

Smart Energy Systems as a Solution for Sustainability

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Abstract

This study examines the critical function of smart energy networks (SENs) in addressing the urgent global challenge of climate change. The study begins by elucidating the significant contributors to climate change, emphasizing the role of traditional energy sources, and underscores the need for a paradigm shift towards sustainable and cleaner alternatives. It explores the many facets of smart energy networks (SENs), including demand-side management, energy storage, smart grids, and the incorporation of renewable energy sources as revolutionary ways to reduce the environmental effect of energy use. The research evaluates the current state of climate change, illustrating the detrimental effects on global temperatures, extreme weather events, and ecosystems. It delineates the causes and impacts of climate change, attributing a substantial portion to conventional energy practices, industrial processes, deforestation, and transportation. The study meticulously examines the challenges encountered in the implementation of SENs, ranging from interoperability and cybersecurity to data management and scalability. Further exploration centres on the integration of solar and wind power within SENs, highlighting their potential in contributing to a sustainable energy mix. The research then projects a future outlook for SENs in the context of the Indian market, postulating policy support, grid modernization initiatives, decentralized energy solutions, and private sector participation as key drivers for scaling up and fostering innovation.

Keywords: Smart energy networks, climate change, sustainable alternatives, renewable integration, environmental impact, global temperatures, interoperability, solar power, wind power, Indian market, policy support

INTRODUCTION

Principally due to rising greenhouse gas emissions, climate change has emerged as one of the most pressing global issues. Since its substantial dependence on nonrenewable energy sources, the traditional energy industry is one of the primary contributors to these emissions. The need to look into creative and sustainable methods to mitigate the consequences of climate change is becoming more and more urgent

as the world gets more urbanized and energy demands rise. A revolutionary and all-encompassing approach to solving this pressing problem has emerged: Smart Energy Networks (SENs).

The State of Energy and Climate Change

Conventional systems that primarily rely on fossil fuels have traditionally characterized the global energy landscape and have made a substantial contribution to the emissions of greenhouse gases, including carbon dioxide. Global temperatures have risen quickly as a result, and there have also been extreme weather events, increasing sea levels, and other negative

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environmental repercussions. Changing to cleaner and more efficient energy systems is imperative given the urgency of addressing climate change. Maintaining the Integrity of the Specifications [1, 2].

Growing Urbanization and Demand for Energy

Energy consumption is significantly influenced by urbanization, especially in nations that are developing quickly. Given a sizable portion of the global population and energy usage, India, for instance, is leading the way in urbanization. It is anticipated that there will be a large increase in the metropolitan population, which will put further demand on energy resources and increase carbon emissions. For cities to be resilient and sustainable, controlling and reducing this spike in energy consumption within the framework of urban development is essential [3].

Smart Energy Networks' (SENs') Function

The energy landscape is changing, and Smart Energy Networks (SENs) are becoming more and more well-known as a comprehensive, technologically-driven solution. Demand-side management (DSM), energy storage options, smart grids, and the Internet of Things (IoT) integrated into energy systems are all examples of the technologies and approaches that make up SENs. Together, these elements seek to improve waste reduction, energy economy and make it simpler to use renewable energy sources [4].

Goals of the Research

- Look into what makes up Smart Energy Networks (SENs).
- Examine how SEN technologies contribute to waste reduction and optimal energy distribution.
- Assess the effects of SEN implementations on the environment, the economy, and society.
- Examine how SENs might help to reduce global warming and advance sustainability. This study will provide a thorough grasp of how Smart Energy Networks can mitigate climate change.

CLIMATE CHANGES AND ENERGY SECTOR EMISSIONS

Causes and Consequences of Global Warming

Causes

Creating Electricity

Fossil fuel consumption is a major source of global emissions when it comes to both electricity and heat production. Two powerful greenhouse gases that cover the Earth and trap solar radiation are carbon dioxide and nitrous oxide, are released during the combustion of coal, oil, or gas, which produces the most of electricity. A little more than 25% of the electricity produced worldwide is produced by renewable energy sources like solar and wind, which also release very little to no pollutants or greenhouse gases into the atmosphere in contrast to fossil fuels [5].

Manufacturing Goods

Industry and fabricating are the most common sources of outflows, primarily from burning fossil power to deliver vitality for the fabricating of things like hardware, plastics, clothing, press, steel, and cement. In expansion to the building division, Gases are too discharged amid mining and other mechanical forms. A few materials, such as plastics, are delivered utilizing chemicals that come from fossil fills, and numerous of the machines utilized in generation are fueled by coal, oil, or gas. The fabricating industry is one of the most causes of nursery gas emanations around the world.

Cutting Down Forests

When woodlands are cleared for cultivating, pastures, or other employments, the carbon that the trees have been putting away is discharged. Each year, around 12 million hectares of timberland are misplaced. Since timberlands retain carbon dioxide, their devastation diminishes nature's capacity to keep emanations out of the air. At the side horticulture and other changes in arrive utilize, deforestation contributes to almost 25% of worldwide nursery gas emanations [6].

Using Transportation

One of the primary producers of emissions of greenhouse gases, particularly carbon dioxide, is transportation, which includes cars, trucks, ships, and airplanes. Although ships and airplanes also make

a substantial contribution, road vehicles account for the majority of the total. Approximately 25% of carbon dioxide emissions linked to energy worldwide come from transportation, and trends point to a sharp rise in energy consumption.

Producing Food

The process of producing food releases methane, carbon dioxide, and other greenhouse gases in a variety of ways, such as when land is cleared for farming and grazing, when crops are grown using fertilizers and manure, and when energy is used to power farming machinery or fishing vessels, which typically involves the burning of fossil fuels. Food production is therefore a major factor contributing to climate change.

The packaging and distribution of food both increase greenhouse gas emissions.

Powering Buildings

Private and commercial buildings utilize more than half of the power utilized universally. Their dependence on coal, oil, and common gas for warming and cooling implies they will continuously be major emitters of nursery gasses. Buildings' energy-related carbon dioxide outflows have gone up as of late as a result of rising possession of discuss conditioning units, developing vitality prerequisites for warming and cooling, and developing power utilization for lights, apparatuses, and associated gadgets.

Overindulging in Consumption

Many factors affect greenhouse gas emissions, such as how much power and energy your home uses, how mobile you are, how much food you eat, and how much waste you produce. Utilizing goods like electronics, clothing, and plastics adds to this as well. Private households are primarily responsible for a significant portion of the global greenhouse gas emissions. Our planet is greatly impacted by the way we live. The wealthiest have the biggest responsibility: the combined richest 1% of the global population emits more greenhouse gases than the bottom 50%.

Consequences

Hotter Temperatures

The concentrations of nursery gasses increment in step with the rise in worldwide surface temperature. The decade traversing from 2011 to 2020 is the hottest on record. Since the 1980s, the temperature has risen in each progressive decade. In for all intents and purposes each arrive zone, the number of hot days and warm waves is rising. Expanded temperatures make working exterior more challenging and compound ailments related to warm. Fierce blazes begin more effortlessly and spread more rapidly in more sultry climate. At slightest twice as quick as the worldwide normal, the Ice has warmed.

More Storms

Dangerous storms have expanded in recurrence and concentrated in numerous ranges. As temperatures rise, more dampness dissipation happens, forces overwhelming precipitation, flooding, and storm movement. The recurrence and concentrated of tropical storms are affected by the warming sea as well. Tropical storms, tropical storms, and tornados bolster on warm sea surface waters. These storms as often as possible cause colossal financial misfortunes and fatalities by crushing homes and communities.

A Rise in Droughts

Climate alter is changing the accessibility of water, making it scarcer in more places. In locales that are as of now beneath water push, worldwide warming makes water shortage more regrettable. This raises the plausibility of rural dry spells that might hurt crops and environmental dry spells that might debilitate biological systems. Dry spells can moreover be the cause of damaging sand and clean storms, which can carry billions of tons of sand over landmasses. Forsake extension is diminishing the amount of arrive appropriate for cultivating. These days, a normal need of clean water postures a risk to numerous individuals.

A Warming, Rising Ocean

The sea assimilates most of the warm produced by worldwide warming. At all profundities, the ocean's rate of warming has strongly expanded amid the past 20 a long time. Since water extends when it gets hotter, the ocean's volume increments. Ocean levels rise due to dissolving ice sheets, putting island and coastal communities in risk. In expansion, carbon dioxide is retained by the sea, anticipating it from entering the environment. In any case, expanded carbon dioxide makes the sea more acidic, undermining coral reefs and marine life. Water ought to be devoured on a customary premise [7].

Spices Loss

Climate alter debilitates both marine and earthly species' capacity to outlive. The dangers increment with the temperature. The globe is losing species at a 1,000- crease quicker rate than at any other point in recorded human history, which is exacerbated by climate alter. Within the another few decades, one million species might go terminated. Climate alter postures various dangers, counting but not constrained to woodland fires, extraordinary climate, obtrusive bothers, and infections. Certain species will be able to move and prosper, whereas others will ended up terminated.

Insufficient Food

Two variables contributing to the worldwide rise in starvation and ailing health are climate alter and an increment in extraordinary climate occasions. Crops, fisheries, and animals seem all go terminated or gotten to be less profitable. The marine assets that bolster billions of individuals are in risk as the ocean's corrosiveness rises. Nourishment sources for grouping, chasing, and angling have been hampered in numerous Ice locales by changes in snow and ice cover. Warm push can diminish trim yields and animals mortality by draining water and meadows for brushing [9].

More Health Risks

The greatest danger to human wellbeing that we confront is climate alter. Discuss contamination, ailment, extraordinary climate, constrained migration, mental wellbeing issues, expanded starvation, and lacking sustenance in places where individuals cannot develop or discover sufficient nourishment are fair many of the wellbeing issues that climate alter is as of now causing. Each year, natural components claim the lives of around 13 million individuals. Climate designs are changing, and extraordinary climate occasions are expanding passings and making it troublesome for wellbeing care frameworks to keep up.

Poverty and Displacements

Climate alter escalate the variables that cause and keep up destitution. Surges have the potential to wash absent urban ghettos, pulverizing homes and jobs. Working exterior within the warm can be troublesome. Crops may endure as a result of water shortage. Weather-related occasions have uprooted ann nestimated 23.1 million individuals per year on normal over the final decade (2010-2019), clearing out numerous more helpless to destitution. Nations most at hazard from climate alter and slightest arranged to bargain with its impacts are domestic to the larger part of refugees.

Role of Energy Sector

The green development, centering on maintainability, vitality preservation, and cognizant customer behavior, has developed as a reaction to climate alter. The Interval Board on Climate Alter (IPCC) reports that we have less than 11 a long time to convert our vitality frameworks and moderate the most noticeably awful impacts of climate alter. To anticipate worldwide warming over 1.5oC, the level of carbon dioxide within the air must be cut by 45% by 2030. The green development could be a significant step towards a cleaner and maintainable future, tending to the root causes of climate alter and recognizing regions where our collective endeavors can make a critical difference. The lion's share of the vitality we utilize is created by fossil fills, which are shaped over thousands of a long time and incorporate coal, oil, and characteristic gas. These vitality sources are restricted in amount and cannot be reestablished or reused. Our reliance on fossil fills to meet our vitality needs has expanded over a

long period of time. Universally, fossil powers have risen to noticeable quality as a source of vitality since the mechanical transformation. Fossil powers as of now supply 91.04% of India's vitality needs (2019).fossil fuel burning contributes altogether to climate alter, with worldwide energy-related CO2 outflows coming to a memorable tall of 33.1 Gt CO2 in 2018. These nursery gasses construct up within the environment, warming the planet and influencing current and future eras. Overwhelming precipitation has driven to surges in Western Europe, whereas Northern Europe faces warm waves. Extraordinary heatwaves in Western North America have caused fierce blazes and set world records for the most smoking temperature in Earth's history. California has experienced its second-hottest temperature since 800 Advertisement, whereas India has experienced heavy rainfall causing cloudbursts, flooding, and avalanches in zones like Bihar, Himachal, and Uttarakhand.

SMART ENERGY NETWORKS: CONCEPTS AND COMPONENTS

In order to increase efficiency, dependability, and sustainability in energy distribution and consumption, smart energy networks—also referred to as smart grids or intelligent energy networks—are updated electrical systems that make use of cutting-edge technologies through digital communication, control, and automation.

Smart Grids

In order to track the flow of energy from production to consumption and allow for real-time load shedding or control, smart grids are electrical systems that make use of automation, communication, and information technology. They can be accomplished by means of consumer integration, renewable energy integration, system operations, and effective transmission and distribution networks. Smart grid solutions can reduce T&D losses, improve service quality, boost reliability, manage assets, integrate renewables, and improve electricity accessibility, ultimately leading to self- healing grids.

Components of smart Grid:

- Cables
- Circuit Breakers
- Collectors Nodes
- Controller's
- Distributed and transmission lines and control centres
- Electric power generators
- Electric power sub-stations
- Smart meters (SMs)

Benefits of smart grid:

- To maintain a dependable and effective power supply while lowering energy consumption and expenses, it is crucial to monitor and optimize the interconnected parts of an energy system
- A smart grid employs "smart meters" to reduce energy waste and maximize energy use.
- Smart meters aid in the calculation of power generation, the recording of voltage failures, and the provision of actionable data to grid operators.

Demand-side-Management (DMS)

To track the movement of power from production to consumption and provide real-time control or load reduction, smart grids are electrical systems that make use of automation, communication, and information technology. They can be accomplished by means of consumer integration, renewable energy integration, system operations, and effective transmission and distribution networks. Smart grid solutions can reduce T&D losses, improve service quality, boost reliability, manage assets, integrate renewables, and improve electricity accessibility, ultimately leading to self- healing grids.

Key Components of Demand-side management at site level:

- Load Shifting

- Peak Demand Reduction
- Smart Metering and Monitoring
- Demand Response Program

Benefits of DMS at site level:

- Cost saving
- Grid reliability
- Environmental Sustainability
- Infrastructure Optimization
- Flexibility and adaptability

Energy Storage Technologies

Energy storage is an important process for capturing and delivering generated energy for future use. It can be accomplished through a variety of methods, including technologies for hydrogen storage, electrical, mechanical, electrochemical, and thermal processes. cutting-edge technologies for energy storage can deliver electricity quickly and provide power backup for extended periods of time. The technology used is determined by the application's requirements and constraints, ensuring the appropriate storage duration, system scale, and response time.

IOT in Energy

The Web of Things (IoT) plays an vital part in changing and optimizing the vitality segment, contributing to the advancement of savvy vitality frameworks. IoT within the setting of savvy vitality alludes to the integration of sensors, devices, and communication systems to gather, dissect, and act on real-time data Smart grid

- Smart meters
- Demand responses
- Energy monitoring and management
- Renewable energy integration
- Grid security
- Data analytics for decision making

INTEGRATION OF SOLAR AND WIND POWER

The two mainstays of the renewable energy scene are solar and wind power, which offer plentiful and clean sources of electricity. Their sporadic character, however, makes grid stability difficult. Advanced technologies like energy storage systems, smart grids, and predictive analytics are needed to integrate solar and wind power efficiently in order to regulate variations and maximize energy output. To optimize the share of wind and solar energy in the overall energy mix, this section examines various tactics and technologies.

Since the larger part of renewable vitality sources have an discontinuous nature, it is pivotal to join a sizeable sum of them into the foundation of the control lattice. Particularly, power streams from centralized plants to buyers in a single heading. But as rising assets renewable vitality ought to be taken under consideration. By accomplishing the integration as appeared in Figure 1 ready to move forward checking procedures, assurance, optimization and the operation [8].

There is less need for local storage when solar and wind power are combined. Cache control is a feature of a super capacitor or flywheel that helps a battery with a higher energy capacity smooth out the transients it experiences and compensate for sudden changes in power. This is an amalgam of multilevel and complementary energy storage technologies. It has been demonstrated that micro grids, also known as hybrid energy systems, are a useful framework for connecting distributed renewable energy sources, loads, and storage locally. Current studies have taken into account both the operation's optimization and the use of DC to connect the resources [8].

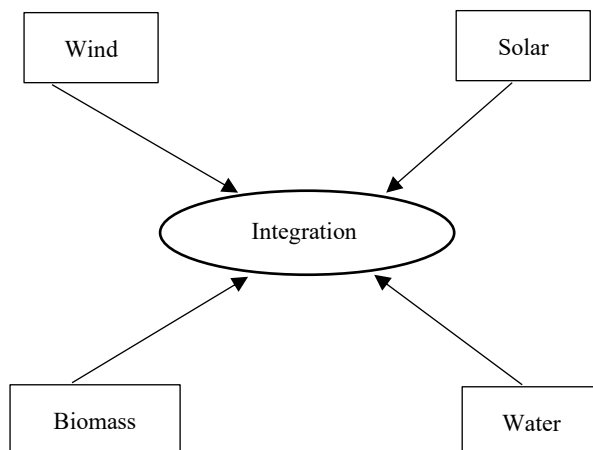


Figure 1. Renewable energy integration.

The system's main benefit is that it can supply the minimal power needed in remote, non-electric places that are still without grid power.

A battery bank stores the vitality created by sun based and wind control sources for utilize at any time. A crossover renewable vitality framework combines two or more energy-producing innovations, most commonly wind and sun based vitality.

The main advantage of a hybrid solar/wind system is that combining solar and wind power improves system reliability [8]. Additionally, Grid Flexibility, Resilience and Distributed Energy Resources also contribute in enhancing Renewable Energy Integration.

Grid Flexibility and Resilience

To adapt to the variable nature of renewables, grid resilience is essential. A flexible grid that can adapt to sudden changes in energy production and demand ensures a reliable power supply. Microgrid deployment, demand response initiatives and smart grid technologies are critical to improving system resilience. This section examines strategies and tools to increase the flexibility and resilience of energy networks in a changing energy environment.

Distributed Energy Resources

As distributed energy resources (DERs) proliferate, power generation becomes more decentralized, turning customers into producers and enhancing grid stability. Energy storage devices, small wind turbines, and solar panels are examples of DERs. The integration of distributed energy resources (DERs) into the energy ecosystem is examined in this section, with a focus on how DERs might increase local resilience, lower transmission losses, and create a more responsive and sustainable energy infrastructure [8].

ENVIRONMENTAL AND ECONOMIC IMPACT

"Smart grids can give us cleaner air, better health, lower electricity bills and reduced carbon dioxide (CO₂) emissions in the atmosphere," according to Succar and Cavanagh's work (2012, p. 4) [11]. In comparison to 2005 CO₂ emission data, smart grids, generation facilities, and end users collectively contribute to a 58% reduction in power sector CO₂ emissions (EPRI 2011). "By lowering reliance on domestic or imported fossil fuels, renewable electricity generation should increase coherence (a reduction in harmful environmental factors) and greenhouse gas emissions. likewise, "the policy centers and international forums developed the idea that smart grids and related technologies offer a chance to foster economic expansion while highlighting environmentally friendly energy reception and transmission techniques" [10] (Table 1).

Table 1. A compilation of the environmental benefits of smart grids, based on the EPRI/DOE framework (EPRI 1020342) [10].

Advantage Sub- Category	Benefit
Surroundings	Electrification
	PEVs
	Increased Energy Effectiveness *
	Storage
	Facilitate Renewables
	Decreased Emissions of CO ₂
	Decreased PM-10, NO _x , and SO _x Emissions

In every industry, both large and small businesses are affected by environmental issues. Even in very established industries like electrical grids, it becomes even more difficult to pursue new and innovative ideas when insecure consumers and non- governmental organizations are included in the mix. Putting in smart grids is one way to make the situation different. It benefits the giver as well as the recipient in terms of the economy and the environment, especially when the recipient has the chance to also become a giver. It has long been discussed to switch from non-renewable to renewable energy sources, and with the installation of smart grids, it is now feasible to address many of the issues caused by non- renewable energy.

Economic

Smart grids have many advantages. They improve the physical and financial aspects of energy supply operations, making them more stable and coherent. They also reduce costs by reducing losses and bring financial benefits to all involved. In today's society, the electrical system is an integral part of the infrastructure. Diverse perspectives exist regarding future smart grid visions. Ideas for small-scale, local network design that are not restricted by a common network architecture range from creating a common European "super" network [10].

The Electrical Power Research Institute (EPRI) has played a significant role in evaluating the potential benefits of smart grids, as well as some associated costs, which are factored into their framework (Table 2).

Social Benefits

Demand Side Management (DSM) is a control mechanism that is typically demanded as part of the social component of smart electricity networks. Smart grids and DSM usually go hand in hand, with supply possibly able to meet demand. The outdated DSM instrument was created to enable a re-peak loading during a period of significantly reduced demand. DSM domestic use is, of course, not entirely new. A presentation to users that allows for some degree of flexibility is required for the DSM function. These settings alter how freezers and refrigerators, as well as washing and drying machines, are used. Additionally, these gadgets need to improve and be capable of remote operation. These devices have a limited amount of flexibility (about 25% of the highest possible performance, with all devices wet but not the cold appliances) [10].

The majority of people in society are not aware of the features, benefits or what smart grids are, so it mostly doesn't matter if they are installed or not. It is important to understand that education plays an important role here as well. Modern electrical grid changes would be much more widely known if more and more people became informed and spread the word about the social benefits of smart grids, even on a small scale through word-of-mouth or public announcements. More people's recognition and acceptance of smart grids would make it simpler for businesses, including those that manufacture electric power grid components, to remain in operation.

Table 2. List of economic smart grid benefits: Based on EPRI/DOE¹ Framework (EPRI 1020342) [10].

AdvantageSub- Category	Benefit
Improved Asset Utilization	Enhanced Generator Performance
	Investments in DeferredGeneration Capacity
	Decreased Cost of AncillaryServices
	Dispersed Production
	Storage
	PEVs ² for Controlling Loadand Storage
	Efficiency in Energy Use
	Response to Demand
	Enhanced Energy Efficiency*
	Reduced Ancillary ServiceCost
	Reduced Congestion Cost
T&D ³ CapitalSavings	Distributed Generation
	Storage
	Demand Response
	Energy Efficiency
	Enhanced Generator Performance
	Postponed Investment inTransmission Capacity
	Postponed Investment inDistribution Capacity
	Reduced Equipment Failures
T&D O&M ⁴ Savings	Enhanced Efficiency in theUtilization of Staff
	Economic Advantage of Additional Staff
	Savings on Operations from AMI ⁵
	Efficiency of T&D
	Reduced Distribution Equipment Maintenance Cost
	Lower Maintenance Costsfor Distribution Equipment
Theft Reduction	Diminished Theft of Electricity
Efficiency inEnergy Use	Improved Efficiency in Energy Use*
	Electrification (Reduced Net Energy Consumption)
	Diminished Losses of Electricity
	Boost in Productivity
	Increased Productivity in the Nation
	Lower Restoration Expense
	Restoration Speed
	Decreased Prolonged Outages
	Diminished Significant Uninterruptions
	Availability
Power Quality	Decreased Intermittent Failures
	Decreased Swells and Sags
	Storage

CHALLENGES AND BARRIERS

Although smart energy grids have many advantages, there are technical obstacles to their implementation. These barriers must be overcome for smart energy systems to be widely adopted and successful. Here are some of the biggest technological barriers to smart energy grids:

Interoperability

Integration of many systems and technologies, including control systems, sensors, smart meters, and communication protocols, can be difficult. Interoperability between multiple devices and platforms is critical for building a seamless and efficient smart energy network.

Cybersecurity and Privacy Concerns

Increased connectedness raises the risk of cyber- attacks. Networks using smart energy are susceptible to cyberattacks, data breaches, and hacking. Securing sensitive information and communication networks and devices is a critical concern.

Data Management and Analytics

Managing the huge volume of data created by smart energy systems necessitates advanced analytics and a solid data management architecture. The processing and analysis of this data in real-time in order to draw useful insights for decision-making presents major technological obstacles.

Scalability

Scalability becomes a problem as smart energy networks develop to accommodate more users and devices. It is difficult to ensure that the infrastructure can manage growing loads, data traffic, and device connections without affecting performance.

Standardization

It is imperative to guarantee the dependability and robustness of intelligent energy systems, particularly in the face of unfavourable circumstances like cyberattacks or natural catastrophes. The task of designing systems with failover and redundancy has to be taken on.

Regulatory and Policy Framework: Energy Storage Integration

Smart energy technologies are developed and implemented at a rate that frequently surpasses that of regulatory frameworks. It is difficult to design flexible and encouraging laws that protect privacy and consumer rights while promoting innovation.

Integration of Renewable Energy

The smooth integration of renewable energy sources such as solar and wind energy into smart grids is hindered by their variability and intermittency. Renewable energy production must be managed and balanced, which requires advanced forecasting and control techniques.

CONTRIBUTION TO SUSTAINABLE DEVELOPMENT GOALS

The Smart City concept is a new approach to urban management that aims to improve sustainability and the quality of life of local residents. In addition, digitization and smart city initiatives must add value to promote environmental and economic sustainability. However, this added value can be expressed more precisely by first deducting the reward from the effort. The challenge of building an infrastructure within an infrastructure with the latest technology that consumes less energy and has a low environmental impact must be addressed. The development of "smart buildings" and more efficient transportation systems is necessary to combat climate change and other environmental problems.

A balanced energy exchange in a smart city requires a self-managing automated system that can convert electrical energy into low productivity. finished product consumption no human intervention. A unified system for smart cities is being developed, which connects different energy, heat, gas and water systems with telecommunications infrastructure to balance electricity production and consumption, reduce production capacity and influence other energy market players. The long-term sustainability of the energy sector depends on the process of electrification of society, so that electricity becomes its main source of energy.

Two-thirds of the world's energy consumption and 70% of CO₂ emissions come from large cities. All governments are committed to working together to address global energy, environmental and climate challenges. China, the US and the EU have all committed to reducing their emissions over the coming decades after signing the first global climate agreement in 2015. Smart city energy systems can help us improve the environment and reduce carbon dioxide emissions. The energy source of the future smart city generation must be carbon and energy-efficient. Several types of energy can be found in a single system from several sources, including transportation, energy distribution and storage, power generation, and conversion.

A city that cares about the climate and its people puts people's needs first. Unlike smart cities, sustainability prioritizes the overall well-being, equity, and protection of the city. The urban environment is integrated with green spaces and environmentally friendly practices to reduce pollution and carbon intensity while protecting natural resources. With the help of information and communication technology and other key strategies, the city can satisfy the demands of current and future generations and, at the same time, increase the quality of life of the inhabitants, operational efficiency, and competitiveness. To reduce carbon dioxide emissions, cities must be more environmentally conscious and smarter. The most important benefits are improvements in waste management, traffic conditions, and renewable energy. Efficient network and water management systems are at the core of many smart city concepts.

Parks, green features, and assistive technology are integral parts of a city's sustainable strategy because they reduce pollution and improve air quality. In the fight against global warming, sustainable cities are increasingly important. Carbon emissions and providing citizens with new options such as e-government services and real traffic standards. The Sustainable Development Goals (SDG) enable the peaceful and harmonious coexistence of all people and the planet. Even in the current situation, following the Sustainable Development Goals, we can all work together to create a prosperous and sustainable future for the environment.

FUTURE OUTLOOK AND POTENTIAL

Scaling Up Smart Energy Networks in the Indian Market in the Post-COVID Era

As the country moves towards a more robust and sustainable energy infrastructure in the post-COVID age, the Indian market is set for a considerable increase in smart energy networks. Clean energy and effective resource management have become increasingly important, and this is in line with the government's resolve to combat climate change and promote innovation in the energy industry.

Policy Support and Regulatory Framework

The Indian government plans to introduce policies and regulatory frameworks to encourage the deployment and scaling up of smart energy networks, including advanced metering infrastructure.

Grid Modernization Initiatives

The focus is on investing in grid modernization, integrating smart technologies to improve resilience, reliability, and efficiency, utilizing advanced sensors, communication networks, and control systems.

Decentralized Energy Solutions

India is expected to see a surge in the use of decentralized energy solutions post-COVID, including distributed generation, renewable energy, and community-based microgrids.

Private Sector Participation

Private sector participation is expected to rise due to increasing demand for innovative energy solutions, including smart grid technologies, energy storage, and IoT-based solutions in India.

Cross-Sector Collaboration

The development of smart energy networks requires collaboration between the energy sector and other industries like technology, telecommunications, and manufacturing, facilitating the integration of emerging technologies.

Innovations and Emerging Technologies in the Indian Smart Energy Market

In the post-COVID era, the Indian smart energy market is poised for rapid innovation and the adoption of emerging technologies to address existing challenges and capitalize on new opportunities.

Artificial Intelligence and Machine Learning

Grid management, predictive infrastructure repair, and energy consumption pattern optimization will all be greatly aided by AI and ML. Real-time decision-making made possible by advanced analytics will increase the overall effectiveness of smart energy networks.

Blockchain Technology

Blockchain is anticipated to be used in decentralized energy markets, smart contracts, and energy transactions. This technology will support a more effective and reliable energy economy by enhancing transactional transparency, security, and traceability.

5G and Edge Computing

The communication infrastructure will be improved with the introduction of 5G networks, which will allow devices in smart energy networks to transmit data faster and more reliably. By enabling real-time computing at the source, edge computing reduces latency and improves system responsiveness.

Advanced Energy Storage

Innovations in energy storage technology, like advanced thermal storage systems and next-generation batteries, will help to mitigate the intermittent nature of renewable energy sources. These advancements will improve grid stability and make it easier to integrate a greater proportion of renewable energy sources.

Internet of Things (IoT) Sensors and Devices

IoT devices and sensors will keep proliferating, offering detailed information on energy usage, equipment condition, and grid performance. With the use of these gadgets, customers will be able to get real-time analytics and improve demand-side management.

Role in Decarbonizing Multiple Sectors in India

In India, smart energy networks will be essential to the country's overall decarbonization of multiple sectors, aligning with the nation's commitment to a sustainable and low-carbon future.

Electrification of Transportation

By providing the necessary infrastructure for charging stations, grid-friendly electric vehicle charging, and demand response programs, smart energy grids will help electrify the transportation industry. This change will have a significant impact on reducing traffic-related carbon dioxide emissions.

Integration of Renewable Energy

Smart energy grids enable the seamless integration of renewable energy sources such as wind and solar energy into the grid. Reliable and efficient use of renewable energy is ensured by advanced forecasting, network management and energy storage technologies, reducing dependence on fossil fuels.

Energy Efficiency Across Industries

The application of smart energy technology will improve industry-wide energy efficiency. Smart grids, IoT-enabled gadgets, and energy management systems will optimize energy consumption, resulting in lower carbon footprints and operating costs across the board, from manufacturing to services.

Rural Electrification and Microgrids

Because they make it possible to install microgrids fueled by renewable energy sources, smart energy solutions will aid in the electrification of rural areas.

By improving energy availability in isolated locations, these microgrids will promote sustainable development and lessen dependency on conventional, carbon-intensive energy sources.

Emission Reduction Targets

India can better meet its carbon reduction targets if smart energy grids are used. The nation can move closer to a low-carbon economy by integrating renewable energy sources, encouraging sustainable practices and optimizing energy use.

The post-Covid era is a phase of transformation for India's smart energy market. By focusing on scaling, embracing innovation and reducing carbon emissions across multiple sectors, the country is poised to create a resilient, sustainable and technologically advanced energy ecosystem. Continued collaboration, policy support and investment in research and development are critical to realizing the full potential of India's smart energy grids.

CONCLUSION

In conclusion, this research underscores the indispensable role of Smart Energy Networks as a viable and comprehensive solution to mitigate climate change impacts. SENs offer a pathway to transition from conventional energy models to sustainable, efficient, and resilient systems, aligning with global efforts to combat environmental degradation. The challenges posed by interoperability, cybersecurity, and scalability are acknowledged as focal points for future research and development.

The study anticipates a promising future for SENs in India, emphasizing the need for collaborative efforts, policy frameworks, and technological advancements. The envisioned innovations, including artificial intelligence, blockchain, and advanced energy storage, position SENs as catalysts for achieving emission reduction targets and fostering a carbon-free economy. As the globe struggles to adapt to the effects of climate change, Smart Energy Networks emerge as integral components in reshaping the energy landscape, ensuring environmental sustainability, and promoting a resilient and technologically advanced future.

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