View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by JScholarship

DECENTRALIZED RENEWABLE ENERGY EFFORTS IN RURAL INDIA

by
Tran Ngoc Vu

A research study submitted to Johns Hopkins University in conformity with the requirements for the degree of Master of Arts in Global Security Studies

Baltimore, Maryland
May 2021

© 2021 Tran Ngoc Vu
All Rights Reserved

Abstract

This paper examines India's progress with decentralized renewable energy (DRE) throughout its rural regions. It looks at various programs implemented in India to gauge whether the country's efforts are sufficient to meet the United Nations' Sustainable Development Goal 7 (SDG7). By assessing India's access to electricity, usage of clean fuels and sources, and renewable energy consumption, this paper determines the success of India's efforts to meet all of SDG7's benchmarks are uncertain.

Research Study Advisor: Dr. Mark Stout

Reviewers: Elly Rostoum and Dr. Syed Mohammad Ali

Preface

This research paper culminated from the guidance of the Research Study Seminar at Johns Hopkins University. My initial interest in the topic of decentralized energy stemmed from my experience in taking the Energy and Environmental Security course in the previous semester. With there being so much material to cover, I narrowed my focus to rural India. I chose specific factors to measure the gathered data in order to produce a stronger analysis of the topic. Overall, it will be interesting to see how decentralized renewable energy systems are implemented in the future.

Acknowledgements

I would like to thank JHU Program Director of Global Security Studies Dr. Mark Stout for offering his guidance and critique on my paper. He helped me constructively question the path of my writing to produce a more cohesive product. I am also grateful towards Dr. Paul Sullivan who was my instructor for the Energy and Environmental Security course. His lectures provided me with the foundation that I was able to use for building this research paper.

Table of Contents

List of Tables

List of Figures

Introduction

Over the past decade, there have been increasing global efforts to use cleaner energy and implement decentralized renewable energy (DRE) in rural and remote regions. Established in 2000 and ending in 2015, the United Nations' Millennium Development Goals framed eight goals to address the world's major development challenges, primarily focusing on poverty and health. The Millennium Development Goals provided plans to increase electricity access and DRE technologies utilization to "make use of traditional fuels in cleaner, safer and more environmentally sound ways."[1] Based on the Millennium Development Goals, the United Nations established the 17 Sustainable Development Goals (SDGs) in 2015. The overlap between the Millennium Development Goals and the current SDGs can be seen in the table below.

Table 1 – Overview of MDGs and SDGs

S. No.	Millennium Development Goals (MDG's)	Sustainable Development Goals (SDG's)
1	Eradicate Extreme Poverty and hunger	SDG 1 & 2: No Poverty. Zero hunger
2	Achieve Universal Primary Education	SDG 4: Quality Education
3	Promote gender equality & empower women	SDG 5: Gender Equality
4	Reduce Child mortality	SDG 3 Good health and well being
5	Improve maternal health	SDG 3 Good Health and Well being
6	Combat HIV/AIDS, malaria & other diseases	SDG -3 Good health and well being
7	Ensure Environmental Stability	SDG 6: Clean water & sanitation SDG 7: Affordable & Clean Energy SDG11: Sustainable Cities & Communities SDG 12: Responsible consumption and Production SDG 13: Climate Action SDG 14: Life below water SDG 15: Life on land
8	Global partnership for development	SDG 17: Partnerships for the goals

Source: (Chopra and Virmani)[2]

[1] "Renewable Energy Technologies for Rural Development," *Current Studies on Science, Technology, and Innovation*, no. 1 (2010), https://unctad.org/system/files/official-document/dtlstict20094_en.pdf.
[2] Shefali Chopra, and Meeta Virmani, "MDG's to SDG's: A necessary shift," *International Journal of Applied Research* 3, no. 6 (2017); 836-839, https://www.allresearchjournal.com/archives/2017/vol3issue6/PartL/3-6-229-365.pdf.

All member states adopted these objectives to "end poverty, protect and ensure that all people enjoy peace and prosperity by 2030."[3] The United Nations actively pushes for the requirements facilitating DRE system investments to end energy poverty by 2030 in rural areas.[4] Additionally, deploying DRE solutions is beneficial due to its efficiency and cost-effectiveness. The United Nations outlines global objectives in the SDGs to provide innovative business models for the private sector.

SDG7 falls under former Millennium Development Goal 7 regarding a more limited perspective of environmental stability. Furthermore, SDG7 highlights initiatives towards universal access to electricity, taking concepts and policies from its preceding Millennium Development Goals, the 2015 Paris Agreement by the United Nations Framework Convention on Climate Change, and the national determined contributions.[5] SDG7 is broken down by these five targets below.

---

[3] "Sustainable Development Goals," United Nations Development Programme, accessed February 13, 2021, https://www.undp.org/content/undp/en/home/sustainable-development-goals.html#:~:text=The%20Sustainable%20Development%20Goals%20.

[4] "Decentralized renewable energy can unlock UN sustainability goal," *Power Engineering International*, April 20, 2017, https://www.powerengineeringint.com/decentralized-energy/on-site-renewables/decentralized-renewable-energy-can-unlock-un-sustainability-goal/.

[5] "The 17 Goals | Sustainable Development," United Nations, accessed February 27, 2021, https://sdgs.un.org/goals.

Table 2 – Sustainable Development Goal 7 Benchmarks

TARGET 7.1	By 2030, ensure universal access to affordable, reliable and modern energy services
TARGET 7.2	By 2030, increase substantially the share of renewable energy in the global energy mix
TARGET 7.3	By 2030, double the global rate of improvement in energy efficiency
TARGET 7.a	By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
TARGET 7.b	By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support

Source: (United Nations Global SDG Database)[6]

The United Nations' Policy Brief #24 described DRE being "renewable energy (solar, wind, small hydro) distributed both through the grid and through mini-grids and off-grid installations."[7] Depending on each area's terrain, access to resources, and technology capability, countries can appropriately customize and size each DRE system. For example, a common DRE system in the United States would be solar panels on rooftops. The energy collected from the panels can power the building it is attached to, and it is independent from the region's main power grid. Smaller grids, also referred to as microgrids, can be separated into either centralized or decentralized systems. Centralized microgrids have a singular microgrid central controller that is responsible for the energy distribution of that region.[8] If the microgrid central controller loses power, the specific units it is responsible for would all be adversely affected. On the other hand, decentralized microgrids contain multiple internal microgrid controllers that are

---

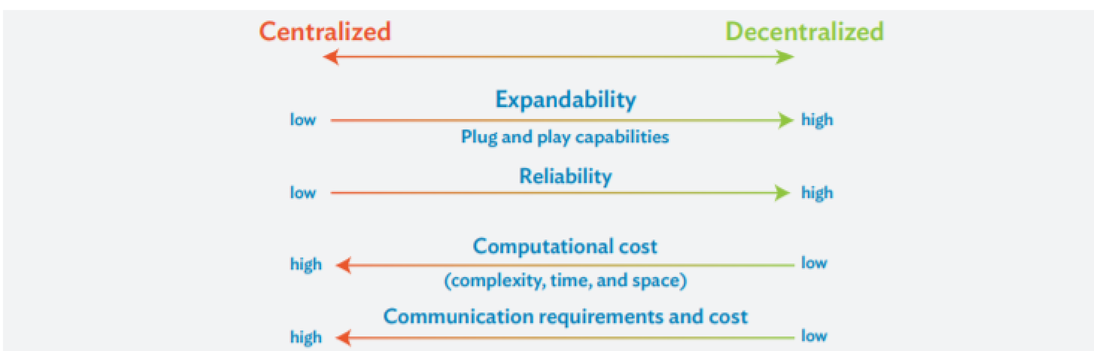
[6] "SDG Indicators," United Nations Global SDG Database, February 19, 2021, https://unstats.un.org/sdgs/indicators/database/.
[7] "Accelerating SDG 7 Achievement Policy Brief 24 Energy Sector Transformation: Decentralized Renewable Energy for Universal Energy Access," U.N. Department of Economic and Social Affairs, 2018, https://sustainabledevelopment.un.org/content/documents/17589PB24.pdf.
[8] "Handbook on Microgrids for Power Quality and Connectivity," *Asian Development Bank*, July 2020, https://www.adb.org/sites/default/files/institutional-document/623446/handbook-microgrids-power-quality-connectivity.pdf.

responsible for each unit they are attached to.[9] This decentralized system makes it easier to control on a smaller level and more resistant to grid outages due to a single point of system failure. Further details regarding the advantages between centralized and decentralized microgrids are shown in the figures below.

Figure 1 – Advantages of Centralized over Decentralized Microgrids

Source: (Solar Energy: Integration of Photovoltaic Systems in Microgrids, 2018)[10]

Figure 2 – Advantages of Decentralized over Centralized Microgrids



Source: (Solar Energy: Integration of Photovoltaic Systems in Microgrids, 2018)[11]

[9] "Handbook on Microgrids for Power Quality and Connectivity," *Asian Development Bank*, July 2020, https://www.adb.org/sites/default/files/institutional-document/623446/handbook-microgrids-power-quality-connectivity.pdf.
[10] "Solar Energy: Integration of Photovoltaic Systems in Microgrids," 2018, accessed February 23, 2021, from https://ocw.tudelft.nl/courses/solar-energy-integration-photovoltaic-systems-microgrids/.
[11] "Solar Energy: Integration of Photovoltaic Systems in Microgrids," 2018, accessed February 23, 2021, from https://ocw.tudelft.nl/courses/solar-energy-integration-photovoltaic-systems-microgrids/.

In order to maximize the many benefits that decentralized renewable energy (DRE) systems offer, countries must implement renewable energy technologies in rural areas. Analysis by the United Nations Development Programme's Rural Energy Development Programme noted the benefits for deploying DRE systems and how they will outweigh the initial costs for installing the systems. DRE systems have the capability to reduce (1) fossil fuels, (2) cost of centralized power generation and distribution, (3) transmission and losses to distribution, (4) power theft problems, (5) peak power demands, and (6) overall costs by decentralizing tariff collections, operations, maintenance, and management.[12] Due to the customizability of DRE, countries modify their systems to different regions depending on availability of resources and equipment. Thus, each country must keep in mind the need and projected economic growth for each area. The United Nations Conference on Trade and Development's Renewable Energy Technologies for Rural Development detailed in 2010 that the use of renewable energy technologies throughout rural areas has increased, in addition to improved access to modern energy services.[13] Renewable energy technologies focus on reducing global carbon emissions by following the guidelines set by the United Nations Framework Convention on Climate Change.[14] Decentralized/distributed energy technologies make it easier to mitigate both "congestion in transmission lines" and fluctuations in electricity

[12] Harish Hande, Surabhi Rajagopal, and Vikshut Mundkur, "Energy for the Poor: Building an Ecosystem for Decentralized Renewable Energy," *Blowing Hard or Shining Bright? Making Renewable Power Sustainable in India*, (2015): 55-63, https://www.brookings.edu/wp-content/uploads/2015/01/renewable-energy_ch7.pdf.
[13] "Renewable Energy Technologies for Rural Development," *Current Studies on Science, Technology, and Innovation*, no. 1 (2010), https://unctad.org/system/files/official-document/dtlstict20094_en.pdf.
[14] "Renewable Energy Technologies for Rural Development," *Current Studies on Science, Technology, and Innovation*, no. 1 (2010), https://unctad.org/system/files/official-document/dtlstict20094_en.pdf.

pricing."[15] These technologies also provide more stable to a country's "energy security" and its electricity grids.[16] For a current power grid, alterations could allow for bypassing the necessity of deploying more generators or battery systems due to the fact that the grid acts as an alternate "generator by providing electricity during downtime."[17] These efforts support the transition to more efficient and modernized energy systems deployed in rural regions.[18] Some benefits include affordable lighting, improved communications, improved health, income growth, equality, and higher education accessibility. If each region alters pre-existing mini-grids accordingly for compatibility, fossil fuel imports may decrease.

Integration of renewable energy sources helps amplify a country's access to energy, and this could result in twice the desired long-term results "in terms of achievement of the [Millennium Development Goals] and the fight against climate change."[19] The International Renewable Energy Agency's global Transforming Energy Scenario notes the potential of addressing demands needed to achieve the desired CO_2 emissions rates. If countries magnify the energy production from renewable sources, there will be less dependence on existing energy systems. Ideally, the production of

---

15 Henerica Tazvinga, Miriam Thopil, Papy B. Numbi, and Temitope Adefarati, "Distributed Renewable Energy Technologies," *Handbook of Distributed Generation*, (2017); 3-67, https://doi:10.1007/978-3-319-51343-0_1.

16 Henerica Tazvinga, Miriam Thopil, Papy B. Numbi, and Temitope Adefarati, "Distributed Renewable Energy Technologies," *Handbook of Distributed Generation*, (2017); 3-67, https://doi:10.1007/978-3-319-51343-0_1.

17 Henerica Tazvinga, Miriam Thopil, Papy B. Numbi, and Temitope Adefarati, "Distributed Renewable Energy Technologies," *Handbook of Distributed Generation*, (2017); 3-67, https://doi:10.1007/978-3-319-51343-0_1.

18 "Distributed Renewable Energy for Energy Access," REN21, accessed February 27, 2021, https://www.ren21.net/gsr-2016/chapter03.php.

19 Gwénaëlle Legros, Kamal Rijal and Bahareh Seyedi, *Decentralized Energy Access and the Millennium Development Goals*, United Nations Development Programme, 2011, http://www.undp.org/content/dam/nepal/docs/reports/UNDP_NP_Decentralized-Energy-Access-and-MDGs.pdf.

renewables would increase from 25% in 2017 to a 2030 target goal of 57% of the world's energy, and renewable energy would replace 29% of energy used.[20] Additionally, renewable energy could result in revenue streams improving if countries maintain grid connections. With increased efficiency in energy usage and cost-effectiveness for microgrids, there are other components that individual regions can add onto the microgrids later down the line.[21] Once implemented into a microgrid, the technologies for distributed energy can prolong the resources during grid outages. In addition to grid outages, forming a reliable source of energy is crucial for the local populations during disasters. Post-COVID recovery measures reported by the International Renewable Energy Agency can ultimately generate a "lasting shift in the global energy mix," and this can be shown at the conclusion of the 2021-2023 recovery phase where an acceleration for energy transition estimates an additional 5.5 million more jobs created.[22]

This paper studies India's efforts with DRE in rural areas to determine whether its renewable energy progress is sufficient to meet the United Nations' SDG7 by the established 2030 deadline. The following section discusses India's progress with general renewable energy efforts. It will also measure India's successes and challenges with DRE systems.

[20] "Post-COVID recovery: An agenda for resilience, development and equality," International Renewable Agency," 2020, https://www.irena.org/publications/2020/Jun/Post-COVID-Recovery.
[21] "Distributed Energy Technologies for Resilience," Office of Energy Efficiency & Renewable Energy, 2019, https://www.energy.gov/eere/femp/distributed-energy-technologies-resilience.
[22] "Post-COVID recovery: An agenda for resilience, development and equality," International Renewable Agency," 2020, https://www.irena.org/publications/2020/Jun/Post-COVID-Recovery.

Literature Review

This literature review summarizes the works used in this paper regarding whether India can meet the objectives towards decentralized renewable energy (DRE). Some authors argue that India is well on its way to achieve the United Nations' Sustainable Development Goals (SDGs) due to its renewable energy efforts. There are other authors, however, who assert that India's past and future challenges will impede the country's ability to meet these goals.

Research Suggesting India Can Use DRE to Meet SDG7

Various pieces of literature discuss India's progress of implementing decentralized renewable energy in rural regions throughout India. Several authors note the potential of DRE benefits and the likelihood of the country meeting the energy objectives of the SDGs. The DRE sector in rural India can be expected to obtain continuous growth for energy access, along with its economic and social sectors, according to the Clean Energy Access Network.[23] Aparna Katre and Arianna Tozzi found that by assessing the sustainability of DRE systems from a technical perspective, they were able to apply a Multi-Tier Framework approach to make it more understandable for policymakers to create strategies towards effective energy policies.[24] This framework measures India's capability of maintaining DRE systems. They rank the tiers and scores

---

[23] Divya Kottadiel, "A shift from energy access to development is transforming the decentralized renewable energy market in India: CLEAN," *Power for All*, September 18, 2019, https://www.powerforall.org/news-media/articles/shift-energy-access-development-transforming-decentralized-renewable-energy-market-clean-report.

[24] Aparna Katre and Arianna Tozzi, "Assessing the Sustainability of Decentralized Renewable Energy Systems: A Comprehensive Framework with Analytical Methods," *Sustainability*, (2018), https://www.mdpi.com/2071-1050/10/4/1058.

under these primary groups: technical sustainability, economic sustainability, institutional sustainability, social sustainability, and environmental sustainability. Benchmarks to determine these sustainability levels include a region's: domestic energy supply, public lighting, energy consumption, livelihood, effectiveness of local governance, community involvement in governance, user satisfaction, and household wellbeing. Katre and Tozzi apply this framework to India, and it provides a comprehensive overview of the country's general sustainability of DRE systems.

In 2020, India's Ministry of New and Renewable Energy stated that it intends to target 175 gigawatts by 2022 for renewable capacity and 450 gigawatts by 2030.[25] Per the SDG Tracker data provided by the World Bank, India's efforts towards rural electrification have been quite notable over the span of the past several years.[26] According to Harish Hande, Surabhi Rajagopal, and Vikshut Mundkur, as well as an article from *Energetica India*, these sources not only highlight lighting systems implemented in India but the emerging presence of DRE systems.[27, 28] The usage of DRE is driving energy solutions throughout the country's rural communities particularly with Energy Service Companies establishing renewable energy-based mini-grid models. Nisha Thirumurthy, Laura Harrington, and Daniel Martin note the potential of India's rural

---

25 Anmar Frangoul, "India has some huge renewable energy goals. But can they be achieved?," *CNBC*, March 03, 2020, https://www.cnbc.com/2020/03/03/india-has-some-huge-renewable-energy-goals-but-can-they-be-achieved.html.

26 "SDG Indicator 7.1.1," SDG Tracker, accessed February 15, 2021, https://sdg-tracker.org/energy.

27 Harish Hande, Surabhi Rajagopal, and Vikshut Mundkur, "Energy for the Poor: Building an Ecosystem for Decentralized Renewable Energy," *Blowing Hard or Shining Bright? Making Renewable Power Sustainable in India*, (2015): 55-63, https://www.brookings.edu/wp-content/uploads/2015/01/renewable-energy_ch7.pdf.

28 "Decentralized Renewable Energy can Drive Modern Electricity System in India," Energetica India, 2019, https://www.world-energy.org/article/5762.html.

areas implementing solar mini-grids.[29] The Jawaharlal Nehru National Solar Mission (JNNSM) set in place by the Ministry of New and Renewable Energy aims to develop two gigawatts of off-grid solar power by 2022. J. K. Jethani, a Principal Scientific Officer from the Ministry of New and Renewable Energy, gave a presentation on the renewable energy framework in India in 2016.[30] Jethani mentions that the JNNSM policy, also known as the National Solar Mission, would further promote the use of solar home lighting systems. The International Energy Agency explained the significance of the JNNSM and how it intends to deploy its systems across India.[31] Other routes for grid-based solutions are also offered by Subhes Bhattacharyya and Debajit Palit.[32] This literature emphasizes the utilization of grids to gather energy more easily and efficiently at the local level, and it details the methodological framework for these grids. With the smaller-scale renewable energy technology, Benjamin Sovacool and Ira Drupady bring up successes and failures from studies.[33] Understanding how and why each system operates depending on region is important, keeping in mind the challenges present before attempting to upscale.

[29] Nisha Thirumurthy, Laura Harrington, and Daniel Martin, "Opportunities and Challenges for Solar Minigrid Development in Rural India," *National Renewable Energy Laboratory*, (September 2012): 1-73, https://www.nrel.gov/docs/fy12osti/55562.pdf.

[30] J. K. Jethani, "Renewable Policy Framework and Wind Energy Programme in India," *Ministry of New and Renewable Energy*, August 22, 2016, https://mnre.gov.in/img/documents/uploads/94e402c36ee44fe29e2b96a6b1b69a30.pdf.

[31] "Jawaharlal Nehru Solar Mission (Phase I, II and III) – Policies," International Energy Agency, last modified April 12, 2018, https://www.iea.org/policies/4916-jawaharlal-nehru-national-solar-mission-phase-i-ii-and-iii.

[32] Subhes C. Bhattacharyya and Debajit Palit, *Mini-Grids for Rural Electrification of Developing Countries: Analysis and Case Studies From South Asia* (Cham: Springer International Publishing, 2014), https://link-springer-com.proxy1.library.jhu.edu/book/10.1007%2F978-3-319-04816-1.

[33] Benjamin K. Sovacool and Ira Martina Drupady, *Energy Access, Poverty, and Development: The Governance of Small-Scale Renewable Energy In Developing Asia* (London: Routledge, 2016), https://doi-org.proxy1.library.jhu.edu/10.4324/9781315579535.

Research Suggesting India Cannot Use DRE to Meet SDG7

Some authors have questioned whether DRE efforts in India are sufficient and practical to overcome challenges presented by the SDGs. They believe that the challenges India faces will keep DRE efforts from being sufficient. Power for All's Director of Research, Dr. Rebekah Shirley, claims that due to the large-scale demand and supply models, it becomes more daunting to efficiently gauge each generation's capacity for implementing DRE. Shirley also states that a setback that the SDGs can face is reluctant acceptance to change by the local population within rural areas. If this is the case with India, then India's progress to meet the SDGs' benchmarks would be hindered by its residents' lack of willingness or comprehension of DRE systems. One piece of the United Nations' literature is under its Policy Brief 24.[34] This brief further details the struggles that the energy sector is facing due to the deployment of DRE systems. Changing the current systems is causing disruptions with implementing newer energy technologies.[35] Alessio Mastrucci *et al*. further emphasize this importance of using DRE to meet the SDG benchmarks.[36] In their article, they argue that the SDGs are too ambitious, and that DRE technologies are necessary to achieve the goal set by SDG7. Additionally, this pushes for the establishment of a regulatory framework to execute a more efficient route for DRE.

---

[34] "Accelerating SDG 7 Achievement Policy Brief 24 Energy Sector Transformation: Decentralized Renewable Energy for Universal Energy Access," *U.N. Department of Economic and Social Affairs*, 2018, https://sustainabledevelopment.un.org/content/documents/17589PB24.pdf.

[35] "Accelerating SDG 7 Achievement Policy Brief 24 Energy Sector Transformation: Decentralized Renewable Energy for Universal Energy Access," *U.N. Department of Economic and Social Affairs*, 2018, https://sustainabledevelopment.un.org/content/documents/17589PB24.pdf.

[36] Alessio Mastrucci, Edward Byers, Shonali Pachauri, and Narasimha D. Rao, "Improving the SDG Energy Poverty Targets: Residential Cooling Needs in the Global South," *Energy and buildings* 186 (2019): 405–415, https://www.journals.elsevier.com/energy-and-buildings.

Additional challenges related to energy are shown by Sujit Jagadale and Manisha Jagadale.[37] A non-government organization, Alternate Energy, focuses on "underdeveloped central India in the field of livelihoods and rural entrepreneurships."[38] While Alternate Energy promotes the necessity of using resources to locally generate energy, it explores the difficulties of balancing this need with not having enough buyers for this energy. Anshuman Gupta and Narendra Dalei explore other challenges.[39] Their work literature observes that while India is experiencing heightened economic growth with more energy usage by non-renewable sources, there has also been an increase in pollution. They explore whether India can propel its renewable energy sources to keep up with increasing globalization. The World Bank's Ejaz Ghani, Arti Goswami, and William Kerr also echo concerns regarding India's pollution levels.[40] It is noted that pollution levels are associated with power outages, and reducing energy consumption strains is crucial to maintaining solutions. Ajay Kumar Vinodia and Dr. Najamuddin additionally highlight the ongoing challenges for rural electrification and implementing microgrids for villages in India as caused by geographic location.[41] This literature weighs how the promotion of DRE systems does not necessarily match up with the execution of these

---

[37] Sujit Raghunathrao Jagadale and Manisha Jagadale, *Creating a Market: Renewable Energy In a Subsistence Marketplace In India* (London: SAGE Publications: SAGE Business Cases Originals, 2018), http://dx.doi.org.proxy1.library.jhu.edu/10.4135/9781526444264.

[38] Sujit Raghunathrao Jagadale and Manisha Jagadale, *Creating a Market: Renewable Energy In a Subsistence Marketplace In India* (London: SAGE Publications: SAGE Business Cases Originals, 2018), http://dx.doi.org.proxy1.library.jhu.edu/10.4135/9781526444264.

[39] Anshuman Gupta and Narendra N. Dalei, *Energy, Environment and Globalization: Recent Trends, Opportunities and Challenges In India* (Singapore: Springer Singapore, 2020), https://www.researchgate.net/publication/335107056_Energy_Environment_and_Globalization_An_Interface.

[40] Ejaz Ghani, Arti Grover Goswami, and William R. Kerr, "Spatial Dynamics of Electricity Usage In India," ResearchGate, 2014, https://doi-org.proxy1.library.jhu.edu/10.1596/1813-9450-7055.

[41] Ajay Kumar Vinodia and Dr. Najamuddin, "Promotion of Renewable Energy in Rural India," *ITPI Journal* 3, no. 2 (2006): 21-28, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.575.6918&rep=rep1&type=pdf#:~:text=India%20is%20endowed%20with%20abundant,the%20generation%20of%20wind%20energy.

systems. The systems must also take into consideration other factors such as building designs to reduce energy consumption. According to Nallapaneni Kumar *et al*., India could face difficulties with DRE systems due to the sporadic nature of the resources that cause unreliable electricity.[42] With this in mind, additional systems such as energy storage systems, must be deployed for better reliability. In Julian Sagebiel *et al*.'s work, they observe the quality and efficiency of India's rural supply for electricity, noting challenges of availability for the urban electrical energy supply.[43] These electrical energy supplies were poor-quality and expensive to maintain, and there was a power-supply shortage in the power sector. Additionally, the lack of government support may not only result in less DRE systems installed, but the systems could also be faulty or poorly maintained. These challenges are expected to inhibit India's development in its energy sector.

To further support this statement, as noted by Lanvin Concessao, Dheeraj Kumar Gupta, and Pamli Deka of the World Resources Institute, a healthcare facility in Eastern India, recently deployed a DRE system to address its area's irregular power supply and power fluctuations.[44] India installed photovoltaic (PV) solar systems to provide stable electricity for critical-care services during the ongoing COVID-19 pandemic. Natural disasters in the area forced the hospital to rely on diesel generators for power which

---

[42] Nallapaneni M. Kumar, Chopra, Shauhrat S., Chand, Aneesh A., Elavarasan, Rajvikram M., Shafiullah, G.M. 2020, "Hybrid Renewable Energy Microgrid for a Residential Community: A Techno-Economic and Environmental Perspective in the Context of the SDG7," *Sustainability* 12, no. 10: 3944, https://doi.org/10.3390/su12103944.

[43] Julian Sagebiel *et al.*, *Enhancing Energy Efficiency In Irrigation: A Socio-Technical Approach In South India* (Cham: Springer International Publishing, 2016), https://link-springer-com.proxy1.library.jhu.edu/book/10.1007%2F978-3-319-22515-9.

[44] Lanvin Concessao, Dheeraj Kumar Gupta, and Pamli Deka, "Solar Power: A Rural Indian Hospital's Key to Fighting COVID-19," *World Resources Institute*, July 14, 2020, https://www.wri.org/blog/2020/07/renewable-energy-rural-hospital-coronavirus.

became very expensive for the hospital to maintain as well as polluting the surrounding area. This type of DRE deployment has provided an example to other rural healthcare communities on how to address energy needs to ensure critical services can be reliably sustained. India continues to need further rural electrification, according to Kartik Arunachalam, Venkateswaran Sankaran Pedinti, and Sanket Goel.[45] By providing greater access to renewable energy resources, this decreases the "Transmission and Distribution (T&D) losses."[46]

[45] Kartik Arunachalam, Venkateswaran Sankaran Pedinti, and Sanket Goel, "Decentralized distributed generation in India: A review," *Journal of Renewable and Sustainable Energy* 8, no. 2 (2016), https://doi:10.1063/1.4944966.
[46] Kartik Arunachalam, Venkateswaran Sankaran Pedinti, and Sanket Goel, "Decentralized distributed generation in India: A review," *Journal of Renewable and Sustainable Energy* 8, no. 2 (2016), https://doi:10.1063/1.4944966.

Methods

This paper assesses whether India's efforts of deploying smaller-scale energy sources is sufficient to achieve the United Nations' Sustainable Development Goals 7 (SDG7). In order to determine whether rural India is on track to meet the SDG7 benchmarks, this research paper will measure three main factors: (1) access to electricity, (2) usage of clean fuels and sources, and (3) renewable energy consumption. This research will primarily pull from India's energy data from its rural regions to observe its rate of progress over the span of approximately the past decade.

Data

This paper uses data from the rates of energy and electrification throughout India's rural regions. The research observes case studies (inside and outside of India) and published reports to determine the progression of India's efforts towards decentralized renewable energy primarily over the past decade.

First, the research pulls data from the United Nations. It breaks down the SDG7 benchmarks (both urban and rural) for evaluating electricity access rate, clean cooking access rate, energy consumption, energy intensity, and international commitments.[47] Below is a table noting India's energy consumption in 2017.

Table 3 - India's Energy Consumption (2017)

Share in total final energy consumption (%)										Final consumption of renewable energy (PJ)		
Renewable Energy	Solid biofuels	Liquid biofuels	Biogases	Hydro	Tide	Wind	Solar	Geothermal	Municipal waste (renew)	Electricity consumption (1)	Heat raising (2)	Transport (3)
32.2	29.3	0.1	0	1.7	0	0.6	0.5	0	0	711.7	6614.5	25.6

Source: (International Bank for Reconstruction and Development)[48]

[47] "Accelerating SDG 7 Achievement Policy Brief 24 Energy Sector Transformation: Decentralized Renewable Energy for Universal Energy Access," *U.N. Department of Economic and Social Affairs*, 2018, https://sustainabledevelopment.un.org/content/documents/17589PB24.pdf.

[48] "Tracking SDG7: The Energy Progress Report 2020," International Bank for Reconstruction and Development, 2020, https://trackingsdg7.esmap.org/data/files/download-documents/tracking_sdg_7_2020-full_report_-_web_0.pdf.

To further explain India's energy capabilities, the Clean Energy Access Network report notes that DRE systems in India have been improving with increases in energy access, economic growth, and social growth. From 2000 to 2007, it was noted that India's economy improved by approximately 77% alongside an increase of 60% in electricity consumption.[49] Recent developments, such as with "solar dryers, freezers, sewing machines...have had uptake in both rural and peri-urban markets, but also created new jobs and avenues for skills development."[50]

Measuring the reliability of grids, the World Bank and the Energy Sector Management Assistance Program use the Multi-Tier Framework to analyze the technical sustainability of about 40 off-grid DRE systems. The Multi-Tier Framework "takes into account...system capacity, durability, quality, reliability, affordability, legality, and safety" while ensuring that regulators can properly audit system logs and data.[51] Sustainability data from all major companies are recorded and fitted to a model for measuring sustainability and impact. The data is split to help validate and update the model as the framework collects additional information. The International Institute for Environment and Development enacted policies to extend the availability of energy services to many rural areas, and it also included small and medium-sized enterprises in proposed policies to further these energy initiatives.

---

[49] Shahidur R. Khandker, Douglas F Barnes, and Hussain A Samad, *Energy Poverty In Rural and Urban India: Are the Energy Poor Also Income Poor?*, Washington, D.C.: The World Bank, 2010, https://www.researchgate.net/publication/228268126_Energy_Poverty_in_Rural_and_Urban_India_Are_the_Energy_Poor_also_Income_Poor.

[50] Divya Kottadiel, "A shift from energy access to development is transforming the decentralized renewable energy market in India: CLEAN," *Power for All*, September 18, 2019, https://www.powerforall.org/news-media/articles/shift-energy-access-development-transforming-decentralized-renewable-energy-market-clean-report.

[51] Aparna Katre and Arianna Tozzi, "Assessing the Sustainability of Decentralized Renewable Energy Systems: A Comprehensive Framework with Analytical Methods," *Sustainability*, (2018), https://www.mdpi.com/2071-1050/10/4/1058.

As access to electricity is one of the main components of SDG7, the United Nations Conference on Trade and Development also notes the significance of the generated electricity supply pulled from "wind, solar, water, tide/wave and geothermal, and the provision of other modern energy services" that are required for every day "activities such as household heating, space conditioning and water pumping."[52] The importance of access to electricity and the capability of rural electrification underscores how the lack of access can be expected to negatively impact SDG7.[53] The interdependencies between these sectors creates interlinkages between the SDGs themselves. With the current COVID-19 pandemic ravaging the planet, it has highlighted the necessity for reliable energy to power healthcare facilities to treat those infected in third-world countries.

This paper acknowledges the challenges that the pandemic brings, potentially hindering India's progress. There are reports regarding global efforts with applying DRE systems. In November 2020, The Rockefeller Foundation stated it would invest $1 billion into expanding healthcare access as well as renewable energy "across Africa, Asia, and Latin America."[54] This financial assistance catalyzes a "more inclusive, climate-friendly recovery" from COVID-19, intending to aid over 800 million people who were adversely affected by energy poverty.[55] The pandemic amplified the gap for energy accessibility,

---

[52] "Renewable Energy Technologies for Rural Development," *Current Studies on Science, Technology, and Innovation*, no. 1 (2010), https://unctad.org/system/files/official-document/dtlstict20094_en.pdf.
[53] Ming Yang, "Rural Electrification: GEF Experience in Renewables-based Microgrids," The Global Environment Facility, 2017, https://www.thegef.org/sites/default/files/documents/GEF-Paper-Inestment-in-Mini-grid-power-Sept-1-2017-V2.pdf.
[54] "Online Event: A Conversation with Rajiv J. Shah: A Vision for Equitable Recovery," Center for Strategic and International Studies, 2020, https://www.csis.org/events/online-event-conversation-rajiv-j-shah-vision-equitable-recovery.
[55] "Online Event: A Conversation with Rajiv J. Shah: A Vision for Equitable Recovery," Center for Strategic and International Studies, 2020, https://www.csis.org/events/online-event-conversation-rajiv-j-shah-vision-equitable-recovery.

and more than 100 million people were unable to pay their electric bills.[56] The World Bank estimates that up to 150 million people will experience "extreme poverty" due to the pandemic.[57,58] The Rockefeller Foundation also partnered with Tata Power for the TP Renewable Microgrid with the intent to deploy up to 10,000 mini-grids through 2026 for "5 million households, create 10,000 new green jobs, support 100,000 rural enterprises, [and] deliver irrigation to 400,000 farmers."[59] As of 2018, about 90% of the global population acquired access to electricity and by 2030, the number will rise to 97%.[60] This report did not take into account the COVID-19 pandemic.

Narrowing down with a COVID-19 study in India, the Nav Jivan Hospital required additional electricity capacity in response to individuals affected by the pandemic. Since stabilizing critical medical operations is crucial where patients need ventilators, this situation turned problematic when there was an "erratic electric supply and regular voltage fluctuations."[61] In response during early 2020, this hospital installed a 10-kWp solar PV system. According to the SDG Tracker data by the World Bank, India's

---

56 "The Rockefeller Foundation commits US$1 billion to catalyse a green recovery from pandemic," The Rockefeller Foundation, October 27, 2020, https://www.eco-business.com/press-releases/the-rockefeller-foundation-commits-us1-billion-to-catalyse-a-green-recovery-from-pandemic/.

57 Stéphanie Hallegatte, and Brian Walsh, "COVID, climate change and poverty: Avoiding the worst impacts," World Bank, October 07, 2020, https://blogs.worldbank.org/climatechange/covid-climate-change-and-poverty-avoiding-worst-impacts.

58 "COVID-19 to Add as Many as 150 Million Extreme Poor by 2021," The World Bank, October 07, 2020, https://www.worldbank.org/en/news/press-release/2020/10/07/covid-19-to-add-as-many-as-150-million-extreme-poor-by-2021.

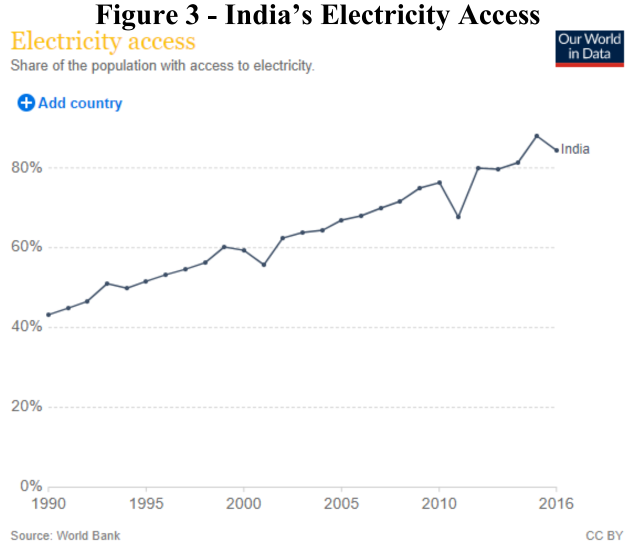
59 "Tata Power and The Rockefeller Foundation Announce Breakthrough Enterprise to Empower Millions of Indians with Renewable Microgrid Electricity," The Rockefeller Foundation, November 04, 2019, https://www.rockefellerfoundation.org/news/tata-power-rockefeller-foundation-announce-breakthrough-enterprise-empower-millions-indians-renewable-microgrid-electricity/.

60 "Tracking SDG7: The Energy Progress Report 2020," International Bank for Reconstruction and Development, 2020, https://trackingsdg7.esmap.org/data/files/download-documents/tracking_sdg_7_2020-full_report_-_web_0.pdf.

61 Lanvin Concessao, Dheeraj Kumar Gupta, and Pamli Deka, "Solar Power: A Rural Indian Hospital's Key to Fighting COVID-19," *World Resources Institute*, July 14, 2020, https://www.wri.org/blog/2020/07/renewable-energy-rural-hospital-coronavirus.

access to electricity in rural areas was 68% in 2010 and 93% in 2018.[62] This source includes more in-depth data for electricity access every two years, noting India's gradual increase in access rates.

Figure 3 - India's Electricity Access



Source: (International Bank for Reconstruction and Development)[63]

With India's high renewable energy potential, the country predicts that by 2050, 60% of the country's overall electricity supply can implement renewable energy, on the condition that the government provides appropriate policy backing.[64] To further these efforts, the Ministry of New Renewable Energy placed rural electrification initiatives in Maharashtra with DRE systems. The government of Maharashtra signed a memorandum of understanding in 2005-2006 with eight private businesses to bolster the electricity

---

62 "SDG Indicator 7.1.1," SDG Tracker, accessed February 15, 2021, https://sdg-tracker.org/energy.

63 "Tracking SDG7: The Energy Progress Report 2020," International Bank for Reconstruction and Development, 2020, https://trackingsdg7.esmap.org/data/files/download-documents/tracking_sdg_7_2020-full_report_-_web_0.pdf.

64 Anand Deshmukh, "The Role of Decentralized Renewable Energy for Rural Electrification" (MS thesis, University of the Aegean, Central European University, Lund University, and University of Manchester, 2009), 1-76, https://core.ac.uk/download/pdf/289931446.pdf.

generation capacity by 12,500 MW.[65] The tables below compare data from the Maharashtra State Electricity Distribution Company Ltd., noting changes for both demand and availability.

Table 4 – Demand Supply in Maharashtra

	2002-2003	**2003-2004**	**2004-2005**	**2005-2006**	**2006-2007**	**2007-2008**	**2008-2009** (up to 03/23/2009)
Demand	11,425	11,357	12,749	14,061	14,825	15,689	15,656
Availability	9,004	9,315	9,704	9,856	10,298	10,412	10,715
Shortfall	2,421	2,042	3,045	4,205	4,527	5,277	4,941

Source: (Deshmukh)[66]

[65] Anand Deshmukh, "The Role of Decentralized Renewable Energy for Rural Electrification" (MS thesis, University of the Aegean, Central European University, Lund University, and University of Manchester, 2009), 1-76, https://core.ac.uk/download/pdf/289931446.pdf.

[66] Anand Deshmukh, "The Role of Decentralized Renewable Energy for Rural Electrification" (MS thesis, University of the Aegean, Central European University, Lund University, and University of Manchester, 2009), 1-76, https://core.ac.uk/download/pdf/289931446.pdf.

Table 5 – Actual Additions to Renewable Energy Generation in Maharashtra (2007-2008)

RE Sources	Cumulative Achievement (up to 03/31/2007)	Achievement in 2007-2008	Cumulative Achievement (up to 03/31/2008)
Solar PV Systems			
SPV Lantern (No.s)	11,231	3,423	14,654
SPV Street Lights (No.s)	2,933	2,351	5,102
SPV Domestic Lights (No.s.)	1,567	1,134	2,701
SPV Pumps (No.s)	228	0	228
Total Solar PV Systems	15,959	6,908	22,685
Solar Thermal Systems (No.s)	48,765	12	48,777
Biogas Program (No.s of plants)	459	0	459
Biogas Program (No.s of improved crematoria and chulha)	433,475	0	433,475
Wind (No.s of monitoring stations)	112	50	162

Source: (Deshmukh)[67]

India installed lighting systems such as solar lanterns, and approximately 1.3 million products related to off-grid solar systems were sold during the first half of 2018.[68,69] The benefits of using DRE for rural electrification are further emphasized in Anand Deshmukh's study from Maharashtra.[70] The Veolia Institute's publication

[67] Anand Deshmukh, "The Role of Decentralized Renewable Energy for Rural Electrification" (MS thesis, University of the Aegean, Central European University, Lund University, and University of Manchester, 2009), 1-76, https://core.ac.uk/download/pdf/289931446.pdf.

[68] Harish Hande, Surabhi Rajagopal, and Vikshut Mundkur, "Energy for the Poor: Building an Ecosystem for Decentralized Renewable Energy," *Blowing Hard or Shining Bright? Making Renewable Power Sustainable in India*, (2015): 55-63, https://www.brookings.edu/wp-content/uploads/2015/01/renewable-energy_ch7.pdf.

[69] "Decentralized Renewable Energy can Drive Modern Electricity System in India," Energetica India, 2019, https://www.world-energy.org/article/5762.html.

[70] Anand Deshmukh, "The Role of Decentralized Renewable Energy for Rural Electrification" (MS thesis, University of the Aegean, Central European University, Lund University, and University of Manchester, 2009), 1-76, https://core.ac.uk/download/pdf/289931446.pdf.

highlighted other studies, noting the DRE development and implementation, as well as the use of mini-grids, energy kiosks for electrification, and any organizational issues that potentially impact upscaling.[71] The Ministry of New and Renewable Energy submitted a proposal in October 2020 outlining a framework for promoting the deployment of DRE systems throughout rural regions. Its proposal provides a more market-oriented approach, appealing to private sectors to create applications that would offer efficient access to "end user finance, introduce standards, monitoring and evaluation mechanisms."[72]

Table 6 – India's Energy Statistics

Access to Electricity 2018 (% of population with access)	**Access to Clean Cooking 2018** (% of population with access)	**Renewable Energy 2017** (% of Total Final Energy Consumption)	**Energy Efficiency 2017** (MJ per US$ PPP 2011)
95	49	32	4.2 (out of 5.0 Global Average)

Source: (Energy Sector Management Assistance Program)[73]

To be more active in these efforts, the International Institute for Environment and Development provides studies to illustrate how DRE policies can effectively incentivize entities in the markets.[74] With variables such as businesses becoming more involved, it is expected that India's economic growth will increase. Another aspect of proactiveness can be seen in Lanvin Concessao, Dheeraj Kumar Gupta, and Pamli Deka's article of the

[71] "Decentralized Electrification and Development," *Field Actions Science Reports*, no. 15 (2016): 1-168, https://www.institut.veolia.org/en/nos-publications/la-revue-de-linstitut-facts-reports/decentralized-electrification-and-development.
[72] "MNRE proposes draft policy for promoting distributed renewable energy," ETEnergyWorld, October 20, 2020, https://energy.economictimes.indiatimes.com/news/renewable/mnre-proposes-draft-policy-for-promoting-distributed-renewable-energy/78761631.
[73] "India," Tracking SDG7: The Energy Progress Report, Energy Sector Management Assistance Program, 2018, https://trackingsdg7.esmap.org/country/india.
[74] "Policies to Spur Energy Access: Volume 2 Case Studies of Public-Private Models to Finance Decentralized Electricity Access," *National Renewable Energy Laboratory*, (September 2015): 1-107, https://www.nrel.gov/docs/fy15osti/64460-2.pdf.

World Resources Institute.[75] While they focus on how India is taking care of patients during the pandemic by using PV solar systems, they highlight the importance of improved healthcare delivery systems and updated financing models. With improved models, the country's potential for economic growth will increase and improve energy poverty conditions. Shahidur Khandker, Douglas Barnes, and Hussain Samad discuss how the energy poverty line is associated with varying levels of household income.[76] They pulled cross-sectional data from surveys conducted in rural and urban areas of India to evaluate the effectiveness of programs in reducing energy poverty.

Additionally, this paper uses data regarding India's efforts of installing DRE systems and energy hubs. The country intended to combat the issue of many residents in rural India being unable to connect to the main national grid. In 2005, India implemented the Rajiv Gandhi Grameen Vidyutikaran Yojana scheme (RGGVY) for increasing rural access to electricity.[77] Then in 2010, the Solar Energy Corporation of India initiated the Jawaharlal Nehru National Solar Mission (JNNSM) policy (referred to as the National Solar Mission). The JNNSM policy promoted the use of solar home lighting systems,

---

[75] Lanvin Concessao, Dheeraj Kumar Gupta, and Pamli Deka, "Solar Power: A Rural Indian Hospital's Key to Fighting COVID-19," *World Resources Institute*, July 14, 2020, https://www.wri.org/blog/2020/07/renewable-energy-rural-hospital-coronavirus.

[76] Shahidur R. Khandker, Douglas F. Barnes, and Hussain A. Samad, "Energy Poverty In Rural and Urban India: Are the Energy Poor Also Income Poor?," ResearchGate, 2010, https://www.researchgate.net/publication/228268126_Energy_Poverty_in_Rural_and_Urban_India_Are_the_Energy_Poor_also_Income_Poor.

[77] Shahidur R. Khandker, Hussain A. Samad, Rubaba Ali, and Douglas F. Barnes, "Who Benefits Most from Rural Electrification? Evidence in India," *The Energy Journal* 35, no. 2 (2014): 75-96, accessed February 8, 2021, http://www.jstor.org/stable/24695761.

solar water pumps, and mini-grids.[78,79] The JNNSM photovoltaics (PV) policy's goal phases are in the table below.

Table 7 – JNNSM PV Goals

Phase I (2010 – 2013)	Target for grid-connected PV (including rooftop) target: 1,000 MW
	Target for off-grid solar PV applications: 200 MW
Phase II (2014 – 2017)	Cumulative target for grid-connected solar PV (including rooftop): 4,000 – 10,000 MW
	Target for off-grid solar PV applications: 1,000 MW
	Scheme for ≥ 25 solar parks (34 approved currently under Gov't), and Ultra Mega Solar Power Projects to target 40 GW solar PV
Phase III 13th Plan (2017 – 2022)	Cumulative target for grid-connected solar PV (including rooftop): 100,000 MW
	Target for off-grid solar PV applications (as share of cumulative): 2,000 MW

Source: (International Energy Agency)[80]

By applying innovative generation methods, systems can harness energy directly from its natural sources.[81] With these efforts in place, each region would establish a more communicative and reliable infrastructure. Taking this into consideration, India's rural areas will ideally improve its annual rates related to electricity, clean fuels, and energy consumption. The below tables detail India's annual data for each of the SDG7 benchmarks.

---

78 J. K. Jethani, "Renewable Policy Framework and Wind Energy Programme in India," *Ministry of New and Renewable Energy*, August 22, 2016, https://mnre.gov.in/img/documents/uploads/94e402c36ee44fe29e2b96a6b1b69a30.pdf.

79 "Jawaharlal Nehru Solar Mission (Phase I, II and III) – Policies," International Energy Agency, last modified April 12, 2018, https://www.iea.org/policies/4916-jawaharlal-nehru-national-solar-mission-phase-i-ii-and-iii.

80 "Jawaharlal Nehru Solar Mission (Phase I, II and III) – Policies," International Energy Agency, last modified April 12, 2018, https://www.iea.org/policies/4916-jawaharlal-nehru-national-solar-mission-phase-i-ii-and-iii.

81 Harish Hande, Surabhi Rajagopal, and Vikshut Mundkur, "Energy for the Poor: Building an Ecosystem for Decentralized Renewable Energy," *Blowing Hard or Shining Bright? Making Renewable Power Sustainable in India*, (2015): 55-63, https://www.brookings.edu/wp-content/uploads/2015/01/renewable-energy_ch7.pdf.

Table 8 – Proportion of India's Rural Population with Access to Electricity (%)

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
66	68	56	72	73	77	83	85	89	92	96

Source: (United Nations Global SDG Database)[82]

Estimated data. Refer to Figure 4 for projected data

Table 9 – Proportion of India's Overall Population with Primary Reliance on Clean Fuels & Technology (%)

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
34	35	37	39	42	45	48	52	56	60	64

Source: (United Nations Global SDG Database)[83]

Estimated data. Refer to Figure 5 for projected data

Table 10 – Renewable Energy Share in Worldwide Energy Consumption (%)

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
42	41	40	39	38	36	34	33	32	32	-

Source: (United Nations Global SDG Database)[84]

Estimated data. Refer to Figure 6 for projected data + additional pie charts for energy consumption

Table 11 – Energy Intensity Level of Primary Energy (Megajoules Per Constant 2011 Purchasing Power Parity GDP)

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
5.77	5.62	5.59	5.54	5.29	5.2	4.89	4.61	4.46	4.38	-

Source: (United Nations Global SDG Database)[85]

Estimated data. Refer to Figure 9 for projected data

[82] "SDG Indicators," United Nations Global SDG Database, February 19, 2021, https://unstats.un.org/sdgs/indicators/database/.
[83] "SDG Indicators," United Nations Global SDG Database, February 19, 2021, https://unstats.un.org/sdgs/indicators/database/.
[84] "SDG Indicators," United Nations Global SDG Database, February 19, 2021, https://unstats.un.org/sdgs/indicators/database/.
[85] "SDG Indicators," United Nations Global SDG Database, February 19, 2021, https://unstats.un.org/sdgs/indicators/database/.

Table 12 – Int’l Funds to Developing Countries for Clean Energy R&D and Renewable Energy Production (Per Million)

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
218	315	1,931	1,150	524	703	930	2,173	834	2,134	-

Source: (United Nations Global SDG Database)[86]

Estimated data. Refer to Figure 10 for projected data

Table 13 – Installed Renewable Electricity-Generating Capacity (Watts Per Capita)

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
276	284	289	296	303	318	333	358	371	389	405

Source: (United Nations Global SDG Database)[87]

Estimated data. Refer to Figure 11 for projected data

A more detailed look at the projection of these numbers by 2030 will be observed in the discussion section of this paper.[88]

[86] “SDG Indicators,” United Nations Global SDG Database, February 19, 2021, https://unstats.un.org/sdgs/indicators/database/.
[87] “SDG Indicators,” United Nations Global SDG Database, February 19, 2021, https://unstats.un.org/sdgs/indicators/database/.
[88] Refer to Figures 4-11 in the Discussion section.

Discussion

This portion of the paper will explore the data presented in the previous section. First, it will detail India's progress towards completing SDG7 by 2030. Second, it will present inhibiting factors India faces on the way of achieving this objective. Third, it will provide an overall assessment of this research to determine India's capability of using DRE systems towards SDG7.

India's Progress Towards SDG7

There are several examples of India's renewable energy efforts towards SDG7. India established the Jawaharlal Nehru National Solar Mission (JNNSM), and it highlighted the importance of combining both "credit financing and subsidies" to make it more affordable for end users.[89] In 2011, India spent about $4.86 billion a year (INR 243 billion) on energy.[90] India's solar resources are intended to be used on a much wider scale by its residents. By 2022, the JNNSM's initial objective was to deploy "20 gigawatts (GW) of grid-connected solar power and 2 GW of off-grid solar."[91] However, since India surpassed this goal by 2018, the JNNSM increased the goal to 100 gigawatts. By achieving this, India is closer to being established as a "global leader in solar energy by

---

[89] J. K. Jethani, "Renewable Policy Framework and Wind Energy Programme in India," *Ministry of New and Renewable Energy*, August 22, 2016, https://mnre.gov.in/img/documents/uploads/94e402c36ee44fe29e2b96a6b1b69a30.pdf.

[90] Nisha Thirumurthy, "Opportunities and Challenges for Solar Minigrid Development In Rural India," Golden, Colo.: National Renewable Energy Laboratory, 2012, https://dx.doi.org/10.2172/1052904, https://www.osti.gov/servlets/purl/1052904.

[91] Nisha Thirumurthy, "Opportunities and Challenges for Solar Minigrid Development In Rural India," Golden, Colo.: National Renewable Energy Laboratory, 2012, https://dx.doi.org/10.2172/1052904, https://www.osti.gov/servlets/purl/1052904.

creating the policy conditions for its deployment across the country."[92] There is potential for smaller-scale DRE programs to replace or improve pre-existing grid extension programs. The solar energy sector has given further support with promoting and implementing these small-scale market-based DRE systems. Solar PV mini-grids have high potential since the designs are cost-effective and reliable through "load profiling, resource profiling and load categorization."[93]

Additionally, Clean Energy Access Network notes that DRE systems need a well-thought-out grid policy by local governments, as well as increased awareness to the public in order to be effective. If the turn-around times are not improved and developed, the growing demand for DRE applications will outpace the time needed to implement these systems. According to the 2019 report, about 78% of surveyed enterprises "changed their business models as a result of government initiatives."[94] As a result, DRE programs have been thriving due to India establishing an aggressive public policy and strong belief in the technology. For instance, initiatives created by Smart Power India have helped individuals establish businesses to oversee local DRE. With prospects of stable revenue, many businesses are expanding to create reliable energy grids.[95] The Global Environment Facility details concepts of newer technology, project investment, and effective

---

[92] "Jawaharlal Nehru Solar Mission (Phase I, II and III) – Policies," International Energy Agency, last modified April 12, 2018, https://www.iea.org/policies/4916-jawaharlal-nehru-national-solar-mission-phase-i-ii-and-iii.

[93] Subhes C. Bhattacharyya, and Debajit Palit, *Mini-Grids for Rural Electrification of Developing Countries: Analysis and Case Studies From South Asia*, Cham: Springer International Publishing, 2014, https://link-springer-com.proxy1.library.jhu.edu/book/10.1007%2F978-3-319-04816-1.

[94] Divya Kottadiel, "A shift from energy access to development is transforming the decentralized renewable energy market in India: CLEAN," *Power for All*, September 18, 2019, https://www.powerforall.org/news-media/articles/shift-energy-access-development-transforming-decentralized-renewable-energy-market-clean-report.

[95] Susie Wheeldon, "Decentralized Renewables & The Rise of the Micro-Enterprise Economy," Renewable Energy World, August 19, 2016, https://www.renewableenergyworld.com/2016/08/19/decentralized-renewables-the-rise-of-the-micro-enterprise-economy/.

technology transfer components for renewable energy-based microgrids. For example, the country's agrifood sector can greatly benefit from the technology. If countries implement this newer and cleaner technology, the agrifood sector can (1) increase efficiency with using water towards more affordable and cleaner energy, including energy-smart food and (2) improve freshwater conservation, inevitably stimulating a more circular economy.[96] Furthermore, the United Nations secretariat mentions there are opportunities throughout the agrifood sector available to meet water and energy demands with off-grid and decentralized energy systems.[97] This approaches the topic from an analytical perspective regarding energy-smart solutions and how they affect sustainable food production.

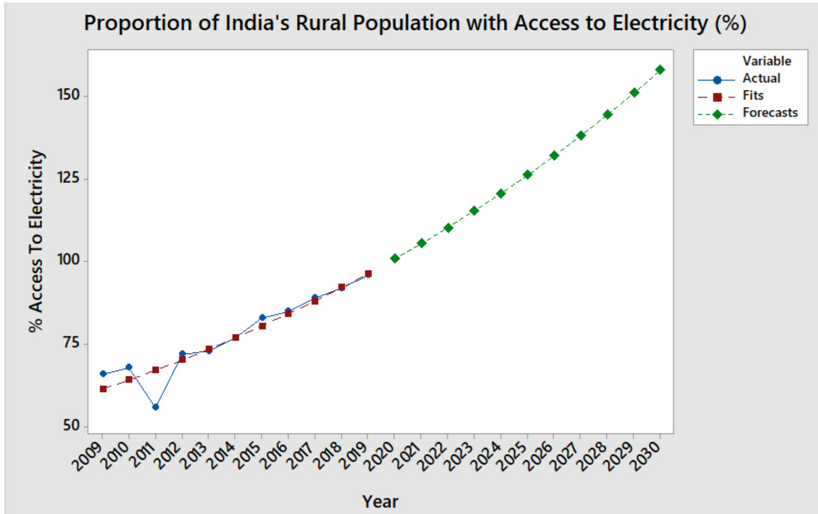
According to the statistics pulled from the United Nations database, India is making great strides towards SDG7 contributions. The graphs below are created from the United Nations' 2009-2019 data mentioned in the previous section to measure the three factors: (1) access to electricity, (2) usage of clean fuels and sources, and (3) renewable energy consumption. Figures 4 and 5 pertain to the 7.1 benchmark. Figure 6 with the two supplemental pie charts pertain to the 7.2 benchmark. Figure 9 pertains to the 7.3 benchmark. Figure 10 pertains to the 7.a benchmark. Figure 11 pertains to the 7.b benchmark.

---

[96] "The 17 Goals | Sustainable Development," United Nations, accessed February 27, 2021, https://sdgs.un.org/goals.

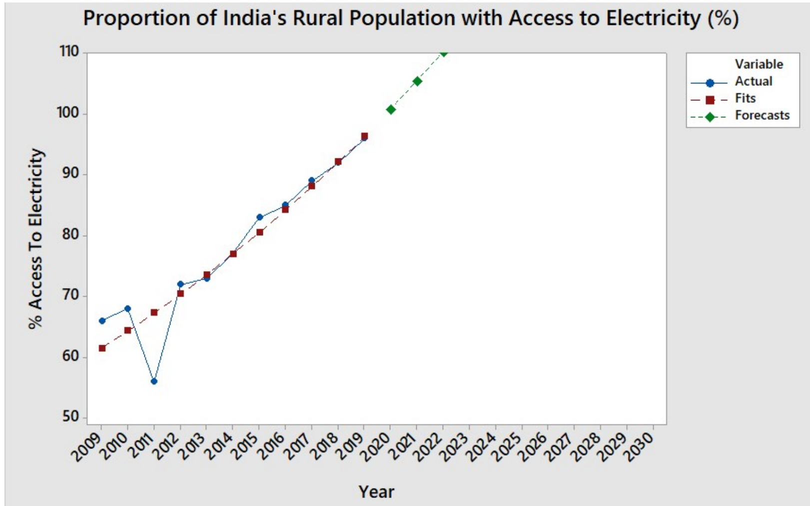
[97] "Off-grid and decentralized energy solutions for smart energy and water use in the agrifood chain," United Nations Framework Convention on Climate Change, January 06, 2020, https://unfccc.int/documents/208414.

Figure 4 – 7.1 Benchmark Graph (of Table 8)



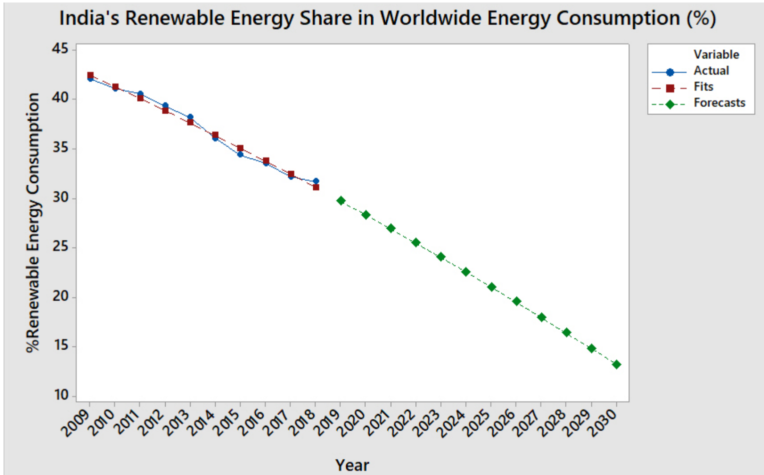
In 2009, the rate was about 65% and by 2019, the rate was about 96%. According to this forecast, India seems to be projected to reach near complete electrification for its rural areas, with the exponential graph estimating full rural electrification by roughly 2021 or 2022. With the COVID-19 pandemic, however, the margin may be slightly skewed, and India's progress can be expected to be pushed back.

Figure 5 – 7.1 Benchmark Graph (of Table 9)



With India's increasing rate for its overall (rural and urban) population relying on clean fuels and technology, this number is expected to reach 100% by 2025.

Figure 6 – 7.2 Benchmark Graph (of Table 10)



This graph shows a decreasing trend line which may suggest that other countries have been increasing their consumption of energy from renewable sources since 2013 while India has not expanded. It would be difficult for India to substantially increase its share of renewable energy consumption with this projected rate. However, an important thing to note is that this decrease in percentage does not necessarily mean that India is consuming less renewable energy. There is the possibility that India's energy demand is outpacing the renewable energy generation.

Figure 7 – Total Energy Consumption in India (2013)

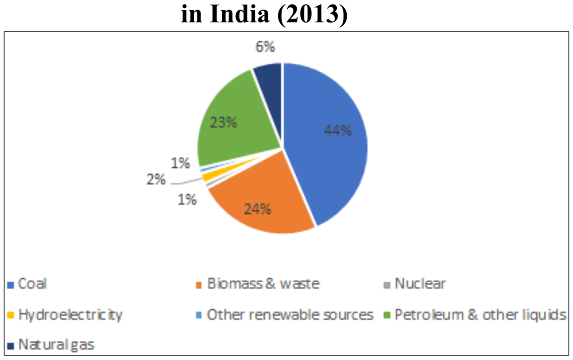
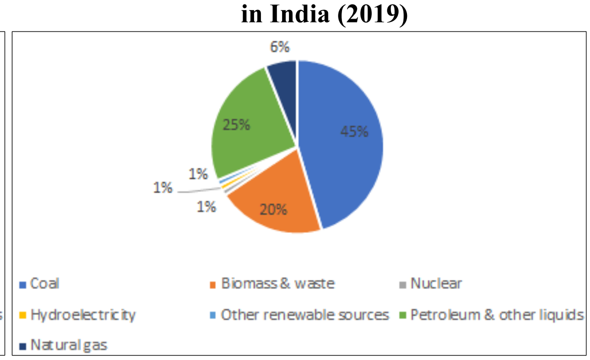


Figure 8 – Total Energy Consumption in India (2019)

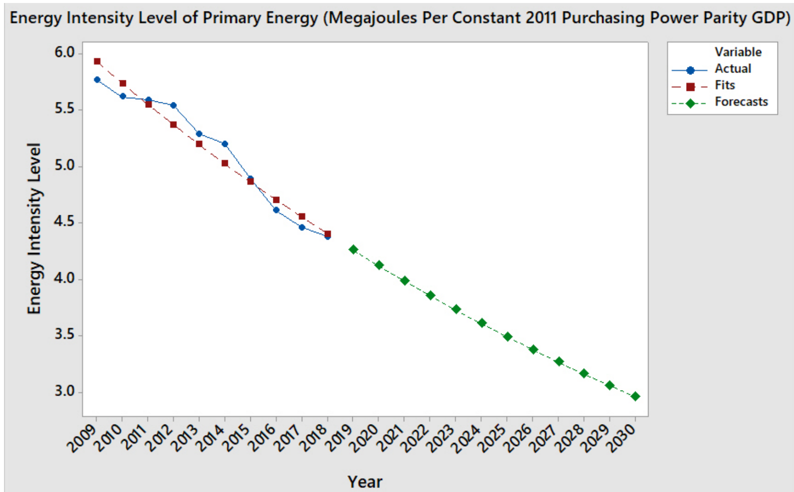


Source: (International Energy Agency)[98]

These pie charts compare India's total energy consumption. In 2013, 33% was from renewables and by 2019, that number decreased to 30%.

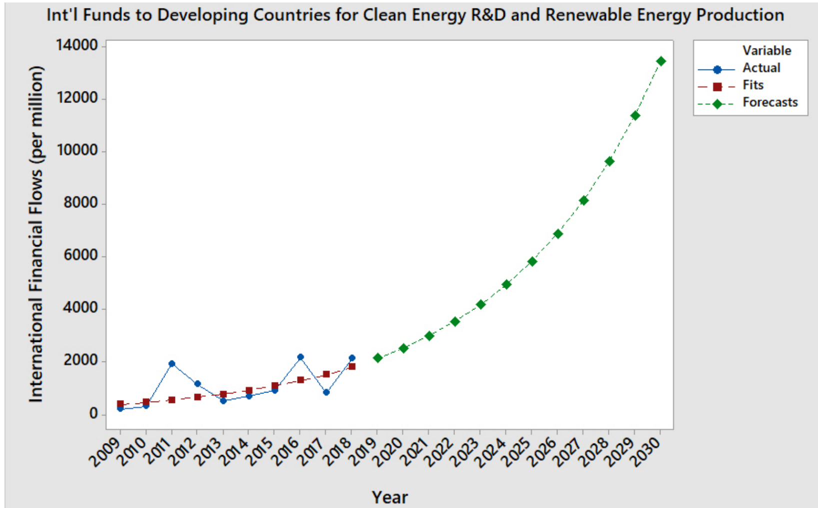
98 "Modern Renewables," International Energy Agency, accessed February 27, 2021, https://www.iea.org/reports/sdg7-data-and-projections/modern-renewables#abstract.

Figure 9 – 7.3 Benchmark Graph (of Table 11)



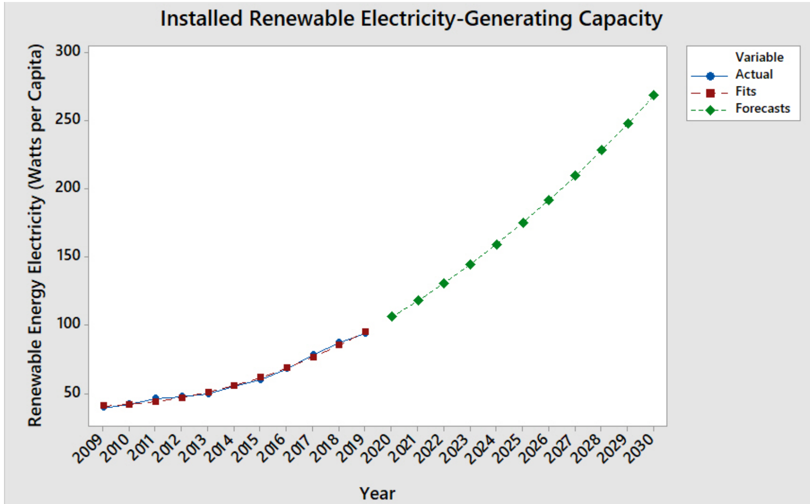
For 2018, 4.38 megajoules was used to produce one unit of economic output, with a 10% improvement from 2015. By 2030, it will take India 2.96 megajoules to produce one unit of economic output. From the 2015 statistics, India will have about 39.5% improvement of energy intensity by 2030, falling short of the SDG7's goal of halving its rate.

Figure 10 – 7.a Benchmark Graph (of Table 12)



The trend line shows that annually, India is receiving an increasing amount of funds from other countries. For this benchmark, the amount of funds shows that there is an increase in international cooperation, which meets the 7.a target.

Figure 11 – 7.b Benchmark Graph (of Table 13)



This graph presents India's renewable electricity-generating capacity of watts per person. With India's 2015 rate of about 60 watts generated per person and its 2019 rate of about 94 watts generated per person, India saw an increase of 56% of its renewable electricity generation. If India continues this trend line, then it will double its generation by 2022. While this forecast suggests that India should meet this benchmark, the United Nations' metric for this target is more subjective than the other benchmarks.

Inhibiting Factors

While India has made progress with implementing DRE systems, the country also faced several challenges. In 2004, the Ministry of New and Renewable Energy implemented the Village Energy Security Programme which was designed to increase India's rural electricity access.[99] While about 65 of these projects were commissioned, over half were either not operational or decommissioned by 2011.[100] By this time, the Village Energy Security Programme deployed about 700 kW of electricity generation equipment, but there was a lack of system maintenance to keep operations running. Additionally, there was a lack of fuel supply and financial incentives for rural communities. Even though this program was not a complete success, its foundation would provide a beneficial framework for accelerating "lasting economic and social development in village communities."[101] Another problematic instance is when India's 2005 Rajiv Gandhi Grameen Vidyutikaran Yojana scheme (RGGVY) implemented objectives for providing electricity to all villages within a five-year time frame.[102] According to the 2005 India Human Development Survey, almost 90% of rural households used fuel wood (190.8 Rs./mo. energy expenditure), and only about 60% had

---

[99] Benjamin K. Sovacool, and Ira Martina Drupady, *Energy Access, Poverty, and Development: The Governance of Small-Scale Renewable Energy In Developing Asia*, London: Routledge, 2016, https://doi-org.proxy1.library.jhu.edu/10.4324/9781315579535.

[100] Debajit Palit, Benjamin K. Sovacool, Christopher Cooper, David Zoppo, Jay Eidsness, Meredith Crafton, Katie Johnson, and Shannon Clarke, "The trials and tribulations of the Village Energy Security Programme (VESP) in India," *Energy Policy* 57, (June 2013); 407-417, https://www.sciencedirect.com/science/article/abs/pii/S0301421513000918.

[101] Benjamin K. Sovacool, and Ira Martina Drupady, *Energy Access, Poverty, and Development: The Governance of Small-Scale Renewable Energy In Developing Asia*, London: Routledge, 2016, https://doi-org.proxy1.library.jhu.edu/10.4324/9781315579535.

[102] Shahidur R. Khandker, Hussain A. Samad, Rubaba Ali, and Douglas F. Barnes, "Who Benefits Most from Rural Electrification? Evidence in India," *The Energy Journal* 35, no. 2 (2014): 75-96, accessed February 8, 2021, http://www.jstor.org/stable/24695761.

electricity (73.9 Rs./mo. energy expenditure) to use.[103] Below is the 2005 India Human Development Survey table for household electrification.

Table 14 – India's Household Electrification (%)

Region	Rural	Urban	All
North	86.7	94.1	88.1
Plains	51.3	93.7	63.4
West	71.5	96.9	81.0
South	86.6	96.5	89.5
East	39.9	88.9	49.4
Northeast	62.3	95.6	71.0
All regions	59.8	94.3	69.4

Source: (Khandker)[104]

However, India's progress with the RGGVY program has brought about insufficient outcomes due to issues of availability, reliability, and quality. The electricity distribution companies were unable to accurately meter and collect rates of energy consumption. Furthermore, political, economic, environmental, social, and technological factors may hinder India's progress towards energy development. In addition to the short-term and long-term factors listed in the table below, India must also take into consideration site remoteness and restricted infrastructure availability.

[103] Shahidur R. Khandker, Hussain A. Samad, Rubaba Ali, and Douglas F. Barnes, "Who Benefits Most from Rural Electrification? Evidence in India," *The Energy Journal* 35, no. 2 (2014): 75-96, accessed February 8, 2021, http://www.jstor.org/stable/24695761.
[104] Shahidur R. Khandker, Hussain A. Samad, Rubaba Ali, and Douglas F. Barnes, "Who Benefits Most from Rural Electrification? Evidence in India," *The Energy Journal* 35, no. 2 (2014): 75-96, accessed February 8, 2021, http://www.jstor.org/stable/24695761.

Table 15 – Factors Involved with Deploying Solar Minigrids in Rural India

FACTORS	Phase 1: Project Planning	Phase 2: Implementation	Phase 3: Operations & Maintenance
Political	• Gov't politics clarity • Land acquisition process/ownership • Procurement process (transparent) • Cooperative societies role • Nodal agency role	• Institutional readiness • Reliable power • Safety inspection	• Design uniformity • Who maintains after 15 years? • Project evaluation • Penalties
Economic	• Funding process • Financially viable • Off-take agreement • Consumer subsidies • Cost to user over time	• Local employment impacts • Theft of power	
Environmental	• Project locations - identification process (land banks) • Permitting process • Water allocation effects • Accurate solar data • Varying resource profiles (solar, biomass, & hydro)	• Disturbed habitat	• Monitoring effects to environment • Water churpon system monitoring
Social	• Consumer buy-in process • Consumer education • Role of/trust in cooperative societies and nodal organizations • Level of social acceptance of RE	• Incentives for household use • Economic impact on families • Household energy use patterns/behaviors • Reliability of energy impact on behavior	• Consumer recourse • Trust in institutions/private sector • Human capacity to adopt • Workforce readiness local employment/training capacity
Technological	• Metering • Pre-qualified solar technologies? • Consumers farther than 3 mi. radius? • System must be modular/flexible • Hydro, geo, biomass roles	• Unbalanced distribution systems • Load sharing • Grid integration • Hybrid tech	• Training • What happens as demand increases?

Source: (Thirumurthy)[105]

[105] Nisha Thirumurthy, "Opportunities and Challenges for Solar Minigrid Development In Rural India," Golden, Colo.: National Renewable Energy Laboratory, 2012, https://dx.doi.org/10.2172/1052904, https://www.osti.gov/servlets/purl/1052904.

Since each region must have the system's technologies customized to meet its needs, there cannot be standardized solutions. Power outages and voltage fluctuations are common in India since there is an unreliable supply of electricity. Another critical component is system maintenance. It faces the ongoing problem of insufficient maintenance of systems and inadequate knowledge to train individuals to install the technology. According to a study covering southern India's Deccan Plateau following the installation of micro-hydro systems, there are still issues with "poor maintenance and lack of local skills in managing the system," and weak institutional structure would inevitably lead to arguments between local and national entities.[106] Thus, these challenges threaten the sustainability of the projects. According to a SELCO Foundation study on behalf of an Indian bank, approximately 70% of reported complaints involved non-functioning systems that resulted in no attempts to fix them from the system supplier. Furthermore, additional coordination and assistance would be required especially when it involves obtaining clearances from the local government to "acquire land or get transmission lines installed."[107] A workaround that some companies used is instead of deploying common distribution systems, they opt for smaller home lighting systems. This would restrict the solar mini-grid development. With Maharashtra, the objective was to focus on the "developmental, social, health and environmental performance" over the "traditional centralized coal-thermal power generation."[108] However, due to "lack of

---

[106] Subhes C. Bhattacharyya, and Debajit Palit, *Mini-Grids for Rural Electrification of Developing Countries: Analysis and Case Studies From South Asia*, Cham: Springer International Publishing, 2014, https://link-springer-com.proxy1.library.jhu.edu/book/10.1007%2F978-3-319-04816-1.

[107] Nisha Thirumurthy, "Opportunities and Challenges for Solar Minigrid Development In Rural India," Golden, Colo.: National Renewable Energy Laboratory, 2012, https://dx.doi.org/10.2172/1052904, https://www.osti.gov/servlets/purl/1052904.

[108] Anand Deshmukh, "The Role of Decentralized Renewable Energy for Rural Electrification" (MS thesis, University of the Aegean, Central European University, Lund University, and University of Manchester, 2009), 1-76, https://core.ac.uk/download/pdf/289931446.pdf.

community engagement," "maintenance and expertise," and "payment recovery (financial sustainability)," Maharashtra did not meet the projected results.[109] In 2020, the International Energy Agency published India's Energy Policy Review, highlighting the 2017 Off-Grid and Decentralised Solar PV Programme that provided financial assistance in maintaining "solar PV applications for lighting and water pumping."[110] Taking this into consideration, Maharashtra could develop a significantly larger capacity for electricity generation installation when compared to other states in India. In doing so, increasing and improving accessible electricity and efficiency would support the United Nations' Millennium Development Goals.[111] The dynamic between energy, health, income, the environment, and education is constantly changing. For example, India's COVID-19 solution of installing solar PV systems is only temporary, the Nav Jivan hospital and other medical facilities in India will need to continuously improve its infrastructure. Establishing robust healthcare delivery systems with stable electricity is necessary to meet increasing demands related to COVID-19 and its lingering effects. Due to the extreme electricity shortages in India, the distribution of electricity must be prioritized but at the same time, the conflicts between the residents and the government could arise if both governmental support and public awareness are lacking.

---

[109] Anand Deshmukh, "The Role of Decentralized Renewable Energy for Rural Electrification" (MS thesis, University of the Aegean, Central European University, Lund University, and University of Manchester, 2009), 1-76, https://core.ac.uk/download/pdf/289931446.pdf.

[110] "India 2020 Energy Policy Review," International Energy Agency, January 2020, https://niti.gov.in/sites/default/files/2020-01/IEA-India%202020-In-depth-EnergyPolicy.pdf.

[111] "UN MDGs," United Nations Millennium Development Goals, 2015, https://www.un.org/millenniumgoals/.

Another hurdle India faces is social acceptance to potential change with the community's living conditions. Alternate Energy is a non-profit organization that has focused on renewable energy models to improve rural living conditions. In order for Alternate Energy to improve the livelihoods of citizens, the decentralized distributed generation was focused on locating energy sources that were closer to consumers while at the same time "decreas[ing] the transmission and distribution losses that are otherwise involved in a grid based energy system."[112] With the Alternate Energy electrification project in Sitapura, there was great potential for interest and resources in establishing a power generation unit that utilized biomass. Afterwards, however, there was a lower demand from villagers for these modern electricity systems. A major hurdle to overcome was convincing these residents to alter their behavior patterns towards energy consumption, aiming to achieve diffusion and social acceptance with the community.

Next, there continues to be a noticeable issue regarding the lack of financial resources for DRE systems. India can follow what the Participatory Microfinance Group for Africa (PAMIGA) did with the creation of Solar Loans in 2013; these loans can be distributed as individual loans or to a group. Rural financial institutions "strengthened the loan appraisal process for Solar Loans and defined repayment schedules tailored to the monthly energy savings allowed by the solar kit (making sure the Solar Loan does not come as an additional burden for the household but can be repaid thanks to the energy savings)."[113] PAMIGA tested an innovative model to "bridge the gap between urban

---

[112] Sujit Raghunathrao Jagadale, and Manisha Jagadale, *Creating a Market: Renewable Energy In a Subsistence Marketplace In India*, London: SAGE Publications: SAGE Business Cases Originals, 2018, http://dx.doi.org.proxy1.library.jhu.edu/10.4135/9781526444264.
[113] "Decentralized Electrification and Development," *Field Actions Science Reports*, no. 15 (2016): 1-168, https://www.institut.veolia.org/en/nos-publications/la-revue-de-linstitut-facts-reports/decentralized-electrification-and-development.

distributors and rural clients: The Energy Entrepreneur model" since coming out with the Solar Loans.[114] The hope is that the modularity of DRE systems in the future will be further developed to allow individuals to tailor small-scale energy sources to their own living situations.

Overall Assessment

With the increasing demand for India's rural electrification, the decentralized distributed generation has prioritized locating sources to generate power that would be closer to the consumers, as well as implementing locally available renewable energy.[115] The decentralized distributed generation pulls from resources such as hydroelectricity, solar, biogas, bio-mass, etc.[116] India could potentially implement a decentralized electrification model that utilizes forest biomass and agricultural waste for rural regions, reducing CO_2 emissions and supply costs.[117] While the potential and means are available to achieve cleaner energy, persuading a community set in its way prevents the adoption of new norms, inevitably impeding India's DRE goals. To solidify collaboration between a village's residents and between village-to-village, regions can establish peer groups to properly educate the residents and potentially be more cost-efficient with bulk

---

[114] "Decentralized Electrification and Development," *Field Actions Science Reports*, no. 15 (2016): 1-168, https://www.institut.veolia.org/en/nos-publications/la-revue-de-linstitut-facts-reports/decentralized-electrification-and-development.

[115] Kartik Arunachalam, Venkateswaran Sankaran Pedinti, and Sanket Goel, "Decentralized distributed generation in India: A review," *Journal of Renewable and Sustainable Energy* 8, no. 2 (2016), https://doi:10.1063/1.4944966.

[116] Sujit Raghunathrao Jagadale, and Manisha Jagadale, *Creating a Market: Renewable Energy In a Subsistence Marketplace In India*, London: SAGE Publications: SAGE Business Cases Originals, 2018, http://dx.doi.org.proxy1.library.jhu.edu/10.4135/9781526444264.

[117] Diego Herran and Toshihiko Nakata, "Design of decentralized energy systems for rural electrification in developing countries considering regional disparity," *Applied Energy* 91, no. 1 (2012): 130-145, https://www.sciencedirect.com/science/article/abs/pii/S0306261911005940.

purchasing.[118] Combining resources and systems from multiple villages will improve information dissemination.

India continues to balance the relationship between the country's rates of economic growth and energy poverty in rural areas. For rural households, biomass fuels are typically used for everyday tasks such as cooking due to its cost efficiency and ease of collection. With rural electrification, time spent on collecting biomass fuels are reduced, and variables such as employment hours and schooling increase.[119] Due to much higher use of biomass, however, energy consumption in rural areas is more than in urban areas, the former relying more on kerosene. The energy poverty is about 57% for India's rural households and 28% for urban households.[120] For rural areas, the combination of more modern cooking fuels and electrification would greatly reduce the country's energy poverty. Moving forward to 2017, India's foreign direct investment in its infrastructure development is noted to continuously improve, in addition to its economic growth.[121] As the country's infrastructure grows, the government should heighten its focus on energy and environmental policy reforms in sectors such as water supply, airports, railway, port, and petroleum. By directing more work in these sectors, additional foreign investment can strengthen India's economy. Unfortunately, the downside of India's rapid economic

[118] Nisha Thirumurthy, "Opportunities and Challenges for Solar Minigrid Development In Rural India," Golden, Colo.: National Renewable Energy Laboratory, 2012, https://dx.doi.org/10.2172/1052904, https://www.osti.gov/servlets/purl/1052904.
[119] Shahidur R. Khandker, Hussain A. Samad, Rubaba Ali, and Douglas F. Barnes, "Who Benefits Most from Rural Electrification? Evidence in India," *The Energy Journal* 35, no. 2 (2014): 75-96, accessed February 8, 2021, http://www.jstor.org/stable/24695761.
[120] Shahidur R. Khandker, Douglas F Barnes, and Hussain A Samad, *Energy Poverty In Rural and Urban India: Are the Energy Poor Also Income Poor?*, Washington, D.C.: The World Bank, 2010, https://www.researchgate.net/publication/228268126_Energy_Poverty_in_Rural_and_Urban_India_Are_the_Energy_Poor_also_Income_Poor.
[121] Anshuman Gupta. ed., and Narendra N Dalei ed, *Energy, Environment and Globalization: Recent Trends, Opportunities and Challenges In India*, 1st ed. 2020, Singapore: Springer Singapore, 2020, https://www.researchgate.net/publication/335107056_Energy_Environment_and_Globalization_An_Interface.

growth is the increasing rate of pollution due to fossil fuels, as well as the fact that there is "less water, land, building material available, and greater congestion."[122,123] India's government would have to direct additional costs towards anti-pollution measures to combat this. Focusing on how spatial dynamics are affected by energy usage and pollution output are key in developing more detailed energy policies for the country.[124]

Based on this research, India is progressing towards achieving SDG7's benchmarks, but it is uncertain whether the country will meet this goal completely by 2030. Additional research may be required following the pandemic. The below color-coded figure shows India's capability of achieving each benchmark. Green means that India is set to complete the benchmark in time, yellow means that India is at risk for falling behind, and red means that India is falling behind its progress.

Table 16 – Sustainable Development Goal 7 Benchmarks – Assessment

TARGET 7.1	By 2030, ensure universal access to affordable, reliable and modern energy services	
TARGET 7.2	By 2030, increase substantially the share of renewable energy in the global energy mix	
TARGET 7.3	By 2030, double the global rate of improvement in energy efficiency	
TARGET 7.a	By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology	
TARGET 7.b	By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States and landlocked developing countries, in accordance with their respective programmes of support	

122 Anshuman Gupta. ed., and Narendra N Dalei ed, *Energy, Environment and Globalization: Recent Trends, Opportunities and Challenges In India*, 1st ed. 2020, Singapore: Springer Singapore, 2020, https://www.researchgate.net/publication/335107056_Energy_Environment_and_Globalization_An_Interface.

123 Ejaz Ghani, Arti Grover Goswami, and William R Kerr, *Spatial Dynamics of Electricity Usage In India*, Washington, D.C.: The World Bank, 2014, https://doi-org.proxy1.library.jhu.edu/10.1596/1813-9450-7055.

124 Ejaz Ghani, Arti Grover Goswami, and William R Kerr, *Spatial Dynamics of Electricity Usage In India*, Washington, D.C.: The World Bank, 2014, https://doi-org.proxy1.library.jhu.edu/10.1596/1813-9450-7055.

Conclusion

In conclusion, India has made significant progress with implementing DRE systems for over the past decade. Its efforts greatly contribute to the United Nations' SDGs, specifically SDG7 for affordable and clean energy. It is uncertain whether India can fully meet all of SDG7's benchmarks. However, this paper finds that India will, at the very least, meet three of the benchmarks. India's projected progress is anticipated to meet the other benchmarks after the targeted 2030 deadline. With the ongoing effects of COVID-19, additional research must be done to evaluate India's rates at a later time for more accurate analyses of its SDG7 progress.

Future Implications

There are several future implications for deploying DRE in rural areas. Grid officials need to prepare safeguards against economic loss and health concerns. With these situations, the residents need to be protected from grid disconnections due to the inability to pay or due to low energy supplies. Governments must form contingency plans in response to the pandemic to keep their country afloat, as well as addressing challenges with the supply chain. To ensure the completion of local renewable energy projects, governments must factor in deadline extensions and remove liability from existing contracts. A fundamental shift in energy supply and demand is required to meet climate change objectives.

Instead of developing an entire infrastructure for a building that would take a lot of time and money to ensure no one is negatively impacted, each region can install smaller units for each household. For areas with aging infrastructure, DRE systems may present a cheaper solution and would not require regions to rebuild their grids. By giving each household their own unit, there is less dependence on large power companies to provide energy. One additional benefit is that blackouts would only affect the household that the failed unit is attached to instead of a whole grid. Those failed units would also be easy to locate for quick repairs. Since DRE systems release low amounts of carbon, the CO_2 emissions from the rural area will decrease as grids bring more systems online.

While there are studies related to the deployment of DRE systems in several countries, some of which possessing similar circumstances in rural regions, no singular situation can be completely applied to India's rural areas. Each country and region (which is dependent on factors such as terrain, resources, and funding) necessitate a customizable system for DRE and mini-grids. As each area changes and develops, the country must also modernize its systems. Some of the studies noted projects starting with hopeful potential but ended up failing due to lack of system maintenance or support from the local government and community awareness. This shows that even if the numbers start off strong with available technology, the societal factor is just as important. Varying rural regions in India experienced different success rates and progression. Since maintaining the systems becomes more difficult than executing them, governments must implement long-term policies and training to ensure consistency and reliability with the systems.

Bibliography

Arunachalam, Kartik, Venkateswaran Sankaran Pedinti, and Sanket Goel. "Decentralized distributed generation in India: A review." *Journal of Renewable and Sustainable Energy* 8, no. 2 (2016). https://doi:10.1063/1.4944966.

Barksdale, Martha, and Kate Kershner, "How LifeStraw Works," HowStuffWorks, accessed February 27, 2021, https://science.howstuffworks.com/environmental/green-tech/remediation/lifestraw1.htm.

Bhattacharyya, Subhes C., and Debajit Palit. *Mini-Grids for Rural Electrification of Developing Countries: Analysis and Case Studies From South Asia*. Cham: Springer International Publishing, 2014. https://link-springer-com.proxy1.library.jhu.edu/book/10.1007%2F978-3-319-04816-1.

Center for Strategic and International Studies. "Online Event: A Conversation with Rajiv J. Shah: A Vision for Equitable Recovery." 2020. https://www.csis.org/events/online-event-conversation-rajiv-j-shah-vision-equitable-recovery.

Concessao, Lanvin, Dheeraj Kumar Gupta, and Pamli Deka. "Solar Power: A Rural Indian Hospital's Key to Fighting COVID-19." *World Resources Institute*. July 14, 2020. https://www.wri.org/blog/2020/07/renewable-energy-rural-hospital-coronavirus.

Deshmukh, Anand. "The Role of Decentralized Renewable Energy for Rural Electrification." MS thesis, University of the Aegean, Central European University, Lund University, and University of Manchester, 2009. https://core.ac.uk/download/pdf/289931446.pdf.

Energetica India. "Decentralized Renewable Energy can Drive Modern Electricity System in India." *Energetic India*, 2019. https://www.world-energy.org/article/5762.html.

ETEnergyWorld. "MNRE proposes draft policy for promoting distributed renewable energy." October 20, 2020. https://energy.economictimes.indiatimes.com/news/renewable/mnre-proposes-draft-policy-for-promoting-distributed-renewable-energy/78761631.

Frangoul, Anmar. "India has some huge renewable energy goals. But can they be achieved?." CNBC. March 03, 2020. https://www.cnbc.com/2020/03/03/india-has-some-huge-renewable-energy-goals-but-can-they-be-achieved.html.

Ghani, Ejaz, Arti Grover Goswami, and William R. Kerr. "Spatial Dynamics of Electricity Usage In India." ResearchGate, 2014. https://doi-org.proxy1.library.jhu.edu/10.1596/1813-9450-7055.

Gupta, Anshuman. ed., and Narendra N. Dalei ed. *Energy, Environment and Globalization: Recent Trends, Opportunities and Challenges In India*. 1st ed. 2020. Singapore: Springer Singapore, 2020. https://www.researchgate.net/publication/335107056_Energy_Environment_and_Globalization_An_Interface.

Hallegatte, Stéphanie, and Brian Walsh. "COVID, climate change and poverty: Avoiding the worst impacts." World Bank. October 07, 2020. https://blogs.worldbank.org/climatechange/covid-climate-change-and-poverty-avoiding-worst-impacts.

Hande, Harish, Surabhi Rajagopal, and Vikshut Mundkur. "Energy for the Poor: Building an Ecosystem for Decentralized Renewable Energy." *Blowing Hard or Shining Bright? Making Renewable Power Sustainable in India*, (2015): 55-63. https://www.brookings.edu/wp-content/uploads/2015/01/renewable-energy_ch7.pdf.

Herran, Diego, and Nakata Toshihiko. "Design of decentralized energy systems for rural electrification in developing countries considering regional disparity." *Applied Energy* 91, no. 1 (2012); 130-145. https://www.sciencedirect.com/science/article/abs/pii/S0306261911005940.

International Energy Agency. "India 2020 Energy Policy Review." January 2020. https://niti.gov.in/sites/default/files/2020-01/IEA-India%202020-In-depth-EnergyPolicy.pdf.

International Energy Agency. "Jawaharlal Nehru Solar Mission (Phase I, II and III) – Policies." *IEA*. Last modified April 12, 2018. https://www.iea.org/policies/4916-jawaharlal-nehru-national-solar-mission-phase-i-ii-and-iii.

International Energy Agency. "Modern Renewables," accessed February 27, 2021, https://www.iea.org/reports/sdg7-data-and-projections/modern-renewables#abstract.

International Institute for Environment and Development. "Policies to Spur Energy Access: Volume 2 Case Studies of Public-Private Models to Finance Decentralized Electricity Access." *National Renewable Energy Laboratory*. September 2015. https://www.nrel.gov/docs/fy15osti/64460-2.pdf.

International Renewable Agency. "Post-COVID recovery: An agenda for resilience, development and equality." 2020. https://www.irena.org/publications/2020/Jun/Post-COVID-Recovery.

Jagadale, Sujit Raghunathrao, and Manisha Jagadale. *Creating a Market: Renewable Energy In a Subsistence Marketplace In India*. London: SAGE Publications: SAGE Business Cases Originals, 2018. http://dx.doi.org.proxy1.library.jhu.edu/10.4135/9781526444264.

Jethani, J. K. "Renewable Policy Framework and Wind Energy Programme in India." *Ministry of New and Renewable Energy*. August 22, 2016. https://mnre.gov.in/img/documents/uploads/94e402c36ee44fe29e2b96a6b1b69a30.pdf.

Katre, Aparna, and Arianna Tozzi. "Assessing the Sustainability of Decentralized Renewable Energy Systems: A Comprehensive Framework with Analytical Methods." *Sustainability*, (2018). https://www.mdpi.com/2071-1050/10/4/1058.

Khandker, Shahidur R., Douglas F. Barnes, and Hussain A. Samad. "Energy Poverty In Rural and Urban India: Are the Energy Poor Also Income Poor?." ResearchGate, 2010. https://www.researchgate.net/publication/228268126_Energy_Poverty_in_Rural_and_Urban_India_Are_the_Energy_Poor_also_Income_Poor.

Korosec, Kirsten. "Tesla Is Helping Puerto Rico Get Power After Hurricane Maria." Fortune. September 28, 2017. https://fortune.com/2017/09/28/tesla-battery-puerto-rico-power/.

Kottadiel, Divya. "A shift from energy access to development is transforming the decentralized renewable energy market in India: CLEAN." *Power for All*, September 18, 2019. https://www.powerforall.org/news-media/articles/shift-energy-access-development-transforming-decentralized-renewable-energy-market-clean-report.

Legros, Gwénaëlle, Kamal Rijal and Bahareh Seyedi. *Decentralized Energy Access and the Millennium Development Goals*. United Nations Development Programme (2011). http://www.undp.org/content/dam/nepal/docs/reports/UNDP_NP_Decentralized-Energy-Access-and-MDGs.pdf.

"Our History," LifeStraw, accessed February 27, 2021, https://www.lifestraw.com/pages/our-history.

Office of Energy Efficiency & Renewable Energy. "Distributed Energy Technologies for Resilience." 2019. https://www.energy.gov/eere/femp/distributed-energy-technologies-resilience.

Power Engineering International. "Decentralized renewable energy can unlock UN sustainability goal." *Power Engineering International*, April 20, 2017. https://www.powerengineeringint.com/decentralized-energy/on-site-renewables/decentralized-renewable-energy-can-unlock-un-sustainability-goal/.

REN21. "Distributed Renewable Energy for Energy Access." Accessed February 27, 2021. https://www.ren21.net/gsr-2016/chapter03.php.

Sagebiel, Julian., Christian Kimmich, Malte Müller, Markus Hanisch, and Vivek Gilani. *Enhancing Energy Efficiency In Irrigation: A Socio-Technical Approach In South India*. 1st ed. 2016. Cham: Springer International Publishing, 2016. https://link-springer-com.proxy1.library.jhu.edu/book/10.1007%2F978-3-319-22515-9.

"SDG Indicator 7.1.1." SDG Tracker. Accessed February 15, 2021. https://sdg-tracker.org/energy.

Sovacool, Benjamin K., and Ira Martina Drupady. *Energy Access, Poverty, and Development: The Governance of Small-Scale Renewable Energy In Developing Asia*. London: Routledge, 2016. https://doi-org.proxy1.library.jhu.edu/10.4324/9781315579535.

Tazvinga, Henerica, Miriam Thopil, Papy B. Numbi, and Temitope Adefarati. "Distributed Renewable Energy Technologies." Handbook of Distributed Generation, (2017); 3-67. https://doi:10.1007/978-3-319-51343-0_1.

The Rockefeller Foundation. "Tata Power and The Rockefeller Foundation Announce Breakthrough Enterprise to Empower Millions of Indians with Renewable Microgrid Electricity." November 04, 2019. https://www.rockefellerfoundation.org/news/tata-power-rockefeller-foundation-announce-breakthrough-enterprise-empower-millions-indians-renewable-microgrid-electricity/.

The Rockefeller Foundation. "The Rockefeller Foundation commits US$1 billion to catalyse a green recovery from pandemic." October 27, 2020. https://www.eco-business.com/press-releases/the-rockefeller-foundation-commits-us1-billion-to-catalyse-a-green-recovery-from-pandemic/.

The World Bank. "COVID-19 to Add as Many as 150 Million Extreme Poor by 2021." October 07, 2020. https://www.worldbank.org/en/news/press-release/2020/10/07/covid-19-to-add-as-many-as-150-million-extreme-poor-by-2021.

Thirumurthy, Nisha, Laura Harrington, and Daniel Martin. "Opportunities and Challenges for Solar Minigrid Development in Rural India." *National Renewable Energy Laboratory*, September 2012. https://www.nrel.gov/docs/fy12osti/55562.pdf.

Turbulent. "Turbulent." Accessed February 27, 2021. https://www.turbulent.be/.

U.N. Department of Economic and Social Affairs. "Accelerating SDG 7 Achievement Policy Brief 24 Energy Sector Transformation: Decentralized Renewable Energy for Universal Energy Access." *United Nations*, 2018. https://sustainabledevelopment.un.org/content/documents/17589PB24.pdf.

United Nations. "The 17 Goals | Sustainable Development." Accessed February 27, 2021. https://sdgs.un.org/goals.

United Nations. "United Nations Millennium Development." 2015, https://www.un.org/millenniumgoals/.

United Nations Conference on Trade and Development. "Renewable Energy Technologies for Rural Development." *Current Studies on Science, Technology, and Innovation*, no. 1 (2010). https://unctad.org/system/files/official-document/dtlstict20094_en.pdf.

United Nations Millennium Development Goals. "UN MDGs." 2015. https://www.un.org/millenniumgoals/.

Vestergaard. "History: The evolution of a Humanitarian Enterprise." Vestergaard. Accessed February 27, 2021. https://www.vestergaard.com/about-us/history/.

Xie, Jenny. "Tesla is sending Powerwall home batteries to Puerto Rico." Curbed. September 29, 2017. https://archive.curbed.com/2017/9/29/16384482/puerto-rico-hurricane-maria-tesla-powerwall-batteries.

United Nations Development Programme. "Sustainable Development Goals." Accessed February 13, 2021. https://www.undp.org/content/undp/en/home/sustainable-development-goals.html#:~:text=The%20Sustainable%20Development%20Goals%20.

United Nations Framework Convention on Climate Change. "Off-grid and decentralized energy solutions for smart energy and water use in the agrifood chain." *UNFCCC*, January 06, 2020. https://unfccc.int/documents/208414.

Veolia Institute. "Decentralized Electrification and Development." *Field Actions Science Reports*, no. 15 (2016). https://www.institut.veolia.org/en/nos-publications/la-revue-de-linstitut-facts-reports/decentralized-electrification-and-development.

Vinodia, Ajay Kumar, and Dr. Najamuddin. "Promotion of Renewable Energy in Rural India." *ITPI Journal* 3, no. 2 (2006): 21-28. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.575.6918&rep=rep1&type=pdf#:~:text=India%20is%20endowed%20with%20abundant,the%20generation%20of%20wind%20energy.

Wheeldon, Susie. "Decentralized Renewables & The Rise of the Micro-Enterprise Economy." Renewable Energy World, August 19, 2016. https://www.renewableenergyworld.com/2016/08/19/decentralized-renewables-the-rise-of-the-micro-enterprise-economy/.

Yang, Ming. "Rural Electrification: GEF Experience in Renewables-based Microgrids." *The Global Environment Facility*, 2017. https://www.thegef.org/sites/default/files/documents/GEF-Paper-Inestment-in-Mini-grid-power-Sept-1-2017-V2.pdf.

Curriculum Vita

TRAN VU

<u>EDUCATION</u>

Johns Hopkins University May 2021
Advanced Academic Program (Online)

- Master of Arts Degree in Global Security Studies
- Certificate in Intelligence

San Diego State University December 2016
San Diego, CA

- Bachelor of Science Degree in Criminal Justice
- Psychology Minor (Personality and Social Studies)
- Interdisciplinary Studies Minor (Honors)

Tran Vu was born on May 14, 1994 in Orange County, CA. She moved to San Diego to attend San Diego State University and graduated in 2016 with a B.S. in Criminal Justice. Afterwards, she attended online courses at Johns Hopkins University in the dual M.A. program in Global Security Studies and Certificate in Intelligence.