LUXOR

Energy Access Diagnostic Report Based on the Multi-Tier Framework

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412371

Contents

ACKNOWLEDGMENTS

The Multi-Tier Framework's (MTF) international initiative would not have been possible without the valued technical and financial support of the Energy Sector Management Assistance Program (ESMAP)

This report, which details the results of the MTF survey implemented at Luxor in 2030, provides an informed account of the status of access to electricity. During the preparation of the report.

First and foremost, I would like to thank the people of Luxor for its enthusiasm and support for this project. Specially Energy division manager of Luxor.

Numerical highlight

Electricity Access

Government of Luxor is successfully accelerating growth in access to electricity. The Luxor government has set a target to achieve 100% electrification by 2026 (60% through grid connection and 40% off grid solutions).

- As of 2020, 64.5% of household have access to electricity from at least one of the source of electricity and 8.5% household do not have access to electricity and 24% uses off grid solution.
- 64.75% of total household have been accessed as having basic access to electricity supply.
  The remaining 35.25% have no electricity source, rely on dry cell batteries, or have a grid or off-Grid electricity supply that does not provide basic energy service (able to light the house and charge phones and available for at least 4 hours a day and 1 hour in the evening.
- 15.75% of household are have at least 8 hours of electricity supply a day including at least 3 hours in the evening.
- 33.25% of household receive electricity 23 hours a day,7 days a week.
- 51.75% of household experience more than 4 electricity disruption a week.
- 90.5% of grid connected household face voltage issue such as low or fluctuating voltage.
- For the 36.25 % of total household cost of standard consumption package 365 kwh per year is more than 5% of household income but not for the remaining 63.75%.
- 30.75% of grid connected household had accident due to electricity connection.
- Phone charging is most common additional service use by household that update their off grid solution followed by radio and television.

Policy Highlight

- Greatest challenge is to provide access to at least basic electricity supply (tier 1 or above) to households without any access (Tier 0).
- Government aims to achieve universal access by 2026 (60% through grid connections and 40% through off-grid solutions). The ultimate goal maybe for all households to be in tier 5,
- 35.25% Most households report that they acquired their off grid product within last 5 years. Off grid solutions are thus promising approach for providing access to at least basic electricity supply to non-electrified households.
- Willingness to pay for a grid connection and off grid solar devices can be enhanced by spreading payments over time.
- Adequate measures should be implemented to boost the use of grid electricity.
- To improve the access to electricity among grid connected household Luxor government need to improve Reliability, Quality and Availability.
- Availability and Capacity keep household with an off grid solar solution in lower tier to access electricity, but solar solution can provide household with over 23 hours of electricity a day, allowing them to reach tier 5 for daily availability.
- The key to upgrading off grid solar solution will be to ensure that household can pay for them

Key Findings and Policy Implications

Technologies, attributes, tiers, and use—those are the key concepts that the Multi-Tier Framework (MTF) uses to assess the access of households to various sources of electricity. It thus goes well beyond traditional binary assessment of energy access—of having or not having a connection to electricity. The MTF achieves this by capturing the many dimensions of energy access and the wide range of technologies that households use for power.

Access to Electricity

The MTF approach measures energy access provided by any technology on seven attributes that capture key characteristics of the energy supply that affect the user experience. Capacity, Availability, Reliability, Quality, Affordability, Formality, and Health and Safety. Based on those attributes, it then defines six tiers of access, ranging from Tier 0 (no access) to Tier 5 (full access).

FIGURE 1 - Multi-Tier Framework attributes for access to electricity

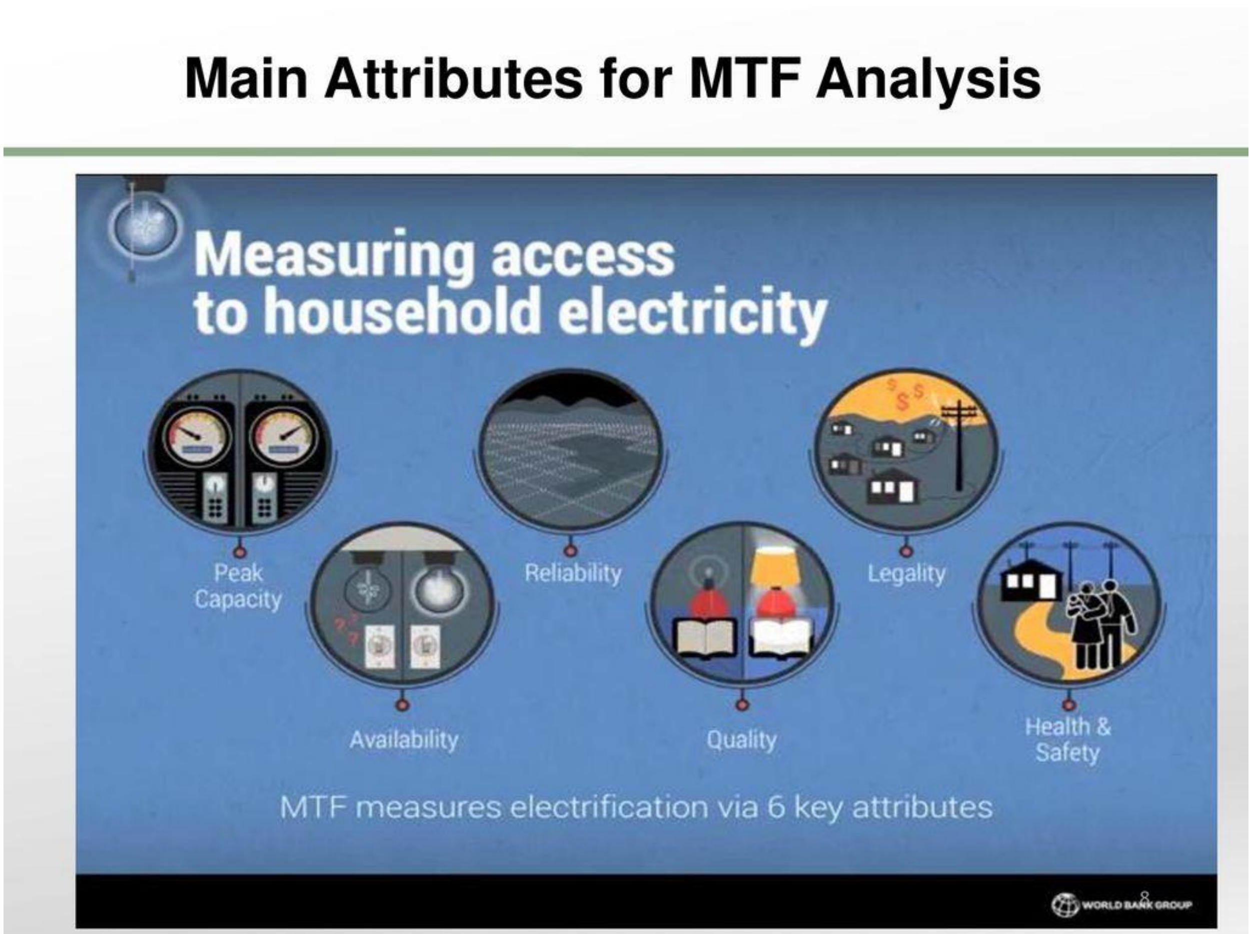
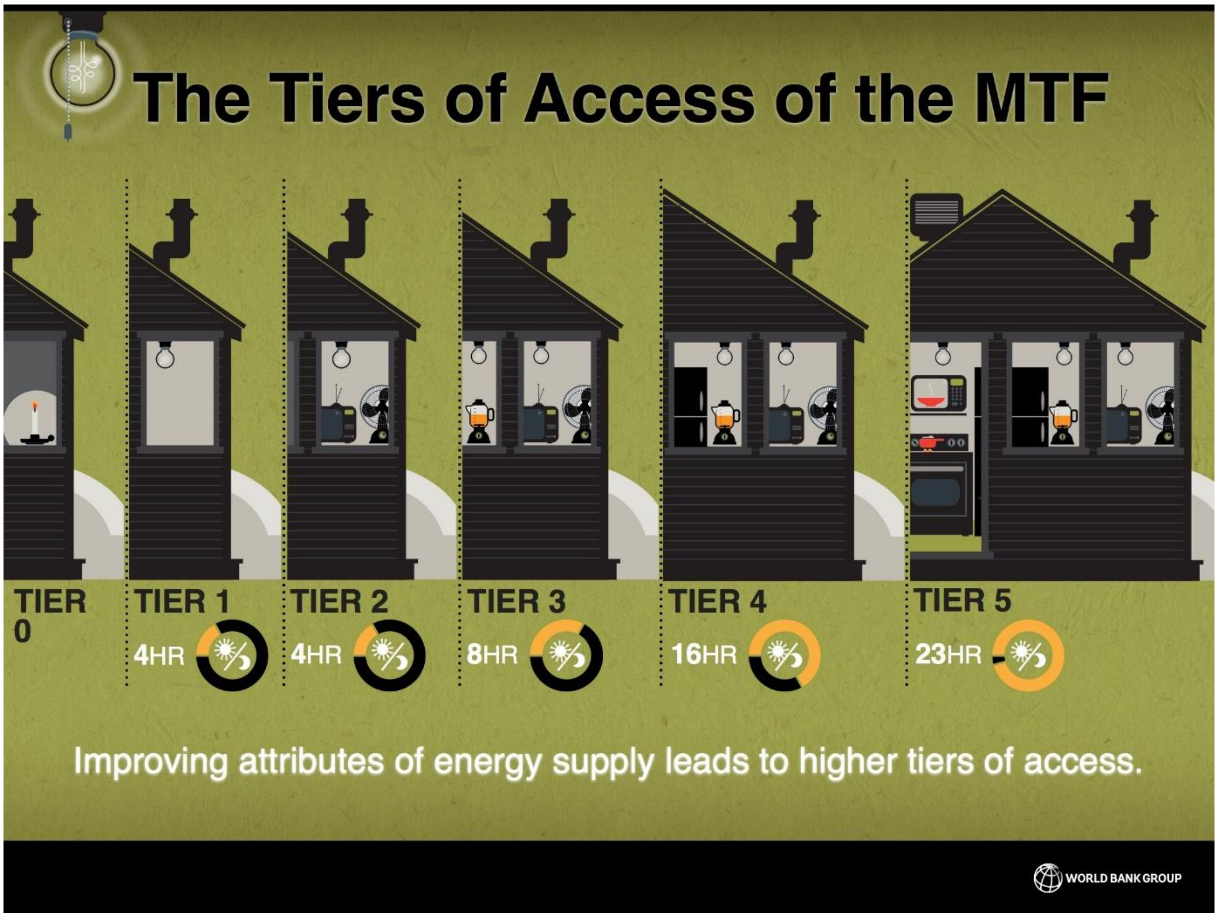


FIGURE 2 –Multi-Tier Framework tiers for access to electricity



A grid is the most likely source for achieving a higher tier, though a diesel generator or a mini-grid, may also do so. Technological advances in photovoltaic solar home systems (SHSs) and direct current–powered energy-efficient appliances also make higher access possible—to Tier 3 and even Tier 4.

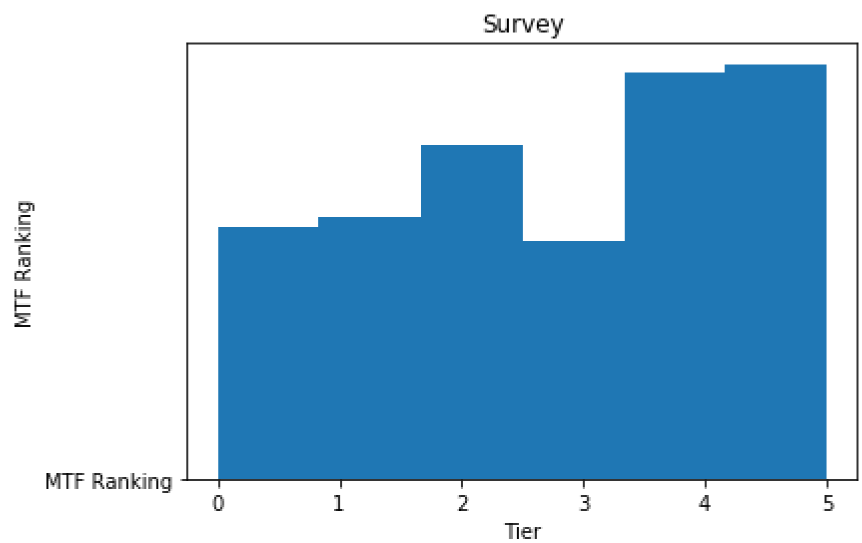
Technologies - 64.75% of total household have been accessed as having basic access to electricity supply. The remaining 35.25% have no electricity source, rely on dry cell batteries, or have a grid or off-Grid electricity supply that does not provide basic energy service (able to light the house and charge phones and available for at least 4 hours a day and 1 hour in the evening. . The share of electrified households that use an off-grid solar solution, while low, is the result of fast progress in off-grid electrification in recent years. The majority of households that use an off-grid solar solution acquired it within the last five years.

MTF Tires- In Luxor, 86.75% households are in Tier 1 or above, and most electrified households (those in Tier 1 or above) are in Tier 5 (figure 3) Households with access to electricity are concentrated in higher tiers: 81.3% of electrified households are in Tier 3 or above. So most electrified households have at least 8 hours of supply a day, including at least 3 hours in the evening, with enough capacity to power medium-load appliances.

FIGURE 3 Most Electrified household are in tier 5

In [26]:
```
plt.hist(data['MTF Ranking'],bins= 6)
plt.xlabel('Tier')
plt.ylabel('MTF Ranking')
plt.title('Survey')
plt.plot ('MTF Ranking')
plt.show
```

Out[26]: <function matplotlib.pyplot.show(*args, **kw)>



Almost all households in Tier 3 or above are connected to the grid. Most households in Tier 0 have no access to electricity.

MTF attributes - A key question that the MTF survey seeks to answer is what prevents a household from moving to a higher tier for access to electricity. The value of access to electricity for households is defined by analyzing MTF attributes (as answered by questions embedded in the MTF survey):

- Capacity: What appliances can I power?
- Availability: Is power available when I need it?
- Reliability: Is my service frequently interrupted?
- Quality: Will voltage fluctuations damage my appliances?
- Affordability: Can I afford to purchase the minimum amount of electricity?

- Formality: Is the service provided formally or by informal connections?
- Health and Safety: Is it safe to use my electricity service or do I risk injuries by using service.

Grid-connected households are considered to receive high-capacity electricity.

Availability of electricity supply is limited for about half of households. Although 33.25% of total household receive electricity 23 hours a days, 7 days a week. , 17% receive 16 hours or less a day.

Most grid-connected households, 51.75% of household experience more than 4 electricity disruption a week. Power outages may occur if the utility tries to cope with generation constraints or network breakdown impacting specific geographic areas.

In Luxor, 90.5% of grid-connected households face voltage issues—such as low or fluctuating voltage. Electric appliances generally require a certain voltage supply to operate properly, and low voltage supply tends to result from an overloaded electricity system or from long- distance low-tension cables connecting spread-out households to a singular grid. Voltage fluctuations and voltage surges can damage electrical appliances and sometimes result in electrical fires.

30.75% of grid connected household had accident due to electricity connection. It is important to ensure that all households are aware of basic safety measures and that wiring is installed according to national standards to prevent accidents when operating electricity under both normal and fault conditions. It would be worth exploring the reasons behind the serious accidents that have occurred in grid-connected households.

Electricity consumption of unconnected households is generally low because most use small solar lanterns or solar lighting systems (SLS) that provide Tier 0 or 1 access to electricity.

Increasing access to higher tiers - There may be a tradeoff between moving households with no access to any source of electricity to Tier 1 or above and moving electrified households in Tier 1 or above to a higher tier. While the ultimate goal may be for all households to be in Tier 5, most households, have their current needs satisfied even if they are in a lower tier. Most households own only very low– or low-load appliances that low-cost off-grid solar solutions can power. Such solutions are likely to be a good and quickly delivered alternative, at least in the short to medium term, for households that are located away from the grid or that cannot afford a grid connection (even with a payment plan). The MTF survey results show that households that use a solar lantern would like to increase the capability of their off-grid solar solution to power additional appliances. Having a solar lantern can be a significant step to move these households from Tier 0 to a higher tier.

Several interventions are likely to increase and improve access to electricity in Luxor such as

1) Improve the Availability, Reliability, and Quality of the electricity supply from the grid to help households in Tiers 0–3 move to a higher tier (over half of grid-connected households are in Tiers 0–3 for access to electricity.

2) Ensure that off-grid solar solutions on the market maximize the level of service their users receive and increase user satisfaction.

3) Establish a renewable energy fund or financial facility to address challenges related to consumer ability to pay for or access to finance to purchase off-grid solar products and provide technical support for existing financial institutions to improve their understanding of off-grid solar products.

The main barriers that prevent households from connecting to the grid are the high connection fee and distance from the grid infrastructure.

Availability and Capacity are the main factors that keep households with an off-grid solar solution in lower tiers for access to electricity. Among households with an off-grid solar solution, 8.5% receive less than 4 hours of electricity a day and are thus classified as not having access based on the MTF. Nonetheless, solar solutions can provide households with over 23 hours of electricity a day, allowing them to reach Tier 5 for daily Availability. Evening Availability is an issue for fewer households: 48.25% receive over 4 hours of electricity between 6 pm and 10 pm. Among households with an off-grid solar solution, 62.85.8% are in Tier, and none is in Tier 3 or higher.

While off-grid solar solutions that allow households to reach Tier 3 or above are rare, advances in solar technologies make it likely that such systems will be available in the future. The key to upgrading off-grid solar solutions (and thus moving households with an off-grid solar solution to a higher tier) will be to ensure that households can pay for them and that the devices perform well. In addition, the performance of solutions on the market differ. Ensuring that households acquire a better solution is likely to improve system performance even if the size of the solution does not change (for example, brighter and longer lasting lights, ability to power more appliances for a longer period of time, and longer life of the product), which can also lead to improved satisfaction.

Access to electricity

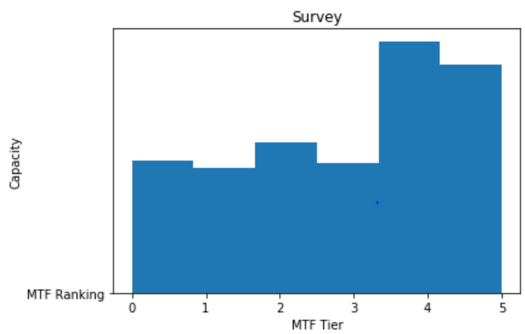
MTF attributes

Capacity - Grid-connected households are considered to receive high-capacity electricity.

FIGURE 4:

```
In [107]: plt.hist(data['Capacity(W)'],bins= 6)
          plt.xlabel('MTF Tier')
          plt.ylabel('Capacity')
          plt.title('Survey')
          plt.plot ('MTF Ranking')
          plt.show

Out[107]: <function matplotlib.pyplot.show(*args, **kw)>
```



Availability – The availability of electricity supply is limited for about half of households. Although 33.25% of households with any source of electricity receive electricity 23 hours a day, 7 days a week.

Figure 5: Source of electricity receive electricity 23 hours a day, 7 days a week.

```
In [109]: plt.hist(data['Availability(Duration-Day)'],bins= 5)
          plt.xlabel('MTF Tier')
          plt.ylabel('Availability(Duration-Day)')
          plt.title('Survey')
          plt.plot ('MTF Ranking')
          plt.show

Out[109]: <function matplotlib.pyplot.show(*args, **kw)>
```

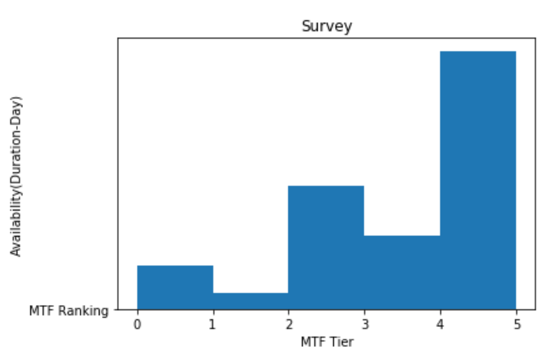
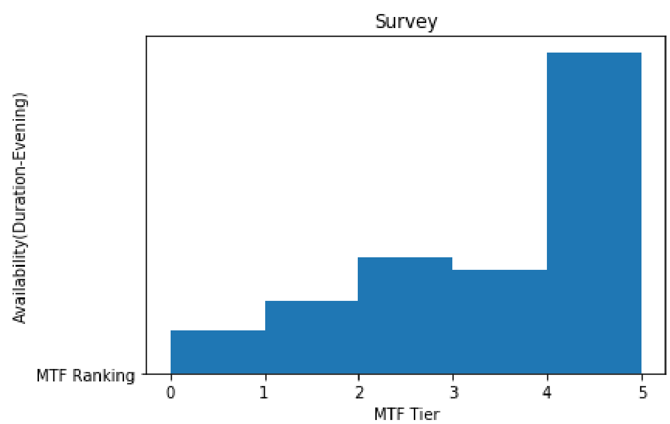


Figure 6: Nearly 48.25 % of households receive 4 hours of electricity in the evening.

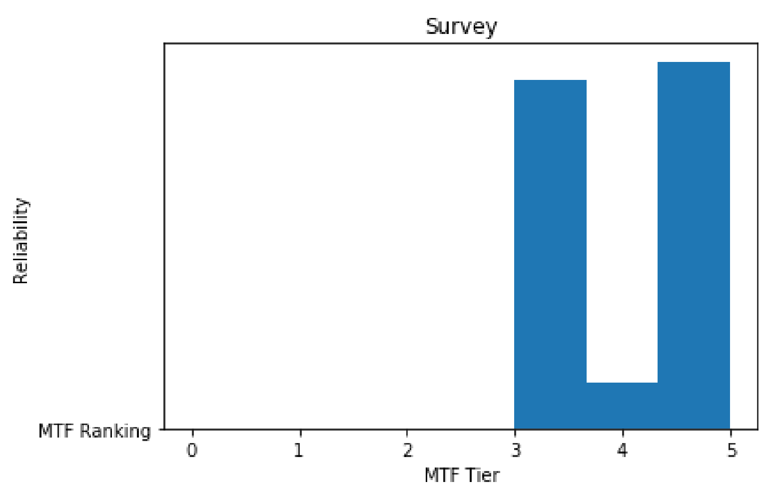
```
Out[110]: <function matplotlib.pyplot.show(*args, **kw)>
```



Reliability –

According to figure 7, at Luxor 51.57% of grid-connected households experience more than four electricity disruptions a week.

Figure 7: Higher tier suffer less disruption.

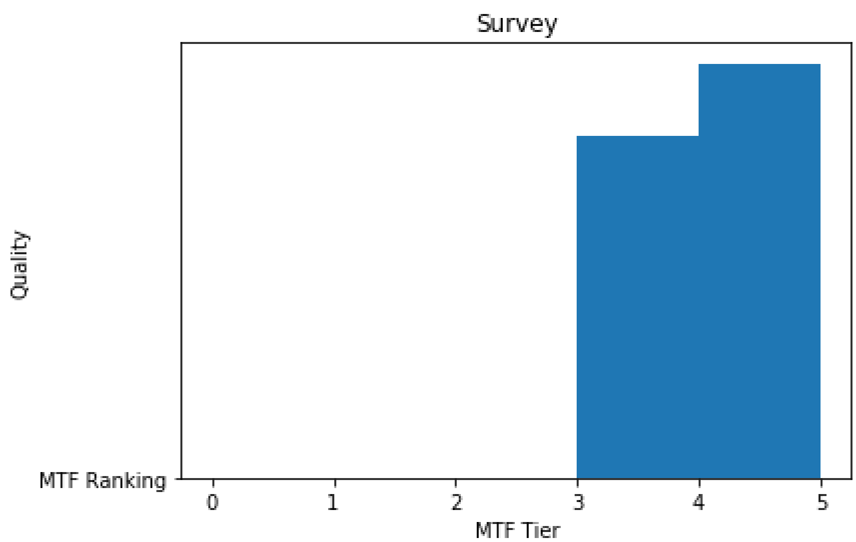


Quality –

Figure 8 show that 45.25% of grid-connected households face voltage issues.

Figure 8 Voltage issue.

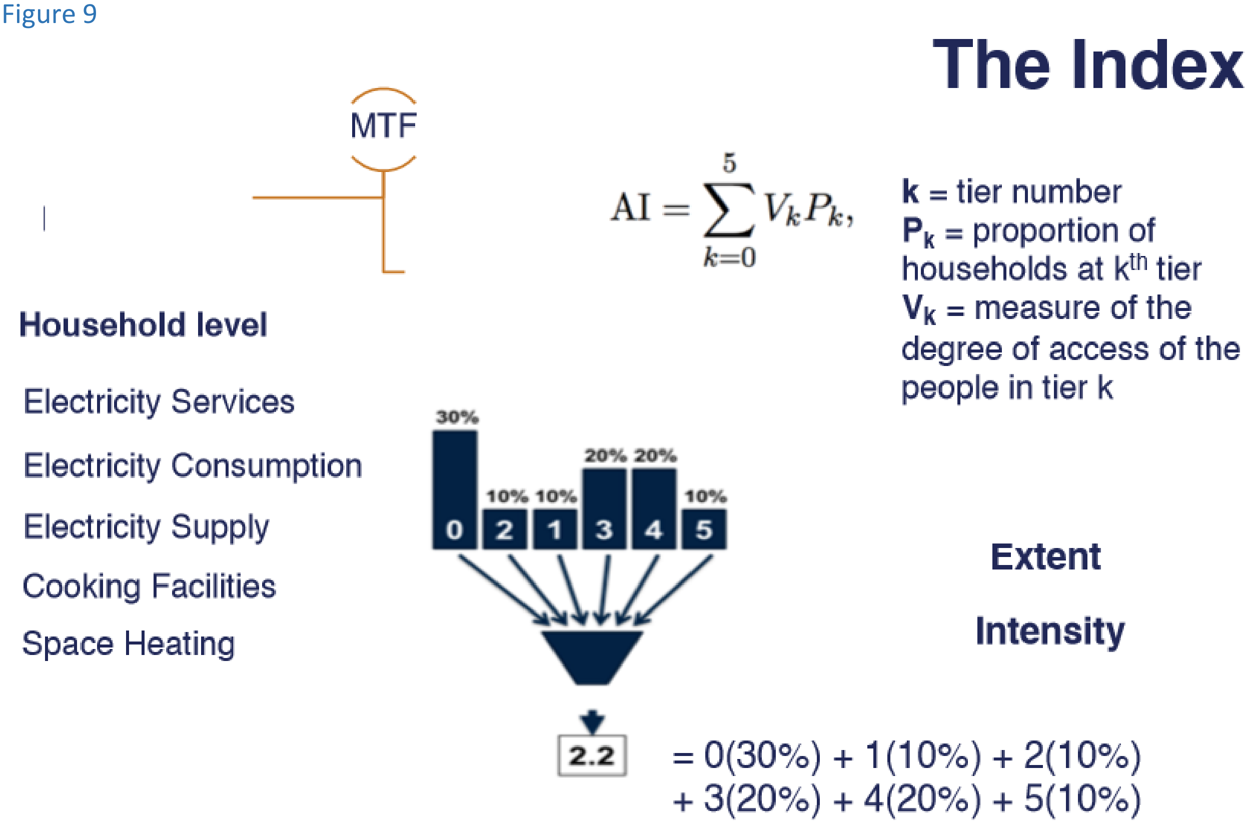
<function matplotlib.pyplot.show(*args, **kw)>



IMPROVING ACCESS TO ELECTRICITY

According to (figure 9) MTF Ranking of Luxor is 2.8

Figure 9



Access among electrified households can be further improved by increasing Availability, Quality, and Reliability of electricity supply, mainly through the grid. Most electrified households are in Tier 3 or 4 for access to electricity. Limited evening Availability (less than 4 hours) and Quality issues (such as inadequate voltage) keep most households in Tier 3 from moving to a higher tier, while Reliability issues (at least four outages a week) and limited daily Availability (16–23 hours a day) keep most households in Tier 4 from moving to a higher tier. Addressing these challenges would move most electrified households to Tier 5. Larger off-grid solar solutions, in turn, could move households in Tiers 1 and 2 to a higher tier.

Affordability could be another factor impeding households from reaching a higher tier for access to electricity. Affordability was not explored in the Rwandan survey, so conclusions regarding its role cannot be drawn in this analysis. If Affordability is an issue for electrified households (that is, if the cost of 365 kWh a year accounted for more than 5% of household spending), many households in Tier 3 or above may be in Tier 2.

WTP for an off-grid solar device that allows households to reach Tier 1 for access to electricity also increases when a payment plan is offered.

Some other insights from coding

Description of collected dataset

```
data.describe()
```

	ID	Capacity(W)	Capacity(Daily Wh)	Availability(Duration-Day)	Availability(Duration-Evening)	Reliability	Quality	Affordability	Formality	Health and Safety	I Rank
count	400.000000	400.000000	400.00000	400.000000	400.000000	400.000000	400.000000	400.000000	400.000000	400.000000	400.00
mean	200.500000	2.915000	3.05250	3.280000	3.380000	4.025000	4.095000	3.912500	4.360000	4.385000	2.80
std	115.614301	1.719059	1.69763	1.597806	1.732948	0.970427	0.996724	1.443972	0.934121	0.924072	1.72
min	1.000000	0.000000	0.00000	0.000000	0.000000	3.000000	3.000000	2.000000	3.000000	3.000000	0.00
25%	100.750000	1.000000	2.00000	2.000000	2.000000	3.000000	3.000000	2.000000	3.000000	3.000000	1.00
50%	200.500000	3.000000	3.00000	4.000000	3.000000	4.000000	5.000000	5.000000	5.000000	5.000000	3.00
75%	300.250000	4.000000	5.00000	5.000000	5.000000	5.000000	5.000000	5.000000	5.000000	5.000000	4.00
max	400.000000	5.000000	5.00000	5.000000	5.000000	5.000000	5.000000	5.000000	5.000000	5.000000	5.00

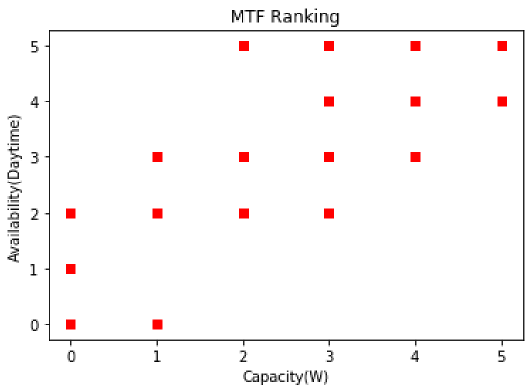
Survey has been conducted between 400 household. Where, minimum tier for Capacity and Availability attribute is 0. And min. tier for Reliability, Quality, Formality, Health and Safety is 3. Tier 2 is the lowest tier for measuring access for energy.

Dependency between Capacity and Availability (Duration-Day)

Figure 9

```
plt.scatter(data['Capacity(W)'],data['Availability(Duration-Day)'], color ='red', marker = 's')
plt.xlabel('Capacity(W)')
plt.ylabel('Availability(Daytime)')
plt.title('MTF Ranking')
plt.show
```

```
<function matplotlib.pyplot.show(*args, **kw)>
```



Households which have less electricity capacity in watt also have less availability during daytime. Households come under tier 2 of capacity attributes are related to tier 2 and 3. Households. Households having capacity more than 200 W receiving electricity throughout day time more than 8 hours.

Pearson corelation heatmap

Correlation for investigating the relationship between two quantitative, continuous variables.

Figure 10

```
sns.heatmap(corelation, xticklabels=corelation.columns, yticklabels=corelation.columns, annot=True)
```

```
<matplotlib.axes._subplots.AxesSubplot at 0x7145622848>
```

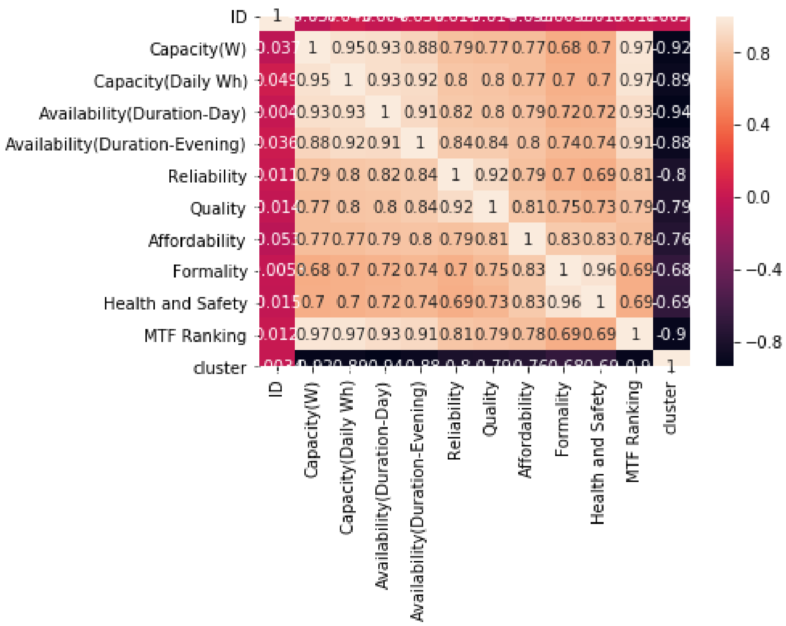


Figure 10 represent that Formality and Health & safety attributes are highly correlated. Also, Availability (Duration-Day) and Capacity (W).

K Means Clustering

K Means clustering between Availability (Duration-Day) and Capacity (W) variables

In [140]:
```
data1 = data[data.cluster==0]
data2 = data[data.cluster==1]
data3 = data[data.cluster==2]

plt.scatter(data1['Availability(Duration-Day)'],data1['Capacity(W)'],color='green')
plt.scatter(data2['Availability(Duration-Day)'],data2['Capacity(W)'],color='red')
plt.scatter(data3['Availability(Duration-Day)'],data3['Capacity(W)'],color='blue')
plt.scatter(km.cluster_centers_[:,0],km.cluster_centers_[:,1],color ='purple',marker = '*',label ='centroid')
plt.xlabel('Availability(Duration-Day)')
plt.ylabel('Capacity(W)')
```

Out[140]:
```
Text(0, 0.5, 'Capacity(W)')
```

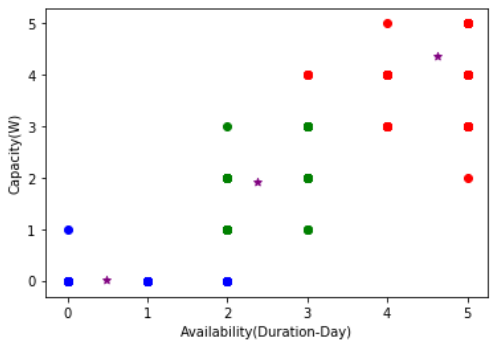


Figure 11 shows clustering of Availability (Duration-Day) against Capacity attributes. And we can see 3 clusters.

Used code for

1. Choosing of k for clustering.
2. Creating K means object.
3. Fit and predict the data frames (Availability (Duration-Day) and Capacity) for assigning the label to clusters.
4. Finding cluster center.

```
km = KMeans(n_clusters = 3)
km
```

```
KMeans(algorithm='auto', copy_x=True, init='k-means++', max_iter=300,
       n_clusters=3, n_init=10, n_jobs=None, precompute_distances='auto',
       random_state=None, tol=0.0001, verbose=0)
```

```
y_predicted = km.fit_predict(data[['Availability(Duration-Day)','Capacity(W)']])
y_predicted
```

```
array([0, 0, 2, 1, 0, 0, 1, 1, 0, 1, 0, 1, 2, 1, 0, 2, 1, 1, 0, 1, 0, 1,
       0, 0, 1, 0, 0, 1, 2, 0, 1, 0, 1, 0, 1, 1, 0, 1, 0, 0, 2, 1, 1, 0,
       1, 2, 0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 2, 1, 0, 0, 1, 1, 1, 2, 0, 1,
       0, 1, 2, 1, 1, 2, 1, 0, 1, 2, 0, 1, 0, 0, 1, 0, 1, 2, 1, 1, 0, 0,
       1, 1, 0, 1, 1, 0, 1, 0, 1, 1, 1, 0, 1, 2, 1, 0, 1, 0, 0, 0, 0, 1,
       1, 1, 1, 1, 2, 1, 1, 1, 1, 0, 0, 1, 0, 0, 1, 0, 1, 0, 1, 1, 2, 1,
       1, 1, 0, 0, 2, 1, 1, 0, 0, 1, 1, 1, 2, 1, 1, 1, 0, 1, 0, 0, 1, 0,
       0, 1, 1, 1, 1, 0, 2, 2, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 0, 2, 1, 1,
       1, 1, 0, 0, 1, 2, 1, 0, 1, 1, 1, 1, 2, 0, 1, 0, 1, 1, 1, 1, 0, 0,
       0, 0, 2, 2, 1, 0, 0, 1, 0, 1, 1, 0, 0, 2, 1, 0, 1, 1, 0, 1, 0, 1,
       2, 0, 1, 2, 0, 1, 0, 0, 1, 1, 0, 2, 1, 1, 1, 1, 0, 1, 1, 0, 0, 1,
       0, 0, 0, 1, 1, 0, 1, 2, 1, 0, 2, 1, 1, 0, 0, 2, 1, 1, 0, 1, 1, 1,
       1, 1, 0, 2, 1, 1, 1, 2, 0, 2, 1, 0, 2, 0, 1, 1, 1, 1, 2, 1, 0, 1,
       2, 1, 1, 0, 1, 1, 1, 0, 1, 0, 1, 2, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0,
       1, 0, 1, 1, 0, 0, 2, 0, 2, 1, 0, 1, 0, 1, 0, 0, 1, 2, 0, 2, 1, 0,
       1, 1, 2, 1, 0, 1, 1, 1, 2, 0, 1, 1, 2, 1, 1, 0, 1, 1, 0, 1, 1, 0,
       1, 0, 1, 0, 1, 0, 2, 1, 1, 0, 2, 1, 0, 0, 2, 1, 1, 0, 1, 1, 2, 1,
       1, 2, 0, 1, 0, 2, 1, 0, 1, 1, 0, 1, 0, 1, 2, 1, 0, 1, 0, 1, 2, 1,
       0, 1, 1, 1])
```

```
data ['cluster'] =y_predicted
data.head()
```

	ID	Capacity(W)	Capacity(Daily Wh)	Availability(Duration-Day)	Availability(Duration-Evening)	Reliability	Quality	Affordability	Formality	Health and Safety	MTF Ranking	cluster
0	1	1	1	2	2	3	3	2	3	3	1	0
1	2	2	2	2	2	3	3	2	3	3	2	0
2	3	0	1	2	2	3	3	2	5	5	0	2
3	4	4	2	3	2	4	3	2	3	3	2	1
4	5	2	2	3	2	3	5	5	5	5	2	0

```
km.cluster_centers_
```

```
array([[2.37323944, 1.91549296],
       [4.62926829, 4.35609756],
       [0.49056604, 0.01886792]])
```

Elbow technique

The goal of this algorithm is to find groups in the data, with the number of groups represented by the variable k.

Following steps we follow to get exact no of cluster.

1. Go thorough no of k, from k = 1to 10

2. Try to calculate sum of square error and plot them to find the elbow

```
k_rng = range(1,10)
sse =[]
for k in k_rng:
    km =KMeans(n_clusters=k)
    km.fit(data[['Availability(Duration-Day)','Capacity(W)']])
    sse.append(km.inertia_)
```

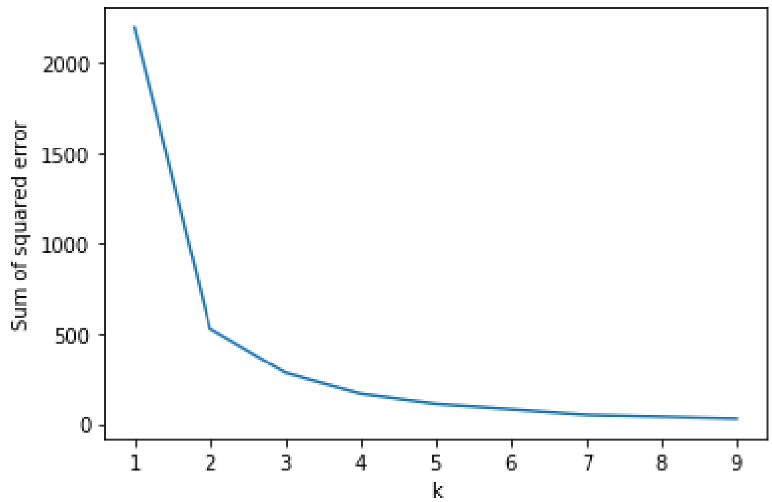
```
sse
```

```
[2197.75,
 528.7416666666667,
 283.2599087391352,
 167.4743799577291,
 111.2571615820063,
 81.60662153001637,
 50.7770478823755,
 40.27199737732499,
 29.264746927479127]
```

3. Plotting of Elbow technique on chart

```
plt.xlabel('k')
plt.ylabel('Sum of squared error')
plt.plot(k_rng,sse)
```

```
[<matplotlib.lines.Line2D at 0x714433c688>]
```



REFERENCE:

- RAWANDA ENERGY ACCESS DIAGNOSTIC REPORT