Gateway to Energy Democracy and Access in India using Off-Grid Solar Home Systems and PayGo platform

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SUBMITTED TO THE MIT SLOAN SCHOOL OF MANAGEMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE – MANAGEMENT OF TECHNOLOGY AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2018

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Submitted to MIT Sloan School of Management on May 11, 2018 in Partial Fulfillment of the requirements for the Degree of Master of Science in Management of Technology.

ABSTRACT

More than a billion people around the world still lack access to electricity with more than 300 million of them living in India. Without any other options, these citizens are forced to either go without power or burn kerosene or wood.

There is an urgent need for the democratization of energy, which is defined as equitable access for smaller, disadvantaged energy consumers to the high-value energy options currently realized only by larger consumers.

This study analyses the problem of energy access in India and it’s background and context and proposes the use of off-grid solar home lighting systems (SHS) using Pay-as-you-Go (PayGo) technology and using Energy-as-a-Service (EaaS) business model as a viable solution. This is a sustainable, equitable and inclusive solution with the potential to empower and improve the lives of many while having the ability to be rolled-out immediately and scaled-up rapidly.

The proposed solution using off-grid SHS enabled by PayGo technology and using EaaS as a business model is an effective and practical first step towards providing access to electricity to people at the bottom of the pyramid who presently have no access and who are forced to use fuel based light sources for illumination.

This solution provides a gateway and a pathway for these people to enjoy modern and clean lighting and enable them to break the bonds of social backwardness and provide them the means to transform their lives. The end goal envisions a holistic solution with a judicious mix of grid connectivity along with off-grid solutions to allow these people to move up the ladder of energy access towards energy prosperity.

Thesis Supervisor: Harvey Michaels
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ACKNOWLEDGEMENTS

This thesis would not have been possible without the help, support and guidance of my thesis advisor – Harvey Michaels. My interaction with Prof. Michaels started with a fortuitous meeting at a dinner at MIT. He has also been very encouraging and supportive of my work not only at MIT but also in India.

I also thank my wife – Nalini who helped and supported me throughout the writing of this thesis. She was my sounding board and provided feedback and critique. I also thank her for her patience while I was busy in my research and work.

I thank Johanna Hising DiFabio and Michelle Pierce at the MIT Sloan Fellows program office for their help and support throughout the year.

I want to also thank Tatiana Mey. Tatiana and I worked together as the co-Content Directors for the 2018 MIT Energy Conference. She was very helpful and supportive with respect to this thesis.

Finally, I thank my brother – Ravi Pittie, founder and CEO of Agni Solar Systems Private Limited, India for all his help.
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GLOSSARY

- AGNI – Agni Solar Systems Private Limited
- BNEF – Bloomberg New Energy Finance
- DER – Distributed energy resources
- DRE – Distributed renewable energy
- EAAS – Energy as a Service
- EPC – engineering procurement and commissioning
- ESMAP – Energy Sector Management Assistance Program
- GHG – Greenhouse gas
- GSM – global system of mobile telephony
- GW – Giga Watt
- IEA – International Energy Agency
- IoT – Internet of things
- KWH – Kilo watt hour
- LCOE – Levelized cost of electricity
- LED – light emitting diode
- MNRE – Ministry of New and Renewable Energy, India
- MTF – multi tier framework
- MW – Mega Watt
- OGS – Off-grid solar
- P2P – peer to peer
- PAYGO – Pay as you Go
- PROSUMER – producer and consumer of electricity
- PV – Photovoltaic
- SDG – United Nations sustainability development goal
- SE4ALL – sustainable energy for all
- SHS – Solar Home System
- SMS – short messaging service
- UJALA – Unnat Jeevan by Affordable LEDs and Appliances for All
- WRI – World Resources Institute
1.0 INTRODUCTION

1.1 Energy access problem

Light is a fundamental human need, and yet it is shocking that even today more than a billion people around the world still lack access to electricity; 95% of these people living in sub-Saharan African or developing Asia, 80% in rural areas, and more than 300 million in India. Without any other options, these people are forced to either go without power or burn kerosene or wood. In addition, without an adequate source of lighting, they are anchored to social backwardness and lack the ability to progress by way of education or opportunities of livelihood.

Figure 1.1: Population without access to electricity

Woman cooking using kerosene lamp illumination.
As such, there is an urgent need for the democratization of energy, which is defined as equitable access for smaller, disadvantaged energy consumers to the high-value energy options currently realized only by larger consumers.

The traditional model of the centralized large electric utility connecting everyone to the grid and supplying reliable and cost-effective electricity has limitations and has failed these people. There needs to be a new model that can bestow the fundamental human need of light and provide inclusivity and equity to the masses. There is a need to re-think the solution from a top-down approach to a bottom-up one.

In India, as well as in most countries around the world, policy planners confront the issue of electricity access gap by looking at solutions that will increase supply generation and grid expansion without paying attention to how consumers actually use and pay for electricity. Connecting customers to the grid is costly, and many governments currently do not have the resources to offer everyone grid power. A lasting and sustainable solution requires a more holistic approach that examines and understands the issue from the consumer’s point of view. Innovative finance models are also needed to provide affordable electricity to consumers alongwith flexible payments well-suited to their incomes.

1.2 Methodology

This study analyses the problem of energy access in India and it’s background and context and proposes the use of off-grid solar home lighting systems (SHS) enabled by pay-as-you-go (PayGo) technology and using Energy-as-a-Service (EaaS) business model as a viable solution.

The study firstly defines and states the importance of the democratization of energy; secondly the background and importance of solar energy and a snapshot of the energy sector in India; thirdly the problem of energy access and energy poverty; fourthly the pathways to power and energy access with a focus on PayGo; fifthly the solution proposed and a focused case study of Agni Solar Systems in India; and finally a brief look at the pertinence of blockchain technology in energy.

1.3 Proposed solution

The proposed solution using off-grid SHS enabled by PayGo technology and using EaaS as a business model is an effective, viable and practical first step towards providing access to electricity to people at the bottom of the pyramid who presently have no access and who are forced to use fuel based light sources for illumination.

This solution provides a gateway and a first step for these people to enjoy modern and clean lighting and enable them to break the bonds of social backwardness and provide them the means to transform their lives. The end goal envisions a holistic
solution with a judicious mix of grid connectivity along with off-grid solutions to allow these people to move up the ladder of energy access towards energy prosperity.

Figure 1.2: Energy sources as a correlation to increasing prosperity

The proposed solution is targeted at low-income consumers, primarily in rural areas in India as well as underdeveloped countries around the world, that are not connected to the grid or have unreliable and erratic grid supply. This solution will empower these people, giving them access to low-cost off-grid solar devices, which in turn will provide them the means to transform their lives.

Woman working using solar powered LED light in rural India.
This model can be replicated in other countries around the world as well. There exists a global potential market of 434 million households without energy access, of which 36% are in India\(^1\).

1.4 PayGo

PayGo technology and solar products driven by these technologies have seen a huge surge in sales recently. Climatescope has estimated that more than 1.1 million solar home systems have been sold to customers worldwide in the last five years\(^2\). These providers have leveraged mobile payments to build scalable business models that make solar home systems accessible for low-income customers. PayGo customers are typically rural, and low-income.

1.5 Agni Solar Systems Private Limited, India

This study focuses on and details a company in India — Agni Solar Systems Private Limited (Agni) which was founded by Ravi Pittie. The company is a rooftop solar photovoltaic player providing engineering, procurement, and commissioning (EPC) services in the range of 10KW-1MW to customers in India. They are now transforming themselves driven by their vision to develop and use PayGo technologies that are usable, cost-effective and accessible to all sections of society, and which can benefit humanity and the world at large.

The company has an aim to deliver low cost lighting solutions to the lowest income segments in the under-developed parts of the world, i.e., to the “bottom of the pyramid.” For these segments, light is a necessity and not a luxury. Thomas Edison once said, “We will make electricity so cheap that only the rich will burn candles.” Agni has tweaked this to say ”We will make off-grid electric devices so cheap to use that only the rich will use grid power.”

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By this business model, the company is providing a straightforward and direct pathway to fulfill the consumer's needs. This is also a sustainable, equitable, inclusive and scalable model with the potential to empower and improve the lives of marginalized and disadvantaged people around the world. This is a great example of end-use pricing and leverages existing technology and infrastructure to provide exceptional value and benefits and hence can be rolled-out immediately and scaled-up rapidly and easily\(^3\).

Agni is also planning to create a sustainable distribution model by partnering with non-profits and creating women micro-entrepreneurs in the regions where they plan to operate. The trained women provide a complete 'ecosystem' approach as clean-technology users, educators, providers and supporters in their communities, which helps make it easier for people to adopt clean energy technologies and products. Once the communities become motivated and adopt clean energy technologies, they begin to transform their villages from non-users to adopters and finally to promoters of clean energy.

\(^3\) Company's website: [http://agnisolar.com/](http://agnisolar.com/) and interviews with the founder - Ravi Pittie
2.0 THE ENERGY DEMOCRACY IMPERATIVE

2.1 What is Energy Democracy

Energy democracy is about providing energy consumers control over the production, distribution, supply, price and choice of energy. It is the concept of a socially just, equitable and inclusive energy system that provides universal access, fair prices, greater value, resiliency and choice.

"Energy Democracy is defined as equitable access for smaller, disadvantaged energy consumers to the high-value energy options currently realized only by larger consumers. By reducing cost and market barriers to energy/climate business and technology innovations, these systems have the potential to induce: greater electricity access where networks are currently inadequate, damaged, or unreliable; greater consumer access to energy democracy, including potential for sharing-economy-type business models; greater economic value for climate-beneficial consumer choices, by reducing friction to positive-NPV solar, battery, electric vehicles, efficiency/control solutions, all resulting in greater market penetration for these climate-friendly solutions; potential for business and job creation, leading to economic growth." 4

Access to energy is one of the greatest barriers to building an inclusive world. The transformation of the electricity sector offers business and government an opportunity to democratize energy and may finally offer the opportunity to address the challenges of electricity access, inclusivity and equity.

2.2 Need for Energy Democracy

Access to electricity is recognized as fundamental to human existence, dignity and development, and many efforts are under way across developing countries to scale up access, both in terms of providing basic supply and enabling people to move up the ladder of energy access.

The relationship between electricity access and development is two-way. Development cannot be accelerated without access to electricity, and financially self-sustaining electricity access cannot be supported without successful development as it underpins strong and sustained demand for electricity services.

There is a need for the following:

a) **Understand electricity demand from the bottom up:**

Traditional electricity planning has relied on top-down projections of future demand based on extrapolations of demand patterns, and forecasts of future economic growth. These methods do not take into account the very different levels of need among consumers.

b) **Link electricity access with local development efforts:**

There is an urgent need to avoid the “vicious cycle of underdevelopment,” in which areas with low levels of economic development have low levels of demand for electricity, which makes them unattractive to electricity service providers. The lack of access to electricity, in turn, perpetuates the lack of economic development in these areas.

Improving the reliability of electricity supply will be key to addressing the electricity access gap and thereby promoting socioeconomic development in these areas. The International Energy Agency (IEA) has projected that attaining universal access to electricity by 2030 will require the adoption of approaches that integrate both conventional grid and distributed generation options. It is estimated that nearly half (45.5 percent) of rural areas lacking electricity will be connected by mini-grids, and a quarter (24.5 percent) of rural areas will rely on small, stand-alone solutions such as solar home systems for first-time electricity access by 20305.

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3.0 RELEVANCE OF SOLAR ENERGY

3.1 Why Solar Energy?

Solar energy has the potential to become the dominant energy source in the near future. It provides a logical and viable solution to not only our growing energy needs but also for mitigating the effects of climate change. Fittingly, in ancient Indian philosophy and in the sacred texts of the Vedic hymns, the sun or Sūrya is symbolized as the dispeller of darkness, the bestower of knowledge, goodness and life and is revered as a deity.

In recent years, photovoltaic (PV) panels have gotten dramatically cheaper, and in 2016, solar PV projects attracted more investment globally than did any other type of power source. 6

The World Energy Council data of 2016 estimates total global installed solar capacity to be 227 GW with most of the production concentrated in Europe, North America and East Asia. According to the International Energy Agency (IEA) 75 gigawatts of solar were installed globally in 2016, bringing the installed global photovoltaic capacity to 303 gigawatts7.

Figure 3.1: Global solar photovoltaic capacity as of 2016 by select country (GW)

6 Sivaram, V. (n.d.). Taming the sun: innovations to harness solar energy and power the planet. Retrieved from https://mitpress.mit.edu/books/taming-sun

7 Snapshot of Global Photovoltaic Markets 2016
3.2 Solar energy in India

In India, Prime Minister Narendra Modi has hailed solar as the ultimate solution to India’s energy problems. Soon after getting elected in 2014, he set an ambitious and audacious target of setting-up 100GW of solar capacity by the year 2022. To put this in context, this is the equivalent of setting-up half of the total solar generation capacity that existed in the world at that time in a span of 5 years and starting from a base of virtually zero.

India, as of 2017, has achieved an impressive 20GW of solar installed capacity against a total energy generating capacity of 329GW and is still confident of achieving its goal of 100GW by the year 2022. Prime Minister Narendra Modi is also driven by his pledge to provide universal energy access to all citizens by 2019 and the Indian government is working at fever pitch to achieve this target.

Figure 3.2: India's progress towards 100GW solar energy target

Most of the planned solar expansion is in the form of utility-scale solar projects accounting for 60GW of the target and 40GW from rooftop and off-grid solutions.

As one of the fastest-growing major economies in the world, India is hungry for power and will use four times as much power by 2040 as it does today. The government is betting that solar PV could displace coal power as its main engine of growth.

In addition, the solar energy initiative will help India tackle its growing air pollution problem and also electrify remote villages.
The result of the rapid expansion in solar capacity has resulted in the World's lowest solar and wind tariffs at the time of bidding in 2017, on a levelized cost basis (LCOE). Prices of utility-scale solar projects dropped to Rs. 2.44/KWh (US$0.038/KWh) in 2017.  

The two most important reasons behind the decline in LCOE in the recent years are increased competition in the market and the decline in capital costs. Lower costs have increased affordability of PV systems for the consumers.

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India also looks likely to meet its United Nations Framework Convention on Climate Change (UNFCCC) Intended Nationally Determined Contribution commitment of sourcing 40% electricity from non-fossil fuel energy sources by 2030.
3.3 Future trends

Solar energy will continue to grow and increase its market penetration. The International Energy Agency (IEA) estimates that global installed solar capacity will be 3000 GW by 2050 and the US Department of Energy (DOE) SunShot estimates that solar could potentially provide 50% of the US energy needs by 2050. However, these ambitious targets will require technological advancement and cost reduction in photovoltaic technology and also massive improvement in battery and storage solutions. These will require revolutionary and not merely evolutionary improvements.
4.0 INDIA’S ENERGY SECTOR IN CONTEXT

4.1 Snapshot of India’s economy and power sector

- India is the sixth largest economy on the basis of nominal Gross Domestic Product (GDP) of $2.45 Trillion in 2017
- As per the World Bank, India is the third largest economy on a Purchasing Power Parity (PPP) basis with a GDP of $9.48 Trillion
- Five-year economic growth rate: 23.00%
- Population: 1,324.17m
- Total clean energy investments, 2011-2015: 46.94$ Billion
- Installed power capacity: 313.86 GW
- Renewable share: 16.00%
- Total clean energy generation: 86,599.28 GWH

India was the world’s sixth largest clean energy investment market in 2016. The total installed power generation capacity of the country was 314GW at the end of 2016, which was surpassed only by China (1.6TW) and the U.S. (1.1TW). Renewable energy capacity now accounts for 16% of the total installed capacity. A record breaking 4.3GW of solar power, including one of the world’s largest PV projects with 648MW was added in 2016⁹.

Figure 4.1: India’s grid connected power generation profile

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4.2 Details of India's Energy Sector

The power sector in India is complex and multi-tiered thereby creating greater complexity and challenges. The power sector is managed by the Ministry of Power. Generation of power is handled by federal government owned companies, state level corporations and private sector companies. The transmission of power is mainly handled by Power Grid Corporation of India. The responsibility for distribution and supply of power to rural and urban areas lies with individual state distribution companies (DISCOMs) though private licensees can be found distributing power in a few big cities like Delhi and Mumbai.

The cost of electricity from rooftop PV has halved in the last five years due to fierce competition in the market and a drop in equipment prices. In contrast, average retail electricity rates have increased by 22% in the same period. This has made rooftop PV cheaper than commercial and industrial grid tariffs in all major states in India.

Figure 4.2: Average rooftop PV levelized cost of electricity (LCOE) and electricity tariffs

<table>
<thead>
<tr>
<th>Rupees/kWh</th>
<th>10</th>
<th>8</th>
<th>6</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY2013</td>
<td>'14</td>
<td>'15</td>
<td>'16</td>
<td>'17</td>
</tr>
<tr>
<td>Residential</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Bloomberg New Energy Finance

Net metering is another important enabler for this growth, as homeowners are usually drawing less power during the hours when their PV panels are producing, making self-consumption much harder.
5.0 THE PROBLEM OF ENERGY ACCESS AND ENERGY POVERTY

5.1 Background and Global Context

More than one billion people around the world lack access to electricity, largely in rural and remote areas, with 95% of these people living in sub-Saharan African or developing Asia, and around 80% in rural areas. More than 300 million of them live in India. Without any other options, these citizens are forced to either go without power or burn kerosene or wood. In addition, without an adequate source of lighting, they are anchored to social backwardness and lack the ability to progress by way of education or opportunities of livelihood.

Figure 5.1: Population without energy access

![Population without electricity, millions](image)

Source: IEA, World Energy Outlook 2015

Figure 5.2: Distribution of countries with the lowest access to electricity in 2016

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Sudan</td>
<td>9.1%</td>
</tr>
<tr>
<td>Chad</td>
<td>6.4%</td>
</tr>
<tr>
<td>Burundi</td>
<td>6.5%</td>
</tr>
<tr>
<td>Malawi</td>
<td>8.8%</td>
</tr>
<tr>
<td>Liberia</td>
<td>9.8%</td>
</tr>
<tr>
<td>Central African Republic</td>
<td>10.0%</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>13.3%</td>
</tr>
<tr>
<td>Sierra Leone</td>
<td>14.2%</td>
</tr>
<tr>
<td>Niger</td>
<td>14.4%</td>
</tr>
<tr>
<td>Tanzania</td>
<td>15.3%</td>
</tr>
</tbody>
</table>

Source: Statista

Additional Information: World Bank, World Development Indicators 2018
5.2 UN Sustainable Development Goal 7

The Sustainable Energy for All (SE4All) initiative launched by the United Nations aims to achieve universal access to modern energy services by 2030. Sustainable Development Goal (SDG) number 7 aims at having universal access to affordable, reliable and sustainable modern energy by 2030.

It is clear and imperative that the energy sector must be at the center of efforts to lead the world on a more sustainable pathway. However, the current and planned policies fall well short of achieving the sustainable development objectives and goals and also fail to provide an inclusive and equitable solution to people without access to electricity.

There has been tremendous progress in delivering universal electricity access in Asia and parts of sub-Saharan Africa, with the number of people without access declining to 1.1 billion in 2016, from 1.7 billion in 2000. But on the basis of current progress, more than 670 million people are still projected to be without electricity access in 2030\(^\text{10}\).

Figure 5.3

Projected population without electricity access worldwide in 2009, 2016 and 2030, by region (in millions)

<table>
<thead>
<tr>
<th>Region</th>
<th>2009</th>
<th>2016</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central and South America</td>
<td>30</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>North Africa</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>58</td>
<td>58</td>
<td>80</td>
</tr>
<tr>
<td>Middle East</td>
<td>6</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>India</td>
<td>29</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>China</td>
<td>0</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Rest of developing Asia</td>
<td>0</td>
<td>54</td>
<td>329</td>
</tr>
</tbody>
</table>

Source: IEA, Statista 2017


Figure 5.4: Cumulative population gaining access to electricity 2017-2030


Providing energy for all would significantly improve the lives of those without access and boost their economic prospects. Women in particular stand to gain the most by cutting the time they spend gathering fuel and cooking and also avoiding air pollution. At present, an estimated 2.8 million people die prematurely each year...
because of the smoky environments caused by burning solid biomass in inefficient stoves or from the use of kerosene or coal for cooking\textsuperscript{11}.

5.3 Energy access problem in India

In India, approximately 300 million still people lack access to electricity. This is despite India being one of the world's largest and fastest growing economies as well as clean energy markets.

In India, although nearly 96% villages are considered electrified, only 69% of homes have electricity connections. This implies that a large part of India's electrification and energy access is only theoretical. In fact, the problem is substantially worse due to inaccuracies in the data and also inconsistencies in the definition of "electrification" as defined by international standards (IEA, World Bank) and according to Indian standards (Ministry of Power).

Figure 5.8: Percentage of village households in India, by state, without electricity

Many people live under or near grid lines, but still lack a household connection. The poor performance of the Indian electricity sector is linked to a complex history of social, political, and institutional dynamics. A large part of this problem is also due to legacy issues of poorly run state-owned enterprises, rampant corruption and apathy.

Despite the present government’s strong push to ensure 100% electrification, state-run power retailers consider supplying rural homes as an unattractive business proposition because of the following:

- low off-take of electricity usage and below-cost tariffs.
- Power distributed to farmers and households under the poverty line is sold at subsidised below-market rates and sometimes supplied free of cost.
- Agriculture represents about 18 percent of electricity consumption in India, and the Indian government and distribution utilities subsidize agricultural energy consumption heavily.
- Electricity retailers lose about one-quarter of the electricity they have for sale through technical and commercial losses—the industry term for power theft.

As such, the distribution companies have no incentive to supply power to rural areas because they don’t get paid and people don’t pay because they have no incentive to pay, because they don’t get quality power creating a vicious cycle.

5.4 Energy Poverty

Energy poverty is another dimension of the problem and afflicts not only the underdeveloped countries but also the developed countries. It can take different forms, including a lack of access to modern energy services, a lack of reliability when services do exist and concerns about the affordability of access. Affordability can be an issue even in developed countries with universal and reliable access to modern energy. IEA estimates this by using spending of households as a measure (proportion of households spending more than 10% of their income on energy). In addition, they take into account survey responses on whether households are able to keep their homes sufficiently warm. Based on this methodology, IEA calculate that an estimated 200 million people in developed economies, suffer from energy poverty\(^\text{12}\).

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5.5 Definition of Energy Access

There is no single internationally-accepted and internationally-adopted definition of modern energy access.

The IEA defines energy access as "a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average". This energy access definition serves as a benchmark to measure progress towards SDG 7.1.
Electricity access entails a household having initial access to sufficient electricity to power a basic bundle of energy services. The average household who has gained access has enough electricity to power four lightbulbs operating at five hours per day, one refrigerator, a fan operating 6 hours per day, a mobile phone charger and a television operating 4 hours per day, which equates to an annual electricity consumption of 1 250 kWh per household with standard appliances, and 420 kWh with efficient appliances.¹³

5.5 Multi-Tier Framework

The multiple services that electricity can provide to households has a variety of profound direct and indirect impacts. Among the benefits are reduced expenditures for energy; more time available due to electric lights and other appliances; improvements in education, health, and communications; enhanced productivity and income levels; and reduced carbon dioxide and black carbon pollution, which are harmful to public health and contribute to global warming.¹⁴

Energy Sector Management Assistance Program (ESMAP), under the SE4ALL initiative, in consultation with multiple development partners has developed the Multi-tier Framework (MTF) to monitor and evaluate energy access by following a multidimensional approach.¹⁵

MTF redefines energy access from the traditional binary metric to a multi-dimensional definition as “the ability to avail energy that is adequate, available when needed, reliable, of good quality, convenient, affordable, legal, healthy and safe for all required energy services”. As such, having an electricity connection does not necessarily mean having access to electricity under the new definition, which also takes into account other aspects such as reliability and affordability. Energy access is measured in the tiered-spectrum, from Tier 0 (no access) to Tier 5 (the highest level of access).


5.6 Policy and regulatory context

In India as well as in most countries around the world, policy planners confront the issue of electricity access gap by looking at solutions that will increase supply generation and grid expansion without attention to how consumers actually use and pay for electricity. A lasting and sustainable solution requires a more holistic approach that examines and understands the dynamics from a multi-dimensional and consumers point of view.

The World Resources Institute (WRI)\(^{16}\), proposes an approach to closing the access gap driven by the belief that electrification must respond to user demand and help improve lives. This proposes three strategies for policymakers, planners and electricity service providers:

a) **Understand electricity demand from the bottom up:**
In most developing countries, electricity planners look to economic growth forecasts to project future demand for electricity. Planners fail to take into account the

---

different levels of need amongst different consumers. A rural household doesn’t need the same amount of electricity as an urban consumer.

Rather than implement a one-size-fits-all approach, there is a need to offer more targeted solutions. For instance, in some rural communities where demand for electricity is low, planners might consider options such as solar home systems or small-scale mini grids coupled with energy-efficient appliances, especially when these options are cheaper than conventional grid extension.

b) Link electricity access with development priorities:
The relationship between electricity access and development is inter-related. Development cannot be accelerated without access to electricity. Likewise, electricity access initiatives cannot be supported without successful development that drives demand for electricity services.

c) Ensure electricity services are reliable, affordable and of good quality:
It is not adequate to just have access to electricity. Consumers must be able to pay for and use it as well. Innovative consumer finance models are needed to provide affordable electricity to consumers and allow them to make flexible payments suited to their incomes.

5.7 Role of energy efficiency in expanding electricity access

Energy efficiency and demand-side management considerations are also important as they enable consumers do more with less electricity.

a) Supply-Side Efficiency
Poor supply-side efficiency results in significant depletion of the electricity that is ultimately available to end consumers and can lead to higher electricity costs for everyone.

Old and poorly maintained transmission and distribution (T&D) infrastructure also results in significant electricity losses, further reducing the electricity available to consumers. Technical losses can be further compounded by commercial losses caused by low metering efficiency, theft, pilferage etc.

b) Demand-Side Efficiency
Demand-side efficiency, for both grid-connected and off-grid consumers, can also play a role in closing the overall supply gaps. Demand-side measures focus on reducing the overall electricity demand of consumers, to enable them to do more with less. The use of higher efficiency end-use appliances can reduce overall peak loads and utilities and energy-service providers will be able to save on investments in new generation capacity. Demand-side efficiency is also relevant in the off-grid context.
5.8 Energy efficiency in India

The relationship between energy efficiency and electricity access has been under-explored in India. On the one hand, expanded access should not end up promoting wasteful consumption or excess consumption, as we’ve seen in many developed nations today thereby creating a moral hazard. On the other, there are energy-efficient technologies that could go hand-in-hand with energy access programs e.g. the Unnat Jeevan by Affordable LEDs and Appliances for All (UJALA) government program in India providing efficient LEDs which has played a lead role in providing lighting at lower costs for rural India.

Lighting itself accounts for about 20% of the total electricity consumption in India. Prime Minister Narendra Modi launched the UJALA initiative to provide LED bulbs to domestic consumers with a target to replace 770 million incandescent bulbs with LED bulbs by March, 2019.

Table 5.1: Progress of Implementation\(^\text{17}\)

<table>
<thead>
<tr>
<th>Metric</th>
<th>Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of LED bulbs</td>
<td>269 million</td>
</tr>
<tr>
<td>Avoided capacity generation</td>
<td>6994 MW</td>
</tr>
<tr>
<td>Energy saved</td>
<td>34.93 billion KWh/year</td>
</tr>
<tr>
<td>Annual reduction in carbon</td>
<td>28.29 million ton</td>
</tr>
</tbody>
</table>

\(^{17}\) NATIONAL UJALA DASHBOARD | EESL. (n.d.). Retrieved February 6, 2018, from http://www.ujala.gov.in/
6.0 PATHWAYS TO POWER

6.1 Approaches to enhancing energy access

Over the last five years, rapid technological progress and cost reduction has enabled renewable energy sources to be at the forefront of providing new energy supply and access worldwide, and this shift is expected to accelerate. The International Energy Agency (IEA) estimates that by 2030, renewable energy sources will power over 60% of new access, while off-grid and mini-grid systems will provide almost half of new access underpinned by new business models using digital and mobile technologies.\(^\text{18}\)

A variety of current options serve electricity demand and provide energy access for distributed and localized generation:

- **Diesel generators** are common throughout India, both as a form of backup for homes and businesses that have an unreliable grid connection, as well as a primary source of electricity.
- **Solar home systems (SHS)** are individually-owned units that consist of a roof-top solar photovoltaic (PV) panel, a battery, a charge controller, and a means of connecting an appliance to the electricity supply. Solar home systems can vary in the size of the PV panel and the size of the battery and thus, can range in cost.
- **Microgrids** are isolated distribution networks that connect as few as two, but potentially many more to a shared source of generation. In India, that source of generation is most frequently solar PV panels.

India has a large energy need for both household and commercial consumption, and it is becoming increasingly difficult to meet these needs through traditional forms of power generation. India has an abundance of resources such as solar, wind and biomass, and yet spends a lot of money on importing oil, coal, and natural gas. A decentralized renewable energy solution, bolstered by the support of innovative financing and business models leveraging mobile and internet connectivity along with support from private investors and the government, can make clean, healthy, reliable and equitable energy access a near-term possibility.

6.2 New Solutions

More innovative consumer finance approaches such as the pay-as-you-go (PayGo) model are overcoming the challenge of reaching bottom-of-the-pyramid consumers through technology-driven financing approaches. This model has seen widespread success in East Africa and recently in India as well.

PayGo businesses have tapped into the widespread reach of mobile phone technology to provide electricity services to rural low income communities by facilitating remote and flexible payments that are well suited to the income-flow patterns of bottom-of-the-pyramid consumers\(^\text{19}\).

Figure 6.1: Electricity access technology options


6.3 Case studies from India

a) **Mera Gao Power (MGP)**
   - They offer customers two solar powered lamps and a mobile phone charger for less than a dollar per week, powered by renewable energy sources as opposed to kerosene. MGP has been providing night-time lighting to over 150,000 people in 1,500 off-the-grid villages in northern Indian state of Uttar Pradesh. This social enterprise is funded by USAID and French electric utility Engie.

b) **Swayam Shikshan Prayog (SSP)**
   - They have built a rural distribution network of 1,100 women entrepreneurs, called sakhis (Hindi for “friends”). These women educate rural communities to adopt clean energy products and services. The Sakhis have reached over 1 million people in Maharashtra and Bihar. They are not only ‘last mile’ distributors but also future leaders of clean energy.

c) **Frontier Markets (FM)**
   - They tackle the everyday struggle of unreliable electricity and hazardous cooking practices of rural households. They train local people to sell and service affordable solar energy products, turning them into clean energy entrepreneurs. Since 2011, FM has sold over 100,000 zero-carbon lighting units, created 500 retail points and 200 women entrepreneurs. FM also trains women to sell solar solutions to other women. The initiative aims to give them the opportunity to be clean energy leaders, and earn extra money for their families.

6.4 The case for solar home systems and decentralized renewable energy solutions

Growing awareness, falling prices and greater access to finance are making off-grid energy solutions – including solar lanterns, solar home systems (SHS) and decentralized renewable energy (DRE) – increasingly attractive to consumers.
Figure 6.2

Number of households using pico-photovoltaics in Africa and Asia as of June 2015, by select country (in millions)

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Households (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>8.1</td>
</tr>
<tr>
<td>Kenya</td>
<td>2.7</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>2.0</td>
</tr>
<tr>
<td>Nigeria</td>
<td>0.3</td>
</tr>
<tr>
<td>Other sub-Saharan African countries</td>
<td>3.2</td>
</tr>
<tr>
<td>Other Asian countries</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Sources:
Bloomberg New Energy Finance; Lighting Global; World Bank; UNEP; GOGLA, © Statista 2017

Additional Information:
Africa; Asia; Bloomberg New Energy Finance; Lighting Global; GOGLA; as of June 2015

Figure 6.3

Projected number of households using off-grid solar worldwide from 2010 to 2020 (in million households)

Source:
Bloomberg New Energy Finance
© Statista 2017

Additional Information:
Worldwide; 2010 to 2015

34
6.5 Overview of DRE enterprises

Two DRE models demonstrate strong potential for commercial viability:

a) **Business-to-consumer (B2C)** models that provide households with only basic lighting (2-3 lights) and mobile charging, with less than 500 W in capacity. Given that these companies can offer households a price lower than kerosene, rural consumers can simply substitute their monthly kerosene expenditure for payments to the DRE provider. As a result, this model can reach many consumers fast, with a small amount of upfront capital investment. Companies can recover costs within one to two years if they are able to attract enough customers and ensure strong collections.

b) **Business-to-business and business-to-consumer (B2B + B2C)** models with installed capacities greater than 25 kW can provide power to commercial anchor clients such as a rural mobile tower or an ATM, in addition to rural households. The commercial anchor client can provide a stable stream of revenue that is enough to cover yearly operating expenses on their own, and excess electricity is then sold to nearby households.

6.6 SHS technology and pricing

SHS products can be broadly divided into three categories: basic, standard, and advanced:

- A basic SHS is less than 10 W and can power one to three lights.
- A standard SHS is up to 150 W and can power multiple lights, as well as some appliances such as DC fans and TVs.
- An advanced SHS is greater than 150 W, and can power lights and large appliances of an entire house.

Prices can range anywhere from US$20 to over US$500, depending on the size and specifications of the product.

6.7 Consumer financing and affordability

An average simple solar lantern is priced at US$13 (INR 800), a multiple functional lantern with added features on average is priced at US$23 (INR 1,400) and a smaller SHS is priced at US$65 (INR 4,000). While rural consumers are willing to buy such products, their limited and irregular incomes make it difficult to make large purchases.
Consumer financing options are therefore an integral part of the SHS product offering, and companies have developed various ways of supporting consumer purchases. Most companies are looking to develop strong relationships with banks and micro-finance institutions in order to ensure access to finance for the consumer, while a few others have launched installment based or PayGo models for payment.

6.8 Market size and impact

Overall, the market size for solar home systems in India is estimated to be US$200-250 million in 2018 with over 3 million units sold. Rural off-grid households use kerosene for much of their lighting, spending roughly US$2-10 a month on lighting. Kerosene lighting produces carbon emissions as well as “black carbon” which has a much stronger greenhouse effect than regular CO2, but the use of solar home systems can offset these carbon emissions. There are also significant social benefits to expanding electricity access to households, including increased study time for children, better health, increase in productivity of rural businesses from longer hours of electricity and the income benefits of increased economic activity.20

Figure 6.4: Fuel mix in selected countries

Energy use and fuel mix are strongly related to development


6.9 Conclusion

The SHS and DRE market in India will grow rapidly as the ability of rural households to pay for products and services increases, and the reach and awareness of these products grows. The truly successful SHS enterprises will be those that can leverage initial relationships with the consumer to cross-sell and up-sell. These companies need to have a strong focus on brand building, develop trust as well as have the capability to innovate and use technology to solve the problem of access, affordability, payment collection and last-mile connectivity.
7.0 PAY-AS-YOU-GO (PayGo) TECHNOLOGY FOR PROVIDING ENERGY ACCESS

7.1 What is PayGo?

In the PayGo business model, a company essentially rents consumers a basic solar home system that comes with a battery, a charge controller, a solar panel and LED bulbs. Basic systems have enough power to charge phones and run lights, and larger ones could power small appliances like radios or TVs. Consumers use basic mobile phones – widespread in India – to make payments on a daily, weekly or monthly basis or on a pay-as-you-use basis and purchase necessary hours of light. This is an example of end-use pricing and allows the consumers to directly purchase what they need, in this case light, and provide the same transparently and directly. The consumers have total visibility with respect to what they are paying for, what they are getting, how much it costs and have full control on their usage and payments.

This is very unlike the traditional utility model wherein even sophisticated consumers have no understanding nor transparency regarding electricity rates, what the “units” of electricity provide i.e. how many lights and for how many hours in lieu of one unit of electricity. Consumers are also interested to pay for what is their end-use and what they need e.g. light, heat, cooling etc.

Through this model, companies can minimize the cost of collections by automating the receipt of payments, while remote rural customers get immediate access to basic electricity without having to take out a loan. By contrast, grid expansion and centralized power generation projects can take years and significant investment to reach a rural or low-income community.

7.2 Status and background of PayGo

PayGo technology and solar products driven by these technologies have seen a huge surge in sales recently. Climatescope has estimated that more than 1.1 million solar home systems have been sold to customers worldwide in the last five years\(^{21}\). These providers have leveraged mobile payments to build scalable business models that make solar home systems accessible to low-income customers. The rapid expansion of these companies implies that they deliver real value and solve a pressing problem for large numbers of customers.

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The primary reason to invest in a solar home system is to end darkness and experience modern lighting. It offers the ability to provide light that is good enough to read, study, or cook by. It also eliminates the risk of fires, smoke and particulate residue caused by candles and kerosene lanterns.

Paying over time and paying for usage brings an expensive asset within reach. Many customers would not be able to buy solar home systems if they had to pay in full at once, which would then force the purchase to compete with other kinds of large and urgent investments and payments such as food, medicines, hospitalization etc. The primary driver of their purchase decision was not to save money but to make a lifestyle change. What really mattered to customers was the ability to invest in a lifestyle transformation.

7.3 PayGo Business model

A customer pays a deposit, and then uses his mobile wallet to purchase necessary hours of light for a small predetermined fee. Customer accounts are automatically debited and the system is re-charged with the credit of hours. The system is disabled when the credit runs out, but new payments reactivate the system even after days of inactivity. Customers can prepay or go without lights several days per week or month without penalty. However, after some period of no payment (typically more than 90 days), units may be blocked, and a larger payment is required to reactivate them.

Proprietary hardware in the solar device regulates usage, disabling the energy services when the customer’s prepaid usage is used up or expires. Under most PayGo models, the device permanently unlocks at the end of the lease period and ownership is transferred to the end customer.

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7.4 Financing for PayGo

Pay-as-you-go solar companies attracted $265 million of investment in 2017. January 2018 has already seen $94 million in new investments\(^{23}\).

Figure 7.1: Financing for PayGo companies ($ million)

![Graph showing financing for PayGo companies from 2013 to 2017.]

Source: Bloomberg New Energy Finance. As of October 30, 2017

7.5 Drivers for PayGo

PayGo enabled SHS are driven by the following factors:

\( a) \) Many governments currently do not have the resources to offer everyone grid power. Most governments are not yet in a position to provide hundreds of millions of people with access to grid power within the next year or even decade. Even if a household can afford the connection cost, they could be waiting years for the connection. Once connected, it may be unreliable. Solar home systems offer immediate access to electricity, and customers do not have to wait months or years for the grid to come to them.

\( b) \) Connecting customers to the grid is costly. In comparison to the cost of off-Grid systems, the on-grid system might appear to be less expensive for the first three years. However, the off-grid system can actually be more attractive and provide significant co-benefits (health, education, etc.) and is also owned

free and clear after 1-3 years, which means that there will be virtually zero or very limited future energy or recurring costs.

7.6 Off-Grid Solar (OGS) status and market size

As of 2017, the global off-grid solar (OGS) sector is providing improved electricity access to an estimated 73 million households, or over 360 million people, thus transforming lives that were previously reliant on kerosene and solid fuels for most of their lighting needs²⁴.

The sector has seen cumulative sales of over 130 million devices since 2010, with rapid growth (~60% CAGR), and significantly increased penetration. The total sales value generated by the OGS sector has exceeded USD 3.9 billion²⁵.

Despite strong grid expansion the potential market for OGS remains large due to the following factors:

a) A large portion of off-grid populations that have been connected to the grid are receiving inadequate power. They have effectively transitioned from off-to unreliable-grid, and continue to represent a potential market for OGS devices.

b) High population growth in some of the most poorly electrified regions keeps the market size large in absolute numbers.

c) Existing customers require replacement devices every 2-4 years, and also have the potential for up-selling and upgrades.


Figure 7.2: Countries with the largest potential markets

Total global potential market of 434 million households

- **India**: 36%
- **Uganda**: 3%
- **Kenya**: 3%
- **Tanzania**: 3%
- **Myanmar**: 3%
- **Congo, Dem. Rep.**: 8%
- **Indonesia**: 4%
- **Nigeria**: 4%
- **Bangladesh**: 5%
- **Pakistan**: 5%
- **Others**: 28%


Figure 7.3: Change in potential market size from 2010-2017 (million households)

- **2010 potential market**: 415
- **Newly connected households**: 163
- **Propportion of new connections with unreliable-grid**: 73
- **Population growth in off- and unreliable-grid regions**: 252
- **2017 potential market**: 434
- **Potential upgraders**: 73
- **Replacement-ready users**: 45
- **New purchasers**: 317

Figure 7.3 illustrates that despite significant electrification gains since 2010, the potential market remains huge at 434 million households. In addition and importantly, the potential revenue potential for the sector has risen as companies realize higher customers’ lifetime value (LTV).

Figure 7.4 shows that an average customer in 2010 was estimated to spend USD 30-80 on an OGS product, is now estimated to have a lifetime value of USD 370-1,120. Established players have created a large product portfolio at various price points to cater to customers’ differing willingness to pay, and also encourage customers to move up the product chain towards more expensive and feature-rich products.

Figure 7.4: Lifetime Value (LTV) potential of OGS consumers ($, 8 year horizon)

Growth has been strong in countries with strong mobile money ecosystems e.g. East Africa. However, despite being the largest OGS market in the world, and having excellent enabling conditions of widespread mobile phone and mobile money penetration, India currently has very low PayGo activity. As such, PayGo is well poised for exponential growth catalyzed by a huge surge in mobile and digital transactions in the country.


Figure 7.5: Number of PayGo players by country and geographic share of the PayGo market


Figure 7.6: Some of the PayGo players along with their product offerings

7.7 Global product sales and size-wise volumes

3.52 million SHS products were sold in the first half of 2017, with 1.77 million units in Sub-Saharan Africa and 1.16 million units in South Asia. The global sales revenue in H1 2017 amounted to about $95.57 million.27

Figure 7.7: Top 10 countries in terms of volume of products sold

<table>
<thead>
<tr>
<th>Country names</th>
<th>Volume of Products Sold</th>
<th>Cash Sales Revenues of Products Sold</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>1,087,282</td>
<td>$26,660,327</td>
</tr>
<tr>
<td>Kenya</td>
<td>413,644</td>
<td>$6,377,033</td>
</tr>
<tr>
<td>Uganda</td>
<td>240,161</td>
<td>$8,275,353</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>210,913</td>
<td>$7,643,643</td>
</tr>
<tr>
<td>Rwanda</td>
<td>190,781</td>
<td>$4,053,835</td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>133,946</td>
<td>$3,366,392</td>
</tr>
<tr>
<td>Nigeria</td>
<td>107,999</td>
<td>$1,702,919</td>
</tr>
<tr>
<td>Tanzania</td>
<td>69,143</td>
<td>$3,422,669</td>
</tr>
<tr>
<td>Senegal</td>
<td>67,603</td>
<td>$499,380</td>
</tr>
<tr>
<td>Philippines</td>
<td>55,197</td>
<td>$1,028,589</td>
</tr>
</tbody>
</table>


As shown in Figure 7.8, about a third of total worldwide sales volume were single light products without mobile charging and powered by a panel in the range of 0-1.5 W. However, revenues from sales of products in the 0-1.5 W range are only 13% of total sales revenues, or just over $12.36 million (Figure 2). This is due to the lower retail price of such products. The next category of product with a single light and mobile phone charging capability powered by a panel in the 1.5-3 W range, accounted for 43% of units sold (1.53 million units). These products generated the majority of overall revenue at $64.76 million, almost 68% of the global sales revenues.28

Figure 7.8: Volume of products sold as per product category

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Volume Sold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>3,515,910</td>
</tr>
<tr>
<td>0-1.5 Wp</td>
<td>1,205,866</td>
</tr>
<tr>
<td>1.5-3 Wp</td>
<td>1,526,460</td>
</tr>
<tr>
<td>3-10 Wp</td>
<td>469,072</td>
</tr>
<tr>
<td>11-20 Wp</td>
<td>81,918</td>
</tr>
<tr>
<td>21-49 Wp</td>
<td>20,905</td>
</tr>
<tr>
<td>50-100 Wp</td>
<td>124,065</td>
</tr>
<tr>
<td>100+ Wp</td>
<td>14,538</td>
</tr>
<tr>
<td>Not specified</td>
<td>0</td>
</tr>
</tbody>
</table>

Volume of Products Sold Globally by Product Category


Figure 7.9: Sales revenue and revenues by product category in South Asia

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Total Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>$30,198,359</td>
</tr>
<tr>
<td>0-1.5 Wp</td>
<td>$3,954,167</td>
</tr>
<tr>
<td>1.5-3 Wp</td>
<td>$20,977,135</td>
</tr>
<tr>
<td>3-10 Wp</td>
<td>$640,190</td>
</tr>
<tr>
<td>11-20 Wp</td>
<td>$1,738,153</td>
</tr>
<tr>
<td>50-100 Wp</td>
<td>$1,161,640</td>
</tr>
</tbody>
</table>

Total Market

7.8 Analytics and monetization of data

PayGo technology enabled SHS devices are opening-up a huge untapped opportunity for the monetization and analysis of information by amassing a significant amount of product usage data. PayGo operators are generating huge amounts of data daily via mobile payment transactions and customer touch points and there are significant opportunities to leverage this data. Predictive analytics and machine learning can enable PayGo operators to customize the product offerings to fit specific market segments. Data analytics will also allow focussed targeting and up-selling opportunities. This data can also be monetized by providing access to it to fast moving consumer goods (FMCG), white goods manufacturers etc. as the this is a very large, untapped and lucrative market segment for many companies.
8.0 CASE STUDY OF AGNI SOLAR SYSTEMS PRIVATE LIMITED, INDIA

8.1 Proposed solution

This study proposes the use of off-grid solar home lighting systems (SHS) supported by pay-as-you-go (PayGo) technology and using Energy-as-a-Service (EaaS) business model as a viable solution. This solution has the potential of providing affordable electricity to unserved and underserved populations and also has the advantages of rapid roll-out and quick scale-up thereby creating maximum impact and improving the lives of many.

This study analyses and details the work of one such innovative solution being pioneered by a company in India – Agni Solar Systems Private Limited (Agni).

8.2 Agni: Company background and history

Started by Ravi Pittie in 1993, Agni began as an R&D outfit to explore new solar technologies. Since then, the company has been a pioneer in bringing innovative solar solutions and new technologies to the Indian market.

The company is a comprehensive solar energy player active in areas of solar water heating, rooftop solar photovoltaic, solar water pumping, solar cookers, and a wide range of small solar devices and gadgets e.g. lanterns, torch, home lighting kits etc.

Product range of small solar devices
Source: www.agnisolar.com
In the rooftop solar photovoltaic vertical, the company provides engineering, procurement, and commissioning (EPC) services in the range of 10KW-1MW to customers in India.

8.3 EaaS business model and PayGo technology platform

Agni is now transforming itself, driven by its vision to develop and use PayGo technologies and Energy-as-a-Service (EaaS) business models that are usable, cost-effective and accessible to all sections of society, and which can benefit humanity and the world at large.

The EaaS model and the PayGo platform allows any person the ability to directly purchase light for the number of hours they want, when they want and pay for it as they use.

With this objective in mind, the company has devised and developed a hardware chip and a software platform to be installed in their products to convert them into a pay-as-you-use model.

![Family having dinner using Agni PayGo SHS in India.](source: Agni Solar Systems Private Limited, India)

The technology has been designed and adapted to local infrastructure conditions and limitations as well as to suit local socio-economic conditions and preferences.
In rural areas of most developing and under developed countries there is no internet at the last-mile and so the technology is suitably flexible and adaptable to allow it to work via mobile phone short messaging service (SMS) rather than internet at the point of use.

Solar home lighting system (SHS) enabled by PayGo technology.
Source: www.agnisolar.com

Solar device enabled by PayGo technology.
Source: www.agnisolar.com
8.4 Features

- If a user sends payment by any payment platform then they receive an SMS code which is fed into the device. The device will then work for the number of hours that has been paid for, in some ways like a pre-paid mobile phone.
- The hardware circuit can be integrated into any device's existing printed circuit board (PCB) with minimal space requirement and so this technology can be integrated into all most all devices.
- A manufacturer need not change their existing design and can easily incorporate this technology into their own existing products.
- Users pay for actual hours of usage and not time.
- Internet access is not required to purchase and pay for light.
- The hardware cost is approximately $1 and so incorporating the technology does not substantially increase the basic cost of the device.
- The design of the platform allows the users to also pay as per intensity of light besides actual hours of usage, so a user pays less for when they are using low brightness mode.
- The platform allows for real time data analysis.
- Mobile app of the software platform allowing data analytics at multiple levels such as for user/distributor/manufacturer.
- Long standing and established supply chain with a manufacturer in China with the capacity and capability to scale-up rapidly as well as incorporate the new hardware into the device.
8.5 Financial model

- Agni will appoint distributors. The distributors will pick-up and stock the devices by paying an interest free refundable deposit of 25% of the selling price of the devices. e.g. if they have picked up devices valued at US$ 5000, then they will pay US$ 1250 as deposit.
- When the user picks-up a device they pay the dealer 25% of the device cost as interest free refundable deposit. The distributor activates that particular device only upon receiving this deposit.
- The distributor or the user can then purchase hours of light by paying money via mobile payments or the internet.
- The distributor also earns a 25% commission from each recharge which is credited back to him. This system keeps the distributor incentivized and motivated.
- Once the user has recharged 75% of the device price, the user’s 25% deposit is appropriated towards the balance and full payment against the device price and the user is sent a final recharge code which makes the device free-for-life.

Figure 8.1: PayGo value chain
8.6 Enabling infrastructure and conditions in India for PayGo

a) Mobile and digital payment system
India has excellent peer-to-peer payment systems with zero transaction costs thereby providing inclusivity to the underserved population and providing them access to banking, credit and government benefits.

The Bharat Interface for Money (BHIM) is a payment app that lets people in India make simple, easy and quick transactions using Unified Payments Interface (UPI) and has the following features:

- can be used without internet
- available in 13 local languages
- provides digital payments through your mobile phone
- Nil transaction charges
- The number of monthly transactions stood at 145 million in December 2017 with transaction values in excess of $2B
- Industry estimates suggest that more than 90% of UPI transactions are peer-to-peer.

b) Mobile phone usage
According to a report by the Cellular Operators Association of India (COAI), the total number of mobile subscribers in India has hit a total number of 953.80 million subscribers as of October in 2017 with a smartphone use base of over 300 million.
c) Internet usage
The number of internet users in India is expected to reach 500 million by June 2018, as per a report by the Internet and Mobile Association of India (IAMAI). The number of Internet users stood at 481 million in December 2017.
Figure 8.4: Number of internet users in the Asia Pacific region as of January 2017 (millions)

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Users (millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>731</td>
</tr>
<tr>
<td>India</td>
<td>462</td>
</tr>
<tr>
<td>Indonesia</td>
<td>132.7</td>
</tr>
<tr>
<td>Japan</td>
<td>117.8</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>63.3</td>
</tr>
<tr>
<td>Philippines</td>
<td>60</td>
</tr>
<tr>
<td>Vietnam</td>
<td>50.05</td>
</tr>
<tr>
<td>Thailand</td>
<td>46</td>
</tr>
<tr>
<td>South Korea</td>
<td>45.49</td>
</tr>
<tr>
<td>Pakistan</td>
<td>35.1</td>
</tr>
<tr>
<td>Malaysia</td>
<td>22</td>
</tr>
<tr>
<td>Australia</td>
<td>21.18</td>
</tr>
<tr>
<td>Taiwan</td>
<td>20.64</td>
</tr>
<tr>
<td>Nepal</td>
<td>14.12</td>
</tr>
<tr>
<td>Myanmar</td>
<td>14</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>6.26</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>6.26</td>
</tr>
<tr>
<td>Singapore</td>
<td>4.71</td>
</tr>
<tr>
<td>New Zealand</td>
<td>4.08</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>0.91</td>
</tr>
<tr>
<td>Fiji</td>
<td>0.43</td>
</tr>
<tr>
<td>Timor-Leste</td>
<td>0.4</td>
</tr>
<tr>
<td>Maldives</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Sources:
- We Are Social, Internet World Stats: US Census
- AFAC, We Are Social
- January 2017
- Sureway; GSMA
- Statista 2018
8.7 Comparison with fuel-based lighting solutions

Encouraged by government subsidies, kerosene-fueled lamps are a common light source and were used by over 380 million in India in 2011 for primary lighting. The most economically accessible and widely used kerosene lamps provide poor illumination relative to electricity and can be highly inefficient, converting as much as a tenth of the fuel to health-impacting and climate-altering particulate matter (PM). The light output from kerosene lamps is also very poor and they are highly inefficient in terms of fuel consumption and light output.

![A typical kerosene lantern used for illumination](http://www.robaid.com/gadgets/student-team-develops-20-solar-lamp-for-remote-parts-of-india.htm)

Using kerosene demand, the estimated financial benefit of an effort that would support residential lighting services using SHS lighting in place of kerosene yields a present value benefit of $18 billion.

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Kerosene lamps are the costliest and dirtiest way to generate the same light output as that of LED bulbs. Apart from wastage of fuel, other problems like smoke, safety, fire hazard, pollution etc. associated with kerosene lamps are not accounted nor assesses here. In addition, the cost of the kerosene lamps, recurring costs to buy wicks etc. is not taken into account.

The switch from kerosene based lighting is inevitable and is being driven-out by the sharp subsidy and quota reductions in kerosene as India seeks to eliminate all subsidies by 2020.

As such, the cost incurred by a typical rural off-grid person using kerosene lamps for lighting is compared with that of using the Agni PayGo model. The calculations are based upon the market price of kerosene.

As can be seen from Table 8.2, total estimated expense of kerosene lamps is $84.90 per year versus $67.38 per year for the SHS. These numbers however do not take into account the lumen output of the two solutions. When we factor the lumen output, the SHS is a significantly cheaper solution per lumen output of light than the kerosene lamps. Furthermore, the kerosene lamps have significant and serious problems related to health hazards, fire safety, pollution and soot. If these costs are quantified and factored-in, then the total direct and social costs would exceed those of the SHS by an order of magnitude. Most importantly, the SHS becomes free for life after the price is paid-off in about one year whereas the kerosene option will continue to incur expenses on a continual basis.

Table 8.2: End User Energy Consumption and Expenses (Base Case: 6h per day in 365 days per year)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Yearly Consumption</th>
<th>Price/Fuel</th>
<th>Total Yearly Energy Expenses</th>
<th>Energy Output</th>
<th>Expense/Lumen /Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>litres/hour</td>
<td>litres/year</td>
<td>US$/litre</td>
<td>US$</td>
<td>Lumen</td>
</tr>
<tr>
<td>Kerosene Lighting</td>
<td>0.04</td>
<td>87.60</td>
<td>0.97</td>
<td>84.90</td>
<td>70.00</td>
</tr>
<tr>
<td>Solar Home System</td>
<td>6.00</td>
<td>2,190.00</td>
<td>0.03</td>
<td>67.38</td>
<td>200.00</td>
</tr>
</tbody>
</table>

2. Considering FX rate of 1 US$ = 65 INR.
3. Price per hour of Solar Home System according to AgniSolar internal data.
8.8 Identifying micro-markets for roll-out in India

A set of objective criteria is essential to help guide off-grid solution providers towards the right markets wherein they can make the most impact. A study by the World Resources Institute (WRI) lists the following criteria:

- households’ capacity to pay
- customers’ proximity to the main grid
- reliability of grid supply

The early adopter market for SHS products will be un-electrified areas where the grid growth is sluggish since the reluctance to invest in SHS products is related to the risk associated with the redundancy of these products once the grid comes in. Based on this analysis, the addressable market in India is estimated to be approximately 67.6 million rural households.\(^3\)

Figure 8.5: India map showing rural un-electrification rates


8.9 Deployment Path and Next Steps

Agni currently has 20 prototypes in field trials in various rural areas of India. The company has also filed an application for worldwide patent, and is preparing to scale-up rapidly by leveraging existing relationships with sub-contract manufacturers in China to produce the SHS kits in large volumes. They are planning to roll-out a large pilot in May 2018, targeting 1,000 users in the State of Maharashtra, India. The pilot is the final phase before commercially launching the platform and the products and will help Agni Solar to fine-tune and refine the financial structure, distribution networks and the software platform and user interface. The pilot is expected to be completed in three months and post this period, Agni will fund-raise from venture capitalists to scale-up in India and other countries around the world.

Agni is also planning to create a sustainable distribution model by partnering with non-profits and creating women micro-entrepreneurs in the regions where they plan to operate. This model borrows on the success and learnings of micro-finance enterprises in India and Bangladesh.

Core to this approach is both the empowerment of women and enhancing access to energy at the last mile. The project’s women entrepreneurs will make clean energy products accessible to people living in their communities, which helps cut greenhouse gas emissions. The trained women provide a complete ‘ecosystem’ approach as clean-technology users, educators, providers and supporters in their communities, which helps make it easier for people to adopt clean energy technologies and products that address climate change.

Solar powered lights enabling micro-enterprise in rural India.
The women entrepreneurs trained by the project place the issue of clean energy at the center of community development by motivating and converting all households in the village into clean-energy users. Once the communities become motivated and adopt clean energy technologies, they begin to transform their villages from non-users to adopters and promoters of clean energy.
9.0 BLOCKCHAIN TECHNOLOGY AND ITS IMPACT ON ENERGY AND ENERGY ACCESS

9.1 What is Blockchain Technology

Blockchain is a global digital ledger, or “trust protocol,” that keeps a chronological record of all transactions. Any asset can have its own blockchain that records information about transactions that have taken place. It is in effect a web-based book-keeping system that uses cryptographic technology to save data in a way that is both immutable, inexpensive and forgery-proof.

Blockchain can also be thought of as a “rules engine” whereby pre-planned contracts are tracked, validated and executed.

Ethereum enables the coding of simple contracts that execute when specified conditions are met. At the technology’s current level of development, smart contracts can be programmed to perform simple functions such as the buying and selling of energy. It also has the potential to “tokenize” physical assets thereby making them easy to trade and automate via smart contracts.

Figure 9.1: How Blockchain works

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[32 Curran Frank, Clean Energy Blockchain Network, Power Ledger North America]
9.2 Blockchain for Energy

In the energy industry, blockchain applications are growing increasingly common. The blockchain ledger is being used to reduce transaction costs, pinpoint origins of energy, and increase the efficiency of exchanges\textsuperscript{33}.

The majority of blockchain energy projects are focused on peer-to-peer (P2P) energy marketplaces. P2P energy sales also open up the possibility of distinguishing where energy is coming from — renewables, coal, oil, and gas — which allows consumers to choose renewable energy, for example.

Blockchain provides the ability to create smart contracts for the energy marketplace that allows operators to write simple rules managing how much money the consumer wants to spend on electricity, how many kilowatts they want to buy, and at what price. Rather than requiring people to interact with other people, which can be slow and complicated, the system intermediates trust and connects everyone into a smart network. In this scenario with a blockchain enabled system people will be able to transact with each other directly. People can sell excess energy to their neighbors thereby realizing a higher price than selling to the utility and in-turn can buy energy from others at negotiated rates less than that of the utility. Such a system has the potential to provide great benefits and flexibility to prosumers thereby unlocking huge value and savings.

To achieve this there is a need for intermediating trust which is what the blockchain technology fundamentally provides. Without the presence of the centralized utility, peer-to-peer trading households must trust that each others’ metering information is correct. They will also need a sufficiently decentralized digital payments system. That’s where the blockchain technology comes in -- providing a structure of trust and a digitally programmable form of money that can communicate and manage IoT devices according to pre-defined smart contracts. This technology is also able to “tokenize” assets thereby creating an easy system for trading with smart contracts and using units of electricity as “tokens”.

In addition, the blockchain allows for fractional ownership of distributed energy resources (DER’s) or solar power plants thereby providing anyone the ability to own and share in the same.
9.3 Case Study of LO3

LO3 established the world's first transactive microgrid using blockchain technology in Brooklyn, New York. This is a peer-to-peer transaction system called Brooklyn Microgrid, which allows users to sell excess energy directly to their neighbors. This creates a peer-to-peer market that allows people to buy locally generated green energy.

Participants in the project install smart meters in their homes, outfitted with LO3 Energy's technology, that measure generated and consumed energy and transact automatically via "smart contracts" using Ethereum blockchain technology. Residents are able to sell energy back to the local utility using "net metering" and also those without solar panels are able to purchase green power credits from their neighbors.

The microgrid is set up by Siemens Digital Grid Division, and includes network control systems, converters, lithium-ion battery storage and smart electric meters.

LO3 Energy's "TransActive Grid," which is the blockchain platform set up for the microgrid, timestamps each transaction as a chain of secure blocks, which means every energy transaction is documented.

Prices can be determined by automatic auctions oriented toward the highest price per kilowatt-hour that an energy consumer is willing to pay.

The Brooklyn Microgrid not only receives energy from rooftop solar, but also from the nearest conventional power plant. So homeowners without solar panels can get credit for "green" energy from their neighbors' PV panels, which is what consumers buy when they choose energy generated from renewable sources.

The Brooklyn Microgrid's goal is to have 1,000 participants by 2018. It also plans to install more battery storage units and even more extensive solar panel systems.

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9.4 Conclusion

Blockchain technology will allow the consumers and prosumers to trade self-produced energy in a peer-to-peer fashion on microgrid energy markets. Thus, consumers and prosumers can keep profits from energy trading within their community. This provides incentives for investments in renewable generation plants and for locally balancing supply and demand.\(^{35}\)

Blockchain offers tantalizing applications and use cases for the energy industry. It holds promise and can deliver value in peer-to-peer trading and smart energy contracts. As such, the technology has the potential to enhance and incentivize the use of microgrids and DER’s and provide more value and choice to consumers and prosumers thereby improving energy access. However, blockchain technology must provide better efficiency, speed and lower friction and transaction costs to be a viable alternative to existing methods and solutions. In addition, there are a lot of unanswered questions with respect to implementation and operation of the technology as well as the issue of the intrinsically high energy usage and complexity of the cryptographic calculations in the blockchain technology itself.

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10.0 Conclusion

There exists an exigent need to enhance energy access to the more than billion people around the world without access to electricity and who as a result are anchored to social backwardness and lack the ability to progress by way of education or opportunities of livelihood.

Figure 10.1: Energy-poverty-environment nexus

This study's proposed solution using off-grid SHS enabled by PayGo technology and using EaaS as a business model is an effective, viable and practical first step towards providing access to electricity to people at the bottom of the pyramid who presently have no access and who are forced to use fuel based light sources such as kerosene lanterns for illumination.

In India, Agni Solar Systems Private Limited (Agni) is driving new innovation and using pioneering PayGo technologies that are usable, cost-effective and accessible to all sections of society, and which can benefit humanity and the world at large. This is a good model as the company is selling what the people need and want - light. By this business model, the company is providing a straightforward and direct pathway to fulfil the consumer's needs. This is also a sustainable, equitable, inclusive and scalable model with the potential to empower and improve the lives of marginalized and disadvantaged people around the world. This is a great example of end-use pricing and leverages existing technology and infrastructure to provide exceptional value and benefits and hence can be rolled-out immediately and scaled-up rapidly and easily.

This solution provides a gateway and a first step for people with no access to electricity to enjoy modern and clean lighting. This enables them to break the bonds of social backwardness and provides them the means to transform their lives and is a pathway to move up the ladder of energy access towards energy prosperity.
Agni is also planning to create a sustainable distribution model by partnering with non-profits and creating women micro-entrepreneurs in the regions where they plan to operate. This model borrows on the success and learnings of micro-finance enterprises in India and Bangladesh. Core to this approach is both the empowerment of women and enhancing access to energy at the last mile. The trained women provide a complete ‘ecosystem’ approach as clean-technology users, educators, providers and supporters in their communities, which helps make it easier for people to adopt clean energy technologies and products. The women entrepreneurs trained by the project place the issue of clean energy at the centre of community development by motivating and converting all households in the village into clean-energy users. Once the communities become motivated and adopt clean energy technologies, they begin to transform their villages from non-users to adopters and promoters of clean energy.

In addition, PayGo technology and EaaS business models provide viable and effective use cases in the energy space beyond merely those of SHS. They can enable P2P energy trading amongst prosumers, improve management of existing energy assets, provide innovative financing solutions for DER’s etc; thereby enhancing energy access not only in rural and underdeveloped areas but also in urban and developed areas and thereby provide greater flexibility, choice, value and control to energy users.

The end goal envisions a holistic solution with a judicious mix of grid connectivity along with off-grid solutions to allow these people to move up the ladder of energy access towards energy prosperity.
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