AMERICAN UNIVERSITY OF BEIRUT

DEFINIG, ADDRESSING AND GAUGING ENERGY POVERTY IN LEBANON

by
GHAIDAA MAHMOUD EL ASSADI

A thesis
submitted in partial fulfillment of the requirements
for the degree of Master of Science
to the Department of Mechanical Engineering
of the Maroun Semaan Faculty of Engineering and Architecture
at the American University of Beirut

Beirut, Lebanon
July 2021

AMERICAN UNIVERSITY OF BEIRUT

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by
GHAIDAA MAHMOUD EL ASSADI

Approved by:

	Signature
Dr. Nesreene Ghaddar, Committee Chairperson Department of Mechanical Engineering	Advisor
	Signature
Dr. Hassan Harajli	Co-Advisor
	Signature
Dr. Kamel Aboughali	Member of Committee
	Signature
Dr. Hiba Khodr	Member of Committee

Date of thesis defense: July 7, 2021

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ACKNOWLEDGEMENTS

I would like to express my deep gratitude to my advisors Prof. Nisreen Ghaddar, Prof. Hassan Harajli, Prof. Hiba Khodr and Prof. Kamal Abo Ghali. A special gratitude to Dr. Hassan Harajli for his expertise, guidance, constructive criticism and for providing me with the data. I would like to thank my husband, Mohammad, for being my excellent conversation partner and a great motivator. I want to thank my parents who kept on motivating me to proceed in my academic life. Indeed, I would like to thank my brother, Yehya and sisters, Hiba, Danya and Aya who stood by me whenever I needed them. I know it’s considered cliché to include my family in my acknowledgment but, sincerely, I express my deep gratitude, for they are my backbone. Last but not least, I would like to thank my son Saad el Dine who gave me a reason to proceed with my academia, for I want him to be proud of his mom.

ABSTRACT
OF THE THESIS OF

Ghaidaa Mahmoud El Assadi for Master of Science
Major: Energy Studies

Title: DEFINIG, Addressing and GAUGING ENERGY POVERTY in LEBANON

This proposal briefly explains the concept of energy poverty, which is defined as the continuous concern about the increasing population being unable to access affordable energy services. The problems of energy poverty are widespread and forecasts of energy poverty levels haven't been very promising. A significant number of people still use traditional biomass for everyday use, subjecting themselves to indoor air pollution and several health consequences. This paper reviews the various definitions of energy poverty, covering the topic's social, psychological, economic and political dimensions. It also seeks to identify the level and scope of energy poverty in Lebanon, based on the definitions and several case studies from other countries, including measures that are recommended to alleviate this energy poverty that's existent in Lebanon.

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LIST OF ACRONYMS

AC: Air conditioner

CO_2: Carbon dioxide

EAE:. energy affordability and energy efficiency

ECC: Energy consumption cleanliness

EDL: Electricite du Liban

EMC: Energy management completeness

EP: Energy Poverty

ESA: Energy service availability

ESCO: Energy Service Company

EV: Energy Vulnerability

EVs: Electric vehicles

FP: Fuel Poverty

GDP: Gross Domestic Product

ICS: Improved cook stoves

IEA: International Energy Agency

IMF: International Monetary Fund

LBP: Lebanese pound

LED: light-emitting diodes

kWh: Kilowatt hour

MoE: ministry of Energy

PV: Photovoltaic

RE: Renewable energy

SHS: Solar heater system

TV: television

TWh: Terawatt hour

UE: Unemployment

UK definition: United Kingdom definition

UNDP: United Nations Development Program

Wp: Watt peak

WtP: Willingness to pay

Y: income

CHAPTER 1

INTRODUCTION

Approximately 1.3 billion people have no access to electricity which cover 16% of the global population. Roughly 2.8 billion people (38% of global population) still don’t have access to clean cooking stoves, subjecting themselves to indoor air pollution due to the solid fuels used in cooking (Papada, 2019). These issues resulted in the death of about 4.4 million people collectively per annum (Papada, 2019).

This research will focus on energy poverty in depth, with several definitions existing in literature, our focus will be to review the various definitions of 'energy poverty’ first including the review of case studies of energy poverty in various countries. We will set out next to prescribe workable indicators for energy poverty for Lebanon, measure energy poverty in Lebanon using the selected indicators, and recommend policies and programs that would assist in improving the poverty indicators selected.

CHAPTER 2

AIMS AND OBJECTIVES

Lebanon has been continually suffering from a major energy crisis that has spanned decades. There is not one sole reason behind this problem, yet several reasons in fact. The overall purpose of the paper is to recognize the energy problem in Lebanon and to assess the extent of this energy crisis. This could be attained through understanding the concept of energy poverty and being able to analyze the reasons behind countries or cities or households suffering from it. Through the understanding of the many aspects of energy poverty, we will be able to fill the gaps present in the case of Lebanon and learn more about it in depth.

In brief this thesis aims to answer two main questions. First, what are the factors causing energy poverty in Lebanon? Second, what are the researches and solutions proposed in other countries targeting similar factors affecting Lebanon? These questions are to conclude my main research question which is:

What are the suggestions, recommendations and policies that can help Lebanese citizens out of energy poverty?

CHAPTER 3

LITERATURE REVIEW

What is energy poverty? Why did this phrase emerge? On what basis can a person, a household or even a country be considered energy poor? and many questions like it looked into thoroughly as we move onto questions like to what extent are these households considered energy poor, the relation between energy services and energy poverty and the definition of energy ladders. With the energy poverty that is being faced increases, this leaves to question how can this energy poverty be eradicated. This phrase may seem trivial yet a lot of misconceptions do emerge, and a repetitive misapprehension regarding the Energy Poverty topic appears where people automatically link it to low-income countries suffering from energy insufficiencies. However, this is not the case; energy poverty occurs across all nations. It definitely has varying aspects compared to the economic status of countries (i.e., developed, emerging, developing) yet any country can encounter energy poverty.

Where is Lebanon exactly in the energy poverty spectrum? How can understanding the different perceptions of energy poverty help in determining the extent of energy poverty in Lebanon? This study reviews academic journals, books and credible sources on the situation in an attempt to answer all the questions proposed above.

3.1 Definition

The notion of energy poverty was first protested back in England in 1970 by "The British Fuel Use Rights Movement" where the intrinsic notion was the incapability to buy energy amenities (Wang, 2015). Perceptibly, the concept hasn't stopped here; researchers endeavored to evolve it. As a matter of fact, the International Energy Agency (IEA), the United Nations Development Program (UNDP), and other organizations and researchers extended the concept through incorporating another important factor. Energy access is another major factor that developing countries mainly suffer from; households in developing countries rely immensely on inefficient traditional biomass. Several definitions might appear to fit the energy poverty concept; however, two dominant definitions seem to prevail with the research's focus in this subject. On one hand, Boardman (2010) defined energy poverty as the inability to afford proper energy services. By this definition, Boardman referred to developed countries while on the other hand, the International Energy Agency (2002) defined energy poverty "as a lack of access to clean and commercial fuels, efficient equipment and electricity and a high dependence on traditional biomass, which is mostly burned in inefficient and polluting stoves." This definition mostly fits the developing countries' situation.

3.2 Misconceptions

This section of the paper briefly revises several misconceptions of energy poverty.

- Location of energy poverty:

  - A large number of governmental executives relate energy poverty to Africa.

- Another fallacy is that energy poverty is a rural issue only.

- The energy poor are benefiting:

  Energy service and access programs intuitively think they're aiding the poor yet instead they are the least benefiting. More basic programs are needed that shed light on more critical issues such as re-compensating the energy poor's loans.

- Energy ingress will not aggravate the Earth's climate:

  A collective misconception concerning the amalgamation of energy poor to the grid is that it would increase energy consumption dramatically and also aggravate the climate change issue.

- Heating and Lighting aren't everything

  Heating and lighting aren't only the major energy needs. Many other energy services are also of major importance such as mechanical power or even transportation.

- There is no unique solution for energy poverty:

  Energy poverty issue is multi-faceted and not fixed. Each country has its own issues which results in specific solutions required.

- Failure is underestimated:

  Learning from failures most of the time may lead to eventual success. Eventually, lots of notions were understood through repeated trials and errors.

- Technology and finances are exclusively major:

  An important misconception that needs to be clarified is that energy access will not automatically emerge after perfecting technology and setting the prices accurately. Factors prohibiting energy access could be due to subjective reasons such as cultural factors.

- Criteria of valuation needs update:

  After covering the aforementioned misconceptions, it is conclusive that the evaluating criteria has been misapprehended. Therefore, new standards of evaluating energy poverty will be needed.

3.3 Impacts of energy poverty

3.3.1 Impacts on health

The use of traditional biomass for cooking and heating has detrimental impacts on health. This includes the indoor air pollution that is caused by the inefficient combustion and lack of ventilation system in regular housing. This causes non-recommended levels of carbon monoxide and other harmful particles to stay in the home and are inhaled by the people living in these homes which may lead to lung diseases and possible death.

In fact, WHO (2009) verified that death due to indoor air pollution overtakes deaths from malaria and tuberculosis. It has been documented that indoor pollution deaths are increasing to the point of competing with the deaths caused by HIV and AIDS, and it looks like one day indoor pollution deaths may even surpass them in numbers. (figure 1).

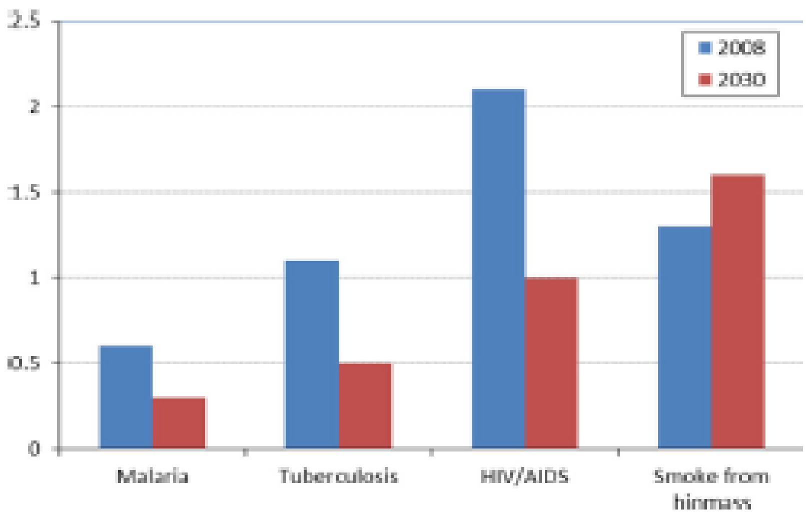


Figure 1 Premature yearly deaths from HH air pollution and other viruses (in million)
Source: M. Gonzalez-Eguino,2015

3.3.2 Impacts on the economy

Energy poverty hampers the growth of production sectors. In the agricultural sector, animals and human labor are usually the go to energy inputs in countries riddled with poverty; whereas direct and indirect energy inputs such as machinery, fuels, chemicals and fertilizers are scarce or too expensive to obtain.

In the educational sector, Khandker (2014) stated the positive impact of increased electricity and lighting access on literacy rates. Access to information and communication technologies may motivate the foundation of new small businesses or join high standard training programs which might stimulate growth in the industry.

Nevertheless, the relationship between energy resources and energy poverty needs to be clarified. Wealthy countries with stable economies and energy resources have no interest in eradicating energy poverty.

3.3.3 Impacts on the environment

The land use variation is the main bond between energy poverty and the environment. As traditional biomass is consistently used as the main source by the poor, as a result of this deforestation, desertification and land degradation increased. However, some studies assume that traditional biomass is not the major reason for land degradation. A recent study estimated that merely 6% of global deforestation is affected by traditional biomass and fuel collection (Sovacool, 2012).

3.4 Thoughts, Nature and an Approach to evaluate Energy Poverty

Energy poverty can be assessed from two different angles. The first angle is affordability, which is an issue that could be encountered by residents of any country regardless of the country's overall economic status. The other is availability, in which there are constraints on the ingress of modern energy services., such cases often emerge within developing countries. Hence, energy poverty in developing countries necessitates more attention than that in developed countries. In income poverty, the nature of the existing energy poverty within them in developed countries is relative whereas in developing countries it is absolute. In other words, major social matters might cause energy poverty in developed countries whilst the main problem in energy poverty in developing countries is their inability to afford minimal sustenance among other factors.

Less attention has been given to energy poverty in developed countries relative to developing countries (Bouzarovski et al., 2012). However, the first attempt to quantify energy poverty was done by the UK whereby any household spending more than 10% of their income on energy services is considered energy poor (Boardman, 1991). An approach to evaluate overall energy poverty was introduced by Sen (1976, 1979), in which he mentions a two-step approach; the first one is identification, i.e., an approach to detect the “energy poor” which is then followed by a complementary step. The second step is termed an “aggregation” step, and this step is basically a headcount fraction, also the “10% indicator” assists in formulating the second step since it collects the energy poor population and establishes the calculation of the ratio of energy poor to total population (Okushima S., 2016).

3.5 Energy vulnerability

Energy vulnerability (EV) rational is a prerequisite for understanding energy poverty. Sticking to this notion, energy poverty and fuel poverty were differentiated from one another at a certain point in time. It is important to note that a fundamental quality of energy vulnerability is its prospective nature, in other words, energy vulnerability focuses on the aspects causing the “likelihood” of assigning a household as ‘energy poor’. Therefore, by varying some conditions, households who are considered energy poor may depart from this situation in the future and conversely, households not considered energy poor may be affected by energy poverty. Energy vulnerability augments the accessibility and affordability dual to further comprehend the essence of the concept of energy poverty.

3.6 Multidimensional nature of Energy poverty

The dimensions of energy poverty are beyond the confines of accessibility and affordability., they branch out into flexibility, energy efficiency, and necessities which are randomly disseminated around inhabited spaces. (Bouzarovski, 2015). Wang et. al. (2015) and Oxford University press (1996) mentioned five multidimensional aspects

Table 1 Energy Poor Vs. Fuel Poor. Source: Illustration of Own Data

Table (1)	Energy Poor	Fuel Poor
Cognizance	Recognized in sealed documents in the 1970s in which the documents mainly focused on technological development. New studies report contribution and governance tasks.	It was recognized in the UK by the end of 1970s, mainly addressing the increasing energy charges and the "the right to fuel". New studies permitted broader topics concerning the problem
Hidden Agendas	principally low electrification rate and further sorts of energy web requirements initiated from economic stagnation and fruitless institutions.	mainly due to increasing energy cost against low households' income, non-insulated housing, heating structures and other device merchandise.
Guise	the use of harmful traditional sources for cooking or lighting and the inability to access modern energy sources nor services such as cooling or heating.	principally insufficient heating issues in the houses among other services cooling, energy devices and other matters related to technology.

Significances	disadvantageous effects on well-being, gender discrimination, learning and economic progress.	LR and SR run psychological and physical well-being, insufficient contribution in civilization
Key strategies	attempt to convert more modern fuels, funds for expanding the power grids or other modern energy technology or through income support or other suitable business models	mix of income support, endowments for lowering the cost of energy and plans for maximizing energy efficiency.

that assist in measuring energy poverty:

1) Cooking
2) Lighting
3) Household appliances
4) Education
5) Communication

Other energy inconveniences that interfere in the dimensions and the measurement of energy poverty would be:

1) The recurrence of ordering or gathering energy sources
2) The distance that the household takes

3) Types of transportation taken
4) The participation of households in energy gathering
5) Duration of energy collecting per unit time
6) The healthiness of the households
7) The participation of children in energy accumulation

Additionally, the number of household members may be important to be taken into consideration, adding to that the common factors that may affect energy poverty such as, politics, social status, culture, and religious factors.

Furthermore, Day et. al. (2016) mentioned the perpetual relationship between energy consumption and well-being which challenged the above-mentioned dimensions. She conceptualized energy use and energy poverty through developing a capability approach. According to the capability framework, it is true that households are concerned with the mentioned dimensions, however, their primary concern is their liberty to maintain their well-being.

3.7 Energy poverty versus fuels poverty

The divergence of conflicts in energy consumptions faced by developed and developing countries generated the term "fuel poverty". Fuel poverty is a moderate form of energy poverty that certain households in developed countries may be facing. In section 3.2, the paper stated that these households in developed countries mainly encounter "cost" conflicts. Fuel poverty designates the "affordability" angle whereas energy poverty comprises multi-dimensional approaches. Economic lethargy and malfunctioned institutions initiate "energy poverty". While, high fuel costs and low household income cause "fuel poverty". In addition, energy poor households face a major energy consumption crisis (deprivation from efficient fuels for cooking, lighting … and heating) as for “fuel poor” households’ improper heating is the major conflict. The differences between energy poor and fuel poor are compared in Table (1) below.

3.8 Energy service

The intricate structure of energy services requires different energy inputs, technology, physical capital, human labor and environment comprising natural resources (Haas, 2008). Technology and social aspects aren’t the only terms to understand energy services, yet they are a mix of conglomerations. Apart from “home”, energy services operate across a variety of systems and settings. Energy services are not fixed to ‘heating’ or ‘transport’ which has been a widespread perception in traditional times. Time intervals, culture, and institutional engagements which are not included in ‘comfort & mobility’ (E. Chove, 2003) might be considered key facets of energy services. In essence, they encapsulate composite achievements effectuating and supporting certain conditions and encounters that are profoundly entrenched in the coordination of appliances, networks, keenness and norms (E. Chove, 2003).

The main driver of energy services is the ‘needs’ that are constrained by social practices (Bouzarovski, 2015). This reflects the vital role of energy services in comprehending the lurking varying aspects which causes energy poverty.

3.9 Energy Ladder

The different inputs of energy services mentioned before are used by energy ladder concepts to illustrate energy poverty for services like heating or cooking.

Usually, in the majority of research papers, households are categorized into households with low income which refer to developing countries then middle- income households, households with high income then households residing in developed countries. There is an energy ladder for household energy consumption among different energy services. The households' income is considered as a function of the usage of different energy fuel. In cooking, for example, energy fuel differs in low-income households which mainly use wood, charcoal or agricultural remains compared to middle-income households who among those things may also use kerosene and biogas compared to high-income households that use liquefied petroleum gas, and natural gas. Lighting is also an energy service that applies on the energy ladder where energy fuel varies from candles and kerosene to electricity as income increases. The energy fuels used in space heating in the lowest income category could be dung or wood. As income increases, energy fuel improves to the use of coal, oil, natural gas and finally electricity. There are no energy fuels for other appliances for low- income households; electricity and batteries are used by middle-income households; households with higher income use only electricity.

After the Lebanese revolution, the price of basic goods had increased almost to double its initial price, while the base pay dropped by about 40%; unauthorized capital controls have restricted depositors to withdraw their own money. Many companies and businesses have also closed down as of this date. (Brennan,2020).

The bottom of the ladder refers to traditional biomasses such as animal manure, wood or candles, whereas more advanced biomasses is more at the top of the ladder the higher up on the ladder the more refined the fuels or electricity are. It can thus be noted that the efficiency of the fuels plays a big role in assigning them on the ladder. There is a positive association between the income of households and the efficiency of the fuel. An energy ladder can, therefore, be defined as the variation of energy inputs as a function of income. These rungs of the energy ladder distinguish the different classes of the population through their energy consumptions.

3.10 The relation between energy poverty and economic development

Acharya (2019) mentioned the negative correlation between economic development and energy poverty. Education is a module of economic development with the greatest impact on alleviating energy poverty with regard to income. Both income and education are negatively correlated to energy poverty. Nevertheless, the study verified that the education index is of greater impact on assuaging energy poverty than income is.

3.11 Energy Efficiency

Prompting a definition for low-income households facing energy poverty would regiment a policy and raise regulatory perceptibility. Yet, it might also neglect the social aspects and local intricacies.

An important factor that affects the vulnerability dynamic which leads to energy poverty is energy efficiency. The main reason behind this is the possible disparate huge loss of useful energy that households might face.

There is no clear relationship between enhancing energy efficiency and the eradication of energy poverty. However, a set of broader welfare for susceptible households, economies, and communities such as enhanced well-being, amplified local expenditures and job opportunities, decreased energy subsidizations, better infrastructures, and also an increase in the value of the properties, communal enclosure…

Nonetheless, these benefits have an exclusive positive relationship with energy efficiency. Recently, studies showed that low-income households who have undergone energy efficiency retrofitting have experienced most of the mentioned benefits. Additionally, it was found that 75% of all general health improvements and benefits were represented by these investments. (Catalunya, 2017).

Also, there is a tight relationship between energy efficiency and the environmental factors like diminished greenhouse gas emissions and energy saving. In the EU, a study showed that buildings are accountable for 36% of carbon dioxide emanations (Fraunhofer ISI, 2014). Moreover, it mentioned that in order for the EU to meet its climate goals, all households without any exception should hit sufficient amounts of energy efficiency.

Not only does this positively impact via the environmental effect but also there exists a rebound effect. This rebound effect enhances the household's well-being, health and efficiency which therefore intensifies the positive impact of energy efficiency. The easiest way to regiment a policy or receive political prominence could be done through coming up with a common definition. However, this may obliterate communal demographic and local convolutions (EP, 2016b).

3.12 Energy Technology and Financial Models

Energy efficiency plays a vital role in abating energy poverty. This research dives into the subject of account energy technologies that promote the efficiency factors.

Modern energy technologies include grid electrification, micro-grids, mini-grids, off-grid or isolated units, improved cook stoves (ICS), solar home systems (SHS), solar lanterns, biogas digesters, biomass gasifiers, and micro-hydro dams (Sovacool, 2016). Although, the financial schemes for endorsing such technologies need to be thoroughly assessed. This research also includes appropriate business models that best fit the recommended technologies. Such models include a technology improvement model, a microfinance model, a project finance model, a cooperative model, a community fund model, a fee-for-service or ESCO model, a cross-subsidization model, and a hybrid model. (Sovacool, 2016).

3.13 Technologies for eradicating energy poverty

3.13.1 Grid electrification

The shortage of power/electricity from the national grid limits the effective hours of the day for enterprise proprietors and heads of households, as well as it inhibits the forms of enterprise to be obtained. Grid electrification, combined with an appropriate government alongside financial, monetary and technical training, could make a ramification of profits generating activities feasible. These include mechanical power which could be used for milling grains, illumination for factories, refrigeration for preserving products and heat for processing crops (Eric and Kartha 2000). Take the Philippines for instance, investments in electrification mostly explained on the grounds that households typically witness income gains of $81 to $150 per month when they become connected to the grid.

In Papua New Guinea, household surveys were conducted concerning electrification by the World Bank in 2004 which found that:

• In all cases, lighting is considered the most important and immediate benefit;

• Knowledge of the outside world and entertainment opportunities offered by it is viewed as of significant benefits, especially by men

• Lighting and TV are said to have contributed positively to the education of children through extended study hours and informal learning.

• Electrified homes have higher incomes than non-electrified homes by 27% compared to a staggering 100%.

• Increases in assets are accredited mainly to the acquisition of electricity-producing equipment and appliances (World Bank 2004).

Similarly, in Vanuatu, household surveys conducted in 2011 indicate that people living in houses without adequate or absence of electricity desperately are in need of it for necessary services such as lighting, water pumping, cold storage meats and food and casual services as in running TVs, and mobile phone charging (Fischer and Pigneri 2011). Improved supplies of electricity provision can also deliver power to schools and small hospitals as well as local industries such as sawmills, workshops, and other emerging forms of micro entrepreneurship.

3.13.2 Micro-grids and mini-grids

A 'mini-grid' refers to an isolated grouping of electricity generation, storage, distribution, and consumption within a restricted geographic space (Kaplan and Sissine 2009). Though mini-grids sometimes can be interconnected to national electricity networks they operate autonomously most of the time while being at lower loads and voltages.

Though definitions vary, according to the Lawrence Berkeley National Laboratory, a Nano grid is *"A small electrical domain connected to the grid of no greater than 100 kW and limited to a single building structure or primary load or a network of off-grid loads not exceeding 5 kW, both categories representing devices (such as DG, batteries, EVs [electric vehicles], and smart loads) capable of islanding and/or energy self-sufficiency through some level of intelligent DER management or controls."* Mini and micro-grids can be powered up by fossil fuels, such as fuel cells or diesel generators, or by renewable energy sources such as micro-hydro dams, biomass combustion, solar PV farms, or wind turbines. When placed together properly, such mini- and micro-grids can operate at a more cost-effective rate than centralized generation from a power grid. Mini-grids are particularly relevant for island states, both developed and developing Mini-grids are particularly relevant for island states, both developed and developing. According to the International Energy Agency, micro- and mini grids are expected to play an instrumental role in global electrification efforts over the next decade, especially in the Asia-Pacific. The IEA's 2011 numbers suggest that national grid extension is the most suitable option for all urban areas and for around 30 percent of rural areas, but it is not a cost-effective option in more remote rural areas, therefore, out of the total electrification requirement of 838 TWh, 56 per cent is expected to be provided through mini-grid and isolated off-grid technology.

3.13.3 Off-grid or isolated units

Rural and poor households throughout the world do not require to be supplied by the micro grids and mini-grids on their own, but, they also receive electricity through isolated micro-hydro dams, photovoltaic solar home systems and solar lanterns.

3.13.4 Improved cook stoves (ICS)

Currently, the poorest households in the under developing and developing world tend to use simple three-stone fires for cooking, agricultural waste, burning wood and manure with high moisture content. This is not an efficient method as it results in high amounts of C02 release alongside a weak release of energy. Many cook stoves in the developing world average 10 to 12 percent in terms of efficiency; this means that as much as 90 percent of the energy content of the wood or charcoal used in them is documented as waste energy or waste product as represented in Figure (2).

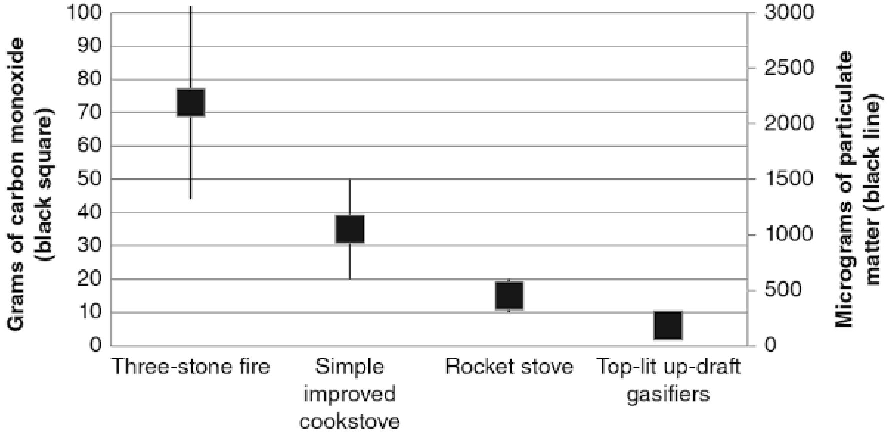


Figure 2 Emissions from four types of cook stoves (five-liter water boiling test) (Halff, 2014)

In most cases, existing cooking stoves can be drastically improved just by adding a chimney or more insulation around the stove to retain its inner heat; in other cases, older stoves may be replaced with new stoves with exponential increase in efficiency. Just as our other technologies, ICSs do have shortcomings. The most obvious one is that the term 'improved' as it always changes over time. An improved stove installed a couple of years ago is probably no longer an improvement over existing models, and suppliers have been known to call stoves 'improved' even when they show no improvement or added features over previous models.

One problem facing new ICSs is the speed of food cooking; some women have expressed concerns that the food is being cooked too quickly; because these people have grown accustomed to the fuel amounts and timing associated with older stoves and have hence becoming quickly frustrated when the new stove ruined their meals.

3.13.5 Solar home systems (SHS)

The typical solar home system consists of a solar photovoltaic module, a charge controller, a battery, and a lamp. Customers in off grid and rural areas usually choose from a variety of systems and technologies ranging from a 10 watt-peak (Wp) unit for the poorest clients to a 150 Wp unit for wealthier clients. Larger systems generally have the capacity to connect televisions, and other electric appliances. SHSs provide a really cost-efficient manner for rural communities round the world to amass energy services while not counting on expensive fossil fuels (such as kerosene) or capital-intensive efforts to increase national electricity grids. Costs of battery charging usually range from $6 to $15 depending on the type of battery, price of energy, and location it is obtained from. One assessment of SHSs in China, Indonesia, Philippines, Kenya, Sri Lanka, Brazil, and Mexico found that complete systems cost as little as $10 per installed Wp in China and as much as $100 per Wp in Brazil, a difference reflecting a multiple of 10. SHSs therefore represent a vital technology employed by multilateral financial institutions in their efforts to restrict energy poverty through off-grid electrification.

Figure 3 Photo (c) Diyana Dimitrova - Getty Images

3.13.6 *Solar lanterns*

Solar lanterns, commonly referred to as ‘Pico-PV systems’ or ‘solar LEDs’, are very small solar units, often independent solar flashlights, that can use light-emitting diodes (LEDs) or other such lighting devices. These small systems, usually less than 10 Wp with a voltage up to 12 V, have some advantages over SHSs because they are often less capital-intensive and more adaptable. When the costs of equipment are amortized over three years inclusive of fuel, energy, replacement lamps, and batteries, it has been estimated that the cheapest option by far is a 1 W solar LED (Mills 2005). In another words, solar lanterns sustain their cost in one month to two years compared to kerosene lamps and have lower costs of lifetime ownership than most of the other systems on the market.

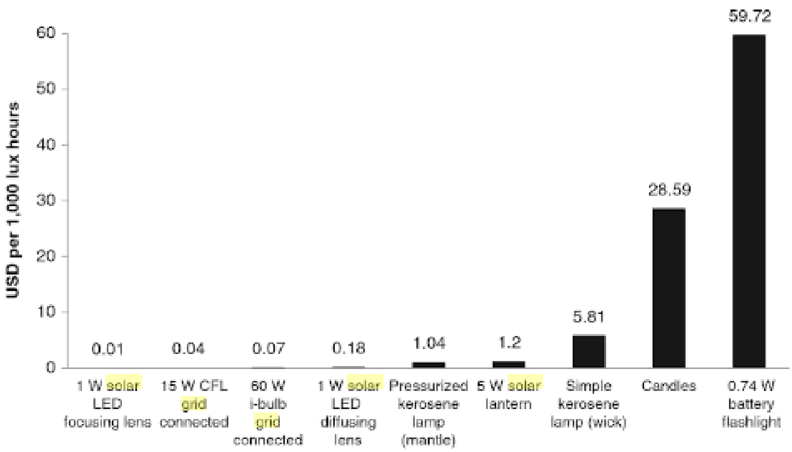


Figure 4 Cost of illumination services for various lighting sources (Halff, 2014)

Even countries with high electrification rates have an efficient market potential for solar lanterns, which can be used in remote areas where grid electricity is unaffordable, or for those who work far from electrical grids, such as farmers and fishers. The cost of illumination is a vital aspect for these people and the studies speak reports and compares the costs of different lighting sources thoroughly as represented in Figure (3).

3.13.7 Biogas digesters and biomass gasifiers

Biogas is a clean fuel produced through anaerobic digestion of animal, agricultural, and domestic wastes in the absence of oxygen. Biogas, a renewable energy source, is produced by anaerobic digestion with methanogen or typically anaerobic organisms, which digest material inside a closed system. Smaller-scales exist as well; two-to-three-cubic-meter biogas plants tend to be used in houses and communities, which are suitable for providing heat for cooking three meals a day for an average-sized family. Commercial-scale systems are a choice as well, with these larger units offering enough heat to meet the energy needs of neighborhoods, restaurants, and bakeries. These larger systems can supply enough gas for up to 1,000 families. By counting on biogas, these units minimize reliance on previous traditional forms of biomass, and charcoal and also protect communities from disease by improving sanitation of nature. Biogas systems literally have people using their own waste to meet their energy needs (Halff, 2014).

3.13.8 Micro-hydro dams

Unlike their larger counterparts which require reservoirs, micro-hydro dams on the other hand utilize low-voltage distribution systems (typically producing from 5 kW to 100 kW of electricity using the natural flow of water) and simpler designs that often have a natural river intake, desanding basin, masonry-lined canal, fore bay, penstock, powerhouse, short tailrace, and an electronic load controller. In addition to providing electricity, they provide mechanical energy for milling, grinding, husking, carpentry, spinning, and pump irrigation.

They are easier to operate clean power with, which is safer and cheaper than the diesel generator sets they often replace; moreover, locals can be trained to handle them without any technical background in engineering or maintenance. These units can also provide electricity in remote mountain areas unsuited for biogas or SHSs (because of consistent fog and cloud cover in mountainous regions). There are however, some drawbacks to using them, in order to function properly, micro-hydro systems need continuous dedicated maintenance. Due to their multi-functionality, a breakdown can become a ‘curse’ when communities are suddenly left without vital technology for lighting, agricultural production, education, and so on. Lastly, the energy produced by micro-hydro units is not always equitably distributed within communities and villages (Sovacool, 2016).

3.14 Finances and business models

The technologies used are only a pawn on the board of decision-making analysis; appropriate financing and business models are a critical requirement as well in order to promote the use of the technology models. After an extensive 4-year assessment of 1,156 energy access and development programs used throughout the Asia pacific region; the wide spread approaches documented were:

3.14.1 A technology improvement model

A technology improved model strives to impel the supply of a given technology by improving its performance, often through research subsidies, warranties, technical standards, or improved manufacturing techniques. This financing model is largely used for solar home systems.

3.14.2 A credit model/Microfinance model

This business model generally works when local dealers sell their products to rural clients on credit against collateral or against any personal guarantees. The model is commonly applied to SHS's, improved cook stoves, and biogas units. Usually, payment is done upon installment and it should be noted that this type of partnership has a high installation expense due to the transaction costs associated with earning credit and high to medium quality products.

The drawback of this model is that it excludes poor families without the ability to pay collateral, in other words, more suited for average – higher paid citizens.

3.14.3 A project finance model

Project finance models support small and medium scale projects with financial assistance and loans from commercial banks. Though, this model is only possible when the project is capable of producing enough money to cover all operating and debt expenses over the whole tenor of the debt. These projects are often on commercial scale and refer micro grids back to the national grid.

3.14.4 A cooperative model

"A cooperative is an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly owned and democratically-controlled enterprise" (Johanna Eichermüller, 2018).

A cooperative model works when households or investors band together to create their own private cooperative which may contribute to all or some of the operations of energy equipment. This model is usually used for larger systems such as commercial scale biogas units, solar micro grids or micro hydro dams.

3.14.5 A community fund model

The community fund model does not direct efforts at the technology itself but rather at building the capacity of public institutions and private companies, or at the energy end-users themselves. The model involves simple parts supervised by the people themselves as displayed in figure (4) respectively.

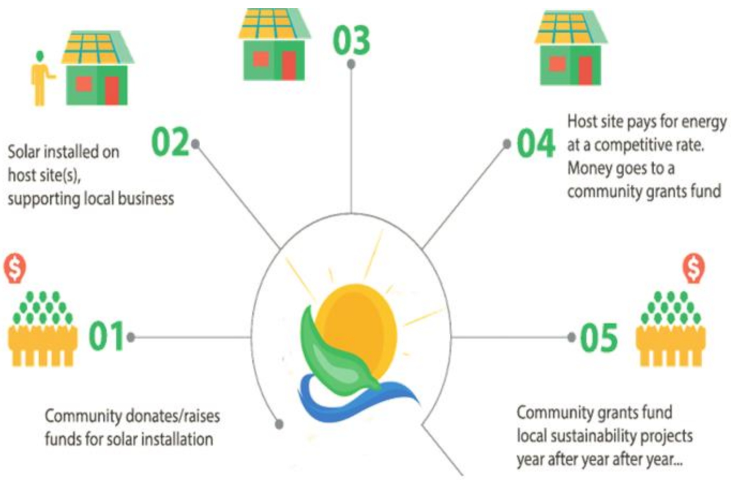


Figure 5 A community fund model

3.14.6 A fee for service or ESCO model

A fee for a service model is a model whereby energy technology is owned, sustained, and maintained by a supplying company; the ESCO provides an energy service to the customers while the customers pay the ESCO for the energy services in return. This method could be utilized for all types of renewable energy with varying degrees of quality and installation cost.

3.14.7 A cross subsidization model

A cross subsidization model operates when particular subclasses of electricity or energy customers (particularly wealthier homes), pay higher than normal energy rates to produce money that then offsets the cost of expanding access to energy for poorer customers.

3.14.8 A hybrid model

The hybrid model involves the combination of one or more of the above models.

3.15 Attempted Methodologies

The attempts to quantify energy poverty evolved over time and there still exists no generalized index that works in all cases as of this date.

Okushima (2016) extracted data about energy expenditure and income from about 50,000 households, which he then conducted a vulnerability index on which is basically a ratio of energy poor households, through a true/false statement, whether the fraction energy cost to income is greater or less than 0.1, to the total population. In 2017, Okushima enhanced his methodology through integrating several additional factors.

A drawback was discovered in the former due to the fact that some “non-energy poor” households were considered energy poor due to their large amounts of energy expenditure which led them to spend more than 10% of their income. This was in term corrected through dividing income data into deciles with the focus on the lowest deciles (up to the third-fourth decile). Moreover, energy efficiency was integrated into the index where surveys were done on the 50,000 households to check whether their houses were insulated; this was also quantified through a true/false statement where 1 is allocated for the true function and 0 otherwise.

It was concluded that households that check all the below conditions can be considered energy poor (Okushima, 2017):

1. Households who consume energy for more than 10% of their income,
2. Households that belong to the lowest 3-4 income deciles,
3. Households' houses that are poorly insulated.

Other methodologies also are used through comparing an ideal population with the population under study. Papada (2019) inspected the vulnerability of Greek mountainous areas apropos of the targeted population.

For multi-stated countries, where further studies shall be attained, a comprehensive vulnerability index was proposed which was comprised of several indices. Such type of methodologies was obtained by Wang et al. (2015) in China where the authors initiated a comprehensive index that is the sum of four indices:

- Energy service availability (ESA) focuses on the consumption versus energy supplied.
- Energy consumption cleanliness (ECC) is concerned about the percentage of carbon contained in the supplied energy which highlights the environmental factor.
- Energy management completeness (EMC) factor which basically symbolizes enhancement capacities on energy management.

- Household energy affordability and energy efficiency (EAE) factors where household expenses, facilities and the percentage of pollution emitted by the residential sector is taken into consideration. (Wang, 2015)

It should be noted that indices are only obtained to approximate the extent of energy poverty in a given country. However, it is only a step forward towards the aim of the study. The second step would be considering appropriate energy technologies that might alleviate energy poverty accompanied by proper financing and business models. Although, estimating the global extent of energy poverty with precise accuracy isn't possible, that doesn't change the fact that it is a serious problem. In the light of this problem, we will introduce technologies and business models for addressing energy poverty.

CHAPTER 4

OVERVIEW OF THE ENERGY STATUS IN LEBANON

Lebanon has been facing various issues in the energy sector for various reasons. The proposal tends to clarify the concept of energy poverty so that Lebanon's case would be analyzed. The research provides a little overview on Lebanon's current case.

Over the last couple of decades, the performance of the electricity sector in Lebanon has been increasingly declining in spite of a convenient physical access to electricity. Electrification levels are sufficient with around 99% of universal network coverage (World Bank, 2009), yet supply deficit persists as a critical issue along with technical and non-technical losses. New power generation plants haven't been installed since 1990. Power generation plants were installed back in the 1970s and 1980s. Then in 1990, two new generation power plants were installed which were designed to function on natural gas which was replaced by highly-priced gasoil.

The international oil price spike in 2008 reflected the government's budget susceptibility and the censorious amelioration of the energy sector in Lebanon. Despite the sharp decline in oil prices by the end the same year, this volatility further reflected the fiscal impact that remained under pressure and at risk.

The Director of the Machrek Department at the World Bank, Ferid Belhaj, mentioned that 65% of populations' electricity expenditure relies on expensive private generators (World bank, 2014). Education, health and others would be facilitated had the Lebanese accessed more consistent and inexpensive electricity. The World Bank Lead Specialist, Husam Beides, added that 15% of the country's gross domestic product corresponds to the public expenses on the energy sector (World Bank,2014).

Electricity rationing is uneven in each region. Many regions face daily blackouts for 12-13 hours on average. Whilst administrative, Beirut experiences only 3 hours of daily outages. The Ministry of Energy claimed that they aim to provide 24-hour reliable electricity by 2015 which was suspended for political and commercial causes. In spite of the clear political factor characterizing this inequity, it could be refuted by Beirut's higher welfare ranks. Lebanese citizens were reluctant to rely on expensive back-up power provided by private generators. This has highlighted Lebanon's energy poverty dimension. A social economic and development group (World Bank, 2009) evaluated energy poverty in Lebanon by regions the results were:

- Beirut: less than 1% which is below the intense poverty line
- Beqaa valley: 10.8%
- South region: 11.6%
- North region: 17.8%

This reflects that the benefits from rationed electricity need to prioritize the poorest energy areas. Moving to heating services, traditional stoves have been used for heating houses in Lebanese rural areas. They consist of a plain combustion room directly linked to the chimney with only one source of air opening. Updated indoor stoves added oil tanks as a source of fuel to produce heat, yet the intense diesel smell is easily inhaled. As long as the households are burning wood or diesel, the heat will dissipate inefficiently with up to 55% underperformance rates. The most appealing privilege of stoves is their cheap, affordable price.

The raw data that will be used in this assessment, which relies on the data collected from Dagher and Harajli (2015), and Harajli and Challak, which resulted in the fact that Lebanon corresponds to the "very poor" category. According to Dagher and

Harajli (2015), half of the respondents don't own air-conditioning systems or own just one that is rarely used. They also added that the electric heaters aren't used or hardly used by 59% of the respondents.

If we apply the UK definition which states in section 3.1. Around 50% of Lebanon's population expend more than 10% of their incomes on the energy sector for electrical purposes. Consequently, on average, half of Lebanese residents could be denoted as "fuel poor" as the price of an oil barrel had exceeded 100 US Dollars (Dagher and Harajli, 2015).

4.1. Crises in Lebanon

The crises that happened in 2020 are not included in this research study but the following data is worth mentioning as it is relevant and has direct and indirect effects on the Lebanese energy poverty.

The IMF initiated its work through assessing its national electricity company, including the fluctuations in fuel oil prices and the variations in the exchange rate. The unfortunate latest events in Lebanon, the purchasing ability of Lebanese people has significantly decreased due to the devaluation of the Lebanese Lira. This devaluation has been fluctuating starting from the initial fixed rate of the 1 US dollar equivalent to LBP 1,515 to LBP 4,000 in the central-bank and bank sectors; and fluctuating up to LBP 15,000 in the black market (Alamuddin, B., & Hatoum, L., 2020).

The IMF refused to link the rise in tariffs on electricity in parallel with the increase of power generation that the Lebanese government adopted. It is worth noting that excluding electricity subsidiaries along with increasing the tariffs are the most essential potential expenditure saving. But, the side effect of this will increase the power charges for the Lebanese citizens,which the majority of are affected already by the economic crises as a result of Lebanese Pound devaluation and the COVID- 19 pandemic.

The total power sector's bill is over $2 billion yearly, approximately 4.5 % of the country's GDP (Alamuddin, B., & Hatoum, L., 2020).

Additionally, the above mentioned crises were severely exacerbated by the unexpected catastrophe in the form of the Beirut explosion that occurred on August the 4th. In summary, Lebanon has encountered a successive set of disasters, on the economic level, in the form of the devaluation of Lebanese currency, on an environmental level and national security level, in the form of the massive explosion that occurred on its shores, on a demographic level as well, in the form of the huge influx of refugees, and on a health level, in the form of the COVID-19 pandemic. The Lebanese nation is in real tragedy to an extent that even providing food for its army became quite unmanageable. Each crisis has affected and had an influence on worsening the other crisis that already happened prior and post each other in different ways. For instance, the explosion which happened after multiple crises had already occurred, worsened the situation on all other levels, especially one of Lebanon's basic mishaps: the lack of stable power generation (Perez, A., 2020).

These crises triggered protests on the streets, people were taking to the streets to fight for their rights. According to the World Bank, power needs are the core trigger of fiscal crisis, especially in countries like Lebanon which has been encountering continuous blackouts, up to 20 hours per day for decades, leading protesters to attempt to storm the Ministry of Energy but their attempt was then aborted. (Perez, A., 2020).

As mentioned earlier, the Lebanese government subsidized power, mainly fuel oil by $ 2 billion dollars annually. These subsidiaries are responsible for 40% of Lebanon's debt, as mentioned by the IMF. Although the Lebanese lira versus dollar crisis was already in full motion, the power debt had to be paid. This payment is another level of burden on the Lebanese citizens due to inflation of lira and scarcity of dollars. Nowadays, modern life directly depends on energy generation. This power crisis is affecting citizens on all levels of life; this will be a consistent crisis that will drive the nation to the edge in case politicians do not manifest a sustainable and final solution to the power problem (Perez, A., 2020).

In the past, the majority of Lebanese citizens lied comfortably in the middle class. These crises have eliminated the middle class and left two distant classes of citizens, excessively rich and severely poor.

CHAPTER 5

SCOPE OF WORK

This research undergoes the below mentioned objectives:

1) Assess the energy consumption in Lebanon
2) Approximate incomes in Lebanon and accordingly bound the energy expenditure extent
3) Calculating fuel poverty based on UK definition in Lebanon
4) Seek for other major factors that impact Energy poverty
5) Quantify the impact of qualitative factors
6) Developing dimensions that assess Energy poverty in Lebanon
7) Quantifying Energy Poverty in Lebanon

CHAPTER 6

METHODOLOGY

The methodology of this paper is divided into two parts. The first one will be checking whether Lebanon is "fuel poor" based on the UK definition explained in section 3.4. The second part will be incorporating the first as a dimension in addition to another set of dimensions in an attempt to form a model defining and evaluating how "energy poor" Lebanon really is. In other words, the first method will be measuring fuel poverty in Lebanon whereas the other will be measuring energy poverty in Lebanon. The methodology of this paper is based on a population with n households such that i=1…. n with dimension, d, greater or equal to 2 (j=1…., d). Therefore, a matrix of attainments in a multidimensional venue will be formed ($A=[a_{ij}]_{n*d}$, a_{ij} is the attainment of households "i" in dimension "j"). A threshold for each aspect will be set and poverty will be considered if this approach underperforms the fixed threshold. Having undergone a shortfall in each attribute, a household will be considered energy poor in its dimension.

This research includes ten dimensions. The research study determines whether the respondent is energy poor had he/she is energy poor in at least three dimensions ($_{10}C_3$).

The price of oil will also be fixed and will not be considered as a variable in this research study.

6.1 Data

This proposal tackles energy poverty in Lebanon using the microdata of household incomes expenditure with a sample of the population residing in Lebanon in 2016. The data was developed anonymously based on the United Nations Development Program (UNDP). The second-round data is the face-to-face interview with 600 adult respondents done by Dagher and Harajli (2015). The inquiry form is composed of a general background on the electricity sector in Lebanon. Then, it is divided into willingness to pay questions and demographic questions.

6.2 Preparing data for analysis

Several data sets were taken in order to mold the methodology of this study:

1) Income: In order to compute the FP method based on UK definition, income is an essential variable. Also, it is necessary to collect income information since the extent of energy consumption is bounded by the purchasing power of the household i.e., his/her income.

2) Energy expenditure: Like income, energy expenditure is the other important variable to evaluate fuel poverty based on the UK definition. The survey includes the 2 data sets:

- average and per month payment on EDL electricity
- average and per month payment on back-up generator.

The sum of the two data sets formed the energy expenditure variable.

After computing the ratio of the first two variables in method 1 as FP, fuel poverty is considered as the first dimension in method 2. This dimension is given the weight of 1 when assessing energy poverty.

3) Blackout-hours: Lebanese citizens face daily blackouts; some face 3 hours of cutout a day others face more than 12 hours of it. In this study, the blackout hour count plays a vital role in assessing energy poverty. A threshold of 3 hours/day is taken in this dimension. By this means, any individual facing more than 3 hours/day is considered energy poor. This variable is given the weight 1 when calculating energy poverty.

4) Back-up electricity and the intensity of back-up power: Trivially, a back-up solution is mandatory when outages are consistent like in the case of Lebanon. The type of back-up or even the fact if individuals have the option to have a back-up is important in the methodology of this study. Considering a back-up power to cover the daily blackouts is an energy poor dimension. The fact that they have to look for back-up gives this image. In this dimension, only individuals with private motors/ generators are not considered energy poor. The study considered the mentioned option not a part of the energy poor for the fact that the individual has the ability to own a private generator. Otherwise, any other option an individual considers will be classified as an energy poor individual. As for intensity of back-up power, individuals register up to 5 amperes are considered energy poor. In this dimension, the paper disregarded the type of fuel used in the back-up generator. This dimension is also given the weight of 0.5 on each variable when assessing energy poverty.

5) AC-usage: Lebanon enjoys the Mediterranean climate where four seasons transpire along the year. In summer, the weather becomes relatively hot and cooling appliances are required to survive the heat comfortably. The option of using an air conditioning system plays a role in evaluating the household

whether they are energy poor or not. The individuals that aren’t able to use air conditioners will be considered as energy poor. This variable is given the weight 1 when calculating energy poverty.

6) Electric Heater Usage: As in the case of summer, when winter arrives heating appliances are mandatory for insulation and to survive the low freezing temperatures. Owning and having the opportunity to use electric heaters also help assess where the household stands. The individuals that aren’t able to use electric heaters will be considered as energy poor. This variable is given the weight 1 when calculating energy poverty.

Both variables are assessed based on seasonal changes.

7) Type of Heating: One of the reasons energy poverty is being recognized as a distinctive issue would be its tie-in to the environment. The type of fuel used to power the energy requirements of humans could be pollutive. This is where the difference between energy poverty and fuel poverty is shed light upon, even if pollutive fuels were affordable, it still affects the environment, hence, energy poverty supervenes. Individuals using electric heaters, AC Split Units/ Central ACs used for heating, electric heating system, electric chimney and radiator water heater are not considered energy poor. The research assessed this dimension based on the percentage emissions of pollutants such as carbon dioxide… This dimension is given the weight of 1.

8) Employment: This variable includes employed, current unemployed, housewife, retired and student individuals. It is urgent for an individual to be employed in order to afford his/her power utilities. This dimension is given the weight of 1.

9) Household Composition and Size: The size of the household is considered as a vital dimension due to the negative correlation with energy expenditure. As the size of the household increases, the energy consumption per capita declines. This is attributable to the economies of scale of households. This plurality is a consumption advantage since they are sharing specific utilities (Schroder et al.,2015). The study considered the 3 as the threshold of the household composition and size. Any household greater than 3 is of consumption advantage. Households whose family members are composed of 3 or less are considered energy poor in this dimension. This variable is given the weight of 0.5.

Also, the number of domestic workers in the household is an important variable to consider. This variable is negatively correlated to fuel poverty, i.e., to energy poverty too. Having at least one domestic worker gives the households advantage to negate energy poverty. This variable is given the weight of 0.5.

10) Formal Education: The education of the individuals is quite important due to its positive relation with income as mentioned in section 3.10. Also, owning higher degrees helps the individual understand the importance of his role in society. By this, the willingness to pay on an individual level would increase in order to help alleviate energy poverty. Individuals who didn’t acquire university diplomas are considered energy poor in this dimension. This dimension is given the weight of 1.

6.3 Descriptive Analysis of the data

The below graph shows the period of outages the respondent’s encounter in a day. The results show that more than 80% of the respondents face more than 3 hours of daily blackouts.

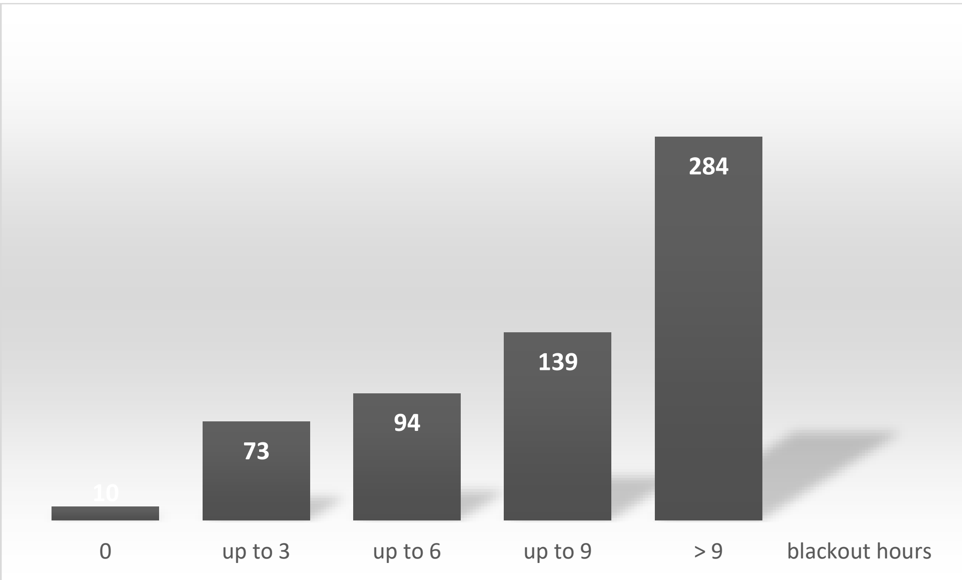


Figure 6 Blackout hours per day. Source: Own illustration of the data

In this case, the need for back-up power is inevitable. Not all citizens are able to afford a private back-up power or even register one. Less than 10% own a private generator and the rest are divided among the other types of back-up power. The most selected back-up type is renting diesel.

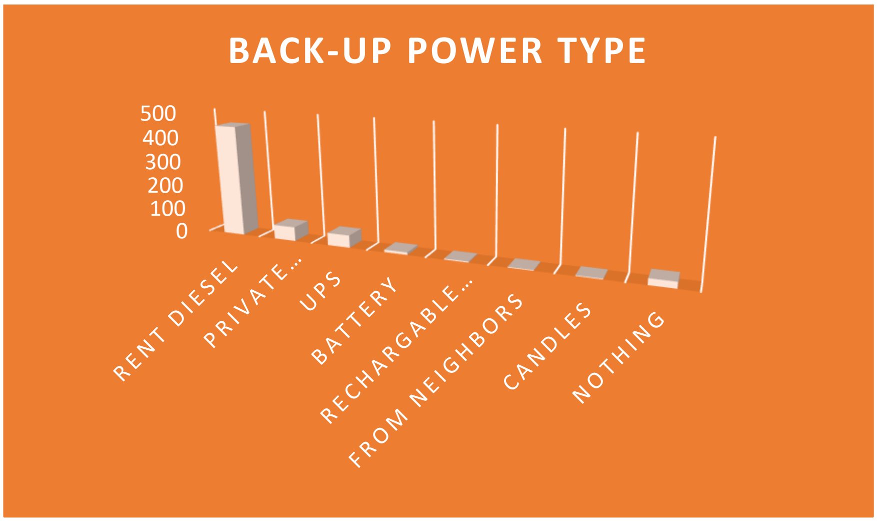


Figure 7 Type of back-up power. Source: Own illustration of the data

Although renting diesel is the most preferred option yet this back-up type falls in the dimensions of the other variable, “the intensity of back-up power”. Almost 70% of the respondents register up to 5 A. (This includes the respondents not able to register at all). Figure (6) demonstrates the different types of backup powers available for common purchase.

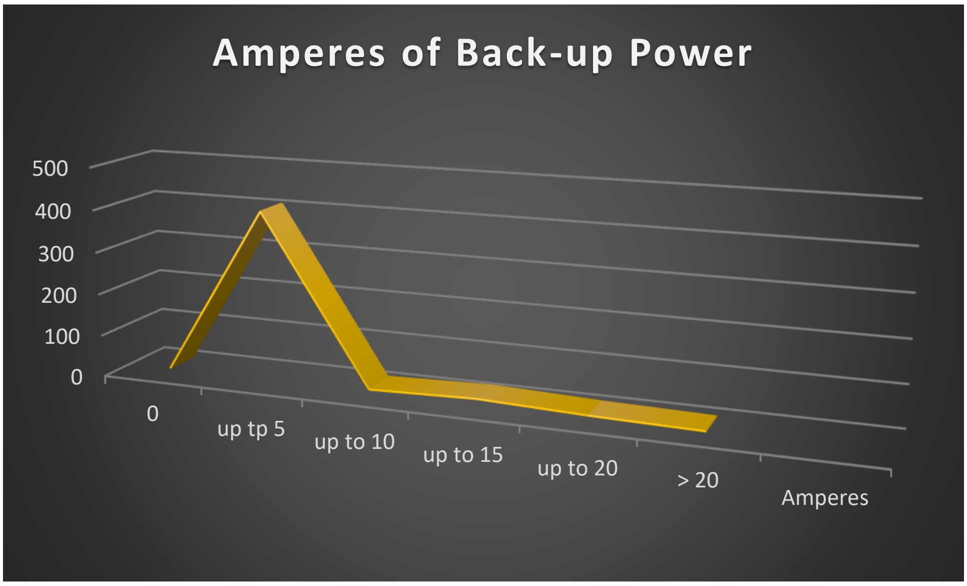


Figure 8 Intensity of back-up power. Source: Own illustration of the data

Moving to the dimensions where the option of heating or cooling is interrogated. About 40% of the respondents aren't able to use air-conditioning systems in the summer and 45% were incapable of using electric heaters in winter. The figures below display and compares the percentages of people who are able to use these appliances and the people who cannot acquire them to get a clearer picture of what we're dealing with.

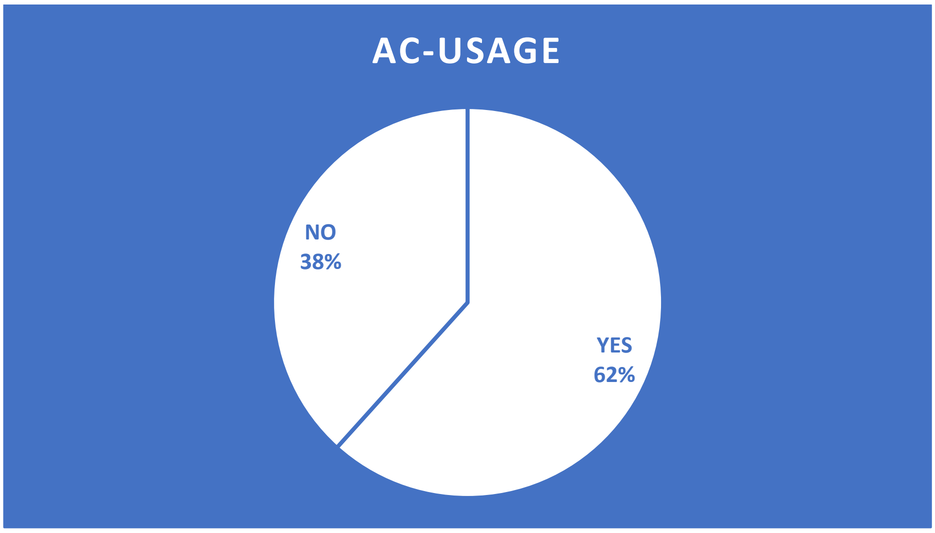


Figure 9 Percentage of air-conditioning use. Source: Own illustration of the data

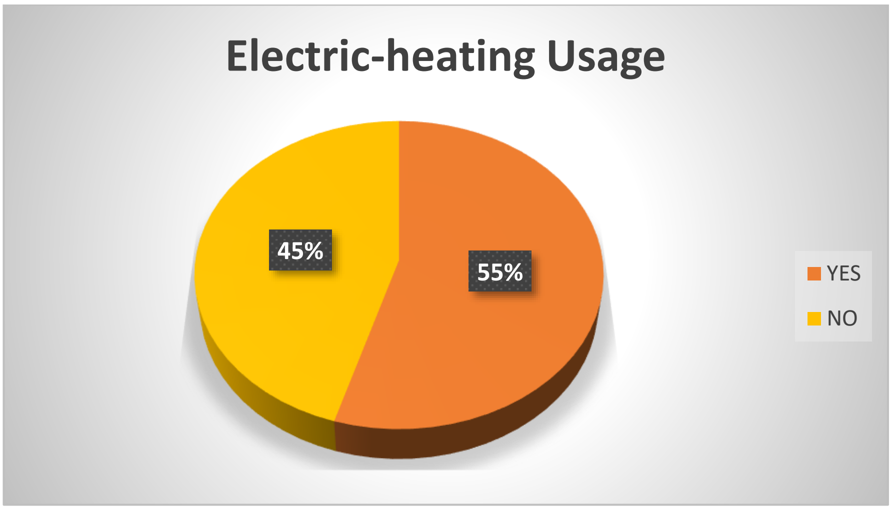


Figure 10 Percentage of using electric heaters. Source: Own illustration of the data

As mentioned above in the previous section, the importance of cleanliness of the environment is hard to maintain while there are still people who use diesel or firewood in their fireplaces to heat up their houses (app. 3 %). Other types of fuel that are harmful to the environment range from kerosene, biomass, to charcoal and many more.

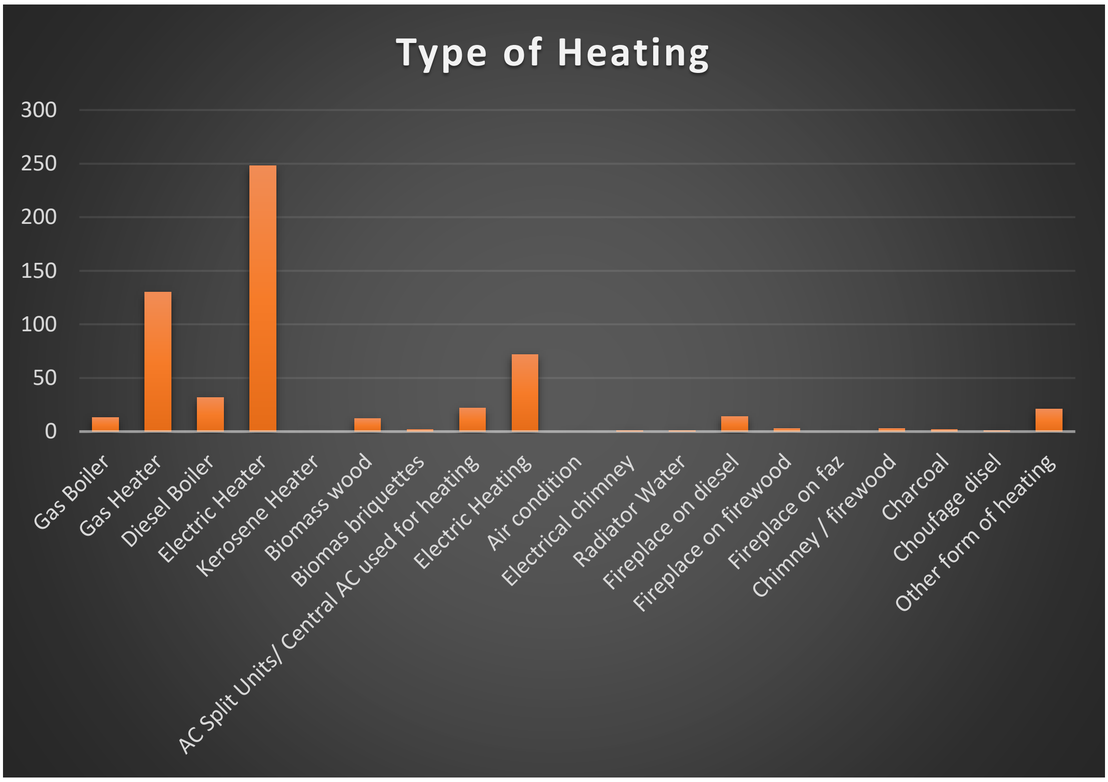


Figure 11 Type of heating. Source: Own illustration of the data

The choice of environmentally friendly fuels falls on the back of well-educated citizens on one hand but, on the other hand, affording them had them required to be citizens that attain higher incomes. It is well-known in society that people who are well-educated obtain higher income. Only 28 out of 600 of the respondents own a masters or doctorate degree. Also, merely 22% of the respondents own a bachelor.

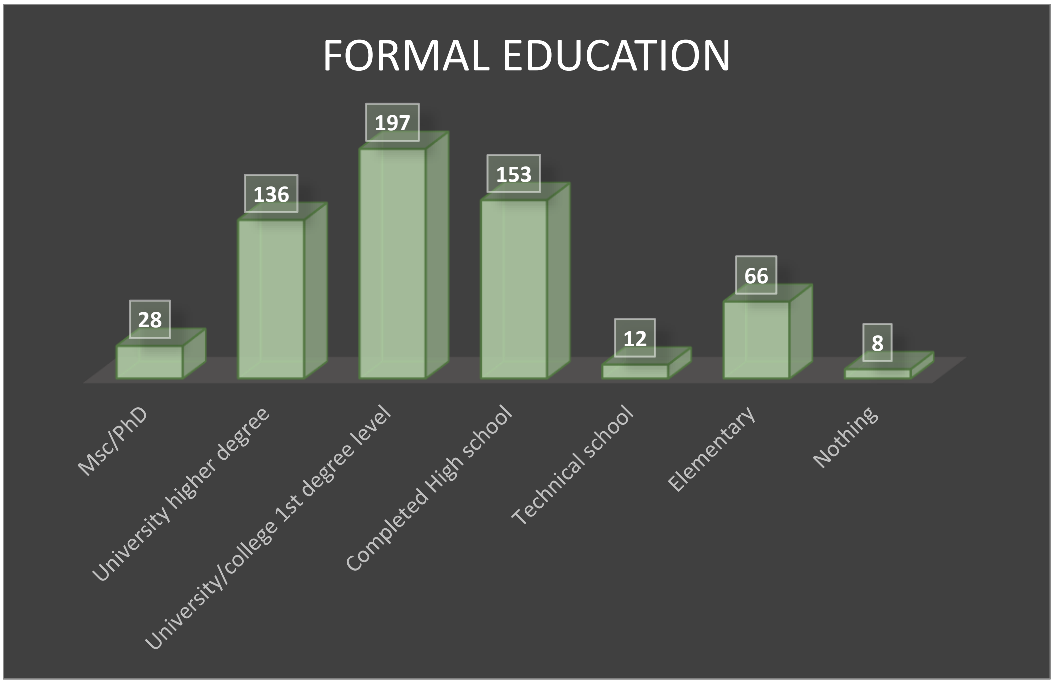


Figure 12 Formal education of the respondents. Source: Own illustration of the data

The employment variable is the back of the affordability angle in this study. Trivially, the source of income is work. App. 70% of the respondents are employees.

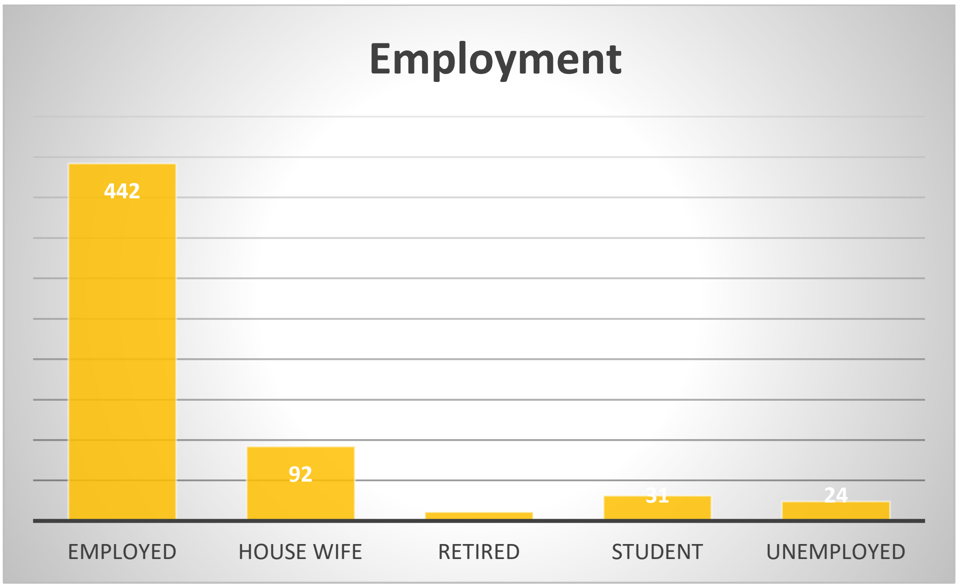


Figure 13 Type of employment of the respondents. Source: Own illustration of the data

The presence of domestic workers in a household gives an impression that the household is not energy poor. The variable of domestic workers at a household was chosen to evaluate energy poverty. This variable is an indicator for the affordability angle in this study, for being able to acquire a domestic worker requires certain income. More than two thirds of the respondents don't have domestic workers at their houses.

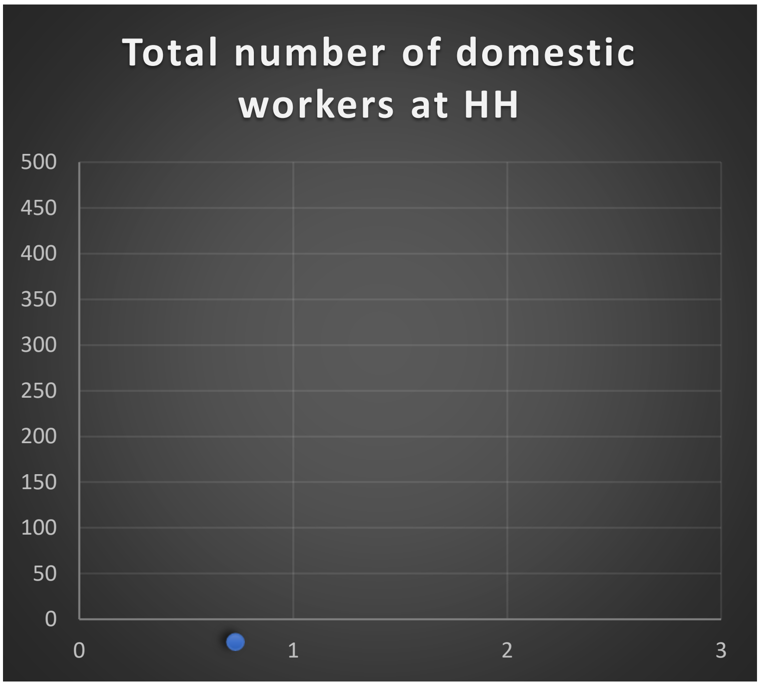


Figure 14 Number of domestic workers in a household. Source: Own illustration of the data

The size of the households is of importance due to the hoarded power. Most of the respondents consist of more than 3 family members which gives them the advantage due to the economies of scale.

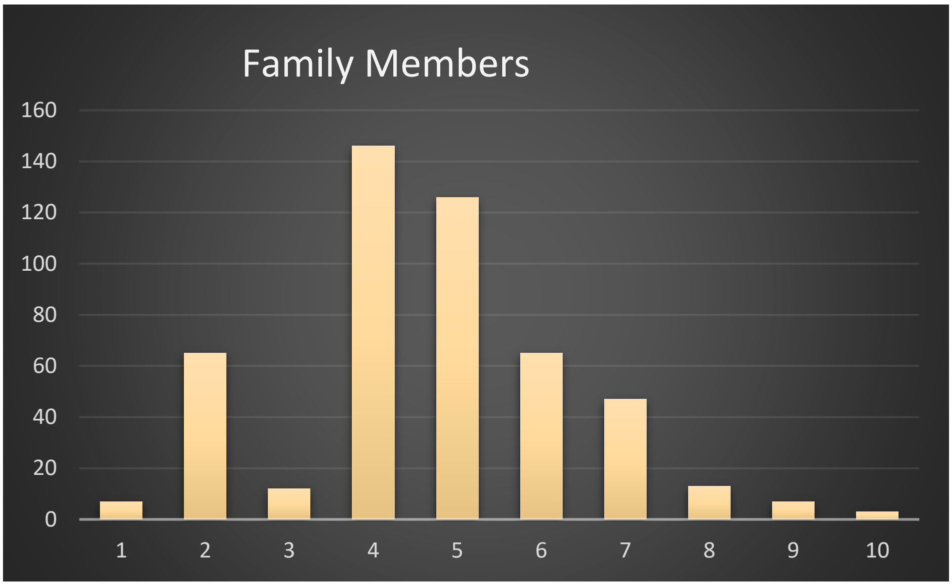


Figure 15 Number of family members. Source: Own illustration of the data

6.4 Method based on UK definition

The mentioned data set includes the income, monthly average EDL utility bill and monthly average backup generator bill. The income ranges were divided into deciles and the sum of the EDL utility bill and backup generator were taken. The ratio of income to the total energy bills were noted as energy poverty (EP).

Table 2 Income ranges used. Source: Own illustration of the data

Income Frequency	Percent	Cumulative
1001$---1500$	147	24.50
1501$---2000$	107	17.83
2001$---2500$	71	11.83
2501$---3000$	16	2.67

3001$---3500$	17	2.83
3501$---4000$	12	2.00
4001$---4500$	1	0.17
4501$---5000$	2	0.33
501$---1000$	193	32.17
< 500$	21	3.50
> 5001$	5	0.83
No Answer	8	1.33
Total	600	100.00

As stated before, the UK defined fuel poverty as the households spending more than 10% of their income on energy utilities. In this section, x was generated which was given the value 0 if EP is less than 0.1 and 1 otherwise.

6.5 Results and discussion of method 1

The results show that 285 out of 600 respondents spend more than 10% of their income on electricity bills. On a bigger scale, it can be anticipated that approximately half of Lebanese households in different areas are “fuel poor”.

Table 3 Fuel poverty results. Source: Own results from Stata/MP 15

Table (3)	Frequency	Percent	Cumulative
0	315	52.50	52.50
1	285	47.50	100.00
Total	600	100.00	

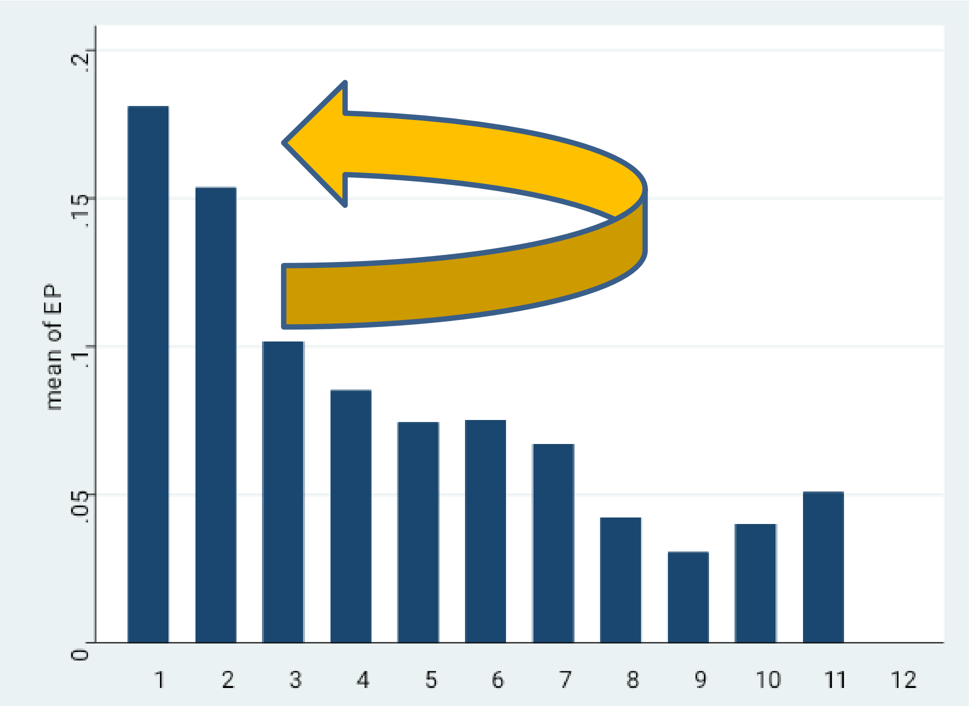


Figure 16 Graph: avg EP as a function of income range. Source: Own results from Stata/MP 15

As mentioned in section 3.15, there might be an error in this method where a household could be overusing energy by choice. Okushima enhanced it by focusing on the lowest 3 deciles. The following table shows that 237 out of 361 of the households earning lowest 3 incomes ranges are “fuel poor”. On a bigger scale, it can be anticipated that approximately 66% of Lebanese belonging to the lowest income ranges are “fuel poor”.

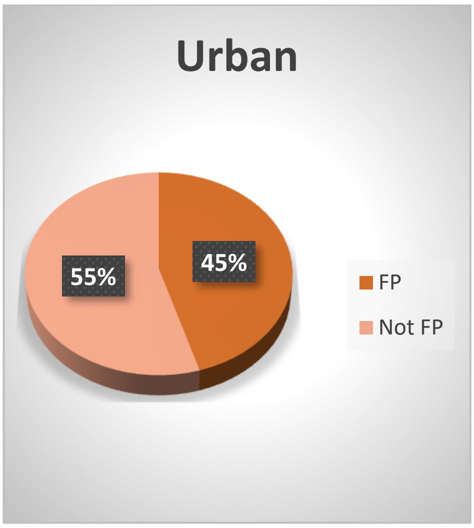
Table 4 Table showing the results of energy poverty. Source: Own illustration of the data

Table (4)	Frequency	Percent	Cumulative
0	124	34.35	34.35
1	237	65.65	100.00
Total	361	100.00	

In section 3.15, a study mentioned that energy poverty dominates in areas located in the mountains and near them i.e. rural areas. The fuel poverty study was analyzed based on the individual’s area.

Figure 17 Fuel poverty in urban areas

Source: Own illustration of the data



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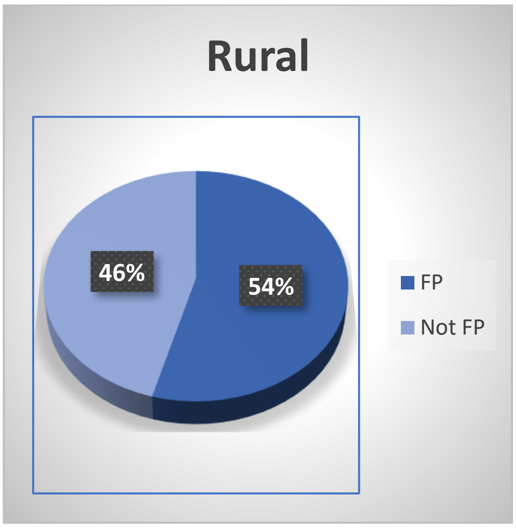

Figure 18 Fuel Poverty in rural areas.

Source: Own illustration of the data

In urban areas, more than half the respondents were not considered fuel poor (55%). In rural areas, more than half the respondents are fuel poor (54%). This indicates that there is a significant number of fuel poor citizens in rural areas. The above results also show that fuel poverty in rural areas is more prevalent in comparison to urban areas. This validates the methodology in section 3.15, the Greek study which compared the mountain areas to the urban areas. The latter was the advantaged population understudy. Higher-income populations reside in urban areas. In the formula used for fuel poverty, higher income obviously results in less fuel poverty.

An attempt to assess fuel poverty based on the different "Mohafazat" of Lebanon was also undertaken.

Table 5 Table of FP by Mouhafaza. Source: Own illustration of the data

Mohafazat	**FP**	**Not FP**	**Total**	**Percentage FP**
North	70	50	120	58 %
Mount Lebanon	107	133	240	45 %
Beirut	21	44	65	32 %
Nabatieh	22	13	35	63 %
South	40	25	65	62 %
Beqaa	22	53	75	29 %

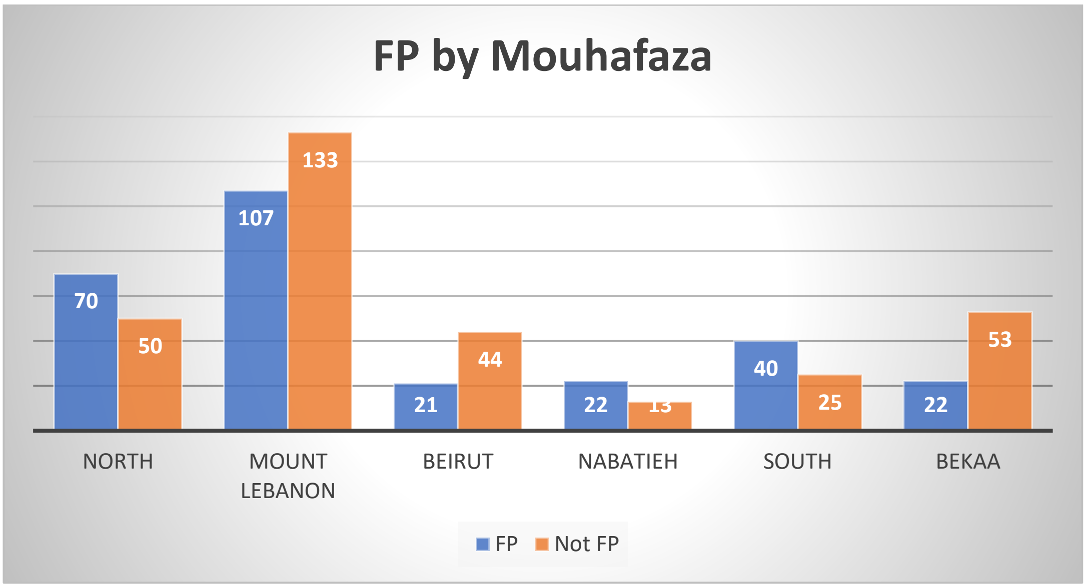

Figure 19 Fuel poverty based on different Mohafazat in Lebanon. Source: Own illustration of the data

The research compared fuel poor populations in each mohafaza, it was concluded that fuel poor populations were higher in the North, Bekaa, South, Nabatieh. The above graph indicates that fuel poverty is spread around the extremities of Lebanon whereas it decreases in the center of the country.

6.6 Results and discussions of method 2:

The study mentioned in section 6.2 displays the conditions and thresholds of each dimension to assess whether a Lebanese citizen is energy poor.

The results of the first dimension are thoroughly discussed in the previous section. As for the second one, the results of the variable blackouts per hour shows that 86% of the respondents are energy poor in this dimension. This reveals that most Lebanese citizens encounter daily blackouts. In other words, facing no outages is a rarity in Lebanon.

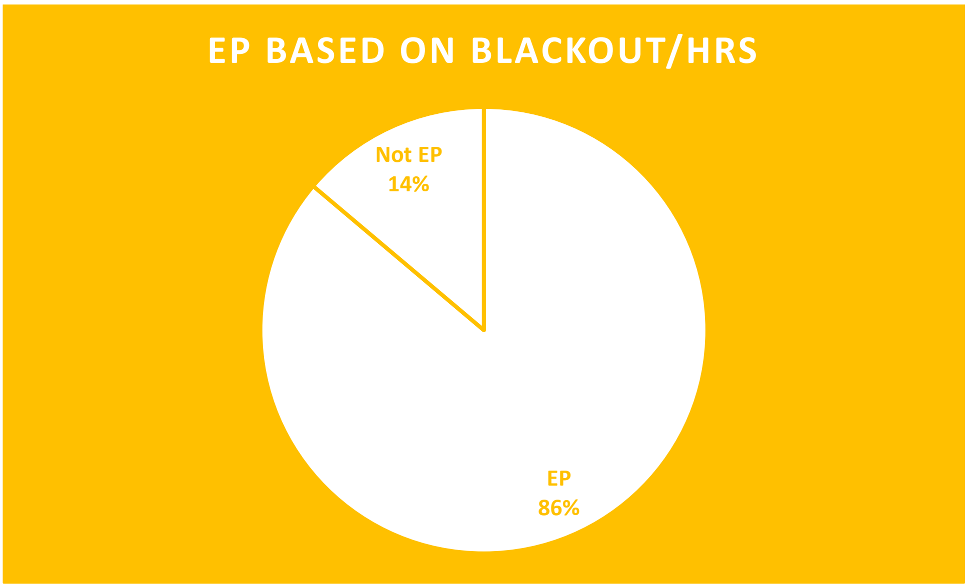

Figure 20 Pie chart showing the results of EP in dimension three. Source: Own illustration of the data

In contrast to the following dimension, where owning a back-up generator is very common in Lebanon; 543 out of 600 rely on back-up power, and approximately 90% of Lebanese citizens depend on the existence of any back-up power to power their daily electrical utilities. However, the intensity of this alternative remains the main issue. More than two thirds of the respondents register a maximum intensity of 5 amperes, including 0 A. This means that almost 70% of Lebanese citizens are bound to limited intensity. Energy poverty in this dimension is assessed to be of approximately 80% (90.5%*0.5+69.8%*0.5).

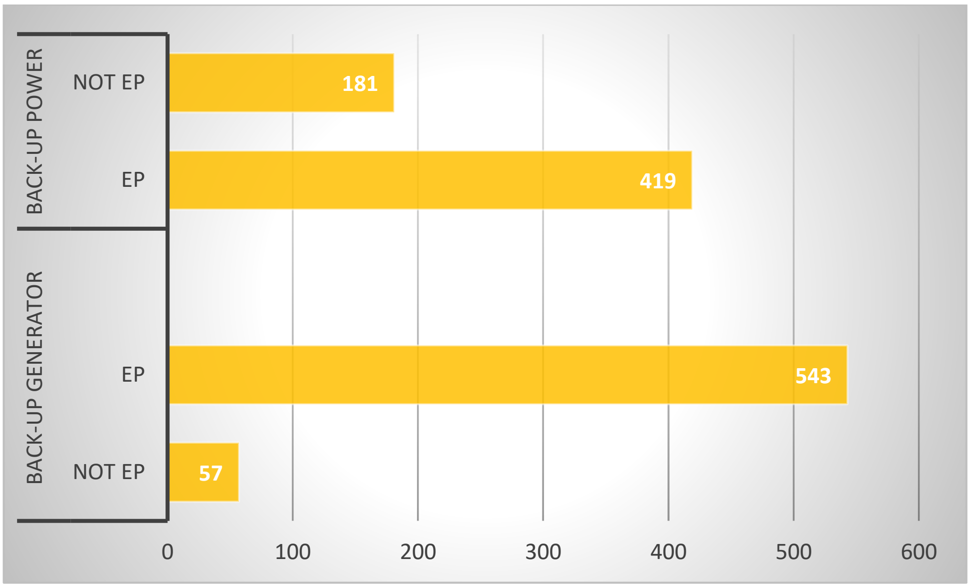

Figure 21 Graph showing the results of EP in dimension four. Source: Own illustration of the data

The next couple dimensions are energy services dimensions. For the cooling service dimension, almost 40% of the respondents do not use air conditioning systems. This includes respondents who don't own an AC. In this dimension, it shows that approximately 40 % of Lebanese citizens are energy poor. In such an advanced era, not being able to choose to own an AC is an indicator of energy poverty. As for the heating service dimension, 328 out of 600 do not use electric heaters which means that approximately 55 % of Lebanese citizens don't use electric heaters i.e., 55% are energy poor in this dimension. This includes persons who do not own electric heaters. Heating services are also considered a major indicator to energy poverty. The inability to enjoy such services gives an idea on the country's status quo.

Table 6 Table showing the results of EP in dimension five. Source: Own illustration of the data

EP	Not EP
230	370

Table 7 Table showing the results of EP in dimension six. Source: Own illustration of the data

EP	Not EP
272	328

The seventh dimension is affiliated to the environment, since variables affecting the environment are considered key indicators to energy poverty. In this study, the type of heating is the variable used to cover environmental importance. In the previous section, the research categorized a set of heating types into categories of energy and non-energy poor. The results show that 43% of respondents use pollutant producing fuels for heating. On a larger scale, significant amounts of people still use befouled fuels in the environment.

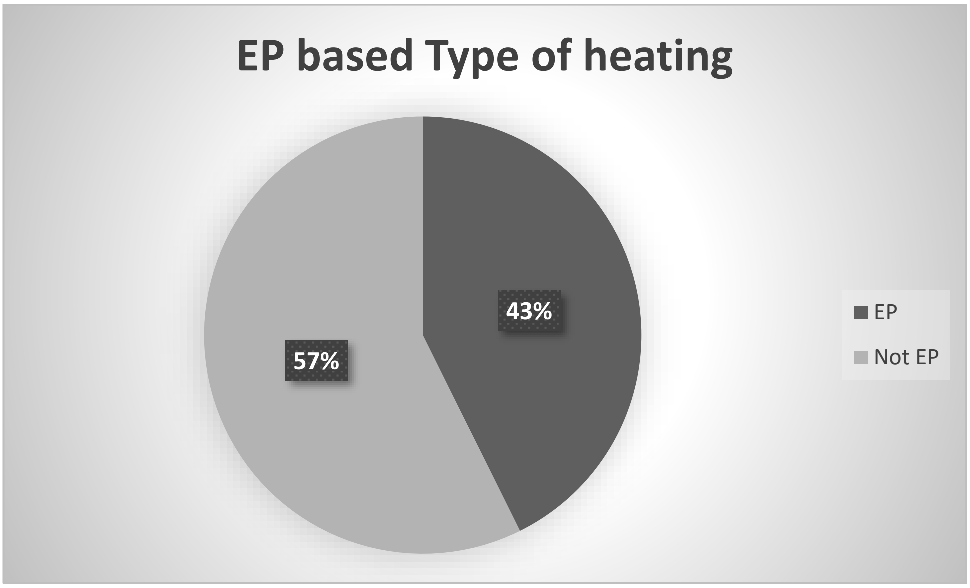

Figure 22 Pie chart showing the results of EP in dimension seven. Source: Own illustration of the data

Moving on to the employment variable, where its necessity was mentioned several times in the study, 74% of the respondents are employed, even though unemployment is a familiar phenomenon in Lebanon. This implies its negative effect on energy poverty due to its negative correlation with income (as UE increases, Y decreases).

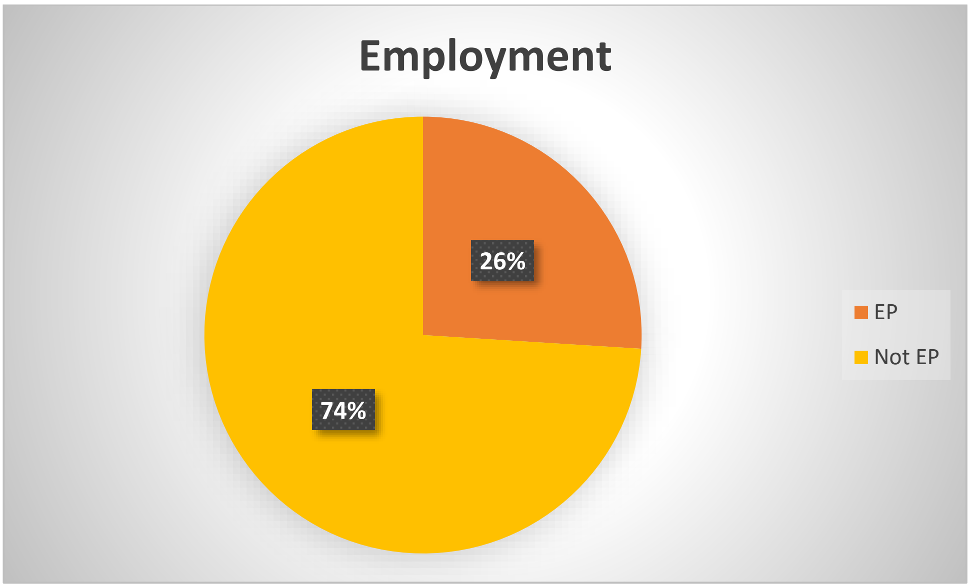

Figure 23 Pie chart showing the results of EP in dimension eight. Source: Own illustration of the data

The ninth dimension is divided into two parts, household composition and the availability of a domestic worker in a household. The results show that 14% are energy poor, for they consist of 3 or less family members. This means that 14% of Lebanese citizens do not enjoy economies of scale. Also, around 79% of the respondents are energy poor, for they do not have at least one domestic worker on employment. This shows that 42% are energy poor in this dimension (14%*0.5+70%*0.5).

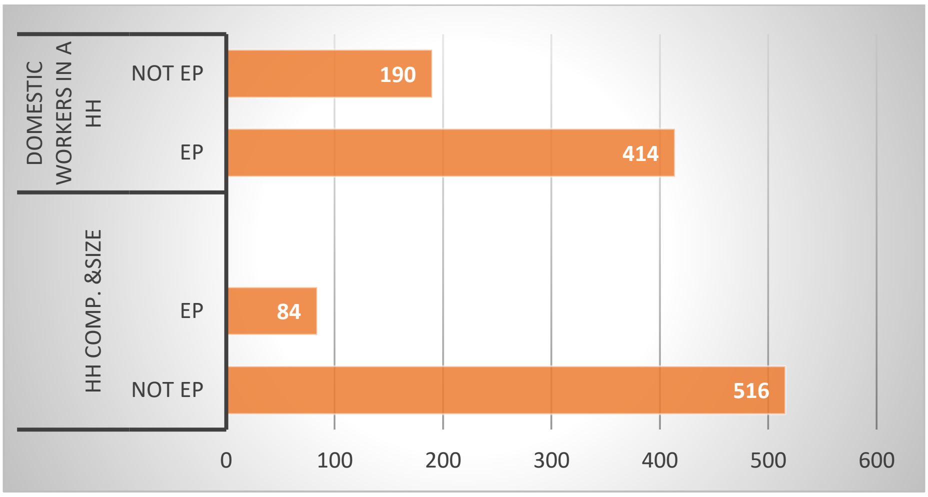

Figure 24 Graph showing the results of EP in dimension nine. Source: Own illustration of the data

Last but not least, this dimension is of equal importance to the previous ones. The results show that 85% of respondents are energy poor. On a larger scale, 85% of Lebanese citizens do not own either a bachelor, masters or a PhD degree.

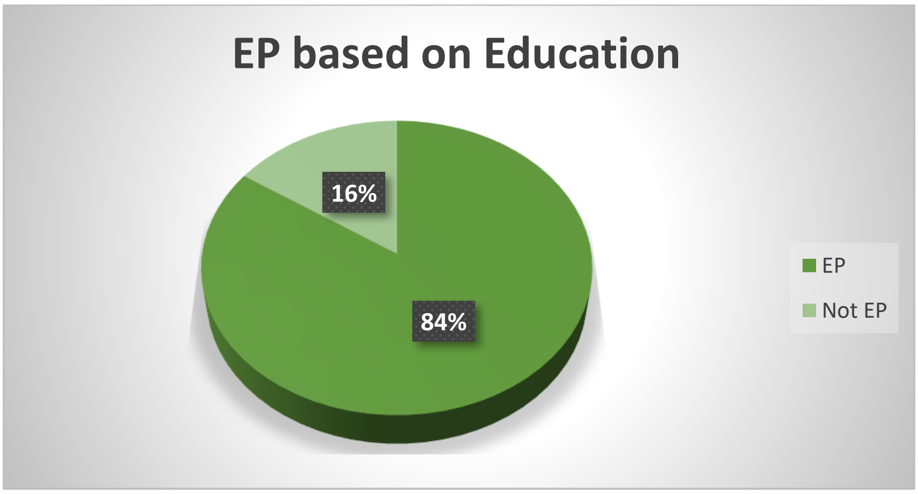

Figure 25 Pie chart showing the results of EP in dimension ten. Source: Own illustration of the data

Having undergone energy poverty in three dimensions, there are 120 possibilities ($_{10}C_3$) for a citizen to become "wholly" Energy Poor.

CHAPTER 7

RECOMMENDATIONS

Energy poverty is a global issue that is barely recognized and never shown in its true magnitude. Wang Et al. (2015) predicts that by 2030, about 1 billion individuals will still be deprived to access modern energy and unpolluted cooking accommodations. A collective collaboration among all stakeholders is needed. The government for example can facilitate:

- investments on enhancements in the energy infrastructure
- investments on new energy technologies and intervention in financing schemes.
- A switch to more cleaner sources of energy like wind and solar energy.
- Adapting, implementing and improving upon sustainable, affordable power.
- Tackling the challenges that come with mastering this better suited technology.
- Adapting better power models like cooperative model, community fund model
- Businesses that promote and sustain these power models
- targeted subsidies for households unable to afford efficient fuel….
- Visualize energy poverty as an idiosyncratic issue.
- The need to ameliorate its citizen's trust since the results of the respondent's opinion in the energy situation aren't an optimistic indicator. By this, it could help in increasing the citizen's WtP.

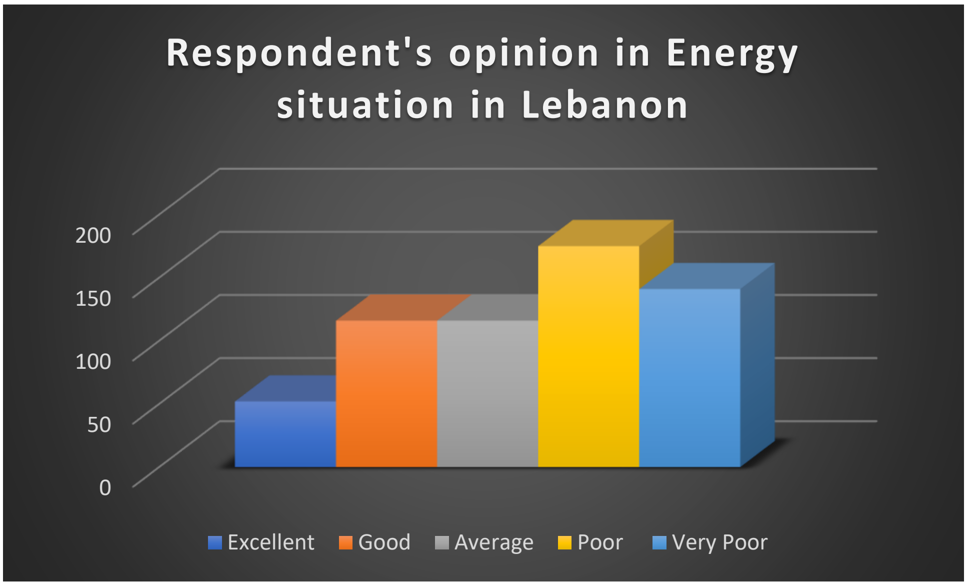

Figure 26 Graph showing Respondent's opinion in Energy situation in Lebanon.
Source: Own illustration of the data

As for the researchers' roles, they might be exploring new dimensions and indicators to assess energy poverty. They might also update the energy poverty index for further assessment and thus achieving a clearer understanding of the underlying concerns.

Social institutions might also benefit through:

- Raising awareness campaigns for households by advising them on how to handle and alleviate energy poverty.
- Encouraging the exploitation of recent unpolluted and resourceful household energy and targeting new plans to diminish the relative cost on residential commercial energy would also help revive energy status in a country.

As for households which are the majority:

- Raising the utilization of non-solid viable energy, and shifting to non-traditional non-polluting biomass.

- The need to enhance the acquaintance with renewable energy. Using the data of the paper, about one third of the respondents have excellent to good knowledge of renewable energy.

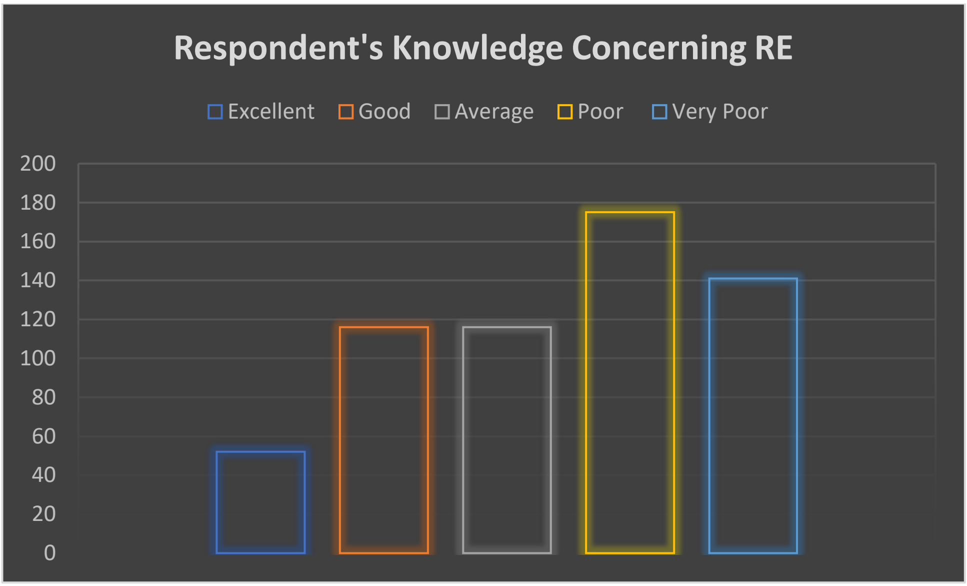

Figure 27 Graph showing the Respondent's knowledge concerning RE. Source: Own illustration of the data

- Although 82% are willing to pay for the enhancement of the power sector in Lebanon, the need of its consistency is still mandatory. The more consistent the citizens are willing to pay the better the results (up to 4, up to 5 years…).

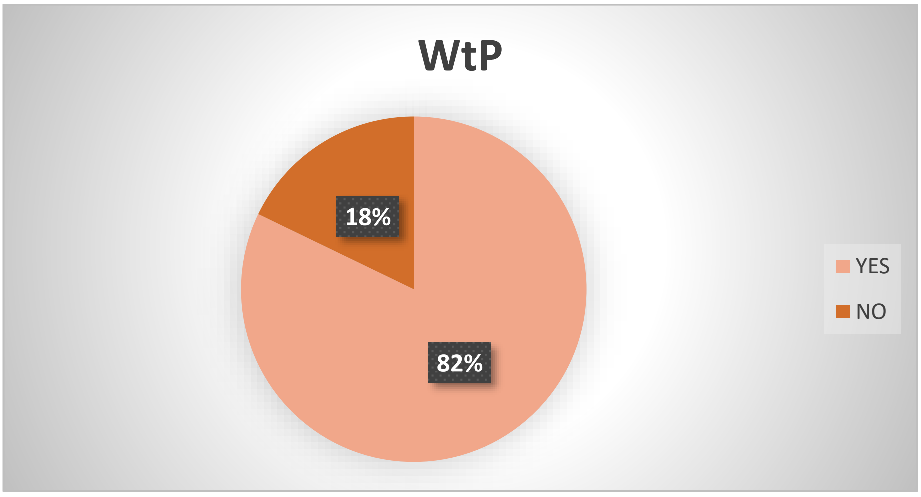

Figure 28 Pie chart showing the willing to pay for better energy sector. Source: Own illustration of the data

Table 8 Table showing the frequency of period of WtP. Source: Own illustration of the data

Period of WtP	**Frequency**
0	107
Always	82
No specific Period	76
Up to 1	37
Up to 2	53
Up to 3	50
Up to 4	23
Up to 5	172

Concludingly, all stakeholders must avoid visualizing energy poverty as a technology or fuel-oriented issue and start viewing it as service-based conflict.

CHAPTER 8

CONCLUSION

All in all, energy poverty is a multi-dimensional issue with an unsatisfactory selection of accessing proper, affordable, consistent, worthy, nontoxic energy services and making sure they're also benign to the larger environment at hand is a whole other issue. Energy poverty is not faced only by developing countries nor merely in rural areas but they exist almost everywhere if you search in the poverty stricken areas in countries and cities worldwide. More energy services are required people don't only require heating and lighting to survive its a much more complex issue moving forward as we're evolving as a society we're becoming more technology based and to power up all that technology we require affordable, reusable, sustainable and eco friendly power. In addition, failing in alleviating energy poverty is equally or may be of greater importance than succeeding in removing it because it is teaching us better ways to preserve this planet and to achieve universal unlimited power for everyone to use freely, we have the means we just need to use them well. In other words, these failures are acquired experience to build upon and move forward to the next step that hopefully will bring us closer to solving energy and fuel poverty. Cultural factors could clarify human behaviors concerning their energy consumptions, habits and usages. The synergy between energy poverty and energy services assists in the comprehension of energy poverty.

Efficient energy technologies are necessary to combat energy poverty with a forethought relating to financing and business models.

Unfortunately, when it comes to countries like Lebanon, corruption overwhelms Lebanon in its sectors. Power distribution will always be controlled by higher ups which makes solving energy and fuel poverty in places like Lebanon to be a more difficult task that requires unconventional means, even though Lebanon has the resources to pull itself up and to become a beacon of light in the middle east, its progression has been halted indefinitely by its rulers. This has caused the energy crisis that is infamous in Lebanon and has been ongoing for years to the point where some children have never seen a normal full day of electricity in their life ever since they were born. This has halted Lebanon's development indefinitely in all aspects and fields, especially the fuel and electricity distribution sectors. Nothing is known of Lebanon’s energy future, it has become the norm for some people and they hold no hopes of it being fixed but hopefully through researches and methods of technology and problem solving like this, with the help and common efforts of people in the Energy sustainability and sufficiency field Lebanon can hope to one day end its energy crisis, decreasing massive number of energy poor and fuel poor citizens and becoming the beacon of light it once was.

To wrap up, energy poverty is a multifaceted issue where capturing the whole picture is far-fetched. However, the need to capture the optimal surrounding is mandatory to alleviate this viral dilemma and address it properly, only through this can we hope to decrease the amount of harm we are causing by continuously promoting these harmful common fuel sources all for the sake of money when we should be looking at the brighter picture the brighter future and make sure it will be bright and clean with renewable energy for the next generations to come.

CHAPTER 9

LIMITATIONS

The study faces some limitations such as integrating the price of oil in the methodology as a variable. This could happen through assessing the amount of oil used by a citizen, then calculating the ratio of price of oil to the citizen's income. Also, monitoring the fluctuations of the price of oil gives the research more credibility. As stated above, in 2019, Lebanon had encountered massive issues concerning the economy, the immense devaluation of the Lebanese lira and its effect on the economy in general and the energy sector in specific was devastating. Incorporating the fluctuations of the dollar in Lebanon would also give a clearer image of the current energy situation in Lebanon.

CHAPTER 10

FUTURE STUDIES

Had Lebanon gone bankrupt, the burden of subsidies increases. Gradual subsidy removal is inevitable. Subsidy removal on the price of gasoline is predictable. The removal of subsidies on EDL is also foreseeable. Assessing the energy situation of Lebanon after subsidy removal would be an interesting future study to make.

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