EXPLORING RENEWABLE ENERGY POTENTIAL TO ELECTRIFY REMOTE SCHOOLS IN INDIA: A LITERATURE REVIEW

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The Indian government is yet to achieve the goal of providing electricity to schools all over the country, and the illiteracy rate seems to emerge from the schools with inadequate infrastructure. Rural schools do not have access to electricity due to the slow electricity grid expansion and continuously increasing electricity demand in the country. However, renewable energy could be the potential answer to assist the government in reaching their goals as renewable energy systems can be used for remote energy generation, eliminating the need for electricity grid extension, or increasing the grid load. This article looked at the viability of renewable energy to support schools' facilities and Information and Communications Technology (ICT) within schools at remote locations in India. The literature showed high wind and solar energy potential in the country, and three case studies illustrated the potential of solar and wind energy systems to support school infrastructure as well as demonstrated positive impacts on the community, finances, and student's educational performance. To conclude, renewable energy sources demonstrated a good potential to support rural school electrification while keeping the environmental impacts to the minimum and contributing to India's renewable energy deployment goals.

Key words: Indian education infrastructure; renewable energy integration in schools; rural school electrification; remote schools

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1. Introduction

An increase in school enrolments has demonstrated the high demand for education in India, whereas a number of schools in remote regions across the country do not have access to basic everyday needs like electricity (Singh, 2018). Problems with the electricity provision are also leading to an increase in illiteracy rate in the rural areas compared to urban regions, which could be due to the lack of ICT employed in teaching as well as a lack of infrastructure development in rural areas (Agrawal, 2014; Singh, 2018). According to Singh (2018), the quality of education is affected by the infrastructure available in the rural schools and currently, the basic needs of public schools such as water, sanitation and electricity are not met in the majority of rural regions. Exploring school electrification in the areas without grid electricity to support schools could provide a better insight into technical developments needed.

While exploring remote school electrification, the pressing concern of climate change would also be an important factor to consider, since the majority of India's current electricity needs are fulfilled by fossil fuels, which are the major drivers of climate change (Ahmad, et al., 2016). Where climate change is the change in

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Earth's climate trends that can negatively impact human health, water, energy, transportation, agriculture, forests and ecosystems (Mielillio, et al., 2014). The use of fossil fuels leads to an increase in carbon emissions, and the higher the carbon emissions, the faster it will affect the climate. In order to keep the environmental impacts to the minimum while supporting rural school electrification, this review examines the viability of renewable energy sources to power the basic necessities of schools as well as ICT.

2. Methodology

To gather in-depth insights into the rural school electrification issues, different areas of the rural Indian education system have been investigated such as the difference in literacy rates, education infrastructure and availability of ICT in the schools in Section 3. The data exploring the education sector have been majorly taken from Indian national school statistics. The focus of this study is then turned to the Indian national electricity grid to investigate the current percentage of renewable energy and fossil fuels, and the potentials of renewable energy sources such as solar and wind energy in India in Section 4. The data on current and projected energy scenario and affiliated Carbon dioxide (CO2) emissions have been taken from BloombergNEF (2020), Central Electricity Authority (2021), IEA (2021), and Carbon Brief (2019), whereas the solar and wind energy potential in India had been taken from Khare et al. (2013), Ramachandra & Shruthi (2007), and National Institute of Wind Energy (2019). Section 4 also considers the feasibility of renewable energy sources to support rural school infrastructure through three case studies. Section 5 integrates the current energy scenario and renewable energy potentials in India with the outcomes from the case studies to explore the possibility of renewable energy to support remote schools. Finally, Section 6 concludes the research by summarising vital findings and highlighting potential opportunities in remote school electrification.

3. Rural Indian Education Infrastructure

3.1 Education in Rural vs Urban India

It was found by Chatterjee et al. (2018) that a considerable number of youths do not go to school and the illiteracy rates were also found to be highest in India for the same reason. The local and national government implemented many policies in the state and the national levels to support education infrastructure, due to which the illiteracy rates started to decline. Significant differences were found in the literacy rates between urban and rural areas with educational infrastructure also unequally divided between the two; students in rural areas not only had inadequate infrastructure and educational resources but also had to cover more considerable distances to reach school compared to those in urban areas (Agrawal, 2014).

A study conducted by the National Sample Survey Organization (NSSO) in 18 states investigated the level of education attained in all the states (Agrawal, 2014). The data were subdivided into many categories such as literacy rate in urban and rural areas, level of education attained in both and their percentage, and changes in literacy rates from the year 1993 to 2009 on a five-year period (Table 1).

From Table 1, the difference in the level of education attained and affiliated population can be seen in the rural and urban areas; the illiteracy rates in the rural areas is twice that of the urban areas. Although illiteracy percentage can be seen declining from the year 1993 to 2009, the difference between urban and rural areas seems to be maintained consistently. The number of students dropping out of the schools after middle and secondary school is also significant in rural areas. One of the reasons is believed to be a lack of financial support by the government, which ceases to support students after age 14 in the government schools (Trines, 2018). The other reasons were found to be the children supporting household tasks or immigrating to urban areas with better infrastructure, facilities and better opportunities (Agrawal, 2014).

According to Trines (2018), the Indian education system is mostly affected by the influence of politics and the competition between a number of education bodies in central and state levels. Rural development

Education level	1993	1999	2004	2009
Rural				
Illiterate	56.96	52.51	47.69	38.34
Below primary	10.09	9.45	8.38	9.31
Primary	10.94	11.03	13.04	13.76
Middle	11.39	13.72	15.25	17.03
Secondary	6.27	7.77	8.24	11.48
Higher secondary	2.73	3.42	4.87	6.84
Graduate and above	1.62	2.10	2.53	3.24
Urban				
Illiterate	26.78	24.01	21.30	17.15
Below primary	8.97	7.47	6.00	5.74
Primary	12.55	11.17	12.33	10.45
Middle	16.47	17.59	18.17	16.41
Secondary	15.26	16.61	15.28	17.75
Higher secondary	9.20	10.21	12.94	15.17
Graduate and above	10.77	12.94	13.98	17.33

Table 1: Education level and Illiteracy rate in urban and rural areas from 1993 to 2009 (Source: Agrawal, 2014)

seems to be affected as a result of this conflict and it has been suggested that the centralisation of education system could facilitate more even development across the country.

3.2 ICT in Indian Market and Education Infrastructure

"Information and communication technologies can be defined as electronic means of capturing, processing, storing, and communicating information." (Heeks, 1999, pp.3). Sarkar (2012) suggests that ICT has the potential to deliver revolutionary changes in teaching methodologies whilst also empowering women through education. Computers specifically have a great potential for delivering and receiving teaching material as the system provides access to information stored on the device, enables a new form of communication, and provides online access to services like e-commerce, education, entertainment and culture (Sarkar, 2012).

ICT is a growing business in the country and has reached all places from multinational organisations to small enterprises. One of the critical reasons for the increase in digitalisation is the government's effort to digitise India, mainly in terms of digital marketing and e-commerce businesses (U.S. Embassies abroad, 2018). It is estimated by U.S. Embassies abroad (2018) that the ICT market is worth 164 billion US dollars in India (£129 billion), and the market is projected to grow by 220-225 billion US dollars (£173-177 billion).

Education infrastructure plays an important part to shape a country's future. A study done in 2019 showed that better access to education plays a pivotal role to foster economic growth (Donou-Adonsou, 2019). India is struggling with the infrastructure in government schools. The ICT use in the country is growing, although, not in the educational sector. According to the U-DISE (2016) report, only 28% of the schools have access to computers, and only 14.11% are in working conditions.

As can be seen from Table 2, access to computers is unavailable in almost 90% of the schools across the country. The school infrastructure also lacks a number of facilities such as boundary walls and washbasins in almost half of the schools. When it comes to electricity connection, the figures indicate 40% of schools lack electricity to support the basic school needs for an adequate learning environment or to support ICT.

Table 3 further breaks down the percentage of computers in working conditions by different states. Some of the developed states like Chandigarh, Lakshadweep and Puducherry are doing exceptionally well whereas states like Bihar, Jharkhand, and Assam not so good. Due to the current development conditions, the schoolteachers mainly have to rely on the textbooks for teaching and ICT plays little to no role in education.

Table 4 breaks down the school electricity statistics. As can be seen from the graph, states like Arunachal Pradesh, Assam and Bihar have electricity in less than half of the government schools whereas some states like Chandigarh, Daman and Diu and Delhi have electricity in nearly all of the schools, leaving some of the states like Chhattisgarh, Mizoram and Sikkim in a moderate position with electricity in around 75% of the schools. It is clear from the data that changes in the education infrastructure is needed in both the areas of continuous electricity provision and accessibility to the ICT.

From the literature analysed in this section, it is clear that Indian schools, especially in rural regions have inadequate infrastructure as well as limited facilities, including the supply of electricity. The need for alternative energy sources to keep the limit the environmental impacts while supporting remote schools can be seen.

Available Facility	**Percentage (%)**
Buildings	98.32%
Boundary walls	57.88%
Drinking water	87%
Toilet for boys	92.53%
Toilet for girls	94.37%
Washbasin	55.55%
Library	82.96%
Playground	61.98%
Electricity connection	60.81%
Computers in working condition	14.11%

Table 2: U-DISE Indian school facilities statistics 2016-17 (Source: U-DISE report, 2016)

States	Percentage of schools with computers in working condition
A and N Islands	46.75
Andhra Pradesh	21.55
Arunachal Pradesh	14.10
Assam	4.42
Bihar	0.57
Chandigarh	92.54
Chhattisgarh	4.24
D and N Haveli	21.33
Daman and Diu	0.00
Delhi	67.53
Goa	29.11
Gujrat	39.76
Haryana	28.03
Himachal Pradesh	14.65
Jammu and Kashmir	10.13
Jharkhand	5.21
Karnataka	27.26
Kerala	70.29
Lakshadweep	91.11
Madhya Pradesh	6.17
Maharashtra	33.47
Manipur	13.34
Meghalaya	4.51
Mizoram	12.45
Nagaland	24.58
Odisha	3.44
Puducherry	99.73
Punjab	42.84
Rajasthan	6.60
Sikkim	35.00
Tamil Nadu	42.14
Telangana	15.49
Tripura	9.01

States	Percentage of Schools with Electricity
A and N Islands	87.95
Andhra Pradesh	93.20
Arunachal Pradesh	36.00
Assam	23.93
Bihar	42.98
Chandigarh	100.00
Chhattisgarh	70.72
D and N Haveli	99.71
Daman and Diu	100.00
Delhi	99.91
Goa	99.87
Gujrat	99.91
Haryana	97.28
Himachal Pradesh	91.85
Jammu and Kashmir	32.16
Jharkhand	32.19
Karnataka	95.57
Kerala	96.51
Lakshadweep	100.00
Madhya Pradesh	29.39
Maharashtra	85.69
Manipur	33.89
Meghalaya	25.34
Mizoram	67.68
Nagaland	48.71
Odisha	34.19
Puducherry	100.00
Punjab	99.94
Rajasthan	58.4
Sikkim	78.36
Tamil Nadu	99.30
Telangana	88.15
Tripura	29.29

Table 3 (left, pg 5): Percentage of computers in working condition in different states (Source: U-DISE report, 2016)
Table 4 (right, pg 5): Percentage of Schools with Electricity in different Indian states (Source: U-DISE report, 2016)

4. Current Energy Senario, and the Case for Renewable Energy and its Potential to Support Remote Schools in India

4.1 Fossil Fuels and Electricity Production

Coal and crude oil are the major sources of electricity production in India; in 2012, they accounted for 44% and 22% of electricity production respectively (Ahmad, et al., 2016). With the increasing population, development and provision of electricity to every household, the country has been developing three coal-powered plants with capacities of 243 gigawatts (GW), 65 GW and 178 GW (Shearer, et al., 2017). India's commitment to reduce its carbon emissions by 33-35% by 2030 will also likely not be met due to the forecasted 123% increase in fossil fuel dominant electricity generation (Shearer, et al., 2017). One of the reasons for the use of coal as a main source of fuel is the abundance of large coal reserves in the country, its reliance in the current energy system and for the provision of electricity to every household in the future, as currently about 300 million people in India still lack access to electricity (Shearer, et al., 2017).

Figure 1 and 2 demonstrate the actual electricity demand (in terawatt hour) and CO2 emissions (in Metric tons of carbon dioxide) until the year 2019 – 2020 as well as the expected increase in both by 2029 - 2030. According to the graphs, electricity generation capacity reached 1,500 TWh, and the affiliated carbon emissions 2,242 MtCO2 in 2019 – 2020. The current electricity demand is expected to go up to 2,700 TWh by 2030, whereas CO2 emissions vary depending on India's future renewable energy scenario and its deviation from its current reliance on coal to fulfil the growing electricity demands. In the last decade, India's net power generation capacity increased by 212GW – nearly the total grid size of France and the projections indicate extensive increase in energy demand (almost double) within the next decade (BloombergNEF, 2020).

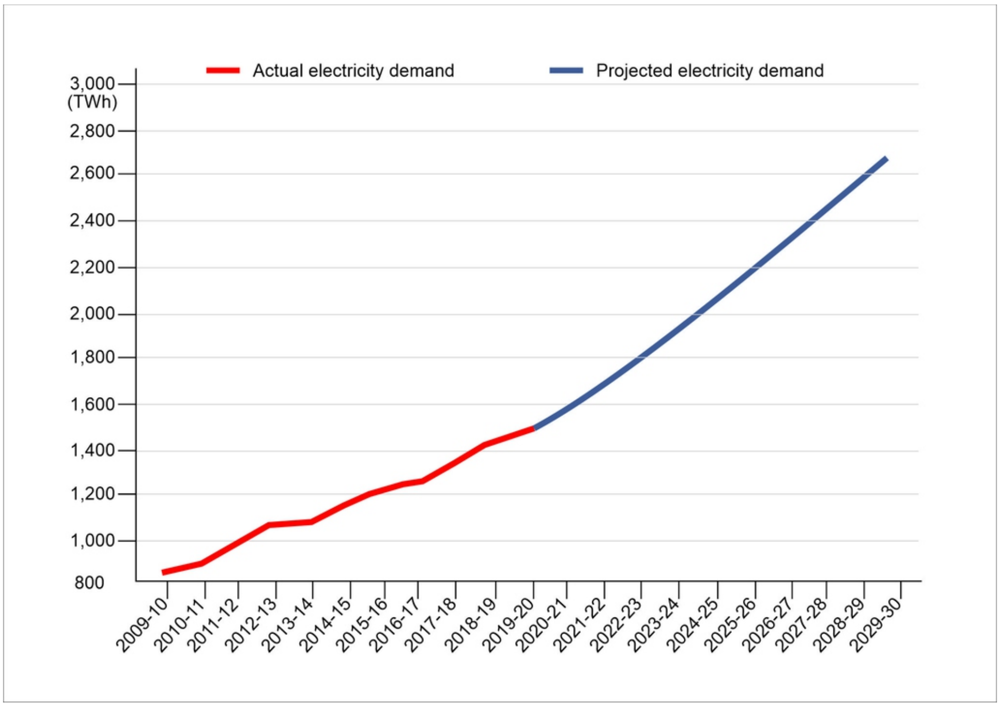

Figure 1: Actual electricity demand and projected electricity demand for India (Data source: Carbon Brief, 2019, BloombergNEF report, 2020)

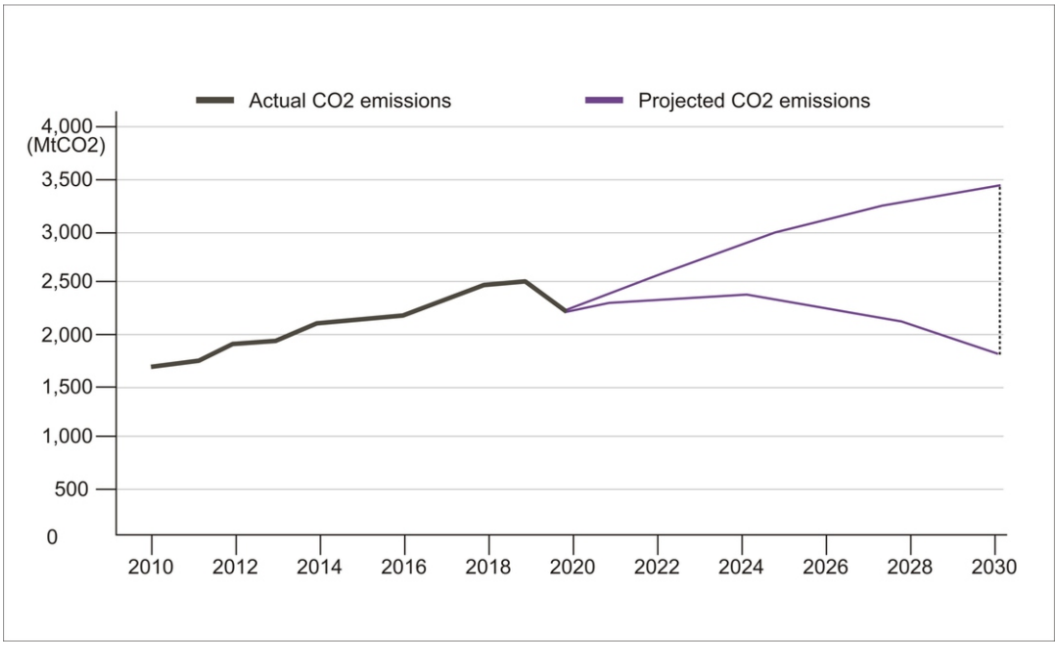

Figure 2: Actual CO2 emissions and projected CO2 emissions range for India (Source: IEA, 2021)

4.2 Renewable Energy and its Potential

Investments have been made by the government to increase the electricity production by fossil fuels, however, investments are also being made in renewable energy technologies and fossil fuel use is expected to reduce by 2030 (BloombergNEF, 2020). India has set ambitious targets to increase renewable energy generation. One of the goals is to increase the renewable energy generation to 175 gigawatts (GW) by 2022 and 450 GW by 2030 (Figure 3); it also seems to be making substantial progress towards reaching the goal (BloombergNEF, 2020).

Figure 3 demonstrates the progress made by the Indian government through investments in renewable energy generation. It can be seen from the figure that large investments have been made in the wind and solar energy sectors. Although reaching the renewable targets seem quite difficult according to the progress made so far, especially its goal to reach renewable energy generation capacity of 175 GW by 2022.

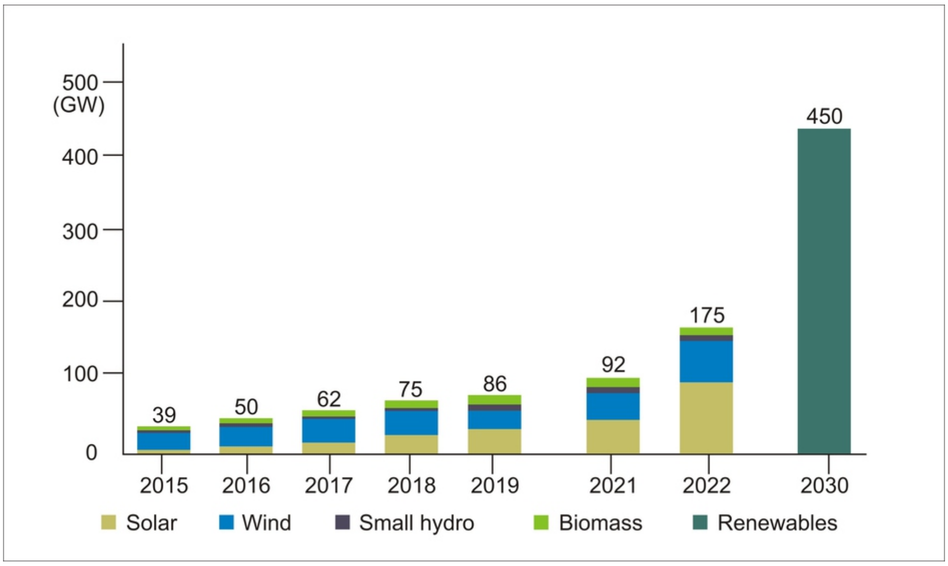

Figure 3: Renewable energy generation statistics and 2022 and 2030 goals for India (Data source: BloombergNEF report, 2020, Central Electricity Authority, 2021)

Figure 4 shows India's potential energy generation targets, which incorporates both renewable energy generation as well as fossil fuels. Both energy sources seem to be increasing, and the increase in fossil fuel power plant is also concerning considering the Paris Agreement target of reducing the carbon emissions within 2 °C by the end of this century (Rogelj, et al., 2016).

Wind energy has been the fastest-growing renewable energy sector in India and is the third-largest annual wind power market in the world (Khare, et al., 2013). Table 5 demonstrates the onshore wind energy potential in India, which was estimated to be 49.1 GW at 50 m height in 2005. The new estimation made in 2019 demonstrated a potential of 695 GW at 120 m height. Wind energy potential was found to be highest in the states of Andhra Pradesh, Gujarat, Karnataka, Maharashtra and Tamil Nadu, having wind speeds ranging from 4.33 - 7.32 m/sec at 50 m height (National Institute of Wind Energy, 2019; Khare, et al., 2013). Apart from these states, scattered wind energy potential was also found in some other parts of the country (National Institute of Wind Energy, 2019).

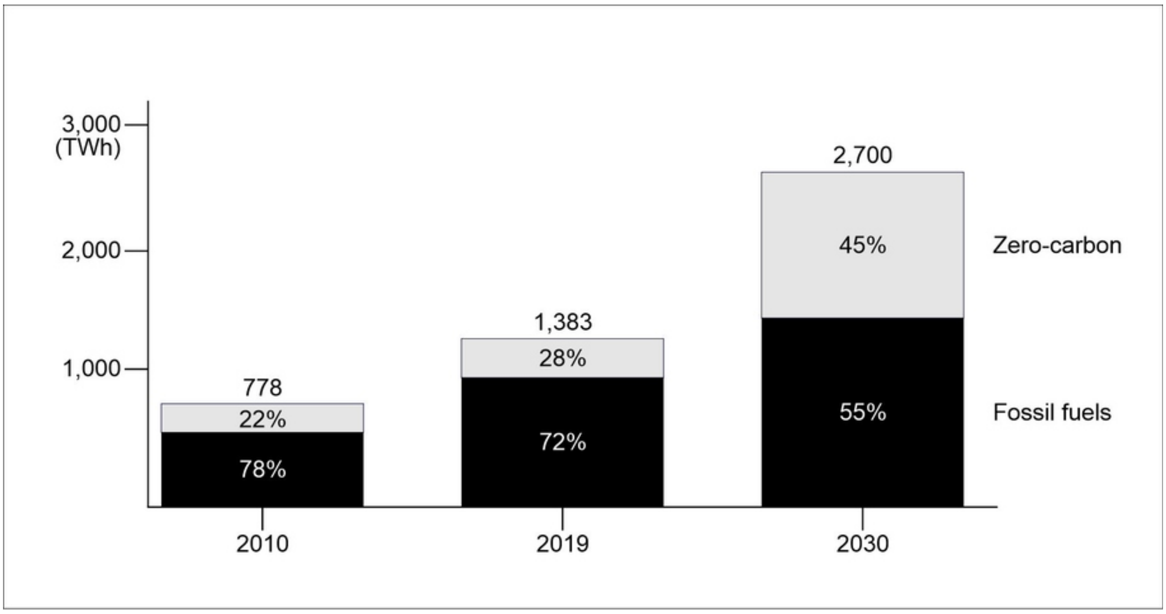

Figure 4: Past energy generation for 2010 and 2019 and potential energy generation targets in 2030 for India (Data source: BloombergNEF report, 2020)

Solar energy potential in India	**Unit(s)**
Daily solar radiation	5 kWh/m^2 approximately
Annual solar radiation seasonal range	1600 - 2200 kWh/m^2
Sunshine hour range	2300 - 3200 hours/year
Wind energy potential in India	
Wind energy potential at 50m height	49.1 GW
Wind energy potential at 120m height	695 GW

Table 5: Solar and wind energy potential in India (Source: Khare et al. 2013, Ramachandra & Shruthi, 2007, National Institute of Wind Energy, 2019)

Solar energy also seems to have great potential to produce electricity. According to Table 5, the daily average global radiation is around 5 kWh/m2 in India with the sunshine hours ranging between 2300 and 3200 per year across the country. Although the total radiation varies from 1,600 to 2,200 kWh/m² according to the season, the equivalent energy potential is about 6,000 million GWh of energy per year (Ramachandra & Shruthi, 2007). The estimates demonstrate a significant solar power potential that to date, has been minimally utilised. If the renewable energy potential could be integrated with the issue of energy provision, the government could greatly benefit from the clean energy.

However, the scope of this research is limited to supporting the rural school electrification. Exploring the case studies of schools integrating renewable energy could provide an insight into the feasibility of the off-grid energy generation to support school facilities.

4.3 Case Studies

4.3.1 Case Study 1: Phomolong Secondary School, Tembisa, South Africa (Samsung, 2011)

Samsung Africa launched its first Solar Powered Internet School (SPIS) model at the Samsung Engineering Academy in B oksburg, South Africa in 2011. The goal of the model was to address Africa's challenges with electrification as less than 25% of the rural areas in the continent have access to electricity, which results in the formation of isolated communities and very limited access to education. To make education accessible to the communities, Samsung Africa built a classroom inside a 12 m long recycled shipping container, which makes it easily transportable to the remote regions of Africa with energy-scarce environments (Figure 5). The classroom had the capacity of accommodating 21 students and included many layers of insulation and a ventilation system to ensure a comfortable environment. The classroom was also equipped with an environmentally friendly air purification system to inhibit infection by airborne viruses and destroying airborne bacteria, fungi, and allergens.

With regards to the ICT, the classroom was equipped with a 50-inch electronic board and a number of tablets and laptops which were optimised to be used in a solar-powered environment. It was also equipped with a 3G internet connection, a file server, a refrigerator and an Uninterrupted Power Supply (UPS) unit. For the efficient usage of equipment, they were equipped with a complete South African school curriculum spanning from the primary grade to the high school, allowing it to useable for all age groups. The classroom was powered with fold-away solar panels which were made from rubber instead of glass to ensure their durability for surviving long journeys across the continent. The energy system had the capacity to powering the classroom for up to nine hours a day, while it could also go for a day and a half without any sunlight at all. In the case of power-outage, a whiteboard and a chalkboard were also installed on top of an LED lighting system with energy storage. The SPIS demonstrates an innovative solution of recycling a shipping container and efficient use of energy produced for supporting ICT and creating a comfortable learning environment to support education in rural Africa.

According to Goldstuck (2014), the classroom reached Phomolong Secondary School in Tembisa, South Africa in 2012. Due to the interactive nature of the classroom and easy access to the curriculum, the students were found to be more enthusiastic about education as compared to the traditional blackboard and chalk teaching method. The average passing rate of the students in the school was about 66% before the introduction of Solar Powered Internet School, whereas within the two years of its introduction, the percentage of students passing went up to 96.5% as well as more than half of the students there qualified for bachelor studies.

Figure 5: Samsung Solar Powered Internet School (Source: www.techcabal.com)

4.3.2 Case Study 2: Gnanmata Sadan School, Talasari District, India (Fernandes et, al., 2008)

Gnanmata Sadan Society (GSS) is an NGO that supports the children of disadvantaged groups of society by setting up residential schools in the state of Maharashtra, India. GSS runs 11 primary schools, 4 secondary schools and a junior college along with its sister institutions. The GSS schools were faced with daily electricity outages and a constant voltage fluctuation from the power grid, which would last for a minimum of 6 hours at a stretch during the peak school hours. Due to these electrical issues, students in the schools also had somewhat limited access to computers, and a number of computers were permanently damaged due to the severe voltage fluctuation. To overcome these issues, GSS considered adopting solar energy as an alternative and consistent source of energy.

A set of 12 solar photovoltaic panels were installed as a unit in one of the GSS schools having a total capacity of 960 W (Watts). Each panel had a capacity of 80 W, 4.70 A (Amperes) and 17 V (Volts). The power generated from the solar unit was stored in a battery system having a capacity of 48 V and 200 A, where the battery system consisted of 8 lead-acid batteries with a capacity of 12 V and 100 A each. The battery system was required due to the intermittent nature of renewable energy, and the stored energy had to potential to be used as a continuous energy source after its conversion from Direct Current (DC) to Alternating Current (AC) from a Converter system consisting of an inverter and solar charge regulator to power eight computers. Schematic diagram of all the system components working together to power the computers can be seen in Figure 6.

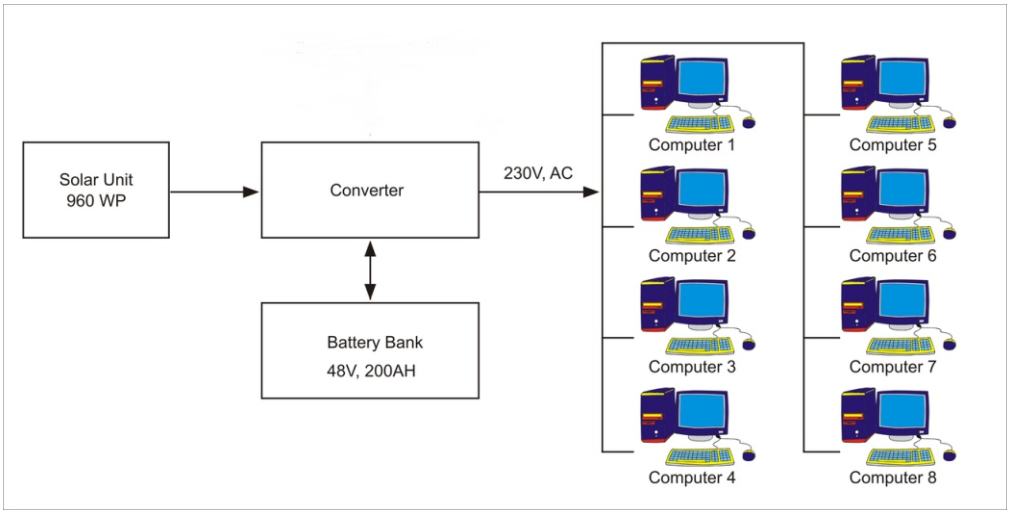

Figure 6: Schematic diagram of solar energy unit powering eight computers in GSS school

The project installation was initiated on February 1st, 2008, and it was completed in two months. The solar energy unit demonstrated the capacity to support all eight computers with a consistent power supply and the discussion with the Gnanmata Sadan administration also considered using the school as a model for spreading solar energy to other schools.

4.3.3 Case Study: The Forest City Community School, Iowa, USA (The Iowa Policy Project Report, 2006)

A number of schools in the Iowa state of the USA started to produce electricity through wind turbines to meet their energy needs primarily due to their perennial struggle with tight budgets and the constant increase in the fossil fuels costs as found by Iowa Policy Project, a nonpartisan, nonprofit research organisation based in Iowa City. The organisation researched the schools in the state having wind turbines installed to develop an understanding of their decisions for choosing wind energy and their experience with the system. Forest City Community School was amongst one the schools. It was found that the wind turbines demonstrated the potential to be used as an energy source in the state as the state has the 10th highest wind potential in the USA as well as it has the capacity to produce 4.8 times more electricity than the Iowans consume.

The Forest City Community School considered installing a wind turbine due to a Physics project conducted by a school student, which demonstrated the wind energy potential in the region. After some examination and research by the school board, it was found that the wind turbine would be an economically feasible project for the school, and the board decided to pursue it. The other goal of the wind turbine was the integration of wind energy into the school's curriculum to teach students about growing technology, and it is currently being used in the Physical Science course. The region of the school had an average annual wind speed of 15.69 mph and a wind turbine with a 600-kW capacity costing $673,000 (£477,796) in total.
After the installation of the wind turbine in 1999, the school has no electricity costs and makes $55,477 in revenue annually through direct utility sales. Its loan was estimated to be paid off in 11-13 years, which was initially less although it was prolonged due to a wind turbine breakdown in 2001. Apart from its use in the curriculum, it has also been supported by the local community. Furthermore, during the summer vacation, it directs its energy to the energy-intensive industries allowing the local power plant to reduce their peak production. Forest City Community School was one of the many cases that had a positive experience with wind energy in Iowan schools (Figure 7). According to the Iowa Policy Project Report (2006), local community-based wind ventures have multiple benefits. They help create awareness about climate change, keep the energy investment returns local, create jobs and diversify local economies while having an educational value in the school with widespread community support, which also increased cohesiveness in the community.

5. Discussion

Many issues faced by Indian school infrastructure have been highlighted such as unavailability of computers in almost 90% of the schools across the country and lack of electricity in almost 40% of schools. Inadequate school infrastructure has also been linked to the difference in illiteracy rates between urban and rural regions, where rural schools have fewer facilities as compared to the schools in urban regions. India has also been investing in three coal-powered plants of capacities 243 GW, 65 GW and 178 GW to overcome the issue of access to electricity across the country. India's target to reduce its carbon emissions by 33-35% by 2030 could also be in danger due to the projected rise in carbon emissions affiliated with the coal-powered plants.

India has also set ambitious targets to increase the renewable energy production of 175 GW by 2022 and 450 GW by 2030 by utilising the renewable energy potential in the country, especially wind and solar which has been minimally utilised. The targets set by the government seem difficult to achieve given the progress momentum so far, as the total renewable energy production reached 92 GW in January 2021 and reaching the capacity of 175 GW within two years would be a big challenge. The energy provision may take a

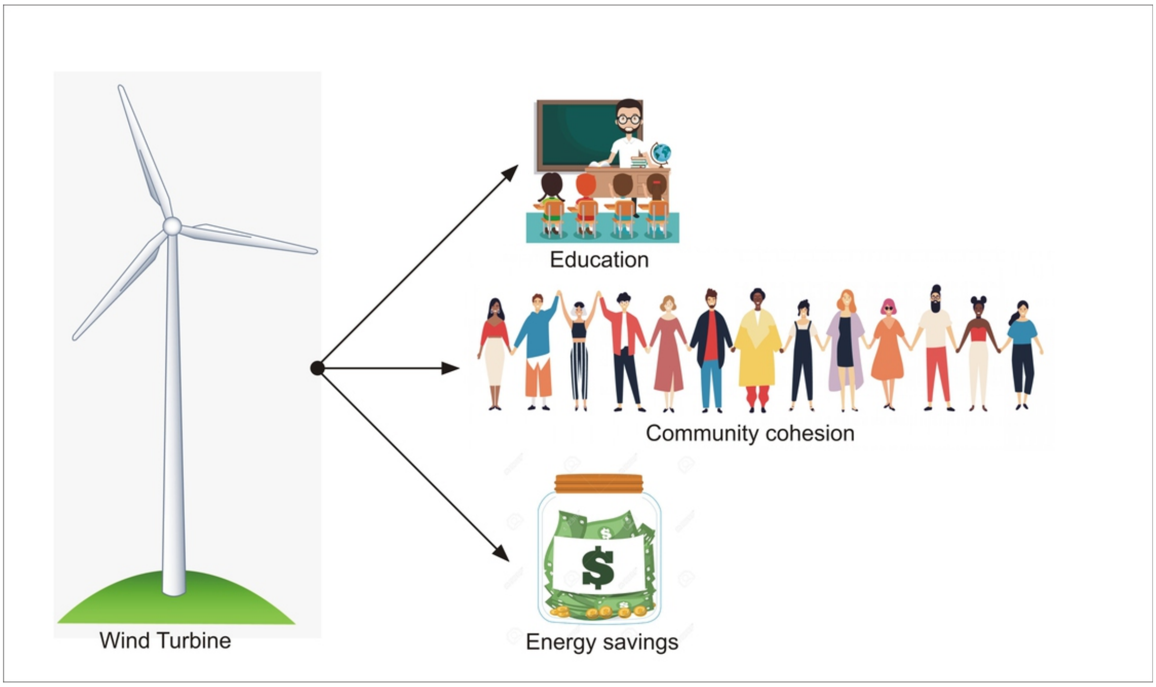

Figure 7: Benefits of installing a wind turbine at the Forest City Community School

long time to reach schools especially in the remote rural regions, and if the electricity is generated through coal-powered plants, it may further increase the dependency of rural school electrification on fossil fuels while increasing carbon emissions. To find a solution for this issue, three case studies exploring remote school electrification through independent renewable energy systems have been thoroughly investigated. The case studies demonstrated a great potential of independent energy generation to support remote schools and its benefits to the stakeholders.

The SPIS at Phomolong Secondary School showed the importance of having a comfortable and interactive learning environment and its effects on students' interest in education. The mobile classroom also demonstrated efficient use of energy sources and ICT, which transformed the percentage of students passing to 96.5% from 66% within two years. The renewable energy systems offer an amazing opportunity for Indian schools to fight the illiteracy rates by providing students with a comfortable and interactive environment, as more students will likely to show an interest in education with good facilities. Drawing from the Forest City Community School, energy systems could also be used as a tool to include renewable energy systems in the curriculum and to educate students about the importance of renewable energy systems while also improving their employment opportunities after graduation. These energy systems could potentially contribute to community coherence and rural development as the students will not likely to migrate to urban areas in search of better education.

Independent energy generation system from GSS school has also demonstrated the utilisation of renewable energy potential to support ICT in a remote Indian school, although supporting other essential facilities were neglected. Combining interactive education infrastructure and learning environment and renewable energy integration in the curriculum could potentially make the best use of remote school electrification. Furthermore, the case studies only considered a single energy source unit (either wind or solar), utilising both solar and wind energy systems as a single energy system could help to create a more efficient energy system due to the intermittent nature of renewable energy depending upon the regions.

6. Conclusions

This literature review highlights issues with the provision of facilities in the infrastructure of Indian schools and the rates of illiteracy linked to the poor infrastructure particularly in rural areas. One of the biggest challenges found was the unavailability of continuous power supply in almost half of the government schools. For the provision of electricity across India, the government had been developing three coal-powered plants with capacities of 243 GW, 65 GW and 178 GW, although, CO2 emissions projected with the plants would further accelerate climate change. The literature has also shown that India has massive potential in solar and wind power, and the country is trying to utilise the potential to increase renewable energy production to 175 GW by 2022 and 450 GW by 2030, which currently stands at 92 KW.

Since the country has good potential in renewable energy, it carries the capacity to support rural schools as well as the governments' goals for future energy provision. To explore this concept, three case studies investigated the potential of solar and wind energy systems to support school facilities and ICT in non-electrified regions in South Africa, India and the USA. The results demonstrated positive impacts of renewable energy systems on education, financial savings, consistent energy supply, and community cohesion. Renewable energy systems could also reduce carbon emissions, which is one of the major drivers of climate change and help to create a clean and sustainable future. The case studies were focused on the impacts of single renewable energy sources, however, exploring combined wind and solar energy systems due to fluctuations in energy generation in different seasons could potentially help develop more efficient energy systems.

References

Agrawal, T., 2014. Educational inequality in rural and urban India. International Journal of Educational Development, Volume 34, pp. 11-19.

Ahmad, A., Zhao, Y., Shahbaz, M., Bano, S., Zhang, Z., Wang, S. & Liu, Y., 2016. Carbon emissions, energy consumption and economic growth: An aggregate and disaggregate analysis of the Indian economy. Energy Policy, Volume 96, pp. 131-143.

BloombergNEF, 2020. India's Clean Power Revolution, s.l.: BloombergNEF.

Carbon Brief, 2019. Analysis: India's CO2 emissions growth poised to slow sharply in 2019. [Online] Available at: https://www.carbonbrief.org/analysis-indias-co2-emissions-growth-poised-to-slow-sharply-in-2019
[Accessed 06 March 2021].

Central Electricity Authority, 2021. All India Installed Capacity of Power Stations, s.l.: Central Electricity Authority.

Chatterjee, I., Li, I. & Robitaille, M. -. C., 2018. An overview of India's primary school education policies and outcomes 2005–2011. World Development, Volume 106, pp. 99-110.

Donou-Adonsou, F., 2019. Technology, education, and economic growth in Sub-Saharan Africa. Telecommunications Policy, 43(4), pp. 353-360.

Fernandes, T., Mascarenhas, G. & D'Silva, F., 2008. Using Solar electricity to power school computers at Gnanmata Sadan Schools, Talasari district, India, Talasari, Thane district: Francis D'Silva.

Goldstuck, A., 2014. Solar-powered schools: Let the sun shine on education. [Online] Available at: https://mg.co.za/article/2014-02-19-solar-power-schools-let-the-sun-shine-in-on-education
[Accessed 04 July 2019].

Heeks, R., 1999. Information and Communication Technologies, Poverty and Development, Manchester: Institute for Development Policy and Management.

IEA, 2021. India Energy Outlook 2021: World Energy Outlook Special Report, Paris: IEA.

Khare, V., Nema, S. & Baredar, P., 2013. Status of solar wind renewable energy in India. Renewable and Sustainable Energy Reviews, Volume 27, pp. 1-10.

Mielillio, J. M., Richmond, T. & Yohe, G. W., 2014. Climate change impacts in the United States:: Highlights. Washington DC: US Government Printing Office.

National Institute of Wind Energy, 2019. India's Wind Potential Atlas at 120m agl, Chennai: National Institute of Wind Energy.

Ramachandra, T. & Shruthi, B., 2007. Spatial mapping of renewable energy potential. Renewable and sustainable energy reviews, 11(7), pp. 1460-1480.

Rogelj, J., Den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., Schaeffer, R., Sha, F., Riahi, K. & Meinshausen, M., 2016. Paris Agreement climate proposals need a boost to keep warming well below 2 °C. Nature, 534(7609), pp. 631-639.

Samsung, 2011. Samsung Africa launches Solar Powered Internet Schools. [Online] Available at: https://news.samsung.com/global/samsung-africa-launches-solar-powered-internet-schools
[Accessed 04 July 2019].

Sarkar, S., 2012. The Role of Information and Communication Technology (ICT) in Higher Education for the 21st Century. The Science Probe, 1(1), pp. 30-40.

Shearer, C., Fofrich, R. & and Davis, S., 2017. Future CO2 emissions and electricity generation from proposed coal-fired power plants in India. Earth's future, 5(4), pp. 408-416.

Singh, J., 2018. Why rural India still has poor access to quality education?. [Online] Available at: https://www.financialexpress.com/education-2/why-rural-india-still-has-poor-access-to-quality-education/1393555/
[Accessed 04 June 2019].

The Iowa Policy Project Report, 2006. Wind Power and Iowa Schools, Iowa City: The Iowa Policy Project.

Trines, S., 2018. Education in India. [Online] Available at: https://wenr.wes.org/2018/09/education-in-india
[Accessed 22 June 2019].

U.S. Embassies abroad, 2018. India - Information and Communication Technology. [Online] Available at: https://www.export.gov/article?id=India-Information-and-Communication-Technology
[Accessed 28 June 2019].

U-DISE, 2016. U-DISE FLASH STATISTICS 2016-17, New Delhi: National Institute of Educational Planning and Administration.