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Using the core principle of Marxism in Smart Grids to reduce energy poverty and energy inequality

Nitin Saidha
Vellore Institute of Technology

The developing world currently faces a problem of extreme inequality, where some people have access to 24X7 electricity that can power multiple televisions, water heaters, microwaves, etc. whilst many live in the literal dark because of lack of access to affordable electricity. In a world that is moving online rapidly, lack of access to electricity is a lack of access to opportunities, safety, and proper healthcare. Smart Grids are an up-and-coming technology that hopes to increase the efficiency of the grid by using two-way communications thereby increasing the amount of usable electricity. However, this does not account for inequity of access and instead relies on a trickle-down approach. Smart Grids, if repurposed to provide electricity based on the needs of individuals can play a huge role in increasing access to electricity. This article seeks to discuss the extent to which this inequality has affected people in rural areas and elaborate on how repurposing Smart Grids in a way that views electricity as a publicly owned utility that needs to be divided based on the needs of everyone can help solve this problem of "energy poverty"

Introduction

Despite electrical grids being around for more than 100 years, equitable access to electricity is still a distant dream. A simple look at the energy ladder (hierarchy of the fuel type(s) used for cooking and heating in a household) shows how inequitable the access to electricity is. Lack of access to electricity is a form of impoverishment. Poverty is a poly-dimensional concept encompassing a variety of factors such as caloric intake, housing quality, and energy. Often, poverty is limited to the income of individuals. However, non-income dimensions (like access to electricity) play an essential role in the quality-of-life people lead and their opportunities. This paper explores individuals' access to energy and how their lives can be improved if they have electricity.

The global state of energy poverty is dire, with more than 10% of the world's population not having access to any electricity (Tracking SDG 7: The Energy Progress Report, 2021). In many countries in Sub-Saharan Africa, less than 30% of the populace has any access to electricity. In most countries there, only half the people have access to electricity (Blimpo et al., 2019). Even in developing countries, many rural and underdeveloped regions lack access to electricity. In regions with limited access to electricity, some people are politically, economically, and socially stronger than the others; these people often get control of the energy access infrastructure, thereby making it difficult for other individuals with less social capital to access electricity. In recent years, there has been a focus on solving energy poverty. Many electrification projects have also been carried out; however, these are insufficient. These solutions revolve around technological advancements that increase the net production of electricity (Vad et al., 2019). The problem with such solutions is that they fail to consider the systematic issues that persist. The only way to solve this issue is to consider these barriers and rethink how electricity needs to be distributed.

A new way of energy distribution can be achieved with the help of Smart Grids. Despite being a new technology, Smart Grids have allowed us to make major strides towards increasing access to energy. A Smart Grid is any networked grid that uses two-way communication, and accurate sensors that relay messages between components and power system components, leading to improved efficiency can be termed a "Smart Grid." Currently, Smart Grids are only seen as a solution to curb energy loss in grids and make them more reliable. This effectively increases available energy, and current policies expect this to lead to increased access to electricity eventually. However, Smart Grid systems don't account for individuals who don't have any access to electricity and or individuals who cannot pay for electricity.

Solving the problem of energy inequity requires energy to be viewed as community-owned rather than a commodity. This is equivalent to the socialization of the means of energy production and thus elimination of trade of energy. Marx's Principle of "From each according to their ability, to each according to their needs" must be at the center of it all. Smart Grids can account for various socio-anthropological factors to create a more equitable grid. They can distribute power to those who need it most and prioritize certain appliances over others. Just as Marx pictured a society where equality for people was not confined to economic revolutions, access to electricity should not be confined to reforms and evolutions in energy generation. This study aims to introduce an alternative approach to using Smart Grids and providing more equitable electricity.

The Extent of the Problem

The problem in today's world is an inequitable distribution of electricity across the globe. Even though more people have access to energy as a percentage of the net global population, the number of people without access to electricity is the highest it has ever been.
A deeper look at data collected by the IEA (International Energy Agency) and World Bank shows how pervasive this problem is. (World Bank, 2017). Currently:

1. 13% of People in the world have access to no electricity.
2. Per-Capita energy consumption varies more than 100-fold across the globe.
3. 40% of the world does not have access to clean fuel for cooking.
4. The global average "Rural Electrification" growth rate is less than 3%.

Figure 1 shows the difference in access to electricity between rural and urban populaces.

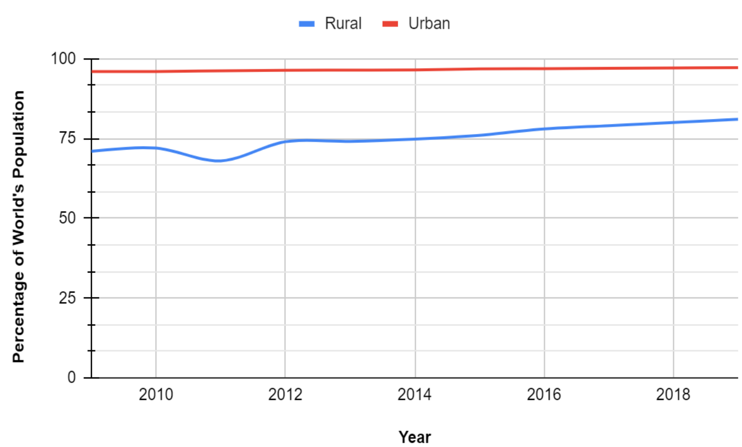

FIGURE 1. Variation in access to electricity over the years.

Smart Grids are unlikely to span countries, given that current international relations are complex and preclude any multilateralism, let alone at such a scale. Therefore, we can look at data from one country (India) to understand how inequitable access to energy exists within a nation.

The data about electrification for India is collected by the World Bank and the Ministry of electricity in India. (Saubhagya Dashboard, 2021).

1. Currently, in India, there is a 7 percent deficit in power production, which only includes people connected to the grid. The government has to raise the cost of electricity or rely on random load shedding to make up the difference between demand and supply.
2. In India, 31 million rural households are not connected to the grid and have no access to electricity.
3. More than 50% of rural areas with access to the grid receive electricity for less than 10 hours a day.
4. Only six states (out of 28) in the entire country have reliable and adequate electricity in rural areas.
5. Less than 20% of households in rural India have access to any internet. Meanwhile, more than 75% of households in urban areas have access to the internet.

Rural areas face multiple challenges, ranging from revenue losses due to high costs of power procurement to power theft and irregularity and delay in disbursement of state subsidies assured to domestic and agriculture consumers. In comparison, major cities have a net abundance of power and are investing in renewables as well. The energy consumption/capita is also much higher in cities due to frivolous electricity use by individuals who choose to pay a slightly higher price than lose out on convenience. This massive discrepancy in living conditions has allowed for an invisibilization of the real issues faced in rural areas.

The problem is not just limited to the current energy capacity but also the amount of energy capacity that can be developed. Simply producing more energy is not a real long-term solution. Given that most countries—like India and China—have committed to phasing out thermal energy production in the next few decades, the only way energy production capacity can increase is if renewable energy capacity increases. The limitations of Renewable energy sources (RES) further inhibit the possibility of creating infinite amounts of energy. There are many barriers to entry including high upfront costs, limited market power in the developing world, and local politics. Furthermore, RES requires efficient, affordable, and reliable energy storage to function, as they are not as consistent as fossil fuels. Though there have been many strides in battery and energy storage technology, the roll-out of such technology has been slow and limited (Kåberger & Tomas, 2018).

The current rate of growth of renewable energy in the developing world is promising. Still, it will not be enough to keep up with the growth in energy requirements in developing countries. (Wolfram et al., 2012). In India, for example, the electricity demand is drastically increasing. By 2030, India's total energy demand will be more than double, while electricity demand will almost triple that today (Renewable Energy Prospects for India-International Renewable Energy Agency Report, 2019). The graph below compares India's projected energy demand rate over the next twenty years (IEA,2019) to the expected capacity of renewable energy sources (Babar et al., 2020). The data shown in the graph for both values are in percentages of the current capacity.

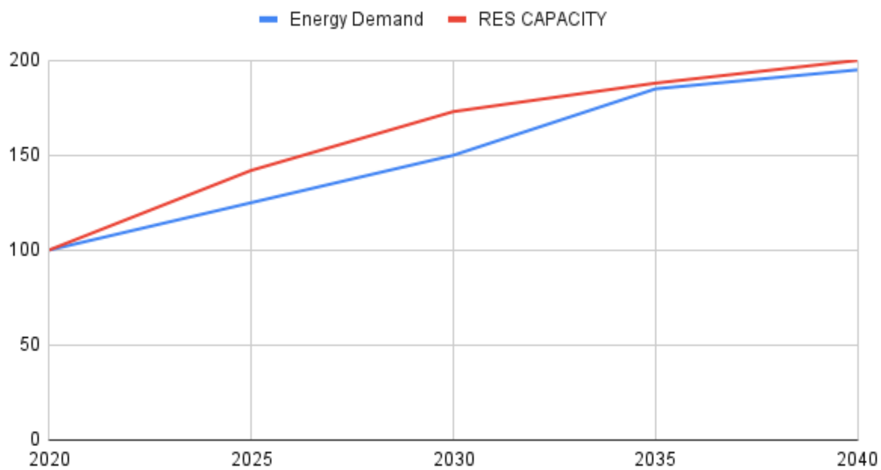

FIGURE 2. Energy Demand and REC capacity (2020-2040).

This graph shows that steps taken to increase the renewable generation capacity (subsidies, heavy investments, tax cuts in the green sector, etc.) will lead to a consistent growth rate of ~5% per year for the next 20 years. However, it is still insufficient to meet the growing demand. It also cannot cater to individuals who currently do not have access to electricity. The current growth rate also precludes completely phasing out thermal power plants in the next 30 years. Collating data from the IEA, the figure below shows energy generation from RES as a percentage of predicted energy demand.

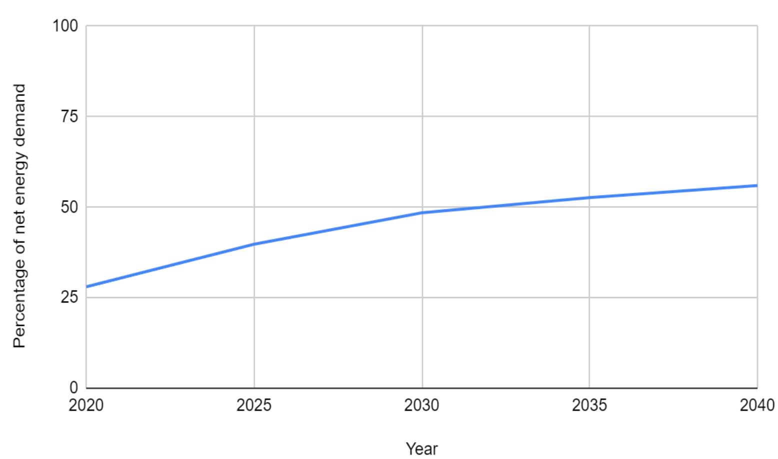

FIGURE 3. RES capacity as a percentage of energy demand.

According to the data, RES should contribute to just above 50% of the total energy demand by 2040. Therefore, better and more equitable management is needed to reduce net energy consumption or at least distribute it more equitably.

Even if electricity production can be ramped up, this does not solve the problems of individuals living in rural areas. Existing electricity costs from the main grid can be prohibitively expensive for such rural households. Even using off-grid systems to serve these dispersed populations can be financially challenging because they cannot reap the benefits of economies of scale. Furthermore, existing off-grid electrification, including mini-grids, is faced with many challenges such as lack of proper policies, inadequate regulations, lack of planning and institutional support, lack of financing for off-grid entrepreneurs, and more. Therefore, even though it is important to increase the net capacity of generation, it may not be enough, and therefore a more equitable distribution of energy is still needed.

This solution is needed as there is a clear correlation between access to energy and increased economic progress, infrastructure development, and individual liberties (Stern et al., 2019). A lack of adequate, sustainable, continuous, and affordable supplies of energy limits real opportunities, employment, and growth of enterprises. Furthermore, this harms human health and welfare, particularly the health of gender and racial minorities. Therefore, energy poverty contributes to chronic or persistent poverty. Energy inequalities are not divorced from income inequalities, communal inequalities, and inequalities in other dimensions. The deepening inequality will lead to the further disenfranchisement of those currently at a disadvantage, especially as an increasing amount of work depends on access to electricity and the internet.

Functioning of Smart Grids

Smart Grids vary in form and function. However, at the core of the Smart Grid is the addition of monitoring, control, analysis, and communications capabilities to existing systems to attain higher efficiency and ensure stable delivery of power. This requires homes to be connected to smart-energy systems; these systems can adjust the run cycle of appliances in homes according to the time of the day. They also collect usage data from all appliances and use the data to optimize energy consumption and convey all the information to the grid (Nosratabadi, Hooshmand, Gholipour, 2017). Renewable projects like solar and wind farms can use this data to send electricity to the grid at such times. Power stations can be turned on and off based on whether the renewables can meet the demand at any given time. Smart Grids, therefore, enable utilities to manage and optimize electricity usage with the consent of the customers, reducing electricity costs. This also allows for electricity production to be more evenly distributed. This reduces outages and lowers peak power. Figure 4 shows a simplified smart grid network with multiple energy sources. The control center is responsible for adjusting prices (demand-side management) based on data collected from home appliances and energy sources.

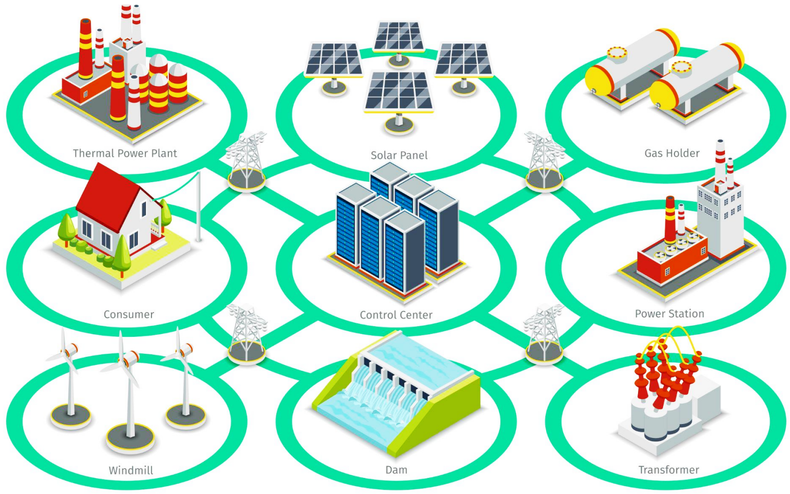

FIGURE 4. Simplified Smart grid network.

Current Goals of Smart Grids

Current Smart Grids don't ensure equitable distribution of electricity. However, they are very beneficial, both environmentally and economically. Economically, using these grids would decrease power usage by increasing overall system efficiency and load management and demand response protocols (Miceli, 2013). Environmentally, the net production and carbon dioxide emissions will be reduced by using a Smart grid; this reduction is achieved through smarter management of both load and consumption, reducing the production during peak time and allowing for an increase in the use of renewable energy sources. On top of all this, a consumer in this network can reduce their consumption by executing flexible practices as the real-time data will encourage them to reduce their carbon footprint (IEEE, 2013). This is achieved by varying the price according to the cost of production and demand; energy is most expensive during peak hours or when renewables cannot function.

Equitable Distribution

The principle of "from each according to their ability, to each according to their needs" must be at the center of it all. In the case of Smart Grids, we can take electricity from power sources based on their efficiency and distribute it to people based on their needs. Marx laid the groundwork for a classless system where all property and wealth are communally, rather than privately, owned. Similarly, in such a system, we would assume power generated anywhere within the grid to belong to everyone on the grid instead of it being owned by electric companies or governments. The electricity must be distributed based on the needs and requirements of individuals. Such a distribution ensures that everyone has enough affordable electricity to power necessities. This is fundamentally distinct from current Smart Grid systems that raise or lower the electricity costs of everyone based on net energy production. In the current system, some people have electricity to power multiple TVs and computers while others are left to study using oil lamps. A system that ensures that everyone's basic needs are met first before others enjoy luxuries can be built by repurposing Smart Grids to function equitably.

Functioning of an Equitable Smart Grid System

All smart grids have demand-side management systems (DSMs) to actively assess variables to adjust prices (Balijepalli et al., 2011). The dynamic pricing models are designed to provide economic benefits for consumers to help manage demand. Smart Grids uniquely allow bidirectional communications between the consumers and the utility to accomplish such tasks. Some Smart Grids use DEMS to achieve this. DEMS uses a real-time communications infrastructure to monitor, change/adjust, coordinate and manage distributed energy assets connected to the utility at a local level. The benefit of all this is more reliable energy and some cost savings (Srinivasan, Kotta & Ramaswamy, 2013). Current Smart Grids use several dynamic pricing modalities for demand response, such as Time-of-Use (TOU), Critical Peak Pricing (CPP), Real-Time Pricing (RTP), and Day-Ahead Pricing (DAP) (Alotaibi et al., 2020). However, this still does not solve the core issue of inequity. This is not a good solution because electricity becomes more expensive for everyone during peak hours, regardless of their need or electricity use. A pricing modality that is dynamic and dependent on electricity use can solve this. The following would be required to implement such a model:

1. Creation of Priority-Groups for electrical appliances:
   Priority groups can be created for all appliances based on how essential they are. The standardization and creation of groups will vary significantly between regions since it is contingent on geological and social factors. Therefore, each country should heavily study and research individual needs before deciding what appliances are essential. However, an approximation of how this would look is given in Table 1.

Table 1. An Approximation of Priority Groups

Group	**Appliances**
A	Lights, Fans, and other essentials
B	Car Charging Stations
C	All Type-C Plugs, Air Conditioning, Heating, Fridge, etc.
D	All Type-D and Type-M plugs, Televisions, Computers, etc.

I	Industrial Electricity

2. Phased distribution of electricity based on needs:
   The electricity distribution during shortages should be phased according to priority groups. Smart meters, HANs (Home Area Network), and Appliances should all report their energy usage and priority groups to the Smart Grid system. Low-priority Appliances can adjust their run cycle not to run when energy production is low, or demand is high. This should reduce the consumers' costs while also ensuring access to basic electricity to others. This also eliminates the need for load shedding.
3. Dynamic pricing modality which accounts for priority groups:
   The cost of electricity being used by less important appliances (Group C and D) should be made higher to subsidize electricity being used for essential functions. (Group A and B). People will be disincentivized from prodigally using their appliances, in turn increasing net available energy. The current Dynamic Pricing models already increase the price of electricity during peak hours, except the rate of increase should be higher for Groups C and D and not for Groups A and B.
   Figure 5. shows how such a dynamic model could look like. The Y-axis is the power demand as a percentage of peak power demand, and the X-axis shows the price of electricity relative to the price when the demand is at its peak.

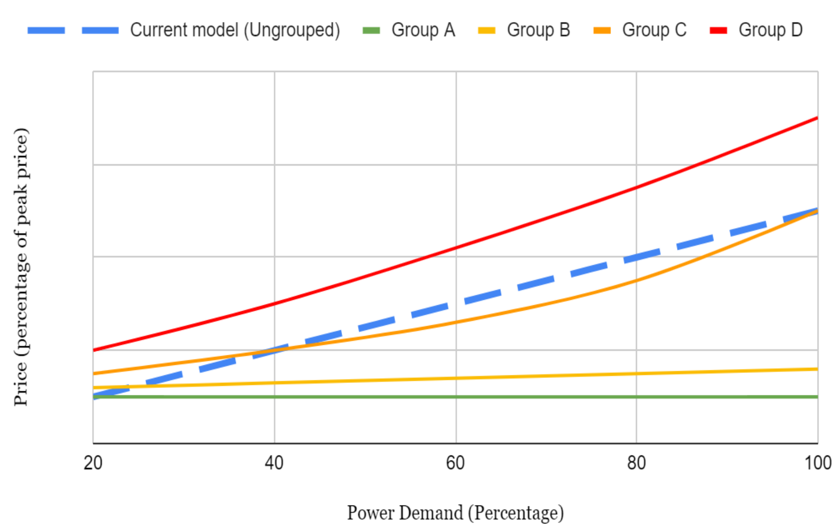

FIGURE 5. Variation of Price with Demand.

4. Create robust hybrid public-private partnerships
   Public-private partnerships are useful vehicles for raising funding to finance energy access projects; this is critical in the developing world. Public-private partnerships are already being used to engage

the private sector to deliver the infrastructure requirements of any governmental body. Establishing such partnerships enables both the public and the private sectors to leverage their unique characteristics, giving them advantages in specific aspects of operations or project delivery. These partnerships are often characterized by collaborative investments, responsibilities, and risks among partners. Using such models can help explicitly reach the unreached that governments often ignore due to inefficiencies (Jacobson & Choi, 2008).

An equitable Smart Grid aids the hybrid models in three key ways:

1. It ensures corporations can recover the costs they spent on building the energy infrastructure.
2. It allows corporations to profit from the energy that is not being used for essential services, thereby reducing the number of subsidies required to incentivize them to join the program.
3. It is cooperative rather than competitive and allows for innovation without sacrificing equity.

Public-private partnerships have already proven to be very useful in the water and sanitation sector. Past studies have shown that private organizations enhance the capacity of government departments to meet demands (Davis, 2005). However, the studies also show that strong governmental oversight is required to ensure that the increase in efficiency benefits stakeholders (Mahalingam, Devkar & Kalidindi, 2011).

Cost of Proposed System

Deployment of smart grid technology requires massive costs but saves more money in the long run. In the US, Smart Grids would save between 56 and 127 billion dollars in the next 20 years if implemented immediately (Kannberg et al., 2003). In India, CBA on Smart Grid projects shows that they are viable and profitable and show an increase in efficiency by 20%. (Padmini et al., 2017). Given that this proposal does not require any new hardware or devices, there is no added cost. The cost of implementation of smart grids, according to various papers, is tabulated below. The CBA for a project in Italy conducted by the JRC (Joint Research Center) and the ACEA uses the NPV method and shows that the Smart Grids are economically viable (Vitiello et al., 2015).

Even though Smart Grids eventually do pay for themselves, implementation costs are also sizable. The implementation costs depend greatly on the country and region where it needs to be implemented. A pilot project in India conducted by the India Smart Grid Forum gives a good approximation of the cost of implementation per million individuals (Pillai, 2019). The project calculated costs for the Smart Grid hardware and the cost to create a Local area network for the operation of the Smart Grid.

Table 2. Cost of Smart Grid Appliances per million individuals in India

Item	Cost/Million in Indian National Rupee
Smart Meter	3,000,000,000
Meter Box	500,000,000
Data Concentrator Unit/Gateway	500,000,000
RF mesh network	50,000,000
Installation	500,000,000
Total Cost per Million Individuals	4,550,000,000

The total cost of 4.5 billion Rupees per million individuals is high but is only 0.16% of the country's GDP. These costs are also expected to decrease over time because the market for Smart Grids systems is growing rapidly, and billions of dollars in funding are being provided by governments and private firms. In the last two years, annual investments in Smart Grid technology rose by 41% in the US (Butt, Zulqarnain, Butt, 2020). These investments aim to reduce the costs at the distribution level. With behemoths like Siemens, Cisco, Schneider Electric, and IBM, as well as thousands of tech startups already in this space heavily focusing on distribution management automation and outage management, there should be significant leaps in reliability and efficiency of these grids.

Benefits of Proposed System

The proposed system works alongside projects that aim to increase net energy production to improve people's lives. If it is implemented, more electricity would be available to rural areas. The energy is also likely to cost less and be more reliable, further increasing buy-in. Furthermore, consumers in urban areas are de-incentivized from using too much electricity. The demand side reduction in energy use should lower electricity costs. The excess electricity should lead to an increase in grid coverage. Lastly, the prioritization of essential utilities during outages and load shedding along with the subsidized cost will ensure, at worst, people will still have access to the internet, lights, fans, etc., leading to tremendous benefits.

1. Increased opportunities, productivity, and efficiency:

The rural populace is cut off from the rest of the world because they cannot participate in an increasingly digitized global economy. Opportunities today are limited to those who have access to the internet; new technologies—from social media and GPS systems to artificial intelligence and digital twins—make all the real opportunities only accessible to those who can get online (Sreekumar et al., 2019). Electrification will make it possible to get more people online and connect them with the rest of the world. Rural electrification also allows for higher efficiency and productivity. Businesses will be able to keep their doors open for longer and generate additional revenues. Farmers will have access to streamlined modern techniques such as irrigation, crop processing, and food preservation. Businesses can also use the internet to better their operations (find better suppliers, search for potential markets, make connections on media platforms that can later help in expansion, learn management skills, etc.). Furthermore, energy expenses currently account for a significant percentage of the expenditure in poor households (Hargittai, Piper & Morris, 2018). Reduced expenditures directly benefit individuals in poverty and also enable them to invest in expanding their income generation.

2. Improvements in access and quality of Education:
   Studies show clear correlations between access to electricity and quality of education (Faisal, 2011). Lighting enables classes to be conducted late at night or early in the morning. In Kenya, for example, interviews with school teachers revealed that access to light has allowed for extra hours of teaching earlier and later in the day to cover material not adequately reviewed during normal hours (Squires, 2015). Students can make use of mass-media tools in their classrooms, such as televisions and computers. Electrified schools also have better statistics for staff retention and outperform other schools on most educational factors. Access to electricity in schools can, in some cases, enable improvements in the social and economic development of entire communities. Furthermore, e-schools allow for education to reach places where brick and mortar schools cannot be built (due to lack of funds), which can reach more students. These allow a higher number of students to access a higher quality of education.
3. Improvements in Healthcare and Safety:
   The availability of electricity can dramatically increase the quality of healthcare provided. Improved lighting increases the time patients can come and get treatment. Refrigerators can be used to conserve precious vaccines and blood. Sterilization measures will be improved, and the implementation of high-tech machines such as x-rays or ultrasound scanners can provide doctors and nurses with the tools they need to perform. Rural electrification will make

> any area safer through outside lighting, safety signs, alarm systems, and even traffic lights. Electricity makes many of our homes and offices safe, and it can do the same for people in rural areas. Lack of safety can often limit the choices of individuals (especially women and gender minorities). Therefore, a safer neighborhood increases opportunities. Just like education, healthcare and safety play a critical role in the development of communities by increasing productivity and sustaining growth.

Possible Limitations of Proposed System

The greatest obstacle to grid reform has been a lack of political will coupled with consumer disengagement. Politicians are not pressured to implement smart grid technologies. In most countries, there is very little will to improve or expand the grid for those who do not have access to it. This is often because people assume that the costs of change and innovation outweigh the potential long-term benefits (Refaat et al., 2020). Therefore, voter acceptance for a Smart Grid is needed since its deployment depends on the end users′ acceptance of smart grid products and services such as smart meters and advanced metering services.

Deployment is also prohibited by the lack of common technical standards for smart grid technologies. Lack of common technical standards hinders innovation and prevents streamlining of the technology. Implementation of an equitable smart grid will also require broad consensus on many issues such as priority groups and the extent of price variation. Another issue is that utilities and their regulators are accustomed to buying power equipment that lasts 40 years or more. Given that the proposed system requires newer appliances and devices, this might slow down or prevent it from achieving its stated goals in the short term. This is because smart meters need to be able to communicate with the devices.

Lastly, there are concerns that complex pricing systems (e.g., variable price modalities) remove clarity and accountability, allowing suppliers to take advantage of the customers. People are already prohibited from adopting Smart Grids, and an even more dynamic pricing model will only make people feel wary of Smart Grids as a whole and may reduce buy-in.

Some limitations and challenges need to be overcome before smart grids can be repurposed to be made more equitable. However, the completely new way of looking at smart grids can benefit countless people. Future research or projects with real repurposed smart grids is needed to estimate costs, the extent of benefits, and the buy-in from people.

Conclusion

Energy poverty and energy inequalities are serious issues, and the concomitant lack of opportunities is leaving communities behind. Smart Grids as a technological device provide a host of benefits and can play a central role in solving this problem. By employing these techniques and repurposing Smart Grids, electricity will be accessible to more people at a much cheaper rate. This increases access to electricity while reducing net electricity consumption and helping the environment. Most importantly, this ensures that when there is a shortage of energy production (As is common in the developing world), basic appliances will still function across the country, therefore mitigating the discomfort caused to people. This paper aimed to propose an alternative model of looking at how Smart Grids should be integrated with society by viewing all electricity as a publicly owned utility. The problem of energy poverty is complex and requires further studies (preferably long-term), and requires technological developments. Therefore, there is a critical need to pursue further research in this area to work on implementation and overcome energy poverty. Simulations and pilot programs can be conducted in small regions to test the viability of the proposed model. This article has provided a different view and a functional model on how we need to approach the problem of energy poverty and inequality. It shows that since the advent of Smart Grids and other technologies, it is no longer a question of whether we can do it or how we can do it, but whether we want to do it.

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