SOCIAL ACCEPTANCE STUDY FOR SOLAR ENERGY ADOPTION IN YEMENI HOUSEHOLD UNDER COMPELLING CIRCUMSTANCES

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This project report is dedicated to:

The Almighty **Allah**, for bestowing me the guidance and blessings.

My beloved *parents* and *wife* for their unconditional love and unlimited support.

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ABSTRACT

Renewable energy is a free and clean source of power, which makes it the best solution for the energy problems worldwide, Yemen included. During the compelling circumstances of civil conflict in Yemen, the public electricity grid fails to deliver any electricity to the conflict areas. This makes the householders search for alternative sources of power. The lack of researches studying the compelling circumstances effects on the intentions of installing solar systems at households poses a literature gap that needs to be bridged. This research focuses mainly on the social factors that can affect the decision taken by the householders. Level of knowledge, environmental concerns, the purchasing power, the satisfaction level and other subjective norms have been studied using a model built based on the Theory of Planned Behavior (TPB) and analyzed by SmartPLS 3 computer program. The three hypotheses of this research propose a positive effect of attitude (H1), perceived behavioral control (H2), subjective norms (H3) on the intention of the Yemeni householders towards the adoption of the solar PV. All hypotheses proved to be correct with positive effect on such intention. However, the subjective norms show no effect after the compelling circumstances are over. Environmental concerns and users level of autarky are major factors that influence positively the decision to adopt the solar PV. Initial cost has shown a negative effect on the decision of using solar PV in the low income households. Recommendations have been drawn to encourage the householders to use the renewable resources to overcome the energy shortage during and after compelling circumstances. Those recommendations are addressed to government, private sectors, NGO's, and public. Using solar PV at household level is a key solution to the energy problems in Yemen.

ABSTRAK

Tenaga boleh diperbaharui adalah sumber tenaga semula jadi yang percuma dan bersih, Hal ini merupakan jalan penyelesaian yang terbaik bagi masalah tenaga di seluruh dunia, termasuk negara Yaman. Semasa ketegangan keadaan akibat konflik di Yaman, sumber tenaga elektrik tidak dapat disalurkan oleh grid elektrik awam ke kawasan yang mengalami konflik. Hal ini menyebabkan isi rumah perlu mencari sumber tenaga alternatif. Kekurangan kajian akan konflik ketegangan keadaan memberi kesan kepada keperluan pemasangan sistem solar di rumah menimbulkan jurang sastera yang perlu dirapatkan. Tumpuan utama kajian ini ialah faktor sosial yang boleh mempengaruhi keputusan yang diambil oleh isi rumah. Tahap pengetahuan, kebimbangan alam sekitar, kuasa membeli, tahap kepuasan dan norma subjektif lain telah dikaji dengan menggunakan model yang dibina berdasarkan Teori Tingkahlaku Dirancang (TPB) dan dianalisis oleh program komputer SmartPLS 3. Tiga hipotesis dalam kajian ini mencadangkan kesan sikap positif (H1), tanggapan kawalan tingkah laku (H2), norma subjektif (H3) mengenai keperluan isi rumah di Yaman ke arah penggunaan fotovoltaik (PV). Kesemua hipotesis tersebut terbukti benar dengan kesan positif. Walaubagaimanapun, tiada kesan ditunjukkan bagi norma-norma subjektif selepas ketegangan keadaan tamat. Isu alam sekitar dan tahap pengguna autarki merupakan faktor- faktor utama yang mempengaruhi keputusan untuk menerima pakai fotovoltaik. Kos awal telah menunjukkan kesan negatif ke atas keputusan menggunakan fotovoltaik dalam isi rumah yang berpendapatan rendah. Cadangan telah disediakan untuk menggalakkan isi rumah menggunakan sumber yang boleh diperbaharui bagi mengatasi kekurangan tenaga semasa dan selepas ketegangan keadaan. Cadangan tersebut ditujukan kepada sektor awam dan swasta, badan bukan kerajaan dan orang ramai. Menggunakan fotovoltaik di peringkat isi rumah adalah penyelesaian utama kepada masalah tenaga di Yeman.

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LIST OF ABBREVIATIONS

AFD	-	Agence Française de développement
ACB	-	Agricultural Credit Bank
ATTD	-	Attitude
AVE	-	Average Variance Extracted
CSP	-	Concentrated Solar Power
DW	-	Deutsch Welle
EIA	-	Energy Information Administration
ENVIRON	-	Environmental
FiT	-	Feed in Tariff
GHG	-	Green House Gases
IDB	-	Islamic Development Bank
INT.	-	Intention
IPCC	-	Intergovernmental Panel on Climate Change
Know	-	Knowledge
MEE	-	Ministry of Electricity and Energy
MEES	-	Middle East Economic Survey
MPIC	-	Ministry of Planning and International Cooperation
MWFP	-	Mocha Wind Farm Project
NGO	-	Non-governmental Organization
PBC	-	Perceived behavioural control
PLS	-	Partial Least Square
PV	-	Photovoltaic Panel
RCREEE	-	Regional Center for Renewable Energy and Energy Efficiency
RE	-	Renewable Energy
REPS	-	Rural Electrification Policy Statement

RESAP	-	Renewable Energy Strategy and Action Plan
R.Y.	-	Yemeni Riyals
SEM	-	Structural Equation Modelling
SEMC	-	Studies and Economic Media Center
SN	-	Subjective Norm
TPB	-	Theory of Planned Behaviour
UNDP	-	United Nations Development Program
UN-OHRLLS	-	United Nations – Office of the High Representative for the Least developed countries, Landlocked developing countries and Small islands developing states.
USD	-	United States Dollar
UTM	-	University of Technology Malaysia
VIF	-	Variance Inflation Factor
YPEC	-	Yemen Public Electricity Corporation

LIST OF SYMBOLS

β	-	Path Coefficient
f^2		Effect size
GW	-	Giga Watt
GWh	-	Giga Watt Hour
kM	-	kilo Meter
kV	-	kilo Volt
kW	-	kilo Watt
kW/M^2	-	kilo Watt per square Meter
MJ/M2/Day	-	Mega Joule per square Meter per Day
MW	-	Mega Watt
mW/cm^2	-	Mille Watt per square Centimeter
Q^2		Cross-validated redundancy
R^2	-	Coefficient of determination

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CHAPTER 1

INTRODUCTION

1.1 Introduction (Background of the Research)

Yemen has been known in history as “Arabia Felix”, a land of happiness and wealth. It is blessed with a wealthy environment (rich of the best agricultural lands, full of valuable mineral mines and its location of land and sea voyages). Nowadays, Yemen is considered as one of the poorest countries not only among the Arab countries but also worldwide.

Figure 1.1 Map of Yemen (University of Texas, 2018)

Nowadays, energy is the baseline of today's modern life quality and requirements all over the world. The country's prosperity is counted by the energy that those countries possess. Therefore, it is one of the major responsible reasons for the economic growth in any country. All sectors require energy, which include industrial, agricultural, transportation, commercial and domestic sectors. Considering the fast growth of nations, energy needs continued exponentially rising year by year to reach tremendous levels. This upsurge in demand makes more reliance on fossil fuels. In a country like Yemen, the household consumes about 58% of the total electrical energy production (Qasem, 2018). Figure 1.2 shows sector wise consumption of electrical energy for the year 2010.

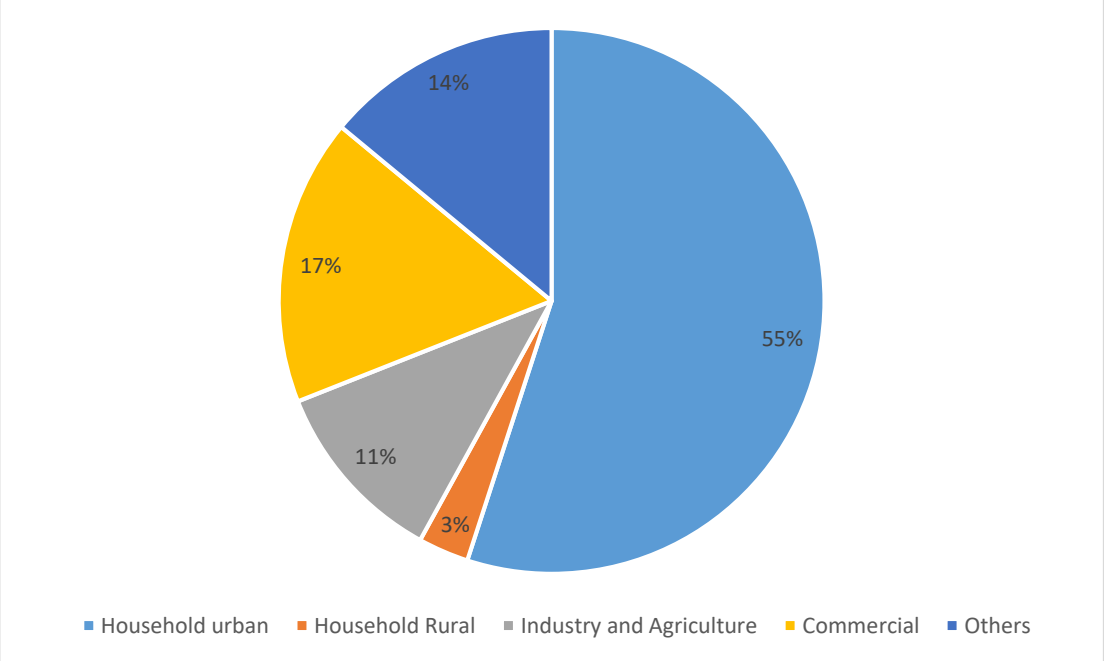

Figure 1.2 Yemen Electricity Consumption Profile (Qasem, 2018)

Energy resources are categorized into either renewable or non-renewable resources. Renewable energy resources embrace those resources that are being continually renewed. Although solar, wind, tidal, geothermal and falling water are considered the most common, they are not the only forms of renewable energy resources. All resources that can be regenerated are considered as renewable resources. On the other hand, the non-renewable resources are the sources that deplete with time like fossil fuel (coal, oil and gas).

Energy resources have been under tremendous pressure, due to significant growth of nations. To meet the growing demand, countries (like Yemen) are increasing its imports of fossil fuels to meet this increasing demand on energy. And because of the fluctuating oil prices and the country poverty level, the energy production is not secured (Al-Shabi *et al.,* 2014). However, satisfying this demand of electricity from a conventional resources power plants comes along with problems as global warming and the depletion of fossil fuel resources (Robert *et al.,* 2006 and Dorian *et al.,* 2006).

This un-secure condition of the electrical energy generation makes the domestic sector searching for alternative resources that can fulfil the needs of the electrical energy demand to maintain at least the minimum life standard necessities.

The compelling circumstance of civil conflict makes the situation worse. Most of the Yemeni cities are suffering from this issue in all areas of life, especially the electrical power sector. In most cities including the capital Sana'a, it is the third year with no electricity coming from the public grid. The remaining cities are facing the same problem but with a different level.

The lack of the electrical power source makes the people of Yemen seek for other energy sources to satisfy their minimum energy requirements. Some are going to the renewable based resources and some of the conventional types of power generation based on fossil fuels.

Renewable energy resources are non-depletive energy sources. They can regenerate themselves in a short period of time, and may become a perfect solution for the fossil fuel problems (Robert *et al.,* 2006). Solar Energy is one of the widely available renewable resources, it consists of either the form of heat source or light source. The heat can be utilized in the form of heating the water in a boiler to provide steam which can be used in many applications not limited to electricity generation. On the other hand, the light can be utilized to illuminate the dark areas inside buildings or to be used for producing electricity. The most commonly known form of utilizing the light radiation of the solar energy is Photovoltaic panels (PV) as shown in Figure 1.3.

The PV is designed to harvest the photons and convert their energy to an electrical energy. Mostly the PV cells are made of semiconductor materials (usually silicon). Once the light reaches the surface of the cell the photons hit the free electrons in these semiconductor surfaces energizing them to make a flow of electrons which eventually makes a useful electrical current.

Figure 1.3 Solar panels at School of Chemical & Energy Engineering, N01a, University Technology Malaysia, Johor Bahru (2018)

Yemen is one of the Arab countries in Southwest Asia at the latitude of 15.0°N and a longitude of 48.0°E is occupying the southern end of the Arabian Peninsula. This location makes Yemen an endowed country with many opportunities to harvest energy from renewable sources especially from the sun with high levels of solar radiation averaging 5.0-7.2 kW/m^2 per day (UNDP, 2013). Additionally, Yemen has a long coastline and high altitudes with a wind speed range of 4 – 15 meters per second (Bin Gadhi *et al.*, 1998).

In September 2004, Yemen approved Kyoto Protocol (UNDP, 2013). Since then several renewable projects that have the potential to reduce GHG in Yemen have been studied including PV, wind and geothermal.

A Renewable Energy Strategy and Action Plan (RESAP) has been initiated by the Yemeni Government in which all different sources of renewable energy (RE) have

been investigated (MEE, 2017). All prospected sources of renewable energy been assessed including wind, solar, geothermal, hydro and biomass. This investigation concluded that the solar and wind energies are having the most potential among the best feasible sources of renewable energy in the country. The RESAP plan has been prepared by the Ministry of Electricity and Energy (MEE) in 2008 (NECRA, 2017). Its objective was to promote the sustainable development and to raise the living standards of the rural areas by providing an affordable access to cleaner energy sources.

Starting with the wind energy, the first step was to measure the potentials of wind energy (UNDP, 2013); therefore, MEE has built two metrological masts near Hodeidah and Mocha cities. These two masts give the capability to have solid measurements that help define which area is the most feasible one. The measurements campaign took place in the early months of 2006 and from which MEE concluded that Mocha site is most suitable location for implementing the wind farm project. Accordingly, Mocha Wind Farm Project (MWFP) of 60 MW was initiated with the purposes of validating the financial feasibility of wind power by building the first wind farm in Yemen. This project will add 60 MW of clean energy to the national grid. The technical and financial feasibility of the project was confirmed in June 2010 by a final feasibility study. A requisition submitted to all of the World Bank, Islamic Development Bank (IDB) and the Agence Française de développement (AFD) to assist in financing this project. But, due to the 2011 situation “Arabic Spring” this project has been halted at early stages.

In addition to solar and wind energies, geothermal energy has a potential in the country especially in the governorate of Thamar. And many other types of renewable energies can be also found feasible in Yemen (Rawea, and Urooj, 2018). Table 1.1 shows potential renewable sources types.

Table 1.1 : Yemen Renewable Energy Potentials (UNDP, 2013)

Resource Theoretical Potential	Theoretical potential energy (MW)	Technical Potential	
		Practical (MW)	Realizable (MW)
Wind	308,722	123,429	34,286
Geothermal	304,000	29,000	2,900
Solar electric	2,446,000	1,426,000	18,600
Biomass-landfills	10	8	6
Hydropower- Major Wadies	12 – 31	11 – 30	-
Solar thermal-Solar Water Heater	3,014	278	278

1.2 Problem Statement and Research Hypotheses

The need to have an alternative source of energy to overcome the public electricity blackout during civil conflict time is vital. Through the last three years, the Yemeni householders already found the alternative sources that can overcome this problem. Some of them choose renewable sources like solar or wind and the others prefer the conventional sources (gasoline and diesel generators).

As discussed in the last part, Yemen is blessed by amble sunny days and the fortunate geographical place makes it as one of the world best places to implement solar farms (direct or indirect). The solar radiation is among the highest levels in the world with an average of 5.0-7.2 kW/m^2 (UNDP, 2013). In addition, the recent situation of the fossil fuels scarcity had its own impact and pushed the householders towards choosing the renewable energy resources as an alternative to the public energy resource which is no longer exist in some parts of Yemen and not guaranteed in the other.

By using the given information, it can be prospected that the Yemeni householders should favor the renewable sources over any other energy sources. Hence, in this research, the significance of the reasons behind this moving toward

using renewables over other resources will be evaluated and the main reasons which make the Yemeni householders prefer one source over the other will be highlighted. The citizens' knowledge level, behavioural intentions and attitudes will be examined to measure the citizens' attitudes towards the solar renewable energy. After that, we are going to analyze those reasons to come with a better clarification and recommendations for the market and the government policies.

In this study, the Theory of Planned Behaviour is being used, which formulated by a three core variables that are going to be our hypotheses in this research. The Theory of Planned Behaviour (TPB) is defined as a social perceptive research framework often used to understand the individuals' behaviours toward a research issue. The theory states that human actions are guided by three kinds of beliefs specifically: behavioural, control, and normative. The behavioural beliefs are those which produce a positive or none positive attitudes toward the behaviour. Control beliefs considered as perceived behavioural control (PBC) which discover the perceived easiness or hardness of performing the specific behaviour, and for normative beliefs are the results of the effect done by the social pressure or subjective norms to do that specific behaviour. This theory is going to be applied to the Yemeni household intentions to install solar PV at their houses during the time of the compelling circumstance. Therefore, all hypotheses have been formed within this context.

The first hypothesis will be formed from an attitude prospective as formulated from the (TPB). In general, the attitude is known as the mixture of an individual's feelings (Positive & Negative) about the act of doing the target behaviour. Studies have shown that the attitude can influence the behavioural intentions of the adoption of renewable energy technologies in general (Ozaki, 2011 and Park and Ohm, 2014). According to this, the first hypothesis has been posited as the attitude influences the Yemeni householders to adopt solar PV at their houses.

H1. The attitude toward solar PV at Yemeni household level positively affects the intention toward adopting it.

The second hypothesis will be formed from the perceived behavioural control which refers to the situations in which individuals do not have a complete control over their own behaviours. Taylor and Todd (1995) define the perceived behavioural controls as "Actual ability (money and time) to perform the behaviour". According to Bamberg (2003), "The belief can exert a strong influence on behavioural intention among people who are highly concerned with the environment." Therefore, changing energy consumption patterns voluntarily can act as a substantial pressure to adopt renewable energy systems. From this the second hypothesis in this research will be:

H2. Perceived behavioural control of solar PV at Yemeni household level positively affects the intention toward adopting it.

The third posited hypothesis is a subjective norm based, subjective norms are concerned with how the people behaviour is influenced by the wish to act in a way that other important referents think the person should act or as they act themselves (Ajzen, 1991). According to him, a person who lives in a society and affected by it will comply with this group direction to present a positive image of himself as a good member of this social group. Social norms are having a strong effect on intentions (Bamberg, 2003). Therefore, subjective norms play an important role in influencing the solar PV adoption.

H3. Subjective norms positively affect the intention toward adopting the solar PV at Yemeni household level.

1.3 Objective of the Research

The main purpose of this research work is to study the social acceptance for solar energy adaption in Yemen household under compelling circumstances, main reasons behind choosing the renewable resource over the conventional ones by the

householders, their significance and the recommendation that can be provided to both government and market.

The specific objectives of this study are:

i. To investigate the behavioural motives behind choosing the solar panels as a source of energy.
ii. To identify to what extent the civil conflict affected the decision of choosing.
iii. To propose necessary actions for governmental policies, market leaders, and charity organizations and NGO's.

1.4 Scope of the Research

The research study focuses on the installation of solar panels at household in Yemen at the civil conflict time. Entire metropolitan and rural, hot and cold climate areas, the ones under the unrest condition and the ones out of the firing range, all blackout cities and the partially powered cities.

To accomplish the research goal, a questionnaire was developed to study the reasons and the barriers behind the acceptance of solar energy in Yemen which currently under compelling circumstances.

The questionnaire covered 4 main areas in Yemen, the mountains, the wadis & hills, the coastal, and the desert areas. The questionnaire was distributed using the social media as a medium. The number of needed responses is calculated to be 384 from the population acceptance statistical formulas, the 384 responses are more than the satisfying threshold of approximately 40 responses due to 10 times rule (Barclay *et al.*, 1995) which is satisfying our PLS-SEM model.

The questionnaire responses were analyzed using the Partial least square – Structural equation model method using SmartPLS computer program. The analyzing outcomes will help us to propose actions and policies to the government and the market to increase the solar energy uptake.

1.5 Significance of the Research

Despite the solid knowledge of the renewable resources advantages over the conventional fossil-based ones and the effects of compelling circumstances in the availability of fossil fuels. The aim towards a renewable energy resource at household level in Yemen still needs a detailed investigation to know the significance of the compelling circumstances impacts and to give the government and the market leaders a realistic view of the major reasons behind this to adjust the governmental policies and the market movements.

This research will also enrich the knowledge level of the solar energy sector at household level in Yemen. In addition, the study statistical data can provide a primary literature for further studies in future.

1.6 Limitation of the Study

The limitation to be acknowledged in this research is the sampling methodology used to perform this study. The self-reported data are very common in the social science research; though, they might be containing biases. The sample used in this study might encounters the same challenge. In this case, the respondents may give answers which do not exactly reflects the truth.

To shrink this impact down, the importance of acting honestly while filling up the survey questionnaire was emphasized. This will have a compensatory advantage for this weakness.

This research is only focused on the recent situation of compelling circumstances in Yemen. The results might not be generalized to other countries even when they are having the same situation. This will be limited according to the cultural differences. According to Lin *et al.* (2007), the determinants of behaviour are context-dependent. Thus, the utilization of this research results in other countries requires further investigations to make it fit for different countries.

1.7 Research Outline

This thesis is divided into five chapters excluding all introductory pages, table of content and abstract. The first chapter (Chapter 1) contains the introduction (Background), problem statement and research hypotheses, objectives of research, the scope of the research, significance of the research, limitation of the study, and outline of the proposal. (Chapter 2) consists of a general overview of the electricity generation in Yemen and the problem faced before and during the time of compelling circumstances, the renewable energy potentials and the real situation challenges of installments and projects, the renewable energy at household level in Yemen, the relevant related previous studies in this topic and their outcomes, and lastly the social behavioural importance for this research. A detailed demonstration of the research methodologies and the research flow scheme were discussed in the third chapter (Chapter 3). The discussed results of this study are summarized in the fourth chapter (Chapter 4). Finally, in (Chapter 5) the research conclusion was drawn to come with proper recommendations for this study and for future work with limitations highlighted.

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