

Alsabbagh, Maha

Article

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Energy Reports

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Suggested Citation: Alsabbagh, Maha (2019) : Public perception toward residential solar panels in Bahrain, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 5, pp. 253-261, <https://doi.org/10.1016/j.egy.2019.02.002>

This Version is available at:

<https://hdl.handle.net/10419/243580>

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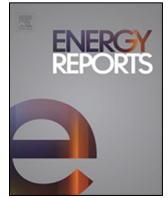
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Research paper

Public perception toward residential solar panels in Bahrain

Maha Alsabbagh

Environmental Management Program, Arabian Gulf University, P.O. Box 26671, Bahrain



ARTICLE INFO

Article history:

Received 31 October 2018
 Received in revised form 27 January 2019
 Accepted 7 February 2019
 Available online 25 February 2019

Keywords:

Climate change
 Public acceptance
 Solar panels
 Survey
 Willingness to pay

ABSTRACT

In 2017, Bahrain's Cabinet endorsed the country's first national renewable energy action plan. The plan included the installation of residential solar photovoltaic cells as a means of using renewable energy in government-built housing units. This was followed by the establishment of the country's first photovoltaic solar panel manufacturing company and the introduction of a net metering policy. However, public acceptance of residential solar panels has not been researched. This study aimed to address this gap through the distribution of an online survey. A total of 764 complete responses were received. The results showed a considerable number of respondents were interested in installing solar panels. However, the respondents recognized several challenges in both buying and installing them, including capital cost, lack of information, and maintenance requirements. This study's findings offer insights on how the public perceives solar panels, along with issues the government needs to address to ensure successful public participation in the use of solar energy in the residential sector in Bahrain.

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1. Introduction

Electricity is considered a daily necessity. More than 25,000 TWh were generated worldwide in 2016, compared with 15,500 TWh in 2000 (IEA, 2018). Owing to its importance, access to energy is emphasized in Sustainable Development Goal (SDG) 7, focusing on three main pillars: access to electricity, penetration of renewable energies (REs), and energy efficiency (EE). Access to electricity receives considerable attention, as it is also appears, before the SDGs, in the Human Development Index. Access in rural areas is relatively high, reaching 70% of the population, in many countries. However, this is not the case for countries with low levels of human development, where the access rate is less than 30% (UNDP, 2018).

The majority of the world's electricity, more than 60% in 2016, is generated from fossil fuels (IEA, 2018a). However, there is a widely observable trend toward use of REs. Global power generated from solar energy amounted to around 442.6 TWh in 2017, growing exponentially from only 7.9 TWh in 2007 (BP, 2018). Globally, solar photovoltaic (PV) energy grew faster than any other energy source in 2016, representing strong potential for REs (IEA, 2017). Solar PV generated 1.3% of all electricity, reaching more than 320,000 GWh in 2016, compared with only 990 GWh in 2000 (Fig. 1) (IEA, 2018a). Additional capacity in solar power accounted for 100 GW in 2017, giving the sum of all REs a 35% share of global power generation in 2017, with around one-third of the capacity installed in China (BP, 2018).

The majority of the installation of solar power capacity is seen in Europe and China, whereas countries with the highest potential

for solar energy still lag (WEC, 2016). One of the main drivers toward increasing adoption of RE technologies is achieving energy security, especially after the oil crisis in the 1970s, and along with sustainability drivers as seen in the European Union and United States (Alsabbagh and Al-Jayyousi, 2019). However, RE implementation in some countries, such as China, is driven by air pollution, while others are driven by the need to electrify remote areas, such as in developing Asian and Sub-Saharan African countries (IEA, 2017; Abdullah et al., 2017).

According to the World Economic Forum, solar energy capacity equivalent to around 70,000 solar panels will be added every hour by 2022, with China expected to contribute around 40% (WEF, 2018). Total solar PV installed capacity worldwide is expected to reach 740 GW in 2022. Addressing challenges such as integration into the electricity grid and the growing amount of subsidies can contribute to even more growth in the solar PV installed capacity sector (IEA, 2017).

Installed PV capacity varies worldwide. The average annual growth rate of solar PV in Organization for Economic Co-operation and Development countries was 38.4% during 2000–2017 (IEA, 2018b). However, solar PV capacity was just 0.1 GW in the Middle East in 2013 and is projected at 94 and 268 GW in 2030 and 2050, respectively, under a high-RE scenario, accounting for 18% of the annual power generation mix in 2050 (IEA, 2014).

Investments in RE technologies in general and solar energy technologies in particular, can be observed in the Gulf Cooperation Council (GCC) countries. The GCC countries have a high potential for RE with a relatively high wind speeds (5–7.5 m/s) in many parts and solar potential of an equivalent of 2000 kWh/m² annually in most areas (IRENA, 2016; Akhonbay, 2019). Most of the GCC

E-mail address: mahamw@agu.edu.bh.

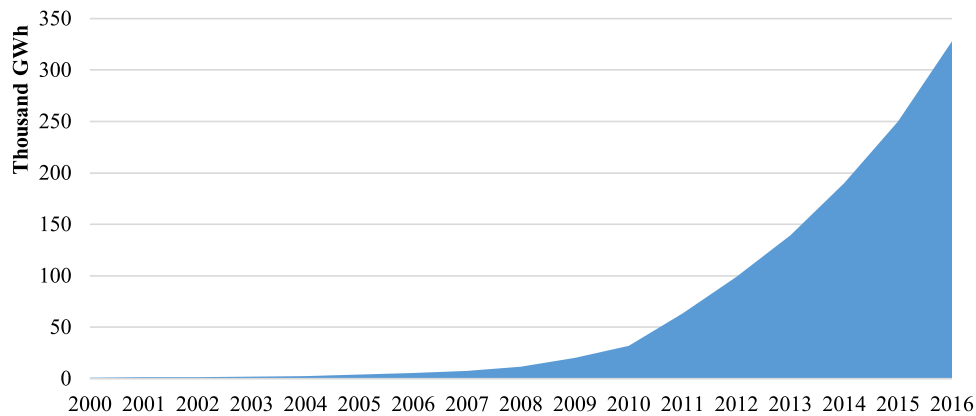


Fig. 1. Global solar photovoltaic electricity generation, 2000–2016 (GWh) (IEA, 2018a).

countries have set targets for the share of RE in the energy mix. The achievement of these targets can achieve 2.5 billion BBOE cumulative fuel savings and a cumulative total of around 1 gigatonne of CO₂ emissions by 2030 (IRENA, 2016).

New investments in solar energy amounted to 161 USD billion worldwide in 2015, 800 USD million of which are in the GCC countries (WEC, 2016; IRENA, 2016). New investments contribute to employment and creating new jobs. In 2017, around 3.4 million people worldwide were employed in the solar energy sector (IRENA, 2018).

RE technologies are improving together with an apparent decline in costs (WEC, 2016). Solar PV systems, however, have a relatively higher cost (IEA, 2014). This necessitates supporting policies so that electricity generated from solar PV systems is an attractive option and can compete with that generated from fossil fuels. One way to achieve this is through embedding the environmental externalities in the electricity tariff to reflect climate change, air pollution, and other environmental impacts (IEA, 2014). Another way is to provide incentives for the different groups that adopt RE technologies. These include imposing feed-in tariffs, feed-in-premiums, auctions, and long-term power-purchase agreements associated with investment tax credits for utilities. For distributed PV systems mostly seen in residential and commercial buildings, two main pricing policies are widely observed: feed-in tariffs in Asia and Europe, and net metering in the United States, which is also associated with investment tax credits (IEA, 2014). The feed-in tariffs for distributed grid-connected PV have proven effective in Germany, and without excessive remuneration (IEA, 2014). However, net metering, as applied in the US and Australia, appears easy in terms of comprehension and administration. Net metering is a good starting option but needs to be carefully reconsidered when the number of customers with installed PV systems increases (IEA, 2014).

The US adopts financial support policies. An example is the third-party financing option for the residential and commercial sectors, which contributed to wide adoption of solar PV. These financing costs are around US\$780/kW for the residential sector and financed around 75% of residential solar PV systems in the US in 2012, bolstering solar PV penetration in the residential sector. Another policy adopted in the US is providing loans for homeowners, through banks and other lenders. However, there are some constraints that require raising stakeholder awareness of potential risks and benefits (IEA, 2014).

Use of solar energy does have certain environmental risks that need to be addressed. Such risks associated with solar panels' life cycle must be addressed by setting clear regulations. One related environmental impact is land use, as utilization of solar energy requires a considerable area of land to be allocated mainly for the purpose of generating electricity from RE technologies. The

expanse of land reaches 36,000 m² per 1 MW of solar capacity installed in the United States, and almost no other activity may be carried out during the roughly 30 to 60-year lifetime of the solar energy infrastructure. Another environmental aspect concerns water use in thermal solar energy power plants. More than 3500 liters/MWh are used for cooling in solar thermal power plants. However, less water is required for use of solar panels – at around 118 liters/MWh – and these are used mainly in the manufacturing and maintenance sectors. Some hazardous materials are also associated with solar technologies, but these depend mainly on the type of technology being used. There is also the issue of greenhouse gases (GHGs) associated with the manufacturing and installation of solar energy technologies. GHG emissions range around 15–50 gCO₂e/kWh depending on the type of solar technology (WEC, 2016).

Other barriers need to be responded to in addition to the financial barriers to solar technologies being addressed through provision of incentives and the potential environmental risks in adoption of the technologies. Addressing them is highly recommended to ensure successful penetration of such technologies in general and solar PV in particular. These barriers include insufficient knowledge about the technology, trust issues, lack of trained and technically skilled labor, and absence of governing bodies and legislation (Abdullah et al., 2017; IEA, 2014). Public acceptance is another key challenge to be addressed.

Public acceptance and willingness to participate are equally, if not more, important than technological advances for saving natural resources and reducing GHG emissions. Public acceptance of RE technologies, and willingness to pay for them, is crucial for ensuring successful adoption. Yet, there is a knowledge gap related to the social aspect of the residential solar PV (Sommerfeld et al., 2017). Majority of the literature on the public opinion comes from the developed countries¹ where focus is usually paid to ex-post assessment of installing residential solar PV. Fig. 2 shows a comparison between selected recent publications on public perspectives in developed and developing countries. Review of studies conducted in developed countries demonstrates the dominance of qualitative research methods along with the use of relatively small samples (e.g., Sommerfeld et al., 2017; Karjalainen and Ahvenniemi, 2019; Palm, 2017). On the other hand, many of the studies conducted in developing countries applied quantitative research methods using relatively large samples (e.g., Abdullah et al., 2017; Bashiri and Alizadeh, 2018; Baharoon et al., 2016). Interestingly, studies conducted in both developed and developing countries adopt a mixture of both methods (e.g., Strazzera and Statzu, 2017). Another

¹ The use of *developing countries* term was eliminated by the World Bank in 2016. However, it is still being used by the UN for statistical convenience.

notable difference is the scope of the studies. It is apparent from the figure that studies in developed countries mainly explore the consumers experience as in Australia (Sommerfeld et al., 2017), Finland (Karjalainen and Ahvenniemi, 2019), and Japan (Mukai et al., 2011). On the other hand, literature in developing countries explores how the public perceive the residential solar PV prior to installation, as in Pakistan (Abdullah et al., 2017) and China (Yuan et al., 2011).

Studies suggest public acceptance is associated with how people perceive RE technologies (Wojuola and Alant, 2017). Knowledge about them influences how members of society position themselves with regard to them, and frame their perspectives. Findings from semi-structured interviews with selected adopters of residential solar PV in Australia support this argument (Sommerfeld et al., 2017). The respondents indicated that they had adequate information prior to installing the PV systems. Acquisition of knowledge on RE technologies, in general, contributes to changing the attitudes of the public, their behaviors, acceptance, and willingness to adopt solar PV, which is potentially more difficult than achieving technological changes (Köhler et al., 2009). Yet, literature on how the public perceive RE technologies in general and residential solar PV in particular in the GCC countries, is lacking.

This study aims to explore the perspectives of Bahrain's public toward the use of residential solar PV. Specifically, it seeks to identify the level of the public's knowledge, its willingness to pay for solar PV, barriers to use of residential solar PV, and preferred channels for communicating information on this topic. The remainder of this paper is as follows. The next section overviews the status of energy and energy policies in Bahrain. The following section highlights the methodology used in this study. Results and discussion are then presented, followed by the conclusion and recommendations.

2. Present energy situation in Bahrain and relevant policies

Bahrain is a group of more than 30 islands located in the south-western part of Asia in the Arabian Gulf. It is one of six countries that form the Gulf Cooperation Council (GCC), whose countries share many similar socio-economic, geographic, and political characteristics. Bahrain's total area is around 780 km², and its population is more than 1.5 million, resulting in one of the world's highest population densities, at more than 1900 people/km². The population has been growing at an annual rate of 4%, with expatriates comprising around 55% of the total (IGA, 2016).

The per-capita gross domestic product (GDP) puts Bahrain among the highest-income countries in the world (T.W., 2018). Crude oil and natural gas are the country's main fossil fuels. The lifetime of their existing reserves is estimated to be nearing its end (Alsabbagh et al., 2017); however, new explorations have revealed a new reserve of 80 billion barrels of tight oil and 10–20 trillion cubic feet of deep natural gas that is expected to begin production in 5 years (Barbuscia, 2018). Energy consumption in Bahrain has grown dramatically over the period 2000–2016; over 6300 kTOE was consumed in 2016 compared with 3000 kTOE in 2000 (IEA, 2018a). Electricity constitutes 37% of the total final energy consumption, with almost complete reliance on natural gas as a fuel for generating electricity. The demand for electricity (from the grid) has grown by 12% per year on average – from 5500 GWh in 2000 to 16,200 in 2016 – with the residential sector being the main consumer, accounting for over 47% of the total consumption (IGA, 2016). Official projections suggest that electricity demand can reach 28,180 GWh in 2030, which would require 909 million cu. ft.³ of natural gas (SEU, 2017).

The electricity price has been highly subsidized for the residential sector, in which consumption of less than 3000 Kwh per household per month was charged only 0.003 Bahraini dinars (BHD; 0.008 USD). Gradual reform of the cost started in 2016, so that

customers will be charged the actual cost of generating electricity (0.029 BHD or 0.77 USD) in 2019. An exemption is given for one residence per Bahraini, for which a subsidized rate is applied.

Bahrain has the opportunity to use different REs, including solar energy. Solar radiation in Bahrain is estimated at 6 kWh/m²/day (Alnaser et al., 2014). The country's global horizontal irradiance is 2160 kWh/m²/year, while direct normal radiation is 2050 kWh/m²/year (IRENA, 2014). Average daily sunshine exceeded 10 h in 2016, further underscoring the potential for solar energy (IGA, 2016).

Several studies have explored the technical aspects of establishing large-scale solar power projects in Bahrain (e.g., Pillai and Naser, 2018), meteorological parameters that impact adoption of RE technologies there (e.g., Shams et al., 2016), and the cost-effectiveness of EE programs aimed at achieving zero-emissions design of houses in the country (e.g., Krarti and Dubey, 2018).

Several solar energy projects, ranging from pilot to large-scale, already exist. Some of the main ones include the 2015 establishment of a zero-emission house that uses both solar and wind energy, and a 5 MW solar and power plant expected to be commissioned for operation this year (Alnaser and Alnaser, 2011). Notably, after Bahrain's establishment of the Sustainable Energy Unit (SEU) in 2014, a radical transition toward launching solar energy projects can clearly be observed. The SEU was established in collaboration between the national government and the United Nations Development Program (UNDP). Several drivers can be identified for the SEU, including complete reliance on fossil fuels, along with the consequent economic and environmental impacts. These accompany the need to use REs to meet several national, regional, and international commitments.

The SEU's establishment led to the National Renewable Energy Action Plan (NREAP) and the National Energy Efficiency Action Plan (NEEAP), in which EE and RE targets were set for the first time for Bahrain, along with corresponding policies and timelines. The SEU has also brought all energy-concerned stakeholders together; they had previously been scattered across various authorities. A 5% target for RE penetration in the total energy mix was set to be achieved by 2025, with a 10% target by 2035.

Adoption of RE technologies contributes to achieving several national and international commitments. The first is the country's RE target. Use of RE also implies decreased use of fossil fuels, which will lead to reduced carbon dioxide equivalent (CO₂e) emissions and thereby contribute to the achievement of climate change mitigation strategies identified in the Nationally Determined Contributions (NDCs) submitted in accordance with Paris 2015. Additionally, reducing fossil fuel use means using less water, because water is used in exploration and other processes associated with these fuels. This helps meet water reduction targets set out in the National Water Strategy for Bahrain.

To achieve the RE target, the NREAP included creating a capacity of 100–150 MW from decentralized urban solar power generation. Several studies have assessed the potential for residential solar PV adoption in Bahrain. One study (Alnaser, 2015) estimated that the amount of electricity generated from residential solar PV in a house met around 12% of the house's total demand. Another study (Alnaser, 2018) found in an ex-post assessment that the actual electricity generated in a building using a smart solar PV system was 26%–37% less than what was estimated. Given the low electricity tariff and relatively high cost of PV, this results in a long payback period (Alnaser, 2018). Interestingly, the amount of electricity generated among the same months in 2015 and 2016 was 23% higher in the latter year. This suggests potential variations in generation over different time periods.

In light of such findings and relevant pilot projects, the SEU identified five opportunities for achieving the RE target, focusing mainly on projects financed by the government and the private sector. These opportunities included installation of a “decentralized rooftop solar on existing residential and commercial

	[15]	[14]	[16]		[21]	[22]	[17]	[7]	[18]
Study	Study the experiences of adopting the system and how to overcome the barriers.	Explore the experiences of the adopters.	Explore the peer effects in adopting solar PV.		Explore willingness and acceptance of the public towards the PV.	Understand how the public perceive solar PV and the level of their acceptability.	Identify the factors influencing the adoption of the systems.	Understand how the public perceive solar PV and identify barriers to adoption.	Identify the public views of renewable energy with particular focus on solar energy.
Objective									
Method	Semi-structured interviews	Semi-structured interviews	Questionnaire Telephone-interview		Interviews Focus groups Questionnaire	Interviews Workshops Telephone-surveys	Questionnaire	Questionnaire	Interviews using structured questionnaires
Sample size	28	22	65 (questionnaires) 16 (interviews)		600 (questionnaires)	4,579	345	350	606
Main results	<ul style="list-style-type: none"> - Adopters relied on trustworthy information and advice from experts and other adopters to overcome barriers. - They were satisfied with the systems but not about the economic profitability. - Adopters think about expanding the use of clean energy. 	<ul style="list-style-type: none"> - Adopters were mainly driven by the increase in electricity prices. - Having adequate information prior to adoption is necessary. - No major environmental motivator was agreed upon - Behavioral change was observed after adopting the system. 	<ul style="list-style-type: none"> - The peer effects were significant in decision making. - The communicated information was mainly about whether the technology worked or not. - Nearly all adopters said that they already knew their peers prior to contacting them with regard to adopting the system. 		<ul style="list-style-type: none"> - Older and retired people are less interested. - Main barriers were the long payback period and limited space in the house. - Demonstration projects are important. - Tailoring effective communication programs is critical. 	<ul style="list-style-type: none"> - Capital cost is the main barrier. - The government supporting policies are still chaos. - There is a need for a new business model to face the barriers. 	<ul style="list-style-type: none"> - The financial supports are attractive for low-income families. - The environmental concerns affect the adoption of solar PV especially in polluted areas. 	<ul style="list-style-type: none"> - Many participants showed interest in solar PV. - Initial cost was the major barrier. - Participants believed that the government should take the lead in adopting solar PV. - They suggested that providing subsidies will encourage the use of the solar PV. 	<ul style="list-style-type: none"> - Participants showed interest to use solar energy and pay for it. - The study recommended providing subsidies, raising awareness, and providing solar energy products.
	Developed countries				Developing countries				

Fig. 2. A comparison between selected studies on public opinion conducted in developed and developing countries (Abdullah et al., 2017; Sommerfeld et al., 2017; Karjalainen and Ahvenniemi, 2019; Palm, 2017; Bashiri and Alizadeh, 2018; Baharoon et al., 2016; Strazzera and Statzu, 2017; Padmanathan et al., 2019).

buildings" (SEU, 2017). The government plans to achieve this through installation of solar PV on government-built houses². A pilot project for installing solar PV on 10 such houses commenced in 2018. The SEU has also released several policies to incentivize adoption of RE technologies. For decentralized rooftop solar, the Cabinet proposed and approved net metering in 2017, targeting residential, commercial, and industrial electricity customers. A scholar-proposed policy involved a feed-in tariff (FIT) for the residential sector. The related study (Alnaser, 2018) suggested a FIT set at US\$1 per 1 kWh, with a reasonably acceptable payback period of 5 years³. Another study (Haji et al., 2017) suggested adopting a FIT policy along with a government subsidy of 30% of the capital cost of the residential PV system. Although net metering is spread widely, it was found to be ineffective for Bahrain because the tariff for residential electricity consumption is relatively low. Net metering is more successful when the tariff is high and per-capita electricity consumption is relatively high (Alnaser, 2018; Haji et al., 2017; RCREEE, 2016).

Adoption of small-scale PV in Bahrain encompasses a number of strengths and weaknesses (SEU, 2017). A strong point is that it can be installed on different surfaces and where electricity generated is consumed on-site. It also helps raise public awareness about REs. Additionally, the cost-effective technology and lower requirements for space offer strong potential. However, there are problems with low electricity generation because it can only be operated during the day. Another problem is related to dust and high humidity that reduce the efficiency of solar PV in the GCC countries (Mas'ud et al., 2018). Interestingly, the overall impact of the weather conditions is around 7.2% only as calculated by researchers in Bahrain (Alnaser et al., 2018). Two comparisons were conducted over a sixteen-month period at the University of Bahrain. The first was between the electricity generation of

cleaned and uncleaned solar PV, and the second was between the electricity generation of uncleaned solar PV and the potential electricity generation prepared by the developer. There was no significant differences found in both cases.

The SEU identified the above-mentioned points and more can be added. The strengths can be extended to include public awareness about the environment and climate change in general, which contributes to changing attitudes and behavior. PV adoption can also contribute to technological innovations through design of applications and technologies in the context of Bahrain. As for the weaknesses, the capital cost of installing residential PV systems is relatively high, which may deter interested customers. The payback period is also long for Bahrainis, which makes it economically infeasible. Additionally, the net metering policy does not appear suitable for Bahrain and may need to be revised. Moreover, public perspectives are not known, which may be a further obstacle for successful penetration of PV, even if there is free installation in government-built housing, as issues may arise concerning maintenance and upkeep.

3. Methods

To date, there have been no studies on public perception of solar PV in Bahrain or in any other GCC country. In fact, compared with technical studies, there are only a few peer-reviewed studies on the social aspects of solar PV. Accordingly, the present research used a cross-sectional design to shed light on public perspectives on this topic in Bahrain. A similar approach is used in other studies (Muro and Jeffrey, 2012; Rauschmayer and Wittmer, 2006; Munda, 2004). Primary data were mainly collected from participants, using both quantitative and qualitative survey questions.

A convenience sample was used to achieve the study's objective. An online questionnaire was prepared using Google Forms, wherein a link with a brief description of the questionnaire was circulated via the WhatsApp messaging application to a network of people and their respective networks. No personal interaction was conducted with participants. This was done with the intent of

² The government builds public housing and sells it to low-income Bahraini households via easy financing schemes.

³ Taking into consideration that a smart energy module was installed at a cost of 43,000 USD.

exploring the study population's actual level of knowledge about residential solar PV.

The questionnaire was prepared with reference to those used in related studies (e.g., Abdullah et al., 2017; Wojuola and Alant, 2017; Chen et al., 2015; Ntanos et al., 2018). It consisted of seven main questions covering: knowledge about solar energy in Bahrain, willingness to pay for residential PV, barriers to installation, preferred sources of information on solar energy, personal information, and general comments. Learning from experiences in conducting social surveys in Bahrain, close-ended questions were mainly used, with the last question being open-ended and allowing free expression of opinions and concerns.

The only restrictions for survey participants were that they had to be Bahraini and over 18 years old. No restriction was made regarding being the owner of a housing unit, as different members of the household (if owned and not rented) were assumed capable of having PV installed if they wanted to do so. Additionally, there were no restrictions on participants' sex, age, or area. The target group was Bahrainis because they are permanent residents in the country, own houses, and are eligible for government-built housing. The questionnaire was prepared in Arabic, the target group's native language, to ensure full understanding of the questions. A pilot study was conducted using paper-based and online questionnaires, from which participants' feedback was used to modify the questions to improve their ease of understanding and readability. The survey was conducted in June and July 2018. A total of 825 electronic forms were received, with 61 excluded because they were filled out by non-Bahrainis or were incomplete. The total sample was therefore 764. Although the sample is not statistically representative of the entire population, it offers insight on how the public perceives residential PV in Bahrain; this sort of interpretation is common in cross-sectional studies, especially if conducted for the first time.

Responses from the online survey using Google Forms were stored in an Excel spreadsheet and then transferred to SPSS Statistics for Windows Version 23.0 (IBM Corp., Armonk, NY, USA) mainly for descriptive statistical analysis.

4. Results and discussion

The results of the questionnaire are discussed below.

4.1. Participants' demographics

A total of 63% of the survey participants were women and 37% were men, with more than 60% residing in the Muharraq and Southern Governorates (Table 1). Around 78% were 31–60 years old, while 71% were either working in the public sector or retired (Table 1). Around 40% of participants had a bachelor's degree as their highest level of educational attainment. Around the same percentage also had a monthly income of 501–1000 BHD (1330–2654 USD) (Table 1) which is close to the average per-capita monthly income for Bahrainis (725–911 BHD (Alayam, 2018b)). More than 80% owned a house or shared one with another family, while the remaining either rented a house, or owned or rented an apartment (Table 1).

4.2. Knowledge about solar energy in Bahrain

The majority of participants were found to have little or no knowledge about the solar energy in Bahrain (53.6%) (Table 2). Participants explicitly expressed this when they were asked to describe their knowledge about the topic. Their knowledge was also examined using a different approach wherein they were asked to agree or disagree with, or state they did know about, four statements concerning whether: it is possible to install residential

Table 1
Respondents' socio-economic characteristics ($n = 764$).

Characteristics	Frequency	Percentage (%)
Sex		
Male	282	36.9
Female	482	63.1
Area		
Capital	103	13.5
Muharraq	280	36.6
Northern	169	22.1
Southern	212	27.7
Age		
<21 years	17	2.2
21–30 years	96	12.6
31–40 years	198	25.9
41–50 years	175	22.9
51–60 years	224	29.3
≥61 years	54	7.1
Job		
Public sector	349	45.7
Private sector	108	14.1
Own business	26	3.4
Retired	194	25.4
Unemployed	14	1.8
Housewife	56	7.3
Other	17	2.2
Highest level of educational attainment		
High school or below	137	17.9
Associate diploma	92	12.0
Bachelor's degree	301	39.4
Postgraduate diploma	77	10.1
Master's degree	123	16.1
Doctorate	34	4.5
Monthly income		
≤500 BHD	114	14.9
501–1000 BHD	313	41.0
1001–1500 BHD	179	23.4
1501–2000 BHD	61	8.0
2001–2500 BHD	44	5.8
≥2501 BHD	53	6.9
Housing type		
Owned house	534	69.9
Rented house	32	4.2
Rented apartment	60	7.9
Shared house	92	12.0
Owned apartment	43	5.6
Other	3	0.4

Table 2
Respondents' knowledge about solar energy ($n = 764$).

Knowledge about solar energy	Frequency	Percentage
Broad	88	11.5
Moderate	267	34.9
Low	285	37.7
None	124	16.2
Total	764	100

PV in Bahrain, there is a PV solar panel manufacturing company operating in the country, PV has already been installed in selected houses in Bahrain, and electricity generation from residential PV reduces the electricity bill. More than 80% answered the first and last correctly, though only around 40% answered the second and third correctly. This result indicates the participants had overall general knowledge about solar energy, but were less knowledgeable about the status of use of solar PV in Bahrain (Fig. 3).

4.3. Willingness to pay

Only around 33% of participants expressed willingness to pay for installing residential PV which costs 3500 BHD⁴ (9300 USD)

⁴ This cost is for installing 24 solar panels that produce 12,500 kWh per year as estimated by the Electricity and Water Authority in Bahrain

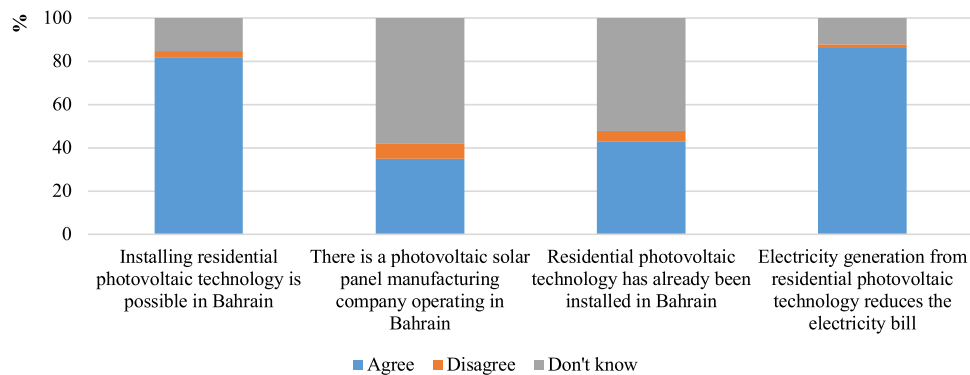


Fig. 3. Respondents' knowledge about statements on solar photovoltaic energy in Bahrain.

(Alayam, 2018a), with 74% willing to pay only 50% of the capital cost (Fig. 4). However, 48.2% expressed interest in installing PV in their house if the government fully subsidized it. This indicates acceptance of solar PV in Bahrain, as a majority of the participants supported it when not factoring in who pays the capital cost. However, to encourage those who expressed some willingness to pay for installing solar PV, and considering the monthly income of around 50% of the participants matches the average per-capita monthly income for Bahrainis (725–911 BHD (Alayam, 2018b)), the findings from this question may be generalized and an exemption from the recently implemented value-added tax should be considered. Surprisingly, 49 participants indicated they were unwilling to install PV even if it was fully subsidized. Additionally, around 13% of respondents were not sure about their willingness to pay.

Results from Pearson's χ^2 test reveal a significant association between the willingness to pay and the income (p -value = 0.017), gender (p -value = 0.018), and education (p -value = 0.000) of the respondents. Cross tabulation results show that majority of participants who were willing to pay the full cost of residential solar PV systems were Bachelor degree holders receiving the average per-capita monthly income for Bahrainis. Statistically significant variations can clearly be observed in the participants' willingness to pay for installing residential PV due to their knowledge about solar energy in general, and its application in Bahrain in particular (p -value = 0.000) (Table 3). Participants willing to pay the full cost of installing the system had the highest level of knowledge about solar energy (Table 4). Conversely, participants with the lowest level of knowledge showed no interest in installing the residential solar PV even if it is fully subsidized (Table 4). This emphasizes the importance of knowledge in shaping the public perception and decision related to installing residential solar PV.

Nevertheless, around half of the respondents were interested in installing the residential solar PV systems if it is fully subsidized. This implies that further deployment of RE is possible with subsidized costs for residential solar PV. This would contribute to achieving the 5% RE target, and reducing fossil fuel consumption and consequent GHG emissions, which would eventually help improve air quality and public health.

4.4. Barriers to PV installation

One objective of this study was to identify the public's perceived barriers to adopting residential PV. The results show various barriers toward use of solar energy in the residential sector, including technical, financial, and informational. Respondents were asked to choose from six possible barriers that would affect them, including the option to enter their own.

The barrier most commonly chosen was the relatively high capital cost, at 37% of all replies (Fig. 5). This seems realistic, as the payback period is not attractive (payback period is around 10 years). This is considering that a net metering policy is implemented, by which the purchasing rate of the generated electricity equals the selling rate.

The next most chosen was a lack of necessary information on PV, followed by maintenance-related issues, at 27% and 21%, respectively. Lack of trust in PV and the relatively low electricity tariff followed. A small number of participants identified other barriers, including lack of roof space and potential health-related risks associated with PV.

The results identified no one specific item was perceived as the barrier. This is likely because installation of solar panels is relatively new in Bahrain and the participants evidently were not clear on the specifics involved. Interestingly, none mentioned there were no barriers to installation of solar PV, which implies the need for effective dissemination of information, as explained later.

The barriers identified by the respondents are in line with those identified in literature, especially the capital cost of the solar PV system and the return of investment (Sommerfeld et al., 2017; Karjalainen and Ahvenniemi, 2019; Wojuola and Alant, 2017; Shahsavari and Akbari, 2018). The financial return of the residential solar PV system plays an important role as a motivator and influences the satisfaction rate of consumers (Abdullah et al., 2017; Mukai et al., 2011). Other barriers such as trust in the solar PV system and provider, lack of information, and low electricity tariff were also evident in literature (Abdullah et al., 2017; Wojuola and Alant, 2017; Shahsavari and Akbari, 2018)

4.5. Dissemination of solar PV information

Respondents chose lack of information on residential solar PV as the second most common barrier, at 26.7%. To assist policymakers in using effective channels to communicate information that will support the public's decision-making on whether to install PVs, a six-option question was asked on preferred channels.

The greatest preference was for social media, at 33% (Fig. 6). The remaining participants most commonly chose television, newspapers, advertisements in public places, leaflets, and other means, in that order. A small percentage (2%; 36 participants) mentioned more personalized ways, such as emails, phone calls, and home visits.

This finding is extremely useful for policymakers not only in advising on how to communicate information on solar energy, but also on how to approach the public, as the survey comprised citizens' responses. Interestingly, no dominant communication channel was chosen, implying that both traditional and new media forms are preferred, with around one-quarter preferring printed

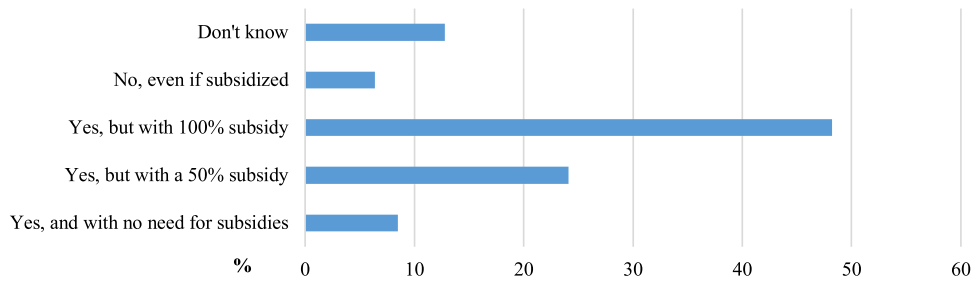


Fig. 4. Respondents' willingness to install and pay for residential solar photovoltaic technology.

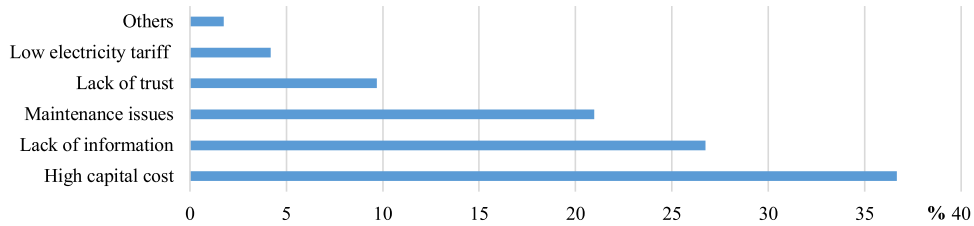


Fig. 5. Barriers to installation of residential solar panels, as perceived by respondents.

Table 3

Significance of Kruskal–Wallis test of participants' willingness to install and pay for residential solar PV according to their knowledge about solar energy.

Item	Significance
Knowledge about solar energy	.000
Installing residential photovoltaic technology is possible in Bahrain	.000
There is a photovoltaic solar panel manufacturing company operating in Bahrain	.349
Residential photovoltaic technology has already been installed in Bahrain	.004
Electricity generation from residential photovoltaic technology reduces the electricity bill	.000

Table 4

Descriptive statistics for knowledge of participants based on their willingness to install and pay for residential solar PV.

Respondents' willingness to install and pay for residential solar photovoltaic technology		Knowledge about solar energy	Installing residential photovoltaic technology is possible in Bahrain	There is a photovoltaic solar panel manufacturing company operating in Bahrain	Residential photovoltaic technology has already been installed in Bahrain	Electricity generation from residential photovoltaic technology reduces the electricity bill
No, even if subsidized	n	65	65	65	65	65
	M	2.17	1.03	2.23	1.95	1.18
	SD	.821	.248	.932	.991	.583
Do not know	n	184	184	184	184	184
	M	2.34	1.14	2.12	1.98	1.10
	SD	.841	.499	.951	.967	.420
Yes, but with 100% subsidy	n	368	368	368	368	368
	M	2.62	1.32	2.26	2.08	1.20
	SD	.877	.716	.939	.982	.586
Yes, but with a 50% subsidy	n	49	49	49	49	49
	M	2.82	1.76	2.20	2.18	1.78
	SD	.993	.902	.912	.928	.941
Yes, and with no need for subsidies	n	98	98	98	98	98
	M	3.04	1.73	2.33	2.42	1.60
	SD	.798	.948	.917	.884	.905

materials. This can be helpful for communicating other information to the public, especially as some suggested email, which is a possible option (an email address is required to use the country's e-government services). This medium also enables easy communication of details or web links to the public, on any topic.

Dissemination of information on residential solar PV received a considerable attention in literature. However, the preferred channels to communicate information differ among various countries.

For instance, television came as the primary source for information in Turkey (Ediger et al., 2018) whereas social media is ranked highest by respondents in this study. Thus, tailoring of the information based on the target group is recommended (Strazera and Statzu, 2017). This is to ensure that potential adopters fully understand how the system operates along with maintenance issues prior to installation (Mukai et al., 2011).

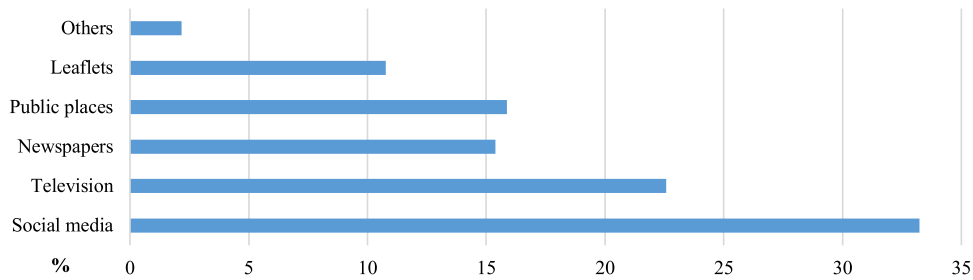


Fig. 6. Respondents' preferred communication channels.

4.6. Issues raised and emphasized by participants

All the survey questions were closed-ended, except for the last, which let respondents express concerns or comments related to residential solar PV; 134 participants did so. The comments can be separated into four main groups. The first emphasized the need for governmental financial support, especially with the capital cost. This corresponds with the most commonly chosen barrier in Fig. 4. The second group emphasized the importance of disseminating information through mass media and focusing on solar and PV in education. In fact, several participants even requested further details and provided their email addresses in a gesture that indicated strong interest. The third group raised issues related to maintenance, safety, and the relatively small area of houses in general and rooftops in particular. It is worthy to note that the relatively small area available for residential PV in is not usually identified as a barrier by the public in similar studies. This also corresponds with an aforementioned barrier and implies a need to address the topic and provide information to the public. The last group of comments asked for fully funded demonstration projects distributed in different areas of the country with results on their effectiveness communicated to the public after 1 year of implementation. The provision of demonstration projects is also identified in literature where the participants from six Mediterranean cities emphasized the need for such projects (Strazzera and Statzu, 2017). All of the comments implied expectations for the government to play the principal role in the entire process, starting from finance and ending in appraisal and dissemination of results. There was no mention of the role of the private sector or how universities and research centers could contribute. In fact, this role also was missing from the NREAP. This is in line with results from an earlier survey concerning mitigation of GHG emissions from the transport sector in Bahrain, in which the general public identified this as a shared responsibility but expected the government to take the initiative and play the main role (Alsabbagh et al., 2017).

It is worthy to note that there was no mention of the potential contribution of solar PV to environmental quality, energy saving, and emission reductions. This raises the issue of the public awareness of environmental issues especially that more than 50% of the respondents indicated that they have no or little information about solar energy in Bahrain. Nonetheless, the same situation was also observed in Australia where the environmental motivations were the least discussed among the sample of adopters of residential solar PV interviewed in 2015 (Sommerfeld et al., 2017).

5. Conclusion and recommendation

There is a clear global trend toward penetration of RE technologies. In the past, this was mainly driven by energy security, but now climate change is the main driver. Per-capita CO₂e emissions in Bahrain are considerably high because of the country's high reliance on fossil fuels. This has led to consideration of RE especially as Bahrain is rich in solar energy potential. An action plan was

approved aimed at fostering the spread of RE in Bahrain, and this includes installation of solar PV in government-built housing. However, there have been no surveys examining public acceptance, which is where this study makes a contribution. The study aimed to explore how the public perceives residential solar PV, its knowledge about solar energy in Bahrain, willingness to pay, barriers to installation, and preferred channels for information communication. The results showed that more than half of the participants had a low level of knowledge about the topic in the context of Bahrain, but greater knowledge about general facts. Interest was seen in residential solar PV, as over 30% of respondents expressed willingness to pay either fully or partially for installation. However, many saw the relatively high capital cost as a barrier. Absence of relevant information was also a commonly chosen barrier, implying the government's efforts were not effectively communicated to the public, as knowledge about solar PV in Bahrain was minimal compared with general knowledge about the topic. The respondents' preference for a number of communication channels for information dissemination that were different from those suggested in the NREAP underscores this.

Several policy implications may be drawn in light of the results of this study:

- Addressing the barriers the respondents' chose is critical not just for deploying RE technologies in Bahrain but also to enhance EE and respond to environmental issues in general.
- Considering establishment of energy service companies (ESCOs) – wherein the private sector takes a role in financing small RE projects – is crucial, especially considering the respondents recognized the high capital cost as a barrier.
- The important issue of a rebound effect needs to be considered when providing financial subsidies to the public. In this scenario, financing the full cost of solar PV (as in demonstration projects and as requested by the public) may result in consuming more electricity, which offsets the amount saved. Studies cite similar cases in which, when more energy-efficient devices are used, the number of devices and hours of use increase, resulting in no increase in energy saved (Barrett and Scott, 2012; Wang et al., 2012; Solaymani et al., 2015).
- Improving communication with the general public using channels the participants preferred is crucial. This is because information dissemination is among the SEU responsibilities, though its intended means differ from those preferred by the participants.
- Collaboration should be strengthened with other GCC countries, with best practices shared along with communicating to the public information on solar PV's effectiveness, cost, and maintenance.

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