 283–297.
18. Paulin, A. (2018). *Smart city governance*. Elsevier.
19. Mohanty, P., & Kotak, Y. (2017). Electric vehicles: Status and roadmap for India. In *Electric vehicles: Prospects and challenges* (pp. 387–414). Elsevier.
20. Khurana, A., Kumar, V. R., & Sidhpuria, M. (2020). A study on the adoption of electric vehicles in India: The mediating role of attitude. *Vision*, *24*(1), 23–34.
21. Berckmans, G., Messagie, M., Smekens, J., Omar, N., Vanhaverbeke, L., & Van Mierlo, J. (2017). Cost projection of state of the art lithium-ion batteries for electric vehicles up to 2030. *Energies, 10*(9), 1314.
22. Agarwal, P., & Alam, A. (2018). Use of ICT for sustainable transportation. *Proceedings of International Conference on Future Environment and Energy, 150*(1), 1–7.
23. Blumm, M. C., & Wood, M. C. (2017). No ordinary lawsuit: Climate change, due process, and the public trust doctrine. *American University Law Review, 67*, 1.
24. Kley, F., Lerch, C., & Dallinger, D. (2011). New business models for electric cars—A holistic approach. *Energy Policy, 39*(6), 3392–3403.
25. Dodds, P. E., Staffell, I., Hawkes, A. D., Li, F., Grünewald, P., McDowall, W., & Ekins, P. (2015). Hydrogen and fuel cell technologies for heating: A review. *International Journal of Hydrogen Energy, 40*(5), 2065–2083.
26. Legatt, M. E. (2017). *An experimental and analytical method for assessing the integration of electric vehicles into the bulk power system.* Doctoral dissertation.
27. Nyström, S., & Bergstedt, E. (2018). *Possibilities of batteries in the distribution system as substitute for a cable reinforcements while maintaining reliable electricity distribution.* Master's thesis.
28. Policy Options for Electric Vehicle Charging Infrastructure in C40 Cities. (n.d.). Retrieved from https://www.innovations.harvard.edu/policy-options-electric-vehicle-charging-infrastructure-c40-cities
29. Heffner, R. R., Kurani, K. S., & Turrentine, T. S. (2007). Symbolism in California's early market for hybrid electric vehicles. *Transportation Research Part D: Transport and Environment, 12*(6), 396–413.
30. Agarwal, P., Chopra, K., Kashif, M., & Kumari, V. (2018). Implementing ALPR for detection of traffic violations: A step towards sustainability. *Proceedia: Computer Science, 132*, 738–743. ISSN: 1877-0509.
31. Agarwal, P., Hassan, S. I., Mustafa, S. K., & Ahmad, J. (2020). An effective diagnostic model for personalized healthcare using deep learning techniques. In *Applications of deep learning and big IoT on personalized healthcare services* (pp. 70–88). IGI Global.

Smart Grid: A Survey

Sehban Fazili and Jyotsana Grover

1 Introduction

Smart grid [1] is a form of electrical grid that tries to intelligently anticipate and respond to the behavior and activities among all electricity clients linked with it—manufacturers, customers, and the ones doing both—in order to provide secure, cost-effective energy services in an efficient manner. The smart grid has three economic objectives: improving efficiency, reducing peak demand and reducing overall energy usage. To meet these objectives, various technologies were developed and incorporated into the electrical network. The Smart Grid framework connects a range of innovations, customer applications and tackles numerous policy and regulatory generators.

A smart grid provides energy to producers and customers using automated bidirectional technologies. It regulates smart appliances at the home or building of consumers in order to save electricity, cut costs and improves reliability, productivity and transparency. A smart grid is supposed to be an upgradation to the existing network for electricity. It offers automated control, security & optimization of the interconnected elements to run. The bidirectional link of electricity and information flows characterizes a smart grid in order to create an integrated, widely dispersed distribution network. In order to provide real-time information and allow for a near-instant supply and demand management balance, it brings the benefits of digital communications to the conventional electricity grid. Several smart grid technologies,

S. Fazili
Department of CSE, Jamia Hamdard, New Delhi, India

J. Grover (✉)
Department of Computer Science and Information Systems, Work Integrated Learning Division, BITS Pilani, Delhi, India
e-mail: jyotsana.grover@pilani.bits-pilani.ac.in

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_9

Table 1 Comparison between old electric grid and Smart Grid

Old Electric Grid	Smart Grid
Communication is exclusive	Communication is bilateral or two-way
Less sensors	More sensors
Monitoring is done manually	Self-monitoring
Electro-chemical	Digital
Generation is centralized	Generation is distributed
Manual maintenance	Self-healing
Not adaptive	Adaptive
Control is limited Less custom friendly	Extensive control More customer oriented and friendly

such as mobile sensor networks and wireless networks, have already been used in other industrial applications and are being designed for use in modern smart & linked systems. This communications system is divided as following:

- Complex units
- Sensing & estimation
- Improved user interfaces and decision-making assistance
- Standards & classes
- Integrated contact

The foundation of a smart grid is the opportunity to communicate with a connectivity network with various organizations (e.g., intelligent appliances, specialized applications, systems, control center, etc.). It follows that establishing a robust and omnipresent connectivity network is essential to both the development and Smart Grid Communication Networks Service. The establishment of a stable communications network to create strong relevant information distribution across WAN (Wide Area Networks) to the distribution feeder and client level is a critical objective in support of this point. For several years, this has been a major focus of study. The significant difference [2–4] between the old electric grid and the Smart Grid are shown in Table 1.

2 Smart Grid: Definitions

There is no clear, obvious concept for smart grid. Some of the leading innovators have defined smart grid in a simpler way. Some of the definitions [5] are as following:

The US Department of Energy defines smart grid as follows:

- “A Smart Grid uses digital technology [6] to improve reliability, security and efficiency (both economic and energy) of the electrical system from large generation, through the delivery systems to electricity consumers and a growing number of distributed generation and storage resources.”

- "The smart grid is the electricity delivery system, from point of generation to point of consumption, integrated with communications and information technology for enhanced grid operations, customer services, and environmental benefits."
- "A smart grid is self-healing, enables active participation of consumers, operate resiliently against attack and natural disasters, accommodate all generation and storage options, enable introduction of new products, services and markets, optimize asset utilization and operate efficiently, provide power quality for the digital economy."

Smart Grid's IEC description:

- "The Smart Grid is a developing network of transmission lines, equipment, controls and new technologies working together to respond immediately to our 21st Century demand for electricity."

Smart Grid IEEE's concept:

- "The smart grid is a revolutionary undertaking-entailing new communications-and control capabilities, energy sources, generation models and adherence to cross jurisdictional regulatory structures."

The E.U. Smart Grid concept is,

- "A smart grid is an electricity network that can intelligently integrate the actions of all users connected to it—generators, consumers and those that do both—in order to efficiently deliver sustainable, economic and secure electricity supplies."

PG & E (Pacific Gas & Electric Co.) definition of Smart Grid is,

- "The Smart Grid is a modernized electric system that combines advanced communications and controls to create a responsive and resilient energy delivery network."

Smart Grid ABB's concept:

- "A Smart Grid is an evolved grid system [5] that manages electricity demand in a sustainable, reliable and economic manner, built on advanced infrastructure and turned to facilitate the integration of all involved."

3 Motivation to Build Future Intelligent/Smart Grids

Decision makers in the Electrical Power industry like services companies, suppliers, manufacturers, consumers and governmental authorities acknowledge the need to tackle the challenging questions motivating the formulation and execution of such a smart grid, as well as its components. The major challenges [7, 8] needed to tackle by the concerned decision makers are:

- Old and low investment infrastructure: Many of the current facilities for electricity systems stretches back or perhaps even earlier to the 1950s and some of the or rather majority of the systems used have reached the end of their life cycle.
- The electricity consumption is rising all over the world and high-power loads are resulting in overloaded systems.
- Activists press legislators to adopt clean energy sources and enact energy efficiency regulations in attempt to cut down on CO_2 emissions.
- Renewable energy sources put a strain on distribution networks. More grid information, baseline load power (hydro, nuclear) generation, and storage are required to compensate for the intermittent nature.
- Economic & regulatory burdens are increased.
- Unbundling of utilities raises trade of electricity.
- For the customer there is a need for transparent consumption and price.
- For sustaining working economies and communities, effective and secure transmission and distribution of electricity is crucial.
- Sustainable development [9, 10].
- The demand must be regulated and the energy requirements must improve.
- Consumers are demanding for lower energy prices [8].

The US Department of Energy released a study to better understand the reasons and priorities of the smart grid which is titled "Implementing the National Broadband Plan by Studying the Communications Requirements of Electric Utilities to Inform Federal Smart Grid Policy" stating

> "A Smart Grid uses information and communications technologies to improve the reliability, availability, and efficiency of the electric system. In Smart Grid projects today, these technologies are being applied to electric grid applications, involving devices at the consumer level through the transmission level, to make our electric system more responsive and more flexible."

Evidently, innovative products and services and smart technologies are used to monitor, control, communicate and self-heal a smart grid [7, 11, 12] to enable customers to contribute to improving the system's operation and provide greater knowledge and distribution options to consumers. A Smart Grid helps in:

- Increasing the durability
- Increasing the energy efficiency
- Environmental benefits
- Security
- Reliability and quality of power
- Price efficiency
- Improved customer service
- Increased profitability
- Increased utilization
- Lower carbon intake of fuel
- Facilitated production of renewable resources

The above given points are the motivating factors in building intelligent/smart grids.

4 Characteristics of Smart Grids

Many researchers have grouped the major characteristics of Smart Grids. Some of them are as following:

(a) Self-healing [3]: The ability to detect, analyse and repair the fault itself without needing any assistance. It is one the major reasons for growth of smart grids.
(b) Efficient: Able to meet increased demand from consumers without any infrastructure addition.
(c) Consumer friendly [8]: Smart grids involve consumers into the grid.
(d) Quality Centred and High reliability [3]: Open to the idea of providing the needed quality of electricity, free from delays and disturbances, ensuring the smooth operation of our increasingly digital economy's data centres, computers, and electronics. Based on the needs of customers.
(e) Cyber-attack immune [1, 4, 6].
(f) Adapts to a broad range of generations and capacity operators that are distributed.
(g) Can easily adapt to new and developing technologies.
(h) Green [1, 8]: Decreasing the advancement of climate change and providing a meaningful route towards substantial environmental improvement in the effects of human-serving electric power.
(i) Helps in cost minimization such as operations and maintenance expenses.
(j) Optimizes asset utilization.

5 Technologies and Architecture of Smart Grids

5.1 Technologies

At the distribution stage, there are a variety of technologies that play an important role. These innovations can be used by a Smart Grid to extend the distribution infrastructure. Modern digital metres, grid automation, lower-cost communications networks, distributed energy infrastructure, wireless network applications communications, actual gradient & potential control & failure monitoring, & strategies are all included in this. These innovations cannot be used as separate problems in a real Smart Grid. It will instead be integrated so as to reap the potential benefits. The change from a traditional electrical grid to a smart grid is possible thanks to the integration of a few technologies. This segment discusses several smart grid developments that will help with the change.

Smart Meters

Smart metering is the most important tool of Smart Grids for collecting data from end-user devices and equipment while also tracking system operation.

AMI (Automatic Metering Infrastructure) systems are commonly used as a control mechanism for Smart Grid implementation. They are based on automatic metre reading (AMR) systems. AMR is a programme that collects diagnostic, usage, and status data from energy metres [7, 13] and transfers it to a central database for billing, debugging, and analysis. AMI varies from conventional AMR in that it allows for two-way contact between metres [2, 6]. As a result, nearly all of this data is available instantly and on demand, allowing for better system operation and consumer power demand control. In the Smart Grid, smart metres give customers information on how and when to use electricity, as well as how much energy they use per kilowatt-hour. It contributes to a greater understanding of prices and more accurate bills, as well as the utility's ability to rapidly detect and resolve outages. Smart metres, which allow two-way communication between the metre and the central system [11, 13], are similar to AMI metres in a number of ways and are frequently referred to as AMI. A smart metre is an electronic metre that records use in 1-h or less intervals and sends the data to the utility for at least periodic monitoring and billing. Smart metering has a variety of benefits from the consumer's viewpoint. They will use smart metres to understand real-time pricing from a utility's perspective, allowing consumers to reduce their demands during peak load times or control power flows based on supply-side data.

Automated Meter Reading

Automated metre reading (AMR) is an innovation used in utility metres to gather data required for billing. AMR, which operates by converting the mechanical dial movement on a metre into a digital signal, requires no direct access or visual check. The information can be transferred over the phone, power line, satellite, cable or radio waves [6, 11] from the metre to the utility company. AMR devices allow tools to observe metres externally, eliminating the need to send an employee to scan each metre individually. Although they have some two-way contact, it is limited and does not increase the power system's performance or dependability. They may not reveal the pattern of energy use in built-in home displays to the consumer, and so the customer is unaware of their energy use. Utilities are unable to communicate their energy usage with consumers because of this, so customers are unable to increase their intake during peak hours in order to save energy. AMR systems cannot be used for systemic regulation on all levels, making the transition to the Smart Grid impossible. AMR is the use of consumer data such as electrical meters and smart meters, and the processing of data to generate the bill. AMR processes the data through three stages [6] which are:

(a) Reading unit: Analog metre readings are translated to digital and the information is processed for transmission to the communication unit.
(b) Communication unit: Transmission of information must be effective, with no loss of information.
(c) Data receiving and processing unit: In this unit data is received and processed for further actions.
(d) Billing system: Last stage, analysis of electricity usage.

V2G (Vehicle to Grid)

It's a system with the ability to revolutionise the energy sector as a whole. It's a system which allows electricity from an electric vehicle's battery to be returned to the electricity grid. A car battery can be charged and discharged using vehicle-to-grid technology based on a variety of signals, such as power generation or local consumption. In a nutshell, vehicle-to-grid works in a similar way to traditional smart charging. Smart charging, also known as V1 G charging, is a technology that monitors the charging of electric vehicles and adjusts the charging power as required. Vehicle-to-grid [2, 6, 13] takes it a step further by allowing charged energy to be temporarily moved back from car batteries to the grid in order to offset energy production and consumption fluctuations. The significant benefits of V2G [2, 6] are that it offers space for storage for generating renewable energy and through regulation it maintains wind generation on a large scale. V2G technology allows us to make the highest suitable use of the current vehicle numbers. The capacity of buildings to align their energy demand with V2G charging stations also increases larger-scale power grid production. This will prove useful when the amount of renewable energy in the power system is increasing, generated with solar energy and wind. Excluding vehicle to grid infrastructure, energy has to be purchased from reserve power stations, which threatens to increase electricity costs at peak hours, and it is a costly operation to ignite these additional power stations. V2G allows energy suppliers to use the grid to play ping pong with electricity. Two simple V2G architectures [6] exist:

(i) Deterministic architecture: Services are delivered straight from the grid system operator to the plug-in vehicles in deterministic architecture. A direct contact line exists amongst plug-in vehicles and the operator of the grid system, thereby treating each car as a deterministic resource.
(ii) Aggregate architecture: In aggregate architecture (Fig. 1), between the grid system engineer & the vehicle is an intermediate collector. When they approach and exit charging stations, individual automobiles may use and disconnect from the collector, and the aggregator/collector can supply users with an auxiliary service at any time.

The aggregate architecture is same, it just adds aggregators to improve the availability and reliability.

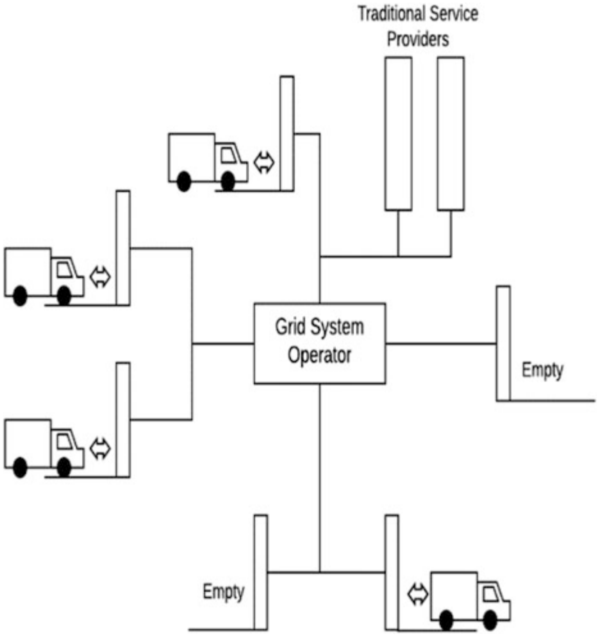


Fig. 1 Deterministic architecture

Smart Sensors

A smart sensor is a computer that performs pre-defined functions using built-in computing resources while sensing and processing specific data before transmitting it. Smart sensors allow more accurate and automatic environmental data analysis from correctly collected data, resulting in less erroneous noise. These instruments are used to monitor and control processes in a variety of settings, including smart grids, frontline identification [2, 14], exploration, and a variety of scientific fields. A smart sensor may contain a number of other components in addition to the primary sensor. Transducers, amplifiers, excitation power, analogue filters, and compensation are examples of such components. A smart sensor also includes software-identified elements that perform data transfer, digital processing, and communication with external devices. Sensors that monitor various signals in an electrical system are essential to safeguard smart grids and increasing grid energy productivity. When a short circuit occurs in a smart grid, it must be detected as quickly as feasible to minimise the duration of the grid outage and the risk for disruption to the electricity facilities along with physical harm. The new fault detection systems range from traditional analogue electromechanical relays to advanced intelligent electronic devices (IEDs). Despite this, both types of sensors have fixed (offline phase) change settings and will not have real-time activity synchronisation.

The changes are detected by a sensing unit, which is then configured and converted to a digital signal by a signal conditioning and digitalization system. The signal conditioning and digitalization unit [6] needs an analogue to digital converter (ADC) to transform the sensed analogue signal to digital. The central processing unit decodes and analyses digital copies of analogue signals [6, 14] that have been captured. A copy of the processed data will be placed in the main processor memory for later use, and local and remote users will be able to access it through local and remote human machine interfaces (HMIs). The smart sensor module also includes a communication interface for sending and receiving the sensed signals and instructions. The primary processor and communication interface performs job management.

5.2 Architecture of Smart Grids

The United States' National Institute of Standards and Technology (NIST) has formed several models for defining Smart Grid architecture [15], with one of the most widely recognized and adapted models serving as the industry and academic reference model. The Smart Grid is made up of seven domains that are all linked together. The four domains are in charge of not only generating, transmitting, and distributing energy, but also maintaining the Advanced Metering System's two-way communication between the consumer and the utility head end (AMI). Markets, Systems, and Service Providers are the three remaining bodies in charge of governing energy markets, managing power delivery, and supplying services.

This architecture defines a Smart Grid system [15] that is multi-layered. At the bottom of this model are Home Area Networks (HANs), Building Area Networks (BANs), and Industrial Area Networks (IANs), which are wired or wireless networks in consumer households, houses, or industrial areas that interconnect devices with smart metres and energy control systems that report the consumer's use to the grid, as seen in Fig. 2.

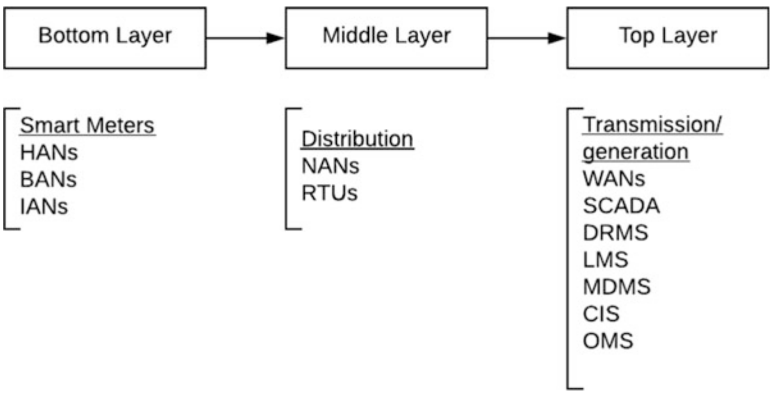


Fig. 2 Smart Grids' multi-layer architecture

Neighborhood area networks (NANs) are networks that span different geographical areas that are responsible for interconnecting smart metres from various types of premises with a delivery access point that aggregates the data they receive and transfers it to the upper layer. Remote terminal units (RTUs), electronic instruments responsible for transmitting telemetry data to the SCADA (top layer), and phasor measuring units (PMUs) [15], synchronised devices that measure electrical waves on the grid, are also included in the NAN.

This top layer contains all of the data obtained by NANs (whether it is information describing the current state of the system or the ac-cumulated use of a city or some other piece of data). The Supervisory Control and Data Acquisition System (SCADA) is in charge of gathering, updating, presenting, and handling data, while the Meter Data Management Systems (MDMS) and Outage Management Systems (OMS) are in charge of billing customers depending on their use.

6 Goals and Benefits

In terms of creating a Smart Grid, these priorities/goals must be considered:

- Observability
- Establishing controllability of properties
- Improving the power system's performance and dependability [4]
- Reducing running, maintenance, and system planning expenses

If these targets are met, several improvements can be made, such as improved system performance metres, improved consumer service and increased capacity to provide data for rate; accountability of service activity, accessibility of information for plan development, and improved digital summary support, as well as improved efficient [1] and cost-effective power distribution.

The benefits of Smart Grids areas following:

(i) Self-healing [4]: senses and reacts to common issues, and recovers quickly when they occur, reducing disruption and economic loss.
(ii) Encourages and connects consumers by offering real-time market transparency and enabling them to choose the quantity and price of the product that is ideally suited to their needs.
(iii) Addresses twenty-first Century Power Quality demands: Offers power free from sags, spikes, disruptions and delays.
(iv) Encompasses all generation and storage possibilities: interconnecting plug-and-play to various and distributed sources.
(v) Facilitating markets: Promoting energy markets that foster research and growth.
(vi) Productive functions: less new infrastructure is installed, more power is distributed across existing networks, and therefore less is expended on operating and maintaining the grid.

Benefits of Smart Grids [6] for Costumers:

(i) Provide customers with up-to-date reports on their power consumption
(ii) Allow electric vehicles to be powered by intelligent appliances and to save money on energy bills, it is designed to turn off during peak hours.
(iii) Offers a broader variety of electricity pricing options.

Benefits to Involved parties:

(i) Minimize energy supply inefficiencies.
(ii) Recover power easily after blackouts.
(iii) Develop distributed energy resource management including micro grid processes and storage management.
(iv) Improve grid stability and outages and blackouts.
(v) Making the grid more stable.

7 The Challenges of Smart Grids

Some impediments will be met at various levels in the way these goals (the above discussed) are accomplished. System scheduling and repair, local resistance to new plants and lines, planning confusion, a shortage of robust real-time system controls, and a lack of focus on supply-side reliability solutions are all crucial problems [1, 16] to consider. The energy sector must address public resistance to regulation, a lack of time-dependent pricing information accessible to consumers, a lack of market participation, and a lack of environmental credit/taxation. A shortage of predictive real-time management tools and connectivity issues between system operators are additional issues. Smart device implementation is hindered by the shortage of adaptive control signals [1, 7] for running equipment and power saving technologies. Last but not least, funding for the Smart Grid is needed to support emerging technologies in this area. It is possible to use a lot of instruments to build a Smart Grid. Accordingly, criteria for assessing these methods/tools should be discussed which includes:

- Durability and effectiveness of power
- Dynamic schedule
- Planning and estimation
- data analysis
- measures
- data mining
- Applications for real-time analysis and state estimation

8 Conclusion

In this chapter, we have provided the detailed description about the smart grid. We've shown that a smart grid focused on sensing, communications, and control technology has a bright future for utilities and consumers alike. We looked at a variety of papers and articles and compiled a list of the basic smart grid specifications. Interconnected devices and systems must be effective, reliable, and secure in order for smart grids to improve. Interoperability must be achieved to avoid being separated by non-competitive technological solutions and the need to completely replace existing power communication systems. Coordination with technological requirements must be matched with maintaining an atmosphere that promotes creativity in order to continue to improve the overall smart grid technology. Based on the above study, to make it more effective and safer, we should concentrate on certain challenges like planning uncertainty, Not focusing enough on supply-side reliability solutions, deregulation faces public opposition and customers have insufficient time-dependent pricing information; and unavailability of precise real-time device controls. It can be seen that Smart Grid is an open and hot field of research, as seen in this chapter. It has several facets to the study. There is some participation from many research teams around the world in this area.

References

1. Hassan, R., & Radman, G. (2010). Survey on smart grid. In *Proceedings of the IEEE SoutheastCon,* North Carolina (pp. 210–213).
2. Fang, X., Misra, S., Xue, G., & Yang, D. (2011). Smart grid—The new and improved power grid: A survey. *IEEE Communications Surveys & Tutorials, 14*(4), 944–980.
3. Butt, O. M., Zulqarnain, M., & Butt, T. M. (2020). Recent ad- in smart grid technology: Future prospects in the electrical power network. *Ain Shams Engineering Journal, 12*(1), 687–695.
4. Alotaibi, I., Abido, M. A., Khalid, M., & Savkin, A. V. (2020). A comprehensive review of recent advances in smart grids: A sustainable future with renewable energy resources. *Energies, 13*(23), 1–41.
5. Shabanzadeh, M., & Moghaddam, M. P. (2013). What is the smart grid? Definitions, perspectives, and ultimate goals. In *28th International Power System Conference (PSC),* Teheran (pp. 1–10).
6. Dileep, G. (2020). A survey on smart grid technologies and applications. *Renewable Energy, 146*, 2589–2625.
7. Yan, Y., Qian, Y., Sharif, H., & Tipper, D. (2012). A survey on smart grid communication-infrastructures: Motivations, requirements and challenges. *IEEE Communications Surveys & Tutorials, 15*(1), 5–20.
8. El-Hawary, M. E. (2014). The smart grid—state-of-the-art and future trends. *Electric Power Components and Systems, 42*(3–4), 239–250.
9. Agarwal, P., & Alam, M. A. (2018). Use of ICT for sustainable transportation. *Eighth International Conference on Future Environment and Energy (ICFEE 2018), 150*(1), 1–7.
10. Agarwal, P., Chopra, K., Kashif, M., & Kumari, V. (2018). Implementing ALPR for the detection of traffic violations: A step towards sustainability. *Procedia: Computer Science, 132*(2018), 738–743.

11. Farhangi, H. (2009). The path of the smart grid. *IEEE Power and Energy Magazine, 8*(1), 18–28.
12. Hashmi, M. H. S. M. K., Hänninen, S., & Mäki, K. (2011). Survey of smart grid concepts, architectures, and technological demonstrations worldwide. In *2011 IEEE PES Conference on Innovative Smart Grid Technologies Latin America (ISGT LA)* (pp. 1–7).
13. Gungor, V. C., Sahin, D., Kocak, T., Ergut, S., Buccella, C., Cecati, C., & Hancke, G. P. (2012). A survey on smart grid potential applications and communication requirements. *IEEE Transactions on Industrial Informatics, 9*(1), 28–42.
14. Alonso, M., Amaris, H., Alcala, D., Florez, R., & D.M. (2020). Smart Sensors for Smart Grid Reliability. *Sensors, 20*(8), 21–32.
15. Komninos, N., Philippou, E., & Pitsillides, A. (2014). Survey in smart grid and smart home security: Issues, challenges and countermeasures. *IEEE Communications Surveys & Tutorials, 16*(4), 1933–1954.
16. Moslehi, K., & Kumar, R. (2010). A reliability perspective of the smart grid. *IEEE Transactions on Smart Grid, 1*(1), 57–64.

Green Building: Future Ahead

Asfia Aziz and Mirza Rahil Beg

1 Introduction

A green building is a building that is designed and constructed in such a manner that when it operates it does not have any negative impact on the environment and human health throughout its life cycle rather it improves the quality of life and helps in preserving precious natural resources. With rapid increase in population and utilization of natural resources this development has been impacting the sustainability of humankind in more ways than one. This continued insult of the environment and consumption of natural resources will in the long run have its bearing on the continued survival of human race. A green building does not have to be an office, it can be a school, a hospital, a community centre and most definitely a home or a residential complex.

Conventional buildings have huge impact on the health and wellbeing of people and the planet, they use resources, generate waste and emit greenhouse gasses throughout their life cycle which may last 75 years or more.

A green building can me made possible with collaborative efforts of architects engineers and construction companies aided by supportive policies made by the concerned governments.

Man has been making green buildings since ages. Ancient civilizations have been building houses and colonies using mud straw wood and stones available locally without damaging the environment.

The rapid urbanisation has again brought sustainability of social, economic, and environmental issues into focus especially in a growing country like ours where it is essential to review the impact of any construction on ecology as it invariably

A. Aziz (✉) · M. R. Beg
School of Engineering Science and Technology, Jamia Hamdard University, New Delhi, India
e-mail: asfiaaziz@jamiahamdard.ac.in; mirzarahilbeg@jamiahamdard.ac.in

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_10

encroaches upon the available green space leading to a cascading impact on environment and climate ultimately resulting in damage to the environment.

The concept of Green building has emerged as a panacea for eco-friendly growth for us as such a building has several economic benefits too. The approach is less about conceptualising the building and more about a holistic approach for sustainable utilisation of the natural resource through proper planning. These include savings on utility bills for residents, lower construction costs and higher returns for those who are engaged in developing green property. As per The Energy and Resources Institute (TERI) estimations, if all the buildings in urban areas were made to adopt green building concept, India could have saved more than 8400 megawatts of power, which is enough to light 550,000 homes a year.

In India, the Green Building Movement was adopted by the Confederation of Indian Industry (CII) about 20 years back when the Indian Green Building Council was formed with a vision "To enable a sustainable built environment for all and facilitate India to be one of the global leaders in the sustainable built environment by 2025". The green footprint in India has increased from 20,000 sq. Ft in 2003 to 450 crores sq. Ft by 2019 [1].

The current chapter seeks to put into perspective what features are a part of a green building the major aspects that need to be considered the issues to taken care of, the benefits that we derive out of such buildings the various bodies that provide guidelines and certifications to such buildings and the various challenges faced and some innovations that though experimental as of now but may well become an important constituent of green buildings in the times to come.

2 Components of Green Building

Components of a green building are not just the materials that go into it but it arises out of an application of multiple processes, concepts and newer ideas that result in a product that is energy efficient during its entire life cycle (Fig. 1).

2.1 Site Planning and Design

The first step in designing a green building is site selection, the best site is one which has a neighbourhood designed around it is giving the residents easy access to all things they need for their day-to-day living. The site should be such that it takes care of the needs of the next generation also and not just the present one. The potential environmental disturbances that may occur need to be taken into consideration at the start of the project, any risk of the area selected falling into a zone where a natural calamity might strike needs to be excluded. Prime farmlands, areas near wetlands, wildlife habitats are sites whose sanctity must be maintained at all times. The community connectivity for daily needs and livelihood of the local population has

Fig. 1 Components of green building

to be always in consideration in selecting a site because the buildings of today must not only withstand the future climate but also cope with developmental pressures of growing population without defiling the environmental sanctity rather leading to shared prosperity.

2.2 Energy

Compared to a conventional building a green building uses less energy, water and other resources. Energy efficiency is the backbone of a green building minimising the release of greenhouse gasses. Not only the energy utilization of the building needs to be optimal but conservation and renewal of energy of the building has to be ensured.

The major sources of energy usage in any building are for heating and cooling depending upon the location of the building followed by the energy usage for appliances of the residents. Use of bioclimatic architecture in designs helps in achieving optimal thermal comfort on the inside and prevents thermal heat pools on the outside reducing heat island effect thereby ensuring that environmental sanctity is a fundamental building block of the green building. A high performing envelope provided by insulation and air sealed construction avoiding any thermal leakage is essential to avoid environmental thermal contamination. A well-insulated building envelope can save up-to 22% of energy [2]. Once the energy loss has been minimised the energy source of the building which includes renewable energy needs to be designed. The energy losses and conservation practices once the building is habited is also essential as it contributes to its sustainability.

Measures to conserve energy by a household also adds to the nett energy equation, day to day behaviour needs to be adjusted to plug unnecessary energy leakages. Behavioural adjustments like turning down thermostats or using smart or programmable thermostats, switching off lights when not in use, using energy efficient bulbs and appliances, smart power strips to eliminate phantom loads decrease energy expenditure. Windows which are a significant source of energy wastage in normal homes can be turned into energy sources. Use of vertical and horizontal greenery has gained a lot of acceptance as it cosmetically enhances the building also. Vegetation around the building also helps in preventing soil erosion and absorbing rainwater thereby maintaining water tables. Use of solar panels on windows cuts down on electricity costs and reduces the carbon footprint.

Energy generation in a building has to be environment friendly with going off the grid being one of the best options, however costs involved may be a limiting factor. Solar power is the most reliable, clean source of renewable energy. The barriers to its use like high costs and low efficiency are no more a factor today and they can be easily incorporated in windows, walls and even roofs.

Wind power which is now the world's fastest growing source of energy can be used to provide for the energy needs either through a power company or by using a small turbine for home. Home scale wind turbines are also available which can generate between 1–10 kW of energy [3]. Geothermal and micro hydro are also potential sources of energy in relevant geographical locations.

A green building may be of two types a Passive House which is so energy efficient that it does not need heating or cooling. Thermal comfort is achieved by reducing the air infiltration and avoiding thermal bridges which makes the system immune to thermal challenges. The second type of building is a Net-Zero building which means that the building does not need any external energy supply, all the energy for the house is generated within the building so it is also known as an Active House.

2.3 Waste Reduction

Reduce, reuse and recycle construction and demolition waste to cut costs and improve build quality is the mantra for a green building. A waste management hierarchy of Reduce-Reuse-Recycle-Compost-Dispose is a sustainable strategy [4]. A proper waste management plan along with resident recycling plan is one of the cornerstones of a successful building. Using floor plans in construction where dimensions match standard sizes result in reduction of waste and cut materials decreasing energy costs. Use of advanced framing techniques helps in improved strength and performance saving material and labour costs. With availability of pre-cut components and finished materials construction costs can be brought down.

Deconstructing buildings is a better alternative to demolition as it enables reuse of materials, helps in isolating toxic materials and brings down disposal costs.

Use of onsite bins and grinders bring down transportation costs.

2.4 Water

Of all the things in life that we take for granted having running water is the foremost. Need to conserve freshwater cannot be overemphasised. The key components of water efficiency in green building are reduction of indoor potable water usage, reduction of water consumption to save energy, and to improve environmental wellbeing. The first step for increasing water efficiency at home is to reduce or stop the use of drinking water for anything other than cooking and drinking purposes. This can be done in two ways one by collecting rainwater and second by reusing and recycling water. Rainwater harvesting is a vital source of freshwater which needs to be conserved using landscaping techniques, pavement modifications and storage and treatment systems to allow rainwater to seep into the ground instead of running off. Increasing plantation in the area around buildings, enhancing any pre-existing water bodies, building stormwater channels and blocking runoff streams will replenish the groundwater. Treatment systems such as oil water separators need to be installed to filter out pollutants that may enter the water bodies during rains.

Choice of plants for landscaping should always be the locally available resident species. Indoor water usage fixture selection is also important, use of low flow systems for fixtures like sinks, bathtubs, shower heads and toilets can bring down water usage by 30–40%.

Using cooling towers which recycle almost 95% of total water are recommended [5]. Treatment of sewage water using plants, fungi and other physical and chemical methods and then using it for irrigation or cleaning purposes. It is prudent to have a water audit for water conservation for all buildings.

2.5 Indoor Air Quality

Good indoor air quality is important for good health and comfort of its residents and is an essential goal for any green building. Good indoor air quality needs a design that involves frequent air exchanges to flush out waste gasses using a well-designed ventilation system along with moisture control to prevent growth of moulds and fungi all of which complement a strategy that achieves clean air, energy efficiency and also lends to building durability. Clean construction practices and use of smart materials reduce dust and volatile organic compounds (VOCs) in the air which circulate indoors and are known to be damaging to human health.

Excluding pollutant sources in design and construction has to be ensured to limit indoor air pollutants. Designing should ensure that fresh clean air flows in and is spaced far away from exhaust and moisture sources. The garage and parking air vented away from residential area as the air from these sources is rich with pollutants.

During construction care should be taken in installing adequate filters, using proper drying time schedule so that concrete, spray insulation, sealants and adhesives do not absorb water and VOCs.

Ventilation plays a crucial role in healthy living by regulating the air flow, temperature humidity and even the levels of contaminants in the air inside the buildings [6]. People living in poorly ventilated homes frequently have recurrent complaints of headache, fatigue, breathing problems, irritation of eyes and throat, these features form part of a syndrome called Sick building syndrome [7, 8].

Maintenance of ventilation systems is key for safety and health of individuals. Some agencies offer a guideline for protection of public health from common chemicals in indoor air [9].

2.6 Materials

The choice of materials is critical as the environmental and health impacts of extracting, manufacturing, shipping, living, with and disposing of each product used in the construction has to be analysed before its usage. A green materials strategy needs to be adopted keeping in mind health and environmental concerns. Recycled content building products are available many of which are cheaper and perform better than conventional equivalents. Recycled materials are available ranging from rubber and glass to steel and ceramics. Eco wood a wood made from bagasse ash of sugarcane can be recycled and re used [10]. Cement a construction material is mixed with fly ash which is obtained and recycled from coal burning power plants and later during the demolition of the building this material is reused as a filler [11].

Use of rapidly renewable materials is to be encouraged at all times. Extracting raw materials impacts a regions biodiversity and the ecosystem of those areas needs time to re-establish their equilibrium, this may take time depending on the raw material, so it is best to use resources that regenerate fast so that the environmental impact is minimised.

Minimising the consumption of conventional materials itself can result in energy savings and also carbon dioxide reduction [12].

2.7 Commissioning

This is the process of checking that the functioning of the building is proper, each system being evaluated for its design, efficiency and comfort. The components of commissioning include the building envelope, the heating cooling and ventilation systems, plumbing, electricals and any other specially added systems. Commissioning agents work in close co-ordination with team members to ensure that ideas are integrated and brought out in the final product and best operating practices ensure that the systems knowledge is passed on to operations and maintenance.

2.8 Marketability

The final goal of a green building is to use minimal resources and to build homes that are not just attractive and comfortable but homes that are appreciated by the residents for their energy efficiency and also their beauty.

2.9 Sustainability

The Earth's ecosystems are critically poised with continued insult from human developmental activities making sustainability issues ever so relevant. New technologies are constantly evolving to decrease the detrimental effects of this growth and development. To assess the environmental impact an approach called LCA or life cycle assessment is done such that an inventory is made of all the inputs and releases of energy and materials during the entire life of a building and informed decision is made of its potential impacts.

3 Health Benefits of Green Buildings

It is a known fact that we spend more time indoors than outdoors so Indoor Environmental Quality (IEQ) has become one of the most important part of a green building and hence its certification also, this important component ensures greater resident satisfaction along with less health risks for its occupants. The concentrations of many indoor pollutants have been found to be higher indoors therefore our susceptibility to harmful effects of these pollutants is also higher. These impact our health and productivity. Studies have shown decreased absenteeism and increased productivity when residents have moved from conventional to green buildings [13]. The green buildings impact our health at the individual level directly and at the level of the community indirectly by decreased energy utilisation thereby reducing pollutants in the environment. These pollutants lead to cardiovascular disease, worsen respiratory disorders along with many adverse health effects.

Scientific evidence published so far shows better health and environmental quality in green buildings. The levels of VOCs, allergens and other chemicals are significantly lower making them safer for humans, with inhabitants reporting fewer sick building syndrome symptoms, fewer respiratory symptoms, fewer absenteeism and therefore better productivity [14].

Research has shown that indoor air quality impacts higher order cognitive function also [15].

4 Green Building Technologies

Advancements in green building technology has made the vision of having green buildings on the planet a reality today. These technological ideas have made the buildings more energy efficient thereby reducing environmental insult by lowering the carbon footprint. During construction each aspect of the building from the site to the materials and systems used are adapted and modified to make it as sustainable as possible.

Sensors such as access cards, RFID scanners, motion detectors are used to sense the presence of humans in any given area of a building and using that information green technology by itself regulates the switching on or off systems like lights, HVAC, heating, cooling preventing wasteful expenditure of energy outflows in areas where it is not needed. This judicious use of energy may contribute to huge amounts of cumulative energy saving considering that at any point of time up to 30% of commercial space may be unoccupied at any point of time thereby saving energy by cutting off supply to these areas.

4.1 Solar Power

One technology that has become the backbone of clean energy is solar energy and it is used both as an active as well as passive power. The active use involves using the radiation to provide for heating and electricity needs, decreasing the dependence on other non-renewable energy sources. Passive solar power design uses innovative designing of walls and windows and use of heat absorbing surfaces to decrease the dependence on heating systems during winters. There are some rules which must be adhered to for effective solar energy utilization through passive solar systems [16].

4.2 Biodegradable Materials

These materials offer an advantage over traditional construction practices by preventing the accumulation of dangerous and toxic chemicals which may persist in the environment and gradually release toxins over time polluting the natural resources.

4.3 Green Insulation

Use of green insulation eliminates the use of non-renewable materials for high end finishes instead recycled materials are used. Efficient insulation is necessary to maintain temperature on the inside of a building with respect to the outside in different climactic conditions. The choice of insulating material is important, commonly used materials are wool insulation, slag slabs, natural fiber insulation, porotherm smart bricks, gypsum board, vermiculite and perlite insulation materials, gasket cork sheet and cementitious foam insulation materials. Preferred material should be fireproof, should not be hygroscopic, should not be vulnerable to deformation and be resistant to insect attacks.

4.4 Smart Appliances

Use of smart appliances in commercial as well as residential buildings with the goal to make them zero-energy using smart-grid machines is strongly recommended and encouraged.

4.5 Cool Roofs

Reflecting sunlight and heat away from buildings helps in lowering temperatures inside decreasing energy consumption resulting in decreased greenhouse gas emissions from power sources [17]. Reflective paints, cool roof shingles and tiles are some of the materials commonly used for constructing cool roofs.

4.6 Sustainable Resource Sourcing

Construction materials should not only be recyclable as well as recycled and remanufactured but also made from sustainable sources.

4.7 Low-Energy House and Zero-Energy Design

The technologies used here have inbuilt mechanisms to decrease energy consumption with the goal being a zero-energy building. Though the initial costs may be on the higher side but long-term returns are worthwhile. Sustainable green construction uses not just materials but also designs which cut energy costs, like strategic placement of windows to capture maximum amount of daylight minimizing electricity consumption along with use of renewable energy such as solar or wind for use in the building. The use of wood as a construction material is also a sustainable option as it has a lower embodied energy in comparison to other commonly used materials like steel and concrete. Smart glass an energy saving technology is all set to become the backbone of zero energy buildings. The buildings are built such that they not only use energy efficiently, but they direct the surplus energy that they generate to a grid where it can be easily stored. The skyscrapers have the extra advantage of using wind turbines on rooftops taking advantage of air currents at higher altitudes generating clean energy.

4.8 Water Efficiency Technologies

Essentially these technologies involve reuse of water and an efficient water supply system. Dual plumbing, greywater re-use, rainwater harvesting, and water conservation fixtures ensure that water is fully utilized with zero wastage. Recycled water is used for non-potable purposes like washing and flushing toilets. Dual plumbing decreases loss of water and encourages re-use on-site. Rainwater harvesting provides water for use in and around the building and at the same time recharges ground water.

4.9 HVAC (Heating, Ventilation and Air Conditioning)

A good HVAC system which is one of the major consumers of energy has to be efficient so that it serves to reduce the consumption. AHU's are interlinked with heat recovery units to reduce the cooling load on the chiller, cooling towers, pumps jet fans with adjustable frequency drives are modulated by centralized IBMS.

4.10 Rammed Earth Bricks

This ancient technology has regained acceptance due to its environmental sustainability, better thermal insulation and use of locally sourced raw materials. Moist earth mixture and gravel and clay mixed with stabilizing elements helps to create dense hard walls which provides good insulation.

4.11 Transportation

Green travelling is an effective travelling mode which compliments a green building, such systems have low pollution, low emission and low energy consumption. People need to be educated and made aware of benefits of green travelling and civic infrastructure modified accordingly, with special emphasis on pedestrians and bicycles [18]. A smooth flow of goods, people and services will automatically lead to lesser and optimal energy utilization [19].

A transport system that involves all stakeholders along with technology adoption leads to a cost and energy efficient system [20].

5 International Rating Systems

There are several rating systems worldwide. The most widely accepted are briefly mentioned here.

5.1 LEED

Leadership in Energy and Environmental Design is a certification system in use in USA where an onsite and third-party verification system exists with four levels of certification. It offers its certification based on nine major areas so that buildings use their resources efficiently and help in keeping the environment safe throughout the building's life cycle. Top users of LEED certification include Intel Corp, Colgate-Palmolive, Mars Inc.

5.2 Well

This is a certification program managed by International WELL Building Institute (IWBI). WELL, evaluates buildings on eleven concepts. Top users of WELL include Wells Fargo, EY, Deloitte and Lenovo.

5.3 Fitwell

Fitwell focuses on the health and wellbeing of the occupants and the surrounding community. Tower Companies is one of the top users of this certification.

5.4 Green Globes

This rating system is in use in USA and Canada, this system uses a different mechanism using a self-assessment and can be used for new as well as old buildings. This system focuses on energy usage, water, waste management, emissions, and environmental management.

The following Table 1 list the information regarding certification and their relevant area of focus.

6 Challenges Being Faced by Green Building Practices

Green building (GB) is increasingly becoming the norm in the construction industry as a viable solution for meeting the growing demand for environmentally friendly or healthy buildings. However, the uptake of GB technologies is not as apparent [21].

6.1 Limited Awareness

A large number of populations continues to be unaware of the benefits of green buildings and those who are aware of it perceive it to be an expensive option. The government and other agencies need to reach out to educate the people, developers and also students of architecture and planning and engineering to encourage incorporation of green practices in all constructions.

6.2 Inadequate Administrative Support

A government that is not responsive to the needs and policy changes needed to encourage builders to incorporate green practices in their buildings can be an impediment to the success of green projects.

6.3 Shortage of Trained and Skilled Manpower

Success of such projects needs people with knowledge and expertise from policymakers to workers. Skilled manpower who can use and also educate others in the use of green technology need to be part of an integrated planning and implementation setup to plug knowledge deficits.

Table 1 Green building certification

Rating institution	Type of standards/certification	Areas of focus
Leadership in Energy and Environmental Design (LEED)	• Building Design and Construction • Interior Design and Construction • Operations and Maintenance • Neighborhood Development • Homes	• Sustainable sites • Water efficiency • Energy and atmosphere • Materials and resources • Indoor environmental quality • Locations and linkages • Awareness and education • Innovation and design • Regional priority
Building Research Establishment Environmental Assess-ment Method (BREEM)	• BREEM New Construction • BREEAM International New Construction • BREEAM Communities • BREEAM Infrastructure • BREEAM In-Use • BREEAM Refurbishment & Fit-Out	• Energy • Health & Well-being • Transport • Water • Materials • Waste • Land use & Ecology • Management • Pollution
GREEN GLOBES	• Existing buildings • New construction	• Energy • Indoor environment • Site • Water • Resources • Emissions • Project/environmental management
WELL	• New and existing buildings • Retail • Education • Restaurant • Commercial kitchen • Multifamily residential	• Air • Water • Nourishment • Light • Fitness • Comfort • Mind
CASBEE	• New construction • Existing building • Renovation	• Energy • Resource and materials • Off-site environment

6.4 Reduction of Costs of Equipment's and Products

Reduction of costs and ready availability of financing options and tax benefits needs to be encouraged by the relevant agencies to encourage people to adopt green practices.

Providing direct incentives in taxes, development fees and any other financial benefits to developers and taxing non green projects may prove to be a bane [22].

6.5 Non-Financial Incentives

A number of non-financial incentives in the form of floor area density, relaxatio, assistance by providing relevant technical support from all government departments, expediting clearances of projects will greatly assist such projects.

7 Future of Green Building

The future of green building technology is full of opportunities and it is incumbent upon us to undo some of the damage that we have inflicted on our planet. There are areas which need further research to plug the knowledge gaps of green buildings and set the references for future research these include areas of corporate social responsibility, the performance of green buildings, ICT applications in green buildings and factors related to safety and health risks of workers involved in these projects [23].

7.1 Some Innovations in the Coming Times

1. Air cleaning materials such as paints and concrete using nanoscale titanium dioxide. Microgrids which re-distribute energy such that they store energy when it is in excess and utilize it later as and when needed. Net-zero buildings at net zero costs. These buildings generate as much as they use over the course of a year. Smart glass, a glass that can tint itself to keep the interior of a building cool. They are of two types electrochromic which responds to electricity and thermochromic which responds to heat from sunlight. Electricity generating glass, which combines smart glass tinting with electricity generation.
2. Self-healing concrete which uses concrete along with water activated bacteria that produce calcite which heals the cracks and has a very long-life span. This technique reduces maintenance costs and cuts greenhouse gases.
3. Pollution absorbing bricks which can filter 30% of fine pollutants and 100% of coarse pollutants resulting in self-sustaining ventilation.
4. Hydro ceramics is the future of self-cooling wall which uses a membrane made of ceramic fabric and hydrogel which absorbs water thereby cooling the building saving on air-conditioning costs.
5. Algae infused building panels; tree debris burned in kilns provide insulation materials for construction of walls which help in thermal insulation.
6. While many of these materials are not in full scale commercial production these may soon become a part of green buildings in near future.
7. Developing technologies for capture at source to lower green-house gas emission may become a part of all future buildings.

The future of green building is as bright as its past. Further advances in green technology will bring in newer designs and materials shaping the future of our buildings.

With the world having been shocked by the pandemic caution about health has only increased motivating people to live in safe and healthy spaces.

8 Conclusion

The future of buildings is without doubt green more so because of its contribution not just to reduction in carbon emissions and global warming but also as a huge investment opportunity. The technologies to build such buildings is readily available and is rapidly evolving at a rapid pace auguring well for future as sustainability is the idea to heal the world. By successfully preserving green there is the possibility and chances for us to help our own world to save the earth from global damage and destruction and at the same time bringing economic prosperity within the community. Government and policy makers should make provisions under their legislative framework to develop green buildings in the urban planning process.

References

1. Manna, D., & Banerjee, S. (2019). A review on green building movement in India. *International Journal of Scientific & Technology Research, 8*, 1980–1986.
2. Zhou, Z., Wang, C., Sun, X., Gao, F., Feng, W., & Zillante, G. (2018). Heating energy saving potential from building envelope design Andoperation optimization in residential buildings: A case study innorthern China. *Journal of Cleaner Production, 174*, 413–423.
3. Ahmed, M. F. A., & Gawad, A. A. (2016). Utilization of wind energy in green buildings. In *Twelfth International Conference of Fluid Dynamics*, Cairo.
4. Chen, Z., Liu, P., & Yang, Y. (2017). Sustainable building and integrated construction waste management challenges and strategies for China. In *Advances in Social Science, Education and Humanities Research*.
5. Das, O., Bera, P., & Moulick, S. (2015). Water conservation aspects of green buildings. *IJRET: International Journal of Research in Engineering and Technology, 9*, 289–294.
6. Laurent, J. C., Williams, A., MacNaughton, P., Cao, X., Eitland, E., Spengler, J., & Allen, J. (2018). Building evidence for health: Green buildings, current science, and future challenges. *Annual Review of Public Health, 39*, 291–308.
7. Wargocki, P., Wyon, D. P., Sundell, J., Clausen, G., & Fanger, P. O. (2000). The effects of outdoor air supply rate in an office on perceived air quality, sick building syndrome (SBS) symptoms and productivity. *Indoor Air, 10*(4), 222–236.
8. Daisey, J., Angell, W., & Apte, M. (2003). Indoor air quality, ventilation and health symptoms in schools: An analysis of existing information. *Indoor Air, 13*(1), 53–64.
9. Steinemann, A., Wargocki, P., & Rismanchi, B. (2017). Ten questions concerning green buildings and indoor air quality. *Building and Environment, 112*, 351–358.
10. Aher, P. D., & Pimplikar, S. S. (2012). Green building design a sustainable future. *International Journal of Engineering Research & Application (IJERA), 2*(5), 857–860.

11. Misra, S., Prasad, G. S., Padhy, A. K., Patra, S., Nath, T., & Pattnaik, S. (2016). An economical and comparative analysis of energy conservation requirements: An approach to get the star rating of green buildings. *International Research Journal of Engineering and Technology (IRJET), 3*(5), 59–63.
12. Reddy, B. V., & Jagdish, K. S. (2003). Embodied energy of common and alternative building materials and technologies. *Energy and Building, 35*(2), 129–137.
13. Zuo, J., & Zhao, Z.-Y. (2014). Green building research–current status and future agenda: A review. *Renewable and Sustainable Energy Reviews, 30*, 271–281.
14. Allen, J. G., MacNaughton, P., Laurent, J. G., Flanigan, S., Eitland, E. S., & Spengler, J. D. (2015). Green buildings and health. *Current Environmental Health Report, 2*, 250–258.
15. Allen, J. G., MacNaughton, P., Satish, U., Santanam, S., Vallarino, J., & Spengler, J. D. (2016). Associations of cognitive function scores with carbon dioxide, ventilation, and volatile organic compound exposures in office workers: A controlled exposure study of green and conventional office environments. *Environmental Health Perspective, 124*(6), 805–812.
16. Perlova, E., Platonova, M., Gorshkov, A., & Rakova, X. (2015). Concept project of zero energy building. *Procedia Engineering, 100*, 1505–1514.
17. Kolokotroni, M., Wines, C., Babiker, R. M., & Silva, B. H. D. (2016). Cool and green roofs for storage buildings in various climates. *Procedia Engineering, 169*, 350–358.
18. Li, H.-R. (2016). Study on Green transportation system of international metropolises. *Proceedia Engineering, 137*, 762–771.
19. Agarwal, P., Hassan, S. I., & Ahmed, J. (2020). Intelligent transportation system: A complete insight. In *IoT and cloud computing advancements in vehicular ad-hoc networks* (p. 22). IGI Global Publisher of Timely Knowledge.
20. Agarwal, P., & Alam, M. A. (2018). Use of ICT for sustainable transportation. *IOP Conference Series: Earth and Environmental Science, 150*, 012032.
21. Chan, A. P. C., Darko, A., Ameyaw, E. E., & Owusu-Manu, D.-G. (2017). Barriers affecting the adoption of green building technologies. *Journal of Management and Engineering, 33*(3), 04016057.
22. Olubunmi, A. O., Xia, B. P., & Skitmore, M. (2016). Green building incentives: A review. *Renewable and Sustainable Energy Reviews, 59*, 1611–1621.
23. Zhao, X., Zuo, J., Wu, G., & Huang, C. (2018). A bibliometric review of green building research 2000–2016. *Architectural Science Review, 62*(1), 74–88.

Reliable and Cost-Effective Smart Water Governing Framework for Industries and Households

Usha Rani Nelakuditi, Mohammad Khasim Shaik, and Naveen Avula

1 Introduction

Water is an essential element for the existence of life on earth. The total populace significantly increased worldwide in the twentieth century and water consumption is increasing at the rate of more than twice the rate of population growth. As per the predictions, in the following 50 years the total populace will increase by another 40–50%. This has made supplying clean water at minimum cost is a challenge for water management authorities.

This populace development combined with industrialization and urbanization will bring about expanding interest in water. As per the World Bank, 40% of the total populace is influenced by water shortages. Assessments show that by 2025, 1.8 billion individuals will live with the shortage.

Two third of the worldwide populace will live in water-focused regions. World Economic Forum2019, recognized water shortage as the most genuine worldwide danger in the following decade.

As per a report by the Ministry of Water Resources, India has around 18% of the total population in the world, however has just 4% usable water sources. The National Institution for Transforming India (NITI Aayog) depicted it as the most exceedingly terrible water emergency in India's set of experiences.

The 2018 Composite Water Management Index (CWMI) noticed that 6% of monetary GDP will be lost by 2050, while water requests will surpass the accessible stock by 2030.

U. R. Nelakuditi · M. K. Shaik (✉) · N. Avula
Department of Electronics and Communication Engineering, Vignan's Foundation for Science, Technology and Research (Deemed to be University), Guntur, Andhra Pradesh, India

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_11

The Central Water Commission expresses that India needs around 3000 billion cubic meters of water a year, whereas 1000 billion cubic meters in abundance with India. The current gap between supply and demand is around 2000 million liters. This alarms that bounty water resources are to be utilized judiciously.

On average one person wastes around 45 l of water each day. To comprehend it better, it is 30% of water necessity per individual every day. One hundred and twenty-five million liters of water wasted every day. These statistics clearly show that there needs to be an effective water management system to reduce the water crisis.

Though it is difficult, this can be resolved by integrating big data and analytics into water management systems. The consistent, end-to-end digitalization of plants and processes helps the water and wastewater industry meet these challenges.

Smart water management implies the mix of frameworks and the selection of a complex of measures to monitor, control, and manage the utilization and nature of water assets and keep up the related hardware (pipes, siphons, and so on).

By frameworks, we mean a wide scope of equipment and programming instruments, including sensors, meters, information handling, and perception devices, actuators, and web and versatile control that interface individual with water frameworks.

The essential goal of smart water management is sensible and feasible utilization and reusing of water assets. Developing populace, expanding ecological issues and tension on the food and agribusiness area make water even an all the more valuable resource.

In the water management process, a greater part of the water wastage happens during supply, dissemination, and utilization. To dodge these sorts of wastages a successful framework is fundamental which screens such spillages through pipelines, a measure of water burned-through, programmed water tank filling, turbidity, PH, and temperature utilizing sensors and makes a vital move by enacting the separate actuators at whatever point deviation happens. Combination and support of the related equipment hardware like lines, siphons, sensors, and meters, just as programming for information preparing and representation is a lot required.

Internet of Things is the best reasonable technology for this sort of use since it gives ongoing observation and the capacity to quickly address distinguished issues. IoT empowers stainable practices by lessening wastage It likewise encourages mechanization and expansion of human force alongside straightforwardness to the interaction in water store network. Supports information perception and investigation along these lines prompts forward-arranging water preservation systems.

2 Literature Survey

There were numerous individuals dealt with water management issues at different levels. Graham Cole [1] proposed a paper about the execution of a savvy water metering framework in Hervey Bay that permitted the neighborhood water utility to record the hourly water utilization of every one of its clients. It gives itemized after-effects of the investigation of the normal hour, top hour, top day, and pinnacle month utilization information.

Beza Negash Getu, Hussain A. Attia [2], have built up a framework that at first tests the accessibility of water in the tank with the assistance of a level indicator and afterward modifies the condition of the water siphon as per the data gathered through the level identifier. This plan utilizes a seven portion show and an engine siphon. The proposed framework comprises of water level sensor and an advanced rationale processor circuit.

J.Navarajan et al. [3] present a remote sensor-based system along with a micro-controller and Zigbee module to quantify water quality. This framework dependent on remote sensor organizes that comprise a wireless water quality monitoring network and remote data center. But this system has a few confinements as the scope of correspondence is less for the Zigbee convention.

Cho Zin Myint et al. [4] introduced a reconfigurable keen sensor interface gadget for the water quality observing framework. The brilliant water quality observing framework comprises of Field Programmable Gate Array configuration, sensors, remote correspondence module, and PC. This framework has a restriction of continuous execution.

Saravanan Krish et al. [5] proposed another Supervisory Control And Data Acquisition (SCADA) framework for continuous water quality checking. It intends to decide the tainting of water, spillage in the pipeline, and proportion of boundaries, for example, temperature, stream, and shade of water progressively.

P. Swetha Reddy et al. [6] built up a framework for the spillage discovery of pipelines during water conveyance to recognize the spillage and gives insinuation to the client about spillage alongside control for programmed engine killing after the identification of spillage. This framework is a dependable one for the execution continuously during the conveyance of water through pipelines.

M.B. Kawarhe et al. [7] built up a framework which screens water level of tank alongside quality checking and recognition of spillages in pipelines with GSM insinuation to the client. It doesn't have an appropriate controlling system which prompts at whatever point the water wastage happens it just underwear however it doesn't make any legitimate move. This framework additionally neglects to follow the measure of water burned-through from the tank which is another inconvenience to control the water utilization through the valve so that overuse or pointless use can be dodged.

Anna Di Mauro et al. [8] presented an IoT-based distinguishing and noticing system to perceive water end-use in private space. The organized plan can normally perceive, accumulate and store significant standards of water end-use usage data persistently. The paper presents crucial results as demonstrated by the data open after 2 months of movement.

Dr. Manjunath Kotari et al. (2019) planned a framework for water tank observing which turns on/off the engine when the water level in the tank arrives at lower and upper edges separately so the overhead water tank filling will be performed consequently. The water level in the tank can be envisioned utilizing the application and the engine can likewise be controlled through the application physically according to the prerequisite of the client. Yet, this framework is restricted to tank level as it were. It doesn't manage wastage during water spillage and utilization.

The proposed system is an integrated model for the water governing purpose with automatic monitoring and controlling facility along with effective data visualization and analytics tool. It is a cost-effective and reliable solution for water management purposes without any wastage. The proposed system will solve all the limitations that are discussed in the above research works regarding water conservation during distribution and consumption in cases of leakage detection and water tank scenario. It also provides an effective overview and analysis of data to take necessary action so that water wastage can be avoided.

3 Existing System

There are distant sources like Pumping stations, Storage offices, Industrial client areas, and Retail client areas from where these devices gather information identified with water. Some of the Commercial off-the-shelf (COTS) items that are accessible in the market that get information from various sources and help water managers in taking better and well-informed choices are

- Supervisory Control and Data Acquisition (SCADA)
- Laboratory Information Management Systems (LIMS) and
- Computerized Maintenance Management Systems (CMMS)

These frameworks have the ability to store water information and afterward perform prompt activities dependent on the equivalent.

Here, information-driven SCADA is viewed as the information assortment measure that helps in better asset observing and improved dynamic by information perception and information ingestion. The essential SCADA framework has programmable logic controllers (PLCs) or remote terminal units (RTUs).

These are microcomputers that can communicate with different items like factory machines, human-machine interfaces (HMIs), sensors, and different gadgets, and afterward course the data to PCs with SCADA software. Supervisory Control and Data Acquisition (SCADA), frameworks are utilized for continuous procurement of sensor information, observing hardware, and controlling cycles in water dispersion.

It additionally screens and controls the innovative boundaries in the water circulation stations, which will permit the ideal working of the siphoning framework, wellbeing, and perseverance development in the supplies and establishments investigating, thus acquiring effective energy use and ideal organization of the drinkable water.

3.1 Working of SCADA System

In the main stage, the SCADA framework contains observation, distribution, and detailing capacities for Water Supply Systems (WSS), such as checking the levels in supplies, streams and pressing factors on the power source of creation siphon stations and water conveyance repositories, control of the chlorination cycle and so on. In the next stage, in person/automated activity for WSS will takes place. There will be three layers in an improved model of the governing framework. The primary layer deals with wiring, automation devices, remote terminal units and instruments those are required for controlling purpose. Instruments for controlling includes electrostatic flow measurers, supersonic ranging devices and transducers along with level, flow, pressure and force automation terminals are placed at the required positions of tanks and pipelines. With the help of transmitting devices information in the form of signals will be sent to respective controlling boards in the next layer.

The authorities can monitor the controllers and can change the particular parameters as per the requirement. Remote terminal units monitor the levels of the tanks and this information will be sent to programmable logic controlling boards through broadband. Workers, a monitoring& controlling station along with an architect's working environment are the main elements of Supervisory Control and Data Acquisition.

3.2 Drawbacks of SCADA

Gadget Interconnectivity

While executing SCADA frameworks, bringing together devices that are made by distinct manufacturers is a near outlandish undertaking. Moreover, when the devices are created by a similar producer, it very well may be hard to utilize them reciprocally as their model may change. They additionally require an even program that can work across a large group of devices, independent of their maker or model.

Presently when we assess IoT, the framework relies upon the thought of interconnectivity. The essential rationale of this is to encourage correspondence across various gadgets. Nothing is dependent on the model or producer of the apparatuses. It utilizes techniques like MQTT to encourage excessive correspondence over all gadgets in a complete framework.

Working Expenses and Costs

To store additional information in a SCADA framework, organizations will unavoidably cause costs for new workers. Likewise, during the time spent programming permitting or getting extra highlights, SCADA clients need to purchase particular licenses for new administrations and need to oftentimes pay for updating the framework.

The Internet of Things can significantly alleviate the equipment and programming costs for organizations, while additionally eliminating the prerequisite of actually empowering programming authorizing and redesigning by executing cloud administrations.

Information Insights

While utilizing SCADA frameworks present deficiencies in dissecting and deciphering noteworthy information, organizations will in general experience these obstacles in breaking down old information and afterward deciphering it. SCADA doesn't zero in on working together or deciphering the knowledge that organizations are producing day by day. The data neither carries any significant experiences to the clients nor does it offer any vital assistance to the chiefs of the business.

Here, IoT eclipses its competitors. It solidifies and gathers information from a few business capacities, and afterward along these lines applies enormous information examination to foresee productivity and dodge any possible vacillations. With the complete astuteness of IoT, enterprises can anticipate unanticipated gear blocks and support necessities.

Adaptability

In SCADA programming, there are devices that present basic data yet have never been used as they require an overhead cost. Additionally, as the quantity of clients builds, the data transfer capacity ought to likewise be made huge enough to deal with the increment which causes security concerns and alleviate most issues. Moreover, it likewise takes a long effort to set up.

IoT can get and handle a lot of information, while likewise empowering clients to interface extra machines at ease. The entirety of this information is shipped off a cloud and got to utilizing login details. Data or information from any place in the world can be seen and gotten to by means of an HMI framework that interfaces them to the clouds.

4 Proposed Framework

An IoT-based smart water governing framework is proposed to perform fundamentally four tasks such as leakage detection, water tank filling, water consumption tracking, and water quality monitoring as appeared in Fig. 1. The functions of each module are explained below.

Fig. 1 Proposed water governing system

4.1 Water Pipeline Leakage Detection Module

This module is intended for the identification of spillages in the long pipeline networks utilizing a flow sensor that quantifies the progression of water through the pipeline. At whatever point if there is a spillage in the pipeline then the stream rate at one flow sensor changes with the flow rate with another sensor of that pipeline, at that point, the leakage will be recognized. As soon as leakage was detected intimation will be sent to the operator through GSM and the motor will be turned off automatically to avoid water wastage.

4.2 Automatic Water Tank Filling Module

In numerous houses, the majority of the water will be squandered during the filling of the overhead tanks. This errand can be mechanized using an ultrasonic sensor. Water tank levels will be arranged with two limits, lower and upper edges. whenever the water level spans underneath the lower edge at that point motor will be automatically turned on through the relay. When the water level arrives at the upper limit motor will be killed and it will stay in the off situation until the water level reaches the lower edge again. Likewise, water wastage due to overflow can be limited. The water level in the tank can be monitored using the Blynk app.

4.3 Water Quality Monitoring

Water quality check is very much required in the case of drinking water and in some industries. The parameters like PH, turbidity, and temperature are monitored using Blynk App. Whenever there is a deviation from the permissible threshold values of parameters then intimation will be given to the user. Based on the required parameter, a specific sensor will be used for that application. The proposed system uses PH, turbidity, and temperature sensors for measuring the respective parameters of water in the tank.

4.4 Water Consumption Tracking

Estimations of household water consumption are very troublesome in intermittent water supply (IWS) systems, where water is conveyed for brief lengths, taps are shared, metering is restricted, and the family stockpiling framework fluctuates generally. Metropolitan water chiefs require estimations of how much water occupants burn through to comprehend examples of water access and water misfortunes, and thus to distinguish powerful measures to improve supply conditions. Notwithstanding, regular water accounting strategies don’t have any significant bearing in unmetered and discontinuous frameworks. Water accounting techniques for funneled water supplies have been set up for the completely compressed and metered frameworks. In many cases in India, there is no accountability in the usage of water due to which people are unaware of water wastage. There is a need to create awareness among the people through proper metering. In this work process flow sensor will be used for tracking water usage which was fitted at the outlet of the tank so that toward the day’s end one can know the amount of water consumed and the same can be observed on the Blynk app. When the measure of utilization is more noteworthy than the set edge then the valve will be naturally killed and the solenoid valve stops the stock.

4.5 Block Diagram of Proposed Framework

The block diagram of the proposed smart water governing framework appears in Fig. 2. It comprises of Arduino Mega Microcontroller for observing and controlling activity and ESP8266 Wi-Fi module to transfer data from controller to the Azure cloud, whose data will be accessed by power BI tool & Blynk app for data visualization and analysis. Sensors such as flow sensor, ultrasonic sensor, PH, turbidity, and temperature sensors are likewise associated with the Arduino Mega

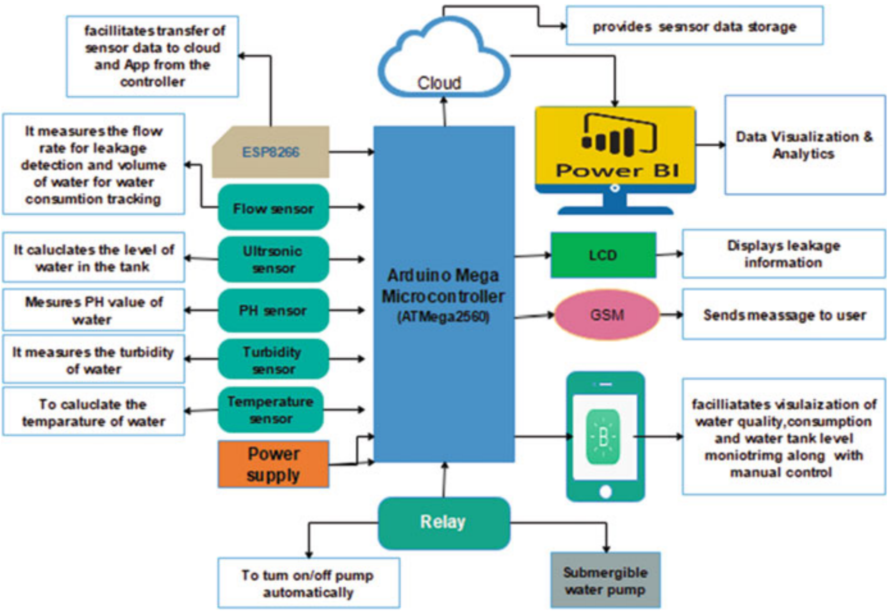


Fig. 2 Block diagram of Smart Water Governing Framework

board. Actuator components such as relay switch, water motor, and solenoid valve for water flow control are interfaced with the microcontroller. GSM is utilized for message correspondence.

All the sensors will ceaselessly detect the information from the actual world and send it to the Arduino Mega microcontroller and it will move the information to Azure cloud through an IoT hub utilizing ESP-8266 Wi-Fi module. Data is obtained from different subsystems like an overhead tank, PH, turbidity and temperature of water in the tank, the measure of water burned-through can be procured utilizing separate sensors and pictured on the Blynk application. The received sensor information will be pictured and broke down utilizing power BI for clear comprehension of framework with successful dynamic to decrease the water wastage in different viewpoints.

4.6 Framework Components and Description

Flow sensor: It is used for flow estimations and to detect any spillage in the pipeline. Accurate water stream flow measurement is an important aspect not only in subjective but also for financial perspectives. Sensor is placed across the waterline which has a pinwheel to measure the amount of water flows through the sensor. For each rotation of pinwheel, an electric signal will be generated by Hall Effect. This flow sensor is used for spillage detection as well water consumption tracking in case of smart water governing framework.

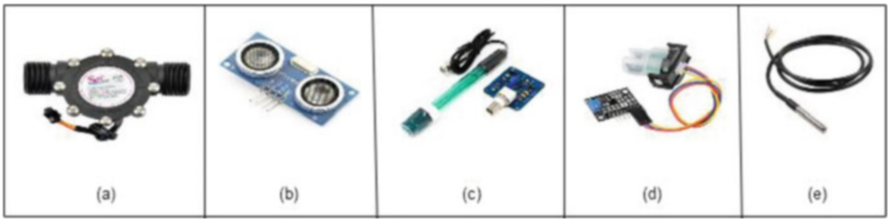


Fig. 3 (**a**) Flow sensor, (**b**) ultrasonic sensor, (**c**) PH sensor, (**d**) turbidity sensor, (**e**) temperature sensor

Ultrasonic sensor: This measures the level of water in the tank to avoid overflow. Sensor continuously emits ultrasonic pulses at regular intervals up to its range. During this time, if any obstacle is present, then the waves will get reflected back and sensor detects the reverberation, based on which distance will be calculated.

PH sensor: It is used for gauging hydrogen quantity in given fluid. Activity of Hydrogen ions under the common logarithm which is a negative one is nothing but the PH of a solution. Amount of carbonate present in water will affect its PH Value. It is one of the important variables for water quality gauge.

Turbidity sensor: This works on the principle of amount of light that can be received by the IR receiver through suspended solid particles in the solution gives the measure of turbidity. If the defer particles are more, turbidity will be more and vice versa. Turbidity of water comes under water quality check sub system in smart water governing framework.

Temperature sensor (DS18B20): available voltage over the diode ends quantifies the temperature of the solution. Amount of voltage generated is directly proportional to temperature. This sensor has high application in case of industrial use (Fig. 3).

GSM (SIM 900a)

A proper GSM supporting mobile with the respective link along with the programmable driver to connect a sequential port or Universal Serial Bus port on a Personal Computer forms a GSM module. Any mobile that allows “extended AT command set” for the communication of message can be used. This module has a major role during sending intimation to the user about the status of the water governing framework on a timely basis.

Relay: Relays are electric switches that utilize electromagnetism to change over little electrical stimuli into bigger currents. These transformations happen when electrical data sources initiate electromagnets to one or the other structure or break existing circuits. The relay is used to avoid water wastage during tank filling & leakage detection by making motor condition into the off state.

Solenoid valve: It is a type of valve that can be controlled electrically. A solenoid is present inside the valve which has a movable magnetic unclogger in the form of

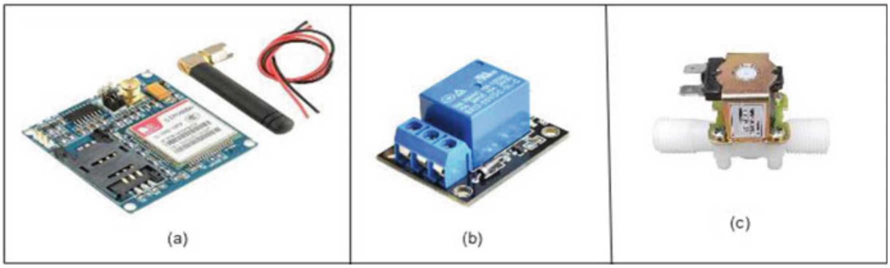


Fig. 4 (**a**) GSM module. (**b**) Relay. (**c**) Solenoid valve

electric loop at the center. When the unclogger is in off state it closes the little hole. When electric field is applied then unclogger will be moved upwards then, hole will get open. This is the basic principle that is used to open and close the valve which will be applied for stopping water supply from the tank when it crosses the threshold limit of consumption (Fig. 4).

ESP8266 Wi-Fi Module: A System on chip (SOC) based independent module with combined TCP/IP protocol stack that provides access to Wi-Fi network and allows this facility to all type of microcontroller boards is nothing but an ESP8266 Wi-Fi Module. This Wi-Fi module is capable of supporting all type functionalities related to Wi-Fi networking with other devices. Data transfer into Azure cloud is one of the essential tasks which will be taken care of by this module. Makes it feasible for data access & visualization afterward, independent of location.

Azure Cloud: It is a Public cloud computing platform that provides Infrastructure, Platform, and Software as services which is used for analytics, virtual processing, stockpiling systems administration, and substantially more. IoT based Azure cloud also supports two way transfer of information among the devices. With the Azure cloud, one can perform both controlling and measurement of the desired system while connecting multiple devices to it.

Blynk App: It is a platform which facilitates the quick assembly of interfaces for monitoring and automating various projects from Android and iOS devices. With the help of arrange buttons, charts, sliders, various widgets one can create a required dashboard. It also supports controlling action through pins and can display the data from the sensors. It provides an effective visual interface to the user which is very handy and reliable for water governing system.

Power BI: Connect to and visualize any data using the combined, adaptable stage for self-administration and endeavor business intelligence (BI) that is easy to use and encourages you to acquire further deeper data insight.

Arduino Mega Microcontroller: ATmega2560 based microcontroller is the Arduino Mega board. Due to its multiple I/O lines & pins (54D, 16A) vast memory, space, simplicity and high RAM makes this board suitable for various complex projects. Low power consumption with fast start-up and easy-to-use features enables the use of this microcontroller effectively.

4.7 Algorithm of Proposed Framework

Step1: Initialization of sensors (flow sensor, ultrasonic sensor, PH, turbidity and temperature sensor) and other components along with microcontroller of smart water governing system (as per the specifications)
Step2: If variation of flow rates between respective sensors > '0' {
Leakage in pipeline, Indication in LCD display, SMS alert will be sent to user
}
Step 3: If leakage time > threshold time {
Put off the motor
}
Step 4 : Initialize the Lower (L_L) and Upper (L_H) water level thresholdsas per the requirement.
Step 5 :If Current Water Level < Lower (L_L) {
Motor will be turned on through relay till water level reaches upper threshold Tank Levelis visualized in BlynkApp }
Step 6: If Current Water Level >Upper (L_H) {
Motor will be turned off till water level reaches again lower threshold. Tank Level is visualized in BlynkApp }
Step7: Monitor the PH, Turbidity and temperature of water in the tank and send that to Blynk app for visualization.
Step8: **If PH value of water in tank <'5'**{
Turn on Buzzer,
PH value indication on Blynk App.
}
Step9 : Track the consumption of water from the tank
Step 10: **If amount of water consumption> threshold amount of water** {
Turn off the solenoid valve ,
Visualization of amount of water consumed on Blynk App.
}
Step 11: Visualize the entire system data on power BI.
Step 12: **Perform Data Analytics for effective conclusion and decision making.**

4.8 Flow Chart

While the sensors are in the action of water management, if any deviation happens like water level variation or quality parameter changes or spillage discovery happens, at that point, legitimate controlling activity will be started on the side of the actuator.

The whole sensor's activities and their relating actuator's response can be observed in the flow chart as shown in Fig. 5.

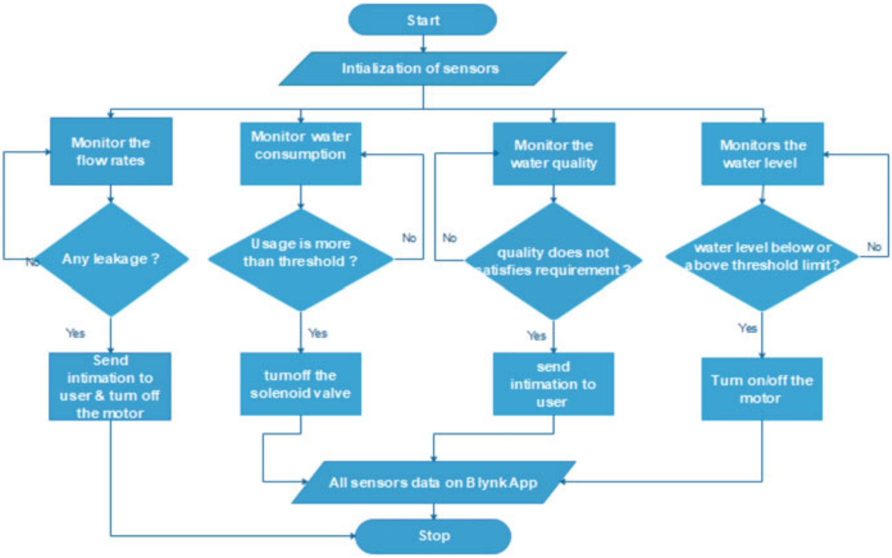


Fig. 5 Flow chart of smart water governing system

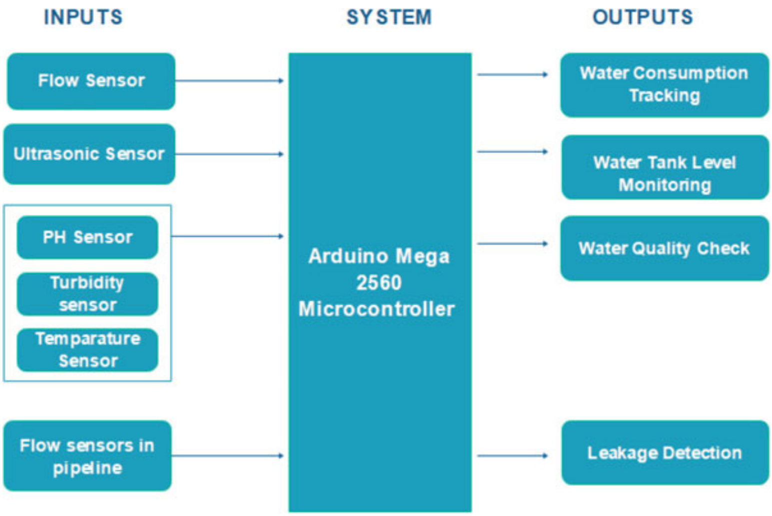


Fig. 6 System representation of smart water governing framework

4.9 System Representation (Fig. 6)

4.10 Schematic Diagram (Fig. 7)

5 Implementation

Arduino based smart water governing system is implemented using hardware and IDE is shown in Fig. 8.

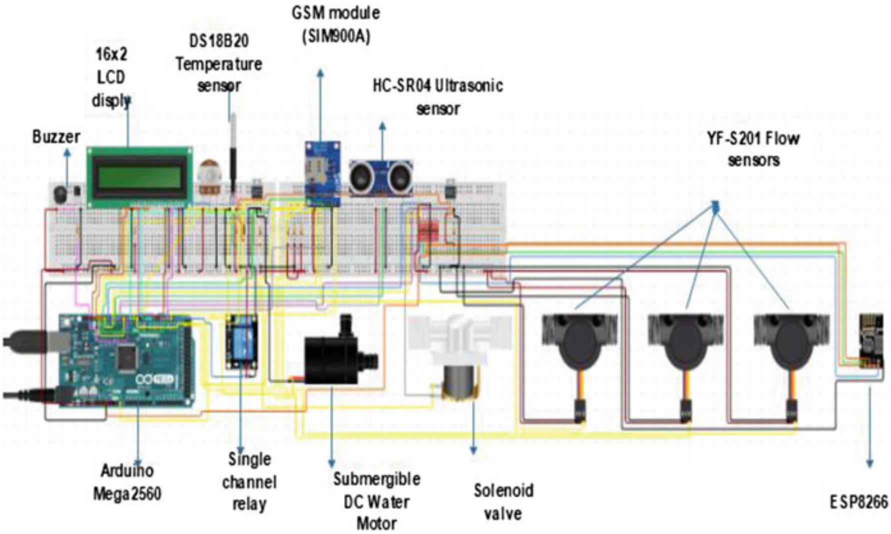


Fig. 7 Schematic diagram of smart water governing framework

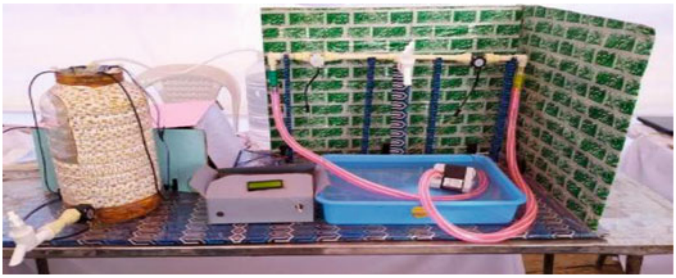


Fig. 8 Smart water governing system

5.1 Construction

For spillage identification, two flow sensors are fixed at the front and backsides of the pipeline are appeared in Fig. 9. To model the leakage while the distribution of water through the pipe, a tap is arranged in between those two flow sensors to gauge the differential flow. GSM modules and LCD module is also added to the framework. Automatic overhead tank filling is observed through the ultrasonic sensor, motor, and the relay associated with the controller.

Water quality check is actualized using PH, turbidity, and temperature sensors inside the tank. Water utilization tracking is finished with the assistance of a flow sensor and valves which are fitted to the power source of the tank as demonstrated in the above figure.

The front and top perspectives of the tank are shown in Fig. 9a, b respectively. The leakage detection framework can be observed in Fig. 9c.

6 Results and Discussion

The function of the system is observed utilizing the Blynk application on the client-side and in Power BI on the host or administrator side. At whatever point it recognizes any spillage in the pipeline (when the tap is turned on for showing spillage, flow variation will happen) it sends a message to the client using GSM and displays the leakage detection data on the LCD module (Figs. 10 and 11).

When the spillage is more than 5 min which is a support time in this situation, the engine will be naturally turned off alongside warning to the client as demonstrated in the above figures.

For the proposed framework, various parameters threshold is set as follows.

- PH value of water is less than 4.5 or greater than 11.
- The turbidity of water is more than 5 NTU.

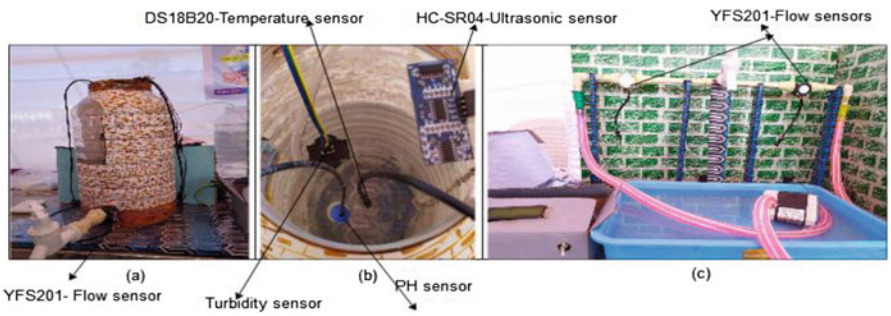


Fig. 9 (**a**) Front view of the tank. (**b**) Top view of the tank. (**c**) Leakage detection system

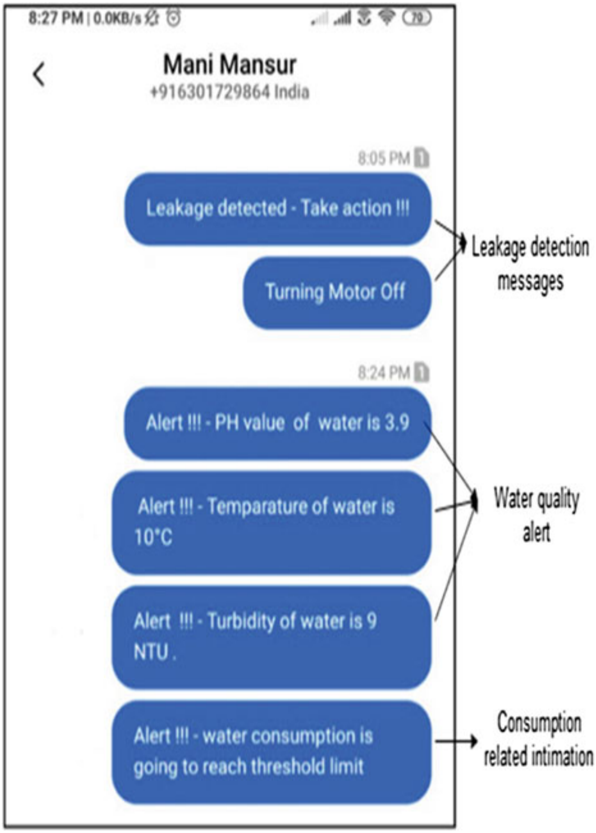


Fig. 10 Status of smart water governing system

- The temperature of the water is less than 15 °C or greater than 50 °C.
- Water consumption reaches 2.5 l, and then intimation will be sent to the user. When consumption reaches 3 l, then the valve will be turned off automatically.

According to the set threshold values, messages are sent to the user which is shown in the above figure.

Tank filling can be monitored automatically which can be observed in the Blynk app as shown in the above figure. App developed for the proposed system visualizes water quality parameters like PH, temperature and turbidity values of water, the volume of water consumed from the tank.

Proposed control mechanisms assure that the smart water governing system model can prevent water wastage during overhead tank filling, distribution, and consumption tracking along with water quality monitoring in the tank.

Blynk app is useful for facilitating effective user interface & provides real-time monitoring on the client-side for visualization of entire system data and to analyze the data to make effective decision making, Power BI comes in to use.

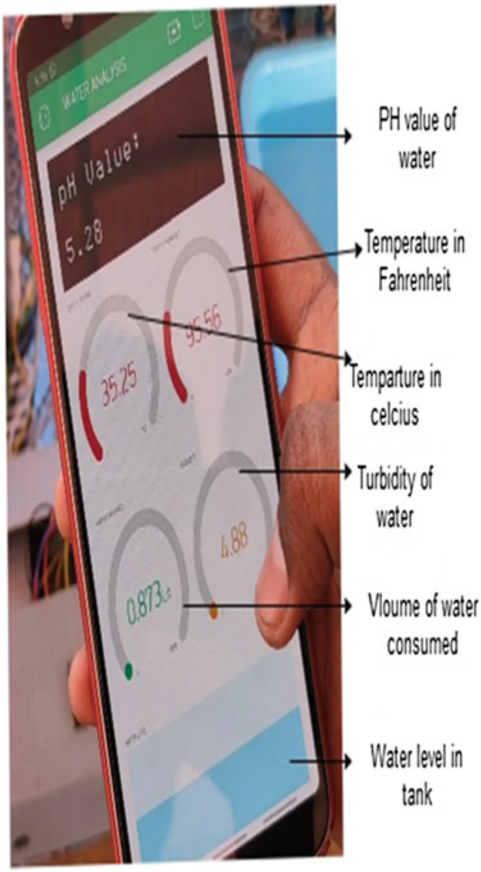


Fig. 11 Sensor readings on Blynk App

Power BI lays the foundation for cutting-edge analytics, opening up a world of opportunities for water management activity—from anticipating maintenance events and forestalling early gear substitution to turning away widespread service blackouts or catastrophes.

New, close to ongoing detailing and significant dashboards are now vital to the utility's operations. From the capacity to now cost-successfully gather and store mass sums of continuously created framework data, to the recently actualized web application alarming framework, the Power BI is revolutionizing data visualization & analytics.

This powerBI based arrangement gives the scale and scientific capacities to meet the utility's future business needs. The solution was, partially, intended to address weaknesses in the utility's heritage SCADA framework. This methodology can decipher across enterprises—especially those that actually depend on SCADA engineering.

All the sensor data will be accessed from the cloud and visualization of entire system data can be viewed in the PowerBI tool in the form of a dashboard as shown in the below figure. Power BI dashboard facilities effective visualization on the host side which includes water distribution corporation authorities. At a glance, one can get an overview of the system data on various timelines using the powerBI dashboard (Fig. 12).

Information that can be extracted from the dashboard is

- Amount of water consumed and water level in the overhead tank by the end of the day as per the need.
- Water quality parameters (PH, Turbidity & Temperature) and leakage detection data throughout the weeks.
- Frequency of occurrence in case of leakage.

Power BI gives viable perception as well as encourages dynamic utilizing of information investigation. different DAX functions are utilized to break down the information. data analytical functions include identify outliers in the data, grouping data together, and binning data for analysis. It also supports time-series analysis. Can work with cutting-edge scientific highlights of Power BI, for example, Quick Insights, AI Insights, and the Analyze include. Power BI allows the host or administration team to make intelligent decisions for efficiently managing the framework operations, making the job simpler & easier

The data analytics dashboard for the smart water governing system is shown in the below figure. Following conclusions can be made after analyzing the data using DAX functions (Fig. 13).

- Highest water utilization among all the days and vice versa
- Relation between water utilization and water level of the tank throughout the days.

After analysis, conclusions that can be drawn are:

- Whenever the water consumption is high, then water level in the overhead tank by that day is low and vice versa.
- On day 14 water consumption is highest throughout all days, whereas on day 15 the consumption is the lowest one.

7 Conclusion

IoT-based Smart water governing framework is a practical and proficient answer for the anticipation of water wastage during supply, conveyance, and consumption which is appropriate for smart cities, smart villages, households, and industries. This framework keeps away from the mediation of the human segment by encouraging programmed checking and controlling activities to dodge water wastage.

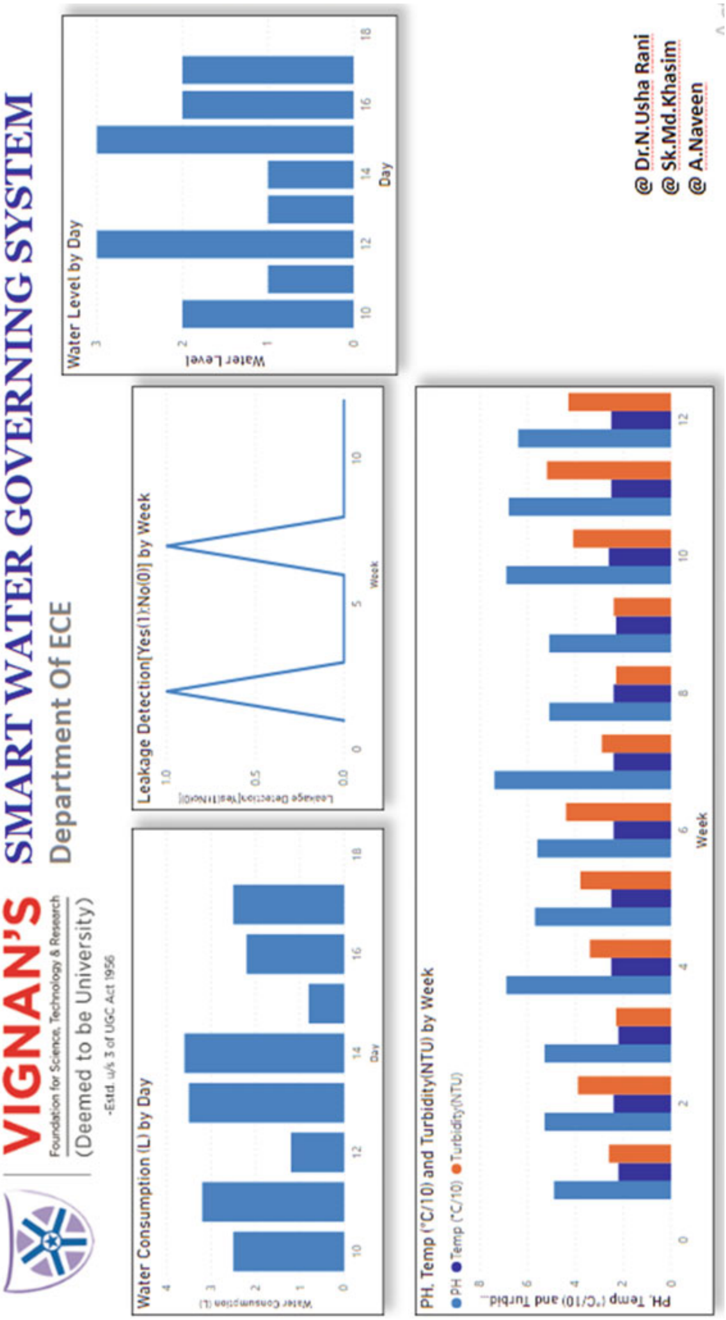


Fig. 12 Power BI dashboard for smart water governing system

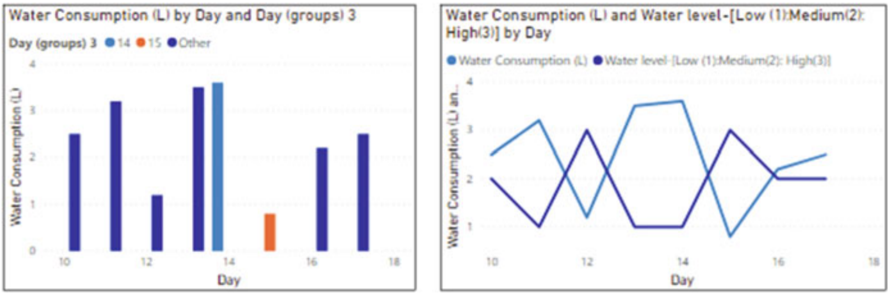


Fig. 13 Data analytics dashboard for smart water governing system

The proposed framework model is appropriate to businesses, family units, schools, and so forth any place the presence of tanks and dispersion of water occurs. It is a convenient and solid arrangement with less establishment and operational intricacy.

Information can be imagined in the type of a compelling user interface using the Blynk application on the client-side and through power BI on the host or administrator side which encourages a viable representation and examination for better end and dynamic to prevent water wastage.

8 Future Scope

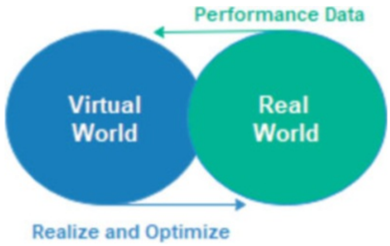
Utilizing Digital twin for smart water governing system, one can able to anticipate various outcomes depending on variable data. After run-the-simulation process, all potential situations can be demonstrated inside the digital environment. With the assistance of data analytics, the digital twin can upgrade the smart water governing framework for the greatest productivity, just as help originators sort out where things should go or how they work before they are genuinely conveyed.

Frameworks like water governing using the Internet of Things, the more exceptionally instrumented gadgets are, the more precisely digital twins can reproduce how the gadgets have performed over the long run, which could help in anticipating future execution and conceivable disappointment.

The intelligent connecting of information from various sources like sensors, water meters will set out new open doors to utilize water all the more effectively. A precondition will be end-to-end networking of system engineering and designing, from dispatching to activity, support, and progressing measure enhancement dependent on a data platform—a converging of the real and virtual worlds.

The enhanced qualitative data and accessibility will lessen the project execution time in reality. Simultaneously, the prospects provided by recreation and demonstrating in the virtual world decrease not only limitless expenses during development stage but also continuous working expenses (Fig. 14).

Fig. 14 Digital twin



References

1. Cole, G., & Stewart, R. A. (2013). Smart meter enabled disaggregation of urban peak water demand: Precursor to effective urban water planning. *Urban Water Journal, 10*(3), 174–194.
2. Getu, B. N., & Attia, H. A. (2016). Automatic water level sensor and controller system. In *2016 5th International Conference on Electronic Devices, Systems and Applications (ICEDSA)*, December 6, 2016 (pp. 1–4). IEEE.
3. Navarajan, J., Kumar, B. A., Venkatesh, S., & Jayachandran, T. (2017). Detection of water pollution and water management using smart sensors with IOT. *International Research Journal of Engineering and Technology (IRJET), 4*(4), 62–66.
4. Myint, C. Z., Gopal, L., & Aung, Y. L. (2017). Reconfigurable smart water quality monitoring system in IoT environment. In *2017 IEEE/ACIS 16th international conference on computer and information science (ICIS)*, May 24, 2017 (pp. 435–440). IEEE.
5. Saravanan, K., Anusuya, E., & Kumar, R. (2018). Real-time water quality monitoring using Internet of Things in SCADA. *Environmental Monitoring and Assessment, 190*(9), 1–6.
6. Reddy, P. S., Chanakya, K. V., Eswari, B., & Bhupati, C. (2018). Water leakage detection monitoring and controlling system using IoT. *International Journal of Engineering and Technology (IJET), 7*(2.7), 120–123.
7. Kawarkhe, M. B., & Agrawal, S. (2019). Smart Water monitoring system using IoT at home. *IOSR Journal of Computer Engineering (IOSR-JCE), 21*(1), 14–19.
8. Di Mauro, A., Di Nardo, A., Santonastaso, G. F., & Venticinque, S. (2019). An IoT system for monitoring and data collection of residential water end-use consumption. In *2019 28th International Conference on Computer Communication and Networks (ICCCN)*, July 29, 2019 (pp. 1–6). IEEE.
9. Chakraborti, R. K., Kaur, J., & Kaur, H. (2019). Water shortage challenges and a way forward in India. *Journal: American Water Works Association, 111*(5), 50.
10. Damkjaer, S., & Taylor, R. (2017). The measurement of water scarcity: Defining a meaningful indicator. *Ambio, 46*(5), 513–531.
11. Khanna, A., & Kaur, S. (2020). Internet of Things (IoT), applications and challenges: A comprehensive review. *Wireless Personal Communications, 114*, 1687–1762.
12. Muntjir, M., Rahul, M., & Alhumyani, H. A. (2017). An analysis of Internet of Things (IoT): Novel architectures, modern applications, security aspects and future scope with latest case studies. *International Journal of Engineering Research and Technology, 6*(6), 422–447.
13. Nguyen, B., & Simkin, L.. The Internet of Things (IoT) and marketing: The state of play, future trends and the implications for marketing. *Journal of Marketing Management*. Taylor and Francis. https://www.tandfonline.com/doi/full/10.1080/0267257X.2016.1257542
14. Wang, D., Hubacek, K., Shan, Y., Gerbens-Leenes, W., & Liu, J. (2021). A review of water stress and water footprint accounting. *Water., 13*(2), 201. https://doi.org/10.3390/w13020201
15. Nishmitha, Manjunath, K., Shraddha, S., Poorna, S., & Sudarshan. (2019). Water tank monitoring system. *International Journal of Engineering Research & Technology (IJET), 7*(8), 2278-018.

16. Dobriceanu, M., Bitoleanu, A., Popescu, M., Enache, S., & Subtirelu, E. (2008). SCADA system for monitoring water supply networks. *WSEAS Transactions on Systems, 1*(7), 1070–1079.
17. Ghosh, S., & Sampalli, S. (2019). A survey of security in SCADA networks: Current issues and future challenges. *IEEE Access, 7*, 135812–135831.
18. Hassan, R., Qamar, F., Hasan, M. K., Aman, A. H., & Ahmed, A. S. (2020). Internet of Things and its applications: A comprehensive survey. *Symmetry, 12*(10), 1674. https://doi.org/10.3390/sym12101674
19. Sarmah, A., Baruah, K. K., & Baruah, A. J. (2017). A brief review on Internet of Things. *International Research Journal of Engineering and Technology (IRJET), 4*, 879.
20. Shahzad, A., Lee, M., Lee, C., Xiong, N., Kim, S., Lee, Y. K., Kim, K., Woo, S. M., & Jeong, G. (2016). The protocol design and new approach for SCADA security enhancement during sensors broadcasting system. *Multimedia Tools and Applications, 75*(22), 14641–14668.
21. Soumyalatha, S. G. (2016). Study of IoT: Understanding IoT architecture, applications, issues and challenges. In *1st International Conference on Innovations in Computing & Net-working (ICICN16), CSE, RRCE. International Journal of Advanced Networking & Applications*, May 12, 2016 (No. 478).
22. Adedeji, K. B., Hamam, Y., Abe, B. T., & Abu-Mahfouz, A. M. (2017). Towards achieving a reliable leakage detection and localization algorithm for application in water piping networks: An overview. *IEEE Access, 5*, 20272–20285. https://doi.org/10.1109/ACCESS.2017.2752802
23. Aros, G., Elgueta, S., Díaz, R., Sepúlveda, G., & Sierralta, C. (2019). Advantages and challenges of the implementation of a low-cost particulate matter monitoring system as a decision-making tool. *Environmental Monitoring and Assessment, 191*(11), 1–20.
24. Arshad, Z., Robaina, M., & Botelho, A. (2020). The role of ICT in energy consumption and environment: an empirical investigation of Asian economies with cluster analysis. *Environmental Science and Pollution Research, 27*(26), 32913–32932.
25. Badawi, W. A., & Ali, W. (2019). Underground pipeline water leakage monitoring based on IOT. *International Journal of MC Square Scientific Research, 11*(3), 01–08.
26. Dawood, O. S. (2017). From requirements engineering to uml using natural language processing–survey study. *European Journal of Engineering and Technology Research, 2*(1), 44–50.
27. De Morais, C. M., Sadok, D., & Kelner, J. (2019). An IoT sensor and scenario survey for data researchers. *Journal of the Brazilian Computer Society, 25*(1), 1–7. https://doi.org/10.1186/s13173-019-0085-7
28. Dogo, E. M., Salami, A. F., Nwulu, N. I., & Aigbavboa, C. O. (2019). Blockchain and internet of things-based technologies for intelligent water management system. In *Artificial intelligence in IoT* (pp. 129–150). Springer.
29. El-Zahab, S., & Zayed, T. (2019). Leak detection in water distribution networks: an introductory overview. *Smart Water, 4*(1), 1–23. https://doi.org/10.1186/s40713-019-0017-x
30. Fuentes, H., & Mauricio, D. (2020). Smart water consumption measurement system for houses using IoT and cloud computing. *Environmental Monitoring and Assessment, 192*(9), 1–6.
31. Geetha, S., & Gouthami, S. J. (2016). Internet of things enabled real time water quality monitoring system. *Smart Water, 2*(1), 1–9. https://doi.org/10.1186/s40713-017-0005-y
32. Huck, J. J., Whyatt, J. D., Coulton, P., Davison, B., & Gradinar, A. (2017). Combining physiological, environmental and locational sensors for citizen-oriented health applications. *Environmental Monitoring and Assessment, 189*(3), 114.
33. Ismail, M. I., Dziyauddin, R. A., Salleh, N. A., Muhammad-Sukki, F., Bani, N. A., Izhar, M. A., & Latiff, L. A. (2019). A review of vibration detection methods using accelerometer sensors for water pipeline leakage. *IEEE Access, 7*, 51965–51981. https://doi.org/10.1109/ACCESS.2019.2896302
34. Jain, R., Thakur, A., Kumar, P., & Pooja, D. (2020). Materials in colorimetric detection of water pollutants. In *Sensors in water pollutants monitoring: Role of material* (pp. 125–145). Springer.

35. Jose, D. P., D'Souza, A. L., Thomas, A. A., & Daniel, D. (2019). IoT based water management using HC-12 and Django. In *2019 International Conference on Data Science and Communication (IconDSC)*, March 1, 2019 (pp. 1–6). IEEE.
36. Kamienski, C., Kleinschmidt, J., Soininen, J. P., Kolehmainen, K., Roffia, L., Visoli, M., Maia, R. F., & Fernandes, S. (2018). SWAMP: Smart water management platform overview and security challenges. In *2018 48th Annual IEEE/IFIP International Conference on Dependable Systems and Networks Workshops (DSN-W)* June 25, 2018 (pp. 49–50). IEEE.
37. Machado, M. R., Júnior, T. R., Silva, M. R., & Martins, J. B. (2019). Smart water management system using the Microcontroller ZR16S08 as IoT solution. In *2019 IEEE 10th Latin American Symposium on Circuits & Systems (LASCAS)*, February 24, 2019 (pp. 169–172). IEEE.
38. Maroli, A. A., Narwane, V. S., Raut, R. D., & Narkhede, B. E. (2020). Framework for the implementation of an Internet of Things (IoT)-based water distribution and management system. *Clean Technologies and Environmental Policy, 29*, 1–3.
39. Nunes, M., Alves, R., Casaca, A., Póvoa, P., & Botelho, J. (2018). An internet of things based platform for real-time management of energy consumption in water resource recovery facilities. In *IFIP International Internet of Things Conference*, September 18, 2018 (pp. 121–132). Springer.
40. Pandey, B., Farulla, G. A., Indaco, M., Iovino, L., & Prinetto, P. (2019). Design and review of water management system using ethernet, Wi-Fi 802.11 n, modbus, and other communication standards. *Wireless Personal Communications, 106*(4), 1677–1699.
41. Sammaneh, H., & Al-Jabi, M. (2019). IoT-enabled adaptive smart water distribution management system. In *2019 International Conference on Promising Electronic Technologies (ICPET)*, October 23, 2019 (pp. 40–44). IEEE.
42. Srihari, M. M. (2018). Intelligent water distribution and management system using Internet of Things. In *IEEE International Conference on Inventive Research in Computing Applications (ICIRCA)*. IEEE. https://doi.org/10.1109/ICIRCA.2018.8597325
43. Zeng, S., Du, H., & Xia, J. (2020). Development of an interface-oriented add-in modeling framework for integrated water system simulation and its application. *Environmental Modelling & Software, 134*, 104840.

Adaptation of Smart Technologies and E-Waste: Risks and Environmental Impact

Lubna Ansari, M. Afshar Alam, Ranjit Biswas, and Sheikh Mohammad Idrees

1 Introduction

In recent years, Smart Cities is a new concept mushrooming around the globe. This life-changing concept is beneficial to people in various aspects of life. The smart city is an ambiguous term and varies from one nation to another. The smart city can be defined as the most simple way i.e. how efficiently and effectively we use our resources to benefit our citizens the most [1]. A Smart city is like a skyscraper well built on three main pillars viz smart citizens, smart technology, and smart governance [2]. Each pillar has its importance but smart governance has supreme value. One of the most important ingredients of a smart city is smart government as it is used to foster rules or government policies and handle related issues by using ICT and by communicating with people [3]. When the citizens of a nation have the liberty to access all the services and information provided by the government when and where they require it, then that nation has successfully implemented smart governance [4]. To content present citizens, smart governance must be sustainable smart governance. Smart governance will be sustainable smart governance if attains three sustainability viz Social Sustainability, Environmental Sustainability, and Economic Sustainability [5]. To successfully implement sustainable smart governance in any smart city, we have to be aware of various factors and parameters that support it and that are barriers to it. Though there are many hurdles to achieve sustainable smart governance, in this chapter we will be discussing on e-waste problem.

L. Ansari (✉) · M. A. Alam · R. Biswas
Department of Computer Science, Jamia Hamdard, New Delhi, India
e-mail: lubnaansari_sch@jamiahamdard.ac.in; aalam@jamiahamdard.ac.in

S. M. Idrees
Department of Computer Science (IDI), NTNU, Trondheim, Norway

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_12

There are many blessings of technology that make the life of a citizen very easy. In today's world, we start ours day by using technology and end the same by using some technology. With today's technology distance is just a number. It is a well-known fact that Electronic devices have transformed every aspect like modern living, education, governance, entertainment, health care, and many more [6]. This in turn increases the production of electronic devices especially mobile phone, laptops, smart TV [6]. ICT became the new parameter for measuring any country's development [6]. Countries with the latest ICT are considered more developed than others. The life span of electronic items is shrinking as the frequency of improvement in technology increases [7, 8]. As the life span of electronic devices is shortening, the number of outdated products increases thereby making the environment polluted [9]. Out of all other electronic devices, the highest usage is of mobile phones. Even in developing countries, every citizen who either belongs to an urban area or rural area possesses mobile phones [10]. Since the usage of mobile is highest its production is highest and shortest life cycle as new models are manufactured with the latest technologies [10]. Thereby making a rich contribution in waste electronic and electrical devices [10]. It has been noted that the amount of electronic waste annually increases by 10% [11]. According to [12] global generation of e-waste will be more than 50 million tons in 2020 and yearly growth will be around 4–5%.

These figures are quite alarming. Many researchers are working in this area to minimize the number. In this paper, we have discussed some of the work of these researchers. We have also proposed a system for the aforementioned problem.

1.1 Electronic Waste

'Electronic waste' also known as e-waste means any electronic or electrical devices which are no longer in use or discarded by their owners [13]. Any electrical or electronic device is considered to be trash when the working period is over. E-waste includes all electrical and electronic devices that reached their end of life [14]. E-waste is a vast term and includes a variety of electronics devices spans from heavy household devices to personal devices like mobile phones, laptops [15]. Another term used for E-waste is WEEE abbreviation for Waste of electrical and electronic equipment. It includes devices like laptops, mobile phones, smart TVs and is expanding exponentially in the European Union [16]. As reported, in 2005 WEEE generated was about 9 million tons and by end of 2020, it will grow around 12 million tons [16]. WEEE comprises various elements which can pollute the environment and can cause health issues due to their poisonous nature [16]. It has been noted that WEEE is expanding three times more quickly than urban waste and the growing rate of WEEE is approximately between 3% and 5% [17, 18]. Around 50 million tons of WEEE are generated and about 1 billion smartphones and 300 million laptops are produced annually [19]. WEEE of about 12.5% is recycled [19].

1.2 Components of E-Waste

WEEE is a composite term as it includes many electronic and electrical device waste. Many components of WEEE are not very harmful, some are precious and can be reused and some of them are very toxic in nature and can cause serious health to humans, animals. Mobile phones consist of about 40 elements and out of which 12 are very toxic and can pollute the environment [10]. Mobile phones contain some precious elements like silver (250 mg), gold (24 mg), copper (9 mg), some very toxic elements like antimony, arsenic, beryllium, cadmium, lead, nickel, zinc, cobalt, tin [20, 21]. The cadmium battery of one cell phone can contaminate 600,000 L of water [21].

Apart from mobile phones, other electrical and electronic devices also contain toxic elements. In transformers and condensers, we have polychlorinated biphenyls, in the insulation foam and the cooling unit we have chlorofluorocarbon, Chromium is used in data tapes, Zinc sulphide is present in the CRT screens [6]. Mercury is used in pocket calculators and LCDs [22].

The exact composition of WEEE cannot be predicted as it contains a variety of elements ranging from large household devices to personal use devices [13]. Broadly we can classify WEEE into five classes: glass, ferrous metals, plastics, non-ferrous metals, and others [13] (Fig. 1).

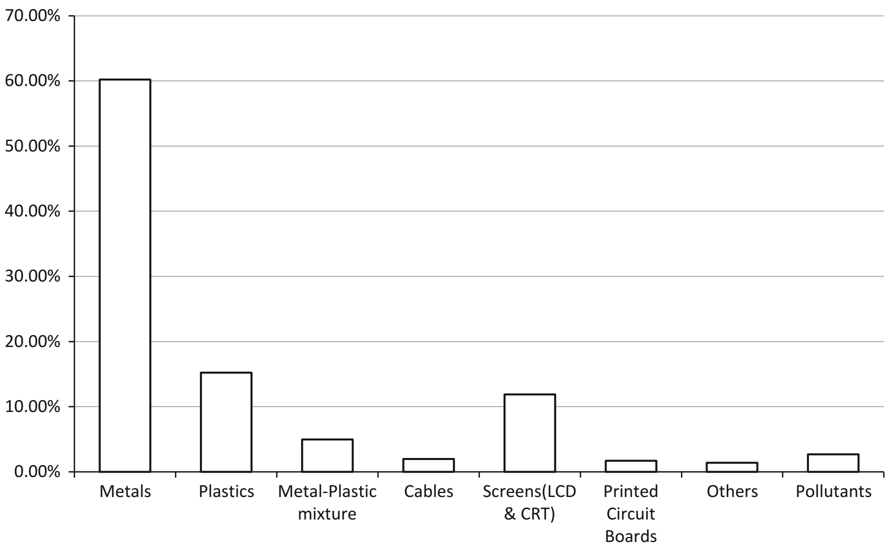


Fig. 1 E-waste material fraction [13, 23]

1.3 Adverse Effects of E-Waste

As mentioned earlier WEEE contains many toxic elements which are very harmful to the environment, humans, and animals. Since WEEE is very complex in nature so it is very hard to recycle sustainably [22]. Lead can cause water pollution, damage the nervous system, higher risk of cardiovascular problems, and can also cause infertility and miscarriage [6]. Cadmium can cause cancer, bone deformation and can affect kidneys [6]. Mercury can have adverse effects on the brain [6]. Polyvinyl Chloride Plastics (PVC) can irritate the eyes, skin and can damage the liver, kidney [6]. Nickel mostly found in batteries and printed circuit boards can cause lung cancer, bronchitis [24]. Barium can cause brain swelling and damages the heart and liver [24]. Beryllium can cause cancer and skin infection [24]. Antimony harms the stomach and leads to diarrhea [24].

2 Issues Regarding E-Waste in Smart Cities

The E-waste issue is global. It is like a Pandora's Box. Every country is facing this arduous problem of WEEE. The various reasons behind this gigantic problem are:

- The partially damaged or problematic devices are discarded straight away without trying to repair them [25].
- Recycling WEEE is another big task as people are not very interested in it [25].
- Inadequate technology [25].
- It is a time taking task [25].
- Labor cost is high [25].
- No strong initiative for recycling WEEE [25].
- High tech design of e-products makes it next to impossible to recycle them as the parts of electronic equipment are attached securely, making it a hard and time taking task [25].
- There is no strict law that can monitor the WEEE disposal [26].

Table 1 shows figures for e-waste generated in major countries. And Table 2 shows e-waste generated per inhabitant.

Africa generates approximately 2.2 million tons of WEEE annually, reported by UN 2017 [27]. Around 1.1 million tons of WEEE are generated every year either locally or imported from outside Nigeria [27]. Nigeria does not have any constructive e-waste management system [28]. ICT devices coming from developed countries are dumped here [28]. To eradicate the digital gap between the developed economies and developing economies electrical and electronic equipment are imported to Lagos port, Nigeria [28]. These devices are either in their last phase of life or need to be repaired [28]. It is been reported that in the year from 2001 to 2013, about 54,050 tons of cell phones were imported to Nigeria [10]. In 2017 288,000 tons of e-waste were imported into Nigeria [27]. There is no efficient

Table 1 The global e-waste status

S. No.	Name	E-waste generations (Mt)	E-waste collected and recycled (Mt)
1	**Africa**	**2.2 Mt**	**0.004 Mt**
	Egypt	0.5 Mt	
	South Africa	0.3 Mt	
	Algeria	0.3 Mt	
2	**America**	**11.3 Mt**	**1.9 Mt**
	USA	6.3 Mt	
	Brazil	1.5 Mt	
	Mexico	1 Mt	
3	**Asia**	**18.2 Mt**	**2.7 Mt**
	China	7.2 Mt	
	Japan	2.1 Mt	
	India	2 Mt	
4	**Europe**	**12.3 Mt**	**4.3 Mt**
	Germany	1.9 Mt	
	Great Britain	1.6 Mt	
	Russia	1.4 Mt	
5	**Oceania**	**0.7 Mt**	**0.04 Mt**
	Australia	0.57 Mt	

Table 2 The global e-waste per inhabitant

S. No.	Name	E-waste generation/inhabitant
1	**Africa**	11.5 kg/inhabitant
	Seychelles	
	Libya	11.5 kg/inhabitant
	Mauritius	8.6 kg/inhabitant
2	**America**	20 kg/inhabitant
	USA	
	Canada	20 kg/inhabitant
3	**Asia**	19.1 kg/inhabitant
	Cyprus	
	Hong Kong	19 kg/inhabitant
	Brunei	18 kg/inhabitant
	Singapore	18 kg/inhabitant
4	**Europe**	28.5 kg/inhabitant
	Norway	
	Great Britain	24.9 kg/inhabitant
	Denmark	24.9 kg/inhabitant
5	**Oceania**	23.6 kg/Inhabitant
	Australia	
	New Zealand	20.1 kg/inhabitant

recycling process in Nigeria, so people use their mobile phones for longer periods [10]. Alhaji Ibrahim Jibril, Ex-Minister of State for the Environment spoke about the e-waste problem, “E-waste is a real problem and environment peril. E-waste can be categorized into two classes one that we all use; the new ones and other category are second-hand devices which are imported into Nigeria” [27]. There is no strict law in Nigeria, which opens the gate for unauthorized transportation of used electronic devices without any checking or testing to see whether they are in good condition or not [27]. Executive Director, Dr. Leslie Adogame of SRADev (Sustainable Research and Action for Environmental Development), said: “E-waste is two-sided coin. It offers employment opportunity but toxic in nature can pollute environment [27].” In Nigeria informal recycling is used for e-waste in which e-waste is dismantle by hands and either burn in open air or dipped into acid to obtain valuable elements [29]. This ultimately effect environment, human health [29].

The USA is the most developed country in the world. It is also on the top when it comes to e-waste [30]. More than 140 million mobile phones are dumped into landfills every year by the USA [19]. If the same amount is recycled then it will produce power for 25,000 households for a year [19]. Approximately 9.4 million tons of electronic devices are discarded by Americans [19]. The electricity consumed by 3500 homes in a year in the US can be produced if we can recycle one million laptops [19]. Mobile phones discarded by the USA yearly contain over $60 million gold or silver [19].

In the US 30% of the e-waste, which is 80% of the total e-waste of the world in 2016, is either landfilled, informally recycled, incinerated, exported, or maybe left out somewhere [31].

India being a highly densely populated country holds fifth position in the generation of e-waste across the globe [32]. In 2014, it was reported that Indians discarded around 1.7 million tons of WEEE. E-waste management in India from collection to disposal is handled by unprofessional people [32]. Citizens of India are unaware of e-waste’s adverse effects and throw away e-waste along with their garbage which is then gathered by rag pickers [32]. Every year 12.5 lakh million tons of e-waste is produced by India [32]. Being a developing economy, many developed countries also export e-waste to India and increases the e-waste. There is a lack of infrastructure, less awareness, and insufficient funds to handle e-waste. There is no formally developed e-waste management in India [33]. E-waste management is neither well defined nor well organized [33]. The current e-waste management system can be divided into three levels; EEE generation, WEEE generation, and WEEE re-processing [33]. There were also no strict law for handling and managing e-waste before 2011 [22].

All these issues must be handled most appropriate and sustainable way possible so that they will harm as minimum as possible to the present generations as well as the future generation.

3 Approaches to Tackle E-Waste in Smart Cities

As there are no strict rules imposed by the government in many countries, there is a emerge of several informal e-waste organizations. Various approaches are implemented by Smart cities to reduce the impact of e-waste. Some of them are very effective, some are still in the processing phase.

Mr. Lawrence Anukam, DG of NESREA (National Environmental Standards and Regulations Enforcement Agency) spoke about the solutions to the e-waste issue in Nigeria and enlighten about Extended Producer Responsibility [29]. In the EPR, the producer of the product bears the responsibility of the product when it is discarded by the user [29]. The producer decides whether the product when reaches its End of Life should be returned or recycled [29]. But this program can only be successful if the user, producer, and recycler take an active part [29].

Each company needs to obey the policy framework before putting its products on the market [27]. All the stakeholders (manufacturers, producers, distributors) have to comply with PRO (Producer Responsibility Organization) [27]. PRO is a buy-back or take-back program in which the producers bear the cost of environmental management throughout the life cycle of their product [27].

In Nigeria, EPR is still not in its full swing and will take time [27]. To eradicate the e-waste problem from Nigeria, the government, users, and manufacturers have to co-operate [27]. The government must be vocal about the consequences of e-waste and run an awareness program for the user [27]. Besides government, other e-waste processing companies like Hinckley Recycling also taking part to remove the e-waste problem from Nigeria [29]. Hinckley works as a “collect and recycles”, gathers e-waste from different places, and recycles it [29].

With the continuous support of the government and recycling companies, WEEE cannot harm the environment and can be converted into a treasure that is beneficial to everyone [27].

Despite being on the top of e-waste generations, e-waste is not a big issue for the USA. The USA is a developed country have many “way out” plan already for this gigantic problem. Between the years 2003 and 2005, approximately 80–85% of the e-waste about to enter their end-of-life phase are dumped in landfills [34]. Such treatment of e-waste not only pollutes the environment but also precious elements in the e-waste remain unused [34].

The U.S. also exports e-waste to developing countries routinely [34]. Though NGOs and governments of some of the developing countries resist this exportation, this trend is increasing yearly [34]. One possible reason for this increment is both the countries, developing and developed country make money by informal recycling [34].

The USA also started to gather and recycle e-waste [34]. California charges extra consumer fees, ARF (Advanced recycling fees) ranging from US$6 to US$10 from the consumer when they purchase items like laptops, TV [34]. Washington also implemented Electronic Product Recycling Law in which manufacturers has to give recycling services in the state at no additional cost to small local government, households, charities, low budget business and school districts [34]. Maine from January 2006 also started an e-waste program which includes e-waste like laptops, TV thrown away by households [34]. In this program, the responsibility is divided between manufacturers and municipalities [34].

To solve this gigantic problem of e-waste from India, the Indian government is actively participating. After 2011, India revised its law regarding e-waste management and handling. India also participating EPR program [35]. Many awareness programs are running to educate Indians about the effects of e-waste and how to reduce the effect and help the government in recycling e-waste [35]. In the next section, we will be discussing some of the smart technologies that have been either developed or proposed by other researchers.

All these concepts are theoretical, we should also focus on something practical. In the following section, we have discussed some of the work which has been either practically implemented or proposed to be implemented.

4 Smart Technologies for E-Waste

The smart technologies developed for handling e-waste involve IoT in every phase of it. To widen our research, we have considered the smart technologies developed or proposed in both waste and e-waste management.

In [36], the author discussed the smart bin which is mostly fitted with some sensors. These sensors can collect data like fill level, temperature, weight, image. Data generated by the sensor not only send the alert but also this data can be analyzed and can be used to take action. For say, based on the information gathered we can not only find the pattern on the frequently the bin is full, but we can also schedule the trash pickup event.

While in [37], use an ultrasonic sensor in the smart bin to detect the threshold level for the smart bin. In addition to the sensor, the author also used an ARM microcontroller to check the whole operation and connected it with ThingSpeak. Here, the author also has an LCD on the bin which allows the user to know how much is the smart bin is occupied without actually opening it.

Reference [38] uses three ultrasonic sensors placed at three levels of the bin. When one level is crossed by the smart bin the notification is sent to the concerned team including the level by text message using GSM technology. The cost of the smart bin will become high as there are three sensors.

Another author [39] utilizes an ultrasonic sensor to check the level of the smart bin. When the bin is full an alert is sent. This work gathers and transfers data using a wireless mesh network. One more proposed system by Zavare et al. [40], uses an ultrasonic sensor and notifies the authority when a bin is 80–90% filled. Notification including id and coordinates of the dustbin is sent by using GSM. Reference [41] also uses SMS to update the authority when the sensor-equipped bin is full in real-time. However, the coordinates of the bin are not sent to the authority thereby it is difficult for them to trace the bin.

Another effort is done in [42], ultrasonic sensor fitted in the bin fetches the data and move the result to the responsible unit using a web application. An efficient model is discussed by [43]. This architecture also uses an ultrasonic sensor to sense the threshold value but the system is simulated and modeled by MATLAB. This system also has RFID technology. RFID tags have all the relevant data and an RFID reader can fetch and analyze the data.

The smart bin discussed in [44] has an efficient embedded device that consists of an IR (infrared) sensor, RF (radio frequency) module, and microcontroller. To easily identify the dustbin a unique ID is also given to the smart bin. When the smart bin is full, a radio frequency signal is sent by the transmitter and will be received by the receiver at the central system. All the required information will be displayed in a web browser.

Another approach is a synergetic effect of the weight sensor and an IR sensor introduced in [45]. Here, when the threshold level is reached the IR sensor activates the other sensor to disseminate the result. The other end of the system has a smartphone with a wifi connection to show data in a browser.

The discussion in paper [46] is about having a load sensor in the smart bin to check the weight of the smart bin, as well as a camera, which is also set up at each location of the smart bin. While the camera keeps on taking pictures of the smart bin, the load sensor will send the signal once the smart bin reached its upper limit. Results from both are taken and analyzed and the respective team is updated.

Another author in [47] uses a synergetic effect of image and GSM. The camera continuously clicks the picture of the bin and the load cell sensor tracks the threshold value of the bin. When the combined result is alarmistic, a message is given to the responsible person.

Paper [48] uses a load cell that functions in the same way as a weight sensor. It senses the weight and notifies the experts. This system also has an RFID concept. RFID reads the tag of the product which has all the information of the user. Arduino Uno is the controller here and manages the input /output of the system. The author uses an attraction, a reward system, which compels the user to discard their e-waste to earn rebate points.

Al-Jabi et al. [49], presented an attractive model where a user has an RFID card that uniquely identifies the user and has to use it each time when the user wants to throw some waste in the dustbin. An RFID reader is attached to the bin along with the sensor (ultrasonic and weight).

Another author discusses an agile methodology for IoT e-waste monitoring system. In [50], the author uses three sensors: flame sensor (senses the heat) to avoid explosions, ultrasonic sensor(level detection), and temperature sensor. The controller used in this paper is Raspberry Pi 3. To analyze the sensor data ThingSpeak is used and notification is updated via the Wi-Fi module. An alert will be posted on ThingSpeak when the level is 90% and a temperament raise hence follows a level-priority-scheduling.

One more approach is presented in [51], the bin is equipped with sensors to indicate if it's full or not. Also, there is an LCD that shows the same status. Two LED also included in the bin if its green means the bin is empty and if it's red then the bin is full and needs to be emptied. In an event of an alert, the same is notified to the user via GSM/GPRS. Furthermore, there is an Android app too to control and combine the information from various coordinates. Another automated system used for separating and controlling garbage is proposed by [52]. The system consists of Keil uVision programmed sensors, LPC2148 microcontroller, WiFi module, and GSM technology. When the sensor senses that the bin is full it sends the alert using GSM to authority.

Kalpana and Jayachitra [53] explained a variant for dealing with the aforementioned problem. In this paper, the author places relevant information regarding the dustbin on the server. Here the user plays a vital role, by checking the bin level and updating the same on the server. The higher management will take the action accordingly. The bin can only be emptied if an end-user raises a request referring to the same.

One more proposed model by Mahajan and Chitode [54], also comprises a sensor-based bin, and once the upper limit of the bin is reached controller ARM7 updates the truck driver of the garbage collection team. And the bin will be emptied by them.

Baby et al. [55] proposed the system which has two sensors(Infrared and ultrasonic) placed in the bin to check the status of the bin. When the bin is almost full, the same is notified to Raspberry Pi and Arduino parallelly. Raspberry Pi transmits the alert by E-mail and SMS and Arduino moves data ahead on the cloud. The same data is then forwarded to the Power Bi platform for real-time analysis and prediction of the data in a particular locality.

A cloud-based smart waste management system [56], follows the same concept of the smart bin having sensors and alert the system when the bin is full. The difference here is the data is transferred and saved in the cloud. The author also included route-optimization and path selection for waste collector trucks for improving efficiency based on the data received.

Smart e-waste reverse system is proposed by [57], use interactive online maps. As per the author, interactive online maps are very efficient and easy to track EoL EEE user requests. If a user wants to discard some e-waste fills all the relevant information in an interactive online map. An essential role is played by Local E-waste operator which stores all the request for collection of e-waste and also connects with the delivery services that processes the request. After the collection of the e-waste, it is transferred to a specialized e-waste processing enterprise.

The author [58] generalizes most of the waste collection systems stating that the difference is in the technologies used. Most of the system follows the same protocol: smart bin has some sensors and notifies to authority by some technology. The author also compared various systems and concluded that none of the systems best to their knowledge used LoRa (Low Range). LoRa is a technology that enhances the lifespan of IoT solutions. It also provides a wider coverage area with low power usage. Also, it is more reliable.

To overcome the waste management problem, a conceptual framework is introduced [59]. Waste management should be a part of every stage of e-product, and this is done by this system. To transform a smart city into a smart city with iota waste we need to focus on three areas: prevent waste generation, smart collection of waste, and smart recovery strategies. The author introduced three elements to accomplish the same viz element 1: is data collection of the product life cycle, element 2: business models which avoid waste generation and promote sharing products, and element 3: the infrastructure of the city consists of smart and connected devices.

A different approach has been proposed by [60] to use the concept of Blockchain Smart Contract. Whenever a product is manufactured its details are inserted into the blockchain network. The details will update in the blockchain if there is a change in the ownership of the product. When the end-user discards the e-product to the e-waste unit a smart contract is generated in the e-waste center and some amount in ether form is transferred to the user. Additional money is locked by the smart agreement when there is a change in the ownership. And when that product reaches the e-waste center the protected sum plus some incentive is transferred to the owner. Hence, giving motivation to the user to discard their e-product. The programming language used is Solidity. VSC is used to develop the front-end of the decentralized app. The stakeholders here are producers, retailers, collection centers, recycling units. Other than these two participants are government and customer.

5 Proposed Solution

There are many adverse effects of e-waste on human health as well as the environment but smart technologies to tackle the same are still in their embryonic stage. To the best of our knowledge, most of the researchers considered only one phase of the e-waste life cycle i.e. collection. But to build an effective e-waste system we have to focus on all the stages of life starting from the collection to the disposal of the e-waste. We are proposing a system that conveniently handles the e-waste lifecycle.

In our proposed model we will be using a sensor in our smart collector bin but it will be an amalgam of load cell sensor and infrared sensor. Most of the state of art does include sensors but mostly a single type of sensor is used. If a single type of sensor is used it will not reflect the accuracy in results. For example, if we use an ultrasonic sensor, it will temper the output of the sensor as temperature changes. Also, how the notification will be transferred from one position to another needs attention. For say, if only GSM is used for the same purpose, it likely to have bandwidth lag. So here also we have to combine two or three technologies to avoid any discrepancy.

In our proposed solution, a unique ID will be provided to the customer, product, manufacturer, retailer, and smart collector bin. The following sections will give a brief about our proposed system.

5.1 Smart Collector Bin

Every smart collector bin will have a unique id. This id can be used to trace the position of the dustbin and the best-suited route to collect the e-waste from it. The route will keep on updating in real-time. We will be using interactive online maps for the same. The smart collector bin is fitted with a slot for inserting an e-waste card and a panel where the user can enter his id and product id in case the e-waste card is missing. Once the user either inserted the card or entered the pin (customer id and e-waste id) the smart collector bin will be open and the user can place the e-waste item in there. Every smart collector bin is equipped with sensors: load cell sensor and infrared sensor. Load cell sensor is used to determine the weight of the smart dustbin and infrared sensor will note the level of the smart collector bin, in case it reaches the threshold value will send an alert to the concerned authority. We will use ThingSpeak, which is an IoT Cloud platform. ThingSpeak can be used to forward sensor data to the cloud as well as to visualize and analyze the sensor data. It is handled by MathWorks. An additional camera will be installed at every location of the smart collector bin, it will weekly capture the image of the smart collector bin and send the same to the higher authority. Installing a camera will rule out the condition where the sensor is inoperative and the smart bin needs to be emptied. Figure 2 shows the smart collector bin and information which is related to it.

SmartBin ID	Location	Level	Route
D119078	Street # 2, Dilshad garden	30%	X → Y → Q
D116709	Street # 6, Anand Vihar	50%	F→ W→ R

Fig. 2 Smart collector bin

Customer ID	Name	Address	List of Product ID
C9090	X	Anand Vihar	P6790, P345, P9123
C7834	Y	Dilshad Garden	P5700, P3895

Fig. 3 Customer

5.2 Customer

Every end-user of the electronic or electric item is a customer in this proposed model. Each customer is given a unique id and with that id, all the relevant information can be fetched. When a customer wants to discard some e-product he has to go to the nearest bin and can either insert his e-waste card or enter the customer id and product id. When an e-waste product is thrown by the customer in the smart collector bin, a decent amount will be added to his account. This amount is a security amount that is included at the time of purchase of the product. To make this transaction authentic, transparent, and secure blockchain will be used. Figure 3 depicts all the necessary information related to the customer.

5.3 E-Product

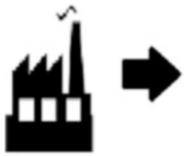
When an e-product is manufactured, a respective product id is assigned to it. The whereabouts of the product can be easily traced by the product id. An RFID tag can also be used for this purpose. Every product ID is mapped with its manufacturer id and if it is already purchased by a customer then the respective customer id is also included in the table. Fields that will be stored with each and e-product are shown in Fig. 4.

5.4 Manufacturer

Every manufacturer also possesses a unique ID. This Id is associated with all the product id manufactured by it. Also, other information like name, address can be tracked by this id. Fields that will be stored with each and manufacturer is shown in Fig. 5.

Product ID	Manufacturer ID	Product Type	Product name	Customer ID
P9022	M1190	Electronic -Personal	Smart Watch	C6758
P8976	M2345	Electronic - Personal	Smart Phone	NA

Fig. 4 E-product



Manufacturer ID	Name	Address	Product ID
M6756	Samsung	XYZ	P2301, P3478
M3478	Nokia	ABC	P8912,P7123

Fig. 5 Manufacturer

5.5 Retailer

Every retailer can be identified by a unique ID. This Id is associated with all the product id sold by it. Also, other information like name, address can be tracked by this id. Figure 6 depicts all the necessary information related to the retailer.

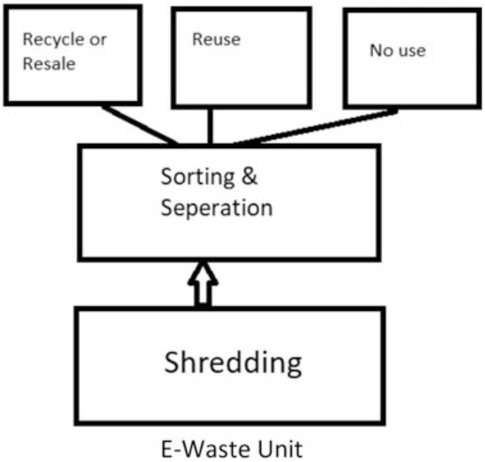
5.6 E-Waste Unit

Every state will have at least one e-waste unit. All the e-waste picked up from different parts of the state will reach here. When e-waste reached recycling facilities, it is processed for further use. Shredding is a process of tearing or cutting e-waste into smaller parts [61]. During shredding, e-waste is shredded into small pieces like 100 mm to make the next step viz sorting and separation easier. After cutting or tearing e-waste into small pieces, it is sorted and separated according to its

Retailer ID	Name	Address	Product ID
R6756	AS shop	XYZ	P2301, P3478
R3478	JK shop	ABC	P8912,P7123

Fig. 6 Retailer

Fig. 7 E-waste plant



properties. The magnetic separation method is used to extract iron and steel, which can further process for reuse or resale [61]. Glass can be separated from plastic by using water separation technology [61]. Other mechanical processes are used to extract aluminum, copper [61]. After sorting and separation, precious metals like copper, silver, gold can be resale. Some of the parts can be recycled and can be reused again in electronic and electrical products. Some elements can be reused for other purposes like water purification, making concrete, and the production of electricity. If there exists any residual part of the e-waste which cannot be recycled or reused, they will be kept in a separate section until there is a possibility to use them again. Figure 7 shows an e-waste plant.

5.7 Working

The manufacturer produces various electronic or electrical items. These products are then handed over to different retailers across the city. The customer purchases these products from the retailer.

At the time of purchase, the customer has to pay an additional amount as security which will be returned to the customer when he disposes of the same product to the smart collector bin. When the e-product reaches its end of life, the customer can throw the same in the smart collector bin. He first has to go to the bin and can either enter the product and his unique id or simply insert his e-waste card in the vent of the smart collector bin. Once the lid of the bin is opened, he can discard the e-product into the smart collector bin.

Once the smart collector bin is full up to its threshold value, it will update to the concerned authority in all the three ways viz by email, SMS, and notification in the webpage.

After that, the specialist team will redirect the e-waste truck to collect the e-waste from the location and empty the smart bin. The truck will use an interactive map to reach the destination. Furthermore, the collected e-waste will move to the e-waste unit. At the e-waste unit, it will be processed accordingly. Figure 8 depicts the control flow of our proposed system.

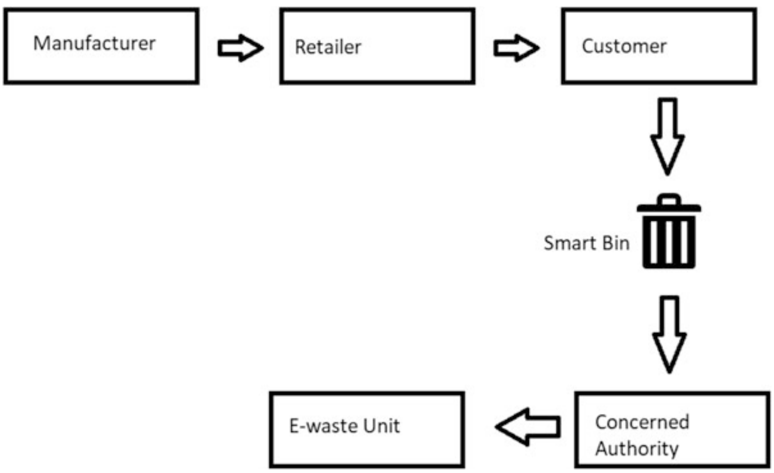


Fig. 8 Control flow

6 Conclusion

With the advancement of ICT, many new problems come into existence. All these problems have their magnitude of seriousness. One such threat is e-waste. E-waste is growing exponentially in Smart Cities and becoming a huge matter of concern for Sustainable smart Governance. E-waste not only affects the environment but humans and animals too and a threat for future generations also. To eradicate the e-waste problem, we have to take initiatives that can reduce the effects of e-waste. Before that one should be aware of the hazardous effects of e-waste so that he can actively participate in cleaning the environment and securing life for future generations. We have observed a good amount of related work and mostly all of them used sensors. But best to our knowledge all of them only discussed about the collection of the waste. As we already discussed, to sort this e-waste problem we have to consider each stage of the life cycle of e-waste. So, we proposed a system that will efficiently handle the e-waste issue.

References

1. Gaur, A., Scotney, B., Parr, G., & Mcclean, S. (2015). Smart city architecture and its applications based on IoT. *Procedia Computer Science, 52*, 1089–1094. https://doi.org/10.1016/j.procs.2015.05.122
2. Nam, T., & Pardo, T. A. (2011). Conceptualizing smart city with dimensions of technology, people, and institutions. In *Proc. 12th Annu. Int. Digit. Gov. Res. Conf. Digit. Gov. Innov. Challenging Times - dg.o'11* (p. 282). https://doi.org/10.1145/2037556.2037602
3. Scholl, H. J., & Scholl, M. C. (2014). Smart governance: A roadmap for research and practice. In *iConference 2014 Proceedings*, no. 1. https://doi.org/10.9776/14060
4. Bishnoi, P. V. (2008). E-governance in india and its benchmarking—Doctor of philosophy business management II.
5. Anderson, D., Wu, R., Cho, J., & Schroeder, K. (2015). *E-government strategy, ICT and innovation for citizen engagement* (Springer briefs in electrical and computer engineering). Springer.
6. Johnson, O. (2015). Technology paradigm for E-waste management in South-Eastern Nigeria. *International Association for Management of Technology*, 802–823.
7. Osibanjo, O., & Nnorom, I. C. (2007). The challenge of electronic waste (e-waste) management in developing countries. *Waste Management & Research, 25*(6), 489–501. https://doi.org/10.1177/0734242X07082028
8. Taylor, P., Oh, C. J., Lee, S. O., Yang, H. S., Ha, T. J., & Kim, M. J. (2012). Selective leaching of valuable metals from waste printed circuit boards selective leaching of valuable metals from waste printed circuit boards. *Journal of the Air & Waste Management Association*, *53*(7), 897–902. https://doi.org/10.1080/10473289.2003.10466230
9. Kang, H., & Schoenung, J. M. (2005). Used consumer electronics: A comparative analysis of materials recycling technologies. In *International Symposium on Electronics and the Environment* (pp. 226–230).
10. Babayemi, J. O., Osibanjo, O., & Weber, R. (2017). Material and substance flow analysis of mobile phones in Nigeria: A step for progressing e-waste management strategy. *Journal of Material Cycles and Waste Management, 19*, 731–742. https://doi.org/10.1007/s10163-016-0472-5

11. Adrian, S. (2011). Assessment of the flow and driving forces of used electrical and electronic equipment into and within Nigeria.
12. *E-waste recycling facts and figures*. https://www.balancesmb.com/e-waste-recycling-facts-and-figures-2878189
13. Widmer, R., Oswald-krapf, H., Sinha-khetriwal, D., Schnellmann, M., & Bo, H. (2005). Global perspectives on e-waste. *Environmental Impact Assessment Review, 25*, 436–458. https://doi.org/10.1016/j.eiar.2005.04.001
14. Garlapati, V. K. (2016). E-waste in India and developed countries: Management, recycling, business and biotechnological initiatives. *Renewable and Sustainable Energy Reviews, 54*, 874–881. https://doi.org/10.1016/j.rser.2015.10.106
15. Puckett, J., et al. (2002). *Exporting harm the high-tech trashing of Asia*. Basel Action Network.
16. *European Commission—Environment*. http://ec.europa.eu/environment/waste/weee/index_en.htm
17. Cucchiella, F., Adamo, I. D., Koh, S. C. L., & Rosa, P. (2015). Recycling of WEEEs: An economic assessment of present and future e-waste streams. *Renewable and Sustainable Energy Reviews, 51*, 263–272. https://doi.org/10.1016/j.rser.2015.06.010
18. Wang, S., Li, W. D., & Xia, K. (2016). Customized disassembly and processing of waste electrical and electronic equipment. *SME Manufacturing Letters, 9*, 7–10. https://doi.org/10.1016/j.mfglet.2016.07.001
19. *Rubicon Global*. https://www.rubiconglobal.com/blog-electronic-waste-problem/
20. Wu, B. Y., Chan, Y. C., Middendorf, A., Gu, X., & Zhong, H. W. (2008). Assessment of toxicity potential of metallic elements in discarded electronics: A case study of mobile phones in China. *Journal of Environmental Science, 20*(11), 1403–1408. https://doi.org/10.1016/S1001-0742(08)62240-8
21. Kaushal, R. K., & Nema, A. K. (2015). An analysis of preferences for hazardous substances free products: Manufacturing, use and end of life of mobile phones. *Waste Management Research, 30*(11), 1169–1177. https://doi.org/10.1177/0734242X12454697
22. Das, A. K. E-waste management in India current scenario, Calcutta. https://www.epa.gov/sites/default/files/2014-05/documents/india.pdf. Accessed on : 14.05.2019
23. Empa. (2005). *The E-waste guide*. http://www.ewaste.ch
24. Kiddee, P., Naidu, R., & Wong, M. H. (2013). Electronic waste management approaches: An overview. *Waste Management, 33*(5), 1237–1250. https://doi.org/10.1016/j.wasman.2013.01.006
25. Bakhiyi, B., Gravel, S., Ceballos, D., Flynn, M. A., & Zayed, J. (2017). Has the question of e-waste opened a Pandora's box? An overview of unpredictable issues and challenges. *Environment International, 110*, 173–192. https://doi.org/10.1016/j.envint.2017.10.021
26. *Planet green recycle*. https://planetgreenrecycle.com/fundraising/e-waste-problem
27. *Nigeria's E-waste mountain by Valentine Iwenwanne*. https://resource.co/article/nigerias-e-waste-mountain-13017
28. Akuru, U. B. & Okoro, O.I. (2010) Electronic Wastes and the Nigerian Experience, Proc. 18th International Conference on Domestic Use of Energy, Cape Town/South Africa, pp. 17–21, March 2010.
29. *Improper e-waste disposal: Nigeria's deadly time bomb by Kayode Ojewale*. https://guardian.ng/opinion/improper-e-waste-disposal-nigerias-deadly-time-bomb/
30. *Electronics waste in US*. https://en.wikipedia.org/wiki/Electronic_waste_in_the_United_States
31. *Each U.S. family trashes 400 iPhones' worth of E-waste a year by Stephen Leahy*. https://news.nationalgeographic.com/2017/12/e-waste-monitor-report-glut/
32. *E-waste management issues challenges and proposed solution by Rohit Sharma*. http://www.legalservicesindia.com/article/2249/E-Waste-Management-Issues-Challenges-and-Proposed-Solutions.html
33. Wath, S. B., Vaidya, A. N., Dutt, P. S., & Chakrabarti, T. (2010). A roadmap for development of sustainable E-waste management system in India. *Science of the Total Environment, 409*(1), 19–32. https://doi.org/10.1016/j.scitotenv.2010.09.030

34. Kahhat, R., Kim, J., Xu, M., Allenby, B., Williams, E., & Zhang, P. (2008). Exploring e-waste management systems in the United States. *Resources, Conservation & Recycling, 52*, 955–964. https://doi.org/10.1016/j.resconrec.2008.03.002
35. Joseph, K. (2007, January). Electronic waste management in India—Issues and strategies. In *Eleventh International Waste Management and Landfill Symposium*, 2014.
36. *How IoT is making waste management smarter*. https://www.reminetwork.com/articles/iot-waste-management-smarter/.
37. Mustafa, M. R., & Azir, K. N. F. K. (2017). Smart bin: Internet-of-things garbage monitoring system. *MATEC Web of Conferences, 140*, 1–4. https://doi.org/10.1051/matecconf/201714001030
38. Meghana, K. C., & Nataraj, K. R. (2016). IOT based intelligent bin for smart cities. *International Journal on Recent and Innovation Trends in Computing and Communication, 4*(5), 225–229.
39. Folianto, F., Low, Y. S., & Yeow, W. L. (2015). Smartbin: Smart waste management system. In *2015 IEEE 10th International Conference on Intelligent Sensors, Sensor Networks on Information Processing ISSNIP 2015* (pp. 1–2). https://doi.org/10.1109/ISSNIP.2015.7106974.
40. Zavare, S., Parashare, R., Patil, S., Rathod, P., & Babanne, V. (2017). Smart city waste management system using GSM. *International Journal of Engineering Science, 5*(3), 74–78. http://ijesc.org/
41. Mohd Yusof, N., Jidin, A. Z., & Rahim, M. I. (2017). Smart garbage monitoring system for waste management. *MATEC Web of Conferences, 97*, 01098. https://doi.org/10.1051/matecconf/20179701098
42. Chaware, P. D. S. M., Dighe, S., Joshi, A., Bajare, N., & Korke, R. (2017). Smart garbage monitoring system using internet of things (IOT). *IJIREEICE, 5*(1), 74–77. https://doi.org/10.17148/ijireeice.2017.5115
43. Papalambrou, A., Karadimas, D., Gialelis, J., & Voyiatzis, A. G. (2015, October). A versatile scalable smart waste-bin system based on resource-limited embedded devices. In *IEEE Conference on Emerging Technologies and Factory Automation ETFA* (Vol. 2015). https://doi.org/10.1109/ETFA.2015.7301466
44. Prakash, & Prabhu, V. (2016). IOT based waste management for smart city. *International Journal Research Computer and Communication Engineering, 4*(2), 1267–1274.
45. Navghane, S. S., Killedar, M. S., & Rohokale, V. M. (2016). IoT based smart garbage and waste collection bin. *International Journal of Advanced Research in Electronics and Communication Engineering, 5*(5), 2278–2909.
46. Kumar Kurre, V. (2016). Smart garbage collection bin overflows indicator using IOT. *International Research Journal of Engineering and Technology, 3*(5), 2395–2356. https://www.irjet.net/archives/V3/i5/IRJET-V3I5485.pdf
47. Prajakta, G., J. K., & M. S. (2015). Smart garbage collection system in residential area. *IJRET: International Journal of Research in Engineering and Technology, 4*(3),122–124.
48. Ramly, R., Sajak, A. A. B., & Rashid, M. (2019). IoT recycle management system to support green city initiatives. *Indonesian Journal of Electrical Engineering and Computer Science, 15*(2), 1037–1045. https://doi.org/10.11591/ijeecs.v15.i2.pp1037-1045
49. Al-Jabi, M., & Diab, M. (2018). IoT-enabled citizen attractive waste management system. In *Proceedings of 2nd International Conference on the Applications of Information Technology in Developing Renewable Energy Process Systems IT-DREPS 2017* (Vol. 2018, pp. 1–5). https://doi.org/10.1109/IT-DREPS.2017.8277804
50. Sajak, A. (2020). IoT E-waste monitoring system to support smart city initiatives IoT E-waste monitoring system to support smart city initiatives. *International Journal of Integrated Engineering, 2*, 1–9.
51. Kumar, S. V., Kumaran, T. S., Kumar, A. K., & Mathapati, M. (2017). Smart garbage monitoring and clearance system using internet of things. In *IEEE International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM).*

52. Dorve, P. J. D., Challani, S., Lanjewar, S., Kutemate, H., & Burde, D. (2020). Smart garbage separation and monitoring system. *International Research Journal of Modernization in Engineering Technology and Science, 6*, 438–442.
53. Kalpana, M., & Jayachitra, J. (2017). Intelligent bin management system for smart city using mobile application. *Asian Journal of Applied Science and Technology, 1*(5), 172–175.
54. Mahajan, K., & Chitode, P. J. S. (2014). Waste bin monitoring system using integrated technologies. *International Journal of Innovative Science and Research Technology, 3*(7), 14953–14957.
55. Baby, C. J., Singh, H., Srivastava, A., Dhawan, R., & Mahalakshmi, P. (2018). Smart bin: An intelligent waste alert and prediction system using machine learning approach. In *Proceedings of 2017 International Conference on Wireless Communications, Signal Processing and Networking, WiSPNET 2017* (Vol. 2018, pp. 771–774). https://doi.org/10.1109/WiSPNET.2017.8299865
56. Aazam, M., St-Hilaire, M., Lung, C. H., & Lambadaris, I. (2016). Cloud-based smart waste management for smart cities. In *IEEE International Workshop on Computer Aided Modeling and Design of Communication Links Networks, CAMAD* (pp. 188–193). https://doi.org/10.1109/CAMAD.2016.7790356
57. Shevchenko, T., Saidani, M., Danko, Y., Golysheva, I., Chovancová, J., & Vavrek, R. (2021). Towards a smart E-waste system utilizing supply chain participants and interactive online maps. *Recycling, 6*(1), 8. https://doi.org/10.3390/recycling6010008
58. Mdukaza, S., Isong, B., Dladlu, N., & Abu-Mahfouz, A. (2018). *Analysis of IoT-enabled solutions in smart waste management* (pp. 4639–4644). IEEE.
59. Esmaeilian, B., Wang, B., Lewis, K., Duarte, F., Ratti, C., & Behdad, S. (2018). The future of waste management in smart and sustainable cities: A review and concept paper. *Waste Management, 81*, 177–195. https://doi.org/10.1016/j.wasman.2018.09.047
60. Poongodi, M., Hamdi, M., Vijayakumar, V., Rawal, B. S., & Maode, M. (2020, July). An effective electronic waste management solution based on blockchain smart contract in 5G communities. In *2020 IEEE 3rd 5G World Forum, 5GWF 2020—Conference Proceeding* (pp. 631–636). https://doi.org/10.1109/5GWF49715.2020.9221346
61. *Introduction to electronics recycling*. https://www.balancesmb.com/introduction-to-electronics-e-waste-recycling-4049386

A Comprehensive Study on the Arsenic Contamination in the Groundwater of Assam and West Bengal with a Focus on Normalization of Arsenic-Filled Sludge from Arsenic Filters

Subhashis Chowdhury, Rajashree Lodh, and Souvik Chakraborty

1 Introduction

India being a big country has a total area of about 32,87,000 square kilometers as on 2020. It is surrounded by oceans in almost all sides, tributaries and lakes are also present in every interior part of India. The fresh surface water as well as groundwater near coastal areas of India is affected by the sea water intrusion in surface and sub-surface water and alluvium soil in those areas. Thus, the scarcity of fresh potable water occurs due to over exploitation of groundwater. Indians are very much dependent on groundwater for drinking purposes as well as domestic usage. As already mentioned, the contamination of surface water is very high near sea and oceans. Majority of groundwater is used for household purposes in rural areas and for industrial needs in urban areas. Withdrawal of the amount of groundwater has enhanced sharply, to meet up various needs and as a result of which the level of groundwater table (GWT) has lowered down touching the lower lithology part containing igneous rocks. Arsenic is found in igneous rocks and thus it gets dissolved in groundwater. It has been found by continuous study that large areas of India groundwater are contaminated with arsenic [1–6]. The rise in arsenic contamination according to BIS standards is beyond the acceptable limits mainly in few districts and states of India. This is a matter of serious concern from different

S. Chowdhury
Dr. B. C. Roy Engineering College, Durgapur, India

R. Lodh (✉)
Heritage Institute of Technology, Kolkata, India

S. Chakraborty
Dr. Sudhir Chandra Sur Institute of Technology and Sports Complex, Kolkata, India
e-mail: schakraborty@dsec.ac.in

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_13

viewpoints, the most important being different health problems in human and animals due to the consumption of arsenic contaminated groundwater and other harmful effects includes damaged agricultural land, irrigation related issues and socio-economic problems etc. Over exposure of human body to arsenic creates skin, lung, and bladder cancer. Rural people of India are more dependent on groundwater for their regular usage like household needs and irrigation purpose as irrigation is the profession of most Indians. The quality of soil is harmed by the application of Arsenic-contaminated water on culturable command area. According to IS 10500:2012 which is drinking water specification, acceptable limit of arsenic in drinking water should be within 0.01 ppm and permissible limit should be 0.05 ppm [7, 8]. Until 2008, most arsenic affected area mainly existed in the Ganga-Brahmaputra flood plains extending seven states namely, Jharkhand, West Bengal, Bihar, Assam, Chhattisgarh, Manipur, Uttar Pradesh and also as per CGWB, 2010 and NIH [9–15]. Until 2014, total number of Arsenic-contaminated groundwater states has been enhanced from 7 to 10 [5, 6]. The present study includes detailed information about two states that are mainly located in the eastern portion of India and northern portion of West-Bengal. Both these states are situated in flood alluvium plain of Ganga or Brahmaputra. The arsenic affected areas in these two states are identified and detailed discussion on the Arsenic-removal technologies have been done. Moreover, the paper explained about the different issues related to the disposition of Arsenic contained sludge from arsenic filters and the probable ways for the safe utilization of Arsenic waste.

2 Arsenic Affected Areas in the States of Assam and West Bengal

Arsenic was first found in the groundwater of West Bengal in 1978 and then in its neighboring territory in Assam in 2004 (CGWB 2009; [11]). Primarily quite a few samples were collected from Dhemaji, Karimganj and Dhubri locations which on analysis showed Arsenic concentration of groundwater was greater than 0.05 ppm [9, 16]. According to UNICEF, 18 out of 23 districts of Assam covering 76 different blocks and 603 habitations were affected by Arsenic contaminated groundwater. They handed over the crucial responsibility of identifying the locations and reducing the amount of contamination to Public Health Engineering Department PHED, Assam Government in joint venture with the UNICEF. The said job was executed in a three layers method by FTK, UV-1. It was declared that 2571 habitations were present in those areas, who were seriously affected by the presence of Arsenic in groundwater.

In 1983, Arsenic concentration in groundwater of West Bengal was more than 0.05 ppm according to BIS standards and was first surfaced from 33 villages of 4 districts, named, North 24 Parganas, South 24 Parganas, Nadia and Murshidabad. CGWB (2010) and NIH indicated that in the year 2008, 9 districts consisting of 3417 villages and hundred eleven (111) blocks were detected as arsenic affected. Among all nine districts Kolkata, the capital of the state has been affected adversely by the presence of arsenic in groundwater. It has been classified into three parts: high risk, moderate risk and no risk based on quantity of arsenic in groundwater. Nine locations of West Bengal include Murshidabad, Nadia, Hooghly, both 24 Parganas, Malda, Brahman, Kolkata and Howrah, where concentration of arsenic in groundwater was more than 0.03 ppm. The concentration of Arsenic was detected in tubewells and had been classified as extremely affected. One lakh thirty five thousand five hundred fifty-five samples of groundwater were tested from the study area of few districts as mentioned earlier, out of which 67,306 test samples were around 50% that showed Arsenic concentration above 0.01 ppm and 25% samples above 0.05 ppm. Interestingly, in all the nine highly affected districts the concentration of arsenic was greater than 0.05 ppm and follows a linear trend along Bhagirathi and some places across Ganga which is carried through Kolkata. The geological formations in those areas are such that it is made up of thick alluvial deposits of such a time when it is of Quaternary age. Most affected areas were located in the vicinity of river towards the pathline of groundwater flow. Pathline of groundwater in study area is in south-east direction. Arsenic affected groundwater layers lie largely in between layers of depth of 15–50 m. The demographic survey of arsenic affected areas executed up to year 2008 by many organizations revealed that fourteen (14) million people have been exposed to arsenic more than contamination level that is above 0.01 ppm, seven (7) million people have been contaminated with arsenic of concentration above 0.05 ppm, out of total 50 million population [9, 16]. Figures 1 and 2 shows the distribution of arsenic contaminated groundwater regions of Assam and West Bengal respectively.

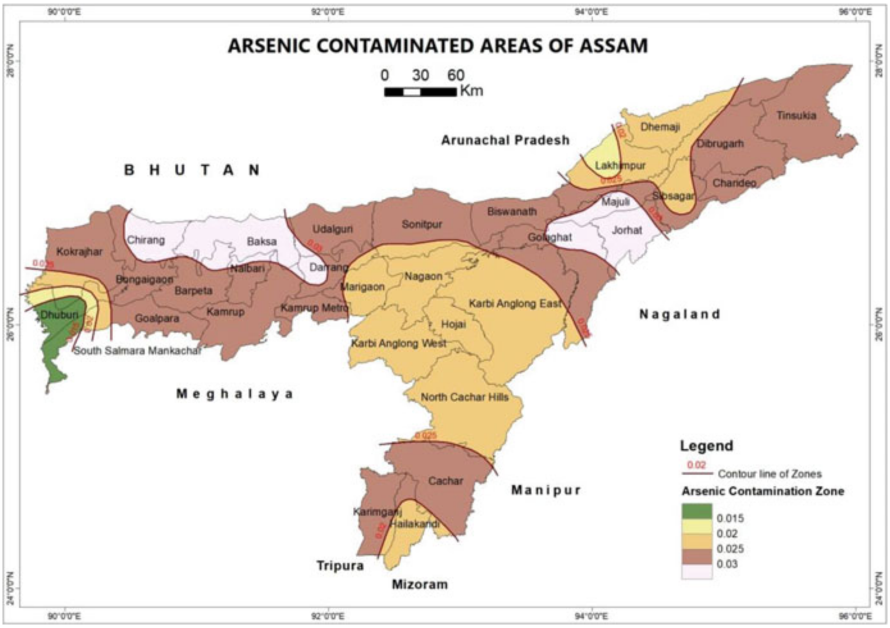


Fig. 1 Arsenic contaminated regions of Assam

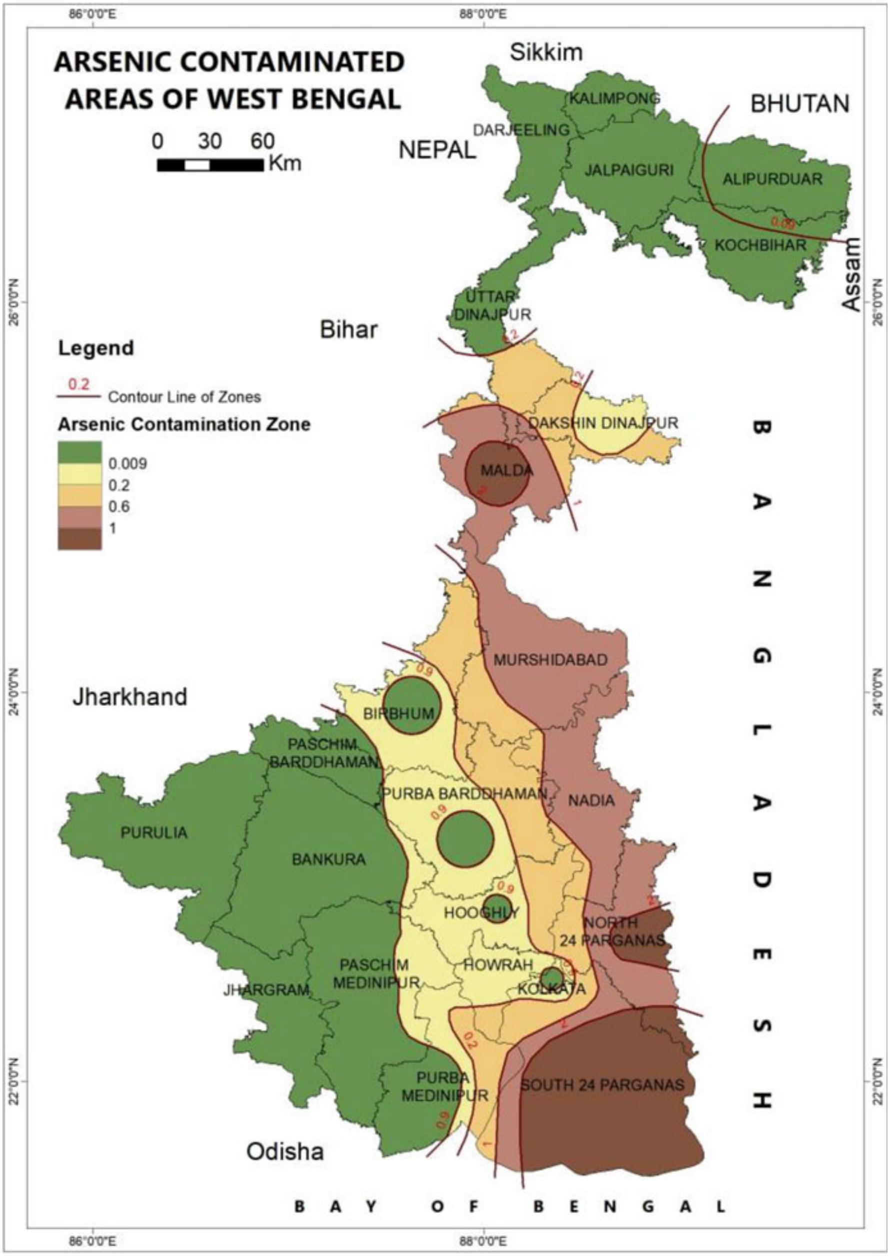


Fig. 2 Arsenic contaminated regions of West Bengal

3 Methodology

The various data and related information have been collected from different sources such as reports of CGWB (Central Ground Water Board), PHED (Public Health Engineering Department), Planning commission, BIS (Bureau of Indian Standards) and NIH (National Institute of Hydrology), SWID (State Water Investigation Directorate) website, and WHO (World Health Organisation) guidelines and also from different journals, Govt. articles etc. to prepare this paper. After collecting the data and studying the scenario, detailed review has been presented along with cartographic representations [10–12, 17–19].

4 Remedial Measures to Reduce the Contamination of Groundwater from Arsenic

The major concerned areas to be focused includes identifying and providing Arsenic free water to Arsenic-infected areas, considering animal and human health exposure to risk, implementing arsenic test centers, maintaining sampling protocols, supplying medical necessity to affected people, adopting arsenic removal techniques, quantifying amount of arsenic in soil and food chain of human beings and enhancing knowledge about arsenic-infection etc [9, 15–17].

For remedy of groundwater contamination by presence of arsenic, various Central and State Government organizations have undergone number of different initiatives for these states such as, identification of sources of contamination, set up of treatment plants, freshwater supply etc. In Assam, the authorities implemented some remedial measures in many Arsenic affected habitations. New dug-wells which discharges water free from arsenic from shallow aquifer have been established in almost three thousand (3000) habitations and Piped PWSS that is basically Schemes for Water Supply through Pipes has been set up for hundred fifteen (115) habitations at a cost of around Rs. Four hundred (400) crore. Moreover, the State has initiated to set up remedial measures for the remaining 359 habitations also, by constructing dug-wells for 18 residences and piped PWSS in around 50 residences at a cost of Rs. Hundred fifty-one (151) crore.

In 1978, the problem of arsenic affected groundwater was found in West Bengal. Initiation of set up of hand pumps in deeper aquifers, water purification plant for community was adopted immediately after the identification of the problem. Various methodologies such as adsorption, chemical precipitation, ion exchange, and sedimentation methods and treatment at site were adopted for installation of the community purification plants. West Bengal Government came up with an idea of long-lasting systematic solution and set up a committee (under different programs of Government of India, such as MsDP/BaDP etc.). The committee is set up on the basis of verdict of 132,267 groundwater test samples, suggested for a Master Plan (2005–2006). According to the Master Plan (2005–2006), it was advised to install twelve (12) numbers of Piped Water Supply schemes (PWSS) for surface water, three hundred thirty-eight (338) nos. of PWSS for groundwater, hundred sixty-five (165) nos. of plants for arsenic removal in addition to existing various groundwater-based schemes. During execution of Master Plan, West Bengal Government Public Health Engineering Department (PHED) has completed implementation of plants in most of Arsenic-contaminated locations of the state [9, 16].

5 Arsenic-Removal Technologies

The important factors that need to be considered-in while considering appropriate Arsenic-removal methods are given below:

- Adoption of new technologies and advancement of cost minimized methods based on availability of effective materials for Arsenic-removal.
- Cost minimization and finalization of techniques for better technical performance or at least comparable to presently available alternatives.
- Continuous improvement of domestic and community-based arsenic removal methods should be considered based on indigenously developed materials.
- Field execution of technologically developed systems to determine their suitability in social aspects.
- Making use of cost-effective methods for removal of arsenic.
- Set up of capacity-building upto designated levels for functioning and maintenance of Arsenic removal units.
- Safe deposition of sludge.

6 Issues Related to Deposition of Arsenic Waste from Arsenic Filters

Nowadays, lot of Arsenic filters are installed wherever required and much more are still to be developed. But the major problem of utilizing arsenic filters is safe disposal of Arsenic contained sediment. Groundwater will be polluted and unsafe for drinking by the seepage of deposited sludge into the ground. Geosynthetic-bounded landfills are unable to solve the problem as their breakage would result in Arsenic contaminated soil and groundwater. Moreover, arsenic can easily find its path to the animals and human beings directly or indirectly, through the roots of the plants. The idea of destroying the Arsenic laden sludge by burning did not worked as it causes air pollution. It has been recommended that earthworms consume Arsenic and it continues to be normalized in the earthworm's body generation after generations, but the idea did not work as the earthworms will deposit all the Arsenic at the time of accidental death [18].

There are few important points which are required to be taken into consideration when discussing about the deposition of Arsenic-containing sludge from filters. The construction industries are afraid of taking risk of using arsenic in manufacturing as arsenic is renowned to be a detrimental element. Altogether, it would bring a never-ending problem, wastage of time and money, psychological trauma and disaster to the builder. The method used is to cast concrete in two steps, one with arsenic mixed concrete in the central core part and the other with arsenic free concrete in the exterior zone. This process of double-stage construction would eventually increase the total time of construction and hence would be uneconomical. As a result, the construction company will have to pay more revenue to the labourers and the rental cost of the equipment will also increase. A public awareness programme is needed to be carried out for a longer period of time to provide alertness among the people that construction engineers are going to use Arsenic containing sludge securely in construction and there is no harm to habitants of the dwellings, that are to be established with Arsenic mixed with non-structural concrete. This programme should be shared through all possible ways like television, radio, road side banner, newspaper advertisements, and other public places, social media etc. It must be noted that the problem of secure disposal of arsenic waste from filters and creating public awareness must be done unitedly by different professionals like structural engineers, environmental engineers, architects, journalists, doctors and lawyers etc.

7 Safe Application of Arsenic-Filled Sludge from Arsenic Filters

1. The preferred option as explained by the authors is to disposal of the Arsenic contained sludge by using this sludge as an admixture to concrete as concrete is an anthropic rock. Arsenic is stabilized and does not go out to the outside environment from the concrete, as the compound Arsenate has the lowest mobility. Arsenic contained sludge is utilized for the concrete that will not be used in construction of structures, but can be used for architectural and ornamental work. Moreover, concrete containing Arsenic is used only in the central portion of total concreting with exterior cast in ordinary Arsenic-nil concrete, for removing the possibility of arsenic to get in touch with the exterior. It has been proved after critical research and by executing numerous experiments on weight-bearing and decomposition characteristics of concrete having arsenic sludge as a part of the admixture, that arsenic-containing concrete is not of lesser quality to ordinary concrete with respect to stiffness and strength, this type of concrete may be used as an ingredient to structure.
2. Alternatively, arsenic containing sludge can be normalized by utilizing it in ornamental bricks in double procedure. First by combining with concrete as an admixture at a constant ratio and second by mixing with clay for manufacturing ornamental bricks. They are described as follows:

(a) The usefulness of Arsenic-containing sludge treatment procedure through cement-based solid methods and normalization is strongly influenced by the type of Arsenic compound. Arsenate is having lowest mobility. It is observed that calcium of cement causes the extraction of water but not the movement of Arsenic. Changing the state into solid and normalizing with lime and (OPC) is a useful means for stabilization of Arsenic-containing sludge. Cement mixture is utilized for treating a large quantity of harmful wastages by upgrading the physical virtue of the disinfectants, by reducing the toxic level and by transferring the contaminants. This process involves combination of the wastes either in the form of sludge, a solid, a liquid into a combined binder system.
(b) When arsenic mixed sludge is normalized using clay, it is found that the sludge is protected when utilized up to 10% of clay volume wise. In case of tiles and ornamental bricks, arsenic-mixed sludge can be utilized securely upto 4% of tiles and ornamental bricks volume wise. It must be kept in mind that with the enhancement in the percentage of sludge, the resistive capacity of bricks diminishes at all fire temperatures.

8 Conclusion

The causes and harmful effects of arsenic in different parts of Assam and West Bengal have been discussed elaborately in this paper. It has been observed that the rapid increase of contamination of Arsenic in groundwater of different districts of Assam and West Bengal are in alarming position and need more attention. The effects of arsenic on human and animal health are slow but hazardous; therefore, it is better known as slow poison. It is necessary to aware the society about the harmful effects of Arsenic at microlevel, and thus the procedure to aware the scientific community and people staying in the arsenic contaminated areas has also been discussed here in detail. Few important methods of deposition of Arsenic-contained waste from Arsenic filters have been discussed in this paper and the most efficient methods are considered in detail. Some recommendations are provided by the authors that can be adopted by the Government to utilize the Arsenic waste from filters. The method of utilizing the waste, the purpose and various positive and negative impacts are also discussed. It has been found that Arsenic waste can be used safely as an admixture to concrete for ornamental and architectural structures and with clay for making ornamental tiles and bricks.

References

1. Acharya, S. K. (2005). Arsenic trends in groundwater from quaternary alluvium in the Ganga Plain and the Bengal Basin, Indian Sub-continent: Insights into influences of stratigraphy. *Gondwana Research, 8*(1), 55–66.

2. BGS (British Geological Survey). (1999). *Groundwater studies for arsenic contamination in Bangladesh. Main report and supplemental volumes 1–3*. Government of the Peoples Republic of Bangladesh, Ministry of Local Government, Rural Development and Cooperatives, Department of Public Health Engineering/Mott MacDonald International Ltd.
3. BGS (British Geological Survey). (2000). Executive summary of the main report of phase I, groundwater studies of As contamination in Bangladesh. British Geological Survey and Mott MacDonald (UK) for the Government of Bangladesh, Ministry of Local Government, Rural Development and Cooperatives DPHE and DFID (UK).
4. Bhattacharya, A. K., Karthik, D. M. P., Gautam, A., Sharma, A., Srinivas, K., & Singh, P. K. (2016). Arsenic contamination in the groundwater of India. *Green and Sustainable Development, 3*(17), 36–60.
5. Bhattacharya, A. K. (2017). Arsenic contamination in Indian groundwater. *Journal of the Institution of Public Health Engineers, India, XXXXV*(2), 18–36.
6. Bhattacharya, A. K. (2017). Arsenic contamination in Indian groundwater. *Indian Journal of Power and River Valley Development, 67*(11&12), 169–182.
7. BIS. (2009). *Drinking water-specification (IS-10500:2009)*, 24p.
8. BIS. (2012). *Drinking water-specification* (second revision). IS-10500:2012, 11p.
9. Bhattacharya, A. K., Lodh, R., Roy, A., Karthik, D. M. P., Singh, A., Mishra, A. K., Kumari, S., Kumari, V., Daksh, K., Kumar, P., & Anurag. (2019). Analysis of arsenic contamination in the groundwater of India, Bangladesh and Nepal with a special focus on the stabilisation of arsenic-laden sludge from arsenic filters. *Indian Journal of Power and River Valley Development, 69* (3&4), 49–67.
10. CGWB. (1999). *High incidence of arsenic in groundwater in West Bengal*. Central Ground Water Board, MoWR, GoI.
11. CGWB. (2011). *Dynamic groundwater resources of India* (as on 31st March, 2009), 225p.
12. CGWB and BARC, (2009). *Studies on arsenic pollution of groundwater using isotopic and geochemical methods in arsenic Bhojpur district of Bihar, India, CGWB-Mid Eastern Region*, 49p.
13. Rajmohan, N., & Prathapar, S. A. (2016). Arsenic distribution in groundwater and soil in the eastern Ganges basin—A review. In *Proceedings, Sixth International Groundwater Conference*, 11–13 February, 2016, Chennai. Paper ID TS4-05, Pages TSIV-78-93.
14. Shah, B. A. (2007). Role of quaternary stratigraphy on arsenic contained groundwater from parts of Middle Ganga Plain, UP-Bihar. *Environmental Geology, 53*, 1553–1561. https://doi.org/10.1007/s00254-007-0766-y
15. Saha, D., Sahu, S., & Chandra, P. C. (2011). Arsenic-safe alternate aquifers and their hydraulic characteristics in contaminated areas of Middle Ganga Plain, Eastern India. *Environmental Monitoring Assessment, 175*(1–4), 331–348.
16. Bhattacharya, A. K., & Lodh, R. (2018). Arsenic contamination in the groundwater of India with a special focus on the stabilization of arsenic-laden sludge from arsenic filters. *Electronic Journal of Geotechnical Engineering, 23*, 575–600.
17. NIH and CGWB. (2010). *Mitigation and remedy of groundwater arsenic menace in India: A vision document*. MoWR, GoI, 184p.
18. Rahman, A. A., & Ravenscroft, P. (2003). Groundwater resources and development in Bangladesh, Chapter 23. In A. S. M. Firoz Mallick & H. K. Das (Eds.), *Options for arsenic removal from groundwater*. The University Press Ltd.
19. IARC (International Agency for Research on Cancer). (2004). *IARC monographs on the evaluation of carcinogenic risks to humans* (Vol. 83), France, 1396p.

Sustainable Approach for Cloud-Based Framework Using IoT in Healthcare

Tabish Mufti, Shahab Saquib Sohail, Bulbul Gupta, and Parul Agarwal

1 Introduction

During the last few years, cloud computing and IoT has become an emerging field in the industry. In earlier days it was very difficult to trace and manage the patient and its related records nowadays with the help of advanced Technologies and applications, it has become convenient easy and efficient to trace patient geography and excess records from previous databases. Due to the advancement in the technological field, the advancement in the architecture of cloud based applications has also changed the way user and client communicates with each other. This has a rapidly changed the models and the components related along with functionality, storage, exchange, manage information. Why IoT for Healthcare is becoming important with respect to time? There are various reasons for growth of the internet of things (IoT) in Healthcare. One of the main reason is the people who live in rural areas are unable to avail Health Services due to distance so in order to bring them closer to the health facilities applications are being developed for the Healthcare [1], so that they can avail health facilities quickly and can be stayed connected. This problem is not limited to rural areas, but it has rapidly increased in Metropolitan cities if anyone needs an emergency service for health related services then it is very difficult for a person to connect to a right health service which is nearest to its place. With the development of the Healthcare monitoring ecosystem system [2], the current health of a patient can be monitored and related measures can be taken.

T. Mufti (✉) · S. S. Sohail · B. Gupta · P. Agarwal
Department of Computer Science and Engineering, SEST, Jamia Hamdard, New Delhi, Delhi, India
e-mail: tabishmufti@jamiahamdard.ac.in; shahabssohail@jamiahamdard.ac.in; pagarwal@jamiahamdard.ac.in

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_14

2 Literature Review

In 1997, Cloud computing was described by Professor Ramnath Chellappa as the current computing model where the lines of computing will be complete with commercial rationale rather than technical limits alone. Google provides cloud services as Google Cloud Platform (GCP). Google gains a powerful game in the world of cloud services. Google cloud platform was launched in the year 2008. Google cloud platform offers so many features. In this one feature is the use of managed VMs (virtual machines). Google enters in the cloud services in 2008 with the viewing of Google App Engine [3]. In this paper PaaS service that enabled purchaser to use Google's platform to develop and host their applications. Problems with Google App Engine were the lack of outstanding developer languages, it supported and the absence of Storage solution. Planners of Google Cloud Platform (GCP) [4] were mandatory write their functions using Python. In 2009, Google achieved more benefits after the extension of multiple services like Google compute engine and to manipulate functions like DNS and data analyst. Java is included as a supported language (Table 1).

Google Cloud Platform is available in 200+ countries across the globe. Google Cloud Platform enables a user to build, deploy, and manage Virtual Machines (VMs) to run workloads in the cloud. Google Cloud Platform offers a free tier that includes a micro instance per month for up to 12 months. It is the easiest way to run your code in the cloud. Also, it is highly available and fault-tolerant [6]. The unified object storage for live or archived data provided for Google Cloud Platform (GCP). This service is used to store and access data in GCP infrastructure. The Google Cloud Platform provides storage that can be attached to instances running in either Google Computer Engine or Google Kubernetes Engine. GCP does not have any disaster recovery service. GCP offers high performance and scalability. Also, it helps in maintaining relational MYSQL, and SQL Server databases in the cloud. GCP provides better pricing than competitors, live migration of Virtual Machines (VMs), improved performance, redundant backups. Some disadvantages Google Cloud Platform support fee is quite hefty, it has a complex pricing schema, downloading data from GCS is expensive (i.e., it's 0.12 per GB). Companies using the Google Cloud Platform are Netflix, Unilever, Kellogg's, Samsung, Spotify, HSBC, Snapchat, etc. [7] (Fig. 1).

In February 2010 Microsoft Azure was launched, and promises to deliver services as infrastructure-as-a-service and service and platform as a service [8]. Microsoft Azure cloud structure the oldest cloud service provider in the industry. It consists of following features.

- Compute
- Networking
- Storage
- Web
- Mobile
- Containers

Table 1 Summary of related work in the area of healthcare and IoT

Paper name	Authors name	Objective	Finding	Area	Method	Citation
Personal Health Care Framework for Children	Nina Sevani	• Adolescent healthcare needs precautions and attentive attention • Healthcare is combined with the finite efficiency of the child • Mainly a child with unique problem, like disorder • Use of holistic structure also protects the adolescent from unaware bacteria	• Adolescent's healthcare requires helpers, such as a pediatrician • Usage of Primary Health Care's framework to control child's health that is also managed according to the health situation of the child [5]	Health Sector	The use of a PHC's framework	[3]
e-Health networking to cater to Rural Health Care and Health Care for the Aged	D. S. Venkateswarlu, K. S. Verma, and K. S. R. A. Murthy	• Healthcare conditions in India engineering that can decrease the amounts it is attracted on • Wireless Electronic Communication Technologies (ICT) on health care	• Usage of elemental CDMA methodology through wireless line diagnostic method	E-Health Networking	Telemedicine, e-health networking	[5]
Healthcare technology management applied to public primary care health	Saulo José Argenta Garcia, Rubia Alves da Luz Santos, Priscila Sousa de Avelar, Renato Zaniboni, Renato Garcia	• The University of Biomedical Engineering of Santa Catarina is established from the Municipal Health Secretariat • Establishment of this institute is for primary health care	• The formation of this structure in the CS of FLN-SMS has given a major effect on the majors of healthcare in initial healthcare	Health care technology management sector	Local Centre of Clinical Engineering	[8]

(continued)

Table 1 (continued)

Paper name	Authors name	Objective	Finding	Area	Method	Citation
Health Informatics for Low-Cost and High-Quality Health Care	Carmen C. Y. Poon, Wenbo Gu, and Y. T. Zhang, Fellow, IEEE	• Standardization of MINDSS machines that needed an analysis, like the calibration method of cuffless blood pressure analysis machines, is reviewed	• P-Health is expected as a future less amount health model that provide best health qualities	Health sector	P-Health	[11]
Designing Interactive Health Care Systems: Bridging the Gap Between Patients and Health Care Professionals	Lisa Graham—IEEE Student Member, Mohammad Moshirpour—IEEE Student Member, Michael Smith—Senior IEEE Member, Behrouz H. Far—IEEE Member	• As sufferers become active about their wellness and grow into techniques such as the Internet of Things (IoT)	• Personal Health Care System (PHCS) and e-Health can give sufferers with data about their wellness while granting them to committing extra data about their health	Scenario-based software engineering	Personal health systems and eHealth systems	[13]
Complexity of Cyber Security Architecture for IoT Healthcare Industry: A Comparative Study	Aysha K. Alharam, and Wael El-madany	• Currently, a huge array of Internet of Things wearable wellness functions has been advanced • Secure healthcare sector from cyber-attacks attacking on Internet of Things based wellness devices	• This paper explained the insoluble problem of cyber security structure for the Internet of Things (IoT) based on health care	Complexity issue of cyber security	IP core architecture	[16]
Development of Health Care System Based on Wearable Devices	Pin-Chieh Huang, Chung-Chih Lin*, Yu-Han Wang, Hisang-Jen Hsieh	• The healthcare structure in this paper is described to consist of wearable machines and information	• In this study, the notification data daily provides information to their place who have a chronic disease	Smart Health Technology	Wearing health devices	[19]

(continued)

Table 1 (continued)

Paper name	Authors name	Objective	Finding	Area	Method	Citation
Health Care in the Age of Interoperability Part 6: The Future of FHIR	Mark L. Braunstein	• The objective of this study is to dramatic transformation in the health care informatics in huge scale because of new Health Level 7 (HL7)	• The main motive of the study is to introduce researchers from other sectors in the recent area of health information	Health field	Patient care	[20]
Toward a Health Care Technology Management Knowledge Base	Jair A. Villanueva P., Fabiola M. Martínez L	• Objective of this paper is to represent the growth of the primary level of a healthcare technology system on the knowledge base	• The motive and main technology is forum of advising for professionals and for those who are interested	Development of health	Health Management	[21]
Improving IOT Based Architecture of Healthcare System	Inderpreet Singh, Deepak Kumar	• Enhance and improve Internet of Things (IoT) based architecture	• It represents the dissimilar section of a medical system and the device sensor being used to set up the biological structure	I Internet of Thing (IoT)	Health framework	[23]

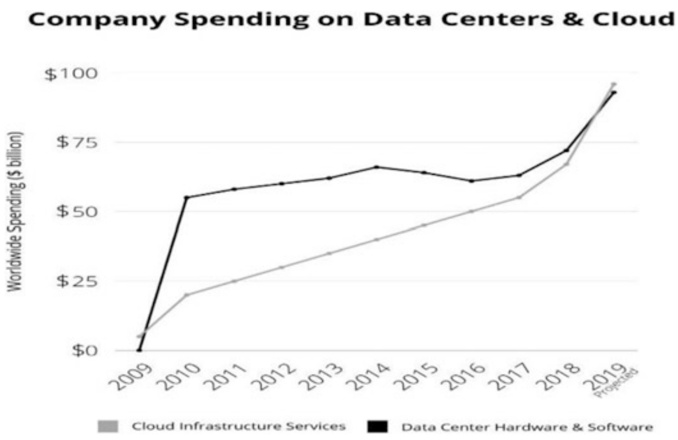


Fig. 1 Investment Cloud Infrastructure. (Source: Synergy Research Group)

- Databases
- Analytics
- Al + Machine Learning
- Internet of things
- Integration
- Identity

Microsoft Azure has a good market value since last more than 10 years, now it is present in more than 140 countries and has the second [9] highest number of customers around the globe after Amazon Web Services; it is the second best Cloud Service Provider in the market after Amazon Web Services.

Microsoft provides many services to its clients, which includes computing services, functional services, networking services, VPN services, etc., on the other hand it also helps its clients to increase or decrease VPN Service according to the usability [10]. Microsoft Azure has various clients from Netflix, Kellogg's, Samsung eBay Pixar Unilever etc. Microsoft Azure provides better development operations strong security profile, cost effective solutions, etc. Some disadvantages of Microsoft Azure are different codebase for cloud and premise, the PaaS ecosystem is not as efficient as IaaS, poor management of GUI and tools, no integrated backup. Azure has a free tier for a year with 750 h per month of Windows or Linux Virtual Machines. Azure functions allow users to build an application using the server less, simple function with a programming language of their choice. Blob Storage offers large amounts of storage and scalability. It stores the object in the tiers; depending on how often the data is being accessed. Microsoft Azure managed disk will allow you to create up to 10,000 VM disks in a subscription. Microsoft Azure is a strategy that allows site recovery by orchestrating and automating the replication process of Azure Virtual Machines (VMs) between regions. Azure eases the migration of SQL server databases without changing the user's applications [11].

Table 2 Microsoft Azure vs. Google cloud platform

Services	Microsoft Azure	Google Cloud Platform
IaaS	Virtual Machines	(GCE) Google Compute Engine
PaaS	Application Service and Cloud Services	Google App Engine
Containers	Azure Kubernetes Service (AKS)	Google Kubernetes Engine
RDBMS	SQL Database	Google Cloud SQL
Server Less Functions	Azure Functions	Google Cloud Functions
Pricing	Pre-Paid service Minute by minute	Pre-Paid service Up to (minimum 10 min)
Model	On demand Prepaid model	On-demand sustained use
Data Transfer	Azure port/Export Service	Storage Transfer Service

Google Cloud Platform (GCP) is one of the leaders among cloud API (Application Programming Interface). Microsoft Azure is the second leading cloud provider after the Google Cloud Platform. We have compared compare in-depth the features of Microsoft Azure and Google Cloud Platform deemed to provide security with a particular focus on confidentiality, integrity, and availability of data. Comparatively Google Cloud Platform gives better pricing than competitors. Azure functions allow users to build an application using the server less, simple function with a programming language of their choice [12]. The Google Cloud Platform provides unified object storage for live or archived data. Google Cloud Platform (GCP) offers high performance and scalability (Table 2).

Internet of things (IoT) is a technology to synthesize several devices on the internet and permits them to share and transfer information, data and resources among them. There are embedded sensors in all the devices we come across like mobile phones, traffic lights, and electrical appliances, etc., these sensors help them to integrate over the internet [13]. This sensor ceaselessly radiates data and helps us track them as well as knowing their proper working. IoT connects all physical devices like microphones, cameras, speakers display screens etc. This technology helps to blend their data and provide a common language to communicate with each other (Fig. 2).

In healthcare, IoT helps the hospital management system to make comprehensive patient records, test results and treatment reports [14].

Although there still are some challenges like

- Unavailability of real time data
- Insufficient smart devices

Internet of things (IoT) could be the solution of all these issues. It can provide real time data and make devices smarter so that they can provide analytics. Internet of things (IoT) [15, 16] makes devices smarter. Internet of things (IoT) empowers healthcare and improves the quality of care. In the end, it directs the un-sustainability rising cost of medical devices.

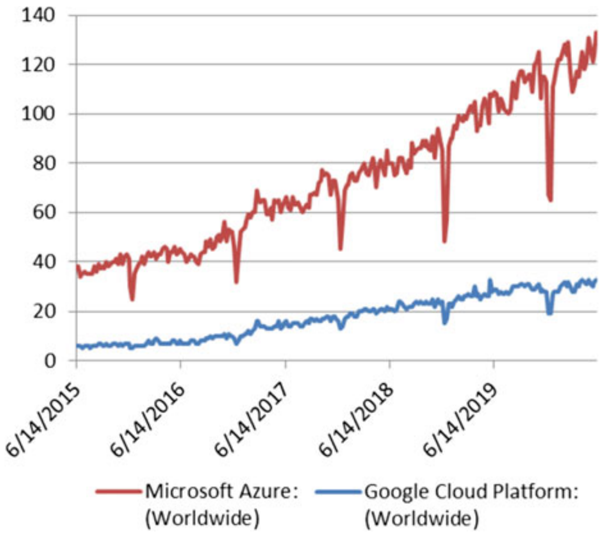


Fig. 2 Growth of Google cloud platform and Microsoft Azure 2015–2019

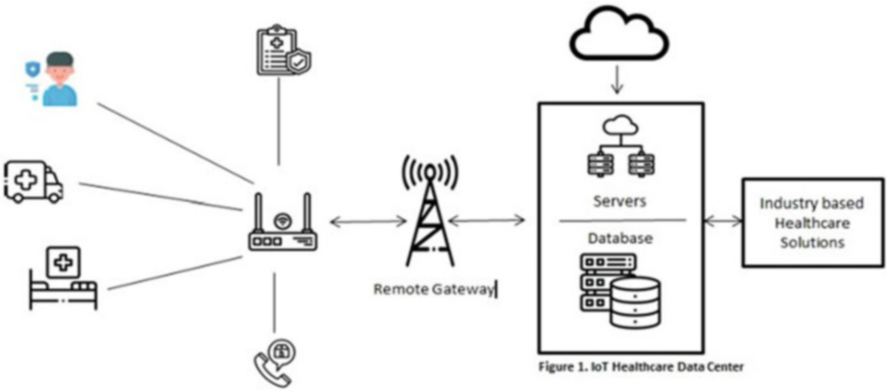


Fig. 3 Internet of things (IoT) Healthcare Architecture

3 Internet of Things (IoT) Healthcare Architecture (Fig. 3)

Google provides an API which application program interface tool for cloud healthcare. The cloud healthcare API is costing consist of various factors like (Tables 3 and 4)

- Data storage
- Network utilization
- Number of requests

Table 3 Data Storage—Plan

Storage class	0–1 GB (per GB per month)	1–1024 GB (1 TB) (per GB per month)
Structured storage	$0.00	$0.39
Blob storage	$0.00	$0.023
Storage class	0–1 GB (per GB per month)	1–1024 GB (1 TB) (per GB per month)
Structured storage	$0.00	$0.39
Blob storage	$0.00	$0.023

Source: Google

Table 4 Request Plan

Category	0–25,000 requests	25,000–1 billion requests	1 billion + requests
Standard requests	$0.00	$0.39	$0.29
Complex requests	$0.00	$0.69	$0.59
Multi-operation requests	$0.00	$0.39	$0.29

Source: Google

4 Applications of Internet of Things (IoT) in Health Cloud

Health Tracking App These types' of software help to track the health of the patient and generate quality of information which can be helpful for the doctor to take necessary steps. These types of apps can track heartbeat [17, 18], blood pressure, pulse rate diabetes, irregular breathing, fever, weight etc.

Internet of Things (IoT) for Patients Internet of things (IoT) has changed the patient's lifestyles, by keeping track of their condition [19]. Wearable devices like fitness bands and some wireless devices like blood pressure and heart rate to monitor the situation of a patient.

Internet of Things (IoT) for Nutrition Nutrition is a very important for individuals to be healthy and to live a happy life. Fooducate is nutrition app. App provide service of comparing various types of food for individual and recommends the best result among all. This app also tracks the food intake, exercise, sleeping time, sleeping hours etc.

Internet of Things (IoT) for Meditation Nowadays, mental health is very important aspect of our real life, due to a busy life, excessive workload and hectic schedule result in mental stress and mental illness. In the field of Internet of things (IoT) [20] meditation app becomes more important in our daily life by reducing our stress by providing peace of mind. Headspace application is a software which is designed in such a manner which provide guided meditations provide SMS alerts, time to chill out and many other functions.

Internet of Things (IoT) for Physicians Physicians can easily track the current situation of a patient using wearable and other devices embedded with Internet of things (IoT) [21]. Doctors are helped by Internet of things (IoT) in healthcare as doctors can identify best suited treatment for the patients.

Internet of Things (IoT) in Hospitals In case of an emergency, the doctor can immediately check the patient's situation and can communicate easily with mobile apps. Patient care is improved by Internet of things (IoT). Internet of things (IoT) [22, 23] devices provides accurate data of a patient and support some features such as monitoring, tracking and real-time alerting. As the Internet of things (IoT) devices help the doctors to get the analysis of the patient's health it also helps [5] the hospitals to keep real time tracking of the various equipment's such as Wheelchairs, Oxygen Pumps, defibrillators, nebulizers and much more. Internet of things (IoT) Devices is Hospitals also helps to manage the assets like pharmacy [24], Health monitoring, Doctor Connectivity, patient monitoring etc.

Internet of Things (IoT) for Hospital Information System Such types of devices are used to collect the information regarding services available in the hospital like number of vacant beds, number of reserved beds, number of patients admitted [25], number of doctors on duty, available emergency services, availability of ambulance service, doctor on call service, doctors appointment, OPD timing, charges of OPD etc.

5 Merits of Internet of Things (IoT) in Healthcare

- Using Internet of things (IoT) reduces data wastage by giving reliable and accurate data with less percentage of error in expensive imaging, mapping and [26, 27] testing which also in one way save cost and resources.
- Continuous monitoring of patients is possible with the help of the Internet of things (IoT) which enables real-time diagnosis and reporting of diseases before it spreads [28] further.
- Internet of things (IoT) promotes research in the healthcare sector because it can effectively collect colossal data about a single case or type of patients, which would otherwise be both difficult and costly if collected in person [29, 30].
- Internet of things (IoT) also helps the large scale policy makers and government decisions by collecting real time data about urbanization, pollution, population, market trends, shopping behaviors etc. [31].
- Internet of things (IoT) technology has the potential to change everything which involves user interaction and generates data for improvements in business, innovations, goal-setting and efficient working of a system [32, 33].

6 Demerits of Internet of Things (IoT) in Healthcare

- Using Internet of things (IoT) for collecting data to help reduce wastage such as testing and expensive imaging and reliable and accurate data gives us less error [34, 35].
- Internet of things (IoT) enables continuously monitor patients, which provide real time data that helps in diagnosis the diseases before it spreads [36].
- Internet of things (IoT) for healthcare can help in research work also as Internet of things enable us to collect massive amounts of data [37, 38] which if collected by a person could cost more.
- As the population is increasing, pollution is also increasing to control the pollution we need real time data and air pattern which is collected by using Internet of things (IoT) device. This helps the policy makers to take decisions and make cities healthier.

7 Conclusion

In this paper, we have reviewed Internet of things (IoT) in healthcare along with Microsoft and Google cloud platform, These are the two big technological [39] competitors, both are there in the market for ages since the introduction of cloud based services now days, till date the competition have reach to the next level. The use of the Internet of things (IoT) with cloud based platform has various domains. All Apps are using cloud based services. One of the domains we covered in this paper is Healthcare. Healthcare is a serious and complex task. Despite 24 h of patients, monitoring doctor is unable to find out the exact medical issue and sometimes in emergency situation doctors couldn't be alerted on time. At this point Internet of things (IoT) [40] comes in the race and fulfills the needs of doctors. Internet of things (IoT) has launched various wearable devices like Hearable which is like a miracle for those who suffer from hearing problems, monitoring machine, smart watches for depression, ingestible sensors and heart rate monitoring. All the Internet of things (IoT) devices are reliable and [38] help us to get medical condition for every minute and whole day long and these devices automatically notify the doctor about the condition and emergency situation. The most common Internet of things (IoT) technology in health care is patient monitors, energy meters and x-rays and imaging devices. Internet of things (IoT) collects accurate data [41], decreases costs as there is no need for visiting doctors, Offer 24 h service at home. However Internet of things (IoT)) enter with some issues. Security is a major issue as sensitive information is shared; data is stored in huge amount, human errors are also determined [39]. According to some prediction till the end of 2020, 90% of the hospitals and organization will implement Internet of things (IoT). So the future of the Internet of things (IoT) is bright and will improve and will implement more devices. We have talked about the Amazon cloud architecture and services provided by both Google and Microsoft, Google is open source [42], provide discount and customer friendly contracts, less data centers while Microsoft can integrate with office tools with a broad feature set, supports [43] hybrid cloud, more data centers etc. As this paper differentiate and review about same technology provided by two different companies along with differences, compatibility and customer demand.

References

1. MacDermott, Á., Kendrick, P., Idowu, I., Ashall, M., & Shi, Q. (2019). Securing Things in the Healthcare Internet of Things. In *2019 Global IoT Summit (GIoTS)* (pp. 1–6).
2. Saha, G., Singh, R., & Saini, S. (2019). A survey paper on the impact of 'Internet of Things' in healthcare. In *2019 3rd International conference on Electronics, Communication and Aerospace Technology (ICECA)* (pp. 331–334).
3. Mufti, T., Sami, N., & Sohail, S. S. (2019). A review paper on Internet of Things (IOT). *Indian Journal of Applied Research, 9*(8), 27.
4. Sami, N., Mufti, T., Sohail, S. S., Siddiqui, J., & Kumar, D. (2020). Future Internet of Things (IOT) from Cloud perspective: Aspects, applications and challenges. In *Internet of Things (IoT)* (pp. 515–532). Springer.
5. Moosavi, S. R., Gia, T. N., Rahmani, A.-M., Nigussie, E., Virtanen, S., Isoaho, J., et al. (2015). SEA: A secure and efficient authentication and authorization architecture for IoT-based healthcare using smart gateways. *Procedia Computer Science, 52*, 452–459.
6. Bui, N., & Zorzi, M. (2011). Health care applications: A solution based on the internet of things. In *Proceedings of the 4th International Symposium on Applied Sciences in Biomedical and Communication Technologies* (p. 131).
7. Farooq, M., Waseem, M., Mazhar, S., Khairi, A., & Kamal, T. (2015). A review on Internet of Things (IoT). *International Journal of Computer Applications, 113*, 1–7.
8. Hassanalieragh, M., Page, A., Soyata, T., Sharma, G., Aktas, M., Mateos, G., et al. (2015). Health monitoring and management using internet-of-things (iot) sensing with cloud-based processing: Opportunities and challenges. In *Services Computing (SCC), 2015 IEEE International Conference on* (pp. 285–292).
9. Abie, H., & Balasingham, I. (2012). Risk-based adaptive security for smart IoT in eHealth. In *Proceedings of the 7th International Conference on Body Area Networks* (pp. 269–275).
10. Atzori, L., Iera, A., & Morabito, G. (2010). The internet of things: A survey. *Computer Networks, 54*, 2787–2805.
11. Koreshoff, T. L., Robertson, T., & Leong, T. W. (2013). Internet of things: A review of literature and products. In *Proceedings of the 25th Australian computer-human interaction conference: Augmentation, application, innovation, collaboration* (pp. 335–344).
12. Zhao, K., & Ge, L. (2013). A survey on the internet of things security. In *Computational Intelligence and Security (CIS), 2013 9th International Conference on* (pp. 663–667).
13. Lee, B. (2014). "Healthcare framework on the IoT open platform," service model, architecture. *International Journal of Applied Engineering Research, 9*, 29783–29792.
14. Kulkarni, A., & Sathe, S. (2014). Healthcare applications of the internet of things: A review. *International Journal of Computer Science and Information Technologies, 5*, 6229–6232.
15. Govinda, K., & Saravanaguru, R. (2016). Review on IOT technologies. *International Journal of Applied Engineering Research, 11*, 2848–2853.
16. Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems, 29*, 1645–1660.
17. Madakam, S., Ramaswamy, R., & Tripathi, S. (2015). Internet of things (IoT): A literature review. *Journal of Computer and Communications, 3*, 164.

18. Suresh, P., Daniel, J. V., Parthasarathy, V., & Aswathy, R. (2014). A state of the art review on the Internet of Things (IoT) history, technology and fields of deployment. In *Science Engineering and Management Research (ICSEMR), 2014 International Conference on* (pp. 1–8).
19. Zhang, Z.-K., Cho, M. C. Y., Wang, C.-W., Hsu, C.-W., Chen, C.-K., & Shieh, S. (2014). IoT security: Ongoing challenges and research opportunities. In *2014 IEEE 7th International Conference on Service-Oriented Computing and Applications* (pp. 230–234).
20. Khoo, B. (2011). RFID as an enabler of the Internet of Things: Issues of security and privacy in Internet of Things (iThings/CPSCom). In *2011 International conference on and 4th International Conference on cyber, physical and social computing* (pp. 709–712).
21. Jing, Q., Vasilakos, A. V., Wan, J., Lu, J., & Qiu, D. (2014). Security of the internet of things: Perspectives and challenges. *Wireless Networks, 20*, 2481–2501.
22. Yang, J.-C., Hao, P., & Zhang, X. (2013). Enhanced mutual authentication model of IoT. *Journal of China Universities of Posts and Telecommunications, 20*, 69–74.
23. Liu, J., Xiao, Y., & Chen, C. P. (2012). Authentication and access control in the Internet of Things. In *ICDCS workshops* (pp. 588–592).
24. Agarwal, P., Chopra, K., Kashif, M., & Kumari, V. (2018). Implementing ALPR for detection of traffic violations: A step towards sustainability, 2018. In *Proceedia: Computer science* (pp. 738–743). Elsevier Journal Publication. ISSN: 1877-0509.
25. Jan, M. A., Nanda, P., He, X., Tan, Z., & Liu, R. P. (2014). A robust authentication scheme for observing resources in the internet of things environment. In *Trust, Security and Privacy in Computing and Communications (TrustCom), 2014 IEEE 13th International Conference on* (pp. 205–211).
26. Mietz, R., Abraham, P., & Römer, K. (2014). High-level states with CoAP: Giving meaning to raw sensor values to support IoT applications. In *Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), 2014 IEEE Ninth International Conference on* (pp. 1–6).
27. Laplante, P. A., & Laplante, N. (2016). A structured approach for describing healthcare applications for the Internet of Things. In *Proceedings of the IEEE 2nd World Forum on Internet of Things*.
28. Catarinucci, L., et al. (2015). An IoT-aware architecture for smart healthcare systems. *IEEE Internet of Things Journal, 2*(6), 515–526.
29. "Nurses Rank as Most Honest, Ethical Profession for 14th Straight Year," Press release. American Nurses Association (ANA), 2015; www.prnewswire.com/news-releases/nurses-rank-as-most-honest-ethical-profession-for-14th-straight-year-300195781.html.
30. Skiba, D. (2013). Emerging technologies: The Internet of Things (IoT). *Nursing Education Perspectives, 34*(1), 63–64.
31. Sami, N., Mufti, T., Sohail, S. S., Siddiqui, J., Kumar, D., & Neha. (2020). Future internet of things (IOT) from cloud perspective: Aspects, applications and challenges. In M. Alam, K. Shakil, & S. Khan (Eds.), *Internet of things (IoT)*. Springer. https://doi.org/10.1007/978-3-030-37468-6_27
32. Al-Hamadi, H., & Chen, R. (2017). Trust-based decision making for health IoT systems. *IEEE Internet of Things Journal, 4*(5), 1408–1419.
33. De Michele, R., & Furini, M. (2019). Iot healthcare: Benefits, issues and challenges. In *Proceedings of the 5th EAI International Conference on smart objects and technologies for social good* (pp. 160–164).
34. Pang, Z. (2013). Technologies and architectures of the internet-of-things (IoT) for health and well-being (Doctoral dissertation, KTH Royal Institute of Technology).
35. Butt, S. A., Diaz-Martinez, J. L., Jamal, T., Ali, A., De-La-Hoz-Franco, E., & Shoaib, M. (2019). IoT smart health security threats. In *2019 19th International Conference on computational science and its applications (ICCSA)* (pp. 26–31). IEEE.
36. Ullah, K., Shah, M. A., & Zhang, S. (2016). Effective ways to use internet of things in the field of medical and smart health care. In *2016 International Conference on intelligent systems engineering (ICISE)* (pp. 372–379). IEEE.

37. Ding, D., Conti, M., & Solanas, A. (2016). A smart health application and its related privacy issues. In *2016 Smart city security and privacy workshop (SCSP-W)* (pp. 1–5). IEEE.
38. Kalarthi, Z. M. (2016). A review paper on smart health care system using internet of things. *International Journal of Research in Engineering and Technology, 5*(03), 8084.
39. Zhang, Y., Deng, R. H., Han, G., & Zheng, D. (2018). Secure smart health with privacy-aware aggregate authentication and access control in internet of things. *Journal of Network and Computer Applications, 123*, 89–100.
40. Hammi, B., Khatoun, R., Zeadally, S., Fayad, A., & Khoukhi, L. (2017). IoT technologies for smart cities. *IET Networks, 7*(1), 1–13.
41. Vippalapalli, V., & Ananthula, S. (2016). Internet of things (IoT) based smart health care system. In *2016 International Conference on signal processing, communication, power and embedded system (SCOPES)* (pp. 1229–1233). IEEE.
42. Agarwal, P., Hassan, S. I., Mustafa, S. K., & Ahmad, J. (2020). An effective diagnostic model for personalized healthcare using deep learning techniques. In *Applications of deep learning and big IoT on personalized healthcare services* (pp. 70–88). IGI Global.
43. Weber, R. H. (2010). Internet of things—New security and privacy challenges. *Computer Law and Security Review, 26*, 23–30.

A Case Study on Evaluation of Energy Management System by Implication of Advanced Technology in Typical Cement Factory Tamil Nadu, India

X. Agnello J. Naveen, A. Arivoli, S. Boopathi, and V. Rajkumar

1 Introduction

In India, the Ultra-red category industries (most polluting) are in high environmental risk factor in energy resource. An adaptation of the capacity building clean development mechanisms intensified in energy conservation projects to overcome the problem. New energy concepts based on under the Bureau of Energy Efficiency scheme. It covers eight different manufacturing industries. These sectors accounts 40% of India's primary energy manufacturing consumption. An alternative technology to be found [1] called has advanced technology. This was introduced by Non-Conventional Energy Sources connecting all state grid with wind power, industrial cogeneration and Bio-power accumulated from the Biomass power or bagasse co-generation plant, Non-bagasse co-generation, Biomass gasified, Urban and Industrial wastes, Small hydropower (up to 25 MW station capacity), and Solar Thermal and Solar Photovoltaic resources. The power output generated from the co-generation plants used to meet the captive requirements and surplus power produced can be connected to state electricity grids to minimize the non-renewable

X. A. J. Naveen (✉)
Assistant Professor, Environmental Science Department of Crop Management, Thanthai Roever Institute of Agriculture and Rural Development (TRIARD), Perambalur, Tamil Nadu, India

A. Arivoli
Department of Environmental Science, Government Arts and Science College, Ariyalur, Tamil Nadu, India

S. Boopathi
Department of Economics, Bharathiar University, Coimbatore, Tamil Nadu, India

V. Rajkumar
Department of Economics, Government Arts and Science College, Thondamuthur, Coimbatore, Tamil Nadu, India

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3_15

energy resources. The funding scheme has a project to help firms, research and development, technical up-gradation, and training facilities for all the large and small scale industries. US Agency for International Development has contributed from subsidy up to 10% equity for nine demonstration projects, training, workshops, newsletters, and outreach activities.Indian renewable energy Development Agency offers multilateral agreement for renewable energy development obtained from international and bilateral institutions. The Bank provides funding for the total installed capacity for four co-generation in India is around 3500 MW [2]. Bagasse/ biomass/co-generation to Clean Development Mechanism has introduced 79 Projects Registered under India's [3]. The United States has funded 19 million dollar efforts for research and development by the Global Environmental Facility, The United States Agency for International Development, Greenhouse Gas Pollution Prevention, Project Bureau of Energy Efficiency, State Electricity Regulatory Commissions, Asian Development Bank [4]. The project is a perspective to provide financing to cooperative sugar mills. To keep an account of energy output can be monitored by Certified Emission Reductions [5] using a systematic approach to compare the conserve energy Year by Year, an energy audit clearance is a mandatory requirement for more energy usage industries like iron and steel, pulp, and paper and cement to maintain and operates Energy management system specifies certification is required by ISO-50001 [6].

2 Statement of the Problem

In the Cement industry, energy loss has been high by wet/dry operational process. Using fuel has high energy escape to identify the point comparing by decreasing the annual report, Cement industries, energy are used at a higher level due to the heavy production process. Mostly dry heat is utilized and recycled in most cement firms due to this characteristic like load variation, escape of energy, energy drops, single-line, power distribution. These are the problem faced by the industries during the operation. To identify and have a holistic analysis of energy points and adopt new cost-cutting technology with eco-friendly technologies.

2.1 Objective

To identify the energy conservation techniques used in the select cement industry by calculating and calibrate by reporting using the Energy management system benchmark.

2.2 Area of Study

The Typical Cement factory for the study, situated in Tamil Nadu, India, is an "Ultra-red" category industry (most polluting). The production capacity is high 4000 kg per day, but we still had to adopt Advanced energy conservation technologies.

2.3 Materials and Methods

Across studying 455 review of literature, there are particular studies using materials, and this is a review that gave insight to this research framework [7–16], from this The motto of the research is a case study to understand the select cement industry, energy management system 50,001; a systematic datasheet, using step by step process from the production line to the end of the operation line every electrical point is checked with a data prepared to analyze the variables and factors depending on EnMS Audit. Five different variables were discussed: (1) General Identification has to be check, for an example road map, and diffusion of Energy-saving technology, (2) They are finding the gaps and analyzing Energy-saving technology, (3) Cost-Advantage, Advantage, and finding gaps, (4) Review and feedback, (5) Adaptation of new technology. The data are the secondary source (descriptive method) retrieve from Energy Engineers, Financial Auditors, Electricity board (EB) reports, and environmental Managers. The data have two parts; qualitative analysis is done by giving scores Note-Yes (✔), No (✗), Checked and Verified—compliance, Noncompliance Reasons: Flexibility, Reliability, Quality, Very high level-VHL, High level-HL, Medium level-ML, Low Level-LL, Very Low Level-VLL, quantitative analysis like crosschecking with older reports, cost analysis, calculation of Savings and loss, Environmental advantages. (2) Quantitative data analysis of the cost variables given below [17, 18].

Concept of Cost Analysis Method

The materials are classified into three different types of cost variables: In Economics fundamental is there are two Capital A and small a, where the Capital A explains the holistic investment of a firm were the small a explains single component subjected to a tool (technologies), are a production line.

Cost Analysis

Cost variables like Fixed cost, Annual operating cost, and annual savings. Under these different variable costs, factors are involved like (1) The investment cost is further classified into Equipment, Civil work, Instrumentation, and Auxiliaries energy tool. (2) Annual operating cost (Fixed cost) is further classified into the cost of capital, Maintenance, Manpower, Energy, Depreciation, and Annual savings (Profit and benefits) are classified in the form of energy like thermal, Electricals, oil saving, stream, (life cycle energy assessment) Miscellaneous cost, raw material cost and waste disposal [19–21].

Methods

The method adopted is Simple net saving per year [22, 23]. Moreover, Payback in months [22, 24] has given below (Fig. 1 and Table 1).

$$\text{A net saving per year (Rs./Year)} = \text{Annual saving} - \text{Variable cost}$$

$$\text{Payback in month} = (\text{Fixed cost/net saving/year}) * 12$$

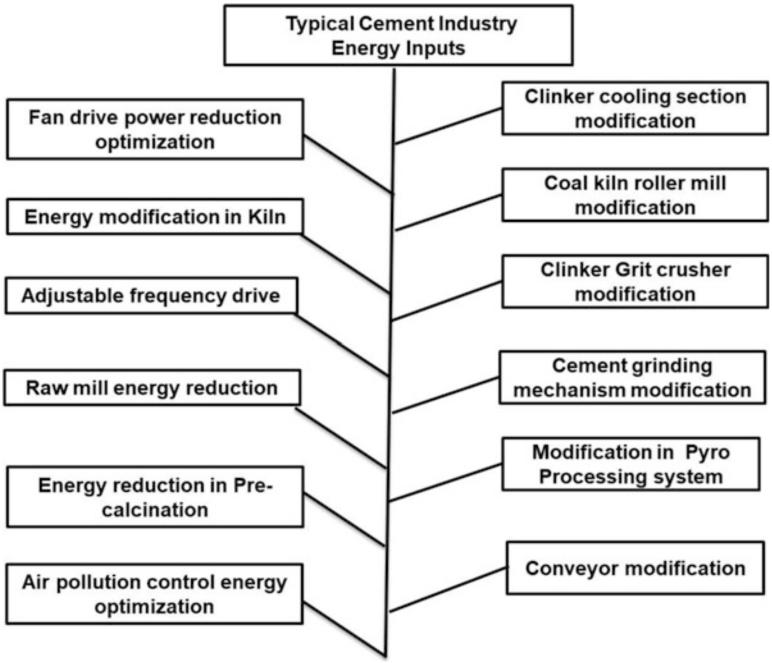


Fig. 1 The Operational flow chart of the Energy Management System in a Typical Cement factory

Table 1 Road map of Energy and Environmental measures taken in a Typical Cement Factory in Tamil Nadu

S. no	Description	Date
1	First to Introduce Vertical Roller Mill for Limestone Grinding in India started up to 1.5 MTPA cement production	1981
2	Captive Power Plant with Heavy Fuel Oil in India	1983
3	Install Modern Pre-Calcinatory Dry Process Kiln in Tamil Nadu	1987
4	QMS ISO-9001 Quality management system	1993
5	Vertical Roller Mill for Cement Grinding (VRM)	1997
6	Increased to 3 MTPA cement production	2003
7	ISO 14001(Environment Management system) Certification from BIS	2004
8	ISO 50001:2011 Energy Management Certification	2011
9	27 MW Captive Power Plant	2005
10	4000 TPD FLS Cement Plant	2006
11	New Pipe conveyors installed in place of conventional conveyors	2010
12	To improve the performance of ESP during direct operation New water spray system has been installed	2010
13	Clinker production increased from 4500 to 6500 TPD by modifying the Kiln inlet Riser duct, Cooler vent Fan, and Primary Air Fan	2011
14	Green belt development crossing 5000 plantation	2011
15	Rainwater harvesting pond increased to 40,000 m^3 with RO	2011
16	Go Green initiative to all cement industry	2011
17	Cement grinding mechanism (roller mill) vertical operations	2012
18	65 numbers of VFD introduced for less amount of electricity consumption	2013

Explanation of Table 2

The Energy management system is a systematic procedure to deal with a step-by-step hierarchy process of collecting information on the energy conservation system. These are classified into five main steps: more application-oriented. Road map and diffusion identification (Parameter), Analysis (Measurement), review, feedback, and implementation. Energy performance indicators (EnPIs), Plan-do-check-action management cycle model, Integration-Energy-Practice (IEP), Environmental consultancy Certification for ISO-50001 Energy Management System, Energy Consumption of Products and Baseline, Improve Energy Performance Indicator, Energy input and out Gas, Electricity, fuel (Oil/Coal), Compressed air, steam, pressure, Thermal turbine (Windmill source) Process flow chart, material balance, and flow chart process diagram, Energy efficiency in utility and process, specific energy consumption, Bio-efficiency assessment Furance, clinker efficiency, cooling water system, Alternate current sets performance, electric system load, lighting system, identification of legal requirements.

Table 2 Interview schedule in Energy management system (EnMS) in Typical Cement Factory (Annexure-1)

S. no	Factors	Element requirement			
A.	General requirement				
	Reference	Auditors			
	Name of firm	Typical cement factory			
	Product/service	Cement			
	Date of operation	20-08-1983			
	Energy budget	DG (LSHS)—12 MW, coal based—29 MW, Windmill—14.5 MW			
	Date of audit reporting	11-11-2019			
	Location	Tamil Nadu, India			
	Industrial pollution categories	Ultra-red (polluting industry)			
	Energy consumption by thermal (kCal/kg of clinker)	700			
	Energy consumption -electrical (kWh/T) of cement (actual)	70.63			
	Energy performance improvement period				
	Fuel	Indian coal, pet coke / imported coal, lignite			
	Renewable source	Yes (9-Windpower)			
	Approval and completion				
B.	Audit requirements				
	Task	Responsible	Start date	End date	Comments
	Internal audit	Energy auditor	05-02-2020	06-02-2020	Verified-non compliance
	Suitable equipment	Electrical engineer	07-02-2020	08-02-2020	Verified-non compliance
	Budget	Financial auditor	10-02-2020	11-02-2020	Verified-non compliance
	Energy-saving potential	Skilled technician	12-02-2020	13-02-2020	Verified-non compliance
	Target (instruments)	Management	14-02-2020	15-02-2020	Verified-non compliance
	New baseline (tariff)	Management	16-02-2020	11-11-2019	Verified-non compliance
	Road map of timeline	As shown in Table 1			
C.	Energy Requirement				
	Has the organization defined an Energy Management System Accordingly, by ISO 50,001? EnMS	Yes			
	EMS+ EnMS	Yes			
	EMS + QMS+ EnMS	Yes			
	Are the specialized skills, human, financial, and technological resources necessary for energy management identified and provided by the board?	Yes			
	Energy policy and regulation	Yes			

(continued)

Table 2 (continued)

C.	Energy Requirement							
	Green rating project (GRP)							
		Qualitative checklist						
D.	Factors and variables	Yes /no	VHL	HL	ML	LL	VLL	Report and Remarks
	EMS + QMS energy policy	✔		✔				Verified noncompliance
	Energy input	✔	✔					Verified noncompliance
	Classification of technology	✔	✔					Verified noncompliance
	Cost analysis variables	✔	✔					Verified noncompliance
	Methods of cost analysis	✔	✔					Verified noncompliance
	Basic factors	✔	✔					Verified noncompliance
	Research and development	✔		✔				Verified noncompliance
	Service and maintenance	✔		✔				Verified noncompliance
	Procurement of energy services, products, equipment, and energy	✔		✔				Verified noncompliance
	Technical instrumentation availability		✔					Verified noncompliance
	Risk assessment			✔				Verified noncompliance
	Safety priority list				✔			Verified noncompliance
	EIA interpretation (green belt) related to air pollution			✔				Verified noncompliance
	Audit report							
	Energy performance improvement period	Continuous improvement						
	Energy performance (%) over an improvement period	5%						
	Total energy cost saving over improvement	30 lakh USD						
	Cost to implement EnMS	Rs. 6,40,000 per year						
	The payback period of EnMS implementation year	0.34 years						
	Total energy saving over an improvement period (GJ)	40,303 Giga joule						
	Total CO_2 emission reduction over the improvement period	38,371 MT of CO_2						

(continued)

Table 2 (continued)

D.	Factors and variables	Qualitative checklist Yes /no	VHL	HL	ML	LL	VLL	Report and Remarks
	Waste fuel recycling		Quantity of waste fuel recycled and reused (tons)—11,210, conventional energy reused (tons of fuel)—4839, waste fuel reused has energy—3.95%					
	High coal CV		Yes (used)					
	Energy management system audit-reporting							
	PDCA (Plan-DO-Check-Act)		Noncompliance, strongly agree					
	Review		Has given by the auditor present and past reports for verification					
	Consulting		Total operating with energy assessment (check)					
	Planning (budgeting)		It still has to improve the energy process escaping heat (upgrading technology LCA, LCEA)					
	Benchmarking		GRP show lower (carbon footprint)					
	Future scope		Resource management (raw material), verified noncompliance					
	Feedback		Noncompliance (still to improve)					

Note: *VFD* variable frequency drive, *kWh* kilowatt per hour, *MT* million ton, *USD* Untied state dollar, *GJ* Giga joule, *KCal* kilo calories, *CV* calorific value, CO_2 carbon dioxide, Yes (✔), No (✗), Checked or tested Verified—compliance, Noncompliance Reasons: Flexibility, Reliability, Quality, *VHL* very high level, *HL* high level, *ML* medium level, *LL* low level, *VLL* very low level, *LCA* life cycle assessment, *LCEA* life cycle energy assessment, *GRP* Green rating project

3 Regulation of Energy Management System

Energy conservation by technology upgrading and foreign exchange earnings in intellectual property rights and outgo has a holistic energy process like co-generation and auxiliary process using add-on technology. The regulation policy is noncompliance with energy resources adopting the that adopt towards reporting EnMS, the calculation for a year, Third-party (Environmental consultant), CPCB, Green rating project.

3.1 Energy Conservation and Cleaner Production Ultra Red Category Industry

It is highly polluting industrial Ultra Red category using a regulation, policy which has been a mandatory process for every industry's Conservation of Energy, Technology Absorption, the Companies act. This rule is used to check the Financial Audit of advanced technology (Energy, Environment, recycling, co-processing reusing) and made mandatory to every large-scale industry in India. A Green rating project by the Centre of science and environment (CSE) gives a rating on life cycle energy assessment LCEA looping cycle.

3.2 Energy Input Identification

The concept of the Second law of energy c is used in energy conservation like Gas, Electricity, Fuel, Pet coke (Oil/Coal), Compressed air, temperature, Steam, pressure, Water, Thermal, Turbine (Windmill source), Internal Audit/ External audit, Energy efficiency in utility and process Specific Energy consumption, Bio-efficiency assessment, Furnace efficiency, (direct current generation) DG sets performance, Electric motor load, Lighting system is given very high level and verified noncompliance.

3.3 Cost Analysis Variables

The firm's total investment (Fixed cost), land, construction, operation, maintenance, total cost, Buyback, Payback, Social cost, Annual saving of Electricity /Fuel/Coal/ non-renewable energy resources (MWh/MT) or in the unit, Annual savings in Rupees (Indian currency) is given a very high level and verified noncompliance.

Methods Used for Energy Cost Analysis

Cost-benefit analysis, like Payback period, returns on investment, simple percentage, and statistical tool. Benefits account (Rs.), Capacity improvement, Raw material saving, Reduction in abatement costs, Improved productivity (T/day), Records and documentation, New Design technology, Purchasing, Analysis, Reference year equivalent = Reference year energy using Production factor Plant-like Energy Performance, Maximizing renewable System Efficiency, Energy Audit Instruments, Electrical Measuring Instruments, Energy modification Calculating the energy input and output usage, Different calibration are used from the initial to final process in the cement industry by calibrating (substitution/subtraction/addition) of raw material usage limestone (calcium carbonate), clay (aluminum silicates), sand (silica oxide), and iron ore to produce clinker, which is ground with gypsum, limestone, etc. to make cement in a step by step process. The operation of the energy process is classified into two dry (combustion) and wet (steam) process, reduce, recovery, low and high temperature/pressure, preheating air compressor systems, Mainly classified into Energy savings in raw material preparation, clinker operation, finish grinding, wastewater treatment process is given very high level and verified noncompliance.

4 Classification of Technology

Technologies are classified into Wastewater treatment, Air, odor, noise, solid waste, Co-processing, co-generation, industrial ecology, recycling/reusing, Total quality, life cycle management, synergy, flowchart operational process, whether utilization of energy has an impact on air pollution, corrective actions and preventive measures, updating/upgrading/ control records in technology, internal audit report. Hazards areas identification, Standard operation procedure (SOP), Personal protective equipment availability (PPE), Employee Training, Communication, Institutional background, Technical up-gradation, Maintenance and service, Fire and damage insurance, Communication Record and documentation, Audits review, Crosscheck with the past report, Risk assessment, Employee feedback or opinion, Environmental, social accountability, Implication cost, is given very high level and verified noncompliance.

4.1 Basic Factors

Fundamental factors are classified into (1) They are identifying energy-saving potential, (2) Energy-saving potential reviewed predefined intervals, (3) Significant energy issues prioritized for further energy analysis, (4) Carbon emission identified and calculated, (5) I was checking the performance, (6) New energy trends, (7) Technicians, (8) Awareness, (9) Training, (10) Maintenances, (11) Any facility for research and development, (12) Communication like updating/upgrading technology input and output review and validation and consolidation. Very high level and verified noncompliance.

4.2 Procurement of Energy Services, Products, Equipments

Energy conservation is used in a variety of systems like water treatment plant, air pollution control, odor, noise, solid waste management (Co-processing system), hazardous waste, risk management system, Co-generation system, inbuilt or modification or integrated system, reuse energy system, industrial ecology, Recycling/reusing, total energy requirement system, life cycle energy assessment, Synergy, Flowchart of the operational process, less in emitting of Greenhouse gas CO_2, CH_4, CO, High sulfur contents in the fuel (characteristic of pet coke) represent a higher percentage of total production costs. High concentration of Volatile lead: The low carbon content ratio is used in higher calorific value volatile organic compounds, Polychlorinated, dibenzodioxins and dibenzofurans, Hydrogen fluoride, Hydrogen chloride, of Environmental health and safety are essential is given high level and verified noncompliance.

4.3 Technical Instrumentation Availability

Checkpoints for energy like a Process flow chart, Different energy points, Dry and wet process, Insulation compressed air, Homogenizing process, Exhaust fan Calibrating mechanism is studied continuously using expressions like units, KVA, kW, MWh, GJ, PF, Hertz, kVA, Amps, and Volts. Electrical Measuring Instruments combustion analyzer, Fuel Efficiency Monitor, Fyrite, Contact thermometer, Infrared Thermometer, Pitot Tube and manometer stroboscopes, Ultrasonic leak detector. Essential factors like register can identify material balance and flow process diagram by identifying energy saving potentials. Is given a very high level and verified noncompliance.

4.4 Research and Development

The cement industry has link with energy industry with the institutional background with research and development is given a high level and verified noncompliance.

4.5 Safety Priority List

Labors are given a periodic Health check-up in 3-month intervals ones strictly following the regulation of the labor regulations like providing them with personal protective equipment (PPEs), helmets to ensure the employee's safety. Is given a medium level and verified noncompliance.

Risk assessment and EIA interpretation (green belt) related to air pollution are given a high level and verified noncompliance (Table 3).

4.6 Description of Tables 2 and 3, Cost Parameter Using Net Saving Per Year and Payback in Months in the Typical Cement Factory

The Typical cement plant selected for energy assessment and evaluation is situated in Tamil Nadu, India. And it has been classified as one of the highest polluting industries by CPCB norms due to its raw material used and the output pollution level. This cement factory has improvised technologies with cost-cutting benefits, from the initial production process to the end-of-life process. Advanced energy technology is prioritized towards recycling, reusing, and reducing concepts because there is a significant heat loss in cement factories. There is no steam heat used by considering beneficial factors for dry heat like thermal, combustion, utilization of oil,

Table 3 Comparative studies between Advanced and Older energy-saving technologies using Net saving per annum and Payback in months in Cement Industry

S. no	Energy technology used	Cost specifications	Cost variables	A net saving per year (lakh in Rs. /year)			Payback in months	
			Energy technology					
			Older	Advanced	Older	Advanced	Older	Advanced
1.	Energy-saving technology-1	1. Fixed cost 2. Operating cost 3. LCAM 4. Savings 5. Advantage	Rs. 905,000 Rs. 2,00,000 per year 24 months **Rs. 200,000 per year** **30.5 (MWh) per year**	Rs. 1,400,000 Rs. 1,05,000 per year 53 months **Rs. 270,740 per year** **58.4 (MWh) per year**	**0.8**	1.27	**70.8**	28.8
2.	Energy-saving technology-2	1. Fixed cost 2. Operating cost 3. LCAM 4. Savings 5. Advantage	Rs. 15,00,000 Rs. 1,30,000 per year 24 months **Rs. 2,13,750 per year** **45 (MWh) per year**	Rs. 16,00,000 Rs. 300,000 per year 60 months **Rs. 4,56,710 per year** **95.9 (MWh) per year**	0.8	**1.5**	98.4	**25.4**
3.	Energy-saving technology-3	1. Fixed cost 2. Operating cost 3. LCAM 4. Net savings 5. Advantage	Rs. 360,000 Rs. 140,000 per year 36 months **Rs. 285,000 per year** **6 (MWh) per year**	Rs. 3000,000 Rs. 320,000 per year 48 months **Rs. 570,000 per year** **120 (MWh) per year**	0.14	**5.38**	102	**75.9**
4.	Energy-saving technology-4	1. Initial investment 2. Fixed cost 3. LCAM 4. Savings 5. Advantage	Rs. 5,00,000 Rs. 44,000 per year 60 months **Rs. 47,500 per year** **39 (MWh) per year**	Rs. 2,000,000 Rs. 115,000 per year 36 months **Rs. 250,000 per year** **52.6 (MWh) per year**	0.03	**1.35**	398.4	**58.8**

5.	Adjustable frequency drive	1. Fixed cost 2. Operating cost 3. LCAM 4. Savings 5. Advantage	Rs. 40,000 Rs. 50,000 per year 24 months **Rs. 28,500 per year** **6 (MWh) per year**	Rs. 10,00,000 Rs. 190,000 per year 48 months **Rs. 246,000 per year** **80 (MWh) per year**	0.23	0.56	10.2	**53.4**
6.	Raw mill energy reduction	1. Fixed cost 2. Operating cost 3. LCAM 4. Savings 5. Advantage	Rs. 80,000 Rs. 8000 per year 24 months **Rs. 33,250 per year** **7 (MWh) per year**	Rs. 2,00,000 Rs. 18,000 per year 48 months **Rs. 76,000 per year** **16 (MWh) per year**	0.25	0.58	19.2	**0.8**
7.	Energy reduction in pre-calcination	1. Fixed cost 2. Operating cost 3. LCAM 4. Savings 5. Advantage	Rs. 1,500,000 Rs. 11,000 per year 24 months **Rs. 23,720 per year** **5 (MWh) per year**	Rs. 1,850,000 Rs. 18,000 per year 48 months **Rs. 81,500 per year** **6.5 (MWh) p.a.**	0.12	**0.128**	745.6	**433.2**
8.	Modification in pyro processing	1. Fixed cost 2. Operating cost 3. LCAM 4. Savings 5. Advantage	Rs. 22,00,000 Rs. 555,000 per year – – –	Rs. 20,10,000 Rs. 220,000 per year 36 years **Rs. 380,000 per year** **80 (MWh) per year**	NA	1.6	NA	49.2
9.	Cement grinding energy optimization	1. Fixed cost 2. Operating cost 3. LCA 4. **Net savings** 5. Advantage	Rs. 410,000 Rs. 15,000 per year 41 months **Rs. 216,250 per year** **3 (MWh) per year**	Rs. 990,000 Rs. 37,000 per year 19 months **Rs. 182,000 per year** **38.5 (MWh) per year**	2	**1.4**	4.96	**49.2**
10.	Energy modification in Klin	1. Fixed cost 2. Operating cost 3. LCAM **4. Savings** **5. Advantage**	Rs. 3,60,000 Rs. 24,500 per year 36 months **Rs. 36,380 per year** **3.45 (MWh) per year**	Rs. 1,195,000 Rs. 84,000 per year 17 months **Rs. 262,200 per year** **55.2 (MWh) p.a**.	0.11	**2.5**	128.4	**35.2**

(continued)

Table 3 (continued)

S. no	Energy technology used	Cost specifications	Cost variables		A net saving per year (lakh in Rs. /year)		Payback in months	
			Energy technology					
			Older	Advanced	Older	Advanced	Older	Advanced
11.	Conveyor modification	1. Fixed cost 2. Operating cost 3. LCAM **4. Savings** **5. Advantage**	Rs. 23,400,000 Rs. 2,50,000 per year 48 months **Rs. 473,300 per year** **36.5 (MWh) per year**	Rs. 40,000,000 Rs. 7,00,000 per year 60 months **Rs. 1,063,000 per year** **55 (MWh) per year**	**2.2**	3.63	318	**264.2**
12.	Air pollution control energy optimization	1. Fixed cost 2. Operating cost 3. LCAM **4. Savings** **5. Advantage**	Rs. 1,000,000 Rs. 5000 per year 72 months **Rs. 42,750 per year** **9 (MWh) per year**	Rs. 1,500,000 Rs. 3000 per year 60 months **Rs. 52,200 per year** **11 (MWh) per year**	**0.4**	0.4	60	**90**

*NA** not available, Energy-saving technology 1—Clinker cooling section modification, Energy-saving technology, 2—Clinker Grit crusher modification, Energy-saving technology, 3—Coal kiln roller mill modification, Energy-saving technology, 4—Cement grinding mechanism, Energy-saving technology, 5—Fan drive Power Reduction optimization. *LCAM* life cycle assessment of the mechanism, *MWh* Megawatt per hour coal where there is a heat escape from every machinery due to heat is reused by different sectors. Using the principle of energy conservation intensity, calculating/calibrating the energy flow by pressure, temperature by output, and input, approximately 60% heat can be conserved using the synergy concept.

The data has been elicited from the energy auditor from the past and present reports in this specific industry. There are two types of energy technology used (1) Older technology (Non-renewable energy resources cannot be recycled/reused) (2) And Advanced technology same in the production process updated version like modification, re-technology Machinery.

There is a total of 12 types of Machinery which is updated in 2020. They are classified into two sections (1) Modifications are done in 6 types of Machinery and upgraded whole Machinery to reduce the energy use.

Energy-Saving Technology-1 Clinker Cooling Section Modification Heat is reduced by frequent recycling of water the net saving per year in Older technology (non-renewable energy) was (Rs. 80,000 per annum), where Advanced technology (Rs. 127,000 per annum). On comparing the two technologies, there is a loss in net saving per year. In terms of Payback on month older application technology (non-recycled energy) (70.8 months) and advanced technology (28.8 months) and terms of Payback returns per month in advanced technology shows a higher benefit like energy-saving 58.4 MWh per annum and profit of Rs. 80,000 per annum. However, net savings per annum showed a loss.

Energy-Saving Technology-2 Clinker Grit Crusher Modification The net saving per year old technology (non-reduced energy) was (Rs. 80,000 per annum), and advanced technology was (Rs. 150,000 per annum). On comparing the two technologies, both show a loss in net saving per year. Payback returns, Older technology (98.4 months) and Advanced technology (25.4 months), and Advanced technology showed a higher benefit. Despite the loss in net saving per year and Payback in the month of Advanced technology, the added benefits like energy benefit of 95.9 MWh per annum and a profit of Rs. 4,50,000 per annum were recorded.

Energy-Saving Technology-3 COAL Kiln Roller Mill Modification In older technology **net savings, is** (Rs. 14,000 per annum), and advanced energy technology (Rs. 5,38,000 per annum). On comparing the two energy technologies, Advanced technology shows a higher profit. In terms of Payback, older technology (102 months) and advanced technology (75.9 months) where advanced technology showed a higher benefit due to interest return month are low. With a loss in net saving per year and gain in Payback in a month, Advanced technology also benefits from saving 120 MWh per annum and gain a profit of Rs. 5,70,000 per annum.

Energy-Saving Technology-4, Cement Grinding Mechanism Comparing the net saving per year in Older technology (Rs. 3000 per annum) and Advanced technology (Rs. 135,000 per annum). On comparing the two technologies recorded a loss in net saving per year. In terms of Payback on month conventional technology (non-renewable energy) (398.4) and Advanced technology (58.8), advanced technology shows a higher benefit. With the loss in net saving per year and gain in Payback per month, the cleaner technology added benefit the energy saved amount of 52.6 MWh per annum and Rs. 2,50,000 per annum.

Adjustable Frequency Drive The net saving for old technology was (Rs. 23,000 per annum). Advanced technology s (Rs. 56,000 per annum). Advanced technology (AFD) shows the highest value in savings. In terms of Payback, older technology (10.2 months) and advanced technology (53.4 months). The old technology showed higher benefit with Quick Payback per month; the advanced technology would still benefit and profit through the energy saved to the extent of 80 MWh, and total profit is Rs. 2,46,000 per annum.

Raw Mill Energy Reduction The net saving in using older technology is (Rs. 25,000 per annum), and Advanced technology was (Rs. 56,000 per annum). On comparing the two technologies were at a loss. Payback per month, older technology (19.2 months) and advanced technology (0.8 months), and advanced technology showed a higher benefit. Energy saved as 16 MWh per year and profit earned as Rs. 7600 per annum, along with loss in net saving per year and higher benefit in Payback in the month Advanced technology.

Energy Reduction in Pre-Calcination The net saving per year in older technology was (Rs. 12,000 per annum), and advanced technology was (Rs. 12,800 per annum). Rs. 800 is higher in using advanced technology, In terms of Payback in months, older technology was (745.6 months), and Advanced technology was (433.2 months), and Advanced technology showed a higher profit return. Additionally, Advanced technology showed benefits in energy saving 6.5 MWh per year and profit as Rs. 30,800 per annum.

Modification in Pyro Processing There is no proper data in older technology used, so the return on advanced technology is (Rs. 1,60,000 per annum), depicting loss. Payback per month, advanced technology is (49.2 months). Though the loss in net saving per Year and Payback in a month for advanced technology, benefits in the form of energy saved 80 MWh per year, and profit earned Rs. 380,000 per annum were high loss. Advantage: Low operational and maintenance cost, automated energy-conserving technology.

Modification in Pyro Processing The older technology, data is not available, and advanced energy technology was (Rs. 140,000 per annum); the two technologies were in the loss. In terms of Payback per month, old technology was (4.96 months), and advanced technology was (49.2 months), leading to advanced technology showing a higher benefit; despite the loss in net saving per year and higher Payback per month, cleaner technology added further benefits through energy saved as 38.5 MWh per annum and profit accrued as Rs. 182,000 per annum.

Energy Modification in Klin Net saving per year old technology was (Rs. 11,000 per annum), and advanced technology was (Rs. 250,000 per annum). In terms of Payback per month, older technology was (128.4) and advanced technology was

(35.2 months), and advanced technology showed benefits. Also, Advanced technology had extra benefits in energy saving 55.2 MWh per year and profit as Rs. 262,000 per annum. Advantage**:** Automated with online digital sensors is available.

Conveyor Modification Energy-saving technology is connected to an adjustable frequency drive. The net saving per year old technology (pipe) was (Rs. 220,000 per annum), and advanced technology (Belt) was (Rs. 363,000 per annum), both losses. In terms of advanced technology was (318 months) and cleaner technology (Belt) was (264.2 months), where advanced technology showed a higher benefit. Added benefits like energy saved 55.5 MWh per annum and profit obtained Rs. 263,000 per annum were attributed to advanced technology.

Air Pollution Control Energy Optimization The net saving per annum older technology was (Rs. 40,000 per annum), and Advanced technology was (Rs. 40,000 per annum). On comparing the two technologies, there is a loss in net savings per annum. In terms of Payback per month, Older technology was (60 months), and Advanced technology was (90 months). Advanced energy technology showed a higher benefit. The energy saved as 11 MWh per annum and profit got as Rs. 52,000 per annum.

The total energy saved by Machinery advanced energy technology is 669 MWh per annum, 575.6 MT per annum, and Profit Rs. 60 lakhs per annum.

5 Findings of Energy Management System Cement Industry

Merits

1. Integrated management strategy (IMS) like EnMS, Good house practices, Occupational, health, fire and safety, Management, and production in one framework certification process gives cost saving.
2. Long-term Advantages, Comprehensive environmental management system, Mandatory, Implementation Check, Decision-Making, Sustainable consumption, accounting, and production, projecting future trends, Productivity, innovation, energy efficiency.
3. Best in class for global certification.
4. Avoid major problems in management and production.
5. Sets Competitive goals and Targets (Energy conserves state-of-art technology for pollution control, Finance, and procurement practices).

Demerits

1. Time-Consuming
2. SME cannot afford the cost is high for Accreditation

3. Just For certification,
4. The corporate industry plays an important role in developing criteria towards Energy management system, so the standard is very high, so the medium and small scale enterprises cannot adopt.
5. In developed countries, confusion between local and international policy, there are different opinions in norms like (EU, OECD, UNEP, EPA, CPCB/SPCB, and also in Energy management system regulations.

6 Completion of the Report

Lead auditor reports the external audit classified the data collected and combining in a format on PDCA-assessment (strongly agree), Detailed compliance/ noncompliance verification, Environmental management budgeting, reporting/ documentation has been given strongly agreed, crosscheck records verified, committee members odor in CSR (no adaptation of odor technology, GHG has compliance (no proper calibration and calculation like Green rating project and life cycle energy assessment is adopted), benchmarking (Resource management) and EnMS-Certification, review, planning. Budgeting is verified as noncompliance reported by the auditor.

7 Audit Report for Energy Management System

In this select cement industry, energy performance is checked, there is a continuous improvement is identified by reporting green rating project, and life cycle energy assessment, energy performance (5%) over an improvement period, the total energy cost saving over an improvement in year 20 lakh USD, and the cost implement for energy management is Rs. 5.4 lakh per annum for the payback period is implemented in 0.34 years and total energy saving over a period of the year is 38,303 Giga Joule total CO_2 emission reduction 40,303 MT CO_2 is an improvement, waste recycling like fuel 11,210 Ton per annum, Energy reused fuel—4839 Ton per annum, Waste fuel recycled and reused has energy—3.97%. High coal—740 tons per annum, MWh of electricity or tons of fuel)—180.44 Metric ton, Waste as percent total energy—0.77, feedback is given by assessing energy parameters with different factors (Crosschecking variables).

8 Energy Management System (Future Scope)

Digital sensors are connected with a continuous monitoring system based on a software data analysis like Big data analytics (datasheet is given computing algorithm software like Flux Analyzer and Meta tool, excel sheet and advance software database ANSS Quake Monitoring System (AQMS) [25] is connected to a storage facility (hardware) based to the EnMS computing algorithm to analysis in the online continuous data system.

9 Conclusion

The select Cement industry is unique using cleaner technology for applications: using energy-saving/cost-cutting technology, inbuilt equipment, Co-generating process, like using wet and dry energy process in a closed-loop system using an integrated approach pet coke, oil, co-processing, renewable resources like wind, solar energy reporting (synergy concept) by self-sustaining towards sustainable development.

References

1. Gargeya, A., & Srinivas Gangishetti, M. (2013). Energy audit in industrial drives. *International Journal of Engineering Research and Technology (IJERT), 2*(3), 1–5.
2. Sengupta. (2004). *Experience of air pollution control in the last two decades in India PPT, CPCB, MoEF*.
3. CDM Registry. (2015). *Sugar industry bagasse/biomass cogeneration projects registered under CDM in India*.
4. Sengupta, B. (2016). Status of co-processing of waste in cement plants as per hazardous and other waste management rules. In *2016 Presented at 3rd International Conference on Alternate Fuels and raw materials in cement industry—towards realizing swachh bharat dream on 23rd and 24th March 2017 at New Delhi, India*.
5. Sirohi, S. (2009). CDM: Is it a 'win–win' strategy for rural poverty alleviation in India? *Climatic Change, 84*, 91–110.
6. Central Statistics Office, Government of India. (2013). *Energy Statistics 2013*. Ministry of Statistics and Program Implementation. http://mospi.nic.in/mospi_new/upload/Energy_Statistics_2013.pdf?status=1&menu_id=216
7. Islam, M. M., & Hasanuzzaman, M. (2020). Introduction to energy and sustainable development. In *Energy for sustainable development* (pp. 1–18). Academic Press.
8. Krarti, M. (2020). *Energy audit of building systems: An engineering approach*. CRC Press.
9. Kumar Verma, Y., Mazumdar, B., & Ghosh, P. (2020). Thermal energy consumption and its conservation for a cement production unit. *Environmental Engineering Research, 26*(3), 200111.
10. Kumar, A., Prakash, O., Chauhan, P. S., & Gautam, S. (2020). *Energy management: Conservation and audits*. CRC Press.

11. Mokhtar, A., & Nasooti, M. (2020). A decision support tool for the cement industry to select energy efficiency measures. *Energy Strategy Reviews, 28*, 100458.
12. Muzzammel, R., Arshad, R., Mehmood, S., & Khan, D. (2020). Advanced energy management system with the incorporation of novel security features. *International Journal of Electrical and Computer Engineering, 10*(4), 3978.
13. Rajić, M. N., Maksimović, R. M., Milosavljević, P., & Pavlović, D. (2020). Energy management system application for sustainable development in wood industry enterprises. *Sustainability, 12*(1), 76.
14. Rathor, S. K., & Saxena, D. (2020). Energy management system for smart grid: An overview and critical issues. *International Journal of Energy Research, 44*(6), 4067–4109.
15. Sola, A. V., & Mota, C. M. (2020). Influencing factors on energy management in industries. *Journal of Cleaner Production, 248*, 119263.
16. Thollander, P., Karlsson, M., Rohdin, P., Wollin, J., & Rosenqvist, J. (2020). *Introduction to industrial energy efficiency: Energy auditing, energy management, and policy issues*. Academic.
17. Maria, R. A. D. U. (2012). Corporate governance, internal audit, and environmental audit—The performance tools in Romanian companies. *Accounting and Management Information Systems, 11*(1), 112.
18. Hassan, N. A., Zailani, S. H. M., & Hasan, H. A. (2019). Integrated internal audit in the management system. *The TQM Journal*.
19. Feldman, S. J., Soyka, P. A., & Ameer, P. (1996). *Does improving a firm's environmental management system and environmental performance result in a higher stock price?* ICF Kaiser.
20. Kleindorfer, P. R. (1997). Market-based environmental audits and environmental risks: Implementing ISO 14000. In *Geneva papers on risk and insurance. Issues and practice* (pp. 194–210).
21. Steger, U. (2000). Environmental management systems: Empirical evidence and further perspectives. *European Management Journal, 18*(1), 23–37.
22. Teke, A., Timur, O., & Zor, K. (2015). Calculating payback periods for energy efficiency improvement applications at a university hospital. *Çukurova University Journal of the Faculty of Engineering and Architecture, 30*(1), 41–56.
23. Venkatesan, T. M. I., & Kundu, G. K. (2020). An empirical study of kaizen events in Indian small and medium enterprises. *International Journal of Services and Operations Management, 37*(2), 197–219.
24. Gorgulu, S., & Kocabey, S. (2020). An energy saving potential analysis of lighting retrofit scenarios in outdoor lighting systems: A case study for a university campus. *Journal of Cleaner Production, 260*, 121060.
25. Hartog, J. R., Friberg, P. A., Kress, V. C., Bodin, P., & Bhadha, R. (2020). Open-source ANSS quake monitoring system software. *Seismological Research Letters, 91*(2A), 677–686.
26. Alberti, M., Caini, L., Calabrese, A., & Rossi, D. (2000). Evaluation of the costs and benefits of an environmental management system. *International Journal of Production Research, 38*(17), 4455–4466.
27. Bartolomeo, M., Bennett, M., Bouma, J. J., Heydkamp, P., James, P., & Wolters, T. (2000). Environmental management accounting in Europe: Current practice and future potential. *The European Accounting Review, 9*(1), 31–52.
28. Bernardi, E., Morato, M. M., Mendes, P. R., Normey-Rico, J. E., & Adam, E. J. (2021). Fault-tolerant energy management for an industrial microgrid: A compact optimization method. *International Journal of Electrical Power & Energy Systems, 124*, 106342.
29. Cantini, A., Leoni, L., De Carlo, F., Salvio, M., Martini, C., & Martini, F. (2021). Technological energy efficiency improvements in cement industries. *Sustainability, 13*(7), 3810.
30. Hui, I. K., Chan, A. H., & Pun, K. F. (2001). A study of the environmental management system implementation practices. *Journal of Cleaner Production, 9*(3), 269–276.

31. Kwak, Y. H., & Ibbs, C. W. (2000). Calculating project management's return on investment. *Project Management Journal, 31*(2), 38–47.
32. MNRE, Government of India. (2014). Biomass power and cogeneration programme. www.mnre.gov.in/schemes/grid-connected/biomass-powercogen/. MNRE, Government of India. (2013). Annual report 2012–2013. http://mnre.gov.in/mission-and-vision-2/publications/annual-report-2/
33. Thwe, E., Khatiwada, D., & Gasparatos, A. (2021). Life cycle assessment of a cement plant in Naypyitaw, Myanmar. *Cleaner Environmental Systems, 2*, 100007.
34. Zhang, C. Y., Yu, B., Chen, J. M., & Wei, Y. M. (2021). Green transition pathways for cement industry in China. *Resources, Conservation and Recycling, 166*, 1053.

Index

P. Agarwal et al. (eds.), *Smart Technologies for Energy and Environmental Sustainability*, Green Energy and Technology,
https://doi.org/10.1007/978-3-030-80702-3