The Architectural Perception of Incorporating Innovative Solar Energy technologies in the Built Environment

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Abstract

Architecture is increasingly becoming interrelated with environmental techniques and sustainability for several reasons including: climate change mitigation; maintaining the environment and attaining human comfort while saving energy. Incorporating solar technologies in the built environment represents a promising source of renewable energy due to the freely available sun.

The perception of architects, engineers, other building professionals and researchers was investigated via an international web-based questionnaire which received 1,295 valid responses. The perceptions, limitations, and recommendations of the participants were analyzed quantitatively and qualitatively. Statistical tests were used to weigh the responses of architects versus engineers and other professionals.

The solar energy technologies were seen by the respondents as an extremely positive contributor to a sustainable built environment. Sustainable factors such as energy saving, and reducing carbon dioxide were highly admired by the participants. Clients were found to play an essential role in incorporating innovative technologies in buildings; however, the priority of incorporation was given to multi-function technologies which combine an energy purpose with architectural design needs. The participants were most supportive of using Domestic Hot Water and photovoltaic for new and refurbished residential buildings and least supportive of wind energy. The outcomes of this study provide valuable information of incorporating innovative solar systems in the built environment which is necessary for researchers and professionals in the buildings sector.

KEYWORDS: solar energy, incorporation/integration, sustainable, architect(s), built environment

1. INTRODUCTION

The built environment is generally powered by fossil fuel energy sources which contribute carbon dioxide (CO_2) emissions and have an impact on climate change. Due to climate change, the buildings' architecture is predicted to be affected in terms of construction methodologies, design features and regulations, comfort level and so forth (Bates et al., 2008). These variable measures comprise challenges for researchers, architects and policy makers to maintain communities against the escalating climate change problem. The mitigation of climate change along with energy efficiency and satisfying human comfort requirements; are all reasons which encourage architecture to increasingly become interrelated with environmental techniques and sustainability.

Energy is a principal factor for any nation's economic development. There are abundant supplies of renewable energy on Earth; and switching to renewable energy sources, backed by an energy saving regime, is a practical approach to substitute fossil fuels. Renewable energy can be supplied to buildings from power plants or generated on-site using integrated technology (Levine et al., 2007). The renewable energy sources for buildings integration considered in this paper are: solar, wind, and geothermal, where the first two are the most common in building envelopes.

2. LITERATURE REVIEW

2.1 Energy Integration

Contemporary renewable energy technologies have steadily been developing since the late 1970s with some government support, particularly in the European Union. The last decade witnessed super-charged growth rates in grid source energy development (Flavin, 2008). Notably, a continuous and rapid growth capacity was reported in 2009 by the status report of the Renewable Energy Policy Network for the 21st century. In particular, an increased growth capacity of 41% was reported for solar thermal. Hence, increasing interest in solar and wind energy is apparent in the recent years (REN21, 2010).

The increased CO_2 emissions from buildings sector have resulted in European Directives and national legislation and incentives to encourage energy efficiency and renewable energy use. These emissions exceeded 48.7% of the total global GHG emissions in 2011 (Mazria, 2011). Within buildings, solar is one of the more commonly adopted renewable energy sources. This may be because designers are already familiar with the concept of utilizing daylight and passive solar energy. In addition, active solar heating systems and photovoltaics can be incorporated into the building envelope. There are also hybrid systems which combine both active solar thermal and photovoltaics. Building integrated solar thermal energy can be used to supply domestic hot water (DHW) and/or space heating or cooling. Solar thermal heating applications, particularly domestic water heating, are very common in Mediterranean areas. However, comprehensive advances in solar thermal integration and performance are essential if solar energy is to substitute for conventional sources of energy.

2.2 Integrated Design

Integrated design intensifies comprehensive involvement of all building stakeholders in the design process from concept till hand-over. Therefore, the building designers are multi-disciplinary teams with professional knowledge and the capability to integrate the vital parts of the whole design (Prowler and Vierra, 2008; Hestnes, 1999). However, many recent solar thermal building integrations have suffered from poor architectural quality which discourages future integrations (Probst and Roecker, 2011). Solar collectors are commonly mounted onto buildings' roofs as purely technical elements; therefore, there is an increasing demand for attractive architectural incorporation. This integration should combine passive design techniques as a basic requisite. Moreover, it has to supply the required heating, cooling, and power from renewable sources (NREL, 2011).

The integrated design process (IDP) draws the road map for designers and stakeholders which has been described by Larsson (2002) as "… a method for realizing high performance buildings …. It is a collaborative process that focuses on the design, construction, operation and occupancy of a building over its complete life-cycle. [and which helps to] develop and realize clearly defined and challenging functional, environmental and economic goals and objectives". It has eight concert objectives to achieve a successful holistic design such as sustainability, aesthetics, and function. A further important term within the whole building design is the integrated process team which includes client, architect, and other stakeholders. Yudelson (2009) mentioned that IDP is becoming more common than conventional design process as many architects in the world are increasingly approaching integration design.

2.2 Research Rationale

The building integration of solar and wind energy remains uncommon. Architects usually lead design teams; hence, they are thought to have the upper hand in integrating such a technology. Therefore, the shortage of building integrated renewable energy technologies is often attributed to low awareness or lack of acceptance by the architects. It is also possible that building owners and investors could be part of the problem.

This paper reports the views of architects, engineers and other building professionals on the perception of integrating renewable energy into buildings and the potential preferences for future integration schemes. Similar studies in the past (e.g. Horvat et al (2011)) have suffered from a lack of statistical analysis. This paper aims to fill this gap.

3. METHOD

The problem was deemed to be a global one. For this reason a web-based questionnaire was designed to ease accessibility for international respondents and to accommodate a large number of participants. The participants were architects, engineers, and other academics and professionals in building design and construction. This study group was accessed via professional associations in each country.

The questionnaire was designed to study parameters such as awareness, perception, preference, limitations, and recommendations of the technology and integration. The questionnaire was tested using a pilot study with selected experts in the UK. After minor modifications, the questionnaire was distributed, with a geographical focus on countries which may benefit from building integrated solar technologies (such as Canada, USA, UK and mainland Europe).

1,295 valid responses were received. These were analysed quantitatively and qualitatively. The data is non-parametric; therefore, there are two suitable statistical tests to address the data: 1. "Pearson's Chi-square test" which explores the significance of relationship and association between two categorical variables, and 2."Spearman's correlation coefficient" which determines the correlational strength and direction between variables (Pallant, 2010; and Field, 2009). The software used to carry these investigations is IBM SPSS 20 "Statistical Product and Service Solutions".

4. RESULTS

The respondents were categorized into three groups in order to allow comparative analysis; 62.1% architects, 22.9% engineers, and 15% other professions. Respondents had a wide range of years of experience, with 64.6% of them having more than 15 years of experience. 73 countries were represented by the respondents. 29.5% from USA, 29.4% from UK, 24.6% from Mainland Europe and 9.6% from Canada.

4.1 Sustainable Characteristics

4.1.1 Contribution to Sustainable Built Environment

The participant's outlook on the contribution of solar energy technologies towards sustainable built environment was explored. 91.4% of the respondents agreed that solar energy technologies made a positive contribution towards the creation of a sustainable built environment. Statistically, there is no significant association between this opinion and profession, work field, academic degree, years of experience or awareness of solar thermal.

4.1.2 Sustainability of Solar Thermal

Having established support for solar energy technologies, the participants' perception of solar thermal technologies was also explored. Almost 78.6% of respondents agreed that they viewed solar thermal technologies as contributing towards the creation of a sustainable built environment (Fig. 1). A slight difference between geographic regions was noticed. The most positive responses were from the Middle East and Australia (87.7%), then Canada (83.9%), Mainland Europe (82%), USA (79.2%) and then the UK (71.4%). However, more UK participants had no opinion (23.4%) than the other regions (16.7% USA, 12.6% Mainland Euorpe, 10.3% Canada, and 7.0% Other Countries).

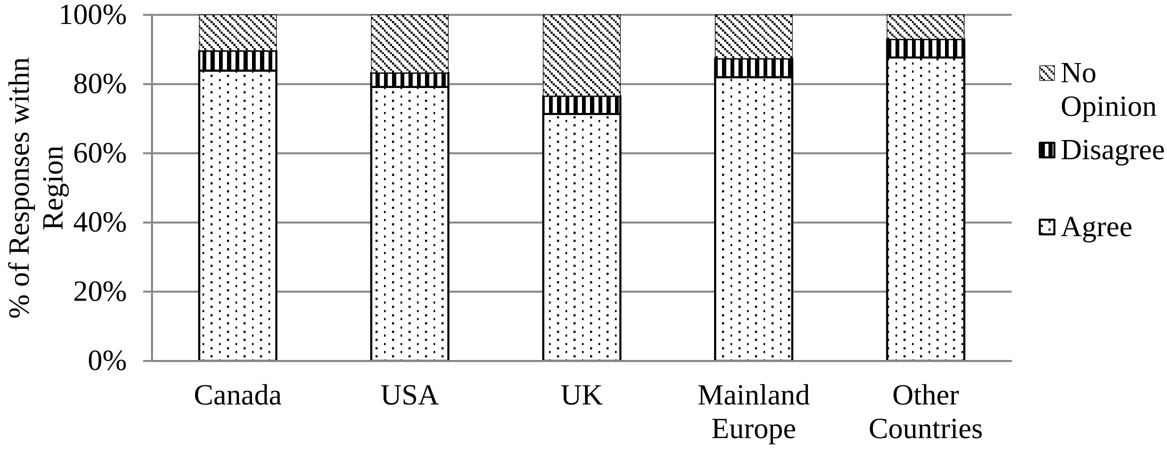

Figure 1. Level of agreement with the statement "Transpired Solar thermal technology, as a source of comparatively low-cost renewable energy, makes a positive contribution towards the creation of a sustainable built environment". Presented based on region of respondent.

4.1.3 Sustainable Factors

Six specific sustainability factors were assessed (i.e. indoor thermal comfort, reducing carbon dioxide, improving indoor air quality, energy saving, cost effectiveness and material used) for importance in relation to solar thermal installations. These were assessed on a Likert scale (-2, -1, 0, +1, +2) where -2 represented "no importance at all" and +2 represented "significant importance". The Likert scale was transposed onto a numerical scale of ±100 (-100, -50, 0, +50, +100) in order to allow the Mean Value to be reported in a percentage form. The -100 represents rating of 'no importance at all' while the +100 represents 'significant importance' and 0 remains neutral. The mathematical mean was calculated statistically for the overall rating of the factors as shown in figure 2.

The factor of energy saving was rated as the most important with mean value of 81.3%. It was followed by indoor thermal comfort (66.7%), then cost effectiveness (58.9%) and reducing CO_2 emissions (58.1%). Indoor thermal comfort and improving indoor air quality was more supported by Architects and Other Professions than by Engineers.

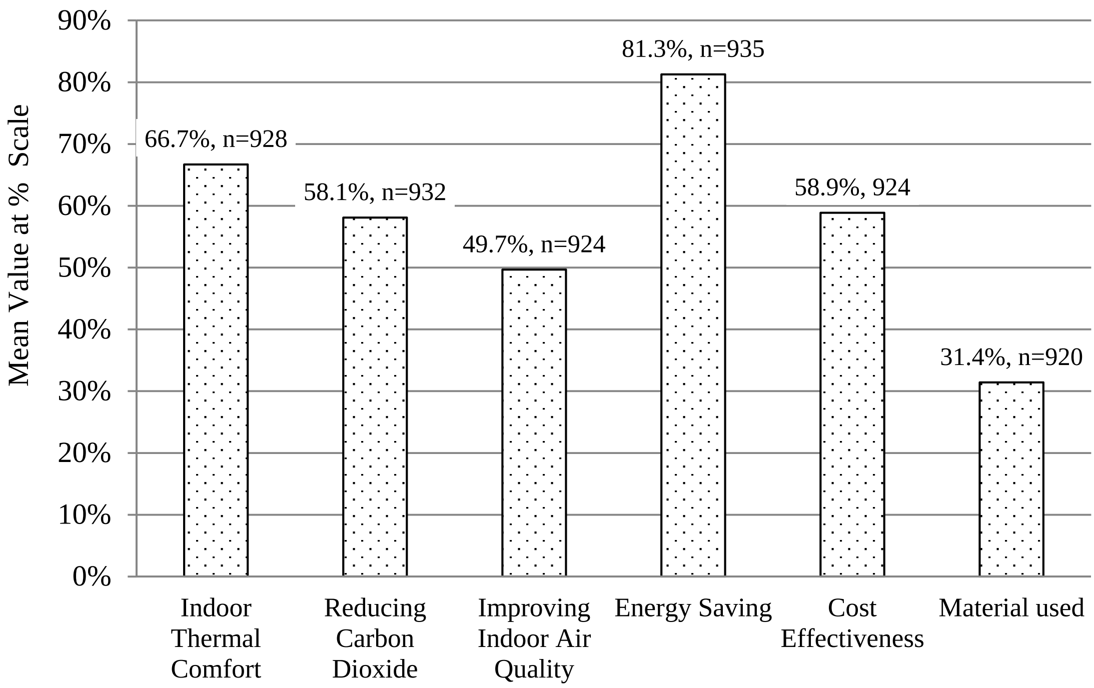

Figure 2. Mathematical mean value of the overall rating of sustainable factors at a ±100 scale, it represents the importance of the sustainable design factors of solar thermal in buildings.

4.1.4 Technical Characteristics

The technical characteristic features of solar thermal technology (i.e. reliabilty, durability, life span, warranty, maintenance, low capital cost) were assessed in terms of importance.. The respondents indicated that reliability is of the highest importance (46%, n=423). In the questionnaire, reliability was defined as constant performance and efficiency exceeding 75%. The next most important characteristic was Low Capital Cost.

4.2 Selection Priority

4.2.1 Client Influence

The clients were found to play an essential role in incorporating innovative technologies in buildings. 74.2% of the respondents indicated that the client had absolute authority in selecting solar thermal type and use for domestic buildings. Although the figure was lower for non-domestic buildings (58.7%), this still shows the client as having a strong role in specification of such technologies.

4.2.1 Function

Respondents were asked to identify the priority for selecting solar thermal technology. Should it function as an energy source, aesthetic element or in a multi-functional way as an architectural design element which satisfies the technical purpose in an aesthetic manner. The multi-functional role was most strongly supported (71.6%, n=685) followed by function (68.4%, n=655) and then aesthetics (49.9%, n=478).

Architects were found to prioritize the multi-functional role more than other professions. Architects also prized the individual aesthetic role more highly than other professions.

4.2.2 New Residential

The preferred technology to be integrated on a new residential building was explored. The options given were Transpired Solar Collector (TSC), Photovoltaics (PV), Hybrid TSC/PV, solar water heating (DHW), wind and ground source heating pump (GHP). Respondents were allowed to choose more than one option. Solar water heating (DHW) was the first choice (70.43%, n=648) followed by ground source heating pump (GHP) (59.02%, n=543), and hybrid TSC/PV (56.52%, n=520) as shown in Figure 3.

Respondents from Other Countries (50%), America (46.3%) and Canada (43.7%) were more likely to select TSC than respondents from Europe (29.9%) and Britain (36.7%). The situation was different for PV; where respondents from Other Countries (62.1%), Britain (62.1%), and America (54.7%) were more likely to select PV technology than respondents from Canada (43.7%) and Europe (44.2%). Wind energy was most supported by respondents from Other Countries (22.4%, n=13) and USA (20.9%, n=60), whereas GHP was most supported by USA (67.6%, n=194).

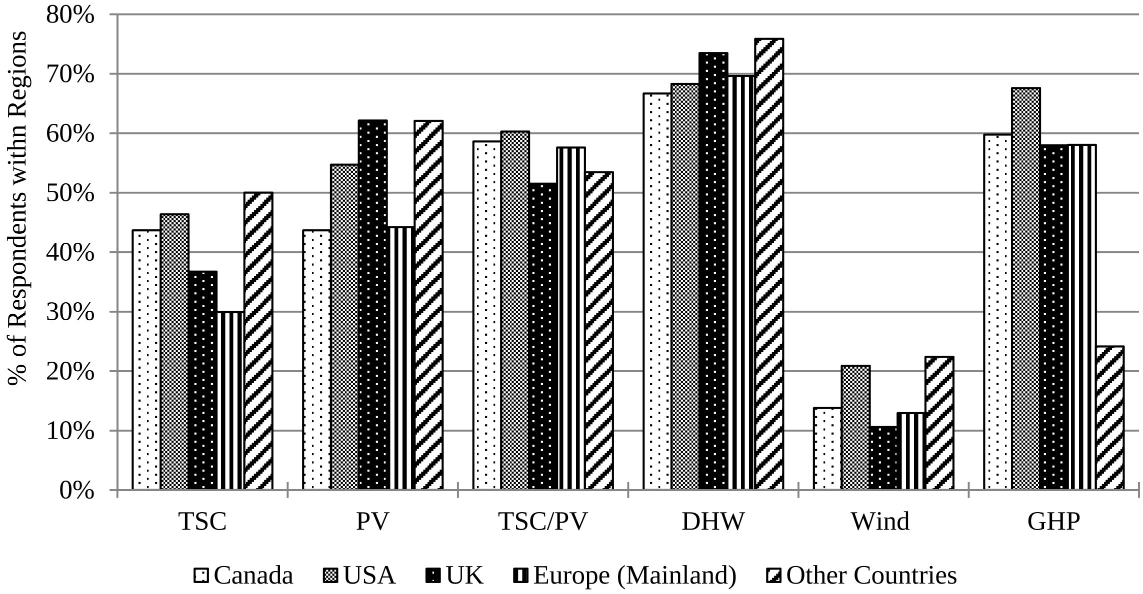

Figure 3: Technology selection preferences for new residential buildings, illustrated by geographical location.
TSC: Transpired solar collectors (thermal), PV: Photovoltaic, DHW: Domestic hot water, GHP: Ground source heating pump

4.2.3 Existing Residential

Refurbishment of existing residential buildings faces different design challenges than new buildings. The preferred technology to integrate during refurbishment was explored using the same options as in the last question (4.2.2). Similar to new buildings, solar water heating (DHW) was the first choice (70.7%, n=645), followed by PV (57.1%, n=521) and hybrid TSC/PV (46.1%, n=420) as shown in Figure 4.

As in the last question (4.2.2) the choices varied depending on the geographic location of the respondent. Canadian participants were most committed to TSC (39.5%, n=34). PV had the strongest support from UK participants (66.5%, n=173)

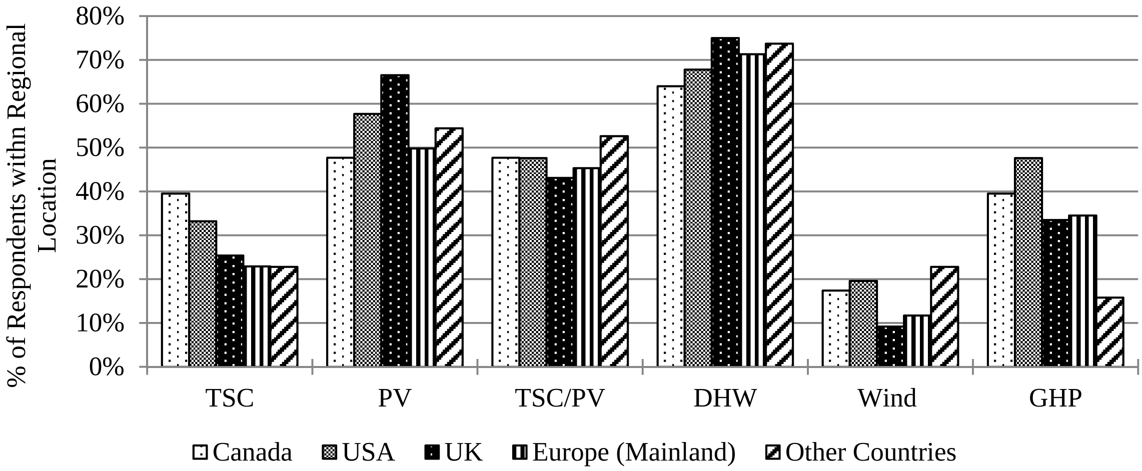

Figure 4: Technology selection preferences for refurbishment of existing residential buildings, illustrated by geographical location.

5. DISCUSSION

91.4% of respondents agreed that solar energy technologies contributed towards a sustainable built environment. This result is in line with responses to the surveys of Horvat et al. (2011) and (Farkas and Horvat (2012)). Solar energy is increasingly of interest to specialists in buildings industry due to its claimed potential to diminish climate change. The statistical analysis indicates that this is a general perception across the respondents (i.e. it is not influenced by geography, profession, etc). Respondents also agree that solar **thermal** technologies contribute towards the creation of sustainable built environment, although this support is not as strong as for solar energy technologies (4.1.2). Although the UK showed lower commitment to solar thermal than other regions, more than two-third of the UK respondents were supportive.

Energy saving has been identified as the most important sustainability factor which has to be satisfied when selecting solar thermal technology (4.1.3), this will also have an impact on utility bills for building owners. Indoor thermal comfort and the reduction of CO_2 emission were also considered to be important. The latter factor is supported by many governments as a step toward reducing climate change. This area might represent a gap between government policy plans and the priorities for building owners. Designers are more likely to prioritize the building owner’s needs rather than the policy plans, as long as regulations are being met. This point requires the study of the professional relation between owners, designers, and policy plans which is outside the scope of this paper.

Clients were found to have absolute authority in selecting innovative technologies for inclusion in buildings. This role was expected as many clients pay significant attention to building materials and design especially when issues such as cost and aesthetics are involved. Hence, within the building IDP team, architects lead the process of incorporating innovative technologies in the design. They furthermore study the potential options in order to propose them for clients’ final decision (4.2.1). Respondents prioritized the multi-functional role of solar thermal technology, where the technology must function as an energy source s well as an integral construction element in the building envelope. Any proposal to a client should therefore be built on this premise.

The most popular technology for new and existing buildings was DHW (4.2.2 and 4.2.3). This may be due to the established use DHW in the Mediterranean. In comparison TSC and PV are more recent technologies. The geographic preferences shown in figures 3 and 4 can be explained. The TSC was developed in Canada and originally patented in North America, so these countries have a longer association with the technology. Its entrance to UK and Mainland Europe is more recent. The strong support for PV technology by UK respondents is attributable to government incentives. However, Canadian and European respondents are less committed to the use of PV panels despite incentive policy plans.

6. CONCLUSIONS

The perception of 1,295 international built environment professionals (62.1% architects, 22.9% engineers, and 15% other professions) was surveyed and statistically analyzed. Solar energy technologies were considered to make a positive contribution towards the creation of sustainable built environment according to 91.4% of the respondents. Slightly fewer respondents (78.6%) also thought that solar thermal technologies contributed towards the creation of a sustainable built environment.

The participants were highly concerned about energy saving as a stand point to select the use of solar thermal technology for buildings. Other factors such as CO_2 reduction and cost effectiveness were also considered to be important.

Building clients were found to have absolute authority in selecting innovative technologies for incorporation in their buildings. However, the IDP team, particularly architects, lead the process of incorporating innovative technologies in the design and advise the clients of the potential benefits of renewable choices. The respondents representing the IDP team favoured the multi-functional role of renewable energy devices in buildings. Of the technologies considered, solar domestic water heating was highly preferred by respondents to be integrated in new residential buildings (70.43%) followed by GHP (59.02%), hybrid TSC/PV (56.52%), PV (53.70%), TSC (39.57%) and finally wind energy (15.43%). The high preference of DHW remained the same for refurbishment of existing residential buildings (70.70%), followed by PV (57.20%), hybrid TSC/PV (46.10%), GHP (37.50%), TSC (28.30%). Wind energy however remained in the end at 14.60% (Fig. 4).

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