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The potential to exploit use of building-integrated photovoltaics in countries of the Gulf Cooperation Council

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ABSTRACT

The use of renewable forms of energy is important throughout the world, not just in countries where there are concerns over the availability of fossil fuels. In order to develop and promote suitable energy policies for the future it is necessary to gain an understanding of stakeholder views in all countries, including those with substantial fossil fuel reserves. The volume of construction work in the Gulf Cooperation Council (GCC) countries has recently been at unprecedented levels, with a huge environmental impact from construction and also from potential future energy demands. The aim of this paper is to assess the potential to exploit use of a particular, but valuable, renewable energy option: building-integrated photovoltaics (BIPV) in those countries. Such exploitation could offset, at least in some part, the future environmental burdens. A large-scale survey, followed by a number of in-depth interviews, has been undertaken in order to examine the use of BIPV. Empirical research findings are presented, and then analysed in order to determine the current viability of a large-scale expansion of BIPV in the GCC region. The research indicates that the main factors hindering expansion are high costs and the negative public perception of BIPV in the countries concerned. Proposals are therefore provided to assist the development of suitable policies and the wider introduction of viable BIPV in the GCC markets.

1. Introduction

The Gulf Cooperation Council (GCC) comprises the Kingdom of Saudi Arabia, the Kingdom of Bahrain, and the states of Kuwait, the United Arab Emirates, Oman and Qatar. These countries have substantial revenues generated by crude oil sales, and are similar in terms of socio-economic, commercial and infrastructural development [1]. It can be observed that over the last 30 years, the GCC region has experienced an unparalleled construction boom; more particularly in the last 10 years. This has led to a swift expansion in the size of cities as well as in a growth in energy consumption per capita that currently exceeds most parts of the world [2,3]. In terms of carbon dioxide emissions per capita, the GCC countries are ranked amongst the highest in the world. Specifically, Qatar, Kuwait and the United Arab Emirates are the top three countries in terms of carbon dioxide emissions per capita [4]. Therefore, it can be argued that ways of reducing the environmental footprint and enhancing the sustainability status of buildings in this part of the world should be sought with some urgency.

At the same time, the use of renewable energy technologies has increased throughout many areas of the world with the aim of expanding more sustainable sources of energy. Given the fact that the GCC region receives some of the most intense sunlight in the world, solar energy appears to be an attractive sustainable option. Building-integrated photovoltaics (BIPV) is a particular type of solar energy that has recently received substantial attention in the global construction industry because it offers the possibility of providing clean power sources for buildings in aesthetically and architecturally interesting ways.

The aim of this paper is to examine the potential use of BIPV in the buildings of the GCC countries through surveying a number of relevant stakeholders in the region. Firstly, however, the current status of BIPV and the need to consider this technology in GCC countries are highlighted. The paper then outlines the design of the primary research that was carried out to assess the likelihood of the widespread use of BIPV. Next, empirical research findings, obtained from surveys and interviews, are analysed and discussed. Finally, the paper proposes a 'diffusion strategy' that, if put into practice, could enhance the viability and image of BIPV technology in the GCC region.

2. An overview of BIPV

Solar photovoltaic (PV) cells have the merit of being able to convert solar radiation directly into electricity, with no

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intermediate stage of heat conversion. Essentially, when sunlight strikes a suitably prepared semiconductor material (normally silicon-based), electrons are released and an electric current is then produced [5]. A detailed historical account of the application of PV is available elsewhere [6]; however, an important trend since the mid-1990s has been the introduction and expansion of building-integrated devices. One of the first major installations of BIPV occurred in 1991 in the then 20-year-old administration building of the Stadtwerke Aachen in Germany. The south-facing glass façade of this building was replaced by a solar façade during the renovation of the heating services [7,8]. In recent years the number of building-integrated systems has expanded rapidly; nowadays, PV modules for building integration are produced and marketed as a standard product, with the potential to fit quite straightforwardly into standard façades and roof structures in various ways. Fig. 1 illustrates the main options for which PV modules can be integrated into buildings.

A review of recent PV press releases reveals that many companies are currently working on developing a range of innovative, extra-thin, and flexible PVs. For instance, whilst many thin-film companies manufacture their products on glass that requires a structure to hold the glass in place, some companies have developed thin-film PV cells with a plastic backing. The use of plastics is expected to enhance the lightweight, flexible features as well as the low production costs of PV [9].

It is interesting to note that PV is experiencing very strong market growth compared with some other renewable energy technologies [10,11], and in many different parts of the world [12]. It has been argued that one major reason for this is that when one uses BIPV, the cost of PV is partially offset by the cost of the building materials which would have been required anyway. Thus, the incremental cost of BIPV can be reduced [13]. The ability to modify the appearance of buildings through use of photovoltaics in architecturally stimulating ways can also help encourage development. It is of relevance here to acknowledge that the initial costs of PV have been declining significantly in recent years, largely due to economies of scale and technological advancements [14]. The current cost of crystalline silicon-based PV material itself is estimated as being around \$600–\$1200/m^2 [15] but some products using other forms of cell are cheaper. Also worth noting is the fact that many BIPV systems have become easier to use with either energy storage in forms of battery or by linking systems into a conventional electricity grid to export excess power and import if required. In some locations a "net metering" system operates [16] but in addition, more attractive "feed-in tariffs" have been introduced in some countries. This approach was pioneered in Germany where utility companies were required to pay a price for PV electricity that exceeded the price of grid electricity [17]. The introduction of such financial incentives helped boost the economic viability of BIPV, which in turn, enhanced the market diffusion of the technology [18,19]. It should be noted, however, that predicting future PV in terms of diffusion and market growth is difficult and depends on many factors such as continued improvement in performance and in cost reduction of PV systems. The cost of fossil fuels and the increasing environmental costs of relying on conventional power sources [6] are also important concerns.

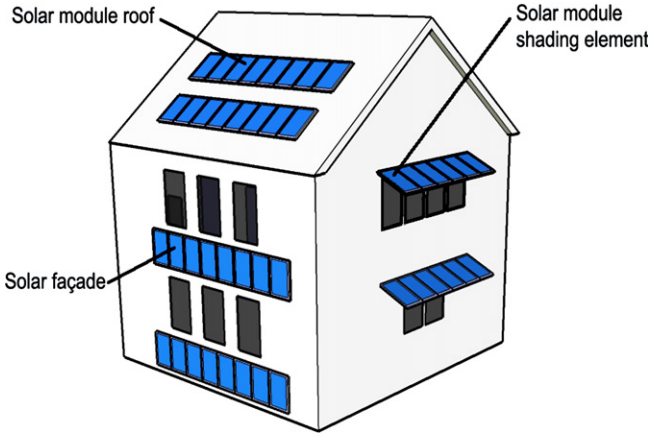

Fig. 1. Typical ways of integrating PV into a building.

Some commentators have characterised the PV industry as depending on a policy-driven market whose key driver is regional economic development [20]; others indicate various sustaining factors that will support further growth in the global PV market (such as grass roots opinion in Germany, long-term strategy in Japan, and higher oil prices) [21]. In essence, the market for BIPV, as for other renewable energies, is developing as part of the broader effort to fulfil the promise of sustainable buildings and hence sustainable development. Such endeavours around the world are motivated largely by concerns over the environmental degradation that is being caused by the depletion of natural resources, the damage to the earth's natural ecosystems, air pollution and climate change [22,23].

3. The need to consider BIPV in GCC countries

It appears that the energy consumption of buildings in the GCC region is amongst the highest in the world. For instance, a study in the United Arab Emirates concluded that energy use per area in domestic buildings is high when compared with typical examples in Europe [24]. Looking into the case of Bahrain, a recent study maintained that the vast majority of Bahraini buildings currently lack sustainability measures [25]. Other studies (e.g. [26,27]) have called for the formulation of strategic policies on both the use of renewable energies and the rational use of energy in order to ensure the sustainability of future buildings and architecture. However, it should be noted that the concept of sustainable architecture entails a diverse range of sustainable features (e.g. passive solar design, construction and materials, waste management, etc.) besides the mere use of renewable energies.

In spite of the current limited application of renewable energies in buildings, it appears that there are some promising projects emerging in the GCC countries. For instance, a \$211 m Green City Project is to be built at the Euro University in Bahrain that aims to use PV to power 10–20% of the campus [28]. In addition, plans were recently announced to construct a skyscraper in Dubai (the Burj al-Taqa) that aims to be the world's first skyscraper to generate 100% of its energy needs from the extensive use of PV and wind turbines [29]. Given the fact the GCC countries currently lag behind the global movement towards alternative energy options, it is of interest to assess the potential to increase the use of BIPV. As part of such an endeavour, it is also of relevance to examine levels of awareness among potential stakeholders with regard to current energy and environmental issues. With this in mind, the next section discusses the methodology that was adopted in order to achieve this aim.

4. Research design

This research takes the form of an extended case study and survey of opinion (case studies have been cited as a suitable research method when the researcher has no control over events and is not able to manipulate the relevant behaviour [30,31]). The use of online questionnaires was also chosen as the most suitable data collection method as it provided a cost- and time-effective approach to acquire information from a large and geographically separated population of respondents (i.e. stakeholders). The survey was designed with the general aim of assessing the level of stakeholders' awareness with

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regard to current energy and environmental issues, and identifying attitudes towards adopting BIPV in the GCC countries. However, since surveys typically suffer from an inherent lack of flexibility, and bearing in mind that input was required from various stakeholders with different levels of knowledge of the subject, it was decided to formulate different survey questions for different groups of research participants. Eventually, 10 different questions were devised for each group (see Appendix A). Four target groups (homeowners, academics, building developers and architects) were chosen as the most relevant stakeholder groups. A fifth group (policy and decision makers) was also initially considered but later omitted due to difficulties in accessing such high-profile individuals.

Bearing in mind the scope of this research, the survey sample was selected to represent as evenly as possible the predetermined target groups and the six GCC countries. The survey was distributed via e-mail to a total of 1293 stakeholders in the six GCC countries in July 2007. At the end of the 1-month survey period, 244 responses had been obtained, reflecting an overall response rate of approximately 19%; this level of response to an online survey is generally considered to be very good [32]. Of the four target groups, academics were most likely to complete their surveys. Nine participants of the 244 respondents (eight academics and one architect) were contacted to participate further in this research through follow-up in-depth telephone interviews.

5. Empirical findings

This section is devoted to analysing and discussing the responses collected from each of the four survey groups, as well as feedback from the follow-up interviews. First, the split of the participants, according to their countries of residency, is analysed; and secondly a short discussion of the responses gathered from each group is presented.

5.1. Homeowners

Fifty-three responses were collected from homeowners in the GCC region. The percentage split of their countries of residence is as shown in Fig. 2.

The survey was distributed to homeowners, arguably very important stakeholders as they represent one group of BIPV technology end-users. Moreover, homeowners can be thought of being a part, though not necessarily a representative one, of the general public. Perhaps among the most striking findings of this survey is that more than half of the GCC homeowners surveyed had not previously heard of the phenomenon of global warming. Nor were the vast majority of them concerned about recent energy and environmental issues, despite their acknowledgement of "high" electricity consumption in their homes. Here, it is interesting to note that several respondents either did not know how would they categorise their level of electricity consumption, or did not really care because electricity was provided cheaply and, in some cases, free of charge. Whilst 41.5% of the respondents failed to name a single type of renewable energy technology, approximately 40% had heard of one or two types. Therefore, when asked about their tendency to either support or oppose the widespread use of renewables, around 32% refused to state an opinion due to their admitted ignorance of the subject, whilst a total of 47% showed a preference to oppose the use of renewables. It appeared, however, that solar power was thought to be more attractive for use in buildings than any other renewable energy option, and many homeowners had few legitimate concerns regarding the fitting of PV in their homes. However, 34% refused to give a preferred renewable energy technology due to their ignorance. Finally, in response to questions about drivers and barriers to the use of BIPV in their countries, outcomes were poor. It seemed that the homeowner respondents' lack of knowledge on the subject affected their views on the potential for the widespread diffusion of PV technology in buildings in the GCC region. Overall, however, the issue of competitive prices seemed to be the key issue for this technology to be more widely accepted among this group of stakeholders.

5.2. Academics

One hundred and two responses were collected from academics in the GCC region. The percentage split regarding their countries of residence is as shown in Fig. 3.

As one might expect, survey participants holding academic posts in the GCC region were more informed about and concerned with regard to energy and environmental aspects than were the homeowners surveyed. For example, approximately 61% of the surveyed academics considered themselves "knowledgeable" and about 16% considered themselves "expert" regarding the subject of global warming. Whilst 41% indicated a readiness to address energy and environmental concerns, only 18% were in strong favour of supporting the widespread use of renewables in the GCC region. Most participants selected "tend to support" as opposed to "strongly support" in response to a question regarding this issue. In-depth discussions in subsequent follow-up interviews indicated that there is a pervading belief in the GCC region that a lot can be done to help the environment apart from the use of renewables. For example, some interviewees stressed the need for promoting effective measures with regard to energy efficiency and conversion.

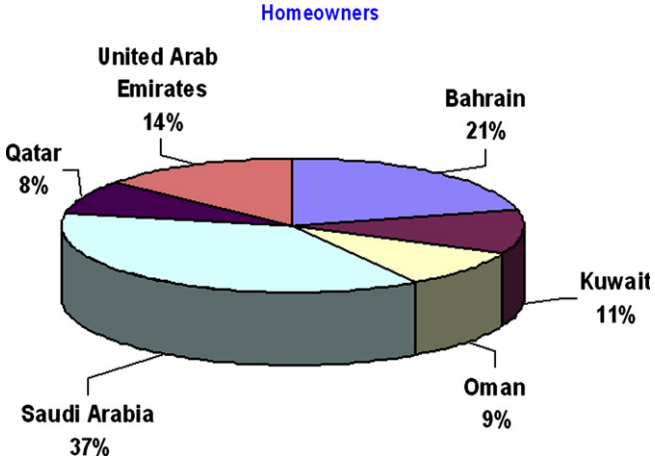

Fig. 2. Countries of residence of the homeowners among the survey participants.

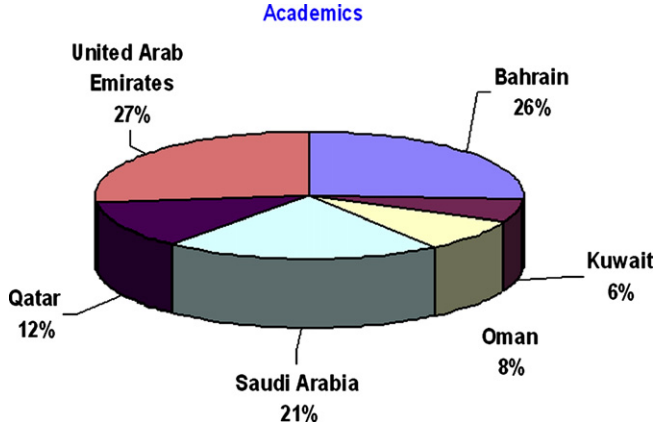

Fig. 3. Countries of residence of the academics among the survey participants.

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In other words, renewables should be seen as only one option among other things that could be done to address energy and environmental concerns. When asked about her attitude towards solar power, one of the academics replied "Like anything in the world, photovoltaics are not perfect; but they can surely contribute towards achieving sustainable development."

When considering the issue of the potential use of BIPV, most of the survey participants in this group suggested that high cost is the main barrier to the effective diffusion of PV. Surprisingly, however, none of the eight follow-up academic interviewees seemed to agree with this view. In fact, they seem, as a group, to believe that the cost of PV has been significantly reduced around the world over a short timeframe, mainly because of economies of scale. As a group, they tended to argue that neither cost nor inadequate technical performance qualifies as the genuine and predominant barrier to diffusion. Instead, six of the interviewees suggested that the lack of public awareness/acceptance is the main barrier, whilst the remaining two saw inadequate political support as the major challenge that PV technology could face in the GCC region. For example, interviewees suggested that governments should start to reduce the heavy subsidisation of the current price of electricity generated using non-renewable energy resources. In addition, they noted that introducing feed-in tariffs could incentivise dwellers to consider fitting BIPV. Nevertheless, whilst admitting that the subjects of sustainability and renewable energy are not adequately covered in their universities/colleges, most of the academics envisaged that a higher media profile and practical demonstrations could enhance public awareness more effectively than could training courses or conferences/seminars.

The last survey question allowed some room for speculation, by giving the seemingly rather knowledgeable participants a chance to have an educated guess on when BIPV would be regarded as being sufficiently viable for applications in GCC buildings. Four respondents presented a rather pessimistic view, suggesting this will never occur. On the other hand, three respondents regarded BIPV technology as being viable at present. However, the majority of the survey respondents (i.e. around 82.3%) anticipated that BIPV will be viable either in between 10 and 20 years (48% of the total respondents), or in more than 20 years (34.3% of the total respondents). Of course, as some interviewees pointed out, such speculations do not mean that renewable energy options could not be integrated into today's buildings. The existing building projects, despite being low in number, affirm that almost all barriers could be overcome if there was a sufficient support regarding the need for sustainable energy. There is evidence that in some GCC countries, especially the United Arab Emirates, governments have shown interest in exploring sustainable energy options. For instance, plans were recently announced by the state-owned Abu Dhabi Future Energy Company (known as Masdar) to develop a $22 billion green urban district in the United Arab Emirates [33].

5.3. Building developers

Forty-three responses were collected from building and property developers in the GCC region. The percentage split of their countries of residence is as shown in Fig. 4.

Disappointingly, the survey indicated that this group of stakeholders seemed unconcerned about the environment, and most actually opposed the widespread use of renewables in their countries. Unlike the previous two stakeholder groups, just 18.6% of the building developers' group displayed concern regarding the way energy is used in relation to global warming, and only 21% displayed some enthusiasm with regard to the use of renewables. Many of these participants' comments, especially from building developers in Kuwait and Qatar, suggested that the sooner solar power was available at affordable prices, the sooner BIPV would become commercially viable. Generally speaking, however, feedback regarding the level of knowledge of these respondents with regard to PV technology revealed a lack of up-to-date knowledge. For example, most of the survey participants seemed not to be aware that PV can now be used for on-grid, as well as off-grid, applications; a total of around 60% of survey participants believed that PV can still only be used for off-grid applications. Out of those 60%, 21% considered PV attractive – if at all – only for off-grid residential applications.

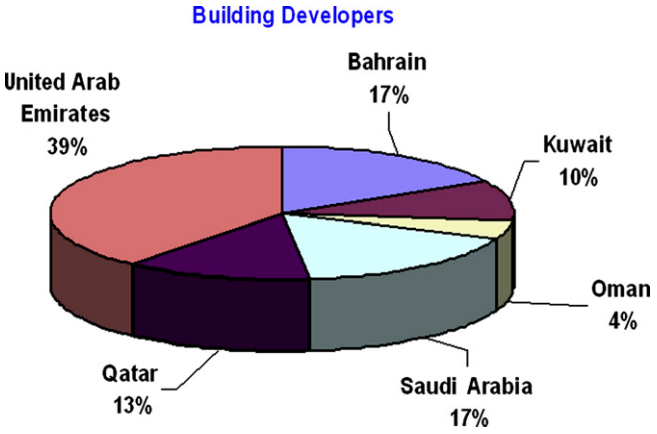

Fig. 4. Countries of residence of the building developers among the survey participants.

5.4. Architects

Forty-six responses were collected from architects in the GCC region. The percentage split of their countries of residence is as shown in Fig. 5. Currently, the United Arab Emirates, and Dubai City in particular, has the highest level of construction activity in the GCC region both in terms of scale and innovation. This may indicate why proportionately more architects from this country responded to the survey than for the rest of the GCC countries.

Compared with the previous stakeholders' groups, the architects surveyed showed an immense interest in renewables and expressed concern over energy and environmental issues. Like the other stakeholders' groups, the architects suggested that, given the apparently plentiful natural resources, solar power is the most suitable form of renewable energy for use in building applications within the GCC region. The architects surveyed also scored highly in their apparent level of knowledge of the current efficiency of PV panels, and more sophisticated questions could be attempted with

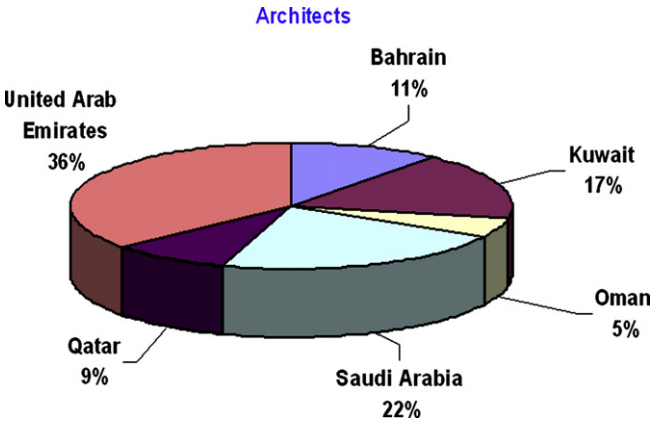

Fig. 5. Countries of residence of the architects among the survey participants.

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this stakeholder group in the future. The architects surveyed were better informed than the building developers with regard to the possibility of the use of PV in on-grid applications (the most commonly selected response was that PV is attractive for use in all buildings applications – that is, both residential and commercial buildings, and both on-grid and off-grid). Surprisingly, when asked whether they thought that using BIPV could adversely affect the quality of their designs, the architects' most popular answer was "never thought of it." Finally, when asked about their personal feelings about being involved in building projects incorporating the use of BIPV technology, 43.5% of the architects surveyed – compared with just 2.3% of the building developers surveyed – indicated enthusiasm.

A quite lengthy and interesting follow-up interview was conducted to a highly reputable architect in Oman, in order to discuss the challenges facing the potential use of BIPV in the GCC region. He affirmed that the main forces driving the global use of BIPV are energy concerns, even though some would argue that environmental issues also have an influence. The magnitude and significance of such complicated issues essentially varies around the world. When attempting to investigate the potential acceptance of alternative energy options in a region where the governments have opposing vested interests and where the public has little concern for the environment, one is likely to discover a minimal interest in BIPV. Ways to change this rather unhealthy situation include, as the Omani architect argued extensively, various government-led financial incentives and large-scale public awareness campaigns.

6. Force field analysis

Force field analysis is an analytical tool taken from the management field. It is usually used in order to conceptualise the forces interacting to support and oppose change in a given situation. Kurt Lewin is often acknowledged as the first to propose this technique in 1951 [34]. Given the rich empirical data gathered from the questionnaires and the follow-up interviews, force field analysis was chosen with the principal aim for data analysis of "bringing order, structure and meaning to the mass of collected data" [35, p. 111]. Force field analysis is also attractive due to its simple and flexible nature that allows for subjectivity in focusing on problems by quantifying the balance of various factors that are causing or aggravating them.

The results of the primary research have enabled the determination of the relative weightings by which factors affecting the potential use of BIPV in the GCC region can be ranked in order of significance and strength. Simply put, a score was allocated to each of the factors considered using a numerical scale from 1 = weak to 5 = strong. These factors were also categorised as being either facilitating or restraining forces with regard to the widespread use (or diffusion) of BIPV in the GCC region. Since influencing factors are numerous, some of these were grouped under generalised categories. For example, issues concerning constancy of supply as well as conversion efficiencies were considered under the category "technical performance." Fig. 6 illustrates the results of this analysis. The length of each arrow represents the relative strength of the force in question (i.e. the longer the arrow, the stronger the force). It should also be noted that these forces are binary, in the sense that governmental support, for instance, is a facilitating force when it is evident, but a restraining force when it is lacking.

The above force field analysis suggests that the restraining forces are currently much stronger than the facilitating forces, such that a successful diffusion of BIPV is not currently viable. In addition, this analysis shows that the current high costs associated with BIPV and its poor public acceptance are amongst the most significant forces limiting the diffusion of BIPV in the GCC region. In order to enhance the viability of BIPV, changes to the status quo may need

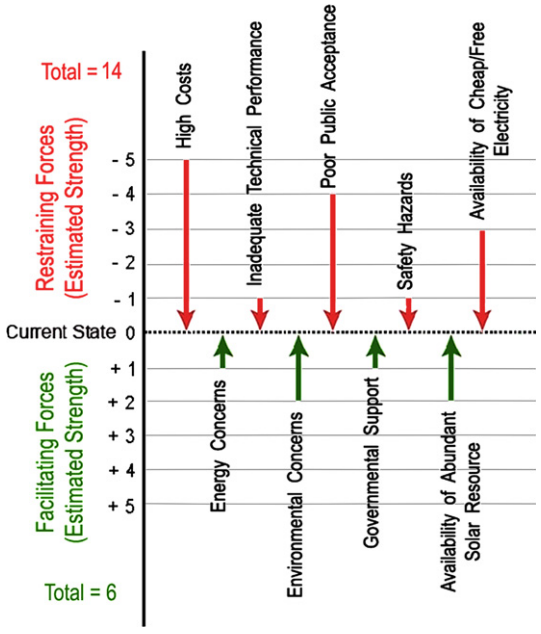

Fig. 6. Simplified force field analysis for the potential use of BIPV in the GCC.

to be made. Such changes would have the aim of strengthening one or more of the facilitating forces, and/or reducing one or more of the restraining forces. Alternatively new facilitating forces could be added, possibly by transforming what was formerly a restraining force. It must also be noted that most of the forces identified in this analysis are in fact inter-related. For instance, if public awareness with regard to the potential environmental benefits of PV were to be enhanced, then not only would the restraining force of "poor public acceptance" be reduced, but also the facilitating force of appreciating "environmental concerns" could be increased.

Having established a broad appreciation of the current issues influencing the use of BIPV in the GCC countries, the next section puts forward a strategy to enhance the possibility of widespread diffusion by addressing the main restraining forces.

7. Strategies for enhancing BIPV diffusion in the market

As previously stated, the most significant hindrances acting against successful diffusion of BIPV in the GCC countries appear to be PV's high cost and inadequate public acceptance/understanding. The vast majority of the responses from the survey participants' suggested that the current high cost is the biggest barrier to adopting PV in buildings in the GCC countries. One way of enhancing appreciation and understanding is for more public and prominent use of BIPV; an opportunity exists (as has been exploited in other locations) for use in more niche building applications such as skyscrapers. This occurs because BIPV can be seen to have a value from its aesthetic and architectural impact which offsets the system costs, or as has been mentioned earlier, from replacement of other cladding materials. In this way it may be possible to use BIPV in less price-sensitive ways compared to conventional residential applications.

To support both niche and more general applications of BIPV, governmental support in the form of incentives (such as introducing feed-in tariffs) will probably be crucial. Many surveyed participants believed that if their governments were to introduce such incentives, the price of BIPV and eventually that of the electricity generated from PV would reach a competitive threshold, although it is unlikely to match the traditionally low price of fossil fuel generated electricity. In order to reduce the price difference, the governments of the GCC might also reduce or remove the

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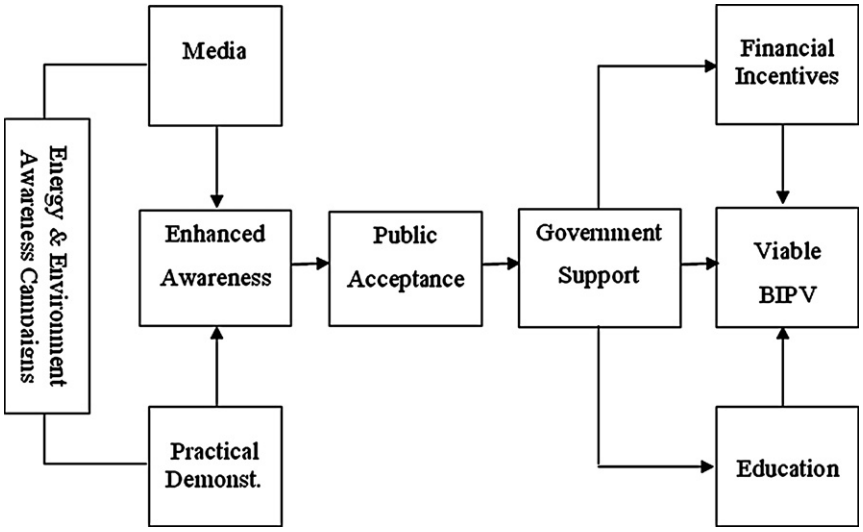

Fig. 7. A suggested diffusion strategy.

effective subsidisation of the current price of electricity generated using these non-renewable energy sources.

It will also be necessary to address the barrier to adoption of the negative perceptions with regard to solar technologies. One could argue that even if cost became competitive, PV manufacturers would not necessarily be able to expand their sales to the public if the technology continued to be negatively perceived. Therefore, public acceptance is a huge issue; to address this, a complex strategy that may well involve incorporating a range of means will likely to be required. One finding of the surveys is that mass-media coverage could provide the most effective means of increasing public awareness of accurate information regarding PV, on the way to attaining PV's legitimacy and subsequently a widespread diffusion in the GCC region. There should be practical demonstrations, as well as extensive campaigns in order to educate the public regarding energy use and environmental issues, in order to create strong community support for the environmentally friendly renewable energy technologies. In essence, media coverage (e.g. on television and in newspapers) and demonstrations could constitute networks, in the sense of being channels for transferring knowledge, and thus could influence the perception of what is desirable among the public and other potential stakeholders. In addition, since young people today will be the users of the renewable energy products of the future, educational programmes are essential in order to sensitise them to environmental issues and the need for considering a range of energy solutions. Universities and colleges also have an important role to play in building a trained workforce to undertake research and development [36,37]. Therefore, formal education is needed, not only to enhance and raise energy and environmental awareness among the younger generation, but also to create the skilled workforce necessary to maintain BIPV modules and to integrate and make efficient use of this technology. In sum, a strategy for supporting the widespread use of BIPV in the GCC region should give due emphasis to the issues of public acceptance and awareness. It seems rational to presume that once there is an adequate public demand for environmentally friendly energy options such as BIPV, political support would follow [38,39]. Fig. 7 summarises the key elements of such a proposed diffusion strategy.

Thus, it is reasonable to argue that the sooner a GCC country realises the elements of such a proposed strategy, the more likely PV will become a viable option in its buildings' market. Bearing in mind that such changes (especially changes in public awareness and attitude) cannot take place overnight, a substantial portion of the surveyed academics might be right in anticipating that PV will not be sufficiently viable for buildings' applications in the GCC region until 10–20 years from now.

8. Conclusion

Renewable energy technologies are being exploited in many countries at this time. The more successful countries have adopted suitable policies, regulations and encouragement to support the development of industries and diffusion of the technologies into the broader marketplace. In this paper the particular case of building-integrated photovoltaics has been examined where the global market is developing as part of the broader effort to fulfil the promise of green and sustainable architecture.

This paper has investigated the potential use of BIPV in the GCC region. The outcomes of a research questionnaire and interviews have been discussed and salient features extracted using force field analysis. The barriers and encouraging features for the viability of BIPV in the GCC region have been examined and a diffusion strategy to introduce viable BIPV to the GCC markets proposed.

In order to ensure the wider use of BIPV in buildings in the GCC region three objectives should be pursued:

- Firstly, energy and environmental consciousness needs to be raised in the GCC countries in order to enhance the legitimacy of BIPV in the eyes of the various potential stakeholders.
- Secondly, GCC governments need to support the use of BIPV as a part of achieving sustainable buildings and helping to address increasing demands for energy in buildings.
- Thirdly, financial incentives need to be introduced so that the costs associated with the use of BIPV technology become both affordable to consumers and competitive with respect to the costs associated with conventional sources of energy.

Given the observed status quo, and the lack of obvious change it would seem the timeframe necessary to effectively achieve these objectives in the GCC region as a whole may be 20 years or more. Within that timescale it is likely that some of the more severe consequences of global climate change will be evident and quite possibly having a disproportionate effect on already warm climates such as experienced in the GCC area. It is therefore vitally important that even if government level action is slow, policies are developed to mitigate some of the worse consequences by suitable encouragement of stakeholders to make better choices in the more immediate future.

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Appendix A. Survey results

Table A.1
Survey results for homeowners

Q1. How extensive would you regard your knowledge of 'global warming'?				
Expert	Knowledgeable	Heard of it	*Never heard of it*	Other
3.8%	7.6%	32.1%	*56.6%*	0%
Q2. How do you feel about the way the world produces and uses energy in relation to 'global warming'?				
Very concerned	Somewhat concerned	*Not very concerned*	Not concerned at all	Other
15.1%	9.4%	*41.5%*	30.2%	3.8%
Q3. Would you be personally willing to take actions to address current energy and environmental concerns?				
Very willing	Somewhat willing	Neutral	*Unwilling*	Other
13.2%	30.2%	18.9%	*32.1%*	5.7%
Q4. How would you categorise the level of your home's electricity consumption?				
High	Average	Low	I do not know	Other
43.4%	20.8%	9.4%	15.1%	11.3%
Q5. To what extent would you support, or oppose, the widespread use of renewable energy in your country?				
Strongly support	Tend to support	Tend to oppose	Strongly oppose	*Other*
7.6%	13.2%	28.3%	18.9%	*32.1%*
Q6. How many types of renewable energy technologies have you heard about?				
5 or more	3–4	1–2	*0*	Other
3.8%	15.1%	39.6%	*41.5%*	0%
Q7. Which type of renewable energy do you think would be the most appropriate for use within the buildings of your country?				
Wind	*Solar*	Geothermal	Biomass	Other
15.1%	*39.6%*	3.8%	7.6%	34.0%
Q8. Which of the factors below, in your opinion, is the biggest barrier in adopting solar power in buildings?				
High maintenance requirements	Inconstancy of supply	*High cost*	Safety hazards	Other
17.0%	5.7%	*35.9%*	32.1%	9.4%
Q9. Which of the following factors would encourage you to using solar photovoltaic in your home building?				
Governmental incentives	Availability of suppliers/technical support	*Lower costs*	Aesthetic use in design	Other
13.2%	9.4%	*39.6%*	28.3%	9.4%
Q10. How do you feel about having solar photovoltaic panels fitted on your home building?				
I strongly like it	*I feel indifferent about it*	I strongly dislike it	I am unsure of how I feel about it	Other
5.7%	*35.9%*	26.4%	18.9%	13.2%

Table A.2
Survey results for academics

Q1. How extensive would you regard your knowledge of 'global warming'?				
Expert	*Knowledgeable*	Heard of it	Never heard of it	Other
15.7%	*60.8%*	19.6%	3.9%	0%
Q2. How do you feel about the way the world produces and uses energy in relation to 'global warming'?				
Very concerned	*Somewhat concerned*	Not very concerned	Not concerned at all	Other
32.3%	*47.1%*	18.6%	2.0%	0%
Q3. Would you be personally willing to take actions to address current energy and environmental concerns?				
Very willing	Somewhat willing	Neutral	Unwilling	Other
41.2%	27.4%	24.5%	6.9%	0%
Q4. To what extent would you support, or oppose, the widespread use of renewable energy in your country?				
Strongly support	*Tend to support*	Tend to oppose	Strongly oppose	Other
17.7%	*38.2%*	18.6%	16.7%	8.8%
Q5. What do you think would increase public awareness to the potential advantages of renewables?				
Conferences and seminars	*Higher media profile*	Training courses	Practical demonstrations	Other
13.7%	*32.4%*	10.8%	24.5%	18.6%
Q6. Do courses offered by your university/college incorporate the subjects of sustainability and renewable energy?				
Yes	To a certain extent	*No*	I do not know	Other
2.9%	10.8%	*47.1%*	27.5%	11.8%
Q7. Which type of renewable energy do you think would be the most appropriate for use within the buildings of your country?				
Wind	*Solar*	Geothermal	Biomass	Other
25.5%	*40.2%*	2.0%	16.7%	15.7%
Q8. Which of the factors below, in your opinion, is the biggest barrier in adopting solar power in buildings?				
Inadequate technical performance	*High costs*	Safety hazards	Availability of cheap/free electricity	Other
13.7%	*35.3%*	2.9%	18.6%	29.4%
Q9. What will enhance the use of solar photovoltaic in buildings' applications?				
Improved technical performance	*Competitive costs*	Incorporating the subject of renewables in the teaching curriculum	Governmental incentives	Other
14.7%	*26.5%*	16.7%	22.5%	19.6%
Q10. When do you think solar photovoltaic will be sufficiently viable for buildings' applications?				
At present	Within 5 years	*10–20 years from now*	More than 20 years from now	Other
3.0%	10.8%	*48.0%*	34.3%	3.9%

Table A.3
Survey results for building developers

Q1. How do you feel about the way the world produces and uses energy in relation to 'global warming'?				
Very concerned	Somewhat concerned	Not very concerned	*Not concerned at all*	Other
2.3%	16.3%	39.5%	*41.9%*	0%
Q2. To what extent would you support, or oppose, the widespread use of renewable energy in your country?				
Strongly support	Tend to support	*Tend to oppose*	Strongly oppose	Other
4.7%	16.3%	*44.2%*	27.9%	7.0%
Q3. Which type of renewable energy do you think would be the most appropriate for use within the buildings of your country?				
Wind	*Solar*	Geothermal	Biomass	Other
32.6%	*51.2%*	7.0%	*4.7%*	4.7%
Q4. What is the average cost of each electrical Watt from solar photovoltaic technology?				
$4	$10	$20	*I do not know*	Other
0%	9.3%	44.2%	*46.5%*	0%
Q5. What type of building application do you consider to be the most attractive for the solar photovoltaic technology?				
Residential only	Commercial only	On-grid only	*Off-grid only*	Other
16.3%	7.0%	2.3%	*39.5%*	34.9%
Q6. If each large complex and skyscraper in the Arabian Gulf countries integrates photovoltaic panels into its roof and windows, by how much – roughly speaking – could the overall electricity demand from the grid be reduced:				
5–15%	15–30%	30–50%	*I do not know*	Other
37.2%	4.7%	7.0%	*48.8%*	2.3%
Q7. Which of the factors below, in your opinion, is the biggest barrier in adopting solar power in buildings?				
Inadequate technical performance	*High costs*	Safety hazards	Availability of cheap/free electricity	Other
9.3%	*48.8%*	4.7%	25.6%	11.6%
Q8. What will enhance the use of solar photovoltaic in buildings' applications?				
Improved technical performance	*Competitive costs*	Increased public awareness	Governmental incentives	Other
0%	*41.9%*	25.6%	18.6%	14.0%

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Q9. Who do you think should bear the responsibility for the current lack of utilising solar power in buildings?				
Architects	*Clients*	Policy and decision makers	All of the above	Other
9.3%	*41.9%*	7.0%	27.9%	14.0%
Q10. How do you feel about executing building projects which incorporate the use of solar photovoltaic technology?				
Interested	I may consider it	Not interested	*Never thought of it*	Other
2.3%	14.0%	30.2%	*48.8%*	4.7%

Table A.4
Survey results for architects

Q1. How do you feel about the way the world produces and uses energy in relation to 'global warming'?				
Very concerned	*Somewhat concerned*	Not very concerned	Not concerned at all	Other
23.9%	*34.8%*	30.4%	10.9%	0%
Q2. To what extent would you support, or oppose, the widespread use of renewable energy in your country?				
Strongly support	Tend to support	Tend to oppose	Strongly oppose	Other
30.4%	23.9%	21.7%	17.4%	6.5%
Q3. Which type of renewable energy do you think would be the most appropriate for use within the buildings of your country?				
Wind	*Solar*	Geothermal	Biomass	Other
34.8%	*50.0%*	0%	2.2%	13.0%
Q4. Which do you think is the best direction of solar photovoltaic panels when installed in buildings to produce electricity?				
North	South	West	East	Other
39.1%	13.0%	6.5%	4.4%	37.0%
Q5. What is the current average efficiency of photovoltaic panels when installed to buildings?				
Approx. 50%	Approx. 30%	*Approx. 15%*	Approx. 5%	Other
0%	13.0%	*54.4%*	28.3%	4.4%
Q6. What type of building application do you consider to be the most attractive for the solar photovoltaic technology?				
Residential only	Commercial only	On-grid only	Off-grid only	*Other*
6.5%	15.2%	4.4%	34.8%	*39.1%*
Q7. What will enhance the use of solar photovoltaic in buildings' applications?				
Improved technical performance	*Competitive costs*	Increased public awareness	Governmental incentives	Other
6.5%	*39.1%*	23.9%	15.2%	15.2%
Q8. Who do you think should bear the responsibility for the current lack of utilising solar power in buildings?				
Architects	Clients	Policy and decision makers	*All of the above*	Other
4.4%	28.3%	23.9%	*43.5%*	0%
Q9. Do you think that using solar photovoltaic technology could adversely affect the quality of your buildings' design?				
Yes	To a certain extent	No	*Never thought of it*	Other
13.0%	23.9%	26.1%	*37%*	0%
Q10. How do you feel about executing building projects which incorporate the use of solar photovoltaic technology?				
Interested	I may consider it	Not interested	Never thought of it	Other
43.5%	28.3%	8.7%	19.6%	0%

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