

# Behavioural and Socioeconomic Drivers Underlying Solar Adoption in Egypt's Cairo and Giza: A Micro-Level Perspective

By Maha El Hini<sup>1</sup>, Hoda Hasaballah<sup>2</sup>, Rasha Hammam<sup>3</sup>

## ABSTRACT:

Although Egypt falls within the solar belt, solar energy use on the household level remains very sparse. This research examines the factors driving and hindering households' willingness to shift from fossil fuels to solar energy. The study evaluates the socioeconomic determinants of households' willingness to adopt photovoltaic (PV) solar panels, based on a random distribution of 301 questionnaires in Cairo and Giza – two of Egypt's most densely populated governorates. Two models were used— a Logistic Model and a Structural Equations Model (SEM) that regresses the willingness to install PV panels on household characteristics. For a deeper analysis of how socioeconomic differences shape renewable energy adoption, we separated the SEM model into behavioural and economic characteristics to be able to identify whether willingness to adopt solar PV systems, (or the lack of), stem from either set of factors. Accordingly, these insights can inform policy and support the implementation of targeted actions in both directions. Behavioural factors include household heads' willingness to take a credit facility to finance solar PV panels, household heads' level of education, living in rural versus urban areas, household size, whether any of the household members needed medical attention owing to heat waves during past year, household heads' age and gender. Economic variables include household heads' monthly income, whether the household owns a farm, whether the household owns gas at home, access to internet connection at home, access to credit facility, the number of times on average the household was disconnected from electricity per week during the past year, and education reflecting the socioeconomic level of the household head. Behavioural variables that positively contribute to adopting solar panels are revealed to be willingness to take a credit facility, age, education and household members needing medical attention owing to heat waves during past year; behavioural variables that contribute negatively to solar panel adoption include gender of the household head (in favour of females) and the geographical dimension (in favour of rural areas). The economic model's results reveal a positive relationship for the average monthly income of the household head, ownership of farmland, and the years of education of the household head. Households with access to internet at home is negatively associated with the willingness to install solar panels. Suggested policy implications include packages that target programs supporting low-income households.

*Keywords: PV Solar Panels, Behavioural & Socioeconomic determinants, Structural Equation Model, Logistic Regression Model*

## 1. Introduction

Energy is a vital necessity to our everyday life. Several initiatives have been made to ensure universal energy access, nevertheless, millions of people around the world, still have limited access to energy since it is unaffordable to many people living in developing countries. Specifically in Africa, where per capita income is low, people experience low standards of living and a high burden of unemployment and poverty limiting their

<sup>1</sup>Associate Professor of Economics, British University in Egypt, Cairo Egypt

<sup>2</sup>Professor of Economics, British University in Egypt, Cairo Egypt

<sup>3</sup> Associate Professor of Economics, Misr International University, Cairo Egypt.

accessibility to affordable energy. The former United Nations Secretary-General, Ban Ki-moon stated that “Energy is the golden thread that connects economic growth, increases social equity, and provides an environment that allows the world to thrive”, (UN, 2014). Similarly, Egypt, being a lower-middle income country, is home to a considerable number of poor people. Nevertheless, by the end of 2019, the adopted structural adjustment program almost completely ended energy subsidies after they constituted a fiscal burden on the Egyptian government. Terminating energy subsidies, however, did not come without social repercussions. A large percentage of the population are vulnerable to the smallest increases in living costs, a situation that presses for alternative, more affordable energy sources such as solar energy, (Diab, 2023).

Egypt’s Solar Atlas declares that it falls within the “sun belt” with 2,000-3,000 kWh/m<sup>2</sup>/year of direct solar radiation, making it a prime location for renewable energy, (Egypt Solar Atlas, 2018). But does this endowment hold opportunities for households to shift to more affordable energy sources, given the termination of energy subsidies? Tapping into the scale of households to shift to new energy sources, such as solar energy, has now become inevitable given the rapid increase in electricity prices. In this light, this research delves into the willingness of households in Egypt to use photovoltaic solar panels (PV). This is achieved via randomly distributing questionnaires to 301 households in Cairo and Giza – two of Egypt’s most densely populated governorates. The questionnaire consists of closed-ended questions that cover demographic and socio-economic characteristics of households, besides questions concerning energy use. The dependent variable measures the willingness of households to install PV panels, and is regressed on various household heads’ characteristics that may influence this decision – age, education, average monthly income, residence in rural versus urban areas, household size, whether the household owns a farm, availability of natural gas from underground pipes, willingness to seek credit facilities to install solar PV system, accessibility to internet at home, the number of times on average the household was disconnected from electricity per week during the past year, whether any of the household members needed medical attention because the house was too hot during past year. Household head characteristics are considered (whether male or female) owing to the norm of having the household head in making the main decisions in the family. To test this relationship, The Structural Equation Model (SEM), and the Maximum Likelihood of Logistic Regression Model are used for robustness owing to the relatively modest sample size of the questionnaire, based on funding from the DAAD<sup>1</sup>.

Empirical analysis using both Structural Equation Modelling (SEM) and Logistic Regression confirms that household decisions to adopt photovoltaic (PV) solar panels in Egypt are primarily shaped by socioeconomic factors, spatial context, and access to financial and informational resources. The objective of this study is to examine the behavioural and economic determinants that shape households’ willingness to adopt solar photovoltaic (PV) systems in Cairo and Giza in Egypt. By estimating separate structural equation models for behavioural and economic characteristics, the study seeks to identify whether adoption decisions and resistance to adoption are driven primarily by attitudinal factors or by financial and infrastructural constraints. The analysis is complemented by a

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<sup>1</sup> Deutscher Akademischer Austausch Dienst <https://www.daad.de/en/>

logistic regression to assess the robustness of the findings across modelling approaches. Ultimately, the study aims to generate evidence-based insights that can inform targeted policy interventions to promote solar PV uptake, particularly among lower-income and less-informed households. Collectively, these findings reveal that solar PV adoption in Egypt is not only a function of income or awareness, but a complex behavioral outcome shaped by financial accessibility, location, and infrastructural contexts.

The paper is organized as follows, section 1 provides theoretical insights underlying the concept of willingness to adopt new technologies such as solar energy systems; section 2 highlights literature on the topic, section 3 discusses the data, methodology and the models used to test this relationship; section 4 displays the results and section 5 provides an analysis of the results, while section 6 concludes and suggests policy implications.

## 2. Theoretical Insights

Since the early 20th century, growing attention has been directed towards understanding factors that influence households' decisions to adopt new technologies such as renewable energy sources (RES). Various theoretical perspectives offer insights into how social, economic and environmental factors shape consumers behaviour towards adopting renewable energy. These perspectives range from arguments emphasising the roles of sociodemographic factors, subjective norms and perceived ease of use in encouraging consumers to adopt RES. Accordingly, this section provides an analysis of the theoretical frameworks that discuss the main factors influencing households' adoption of RES.

Since the Diffusion of Innovation Theory was introduced in 1962 by Everett Rogers, explanation on how new ideas, products or technologies spread among members of a society impacted their decisions to consume new products. Rogers believed that adopting new technology does not occur simultaneously across individuals; however, it is a process whereby some individuals are more willing to adopt technologies than others. Moreover, he added that those who adopt a new technology earlier have different characteristics than those who adopt the technology later. In this light, Rogers proposed five adopter categories. The first category of consumers are the innovators who are more open to risk and are the first to shift to new technologies. The second category are the early adopters; this group of people are aware of the need for change. This group of people do not require more information about new technologies to be compelled to make this shift, they only need to know how to use the technology. The third category is the early majority; these are the ones who adopt new technologies before the average person. This type of people needs to try the technology before adopting it to make sure it is working efficiently. The fourth category is the late majority. These people are reluctant to change and will only adopt the technology after it has been used by the majority. Finally, the fifth category constitutes the laggards, who are the hardest to convince since they are bound to tradition and very sceptical towards adopting new technologies, (Rogers, 1962).

Rogers also proposed four factors that affect individuals' willingness to adopt a new technology. These are, first, relative advantage which is the degree to which a technology is regarded as beneficial; compatibility, which refers to how consistent the technology is with the values and needs of individuals, third, complexity which refers to how difficult the technology is when used, fourth, triability which refers to the extent to which the technology can be tested before adopting it and fifth, observability which is the extent to which the technology provides visible benefits. Furthermore, Rogers advocated certain factors that can influence the rate of innovation diffusion. These include communication channels such as access to the internet and social media, the place of residence such as rural versus urban areas, the level of a country's development as well as promoting government policies and initiatives that help in adopting new technologies; these include subsidies and credit facilities from financial institutions. Moreover, demographic factors such as age, income, and education affect the rate of adopting new technologies such that younger and more educated people earning high incomes tend to be early adopters as they are more willing to take risks, (Rogers, 1962).

The Technology Acceptance Model (TAM) is the most widely used for identifying factors that encourage consumers to switch to a new technology. The model was developed by Fred Davis in 1985 and is based on the idea that consumers' attitudes towards adopting a new technology are shaped by two key factors, perceived ease of use and perceived usefulness. Ease of use pertains to wider public acceptance of a new technology if consumers find it to be user-friendly and family friendly. Whereas user's acceptance of a new technology is the perceived usefulness, which refers to the degree to which consumers believe that using a new technology would be beneficial and aligned with their needs. In terms of renewable energy sources, perceived usefulness refers to the extent to which consumers believe that adopting this technology will benefit them. This includes benefits such as reducing electricity bills, improving energy efficiency, having access to a renewable power source and protecting the environment. Hence, if consumers believe that adopting RES is beneficial and useful for meeting their needs, they will be more willing to adopt it, (Davis, 1985).

In 1991, Icek Ajzen proposed the Theory of Planned Behaviour (TPB) building on the Theory of Reasoned Action which was proposed by Martin Fishbein and Icek Ajzen in 1967. According to the TPB theory, individuals' intentions to adopt a new technology is driven by attitudes, subjective norms, and perceived behavioural control. First, attitude refers to how individuals feel about taking an action, in other words, it refers to individuals' positive or negative evaluation regarding a certain behaviour. In terms of renewable energy, a positive attitude might arise from the belief that adopting RES will decrease electricity bills and help protect the environment. This will potentially make consumers more inclined to adopt RES.

On the other hand, if consumers believe that RES are expensive and hard to maintain, their attitude will be negative, leading to reluctance in adopting them. Subjective norms are when individuals review the attitudes of other family members, friends, colleagues or neighbours towards a specific product. It refers to social pressure that may influence individuals' decisions regarding adopting or not adopting a certain behaviour. In the context of renewable energy, if consumers feel that their peers, family or neighbours are adopting RES, they are more likely to follow the same behaviour to maintain their

social image and enhance their social status. The final factor is the perceived behavioural control which refers to the extent to which individuals feel they are able to engage in a certain behaviour. To emphasise, the perceived behavioural control reflects how much control an individual has over a behaviour and how confident he or she feels about being able to perform this behaviour. This is determined by internal factors such as an individual's ability, knowledge and confidence (self-efficacy) and external factors such as the presence of facilitators or barriers. Hence, perceived behaviour reflects the extent of control individuals feel they have over an adopted renewable energy source. Further, people need to have confidence in understanding and using the technology and ensure access to maintenance support or financing options. If consumers feel confident and have the necessary resources, they are likely to adopt RES, (Ajzen, 1991).

The Value Belief Norm theory (VBN) proposed by Stern *et al.*, (1999) is one of the most prominent theories of environmentalism which analyses the factors that influence individuals' pro-environmental behaviour. According to the theory, individuals are influenced to adopt pro-environmental behaviour due to a chain reaction between values, beliefs and personal norms. Values refer to principles that guide individuals' choices and actions. According to the theory, there are three types of values: altruistic values, egoistic values and biospheric values. Altruistic values refer to prioritising the well-being of others. People with strong altruistic values are more willing to engage in environmentally friendly behaviour to improve the society and protect others health. On the other hand, egoistic values refer to values that reflect individuals' concern about the environment only for their self-interest. People with strong egoistic values engage in environmentally friendly behaviours only for their own personal benefits such as reducing their own electricity bill. As for biospheric values, this refers to prioritising environmental protection. Those who have strong biospheric values are more concerned about preserving the environment and other species rather than their own well-being. The VBN theory postulates that these values in turn generate beliefs. Beliefs refer to individuals' thoughts about the relationship between behavior and natural environment. As individuals develop beliefs concerning environmental protection, awareness of consequences develops. The awareness of the consequences refers to the belief that human actions will either improve or threaten the environment and other people's health. It tends to generate a sense of responsibility to behave in a specific manner. According to the theory, the awareness of consequences is accompanied by the ascription of responsibility. Activation of responsibility is the individuals' sense of responsibility and the belief that their actions can promote or prevent any potential negative effect on the environment. When individuals hold enduring beliefs that are essential to preserving the environment this leads to personal norms. Personal norms are the feelings of moral obligation to protect the environment. They refer to the expectations that an individual is ethically obliged to engage in pro-environmentally behaviour after recognising the consequences of certain behaviours and the efforts one can make to alleviate those consequences. Based on this, pro-environmental behaviours occur when an individual's feeling of moral obligation to perform or refrain from specific behaviours are activated by awareness of consequences and ascription of responsibility.

It can be emphasised that communication channels and sociodemographic factors are essential in influencing the rate of diffusion of an innovation. Also, the perceived ease of use and perceived usefulness are further key factors influencing consumers' decision to

adopt renewable energy. Moreover, it was postulated that individuals' decisions to adopt renewable energy are driven by attitudes, subjective norms and perceived behavioural control. The following section highlights previous literature on factors that influence households' willingness to adopt renewable energy.

### 3. Literature Review

There is a growing body of literature that examines factors influencing households' willingness to adopt renewable energy sources (RES). By conducting surveys and applying structural equation modelling, studies on China show that age negatively influences households' willingness to pay for solar energy indicating that younger individuals are more open to more innovative energy sources relative to older people. The literature also shows that families belonging to higher income groups are more willing to risk payment in RES, although high costs of RES negatively influence households' willingness to pay for RES. Households who live in the same neighbourhood may usually have similar characteristics and share more or less the same educational levels and environmental awareness. So, within cluster influence may result in neighbours adopting similar RES consumption. Studies also show that as households' trust in their government increases, their willingness to pay for RES rises, (Asif et al. 2022; Irfan et al. 2021; Liu et al. 2012; Sun et al. 2015; Yuan et al., 2011). On the other hand, Wang et al. (2011) conducted a survey and applied the logistic regression model and showed that older Chinese households, especially those who are retired, are more willing to engage in environmentally friendly behaviours than younger households. Moreover, they found that high electricity bills and government-subsidized renewal energy motivate consumers to switch to solar energy.

Similar to China, research on Greece (Karasmanaki et al., 2019) applied probit and logistic models to survey data, revealing that households who receive higher income and are more educated are more willing to engage in environmentally friendly behaviours since they are keen on protecting the environment. These households also have more knowledge about RES and how to use them.

Moreover, the Greek culture values close-knit family relationships and community bonds. This is why social influence is one of the main drivers of switching to solar energy in Greece. Subsidies provided by the government, and rising costs of electricity and shortages were mentioned as key factors that increased households' willingness to switch to RES. However, the cost of installation and maintenance were found to be the main obstacles, (Ntanos et al., 2018; Sardianou and Genoudi 2013; Zografakis et al., 2009).

Research on Turkey applied structural equation modelling and path analysis to show that high-income and more educated households are more willing to switch to solar energy since they are more environmentally aware and have more knowledge about the benefits of renewable energy sources, (Acikgoz and Yorulmaz, 2024). Moreover, subjective norms and neighbours' participation in adopting renewable energy encourage consumers to follow the same behaviour, (Albayrak et al., 2013; Harorli and Erciş, 2023). By applying Tobit, Probit and Logit models, Dogan and Muhammad (2019) found that Turkish male households are more willing to pay for solar energy relative to females and that individuals with lower education levels are more likely to pay for solar energy compared to those with

higher education levels, contradicting previous results on China and Greece and Turkey. Additionally, younger households have a higher willingness to pay (WTP) for RES than older households. Nevertheless, by applying one-way ANOVA, Muhammad *et al.* (2020) found that elderly households in Turkey have higher WTP for RES than the younger ones. It was highlighted that the expensive cost of switching to solar energy is the main obstacle Turkish households faced. Similarly, by applying the partial least square model, it was found that in Mexico, the main barriers impeding households' from adopting RES are the high installation costs, lack of relevant government subsidies as well as uncertainty about the functionality of the system. However, environmental awareness, subjective norms and the higher socioeconomic levels of households increase the intention to adopt RES, (Arroyo and Carrete, 2019) and (Reyes-Mercado & Rajagopal, 2017).

In Southeast Asia, studies by Bilal and Andajani (2023) and Ulkhaq *et al.* (2018) were conducted to identify the factors that influence Indonesian households' willingness to adopt renewable energy. By applying the partial least squares-structural equation model and logistic regression model, their findings showed that Indonesians who are keener about environmental protection are more willing to engage in environmentally friendly behaviours. Moreover, the most influential factors were high income, subjective norms, increased cost of non-renewable sources, relative advantage and government initiatives. These results indicate that Indonesians emphasise government support for renewable energy. However, the main barrier that face Indonesians is the high cost of installing RES. In Thailand and Malaysia, households' decisions were also examined by carrying out surveys and employing multiple regression and structural equation model. The studies revealed that access to social media, knowledge about renewable energy, environmental awareness, perceived behavioural control, perceived usefulness, perceived ease of use motivate individuals to switch to RES.

Moreover, peer influence was regarded as the most influential factor since it was found that households' demand for RES will increase if it enhances their social pride. Again, installation costs act as a barrier to this transition, (Ahmad *et al.*, 2017; Alam *et al.*, 2014; Alam *et al.*, 2021; Aziz *et al.*, 2018; Lau *et al.*, 2020; Wall *et al.*, 2021; Zahari and Esa, 2018). On the other hand, in South Asia, several studies have been conducted in Pakistan to determine the factors that influence households' adoption of solar energy. By conducting surveys and applying partial least squares-structural equation modelling, it was found that more educated, wealthier and younger individuals are keener to switch to renewable energy sources. Pakistanis who have access to social media tend to be more encouraged to switch to renewable energy since social media exposure helps in spreading awareness and information about using and maintaining RES. Social media is regarded as one of the most influential factors encouraging the adoption of renewable energy. Pakistan is a lower-middle income country where prices are a crucial factor that influences consumer behaviour. At the same time, many people in Pakistan suffer low accessibility to electricity. Although there has been progress in shifting to renewable energy sources, the cost of RES remains the main challenge to achieving this shift, (Ali *et al.*, 2019; Ali *et al.*, 2020; Asif *et al.*, 2023; Elahi *et al.*, 2022; Fatima *et al.*, 2021; Hasheem *et al.*, 2022; Irfan *et al.*, 2020; Jabeen *et al.*, 2020; Nazir and Tian, 2022; Qureshi *et al.*, 2017; Zeng *et al.*, 2022).

Studies on India highlight that subjective norm, (family and peer influence) play an important role in encouraging Indian households to adopt RES. Moreover, those who

are aware of renewable energy and their benefits are more inclined towards adopting it. Job creation in the renewable energy sector was found to motivate Indians to adopt RES. Indians feel that by adopting RES, India will be self-sufficient and will reduce its trade deficit by reducing oil imports. Nevertheless, the cost of installing RES was also found to be a considerable barrier that affects Indian consumers decisions, (Aggarwal et al.,2019; Batool et al.,2024; Fathima et al., 2022; Kar et al., 2024; Kushwah et al., 2024; Yadav and Pathak, 2016). As for Bangladesh and Sri Lanka, by applying the structural equation model, it was found that knowledge about RES is associated with perceived ease of use. This indicates that Bangladeshi consumers who have more knowledge about RES will be motivated to adopt them. However, similar to previous results, households tend to be demotivated owing to high installation costs and inadequate financial support, (Alam et al., 2022; Bandara and Amarasena, 2020; Masukujjaman et al., 2021).

Sub-Saharan Africa receives high solar radiation making solar energy a potential key renewable energy source for residents there. Several studies have been conducted to identify the factors that influence households' decision towards using renewable energy. By conducting surveys and employing probit models, Twerefou (2014) found that in Ghana, wealthier and more educated people are more willing to switch to renewable energy. Moreover, it was found that smaller family size and male household heads have higher tendency to adopt RES. In Ethiopia, by carrying out a survey and applying the probit model, Arega and Tadesse (2016) found that older and unmarried individuals are more willing to pay for RES than younger and married individuals. This is explained by the fact that unmarried individuals do not face as many expenses as married couples and hence have higher potential to adopt RES. However, female headed households are less willing to pay for RES compared to their male counterparts, being risk averse. Moreover, it was observed that larger house sizes and larger roof surfaces give more flexibility to install solar panels on their roof tops. In addition, access to training positively influences Ethiopians decisions to adopt RES since they will be more able to use and maintain them. Similarly, Guta (2020) and Meried (2021) applied probit and logit models and found that richer, more educated households and those who have access to credit from financial institutions are more likely to switch to solar energy. In the same vein, by employing logistic regression models, Etongo and Naidu (2022) revealed that in Seychelles, access to credit facilitates the purchase of RES, encouraging households to adopt them. Whereas in Zambia and Nigeria, by applying the structural equation model, Zulu et al. (2021) and Ashinze et al. (2021) discovered that subjective norms, peer influence and perceived ease of use are the most influential factors that drive consumers to adopt renewable energy. Also, the cost of installation is the main barrier that impedes households from switching to renewable energy. In the case of Kenya, Nyangaresi (2023) conducted a survey and applied a multiple regression model and found that Kenyans are relatively more concerned about the environment, feel that they can easily use renewable energy sources and are more willing to adopt them. However, unavailability of government subsidies and lack of access to credit create a formidable obstacle for Kenyans, hindering their ability to transition to RES.

The MENA region is one of the most dependent regions on fossil fuels such as oil, since eight out of the thirteen-member countries in the OPEC are located in the MENA region, the largest of which is Saudi Arabia. Although Saudi Arabia is one of the

oil-richest countries and the largest oil exporter, it has been making progress in terms of protecting the environment and shifting to solar energy. A study by Mosly and Makki (2018) was conducted to estimate drivers of Saudis to adopt renewable energy sources. By conducting a survey applying descriptive and inferential statistics, they uncovered patterns in households' attitudes and motivations. They highlighted that sociodemographic factor play an important role in shaping Saudis' attitude toward solar energy. Among these factors, the level of education was the most significant. Moreover, findings revealed that younger Saudis are more eager than older Saudis to switch to RES. Similarly, by applying structural equation modelling, Bouaguel and Alsulimani (2022) revealed that while many Saudi households view solar energy as beneficial and environmentally friendly, the cost of switching remains a significant barrier. Nevertheless, factors such as perceived ease of use, positive attitude towards solar energy, environmental awareness, perceived usefulness and relative advantage continue to be drivers for switching to solar energy.

By applying the same methodology, Alsulami *et al.* (2024) found that subjective norms are an essential aspect of encouraging Saudis' adoption of solar energy. They believed that the power of peer influence is highly significant in Saudi Arabia due to the country's culture of close-knit extended families and tribes. Moreover, family size plays a role in affecting consumers' intention towards solar energy. It was highlighted that males are more environmentally aware than females and that having a large family positively influences households' decision to switch to solar energy. This can be attributed to the fact that a larger family lives in a bigger house and pay higher electricity costs. So, larger families find it more cost-efficient to switch to solar energy. Although it was anticipated that high-income individuals are more willing to adopt solar energy, the study found that income level is insignificant. This is due to lower-middle income households believing that the Saudi government will provide them with subsidies to install RES. Similar research was conducted in Jordan by Almrafee and Akaileh, (2023) who found that by applying the multiple regression model, attitude, education, high income, perceived behavioural control, knowledge about renewable energy as well as younger individuals are all factors that positively influence Jordanians' decision to adopt renewable energy. In the Bahraini context, Alsabbagh (2019) conducted a questionnaire survey and found that lack of knowledge about solar energy is the most significant hurdle. Nevertheless, consumers were interested in switching to solar energy if it were fully subsidised by the government since they believe that the cost of switching is expensive. Nevertheless, most households who were educated and receive high income were willing to switch to solar energy.

By conducting a survey and applying structural Equation Modelling, Yazdanpanah *et al.* (2015) found that in Iran and Morocco, self-efficacy, (consumers' confidence in being able to use RES) and perceived usefulness in terms of protecting the environment, are the main factors that positively influence households' decision towards renewable energy. Similarly, by employing structural equation modelling and logistic model, it was highlighted that Iranian females have more tendency to switch to solar energy than males since they are more aware of renewable energy and are more concerned about protecting the environment. It was also found that households in rural Iran are more willing to switch to renewable energy since they have poor electricity infrastructure. Individuals who own big houses and have large families are more willing to install renewable energy sources since they are expected to face fewer obstacles and are expected to reduce the high cost of

electricity. Nevertheless, the cost of installing renewable energy systems remains a significant barrier that impedes Iranians from installing these systems, (Bashiri and Alizadeh, 2017; Komendantova and Yazdanpanah, 2017; Rezaei and Ghofranfarid, 2018). In the Yemeni context, by carrying out a survey it was found that urban households are more knowledgeable and aware about renewable energy than rural households, a discrepancy that holds as the most crucial factor influencing Yemenis' decision to adopt solar energy, (Baharoon et al. 2016).

Overall, most studies revealed that environmental awareness, knowledge of RES, high-income, highly educated, younger individuals and subjective norms, relatives' and neighbours' decisions are the most common factors that positively influence households' decision to adopt RES. In contrast, the cost of installation is found to be the main obstacle to adopting RES. Moreover, it is evident that a gap in the literature exists in studying the factors that influence households' willingness to pay for RES in Egypt. This research aims to measure the factors that drive Egyptian household demand for RES. The following section discusses the empirical investigation of the willingness of households to install PV solar panel in Egypt.

#### **4. Data and Methodology**

This section displays the primary data collected to investigate the willingness of households in Cairo and Giza, Egypt to install PV Solar systems. This section explains the empirical model and methodology adopted, followed by the results.

##### *4.1 Descriptive Analysis*

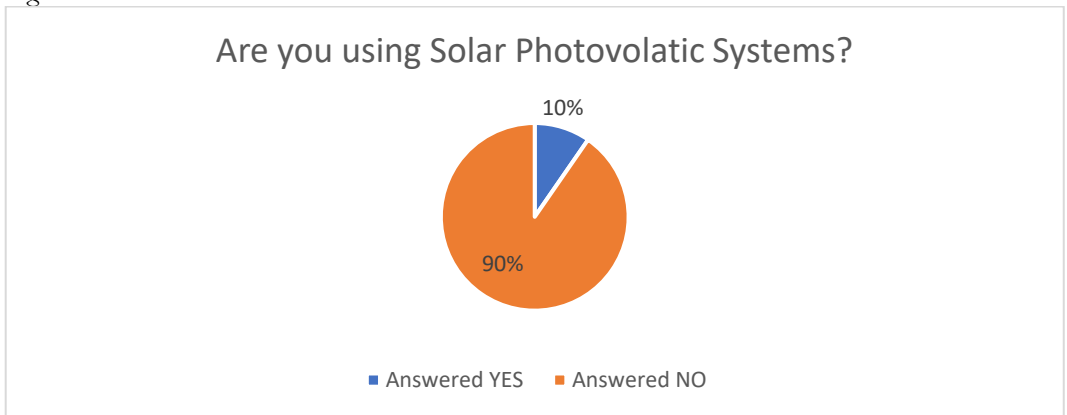
A questionnaire was randomly distributed to 301 households in Cairo and Giza in Egypt. The limited number of observations was owing to the scope of the financing of the project. The persons interviewed in each family were the household heads owing to the belief that in the Egyptian culture, the household head is the main breadwinner, and the primary decision maker regarding the allocation of household expenses. The interviews showed that 31% of the sample are residing in rural areas whereas 68 % were in urban areas, with 1 % nonresponse rate to the area of residence. The respondents' age bracket is between 30-59 years old. Respondents' educational level showed that 7% are uneducated, while 74% have a bachelor's degree and 18% have Masters or PhD degrees. The employment status of the household heads shows that 65% are employed full-time in the private sector followed by the public sector and the least are in the informal sector.

The questionnaire showed that shifting to solar PV systems in Egypt is far from an easy task since only 10 percent of the respondents are using solar PV systems (figure 1 below), and 93% of the respondents heard about solar energy (figure 2 below). Interestingly, 64% of the non-users are not thinking of using solar PV despite credit availability (figure 3). When asked whether they are willing to attain a credit facility to install solar PV, 88% of the respondents answered that they are not willing to attain a credit facility to install solar PV. This may be owing to the high installation costs or to risk factors pertaining to usability knowhow.

Households revealed that the main barriers to solar PV usage are high installation costs followed by lack of enough information about PV, high repair costs, regulations, infrastructure issues, limited installation area, lack of government support/policy and financial assistance, few selling outlets, and low incentives. Most households are dependent on fossil fuel energy sources such as electric or gas, which will be discussed in more detail in the analysis section below.

From the sample of solar users, 2% stated that their degree of satisfaction from using solar PV systems is very good in contrast to 6% who stated that their satisfaction was good. Only 7% of respondents said that they used electricity first and then shifted to PV. These results are alarming due to the limited number of households using solar panels with a majority not intending to use it in the future. Overdependence on fossil fuels owing to lack of trust in shifting to renewable energy should constitute an alarm to policy makers.

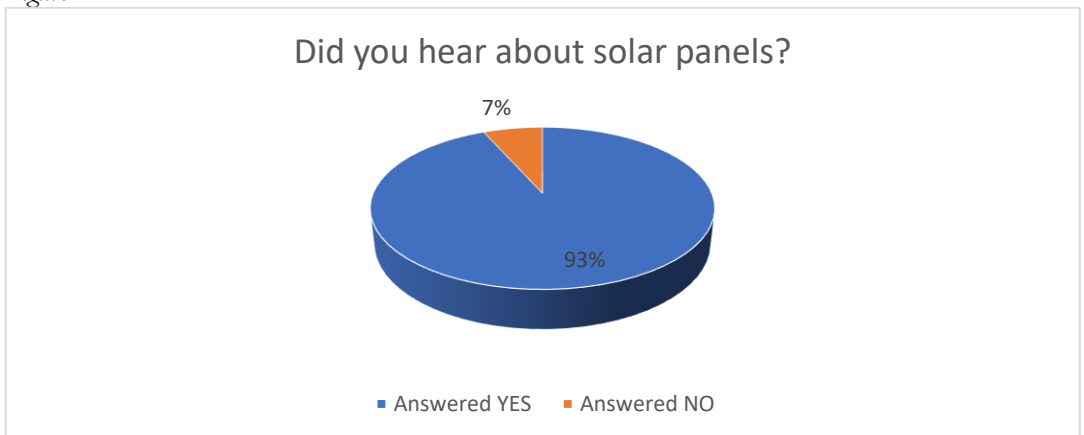
Figure 1



Source: Authors' Results

Figure 1 above shows that 90% of the respondents do not use Solar Panels, and only 10% have used them.

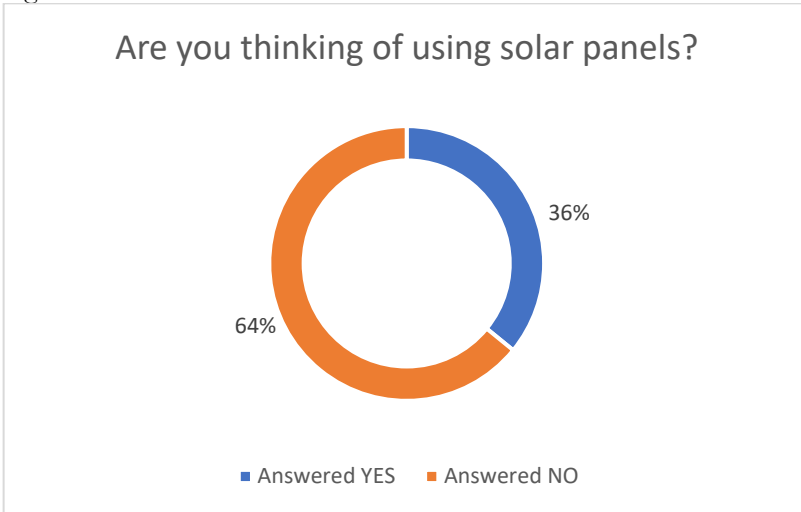
Figure 2



Source: Authors' Result

Figure 2 above shows that 93% of the respondents have heard about solar panels, and 7% have never heard about solar panels.

Figure 3



Source: Authors' Results

Figure 3 above shows an alarming 64% of respondents who are not thinking of using solar panels.

Figure 4

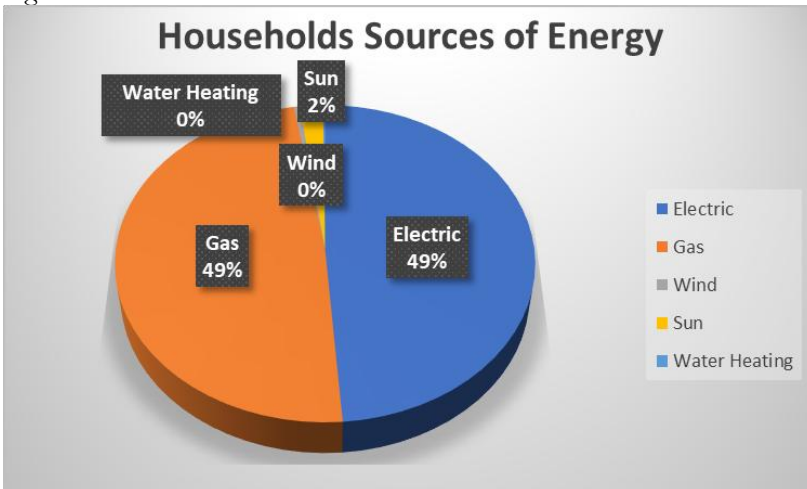


Figure 4 above shows that most households in the sample use fossil fuels as energy sources, with electric and gas sources constituting 98% of the total use, and only 2% use solar energy.

Figure 5

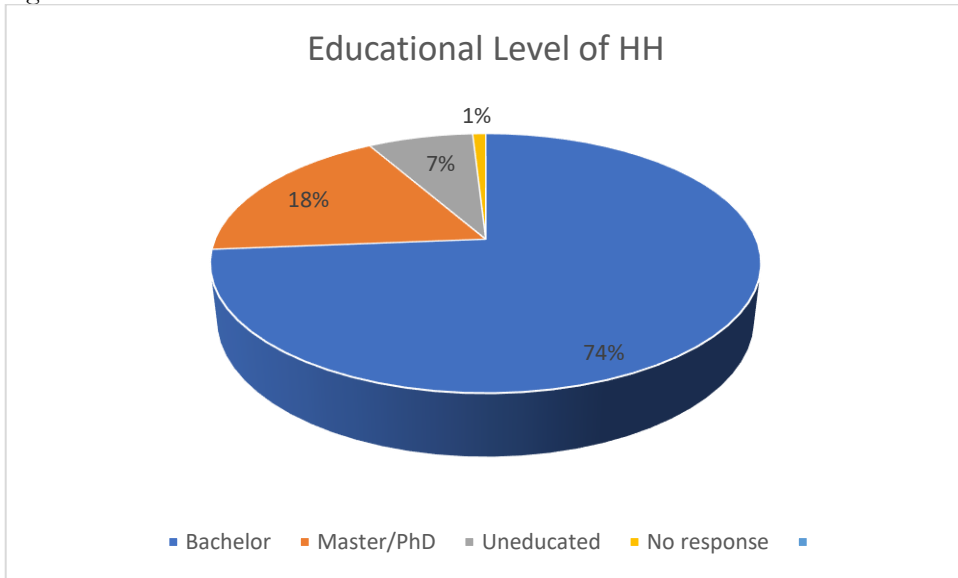


Figure 5 above shows the different educational levels of respondents, the majority having a bachelor's degree, 18% have graduate level education, and 7% are uneducated.

The following section explains the regression models used to estimate the willingness of households to shift to solar PV.

## 4.2 Methodology

The aim of this paper is to investigate the willingness of households to shift to renewable energy usage at home by installing PV solar panels. Hence, the dependent variable is the willingness of households to install solar panels. The response of 1 represents when the household is willing to install solar panels, while the response of 0 if the household is not willing to install PV solar panels. The independent variables encompass the determinants of the willingness of household to install PV solar panels. The model is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \varepsilon, (1)$$

Where  $Y$  is dependent variable representing the household heads' willingness to adopt solar panels at home,  $\beta_0$  is a constant;  $\beta_j$  is the regression coefficient ( $j = 1 \dots 10$ ),  $X_1$  is *age* of the household head,  $X_2$  years of *education* of the household head,  $X_3$  represents the average monthly *income* of the household head,  $X_4$  is a dummy variable for whether the household resides in an *urban or rural area* (1 if urban and 0 if rural),  $X_5$  is the *household size*,  $X_6$  is a dummy variable for whether the household owns a *farm land* (1 if yes and 0 if no),  $X_7$  is a dummy variable for the availability of *natural gas* from underground pipes (1 if yes and 0 if no),  $X_8$  is a dummy variable for the willingness of household to get *credit* facility

to install solar PV system (1 if yes and 0 if no),  $X_9$  is a dummy variable for having access to *internet* at home (1 if yes and 0 if no),  $X_{10}$  is how many times on average was household *disconnected from electricity* per week during the last year, and  $X_{11}$  is a dummy variable for whether any of the household members needed *medical* attention because the home was too hot during last year (1 if yes and 0 if no),  $X_{12}$  is *gender* (1= male and 0= female),  $X_{13}$  is whether the household has access to credit facility, and  $\varepsilon$  is the error term.

Two methodologies are employed to test for the above relationship: The Structural Equation Model (SEM) and Maximum Likelihood of Logistic Regression Model. The estimation techniques and tests are explained in the following sections.

#### 4.2.1 Structural Equation Model:

The Structural Equation Model (SEM) is a methodology for estimating a theoretical network of (mostly) linear relations between variables (Rigdon, 1998). SEM accounts for variation and covariation of the employed variables. Path analysis (e.g., regression) tests models and relationships among MVs. One of the Special cases of SEM is regression (Kline, 1998). The structural equations are estimated simultaneously under OLS method.

Two structural equation models are estimated. The factors believed to influence the decision to shift to solar energy are divided into behavioural and economic determinants, which are incorporated into two separate models. This approach allows for a deeper understanding of the underlying drivers of solar energy adoption. Behavioural variables refer to factors that shape household heads' decisions independently of direct economic pressures and are seen to directly or indirectly influence the adoption of solar usage. These factors include gender, educational attainment, urban versus rural residence, household size—which may collectively influence the decision-making process, and previous medical conditions pertaining to heat waves among family members that could reinforce the preference for cleaner energy sources. In addition, the household's willingness to obtain a credit facility to purchase a solar system is considered a behavioural determinant, as it reflects attitudes and openness toward adopting new technologies rather than purely financial capability.

Economic variables encompass the financial and resource-based conditions that directly shape a household's ability to transition to solar energy. These include the household head's monthly income, which determines its capacity to meet the upfront investment cost; farmland ownership, which may provide additional financial stability or physical space for installation; access to credit facilities, which can reduce liquidity constraints; and the use of gas as an energy source, which may influence the perceived cost–benefit trade-off of switching to solar power. Internet access is also considered an economic factor, as it enables households to obtain information on solar system prices, installation requirements, user reviews, and potential subsidies. In addition, disconnection from the national electricity grid represents an economic and infrastructural constraint that may push households toward alternative energy solutions. Together, these variables capture the material, financial, and infrastructural foundations that either enable or inhibit the adoption of solar energy.

#### A) Behavioral Structural Equation Model

The structural equations are designed as follows:

$$PV = c(1) + c(2)age + c(3)gender + c(4)edu + c(5)urban + c(6)household\ size + c(7)medical + c(8)credit \text{ (Eq. 2)}$$

$$PV = c(9) + c(10)urban * edu + c(11)age * edu + c(12)age * medical \text{ (Eq.3)}$$

$$Credit = c(13) + c(14) * age + c(15)urban * edu + c(16) * PV \text{ (Eq.4)}$$

B) *Economic Structural Equation Model*

$$PV = c(1) + c(2)income + c(3)farm + c(4)edu + c(5)accesscr + c(6)gas + c(7)internet + c(8)cdisconnectfrom\ electricity \text{ (Eq. 5)}$$

$$PV = c(9) + c(10)income * farm + c(11)income * accesscr + c(12)gas * internet \text{ (Eq.6)}$$

$$Income = c(13) + c(14) * farm + c(15)accesscr + c(16)edu \text{ (Eq.7)}$$

#### 4.2.2 Maximum Likelihood of Logistic Regression Model

Maximum Likelihood of Logistic regression model is employed to investigate the determinants of the willingness of household families to install PV solar panel. The logistic regression model is utilized when the dependent variable is binary or dichotomous; that it only contains data observation as 1 ('True', 'Yes') or 0 ('False', 'No'), (Hosmer and Lemeshow, 1980).

The dependent variable which is the willingness of household to install PV solar panel is a function of the likelihood that a particular observation (household) will be in one of the two categories of the dichotomy.

$$f(Z) = \frac{e^z}{1 + e^z} = \frac{1}{1 + e^{-z}}$$

where Z encompasses the measure of the overall contribution of all independent variables in the model, while  $f(Z)$  is the likelihood of a specific outcome that ranges between zero and one. In this context, a negative co-efficient implies that the independent variable decreases the likelihood of the willingness of the household to install the PV solar panel. Further, a high value of a positive co-efficient implies that the independent variable increases the likelihood of the willingness of the household to install the PV solar panel. On the other hand, low positive co-efficient implies small effect of the independent variable on the likelihood of willingness of household to install PV solar panels (Karasmanaki *et al.*, 2019).

## 5. Results

### 5.1 Structural Equation Model Results

Table 1 below displays the results of the behavioral structural equation model in which the determinant of the residual covariance matrix is zero, implying that the estimates are efficient. The results reveal positive significant effects of the variables age of the household head, years of education of the household head, household members needing medical attention because the home was too hot during last year, and the willingness of household to get credit facility.

Results that have a negative significant relationship with the willingness to use solar panels are gender, implying female household heads are more environmentally aware, and the households located in rural areas.

Interaction terms between years of education and households located in urban areas have a positive significant effect on the willingness of households to install PV solar panels, in favour of urban residence. In addition, the interaction term between years of education and age of the household head has a highly positive significant effect on the willingness of households to install PV solar panels. Further, interaction between the age of the household head and household members needing medical attention because the home was too hot during last year is positively associated with the willingness of households to install PV solar panels. Also, the willingness of households to install PV solar panels is positively associated with the willingness of households to get credit facility on the willingness of household to install PV solar panels.

Table 2 below displays the results of the economic structural equation model in which the determinant of the residual covariance matrix is zero, implying that the estimates are efficient. The results reveal positive significant effects of the average monthly income of the household head, the ownership of farmland, and the years of education of the household head on the willingness of household to install PV solar panels. While the household with access to internet at home is negatively associated with the willingness of household to install PV solar panels.

Besides, the interaction term between average monthly income of the household head and the ownership of farmland has high positive significant effect on the willingness of household to install PV solar panels. Further, the interaction term between the average monthly income of the household head and the access of the household to a credit facility to install PV solar panels has positive significant impact on the willingness of household to install PV solar panels. Moreover, years of education of the household head has positive significant impact on the average monthly income of the household head. Yet, the interaction term between availability of natural gas from underground pipes and the household with access to internet at home has a high negative significant impact on the willingness of household to install PV solar panels.

**Table (1):** Behavioural Structural Equation Model Results

	Variable	Co-efficient	P-value
C(1)	Constant	0.126	0.526
C(2)	Age	0.004	0.039**
C(3)	Gender	-0.126	0.059*
C(4)	Edu	0.019	0.024**
C(5)	Urban	-0.129	0.013**
C(6)	Household size	-0.018	0.258
C(7)	medical	0.295	0.081*
C(8)	Credit	0.756	0.000***
C(9)	Constant	0.269	0.014**
C(10)	urban*education	-0.007	0.068***
C(11)	age*education	0.000	0.092
C(12)	age*medical	0.006	0.092
C(13)	constant	0.084	0.365
C(14)	Age	-0.002	0.076*
C(15)	Urban*Education	0.002	0.318**
C(16)	PV	0.338	0.000***
C(17)	Income*Edu	0.000	0.981
C(18)	PV	0.324	0.000***
Determinant residual covariance 0.000			
Adjusted R-squared	Eq(2): 0.29	Eq(3): 0.03	Eq(4): 0.25

\*\*\*, \*\*, and \* show level of significance at 1%, 5%, and 10% respectively

**Table (2):** Economic Structural Equation Model Results

	Variable	Co-efficient	P-value
C(1)	Constant	0.340	0.013**
C(2)	Income	0.000	0.000***
C(3)	Farm	0.249	0.000***
C(4)	Education	0.025	0.000***
C(5)	Access Credit	-0.102	0.149
C(6)	Natural Gas	-0.124	0.116
C(7)	Internet	-0.416	0.000***
C(8)	Disconnect from Electricity	0.013	0.351
C(9)	Constant	0.537	0.006***
C(10)	Income*Farm	0.000	0.0156***
C(11)	Income*Access Credit	0.000	0.003***
C(12)	Gas*Internet	-0.36	0.000***
C(13)	constant	3790.7	0.0166**
C(14)	Farm	393.1	0.653
C(15)	Access credit	798.98	0.325
C(16)	Education	182.1	0.078*
Determinant residual covariance 0.000			
Adjusted R-squared	Eq(2): 0.20	Eq(3): 0.12	Eq(4): 0.01

\*\*\* and \*\* show level of significance at 1% and 5% respectively

**Table (3):** Logistic Regression Model Results

Variable	Co-efficient	P-value
Age	0.022	0.096*
Gender	-1.215	0.002***
Edu	-0.023	0.815
Income	-0.0002	0.381
Household size	-0.045	0.651
Farmland	1.132	0.005**
Natural gas	-0.827	0.054*
Internet	-2.37	0.000***
Medical	0.997	0.287
Disconnected from electricity	0.083	0.256
constant	0.492	0.775
Edu*Income	0.0002	0.11
LR statistic	84.24	
Prob (LR statistic)	0.000***	
Pseudo R-squared	0.218	
Hosmer Lemshow statistic	8.37	
Prob. Chi square (df=8, Hosmer Lemshow statistic)	0.398	

\*\*\*, \*\* and \*show level of significance at 1%, 5% and 10%, respectively

### 5.2 Logistic Regression Model Results

Table 3 below reports the results of the binary logistic regression model, which further examines the determinants of households' willingness to install PV solar panels. The model exhibits strong explanatory power, as indicated by the Likelihood Ratio (LR) statistic of 84.24 ( $p < 0.01$ ) and a Pseudo R-squared of 0.218, showing that approximately 22 percent of the variation in adoption decisions is explained by the included predictors. The Hosmer–Lemeshow test statistic ( $\chi^2 = 8.37$ ,  $p = 0.398$ ) confirms that the model fits the data well, as the null hypothesis of good fit cannot be rejected.

Results that are consistent with the SEM are gender with a negative and highly significant effect, reinforcing that male-headed households are less likely to adopt solar PV systems. Farmland ownership, showing a positive and highly significant coefficient, again underscoring the role of agricultural households in promoting green energy transitions. Similarly, internet access is negatively significant. The age of the household head is positively significant at the 10 percent level, indicating that older household heads are slightly more predisposed to invest in PV systems. Natural gas availability has a negative and marginally significant effect, implying that households with access to cheaper fossil-fuel energy sources are less motivated to transition to solar power. Other variables such as education, income, and household size are not statistically significant, in this model suggesting that these factors, when considered individually, may not fully capture the complex behavioural and socioeconomic dimensions influencing solar energy adoption.

In summary, the logistic model validates the SEM findings by confirming the importance

of demographic, informational, and infrastructural variables. The significant negative coefficients for gender and natural gas access, and the strong positive effects of farmland ownership and internet connectivity, collectively demonstrate that solar PV adoption among Egyptian households is primarily shaped by socio-spatial context, digital inclusion, and alternative energy access.

## 6. Analysis

The empirical results derived from both the Structural Equation Model (SEM) and Logistic Regression collectively provide valuable insights into the socioeconomic and behavioural dynamics influencing household willingness to install photovoltaic (PV) solar panels in Cairo and Giza. Findings from the behavioural model confirm that age, education, willingness to access credit facilities to buy solar panels, and medical conditions pertaining to heat waves, play critical roles in shaping adoption decisions.

As households mature and attain higher levels of education, they may become more willing to take calculated risks to safeguard their families' well-being, particularly in light of escalating and repeated heat waves. Previous heat-wave-related medical conditions within the household appear to further motivate families to adopt solar panels, likely as a strategy to mitigate the risk of complete power disconnection and ensure a reliable source of energy during extreme weather events. Moreover, families are willing to pursue credit facilities in order to cover the substantial upfront investment costs required for solar installation, which they had mentioned as a barrier. There may also be additional costs associated with modifying rooftops, gardens, or façades to accommodate solar panels. Although the decision to shift to renewable energy is not straightforward, and extends beyond purely economic considerations, there remains significant scope for households to adopt solar systems when offered appropriate financial arrangements. Such incentives—whether provided by financial institutions or directly by solar system suppliers—could include instalment-based payment schemes or reduced installation costs, both of which may enhance the attractiveness and accessibility of solar energy adoption.

Conversely, the negative effect of gender highlights structural inequalities in household energy decisions, possibly linked to sociocultural norms that limit women's participation in technical or financial decision-making. Female-headed households may exhibit stronger environmental consciousness in line with the Value-Belief-Norm (VBN) Theory, which associates pro-environmental behaviour with moral and value-driven awareness.

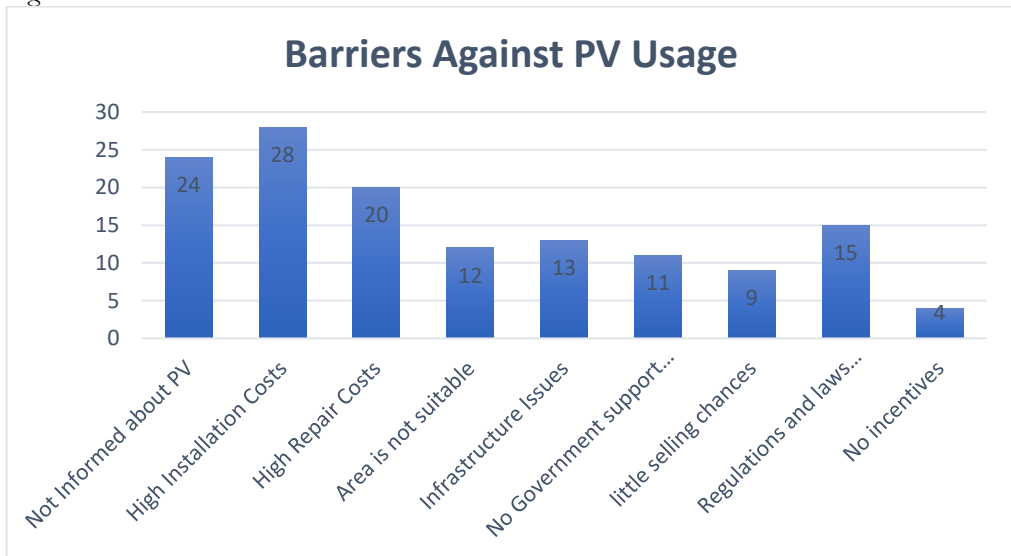
Interestingly, urban households display lower willingness to adopt PV technology, possibly due to grid reliability, limited rooftop space, or bureaucratic barriers in metropolitan areas. In contrast, rural and agricultural households, particularly those owning farmland, show stronger adoption intentions, reflecting the potential of solar energy to reduce energy insecurity and production costs in the agricultural sector.

From an economic perspective, households with higher income levels, those with farmland ownership, and higher educational attainment appear more willing to shift toward clean energy. Conversely, lower-income households tend to exhibit limited awareness of the benefits of solar technology. This can be attributed to lower levels of education which may reduce exposure to information about solar energy. Moreover,

greater financial constraints that restrict access to credit facilities especially for poorer household will remain a barrier towards making any clean energy shifts. These findings are consistent with the Diffusion of Innovation Theory, which posits that new technologies are first adopted by individuals with greater financial capacity and access to information. In this context, households in higher income quintiles are better positioned to absorb the initial costs associated with solar adoption.

Moreover, the negative coefficient on natural gas usage suggests that households dependent on relatively inexpensive and reliable fossil-fuel energy face limited incentives to transition to renewable alternatives. This finding reflects the currently weak incentive structures for shifting to clean energy and indicates low awareness of the environmental and long-term risks associated with continued fossil-fuel dependence. These outcomes underscore the need for more effective energy-pricing reforms and targeted incentive schemes. Interestingly, the results also reveal a negative relationship between internet access and willingness to adopt solar panels. Although digital connectivity typically enhances access to information, this pattern may reflect the current Egyptian context, where online platforms often feature shared complaints, negative reviews, and reports of the technical and financial challenges associated with purchasing and/or installing solar systems in a still nascent household-level industry. Moreover, digitally connected and urban households who are already benefiting from stable grid electricity, may perceive solar systems as less essential. In contrast, rural households, which often lack reliable internet access and grid stability, continue to rely more heavily on off-grid solutions, including solar energy.

Figure 6



Source: Authors' Results

Respondents identified several barriers to adopting solar panels, as shown in Figure 6. The most frequently cited obstacle was the high initial installation cost, a constraint that could

be alleviated through access to credit facilities. This aligns with the empirical results, which indicate a strong preference among households for obtaining credit as a means of financing solar energy installations at home. Second, comes lack of sufficient information about solar panels. Firsthand user information may be best compared to online information, especially in the light of the negative association with internet access. Households may also be encouraged to adopt solar systems when they observe neighbouring families successfully installing and benefiting from them, reinforcing the role of social influence and demonstration effects in shaping adoption decisions. Third comes high costs of repairs. It is not guaranteed that the purchase of solar systems will be followed by responsive customer service on part of the sellers, which may spur fears for first-time users. Fourth, unclear laws and regulations regarding installation permits, licenses and the required paperwork. Although Egypt is making significant progress toward digitalizing public services, it remains unclear whether the renewable energy sector is fully integrated into these digital platforms. Fifth, respondents have mentioned infrastructure barriers regarding installation areas. So far, solar panels must either be placed on rooftops, or in gardens with ample sunlight. This limits the users to those who own/rent standalone houses, or have farms as is consistent with the empirical outcomes. Once solar panels are logistically and technically extendable to fit fixed on residential blocks where housing is in the form of apartments, that is, layouts of poorer neighbourhoods. This may help extend the number of users massively. In this context, families in separate apartments may share larger solar panels that are divided across various grids. This provides scope for further research on the technical, behavioural and economic fronts.

Respondents noted that they require government support to purchase or install solar panels. This may indicate underlying trust issues with private suppliers and/or government regulators, particularly regarding pricing, storage capacity, resale options, and related concerns. A smaller proportion of respondents reported limited knowledge of reputable suppliers, while others cited the absence of sufficient incentives to motivate a transition to solar energy.

The identified barriers point to the importance of transparent pricing mechanisms, reliable maintenance services, and accessible financing instruments. However, improving awareness remains challenging when affordability concerns and limited institutional trust persist. Strengthening the alignment between subsidy reform and targeted communication strategies could help address these issues, making solar systems more viable, particularly in rural areas where frequent grid disruptions heighten household vulnerability.

## 7. Conclusion and Policy Implications

From a policy standpoint, the results underscore the need for a just, inclusive, and multi-dimensional energy transition strategy in Egypt—one that operates not only at the national level but also through grassroots, community-based engagement. Expanding access to affordable financing such as green microcredit, low-interest loans, or instalment schemes can substantially increase adoption rates, particularly among low- and middle-income households who face high upfront installation costs. These financial measures should be implemented alongside locally grounded awareness and demonstration

initiatives, delivered through government bodies, neighbourhood centres, schools, community organisations, and trusted local actors. Such interventions can leverage social influence by enabling households to observe the tangible benefits experienced by neighbours into the community who have successfully adopted solar systems.

Addressing gender disparities remains critical; programmes that promote women's participation in renewable energy training, entrepreneurship, and household-level energy decisions can enhance inclusiveness and strengthen behavioural drivers of adoption. Moreover, to build trust in the market and reduce concerns about system reliability, establishing community-based maintenance hubs and local registries of certified installers would help improve after-sales service and provide households with credible, accessible support networks.

The positive influence of farmland ownership further indicates that rural electrification initiatives should integrate PV systems into agricultural production processes, such as irrigation and cold-chain storage, supported by tailored incentives for hybrid energy solutions. In urban settings, promoting shared solar systems at the neighbourhood or building scale and offering modular or mobile panel options can extend renewable energy access to residents with limited rooftop capacity.

Lastly, although internet connectivity currently shows a negative association with adoption, strengthening digital inclusion remains essential. Integrating renewable energy services into digital platforms—and supporting this through local digital-access points—can improve transparency in subsidy allocation, streamline financing applications, and broaden access to technical information for households and technicians alike. Collectively, these interconnected measures can bridge financial, informational, and trust gaps, enabling a more equitable and effective solar transition in Egypt.

In conclusion, Egypt's solar transition requires an integrated strategy at the grassroots level that links financial access, education, gender inclusion, and infrastructure development. The study provides empirical evidence supporting Egypt's renewable energy agenda and contributes to the broader Mediterranean discourse on climate adaptation and sustainable energy equity. Achieving the goals of Egypt Vision 2030 and the EU–Mediterranean Green Transition will depend on harmonizing behavioural, social, and economic dimensions within the national energy framework.

Future research should investigate whether digital access genuinely promotes solar adoption or alternatively strengthens dependence on conventional energy among urban households. Further exploration of how information credibility, risk perceptions, and social networks shape adoption decisions would help unpack this relationship. Extending the analysis to additional governorates beyond Cairo and Giza would also enhance national representativeness and provide stronger evidence for designing targeted renewable energy policies.

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