

Measuring Access to Energy in Rural Areas of Pakistan: A Multi-Tier Framework Approach

Sheraz Khan¹, Islam Nabi², Rafi Ullah³, Majid Ullah⁴, Syed Kamal⁵

^{1,2,3,4,5} U.S. Pakistan Center for Advanced Studies in Energy, University of Engineering and Technology Peshawar, Pakistan

skhan63@asu.edu¹

Received: 09 November, Revised: 22 November, Accepted: 08 December

Abstract— The prosperity and living standard of any nation depends on the amount and quality of energy services they are using. The introduction of new technologies and high performance appliances have very much improved the life style as well the economic conditions of people. But still there are many remote areas which are lacking access to clean energy, and most of those are rural areas. This work is focused on northern areas of Pakistan being electrified by off grid systems, mostly Micro Hydro-Projects (MHPs). We have evaluated the World Bank's Multi-Tier Framework (MTF) for measuring the household electricity access because the traditional binary indicators are not accurate and might be misleading in some cases. Data from surveys and interviews is used for the targeted areas where Micro Hydro Projects (MHPs) are installed by government as well as national and foreign funding agencies. This study has shown the energy access conditions in Shangla, Kalam and Chitral areas of Pakistan by using a Multi-Tier Framework approach. It has also tried to explain that MTF addresses multiple objectives and it declares that access to energy measurement is highly sensitive to any changes in data availability and parameter values. We have also discussed some of the observations and limitations of this framework that needs some improvement for its application in future.

Keywords— Access to energy, Household Electricity Access, Micro Hydro Projects (MHPs), Multi-Tier Framework (MTF).

I. INTRODUCTION

About 1.2 billion people in the world do not have access to modern electricity according to a report shared by International Energy Agency in 2015. Also it is expected that about 1 billion people will not be able to access to energy modern energy services by 2030 particularly in rural regions due to growth and underdevelopment in energy infrastructure [1]. According to the statistics available, around 95% of the population living without electricity access are located in Sub-Saharan Africa/Asia and majority of them are located in rural areas [2]. Beside the fact that electricity can create conditions for economic development, it is also required for basic human needs and economic activities [3]. A majority of studies taken place all around the world

suggest a strong relation between access to energy and rural poverty, also this relation is due to the fact that electricity is required for all productive activities [4]. Due to no access to modern, safe and reliable energy services, people in rural areas usually suffer considering education, health and economic issues [5]. This means eradicating energy poverty is closely related to eradicating poverty as a whole.

II. PAKISTAN ENERGY SCENARIO

Power sector of Pakistan is a developing market, the gap between demand and supply has been an unresolved issue from years [6]. The demand for electrical energy is increasing day by day. The installed electrical power generation capacity in 2015 was 23.8 GW, but the actual generation was always less than this number which was about 106,966 GWh, where as the demand was ominously high than this number [7]. The growth rate of electrical power demand in Pakistan is close to 8% each [20]. At present, the generation of electricity comprises of indigenous natural gas (26.5%), oil (36.8%), hydel (30.4%) and 6.2% others including coal, renewable and nuclear [7]. If we scrutinize this mix, it shows that it has a huge burden on Pakistan's economy due to hydrocarbon imports, also some serious threats to this mix are due to rapidly shrinking domestic gas reserves, which contributes a major portion to electricity generation [8]. The exhaustion of these natural resources and the growing demand of energy have forced national planners as well as policy makers to opt for renewable energy sources and off-grid energy solutions [9]. The lack of access to energy is mostly in the rural and remote areas because there are many challenges involved in connecting those areas with grid. The purpose of this study to indicate those challenges and show how effective off-grid solutions can be, in those areas by measuring access of electricity through applying a Multi-Tier Framework approach.

III. WHY MULTI-TIER FRAMEWORK (MTF)

Access to electricity is usually measured through binary indicator, which shows whether a community have a grid connection or not, but this information is not enough to measure the exact level of energy access and we need some specialized tool or framework that answer questions like

1. What does it mean to have access to electricity?

2. Is this access sufficient for that area?
3. Is this provided services are of desired quality and quantity?
4. Is it reliable and affordable for the people living in those communities?
5. What are the gaps in energy access?
6. How to design the right metrics to measure it?

Many international agencies and organization have been working to design a tool that answer these questions. One the framework is developed by Energy Sector Management Assistance Program (ESMAP) working under World Bank, known as Multi-Tier Framework (MTF). This framework uses different dimensions known as attributes and those are:

1. Capacity
2. Availability
3. Reliability
4. Quality
5. Affordability
6. Legality/Formality
7. Health and Safety

These attributes can be categorize into different tiers ranging from Tier 0 to Tier 5 with Tier 0 being the lowest, as shown in Figure 1. MTF is designed to transition from simple surveys that focus on binary measurements and outcomes to more comprehensive data collection methods. The assignment of tier and these attributes are aggregated by some rules and decisions in order to determine the overall assignment of the tier which further defines the level of access of electricity getting by a household. The framework scores participants across tiers and tells us about the situation of access to energy in applied areas.

ATTRIBUTES	TIER 0	TIER 1	TIER 2	TIER 3*	TIER 4	TIER 5
Capacity	Power capacity ratings (W or daily Wh) Less than 3 W Less than 12 Wh	At least 3 W At least 12 Wh	At least 50 W At least 200 Wh	At least 200 W At least 1 kWh	At least 600 W At least 3.4 kWh	At least 2 kW At least 8.2 kWh
Services	Lighting of 1000 lmhr per day	Lighting of 1000 lmhr per day	Electrical lighting, air circulation, television, and phone charging are possible			
Availability*	Daily Availability Less than 4 hours	At least 4 hours	At least 8 hours	At least 16 hours	At least 20 hours	At least 23 hours
	Evening Availability Less than 1 hour	At least 1 hour	At least 2 hours	At least 3 hours	At least 4 hours	
Reliability	More than 14 disruptions per week		At most 14 disruptions per week or at most 3 disruptions per week with total duration of more than 2 hours	0-3 to 14 disruptions / week) or 0-3 disruptions / week with total duration of less than 2 hours	At most 3 disruptions per week with total duration of less than 2 hours	
Quality	Household experiences voltage problems that damage appliances			Voltage problems do not affect the use of desired appliances		
Affordability	Cost of a standard consumption package of 365 kWh per year is more than 5% of household income		Cost of a standard consumption package of 365 kWh per year is less than 5% of household income			
Formality	No bill payments made for the use of electricity			Bill is paid to the utility, prepaid card seller, or authorized representative		
Health and Safety	Serious or fatal accidents due to electricity connection			Absence of past accidents		

Figure 1: Multi-Tier Framework (MTF)

Figure 2 and 3 shows two studies carried out in Kinshasa, Congo and Ahmara Region, Ethiopia respectively [10]. These figures show measurement of access to electricity both by binary indicators as well as using MTF. The binary definition shows that Kinshasa area is 91% electrified, that means 91% of the population have access to electricity services. Out of this 91% population, 88% are connected to grid whereas 3% are

connected to other electricity services. The rest 9% population are living without the access to any grid or off grid electricity supply. Now if we look at the MTF measurement, we can see that 46% of the population having access to electricity according to binary definition are placed in Tier 1, which means either they are not getting electricity in their connection line or the supply is for insufficient hours, 50% of the electrified population are in Tier 2, this also shows either the supply is for insufficient hours or they are facing some quality issues. Only 4% of population are in higher tiers which is tier 3 or above. The study in Ahmara Region, Ethiopia shows that according to binary definition, 94% of the population have access to electricity while only 6% of population are lacking access whereas MTF results show that 49% out of the total electrified population are in Tier 0. 1% of the electrified population is in Tier 1, 22% is in Tier 2 and the rest are in Tier 3 or above.

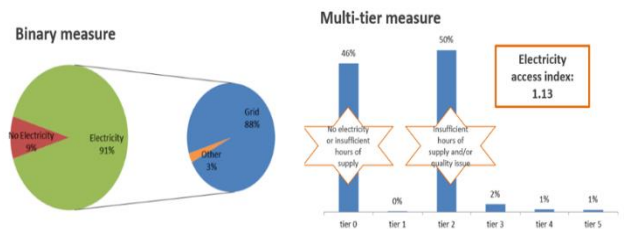


Figure 2: MTF at Kinshasa, Congo

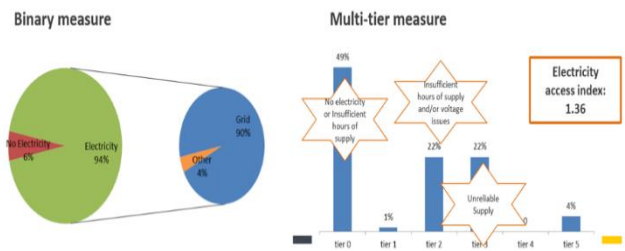


Figure 3: MTF at Ahmara Region, Ethiopia

IV. APPLYING MTF IN NORTHERNER AREAS OF PAKISTAN

Energy now a days is the basic need of life and is required both by urban as well as rural population. Two Third of the population in Pakistan is electrified or have access to electrical energy services and only 20 percent population have access to gas [11]. The remaining one third population with no electricity are mostly living in rural areas where either there is no national grid connection or people cannot afford it [11]. These statistics show that one third of population in Pakistan is living difficult and below standard life because this is the age of modern technologies and electricity is required for almost everything. Northern areas of Pakistan are the challenging part of country when we talk about access to reliable energy sources. Most of these areas are not connected to national grid and hence provincial government of Khyber Pakhtunkhwa initiated off-grid energy projects with the help of different national and

international funding agencies. Most of them include Micro Hydro Projects (MHPs) because of a huge potential of such projects in those areas. For this study we have gathered data from Shangla District, Kalam Valley, and Chitral district of Khyber Pakhtunkhwa to measure the level of access to electricity provided by off-grid projects with the help of MTF. The selected districts cover a very large area and getting data from whole areas is very difficult, so rather a sampling technique was used in getting data. The technique was designed in such a way to gather maximum possible data for which we divided each village in different neighbourhoods and data was collected in some neighborhoods of every village. The same data was assumed for other neighborhoods with same (or nearly the same) population and conditions of access to electricity. In this way we were able to get maximum data required for applying MTF.

A. SHANGLA

Shangla is a district located in Malakand Division Khyber Pakhtunkhwa (KPK) province of Pakistan. A total of 120 households were surveyed in different union councils of Alpuri. 87% of the households were electrified whereas 13% lack an electricity connection (figure 4). The electrified households include electricity connections from national grid (33.4%), MHPs (60.67%) and MHPs as well as national grid (6%) as shown in figure 5

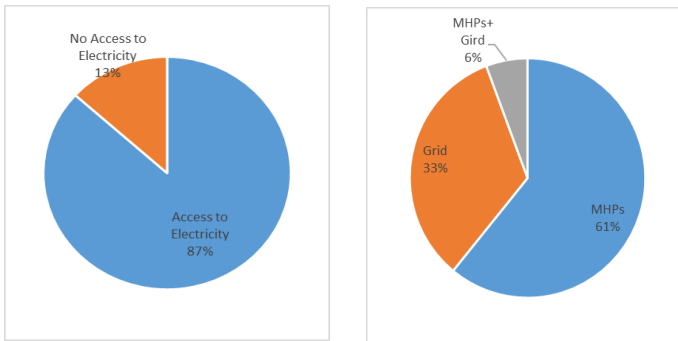


Figure 4: Access to Electricity at SHANGLA

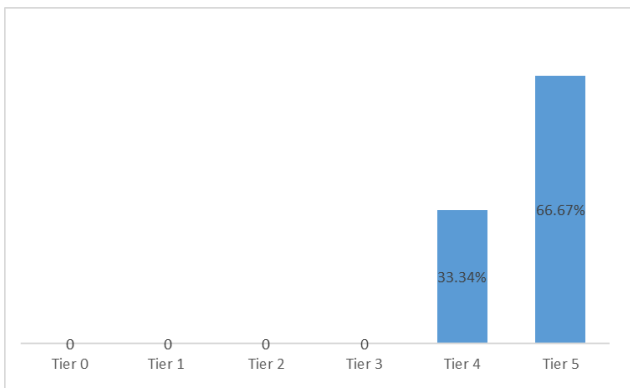


Figure 5: MTF at SHANGLA

The supply of electricity by off-grid sources was constant and there was no scheduled load shedding. The areas connected to MHPs were receiving electricity for almost 24 hours. However, the households connected to national grid were facing

load shedding of 6-8 hours (including 2-3 hours in evening) in 24 hours. Based on these numbers the households connected to MHPs or both national grid and MHPs which are 66.67% of the total electrified households, can be placed in tier 5 whereas the rest 33.34% of the electrified households connected to national grid can be placed in tier 4 as shown in the figure 5. All the remaining attributes were fulfilling the minimum requirements to be placed in Tier 5.

B. KALAM

Kalam is a famous and beautiful place located in the northern side of Swat valley of KPK province, Pakistan. Its mountainous territory has many water streams which has the potential to generate electricity using hydro turbines. The whole Kalam valley is electrified by MHPs. Before the implementation of MHPs in Kalam, WAPDA which a government body responsible for water and power services in Pakistan, was responsible to supply electricity to the whole area. Electricity supply by WAPDA was not satisfactory and electricity services were provided only for few hours. Two major parts of Kalam including Ashuran and Jungle Inn were targeted for data collection and data for about 100 households was collected and used to apply in the MTF. As the area of Kalam have extreme winter conditions due to snow fall, most of the population migrate to plain areas in winters whereas in summers the population density becomes high and hence increases overall electrical load of the area. In winters, short-circuit problems occur quiet often while in summers 4-5 disruptions per month occur. The availability of electricity is almost for 22 hours including more than 4 hours in evening.

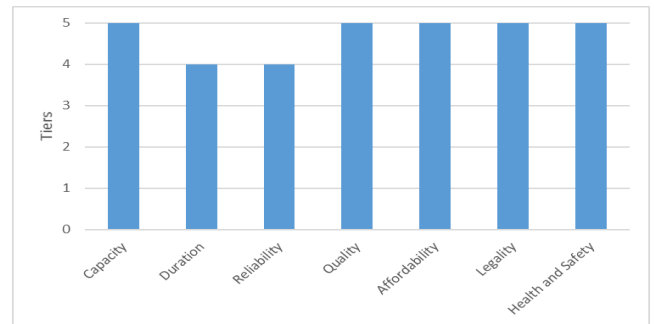


Figure 6: MTF at KALAM

There are no quality problems like voltage spikes, tariffs are highly affordable, no electricity theft found, people can run the appliances they own and also, no accident or health problems happened because of the services provided by off-grid projects. Based on analysis of data only duration and reliability attributes can be placed in Tier 4 while the remaining can be referred as Tier 5 attributes as shown in figure 6.

C. CHITRAL

Chitral is area wise, the largest district of Khyber Pakhtunkhwa Province in Pakistan covering an area of about 14,850 Sq. kilometers. As it is a large district with a high population rate, only few sites and villages were selected for conducting survey according to the sampling criteria. A total of 100 household's data was collected out of which only 18% households were not able of having electricity connection as

shown in figure 7. Different sites like Ayun, Jingiret (Nagar Gol), Golin Payeen, Kuji Bala, Moroi Payeen and also 1 MW WAPDA hydro plant were encountered while conducting the survey.

In Chitral, the electricity is supplied both by national grid as well as different MHPs, although there are some parts where electricity is only provided by MHPs. While surveying, it was found that households connected to one of the off-grid projects, faces the problem of restriction on use of certain appliances and were allowed to use only lights and very small power appliances but this population only accounts to 10% of the total electrified area. This 10% area can be placed in Tier 1 for capacity attribute whereas the rest of population in Tier 5 as they never face such problem. The availability of electricity is almost constant without any scheduled interruptions in the whole area and fulfill the requirement for highest tier. The electrified areas do not experience any frequent disruptions and power outages. MHPs need some maintenance work once or maybe twice in a month which accounts for 10-12 hours in 6 months' season and the duration of each disruption is usually less than 2 hours, this data place the reliability attribute of MTF in Tier 5. About 30% of the population faces the issues of voltage fluctuations and changing frequency problems that sometimes cause damage to few appliances, the quality attribute for this population can be placed in Tier 3 while remaining 70 % households experiences no such problem. The tariffs for electricity services provided are affordable in Chitral.

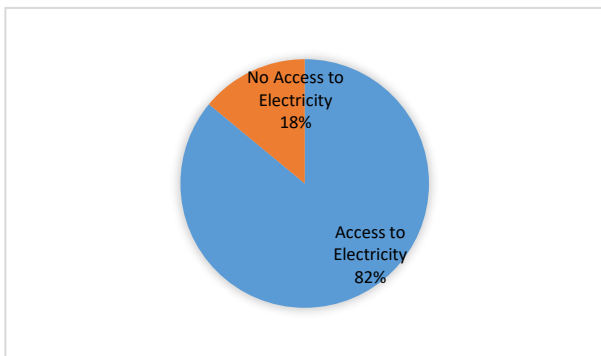


Figure 7: Access to Electricity at CHITRAL

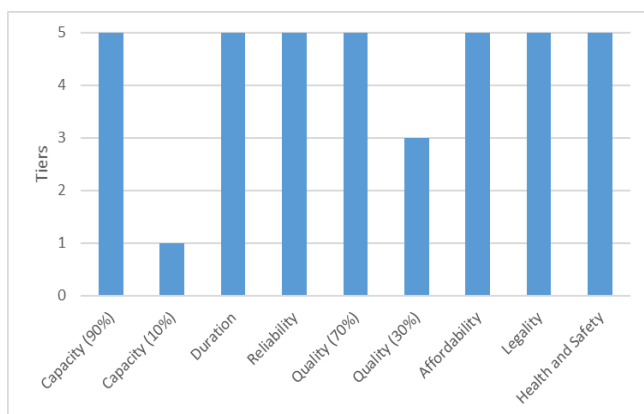


Figure 8: MTF at CHITRAL

The average household income varies from 20,000-25,000 PKR whereas the average monthly electricity expenses are about 800-1000 PKR which is less than 5% of the income. Moreover, the whole area is getting electricity legally and no health problems or accident found in the area. The summary of the MTF is shown in the figure 8.

CONCLUSION

The main objective of measuring access to energy is to know whether the supply of energy services is able to run some vital appliances and services, and not just measuring the level supply of energy or electricity. The traditional binary metrics for measuring access to energy are not able to achieve this objective and the ultimate SE4All goal. From the results of this study, it strongly advocates frameworks like MTF to be used for knowing the actual level of access to energy. We have seen that MTF is able to provide a very accurate data for the services that households actually receive which makes it a power full tool in making investment decisions and policy making.

We have also seen the impact of off grid energy projects like MHPs in the rural population. In most parts of the northern areas of Pakistan, either there is no national grid connected or in bas condition due to poor infrastructure which resulted in the poor living lifestyle of the local communities residing in those areas. From past two decades, the government and different national as well as international funding agencies have shown interest in electrification of these areas and installed micro hydro projects in different sites. The presence of those power projects have improved the level of access to electricity. As we have seen in this study, most of these areas being electrified by MHPs are in higher tiers which has impacted and improved the standard of lives including health, education, economic activities and reduced work load on females.

OBSERVATIONS AND RECOMMENDATIONS

Although Multi-Tier Framework (MTF) is currently the best available criteria for measuring the actual level of access to energy services but still some of the lackings were identified during this study which are mentioned below along with some recommendations:

1. Different attributes are independent of each other, and cannot be assumed to improve simultaneously across tiers.
2. The complex multi-tier framework requires extensive collection of data, which may not always be affordable.
3. MTF is still a supply side analysis rather than demand side.
4. It should include about requirements of the community which should cover demand side analysis as well.
5. Also it doesn't identify the gaps in energy access.

REFERENCES

- [1] ic-sd.org/wp-content/uploads/sites/4/2017/01/Matthew.pdf
- [2] International Energy Agency (IEA) and the World Bank. 2015. "Sustainable Energy for All 2015—Progress Toward Sustainable Energy"

(June), World Bank, Washington, DC. Doi:10.1596/978-1-4648-0690-2
License: Creative Commons Attribution CC BY 3.0 IGO

- [3] IEA. (2014). Africa energy outlook (Rep.). Retrieved https://www.iea.org/publications/freepublications/publication/WEO2014_AfricaEnergyOutlook.pdf
- [4] Torero, M. (2014). The Impact of Rural Electrification: Challenges and Ways Forward.
- [5] Peter Alstone; Dimitry Gershenson; NickTurman-Bryant; Daniel M. Kammen; Arne Jacobson. 2015 Off-Grid Power and Connectivity: Pay-As-You-Go Financing and Digital Supply Chains for Pico-Solar. Berkley, California:Lighting Global
- [6] <https://rael.berkeley.edu/wp-content/uploads/2015/05/LG-2015-PAYG-Report-Alstone-et-al.pdf>
- [7] An Overview of Electricity Sector In Pakistan. Available from:http://icci.com.pk/data/downloads/63/1293619048_1.pdf
- [8] Yearbook, Pakistan Energy. "Hydrocarbon Development Institute of Pakistan; June 2016: Islamabad. Pakistan." (2015)
- [9] Farooqui, S.Z., 2014. Prospects of renewables penetration in the energy mix of Pakistan. Renewable and Sustainable Energy Reviews, 29, pp.693-700
- [10] Mirza, Umar K., et al. "Wind energy development in Pakistan." Renewable and Sustainable Energy Reviews 11.9 (2007): 2179-2190
- [11] Angelou, N., Portale, E. and Raabe, T., 2014. " A New Multi-Tier Approach for Measuring Energy Access." Energy Sector Management Assistance Program, Washington
- [12] ALI, AKHTAR, and BY SYED. "Electricity for All: Rural electrification-I." (2018).

How to cite this article:

Sheraz Khan, Islam Nabi, Rafi Ullah, Majid Ullah, Syed Kamal "Measuring Access to Energy in Rural Areas of Pakistan: A Multi-Tier Framework Approach", International Journal of Engineering Works, Vol. 8, Issue 12, PP. 289-293, December 2021,
<https://doi.org/10.34259/ijew.21.8012289293>.

