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Article

Mandatory Policy, Innovations and the Renewable Energy Debate: A Case Study on Building Integrated Photovoltaics

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Abstract: Innovations in buildings help to reduce energy consumption and promote environmental protection and as well as the use of renewable energy technology. However, there is a conflict when the need for an innovation clashes with the financial burden and the complex adoption processes. As a result, the negative impacts of buildings remain, and the low adoption of strategic innovations remains unaddressed. This study aims to explore this challenge, the various sides of this debate and provide a practical guide which promotes energy and building-related innovations driven by policy. This paper is an extract from a recent doctoral study conducted using an exploratory qualitative model and interviews with eighty-six residents in the United Arab Emirates (UAE). Building Integrated Photovoltaics (BIPV) was selected as a case study energy innovation and the thematic analysis of the data collected suggests that BIPV adoption is limited by multiple barriers. The debate arising from the findings highlights two opposing viewpoints. One view claims that mandatory policies are necessary to promote innovation adoption. The other view argues that the merits of mandatory policy are lost since multiple barriers significantly discourage adoption in the first place. The study takes a proactive step towards resolving the debate using a systematic approach that recommends specific drivers backed by supporting policies to guide human-centered, stakeholder-driven renewable energy transition.

Keywords: innovations; building integrated photovoltaics (BIPV); interviews; mandatory policy; renewable energy; stakeholders

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1. Introduction

The built environment and the building industry account for over 40% of global energy consumption, 36% of all CO_2 emissions [1,2] and 28% of greenhouse gas emissions [3]. The implication of these facts is that the building industry is in dire need of global strategies to reduce its negative environmental impacts. A considerable part of the energy used in buildings is needed for space heating and cooling. While heating, ventilation and cooling account for 35% of primary energy use in America, pre-COVID-19 projections suggested that China will reach the same level by 2022 [4]. However, the United States Energy Information Administration (EIA) has predicted that global energy demand will increase by 50% by 2050 [5] The International Energy Agency has also stated that due to rising temperatures in the summer, the cooling demand for buildings has risen sharply, causing energy consumption to increase [6].

From an international and historical perspective, several initiatives and agreements have sought to address this scenario. These include the 1992 Kyoto Protocol, 2016 Paris Agreement, the Millennium Development Goals (MDGs) and the Sustainable Development Goals (SGDs) of the United Nations. Although multiple strategies have been put forward, one connecting theme, and frequently discussed solution is the advocacy for and transition to renewable energy. The strategic potential of renewable energy sources to achieve zero emissions has been developed into roadmaps to facilitate the global call for mitigation [7].

Other benefits include environmental safety, energy security, health [8] and economic development [9], with future projections of reducing 50% of CO_2 emissions by 2050 [1].

1.1. Research Context, Scope and Justification

The conceptual framework and research orientation which positions this study within the current discourse and broad dimensions of renewable energy transition is multi-layered. On one hand, this study focuses on mandatory policies and its impact on renewable energy transition which many studies have investigated in different contexts (See Section 2). On the other hand, the investigative lens which this study applies is the experience and perspective of stakeholders in these contexts, who are directly impacted by the policies and initiatives to promote the energy transition. This second aspect provides the basis for the intellectual debate on renewable energy adoption, acceptability and diffusion, as well as the critical human-centered emphasis which this investigation is focused on.

In the literature, Curtius carried out multiple studies to acquire information on factors which impact and condition stakeholders towards adopting innovative renewable energy technologies based on social connections and peer effects [10,11]. Another study by Petrovich also sought to provide insightful information on adoption factors due to the lack of insights into how potential stakeholders view renewable energy innovations [12]. Yet, another study was conducted to investigate stakeholder acceptance in lieu of effective communication channels in relation to information access [13]. In previous studies, we have summarized the literature on stakeholder concerns; on barriers and drivers which impact renewable energy innovations using examples from different countries [14–16]. These various investigations reveal that there is limited information in literature on this topic in some regions.

Due to several distinct social and environmental reasons, as well as market- and research-related concerns reported in literature [16], and summarized below, the United Arab Emirates (UAE) was selected as a case study for this investigation. Based on the foregoing, the study was framed to provide fresh insight and information, add to the existing body of knowledge and guide similar studies in other countries. This would include countries or regions with a similar environment characterized by a hot and humid desert climate or social character such as high expatriate population or other unique community demographics. The context also characterizes other countries or regions with huge potential and interest, but low diffusion of renewable energy opportunities in the built environment. Thus, although the study focuses on the UAE, the social, environmental, market, policy and research landscape related to renewable energy adoption in the region could be widely applicable to several other countries.

1.2. The Study Context

The UAE is a foremost emerging economy with over 10% of the world's oil reserve and a leading hub for innovation. Abu Dhabi is the capital city and is one of its seven emirates, the others are Ajman, Dubai, Fujairah, Sharjah, Ras Al Khaimah and Umm Al Quaim. However, the social context of the country is different from most countries; of the 9.3 million residents of the UAE, about 80% are foreigners from over 200 countries of the world. Population growth, urbanization and industrialization in the UAE have led to the challenge of rising energy demands over the past few decades [17,18]. In addition, urbanization, economic growth and financial development increase residents' purchasing power [19]. Combined, these factors directly and indirectly increase the propensity for greater energy consumption via appliance purchases, housing demand, city infrastructure and overall economic activity [9,19]. About 70% of electricity produced in the UAE is consumed by buildings, with almost 70% used for cooling [20,21]. Additionally, the weighted average for per capita energy consumption in the Gulf Cooperation Countries (GCC) is seven times higher than the global average [22].

In response to the above, the UAE 2050 National Energy Strategy indicates a planned transition to a modern 21st century sustainable economy [23], aimed at having 50% clean energy in the energy mix by the middle of this century [24]. In line with this, there was a 360% increase in solar technologies adopted in the UAE between 2013 and 2018 [25]. Therefore, the environmental context of the UAE, the climate and high solar radiation present a strong case for this transition. Although the UAE has given significant attention to renewable energy and other sustainable policy initiatives, much of these require innovative technologies to meet these requirements. To be specific, the UAE has shown substantial interest in solar energy building technologies such as utility-scale PV, solar hot water systems (SHWS), building integrated photovoltaics (BIPV) and rooftop solar PV.

Several international studies referenced have already asserted a clear connection between the growth of these innovations, stakeholder engagement and the renewable energy transition in the built environment. However, as previously stated, literature is scare on studies in the UAE which give focused attention to stakeholder research in relation to the diffusion of renewable energy technologies in the construction industry. The current challenge, therefore, is that among UAE residents, there are multiple uninvestigated perceptions and opinions towards innovative solar technologies, compared with other conventional energy sources [16]. The lack of access to this information ultimately cripples effective policy planning, which makes it difficult for customer-focused product development and stymies the adoption of these innovative technologies.

On another note, for countries similar to the UAE which are interested in innovative energy technologies, the unaddressed and conflicting views have generated a layered energy debate. One opinion is that innovative technologies are needed to promote sustainability but on the other hand, these innovations have also been reported to be either expensive or complicated which makes adoption or diffusion a problematic endeavor [10,15]. The critical issue here is not a scholastic debate on merits and demerits of innovations but on mandatory policy which compels residents and professionals to adopt innovative technologies. In a recently completed PhD research by the first author [16], this scenario was broadly investigated based on a rigorous literature review and a focus on building integrated PV (BIPV) as a case study.

1.3. Research Aim and Structure

This current paper is a subset of a broader investigation to identify the barriers and drivers of BIPV adoption. The key emphasis and aim of this paper is the policy debate: *should mandatory policies be made to compel the adoption of innovative energy technologies such as BIPV?* The aim of paper is to highlight the two sides of this debate and outline a rationale for guiding future policy development. It is specifically framed to position policy as a bridge between barriers and drivers of adoption and examine the perspectives which provide a systematic resolution of the debate.

The outline for this paper is as follows. Section 2 summarizes key literature that highlight the benefits and barriers associated with innovative technologies, and key energy polices in the UAE. Section 3 describes the qualitative research design that was used for this investigation while Section 4 presents the findings of the thematic analysis. Section 5 provides critical insights from the findings, and the systematic approach which projects policy development as a driver and answer to the debate surrounding innovation adoption. Finally, the conclusion of this study is presented in Section 6.

2. Innovative Energy Technologies

Critics argue that innovations are difficult to measure, disrupt systems and conflict with the status quo [26], thus creating stress on existing lifestyles and culture. Nevertheless, innovations solve problems, provide a new perspective to erstwhile complex challenges and promote technological growth that generally benefits our way of life as humans [16]. The Organization for Economic Co-operation and Development (OECD) defines innovation, *"as the implementation of a new or significantly improved product (good or service), process, or delivery method, a new marketing method, or a new organizational method in business practices, workplace organization or external relation"* [27].

Building integrated photovoltaics (BIPV) is an innovation in photovoltaic (PV) technology which converts the building from an energy consumer to an energy producer [28]. BIPV multi-functionality means that this innovation can serve multiple functions simultaneously or independently depending on its design. For example, BIPV can serve as a means of advancing net-zero targets [29], to allow daylighting and view or to serve as cladding material, safety glass, shading device or a privacy screen [30–32]. An example of a BIPV installation is found in the Copenhagen International School built in 2017 in Denmark. C.F. Moller Architects designed the building façade to mimic a series of sequins with 12,000 solar vertical solar panels tilted creatively off their axis. Figure 1 below shows the building with the solar panels which cover about 6000 square meters and produce about 200 MWh per year of power.

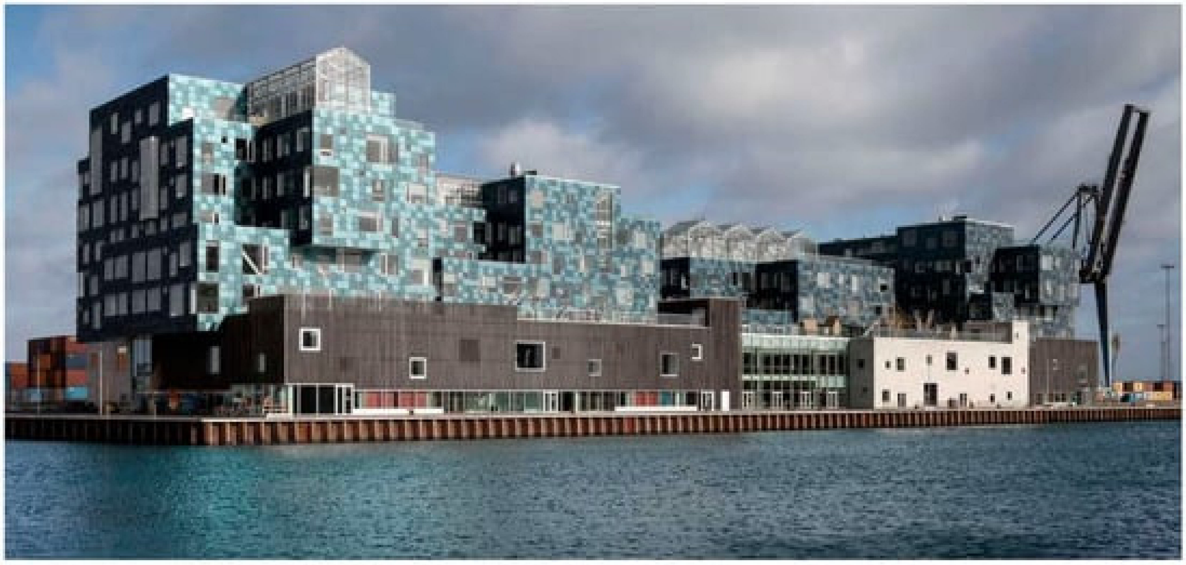

Figure 1. Sea view shot by Adam Moerk of the Copenhagen International School, Denmark [33].

BIPV represents architectural innovation and building component advancements which promote green product ingenuity as it harnesses renewable energy. Such product developments have been described as valuable radical innovations which embrace both a technological and business perspectives [34].In the discussion on BIPV technology, these assertions and concepts can provide a holistic guide towards understanding the potential characteristics of the BIPV technology. At the same time, they may be able to shed light on developing a sound, research-based strategy for facilitating its adoption.

2.1. BIPV Adoption Studies and Trends around the World

In this section, an overview of BIPV adoption from the dual focus of its importance and international policy trends is presented as a basis for engaging this subject matter within the research context. In an Australian study by Sommerfeld et al. 2017, the authors expanded the focus given to residential PV-related consumer's adoption in view of external factors which impact decision making. The study findings suggested that social factors and economic factors played a greater role than environmental factors in the client's decision-making process [35]. Another study carried out in Singapore by Lu et al. 2019 addressed a holistic investigation of stakeholder perception with regard to barriers and drivers, and the impact on patterns and trends of diffusion. The study found out that while the perceptions on drivers was similar, the perceptions on barriers was different [36]. A study conducted in Finland also revealed that by engaging early adopters, it is possible to derive insights into their experiences and perceptions with the key target of speeding up future growth and diffusion [37]. These studies show a broad approach towards promoting BIPV trends, which yet another study suggests is best addressed by understanding the social dimension of innovations [38]. The authors of this study suggest that new technologies and innovations are subject to some tension during negotiations and concluded that this ultimately impacts stakeholders and the design process.

Several other studies have recently assessed the trends relating to BIPV adoption and policy in various countries. A study by Lucchi et al. investigated BIPV diffusion in Italy and Switzerland from a comparative legislative and policy-related perspective on both territories in relation to the general policy landscape [39]. The findings show that when Italian policies became complicated and fragmented, it had a negative impact on the adoption and implementation process. Conversely, by boosting procedural clarifications that posture BIPV projects with clear criteria for its' adoption, there was a positive growth in diffusion in the Swiss territory.

Another study was conducted by Vroon et al. to investigate the future growth of BIPV, departing from its 'niche or bespoke' position to larger scale diffusion and integration with conventional building materials and components [40]. One key finding discovered in the study was that lack or inadequate policy support that guides the processes related industrialization and commercialization, is a clear barrier to diffusion. To counteract this, the authors suggested that coordination and collaboration across research, industrial and commercial sectors should be encouraged. They also suggested the creation of economic conditions that favor capacity development of companies via access to the financial capital.

In yet another study, the diffusion of BIPV in India was investigated and the discourse engaged with a keen attention to the policy dimension [41]. The study showed that barriers impact diffusion even in the light of various support policies. However, the authors argue that by promoting policy recommendations, the potential for growth is possible. They suggested that the government should eliminate barriers by improving the building code and standards to accommodate BIPV technology. Additionally, they opined that incentives should be made available to encourage diffusion through access to grants, and research should be supported through funding and partnerships.

A recent review assessed 35 studies which developed testbeds for BIPV systems in multiple countries [42]. The assessment metrics outlined show a concern for energy performance and also economic and design -related aspects of the systems. Similarly, a recent review on BIPV as a technological innovation suggests that the various aspects of energy-related behavior which characterize BIPV modules impacts how it is integrated in buildings [43]. However, the authors agree with other aforementioned studies that this warrants a need for further research into the standardization but also argued for the crucial aspect of technological acceptance.

Based on the international trends reviewed thus far, and the indictor of the social aspect of stakeholder acceptance, Sections 2.2 and 2.3 present a BIPV adoption debate built on the foundation that BIPV is a multifunctional, multi-dimensional technology and also on stakeholder views which, argue that it has significant limitations. Thus, the debate suggests that besides the technical energy aspects of BIPV, there are other critical considerations related to BIPV diffusion which present conflicting views on the benefits and barriers of adopting the technology in the first place.

2.2. The Debate: Benefits of Adoption

There are significant benefits associated with the adoption of BIPV and these suggest a supportive perspective that it should be promoted by policies in view of the environmental need already highlighted in the Introduction. Stakeholders believe that BIPV provides one of the best methods for on-site energy generation while promoting green building strategies [44]. In the literature, there are about four classes of added benefits related to the use of BIPV as an energy source or as a building material, such as its design, economic, social and environmental advantages. Some economic benefits are financial advantages which accrue to users, including energy cost savings [45,46] and building material cost reduction [47]. Environmental benefits can be on a micro-level relating to the project [48,49] or macro/environment level relating to less embodied energy of materials [50]. Social benefits imply a direct impact on the lives of individuals and the community at large [32] and on the health of the public or the environment [46]. Finally, design benefits imply architectural design gains of BIPV as a building component such as aesthetics [47], view and daylighting manipulation [32,51] and as shading devices [47,52].

In a previous work, the significance of BIPV from an energy and building dimension was reviewed [14] to shed light on the benefits from a different perspective. The review expounded on the energy-related and design-related benefits of BIPV as a building component. BIPV maintains the clean renewable energy status of the PV technology but also goes beyond to address some of the challenges faced by utility-scale PV. As a decentralized or onsite energy-generating source, BIPV provides power right next to the point of use. This addresses the transmission and conversion losses of utility-scale photovoltaics as it provides micro-energy power generation close to the primary load [53–56]. In the process, this removes the need for the transmittance of electricity over long distances from power generation stations and could incidentally reduce transmission and distribution (T&D) costs and line losses [48,49,57]. Capital expenditure for land, infrastructure and maintenance is also removed as the building envelope provides the needed supporting structure for the solar panels [46,48,49,58]. From a social point of view, BIPV also provides users with a degree of energy security, supply, control and autonomy as it potentially encourages household load-shifting and reduced levels of energy consumption [59,60]. Cost benefits with BIPV and financial savings from feed-in tariffs (FITs) lower cumulative costs and improve the cost balance such that the equivalent cost of electricity is close to zero [45,46,61].

2.3. The Debate: Barriers of Adoption

Internationally, existing literature affirms the presence of BIPV adoption barriers. In previous studies, barriers of BIPV have been elaborately described [10,16,36,62]. Several considerations raised relate to the economic, knowledge, design and social, environmental, industrial as well as policy contexts. In relation to the policy aspects, there have been studies which highlight how it stands as a significant barrier in the bid to promote the adoption of renewable and innovative technology. In general, the absence of standards backed by policy tends to make the adoption process more complicated [63]. This impacts the processes of approval, design, fire safety and product development [44,63].

One another note, Boesiger and Bacher argue that when owners and architects are not pressured by policy or politics, there is simply insufficient reason that persuades them to adopt BIPV [64]. Another study reported that based on low approval rates, local authorities seem to disprove BIPV, and this could hinder the possibility of future built projects [36]. The study also reported the lack of precise standards and codes for BIPV, while noting that this does not give guidance for planning. Curtius also agrees that when BIPV-related building codes and standards are not established, diffusion is invariably hindered [10].

In the absence of policy guidelines to predefine which projects are approved or which codes to adhere to, Strazzera and Statzu report that condominium dwellers who were interested in installing solar PV, complained of not obtaining an approval [65]. However, Curtius (2018) explained that in the approval and vetting process, municipal building commissions aim to maintain or preserve the local character of the urbanscape [10]. As a result, BIPV façade proposals, for example, are met with very stringent constraints. The absence, inadequacy and changing character of government incentives were noted as limiting factors to the diffusion of BIPV. It was also reported that frequent policy changes or fluctuating agreements create stress in the administrative procedure for BIPV adoption [64]. Low government support combined with unwilling developers [66,67] as well as an overall lack of market establishment were noted as interrelated challenges [68].

2.4. Current UAE Scenario: Growth in Solar PV Development

Member nations of the Gulf Cooperation Countries (GCC) include Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE). These nations are rich in oil and depend on this resource for domestic use and export. It has been reported that all GCC countries are listed among the top 25 nations, globally, with the highest per capita carbon dioxide emissions [23]. The UAE consists of the seven emirates or states; Abu Dhabi is the largest, controlling 90% of all oil and gas reserves. Beyond its vast fossil fuel resources, the UAE has, however, shifted its attention to sustainability and energy accountability towards a safe environment [69], reducing dependency on non-renewable sources and increasing its economic diversity in the process. As a classic example of this, oil rents in 1979 contributed 60% of the UAE's Gross Domestic Product (GDP) and fell to only 18% in 2010 [70].

In 2008, Abu Dhabi invested USD 15 billion to build a novel ultramodern zero-waste, carbon neutral urban development called Masdar City 11 miles outside the city for 50,000 people [71,72]. Since then, other investments in renewable energy projects have been made, as shown in the list below:

- 1013 MW Mohammed bin Rashid Al Maktoum (MBR) Solar Park, which is the largest solar park in the world
- 1177 MW Sweihan solar power plant
- 100 MW Abu Dhabi's Shams 1
- Over 145 MW rooftop projects across the country (MESIA, 2018)
- 2 GW Al-Dhafra Solar PV IPP project.

Beyond this list of mega renewable projects are government policies which support innovative energy technologies in the UAE. Specifically, there is also a push for programs and green grating systems such as *Estidama's* Pearl Building Rating System (PBRS) in Abu Dhabi, Dubai's Green Building Rating System and Ras Al Khaimah's *Barjeel* Green Building Rating system. As a focus on the national capital, Abu Dhabi, *Estidama*—which means sustainability in Arabic—was set up in 2010 as an initiative developed and promoted by Abu Dhabi Urban Planning Council (UPC). It aims to build, sustainable and related, system regulations which when applied, can, among other criteria, impact the consumption of energy and water with a 30% reduction [73], through its green building rating system the Pearl Building Rating System (PBRS). It was developed using elements from the Leadership in Energy and Environmental Design (LEED) and the British Building Research Establishment Environmental Assessment Method (BREEAM) rating systems. This was done, however, by considering the unique local context, its environment and related concerns [74].

One study suggests that the concept of sustainability in the UAE has grown across the country and is recognized by the academia, research and political sectors [75]. The authors also assert that the current target is to bridge the gap between policy formulation and policy implementation. Thus, this research seeks to answer the opposing perspectives towards promoting innovations in line with national policy initiatives.

3. Method

A detailed description of the research design for this paper and the dissertation has been reported elsewhere [16]. Beginning with a social constructivist worldview which has become embroiled in research philosophy, the study design aimed and worked with the notion that the construction of knowledge is based on the individual's social interaction [76,77]. It upholds the idea that in any social setting akin to a research context, knowledge is the result of social interaction, while experiences and backgrounds become the source of ideologies and opinions. Generally, a qualitative research approach is deemed appropriate when the priority is the evaluation of a subject by authentic human experience; unhinged by constraints of firmly defined prescriptive procedures, guidelines or numerical statistics common to the quantitative ideology [78].

A series of qualitative interviews were conducted with 86 study participants in the UAE. The sampling was random but purposeful to elicit information from the most credible sources. Sequel to selecting the right participants from defined stakeholder groups in line with theoretical principles and previous studies, developing the right questions, and determining the appropriate kind of interviews were also considered to facilitate the data collection process. These important steps were taken to guide the researcher during the interviews process. The interviews conducted were carried out in two phases: phase 1 was

18 informal conversation interviews, and phase 2 was 68 semi-structured interviews. A few pilot interviews were also conducted before each stage.

Stakeholders targeted included architects (A), researchers (AR), PV specialists (PV), other consultants such as electrical engineers (OC), policy makers (PMI) and developers (DEV) and other residents/potential clients (C) from a non-technical background (See Figure 2). The study was approved by the UAEU Ethics Committee, participants were sent prior notice to request consent and meeting location, and the interviews were recorded after permission was given to do so. The interviews were an average of 30 min and were all conducted in English. The analysis of the interviews was conducted using a thematic and a comparative analysis of the transcribed interviews based on literature (Braun & Clarke, 2006). Networks and charts were used to outline, delineate and summarize 660 pages of transcripts into multiple diagrammatic representations of the narrative which was distilled from the interviews. This paper focuses on the findings from the doctoral study [16] which relate specifically to the role of policy in the diffusion of innovations.

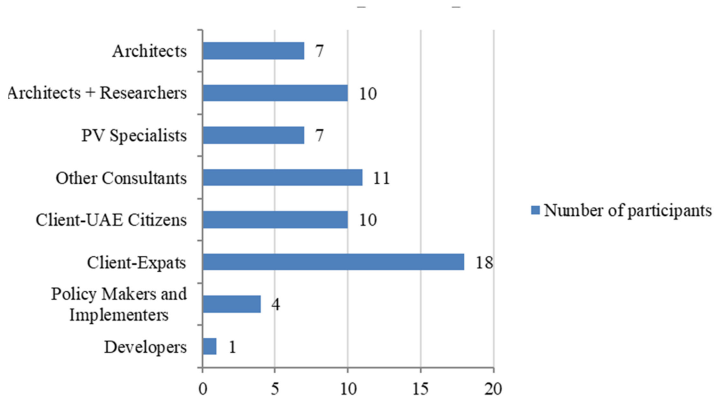

Figure 2. Breakdown of study participants by stakeholder group.

4. Findings

The findings of the thematic analysis are presented in this section to summarize the data collected and show the wide breath of information collected during the interviews. This section describes the top five barrier themes which were identified in this study using anonymous stakeholder comments to explain each. This section sets the stage to introduce the debate related to mandatory policy, which is the focus of the paper, and is discussed in Section 5. The themes are broad groupings of multiple adoption barriers and concerns of the BIPV innovation that were mentioned by stakeholders who participated in the study.

4.1. Knowledge and Awareness

The knowledge theme covers issues relating to public awareness, information and understanding of BIPV as a technological innovation. Participants' opinions reflect the impact of a lack of general knowledge and awareness about BIPV, skepticism and misinformation. A professional from a leading construction firm shared his experience during the interviews, " ... *If you went to most of the MEP consultants in this part of the world and demonstrated integrating solar panels into a building, they'd look at you with a blank face because they wouldn't have a clue" (R26OCE).* He inferred that very few consultants who ought to be involved in BIPV design and specification do not even know about it. However, clients also have limited knowledge which a PV specialist explained: " ... *I speak with people, they ask why the Shams Dubai installed PV on buildings ... But people say funny things like, they think they won't have to pay DEWA for electricity bills, or they will use it for the ACs" (R21PVE).* These comments show that the application and use of BIPV is not well understood by both professionals and non-professionals.

The analysis revealed several sub-themes under this theme, extracted from comments made by forty-seven participants (69%). Of this number, twenty-four were made by technical and twenty-three by non-technical participants. Figure 3 below shows these knowledge barriers as sub-themes of this theme and the number of participants who commented on issues relating to these barriers. Interestingly, the figure shows that the number of participants, comparing technical and non-technical, for the top three sub-themes was significantly similar, with much fewer comments on misinformation.

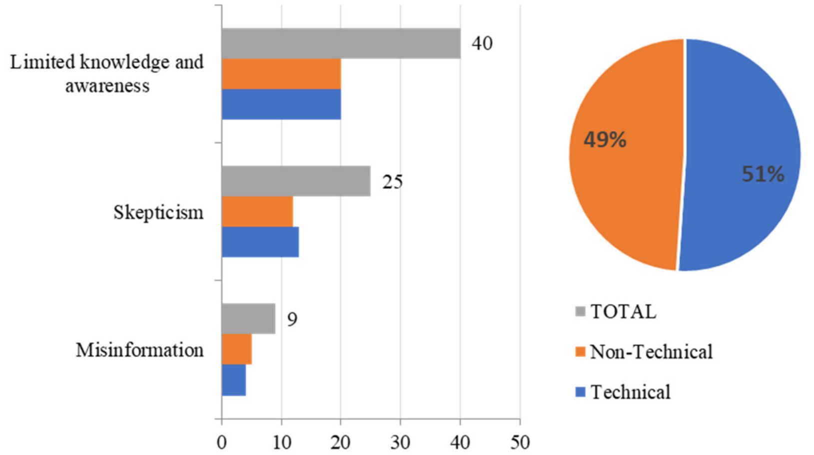

Figure 3. Knowledge and awareness barrier sub-themes with the number of participants who commented.

Across all barrier themes, this theme was one of the most emphasized and the data suggests that it is important to both technical and non-technical stakeholders in the UAE. In other studies, researchers have also noted that when stakeholders are unfamiliar with BIPV, there is usually limited knowledge and awareness about it [38,67]. The multiplied effect of this is that, in some cases, this lack of knowledge leads to a lack of interest, which is even present when partial one-year subsides (R24PVU) or the government provides full PV subsidies [38].

4.2. Design

This theme covers issues that are related to the conceptualization, design and installation of both the BIPV and the PV system which supports it. Within these stages, barriers were identified by the interviewed stakeholders which relate to the product, design requirements and the architectural design process. Speaking on the topic, an architect with a research background noted about BIPV " … *it's a strange idea. It could open new doors for the clients or new door for questions for the client, and then new headache for the consultant" (R11ARE).* He was implying that within the design process, the novelty of BIPV as well as uncertainties behind it would combine to raise more questions which would complicate the successful completion of the project. Another comment from a potential client raised the concern of poor aesthetics of BIPV installations. *"If it looks like what I've seen then it will be big and bulky and just more functional looking; it wouldn't be the first thing I would go buy … just looking at it, I don't think I would like it" (R56CE).* This concern with building appeal although valid is debatable due to the presence of colored, frameless and flexible BIPV solutions in the market not seen on many buildings in the study area.

A total of forty-one participants (60%) mentioned one or more design-related issue as potential barriers to BIPV adoption. Of this number, twenty-two were from the technical group and nineteen from the non-technical group. Figure 4 below shows all the design barriers as sub-themes of this theme and the number of participants who commented on issues relating to these barriers. The data suggest that the emphasis which the participants gave to the sub-themes was significantly different.

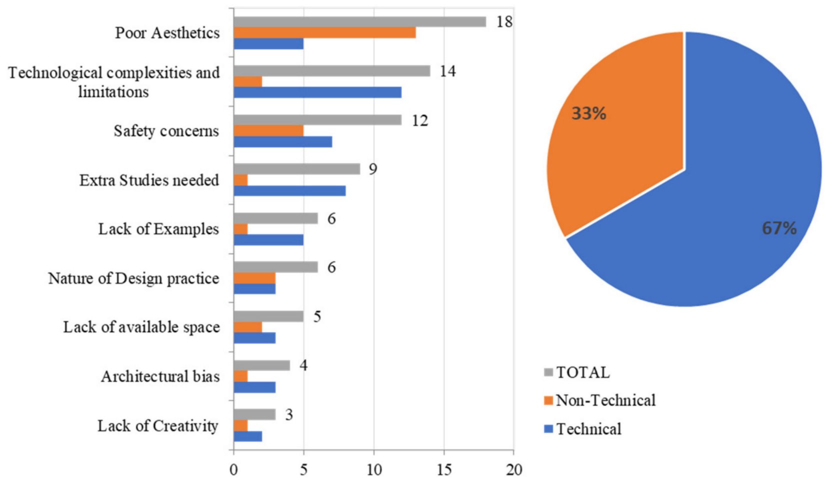

Figure 4. Design barrier sub-themes with the number of participants who commented.

The findings of the current study agree with some other studies conducted by Koinegg et al., and Boyd & Larsen. One argues that there is a conflict between aesthetics and maximum energy and the lack of energy generation considerations in pre-design stages are added factors which complicate the adoption of BIPV [79]. Additionally, confirming the results, the present concern relating to the time of integration and attempts to force BIPV in later design stages may result in negative impact on power generation due to unforeseen design conflict and compromise [38].

4.3. Social

The social connection between innovation, BIPV and the UAE context was a key consideration of this investigation. This theme is in line with barriers which possess a strong bearing on everyday life in the UAE. Home ownership and its related challenges to expatriates, aspects of UAE culture and preferences of citizens as well as the general lack of interest highlight the sub-themes under this section. Speaking on the unique perspective of expatriates as foreigners in the country, two participant views reflect how their social status is a barrier to BIPV adoption. *"I would love to have technologies in my house, but you know it's not always in our hands. It's the owner's decision from the beginning and at the end" (R14ARE). "I only want the system if it's my house . . . to put a system on you landlord's property, number one it comes with permissions that you have to get and all kinds of different stuff. And then what happens next year if he decides he no longer wants to rent the house to me? I've got solar panels that I need to deal with, so . . . " (R62CE).* These views are the opinions of expat residents who make up about 80% of the UAE's population and more often, live in rented accommodations.

Thirty-five participants (52%)—fourteen technical and twenty-one non-technical participants—made comments from which these social dimensions of BIPV adoption barriers were deduced. Figure 5 below shows all the social barriers as sub-themes of this theme and the number of participants who commented on issues relating to these barriers.

The social barriers identified by this study tend towards the form of a subjective construct and it is hard to pinpoint a single causal social factor, since several identified issues are interrelated. The top barriers mentioned by study participants were home ownership, lack of interest and challenges of expat living in the UAE, as well as competing alternatives. Although there are relatively recent policies, with specific requirements, which permit foreigners to purchase property in the UAE, it was also gathered that expatriates tend to change residence often in the UAE, sometimes every other year, or on average every three to four years. Other participants suggested that they are not keen to own a house in the UAE due to their temporary status and fluctuating job contracts. The analysis suggests that residents who do not own a house are not inclined to adopt BIPV, rooftop PV or Building Applied PV (BAPV).

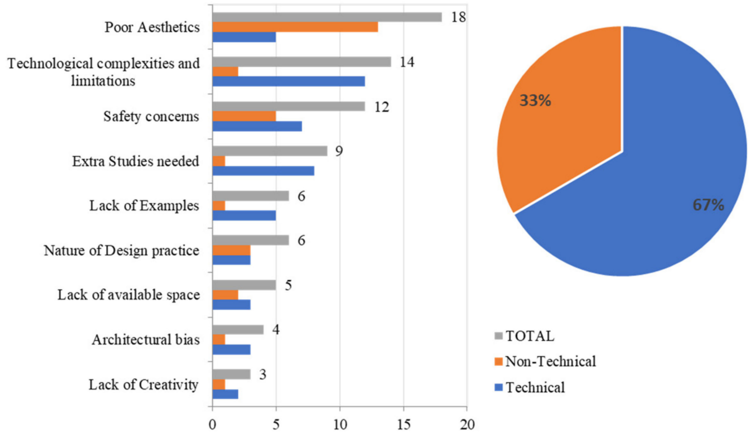

Figure 5. Social barrier sub-themes with the number of participants who commented.

4.4. Economic

In this study, this theme refers to various shades of financial considerations in the adoption of BIPV, relating directly or indirectly to the price the customer will incur in the acquisition of a BIPV system. It covers areas such as the presumed high-cost considerations, long return on investment (ROI) and impact of the subsidy on conventional energy infrastructure provided by the UAE government which is a clear alternative to BIPV. From a business or practice point of view, consultancy firms are faced with the priority of profit and economic benefits to justify their investments. One the one hand, an architect argued, *" ... clients are afraid to try it because it costs a lot" (R03AE)*. On the other hand, a PV specialistic debated, *"Look at the idea of the cost of BIPV. It is a misconception. I did my personal research, and it is just about 10–20% extra on the cost" (R19PVE)*. Such divergent views reflect the challenges of the financial concerns surrounding BIPV adoption.

The three sub-themes identified were deduced from the comments of thirty-six (55%) participants. Figure 6 below shows all the economic barriers as sub-themes of this theme and the number of participants who commented on issues relating to these barriers.

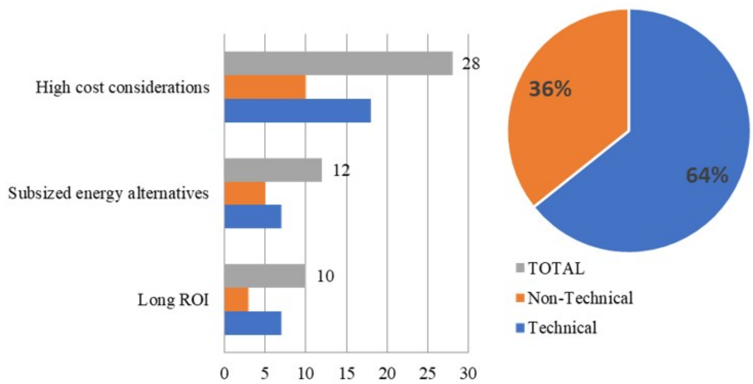

Figure 6. Economic barrier sub-themes with the number of participants who commented.

Although the subject of cost is subjective, debatable and varies by context, project or client, several studies have noted that BIPV systems are considered as an expensive technology [10,68,80]. In this study, this barrier was noted as having two dimensions: fact, and perception, which in part, resonates with other claims in literature [79]. Some studies report that both the technological BIPV material [67] and investment costs of this innovation are high [10,68].

4.5. Environmental

It is a fact that solar-based technology produces clean, sustainable and renewable energy from the sun. Nevertheless, critics debate that BIPV is inherently dependent on the sun and limited by its intermittent supply. In the current study, the desert climate, maintenance challenges and high weather temperatures were noted as environmental demands exerted on would-be clients by this technology. To quote a mechanical engineer who participated in this study, *"The main problem is fine sand and fine dust going and settling and you know with a little bit of moisture it sticks to it. That is what the problem is. If you put them on the roof and there is some sand or something like that that settles, then it is blocked . . . but the main problem is the unscheduled maintenance that kills you" (R28OCE).*

Indeed, BIPV has environmental challenges which are unique to the UAE as expressed by twenty-four and seven technical and non-technical participants, respectively. This totals thirty-one participants or 45% of the total number of study participants who commented on four identified environmental-related sub-themes relating to the sand and dust, maintenance and high regional temperatures. Figure 7 shows all the environmental barriers as sub-themes of this theme and the number of participants who commented on issues relating to these barriers.

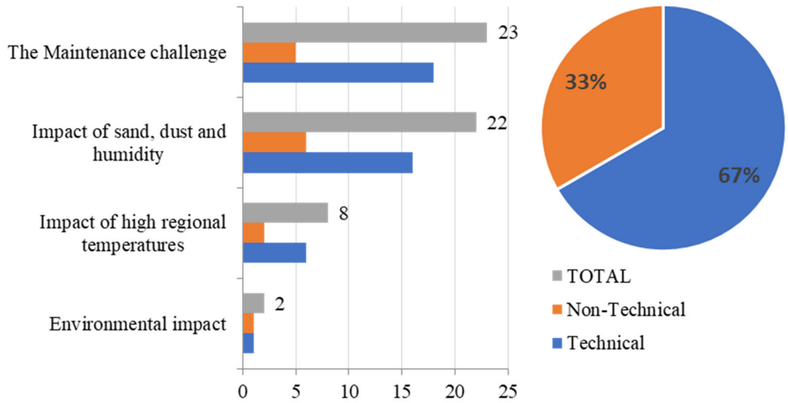

Figure 7. Environmental barrier sub-themes with the number of participants who commented.

The environmental factors which impact BIPV in the UAE represent a unique consideration for its discussion because, as an external device, BIPV is exposed to the impact of sand, dust, humidity and the high desert heat. Considering the number of comments received, technical participants' comments were thrice as much as comments from the non-technical participants. These findings suggest that the environmental dimension of BIPV is perhaps more of a technical concern and thus, was so appraised. Not much is present in the literature on stakeholder opinions about the impact of the weather or climate on BIPV as it relates to adoption. The findings of this study suggest that a focus on stakeholders and climatic impact on BIPV is lacking.

5. Discussion

The first fundamental insight which was evident from the study was the presence of multiple, as well as opposing views which stakeholders have relating to the BIPV innovation and its adoption. This section distills comments made by participants into these differing opinions about BIPV and outlines the underlying debate that fuels these opposing perspectives. By juxtaposition, the interviews conducted reveal that there are two broad views in the evolving debate on mandatory policies for innovative energy technologies. The first view is the position is that policies should not be made mandatory because the said innovation has multiple barriers. The second position suggests that since people do not change unless compelled by some regulations or fines, mandatory policies are crucial.

5.1. Perspective 1: Mandatory Policies Should Not Be Promoted

This perspective is supported by a multi-layered network of BIPV barriers which make adoption difficult and thus suggest that it should not be supported by mandatory policies. In light of the barriers mentioned, this perspective argues that the BIPV innovation is problematic and mandatory policy would be untimely. One point in this argument is that *"It (BIPV) is complicated because ninety-nine percent of the architects or designers do not have enough knowledge about PV. That is complicated" (R09ARE).* Fundamentally speaking, if a large percentage of professionals do not know about the technology, adoption, this will be a huge challenge. On the other hand, the UAE has a larger expatriate than citizen population who do not often own a house. Thus, *" ... they just rent whatever is available. So, they don't have the choice of putting something on the roof, you know it's not their own house" (R46CE).* Thus, these stakeholders argue that professionals have insufficient knowledge and expatriates who make up 80% of the population, do not even have personal homes for adoption in the first place.

The complexities with design, cost and maintenance also formed the basis for this perspective. Firstly, the aesthetics issue *"To me as an architect, currently using these solar panels to provide a good aesthetic for the structure for the building doesn't always work out. It's mostly ugly buildings; it's hard sometimes to integrate it to make good looking buildings" (R04AE)*. This stakeholder sounds interested but faults design integration as a challenge. Next, a potential client mentioned, *"I think it's the cost. The cost of the technology is expensive, and the comparative service or product, which is electricity, is relatively cheap" (R63CE)*. Beyond the cost barrier, the argument here is that conventional electricity is comparatively cheaper. Hence, the logic of adoption is mute. Finally, *"I have to open a hatch in my ceiling, pull down a ladder, climb up it, get water through the hatch on to my roof, get on to it, which has a parapet which is only 400 mm high. So, really, I shouldn't be going up there, or asking any family members or people who work for me to go up there" (R05AE)*. This is the maintenance challenge presented as definitive inconvenience; this stakeholder was particularly interested in BIPV but could not reconcile with the reality of cleaning the panels.

5.2. Perspective 2: Mandatory Policies Should Be Promoted

The opinions behind this perspective argue that although there is a critical need for sustainable innovations, people do not act without pressure from mandatory policies. Study participants argued that mandatory regulations are a positive force which gives people a 'why' or a reason to adopt BIPV (RO4AE). Thus, policies increase the level of acceptability, which may eventually compel more knowledge or understanding (R05AE). For example, an architect with a research background commented, *"If the government were to make the application of solar PV/BIPV a policy, a part of the building code or regulations" (R12ARE)*, *" ... with mandatory policy control to mandate it "(R18PVE),* stakeholders believe this will lead to a change in the status quo. Two participants said that this kind of mandate would definitely make people start to use said technologies (R18PVE), because *"no one wants to pay a fine"* (R12ARE). On another note, rating systems such as *Estidama*, or DEWA and Abu Dhabi Manuals for Energy and Water (R29OCE), were raised as strategies to further encourage residents to adopt the BIPV technology (R03AE; R13ARE; R16ARE: R32OCE; R34OCE).

However, there was another dimension presented to support this perspective: the place of supporting policies. Stakeholders who participated in the study argued that various mechanisms can be initiated by the government to make both adoption and compliance easier. For example, funding assistance and subsidies were mentioned *"The government should identify the problem as the maintenance and give incentives for companies or research institutions to work out solutions to automated maintenance"* (R28OCE). Another opinion was raised in the light of net metering for rooftop solar in the UAE. *"So, we are not working with a feed-in-tariff here we are working with the net metering; in netting you basically consume what you produce, and if you produce more it's going to be fed into the grid and then basically credited in the future months so that you can actually take it back from the grid; it's a netting mechanism which has been very successful"* (R31OCE). Behind these views is the argument that mandatory policy would serve as a reliable strategy to drive the adoption of BIPV.

5.3. Resolving the Debate

To resolve the debate, it is important to acknowledge that both views are logical. However, to view policy as a proactive solution in the context, requires a combination of theory, facts from literature, the UAE policy landscape and solid analytical data. Once applied, the "policy solution" can be applied to different innovations and different contexts. This section is devoted to systematically applying this solution, based on these considerations. From a theoretical perspective, Wisdom et al. (2014) assert that government policy and regulation are positively associated with innovation adoption. The lack of policy-induced pressure to act, notwithstanding the sustainable drive and agenda of the UAE government, reveals that there is a need for a regulatory framework for BIPV.

To address this scenario, policies such as BIPV-related codes and standards, as well as specific guidelines to direct specifications for product and building integration aspects such as, material selection, thermal properties and fire protection are needed. Policy and code development of BIPV products need to be statutorily backed to define design guidelines and product specifications for manufacture, installation and maintenance. Additionally, the procedure for how BIPV projects are initiated, designed, tendered, vetted and approved is critical. Other suggested policy aspects include fixed or flexible percentages of energy demand covered by BIPV, grid integration and specific policies or guidelines for financial incentives, maintenance, transfer of ownership and approval process. Combined, these strategies could help to address the multi-dimensional barriers which fuel the perspective against both BIPV adoption and mandatory policies which promote innovations in general.

It was discovered during this investigation that a policy framework for BIPV was being studied by the Dubai Electricity and Water Authority's Research and Development Centre (DEWA R&D). This will be a critical step in promoting BIPV, receiving government support and approval to guide the emerging BIPV industry. Considering that the UAE has taken a major stake in the PV industry for over a decade, a timely focus on BIPV's "emerging status" seems to be the next evolutionally step in energy innovation for the country. To fast-track this process, the UAE may well need several departments to support the work carried out by DEWA R&D in BIPV product design, policy development and implementation, and focused research and outreach to both professionals and UAE residents. One strategic approach in this regard would be to corroborate existing work in the Emirates of Abu Dhabi, Dubai and Ras Al Khaimah (RAK), the DEWA R&D Centre and the Energy Efficiency Department and the RAK Municipality through guided collaborations.

In addition, another short term but vital need is regulations geared towards BIPV which relate directly to people and not only the product. The client, developer, consultants and other stakeholders are a critical part of the intangible but very significant ecosystem that drives innovation adoption. Quite beneficial to adoption would be the use of Continuing Professional Development (CPD) courses on BIPV which could be made compulsory for consultants. At some point, stakeholders need to be held accountable and the use of punitive measures considered if policies and regulations are not adhered to.

Two Examples on Resolving the Debate

Based on the findings of the qualitative study, there are over thirty-two adoption barriers and twenty-seven possible drivers of BIPV in the context which have been reported elsewhere [16]. Due to the large number of BIPV adoption barriers extracted from stakeholder views during the study it is difficult to address all barriers within the limits of this paper. However, a detailed interpretative analysis of the multiple barriers and connections between these barriers, both internationally and contextually, has been documented in previous studies [10,11,15,16,36,66].

The novel contribution of this section is to explore a solution to the debate on mandatory policy by engaging a proactive approach using two selected case study barriers. In this section, two of the barriers reported by stakeholders and which formed the basis for the argument against mandatory policies have been selected to show exactly how policy can have a positive effect towards BIPV adoption. Firstly, "poor aesthetics" was selected because it resonates quite importantly with the identity of a BIPV project as both the BIPV modules and the building are influence by this concern. Another reason it was chosen is because, aesthetics connects with both the non-technical client and the professional consultant. Hence, both groups of stakeholders are impacted. Finally, because building aesthetics is both directly and indirectly impacted by the local building code, it falls under the purview of government policy decisions.

The other barrier selected was "the maintenance challenge" which represents the impact of dust and sand covering the BIPV module surface, plus the required frequent maintenance of the modules and other components of the system. This barrier was selected due to the following reasons. One, the context is prone to dust-storms which cover the BIPV modules. Two, the skepticism that specialist skill is needed for all maintenance and cleaning. Three, the inconveniences and cost, and consequently, the lack of interest in BIPV due to this barrier.

Figures 8 and 9 below show the examples of the BIPV adoption barrier "poor aesthetics" and "the maintenance challenge", respectively, with potential drivers and policies which can promote the drivers to address them. The figures are based on interview data collected and suggest that identified barriers can be surprisingly viewed as a platform for systematically promoting adoption.

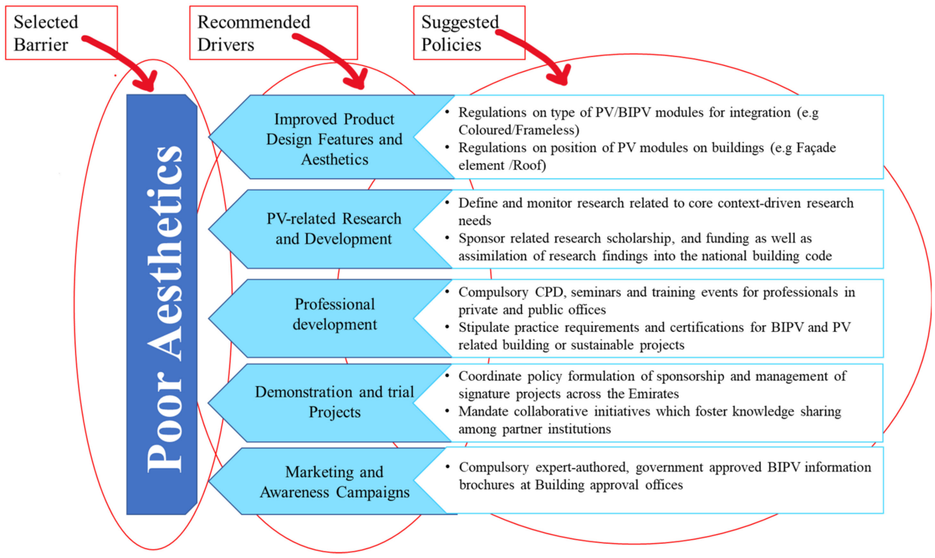

Figure 8. Resolving the poor aesthetics barrier using recommended drivers and suggested policies.

In this example, there are certain key things to note.

1. Poor aesthetics is a barrier which is both "real" and "presumed"; real if one considers that conventional PV modules put on buildings lack aesthetics. On the other hand, it is also deemed "presumed" since there are aesthetically pleasingly colored, flexible and frameless modules in the market. This implies the actual barrier could be a lack of knowledge.
2. For both the "real" and "presumed" concerns, there are specific and potential drivers and some other drivers which apply to both.
3. For "real", improvements to BIPV solutions with enhanced aesthetics can help, as well as PV-related research in this direction.
4. For "presumed", marketing and awareness campaigns as well as professional development programs are recommended.
5. For each driver, a set of suggested mandatory policies are listed. Each policy thus serves to promote the driver which resolves the barrier.

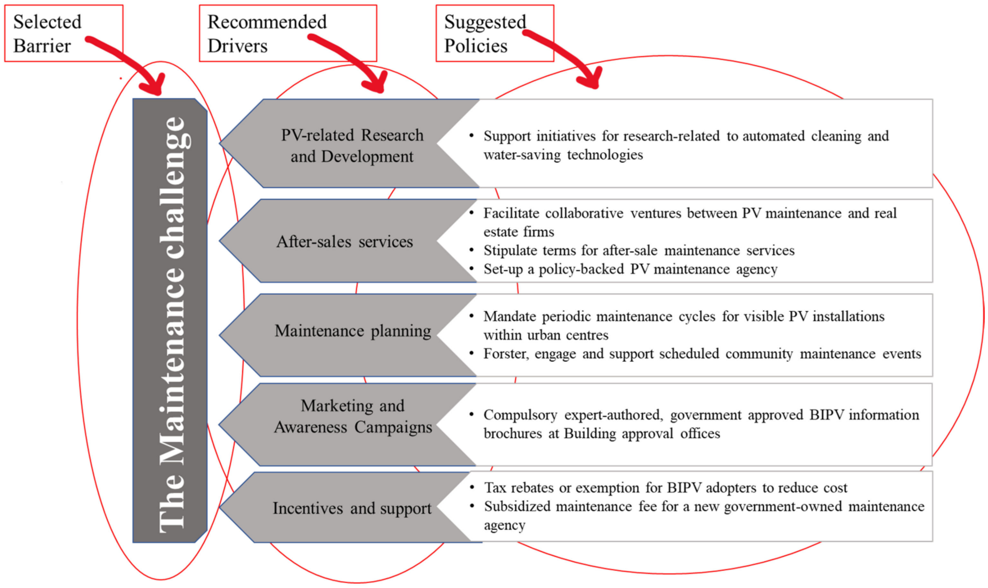

Figure 9. Resolving the maintenance challenge barrier using recommended drivers and suggested policies.

Similar to the resolution of the previous barrier, Figure 9 shows that there are multiple mandatory policies, supported by at least five other adoption drivers which can address this barrier. For example, to promote the research and development driver, policies and support initiatives should be promoted which foster research in automated, low-water, cleaning technologies. Additionally, government energy agencies could be encouraged to setup, sublet or collaborate with PV maintenance firms to provide after-sale services. This would imply that adopters are free of the demand for frequent cleaning, the BIPV value-chain is better structured and industrial or private–public partnerships are encouraged.

The resolution of these barrier examples can be replicated for each barrier and the recommended drivers can be aligned with current trends or literature (Attoye, 2020). The policies suggested serve as a critical means of systematically resolving both the barriers and the debate on the merit of mandatory policies which advance innovation diffusion.

5.4. Further Research

Qualitative studies provide significant and systematically engaging pathways for future research for possibilities for forward-looking researchers. In this study, the attempt has been to use an exploratory qualitative study as the backdrop for investigating BIPV adoption as a case study of innovations. The attention given to policy in this study can be elaborated in other contexts to review a plethora of existing or new policies, to track key performance indicators or to explore other innovation drivers.

There are several aspects for future studies which this study provides, relating to methodology, scope and region. Firstly, a quantitative study could be deployed to generalize the findings, explore a wider range of potential perspectives and review existing policies from the view of residents. Secondly, there are specific issues which this study was not able to investigate due to the fact that it is one of the first in the region. Consequently, other researchers may choose to focus on a more structured scope such as the role of construction innovation principles and practices in the UAE in relation to the UAE building code. Elaborations from a theoretical, conceptual, ideological or statistical position may also be engaged. Finally, the UAE is composed of seven different emirates with energy and governance patterns which differ slightly. In relation to energy and the built environment, studies which focus on a particular emirate or a different country entirely, which review the diffusion of innovations in line with energy policies may provide significant insight.

Additionally, comparative studies across the country, reviewed with data from studies in other countries, would provide lessons and new insights which may be applicable to promote global renewable energy transition. Comparative studies relating to BIPV might provide evidence for the profitability of drivers or, a deeper understanding of the nature of different barriers when they occur in different contexts. These studies can be significantly useful to ensure that proposed strategies are pre-tested before they are applied and may potentially provide similar insight to quantify the impact of barriers. Several options exist for comparative evaluations, these may include reviewing acceptance rates, directed towards financial versus non-financial incentives and strategies for addressing environmental barriers in desert versus tropical or temperate climates. Others may relate to policies, design preferences, ownership status including renters versus owners and peer influence in various countries.

6. Conclusions

This study focused on the the challenges of BIPV adoption as an innovative energy technology and the debate surrounding the use of mandatory polices in promoting renewable energy transition. BIPV was used as an example of sustainable energy innovations which reduce the negative impact of buildings on the environment. The comments from 86 stakeholders who participated in this study were analyzed and they revealed two opposing perspectives which fuel the debate behind mandatory policy. One set of views argues that without policies there will be no adoption or change. The other perspective disagrees on the basis of the fact that the innovation has significant challenges; thus, mandatory policies are not practical. To resolve the debate, policy was discussed in light of three critical points: it has served as a driver in other large-scale projects, it can be used to promote recommended drivers which will address specific barriers and finally, policy is a flexible tool, a systematically strategic means of motivating change, providing financial and non-financial support. This adaptability of policy was presented using a simple but pragmatic network diagram which serves as a planning tool to track and resolve innovation barriers with policy-backed drivers.

In conclusion, buildings need innovations and innovations need policies, but policies need to be developed based on a clear insight into stakeholder perspectives to truly promote adoption and change. In addition, recommended drivers and supporting incentives or policies, provide the critical help necessary to reduce complications with adoption while also resolving the debate which surrounds the diffusion of renewable energy innovations.

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