# Estimating the Energy Demand of Refugee Camps

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**Abstract**

*In the midst of the largest refugee crisis in history, refugee camps built to temporarily accommodate displaced individuals are increasingly becoming long-term settlements. To support meeting the energy needs of refugee camps in a safe and sustainable manner, this research project presents an end-use electricity consumption model for refugee camps. This has been achieved through scaling up the electricity demand of refugee households and refugee camp services subject to the camp's population. Preliminary findings suggest a camp with a population of 30,000 refugees requires 600 kWh/day for basic access to electricity. Using the load profile created through this end-use electricity consumption model, this project investigates the cost trade-offs present between various renewable and non-renewable energy solutions. The outcomes of this research project generate foundational data to allow humanitarian organisations to better understand the needs of refugee camps, facilitating the appropriate allocation of funding and formation of sustainable energy solutions.*

## 1. Introduction

By the end of 2015, 65.3 million individuals were forcibly displaced worldwide as a result of persecution, conflict, generalized violence, or human rights violations (UNHCR, 2016). Many of these individuals are housed in refugee camps, settlements built to accommodate displaced persons who have fled their home country. The majority of these refugee camps have very limited access to reliable forms of energy, a crucial input to nearly all goods and services of the developed world, and underpinning almost all aspects of human security and well being (Lahn and Grafham, 2015).

Increased access to energy stimulates both social and economic development (Stern, 2011). Without access to modern energy, refugees' time available for livelihood, educational, social and other activities is significantly reduced (UNHCR, 2014); lighting provides the camp with safety at night, and allows children to study in the absence of daylight (Independent Evaluation Group, 2008). Humanitarian agencies are often inadequately prepared to meet the ongoing energy needs of refugee camps (Lahn and Grafham, 2015). Energy infrastructure is typically viewed as a long-term investment with other emergency relief such as food, sanitation, and shelter taking precedence. This aligns with the intention for a refugee camp to be a temporary solution to an emergency crisis. However, when emergencies become protracted, this approach often results in unsustainable energy practices. In the midst of the largest refugee crisis to date, many camps are lasting over 10 years, with some still occupied after decades. Present circumstances henceforth necessitate energy planning as an integral part of the humanitarian emergency response.

In line with this, the UN Refugee Agency (UNHCR) has developed a global strategy for safe access to fuel and energy (UNHCR, 2014), emphasising the importance of meeting the energy needs of refugee camps in a safe and sustainable manner. Part of this strategy involves analysis of the energy use of refugee camps, as very little data exists in this area.

## 2. Methodology

The energy needs of refugee camps have been broken down into two high level categories - household and camp services. Household usage refers to the energy usage typical of refugee living accomodation. Camp services consist of healthcare clinics, schools, administrative centres, and street lighting. These camp services have been highlighted as critical elements of a refugee camp (Corsellis and Vitale, 2005). Due to the large variation in the level of electricity access present across refugee camps (Practical Action, 2016), it is necessary to seperate household and school energy demand into 'Basic' and 'Advanced' levels of access. 'Basic' access denotes a lower level of electricity usage, demonstrating a baseline energy demand. 'Advanced' access denotes a higher level of electricity usage, demonstrating the energy demands when higher power electrical equipment is used, or utilisation of appliances for longer periods of time. 'Advanced' access seeks to consolidate refugees' desire for higher power equipment with the practical funding limitations of the UNHCR. The breakdown of a refugee camp's energy demand is illustrated in Figure 1.

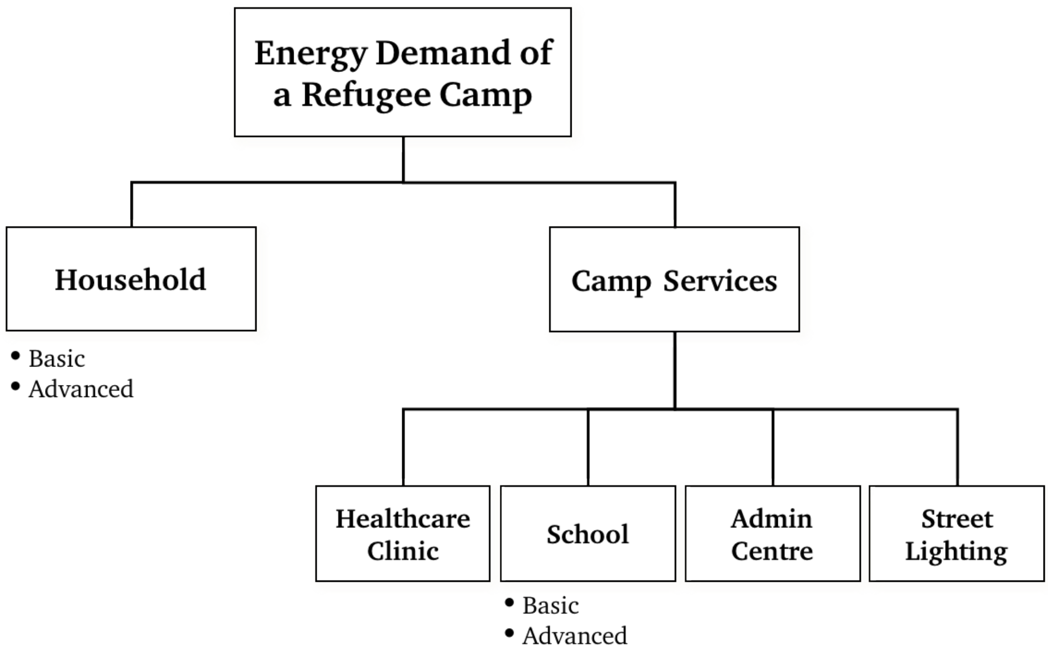


**Figure 1 Energy Demand Breakdown of a Refugee Camp**

A load profile is determined for each unit in Figure 1. Using the relationship between these units and the camp's total population (e.g. average of five refugees per household; the UNHCR specifies one primary health facility per 10,000 refugees (UNHCR, 2007), etc.) the overall load profile is established (note that due to spacial contraints this conference paper will only explore the jusitfication of the basic household model).

## 2.1 Household – Basic

The 'Basic' level of household usage aims to establish the fundamental energy requirements for a minimum level of electricity access. Lighting and mobile phone charging are consistently ranked highly in energy access priority surveys conducted on refugee populations (Practical Action, 2016). The UNHCR has recognised this; many of the solar lanterns and street lighting distributed in refugee camps also have mobile phone charging capabilities. Basic lighting and phone charging do not consume large amounts of energy (Rosen and Meier, 2001), making them suitable items in a household with a low level of electricity access.

Total Energy Access Standards (Practical Action, 2012) stipulate 300 lumens for 4 hours per night as the minimum standard for lighting access at a household level. The lumens per watt produced will depend on the light bulb technology (Dilaura *et al*., 2011). Compact fluorescent lamps are chosen for lighting, being a practical compromise between the initial cost of the bulb and power consumption. With an average of 60 lumens/watt (Khan and Abas, 2011), a single 5 W globe satisfies the minimum lighting requirement of 300 lumens. This light is provided in the evenings when the sun is down, from 6pm-10pm.

People typically charge their mobile phones at night, at a time of around 6pm-8pm (Ferreira, Dey and Kostakos, 2011). A mobile phone charger has an average active power of 5 W (Rosen and Meier, 2001). Depending on the particular mobile phone model, it can take anywhere from 1.5-4 hours to fully charge (Ravishankar Rao, Vrudhula and Rakhmatov, 2003). Given that phone charging usually occurs when battery levels are around 40% (Arslan *et al*., 2015), 2 hours is used as an overestimate for the time taken to charge a single mobile phone. Data from a mobile phone and internet survey done in the Zaatari refugee camp revealed the vast majority of refugees own a mobile phone (Maitland *et al*., 2015). Accounting for the approximately 16% of refugees that are under 5 years old (UNICEF, 2016), a typical household of five refugees (OXFAM, 2013) is hence estimated to have four mobile phones per household. With two phones charging simultaneously, this results in a cumulative load profile of 10 W between the hours of 6pm-10pm. Plotting the power consumed by all appliances against the hour of the day, a load profile is established, shown in Figure 2.

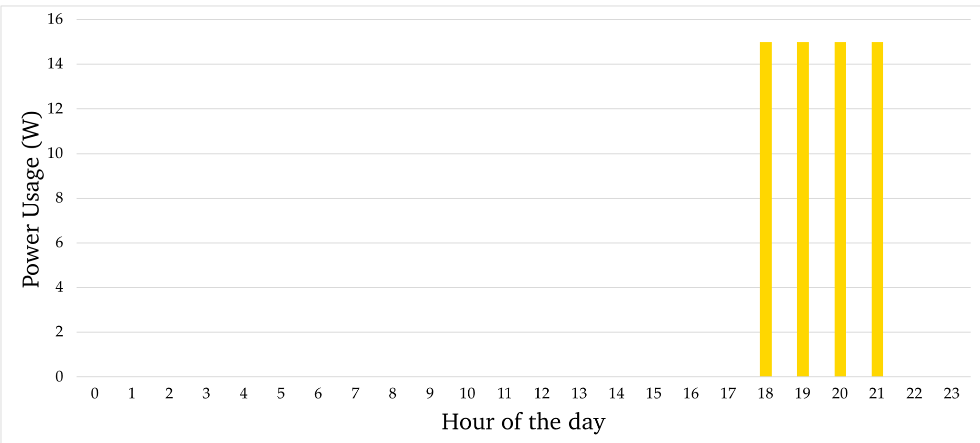


**Figure 2 Basic Household Load Profile**

# 3. Results

Consolidating the models for the various components of demand, the complete load profile may be establshed. Using the population of refugees present at the camp, the model creates a load profile for a chosen level of energy access - 'Basic' or 'Advanced'. This is achieved through scaling up the energy demands of camp services and total household usage relative to the camp's population. A case study will investigate the optimisation of a hybrid energy generation system for the Azraq refugee camp. The Azraq refugee camp has a population of approximately 30,000 refugees, and is located approximately 90 km south of the Jordan-Syria border (GPS coordinates 31.9054°N 36.5809°E). To optimise the energy generation system, the software package Hybrid Optimization of Multiple Energy Resources (HOMER) is used. HOMER models a generation system's life-cycle cost, which is the total cost of installing and operating the system over its life span. To achieve this the location, component costs, and load profile must be input into HOMER. The Azraq camp's population of 30,000 refugees is input into the end-use consumption model, specifying the 'Basic' level of electricity access present at the camp. From this, the load profile shown in Figure 3 is generated, representing ~600 kWh of daily demand. Inputting this load profile into HOMER, the optimal energy generation system can now be determined.

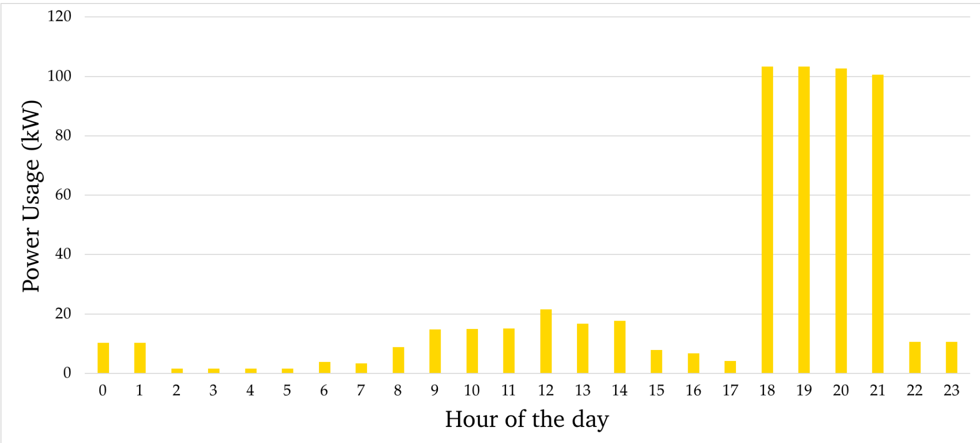


**Figure 3 Camp Load Profile for Azraq Refugee Camp**

The results from the HOMER simulation have been plotted in Figure 4. The figure displays three parameters within the same graph: the net present cost (x-axis), operating cost (y-axis), and the capital cost (size of the bubble). The renewable energy fraction is defined as the percentage of the load that originated from renewable power sources. The hybrid solution presented in Figure 4 has a renewable energy fraction of 34%, explaining why its costing metrics resemble that of the diesel generator solution. It can be observed that the hybrid solution has the lowest lifetime cost over the 20 year project lifetime, with a NPC of $1.22 million. The pure diesel solution has a slightly lower capital cost but suffers from a higher NPC and operating cost. The pure solar solution has a very large upfront capital cost and NPC, but has a smaller operating cost. Unless operating cost is highly prioritised over other metrics of a project's cost, it would be unlikely that a pure solar system would be perceived as a more financially viable solution than the hybrid system. Similarly unless capital cost is highly prioritised, a slight increase in capital cost from the pure diesel to a hybrid solution would be warranted to realise decreased lifetime project costs, as well as lower operational costs.

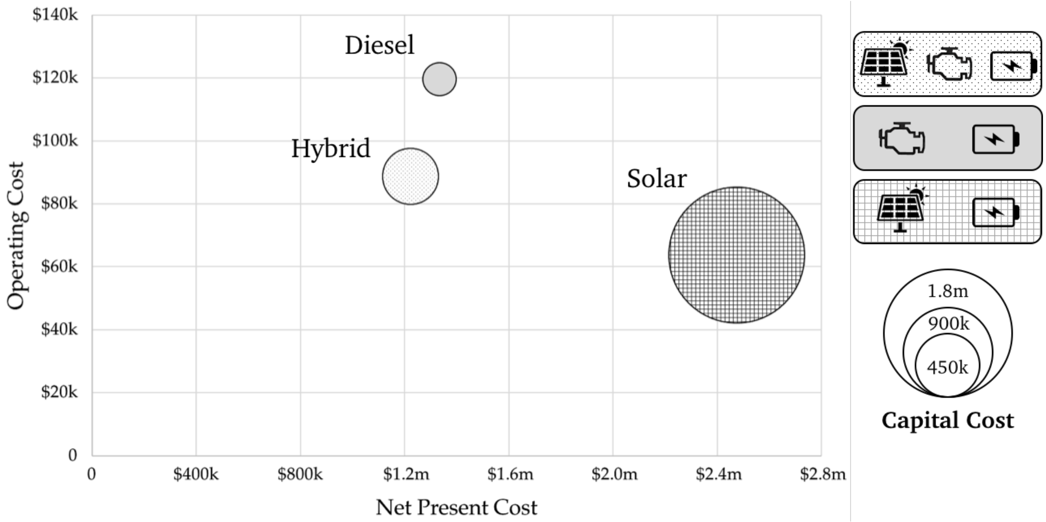


**Figure 4 Cost Trade-offs Between Energy Generation Systems**

# 4. Conclusions and Future Work

An end-use electricity consumption model has been developed to capture the energy needs of refugee camps. This has been achieved through deconstructing total energy demand into its constituent elements, and scaling up the usage subject to the camp's population. Using the load profile created through this end-use electricity consumption model, this project was able to explore the optimal energy generation system for the Azraq refugee camp, with an estimated 600 kWh/day required for a basic level of electricity access. The cost trade-offs present between a hybrid, pure solar, and pure diesel energy generation system were explored; the hybrid solution was found to have the lowest net present cost of $1.22 million.

As refugee settlements become increasingly mature, future work in this area should look to explore modelling the energy demands of small businesses and water pumping. It should also to seek ways to effectively implement changes in behaviour that facilitate load shifting to periods where solar radiations is at its highest, at around noon. The modelling of refugee camp energy demands should be validated and refined with real-world energy metering data placed on refugee camps.

# 5. Acknowledgements

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