IOP Conference Series: Earth and Environmental Science

Off-Grid Systems

OFF-GRID SYSTEMS

E Pollock[1], H Kaur[2], R Shinde[2], S Batineih[2], A Dandapath[2]

[1] Lecturer, Metropolia UAS, Helsinki, Finland
[2] Master students, ConREM, Metropolia UAS, Helsinki, Finland

E-mail: eric.pollock@metropolia.fi

Abstract. The term sustainability is frequently associated with our future cities. However, in the most remote and unprivileged corners of the world off-grid systems have already established a new dimension for sustainability. With no infrastructure nor grid connections, off-grid systems offer a way to be self-sustainable and thrive with the least resources. If dealt with proper planning and caution, off-grid systems can be beneficial on a large scale and can also contribute to local integrated networks.

Off-grid systems exist in various forms such as electricity generation, bioenergy, off-grid housing, etc. As sustainability is of global interest the issue of off-grid is reviewed globally in remote locations of India and Jordan. The latest advancements in technology are considered.

Social, economic, and environmental sustainability are central themes of consideration. This paper displays how off-grid systems are advantageous in terms of the basic needs of life e.g. shelter, energy, and food. Included are a wide array of crucial case studies in different continents. The main case studies include biogas plants, and solar electricity in India and Zaatari refugee camp in Jordan.

Keywords: Sustainability, off-grid, bio-energy, water supply, electricity, waste management, refugee camps, solar.

1. Introduction

The term sustainability can be misunderstood as to how far we are prepared to sacrifice our present needs and lifestyle in order to meet the demands of the future. However, sustainability can be achieved by meeting our needs today and keeping the promises of the future alive simultaneously. One of the most significant testimonies to this fact is off-grid systems. The idea has been implemented and verified. It has also been widely accepted by government organizations, local communities and as well as NGOs (Louie, Dauenhauer, Wilson, Zomers, & Mutale, 2014).

The popularity of off-grid systems has emerged from the imbalance between supply and demand. It is a noble approach towards development being independent of any initiative from higher or external authorities. In places where there is negligence from the government or development has not reached yet with all its fruits, off-grid is critical for self-help development. Off-grid provides scope for sustainability in all three aspects e.g.-social, economic, and environmental. Furthermore, it also helps to maintain a balance between them.

One of the world's biggest concern at present is sustainable energy production. The off-grid system offers possibilities in and not limited to electricity from solar power, hydropower and wind power systems, self-supply of water and sanitation, energy generation from biogas, food production, etc. Apart from these, there is a considerable amount of innovative systems which often go unnoticed due to the small scale or remoteness of the location.

In the last thirty years, remarkable acceleration has been seen in the pace of off-grid improvements in the sunny southern hemisphere. Globalization has helped technology and innovation to spread across borders. The remote areas of India comprise one of the lower economical sections of the country. Therefore, the need to promote off-grid projects is essential to meet the demands of the people. The case studies mentioned here clearly state that the small scale off-grid projects are creating a difference in the lives of the people. If government support is given on a large scale then definite progress can be made on a vast scale.

In remote areas of India off-grid systems are used mostly in electricity generation and cooking. The previous uses of wood caused air pollution and health hazards from the cooking smoke. In many present off-grid systems utilization of charcoal improves the situation environmentally and health-wise. The biogas is used widely in domestic and community-scale in rural areas. The small-scale implementation off-grid systems in the villages in India is a recent but widely accepted phenomenon. It generates the opportunity for cheap production and social employability. Being a religious country India also witnesses waste to energy and solar systems in some major temples of the south.

Another important case is the discussion on refugee camps in Jordan. It deals with the whole life-cycle of the product of 10 years or more. The construction was started in 2011 and finished within 7 months. It has been able to provide all the facilities such as energy, water, etc. to the refugees. With no infrastructure and network in the desert, it has offered a home to 80,000 people with the help of a limited budget from the UN. The project developed through many steps like supplying water through reservoirs, installing solar panels, etc.

The need for energy in our society is ever increasing. We are having more awareness and usage of renewable energy resources. However, 85% of our energy consumption (Harvard, 2012) comes from burning fossil fuel (oil, coal, and gas). Off-grid is one of the newest and most innovative approaches in this area. The term off-the-grid (OTG) is referred to the system which is independent of the grid infrastructure such as electricity, water et al. The concept is becoming popular mainly for two reasons. Sustainability and independent energy generation. Research and application have included single houses to large communities, ranged from energy generation to distribution. Off-grid can be considered as an effective solution to meet the demand of our climate change goals.

The practical infeasibility and financial availability of grid extension into remote areas assign a remarkable contribution to the off-grid energy generation *(Sen & Bhattacharya, 2014).* Roughly, the cost of electricity generation depends upon the efficiency of the off-grid model. A third of increased demand in world energy comes from India *(International Energy Agency, 2017*). In India, HOMER or Hybrid Optimization Model for Electric Renewables is a limited and popular field of research. In many parts of the country, the Integrated Energy Renewal System (IERS) is suggested (Kanase-Patil et al., 2010) to meet the demand for electricity and cooking. India is large as a continent consisting of remote areas where till date energy from the traditional grid has not been made available.

In other developing countries the usage of the off-grid model is popular especially in electricity generation and cooking. Electricity is one-third part of energy consumption. Others are transportation and cooking etc. In southern Asia observations on off-grid has shown a mixed trend (Palit & Chaurey, 2011) in various countries. The bridging of the financial gap between affordability and electricity cost (Mainali & Silveira, 2011) can be addressed by off-grid.

IOP Conf. Series: Earth and Environmental Science **297** (2019) 012021 doi:10.1088/1755-1315/297/1/012021

Solar Energy is the most popular in all off-grid systems. It includes various applications such as solar lighting system, heating system, lanterns, cooking, etc. In climates like India where there is an abundance of solar power, it is not difficult to understand the wide implementation of PV based off-grid systems. In the numerous remote locations in India solar off-grid lighting systems (SOLS) i.e. Solar Lanterns (SLs) and Solar home lighting systems (SHS) (Choragudi, 2013) are now possible. These systems provide the opportunity to have lighting systems without the cost of electricity production in remote areas of the Indian subcontinent.

However, the scope of off-grid in developing regions is often limited (Bhattacharya, 2012). Major issues being a lack of resources, infrastructure, and poor technology. From the electricity generation to storage the off-grid model demands efficiency. There is a considerable amount of scope in improvement in off-grid systems.

2. Off-Grid Housing - Electricity generation a major factor Introduction

Around 1.6 billion people in the world will be forced to live without electricity, not because of the non- availability but due to the dispersed population living in the off-grid area. Therefore the concern of producing electricity in these areas become a relevant area of discussion (www.world statistics.com).

The major source of energy production in remote areas is from fossil fuels. The energy produced by this is not efficient enough to cater to the needs of the population and also this produces a lot of carbon dioxide (CO2) and Carbon Monoxide (CO) resulting in an increase in the greenhouse effect. This definitely provides a motivation to look for alternatives that do not emit green-houses gases. The challenge is to find a solution for the off-grid areas without disturbing the ecosystem.

Remote Areas of India

There are approximately 649,481 villages in India (List of villages in India, 2018). Although there is a universal electrification policy adopted by the Indian government still, one-third of the populated areas are without electrification. The census states that 93 % of urban households and 55% of the rural household currently receive electricity (India Village Directory). Therefore India needs an alternative solution to cater to this problem. Looking towards the possible options to provide electrification to such a vast country with almost 1.4 billion people, off-grid housing definitely stands out to be the best possible solution.

The ministry of new and Renewable energy (MNRE) is supporting off-grid technology and is trying to electrify India completely. The new scheme launched by MNRE is “Off-Grid and Decentralized Concentrated Solar Thermal (CST) Technologies for Community Cooking, Process Heat and Space Heating & Cooling Applications in Industrial, Institutional and Commercial Establishment” (Gupta, 2018). The main objective of this scheme is to promote off-grid technology and to meet/supplement heating /cooling systems and to generate electricity through solar and thermal energy (Off-Grid Power, 2018).

IOP Conf. Series: Earth and Environmental Science **297** (2019) 012021 doi:10.1088/1755-1315/297/1/012021

Off-Grid Projects

Bioenergy Gasifier

"Biomass is an industry term for getting energy by burning wood, and other organic matter. Burning biomass releases carbon emissions but has been classed as renewable energy in the European Union and United Nations legal frameworks, because plant stocks can be replaced with new growth" (Page, 2016).

Biomass has a high potential energy source in India, it enjoys great support from the state and the Centre. Currently, India is a leading country in Bioenergy. *Gosaba Island* gasifier is an epitome of how biomass energy can be utilized to change the lives of people in remote areas in India.

Case: Gosaba Island Gasifier

Gosaba Island is an island in West Bengal's Sundarban region and was deprived of electricity as it was not economically feasible to extend power from the grid to these widespread islands. West Bengal Renewable Energy Development Agency (WBREDA) took the initiative to provide electricity to the island. The Vadodara based Ankur Scientific energy technology in collaboration with WBREDA opened a biomass plant in the village. The island that was once lit with kerosene lamps gave way to the electric bulbs and soon the island became a small town.

Case: Turning Destructive Pine to Productive gas; Kumaon Valley

AVANI- a voluntary organization helped the people of Kumaon valley in Uttarakhand to produce electricity by the use of pine needles. The organization aims to produce about 14.65MW of electricity from the biomass (Avani, 2014). The state has the opportunity to electrify the area through the gasifier which is more accessible and cheap.

The gasifier volatize the pine needles into a producer gas which is a combination of the combustion gas. The gas is passed through the filters consisting of the sawdust and fine cloth to remove the impurities from it, the resultant gas is used to run the diesel engine which generates electricity.

Figure 1: Pine needle gasifier, Kumaon Valley (Avani, 2014)

Benefits from the Gasifier

The pine based gasifier guarantees to benefit the common household kitchen by allowing them to use charcoal effectively as it is one of the byproducts (10% of the residue) of the gasifier, this allows for a smoke-free household eliminating pollution and lung diseases. Charcoal produced by the 120 KW gasifier is sufficient to meet the household demands of at least 100 homes in the area. The villagers can pay for the charcoal or can collect the pine needles and get it in exchange. This project aims at increasing the employment growth in the area and as well as providing them with electricity and also a smoke-free alternative to cooking food. The efficient charcoal is also considered as a substitute for the LPG gas which is very expensive and limited in India. Therefore the project actually aims towards the off-grid solution leading towards sustainability. According to the estimates, the pine gasifier has the potential to generate electricity in the whole Himalayan region thus meeting the need of 1.4 families (Avani 2014).

Case: Hybrid Vermicompost Biodigesters

Karnataka is a developed state of India. Bengaluru, the capital of Karnataka is known as the silicon valley of India. However, the rural areas of this state are still deprived of modern technology and survive on open-fire cooking, which is a threat to the environment. The women generally collect wood from the forests to support their traditional cooking.

SKG Sangha (SKGS), a non-profit organization of Kolar district of Karnataka has pledged to provide safe and clean cooking gas to the people of this district and also generate a source of income by selling the fertilizers made from the biogas as a byproduct. The biogas is prepared by cow dung, it consists of an underground brick-built digester, an inlet at the ground level to feed the digester with new feedstock and two separate outlets to collect biogas and to remove the residue" (Sangha, S 2013). The galvanized steel and HDPE pipes are used to transport the gas from the plant to the kitchen stoves.

The biogas has the capacity of producing up to 4 ^{3} gas/day from an input of 50-100 kg cow dung. The liquid residue produced from the plants accounts for 36 to 72 tons and can be used directly in the fields but to transform the liquid fertilizer to the organic matter SKGS use the Vermiculture technique. This technique involves the storing of the liquid residue into a compost and then athe ddition of fibrous materials to decompose it for at least 3 weeks. After the decomposition is completed, the earthworms are added to the mixture. The top layer of the worm casts are used as vermicompost (Sangha, S 2013). Benefits of the Project:

- Smoke-free household generated decreasing the respiratory problems for women.
- Saves a lot of time for women as they search for wood is a tiresome activity.
- Generates employment for the people of rural areas.
- The vermicompost replaces the chemical fertilizers
- Increases the soil fertility and the water retention of the soil.

Case: Jatropha plant, an emerging option for rural electrification

'Ranidhera' village in Chhattisgarh is one of the electricity-deprived villages. The electricity was generated after the 'Winrock International India' started an innovative project of producing electricity by the extraction of biofuel from the seeds of the Jatropha plant. The project was collaboratively supported by the British High Commission, the Swiss Agency for Development and Cooperation and the Ministry of New and Renewable Energy. The aim of the project was to electrify around 6000 remote areas of the country.

The power plant initially (April 2007) had the capacity of producing 11 KW of electricity thus providing 3 hours of electricity for households and around 3.5 hours for the street lighting. The off-grid projects helped in producing the cheap electricity for the remote areas (Gmünder et al, 2010).

The most abundant form of energy available in India. "India is located in the equatorial sunbelt of the earth, thereby receiving abundant radiant energy from the sun" (Garud and Purohit, 2007). According to the recent report, India has a capacity of 20 GW of electricity generation (Priya S 2018). India aims to achieve 100 GW target by 2022 (Reuters, 2015). India's largest solar power plant known as 'Shakti Sthala' is installed in the State of Karnataka, India. It generated 2000 MW of electricity and is laid upon on 13000 acres covering almost 5 villages (NDTV, 2018).

Figure 2: Solar panel installed in Karnataka (Verma, P)

Case: Tirupathi, The Green Temple

'Tirumala Tirupathi Devasthanam' is the richest temple in the world. It has the largest number of devotees visiting on a single day. The temple is located in the southern part of India in Andhra Pradesh and has been trying to adopt renewable sources of energy for meeting its everyday requirements. The temple has a wastewater treatment plant that recycles and purifies the water. The canteen of the temple provides free mineral water to discourage plastic bottles and they also use solar energy for cooking. The solar cooker was installed in 2002 and has the capacity to prepare 50,000 kg of rice along with curry for 15000 persons in one cycle. The solar technology is installed by the Gujrat based company 'Gadhia Solar' and the HTT Gmbh. of Germany (Gadhia Solar).

The installation cost of the system is around 11 million rupees. The expenses were covered by the temple as well as the Union Ministry of Non-Conventional Energy sources. The solar cooker needs no modification and has a lifespan of 25 years.

***Figure 3: Solar Steam cooking at Tirumala Tirupathi Temple** (**Terienvis, 13/10/2015**)*

Future Plans are for the temple to utilize the steam produced in the solar plant to meet the requirements of the Kalyanakatta, where the pilgrims do the rituals of head tonsuring. The Gadhia is also planning to install a 500 KW solar thermal system in the temple (Gadhia Solar).

3. Zaatari Refugee Camp, Jordan

Introduction

Politics play a major role in today's communities, and lately, the world has been facing critical situations and wars, unfortunately, all of that creates instability in the existing communities where conflicts occur, resulting in large populations forced to immigrate to safer areas and build their new communities. One of the latest conflicts is in Syria in 2011, which so far has forced millions to evacuate their homes and become homeless or refugees. Many refugee's camps have been established in remote areas to host those people and try to secure basic life needs for them, but with lack of resources, infrastructure, and communications it was a huge challenge; water supply, food production, energy, waste treatment, medication, education and others in the built-up camps (Fisher, 2016).

Zaatari Camp in Jordan is one of the largest camps for Syrian refugees around the world which was established in 2012 covering an area of 5.3 sq.km in northern Jordan, near to Al Mafraq which is a desert area with lack of water resources, food supply, and energy. The challenge was to secure these needs for more than 80,000 refugees. The population is growing, at least for the next 15 years, with some refugees in the camp for a lifetime, no temporary solutions would be practical or even acceptable. Off-grid housing is a convincing approach in such situations, a need to develop a self-standing sustainable community to host all these people for years. Tents were pitched as a place for them to live in temporarily which will be replaced by better housing options later on, such as shelter programs supplying donated caravans, cabins & built-up units (Fisher, 2016).

Syrian refugees numbering 461,701 have passed through the camp, and on 26 March 2015, the camp population was estimated at 83,000 refugees by United Nations High Commissioner for

Refugees (UNHCR), with an average of 80 births per week, while statistics show that 19.9 % of the population are children below 5 years' old who need intensive care (Fisher, 2016).

Water Supply

Water is essential for any living creature and it is one of the main needs for humans, without water or even lack of it no life can be assured, so organizations along with the Jordanian government had to implement a plan to secure water supply for the camp.

Figure 4: Housing in Zaatari Refugee Camp

(UN Photo/Sahem Rababah, 27 March 2017, Zaatari Camp, Jordan, Photo # 718441)

As an initial temporary plan water was supplied by trucks to the camp, although It was expensive and time-consuming and can be delayed or interrupted but it was the only solution at that time till the drilling of the two new internal boreholes near the camp are completed provides 3.2 million liters of drinking water per day (UNHCR, reliefweb, 2017). Also work is ongoing to improve the water supply in villages surrounding Zaatari, which will benefit both Syrian refugees and host communities. In addition to some expansions in MAFRAQ pipeline which feeds the nearest city to the camp will benefit 25,000 Syrian refugees and local residents (Bhai 2018).

The results and goals of these projects are that "People living here will get double the amount of water, better pressure and more reliable. The work we're doing here will not only help the Syrian refugees in the camp but also serve the people in the surrounding communities," says Mr. Hameed. Water distribution presently takes place via a fleet of approximate 82 trucks delivering water to the communal public and private water tanks (Bhai, 2018).

Energy

Electricity as a power supply is one more requirement to establish a new residential area, provides an essential lifeline for camp residents, from lighting shelters to preserving food and maintaining hygiene, "Light is absolutely essential," said Anne-Marie Grey, the executive director and CEO of USA for UNHCR, in an interview. "When you go into a camp, you realize how it's a safety issue as much as a right to light or a right to energy issue" (UNHCR 2017). As stated before, in the case of Zaatari camp the challenge was to provide enough power to supply all population in that remoted area, using generators and some connections from the local network was defiantly a temporary solution; as it was costly and insufficient; especially with a monthly bill of 800,000 $ (Pyper 2015), so UN started considering the idea of constructing a renewable power supply project to serve the area's needs.

The UNHCR's three-year Energy Strategy 2015-2018 plan was to build a solar plant which will be the largest ever built in a refugee camp, providing clean and much-needed power to the Syrian refugees in the camp. According to UNHCR "The plant will reduce annual carbon dioxide emissions from the camp by 13,000 metric tons per year, equivalent to 30,000 barrels of oil. It will also deliver annual savings of around US$5.5 million, which UNHCR – the UN Refugee Agency – will be able to reinvest in vital humanitarian assistance" (UNHCR 2017).

Figure 5: World's biggest solar power plant for a refugee camp opens in Zaatari (Luck, 2017)

Briefly, The 40,000 photovoltaic panel solar plant was constructed on the outskirts of the camp with an approximate area of 0.8 square km, arranged in rows hundreds of meters. According to UNHCR "the 12.9-megawatt peak solar photovoltaic plant was funded by the Government of Germany with a cost of 15 million euros (US$ 17.5 million)" and will be operational by the end of 2017 (Luck 2017).

Community and Social Services
The Zaatari camp hospital services include primary health care, maternity care, dental care, mental health, and nutritional care. Community centers provide psychosocial support & recreational activities (UNHCR, reliefweb, Feb 2017).

The Zaatari Camp schools have over 20,000 school-aged children enrolled. Textbooks and school supplies are distributed to all children in the camp. (UNHCR 2014).

Waste Management
Waste management considers two main categories; wastewater and solid waste, in order to maintain a healthy hygienic life in the camp it is necessary to develop a plan to control, dispose

and even recycle general waste. According to UNHR approximately 2,100m3 of sludge is collected by desludging trucks every day; regularly 28–50 tons of unsegregated solid waste is collected every day. A wastewater treatment plant was established to treat approximately 80% of the wastewater generated in the camp.

Figure 6: Waste Management in Zaatari Refugee Camp (OXFAM, 2017)

Currently, all houses are connected to septic tanks, which means that desludging trucks make the rounds of the camp every day to empty septic tanks. In order to increase the efficiency of the camp's sanitation system, the next step, as from next year, will be to connect all the septic tanks to the main pipeline that will take all the waste to the treatment plant. (Aljaradin 2016). For solid waste, some efforts have been done so far, it is collected by trucks and transferred to external solid waste facilities, in order to consider recycling an approach to start separating the solid waste; plastic, paper, cardboard, glass & metal has been taking place (Saidan M, 2016).

Turn Waste into Energy

An approach to turn food and animal wastes into clean and safe fuel and fertilizer, although eliminating pathogens from the biowaste is a challenge due to it's potential to cause illness and attract disease-carrying animals, it has been possible by involving educated biogas technicians and closed-loop farmers. This will provide energy and even a chance to residents for learning, sharing and implementing clean and renewable energy solutions within Zaatari Refugee Camp. Studies proved that this approach will reduce fossil fuel usage and indoor air pollution by properly managing food waste (Initiative, 2016).

4. Conclusion

Unfortunately, the off-grid systems are sluggish and unable to meet the demand of the rapidly growing energy need (Louie, Dauenhauer, Wilson, Zomers, & Mutale, 2014). The scale of these is also tiny compared to Cities. We need more ideas, innovation, attention, knowledge, and attention to make these systems beneficial for our future 'Sustainable cities'.

IOP Conf. Series: Earth and Environmental Science **297** (2019) 012021 doi:10.1088/1755-1315/297/1/012021

The small-scale implementation of off-grid systems in rural areas of India brings much hope but is not sufficient to cater to the massive demand for energy of growing India. The government needs to come up with innovative measures to accommodate the benefits of these systems into our future cities. The economies of scale of the systems have to grow critically to be comparable to cities. Technological advancement should be adopted to integrate the on-going systems to the main grid for achieving the optimum sustainable outcomes.

The refugee camp is a unique example of off-grid systems. However, this model is crucial to study as a remedy for crisis (Natural or political) situation of the cities. It shows a quick response in developing a sustainable community which can be an effective lesson dealing with natural disasters in cities. However, one has to think about larger case solutions more apt for a sustainable city. The situation is highly undesired as a permanent or even a temporary state in any city.

References

1. Adani Group 2016 Financial express. Retrieved February 18, 2018, http://www.financialexpress.com/photos/business- gallery/536047/world-largest-solar-power-plant-adani-group-tamil-nadu-india-features-and-highlights/

2. Acted 2016. Retrieved from acted.org: http://www.acted.org/en/photostory-providing-water-refugees-za-atari-camp AFP 2012 Jordan opens the first refugee camp for Syrians. 7/29/2012, http://english.ahram.org.eg/News/48962.aspx Aljaradin, M (2016). Waste management in Zaatari refugee camp- Mafraq-Jordan.

3. Avani 2014 Sanskrit. Retrieved March 12, 2018, from www.esamskriti.com: https://www.esamskriti.com/photograph/2_2352.jpg

4. Avani 2014, http://avani-kumaon.org/programmes/clean-energy/

5. Bhai, A, (2018) UNHCR WASH Officer Water at Za'atari Camp, https://www.unhcr.org/7steps/en/water/

6. Choragudi, S. 2013 Off-grid solar lighting systems: India's sustainable and inclusive development goals. Renewable and sustainable energy reviews, 890-899.

7. Das, K N 2015 India's Modi raises solar investment target to $100bln by 2022

8. Dayalu, A, Harvard 2012, "Why we need sustainable Energy" and the United States Energy Information Administration. (2012). "Annual Energy Review 2011" http://www.eia.gov/totalenergy/data/annual/archive/038411.pdf

9. Gadhia Solar 2012 https://mnre.gov.in/file-manager/UserFiles/Ghadia_solar_cookers.pdf, www.gadhia-solar.com, ended 2012

10. Garud S and Purohit I, 2007 Making Solar Thermal Power Generation in India a Reality Research associates within the Energy and Resources Institute (TERI), New Delhi, India

11. Gmünder, S,Zah, R, Bhattacharjee,S, Classen, M, Mukherjee, P, Widmer, R, 2010 Life cycle assessment of village electrification based on straight jatropha oil in Chhattisgarh, India, Technology and Science lab, Swiss Federal Laboratories for materials and testing research EMPA, Biomass and Energy 34, 347-355

12. Gupta, A. 2018. EQ international. Retrieved February 18, 2018 http://www.eqmagpro.com/off-grid-and-decentralized-concentrated-solar-thermal- cst-technologies-for-community-cooking-process-heat-and-space-heating-cooling-applications-in-industrial-institutional-and-commercial-esta/

13. Initiative 2016 www.clintonfoundation.org/clinton-global-initiative/commitments/turning-waste-energy-zaatari-refugee-camp-jordan

14. Fisher, M, 2016 NYTimes, Straightforward Answers to Basic Questions About Syria's War.

https://www.nytimes.com/2016/09/19/world/middleeast/syria-civil-war-bashar-al-assad-refugees-islamic-state.html

15. Off-Grid Power. Retrieved March 26, 2018, from mnre.gov.in: http://www.mnre.gov.in/grid-power
16. Kanase-Patil, A & Saini, R & Sharma, M 2019. Integrated renewable energy systems for off-grid rural electrification of remote area. Renewable Energy. 1342-1349
17. List of villages in India 2018 Retrieved March 26, 2018, https://en.wikipedia.org/wiki/List_of_villages_in_India
18. Louie, H., Dauenhauer, P., Wilson, M., Zomers, A., & Mutale, J. 2014 Eternal Light: Ingredients for sustainable off-grid energy development. IEEE Power and Energy Magazine, pg 70-78.
19. Luck, T. (2017, November 13). The National. https://www.thenational.ae/world/mena/world-s-biggest-solar-power-plant-for-a-refugee-camp-opens-in-Zaatari-1.675484
20. Motasem N. Saidan A, 2016. Solid waste composition analysis and recycling evaluation: Zaatari. Science Direct.
21. Mainali, B & Silveira, S 2011. "Financing off-grid rural electrification: Country case Nepal," Energy, Elsevier, vol. 36(4) 2194-2201.
22. NDTV. 2018. Retrieved March 26, 2018, from NDTV: https://www.ndtv.com/india-news/shakti-sthala-launched-in-karnataka-is- worlds-largest-solar-park-1818803
23. OXFAM 2017 Recycling project in Zaatari Camp, Jordan [Motion Picture].
24. Page, ML 2016, September 26. The Renewable energy scam. Retrieved March 26, 2018, from New Scientist: https://www.newscientist.com/article/mg23130922-600-revealed-the-renewable-energy-scam-making-global-warming-worse/
25. Priya S 2018 Markets & Policy, Solar, Top solar and other renewable Energy News Headlines for India in Nov 2017
26. Reuters 2015 / India's Modi raises solar investment target to $100 bln by 2022
27. Shaw A 2012 Poverty facts and stats. Retrieved March 18, 2018,

    http://www.globalissues.org/article/26/poverty-facts-and-stats Saidan M 2016
28. http://www.academia.edu/35713876/Solid_waste_composition_analysis_and_recycling_evaluation_Zaatari_Syrian_Refugees_Camp_Jordan
29. Sangha, S. (2013). Biogas Plant Construction manual. foundationskgsangha. ttp://foundationskgsangha.org/biogastechnology4.html
30. Sen, R & Bhattacharyya, S 2014. Renewable Energy-Based Mini-Grid for Rural Electrification: Case Study of an Indian Village. 10.1007/978-3-319-04816-1_9
31. Solar 2010. https://solarenergydemystified.wordpress.com/2010/03/08/solar-steam-cooking-system-at-tirumala/

32. Terienvis 2015 Retrieved March 18, 2018, http://terienvis.nic.in/index4.aspx?ssslid=4243&subsubsublinkid=365&langid=1&mid=1

33. UNICEF2012 At Za'atari refugee camp in Jordan, as a million liters of clean water, arrive each day, focus turns to conservation and future supply of water 2012, https://www.unicef.org/wash/jordan_66227.html

34. UNHCR 2014 https://www.unhcr.org/news/updates/2014/11/5465c15d9/jordan-inter-agency-update-september-october-2014.html?query=Zaatari

35. UNHCR 2017 Jordan’s Za’atari camp goes green with new solar plant Marwa Hashem

36. Verma, P, https://www.flickr.com/photos/rayspowerinfra/27580564457/