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Perception and Diffusion of Photovoltaic Systems among Potential Adopters in Rural Communities in Mexico

Case Study in Chiquilistlán, México

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ABSTRACT:
This study identifies the current perceptions high school students between the ages of 15-18 in rural communities in México have of photovoltaic (PV) systems and suggests proper ways to diffuse them. The empirical data was gathered through questionnaire-type surveys and semi-structured interviews conducted among high school students in Chiquilistlán, México.

PV systems exist and are readily available worldwide. However, the desired implementation levels have not yet been reached in developing countries such as México, where approximately 1.5 million people lack access to electricity. The most significant impact of PV systems ought to be seen in rural communities, which account for 23% of the Mexican population. Due to their low population density and remoteness, rural areas tend to have deficient infrastructure that impedes their inclusion in the national electricity grids. Therefore, the need to locally supply electricity arises, and PV systems become the means to close the existing energy gap in the country. Furthermore, considering the yearly rise of the median age in México, the population is getting older. Hence the importance of knowing how younger generations in rural communities perceive PV systems.

From the reasons stated above, the following research question was derived: *how are photovoltaic systems perceived among potential adopters in rural communities and how to diffuse them properly?* In order to answer to this question, three objectives were considered: (1) to identify the core perceptions of PV systems among potential adopters in Chiquilistlán, México; (2) to understand the socio-demographic aspects of potential adopters and identify relationships with their perceptions; and (3) to propose appropriate diffusion processes suitable for rural communities.

Results show a higher perception of *relative advantage* of PV systems, followed by *observability*, *compatibility*, and *simplicity*. The primary motivators of potential adopters to positively perceive PV systems were generation monitoring, solar power potential, and income monitoring. On the other hand, maintenance, installation costs, and access to providers were the main barriers to a positive perception. Additionally, it was found that the kind of stove present at their homes, having (or not) internet access every day, their overall acceptance (or rejection) of PV systems, and their environmental awareness scores had a significant impact on how they currently perceive PV systems.

Given the previous finding and based on interviewees' responses, three main ways to approach potential adopters are proposed: face-to-face, online discussion groups, and printed information. If successfully performed, the perception of PV systems in rural communities in México will positively increase, leading to broader implementation in the medium and long run.

The exploratory nature of the study allowed the researcher to make recommendations for future studies. The previous will contribute to closing the existing research gap to a reasonable extent.

KEYWORDS: Perceived attributes of innovations, photovoltaic systems, rural communities, México

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To my mother.

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Abbreviations

AC	Alternate Current electricity
BOS	Balance-Of-System equipment
BP	British Petroleum
CONEVAL	National Council for the Evaluation of Social Development Policy *(Consejo Nacional de Evaluación de la Política de Desarrollo Social)*
DC	Direct Current electricity
DOI	Diffusion of Innovations
EEA	European Environment Agency
FAO	Food and Agriculture Organization of the United Nations
G20	Group of twenty
GDP	Gross Domestic Product
GHG	Green House Gases
ICT	Information and Communication Technologies
IFAD	International Fund for Agricultural Development
IEA	International Energy Agency
IIEG	Institute for Statistics and Geographic Information of Jalisco *(Instituto de Información Estadística y Geográfica de Jalisco)*
INEGI	National Institute for Statistics and Geography *(Instituto Nacional de Geo grafía y Estadística)*

IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LPG	Liquefied Petroleum Gas
MW	Megawatt
NGV	Natural Gas for Vehicle
PV	Photovoltaic
RE	Renewable Energy
RET	Renewable Energy Technology
SEDESOL	Ministry of Social Development *(Secretaría de Desarrollo Social)*
SENER	Ministry of Energy *(Secretaría de Energía)*
SEP	Ministry of Public Education *(Secretaría de Educación Pública)*
SWH	Sun Water Heating
TV	Television
UN	United Nations
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
USD	United States Dollars
USMCA	United States - México - Canada

1 Introduction

1.1 Background

The use and quality of energy must be seen as a crucial factor in the evolution of humanity. If history is revised, the most important technological developments were those that represented the opportunity to obtain energy from natural resources. These technological developments ultimately implied economic improvements, increased resource availability, more splendid energy service for consumers, and business opportunities (Malanima, 2014; Harvey, 2017; Cherif, Hasanov, & Pande, 2017.)

Mastering better and improved energy flows has allowed societies to grow and prevail. In old civilizations, any energy-related discoveries or innovations did not mean a replacement of the existing sources or methods but rather an addition to the energy balance. An example of it was the windmills and waterwheels, which did not substitute the broadly used organic vegetable sources but were jointly operated. However, the emergence and extensive popularization of fossil sources in the last two hundred years meant an increase of 45 to 50 times in the global energy demand and indeed a partial, nearly absolute, substitution of the already existing energy sources. This substitution has dominated until today and has led to a tremendous increment in the number of gases in the atmosphere. (Smil, 2004; Cottrell, 2009; Malanima, 2014.)

Such gases (e.g., carbon dioxide, sulfur dioxide, and nitrogen monoxide) are called Green House Gases (GHG). Around two-thirds of the GHG in the atmosphere nowadays exist due to the extensive use of fossil energy sources (IPCC, 2014). GHG are held responsible for the temperature rise, which is consequently melting the poles and rising the sea levels, increasing the negative impacts on the environment and societies worldwide. Therefore, a rapid progression towards a life with less -and even without, fossil fuels is needed (Shahzad, 2015; Szabó, 2017).

According to the International Renewable Energy Agency (IRENA), as of 2018, renewable sources contributed only 18% of the total energy generated globally. Though, to be in line with the *Paris Agreement* and keep the global temperature rise below 2° Celsius in the 21st century, renewable sources ought to account for 66% by the year 2050 (UNFCCC, 2015). Fortunately, it is conceptually and technically possible to reach this goal, increasing energy availability and reducing fossil-based energy generation's global share (Gielen et al., 2019; IRENA, 2020).

Even though the technology to obtain energy from renewable sources exists and is readily available worldwide, it has mostly been extensively deployed in developed, highly industrialized countries (IEA, 2009). It has not reached the desired implementation levels in developing countries since the mere fact of releasing new energy technologies is not enough. They must be spread and diffused.

As of 2015, around 15% of the global population did not have access to energy, out of which 84% lived in rural areas (Expansión, 2016). Due to their low population density and remoteness, rural areas worldwide tend to lack the needed infrastructure to be included in the national energy grids. Therefore, energy ought to be supplied locally. The adoption of renewable energy technologies by developing countries, and especially by rural communities, will not only contribute to grant them access to energy and to decrease global carbon emissions, but to earn socio-economic benefits, such as new jobs, a cleaner environment, and energy security (Pfeiffer & Mulder, 2013; Reyes-Mercado, 2013).

Diffusion and adoption of renewable energy innovations are of particular interest in Mexico, a developing country according to the United Nations (2019) and with a very high potential for renewable source exploitation. Mexico plays a vital role as it is the only developing country in North America yet a member of the G20, a group of countries that accounts for 90% of the world economy and 80% of the international trade (Gobierno de México, 2015).

In Mexico, the energy generated from renewable sources represented only 5.77% in 2019. Interestingly, only 11.76% of the total RE installed capacity in Mexico belonged to photovoltaic (PV) solar energy in the same year (BP, 2020). The latter is surprising considering that Mexico's PV energy potential is amongst the highest in the world since it is located in the so-called "Solar Belt" and has the most extensive PV system manufacturing network in Latin America (Alemán-Nava et al., 2014). Hence, the potential market for PV systems in Mexico is immense.

Furthermore, the Mexican energy grid supplies 98.7% of the population (INEGI, 2015), leaving the remaining 1.3% (approximately 1.5 million people) from rural communities and other remote and underdeveloped areas with deficient availability or even entirely out of the system. It has been estimated that around 6,500 communities lack energy access all over the country (Rodríguez, 2019).

Given the PV energy potential and the size of the potential market in rural communities (23% of the Mexican population is considered rural (FAO, 2018)), PV systems' implementation could have a significant impact. Nevertheless, they have not been adequately positioned, and therefore their implementation by individual adopters is relatively low.

1.2 Research gap, question, and objectives

As stated by the Mexican Ministry of Energy (SENER, 2009), Mexico has an average solar irradiance potential of 5 kilowatt-hours per day per square meter (kWh/day/m^2). According to the World Bank (2020), an area of 0.1% of the Mexican territory (~ 2,000 km^2) would suffice to generate enough energy to cover the country's existing demand. Due to the previous, Mexico's solar energy potential is practically infinite.

Cullell (2019) reported that over 85% of the Mexican territory gets optimal solar radiation. However, according to INEGI (2015), only 0.5% of the total number of households (approximately 160 thousand (out of 31 million) have implemented photovoltaic systems by their own choice by 2015. A meager amount of these households -perhaps insignificant- belongs to rural and remote areas. Thereby, PV systems emerge as a viable means to close the existing "energy gap" in Mexico.

One of the energy-related disadvantages of rural communities is their remoteness, making it expensive for energy providers to reach them and supply the energy. Without energy, rural businesses and farmers encounter challenges to adopting new and enhanced technologies, thus leaving them out of value chains and preventing them from growing (IFAD, 2018).

International experience has shown that RET (Renewable Energy Technology) implementation brings a wide range of economic, social, and environmental benefits (SENER, 2009). As claimed by the Food and Agriculture Organization of the United Nations (2000), better known as FAO, it is vital to find and implement new, inexpensive, and healthy means to produce energy in rural communities. These "enhanced" means will improve rural societies' welfare and business performance. The FAO (2000) argues that photovoltaic systems are crucial to this solution as they are flexible, require little maintenance, and are environmental-friendly.

Private investors have funded PV grids in remote communities in Mexico, benefiting thousands of families (World Bank, 2017; Iberdrola México, 2019). Notwithstanding, people from the benefited communities may not have had a say in these massive projects. What do they think of the PV systems? How do they perceive them? What factors prevented them from their earlier implementation? Are these systems compatible with their needs and beliefs? In these cases, the decisions over the installation of the PV grids were of the type of *Authority Innovation-decision*, which according to Rogers (2003: 403), are the choices made by relatively few members of a system who hold positions of power, technical expertise, or high social status.

There is currently a lack of data and available research regarding individual adoption of PV systems in Mexico's rural communities. This kind of decision is called *Optional Innovation-decision,* and it refers to the choice made by an individual independent of the choices made by other members of a system (Rogers, 2003: 403). It is crucial to understand how individual adopters perceive PV systems. Once these perceptions are understood, proper ways to diffuse them among communities can be developed. If the previous is accomplished, implementation rates will increase, with more people with electricity and a better quality of life. A vast number of studies addressing these matters will be needed to close the existing research gap to a reasonable extent.

Even when an idea has obvious advantages, it is difficult for it to be adopted (Rogers, 2003: 1). This paper aims to provide diffusion insights for authorities, opinion leaders, and providers based on the future market's current perceptions about photovoltaic systems. Although the study spots rural communities in Mexico, it focuses explicitly on high school students in Chiquilistlán, México, as future potential adopters. The main research question (RQ) is stated as follows:

RQ: *How are photovoltaic systems perceived among potential adopters in rural communities, and how to diffuse them properly?*

The following research objectives (RO) are considered to answer the research question:

RO1: *To identify the core perceptions of photovoltaic systems among potential adopters in Chiquilistlán, México.*

RO2: *To understand the socio-demographic aspects of potential adopters in Chiquilistlán, México and identify relationships with their perceptions.*

RO3: *To propose appropriate diffusion processes suitable for potential adopters in rural communities.*

1.3 Definitions and limitations

Perceived attributes of innovations

It refers to the perceived characteristics of innovations established by Rogers (2003). These attributes help researchers understand adopters' behavior towards innovations and will, in the end, determine their likelihood for adoption or rejection. The perceived characteristics are:

- *Relative advantage*: the extent to which a new idea is considered better than the one it is attempting to set aside, perhaps eventually replace.

- *Compatibility:* the degree to which an innovation is coherent with the already existing values, experiences, and necessities of the adoption unit.

- *Complexity:* the perception of an innovation being challenging to understand and use.

- *Trialability:* the extent to which an innovation is tried before it is adopted.

- *Observability:* the degree to which an innovation's results are observable by the unit of adoption.

The concept of *perceived attributes of innovations* belongs to the broader Diffusion of Innovations (DOI) (Rogers, 2003). The previous represents a limitation for this research as it will focus the analysis on the perceived attributes of innovations and not on the whole DOI theory, its variables, and processes.

Photovoltaic systems

Photovoltaic (PV) means "electricity from light." PV systems often referred to as solar cells, are electronic devices that absorb the sunlight to convert it into electricity in a clean and renewable manner. The generation of electricity through this process prevents the emissions of carbon dioxide (CO^2). (Jones & Mayfield, 2016: 48; Mughal, Raj Sood, & Jarial, 2018.)

The limitation of this research is found in the fact that it focuses on PV systems. In other words, it studies the systems used to transform sunlight into electricity. It does not consider those technologies that capture the heat from the sunlight to heat water or generate steam.

Rural communities

According to Chomitz, Buys, and Thomas (2005), "rural" and "urban" terms are somewhat imprecise. These terms have been traditionally taken as a dichotomy, representing opposing (sometimes entirely different) ideas. Thence, Chomitz et al., (2005) suggest stopping to see rurality and urbanity as a dichotomy and think of them as a gradient. Their research, conducted in Latin American and Caribbean countries, proposed defining rural-urban gradient based on two dimensions: population density and remoteness from larger cities.

Considering the dimensions stated above and the results from Chomitz et al., (2005) study, a community is considered rural if: (1)it has a population density lower than 150 inhabitants per square kilometer, and (2) it is located more than one hour away from cities with a population >100,000.

Limitations of the present document are found in the fact that "rural" communities located in regions of the world different than Latin American and the Caribbean may not be comparable to the results obtained here. Additionally, several definitions for “rurality” can be found in the existing literature, and they tend to vary slightly. This definition is only one of many, and therefore others may not be a fit for this study.

Mexico

México is a democratic country divided into 32 states. Located in North America, it borders the United States in the north and Guatemala and Belize in the south (UNDP, 2021). It covers a geographic area of 1,960,670.2 km^2 with 119,530,753 inhabitants per the 2015 census (INEGI, 2015). Spanish is the official language, and there are 68 indigenous dialects spoken across the country (Gobierno de México, 2018). In 2019, its GDP per capita was USD 9,946.03 (World Bank, 2021).

This research focuses on Chiquilistlan, a municipality located in the state of Jalisco in Mexico. Within Chiquilistlán, the focus is put on high school students between the ages of 15-18. The study does not contemplate what type of knowledge in renewable energies in general and PV systems in particular these age group has. Moreover, it does not consider other rural communities, neither in Mexico nor in other Latin American or developing countries.

1.4 Structure of the study

The first chapter contains the introduction of the thesis. It starts with a general overview of the renewable energy scheme in the world and Mexico. It also contains the problem statement, briefly explains the existing literature gap about this topic, and presents the research question and objectives that will be discussed later in the document. In this same chapter, keywords are defined, and the limitations of the study are stated. It then continues by explaining how the subsequent sections will be structured.

Chapter 3 explains the photovoltaic principle and describes the general configuration and functionality of a PV system. Also, this chapter outlines the Diffusion of Innovations theory and its different elements, such as the perceived attributes of innovations. The theoretical framework is presented.

Chapter 3 emphasizes the case country (México) and community (Chiquilistlán) being analyzed in this thesis. It provides an overall description of the socio-economic and energy situations at both levels. At the community level, the PV potential for energy generation is displayed, and the poverty situation in Chiquilistlán is briefly introduced. The decision for Chiquilistlán being the community for analysis is justified.

Chapter 4 describes the methodology used in this thesis. It includes the research design, research strategy, research approach, and sampling design.

Chapter 5 focuses on the empirical analysis and the interpretation of the results. The different methods used to collect and analyze data are described. Descriptive and inferential statistics were used to analyze quantitative data, whereas narrative analysis was conducted for qualitative data. The last part of this chapter states the validity and reliability of the study.

Lastly, Chapter 6 summarizes the document as a whole and recapitulates the main findings while giving them a further interpretation. Courses of action are suggested based on this thesis's results to improve how potential adopters perceive PV systems in rural communities in México. Future research suggestions are provided in the very last sub-section of this document.

2 Literature review

2.1 Photovoltaic principle and system configuration

"Solar photovoltaic" is the name given to the technology that converts sunlight into electricity. Photovoltaic means "electricity from light," and through the photovoltaic effect, sunlight is converted into electricity. The PV effect results when the semiconducting material in a PV solar cell absorbs solar photons. When the negatively charged semiconducting material (N-type material) has absorbed enough photons, atoms in the material eject their electrons. Electrons are negatively charged, thus they are attracted to the front of the solar cell, which is covered by positive charges (P-type material). A voltage potential is created from the attraction of negative and positive charges in the layer where the two materials join (P/N junction), thus generating a flow of electricity. (Jones & Mayfield, 2016; Mughal et al., 2018; Ashok, 2020.)

The discovery of the photovoltaic effect is owed to Edmond Becquerel, a French scientist who in 1839 studied the electrical effects of electrodes immersed in electrolytes. Until 1954, Daryl Chapin, Calvin Fuller, and Gerald Pearson developed the first silicon solar cell already with a 6% efficiency (Chodos, 2009; Lincot, 2017; Mughal et al., 2018; Energy Matters, 2021).

Solar cells have continuously evolved since their first creation, with ever-increasing improvements in designs and materials, allowing scientists and engineers to create cells with an efficiency of 40% (Chodos, 2009). Nowadays, there are different types of solar PV panels, for instance, monocrystalline silicon, polycrystalline silicon, thick-film silicon, and amorphous silicon (Mughal et al., 2018).

Photovoltaic systems have been widely studied, and they are no longer considered innovations in the global energy scope. However, as Rogers (2003) stated, it matters little whether the innovation is new if measured with respect to time. If an individual perceives an innovation as new, then it is an innovation. Following Rogers' concepts, PV systems are still perceived as innovations by renewable energy novices in different social contexts (Hai, 2019). For that reason, research needs to be done in diffusing and understanding potential adopters' perceptions towards PV systems. The present study attempts to address the latter issues.

General configuration and functioning of a PV system

Regardless of the semiconductor materials solar cells are made of (e.g., crystalline silicon, zinc sulfide, gallium arsenide, cadmium telluride) they all work under the same principle and have the following main components: PV array and Balance-Of-System (BOS) equipment. A *PV array* is a set of PV modules, which contain solar cells that convert the sunlight into electricity. It is the biggest component of the system. The *BOS* is divided into power conditioning equipment and energy storage. *Power conditioning equipment* refers to chargers, inverters, controllers, and wiring that condition the generated electricity and make it suitable for utilization loads. *Energy storage*, mainly constituted by batteries, allows the system to store energy and access it when there is no solar radiation available (Dunlop, 2012; Zekry, Shaker, & Salem, 2018).

At the beginning of this section, the photovoltaic effect, the main principle under PV systems work, was explained. However, much more than that is needed to store and use the energy generated in the system. First of all, as discussed earlier, sunlight strikes the solar panels formed by cells. These are made of a P-type material and an N-type material (positively charged and negatively charged, respectively). The panel's cells convert the sun's energy into Direct Current (DC) electricity, and it is sent to an inverter. The inverter converts DC into Alternate Current (AC), the most commonly used form of electricity. The AC electricity flows from the inverter to the load center and is thus directed to the house appliances and lightning devices as electrical load. When the energy system generates more electricity than needed, unused energy automatically flows to the utility company and into the grid. Some systems also have batteries to store unused energy when demand exceeds solar production without requiring electricity from the grid (Dunlop, 2012). The previously described process is depicted in Figure 1 below.

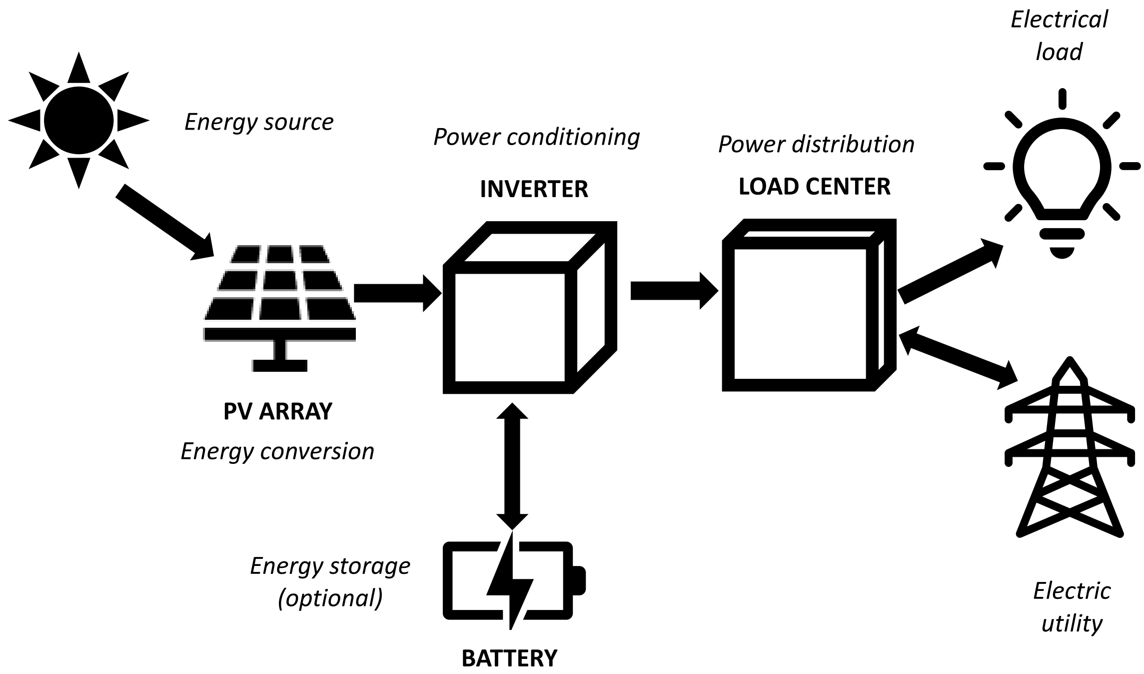


Figure 1. General configuration a PV system. (Adapted from Dunlop, 2012)

2.2 Diffusion of Innovations theory

Fossil fuels' vastly established infrastructure makes it easy to transport and access them anywhere in the world, thence making them the primary source of energy. Unfortunately, transport and access to renewable sources of energy are more complicated. Innovation can help renewable surpass fossil sources' share in the global energy balance (EEA, 2020). However, the mere fact of releasing new energy technologies is not enough. They must be spread and diffused.

Ye, Jha, and Desouza (2015) claim that their business values must be effectively diffused and communicated in order for innovations to succeed. The latter statement also applies to the innovations within the field of renewable energy. By following the "Diffusion of Innovations"

(DOI) theory framed by Rogers (2003), perception and diffusion of PV systems will be analyzed among potential adopters in Chiquilistlán, Mexico.

The process of adopting and diffusing innovations has been widely studied since the 20th century, and it has not been exclusive to one discipline (Hölttä, 1989; Sahin, 2006). Diffusion theories attempt to explain the adoption of new ideas and practices by individuals and social systems (Musa Ibrahim, Gbaje, & Monsurat, 2015; Trott, 2017: 98). Unlike other innovation diffusion theories (e.g., Ryan and Gross' (1943)), the *Diffusion of Innovations* (DOI) theory constructed by Everett Rogers (1962) has been extensively tested and implemented in a variety of disciplines such as economics, communications, political science, history, public health, education, and technology (Mahajan & Peterson, 1979; Dooley, 1999; Stuart, 2000; Karakaya, Hidalgo, & Nuur, 2014; Musa Ibrahim et al., 2015).

Even though it was first established in 1962, Roger's DOI theory has evolved through time and continued to influence many studies and models. It has become the most widely accepted and used innovation diffusion theory, thus the dominant framework in diffusion research (Dooley, 1999; Stuart, 2000; Sherry & Gibson, 2002; Sahin, 2006; Aizstrauta, Ginters, & Piera-Eroles, 2015; Tanye, 2017).

According to Robinson (2012), Rogers' theory has a different approach than other change theories: it is not individuals who ought to change, but innovations are. *Diffusion of innovations* theory does not aim to persuade potential adopters to change but instead sees change as the evolution of products and attitudes to reach a broader implementation in individuals and groups.

Rogers built his DOI theory based on Ryan's and Gross's (1943) work. The latter two authors conducted a study about the diffusion of hybrid corn seeds among farmers in Iowa, USA. Their main goal was to find why some farmers were adopting the hybrid seeds earlier than others and what factors were influencing their decision. In the end, they demonstrated that innovation diffusion was indeed a social process and that individual adoption of advantageous innovations happens at the same time within the social system (Valente, 1995: 2). From these findings and after analyzing other similar studies, Rogers was able to draw the following conclusion. Regardless of the innovation, diffusion patterns are the same within a particular social system (Raymond, 2010: 17).

Rogers (2003:5) defined *Diffusion of innovations* as “the process by which an innovation is communicated through certain channels over time among the members of a social system”. Valente (1995) puts it in other words by stating that diffusion consists of the spread of innovations in a community or social group by a process in which adopters invite those who have not yet adopted to adopt. Four main elements are found in Rogers’ definition: innovation, communication channels, time, and social system.

Innovation

It refers to “an idea, practice, or object that is perceived as new by an individual or other unit of adoption”. Disregarding the newness of the idea with respect to the time of its discovery or first use, the only thing that matters is how it is perceived. As long as the idea is new to the individual, it can be considered an innovation. Traditionally, the concept of *innovation* is associated with *technology,* which is defined by Rogers (2003) as “a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving the desired outcome”. Uncertainty is frequently translated to lack of structure, of information, and the impossibility to predict. (Rogers, 2003: 11-12.)

All innovations are not equivalent units of analysis. Evidence of this is that some innovations succeed, and others fail (Aizstrauta et al., 2015). Each innovation has its own unique “objective” attributes, but it is the individual’s perception of the innovation attributes and not the “objective” ones that determine the innovation adoption (or rejection). Rogers reported that from 49% to 87% of the variance in the adoption decision-making is determined by these perceived attributes (Rogers, 2003: 221).

The perceived attributes of innovations refer to the perceived characteristics of innovations established by Rogers (2003). These attributes help researchers understand adopters' behavior towards innovations and will, in the end, determine their adoption or rejection likelihood. The perceived characteristics are relative advantage, compatibility, complexity, trialability, and observability. Since the perceived attributes of innovations are the most significant factor influencing their adoption of rejection, the following section provides an in-depth analysis of the attributes proposed by Rogers in his DOI theory.

Communication channels

The second element is *communication channels.* To Rogers, communication is the “process by which participants create and share information to reach a mutual understanding”. Communication implies that individuals move towards each other (or apart) through the exchange of information and is then a process of convergence (or divergence). Furthermore, *communication channels* are the way by which messages go from one individual to another. There are two main communication channels. On the one hand, mass media channels refer to all those means of transmitting messages that require a mass medium and allow one individual to reach large audiences to inform them effectively. On the other hand, interpersonal channels require face-to-face interaction of two or more individuals and have greater effectiveness when persuading individuals to embrace and adopt an innovation (Rogers, 2003: 5-6, 18-19; Mahapatra & Gustavsson, 2008.)

Time

The third element of the diffusion of innovations process is *time.* As reported by Rogers, many behavioral science studies ignore the time dimension. Considering *time* in diffusion research is crucial, as an individual’s adoption or rejection of an innovation is not instantaneous but rather a process. Rogers includes the time dimension in the innovation-decision process. (Rogers, 2003: 20.)

The innovation-decision process refers to the process by which the unit of adoption goes from first knowledge of an innovation, to forming an attitude concerning the innovation, to a decision to adopt (or reject), to implement and use the innovation, and to the confirmation of the decision previously made. Five main steps constitute the innovation-decision process: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation.

Knowledge is acquired when the decision-making unit becomes aware of the existence of the innovation and learns something about its functionality. *Persuasion* occurs when the unit develops an attitude towards the innovation, whether it is favorable or unfavorable. *Decision* occurs when the individual commits to activities that guide to a choice of adoption or rejection of the innovation. *Implementation* happens when an individual starts using the innovation. *Confirmation* results when individuals convince themselves of the decision that has been made. (Rogers, 2003: 20.)

Social system

The fourth and last element is the *social system*, which is defined as “a set of interrelated units that are engaged in joint problem solving to accomplish a common goal. The members of a social system may be individuals, informal groups, organizations and/or subsystems” (Rogers, 2003). Rogers claims that each member of a social system is different from other members and that all units attempt to reach common objectives. (Rogers, 2003: 23-25.)

The structure of a social system shapes the diffusion process, and the social system itself represents a boundary (or a means) by which the innovation diffuses (Rogers, 2003). Early diffusion scholars such as Katz (1961) remarked that not knowing the social structures of the systems where potential adopters are located makes diffusion studies impossible and compared it to wanting to study blood circulation without having proper knowledge of veins and arteries.

Researchers have found that potential adopters' adoption decisions are highly influenced by the social system in which adopters are immersed (Sidiras & Kuokios, 2004; Jager, 2006; Ozaki, 2011), and thence social influence is of great importance in technology adoption (Rogers, 2003; Young, 2009).

Two important aspects of the social system's structures are innovation-decisions and the role of opinion leaders and change agents. The *types of innovation-decision* are an important influence in the diffusion of new ideas across a social system. Rogers (2003: 28-29) established three different types of innovation-decisions that lead to the adoption or rejection of them:

- *Optional innovation-decisions:* adoption or rejection of innovations depend solely on the individual, no matter what the decision of the social system is. However, decisions of this kind might be influenced by interpersonal connections and norms of the social system the individual belongs to. The individual adopter has nearly total responsibility for the decision.

- *Collective innovation-decision*s: adoption or rejection of innovations is decided after consensus of the social system members. Generally, all the individual members of the system must comply with the system's decision. The individual adopter has a say in the decision.

- *Authority innovation-decisions:* a few individuals possessing power, status, or technical expertise within the system decide the adoption or rejection of innovations. The individual adopter does not influence the decision.

Opinion leadership alludes to the degree to which an individual can informally influence other individual's behaviors and attitudes. This kind of leadership derives from the individual's technical competence, compliance with system norms, and interpersonal communication networks. When comparing opinion leaders with their followers, they are more cosmopolite and exposed to more ways of external communication, have a higher socio-economic status, and are more innovative. Therefore, they can lead to embrace innovative changes or reject them. (Rogers, 2003: 27).

Another kind of individuals that exert their influence in the system is *change agents*. They are professionals representing change agencies from outside the system and influence client's innovations-decisions in the direction that the change agency wants. Change agents usually seek to obtain the adoption of innovations, but sometimes they may prevent or stop the diffusion and implementation of ideas. Change agents tend to use opinion leaders for their diffusion activities. (Rogers, 2003: 27.)

2.3 Perceived attributes of innovations

While some innovations are not appealing to the end customers, others are diffused and adopted rapidly (Atkinson, 2007). The success or failure of an innovation is determined by how potential adopters perceive it. As mentioned in the previous section, these are the so-called perceived attributes of innovations, which according to Rogers, explain 49% to 87% of the variance in the adoption process (Rogers, 2003: 221). The perceived attributes of innovations have been shown to have an effect on the adoption decision-making in a social system (Cullen, 2001) and are found to be better predictors of consumer adoption than individuals' characteristics (i.e., socio-demographic variables) (Elmustapha, Hoppe, & Bressers, 2017).

Although the perceived attributes of innovations have explanatory power, little research has been conducted in this regard (Rogers, 1995). Atkinson (2007) suggests that there is not much literature available about the perceived attributes of innovations because the findings are kept confidential and used for market research purposes.

Rogers (2003) considers that diffusing innovations is an “uncertainty reduction process”. He further described that the core of the DOI theory resides in the perceived characteristics of innovations. These attributes help decrease adopters’ uncertainty levels concerning the innovations and will, in the end, determine their adoption or rejection. The perceived attributes of innovations are relative advantage, compatibility, complexity, trialability, observability (Rogers, 2003: 15-16).

Relative advantage

It refers to the extent to which an innovation is considered better than the object or idea it is attempting to set aside, perhaps eventually replace. Of notable importance is if the adoption unit considers the innovation to be advantageous: the greater the perceived advantages, the faster the adoption will be. (Rogers, 2003: 229-240.)

The perceived relative advantage can be of any nature. Traditionally, it has been measured in economic, social (e.g., social prestige), or personal terms (e.g., satisfaction, convenience) (Elmustapha et al., 2017). Several researchers have found that relative advantage has a meaningful, constructive influence on adopting new environmental technologies. Guagnano, Hawkes, Acredolo, and White (1986), and Labay and Kinnear (1981) found perceived relative advantage to influence solar energy systems adoption; Jansson (2011) on alternative fuel cars; and Völlink, Meertens, and Midden (2002) on the willingness to adopt devices that measure home energy use.

When conducting their study on the adoption of micro-generation technologies, Caird, Roy, and Herring (2008) and Caird and Roy (2010) found that the main motive for adopting them was to lower energy bills energy savings. Other studies reported that initial costs (Mahapatra & Gustavsson, 2008) and maintenance costs (Willis, Scarpa, Gilroy, & Hamza, 2011) were the main reason for the non-adoption of micro-generation technologies. Nevertheless, according to Robinson (2012), “there are no absolute rules for what constitutes relative advantage. It depends on the particular perceptions and needs of the user group”.

Compatibility

It is defined as the extent to which an innovation is perceived as coherent with the already existing values, experiences, and necessities of the potential adoption unit. On the one hand, the more compatible the innovation is, the faster its adoption will be, as fewer changes in behaviors towards adoption will be needed (Jansson, 2011; Ozaki & Sevastyanova, 2011). On the other hand, if the innovation is incompatible, the adoption process will be slower since new values and norms will have to be adopted in advance in the social system (Rogers, 2003: 240-257).

The perceived attribute of compatibility has been often studied under a different approach than the one given by Rogers (Elmustapha et al., 2017). Researchers such as Guagnano et al., (1986) and Völlink et al., (2002) suggested that compatibility is all about being consistent with values in the social system.

Complexity (Simplicity)

This attribute refers to the perception of an innovation to be difficult to understand and use. Innovations that are simpler to understand are adopted faster by the social system than those requiring adopters to develop new frames of mind and acquire new knowledge (Rogers, 2003: 16, 257-258). Because *complexity* is the only attribute negatively related to adoption, several researchers have used *simplicity* instead, which gives the attributes the same direction concerning the adoption process (Goldman, 1994; Atkinson, 2007). This research uses *simplicity* as an attribute.

Labay and Kinnear (1981) studied consumers' perception of solar energy systems. They concluded that individuals who have already adopted these systems perceive them as less complex (simpler) than individuals who have not yet adopted. The latter proved actual what Rogers (2003: 257-258) stated: complexity negatively influences innovation adoption.

Trialability

It is the extent to which an innovation can be tried, most likely on a limited basis, before its adoption. It has been proven that if the innovation is tried before it is adopted, uncertainty towards it will decrease, and it will be adopted at a faster rate (Rogers, 2003: 258). Therefore, the “experimentation” period is used to persuade potential adopters to adopt (Dibra, 2015).

One of the most outstanding examples to better understand this attribute is Ryan and Gross’s (1943) research. They discovered that Iowa farmers, who first refused to use hybrid corn seeds, finally adopted their use after trying them on a partial basis. However, some innovations are more difficult to be experimented with than others (e.g., photovoltaic systems) (Rogers, 2003; Alrashoud & Tokimatsu, 2019). Labay and Kinnear (1981), Janssen and Jager (2002), and Völlink et al., (2002), identified no relation of trialability with the adoption process of solar energy systems. Due to the reasons above, trialability is not considered for the purpose of this research.

Observability

Observability is the degree to which an innovation’s results are observable by the unit of adoption. If the results are easily observable, the likelihood of adopting the innovation will be higher, and the adoption process is faster (Rogers, 2003: 16, 258-265). Dibra (2015) claims that the visibility of an innovation propitiates general discussion among members of a social system, stimulating them to seek information about the innovation in question.

A clear example of observability is found on sun water heating (SWH) systems. These systems are traditionally located on households' rooftops, making them highly visible (Elmustapha et al., 2017). Guagnano et al., (1986), Jager (2006), and Jansson (2011) reported that the observability of green energy technologies positively influences their adoption. Nonetheless, Labay and Kinnear (1981) revealed that innovations become less observable as consumers' familiarity with them increases.

In summary, to Rogers (2003: 16), those innovations perceived by the unit of adoption as more advantageous, more compatible, simpler, more triable, and more observable are subject to be adopted sooner than those perceived otherwise.

Even if the advantages of innovations in the renewable energy sector are confirmed, getting them widely adopted is usually complicated. México has undeniable reasons to adopt them urgently. Understanding how potential adopters perceive innovations will be vital to diffuse them and foster their adoption. The challenge then is to ensure the successful transfer of the renewable energy technologies to the country, understanding then that their lack of implementation does not lay on the innovations themselves and their advantages, but on their diffusion. (Reyes-Mercado, 2013.)

Table 1. Summary of the perceived attributes of innovations and their relationship with adoption. (Adapted from Rogers, 2003)

Perceived attribute	Definition	Relationship with adoption
Relative advantage	The extent to which an innovation is considered better than the object, practice, or idea it is attempting to set aside, perhaps eventually replace.	Positive (+)
Compatibility	The extent to which an innovation is perceived as coherent with the already existing values, experiences, and necessities of the potential adoption unit.	Positive (+)
Simplicity	The perception of an innovation to be easy to understand and use.	Positive (+)
Trialability	The extent to which an innovation can be tried, most likely on a limited basis, before its adoption.	Positive (+)
Observability	The degree to which an innovation's results are observable by the unit of adoption.	Positive (+)

2.4 Theoretical framework

Tareq (2017) focused his research on potential adopters' willingness to pay for PV systems in Bangladesh. Additionally, Parsad, Mittal, and Krishnankutty (2020) studied the motivators and preventors for PV system adoption in India. Nevertheless, Rogers's (2003) theory was not used in either of these studies.

Even though they have not been widely researched within renewable energies, Rogers' perceived attributes of innovations were found in a few studies. Teeraswasdi's (2003) research about the replacement of gasoline for gasohol found that the factor that has most influence in the adoption of gasohol is its lower price compared to gasoline. Suwansaard's (2009) study about the use of liquefied petroleum gas (LPG) and natural gas (NFV) instead of oil fuels for vehicles concluded that the more affordable price of LPG and NGV was the primary motivation for the adoption of these fuels.

Only two studies about potential adopters' perceptions specifically regarding PV systems were found. Suppanich and Wangjiraniran (2015) in Thailand and Alrashoud and Tokimatsu (2019) in Saudi Arabia studied the factors that influenced the perception and acceptance of PV systems. The former discovered that preventing global warming was the first motivation for adopters, while the latter found that the sun's unlimited power was adopters' primary motivation. These studies used a case study approach referring to Rogers' DOI theory and included the different factors that could affect the decision-making process in terms of PV systems adoption.

Suppanich and Wangjiraniran (2015) and Alrashoud and Tokimatsu (2019) followed similar methodologies. A questionnaire divided into parts gathered the following information: personal and socio-demographic data about respondents (i.e., gender, age, income, education, occupation). Another pasrt consisted of one question asking respondents if they would adopt or reject PV systems, to know the rejection and acceptance shares. The last part contained twenty 5-point Likert-type questions aimed to gather information about respondents' perception of PV systems. The twenty questions of this part were based on Rogers' DOI theory and are the aforementioned "factors" that may serve as motivators or preventors for PV adoption. Alrashoud and Tokimatsu (2019) used one additional part, which consisted of questions regarding general knowledge about solar energy.

Five different factors within each of the perceived attributes established by Rogers (2003) were used, except for the *trialability* attribute, since as explained in section 2.3, this attribute was found to have no relation with the adoption of solar energy systems (Janssen & Jager, 2002; Völlink et al., 2002). The factors used by these studies are shown with their corresponding definition in Table 2.

. (Adapted from Suppanich & Wangjiraniran, 2015 and Alrashoud & Tokimatsu, 2019)

Perceived attribute	Factors		
	Suppanich and Wangjiraniran (2015)	**Alrashoud and Tokimatsu (2019)**	**Definition**
Relative advantage	Revenue	Revenue	Reduce electricity consumption/sell energy surplus
	Environment protection	Environment protection	Reduce GHG emissions
	Unlimited power	Unlimited power	Infinite/Limitless power from the sun
	Global warming	Global warming	Reducing climate change impact
	Technology development	Technology development	Solar power technologies will further develop in the future
Compatibility	Power system	Power system	Effect of the new system on the already existing one
	Land use	Land use	Effect of the installation area on adopter's life
	Installation cost	Installation cost	High installation costs' effect on adopter's living costs
	Global trends	Global trends	PV systems are gaining popularity around the world
	Social values	Social values	Compatibility of PV systems with social values
Complexity (Simplicity)	Installation space	Installation space	Area needed for the installation of the PV system
	Availability of service providers	Availability of service providers	Difficult to access service providers
	Building location	Residence location	Solar radiation potential of the place of installation
	Maintenance	Maintenance	Difficulty to provide maintenance
	Building structure	Residence structure	Ability of the residence structure for the installation of the system
Observability	Income statistics monitoring	Income statistics monitoring	Revenue from energy surplus selling can be monitored
	Neighbor attitudes	Neighbor attitudes	Attitude towards environmental protection
	Power production monitoring	Power production monitoring	Energy generation can be monitored
	GHG reduction monitoring	GHG reduction monitoring	Emissions of GHG can be monitored
	Solar energy knowledge	Solar energy knowledge	PV systems installation will increase people's knowledge about them

Although both of the above-described studies utilized practically the same factors as motivators/disincentives for PV adoption, the performed analysis varied from one study to another. Suppanich and Wangjiraniran (2015) evaluated the frequencies and proportions of the demographic responses and the mean scores obtained from the Likert-type questions for each of the factors for "acceptors" and "rejectors". Then arranged them in descending order to know which was the main driver for those willing to adopt PV systems and the main constraint for rejectors.

On the other hand, Alrashoud and Tokimatsu (2019) also evaluated the frequencies and proportions of the demographic responses. In addition to that, he evaluated the proportion of Likert-scale responses concerning solar energy knowledge. Moreover, they measured the perceived attributes based on the factors mentioned above, obtained the Likert-scale proportions for each factor, and compared "acceptors" and "rejectors" mean values. Since their responses were not normally distributed, non-parametric statistics were utilized to describe and assess the results.

3 Case country and community background

3.1 México: socio-demographics and energy situation

México is a democratic country divided into 32 states. Located in North America, it borders the United States in the north and Guatemala and Belize in the south (UNDP, 2021). It covers a geographic area of 1,960,670.2 km^2 with 119,530,753 inhabitants per the 2015 census (INEGI, 2015), thus yielding a population density of 60.96 inhabitants/ km^2. Spanish is the official language, and there are 68 indigenous dialects spoken across the country (Gobierno de México, 2018). In 2019, México's Human Development Index was high and with a value of 0.779 (UNDP, 2020), and its GDP per capita was USD 9,946.03 (World Bank, 2021). The currency is the Mexican Peso (MXN) (Forex Bank, 2021).

Picture 1. México in a world map (Free World Maps, 2019)

Socio-demographic profile and basic services availability

As claimed by the Mexican National Council for the Evaluation of Social Development Policy (CONEVAL), 44% of the Mexican population was poor, and 8% was extremely poor in 2015

(CONEVAL, 2018). It is essential to notice the differences between the two types of poverty identified in México. The following social indicators are considered: average income per capita, formal education, access to health services, access to social security, household quality and size, access to basic house services, and access to food. On the one hand, a person is "poor" if their income is below the average welfare line (set by the government each year) and lacks at least one social indicator. On the other hand, a person is "extremely poor" if their income falls below the minimum welfare line (also set by the government) and lacks at least three of the social indicators (CONEVAL, 2015).

In 2015, there were 31,949,709 households (with an average of 3.7 occupants per household) in the whole Mexican territory, out of which 25.9% did not have access to piped water, 6.8% did not have access to the sewer system, and 2.9% lacked toilet infrastructure. Regarding ICT, 67.1% of the households did not have Internet access, 59.4% lacked cable TV, 67.4% did not have any computers, and 21.4% did not have any mobile phones among the household's occupants. Lastly, 1.3% of the households lacked access to electricity, and only 0.5% have installed a PV system (INEGI, 2015). The latter percentage may have changed from 2015 to 2021, but more recent data was not found.

Energy situation and policy

It is important to understand the current state of the Mexican energy system. México is ranked 11th amongst the largest oil producers in the world and 10th oil consumer; 13th country with the most significant greenhouse gas emissions; 13th and 15th electricity producer and consumer, respectively; 9th natural gas consumer in the world (Sarmiento, Burandt, Löffler, & Oei, 2019).

México is driven by fossil-based sources of energy. In 2019, fossil fuels (oil, natural gas, and coal) contributed 92.53% of the energy generated in Mexico (BP, 2020). British Petroleum (BP), the United Kingdom-based oil company, publishes the "Statistical Review of World

Energy" every year since 1952, with which timely and objective energy data is provided. From that report, in its 2020 version, data regarding energy generation in México was obtained. México generates 67.40% of its energy from oil, 20.71% from natural gas, 5.77% from renewables, 4.41% from coal, and 1.70% from nuclear sources (BP, 2020). Nevertheless, although only 5.77% of the energy generated in the country in 2019 came from renewables, Mexico has a great and varied base for these types of "green" sources (Reyes-Mercado, 2013; IRENA, 2015; Sarmiento et al., 2019).

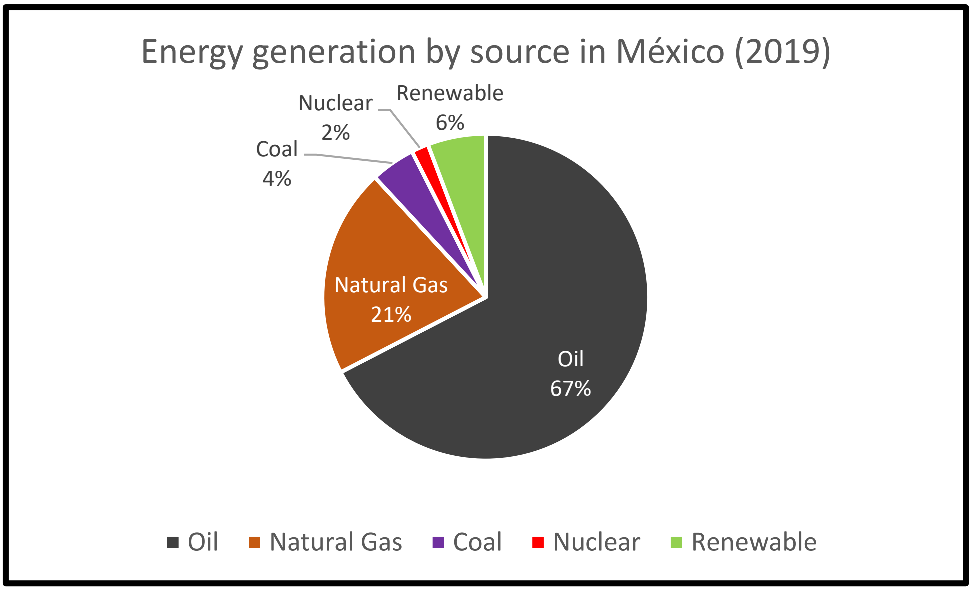


Figure 2. Energy generation by source in México (2019) (BP, 2020)

Due to its geographical location within the so-called "Solar Belt," Mexico is among the top five countries to invest in solar energy generation, only behind China and Singapore. Regarding wind energy, Mexico has a potential of 71,000 MW, but it has been barely exploited. The full potential has not yet been estimated about hydropower, but over 100 locations for its exploitation have been detected. Geothermal energy also has excellent potential as Mexico is ranked the 4th most significant generator of this type of energy in the world. Mexico is the 3rd largest country in Latin America concerning croplands. Therefore, the residual biomass from them represents an attractive option for energy generation in the form of biofuels. (Alemán-Nava et al., 2014.)

Out of the renewable energy generated in México in 2019, 61.76% came from hydro sources, 17.65% from wind, 11.76% from solar, and 8.82% from other sources (geothermal and bio-mass) (See Figure 3) (BP, 2020).

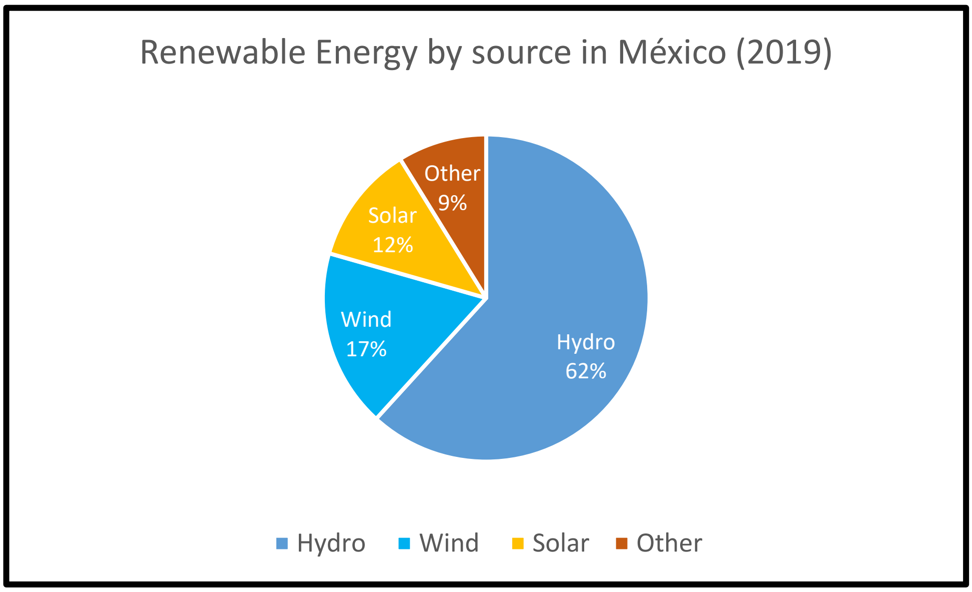


Figure 3. Renewable Energy by source in México (2019) (BP,2020)

In 2015, the *Paris Agreement* was signed by 195 countries, including México. The agreement consists of an understanding between member countries to prevent global warming from going above two degrees Celsius. The objectives are common for all the member nations, but each country is free to develop its own strategies to reach them. Some of these strategies are to increase the share of RE. (Sarmiento et al., 2019.)

Mexico has set ambitious goals towards RE: 35% share in 2024, 40% in 2035, and 50% in 2050 (EY México, 2018; Sarmiento et al., 2019). In order to achieve these goals, renewable energy sources must be efficiently exploited, and most importantly, fast, to gradually increase the share of RE in the total energy produced in the country and improve the 1:9 proportion of renewable energy compared to fossil.

The Mexican energy sector's history shows exclusive intervention from the estate and nearly null participation from the private sector for most of the time. It changed in 2013 when constitutional reforms were achieved to break the oil and energy monopoly, among other reasons, because the estate-owned system was no longer capable of generating enough energy to cover the country's demand. The energy reform allowed private capital to freely enter the sector, promote and exploit cleaner energy sources. (Reyes-Mercado, 2013; IRENA, 2015; EY México, 2018.)

The energy reforms aimed for an increase of clean sources in the energy share. However, Mexico's current administration (2019-2024) is clearly against renewable energies and private investments. Priority has been given to fossil fuels. Therefore, critical actions towards sustainability initiated with the reform were suspended or canceled because, according to the government, the country must have "exclusive control" over the energy industry and oil extraction. That mindset contradicts international treaties, such as the *Paris Agreement* or the *United States-Mexico-Canada (USMCA)* trade deal, obstructs its own goals of reaching RE share of 35% by 2025 and 50% by 2050, and, above all, it opposes the global efforts headed for a renewable source-based future. (Piña-Navarro, 2020; Vidal-Valero, 2021.)

As it can be inferred from the previous paragraph, fostering the use of renewable energy systems is not yet on the scope of the country. Nevertheless, in Mexico's *National Development Agenda 2019-2024*, a minor reference to energy production through renewable sources in rural, small, and isolated communities can be found (Piña-Navarro, 2020). Rural communities represent around 23% of the population (FAO, 2018), accounting for almost 28 million people in around 6.5 thousand communities, resulting in 1.5 million people with unsatisfactory access to energy or not access at all (INEGI, 2015).

Given the PV energy potential and the size of the potential market in rural communities, PV systems' implementation could have a significant impact. Nevertheless, they have not been adequately positioned, and therefore their implementation by individual adopters is relatively low.

3.2 Chiquilistlán: socio-demographics and energy situation

Chiquilistlán is one of the 125 municipalities in Jalisco, which is one of the 32 states in México. Located in the south eastern part of Jalisco, Chiquilistlán borders the municipalities of Tecolotlán and Atemajac de Brizuela to the north; Atemejac de Brizuela and Tapalpa to the east; Tapalpa, Tonaya, Ejutla and Juchitlán to the south; and Juchitilán and Tecolotlán to the west (SEDESOL, 2013). Chiquilistlán covers a geographic area of 432.31 km^2 (Gobierno de Jalisco, 2015) and ha6,102 inhabitants (IIEG, 2019) yielding a population density of 14.11 inhabitants per square kilometer.

Picture 2. Jalisco in Mexico (Wikipedia, 2021)

Conditions for rurality

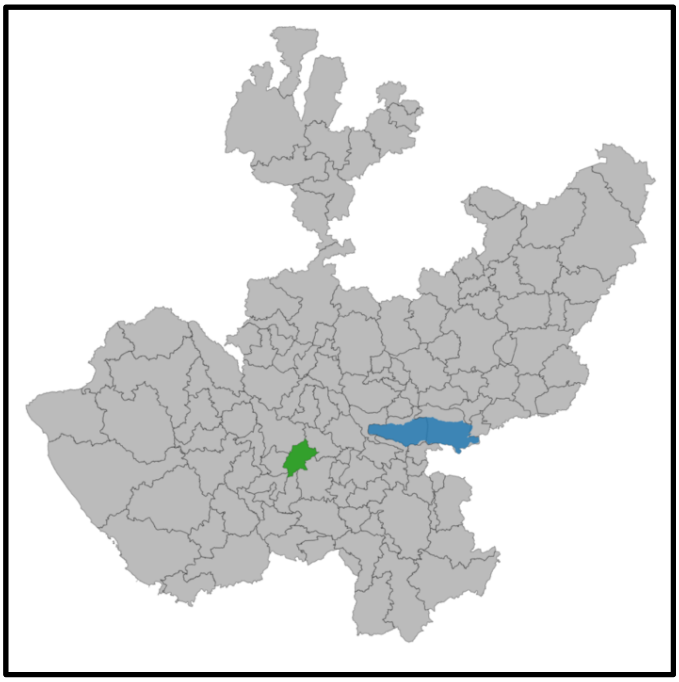
According to Chomitz et al., (2005), a community is considered rural if it meets two conditions: (1) it has a population density lower than 150 inhabitants/km^2, and (2) it is located more than one hour away from cities with a population greater than 100 thousand. Having a population density of 14.11 inhabitants/km^2, Chiquilistlán meets the first condition for rurality.

There were eleven cities in Jalisco in 2020 that exceeded the population mentioned above of 100 thousand inhabitants. The names of these municipalities and their population were obtained from INEGI (2020), and the corresponding “distance in time” from Chiquilistlán to each of them were retrieved from the web tool called “Distancias KM” (2021). All that information is sorted by population, from greatest to smallest, and observed in Table 3 below.

Table 3. Municipalities exceeding one hundred thousand inhabitants in Jalisco (INEGI, 2020)

Municipality’s name	**Population (Inhabitants)**	**Time from Chiquilistlán (HH:MM)**
Zapopan	1, 476, 491	02:12
Guadalajara	1, 385, 629	02:20
Tlajomulco de Zúñiga	727, 750	01:45
San Pedro Tlaquepaque	687, 127	02:24
Tonalá	569, 913	02:16
Puerto Vallarta	291, 839	04:48
El Salto	232, 852	02:21
Lagos de Moreno	172, 403	03:43
Tepatitlán de Morelos	150, 190	02:42
Zapotlán el Grande	115, 141	01:56
Ocotlán	106, 050	02:23

As seen in the table above, no human settlement with over one hundred thousand inhabitants was found to be less than one hour away from Chiquilistlán. Hence it meets the second condition for rurality, according to Chomitz et al., (2005).



Picture 3. Chiquilistlán in Jalisco (in green) (Wikipedia, 2020)

Socio-demographic profile and basic services availability

As reported by CONEVAL (2020), Chiquilistlán had the second-highest population percentage (78.4%) living in poverty, and the third-highest (25.7%) of people living in extreme poverty, both at the state level and during the year 2015. The difference between being "poor" and being "extremely poor" in México has been previously described in section 3.1. With a moderate degree of marginalization and high migratory intensity, Chiquilistlán stands as the 16th most marginalized and the 51st municipality with the highest migration rate in Jalisco. Moreover, Chiquilistlán has a low degree of land connectivity regarding highways and roads (IIEG, 2019).

In 2015, there were 1,463 households (with an average of 4.2 occupants per household) in Chiquilistlán, out of which 32.7% did not have access to piped water, 6.3% did not have access to the sewer system, and 7.5% lacked toilet infrastructure. Regarding ICT, 92.5% of the households did not have Internet access, 37.9% lacked cable TV, 84.5% did not have any computers, and 34.3% did not have any mobile phones among the household's occupants. Lastly, 2.1% lacked access to electricity, and only 0.1% of the households have installed a PV system. (INEGI, 2015.)

Photovoltaic potential in Chiquilistlán

Even though Chiquilistlán has significant solar irradiance variation depending on the seasons, for most of the year, it has a higher solar incidence than the national average, which has been stated earlier in this study to be 5 kWh/day/m^2 (SENER, 2009).

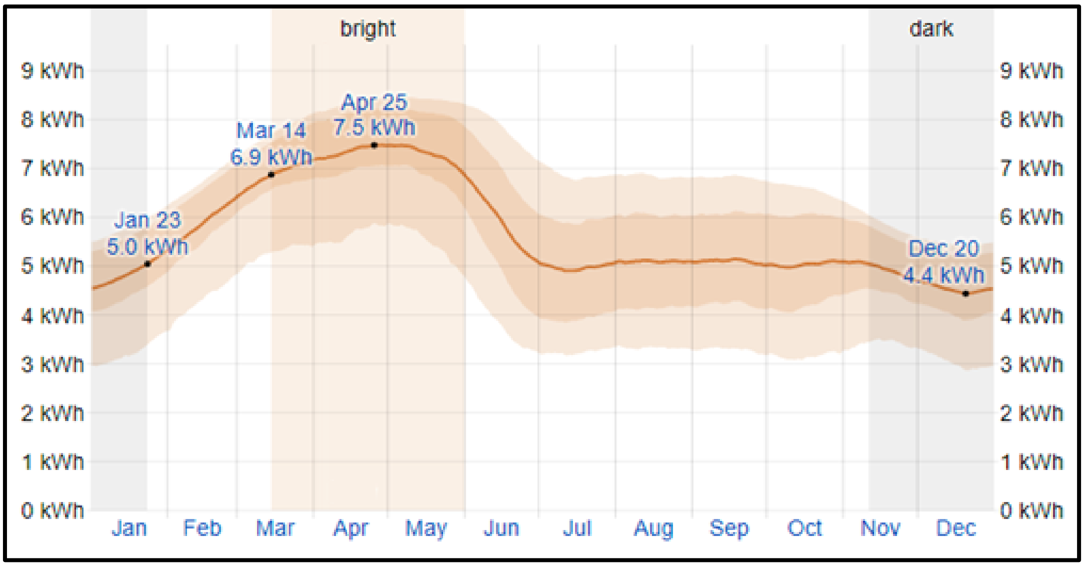


Figure 4. Solar irrandiance in Chiquilistlán. (Retrieved from Weather Spark, 2021)

During the brighter period of the year, from March 14th to June 1st, the average daily incidence is 6.9 kWh/day/m^2, being April 25^{th,} the day with the highest score (7.5 kWh/day/m^2). Whereas in the darker period of the year, from November 11th to January 23rd, the average daily incidence is 5 kWh/day/m^2, being December 20^{th,} the day with the lowest score (4.4 kWh/day/m^2) (Weather Spark, 2021).

Despite Chiquilistlán's relatively optimal solar irradiance throughout the year, INEGI has reported a household rate of adoption of PV systems in Chiquilistlán to be at 0.1% in 2015, meaning that approximately one house has implemented this technology. Below Chiquilistlán, there was only one municipality in Jalisco with a 0.0% PV implementation rate. The same adoption rate of 0.1% was shared with nine other municipalities in the state (INEGI, 2015). This percentage may have changed from 2015 to 2021 but not up-to-date data regarding PV adoption in Chiquilistlán was found.

Justification

There is a low PV implementation rate in the Mexican territory: 0.5% of the households have adopted this technology (INEGI, 2015)mostly in urban and suburban areas. Even though little research can be found concerning general renewable energy matters in México, literature focused on individual perception and adoption of PV systems in rural communities is lacking.

There are two main reasons why Chiquilistlán was of interest to be analyzed in this document. They are both social and personal reasons. The social reasons have been stated above and summarized here: being one of the poorest municipalities in Jalisco, its scarce access to ICT and basic services, having one of the lowest PV implementation rates in the state despite its optimal solar irradiance. Many municipalities in Jalisco and in México share similar conditions to the ones described. Therefore, the findings obtained from one of them, together with the consequent actions, can later impact others by replicating those actions.

The personal reason is that I find myself familiar with Chiquilistlán. My father was born there, and members of my family currently live there. Although I have not personally lived in Chiquilistlán, I have spent much time there during my life. Thus, I have a genuine affection for it and want to contribute with this research for the community to improve its overall welfare.

Within the community, the sample to be studied is comprised of high school students. There is only one high school in Chiquilistlán. It is public, belongs to the Universidad de Guadalajara high schools' network, and is incorporated into the SEP (Ministry of Public Education). As per the school year 2020-2021, there are 209 registered students in Chiquilistlán's high school (Universidad de Guadalajara, 2020).

According to Quiles and Zaragoza (2014), high school students in México are between 15 and 17 years old on average. The aim here is put on students as *potential adopters* since they will statistically become economically independent by the age of 21-26 (Ventura, 2018) and will have the last say in terms of energy technologies in their own households. More so, given that the median age in México was 21 in 1995, 22 in 2000, 24 in 2005, 26 in 2010, 27 in 2015, and 29 in 2020 (INEGI, 2020), it can be implied that the population is getting older. Hence the importance of knowing younger generations' current perceptions of PV systems with particular emphasis on rural communities in order to, if needed, tailor those perceptions towards the "positive side" to increase the willingness of adoption by the proper use of diffusion methods in the short and medium run.

Therefore, this study attempts to understand better how potential adopters perceive PV systems in particular and find if there are any relationships between their perceptions and their current societal conditions. Furthermore, this thesis intends to propose diffusion techniques that are compatible with the population and its characteristics.

It has been said earlier in this document that the implementation of renewable energy technologies, in this case, PV systems represent economic, environmental, and social benefits to the community that adopts them (SENER, 2009). Thus, the findings obtained from this research will be of use to positively impact this community's overall welfare and possibly other similar communities too.

4 Research design and methodology

4.1 Research design

Creswell and Plano Clark (2007: 58) defined *research design* as the “procedures for collecting, analyzing, interpreting and reporting data in research studies”. It establishes the necessary process to define the data collection and analysis methods to answer the research question (Grey, 2009). According to Robson’s (2002) classification, which was made based on the purpose of studies, three types of research design: descriptive, explanatory, exploratory. *Descriptive research* aims to provide a glance of the phenomenon, individuals, or situations (Blumberg, Cooper, & Schindler, 2005), yet not to give explanations as to why certain circumstances have occurred (Punch, 2005). *Explanatory research* is meant to look for reasons and provide explanations for descriptive information (Boru, 2018).

This thesis follows an *exploratory research* design, which according to Yin (1994) and Saunders, Lewis, and Thornhill (2007), is the most suitable research design when addressing broad, unclear, or not well-defined problems. Providing conclusive, definite answers to research questions is not the aim of this type of research design. Instead, its goal is to explore the research topic and set the basis for further research and provide insights on a specific situation (Singh, 2007: 64).

It was stated in section 1.2 that there is currently a lack of data and available research regarding individual adoption of PV systems in rural communities in Mexico. Hence, this research is meant to explore the latter problem, as it is the nature of exploratory research to address understudied topics (Brown, 2006). Suggestions for future explorations of the topic are provided at the end of this document.

4.2 Research strategy

Yin (1994) states the main conditions that determine the strategy to use when conducting research: (1) the kind of research question, (2) the control the researcher has over events, and (3) the extent to which the research is focused on contemporary events. Schell (1992) framed these conditions in a table depicted below.

Table 4. Differences between research strategies. (Adapted from Schell, 1992)

Research strategy	Research question	Control over behavioral events?	Contemporary events?
Experiment	how, why	Yes	Yes
Survey	who, what, where, how many, how much	No	Yes
Archival analysis	who, what, where, how many, how much	No	Yes/No
History	how, why	No	No
Case study	how, why	No	Yes

This thesis follows a case study strategy for the reasons explained later in this sub-chapter. Simons (2009) defines a case study as "an in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular project, policy institution, program or system in real life". In other words, Starman (2013) explains that a case study can be understood as an extensive description of a single case and its analysis. It is important to remark that case studies should be considered a design frame that includes various methods, not a method of itself (Stake, 2005; Simons, 2009).

Research conducted under the case study strategy has produced much of the empirical knowledge available nowadays. Such has been their impact that case studies represent some of the most valuable findings in many practice-oriented disciplines: management, psychology, education, social work, medicine, public administration, and history (Flyvbjerg, 2011;

Starman, 2013). A case study is considered a robust research strategy in management and organizational fields due to its capacity to address one or multiple research questions regarding a specific environment or context (Schell, 1992).

Case studies are different from other research strategies because they attempt to obtain unique findings of the situation under analysis (Sammut-Bonnici & McGee, 2015). The previous is accomplished by focusing on the context where the individual, project, or phenomenon lives, is performed, or occurs, respectively (Starman, 2013).

As observed in Table 4, Schell (1992) argues that a case study as a research strategy is best used with *how* and *why* questions. He also shows that case study research is best suitable when the researcher has little to no control over behavioral events. These two assertions are precisely the reasons why the case study was chosen as the research strategy.

It is important to note that, in this case, the researcher has no control over behavioral events. For purposes of this study, behavioral events refer to the perceptions of potential adopters about PV systems. Data gathered from individuals is processed and interpreted, but there is no control over it.

This thesis' research question has been reviewed in section 1.2 of this document: *How are photovoltaic systems perceived among potential adopters in rural communities, and how to diffuse them properly?* If attention is put in the question's structure, it is a 2-in-1 question, both starting with *how.* By answering the research question, insights on the perception of PV systems by potential adopters and proper ways to diffuse them are obtained.

Three research objectives are derived from the research question: (1) *To identify the core perceptions of photovoltaic systems among potential adopters in Chiquilistlan, Mexico;* (2) *To understand the socio-demographic aspects of potential adopters in Chiquilistlán, México and identify relationships with their perceptions;* (3) *To propose appropriate diffusion processes suitable for potential adopters in rural communities.* These research objectives, specially the second one, served as the base to understand the *why* part of this research: *why* PV systems are perceived the way they are perceived by finding any particular relationships between the perceptions and individuals' socio-demographic characteristics, and *why* potential adopters prefer specific diffusion techniques.

In line with Simons' (2009) definition, by working on the three research objectives to answer the research question, an in-depth exploration of the unit of analysis has been done, resulting in unique findings of this particular real-life matter. Furthermore, just as Stake (2005) and Simons (2009) remarked, various methods were used to reach those findings. These methods are described in the following sections.

4.3 Research approach

Several authors find three main approaches to conduct research: quantitative, qualitative, and mixed-methods approach (Creswell & Plano Clark, 2007). On the one hand, *quantitative* refers to the one that focuses on explaining events based on numerical data and statistical methodologies, yielding quantifiable, measurable information (Marshall, 1996; Aliaga & Gunderson, 2002). On the other hand, *qualitative* research is the one aiming to provide insights into the phenomenon based on the observation and interaction with the individuals, situations, or institution being studied, generating valuable descriptions of the participants' perceptions over an event (Creswell, 2003; Denzin & Lincoln, 2008).

The mixed-method approach is then the collection of quantitative and qualitative data in a single study (Creswell, Clark, Gutmann, & Hanson, 2003; Jansen & Warren, 2020). Sammut-Bonnici and McGee (2015) argue that a meaningful case study follows the mixed-method approach. It is helpful for researchers to answer certain questions that could not be answered otherwise. It provides the researcher with trends and measures from quantitative data and thorough descriptions of participants' perceptions (Boru, 2018).

Even though the wrong idea of a case study being limited to qualitative research has been generalized, Schell (1992) and Starman (2013) argue that case studies may contain quantitative and qualitative elements. Thence, this study follows a mixed-method approach by using different data collection methods explained below.

4.4 Sampling design

The selection of high school students as the sample for this study followed non-probability sampling methods: convenience sampling and voluntary response sample (see Figure 5). A *non-probability sampling method* uses non-random criteria to select the sample. Particularly about this study, high school students were chosen because access to them was granted, making the data collection process more manageable. These kinds of sampling methods are commonly applied in exploratory research that attempts to create a first understanding of a phenomenon rather than test hypotheses. (Babbie, 2010; McCombes, 2019.)

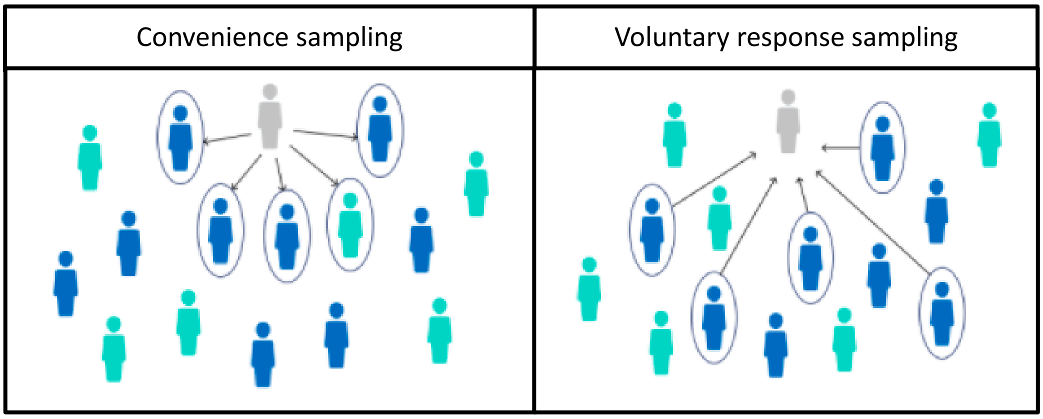


Figure 5. Convenience sampling and Voluntary response sampling. (Retreived from McCombes, 2019)

Convenience sampling was used when conducting the questionnaire-type survey, as they were the individuals to which the researcher had the most accessible access. *Voluntary response sampling* was the approach to conduct the semi-structured interview. Respondents were asked in the questionnaire if they would be willing to participate in an interview with the researcher. Only those who agreed were contacted to conduct the semi-structured interview, thence making it voluntary. (McCombes, 2019.)

5 Empirical study and analysis

5.1 Data collection process

Quantitative and qualitative data was required to answer the *how* and *why* questions. In order to collect quantitative data, a cross-sectional online questionnaire-type survey was created (see Annex 1) using the Google Forms interface. The questionnaire was translated to Spanish in order for respondents to be able to complete it. A *questionnaire-type survey* refers to a list of questions administered to respondents, who answer it themselves. This method is suitable to gather information about preferences and perceptions (Creswell, 2003; McCombes, 2020). It was cross-sectional since data was collected only once (Yin, 2014). For this study, one professor from the high school in Chiquilistlan was contacted to be the intermediary between the researcher and the students. As per the school year 2020-2021, there are 209 registered students in Chiquilistlán's high school (Universidad de Guadalajara, 2020). Each of the 209 students in the high school was provided with the link to the survey, and 43 responses were collected, thus yielding a response rate of 20.57%.

For the collection of qualitative data, six semi-structured interviews were conducted (see Annex 1). The interviewees volunteered to participate in the round of semi-structured interviews by marking a box in the survey stating their willingness to continue in the study. The semi-structured interviews were conducted online via Zoom and lasted for 40 minutes on average. They aimed to collect insightful data that otherwise would have been difficult to collect with the questionnaires. The semi-structured interviews addressed topics concerning the diffusion of PV systems in their community.

A *semi-structured interview* is a method that combines both the highly structured approach of surveys and the freedom of focus groups, hence offering interviewers the possibility to use open and close-ended questions. They are conducted in the form of a conversation, one person at a time. They usually require further "why" and "how" questions based on respondents' answers, which will, in the end, lead to the discussion of the topic as planned and often even to some unexpected matters. (Adams, 2015.)

Further discussing the quantitative data collection process, five general parts were included in the questionnaire, each of them addressing different topics: (1) socio-demographic characteristics, (2) environmental awareness, (3) perception of PV systems, (4) general acceptance/rejection, (5) exposure to media, networking, and decision-making. The previously-described survey parts were adapted from the ones discussed earlier in this document's section 2.4 and used by Suppanich and Wangjiraniran (2015) (parts 1, 2, and 3) and Alrashoud and Tokimatsu (2019) (parts 1, 2, 3, and 4, with a slight change in 2, making it about "environmental awareness" instead of "solar energy knowledge). The part concerning exposure to media, networking, and decision-making was not included in previous literature but was added to this study to acquire a better understanding of the perceptions and more data to find possible relationships. The matters addressed in part 5 of the survey were drawn from Rogers' (2003) DOI theory.

Parts 2 and 3 of the survey were structured using Likert-type questions. Likert scale refers to a popular rating scale used to assess responses in survey research. First introduced by Rensis Likert in 1932, the scale gives numerical scores to perceptions or opinions, which otherwise could not be numerically assessed. It is usually a 5-to-7-point scale that measures respondents' frequency (e.g., never, rarely, sometimes, sometimes, often, always), satisfaction (e.g., very dissatisfied, somewhat satisfied, neither satisfier nor dissatisfied, somewhat satisfied, very satisfied) or agreement (e.g., strongly disagree, disagree, neither agree nor disagree, agree, strongly agree) towards different statements (Likert, 1932; Bhandari, 2020).

In order to ease the quantitative analysis, this particular study used a 5-point Likert scale to measure respondents' level of agreement or disagreement to a set of statements regarding PV systems. Each step of the scale was given a numerical value from 1 to 5 (1: strongly disagree, 2: disagree, 3: neither agree nor disagree, 4: agree, 5: strongly agree).

Rogers' (2003) *perceived attributes* were split into five influential factors that lead to the adoption or rejection of PV systems. The perceived attributes' influential factors used in this study were adapted from Suppanich and Wangjiraniran (2015) Alrashoud and Tokimatsu (2019) and are observed in Table 5.

As explained in section 2.3, the *Trialability* attribute was not used due to its lack of relationship with the adoption of solar energy systems (Janssen & Jager, 2002; Völlink et al., 2002). Moreover, to give a similar directionality to all the attributes, the *Simplicity* attribute was used instead of *Complexity*.

Table 5. Influential factors on PV adoption. (Adapted from Suppanich & Wangjiraniran, 2015 and Alrashoud & Tokimatsu, 2019)

Perceived attributes	**Factors**	**Definition**
Relative advantage	Economic	Getting an economic benefit: cost saving/profit making
	Environment protection	Reduce GHG emissions
	Solar power potential	Power from the sun is inexhaustible
	Convenience	Extent to which PV systems will provide a better life
	Social prestige	Social status is given once PV systems are installed
Compatibility	Social values	Compatibility of PV system with social values
	Installation costs	High installation cost
	Global trends	Join the trend of becoming "green"
	Land use	The house having enough space for the installation
	Current needs	Extent to which the adopter needs PV systems
Simplicity	Functionality	Easy to understand how PV systems work
	Access to providers	Easy access to providers
	Learning attitude	Willingness to learn about PV systems on their own
	Maintenance	Easy to provide maintenance
	Infrastructure	Suitability of the household for the installation
Observability	Visibility	Eagerness to learn more if a PV system is seen
	Neighbor attitude	Attitude towards environmental protection
	Generation monitoring	Energy generation can be monitored
	Income monitoring	Profit made from selling energy is monitored
	Knowledge dissemination	Willingness to tell others the pros and cons of PVs

5.2 Data analysis

Different data analysis methods were applied due to the mixed-methods approach followed in this study. Descriptive and inferential statistics were used to analyze quantitative data. Descriptive analysis's main job is to summarize data and provide absolute values in the form of mean, median, mode, frequencies, and percentages (Humans of Data, 2018), making it easier to look at data. According to Kaur, Stoltzfus, and Yellapu (2018), descriptive statistics should be performed before making any inferential statistics calculations.

On its part, inferential statistics are more intricated to understand and compute. As Kern (2013) defined, inferential statistics "attempt to create conclusions that reach beyond the data observed". In other words, when properly conducted, this type of statistics can show relationships between multiple variables (Humans of Data, 2018).

5.2.1 Descriptive analysis

Socio-demographic and PV-related characteristics

Responses from parts 1, 4, and 5 from the survey are summarized here. They pertain to socio-demographic characteristics, general PV system acceptance/rejection, and exposure to media, networking, and decision-making, respectively. Data from survey parts 4 and 5 are hereafter referred to as "PV-related characteristics". Table 6 shows the summary of the socio-demographic characteristics. Each characteristic was divided into two or more categories depending on the answers from the survey. The sum of the frequencies of all the categories within one characteristic is 43 (total number of respondents). Similarly, the sum of the percentages of all the categories within one characteristic is 100%.

Table 6. Summary of socio-demographic characteristics

Socio-demographic characteristics	Categories	Frequency	Percent
Gender	Female	23	53.49%
	Male	20	46.51%
Age	15-16	28	65.12%
	17-18	15	34.88%
Household members	1-2	2	4.65%
	3-4	19	44.19%
	5-6	12	27.91%
	7-8	10	23.26%
Electricity at home	Yes	40	93.02%
	No	3	6.98%
Cooks with (stove)	Wood-burning	10	23.26%
	Gas	28	65.12%
	Electric	5	11.63%
Parents' literacy*	Yes yes	34	79.07%
	Yes no	4	9.30%
	Yes noX	2	4.65%
	No no	2	4.65%
	No noX	1	2.33%

(*) Based on the ability of the parents to read and write: "yes yes" = both parents do read and write; "yes no" = one parent does not; "yes noX" = raised by one parent who does; "no no" = neither of the parents do; "no noX" = raised by one parent who does not.

Table 7. Summary of PV-related characteristics

PV-related characteristics	Categories	Frequency	Percent
Family abroad	Yes	35	81.40%
	No	8	18.60%
Traveled abroad	Yes	5	11.63%
	No	38	88.37%
Visits other municipalities	Never	6	13.95%
	Less than once/month	21	48.84%
	Once or twice/month	7	16.28%
	Once or more/week	9	20.93%
Know someone with PV	Yes	13	30.23%

	No	30	69.77%
Conversations about environment/RET	Never	25	58.14%
	Less than once/month	10	23.26%
	Once or twice/month	6	13.95%
	Once or more/week	2	4.65%
Internet every day	Yes	24	55.81%
	No	19	44.19%
Social media	Yes	41	95.35%
	No	2	4.65%
TV exposure/week	No TV	5	11.63%
	0-2 hours	14	32.56%
	3-5 hours	16	37.21%
	6-8 hours	6	13.95%
	+9 hours	2	4.65%
Decision making	Optional	23	53.49%
	Collective	18	41.86%
	Authority	2	4.65%
Accepts PV systems	Yes	35	81.40%
	No	8	18.60%

Each of the characteristics showed tables 6 and 7 represent a "nominal" variable since they are split into categories (Sugianto, 2016). Those variables that take only two values (e.g., Yes or No) can be referred to as "dichotomous" (University of South Australia, n.d.).

Environmental awareness

Part 2 of the survey was in charge of assessing respondent's environmental awareness. This survey part was comprised of 5 Likert-type questions, which measured the respondents' degree of agreement towards a set of statements, which were re-coded (EA1 to EA5) to ease the analysis of variables later on. The complete statements and their corresponding "codes" can be seen in part 2 of the survey in Annex 1.

Figure 6 depicts the overall agreement share in terms of environmental awareness. This chart considers a total of 215 responses for its calculation (5 responses per each of the 43 respondents). It is important to remember that all the statements were structured in the form “the higher the agreement/score, the more environmentally aware the person is”. That is, they all had the same directionality. A share of 71.16% of the responses are on the *agree side* (42.70% strongly agree and 28.37% agree), 16.74% belongs to the *disagree side* (11.16% strongly disagree and 5.58% disagree), whereas 12.09% have a neutral answer. It can be inferred that respondents had, as a group, a high level of agreement towards the statements.

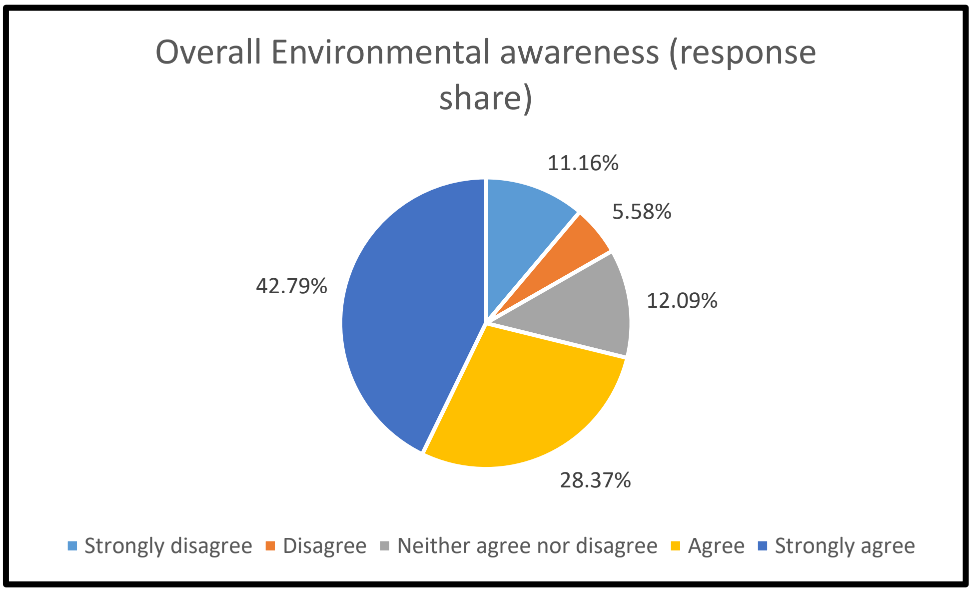


Figure 6. Overall Environmental awareness (response share)

According to Gruzovnik (2012), many people in the world still refuse to acknowledge the environmental problems, even when there is scientific evidence of their existence. The population sample was not an exception, and it can be observed in the fact that the share of responses on the *disagree side* surpasses the *neutral* share. It can be argued that there are more people who have information about environmental problems and RETs and prefer to underestimate their severity and potential, respectively, than there are people who ignore them and have a relatively neutral position towards those matters.

The analysis was brought to a more specific level, making it statement by statement (see Figure 7). Among all the environmental awareness statements, the "Strongly agree" share was the highest in all of them (EA1: 48.84%; EA2: 37.21%; EA3: 41.86%; EA4: 39.53%; EA5: 46.51%). Interestingly, the percentage of "Strongly disagree" responses is higher than "Disagree" in all statements (EA1: 9.3 vs. 4.65%; EA2: 13.95 vs. 9.3%; EA3: 9.3 vs. 6.98%; EA4: 9.3 vs. 4.65%; EA5: 13.95 vs. 2.33%). The previous seems to be in line with Gruzovnik (2012), as people still deny environmental problems and benefits of RET. Respondents tended to have a more "all or nothing" mindset, therefore opting to answer "Strongly disagree" more often than "Disagree".

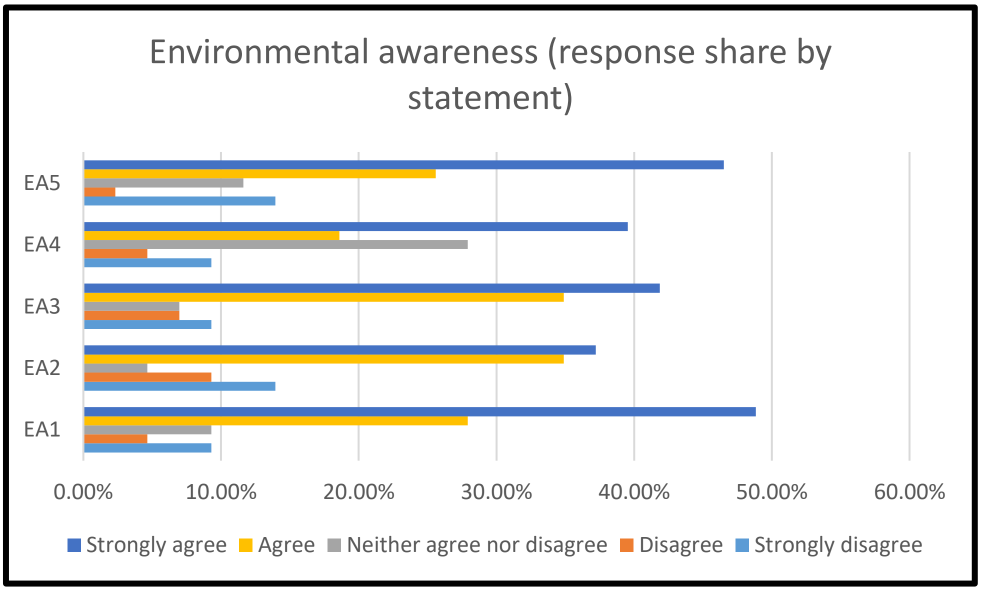


Figure 7. Environmental awareness (response share by statement)

Considering that each point of the "agreement" scale was given a numerical value from 1 to 5 as explained in section 5.1 "Data collection process" of this thesis, the maximum environmental awareness score a respondent could get was 25, and the lowest was 5. A total of eight respondents scored 25, and two scored the minimum of 5. However, as per the mode, the highest score was the most common among respondents. Overall, the sample had a relatively high environmental awareness score with a mean of 19.30.

Perceived attributes

Part 3 from the survey collected responses about the perceived attributes of PV systems. Figure 8 presents the agreement share considering the four perceived attributes of innovations used in this study. This chart considers a total of 860 responses for its calculation (20 responses per each of the 43 respondents). Likert items (questions) in the survey were formulated with the same directionality as it was done in the environmental awareness part.

The *agree side* is comprised of 45.70% of the responses (13.26% "Strongly agree" and 32.44% "Agree"), the *disagree side* has 28.14% of the responses (15.58% "Disagree" and 12.56% "Strongly disagree"), while 26.16% of the responses were neutral. Compared to the overall level of agreement in the environmental awareness part, the "Strongly agree" share dropped dramatically from 42.79% to 13.26%. In contrast, the share of "Agree" responses increased from 28.37% to 32.44%, and the neutral share had a considerable increase, going from 12.09% to 26.16%. On the *disagree side,* both shares of "Disagree" and "Strongly disagree" had an increase, going from 5.58% to 15.58% and from 11.16% to 12.56%, respectively.

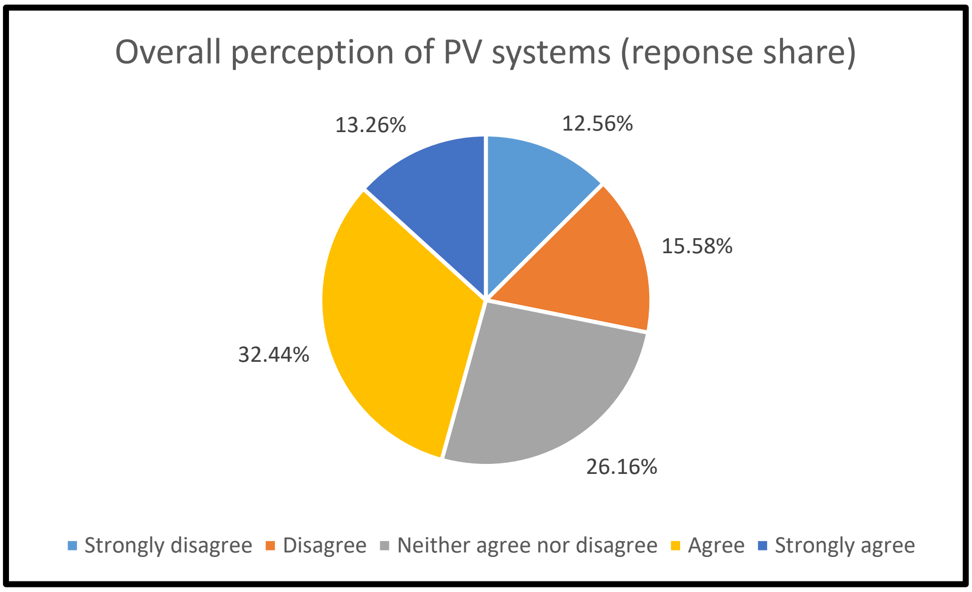


Figure 8. Overall perception of PV systems (response share)

The previous comparisons make clear that respondents have a better understanding, in general terms, of environmental problems and RETs than they do about PV systems in particular. On the one hand, the fact that the "Strongly agree" share is smaller than the "Agree" one in terms of PV perception can be interpreted as if the sample population has had information about PV and favors them. However, they are not convinced of their benefits and usability yet. On the other hand, the increase in both shares on the *disagree side* shows that respondents understand the PV systems' benefits but prefer not to stand in favor of them. Moreover, having more than one-quarter of the responses as "Neither agree nor disagree" can be interpreted as inadequate knowledge and comprehension of the PV systems, thus making respondents have an unclear attitude towards them.

Considering that each point of the Likert scale was given a numerical value from 1 to 5 and five factors with each perceived attribute, the maximum score a factor could get is 215 (5 for each of the 43 respondents. Therefore, the maximum score a perceived attribute could get is 1,075 (215 per each of its five factors). Given the previous, figure 9 shows the total scores obtained by each perceived attribute.

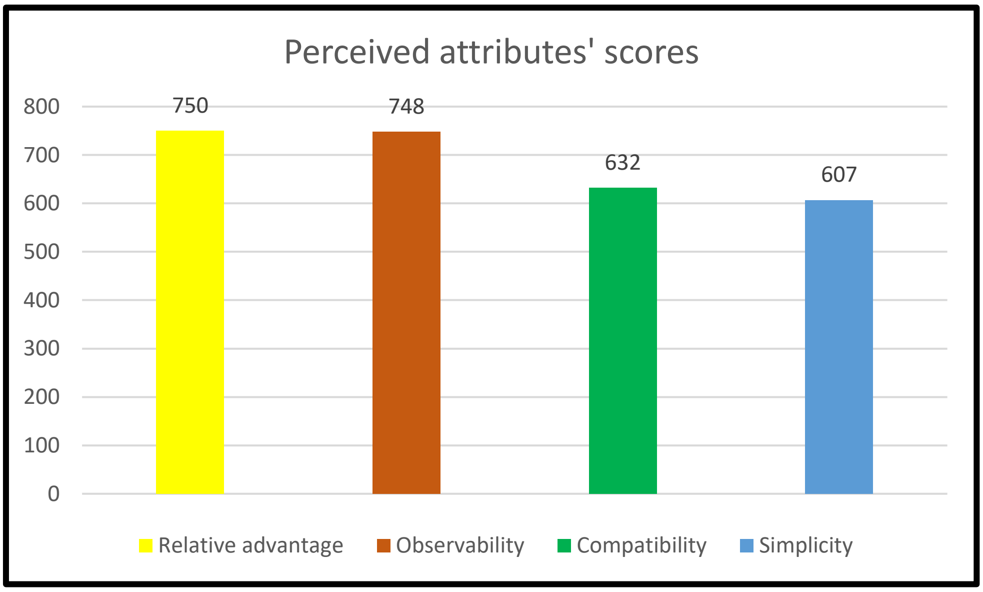


Figure 9. Perceived attributes' scores

Relative advantage was the best-ranked attribute with 750 (69.76% of the maximum score possible). Observability occupies the second position scoring 748 (69.58%). Compatibility in third place with a score of 632 (58.79%). The fourth place is taken by the Simplicity attribute scoring 607 (56.46%). From an overall view, it can be said that respondents had a higher level of agreement towards the relative advantage of the PV systems than they did of the observability of the PV systems benefits, the compatibility to their social system or the simplicity to use and understand the PV systems.

To better understand the scores obtained, the analysis was brought to a more detailed level, making it factor by factor. It has been said before that the maximum score a single influential factor could get is 215 (5 per each of the 43 respondents). Figure 10 portrays the scores obtained by each influential factor for PV adoption in descending order.

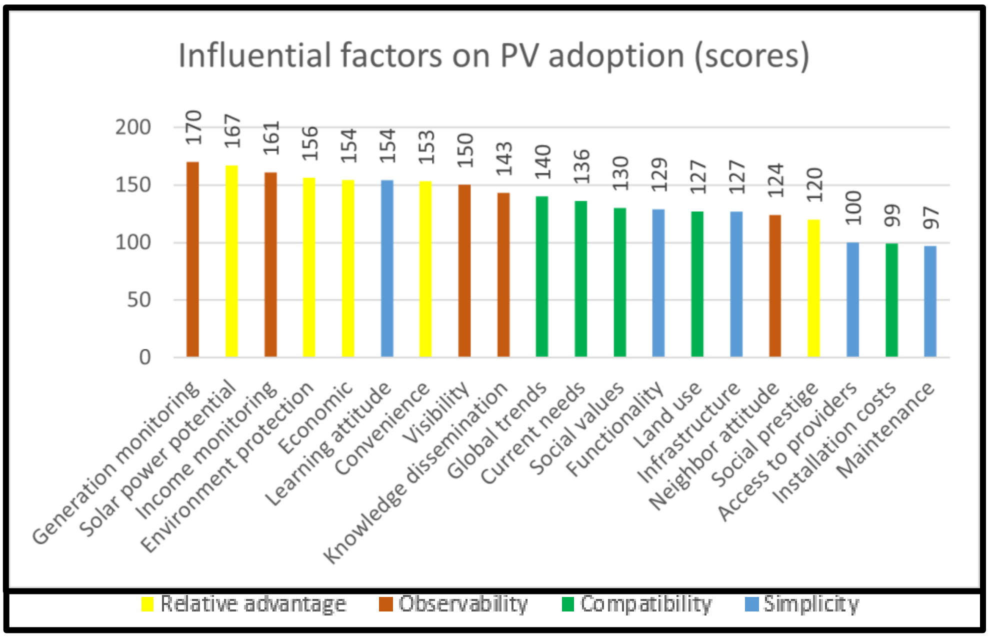


Figure 10. Influential factors on PV adoption (scores)

It is observed that eight out of the top ten factors belong to either the relative advantage or observability attributes. In contrast, eight out of the bottom ten factors belong to the compatibility or simplicity attributes. The previous is supported by the data shown in figure 9, having Relative advantage and Observability as the highest-ranked perceived attributes and Compatibility and simplicity as the lowest-ranked. However, even though the Relative advantage attribute received the highest overall score, the first and third most influential factors on PV adoption turn out to belong to the observability attribute (“Generation monitoring” and “Income monitoring”, respectively), while the second was indeed drawn from the relative advantage attribute (“Solar power potential”). With this information, it is understood that the possibility of keeping track of the energy generated, the limitless power from the sun, and the chance to know how much money is being made or saved while generating electricity, are the main drivers for PV systems adoption.

On the other end of the chart, the factors that act as the least encouraging (or most discouraging) for potential PV adopters are “Maintenance”, “Installation costs”, and “Access to providers”. The perception of PV systems being hard to repair if they stop functioning, the lack of financial resources for PV installation, and the difficulty to access PV providers are the main constraints for potential adopters.

Considering that each point of the “agreement” scale was given a numerical value from 1 to 5, the score about perceived attributes each individual could get was 100, and the lowest was 20. None of the respondents got the maximum score possible. The highest score obtained was 85, and the lowest was 26, both appearing only once. The mean score was 63.65, median 66, and mode 65.

5.2.2 Inferential analysis

Inferential analysis ought to be conducted to find relationships between variables. Since the perception of PV systems among potential adopters in Chiquilistlán is the focal point of this study, respondents' perceived attributes individual scores were tested against each of the socio-demographic characteristics, PV-related characteristics, and individual environmental awareness scores. All the statistical tests were computed with the Real Statistics Add-In for Excel developed by (Zaiontz, n.d.).

Kruskal-Wallis non-parametric test (Kruskal & Wallis, 1952) was the statistical test used to look for relationships between the continuous dependent variable (individual scores about perceived attributes) and each of the nominal independent variables (socio-demographic characteristics and PV-related characteristics). It was the most suitable test to be conducted as it is a distribution-free test (Statistics Solutions, n.d.). It makes no assumptions about the normal distribution of the observations (Ostertagová, Ostertag, & Kovac, 2014) and requires one of the variables to be continuous and the other one to be nominal (Medium, 2018). If a Kruskal-Wallis test is significant, there is a dominance of at least one category over the other(s). However, it does not tell how many categories exert dominance nor how strong the dominance is (Medium, 2018). Those Kruskal-Wallis tests that resulted in being significant were further tested with a point-biserial correlation test.

The point-biserial correlation test provides the correlation coefficient (r_{pb}) of two variables (one continuous and one nominal). This coefficient has a value ranging from -1 to +1. The closer the coefficient is to -/+ 1, the stronger the relationship is between the variables. Correlation coefficients with values close to zero show that there is no relationship between the two variables. When there is the case that the nominal variable is not dichotomous (i.e., it has more than two levels), then the point-biserial correlation coefficient of all combinations of pairs is calculated. (Khamis, 2008.)

Whenever an inferential statistical analysis is conducted, a test statistic and its corresponding p-value (*P*) are obtained (Andrade, 2019). To know whether the result from the test is significant or not, *P* is compared to a pre-set alpha (α) value. The p-value means that there is a *P* probability that the test results were obtained by chance. The test is considered significant if $P < \alpha$, meaning that there is a probability of 1-*P* that the findings hold true even out of the population sample at a significance level of α (Andrade, 2019). For this study's purposes, a significance level of α=5% was considered. The previous is based on the conventional use of that value for alpha, which in turn is based on the claim that there is one in twenty chances to experience an unexpected sampling issue (Moore & McGabe, 1998: 473).

As stated before, Kruskal-Wallis tests were conducted first. Table 8 shows the pairs of variables that were tested, the p-values obtained, and whether the relationship between variables was significant or not. Interpretation of the obtained values and their significance is provided immediately after the table below. Those p-values marked with (*) were significant and thus further tested with point-biserial correlation test. Refer to table 6 and table 7 to recall the nominal variables being tested here.

Table 8. Pairs of tested variables and their p-values

Test number	**Nominal independent variable**	**Continuous dependent variable**	**p-value (*P*)**
1	Gender	PV systems perception	0.4354
2	Age	PV systems perception	0.7499
3	Household members	PV systems perception	0.4187
4	Electricity at home	PV systems perception	0.0282(*)
5	Cooks with (stove)	PV systems perception	0.0161(*)
6	Parents' literacy	PV systems perception	0.06
7	Family abroad	PV systems perception	0.31
8	Traveled abroad	PV systems perception	0.155
9	Visits other municipalities	PV systems perception	0.553
10	Know someone with PV	PV systems perception	0.0698
11	Talks about RET	PV systems perception	0.7398
12	Internet every day	PV systems perception	0.0071(*)
13	Social media	PV systems perception	0.9081
14	TV exposure/week	PV systems perception	0.116
15	Decision making	PV systems perception	0.431
16	Accepts PV systems	PV systems perception	0.0363(*)
17	Environmental awareness	PV systems perception	0.0016(*)

(*) Statistically significant values

(1) Gender and PV systems perception scores

In some countries, women stand as household energy managers (UNDP, 2016) and tend to make more sustainable consumption decisions (Carlsson-Kanyama & Linden, 2007; Lee, Park, & Han, 2013). In México, a country where women do more than twice as much domestic work as men (Santoyo & Pacheco, 2014), hence spend more time at home. Nevertheless, as per this study's sample, the perceived attributes scores did not show a significant dependence on the gender variable.

(2) Age and PV systems perception scores

In terms of the relationship between age and the perception of PV systems, the test turned out to be non-significant. Therefore, age and PV scores are independent of each other. Rogers (2003) reported conflicting evidence about the age and its relationship with new technologies' adopters. The latter can be translated as age not having an influence over the perception and consequential adoption of RETs, in this case, PV systems.

(3) Household size and PV systems perception scores

Even though it has been found that household size has a negative correlation with the perception of renewable energies (Kaya, Florkowski, Us, & Klepacka, 2019), this study's observations demonstrated there is no significant relationship between the household size groups and the perception of PV systems.

(4) Electricity at home and PV systems perception scores

No data was found in literature concerning existing relationships between individuals having access to electricity at home and their perceptions over PV systems. However, this study showed a significant relationship between the variables above, and it can be seen in Figure 11 below. Being No=0 and Yes=1 (X-axis), it is clear that PV systems' perception scores (Y-axis) tend to increase when transitioning from not having electricity at home to having electricity at home. Since this relationship was significant, a point-biserial correlation test was performed, yielding r_{pb}=0.35906. This value corresponds to a weak correlation (Cohen, 1988; Schober, Boer, & Schwarte, 2018).

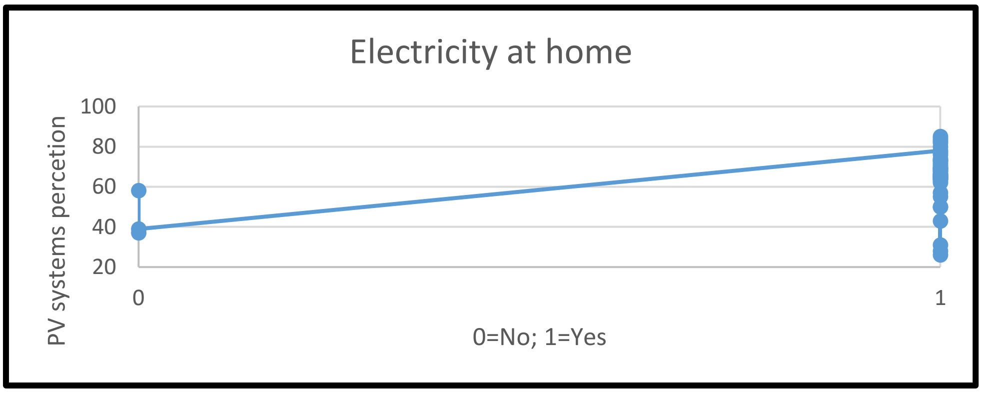


Figure 11. Electricity at home

(5) Cooks with (stove) and PV systems perception scores

McCarron et al., (2020) stated that people living in households where a wood-burning stove is used lack understanding about the increased chances of mortality due to household air pollution from biomass burning for cooking purposes. Blagojevic (2019) and McCarron et al., (2020) claim that using wood to cook or heat the household is linked to insufficient awareness of different, more efficient, and less harmful health technologies and resources.

The Kruskal-Wallis test conducted yielded a statistically significant relationship between the kind of stove (i.e., wood-burning, gas, electric) respondents have at home and their PV system perception scores. Figure 12 shows how the PV system perception scores (Y-axis) tend to increase when going from 1 (wood-burning) to 2 (gas) and from 2 to 3 (electric) on X-axis. Three combination pairs were established to obtain their corresponding point-biserial correlation coefficients. The combination and results were as follows: 1-2 (r_{pb}=0.3316), 2-3 (r_{pb}=0.1363), and 1-3 (r_{pb}=0.5696). Combination 1-2 and 2-3 represent weak correlations (Cohen, 1988; Schober et al., 2018), whereas combination 1-3 represents a moderate correlation according to Schober et al., (2018) and a strong correlation according to Cohen (1988).

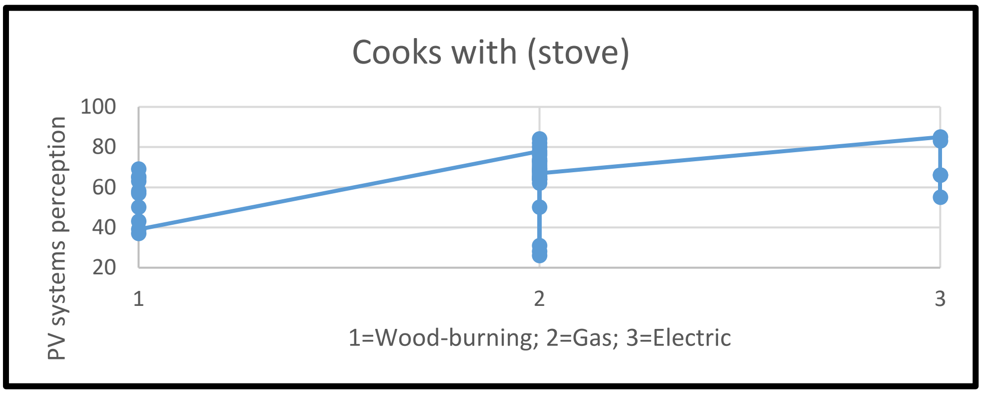


Figure 12. Cooks with (stove)

(6) Parents' literacy and PV systems perception scores

This particular study addressed high school students, and therefore it can be inferred that all respondents have practically the same level of formal education. The previous was why parents' literacy was tested instead since, according to Morales-Sierra et al., (2009) and Segura (2015), parents' illiteracy limits their sons and daughters' ability to grasp new significant knowledge and ideas. With a p-value of 0.06, the relationship between individuals' parents' literacy and perceptions about PV systems resulted in being non-significant out of the sample population.

(7) Family abroad and PV systems perception scores

Rogers (2003) stated that a person has a better perception of an innovation (namely PV systems) and is more likely to adopt it if they have an extended personal network outside of their own social system. This study tested whether the fact of having family abroad had an impact on the perception towards PV systems. Chiquilistlán has a high migratory intensity (IIEG, 2019), and it was demonstrated with an overwhelming 81.4% of respondents reporting to have family abroad (all of them in the United States of America). Nonetheless, this study's observations were non-significant.

(8, 9) Travel abroad, visit other municipalities and PV systems perception scores

Similarly, a person has a better perception of an innovation if he or she is more cosmopolite than others (Rogers, 2003). This person travels more and his or her involvement in different kinds of situations goes beyond their own social system. In this study, the facts of having traveled abroad and how often they commute to different municipalities were tested. None of these variables had a statistically significant relationship with individuals' PV systems perceptions. On the one hand, only five respondents (11.63%) have been abroad (all of them to the United States).

On the other hand, the municipalities that the respondents most visit have only a slightly higher PV implementation rate than does Chiquilistlán. Therefore, the exposure respondents have when visiting these municipalities is low. Table 9 shows the municipalities from the most visited the least, their PV implementation rates according to INEGI (2015), and the potential exposure considering the number of households in the municipalities.

Table 9. Most visited municipalities, PV implementation rate, and potential exposure

Rank	Municipality	PV implementation rate (%)	Potential exposure (# of households with PV)
1	Tecolotlán	0.3	14.96
2	Cocula	0.2	14.10
3	Guadalajara	0.5	1967.65
4	Tapalpa	0.5	22.04

5	Autlán de Navarro	0.3	50.51
6	Ciudad Guzmán	0.4	111.79
7	Juchitlán	0.3	4.67
8	Sayula	0.2	18.49
9	Chapala	1.5	203.96
10	San Gabriel	0.1	4.22

(10) Know someone with PV and PV systems perception scores

People who first adopt an innovation have, most of the times, enough financial resources to absorb an eventual setback in case the innovation fails to do its job (Rogers, 2003). These people are called *innovators* and have an essential role, as they are the first ones to introduce new ideas into their social systems (Rogers, 2003). Due to the importance of *innovators* in the system, knowing someone who has implemented PV systems in Chiquilistlán was tested to have a relationship with the current perception of PV systems by potential adopters. According to the results of the Kruskal-Wallis test conducted with this study's observations, there was no statistically significant relationship between the two variables.

(11) Conversations about environmental problems/RETs and PV systems perception scores

Rogers (2003) argues that a person is more likely to perceive positively and adopt an innovation earlier than others if he or she is more exposed to interpersonal communication channels. In the survey, respondents were asked how often they had conversations concerning environmental problems or RETs. Their responses were tested to find whether there was a relationship with their perception scores. No significant relationship was found between the two variables.

(12, 13, 14) Internet access, social media, TV exposure, and PV systems perception scores

Exposure to mass media is related to how positively or negatively a person perceives an innovation and how early or late this person adopts it (Rogers, 2003). The previous was tested by asking respondents if they had access to Internet every day, if they were users of any social media channel, and how many hours a week they spent watching TV. From these three variables, only one resulted in impacting the perception of PV systems: having Internet every day. The correlation coefficient between the two variables (Internet access every day and scores of PV system perception) was weak (Schober et al., 2018) and moderate (Cohen, 1988) with a value of r_{pb}=0.3828. The positive relationship can be observed in figure 13, as it is evident that PV system perception scores increase (Y-axis) when moving from 0 (No Internet access every day) to 1 (Internet access every day) in X-axis.

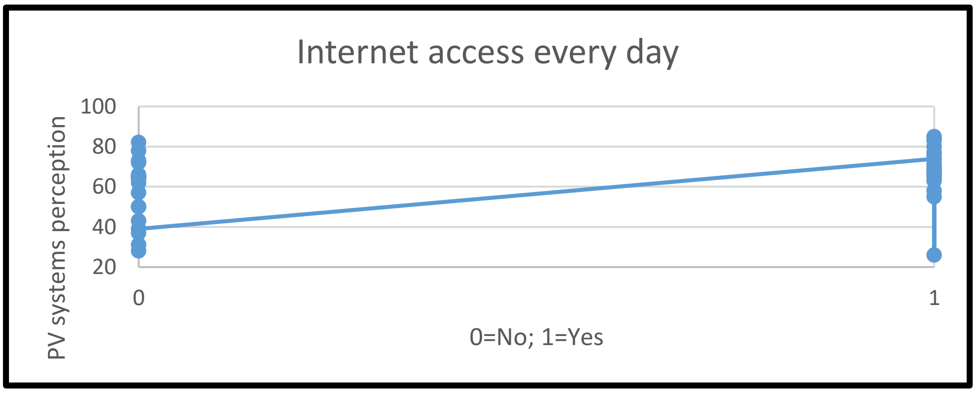


Figure 13. Internet access every day

(15) Decision-making and PV systems perception scores

Rogers (2003) established the types of decision-making concerning innovations to be optional, collective, and authority, described in detail in section 2.2 “Diffusion of Innovations theory”. The variable of *decision making* was tested upon the PV perception scores to find relationships, but no statistically significant results were obtained.

(16) Acceptance of PV and PV systems perception scores

The general acceptance of PV systems is closely related to what Rogers (2003) said about potential adopters and their ability to cope with uncertainty, their position in favor of science, and their positive attitude towards change. The more uncertainty a person can stand and the more favorable attitude towards science and change means that the person is more likely to perceive innovations as positive and to adopt them earlier than other individuals in the system. The Kruskal-Wallis test had a statistically significant result. Respondents who at the moment stand in favor of PV systems had higher perception scores. The previous can be interpreted as these respondents are more prone to cope with uncertainty and have a favorable attitude towards science and change. The correlation coefficient (r_{pb}=0.3682) weak (Schober et al., 2018) and moderate (Cohen, 1988). The positive relationship is depicted in figure 14: PV systems perception scores (Y-axis) increase when moving from 0 (No acceptance of PV systems) to 1 (Acceptance of PV systems) in the X-axis.

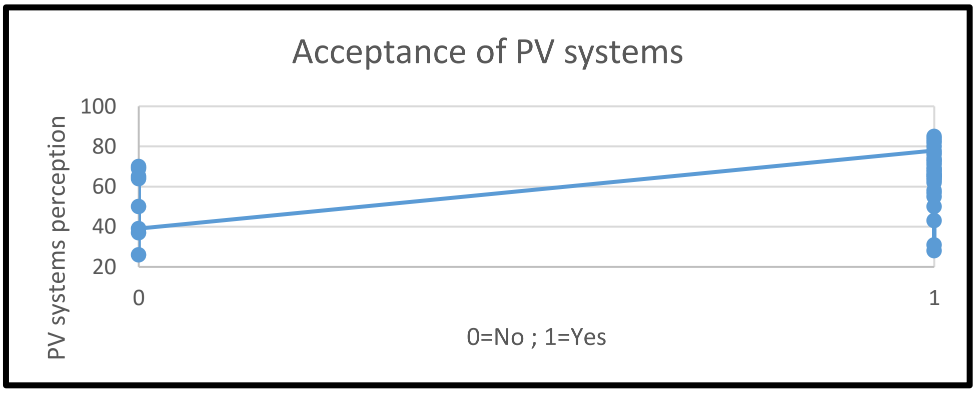


Figure 14. Acceptance of PV systems

(17) Environmental awareness scores and PV systems perception scores

In order to be able to perform the Kruskal-Wallis test using the environmental awareness scores and the PV systems perception scores, the former variable was artificially grouped. Four score groups were created as follows: scores from 5 to 10, from 11 to 15, from 16 to 20, and from 21 to 25. The test result was significant at an alpha level of 5%, meaning that one group or more exert some dominance over the others. The previous means that an individual's degree of environmental awareness impacts how they perceive PV systems. According to Dietz, Fitzgerald, and Shwom (2005), the lower EA is, the more negative impacts it has on perception and adoption of cleaner sources of energy.

Since the two variables assessed here are continuous, it was possible to conduct Pearson's correlation coefficient test (Statistics Solutions, n.d.). The correlation ρ=0.7674 was strong (Cohen, 1988; Schober et al., 2018). The 43 observations were displayed and in a scatter plot (see Figure 15). The trendline can be observed along with the equation approximation. It is evident that as EA score increases, so do the PV systems perception scores, thus being in alignment with Dietz et al., (2005).

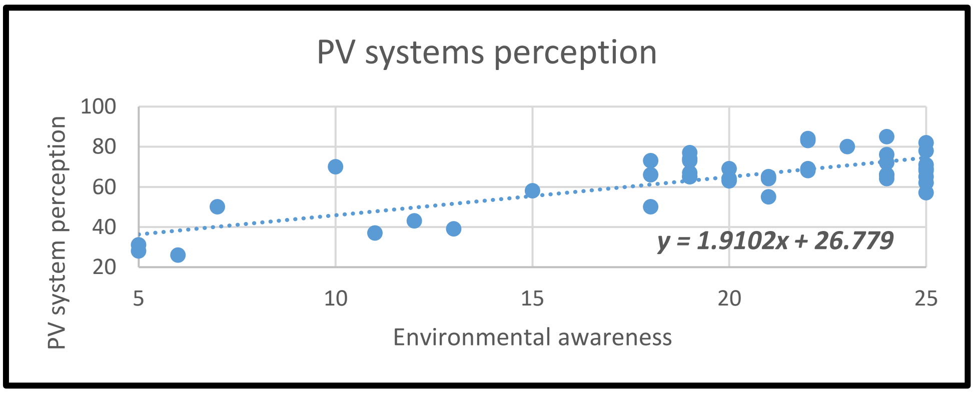


Figure 15. PV systems perception (trendline and approximation equation)

5.2.3 Narrative analysis

It has been stated in section 5.1 "Data collection process" of the document at hand, that six semi-structured interviews were conducted. Despite having a pre-established structure for the interview, they were conducted more in the form of a casual conversation. The narration of the interviewee's responses is shown below.

The conversation started by asking them the reasons for their position (for or against) PV systems based on their answers to the question in part 4 of the survey. Interestingly, two out of the six interviewees stood against PV systems. One of the "rejectors" stated the following:

> *The benefits of using PV systems are indeed evident. But I do not completely like them because they also have a downside. When manufacturing them, some negative impacts are made to the environment. Also, when using and disposing of them. I am not aware of the specific negative impacts PV systems have on the environment, but I know they are kind of severe, and nobody talks about them. That is why I stand against them. I would be good if manufacturing processes and disposing of policies changed so that there is a smaller impact.*

The other "rejector" seemed to be less knowledgeable about PV systems in general and provided a relatively poor answer saying "

> *Why would I accept them? My family or I cannot afford them anyway. We already have access to electricity in our house. I believe my parents will not be willing to give up all their savings for this. Maybe I will when I have my own house, but there are still a few years to go. We will see.*

The four respondents having a favorable attitude towards PV systems had all similar answers. They all reported to like and accept PV systems because they represent an opportunity to save some money from the electricity bills, relating to the economic factor.

All the interviewees had close family members living in the United States. Respondents reported having a certain admiration for them. They look up to them and respect their actions. Three respondents said that their close relatives living abroad come to Chiquilistlán at least once a year and always bring new gadgets and previously unknown devices. Migrants returning home to visit can be considered opinion leaders, as they are respected and influential when introducing new technologies into the system. The previous is in alignment with what Rogers (2003) said about *opinion leaders* being those individuals able to influence other individuals' attitudes towards a particular matter.

Since admiration was mentioned, a new question came up. Interviewees were now asked if there was a person they admire in Chiquilistlán because of what he or she has achieved or represents in the municipality. Only two respondents reported admiring someone in Chiquilistlán. They both stated that these people's actions and values have allowed them to grow and achieve their goals in life. One of them even related the question to PV systems, saying that she admires someone who seeks to protect the environment and has installed solar panels in his house. No names or positions within the system of these admire people were given.

Rogers (2003) argues that individuals who have closer contact with change agents will be more likely to have a positive perception of an innovation and adopt it earlier than other social system members. According to Karakaya and Lundberg (2020), when it comes to PV systems, the change agent role is played by "a solar system provider ideally located in close geographical proximity". Therefore, interviewees were asked if they knew a PV system provider in the municipality or adjacent areas. Five of them reported not knowing if there was any. The remaining respondent claimed to be sure there was not any provider in the area.

An additional question arose from the previous statements. Interviewees were asked if they had seen someone (e.g., provider, environmental agency, government) promoting the use of PV systems in Chiquilistlán. The one who said being sure there was no provider in the area said to have seen one person giving out flyers explaining PV systems on the street but overlooked the organization/company she was working for. The rest of the respondents claimed to have not seen anyone promoting the use of PV systems. One of them said:

> *I never see people coming to Chiquilistlán to explain how these things work. That makes me think about whether the government or private business care for this municipality. I wish we had more personal interaction with people that know about solar energy. Maybe the local government or schools could organize some events where these topics are addressed.*

Finally, interviewees were asked how they would like to be approached with PV systems matters specifically and RETs in general. The (summarized) responses are provided below:

I would like it to be a young person who explains the benefits of installing PV systems. Since we are young people, sometimes we find older people boring. Speakers need to engage with the audience, and having the same age could help.

An expert in that kind of technology should come to Chiquilistlán and explain interested people how they work, and their advantages and disadvantages are. I don't like when companies just try to sell. We need to know if PV systems are a fit for our lives and houses.

I think I prefer to receive information on social media. Someone could create a group where topics related to PV systems are discussed. That way we receive more information. I do not want someone to come to me. If I want information about it, I will look for it on my own.

A person should come to the school and explain how PV systems work. We already take some courses where we learn how to care for the environment. It could be possible to invite experts as guest lecturers.

I like face-to-face interaction. So, talking with an expert about this would be very beneficial for my community and me. I would like to learn more about these devices and why there are good for the environment. Also, knowing how they can make us save money in the future is something that interests me.

I like printed information. It would be nice if we were given some flyers in the school or maybe someone outside the church on Sundays, where many people are gathered. Some people in Chiquilistlán do not know how to read, so having pictures and figures is important to understand the benefits. For young people, maybe social media could work.

As per interviewees' responses, they would like a young person, who has been proven to be an expert in the topic, to come to them and explain their benefits. Different approaches can be tried: social media, conferences in school, printed information. Since no change agents were reported to be seen in Chiquilistlán or the nearby areas, the local government, together with the high school, can invite some PV system providers to explain how the technology works, and also some government representative to explain possible financial aids people could apply for in order to purchase the PV system for their households.

5.3 Reliability and validity

Reliability and *validity* are two terms often used in research, and they are used to assess the quality of it. Several authors consider it crucial to bear in mind these two concepts when conducting research (Middleton, 2019). *Reliability* is defined as the degree to which a measurement device (e.g., test, experiment) produces consistent results on several trials and under the same conditions. This concept is often understood as "repeatability" (Carmine & Zeller, 1979; Moser & Kalton, 1989). In this research, the questionnaires were sent to the respondents by a person of their trust (their professor) with whom the contact was made in the first place to reach the students. If another researcher follows this same process, similar results ought to be obtained. Consequently, it can be said that this research has relatively high reliability.

The internal consistency of the sample was measured by assessing the reliability of parts 2 and 3 of the survey (environmental awareness and PV systems perceptions, respectively). The method used was developed by Lee Cronbach (1951) and was named after him as Cronbach's alpha. This test shows if constructs and scales used as an instrument for research projects are fit for the purpose they were established to fulfill (Taber, 2017). This test yields a measure of internal consistency. It is represented as a number ranging from 0 to 1 (Tavakol & Dennick, 2011); the higher the alpha, the more consistent the sample is. Using the Real Statistics Add-In developed by Zaiontz (n.d.), the Cronbach alpha of the previous survey parts was calculated. The Cronbach's alpha value obtained from part 2 was 0.9278 and for part 3 was 0.9289. They both are interpreted as the sample having an excellent internal consistency (Streiner, 2003; Habidin et al., 2015; Mohd Arof, Ismali, & Saleh, 2018)

The other concept to consider is the *validity* of the study. It refers to the ability of a method to accurately measure what it is supposed to measure (Saunders et al., 2007; Middleton, 2019). Validity can be seen from both an internal and an external perspective, also called constructive and realist, respectively (Yin, 1994). *Internal validity* consists of determining the proper ways to measure the concepts being analyzed, meaning that both the researcher and the respondents have a good understanding (Yin, 1994). According to existing literature, this study’s key concepts (perceived attributes of innovations, photovoltaic system, rural communities and México) were defined. The researcher and respondents had a clear understanding of these concepts’ meaning. It can be inferred that there is high construct validity.

E*xternal validity* refers to the degree to which research results can be generalized (Yin, 1994). To prove its validity, socio-demographic and statistical data used in this research were retrieved from multiple sources, not to mention that the primary data was obtained directly from the respondents via a questionnaire-type survey and semi-structured interviews.

6 Summary and conclusions

6.1 Summary of the study

Chapter 1 of the research starts by providing the reader with the background of the energy situation worldwide, narrowing down the scope to a national level (México) and introducing the need for PV systems implementation in rural communities in the country. Consequently, the research gap was identified as the lack of available data concerning PV system perception in rural communities in México. Therefore, the research aimed to find how potential adopters currently perceive PV systems in rural communities, being Chiquilistlán the case community for analysis, and to propose adequate diffusion methods in the community. The following research objectives were established in order to fulfill this study's goal:

1. To identify the core perceptions of photovoltaic systems among potential adopters in Chiquilistlán, México.

2. To understand the socio-demographic aspects of potential adopters in Chiquilistlán, México and identify relationships with their perceptions.

3. To propose appropriate diffusion processes suitable for potential adopters in rural communities.

Chapter 1 ends with the definition of the keywords and the description of the study's limitations. Chapter 2 starts with a more in-depth description of the photovoltaic principle and the general configuration of PV systems (i.e., PV array, inverter, load center, battery). The Diffusion of Innovations (DOI) theory is introduced. DOI's main elements (i.e., innovation, communication channels, time, and social system), together with the perceived attributes of innovations (i.e., relative advantage, compatibility, simplicity, trialability, and observability), are described in detail in this chapter. Moreover, the theoretical framework is presented.

Chapter 3 describes México as the case country and Chiquilistlán as the case community for analysis. Socio-demographic and energy-related data at both levels is provided. Particularly about the community, the potential for PV energy generation is depicted together with the scarcity of services and its situation of poverty. This chapter concludes by justifying the decision to use Chiquilistlán as the case community.

In chapter 4, the methodology followed for this study's purposes is described. The research design (exploratory), research strategy (case study), research approach (mixed-methods), as well as sampling design (non-probability sampling method) are explained.

Chapter 5 dealt with the empirical part of the study, the analysis of the results, and the findings. This chapter introduces the data collection methods used for this research (questionnaire-type survey and semi-structured interview). Quantitative data were analyzed using descriptive statistics, namely tables and charts of frequencies and percentages. Additional analyses were conducted by the use of inferential statistics. Due to the nature of the sample data, the Kruskal-Wallis test was used to find relationships between variables. Those variables that yielded a significant Kruskal-Wallis test were further tested with a point-biserial correlation test to discover the kind of existing relationship and its directionality. A narrative analysis method was used in terms of quantitative data, based on which interviewees' responses were presented. To conclude this chapter, arguments for the reliability and validity of the study are stated.

6.2 Conclusions of the study

The ultimate goal of this study is to provide diffusion insights to authorities, opinion leaders, and change agents (e.g., PV system providers) based on the perceptions the potential market has of PV systems. Considering the research objectives stated in chapter 1, key findings were obtained, and therefore, the research question was answered accordingly.

Even though it was stated in section 1.2 that there is a lack of literature concerning implementations of PV systems in rural communities in Mexico, this study's findings resulted in being to some extent aligned with the general literature regarding the diffusion of innovations, RETs adoption, and PV implementation. For instance, the fact of *relative advantage* being the highest-scored perceived attribute relates to Labay and Kinnear (1981), who found perceived relative advantage to influence solar energy systems adoption. Two of the lowest scored factors (installation costs and maintenance) are in line with what has been said by Mahapatra and Gustavsson (2008) and Willis et al., (2011). Additionally, Caird, Roy, and Herring (2008) and Caird and Roy (2010) found that the main motive for adopting micro-generating technologies (e.g., PV systems) was the economic the incentive to lower energy bills. This study found that income monitoring stands as one of the most influential contributors for a positive perception.

Given the results described in chapter 5, specific actions are suggested to improve the perception of PV systems among potential adopters in Chiquilistlán. They are starting with the fact that having electricity at home affects individuals' perceptions. On a local level (Chiquilistlán), according to INEGI (2015), 97.9% of households have access to electricity. However, from this study's sample, only 93.02% do. A combined effort between local, state, and national governments should grant these households electricity access through the conventional grid. Otherwise, potential adopters could opt to install a PV system if their personal and societal conditions allow them in the medium or long run. Either way, the mere fact of having electricity at home would develop a more favorable perception of PV systems.

It was found that the type of stove respondents have at home impacted their perception of PV systems. The most significant impact was observed when transitioning from a wood-burning stove to an electric one. The second most significant impact was found to be when moving from wood-burning to gas stove. The lowest impact was seen from gas to electric stove. Moving from a wood-burning stove to any of the other two has a significant impact. Therefore, campaigns should be held in Chiquilistlán to create awareness of the health risks of using wood-burning stoves at home. The latter should be accompanied by funds provided by the government and/or private stakeholders to support individuals on the acquisition of a different kind of stove, as they might not afford it (recall the poverty status in Chiquilistlán, see section 3.2). Funding policies have been successfully executed in other developing countries such as Ecuador (Lagunes-Díaz, González-Ávila, & Ortega-Rubio, 2015).

With only 55.81% of the respondents having access to Internet every day, this variable resulted in having an impact on the perception of PV systems. Blanco (2021) reported that local and state authorities of Jalisco had launched a program that, among other goals, aims to provide Chiquilistlán and surrounding municipalities with free high-speed Internet connection in public places and schools. If the previous is achieved, the share of individuals with access to the Internet will increase, and consequently, the perception of PV systems will increase. Moreover, it will represent an opportunity for more people to join the online discussion groups suggested earlier in this section.

A strong relationship between environmental awareness scores and the perception of PV systems by potential adopters. The higher the environmental awareness, the better the perception. According to Jacobsson and Johnson (1998), social acceptance of renewable sources can be enhanced by society's acknowledgement of the benefits of using renewable sources and the awareness of the effects current energy systems have on the environment. This can be achieved by implementing the diffusion methods described below:

- Face-to-face: if approached personally, respondents prefer it to be by a young person who is knowledgeable about PV systems. This "expert" person is to be able to answer questions people from the community might have. The focus of the conversation should be on both technical aspects and the benefits the systems bring to the people implementing them. The local government and schools should organize these live conferences.

- Online discussion groups: foster the use of discussion groups in online platforms. Ideas, opinions, and thoughts are shared. People who would like to know more about the topic should look for experts on PV systems to further discuss any concerns.

- Printed information: since some individuals might not have time to attend a conference or might not have Internet access to take part in the online discussion groups, printed flyers were suggested as a means to reach more people and provide valuable information about PV systems. These printed outlets should include images and figures to understand the content better.

Based on the findings mentioned above, the research question (*How are photovoltaic systems perceived among potential adopters in rural communities, and how to diffuse them properly?*) can be answered as follows: photovoltaic systems are perceived as relatively advantageous, being “generation monitoring”, “solar power potential” and income monitoring” the main contributors to this perception, whereas the proper ways to diffuse the PV systems (e.g., functionality, advantages, disadvantages) are via face-to-face interaction with experts, through social media (for instance discussion groups) and printed materials.

In conclusion, innovation and technology cooperation is required. Public, private, and academic institutions must collaborate to increase the deployment of information regarding renewable energy. This collaboration should include joint strategic dissemination projects between the aforementioned entities with the aim of providing potential adopters with conceptual and technical training, and even perhaps economic support. Non-governmental agencies should also take part spreading and marketing such projects and the benefits they offer. The previous, striving for an increase in environmental awareness, which will cause an increase on PV implementation rates and thus, better economic, social and environmental conditions will be experienced in rural communities in México.

6.3 Future study suggestions

As stated in section 4.2 “Research design”, this research follows an exploratory design. Thereby, it is not meant to provide definite answers but rather to explore the research topic and to set the basis for further research while providing insights about a specific phenomenon (Singh, 2007: 64). Due to the previous reason, the following could be considered as suggestions for future research:

1. *Perception and diffusion of PV systems in other rural communities*

This will involve conducting a similar study than the one at hand in other rural communities in México. It will be crucial to find whether the relationships between variables are the same or if different variables are found to be the impactful ones. If there are similar results when studying different communities, national policies to foster PV systems can be designed to benefit these communities. Else, only local, or regional policies should be implemented.

An interesting case is the one of Mezquitic in Jalisco. This municipality is ranked first in both the poverty and the extreme poverty categories in the state, yet it is the municipality that has the highest PV implementation rate (18%) (INEGI, 2015). Chiquilistlán has the second-largest share of population living in poverty and the third-largest living in extreme poverty, and only a PV implementation rate of 0.1%. Further research is suggested to know why the PV implementation in Mezquitic is much larger than Chiquilistlán’s and learn what diffusion methods have been implemented to achieve such a high share.

2. *Home-returning migrants and how they could impact rural communities’ perceptions of renewable energy technologies*

It would be beneficial to study the impacts the abroad-family members could have on rural communities if the former play a conscious role of opinion leaders in terms of PV systems in particular and RETs in general. These relatives living, for instance, in the United States, a highly developed country, are more exposed to new technologies and could perhaps better understand innovations. Their close contact with individuals in rural communities could signify an increase in the PV systems perception score.

3. Opinion leaders in rural communities.

A certain degree of admiration was found among members of the same social system. Research is advised to find who these “admired” people are and train them to become opinion leaders in the community. Studying potential adopters’ perceptions before and after exposure to opinion leaders is crucial to discover how meaningful the impact is.

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Appendices

Appendix 1. Survey

<u>Part 1: Socio-demographic characteristics</u>

*Check the box that best describes yourself.

Gender:

- ☐ Female
- ☐ Male
- ☐ Other

Age:

- ☐ 15-16
- ☐ 17-18

How many people live in the same house as you do?

- ☐ 1-2
- ☐ 3-4
- ☐ 5-6
- ☐ 7-8
- ☐ 9 or more

Do you have electricity at home?

- ☐ Yes
- ☐ No

What kind of stove is there in your house?

- ☐ Wood-burning
- ☐ Gas
- ☐ Electric
- ☐ Other

Describe your situation:

- ☐ Both of my parents know how to read and write
- ☐ Only one of my parents know how to read and write
- ☐ Neither of my parents knows how to read and write
- ☐ I was raised by one parent who knows how to read and write
- ☐ I was raised by one parent who does not know how to read and write

Part 2: Environmental awareness

*How much do you agree with the following statements? Consider 1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree

Statements	1	2	3	4	5
(EA1) Renewable energies are needed to have a "cleaner" future					
(EA2) Implementation of renewable energy technologies will bring environmental, social, and economic benefits to my community and the world					
(EA3) Energy generation based on renewable sources is less harmful to the environment than that based on fossil sources					
(EA4) Solar-based energy systems generate enough to cover my daily energy needs					
(EA5) People will care more for the environment when they become more aware of the current problems it is facing					

Part 3: Perceived attributes of PV systems

*How much do you agree with the following statements? Consider 1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree

Relative advantage

Statements	1	2	3	4	5
(Economic) The implementation of PV systems in my house will help me reduce the energy bills cost and get some profit from the sale of unused generated energy					
(Environment protection) The use of PV systems contributes to the reduction of harmful emissions to the environment					
(Solar power potential) The power of the sun is inexhaustible					
(Convenience) The use of PV systems will make my life better.					
(Social prestige) The use of PV systems will afford me a higher status in my society					

Compatibility

Statements	1	2	3	4	5
(Social values) Members of my society positively view the implementation of PV systems					
(Installation costs) I can afford the installation of a PV system in my house					
(Global trends) I want to be in line with the global trend of “going green”					
(Land use) I have enough space in my property (land or rooftop) to install the PV system					
(Current trends) I need solar-based energy in my life					

Simplicity

Statements	1	2	3	4	5
(Functionality) It is easy to understand how PV systems work.					
(Access to providers) It is easy to access service providers in the municipality					
(Learning attitude) I am willing to learn more about PV systems on my own.					
(Maintenance) If it breaks, it will be easy to fix it myself.					
(Infrastructure) My house is suitable for the installation of a PV system.					

Observability

Statements	1	2	3	4	5
(Visibility) If I see a PV system on a rooftop, I would like to know more about it.					
(Neighbor attitude) My neighbors will support my decision to implement PV systems in my house.					
(Generation monitoring) It is essential to know the amount of energy my PV system generates.					
(Income monitoring) It is essential to know how much money I make from the sale of my surplus energy.					
(Dissemination) I am willing to spread the word about the pros and cons of the installation of PV systems.					

Part 4: General acceptance/rejection of PV systems

*Check the box that best describes yourself.

In this moment of your life, do you stand in favor or against PV systems

- ☐ Yes
- ☐ No

Part 5: Exposure to media, networking, and decision-making

*Check the box that best describes yourself.

Do you have family living abroad?

- ☐ Yes
- ☐ No

Have you traveled abroad?

- ☐ Yes
- ☐ No

How often do you visit other municipalities?

- ☐ Never
- ☐ Less than once a month
- ☐ Once or twice a month
- ☐ Once per week or more

Do you know someone who has installed a PV system?

- ☐ Yes
- ☐ No

How often do you have conversations related to environmental issues of renewable energies?

- ☐ Never
- ☐ Less than once a month
- ☐ Once or twice a month
- ☐ Once per week or more

Do you have access to Internet every day?

- ☐ Yes
- ☐ No

Do you use any kind of social media?

- ☐ Yes
- ☐ No

How much time per week do you spend watching TV per week?

- ☐ I do not have a TV
- ☐ 0-2 hours
- ☐ 3-5 hours
- ☐ 6-8 hours
- ☐ 9 hours or more

When you implement a new technology or practice in your life:

- ☐ It is my decision. I do not care what other people think
- ☐ I seek consent and advice from other members of my community
- ☐ Someone within my community who has more authority or power tells me what to do

Appendix 2. Semi-structured interview

1. Why do you stand in favor or against PV systems in this moment of your life?
2. What do you think of your relatives living abroad?

   Do you think you admire them?

   When they visit, do they bring any kind of technology you did not know before?
3. Do you know if there are any PV systems providers in Chiquilistlán?
4. How would you like to receive information about PV systems?

   By which means of communication?

   What kind of information concerning PV systems would you like to receive?