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This three-article dissertation investigated the main factors shaping consumer preferences for residential rooftop solar panels in Saudi Arabia. Particular attention is focused on how individual socio-economic characteristics, the built environment, social networks, and fiscal incentives influence the willingness to adopt and pay for solar panels. Much of this sort of research has been neglected in a non-Western setting.

Drawing from data collected through an online survey of 1,647 respondents in Saudi Arabia, the three papers employed chi-square tests of association to unravel these interactions for three different, nonwestern geographic settings in Saudi Arabia: a large urban area (Riyadh City), a medium-sized urban area (Buraydah City), and the rural areas of Al-Qassim Province.

The first study revealed that the willingness to adopt was influenced by personal environmental values, financial incentives, previous cost-benefit perceptions, and the built environment. The second study found that the willingness to pay was strongly associated with prior perceptions and expectations linked to household energy budgets and solar panel costs, fiscal incentives, and existing environmental beliefs. In the third study, the focus shifted to the actual price individuals were willing to pay for solar installations, where socio-economic factors such as gender and income levels emerged as significant determinants.

Geographic variation was evident in the associated factors with the willingness to adopt, pay, and price preference for rooftop solar panels. The study's results underscore the necessity for customized policy approaches to promote renewable energy use in Saudi Arabia, contributing to a more nuanced understanding of the local solar energy market and offering insights for policymakers to foster inclusive and sustainable energy transitions.

NAVIGATING RENEWABLE ENERGY MARKETS IN SAUDI ARABIA: RESIDENTIAL ROOFTOP SOLAR PANELS AND POTENTIAL CONSUMER PREFERENCES

by

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Dr. Keith Debbage
Committee Chair

DEDICATION

I dedicate this dissertation to those whose unwavering support has propelled me through the highs and lows of this academic journey. To my beloved parents, your encouragement, sacrifices, and unlimited support have been the cornerstone of my success. To my dear wife, your support and understanding made my study abroad experience possible, enriching my academic pursuits immeasurably. To my cherished family and friends, your constant help and support have been a source of strength. And to my esteemed mentor, Dr. Debbage, your guidance, wisdom, and unwavering belief in my potential has been transformative. This dissertation stands as a testament to the profound impact of your support.

APPROVAL PAGE

This dissertation written by Sami A Alwulayi has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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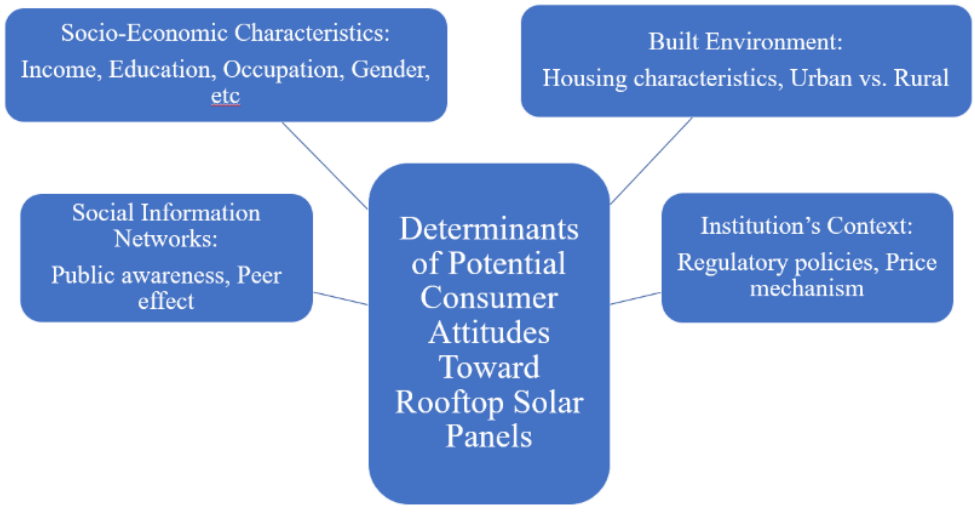
CHAPTER I: INTRODUCTION

Urban and economic sustainability goals are among the mandates that countries have begun to pursue, especially in the context of adopting renewable energy (Ahmed & Shimada, 2019; Spiliotopoulou & Roseland, 2020). One of those urban sustainability endeavors is to obtain "clean" energy to meet the demands of a growing population and an expanding economy, thus mitigating urban environmental impacts (Bibri & Krogstie, 2017). Concurrently, economic sustainability focuses on reducing reliance on non-renewable energy sources, such as oil, which is particularly relevant for oil-rich nations like Saudi Arabia (Opeyemi, 2021). By prioritizing renewable energy, countries like Saudi Arabia can enhance economic sustainability by preserving oil reserves for export and refining into higher-value products instead of domestic energy consumption, thus generating significant financial savings and promoting a more sustainable economic model (Fattouh et al., 2019).

In the dynamic of free markets, consumer demand can significantly influence trends and shape industries (Prahalad & Ramaswamy, 2004). Analyzing individual attitudes regarding the transition to renewable energy can help us to better understand the market and address the challenges and opportunities facing renewable energy markets. Although numerous studies have explored individual attitudes and perceptions toward renewable energy in Western settings (Claudy et al., 2011; Ozkan & Le Gallo, 2018; Karytsas et al., 2019), research remains limited in Middle Eastern contexts. An economic geography perspective on these matters can provide a more rigorous theoretical framework through which we can examine how consumer attitudes vary by location and why certain consumer market dynamics might impact the renewable energy sector (Smith, 1674; Ottaviano & Thisse, 2005; Öner & Klaesson, 2017).

Many studies have highlighted the importance of assessing societies' readiness to embrace renewable energy in terms of their willingness to adopt various renewable innovations (Wüstenhagen et al., 2007; Kumar & Nayak, 2023). These studies have examined the attitudes of potential consumers and investigated their willingness to pay, and the price they are inclined to invest in renewable energy, to better understand the economic dimensions of consumer behavior (e.g., Zografakis et al., 2010; Karytsas et al., 2019). Most of the existing literature suggests that consumer behavior and attitudes with respect to residential rooftop solar panels in terms of the willingness to adopt, pay, and price preference can be shaped by four groups of determinants including socio-economic characteristics (e.g., income, education level, gender, etc.), the built environment (e.g., urban vs rural, housing characteristics, population density, etc.), social networks (e.g., public awareness, peer effect, etc.), and government policy (e.g., financial subsidies, tax reductions, etc.) (Figure 1).

Figure 1. The Broad Determinants of Potential Consumer Attitudes Toward Rooftop Solar Panels.



In the context of Saudi Arabia, while some research has addressed these topics (Mosly & Makki, 2018; Makki & Mosly, 2020; Alrashoud & Tokimatsu, 2020), the varied geographical context of the Kingdom has often been overlooked, limiting the broader applicability of their findings. This three-article dissertation aims to fill this gap by focusing on the willingness to adopt, the willingness to pay, and specific price preferences for residential rooftop solar panels across three distinct geographical contexts in Saudi Arabia (e.g., large urban areas – Riyadh City; medium-sized urban areas – Buraydah City; and rural areas – Al-Qassim Province). By examining these diverse geographical contexts, this study seeks to provide nuanced insights into the potential consumer attitudes toward renewable energy, thereby enhancing the generalizability of the findings within the Saudi context and contributing to a more comprehensive understanding of the key factors potentially influencing the renewable energy market in the Middle East.

While the conditions in Saudi Arabia are considered ideal for using solar energy, only 2% of the population currently uses solar energy, which raises questions about the reasons behind the low adoption rate for solar energy (Tarawneh & Chowdhury, 2018; General Authority for Statistics, 2023). Given the increase in electricity demand, particularly from the residential sector which accounts for half of the country's electricity consumption, there is an urgent need to explore solar energy as a solution particularly as consumers begin to shift away from fossil fuels (General Authority for Statistics, 2023; Ministry of Finance, 2023). While the establishment of solar farms on natural lands by some governments has helped it has also led to negative impacts on natural habitats, and generated high operational and maintenance costs. Better utilizing the built environment in urban areas, particularly residential rooftops, for solar panel installation could provide a viable alternative solution (Turney & Fthenakis, 2011; Vervloesem et al., 2022).

This approach will not only address the negative impacts associated with large-scale solar farms but also better engage the population more directly in the clean energy transition.

Moreover, the Kingdom of Saudi Arabia's comprehensive development plan titled "Vision 2030", launched in 2016, underscores the national commitment to diversify the economy and reduce oil dependency as a source of income and energy in order to reach more sustainable outcomes (Vision 2030, 2023). This strategic shift toward environmental and economic sustainability re-emphasizes the importance of better understanding the behaviors of potential consumers of renewable energy, which is likely crucial for successful market adaptation and the development of effective policies (Bergquist et al., 2020; Inderberg et al., 2020).

This three-article dissertation, grounded in data from 1,647 online survey participants collected between October and December 2022, employed a chi-square association test to explore various aspects of potential consumer perceptions of, and preferences for, residential rooftop solar panels in Saudi Arabia. By comparing responses from residents of three different geographical settings, the study highlights the diverse factors influencing solar energy adoption across different demographic and geographic contexts. The first paper examined the willingness to adopt solar panels, the second investigated the willingness to pay for them, and the third delved into consumers' price preferences. The existing literature and theoretical frameworks have suggested such behavior in western settings is typically driven by a mix of individual socio-economic characteristics, the nature of the built environment, social networks and government policy particularly as it relates to financial incentives.

Through this comprehensive analysis, this dissertation aims to clarify the perceptions and preferences of potential solar energy consumers in the Kingdom of Saudi Arabia, thus providing

insights that can expand the existing theoretical literature, enhance solar energy utilization rates and contribute to achieving the country's sustainable development goals.

CHAPTER II: FACTORS AFFECTING THE WILLINGNESS TO ADOPT RESIDENTIAL ROOFTOP SOLAR PANELS: EVIDENCE FROM SAUDI ARABIA

1 Introduction

Energy is crucial for modern communities, supporting extensive economic activities and manufacturing (Shakeel & Salam, 2020). The global economy heavily relies on fossil fuels for electricity and power production (Mohammadi & Mehrpooya, 2018). However, this reliance can harm the environment and economy, leading some countries to transition to sustainable renewable energies like solar and wind (Viebahn et al., 2015; Olanrewaju et al., 2019).

This paper will focus on analyzing the willingness to adopt new renewable energy sources in Saudi Arabia, which has a desert climate with long hot and dry periods (Tarawneh & Chowdhury, 2018). Saudi Arabia has enormous potential for renewable energy, especially solar energy due to the country's location and natural characteristics such as high levels of solar radiation. Despite the potential for more solar energy alternatives in Saudi Arabia and related government investments, less than 2% of the residents currently use rooftop solar panels to generate electricity (General Authority for Statistics, 2023). All of these issues create a rationale for analyzing the key predictors that determine what might drive residential receptivity to rooftop solar energy panels in Saudi Arabia, and whether this might vary by place in different geographic settings.

While many studies have explored the socio-economic and technical factors shaping renewable energy adoption, few have considered geographical variations, particularly in non-western settings. Balta-Ozkan and Le Gallo (2018) have suggested that “the existing literature ignore(s) the role of spatial factors on energy attitudes and perceptions …” (p. 1). In line with

Balta-Ozkan and Le Gallo (2018), most previous studies on energy behavior in Saudi Arabia have used small samples or a research sample without a geographical focus (e.g., Mosly & Makki, 2018; Makki & Mosly, 2020; Alrashoud & Tokimatsu, 2020). This limits the generalizability of the findings and prevents researchers from understanding the role of spatial factors on energy attitudes and perceptions. This paper addresses this gap in the literature and aims to better understand variations in the willingness to adopt solar panels in different Saudi communities.

Overall, in terms of the central research questions or themes, it is hypothesized that the willingness to adopt rooftop solar panels will be shaped by a combination of factors that include several key socio-economic predictors, variations in the built environment, the institutional context, and various social information network effects (Figure 2). Specifically, this research will address the following research questions:

1- Is there a spatial variance in the willingness to adopt residential rooftop solar energy panels across different types of built environment in Saudi Arabia?

2- What are the variables that are most closely associated with the willingness to adopt residential rooftop solar energy panels in Saudi Arabia?

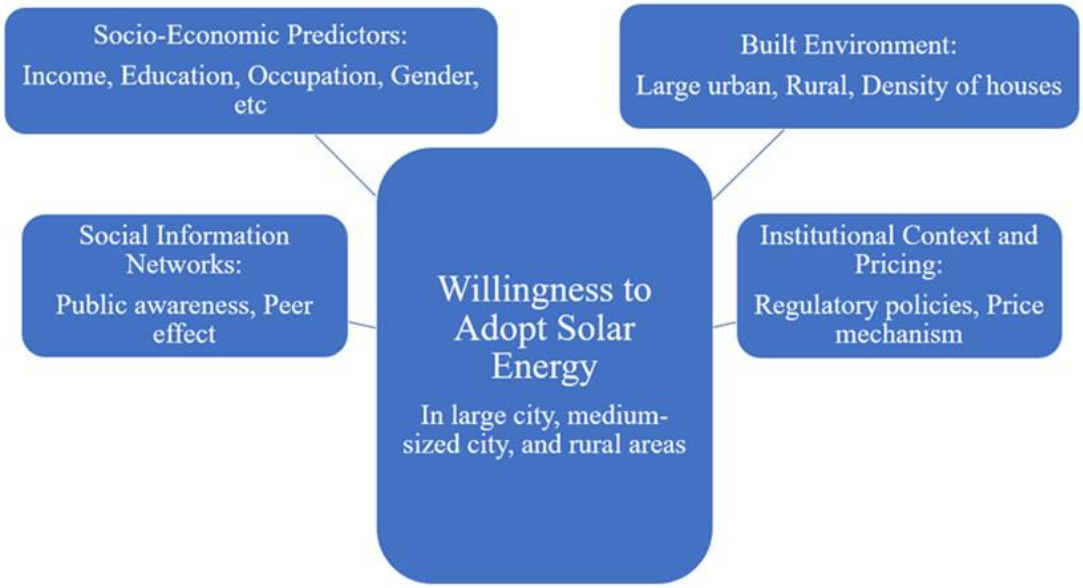
3- Is there spatial variation in those key factors most associated with a strong willingness to adopt residential rooftop solar energy panels?

2 Literature Review

In the existing literature, residential receptivity to rooftop solar panels is widely considered to be influenced by four primary determinants: socio-economic predictors (e.g., age, income, education), the built environment (urban vs. rural), social information networks (e.g., peer effects, knowledge spillovers), and the institutional context and pricing (e.g., subsidies,

energy rates) (Noll et al., 2014; Karytsas & Theodoropoulou, 2014; Ribeiro et al., 2014; Yuan et al., 2015; Palm, 2017) (Figure 2).

Figure 2. Conceptual Framework



Note. Derived from Balta-Ozkan and Le Gallo, 2018

2.1 The Socio-Economic Predictors

Several previous studies have highlighted the role of socio-economic factors in shaping renewable energy adoption rates. Factors like income, age, education, and occupation can impact the knowledge and acceptance of renewable energy (Komatsu et al., 2011; Ribeiro et al., 2014; Mosley & Makki, 2018). In some cases, higher-income households are more inclined to embrace renewable energy, while younger, better-educated individuals are likelier to embrace solar alternatives (Komatsu et al., 2011; Karytsas & Theodoropoulou, 2014; Purwanto & Afifah, 2016).

For instance, Ek (2005) studied Swedish homeowners and found an inverse relationship existed between support for renewable energy and both, age, and income. However, Lay et al.

(2013) conducted a study on energy choices among Kenyan homeowners and found that increasing household income has a significant impact on solar adoption rates. Komatsu et al. (2011) noted that higher-income households and larger families in Bangladesh were more likely to adopt solar panels due to their financial resources. Additionally, larger families frequently switched to solar energy to reduce indoor pollution caused by traditional kerosene-powered lighting (Komatsu et al., 2011).

In a 2018 survey in Bahrain, Alsabbagh (2019) found a positive relationship existed between income and the inclination to adopt solar panels, with 48.2% of participants expressing the desire to adopt solar panels. In Greece, Sardianou and Genoudi (2013) observed that middle-aged individuals and those with higher education levels were more willing to adopt renewable energy. A survey in Shandong province, China (Yuan et al., 2011), revealed that individuals with higher education levels were more familiar with and supportive of renewable energy for home use.

2.2 Built Environment

Schunder et al. (2020) have argued that the "geographic context is a major determinant of rooftop solar adoption" (p. 2). The built environment refers to settlement type, which can range from large urban areas to rural settings with varying population densities. Numerous studies have explored how the type of built environment affects the acceptance of renewable energy, either directly or indirectly, by examining how community settings and population density levels influence the willingness to adopt rooftop solar panels (Ramachandra & Shruthi, 2007; Olson-Hazboun et al., 2018; Wang et al., 2019).

Crago and Chernyakhovskiy (2017) investigated how rooftop solar panel usage varied in 13 US states from 2005 to 2012. They found that higher levels of urbanization decreased the

adoption of rooftop solar panels, while a higher density of owner-occupied homes increased adoption rates, as homeowners are more likely to install solar panels than renters. Jacksohn et al. (2019) analyzed solar energy adoption rates in Germany from 2008 to 2015, finding higher rates in rural areas than urban areas, although they didn't provide a specific explanation. Zahran et al. (2008) explored factors affecting solar energy use in the United States and identified a positive correlation between urbanization levels and adoption rates due to the concentration of high-income individuals in urban areas.

Kwan (2012) studied solar energy adoption rates in the US, considering factors like housing density, socioeconomic characteristics, and environmental factors. The study revealed that “a one standard deviation increase in housing density reduces the expected residential solar PV (photo-voltaic) share by 20.4%” (p. 339). Balta-Ozkan et al. (2015) investigated solar energy use in the UK based on socioeconomic and physical characteristics. They found that per capita income and the share of detached houses positively influenced solar energy demand, while an increase in owned homes and population density hindered rooftop solar energy usage due to the lack of space for panel installation. Balta-Ozkan and Le Gallo (2018) found geographical differences existed between large urban areas, small urban areas, and rural regions in European energy perceptions and attitudes. Rural residents saw low energy prices as a national issue, while large urban areas residents favored energy supply continuity and protecting the environment over low prices.

2.3 Social Information Networks

Social information networks can also influence spatial variations in rooftop solar panel adoption rates in residential areas, driven by access to information, peer effects, and knowledge spillovers that can shape solar energy demand (Kwan, 2012; Dharshing, 2017). These networks

provide valuable access to information on pollution, renewable energy benefits, and the role of renewable energy in addressing fossil fuel-related issues (Sovacool & Ratan, 2012; Severo et al., 2019). Well-connected communities with access to this sort of information are more likely to adopt solar energy, potentially triggering peer effects (Palm, 2017). Moreover, visible solar panels on the roofs of homes can be a key factor that increases the desire to adopt solar panels. Schunder et al. (2020) stated "empirical evidence suggests that the presence of rooftop solar systems in a neighborhood or social network encourages further adoption by making benefits observable and reducing uncertainty" (p.2).

Noll et al. (2014) examined the influence of U.S. solar energy organizations that provide information on economic and environmental benefits. The study concluded that community organizations focused on solar energy play a vital role in promoting its adoption among residents. For instance, in San Antonio, Texas, the presence of solar energy organizations has contributed to a high level of familiarity and desire to adopt solar energy systems among residents (Noll et al., 2014). Crago and Chernyakhovskiy (2017) reported a peer effect, where more solar energy users can help to reduce uncertainty in adopting rooftop solar panels. Dharshing (2017) examined rooftop solar panel patterns in Germany and identified significant spatial spillover effects between neighboring counties, leading to the formation of "solar cluster" adoptions over time.

Graziano and Gillingham (2015) examined solar energy adoption patterns in Connecticut and found that the presence of an additional installation within 0.5 miles of adopting households increased the number of installations in a block group by an average of 0.44 PV systems. Palm (2017) found that peer effects in Sweden serve as a motivator for individuals already interested

in solar energy. Additionally, the study revealed that peer effects are strongest within close social relationships, as they provide confirmation that the solar energy system functions effectively.

2.4 Institutional Context and Pricing

Government policies and financial support play a significant role in shaping public acceptance and the adoption of renewable energy (Simpson & Clifton, 2016; Mosley & Makki, 2018). The higher costs associated with some renewable energy technologies can hinder their adoption rates such that government subsidies become crucial in overcoming this barrier (Dulal et al., 2013; Yuan et al., 2015). The cost of solar panels specifically has been found to negatively impact consumers' willingness to adopt solar energy (Irfan et al., 2021).

Dulal et al. (2013) have argued that "in the absence of government support, large-scale diffusion of renewable energy is impossible because of the high up-front capital costs" (p. 306). Also, they suggested that consumers' access to renewable energy technologies can be limited due to the high cost, unless the governments support them by subsidizing these technologies. Liming (2009) highlighted the importance of government funding and subsidies in increasing the spread of renewable energy, particularly in rural areas of China and India. Painuly (2001) meanwhile emphasized the need for governmental intervention to address market imperfections and create favorable financial, institutional, and regulatory environments for promoting renewable energy technologies.

Peidong et al. (2009) identified government financial support, including subsidies for products and users, as the most effective method for promoting renewable energy adoption in China. Similarly, Timilsina et al. (2012) emphasized the significance of financial support packages, such as subsidies for households and investors, in driving the use of solar energy globally. Mosley and Makki (2018) found that while individuals express support for renewable

energy and environmental protection, they may not be willing to pay the high costs typical of renewable energy installations. Moreover, Sardianou and Genoudi's (2013) study in Greece emphasized the pivotal role of financial incentives, particularly tax deductions, in influencing a consumers' intentions to adopt renewable energy systems in their homes.

3 Methodology

The purpose of this paper is to develop a better understanding of how the willingness to adopt rooftop solar panels varies across three different geographic scales and contexts in Saudi Arabia (i.e., large urban area – Riyadh City; medium-sized urban area – Buraydah City; and rural area – Al-Qassim Province) (Figure 3) based on four potential clusters of determinants (i.e., various socio-economic variables, the built environment, social information networks, and the institutional and pricing context) (Figure 2). Because the data were collected via survey, the key variable – willingness to adopt – was constructed based on a Likert scale response that included seven categories ranging from Strongly Disagree to Strongly Agree.

A series of additional questions were asked to both help establish a socio-demographic profile of the survey respondents (e.g., age, income, level of educational attainment) and also where each respondent stood on a wide range of issues (e.g., willingness to adopt, climate change, solar panels, potential costs, etc.). To gather data for this study, a survey was constructed using Qualtrics software and distributed online between November and December 2022 in Saudi Arabia (Appendix A). The survey was generally distributed online primarily through WhatsApp, Facebook, and X, but participants outside the prescribed study areas were excluded.

Figure 3. Map of Saudi Arabia and the Three Study Areas (Riyadh, Buraydah, and Al-Qassim Province).

Additionally, a number of residents in the targeted areas were asked randomly on the streets and in places of gathering to share the survey on WhatsApp and in online groups they were part of, resulting in a snowball sampling approach. Additionally, prominent X and WhatsApp users were approached to distribute the survey, with a focus on accounts widely followed by residents of the three study areas, especially those recognized for sharing local news. In total, 1,647 fully completed survey responses were collected from these targeted areas.

The three study areas were chosen due to their significant disparities across various metrics, including population density, educational attainment levels, median household income,

and housing characteristics, as outlined in Table 1. Riyadh City stands apart from Buraydah and the rural areas of Al-Qassim Province in several key aspects. Riyadh boasts a larger population and notably higher population densities when compared to the relatively sparser populations of Buraydah and the rural areas of Al-Qassim Province. Furthermore, Riyadh City exhibits distinctive socio-economic characteristics, characterized by a higher median household income and a greater proportion of residents holding bachelor's or more advanced degrees.

The data analysis involved the use of Chi-square for independence to analyze the association between willingness to pay and other key variables. The association of the relevant variables was arranged according to Cramer's V. The chi-square test for independence was chosen because of the nature of the categorical data used in the study and because of the survey design, as it is suitable for evaluating the association between the study variables (Crewson, 2023).

The online survey method was selected due to its ease of distribution, accessibility, cost-effectiveness, and its suitability for researchers targeting large areas (Sue & Ritter, 2012). Additionally, the online survey method has proven successful in several Saudi studies for collecting data while ensuring participants' privacy (Sue & Ritter, 2012; Alsabbagh, 2019; Karytsas et al., 2019; Alrashoud & Tokimatsu, 2020). Moreover, 96% of the Saudi population aged 15 years or older use smartphones connected to the Internet, making online surveys an effective means of reaching the target sample through social media (General Authority for Statistics, 2023). Two sampling methods were employed to collect the data: convenience sampling and snowball sampling approaches. The convenience sampling approach was chosen to facilitate a broad and swift distribution of the survey, allowing all members of the population who wished to participate to respond (Alwelaie, 2012). Compared with the data from the Saudi

census, the data for the 1,647 respondents was highly representative of the socio-economic characteristics of Riyadh City, Buraydah City, and Al-Qassim Province based on education, income, and housing status.

Table 1: Key Statistical Indicators for Riyadh City, Buraydah City, and Al-Qassim Province, 2022

	Riyadh	Buraydah	Al-Qassim
Population	6,924,566	571,169	765,010
Population density per km2	3,846.98	828.3	395.06
Median age	30	28	27
% Children (≤ 15 years old)	22.11	25.40	26
% Workforce (16 to 64 years old)	75.50	72.20	71.30
% Elderly (≥ 65 years old)	2.20	2.40	2.70
Median household monthly income (SR) *	12,688	8,815	9,043.50
% Male	63.2	60.8	57.7
% Female	36.8	39.2	42.3
Less than bachelor degree (% of total population) *	64.5	88.66	85.30
Bachelor degree (% of total population) *	23	10.68	14.48
Master and PhD (% of total population) *	2	0.66	0.22
Average family size	3.5	3.9	4.2
% Multi-family dwelling units	58.1	41.8	37.6
% Single-family dwelling units	41.9	58.2	62.4
% Owner-occupied units	56.2	67.9	69.1

Source: Derived from General Authority for Statistics, 2023.

(* Based on 2018 data from General Authority for Statistics)

The data analysis involved the use of a Chi-square Test for Independence to analyze the association between WTP and the other key variables. The level of association of the relevant variables was ranked according to Cramer's V. The chi-square test for independence was chosen because of the nature of the categorical data used in the study and because of the survey design, as it is suitable for evaluating the associational links between various variables (Crewson, 2023). The contingency tables based on the Chi-square Tests were selected based on an analysis of all

the willingness to adopt contingencies as they relate to all the other key variables included in the survey. Only those variable pairs that were significant at the 5% level were included in this analysis.

4 Findings

In this paper, the data from the 1,647 fully completed survey responses in the three targeted areas, revealed a broadly-based willingness to adopt rooftop solar panels (WTA) ranging from 89.7% of all respondents in Riyadh City to 88.8% in Buraydah City, and 92.7% in rural areas in Al-Qassim Province. By contrast only 3% of all respondents in the aggregate were unwilling to adopt rooftop solar panels while 6.8% had no opinion on the matter. These survey results align well with previous studies of renewable energy in Saudi Arabia, which have consistently demonstrated a high awareness and a general desire to adopt renewable energy sources among the population (e.g., Mosly & Makki, 2018; Makki & Mosly, 2020; Alrashoud & Tokimatsu, 2020). For instance, Mosly and Makki (2018) found that 79.9 % of participants in Saudi Arabia were willing to adopt rooftop solar panels in their homes. A detailed examination of the Willingness to Adopt Likert scales in Table 2 and Figure 4 reveals a consistent response pattern across all three study areas where very few respondents were unwilling to consider adopting rooftop solar panels in the foreseeable future.

The broader implication is that changes in geography and geographical scale do not seem to substantially impact how Saudi residents might view rooftop solar panels. The recent rise in electricity costs from the local network may be a reason behind the high desire to adopt renewable energy sources – as a means to reduce the costs of electric energy – which has doubled in recent years, as part of achieving the goals of financial balance and reducing electricity consumption in the country (Saudi Arabia Ministry of Finance, 2023). Also, Saudi

society, in general, broadly agrees with the government regarding the comprehensive development plan (i.e., Vision 2030), which includes switching to renewable energy sources, due to the speed of positive reforms that have taken place in society since the launch of the plan in 2016 (Saudi Vision 2030, 2023). Although Saudi residents appear very willing to adopt rooftop solar panels across the board, and this does not appear to vary much by place (Figure4), it is less clear what factors are most closely associated with these strong sentiments to adopt rooftop panels and whether or not these factors might vary by place. The deeper question is what are the key variables that best explain what might be triggering these responses both collectively and by study area.

4.1 Test of Independence for Willingness to Adopt – the Key Variables

This paper employed the chi-square test of association to identify links that might exist between the willingness to adopt rooftop solar panels and some of the related variables identified in the literature that might best help explain respondent outcomes across three different geographic scales and contexts in Saudi Arabia. The chi-square test is apt for assessing associations between categorical variables like the willingness to adopt variable that is constructed based on a Likert scale (Crewson, 2023). Moreover, Cramer's V will be used to rank the strength of an association between the willingness to adopt and related variables because it is a simple method to determine if a substantive relationship exists between two variables (Akoglu, 2018; Crewson, 2023). Crewson (2023) stated that “a Cramer's V of 0.1 provides a good minimum threshold for suggesting there is a substantive relationship between two variables” (p. 80). Cramer's V coefficients, which vary between 0 and 1, typically suggest a substantive relationship between two variables when the coefficient is at least 0.10, with values between 0.1

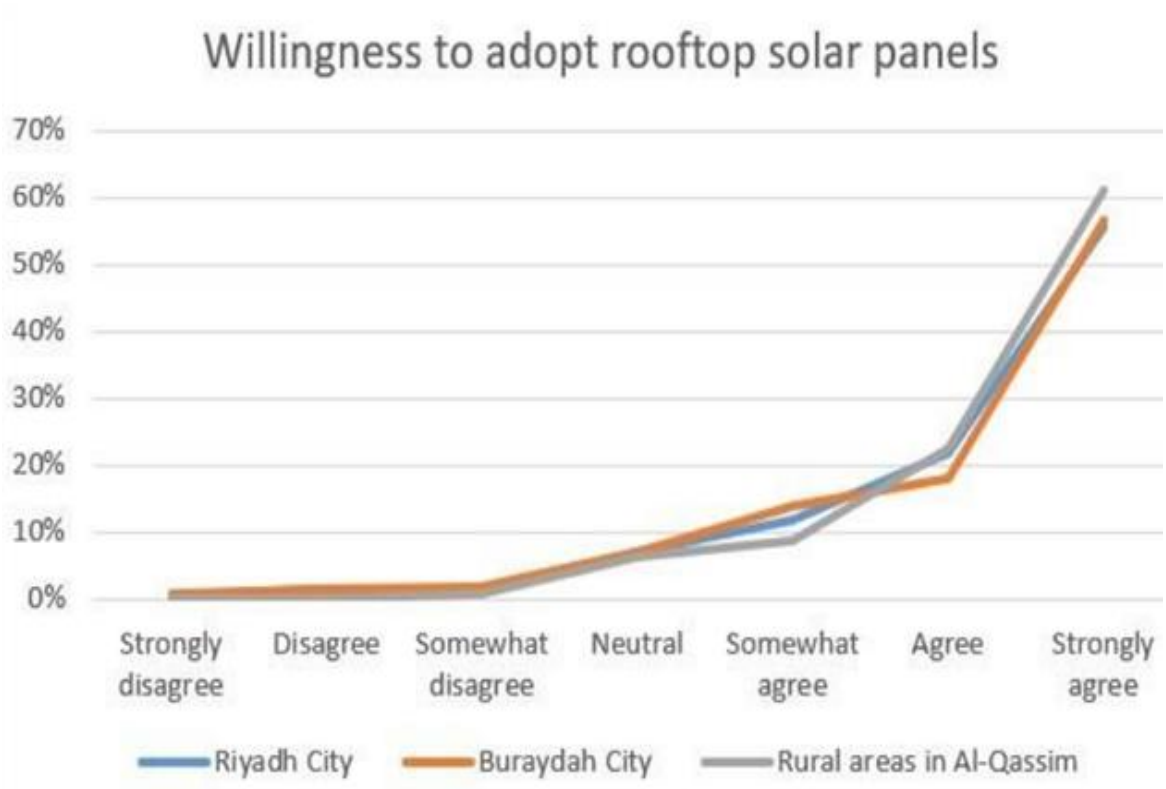
to 0.3 indicating some association, 0.3 to 0.5 indicating moderate association, and above 0.5 indicating high levels of association (Crewson, 2023).

The analysis in this paper only focused on those respondents that expressed some degree of willingness to adopt rooftop solar panels due to the positive skew in the data, and the small number of respondents that disagreed or were neutral on the Likert scale responses across all three study areas (Figure 4). This approach was supported by the fact that previous studies in Saudi Arabia had similarly found a substantial majority that was more than willing to embrace various renewable energy alternatives (e.g., Mosly & Makki, 2018; Makki & Mosly, 2020; Alrashoud & Tokimatsu, 2020). In this way, it becomes possible to conduct a more nuanced analysis that distinguishes between groups with differentiating levels of support.

Table 2: Survey Results for Willingness to Adopt for Riyadh City, Buraydah City, and Al-Qassim Province (n = 1647)

		Riyadh	Buraydah	Al-Qassim	Total
Willingness to Adopt	Strongly agree	474	240	226	940
	% of strongly agree	55.6%	56.5%	61.1%	57.1%
	Agree	187	76	84	347
	% of agree	21.9%	17.9%	22.7%	21.1%
	Somewhat agree	104	61	33	198
	% of somewhat agree	12.2%	14.4%	8.9%	12%
	Neutral	59	30	23	112
	% of neutral	6.9%	7.1%	6.2%	6.8%
	Somewhat disagree	11	8	3	22
	% of somewhat disagree	1.3%	1.9%	0.8%	1.3%
	Disagree	14	7	1	22
	% of disagree	1.6%	1.6%	0.3%	1.3%
	Strongly disagree	3	3	0	6
	% of Strongly disagree	0.4%	0.7%	0.00%	0.4%
	Total	852	425	370	1647

Figure 4. Willingness to adopt rooftop solar panels across the three study areas



To perform the chi-square test of association, the responses related to both the willingness to adopt rooftop solar energy and the other related variables that used the Likert scale were categorized into two distinct groups. The first category, labeled as “moderate agreement”, consisted of responses from participants who either “somewhat agreed” or “agreed” with the willingness to adopt. The second category, designated as “strong agreement”, referred to responses from participants who “strongly agreed” regarding their willingness to embrace rooftop solar energy panels in the foreseeable future. By classifying the data in this manner, it became possible to distinguish between individuals with a strong desire to adopt rooftop solar panels from those with less intense levels of support, thus facilitating a more focused and insightful chi-square analysis.

Almost all the reported results listed in Table 3 are statistically significant, with p-values below 0.05. The findings illuminate both differences and similarities among the study areas concerning the links between willingness to adopt and the various other variables. The results in Table 3 were ranked based on the Cramér's V coefficient score for Riyadh City, primarily because half of the participants in the survey were from Riyadh City, and also because Riyadh holds the distinction of being the capital of Saudi Arabia, as well as the most populous and expansive city in the country.

While at least some elements of the four broad clusters of predictor determinants outlined in Figure 2 are prominently featured in Table 3, it is also clear that, in some cases, the strength of these associational links varies both geographically and by variable. Based on the chi-square test analysis, the willingness to adopt rooftop solar panels in Riyadh City seems to be strongly linked to broader concerns and attitudes linked to whether or not climate change is real since this variable generated the largest χ^2 (i.e., 70.185) and Cramer's V (i.e., 0.32) scores (Table 3).

Specifically, 36.2% (248) of all Riyadh respondents that strongly agreed that climate change is real also strongly agreed that they would be willing to consider installing rooftop solar panels in the foreseeable future (Table 4). By contrast, only 9.3% (64) of all Riyadh respondents that expressed more moderate levels of support for rooftop solar panels also strongly agreed that climate change was real. Similar outcomes were found regarding whether or not respondents believed that renewable energy can be effective in protecting the environment from pollution which generated the third highest scores in Riyadh City ($\chi^2 = 62.952$, Cramer's V = 0.295) (Table 4).

Table 3: Results for Chi-squared Test of Independence (χ^2) for the Willingness to Adopt Rooftop Solar Panels and Related Variables Ranked by Cramer's V Coefficient

	Riyadh City		Buraydah City		Al-Qassim rural areas	
Variable	χ^2	Cramer's V	χ^2	Cramer's V	χ^2	Cramer's V
Climate change is real	70.185	0.32	26.548	0.287	4.955	0.132
I would consider using rooftop solar panels if the government subsidized the financial cost	69.321	0.307	79.301	0.467	35.007	0.33
Renewable energy can be effective in protecting the environment from pollution	62.952	0.295	48.717	0.367	10.144	0.177
I would consider using rooftop solar panels if they are tax deductible	60.424	0.291	57.088	0.403	32.181	0.32
If you installed rooftop solar panels you would expect it to provide at least 20% of the total energy needs for your household	33.49	0.279	23.772	0.325	10.511	0.225
If you installed rooftop solar panels you would expect it to provide at least 50% of the total energy needs for your household	32.024	0.266	27.993	0.344	19.569	0.296
Buying and installing solar panels will likely be expensive	40.324	0.25	14.186	0.204	22.472	0.268
The so-called "ecological crisis" linked to extreme weather events like droughts and floods has been greatly exaggerated	22.095	0.21	13.791	0.237	*	*
If you installed rooftop solar panels you would expect it to provide at least 100% of the total energy needs for your household	13.128	0.187	30.015	0.275	10.827	0.237
Employed/Unemployed	9.809	0.113	*	*	*	*
House ownership status	*	*	6.348	0.13	*	*
Type of house	*	*	5.904	0.125	12.19	0.189

* Not statistically significant

Table 4: Contingency Table for Willingness to Adopt and Environmental Attitudes: Riyadh City

Variable	Category	Willingness to adopt				
		Moderate agreement		Strong agreement		Total
Climate change is real	Moderate agreement	193	28.1%	181	26.4%	374
	Strong agreement	64	9.3%	248	36.2%	312
	Total	257	37.5%	429	62.5%	686
Renewable energy can be effective in protecting the environment from pollution	Moderate agreement	161	22.3%	140	19.4%	301
	Strong agreement	104	14.4%	318	44.0%	422
	Total	265	36.7%	458	63.3%	723

These findings align well with previous research underscoring the interconnectedness of an individuals' environmental consciousness, and their propensity to adopt renewable energy sources (Bang et al., 2000; Ribeiro et al., 2014; Lin & Syrgabayeva, 2016). As pointed out by Khalid et al. (2021), more broadly based "environmental concern has a significant and positive effect on renewable energy adoption" (p. 10). In support of this notion, Shah et al. (2021) posit that social networks can effectively expose individuals to environmental and climate change-related information, thereby shaping more pro-environmental behaviors.

However, these sorts of environmental values do not appear to play out in quite the same way in Buraydah City or the rural parts of Al-Qassim Province where the χ^2 and Cramer V scores do not rank quite as highly as in Riyadh City. For example, it appeared that the association between belief in the reality of climate change and the willingness to adopt rooftop solar panels was ranked sixth out of 11 variables in Buraydah City, and ranked last in Al-Qassim Province. These disparities in environmental attitudes between the more urbanized Riyadh City, and the lesser populated Buraydah and Al-Qassim suggest that the strength of broadly held

environmental values may vary by place. For example, in a study conducted in China, Yu (2014) has observed that "urban residents are more concerned about the environment than rural residents" (p. 47).

Furthermore, the results of the analysis indicate that the willingness to adopt rooftop solar panels in Buraydah City and rural areas of Al-Qassim may be more strongly associated with financial incentives linked to government subsidies and tax deductions rather than the broader environmental values that featured more prominently in Riyadh (Table 3). Specifically, for Buraydah respondents, government subsidies generated the largest χ^2 value (i.e.,79.3) and the strongest association based on the Cramer's V score (i.e., 0.47) when compared to the other places and variables listed in Table 3. In Buraydah, 53.3% (194) of all respondents strongly agreed that they would consider using rooftop solar panels if the government subsidized the financial cost (Table 5). Similar outcomes can be found regarding tax deductions which generated the second largest χ^2 (i.e., 57.1) and Cramer's V (i.e., 0.40) when compared to the other variables listed in Table 3. In Buraydah, 48.6% of all respondents strongly agreed they would consider rooftop solar panels if they were tax deductible (Table 5). Rural areas of Al-Qassim Province exhibited similar trends where government subsidies and tax deductions ranked first and second based on the Cramer's V although the level of association was not as strong as in Buraydah.

Prior research has consistently emphasized the pivotal role of government support, including tax deductions and subsidies, in promoting the widespread utilization of renewable energy technologies, primarily due to the high initial costs associated with these technologies (Timilsina et al., 2012; Dulal et al., 2013; Yuan et al., 2015; Simpson & Clifton, 2016). The significance of the government's role in expediting the adoption of renewable energy

technologies (RET) was underscored by Abbas et al. (2022), who concluded that "the problem of adoption delay emphasizes the importance of adequate technical and financial governmental support when promoting the adoption of RETs" (p. 393). Given the much lower median household monthly incomes in Buraydah and Al-Qassim when compared to Riyadh, it is not surprising that financial considerations might feature more prominently in these locations when considering whether or not to purchase rooftop solar panels. However, financial considerations are also a major concern in Riyadh since government subsidies and tax deductions also featured prominently in Table 3, ranking second and fourth respectively regarding the χ^2 and Cramer V scores.

Table 5: Contingency Table for Willingness to Adopt and Financial Incentives: Buraydah City

Variable	Category	Willingness to adopt				
		Moderate agreement		Strong agreement		Total
I would consider using rooftop solar panels if the government subsidized the financial cost	Moderate agreement	82	22.5%	40	11.0%	122
	Strong agreement	48	13.2%	194	53.3%	242
	Total	130	35.7%	234	64.3%	364
I would consider using rooftop solar panels if they are tax deductible	Moderate agreement	82	23.3%	58	16.5%	140
	Strong agreement	41	11.6%	171	48.6%	212
	Total	123	34.9%	229	65.1%	352

Given the critical importance of financial incentives for those that seem most willing to adopt rooftop solar panels, it is perhaps not surprising that many respondents expected that buying and installing solar panels was likely going to be expensive (Table 6). Such a sentiment was particularly strong in the rural areas of Al-Qassim, where 50.3% of those most willing to

adopt solar panels also strongly agreed that solar panels would be expensive. By contrast, the comparable results for Riyadh (i.e., 41.8%) and Buraydah City (i.e., 46.6%) were a little lower in percent share. The Cramer's V (i.e., 0.27) for solar panel expenses in Al-Qassim ranked fourth (Table 3), suggesting that cost considerations could play a more prominent role in the rural areas of Al-Qassim especially when compared to Riyadh and Buraydah where they played a less prominent role.

Table 6: Contingency Table for Willingness to Adopt and Expected Solar Panel Expenses

Variable	Category	Willingness to adopt				
		Moderate agreement		Strong agreement		Total
Riyadh City						
Buying and installing solar panels will likely be expensive	Moderate agreement	141	21.8%	142	22.0%	283
	Strong agreement	93	14.4%	270	41.8%	363
	Total	234	36.2%	412	63.8%	646
Buraydah City						
Buying and installing solar panels will likely be expensive	Moderate agreement	58	17.0%	67	19.6%	125
	Strong agreement	57	16.7%	159	46.6%	216
	Total	115	33.7%	226	66.3%	341
Al-Qassim Province						
Buying and installing solar panels will likely be expensive	Moderate agreement	53	17.0%	59	18.9%	112
	Strong agreement	43	13.8%	157	50.3%	200
	Total	96	30.8%	216	69.2%	312

The costs of purchasing and installing renewable energy technologies are frequently considered a crucial barrier for people who are considering renewable energy (Yuan et al., 2015; Irfan et al., 2021). Lower-income households are likely to be more affected by high renewable energy costs, which is the case for rural areas of Al-Qassim Province, where household incomes are lower than in Riyadh. Although lower income levels may not be the leading cause for being reluctant to embrace solar energy options (Komatsu et al., 2011; Lay et al., 2013), Yadav et al.

(2019) have recently argued that “some of the path limiting factors in the adoption of decentralised solar in rural areas include: high cost; lack of financial support; and limited awareness” (p. 2).

Along with financial considerations, the expectation that rooftop solar panels might contribute significantly to the total energy needs of a household tended to covary by both place and by the level of willingness to adopt solar panels. It seems that the respondents who have a high willingness to adopt solar panels also have high confidence in the ability of solar energy to generate 100% of the entire household’s electricity needs rather than just 20% or 50%. In Riyadh, those most willing to adopt rooftop solar panels were more inclined to expect solar panels to cover 100% of their total household energy needs (i.e., 37.6% of all respondents) when compared to those that expected it to cover at least 50% (i.e., 24.3%) or 20% (i.e., 24.4%). Similar trends occurred in Buraydah and Al-Qassim, although for those most willing to adopt rooftop panels, the percent of all respondents that expected the panels to provide 100% of total household energy needs was much higher in both Buraydah (i.e., 42.6%) and Al Qassim Province (i.e., 48.4%), than in Riyadh City.

The different energy attitudes and perceptions across rural, small urban, and large urban areas was noted by Balta-Ozkan and Gallo (2018) who indicated that these disparities may be a result of the difference in the level of knowledge about renewable energy sources between rural and urban residents. Positive public perceptions of solar energy, such as the expected economic and energy benefits of rooftop solar panels, are frequently considered key factors in determining adoption rates (e.g., Wall et al., 2021; Ahmed et al., 2022). Wall et al. (2021) have argued that strong “beliefs about renewable energy benefits positively influence consumer adoption of renewable energy” (p. 15).

Another key factor that can determine rooftop solar panel adoption rates is variations in the nature of the built environment, and especially house type (i.e., single-family versus multi-family housing units) (Karytsas & Theodoropoulou, 2014; Ribeiro et al., 2014; Graziano & Gillingham, 2015; Lan et al., 2021). Although this was not a statistically significant factor in Riyadh, where the population density is significantly higher (Table 1), that was not the case in less densely settled Buraydah and Al-Qassim Province, where the chi-squared scores were statistically significant. In the rural areas of Al-Qassim Province, those most willing to adopt rooftop solar panels were more likely to reside in a single-family unit (i.e., 38.8%) than in multi-family units (i.e., 27.1%) (Table 7). Similar trends occurred in Buraydah.

Additionally, in the rural areas of Al Qassim Province, the Cramer V scores for house type (i.e., 0.19) were higher than for more broadly based environmental belief factors linked to ideas that "climate change is real" (i.e., 0.13) or that "renewable energy can be effective in helping to protect the environment" (i.e., 0.18) (Table 3). That is in stark contrast to the Riyadh respondents where the "climate change is real" Cramer V scores ranked first (i.e., 0.32) and the "belief that renewable energy can help to protect the environment" ranked third (i.e., 0.29).

Table 7: Contingency Table for Willingness to Adopt and House Type: Rural Areas in Al-Qassim Province

Variable	Category	Willingness to adopt				
		Moderate agreement		Strong agreement		Total
Type of house	Multi family	26	7.6%	93	27.1%	119
	Single family	91	26.5%	133	38.8%	224
	Total	117	34.1%	226	65.9%	343

In some cases, the built environment, and especially house type, can play a pivotal role in shaping attitudes toward renewable energy adoption rates and transitioning to alternative energy sources According to Balta-Ozkan et al. (2015), a disproportionate share of detached houses can

increase solar energy demand because detached houses have more convenient, direct access to rooftops to install solar panels. Furthermore, Graziano and Gillingham (2015), have reiterated this point by suggesting that “PV systems are most suitable for single-family housing, due to the larger roof space” (p. 827). All this underscores the importance of accounting for the unique variations in settlement patterns when attempting to better understand geographic differences in rooftop solar panel adoption rates.

Unlike other studies (e.g., Ek, 2005; Komatsu et al., 2011; Ribeiro et al., 2014), this analysis did not reveal any statistically significant associations between a willingness to adopt rooftop solar panels and a whole range of socio-economic indicators (e.g., income, age, or family size). Although it is possible that some of these factors may be acting as surrogate variables in this analysis, it seemed that environmental beliefs, financial considerations and, in some cases, the built environment were the key statistically significant factors in Saudi Arabia with respect to the willingness to adopt rooftop solar panels. Additionally, despite the prominent role of social networks in the literature, this factor did not prominently feature in our analysis. For example, survey participants were asked whether they knew about other individuals using solar energy or were aware of websites specializing in disseminating information about solar energy, (such as 'Shamsi', which is a website established by the Saudi government to provide information on solar energy) (Shamsi, 2023). The results indicated that few respondents knew about such programs although the limited impact of social networks could also be attributed to the fact that only 2% of the population in Saudi Arabia currently employs solar panels in their households, thus potentially substantially constraining the role of social networks in this context.

5 Conclusion

Rooftop solar panels have increasingly become a more feasible energy option for many households across the world although the willingness to adopt such panels can vary by location. Much of the existing literature suggests that some of the key predictors regarding the willingness to adopt rooftop solar panels include various socio-economic indicators, the nature of the built environment, social networks and various financial incentives.

In our analysis, based on survey data collected from respondents in Riyadh City, Buraydah City, and the rural areas of Al-Qassim Province in Saudi Arabia, a majority of participants expressed a willingness to embrace and adopt rooftop solar panels in the foreseeable future. However, when differentiating between those respondents that expressed a strong willingness to adopt rooftop solar panels from those with more moderate levels of support, the survey data also revealed both differences and similarities by place in the respondents' perceptions and beliefs regarding solar energy and related environmental issues.

In Riyadh, those that were most willing to adopt rooftop solar panels tended to be more likely to believe that climate change is real, and that renewable energy can be effective in protecting the environment from pollution. These more broadly based environmental concerns can have a positive impact on renewable energy adoption rates. By contrast, in Buraydah City and the rural parts of Al-Qassim Province, the willingness to adopt rooftop solar panels seemed to be more closely associated with financial incentives linked to government subsidies and tax deductions. Concerns about the cost of buying and installing solar panels was also particularly strong especially in Al-Qassim.

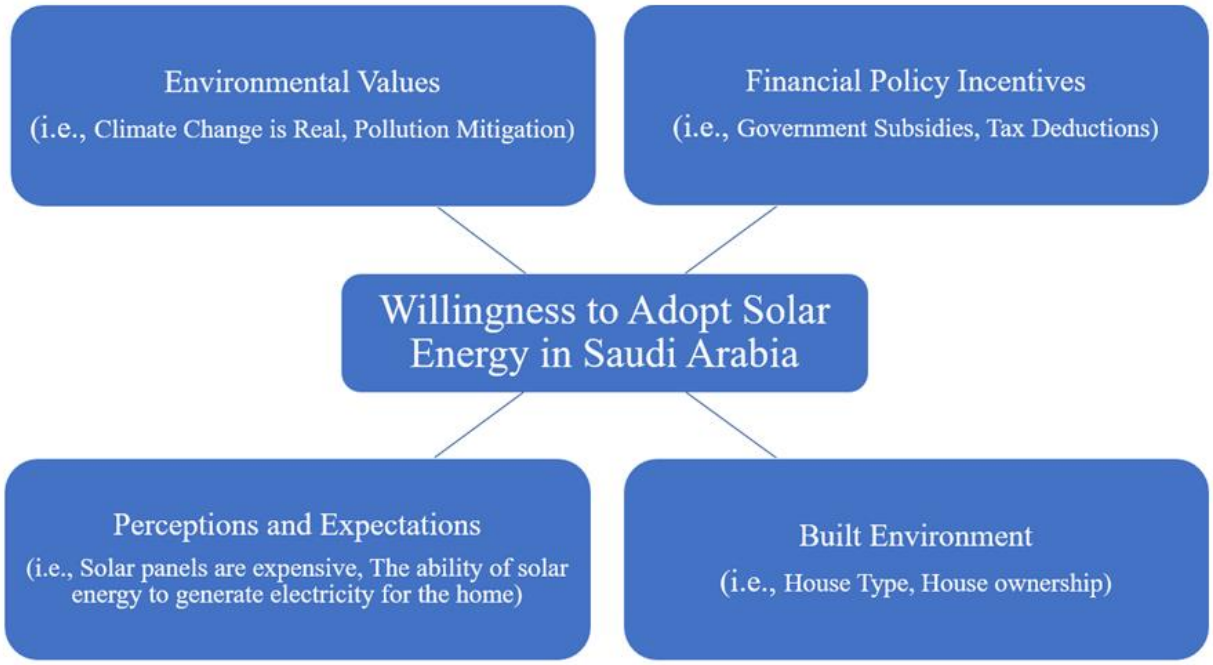
These findings echo the well-established understanding that government interventions are vital for mitigating the prohibitive high upfront costs associated with renewable energy

technologies, which could otherwise hinder widespread adoption (Liming, 2009; Dulal et al., 2013). Additionally, the general perception among survey respondents that installing solar panels is expensive confirms the importance of policy incentives such as government subsidies in resolving this issue and motivating the population to adopt solar energy panels. These policy incentives are likely to be effective in all three study areas because of the positive viewpoint that many of the respondents most willing to adopt rooftop solar panels held regarding the expectation that installed rooftop solar panels would provide 100% of total household energy needs.

It should also be noted that the nature of the built environment also seemed to play a role especially in both Buraydah and Al-Qassim, where the strongest proponents for rooftop solar panels were more closely associated with single-family dwellers rather than multi-family dwellers. However, this was not the case in Riyadh where population densities were higher and it is more difficult to gain rooftop access.

Overall, while it appears that strong support exists in Saudi Arabia for rooftop solar panels across the board, some subtle spatial differences do exist. Some of these key differences by place are most closely associated with prior environmental belief systems, various financial incentives, prior perceptions and expectations, and variations in the nature of the built environment (Figure 5). Unlike much of the prior literature, various socio-economic metrics (Figure 1) seem to play a more muted role in Saudi Arabia possibly because of a consensus across demographics that embracing rooftop solar panels is a good thing for the country.

Figure 5. Willingness to adopt rooftop solar panels: the empirical evidence from Saudi Arabia



Saudi Arabia has the potential to significantly increase rooftop solar energy adoption rates, especially given the prevailing positive attitudes towards renewable energy alternatives. By implementing a holistic approach that combines enhanced awareness, fiscal incentives, education, and regulatory support, the government can accelerate the transition towards sustainable energy practices while benefiting both the environment and its citizens. The findings of this study are a first step in providing a conceptual framework for shaping policies and strategies that better align with the aspirations of the Saudi population and the larger global shift towards clean energy.

Our analysis also presents avenues for future research. In this paper, survey data was collected for two cities and also the rural part of a province, but did not include data by neighborhood. In the future, collecting data by neighborhood may be useful if we are to better

understand the dynamics of rooftop solar panel adoption rates at a more disaggregated scale of analysis. Additionally, since policy incentives such as subsidies or tax deductions can potentially boost rooftop solar panel adoption rates, it may be helpful to better understand, not just the willingness to adopt, but also the willingness to pay for such panels.

CHAPTER III: FACTORS AFFECTING THE WILLINGNESS TO PAY FOR RESIDENTIAL ROOFTOP SOLAR PANELS: EVIDENCE FROM SAUDI ARABIA

1 Introduction

In the contemporary era, the pursuit of sustainable development has prompted governments worldwide to prioritize renewable energy, aiming to mitigate pollution from fossil fuels and combat global warming (Lau et al., 2012; Chung et al., 2018; Kutan et al., 2018). While governmental initiatives play a pivotal role, residents' active participation is equally vital for fostering sustainable development, particularly through the adoption of renewable energy technologies like rooftop solar panels (Walker & Devine-Wright, 2008; Pitt & Michaud, 2015; Hao et al., 2020). However, numerous challenges, such as the financial burden associated with solar panel installation, have impeded widespread adoption (Irfan et al., 2021).

This paper focuses on an assessment of the willingness to pay (WTP) for rooftop solar panels at three distinct geographical scales in Saudi Arabia (e.g., large urban areas – Riyadh City; medium-sized urban areas – Buraydah City; and rural areas – Al-Qassim Province). Given the country's abundant solar radiation potential (Almasoud & Gandayh, 2015) and substantial government investments in renewables, Saudi Arabia is an excellent case study particularly considering that the current adoption rate of rooftop solar panels remains at only 2% among Saudi residents (General Authority for Statistics, 2023). These sorts of challenges underscore the need to better understand the key variables that might shape residential receptivity to rooftop solar panels in Saudi Arabia and whether this varies based on different geographic settings.

While some existing research has examined the socio-economic and technical factors that drive renewable energy adoption rates, few studies have considered how this may vary spatially,

particularly in non-western contexts. Balta-Ozkan and Le Gallo (2018) have argued that the existing literature has overlooked the role of spatial factors in shaping energy attitudes and perceptions. Furthermore, the previous research on renewable energy behaviors and attitudes in Saudi Arabia has often employed small or non-geographically focused samples, limiting the generalizability of findings (e.g., Mosly & Makki, 2018; Makki & Mosly, 2020; Alrashoud & Tokimatsu, 2020). This paper aims to fill this gap by investigating the key factors that might shape the WTP for rooftop solar panels across diverse communities in Saudi Arabia. By analyzing WTP, this paper hopes to come to an improved understanding of what drives an individual's willingness to allocate financial resources to obtain rooftop solar panels in residential areas across Saudi Arabia (Rao, 2009).

In terms of the central research questions, it is hypothesized that the WTP for rooftop solar panels will be influenced by several key factors based on the prior literature including: several socio-economic predictors, variations in the built environment, the institutional context, and various social information network effects (Table 8). In detail, this paper aims to address the following research questions:

1- Is there a spatial variance in the WTP for residential rooftop solar energy panels across different types of built environment in Saudi Arabia?

2- What are the key variables that are most associated with the WTP for residential rooftop solar energy panels in Saudi Arabia?

3- Is there spatial variation in those key factors most associated with the WTP for residential rooftop solar energy panels?

2 Literature Review

In the existing literature, utilizing solar energy and the WTP for rooftop solar panels is widely considered to be influenced by four primary determinants: socio-economic predictors (e.g., income, education, age), the built environment (e.g., urban vs. rural), social information networks (e.g., peer effects, knowledge spillovers), and the institutional context and pricing (e.g., subsidies, tax deductions) (Faiers et al., 2007; Mills & Schleich, 2009; Claudy et al., 2011; Willis et al., 2011; Ruokamo, 2016; Karytsas et al., 2019). Table 8 provides an overview of the key factors associated with the WTP for renewable energy in general, and solar energy in particular, based on the existing literature.

Table 8: Key Factors Associated with the WTP for Renewable Energy

Socio-Economic Predictors	Income (e.g., Komatsu *et al*., 2011; Karytsas *et al*., 2019).
	Education (e.g., Ortega-Izquierdo *et al*., 2019; Zeru & Guta, 2021).
	Age (e.g., Mosly & Makki, 2018; Ortega-Izquierdo *et al*., 2019).
Built Environment	Housing characteristics (e.g., Zografakis *et al*., 2010; Karytsas *et al*., 2019).
	Urban vs. rural (e.g., Zahran *et al*., 2008; Ortega-Izquierdo *et al*., 2019).
Social Information Networks	Knowledge about renewable energy (e.g., Zografakis *et al*., 2010; Ortega-Izquierdo *et al*., 2019).
	Perceptions (e.g., Ntanos *et al*., 2018; Nazir & Tian, 2022).
	Environmental concerns (e.g., Zografakis *et al*., 2010; Pleeging *et al*., 2021).
Institutional Context and Pricing	Subsidies (e.g., Sarzynski *et al*., 2012; Ntanos *et al*., 2018).
	Tax policies (e.g., Bauner & Crago, 2015; Sahu, 2015).

Source: Derived from Karytsas *et al*. (2019).

2.1 The Socio-Economic Predictors

Several studies have explored the influence and relationship of various socioeconomic factors, such as income, education, and age, on renewable energy attitudes and consumption rates (e.g., Zografakis et al., 2010; Komatsu et al., 2011; Mosley & Makki, 2018; Karytsas et al., 2019). Some have argued that higher-income households are more inclined to pay for renewable energy, while younger and better-educated individuals are also more likely to embrace solar alternatives (Komatsu et al., 2011; Karytsas & Theodoropoulou, 2014; Purwanto & Afifah, 2016; Azlina et al., 2022).

In 2019, Karytsas et al. examined the various socioeconomic factors that most influenced consumers in Greece, Portugal, and Spain regarding the WTP for a residential hybrid system, encompassing solar thermal panels and thermal energy storage. Survey results indicated that a positive correlation existed between income levels and the WTP where participants with above-average incomes exhibited a higher WTP. Similarly, Broughel's (2019) study on early adopters in Mexico demonstrated a positive association between income and the WTP for solar energy systems, particularly for the highest income adopters. Zografakis et al. (2010) explored public acceptance and WTP rates for renewable energy sources, revealing a higher WTP among individuals with higher incomes in Crete.

Entele (2020) investigated rural household preferences and WTP for solar energy connections in Ethiopia, identifying household income as a statistically significant factor that positively influenced WTP and solar energy adoption rates. Zeru and Guta's (2021) study in Ethiopia, focused on those factors that most influenced the adoption of solar home systems, and found a positive correlation existed between household income and occupation, and the educational status of the head of household, with the likelihood of adopting solar home systems.

Ortega-Izquierdo et al. (2019) also analyzed the key decision-making factors that influenced the choice of heating and cooling systems powered by renewable energy, which includes solar energy, in various Spanish households. The survey results indicated that individuals with above-average income levels exhibited a greater WTP for renewable heating and cooling systems. Yadav et al. (2019) found that increases in income and education positively impacted the WTP for solar panels.

Karytsas et al. (2019) argued that higher education levels among respondents in Portugal and Spain were positively associated with the WTP for hybrid residential systems, potentially due to an elevated knowledge of the benefits of renewable energy technologies. Similarly, Entele (2020) found that the level of education of the head of household is a significant and positive factor influencing the WTP for solar energy. Ortega-Izquierdo et al. (2019) also observed that young individuals and those with university education backgrounds exhibited a greater WTP for renewable heating and cooling systems. Additionally, the research suggested a higher awareness of these systems among men, young people, and those with university degrees.

Borchers et al. (2007) explored consumer preferences and WTP for green energy electricity programs, focused on distinguishing the key preferences that existed for different types of green energy sources using data from New Castle County, Delaware. The results revealed a positive WTP existed for green energy electricity, with a preference for solar energy over generic green or wind sources. They suggested that a clear preference for a green alternative increased among respondents over the age of 50 and under 30 years old. Mosly and Makki's (2018) research in Saudi Arabia investigated public perception and a willingness to adopt renewable energy technologies (RETs) in the residential sector in the western region of the country. Despite a high willingness to adopt RETs (79%), only 26% expressed a WTP more for

RET sources like solar energy. Also, they found that age proved to be a significant determinant, with respondents aged 18-29 years old expressing a higher WTP for renewable energy.

Aravena et al. (2012) examined Chilean household preferences for additional electricity supplies, including fossil fuels and renewable energy sources. Their study suggested a generally higher WTP existed for renewable energy sources among younger individuals. In contrast, Entele's (2020) study indicated that the age of the head of the household is a negative influence on the WTP, with older respondents being less likely to pay for solar energy. Furthermore, Karytsas et al. (2019) noted that gender and occupation significantly impacted the WTP for a renewable hybrid system, with male respondents exhibiting a higher WTP.

2.2 Built Environment

The built environment and spatial context can also play crucial roles in shaping a residents' attitudes toward renewable energy, and both can directly or indirectly influence adoption rates and the WTP (Bergmann et al., 2008; Zografakis et al., 2010; Balta-Ozkan & Le Gallo, 2018; Ortega-Izquierdo et al., 2019). Schunder et al. (2020) suggested that the "geographic context is a major determinant of rooftop solar adoption" (p. 2) as place and its various components can have an impact on WTP, starting from the geographical location associated with solar radiation to the geographical scale of the settlement, as rural areas tend to provide a larger and more accessible area for the installation of solar panels.

Karytsas et al. (2019) underscored the impact of the built environment, specifically housing characteristics such as the size and age of the housing stock, on the WTP for renewable energy technologies. Their findings indicated that residents in detached houses exhibited a greater willingness to adopt and pay for hybrid renewable energy technologies compared to apartment residents largely because it is more convenient and more accessible. Karytsas et al.

(2019) also mentioned that the age of the home can play a role in affecting the WTP, with homeowners of new homes demonstrating less WTP, potentially due to a reluctance to modify modern homes. Owners of very old homes demonstrated a similar reluctance, likely due to the elevated technical and economic feasibility constraints common to older housing stock. Karytsas et al. (2019) also argued that larger home size correlates well with a higher WTP, possibly because larger homes are more suitable for renewable energy installations. Similarly, Zografakis et al. (2010) found that residents in larger houses in Crete are more willing to pay for renewable energy sources, suggesting a link potentially exists between house size and higher incomes.

Balta-Ozkan et al. (2015), analyzed solar energy use in the UK, and suggested that per capita income and the share of detached houses positively influenced solar energy demand. Conversely, an increase in population density and owner-occupied homes hindered rooftop solar energy usage due to the limited space for panel installation in more dense locations. They explained the negative relationship between solar energy use and home ownership as being linked to more affluent households having fewer financial constraints, which made energy-saving measures, such as using solar energy, less of a priority. Crago and Chernyakhovskiy (2017) explored rooftop solar panel adoption rates across 13 US states from 2005 to 2012 and argued that higher levels of urbanization decreased the adoption of rooftop solar panels, while a higher density of owner-occupied homes increased adoption rates, as homeowners are more likely to install solar panels than renters. Although Crago and Chernyakhovskiy (2017) did not explicitly examine WTP in their adoption rate analysis, they suggested that certain built environment tendencies may apply to WTP such as urbanization and population density.

In Spain, Ortega-Izquierdo et al. (2019) discovered a high awareness of renewable energy technologies in urban areas, attributed to a higher percentage of people with better education

levels in those areas. However, rural residents exhibited a greater WTP for renewable technologies when compared to urban residents, who often needed approval from their neighbors, who frequently shared the building's rooftop when using renewable energy. Similarly, Jacksohn et al. (2019) observed higher solar energy adoption rates in rural areas in Germany from 2008 to 2015, although they did not provide a specific explanation. Karytsas et al. (2019) noted that living in rural areas positively impacts the WTP for renewable energy technologies, likely due to larger available areas for installations and distinct housing characteristics such as the type of dwelling and size of the house.

Even though there is limited work on the WTP for solar energy as it relates to the built environment, some of the willingness to adopt literature can be very useful because it may show tendencies that also apply to the WTP. For example, Zahran et al. (2008) identified a positive correlation between urbanization levels and solar energy adoption rates in the United States, attributed to the concentration of high-income individuals in urban areas. Kwan (2012) explored solar energy use rates in the US, revealing an inverse relationship existed between housing density levels and rooftop solar panel use rates, as the study revealed that “a one standard deviation increase in housing density reduces the expected residential solar PV (photo-voltaic) share by 20.4%” (p. 339).

2.3 Social Information Networks

The influence of social information networks on an individuals' decisions regarding renewable energy has garnered widespread recognition in the literature (Kwan, 2012; Ortega-Izquierdo et al., 2019; Nazir & Tian, 2022). The dissemination and exchange of information about renewable energy via social networks can play a pivotal role in shaping the WTP for renewable energy technologies (Nazir & Tian, 2022). Social information networks can take

many forms including various social networking websites or ‘peer effect’s that are capable of transmitting information that might influence renewable energy attitudes. Such information may include knowledge about the benefits and ease of use of renewable energy or play a more educational role by elevating individual awareness levels of important environmental issues such as climate change and pollution levels (Calvó-Armengol et al., 2009; Severo et al., 2019; Sánchez-Arrieta et al., 2021; Nazir & Tian, 2022). Schunder et al. (2020) argued that the “empirical evidence suggests that the presence of rooftop solar systems in a neighborhood or social network encourages further adoption by making benefits observable and reducing uncertainty” (p. 2).

Ortega-Izquierdo et al. (2019) emphasized the importance of information networks in the decision-making process for selecting renewable energy technologies. Their study underscored the significance of consumer knowledge levels about renewable energy technologies, with professional and personal networks being primary sources of consultation. Furthermore, their findings revealed that 63% of respondents were familiar with renewable energy technologies, and over half expressed a WTP more for these systems, with solar thermal energy being the preferred technology. Zografakis et al. (2010) found that individuals with better knowledge levels about renewable energy, such as the ability to generate and save on energy costs, tended to be more willing to pay for renewable energy sources compared to those without such information. Palm's (2017) study in Sweden demonstrated the motivating role of peer effects for individuals interested in solar energy, with the strongest impacts observed within close social relationship networks that confirmed the effective functioning of solar energy systems.

In Pakistan, Nazir and Tian (2022) found a significant positive relationship existed between the WTP, or what they called purchase intention, toward renewable energy technology

and social media exposure levels, and relative ease of use, and awareness. Similarly, Ahmed et al. (2022) identified perceived usefulness, ease-of-use, compatibility, observability, and trust as key determinants of a consumers' attitudes and intentions to adopt solar photovoltaic systems in both Somalia and Pakistan.

Ntanos et al. (2018) examined public perceptions and the WTP for renewable energy in Greece, focusing on the key factors shaping opinions about renewable energy sources and related preferences. Their analysis revealed that environmental awareness programs that emphasized saving the environment was the primary motivator for investing in renewable energy systems. Respondents expressed a strong WTP for the expansion of renewable energy sources, emphasizing the importance of environmental considerations in energy decision-making. Zografakis et al. (2010) noted that individuals who view climate change as a major issue exhibited a higher WTP for renewable energy.

Pleeging et al. (2021) extended this by investigating the relationship between WTP for renewable energy and attitudes toward climate change, finding that individuals in the Netherlands who are more concerned about climate change are more willing to pay. Huang and Shen's (2020) study suggested that social beliefs related to the environmental benefits of solar panels, such as reducing carbon dioxide emissions, often exert a greater impact than economic benefits. Mosley and Makki (2018) found that 90% of surveyed households in Saudi Arabia expressed a desire to save the environment, and 79% were willing to operate renewable energy sources to help mitigate some of the negative externalities.

2.4 Institutional Context and Pricing

Governments play a pivotal role in promoting the widespread adoption of renewable energy technologies in the residential sector through key policies such as financial subsidies and

tax deductions, aimed at addressing the high upfront costs associated with these technologies (Dulal et al., 2013; Yuan et al., 2015; Simpson & Clifton, 2016; Mosley & Makki, 2018). This was underscored by Dulal et al. (2013), who stated that "in the absence of government support, large-scale diffusion of renewable energy is impossible because of the high up-front capital costs" (p. 306). The cost of solar panels, in particular, stands out as one of the major barriers limiting their widespread adoption, suggesting that government intervention is crucial to stimulate demand (Dulal et al., 2013; Irfan et al., 2021).

In Lithuania, Su et al. (2018) investigated a household's WTP for renewable energy microgeneration technologies, specifically solar photovoltaic systems. The study revealed that high installation costs reduced the willingness to adopt and pay for renewable energy alternatives. Borchers et al. (2007) suggested that a decrease in the costs of renewable energy, such as solar energy, coupled with increased financial benefits in savings on the power bill, would likely result in a higher probability of its adoption and therefore positively impact the WTP.

Examining financial incentives targeting residential rooftop solar photovoltaic systems in Australia, Zander et al. (2019) found that increased installation costs negatively affected the choice of a photovoltaic system, while a rebate of AUD 4,000 served as a significant motivator. Crago and Chernyakhovskiy (2017) assessed the effectiveness of policy incentives for residential solar power installations in the Northeastern United States, revealing that rebates, as direct cash subsidies, had a substantial impact, with an additional $1 per watt rebate significantly increasing annual photovoltaic capacity demand. Bauner and Crago (2015) showed that financial incentives, particularly rebates and tax credits, contributed to an elevated adoption rate for residential solar

power systems, emphasizing the importance of policies that aim to alleviate uncertainty regarding investment costs in residential solar PV technology.

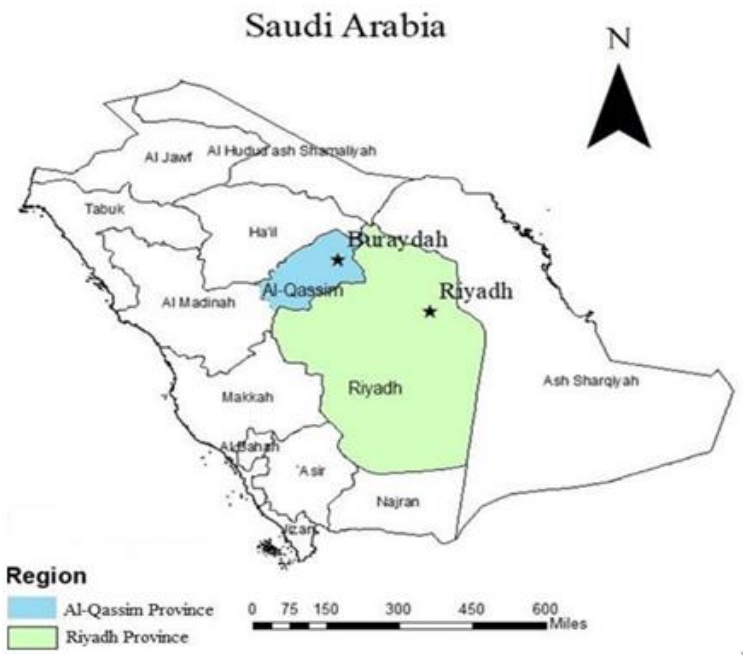
Moreover, Sahu (2015) highlighted the correlation that existed between high rates of solar energy usage and incentive policies, such as subsidies and tax deductions. In Greece, Sardianou and Genoudi's (2013) study emphasized the pivotal role of financial incentives, particularly tax deductions, in influencing consumer intentions to adopt renewable energy systems. A comprehensive analysis by Hanson et al. (2023) on incentive policies at the state level in the United States found that residential solar tax credits and rebates were associated with higher rates of photovoltaic adoption. Sarzynski et al. (2012) employed a cross-sectional time-series approach, spanning from 1997 to 2009, demonstrating that states offering cash incentives, such as rebates and grants, experienced more extensive and rapid deployment of solar photovoltaic technology compared to states without such incentives. Ntanos et al. (2018) found a positive association existed between the WTP for renewable energy sources and state support in the form of subsidies.

3 Methodology

This paper aims to enhance our understanding of the variability in the WTP for rooftop solar panels in Saudi Arabia across three distinct geographic scales and contexts: a large urban area (Riyadh City), a medium-sized urban area (Buraydah City), and in the rural area of Al-Qassim Province (Figure 6). It is argued that the key drivers of WTP are grounded in four potential clusters of determinants: various socio-economic variables, the built environment, social information networks, and the institutional and pricing policy context (Table 8). The data used in this paper were obtained through a survey, where the dependent variable, WTP, was

derived from a Likert scale response comprising seven categories, ranging from "Strongly Disagree" to "Strongly Agree."

Figure 6. Map of Saudi Arabia and the Three Study Areas (Riyadh, Buraydah, and Al-Qassim Province).



A series of additional questions were included to both establish a socio-demographic profile of each survey respondent (e.g., age, income, level of educational attainment) and where each respondent stood on a wide range of issues (e.g., WTP, climate change, perceptions about renewable energy, potential costs, etc.). To collect data for this study, a survey was designed using Qualtrics Software and distributed online between November and December 2022 in Saudi Arabia (Appendix A). The survey questions were developed after reviewing previous relevant studies and received Institutional Review Board approval from our host university. The survey was predominantly distributed online through platforms such as WhatsApp, Facebook, and X (formerly Twitter); however, participants outside the designated study areas were excluded. Additionally, residents in the targeted geographic study areas were approached randomly on the

streets and in various gathering places and encouraged to share the survey on WhatsApp and in online groups they were members of, resulting in a snowball sampling approach. Prominent X and WhatsApp users were also approached to distribute the survey, with a focus on accounts widely followed by residents of the three study areas, especially those recognized for sharing local news. In total, 1,647 fully completed survey responses were collected from these targeted areas.

The selection of the three geographic study areas was based on identifying places with a diverse range of metrics, including variations in population density, educational attainment levels, median household income levels, and various housing characteristics, as detailed in Table 9. Riyadh City distinguishes itself from Buraydah City and the rural areas of Al-Qassim Province in several key aspects. In terms of population, Riyadh boasts a much larger population and notably higher population densities compared to Buraydah and the rural areas of Al-Qassim Province. Additionally, Riyadh City exhibited distinctive socio-economic characteristics, marked by a higher median household income and a greater proportion of residents holding bachelor's or more advanced degrees.

The online survey method was chosen for its ease of distribution, accessibility, cost-effectiveness, and suitability for researchers targeting large areas (Sue & Ritter, 2012). Additionally, the online survey method has proven successful in several Saudi studies for collecting data while ensuring participants' privacy (Sue & Ritter, 2012; Mosley & Makki, 2018; Alsabbagh, 2019; Alrashoud & Tokimatsu, 2020). Moreover, 96% of the Saudi population aged 15 years or older use smartphones connected to the Internet, making online surveys an effective means of reaching the target sample through social media (General Authority for Statistics, 2023). Two sampling methods were employed to collect the data: convenience sampling and

snowball sampling approaches. The convenience sampling approach was chosen to facilitate a broad and swift distribution of the survey, allowing all members of the population who wished to participate to respond (Alwelaie, 2012). Compared with the data from the Saudi census, the data for the 1,647 respondents was highly representative of the socio-economic characteristics of Riyadh City, Buraydah City, and Al-Qassim Province based on education, income, and housing status.

Table 9: Key Statistical Indicators for Riyadh City, Buraydah City, and Al-Qassim Province, 2022

	Riyadh	Buraydah	Al-Qassim
Population	6,924,566	571,169	765,010
Population density per km2	3,846.98	828.3	395.06
Median age	30	28	27
% Children (≤ 15 years old)	22.11	25.40	26
% Workforce (16 to 64 years old)	75.50	72.20	71.30
% Elderly (≥ 65 years old)	2.20	2.40	2.70
Median household monthly income (SR) *	12,688	8,815	9,043.50
% Male	63.2	60.8	57.7
% Female	36.8	39.2	42.3
Less than bachelor degree (% of total population) *	64.5	88.66	85.30
Bachelor degree (% of total population) *	23	10.68	14.48
Master and PhD (% of total population) *	2	0.66	0.22
Average family size	3.5	3.9	4.2
% Multi-family dwelling units	58.1	41.8	37.6
% Single-family dwelling units	41.9	58.2	62.4
% Owner-occupied units	56.2	67.9	69.1

Source: Derived from General Authority for Statistics, 2023.

(* Based on 2018 data from General Authority for Statistics)

The data analysis involved the use of a Chi-square Test for Independence to analyze the association between WTP and the other key variables. The level of association of the relevant variables was ranked according to Cramer's V. The chi-square test for independence was chosen

because of the nature of the categorical data used in the study and because of the survey design, as it is suitable for evaluating the associational links between various variables (Crewson, 2023). The contingency tables based on the Chi-square Tests were selected based on an analysis of all the willingness to pay contingencies as they relate to all the other key variables included in the survey. Only those variable pairs that were significant at the 5% level were included in this analysis.

4 Findings

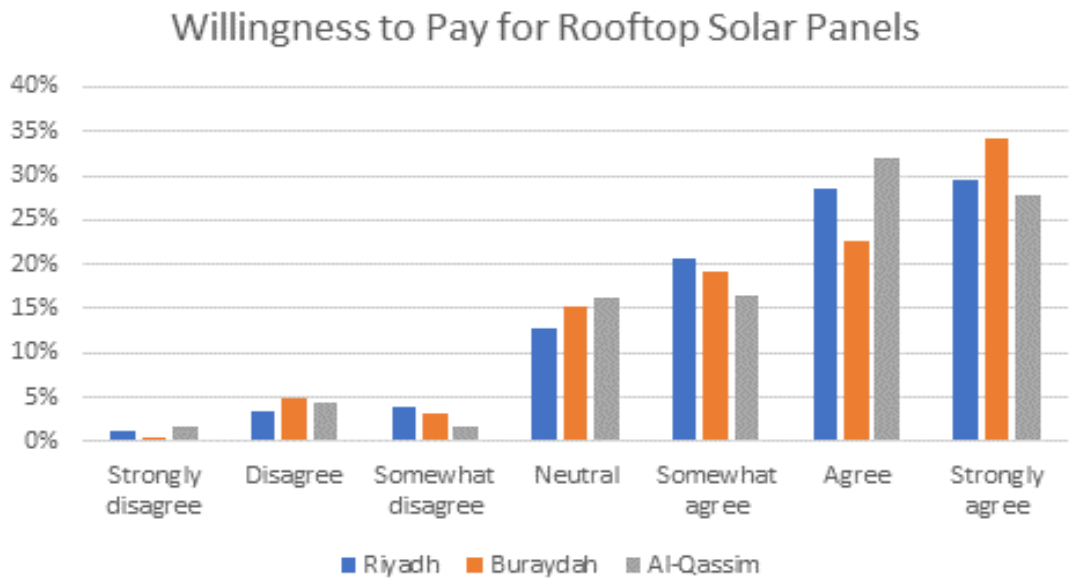
In this paper, survey data from all 1,647 respondents in the three geographic study areas, collectively revealed a broadly-based WTP for rooftop solar panels (i.e., strongly agreed, agreed, and somewhat agreed) ranging from 78.8% of all respondents in Riyadh City, to 76% in Buraydah City, and 76.2% in rural areas in Al-Qassim Province. By contrast, only 8.3% of all respondents in the aggregate were unwilling to pay for rooftop solar panels (i.e., strongly disagreed, disagreed, and somewhat disagreed) while 14.2% had no opinion on the matter. A detailed examination of the WTP Likert scales in Table 10 and Figure 7 reveals a consistent response pattern across all three study areas where most respondents were willing to consider paying for rooftop solar panels.

It appeared that the inclination to pay for rooftop solar panels among Saudi residents remained relatively consistent across the study areas. However, conducting a comprehensive investigation of the key variables that might impact WTP could provide additional insight into what might shape these WTP outcomes. Furthermore, understanding how these factors change by geographical setting could empower policymakers to formulate better plans and strategies to ensure the promotion of renewable energy adoption across diverse locations.

Table 10: Survey Results for WTP for Riyadh City, Buraydah City, and Al-Qassim Province (n = 1647)

		Riyadh	Buraydah	Al-Qassim	Total
Willingness to Pay (WTP)	Strongly agree	252	145	103	500
	% of strongly agree	29.6%	34.1%	27.8%	30.4%
	Agree	243	96	118	457
	% of agree	28.5%	22.6%	31.9%	27.7%
	Somewhat agree	176	82	61	319
	% of somewhat agree	20.7%	19.3%	16.5%	19.4%
	Neutral	109	65	60	234
	% of neutral	12.8%	15.3%	16.2%	14.2%
	Somewhat disagree	33	14	6	53
	% of somewhat disagree	3.9%	3.3%	1.6%	3.2%
	Disagree	29	21	16	66
	% of disagree	3.4%	4.9%	4.3%	4.0%
	Strongly disagree	10	2	6	18
	% of Strongly disagree	1.2%	0.5%	1.6%	1.1%
	Total	852	425	370	1647

Figure 7. WTP for Rooftop Solar Panels by Study Area

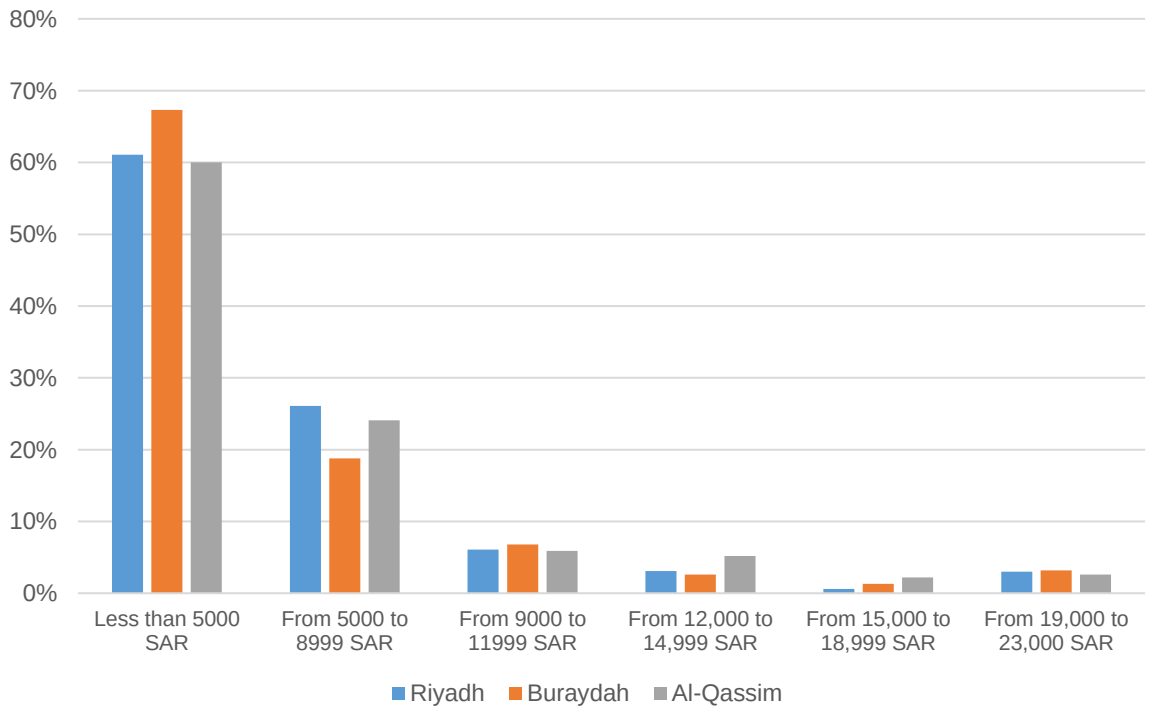


Alwulayi and Debbage (in review) in a closely related analysis focused exclusively on the willingness to adopt (not pay for) rooftop solar panels among these same residents in Riyadh City, Buraydah City, and Al-Qassim Province. They found that a noticeably larger majority of respondents were willing to adopt (i.e., strongly agree, agree, and somewhat agree) relative to the WTP rates uncovered in this paper. In the Alwulayi and Debbage (in review) analysis, the willingness to adopt was 88.8% for all respondents in Buraydah City, 89.7% in Riyadh City, and 92.7% in the rural areas of Al-Qassim. It is likely not surprising that those expressing a WTP may be fewer in number than those that are willing to adopt. The suggestion here is that the WTP is a much stronger indication of intention since it involves a professed financial commitment, while the willingness to adopt may be a more idealized intention (perhaps if the price is right). Despite all this, it should be noted that the findings presented in this paper regarding WTP align well with those of Mosly and Makki (2018) in terms of a general inclination to embrace renewable energy.

To better understand and more precisely define the WTP, survey participants in this paper were queried about the actual price they would be willing to pay for rooftop solar panels capable of reducing their monthly electric bill by 150 SAR ($40). The computation of the average cost for a residential rooftop solar panel installation of 12,000 SAR ($3,199) and the anticipated reduction in the monthly electricity bill of around 150 SAR was derived from the Shamsi website based on the geographical location of the study areas. 'Shamsi' is a website established by the Saudi government to provide accurate information on solar energy in the country that offers rigorous cost estimate data while also outlining the potential financial benefits (Shamsi, 2023). The estimated cost calculations by Shamsi were similar across the three study areas, which may be a result of similar climatic and cost conditions.

The majority of respondents in our survey indicated a WTP less than 5,000 SAR ($1,332), a value significantly below the average estimated system cost of 12,000 SAR provided by Shamsi (Figure 8). As suggested by Su et al. (2018), the WTP for renewable energy technologies can be problematic, noting that usually consumers are only willing to pay far less than the market price, and in some cases, they are not willing to pay at all. Figure 8 shows a consistent response pattern in all three study areas, where the majority were willing to pay less than 5,000 SAR ranging from 67.1% of all respondents in Buraydah City, to 62.6% in Riyadh City, and 59.2% in the rural areas of Al-Qassim. By contrast, only 7.6% of all respondents in the three study areas were willing to pay the estimated price (i.e., 12,000 SAR) or more for a solar energy system.

Figure 8. The Price that Participants are Willing to Pay for Rooftop Solar Panels



The broader implication is that changes in geography and geographical scale do not seem to substantially impact the Saudi residents' inclination to pay for rooftop solar panels. Despite

this reluctance to pay the market rate for rooftop solar panels, the high proportion of residents that appear willing to pay something across the different geographies, suggests that carefully crafted policies and marketing strategies might be able to leverage and further stimulate demand.

Furthermore, the surge of investment in renewable energy by the Saudi Arabian government has been particularly noteworthy in recent years, aligning well with the nation's goals of achieving financial balance and reducing overall electricity consumption from non-renewable energy sources (Ministry of Finance, 2023). Additionally, the general consensus within Saudi society seems to support the government's comprehensive development plan, including the transition to renewable energy sources outlined in Vision 2030. This widespread agreement may be attributable to the positive societal reforms initiated since the plan's inception in 2016 (Saudi Vision 2030, 2023).

Despite the overall willingness of Saudi residents to pay for rooftop solar panels, which appears consistent across different locations (Figure 7), there is still lingering uncertainty regarding the key factors that may be most closely associated with various WTP outcomes, and whether these key factors exhibit variations based on location. Better understanding the key variables that best elucidate what triggers elevated WTP rates could help add to the burgeoning literature on this topic, while also providing improved insight into what works best in Saudi Arabia across a diverse range of geographies.

4.1 Test of Independence for WTP – the Key Variables

This paper used the chi-square test of association to explore potential connections between the WTP for rooftop solar panels and various related variables identified in the literature that might help best explain respondent outcomes. The chi-square test is well-suited for assessing associations among categorical variables, such as the WTP variable constructed based on a

Likert scale (Crewson, 2023). Additionally, Cramer's V will be employed to rank the strength of association between the WTP and related variables. This method is chosen for its simplicity and effectiveness in determining the existence of a substantive relationship between two variables (Akoglu, 2018; Crewson, 2023). Crewson (2023) stated that "a Cramer's V of 0.1 provides a good minimum threshold for suggesting there is a substantive relationship between two variables" (p. 80). Cramer V coefficients typically suggest a substantive relationship exists between two variables when the coefficient is at least 0.10, with values between 0.1 to 0.3 indicating some association, 0.3 to 0.5 indicating moderate association, and above 0.5 indicating high levels of association (Crewson, 2023).

The analysis in this paper only focused on those respondents who expressed a positive WTP for rooftop solar panels due to both the positive skew in the data, and the small number of respondents that disagreed or were neutral on the Likert scale responses across all three study areas (Figure 7). This approach was supported by the fact that previous studies in Saudi Arabia had similarly found a substantial majority that was more than willing to embrace various renewable energy alternatives (e.g., Mosly & Makki, 2018; Makki & Mosly, 2020; Alrashoud & Tokimatsu, 2020). In this way, it becomes possible to conduct a more nuanced analysis that distinguishes between groups with differentiating levels of support.

To perform the chi-square test of association, the responses related to both the WTP for rooftop solar energy and the other related variables that used the Likert scale were categorized into two distinct groups. The first category, labeled as "moderate agreement", consisted of responses from participants who either "somewhat agreed" or "agreed" with the WTP. The second category, designated as "strong agreement", referred to responses from participants who "strongly agreed" regarding their WTP for rooftop solar energy panels. By classifying the data in

this way, it became possible to distinguish between individuals who have a high willingness to purchase solar panels, and are more willing to allocate financial resources, from those who are less willing to purchase, thus facilitating a more focused and insightful chi-square analysis.

Nearly all the reported results listed in Table 11 are statistically significant, with p-values below 0.05. The findings show both differences and similarities among the study areas regarding the links between WTP and the various other variables. The rankings in Table 11 were determined by the size of the Cramér's V coefficient score for Riyadh City. This prioritization is justified due to the survey's substantial representation from Riyadh City, encompassing half of the participants, and the city's unique status as the capital, as well as the most populous and expansive urban center in Saudi Arabia.

In Table 11, certain elements from the four broad clusters of predictor determinants outlined in Table 8 are prominently featured. It is clear that, in certain cases, the strength of these associational links exhibits variations both in terms of geography and type of variable. Based on the chi-square test analysis, the WTP for rooftop solar panels in Riyadh City seems to be broadly linked to certain expectations regarding household energy needs, financial considerations linked to tax deductions and subsidies, and broader concerns and attitudes linked to whether or not climate change is real, and whether or not renewable energy can be effective in mitigating pollution.

Table 11: Results for Chi-squared Test of Independence (χ^2) for the WTP for Rooftop Solar Panels and Related Variables Ranked by Cramer's V Coefficient

	Riyadh		Buraydah		Al-Qassim	
Variable	χ^2	Cramer's V	χ^2	Cramer's V	χ^2	Cramer's V
If you installed rooftop solar panels you would expect it to provide at least 20% of the total energy needs for your household	59.2	0.39	19.5	0.31	43.6	0.50
I would consider using rooftop solar panels if they are tax deductible	86.1	0.37	24.9	0.28	32.2	0.34
Climate change is real	78.4	0.361	20.1	0.26	*	*
Renewable energy can be effective in protecting the environment from pollution	79.9	0.356	36.9	0.34	6.1	0.15
I would consider using rooftop solar panels if the government subsidized the financial cost	64.9	0.318	38.5	0.35	21.7	0.28
If you installed rooftop solar panels you would expect it to provide at least 50% of the total energy needs for your household	41.06	0.317	30.3	0.39	52.8	0.54
If you installed rooftop solar panels you would expect it to provide 100% of the total energy needs for your household	33.04	0.309	13.5	0.27	18.06	0.33
The so-called "ecological crisis" linked to extreme weather events like droughts and floods has been greatly exaggerated	41.1	0.301	18.3	0.29	23.5	0.35
Buying and installing solar panels will likely be expensive	40.8	0.26	27.6	0.304	6.9	0.16

* Not statistically significant

The chi-square test revealed a significant association existed between WTP and the expectation that rooftop solar panels could contribute significantly to a household's energy needs. Specifically, in Riyadh, the strongest association was observed between WTP and the expectation that installed rooftop solar panels would provide at least 20% of total household energy needs since it generated the largest Cramer's V score (i.e., 0.39). Additionally, WTP was also statistically significant in Riyadh regarding the expectation that installed rooftop solar panels would cover at least 50% and at least 100% of total household energy needs, ranking 6th and 7th, respectively, based on the Cramer V scores (i.e., 0.317 and 0.309, respectively) (Table 11).

In detail, 20.6% (79) of the total respondents in Riyadh strongly agreed that installing rooftop solar panels would provide at least 20% of their total household energy needs and this increased to 28% (97) if the panels provided 100% of the total household energy budget (Table 12). By contrast, those expressing more moderate levels of support, regarding both the WTP and the expected household energy budget contribution by rooftop solar panels, tended to decline in relative and absolute terms (i.e., from 51.4% and 197 respondents to just 37.3% and 129 respondents) as the expectation regarding the contribution of rooftop solar panels to the household energy budget increased from 20% to 100%. The suggestion here is that as individual expectations regarding the manner in which solar energy might meet household energy budgets increased, the more likely respondents will be more supportive regarding their WTP intentions.

By way of caveat, it should also be noted that a majority of respondents in Riyadh (i.e., 51.4% and 197 respondents) were less reluctant to pay for rooftop solar panels and were less likely to believe that the rooftop panels would contribute at least 20% of the total household energy budget. Such an outcome likely suggests a healthy degree of skepticism still exists in

Riyadh regarding the existing ability of rooftop panels to substantively change the energy market for the good.

Table 12: Contingency Table for WTP and Household Energy Budget Expectations for Solar Panels: Riyadh City

Variable	Category	WTP				
		Moderate agreement		Strong agreement		Total
If you installed rooftop solar panels you would expect it to provide at least 20% of the total energy needs for your household	Moderate agreement	197	51.4%	69	18.0%	266
	Strong agreement	38	9.9%	79	20.6%	117
	Total	235	61.4%	148	38.6%	383
If you installed rooftop solar panels you would expect it to provide at least 50% of the total energy needs for your household	Moderate agreement	201	49.3%	88	21.6%	289
	Strong agreement	42	10.3%	77	18.9%	119
	Total	243	59.6%	119	29.2%	408
If you installed rooftop solar panels you would expect it to provide 100% of the total energy needs for your household	Moderate agreement	129	37.3%	46	13.3%	175
	Strong agreement	74	21.4%	97	28.0%	171
	Total	203	58.7%	143	41.3%	346

Similar trends applied in Buraydah City and Al-Qassim Province although in both cases the largest Cramer V score (i.e., 0.37 and 0.54, respectively) (Table 11) was for the expectation that rooftop solar panels would be expected to contribute at least 50% of the total household energy budget, which highlights the geographic differences between the study areas. Most of the logic for this is that in both places a large majority of respondents that were less inclined to pay

for rooftop solar panels were also more skeptical that it might be able to meet at least 50% of the energy budget needs.

These findings pertaining to the expected contribution of solar panels to total household energy needs, largely align well with previous research that underscores the benefits of renewable energy sources that include potential savings in the electricity bill, which can influence both the WTP and adoption rates (e.g., Ntanos et al., 2018; Wall et al., 2021; Ahmed et al., 2022). The observed increase in WTP when the electricity generation from solar panels increases across the three study areas corresponds to findings by Ntanos et al. (2018), who stated, "when the score on perceived RES benefit rises, WTP becomes higher" (p. 8). However, more research is needed to better understand the key drivers that shape the more skeptical respondents that seem to proliferate in Riyadh, Buraydah and Al-Qassim regarding how rooftop solar panels might contribute to household energy budgets.

In addition to the expectations related to how rooftop solar panels might contribute to household energy budgets, fiscal incentives such as tax deductions and government subsidies also seem to be linked to WTP across all three study areas (Table 11). In Riyadh, tax deductions generated the second-largest Cramer's V score (i.e., 0.37) and the largest χ^2 score (i.e., 86.1). More specifically, 31.5% (198) of all respondents in Riyadh that showed a strong WTP for rooftop solar panels also strongly agreed that they would be more likely to consider using rooftop solar panels if they were tax deductible (Table 13). By contrast, only 6.2% (39) of all Riyadh respondents that were less inclined to use tax deductions expressed a strong WTP for rooftop solar panels. Similar trends were uncovered in Riyadh regarding the role of government subsidies although the Cramer V score (i.e., 0.32) only ranked fifth (Table 11) suggesting Riyadh

residents may have a preference for tax deductions over subsidies when considering whether or not to pay for rooftop solar panels, an important policy distinction.

Table 13: Contingency Table for WTP for Rooftop Solar Panels and Financial Incentives: Riyadh City

Variable	Category	WTP				
		Moderate agreement		Strong agreement		Total
I would consider using rooftop solar panels if they are tax deductible	Moderate agreement	211	33.5%	39	6.2%	250
	Strong agreement	181	28.8%	198	31.5%	379
	Total	392	62.3%	237	37.7%	629
I would consider using rooftop solar panels if the government subsidized the financial cost	Moderate agreement	165	25.7%	29	4.5%	194
	Strong agreement	230	35.8%	218	34.0%	448
	Total	395	61.5%	247	38.5%	642

Similar trends were uncovered in Al-Qassim, although in Buraydah, the survey respondents seemed to be more likely to prefer government subsidies over tax deductions with respect to the WTP for rooftop solar panels. Unlike Riyadh, in Buraydah, government subsidies generated the second-largest Cramer's V score (i.e., 0.351) and the largest χ^2 (i.e., 38.5) while tax deductions ranked fifth. Some of this may be attributable to a lack of familiarity with the new tax system that was first introduced in 2018 (Bogari, 2020).

Previous studies have consistently underscored the crucial significance of government backing, such as tax incentives and subsidies, in promoting the purchase of renewable energy technologies which is mainly attributed to the substantial initial costs linked to these technologies (Lungu et al., 2014; Ntanos et al., 2018; Su et al., 2018). Implementing policies that incentivize the consumption of renewable energy technologies is crucial especially in the early

stages, as installation and operating costs are relatively high, and this can have a potentially negative impact on consumer behavior over time (Lungu et al., 2014). Bauner and Crago (2005) highlighted the efficacy of government policies in diminishing the expenses associated with home PV systems. They asserted that, "in the state of Massachusetts, the combination of federal and state incentives has lowered the cost of a typical 6-kw residential system by over 50%, from about $33,000 to $16,000" (p. 27). Specifically, regarding the role of the government's financial incentive policies in stimulating WTP for renewable energy sources, Ntanos et al. (2018) argued that the "willingness to pay was found to be positively associated with education, energy subsidies, and state support" (p. 1).

Besides fiscal incentives, the WTP for rooftop solar panels can also be shaped by an individual's broader environmental beliefs and attitudes. Based on the chi-square test analysis, the willingness to pay rooftop solar panels in Riyadh City seemed to be strongly linked to whether or not an individual believed that both climate change is real and that renewable energy can be effective in protecting the environment from pollution. The climate change variable generated the 3rd largest Cramer's V score (i.e., 0.36) and χ^2 score (i.e., 78.4) in Riyadh (Table 11) with respect to WTP. More specifically, those that strongly agreed that they were willing to pay for rooftop solar panels were also much more likely to strongly agree that climate change is real (i.e., 25.6% and 154 of all Riyadh respondents) compared to those less inclined to such beliefs (i.e., 11.8% and 71 respondents) (Table 14). However, it should be also noted that 43% (295) of all Riyadh respondents were also less inclined to believe that climate change was real when expressing more moderate levels of support regarding their WTP for rooftop solar panels.

Similar trends occurred regarding the link between WTP and the effectiveness of renewable energy in mitigating pollution. In Riyadh, the link between these two variables

generated the 4th largest Cramer's V score (i.e., 0.356) and the 2nd largest χ^2 score (i.e., 79.9). In detail, when examining only those that strongly agreed they were WTP for rooftop solar panels, 30.7% (194) of these same Riyadh respondents also strongly agreed that renewable energy can be effective in protecting the environment from pollution (Table 14). That compares to just 7.8% (49) when analyzing only those Riyadh respondents that were less inclined to believe that renewable energy can be effective in protecting the environment from pollution. Once again, it should also be noted that 34.7% (219) of all Riyadh respondents were less inclined to believe that renewable energy can be effective in protecting the environment from pollution when expressing moderate levels of support with respect to their WTP for rooftop solar panels (Table 14).

Table 14: Contingency Table for WTP and Environmental Attitudes: Riyadh City

Variable	Category	WTP				
		Moderate agreement		Strong agreement		Total
Climate change is real	Moderate agreement	259	43.0%	71	11.8%	330
	Strong agreement	118	19.6%	154	25.6%	272
	Total	377	62.6%	225	37.4%	602
Renewable energy can be effective in protecting the environment from pollution	Moderate agreement	219	34.7%	49	7.8%	268
	Strong agreement	170	26.9%	194	30.7%	364
	Total	389	61.6%	243	38.4%	632

These environmental beliefs played a less prominent role in shaping WTP in Buraydah and Al-Qassim. The belief that climate change is real ranked just 9th in Buraydah based on the Cramer's V score (i.e., 0.269) and no statistically significant link existed between WTP and the belief that climate change is real in Al-Qassim. By contrast, the chi-square test indicated that the

WTP was more notably associated with the belief that renewable energy can be effective in protecting the environment from pollution in Buraydah generating the third-largest Cramer's V score (i.e., 0.345). By contrast, the equivalent Al-Qassim Cramer's V score (i.e., 0.15) ranked last suggesting that environmental beliefs may be less influential in shaping WTP in these sorts of places.

These results are consistent with earlier studies that emphasized the interrelationship that existed between an individual's environmental awareness levels and their inclination to embrace renewable energy (Nemet & Johnson, 2010; Zografakis et al., 2010; Krishnamurthy & Kriström, 2016; Su et al., 2018). Ntanos et al. (2018) stated that "environmental protection is seen as the most important reason for investing in a renewable energy system" (p. 1). Similarly, Zografakis et al. (2010) noted that participants who see climate change as a real problem are usually willing to pay more for the development of renewable energy sources. In support of this notion, Shah et al. (2021) posited that social networks can effectively expose individuals to environmental and climate change-related information, that can thereby shape more pro-environmental behaviors.

Additionally, the geographic disparities in environmental attitudes between the more urbanized Riyadh City and the less densely populated Buraydah and more rural areas of Al-Qassim province suggest that the strength of widely shared environmental values may vary based on geographic setting. Balta-Ozkan and Gallo (2018) indicated that these spatial differences may be a result of the disparities that might exist in the level of knowledge about renewable energy sources between rural and urban residents. For instance, a study in China by Yu (2014) observed that "urban residents are more concerned about the environment than rural residents" (p. 47).

Another key factor that can shape WTP is whether individuals consider buying and installing solar panels to be expensive. Although this concern did not feature prominently in

Riyadh where it ranked last based on the statistically significant Cramer V scores (i.e., 0.26) nor in Al-Qassim where it ranked 7th (Table 11). However, in Buraydah, the concern about the cost of buying and installing solar panels as it relates to WTP ranked 5th based on the Cramer V score (i.e., 0.30) In Buraydah, those that strongly agreed they would be WTP for rooftop solar panels were much more likely to also strongly agree that buying and installing solar panels would be expensive (i.e., 37.1% of all respondents) (Table 15). In Riyadh and Al-Qassim the equivalent response rates were much lower (i.e., 27.3% and 27.5%, respectively).

Table 15: Contingency Table for WTP and Expected Solar Panel Expenses: Buraydah City

Variable	Category	WTP				
		Moderate agreement		Strong agreement		Total
Buying and installing solar panels will likely be expensive	Moderate agreement	79	26.4%	28	9.4%	107
	Strong agreement	81	27.1%	111	37.1%	192
	Total	160	53.5%	139	46.5%	299

The importance of the price of renewable energy technologies and the cost of installing them as obstacles for consumers is highlighted in several studies (Borchers et al., 2007; Su et al., 2018; Irfan et al., 2021). In the context of perceptions of cost, Zhai and Williams (2012) explored consumer perceptions of the expected cost of solar panels and the differences that exist between adopters and non-adopters of solar panels. They found that non-adopters had a perception that solar panels were more expensive than adopters. Additionally, Zhai and Williams (2012) noted that “for non-adopters, cost was the most important factor” (p. 353). The reason for the difference between the three study areas regarding the perceptions of the cost of solar panels is less clear, since in all three geographic settings, those most WTP all seemed to be more likely than not to be aware that buying and installing solar panels would be expensive, especially in Buraydah.

We should note that several variables identified in the literature as key determinants in shaping the WTP did not feature prominently in Table 11. While many studies have demonstrated the significance of socio-economic indicators (e.g., income, education, occupation or family size) in influencing the WTP (e.g., Karytsas et al., 2019; Ortega-Izquierdo et al., 2019), it is noteworthy that in the context of the emerging solar energy market in Saudi Arabia, these conventional links seem less pronounced. The relatively nascent stage of the solar energy market in Saudi Arabia, especially compared to more established Western markets, and the relatively small number of Saudi residents with rooftop solar panels, may mean that the conventional sorting of socio-economic differences has yet to fully play out in Saudi Arabia.

Furthermore, despite the acknowledged significance of the impact of social networks on WTP in the existing literature (e.g., Kwan, 2012; Ortega-Izquierdo et al., 2019; Nazir & Tian, 2022), in this analysis these networks were largely muted. For instance, survey participants were asked whether they knew about other individuals using solar energy or whether they were familiar with renewable energy websites like 'Shamsi' that provided valuable information about solar energy. The results indicated that only a few respondents were acquainted with such networks or programs. The limited impact of social networks in this analysis could also potentially be attributed to the fact that only 2% of the Saudi Arabian population currently utilize solar panels in their households, thus, substantially diminishing the potential impact of "peer effects" on WTP rates.

5 Conclusion

The significance of solar energy lies in its effectiveness as a means of generating clean energy, particularly in the residential sector, a substantial consumer of energy. Integrating solar panels into residential environments offers the potential to alleviate current and future energy

burdens while simultaneously generating clean electricity – a crucial step toward promoting a sustainable environment.

In the broader literature, the WTP for rooftop solar panels seems to be shaped by four key determinants: various socio-economic indicators, the built environment, certain fiscal policies, and social networks. To better understand these WTP preferences and related key determinants in Saudi Arabia, and how they may differ from Western environments, we utilized survey data collected from respondents in Riyadh City, Buraydah City, and the rural areas of Al-Qassim Province in Saudi Arabia. The results indicated that most respondents expressed a strong WTP for rooftop solar panels across all three geographic settings although the survey results also revealed that the majority of the participants were only willing to pay up to 5,000 SAR ($1,332) for a solar panel installation valued at 12,000 SAR ($3,199).

When examining the distinction between respondents with a strong versus moderate WTP for rooftop solar panels, the survey data revealed common themes and differences by geographic setting. In detail, the WTP seems to be particularly linked to certain expectations regarding individual household energy needs, various financial incentives (e.g., tax deductions and subsidies), and broader environmental values regarding whether or not climate change is real and the role of renewable energy in mitigating pollution. A key spatial difference is that those that were most WTP in Riyadh City preferred tax deductions over subsidies. The opposite held true in Buraydah City.

These results align with the previous emphasis on the importance of government interventions to reduce the financial burdens associated with the purchase and installation of renewable energy technologies, which could limit the spread of their use in the residential sector (Lungu et al., 2014; Su et al., 2018). Additionally, the prevailing belief among survey

participants that the installation of solar panels is costly, particularly in Buraydah, underscores the significance of policy incentives, such as government subsidies, in addressing this concern when attempting to encourage the public to embrace solar energy technologies.

It should also be noted that those respondents that were the most WTP, strongly agreed that climate change is real, and that renewable energy can mitigate pollution levels, especially in Riyadh and Buraydah, although less so in the rural areas of Al-Qassim Province. This underscores the potential influence of broader environmental values on the intention to purchase rooftop solar panels.

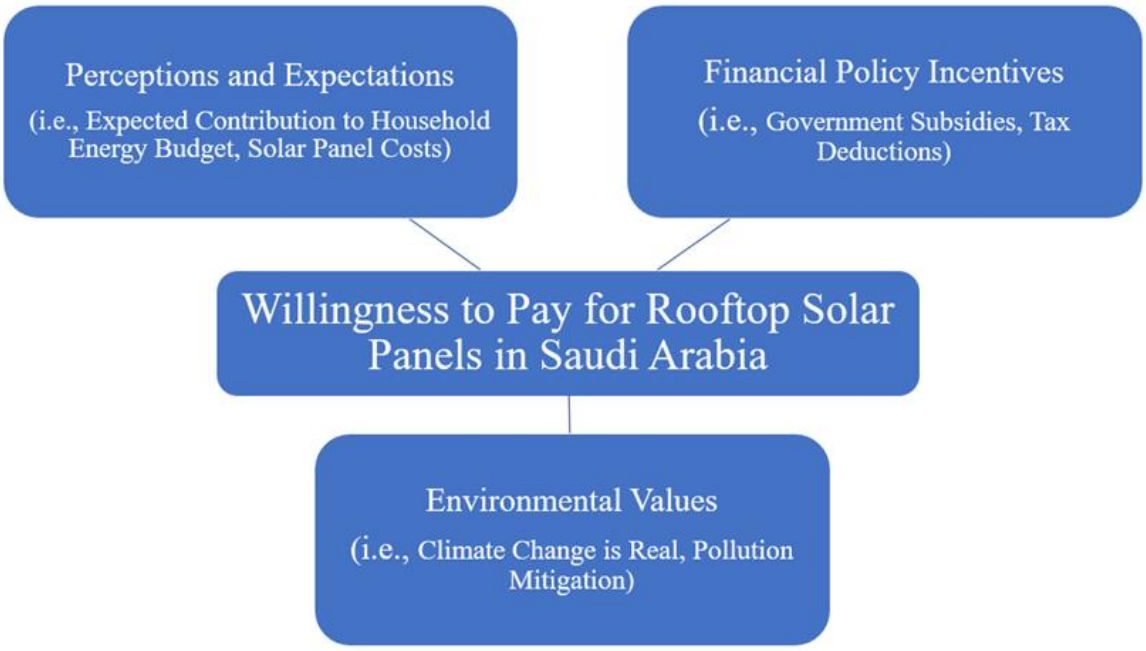
Our findings also diverged from the conventional literature regarding the role of various socio-economic indicators, and social networks in determining WTP. Unlike previous research, our findings revealed no statistically significant link existed between WTP and various metrics linked to age, income, gender, or educational background possibly because the market for rooftop solar panels is relatively new and still emerging. Also, the acknowledged importance of social networks in shaping WTP preferences did not feature prominently in our analysis, which may be connected to the fact that only 2% of the Saudi population currently use rooftop solar panels.

In general, while robust support for rooftop solar panels existed in Saudi Arabia across diverse geographical scales, subtle spatial variations are evident in terms of the strength of the association and the ranking of the variables. These differences manifest notably in attitudes regarding solar panel effectiveness, the type of financial incentives offered, and various individual environmental beliefs and concerns (Figure 9).

Our analysis is a modest first step in providing a theoretical framework for analyzing the rooftop solar panel market that has been customized to the Saudi Arabian experience while also

providing policymakers with some insights into the common themes and geographic differences in WTP preferences. Conducting similar studies that delve more deeply into the detailed price preferences of potential rooftop solar panel consumers could offer an even more accurate understanding of the renewable energy market in Saudi Arabia and how it might match or differ from the theoretical expectations of the established literature.

Figure 9. Willingness to Pay for Rooftop Solar Panels: A Conceptual Framework for Saudi Arabia – The Key Factors



CHAPTER V: PRICE PREFERENCES FOR ROOFTOP SOLAR PANELS IN SAUDI ARABIA

1 Introduction

In the 21st century, nations confronted numerous challenges stemming from escalating reliance on fossil fuels, including climate change and the imperative for urban and economic sustainability (Güney, 2019; Abbasi et al., 2022). Renewable energy has emerged as the linchpin for a sustainable future, offering pathways to preserve the environment while fortifying cities' resilience, both environmentally and economically, against the relentless surge in energy requirements (Bilgen et al., 2004). Particularly in urban landscapes, where demands from residential and industrial sectors surge, the adoption of renewable energy solutions transcends mere choice; it becomes imperative for securing enduring prosperity and steering energy sourcing away from fossil fuels to meet future demands. Therefore, the participation of the population in the transition to renewable energy is no less important than the efforts of governments to ensure sustainable growth (Pitt & Michaud, 2015; Hao et al., 2020).

This paper focuses on evaluating the preferred price to pay for rooftop solar panels at three distinct geographic scales in Saudi Arabia (e.g., large urban areas – Riyadh City; medium-sized urban areas – Buraydah City; and rural areas – Al-Qassim Province). Saudi Arabia has good natural conditions for using solar energy, such as solar radiation (Almasoud & Gandayh, 2015), but the population’s share in using solar energy is very low, amounting to only 2% of the total population (General Authority for Statistics, 2023). The challenges related to the need to shift to renewable energy, and the population’s currently low adoption rate for rooftop solar panels underscore the need to better understand the price preferences for such panels since

household financial constraints may stymie the spread of rooftop panels across different geographic settings in the Kingdom of Saudi Arabia.

Previous research has pointed to social, economic, and technical factors related to adoption rates for solar energy. However, most of these studies do not consider the impact of spatial context, which is especially true in research conducted in Middle Eastern countries. Balta-Ozkan and Le Gallo (2018) have argued that the existing literature has overlooked the role of spatial factors in shaping energy attitudes and perceptions. Moreover, previous research conducted in Saudi Arabia related to the Saudi public's attitudes toward solar energy mostly used a small sample or did not consider the spatial context (e.g., Mosly & Makki, 2018; Makki & Mosly, 2020; Alrashoud & Tokimatsu, 2020).

This paper aims to address the critical gap in research related to possible consumer price preference differences for rooftop solar panels in diverse geographical settings in Saudi Arabia. As the Kingdom embarks on its journey toward a renewable energy future, understanding the potential consumer behavior and price preferences becomes essential for policymakers, businesses, and investors (Ayodele et al., 2021). By highlighting the emerging solar market and identifying key factors influencing consumer decisions, this research seeks to inform strategic initiatives that will accelerate the transition towards a more sustainable future for Saudi Arabia.

In terms of the central research questions, it is hypothesized that the price preferences for rooftop solar panels will be linked to several key factors, including diverse socio-economic predictors, variations in the built environment, the institutional context, and various social information network effects. In detail, this paper aims to address the following research questions:

1- Is there spatial variance in the price preferences for residential rooftop solar energy panels across different types of built environments in Saudi Arabia?

2- What are the key variables that are most associated with the price preferences for residential rooftop solar energy panels in Saudi Arabia?

3- Is there spatial variation in those key factors most associated with the price preferences for residential rooftop solar energy panels?

2 Literature Review

Previous research has well demonstrated that behaviors and attitudes related to the acceptance of renewable energy are complex and influenced by various factors (Faiers *et al*., 2007; Mills & Schleich, 2009; Claudy *et al*., 2011; Willis *et al*., 2011; Ruokamo, 2016; Balta-Ozkan & Le Gallo, 2018; Karytsas *et al*., 2019). The literature has largely focused on the willingness to adopt or willingness to pay, while fewer studies have addressed the potential consumer preferred price for renewable energy. Previous research in Saudi Arabia indicated that the theoretical framework for the willingness to pay is linked to attitudes regarding solar panel effectiveness in contributing to the house energy budget, the type of financial incentives offered, and various individual environmental beliefs and concerns (Alwulayi & Debbage, in review). However, existing literature indicates that the preferred price to pay for renewable energy is affected by four primary broad determinants: socio-economic predictors (e.g., income, education, age), the built environment (e.g., urban vs. rural), social information networks (e.g., peer effects, knowledge), and the institutional context and pricing (e.g., subsidies, tax reductions) (Aravena *et al*., 2012; Soon & Ahmad, 2015; Zander *et al*., 2019; Mamkhezri *et al*., 2020).

2.1 The Socio-Economic Predictors

Numerous studies have investigated the influence and links between different socioeconomic variables, including income, education, and age, on attitudes towards and utilization of renewable energy (e.g., Zografakis et al., 2010; Komatsu et al., 2011; Karytsas & Theodoropoulou, 2014; Karytsas et al., 2019). In the context of emphasizing the link between some socio-economic elements and attitudes towards solar energy, according to Zander et al. (2019), “early adopters and those who initially intending to install solar PV systems can be characterised as being well educated and wealthy” (p. 329). Also, some studies have shown that variables such as family size and gender are related to the willingness to pay for renewable energy (e.g., Cheng et al., 2017; Ayodele et al., 2021).

Aravena et al. (2012) examined household preferences for various electricity generation sources in Chile, including renewable energy sources (RES), finding that households were willing to pay an additional 3,401 CLP ($7.24) per month in their electricity bill to support RES development. They observed a positive correlation between education and income levels and the willingness to pay for RES, with higher-educated and higher-income individuals expressing a greater willingness to pay. Conversely, they noted a negative correlation between age and willingness to pay, suggesting that younger individuals were more willing to pay for RES compared to older individuals due to their better understanding of renewable energy. Bergmann et al. (2008) utilized a Choice Experiment to explore an individuals' preferences to support renewable energy projects in Scotland based on different criteria like and increase in the household electric bill from £0 to £45 a year. Their study revealed that age and education significantly influenced support for renewable energy, with younger individuals and those with higher education degrees more likely to favor such projects. However, income levels did not

show a significant impact on the choice, potentially attributed to the modest increase in electricity prices tested in the experiment, which remained affordable to all respondents.

Zarnikau (2003) investigated the willingness to pay for electric utility investments in renewable energy and energy efficiency resources in Texas. The study highlighted the influence of age, education, and income on the reported willingness to pay for these investments, noting that respondents over 65 years are willing to pay $6.79 less compared to younger respondents who showed greater interest in paying higher costs for renewable energy resources. Moreover, participants who live in rented houses are willing to pay $2.16 more to support renewable energy resources compared to homeowners. Additionally, Zarnikau (2003) found that the price to be paid for renewable energy resources tended to increase with income and higher levels of educational attainment. Moreover, Wiser (2007) investigated the willingness to pay $0.5, $3, or $8/month for renewable energy among U.S. residents based on survey data for 1,574 respondents. The study found that females are likely to pay more for renewable energy, while respondents who have children tended to pay lower prices. Additionally, older respondents tended to pay less, while respondents who had higher levels of education were more willing to pay more for renewable energy.

Bigerna and Polinori (2014) explored the willingness to pay for green electricity based on a nationwide survey of households in Italy. Their findings revealed a noticeable willingness to pay among Italian households for green electricity, with estimated payments ranging from €4.62 to €8.05 every two months per household. They noted that age was negatively correlated with willingness to pay, while income, education, and professional status positively influenced the willingness to pay, indicating that younger individuals, higher-income earners, and those with higher education levels were willing to pay higher prices for green electricity. Also, they found

that males were willing to pay higher prices than females. Bollino (2009) also investigated how much the consumers in Italy were willing to pay for electricity produced from renewable energy. The study found that on average consumers were willing to pay an additional €9.11 on their electricity bill if the electricity is generated from renewable energy sources. Also, Bollino (2009) found that participants with higher education, high income, and also homeowners were willing to pay higher prices while females tended to be less willing to pay compared to males.

Zorić and Hrovatin (2012) analyzed the willingness to pay for electricity generated from renewable energy sources in Slovenia. They found that on average the participants were willing to pay €4.18 more on the monthly electricity bill for green electricity. The results showed that as age increased, the amount to be paid decreased from €4.62 for participants under 30 years of age to €3.35 for participants older than 60 years. Similarly, household size was negatively related to the willingness to pay where households of 4 people are willing to pay more compared to households of 6 people or more. Also, they found that females were willing to pay €0.68 more than males. Additionally, education and income also had a positive impact on the amount to be paid, as they indicated that the amount increases with educational level and income level.

Longo et al. (2008) looked into the nuanced determinants of willingness to pay £6.5, £16, £25, and £38 every 4 months for renewable energy sources (RES) among residents of Bath, England. They found a positive correlation existed between income levels and the willingness to pay. Also, they found that respondents who have a college degree and children are willing to pay £45.54 for renewable energy sources in addition to their electricity bill. Zografakis et al. (2010) examined public acceptance and willingness to pay for renewable energy sources (RES) in Crete. They found a positive correlation between income level and willingness to pay where individuals

with higher annual incomes are willing to pay higher prices for RES compared to those of low incomes.

2.2 Built Environment

The built environment and spatial context are significant factors that can impact residents' perspectives on renewable energy, influencing both the adoption rates and the price individuals are willing to pay for such energy sources, either directly or indirectly (Zografakis et al., 2010; Zorić & Hrovatin 2012; Balta-Ozkan & Le Gallo, 2018; Ortega-Izquierdo et al., 2019). Schunder et al. (2020) suggested that the "geographic context is a major determinant of rooftop solar adoption" (p. 2) as location and its diverse elements can influence the rates at which solar energy is used, beginning with the geographic positioning affecting solar radiation and extending to the size of the settlement area, where rural residents often have more space for installing solar panels.

In their study, Bigerna and Polinori (2011) examined consumers' willingness to pay for electricity from green energy, revealing a mean willingness to pay of €9.39. They observed that residents in North and Central Italy demonstrated a higher willingness to pay for renewable energy, while those in urban areas with over 100,000 inhabitants expressed a lower willingness to pay compared to residents of smaller towns. In investigating the willingness to pay for electricity produced from renewable energy in Slovenia, Zorić and Hrovatin (2012) found a clear difference in the price to be paid between urban and rural residents, as rural residents were willing to pay €0.93 higher than urban residents. Zorić and Hrovatin (2012) indicated the reason that rural residents are willing to pay a higher amount is because "this part of the population is more attached to nature and is thus more inclined to support various green programmes" (p. 186). Moreover, they also found that the price to be paid varies depending on the characteristics

of the home where the residents of single-family homes are willing to pay €0.47 more than those who live in multi-family dwelling.

Mamkhezri et al. (2020) investigated consumer preferences and willingness to pay for renewable energy in New Mexico. They found that urban respondents exhibited a higher willingness to pay for rooftop solar panels (i.e., $0.71) compared to rural residents. Moreover, Soon and Ahmad (2015) used data from different studies to compare countries regarding the willingness to pay for RES use. They found a difference existed between metropolitan residents in North America and rural residents in Asia regarding willingness to pay where they are willing to pay $11.14 per month compared to rural residents in Asia who are willing to pay only $2.27. They explained the difference between the residents in North America and rural residents in Asia as differences resulting from exposure to information and knowledge related to renewable energy.

Bergmann et al. (2008) in an analysis of the willingness to pay between urban and rural residents for renewable energy projects in Scotland found statistical differences based on the impacts of these projects. They found that rural residents were willing to pay £1.08 more annually for solar projects than urban residents in order to create jobs in their areas. Similarly, Entele (2020) investigated rural household preferences and willingness to pay for solar energy connections in Ethiopia, uncovering a mean monthly willingness to pay of $12.5. However, disparities were observed across rural areas, with those having access to cheaper energy sources demonstrating a lower willingness to pay for solar panels. Meyerhoff (2013) examined the willingness of residents in Leipzig city and surrounding rural areas in Germany to pay €0, €1, or €6 more every month for electricity sourced from renewable energy. Although the study did not specify the exact amount to be paid, it highlighted distinct preferences between urban and rural

residents, with urban residents exhibiting lower willingness to pay compared to their rural residents. Meyerhoff (2013) suggested that the higher willingness to pay among rural residents could be attributed to their potentially greater exposure to renewable energy projects in their surroundings compared to urban residents.

Sun et al. (2023) examined provincial residents' willingness to pay for renewable electricity in China. They found that the average willingness to pay for renewable electricity among Chinese residents was 0.85 yuan/kWh, exceeding the current electricity price of 0.5 yuan/kWh. Additionally, urban residents generally exhibited a higher willingness to pay than rural residents, and residents of larger houses displayed a positive correlation with the willingness to pay, indicating a greater willingness to pay for renewable electricity. In their study, Maxim et al. (2022) aimed to determine the extent to which the population in the northeast region of Romania is willing to pay a premium for the development of renewable energy. They found that for scenarios such as independence from importing energy and creating new jobs, urban residents and individuals living in apartments were willing to pay more, while rural residents were willing to pay less. Conversely, for the scenario of reducing pollution effects, rural residents were willing to pay more.

Zografakis et al. (2010) aimed to analyze citizens' public acceptance and willingness to pay for renewable energy sources in Crete. They found that the mean willingness to pay per household was €16.33 to be paid quarterly as an additional charge on the electricity bill. Additionally, they found that respondents living in large houses were willing to pay more on average for RES compared to those residing in small houses, which was an anticipated result given the implication of a high welfare level associated with living in larger houses. Claudy et al. (2011) in a study on willingness to pay for renewable energy technologies in Ireland found that

the mean willingness to pay for solar panels is €6,207.80. They also found that housing characteristics influenced willingness to pay, as owners of larger and newer homes are willing to pay a lower price for solar panels.

2.3 Social Information Networks

The impact of social information networks on individuals' decisions regarding renewable energy has been widely acknowledged in the literature (Kwan, 2012; Ortega-Izquierdo et al., 2019; Nazir & Tian, 2022). The dissemination and exchange of information about renewable energy through social networks can significantly influence the willingness to pay for renewable energy technologies (Nazir & Tian, 2022). These networks, which may include various social networking platforms or 'peer effects,' can convey information that shapes attitudes towards renewable energy, including knowledge about its benefits and ease of use, as well as raising awareness of environmental issues such as climate change and pollution levels (Calvó-Armengol et al., 2009; Severo et al., 2019; Sánchez-Arrieta et al., 2021; Nazir & Tian, 2022).

Ivanova (2013) delved into the willingness to pay an additional amount on the electricity bill for renewable energy in Queensland, Australia. On average, respondents were willing to pay approximately $28/quarter to support increased electricity generation from renewable sources. Additionally, individuals with environmental concerns regarding climate change were willing to increase the amount paid from $14 to $29, highlighting the influence of environmental consciousness on willingness to pay. Ntanos et al. (2018) investigated public perceptions and willingness to pay to increase renewable energy in Greece. They discovered that the average willingness to pay to increase renewable energy by 10% is €26.5 per household. Their analysis highlighted that environmental awareness programs emphasizing environmental conservation were the primary motivators for investing in renewable energy systems. Respondents expressed a

strong willingness to pay for the expansion of renewable energy sources, underscoring the significance of environmental factors in energy decision-making.

Pleeging et al. (2021) investigated the willingness to pay for green energy in the Netherlands and found the average amount to be paid is about €22. They found that the willingness to pay for green energy correlated with environmental attitudes, especially climate change, where individuals who are more concerned about climate change are more willing to pay more than the average. Rowlands et al. (2003) studied potential purchasers of green electricity in Canada, focusing on attitudinal traits like ecological concern, liberalism, and altruism. Nearly half of the respondents were willing to pay an additional $10/month for green electricity. Notably, those with pro-environmental attitudes and concern for energy issues demonstrated a greater willingness to pay above the average.

In the context of knowledge related to renewable energy sources and their benefits, Zografakis et al. (2010) discovered that individuals with higher levels of knowledge about renewable energy, including its capacity for energy generation and cost savings, exhibited a greater willingness to incur additional costs on their four-month electricity bill for renewable energy sources compared to those lacking such information. Furthermore, they observed that respondents who prioritize environmental concerns and recognize the significance of safeguarding it from the impacts of fossil fuels and pollution display a heightened willingness to pay. Moreover, in Zarnikau's (2003) paper on the willingness to pay for electric utility investments in renewable energy in Texas, participants were provided with information regarding renewable energy, including costs and environmental preservation, to determine the additional amount they were willing to pay. Zarnikau (2003) noted that “intensive exposure to information about energy resource issues led to an increase in the number of respondents

interested in paying a modest premium to support investments in both renewable energy resources and energy efficiency" (p. 1661). Furthermore, the paper indicated that respondents most willing to pay were those who prioritized environmental protection.

Wiser (2007) found people who have environmentally friendly practices such as recycling and purchasing pesticide-free food are willing to pay a higher price for renewable energy. Moreover, Nazir and Tian (2022) discovered a notable positive correlation in Pakistan between the willingness to pay (referred to as purchase intention) for renewable energy technology and exposure levels on social media. This exposure facilitated knowledge spillover about the benefits of solar energy and its ease of use. Palm's (2017) study in Sweden demonstrated the motivating role of peer effects for individuals interested in solar energy, with the strongest impacts observed within close social relationship networks that confirmed the effective functioning of solar energy systems. Palm's (2017) study in Sweden highlighted the motivating role of peer effects on individuals interested in solar energy, which may create a positive influence on the perceived price of renewable energy systems. Lastly, Mosley and Makki (2018) found a strong desire among households in Saudi Arabia to save the environment, with a significant percentage willing to operate renewable energy sources to mitigate negative externalities.

2.4 Institutional Context and Pricing

Governments play a crucial role in encouraging the extensive uptake of renewable energy technologies in residential settings by implementing significant policies like financial incentives and tax breaks. These measures aim to tackle the substantial initial expenses linked with these technologies, as highlighted by Dulal *et al*. (2013), who emphasized that "in the absence of government support, large-scale diffusion of renewable energy is impossible because of the high

up-front capital costs" (p. 306). The expense associated with solar panels, particularly, emerges as a primary obstacle hindering their widespread adoption, emphasizing the necessity of government involvement to stimulate demand (Dulal *et al*., 2013; Irfan *et al*., 2021).

The renewable energy market sector is significantly influenced by the high costs associated with purchasing and installing renewable energy technologies, which may constrain consumer preferences and desires for adoption (Borchers *et al*., 2007; Mamkhezri *et al*., 2020). For instance, Su *et al*. (2018) investigated the willingness of Lithuanian households to pay for renewable energy technologies, revealing a preference for lower-cost technologies. Their findings underscored the importance of installation costs, indicating that a €1 increase in the monthly bill for installing renewable energy required an average decrease in installation costs of €90. Similarly, Zander *et al*. (2019) found a negative relationship between increased installation costs for solar energy systems and purchase intent among Australian households. Moreover, Borchers *et al*. (2007) suggested that a decrease in the costs of renewable energy, such as solar energy, coupled with increased financial benefits in savings on the power bill, would likely result in a higher probability of its adoption and therefore a willingness to pay a higher price for it.

In highlighting the government's role in supporting renewable energy, Mamkhezri *et al*. (2020) stated that "renewable electricity generation has increased considerably in the past decade in the U.S. This is due to several factors, including cost competitiveness and state and federal policies, such as production and income tax credits, RPSs [renewable portfolio standards], and state-level subsidies for solar energy" (p. 178). Crago and Chernyakhovskiy (2017) assessed the effectiveness of policy incentives for residential solar power installations in the Northeastern United States, revealing that rebates, as direct cash subsidies, had a substantial impact, with an additional $1 per watt rebate significantly increasing annual photovoltaic capacity demand. This

suggests that financial incentives may make potential consumers willing to pay higher prices for renewable energy. Similarly, Bauner and Crago (2015) indicated that governmental financial incentives, such as rebates and tax credits, played a significant role in increasing the adoption of residential solar power systems. Their findings underscored the significance of policies aimed at reducing uncertainties related to investment costs in residential solar PV technology. Even though their study is not about price preferences, governmental financial incentives may positively affect the price to be paid for renewable energy. Sardianou and Genoudi (2013) investigated consumers' willingness to pay extra for renewable energies in the residential sector. Their findings revealed that energy tax deductions and subsidies were statistically significant factors positively associated with the willingness to pay extra for renewable energies, where the energy subsidy was more effective than a tax deduction. Ntanos *et al*. (2018) discovered that government subsidies for RES are a significant incentive, positively correlating with the willingness to pay among Greek respondents.

Pleeging *et al*. (2021) found that most participants, on average, paid around €22 for green energy per month in the Netherlands. However, some participants indicated that they are not willing to pay any amount because they believe that the government should pay the additional amounts for renewable energy. Gao *et al*. (2020) assessed the impact of willingness to pay on achieving future renewable energy targets in Japan. They found that the average median willingness to pay per household for renewable energy is 1,340 JPY/ month. They stressed the importance of subsidies in low-income areas to achieve the goals of transitioning to renewable energy more than in high-income areas. Ayodele *et al*. 2019 found that the amount to be paid for green energy is low, noting that 87.5% of respondents in Nigeria are willing to pay between 5% and 10% in addition to their current energy bill for green electricity. They stressed the need to

create financial incentive programs such as subsidies in order to encourage the use of green energy. Jung *et al*. (2016) aimed to identify the current status of public perceptions regarding renewable energy technologies (RETs) available in the Finnish market and associated influencing factors. They found that respondents prefer to pay €6000 for RETs. Additionally, they noted that 61.9% of respondents preferred tax deductions.

3 Methodology

The goal of this paper is to develop an elevated understanding of what drives price preferences concerning rooftop solar panels in Saudi Arabia across three distinct geographical settings: a large urban area (Riyadh City), a medium-sized urban area (Buraydah City), and the rural area of Al-Qassim Province (Figure 10). It posits that the primary determinants influencing price preferences for rooftop solar panels can be categorized into four potential clusters: various socio-economic variables, the built environment, social information networks, and the institutional and pricing policy context. The data used in this paper were obtained through a survey, where the dependent variable, price preferences, was derived from a Likert scale response comprising six categories, ranging from "less than 5,000 SAR ($1,332)" to "from 19,000 to 23,000 SAR ($5,066 to $6,132)."

In the survey, questions were included to establish the socio-demographic characteristics of each participant, such as age, income, and educational level, as well as to determine where each participant stood on various topics, including price preferences, climate change, perceptions of renewable energy, and potential expenses. To collect data for this study, a survey was designed using Qualtrics Software and distributed online between November and December 2022 in Saudi Arabia (Appendix A). The survey questions were developed after reviewing previous relevant studies and received Institutional Review Board approval from our host

university. The survey was predominantly distributed online through platforms such as WhatsApp, Facebook, and X (formerly Twitter); however, participants outside the designated study areas were excluded. Additionally, residents in the targeted geographic study areas were approached randomly on the streets and in various gathering places and encouraged to share the survey on WhatsApp and in online groups they were members of, resulting in a snowball sampling approach. Prominent X and WhatsApp users were also approached to distribute the survey, with a focus on accounts widely followed by residents of the three study areas, especially those recognized for sharing local news. In total, 1,647 fully completed survey responses were collected from these targeted areas.

Figure 10. WTP for Rooftop Solar Panels by Study Area

The choice of the three geographic study areas was made by selecting locations with a diverse range of metrics, such as differences in population density, levels of educational

attainment, median household income, and various housing attributes, as outlined in Table 16. Riyadh City stands out from both Buraydah City and the rural areas of Al-Qassim Province across several pivotal dimensions. Regarding population, Riyadh boasts significantly higher population numbers and notably higher population density compared to Buraydah and the rural areas of Al-Qassim Province. Additionally, Riyadh City exhibited distinctive socio-economic characteristics, characterized by a higher median household income and a larger proportion of residents holding bachelor's degrees or higher qualifications.

Table 16: Key Statistical Indicators for Riyadh City, Buraydah City, and Al-Qassim Province, 2022

	Riyadh	Buraydah	Al-Qassim
Population	6,924,566	571,169	765,010
Population density per km2	3,846.98	828.3	395.06
Median age	30	28	27
% Children (≤ 15 years old)	22.11	25.40	26
% Workforce (16 to 64 years old)	75.50	72.20	71.30
% Elderly (≥ 65 years old)	2.20	2.40	2.70
Median household monthly income (SR) *	12,688	8,815	9,043.50
% Male	63.2	60.8	57.7
% Female	36.8	39.2	42.3
Less than bachelor degree (% of total population) *	64.5	88.66	85.30
Bachelor degree (% of total population) *	23	10.68	14.48
Master and PhD (% of total population) *	2	0.66	0.22
Average family size	3.5	3.9	4.2
% Multi-family dwelling units	58.1	41.8	37.6
% Single-family dwelling units	41.9	58.2	62.4
% Owner-occupied units	56.2	67.9	69.1

Source: Derived from General Authority for Statistics, 2023.

(* Based on 2018 data from General Authority for Statistics)

The online survey method was selected due to its simplicity in distribution, accessibility, cost efficiency, and applicability for researchers targeting expansive regions (Sue & Ritter, 2012). Moreover, the effectiveness of online surveys has been proven in various studies conducted in Saudi Arabia, ensuring participant privacy (Sue & Ritter, 2012; Mosley & Makki, 2018; Alsabbagh, 2019; Alrashoud & Tokimatsu, 2020). Furthermore, with 96% of Saudis aged 15 years or older using internet-connected smartphones, online surveys offer an effective way of reaching the targeted sample through social media platforms (General Authority for Statistics, 2023). Two sampling approaches were employed for data collection: convenience sampling and snowball sampling methods. The convenience sampling approach was chosen to facilitate the widespread and rapid distribution of the survey, enabling all interested members of the population to participate (Alwelaie, 2012). Compared with the data from the Saudi census, the data for the 1,647 respondents was highly representative of the socio-economic characteristics of Riyadh City, Buraydah City, and Al-Qassim Province based on education, income, and housing status.

The data analysis involved using a Chi-square Test for Independence to examine the links between price preferences and the other independent variables. Cramer's V was utilized to assess the strength of association among these variables. Given that both the dependent variable 'price preferences' and the independent variables are categorical, the chi-square test was chosen to evaluate their association (Crewson, 2023). The contingency tables based on the Chi-square Tests were selected based on an analysis of all the price preferences contingencies as they relate to all the other key variables included in the survey. Only those variable pairs that were significant at the 5% level were included in this analysis.

4 Findings

The cost of purchasing and installing a rooftop solar panel system was estimated at 12,000 SAR ($3,199) using the Shamsi website, which considers the geographical location of the study areas. According to Shamsi (2023), this system is expected to contribute to reducing the monthly electric bill by approximately 150 SAR ($40). 'Shamsi' is a government website that provides precise information on residential solar energy in Saudi Arabia, offering cost estimates and outlining potential financial benefits (Shamsi, 2023). Due to the similarity between the study areas in terms of proximity and natural conditions, the estimated cost of the solar energy system was similar across all three study areas.

The data from Table 17 reveals a significant preference among respondents across all study areas to pay less than 5,000 SAR ($1,332), which falls well below the average estimated system cost of 12,000 SAR ($3,199) provided by Shamsi. This is consistent with findings by Su et al. (2018), indicating that the willingness to pay for renewable energy technologies can often be lower than the market price, with some individuals unwilling to pay at all. Specifically, respondents across all three study areas consistently expressed a preference to pay less than 5,000 SAR, including 67.3% (208) in Buraydah City, 61.1% (391) in Riyadh City, and 60% (162) in rural areas of Al-Qassim (Table 17). However, a significant proportion of respondents in all three study areas expressed a willingness to pay more than 5,000 SAR including 32.7% (101) in Buraydah City, 38.9% (249) in Riyadh City, and 40% (108) in the rural areas of Al-Qassim province.

Table 17: Preferred Price for Rooftop Solar Panels in the Three Study Areas

Preferred price	**Riyadh**	**%**	**Buraydah**	**%**	**Al-Qassim**	**%**	**Total**	**%**
Less than 5000 R	391	61.1%	208	67.3%	162	60.0%	761	62.4%
From 5000 to 8999 R	167	26.1%	58	18.8%	65	24.1%	290	23.8%
From 9000 to 11999 R	39	6.1%	21	6.8%	16	5.9%	76	6.2%
From 12,000 to 14,999 R	20	3.1%	8	2.6%	14	5.2%	42	3.4%
From 15,000 to 18,999 R	4	0.6%	4	1.3%	6	2.2%	14	1.1%
From 19,000 to 23,000 R	19	3.0%	10	3.2%	7	2.6%	36	3.0%
Total	640		309		270		1219	

The broader implication is that changes in geography and geographical scale do not seem to substantially impact the price preference for rooftop solar panels among Saudi residents. Despite the fact that the majority of the respondents are willing to pay less than 5,000 SAR which is far less than the market rate for rooftop solar panels, it also indicates the importance of taking into account financial incentive strategies, such as tax deductions and subsidies based on the characteristics of the region, to further stimulate renewable energy demand in Saudi Arabia.

Moreover, the substantial increase in investment in renewable energy by the Saudi Arabian government has been especially notable in recent decades, aligning closely with the country's objectives of attaining financial equilibrium and decreasing overall electricity usage derived from non-renewable sources (Ministry of Finance, 2023). Furthermore, there appears to be a prevailing consensus within Saudi society endorsing the government's holistic development strategy, which includes the transition to renewable energy sources as delineated in Vision 2030.

This widespread approval could be attributed to the positive societal reforms initiated since the inception of the plan in 2016 (Saudi Vision 2030, 2023).

Although the three study areas seem to have similar preferred price points for rooftop solar panels (Table 17), there remains a degree of uncertainty regarding the key determinants that might shape the preferred price outcomes, and whether these factors vary depending on location. Gaining a clearer understanding of the pivotal variables that most accurately explain the preferred prices for rooftop solar panels can contribute to the expanding body of literature on this subject, while also offering enhanced insights into the Saudi Arabia experience.

4.1 Test of Independence for Price Preference– the Key Variables

The research focused on the price that participants consider appropriate for solar panels with the ability to reduce the monthly electric bill by 150 SAR. The chi-square test of association was used in this analysis to explore potential links between the preferred price to pay for rooftop solar panels and various related variables identified in the literature that might help best explain respondent outcomes. The chi-square test is well-suited for assessing associations among categorical variables, such as the preferred price variable constructed based on a Likert scale (Crewson, 2023). Additionally, Cramer's V will be employed to rank the strength of association between the preferred price and related variables. This method is chosen for its simplicity and effectiveness in determining the existence of a substantive relationship between two variables (Akoglu, 2018; Crewson, 2023). Crewson (2023) stated that “a Cramer's V of 0.1 provides a good minimum threshold for suggesting there is a substantive relationship between two variables” (p. 80). Cramer V coefficients, which vary between 0 and 1, typically suggest a substantive relationship exists between two variables when the coefficient is at least 0.10, with

values between 0.1 to 0.3 indicating some association, 0.3 to 0.5 indicating moderate association, and above 0.5 indicating high levels of association (Crewson, 2023).

The chi-square test of association was performed by initially categorizing responses related to the preferred price to pay for rooftop solar panels into two distinct categories. Based on the information provided in Table 17, it was observed that the majority of respondents across all study areas overwhelmingly preferred to pay less than 5,000 SAR for rooftop solar panels. Specifically, 62.4% of respondents from all areas fell into the category of preferring to pay less than 5,000 SAR, while only 37.6% of all respondents preferred to pay 5,000 SAR or more. Given this disparity in preference distribution and to simplify the analysis, the analysis used two price categories, less than 5,000 SAR and 5,000 SAR or more. This consolidation allowed for a clear interpretation of the data and enhanced the statistical power of the chi-square test by ensuring an adequate sample size in each category.

Additionally, the responses associated with the Likert scale for the other variables utilized in this analysis were classified into two groups due to the positive skewness in many of these responses. The first category, designated as "moderate agreement," comprised responses from participants who either "somewhat agreed" or "agreed." The second category, labeled as "strong agreement," included responses from participants who expressed "strong agreement." This approach enabled a more nuanced analysis that distinguished between groups with different levels of support.

Many of the reported results listed in Table 18 are statistically significant, with p-values below 0.05. The findings show both differences and similarities among the study areas regarding the links between the preferred price and the various other variables. The rankings in Table 18 were determined by the size of the Cramér's V coefficient score for Riyadh City. This

prioritization is justified due to the survey's substantial representation from Riyadh City, encompassing half of the participants, and the city's unique status as the capital, as well as the most populous and expansive urban center in Saudi Arabia.

Table 18: Results for Chi-squared Test of Independence (χ^2) for the Preferred Price for Rooftop Solar Panels and Related Variables Ranked by Cramer's V Coefficient

	Riyadh City		Buraydah City		Al-Qassim	
Variable	χ^2	Cramer's V	χ^2	Cramer's V	χ^2	Cramer's V
Gender	23.6	0.19	12.4	0.20	9.5	0.186
Income	12.7	0.14	13.8	0.21	15.8	0.242
I would consider using rooftop solar panels if they are tax deductible	5.9	0.100	*	*	12.1	0.21
I would consider using rooftop solar panels if the government subsidized the financial cost	*	*	5.3	0.13	*	*
Climate change is real	*	*	*	*	20.8	0.30
Education	*	*	*	*	16.2	0.244
Renewable energy can be effective in protecting the environment from pollution	*	*	*	*	9.1	0.187

* Not statistically significant

Table 18 presents some of the key predictors associated with the preferred price to pay for rooftop solar panels that have been reported in the previous literature, showcasing variations in association and strength of association across different geographical settings. The chi-square test analysis indicates that the strongest links between the preferred price of rooftop solar panels in Riyadh City are with the individual socio-economic characteristics of each respondent, specifically, with gender type and monthly income levels. Notably, gender yielded the highest χ^2 (23.6) and Cramer's V (0.19) scores in Riyadh, the second-highest χ^2 (12.4) and Cramer's V

(0.20) scores in Buraydah, and the second-lowest χ^2 (9.5) and lowest Cramer's V (0.186) scores in Al-Qassim (Table 18). Specifically, among Riyadh respondents, females were 2.7 times more likely (i.e., 177/65) to prefer paying less than 5,000 SAR (Table 19), while males were only 1.12 times more likely (i.e., 214/184) to prefer paying less than 5,000 SAR.

Table 19: Contingency Table for Preferred Prices for Solar Panels and Gender: Riyadh City

Variable	Category	Preferred Price for Rooftop Solar Panels				
		less than 5,000 SAR		5,000 or more SAR		Total
Gender	Female	177	27.7%	65	10.2%	242
	Male	214	33.4%	184	28.8%	398
	Total	391	61.1%	249	38.9%	640

Even more acute gender differences were observed in Buraydah. Specifically, females were 5.4 times more likely (i.e., 60/11) to prefer paying less than 5,000 SAR than to pay a higher price in Buraydah, In Al-Qassim, those gender differences were less pronounced where females were 2.5 times more likely (i.e., 75/30) to pay less than 5,000 SAR. These results are in line with the results of Bigerna and Polinori (2014) and Zarnikau (2003) who stated that "males report a greater willingness to pay for renewable energy than females" (p. 1663). The difference between females and males in terms of price preference for solar panels in Saudi Arabia may be an indirect result of the influence of the local culture, where it is the adult male/husband that traditionally controls the household budget (Abalkhail, 2017).

Furthermore, the analysis results demonstrated that a link existed between the preferred price for rooftop solar panels and monthly income levels across the three study areas. Specifically, monthly income yielded the highest χ^2 (13.8) and Cramer's V (0.21) scores in Buraydah, the second highest χ^2 (12.7) and Cramer's V (0.14) scores in Riyadh, and the third highest χ^2 (15.8) and Cramer's V (0.242) scores in Al-Qassim. In particular, in Buraydah,

participants with monthly income levels of less than 12,000 SAR, which is the national average for household monthly income, were 3.3 times more likely (i.e., 123/37) to prefer paying less than 5,000 SAR than to pay more. Conversely, participants with monthly income levels of 12,000 SAR or more were 1.3 times more likely (i.e., 85/64) to prefer paying less than 5,000 SAR than to pay more, indicating a less pronounced inclination towards lower pricing compared to their counterparts in the lower income category (Table 20).

Table 20: Contingency Table for Preferred Price for Solar Panels and Participants Monthly Income: Buraydah City

Variable	Category	Preferred Price for Rooftop Solar Panels				
		less than 5,000 SAR		5,000 or more SAR		Total
Monthly income	Less than 12,000 SAR	123	39.8%	37	12.0%	160
	12,000 SAR or more	85	27.5%	64	20.7%	149
	Total	208	67.3%	101	32.7%	309

Similar outcomes are observed in Riyadh and Al-Qassim. Specifically, individuals with monthly income levels of less than 12,000 SAR were 2.1 times more likely (i.e., 223/106) to prefer paying less than 5,000 SAR compared to opting for paying a higher price in Riyadh, and 2.2 times more likely (i.e., 118/53) in Al-Qassim. The prominence of income as a factor associated with the preferred price is likely unsurprising, as numerous studies have highlighted its influence on individuals' willingness to pay for renewable energy sources (Zarnikau, 2003; Bollino, 2009; Aravena et al., 2012; Bigerna & Polinori, 2014). Broughel (2019), in a study on the willingness to pay for solar-powered devices in Mexico, noted that “higher income was associated with higher WTP [willingness to pay]” (p. 6). Additionally, individuals with lower income levels are likely to have limited financial resources, making them more inclined to opt for lower prices.

With respect to other individual socio-economic characteristics, only Al-Qassim province featured prominently in Table 18, where the level of educational achievement was statistically significant generating the second-highest χ^2 (16.2) and Cramer's V (0.244) scores. Respondents with educational levels lower than a Bachelor's degree in Al-Qassim were 3.4 times more likely (i.e., 68/20) to prefer paying less than 5,000 SAR (Table 21). Conversely, those with a Bachelor's degree or higher in Al-Qassim were only 1.1 times more likely (i.e., 94/88) to prefer paying less than 5,000 SAR suggesting that those with higher levels of educational achievement were more likely to tolerate higher prices with respect to solar panel installation costs.

Several studies have indicated the positive effect of education on the willingness to pay higher prices for renewable energy (Aravena et al., 2012; Zander et al., 2019). In an investigation of the willingness to pay for renewable energy in Australia, Ivanova (2012) stated that "age and education are significant predictors of a respondents' willingness to pay for renewable energy" (p. 763). The suggestion here is that those with higher education levels may be more aware of the benefits of renewable energy, environmental, and financial benefits of renewable energy particularly through savings on electricity bills. More research is needed though if we are to fully understand why educational achievement levels did not feature more prominently as a key factor in Riyadh or Buraydah.

Table 21: Contingency Table for Preferred Price for Solar Panels and Level of Educational Achievement: Rural Areas of Al-Qassim Province

Variable	Category	Preferred Price for Rooftop Solar Panels				
		less than 5,000 SAR		5,000 or more SAR		Total
Education level	Lower than Bachelor's degree	68	25.2%	20	7.4%	88
	Bachelor's degree or higher	94	34.8%	88	32.6%	182
	Total	162	60.0%	108	40.0%	270

In addition to the socio-economic predictors, fiscal incentives such as tax deductions and/or government subsidies were also significantly linked to the price preferences for rooftop solar panels in all three study areas (Table 18). In particular, tax deductions generated the fourth-largest χ^2 (12.1) and Cramer's V (0.21) scores in Al-Qassim. More specifically, 68.5% (191) of all respondents in Al-Qassim strongly agreed that they would consider using rooftop solar panels if they were tax deductible, particularly for those respondents who were only willing to pay less than 5,000 SAR for a solar panel installation (i.e., 48.5% of all respondents) (Table 22).

Table 22: Contingency Table for Preferred Price for Solar Panels and Tax Deductions: Rural Areas or Al-Qassim Province

Variable	Category	Preferred Price for Rooftop Solar Panels				
		less than 5,000 SAR		5,000 or more SAR		Total
I would consider using rooftop solar panels if they are tax deductible	Moderate agreement	29	11.2%	40	15.4%	69
	Strong agreement	126	48.5%	65	25.0%	191
	Total	155	59.6%	105	40.4%	260

Moreover, in Buraydah the role of government subsidies showed a statistically significant association with the preferred price for rooftop solar panels where 50.5% (151) of all respondents who preferred to pay less than 5,000 SAR for rooftop solar panels also strongly agreed that they would consider using rooftop solar panels if the government subsidized the financial cost (Table 23). These findings concerning government fiscal incentives match the findings in previous studies (e.g., Dulal et al., 2013; Sardianou & Genoudi, 2013; Crago & Chernyakhovskiy, 2017; Mamkhezri et al., 2020), where it was clear that tax deductions and government subsidies can shape an individual's tolerance for higher price points with respect to rooftop solar panel installations.

Table 23: Contingency Table for Preferred Price for Solar Panels and Government Subsidies: Buraydah City

Variable	Category	Preferred Price for Rooftop Solar Panels				
		less than 5,000 SAR		5,000 or more SAR		Total
I would consider using rooftop solar panels if the government subsidized the financial cost	Moderate agreement	51	17.1%	37	12.4%	88
	Strong agreement	151	50.5%	60	20.1%	211
	Total	202	67.6%	97	32.4%	299

In addition to the fiscal incentives, the preferred price for rooftop solar panels was also statistically significantly linked with an individual's environmental belief system regarding whether or not climate change is real and/or that renewable energy can be effective in protecting the environment from pollution. In the rural areas of Al-Qassim Province, the "climate change is real" variable generated the largest χ^2 (20.8) and Cramer's V score (0.30) in Table 18. However, the implication seemed to be that even if an individual believed that climate was real in Al-Qassim they were still likely to prefer to pay less than 5,000 SAR for a solar panel installation (i.e., 32.6% versus just 8.9% of all respondents who would pay more than 5,000 SAR) (Table 24). These trends were even more acute in Al-Qassim province with respect to whether or not renewable energy can be effective in protecting the environment from pollution.

While multiple studies have indicated that an individual's environmental values can significantly shape attitudes linked to renewable energy in a positive manner (e.g., Rowlands et al., 2003; Ivanova, 2013; Ntanos et al., 2018; Pleeging et al., 2021), the results for Al-Qassim show this may not always be applicable. In the context of emphasizing the importance of environmental attitudes in positively influencing the willingness to pay for renewable energy, Mozumder et al. (2011) mentioned that a "higher level of perceived environmental conscience

positively contributes to the willingness to pay for renewable energy" (p. 1122). It is unclear why the preferred price to pay for solar panels in Al-Qassim does not seem to be positively shaped by environmental attitudes, although this may be partly attributable to the influence of other variables that were not included in the analysis.

Table 24: Contingency Table for Preferred Price for Solar Panels and Tax Deductions: Rural Areas or Al-Qassim Province

Variable	Category	Preferred Price for Rooftop Solar Panels				
		less than 5,000 SAR		5,000 or more SAR		Total
Climate change is real	Moderate agreement	68	28.8%	70	29.7%	138
	Strong agreement	77	32.6%	21	8.9%	98
	Total	145	61.4%	91	38.6%	236
Renewable energy can be effective in protecting the environment from pollution	Moderate agreement	44	16.9%	51	19.6%	95
	Strong agreement	108	41.5%	57	21.9%	165
	Total	152	58.5%	108	41.5%	260

It should also be noted that several variables identified in the literature as key determinants in shaping the preferred price for rooftop solar panels did not feature prominently in Table 18. According to previous studies, this includes the age of an individual and housing characteristics (e.g., multi or single-family housing) (e.g., Bergmann et al., 2008; Zografakis et al., 2010; Aravena et al., 2012; Sun et al., 2023), yet these predictors did not feature prominently in this analysis. The absence of these sorts of variables can be partly attributed to the fact that the sample demographics or characteristics in this study likely differ from those in previous research, which may lead to variations in the relevance and influence of certain variables. Additionally, the methodology employed in this analysis, such as the survey design or data collection techniques, may not have fully captured or accounted for these variables.

Moreover, despite the recognized importance of social networks in the existing literature on the preferred price or the willingness to pay for solar panels (e.g., Ortega-Izquierdo et al., 2019; Nazir & Tian, 2022), this analysis found that these networks were not statistically significant. For example, survey participants were queried about their awareness of other individuals using solar energy or their familiarity with renewable energy websites such as 'Shamsi', which offer valuable information about solar energy. The findings revealed that only a small portion of respondents were familiar with such websites. The limited impact of social networks in this analysis could also be attributed to the fact that only 2% of the Saudi Arabian population currently utilizes solar panels in their households, significantly reducing the potential impact of "peer effects" on preferred price outcomes.

5 Conclusion

The importance of solar energy stems from its efficiency in producing clean energy, especially in residential settings, which consume a considerable amount of energy. Incorporating solar panels into homes holds promise for easing present and future energy demands while producing clean electricity— which is an important step in fostering environmental and economical sustainability. Furthermore, the residential sector and its population play a significant role in driving the transition to renewable energy, emphasizing the importance of their contribution to this endeavor.

In the existing literature, the price preference for rooftop solar panels seems to be shaped by four key determinants: various socio-economic indicators, the built environment, certain fiscal policies, and social networks. To better understand these price preferences and related key determinants in Saudi Arabia, and how they may differ from other geographies, we utilized survey data collected from respondents in Riyadh City, Buraydah City, and the rural areas of Al-

Qassim Province in Saudi Arabia. The results indicated that most respondents preferred to pay less than 5,000 SAR ($1,332) for a solar panel installation valued at 12,000 SAR ($3,199).

When examining the distinction between respondents who preferred to pay less than 5,000 SAR versus those who preferred to pay 5,000 SAR or more for rooftop solar panels, the survey data revealed several common themes and differences by geographic setting. Specifically, the preferred price points seem to be statistically significantly associated with individual socio-economic indicators (i.e., income, gender, education), various financial incentives (i.e., tax deductions and subsidies), and broader environmental values regarding whether or not climate change is real and pollution mitigation. These findings also diverged from some of the conventional literature regarding the role of some socio-economic indicators such as age, housing characteristics (i.e., multi-family vs. single-family), and social networks in determining preferred prices.

These findings also suggest that the Saudi government may need to implement financial measures aimed at bridging the gap between the actual cost of solar panels and the desired price point, thereby encouraging wider adoption of renewable energy among the populace. Alternatively, greater emphasis on educational initiatives could be beneficial in raising awareness about the financial and environmental advantages associated with solar energy usage.

Our analysis is a modest first step in providing a theoretical framework for analyzing the rooftop solar panel market that has been customized to the Saudi Arabian experience while also providing policymakers with some insights into the common themes and geographic differences in the price preferences that may exist for rooftop solar panels. Conducting similar studies that delve more deeply by using different variables that are not included in this paper or choosing

different study areas may help to deepen our understanding of price preferences for rooftop solar panels.

CHAPTER VI: CONCLUSION

The significance of renewable energy is increasingly recognized as a crucial component of sustainable development goals in the modern era, particularly in the context of global efforts to reduce fossil fuel consumption. In Saudi Arabia, the potential of solar energy is highlighted by the nation's new development objectives that stress the rapid adoption of solar energy networks as a way to transition out of a conventional fossil-fuel trajectory even though only 2% of the population currently actively utilize solar energy. This dissertation explored the key determinants that might help shape consumer behavior and attitudes regarding solar energy across various geographical contexts within Saudi Arabia, with the goal of better understanding and enhancing the rate of solar energy adoption.

Regarding consumer attitudes toward residential rooftop solar panels in Saudi Arabia, the general findings indicated that 57.1% of the total participants expressed a strong willingness to adopt rooftop solar panels, while 33.1% reported a moderate willingness. Additionally, the survey revealed that 30.4% of participants exhibited a strong willingness to pay for rooftop solar panels, while 47.1% showed a moderate willingness to pay. Moreover, 62.4% of respondents preferred to pay less than 5,000 SAR ($1,332) for solar panels, a price lower than the market rate. However, the geographical disparities among the study areas concerning the willingness to adopt, pay, and the preferred price differences were minimal. For example, the strong willingness to adopt was slightly higher in Al-Qassim (i.e., 61.1%) compared to Riyadh (i.e., 55.6%) and Buraydah (i.e., 56.5%), which is the same pattern for both the willingness to pay and the preferred price.

The first article of this dissertation provided a detailed analysis of Saudi residents' willingness to adopt rooftop solar panels, revealing a strong willingness across all three study

areas. In the survey results, 55.6% of participants in Riyadh, 56.5% in Buraydah, and 61.1% in Al-Qassim strongly expressed their willingness to adopt rooftop solar panels in their homes. Furthermore, the findings suggested that the willingness to adopt correlates well with various factors such as prior environmental beliefs, government incentives, prior expectations regarding the cost and benefits of solar panels, and the built environment. Geographic disparities were evident in the factors influencing willingness to adopt. For instance, environmental beliefs, such as the acknowledgment that climate change was real, was a more significant factor for Riyadh residents compared to those in Buraydah and Al-Qassim. Moreover, financial incentives were strongly associated with the willingness to adopt in Buraydah and Al-Qassim, more so than in Riyadh. Contrary to numerous previous studies, socio-economic factors and social networks did not appear to be associated with the willingness to adopt, possibly due to a widespread consensus regarding the benefits of rooftop solar panels for the country, and/or the nascent stage of the solar energy market in Saudi Arabia compared to Western markets, rendering demographic differences less marked at this early stage.

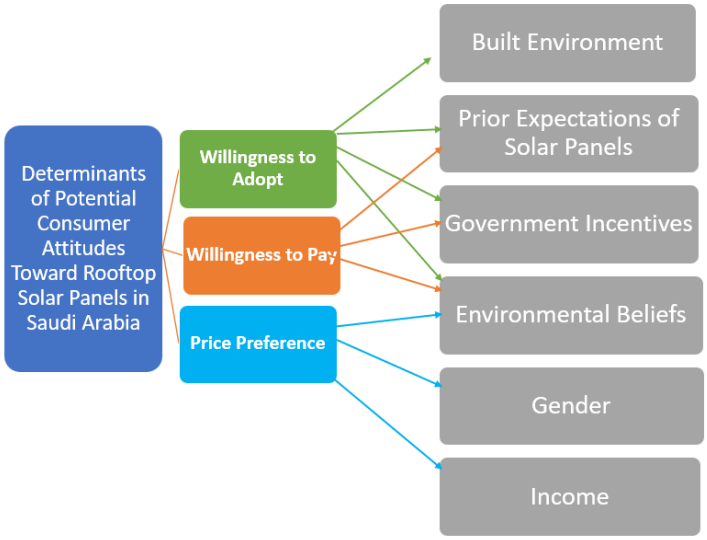
The second paper's exploration of the willingness to pay for rooftop solar panels revealed a general inclination towards solar energy investment across the study areas. Specifically, 29.6% of participants in Riyadh, 34.1% in Buraydah, and 27.8% in Al-Qassim strongly expressed their willingness to pay for rooftop solar panels. In contrast, 49.2% in Riyadh, 41.9% in Buraydah, and 48.4% in Al-Qassim exhibited a moderate willingness to pay. The willingness to pay was found to be significantly associated with household energy budget considerations, expectations about solar panel costs, government incentives, and environmental beliefs where geographical differences appeared between the study areas based on these determinants. For example, one of the most notable geographical differences was that respondents with the strongest willingness to

pay in Riyadh preferred tax cuts compared to respondents from Buraydah and Al-Qassim, where respondents with the strongest willingness to pay showed a preference for government subsidies. Also, the willingness to pay was significantly associated with the belief that climate change is real in just Riyadh and Buraydah. These results diverge from prior literature, indicating that traditional factors like socio-economic status, the built environment, and social networks have little effect on the willingness to pay in Saudi Arabia. Some of this may be linked to the fact that the solar energy market is an emerging market in Saudi Arabia, which may render significant demographic differences mute, and the fact that only 2% of the population uses solar energy, which likely means the role of social networks is limited.

The third paper focused on exploring the preferred price to pay for rooftop solar panels by potential consumers. The results showed that the majority of the participants preferred to pay less than 5,000 SAR ($1,332) for a solar panel installation valued at 12,000 SAR ($3,199). The results of the analysis also showed that the preferred price outcomes are significantly linked to individual socio-economic indicators (i.e., income, gender, education), government incentives (i.e., tax deductions, government subsidies), and environmental beliefs (i.e., climate change is real, pollution mitigation). Several geographical differences emerged between the three study areas concerning the links between preferred price and other related factors. For example, education appeared to have a statistically significant and strong association only in Al-Qassim. By contrast, financial incentives in Riyadh and Al-Qassim, like the tax deduction appeared to be significantly linked to various preferred price outcomes, while in Buraydah, government subsidies appeared the key factor. In contrast to the previous literature, the results of the analysis did not show any association between preferred price and factors such as age, housing characteristics, or social networks.

This dissertation provides a theoretical framework regarding consumer attitudes toward residential rooftop solar panels in Saudi Arabia that is more nuanced relative to the existing literature as summarized in Figure 11. Unlike the previous literature, which often heavily emphasized the impact of socio-economic status and social networks on the willingness to adopt/pay for rooftop solar panels, this research found these determinants to be relatively mute in Saudi Arabia. Instead, prior environmental beliefs linked to climate change, various government incentives like tax deductions and subsidies, and prior expectations regarding the estimated costs and benefits of solar panels featured more prominently in shaping consumer behavior linked to rooftop solar panels in Saudi Arabia.

Figure 11. Consumer Behavior Linked to Residential Rooftop Solar Panels in Saudi Arabia: A Broad Theoretical Framework and the Key Determinants



This dissertation underscores the need for a more nuanced, and sophisticated approach when prioritizing national policies linked to accelerating the adoption rate for residential rooftop solar panels in Saudi Arabia. The prior literature and theoretical frameworks can provide some guidance, but it is important for policymakers to acknowledge the unique nature of the Saudi

Arabian experience. Moving forward, Saudi policymakers need to fully acknowledge these differences if they wish to succeed.

While this dissertation is a modest first step towards embracing these differences, it is crucially important that future solar energy policies are carefully tailored to the local socio-economic conditions of the various regions of Saudi Arabia. Such strategies are essential if we are to achieve the objectives set out in the "Vision 2030" plan for Saudi Arabia. The findings offered in this dissertation could potentially help policymakers to better formulate strategies that might increase solar energy adoption rates in Saudi Arabia, especially by emphasizing the need to bridge the gap between consumer price preferences and actual market rates. Further research is recommended to explore consumer attitudes towards solar energy more deeply, using diverse methodologies and exploring new areas to help more fully understand the drivers of renewable energy adoption in Saudi Arabia.

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APPENDIX A: RESIDENTIAL ROOFTOP SOLAR PANELS IN SAUDI ARABIA: A SURVEY OF THE WILLINGNESS TO PAY

Q1: Do you want to participate in the survey?

- Yes
- No

Q2: Do you currently have rooftop solar panels on your house?

- No
- Yes

Q3: If no, would you be willing to consider using solar energy or other forms of renewable energy for your house?

- No
- Yes

Q4: If yes, would you be willing to pay for residential solar panels to be placed on your rooftop?

- No
- Yes

Q5: Are you familiar with websites like "Shamsi" or other similar websites that help you to calculate the cost of solar panels and their effectiveness?

- Yes
- No

Q6: Do you know someone who uses rooftop solar panels?

- No
- Yes

Q7: Is there someone who uses rooftop solar panels in your immediate area?

- No
- Yes

Q8 Why you are not using solar energy in your home?

- Useless in providing the minimum electricity for the house
- High cost

- Difficulty in installation and extension
- The house is not suitable for installing solar panels
- Other

Q9: I would be willing to use rooftop solar panels in my home in the future

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

Q10: I would be willing to pay for rooftop solar panels in my home in the future

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

This section of the survey is designed to find out how much do agree or disagree with the following statements on seven-point Likert scale

Q11: Climate change is real

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

Q12: Renewable energy is effective in protecting the environment from pollution

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

Q13: I will use solar panels if they are tax deductible

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

Q14: I will use solar panels if the government subsidized the financial cost

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

Q15: Buying and installing solar panels will likely be expensive

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

Q16: The so-called “ecological crisis” like the environmental disturbances such as droughts and floods facing humankind has been greatly exaggerated

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

Q17: How much would you pay for a solar energy system that would likely reduce your monthly electricity bill by up to 150 riyals per month ($40), knowing that the average life of the renewable solar energy system is 20 years? The reduction value and the cost of the solar energy system were projected by using the Shamsi website by calculating the average cost of a system capable of reducing the monthly electricity bill in Riyadh City and Buraydah City.

- Less than 5,000 S.R
- 5,000 - 8,000 S.R
- 8,000 - 12,000 S.R
- 12,000 - 15,000 S.R
- 16,000 - 19,000 S.R
- 20,000 - 23,000 S.R

Q18: You would expect rooftop solar panels to provide 20% of the total energy needed for a home

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

Q19: You would expect rooftop solar panels to provide 50% of the total energy needed for a home

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

Q20: You would expect rooftop solar panels to provide 100% of the total energy needed for a home

- Strongly agree
- Agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Disagree
- Strongly disagree

This section of the survey is designed to collect data about the socio-demographics characteristics and location:

Q21: What is your gender?

- Male
- Female

Q22: What is your highest level of education?

- Lower than high school
- High school
- Bachelor's degree
- Masters or PhD

Q23: What is your marital status?

- Married
- Divorced
- Widowed
- Never married

Q24: What is your age?

- Less than 18 years
- 18 to 20 years
- 20 - 29 years
- 30 - 39 years
- 40 - 49 years
- 50 - 59 years
- 60 years and more

Q25: What is your monthly income?

- No income
- Less than 5000 S.R
- From 5000 to 7999 S.R
- From 8000 to 11999 S.R
- From 12,000 to 14,999 S.R
- From 15,000 to 18,999 S.R
- From 19,000 to 25,999 S.R
- 26,000 S.R or more

Q26: How many people permanently live in your house?

- 1
- 2
- 3
- 4 - 6
- 7 - 9
- 10 or more

Q27: Do you own or rent the house you live in?

- Own
- Rent
- Other

Q28: What is the type of house you live in?

- Villa
- Apartment
- Other
- Duplex
- Farm

Q29: What is the floorspace of your house?

- Less than 149 m2
- 300 - 399 m2
- More than 800 m2
- 150 - 199 m2
- 400 - 599 m2
- 200 - 299 m2
- 600 - 800 m2

Q30: When was your house built?

- Less than 5 years
- 5 - 9 years
- 10 - 15 years old
- More than 15 years

This section of the survey is designed to collect data about the location of the respondent

Q31: In which administrative region do you live?

- Riyadh
- Al-Qaseem
- Northern Borders
- Makkah Al-Mokarramah
- Eastern Region
- Jazan
- Aseer
- Najran
- Al-Madinah Al-Monawarah
- Tabouk
- Al-Baha
- Hail
- Al-Jouf

Q32: Where in Riyadh Region do you live in?

- Riyadh
- Diriyah
- Al-Kharj

- Dawadmi
- Al-Majma'ah
- Al-Quway'iyah
- Wadi ad-Dawasir
- Al-Aflaj
- Al-Zulfi
- Shaqra
- Hotat Bani Tamim
- Afif
- As-Sulayyil
- Dhurma
- Al-Muzahmiyya
- Rimah
- Thadig
- Huraymila
- Al-Hareeq
- Al-Ghat

Q33: Where do you live in Al-Qassim?

- Buraydah
- Unayzah
- Arrass
- Almidhnab
- Albukayriyah
- Albadai
- Alasyah
- Annabhaniyah
- Uyun Aljiwa
- Riyadh Alkhabra
- Ashshimasiyah

Note: The survey was approved by the University of North Carolina at Greensboro Institutional Review Board in November 2022 (IRB-FY22-717