Evaluating the Public Health Benefits of Renewable Energy Systems: How Smart Grid Technology Can Be Used to Enhance Community Health

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KEYWORDS

Public, Health, Benefits, Renewable, Energy, Smart Grid, Technology, Community, Social, Optimisation

ABSTRACT

Integrating smart grid technologies into renewable energy systems, however, is still limited by several barriers. Technical complexity, high initial costs, intricate infrastructure and potential cyber threats are all part of the game. Solving this problem is what the proposed Enhanced Social Energy Levels Optimization Analysis (SELOA) approach aims at; it is also targeted at ensuring that there is equal participation for each person in the society during the shift to renewables hence improved justice in energy consumption and distribution. Proposed application areas for residential energy management, public health monitoring and emergency planning are hardly exhaustive. SELOA use can promote healthier communities while achieving sustainable use of energy. The method was tested through simulating SELOA on various actual situations. Thus this research has indicated that less pollution from conventional power generation as well as more efficient generation methods would lead to improved health among people in various communities. These results imply that integration of Smart Grid technology with renewable energy systems could be a major contribution towards both appropriate sustainability and public health based on our finding.

1. Introduction

The transition to a renewable energy system offers unique opportunities for public health; Given the need to mitigate climate change and prevent environmental degradation [1]. An important part of this transformation is the adoption of smart grid technologies that provide robust tools for monitoring and optimizing electricity consumption [2–3]. Smart grids are also designed to support part of the electricity supply through renewable sources such as solar and wind [20]. For example, these systems reduce air pollution from breathing fossil fuels but also reduce cardiovascular or neurological disease [5]. Smart grids enable real-time monitoring and control of energy consumption thus providing an efficient and robust energy system [6] [10]. This is especially important in such diseases when considering fragile regions with high electrical conductivity due to hypoventilation [21]. Furthermore, smart grid technologies can foster local innovation that enhances community participation and economic benefits [8–9]. As they become more sustainable and energy efficient, communities become healthier and more resilient [22-23]. Thus, using smart grid technology to address the public health implications of renewable energy emphasizes the environmental benefits but also emphasizes how to further promote community health Therefore to conclude, this technology, energy policy and public health alliance is a potential way to ensure environmental sustainability along with improvements in public health [24]. Explore the feasibility of smart grid integration into renewable energy systems to reduce environmental impact, slow rapid climate change, and improve public health [14]. Use SELOA to address technical challenges, high initial costs, infrastructure requirements, and potential cybersecurity concerns that arise when integrating smart grid technology into alternative energy systems[7].

Positive community health outcomes can be achieved by using SELOA to optimize energy consumption and distribution [12]. This will help with household energy management, public health surveillance and emergency preparedness, while providing equal access. A summary of the last section of the report is as follows: Assessing the Positive Impact of Renewable Energy Systems on Public Health[4]: Opportunities for Smart Grid Technology to Promote Well-Being in Communities is the subject of Section II. Analysis for SELOA is presented in Section III. The comprehensive assessment is included in Section IV and includes the effects as well as comparisons to earlier approaches. The results summary can be found in Section V.

2. Literature Review

This review summarises significant research' methods and findings to highlight energy solution improvements and possibilities. Comparing these techniques shows the necessity for comprehensive evaluation frameworks and transdisciplinary tactics to optimise energy systems locally and globally. The approach put forth by Jaiswal, K. K. et al. [15] makes use of bioreactors and biorefineries, which are examples of Advanced Technology (AT), to produce energy from lignocellulosic biomasses [13]. Better energy security, easier access to energy, social and economic advancement, and lessened ecological and health repercussions from climate change are all outcomes. An all encompassing evaluation of Smart Grids utilising a Comparative Analysis (SG-CA) of current approaches, including revisions post-COVID-19, is the suggested approach by Kwilinski, A., et al. [16] Among the results are precise smart grid efficiency indicators, assistance for lawmakers in crafting efficient energy efficiency programmes and legislation, and resolution of both the immediate and long-term consequences of smart grid deployment [11].

An Multidisciplinary Approach (MA) that integrates technological and socioeconomic factors is central to the strategy put forth by Ceglia, F. et al., [26] which investigates existing literature and theoretical frameworks concerning smart energy systems in local communities. Achieving sustainable energy systems, optimising energy sharing, establishing intelligent energy communities, and reducing pollutants and economic inefficiency are all outcomes [14]. Researching Smart Grids (SG) as forerunners to the Energy Internet and doing a comprehensive literature analysis on the infrastructure, functionality, and market dynamics of the Energy Internet are the steps that Joseph, A. et al. [18] recommend. Results show that infrastructure and technology are ready on a global scale, and also reveal legislative and regulatory barriers that must be removed for the Energy Internet to be implemented successfully on a national scale [17]. The suggested approach by Alsagri, A. S. et al. [19] assesses a Hybrid Energy System (HES) power system for outlying medical facilities that combines solar panels, a diesel engine, and a battery bank. The results show that the system can function adequately off-grid for low loads, with a cost of $0.105/kWh, a renewable fraction of more than 30%, and a grid breakeven distance ranging from 1.2 to 5.8 km. The Enhancing SELOA is the most effective method for optimising energy consumption and distribution, ensuring equitable benefits, and addressing modern energy system challenges.

3. Methodology

Reducing pollutants, preventing weather alternate, and advocating for environmentally friendly strength are three ways wherein a shift to renewable power ought to have large public health blessings. An critical part of this modification is sensible grid era, which can improve electricity deliver and intake. Nevertheless, many obstacles can be conquer inside the integration of smart grid technology and renewable energy systems. These consist of cybersecurity issues, enterprise desires, excessive upfront costs and technical troubles. SELOA is an innovative method that goals to enhance public health for the benefit of all citizens by way of optimizing strength allocation and management. This study goals to solve those challenges.

Smart Grid Block Diagram

Improving air quality, lowering healthcare expenses, and overall community well-being are some of the public health benefits that result from the integration of energy from renewable sources with advanced technologies like smart meters, energy information analytics, and distributed energy management. The diagram also shows how microgrids and energy distribution systems work together to increase grid stability and reliability, which in turn leads to increased energy efficiency and emission reductions.

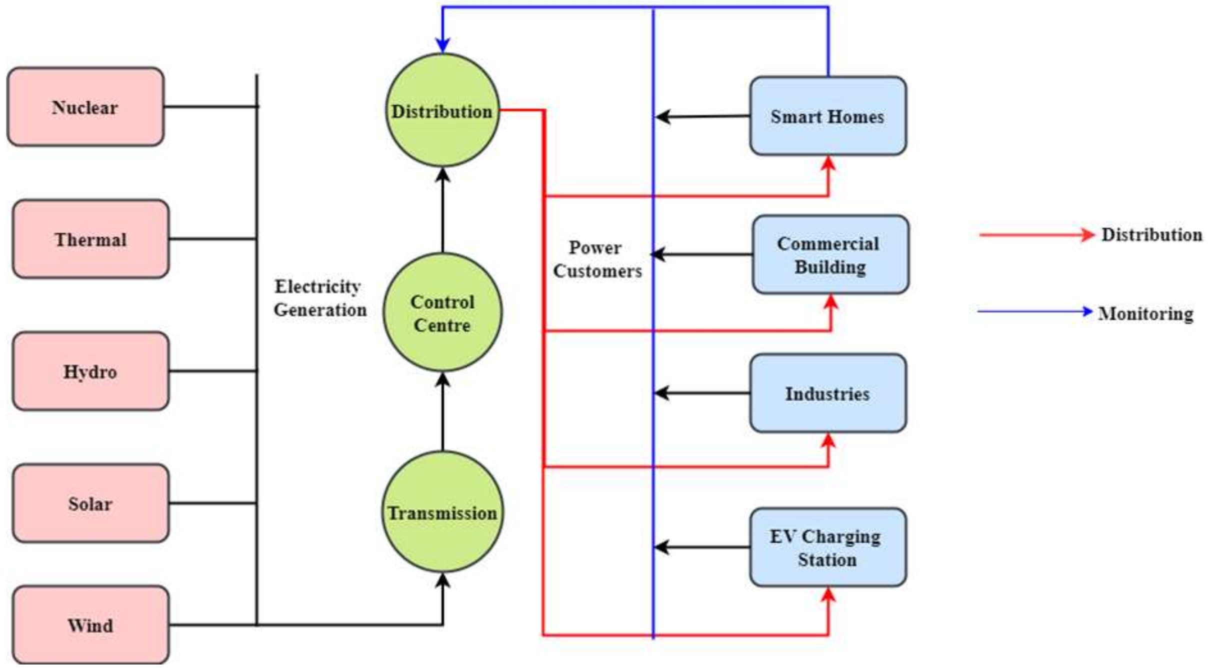

Figure 1. Smart Grid Block Diagram

The most recent and promising innovation in smart energy is the smart rectangular," a system that allows for remote control and maintenance of power production and delivery. So, it's a network that uses digital communication technologies in tandem with conventional electrical networks to cut down on power waste and expenses. A variety of energy sources, including wind turbines, solar panels, nuclear energy facilities, thermal power stations, and so on, may be used to generate electricity. By facilitating data exchange and energy, smart grids provide a two-way connection between power stations, distribution hubs, and end users. A smart meter allows a smart house to interact with a smart grid, which in turn helps homeowners control their energy costs by assessing the home's electricity usage and delivering power as needed. The control center is an integral part of the energy management system that links all of the smart appliances in a building to form a home area network (HAN). To keep up with and anticipate the ever-changing electrical demands of consumers, the control center employs real-time monitoring. By doing so, one may reduce power consumption by scheduling the operation of each equipment. So, to feel the supply and consumption, IoT sensors are crucial.

Smart Grid Technologies

Public health is enhanced via reduced pollution and climate change mitigation when smart grid technologies are combined with renewable power systems. This results in cleaner air and improved health outcomes. Consistent electricity for vital health services is assured by improved energy dependability, which in turn reduces healthcare expenditures. Sustainable energy usage is encouraged by this integration, which adds to the general well-being and resilience of the community.

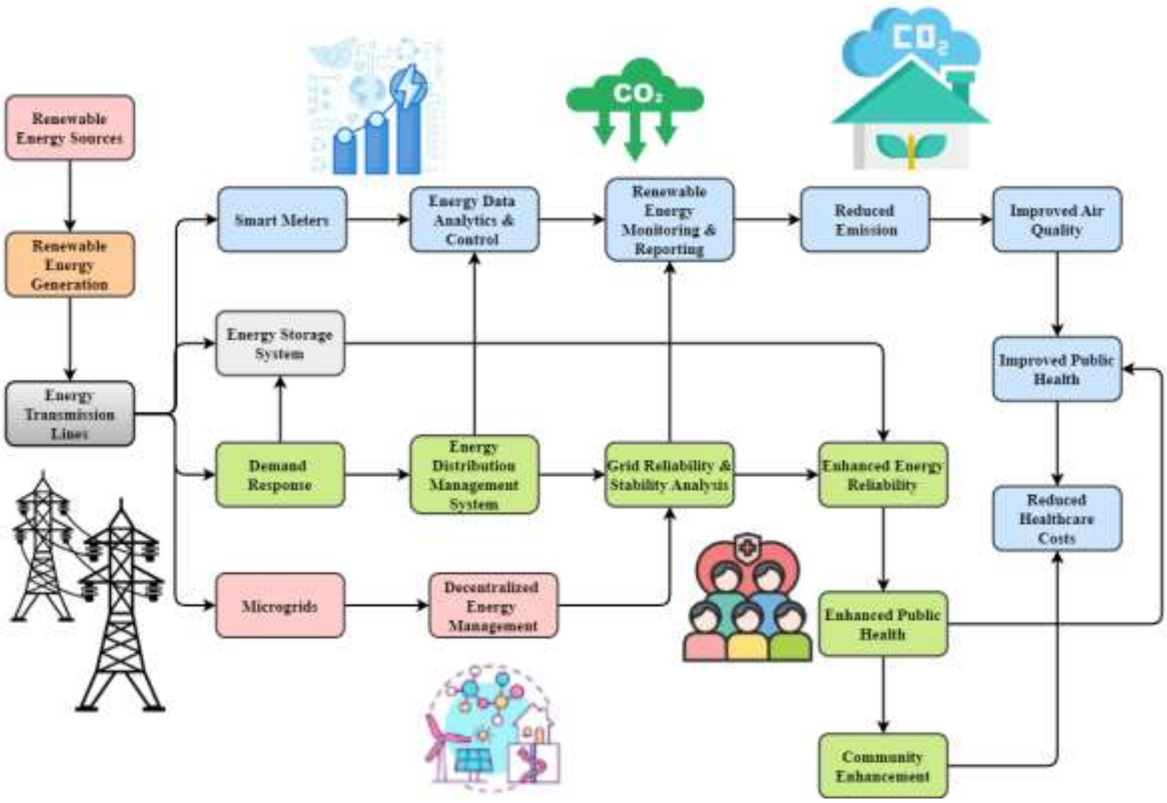

Figure 2. Benefits to Public Health from Combining Smart Grid Technologies with Renewable Power Systems

The whole strategy for improving public health outcomes via smart grid integration with renewable energy sources is shown in Figure 2. Energy transmission lines carry the generated power from renewable sources to where it has to go. Energy data may be more easily collected and distributed with the use of smart meters and a storage system. This information is processed by the data about energy analytics and control units to improve energy use and stability. Central to the control of energy flow is the energy distribution and management system, which uses demand response mechanisms to strike a good balance between supply and demand. Consistent and predictable electricity distribution is ensured by grid reliability and stability examinations. To keep tabs on emissions reductions, which affect air quality and, by extension, public health, it is essential to monitor and report on renewable energy sources [25]. A strong and stable energy supply is guaranteed via decentralized energy administration and microgrids, which increase energy dependability. By lowering healthcare expenditures linked to poor air quality and unstable energy and providing constant energy for healthcare institutions, this dependability helps to improve public health. In the end, these systems work together to improve communities, which shows how intelligent grid technology in renewable power plants is good for the public's health.

Renewable Energy Integration

Optimizing energy distribution, improving grid stability, and increasing energy efficiency are all possible outcomes of integrating solar energy with smart grid technology. In addition to lowering emissions, this synergy also promotes sustainable energy usage and guarantees a steady supply of electricity. Community health and environmental sustainability are both enhanced as a result.

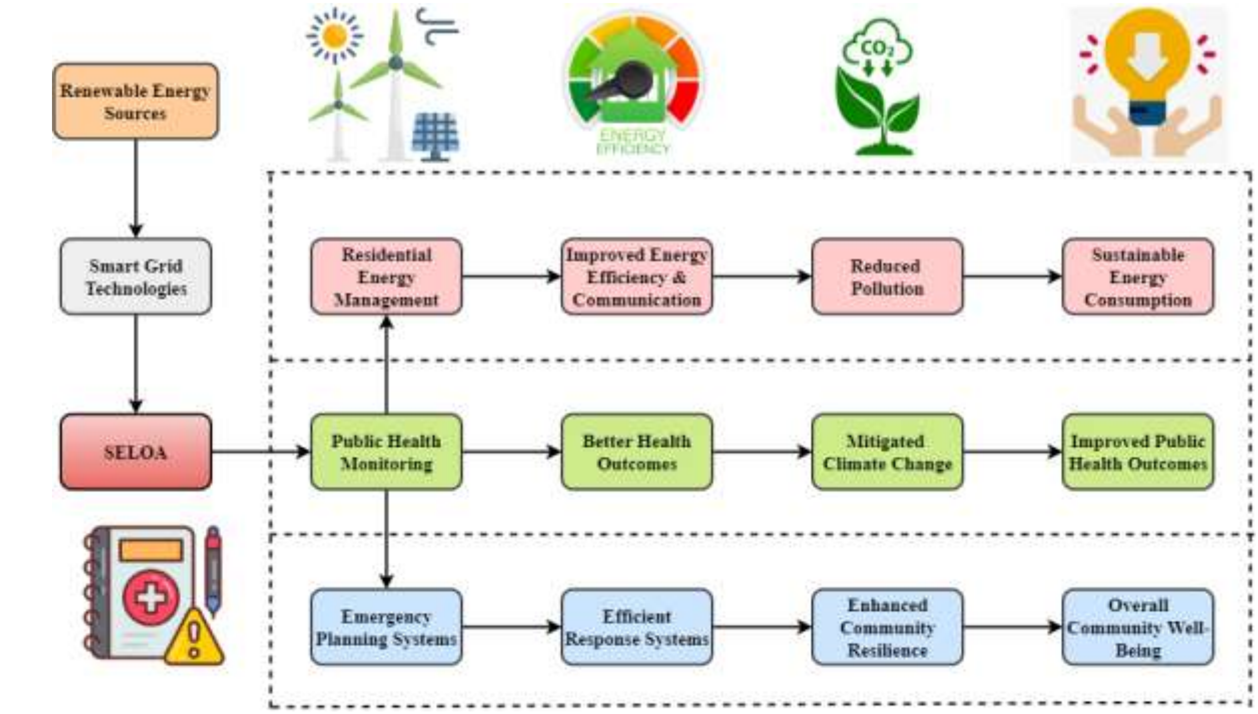

Figure 3. Renewable energy and smart grid integration

SELOA's contribution to better public health

The integration of renewable energy and smart grid technologies into the SELOA approach to improve public health outcomes is illustrated in Figure 3. smart grid technologies integrate renewable energy sources; SELOA then contacts these sources. Home energy management, public health care and disaster preparedness are all heavily dependent on SELOA. Energy efficiency and sustainability are the objectives of the SELOA home energy efficiency system, which can produce less pollution and introduce sustainable energy In the environment to go so besides promoting sustainability, this approach is clean by improving energy efficiency in families It also creates a healthy living environment. Lower emissions result from increased energy efficiency, which in turn leads to better air quality and public health. Public health management and emergency planning are other areas of focus for SELOA. Public health management facilitated by SELOA improves health outcomes by monitoring and prioritizing health problems. To protect public health, communities need emergency preparedness systems that can ensure rapid and effective response in the event of an emergency. Together, these programs help reduce the effects of climate change, improve public health, and improve the lives of everyone in the community. This comprehensive program highlights the significant impact of SELOA's combination of smart grid and renewable energy technology to advance public health and environmental sustainability.

The effectiveness of the proposed method was evaluated using statistical equations

This paper evaluated using a statistical model that simulated several social scenarios. The total gains in efficiency, pollution reduction, and positive public health impacts were quantified in this way. The findings demonstrated the utility of this approach, which proved to improve energy efficiency and community health.

$$r_{p-k}^{m} = V_b K log\left(1 + \frac{[K_{p,U}] + B_{r,k}}{fg - kp}\right) - T_{y+1}(wq - r) \quad (1)$$

The baseline voltage is represented by the equation 1 V_b, a proportional constant is denoted by $klog$, and the logarithmic term deals with the improvement in energy management r_{p-k}^{m} that smart grid technologies bring about. The components of the equation represent the equilibrium between energy supply ($\frac{[K_{p,U}] + B_{r,k}}{fg-kp}$) and market variables ($T_{y+1}$), and the reduction of temporal impacts $wq - r$.

$$M_{w-k} = r^s(b-kp) + \left(2 - \frac{f_e g}{[V] + F_{ew}} + \sum_{l=1}^{f}(dw+gp)\right) \quad (2)$$

Here, $b-kp$ represents the baseline equilibrium in energy affected by demand, and the resilience factor is represented by Equation 2 M_{w-k}. The variable changes in energy distribution, balancing generation factors, voltage limitations, and cumulative demand are represented by the expression $\frac{f_e g}{[V]+F_{ew}}$. To optimize energy utilization for better community health and sustainability $(dw+gp)$.

$$d_{g-1}^{E} = \sum_{r=s}^{d}\frac{g_p}{q_e-1} - \frac{[s_{p-1}] + j_{r+1}}{\forall^2} \quad (3)$$

The energy output at a node is represented by the equation 3 g_p, while the energy efficiency loss is denoted by d_{g-1}^{E}. The equation $\frac{g_p}{q_e-1}$ represents the effect of distribution losses j_{r+1} and cumulative energy needs $[s_{p-1}] + j_{r+1}$. By maximizing efficiency and decreasing waste $\forall^2$, this equation highlights SELOA's approach to improving community health.

$$f_{w+2} = \frac{(d+sp) + W_{q-1}}{\propto -\delta\Delta} + \sum_{f=w}^{T}(\delta - 1p) - \left(\sum\nolimits_{w}^{2}(es-fp)\right) \quad (4)$$

The combined energy demand and prior energy states are represented by the equations 4, f_{w+2}, respectively. While the correction for energy distribution efficiency is denoted by $(d+sp) + W_{q-1}$. The cumulative influence of energy flow $\propto -\delta\Delta$ and consumption patterns $(\delta - 1p)$ is shown by combining the terms $(es-fp)$.

$$C_{f-e}(n-wq) = \frac{R_{w-1}}{\times_{\forall\partial}} - (pq-1) \times W_q + \frac{(f-er) + Q^{w+2}}{\forall - \partial \propto} \quad (5)$$

The energy resources about distribution restrictions are represented by the equation 5, $C_{f-e}(n-wq)$, and the cost effect of energy inefficiencies is denoted by $\frac{R_{w-1}}{\times_{\forall\partial}}$. Equation $(f-er) + Q^{w+2}$ captures the equilibrium between changes in energy production $\forall - \partial \propto$ and demand W_q.

$$D_v = \frac{g}{k-jp}(r-sa) + f_{er} - \frac{(S_{f-1}^{e} - pky)}{r} \quad (6)$$

The influence of renewable energy integration is denoted by f_{er} and the link r between the production of energy D_v, consumption $\frac{g}{k-jp}$, and efficiency losses $r-sa$ is represented by the equation, 6 $S_{f-1}^{e} - pky$.

$$P_{j-u} = S^{w-1} + \frac{n}{g-pu}(py-sw) + g + 1_{deq} - \frac{[e2(r^{n-1})]}{t} \quad (7)$$

The energy consumption analysis is represented by the equation 7, S^{w-1}, while the efficiency of energy transportation $\frac{n}{g-pu}$ and consumption is modeled by P_{j-u}. The variable \ $py-sw$ represents energy loss $g+1_{deq}$ and system inefficiencies, whereas the expression $\frac{[e2(r^{n-1})]}{t}$ represents the incremental energy demand.

$$P_j(w-sq) + (z+2) = (s-aq) + fps^{f+p} - 4w(ku-sp) \quad (8)$$

The performance analysis that is impacted by variables related to supply $s-aq$ and demand is represented by the equation 8, $P_j(w-sq)$, where $z+2$ is an adjustment constant fps^{f+p}. The equation $4w(ku - sp)$ represents the effect of inefficiencies and losses, whereas the terms represent the dynamics of energy production and consumption.

SELOA is a suggested approach that seeks to optimize energy distribution and consumption fairly among communities by integrating smart grid technologies with renewable energy sources. To make sure that everyone can reap the advantages of the shift to renewable energy, SELOA improves home energy administration, public health observing, and disaster preparedness. By simulating real-world situations and analyzing the results, SELOA proved it could increase energy efficiency, decrease toxic waste from conventional power plants, and improve public health. The research indicates that by integrating smart grid technology with renewable energy systems, SELOA's deployment has the potential to greatly improve public health and sustainability.

4. Results and discussion

Public health, emergency readiness, and smart energy use are affected by SELOA's energy distribution and consumption optimisation. Simulations show that SELOA can boost energy efficiency and lower traditional power generation emissions, enhancing community health over time.

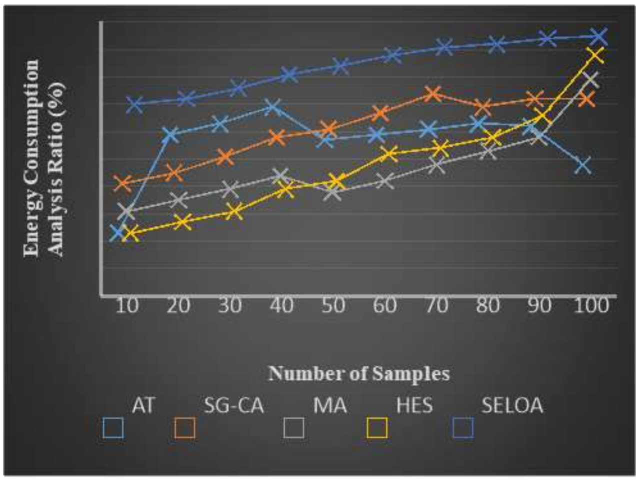

Figure. 4 Energy Consumption Analysis

This research builds on previous work that has shown the possible public health advantages of renewable energy sources that use smart grid technology is explained in figure 4. Reduced pollution and slowed climate change are two ways in which shifting to renewable energy sources helps create a healthier environment. The paper proposes a SELOA to handle integration difficulties, such as high service demand, high costs, cybersecurity risks, and technological issues. The purpose of SELOA is to ensure that communities distribute and use energy efficiently; this has implications for public health management, disaster preparedness, and smart energy management. Our simulation analysis indicates that SELA is helpful by highlighting the negative impacts of conventional power generation and the positive effects of improving energy efficiency. These advancements suggest ways to enhance community health in the long run. Integrating smart grid technologies into renewable energy systems achieves sustainable energy, dramatically improves public health outcomes.

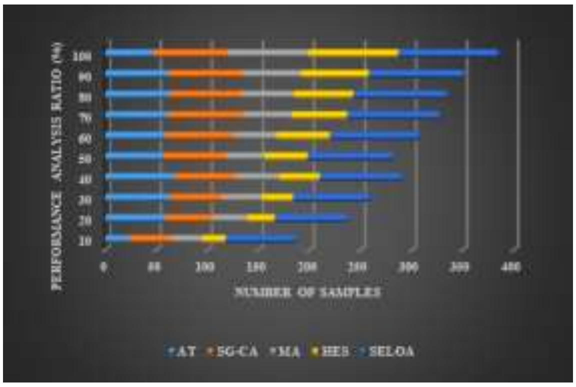

Figure. 5 Performance Analysis

Renewable energy enhances human health by reducing the negative effects of pollution and climate change is explained in figure 5. Utilising the suggested SELOA, the research tackles critical integration obstacles like technological complexity, expensiveness, service demand, and cybersecurity risks. Residential energy management, public health monitoring, and emergency preparedness are some of the sectors that SELA supports in its mission to guarantee the equitable use and distribution of energy. Simulation results confirm SELOA's assertions that conventional power plants could reduce their harmful emissions in shared while additionally improving efficiency by a significant margin. Better community health is the result of these upgrades, which indicate a path towards an energy future. The research proves that renewable energy systems that incorporate smart grid technology produce sustainable power, greatly improve public health.

Together, these studies recommend integrating smart grid technologies with renewable energy systems for sustainable energy and public health advantages.

5. Conclusion and future scope

Finally, this research highlights the importance of renewable energy systems supported by smart grid technology in improving public health. The transition to renewable energy already improves health outcomes by reducing pollution and reducing the impact of climate change. Technical difficulties, expensive costs, complex infrastructure, and cybersecurity risks are some of the key issues that the proposed SELOA attempts to report. Residential energy consumption, public health management, and emergency preparedness are all impacted by SELA programs that influence the equity of energy consumption and utility throughout the community. By showing significant increases in energy efficiency and reductions in harmful emissions from traditional electricity sources, our simulation study confirms the performance of SELA. The sustainable road ahead is evident in these improvements, which translate into significant public health benefits. The results show that renewable energy systems and smart grid technologies work together to provide healthy and sustainable communities. To improve community health and achieve sustainability goals in the long term, this integrated approach is a compelling approach.

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