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REVIEW ARTICLE

Citizen Science- A bottom-up approach for harnessing Renewable Energy in India

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ABSTRACT

India intends to meet its sustainable and clean energy demand by switching to renewable energy (RE) resources and reducing its dependency on fossil fuels. India may achieve RE demand of 500 GW by 2030, through using renewable resources such as solar, wind, biomass, biofuels, and geothermal. Participatory/ Citizen science approach is an emerging way to effectively manage the RE crisis of any country which includes participation of children, women and other stakeholders. A bottom-up approach is recommended to bring widespread change in energy resource management which involves families, educational institutes, industrial sector, and citizens of all age group. The present review discusses the current status of citizen science approach and its contribution towards imparting energy literacy in India.

Keywords: *Biofuel, Citizen science, Fossil fuel, Renewable energy, Sustainable.*

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INTRODUCTION

In the recent decade, most of the developing and developed countries have introduced strategic policies to combat land degradation and energy crises. Energy demands are growing rapidly with increasing urbanization and population growth across the globe. Particularly in Asia, India which is a highly populated country needs to switch its energy demands to cleaner and sustainable sources of energy. By 2030, 660 million people, or almost 9% of the global population may still lack electricity accessibility [1]. It is very challenging for a developing country like India to fulfill its energy demands while addressing environmental concerns. India, Brazil, and the United States are among the major producers and consumers of biofuel. These three nations together account for 85% of production and 81% of consumption of ethanol globally. Across the world, the ethanol market is estimated to be worth around 99 billion USD in 2022 and is projected to increase by 5% annually by 2032 [2]. Currently, in India, only 2% of the fuel demand in the transportation sector is fulfilled by biofuel, and the rest of 98% is still based on fossil fuels. The enormous growth in the ethanol market creates huge opportunities for Indian farmers and industrialists which contributing to the socioeconomic growth of the Indian ecosystem.

Humankind is facing many environmental problems either directly or indirectly due to energy utilization and conservation [3]. The synergy between mitigating environmental problems and ways to meet increasing energy demand makes sense. Phenomenon like climate change, global warming (currently turning to global boiling), land use change, and ocean acidification have proved that educational planners, policies, and administrators need to develop courses and focus on training students. The future leaders of our nation, the students are to be trained for a variety of environmental issues and wise and sustainable use of available resources. Energy education with a special focus on renewable energy is relevant for all developing countries of the world. The use of polluted land for renewables like biomass and biofuel production is a promising approach for sustainable land use and the production of biofuel crops thereby reducin g CO2 emission [4]. Castor bean, prickly acacia, *Acacia*

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modesta, and *Calotropis procera* wild cane, hemp, and Indian mustard are some of the potential biofuel crops [5,6]. Therefore, the present review discusses the current status of citizen-science approach and its contribution towards imparting energy education and understanding of renewable energy in India through data available in literature.

METHODOLOGY

This review is conducted using Web of Science, Google Scholar, Springer, Wiley, and Scopus as primary sources of research papers. The United Nations Framework Convention on Climate Change (UNFCCC), International Energy Agency (IEA), International Renewable Energy Agency (IRENA), UN Department of Economic and Social Affairs (UNDESA), and the Indian government's official websites were also used to get accurate data. Almost 82 published papers and regularly published reports from authentic official websites were studied. This paper highlights and identifies the current scenario of renewable energy sector in India and role of Citizen Science in its understanding.

CURRENT RENEWABLE ENERGY SCENARIO AND POLICY SUPPORT

India aspires to install 500 GW of non-fossil fuel energy capacity. The Ministry of New & Renewable Energy (MNRE), India is a nodal agency at the central level to encourage the use of renewable energy resources to reduce the environmental concerns occurring through anthropogenic activities. In 2022, the Government of India (GoI) amended the National Policy on Biofuels (NPB) 2018 to increase the contribution of domestic biofuel production. The amendments include the advancement of the deadline of 20% blending of bioethanol in petrol to 2025-26 from 2030 [7]. The amendment committee also approved the allowance of more feedstocks for biofuel generation and the promotion of biofuel production through the Make in India Program. As of November 2023, India has installed a total capacity of 178.98 GW of energy from non-fossil fuel energy, including 132.13 GW RE, and 46.85 GW of hydro energy [8]. The major RE resources in India are explained below:

Solar Energy

Solar energy has emerged as a proper choice in this transitional phase of energy. Approximately 72.01 GW of solar energy capacity installed in India by November 2023. Various schemes like Solar Park Scheme, Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM), National Programme on high efficiency Solar PV Modules, Green Energy Corridor Scheme for Intra-State Transmission System were launched by GoI to promote the solar energy capacity of the country [7]. The Bureau of Energy Efficiency (BEE), India has launched the “Star Labelling Scheme” for installation of solar photovoltaic (PV) modules between 1 Jan 2024 to 31 Dec 2025, to ensure the brand and efficiency of installed solar panels [9]. It is predicted that almost 30 million tonnes per annum of CO2 can be reduced by 2030 through the Star Labelling Scheme [9].

Wind Energy

As per reports of MNRE India, the installed wind energy capacity was 4.42 GW in November 2023 and it is likely to enhance this wind energy capacity generation to 99.99 GW by 2029-30 [7]. Wind energy generation is site-specific and Andhra Pradesh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, and Telangana are the major wind energy producers in 2022-23[7].

Small Hydro Energy

Jal-Urjamitra Skill Development Programme was launched by GoI to train professionals and almost 1700 skillful manpower for a period of five years 2021-22 to 2025-26 for ongoing small hydro energy plants. As of November 2023, India has an installed capacity of 4.98 GW for small hydro energy generation [7].

Geothermal Energy

Geothermal energy is harnessed from the deep within the earth's crust. Volcanoes, erupting geysers, fumaroles, hot springs, and steaming fields are the major surface geothermal sources of energy. Cambay Graben, Chhumathang, Puga, Manikaran, Surajkund, Tattapani are the most potential sites in India for geothermal energy production [10]. If geothermal energy resources are fully utilized, they may generate a surplus of electricity for India. The Geological Survey of India (GSI) located 340 hot springs in India and geothermal energy capacity is estimated at almost 10 GW. According to the present database, geothermal potential in Manikaran, Puga-Chhumathang, West Coast, Tapoban, and Tatapani has been evaluated for shallow reservoir potential [11]. However, to determine whether a power plant is viable, an extensive geothermal investigation is needed.

Biomass Energy

Besides being a clean source of energy, biomass energy is very useful in reducing carbon emissions from the atmosphere. About 70% of the population is dependent on biomass for their energy demands

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in India, with 32% of energy consumption derived from biomass resources [12]. The GoI has taken crucial steps to improve biomass-based technologies to enhance its share in the economy of India. In October 2018, Sustainable Alternative Towards Affordable Transportation (SATAT) launched to promote BioCNG, while, in November 2022, the National Bioenergy Programme launched to set up bioenergy plants. Approximately 10.26 GW of installed capacity of biomass power, bagasse cogeneration, and non-bagasse cogeneration plants were set up by GoI in November, 2023 [2], and bioenergy use is expected to double by the year 2035 with power sector one of its major consumers [13]. Some energy plants like Beta vulgaris, Populus, Maize and Camelina sativa are sustainable approach to conserve environment as they help in phytoremediation, greenhouse gas emission reduction, preserving non-renewable sources of energy [14]. Plants which are grown on environmental stressed ecosystems are wise and sustainable choice for bioenergy and biomass use [15]. Biogas production from co-digestion of micro-algae is another promising way to generate biomass energy [16].

Biofuel Energy

India is one of the global leaders in biofuel production. In 2016, India allowed hydrogen as the automobile fuel. Pradhan Mantri JI-VAN (Jaiv Indhan - Vatavaran Anukool fasal awashesh Nivaran) Yojana started to promote the production of 2nd generation ethanol from cellulosic and lignocellulosic biomass. NPB 2018, was launched with an objective of 5% blending in biodiesel and 20% blending of bioethanol in petrol by 2030 [17]. During the G20 summit 2023, India announced the Global Biofuel Alliance (GBA), a towards clean energy goals. GBA is an India-led program initiated to achieve sustainability goals and green energy through the implementation and adoption of internationally recognized new technologies and policies [7]. Microalgae based carbon capture and utilization of CO2 is another way to generate biofuel and other value added bioproducts [18].

Waste-to-Energy

The population of India is growing rapidly, and so is the waste generation increasing. According to the State of India's Environment, 2023 report [19] almost 1,50,000 tonnes of municipal solid waste (MSW) is generated in India per day, and more than half of it is directly dumped in landfill sites or remains unattended [19]. This uncontrolled growth of waste generation has become an alarming threat to human and soil health. MNRE, India is working very efficiently on the waste-to-energy plan where the ministry has initiated sustainable approaches to tackle the issue by enhancing the recovery of energy from various sectors including agricultural leftovers, industrial, urban waste, municipal solid waste, and sewage treatment plant effluent [7]. It is estimated that 573.46 MW of energy capacity is being generated with waste-to-energy plants by November 2023 [7].

BOTTOM-UP APPROACH FOR HARNESSING RENEWABLE ENERGY

The MNRE, India intends to institutionalize renewable energy education and training to fulfill the requirement of qualified and trained manpower in India [7]. The components includes training and skill development, fellowships for higher studies, improvement of renewable energy education, enhanced training infrastructure, and a RE internship Programme at the National level. The GoI through the Human Resources Development (MHRD) division also plans to develop course material including pedagogy through expert institutions and experts. MHRD will develop course modules/ study materials/syllabi for regular and short-term certificate/degree courses for renewable energy. The MNRE, India is empowering women in the sector of renewable energy and women are making significant contributions to this sector [7]. All these initiatives, though many are top-down approach towards energy literacy.

Many research studies that investigate attitudes, opinions, and acceptance of renewable energy use has been done mostly involving university students [20]. This approach though useful has its limitations as it excludes a large segment of citizen participation in increasing public understanding and awareness of renewable energy especially among all stakeholders. As a part of UN Decade on Education for Sustainable Development (2005-2014), few citizens led initiatives across various countries related to renewable energy sectors its awareness and understanding were carried out [21-25]. A study which focused on exploring future scientists' awareness and attitude towards renewable energy sources found positive environmental attitudes in students in Greece, 2019 [23]. An affirmative attitude of students towards sustainable consumption and environmental preservation in energy sector was studied for examining the knowledge and attitude of university students in Malaysia [24]. Study of social acceptance of renewable energy in different sectors in Switzerland found that respondents prefer to use low-carbon energy sources in an environmentally responsible way [22]. A public awareness analysis on renewable energy conducted in Malaysia, 2018 found that defining renewable energy syllabi for educating children since kindergarten is important [21].

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The participatory or citizen science approach is a widely used approach to understand problems and provide solutions and is a transparent mechanism for decision-making. Education about renewable energy should taught at primary school to provide early knowledge, values, and awareness to students so that they may understand the topic at universities and technical colleges [26]. Creating community awareness, Knowledge, and skills, at schools and universities is highly acknowledged as public awareness of renewable energy helps to overcome obstacles and proper implementation of energy policies [27]. The participatory approach is an interdisciplinary approach that helps to understand socioecological conditions, problem identification, and solution management majority of which are context-specific [28]. For effective implementation and assessment of any policy, the focus should be on reflecting local sustainability goals and challenges, capacities, and context and should be accessible and feasible for local stakeholders [29]. This concept of citizen science has gained much popularity in recent years, but its utility for renewable energy production is yet to be explored. The regional planning for harnessing renewables according to available resources and demands in any region with a participatory approach such as citizen science will prove helpful in proper planning and efficient use of resources.

WAY FORWARD

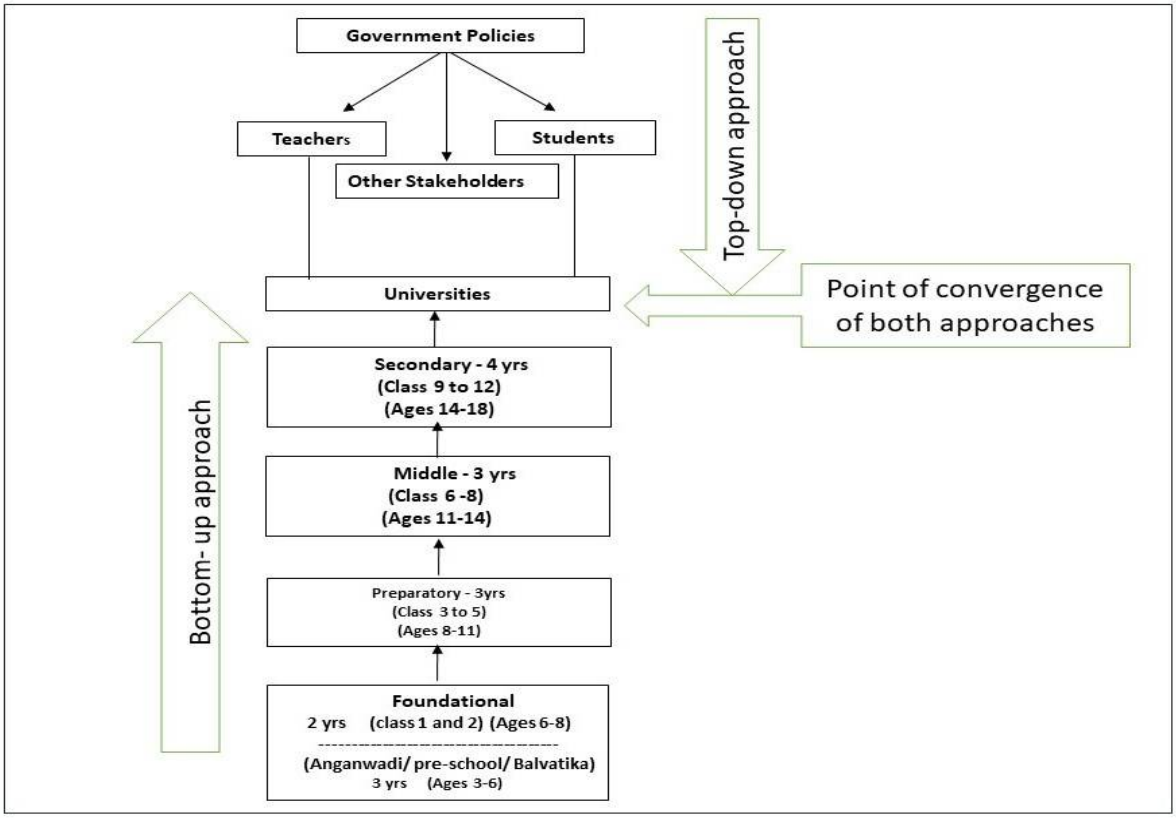

Figure 1: As per National Education Policy (NEP) 2020, the proposed educational system and implementation bottom/top up approach for renewable energy.

The GOI is planning to fulfill this renewable energy gap by using solar and geothermal energy. For this, confirmation of the feasibility of geothermal power plants, intensive investments, knowledge transfer of research, foreign financing, and encouraging financial incentives is required. More focus on bottom-up approach for sustainable and efficient use of energy is need of the hour. Therefore, efforts to increase RE being promoted worldwide, which further needs public participation by citizen-science based approach. The involvement of different stakeholders like the education sector, energy sector, different ministries, and citizen science participation is required to utilize the full potential of renewables (Figure 1). Therefore, in place of a top-down approach, a bottom-up approach may be recommended to bring widespread change in understanding of renewable energy concepts and resource management. Government along with the higher education institutes should take part in

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developing initiatives to impart education to the improvised women which can further improve the understanding about renewable energy and citizen science in the whole society.

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AUTHOR CONTRIBUTION
Naveen Kumar: Writing original draft, Conceptualization, Methodology, Editing; Sudeepa Kumari: Writing original draft, Conceptualization, Methodology, Editing; Kavita Shah: Reviewing, Editing, and Supervision.

DATA AVAILABILITY
This paper includes all the relevant data or supplementary information.

COMPETING INTERESTS
The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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