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A framework for evaluating WTP for BIPV in residential housing design in developing countries: A case study of North Cyprus

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HIGHLIGHTS

- To explore households' preferences for BIPV system at the design stage in Northern Cyprus.
- A novel methodology was developed to give a better understanding to both suppliers and consumers.
- It uses the virtual platform of BIM technology and teaching method for clarification of terminologies.
- It uses a contingent valuation method to assess the WTP and WTA compensation.

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ABSTRACT

This paper explores people's preferences for a Built in Photovoltaic (BIPV) renewable energy system to be integrated into housing construction. A novel methodology was developed, to study the case of Northern Cyprus, for better understanding of possibilities that abound in BIPV integration. The methodology incorporates Building Information Modeling (BIM) as a real-time design and economic assessment tool for BIPV choices. This serves to benefit both the construction companies and potential house owners in their decision-making. In addition, it uses a Contingent Valuation (CV) method to assess the Willingness to Pay (WTP) and the Willingness to Accept (WTA) compensation. The results indicate that the capital cost of PV is not instrumental in choice, and a lower feed-in tariff could be acceptable.

1. Introduction

The residential sector is heterogeneous in its energy consumption pattern, because it is influenced by many factors. The level of awareness of an individual of the need and the methods of conservation of energy, the nature of the building(s) and their characteristics are some of the factors. The importance of energy conservation cannot be overstated. Parameters influencing energy conservation include the materials used during the construction process and the nature of the construction, geographic and climatic factors, and also the financial status of the individual(s) occupying the building. Residential buildings are considered as a huge and dynamic energy sink (Swan and Ugursal, 2009), they consume a great deal of electricity for cooling and heating systems and for electrical appliances. For instance, in the UK, 34% of energy fed consumption by the residential sector is mainly for space heating. The UK government attempts to reduce this consumption by modifying the building regulations, provision of financial aids and advice to the households on measurement of energy-saving or efficiency and building insulation (Ward, 2008). Studies have been undertaken with the intention of developing new and practical methods and tools for energy conservation and optimization within building spaces. Pless et al. (2007) highlighted certain parameters which should be considered early in the design process such as set points of temperature and humidity, maximum *U*-values of windows and night setback and any other variables with potential impact on energy demand and consumption. Pre-construction energy cost modeling becomes very important because it serves as a major tool for forecasting energy costs especially in the lifecycle operation of a prospective building (Liu et al., 2011).

Renewable energy increases the scope of sources of energy supply as well as saving the non-renewable energy sources. Solar energy is amongst one of the renewable energy sources with a great potential of deployment in residential sector.

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Zhai et al. (2007) argue that Building Integration of Photovoltaic Systems (BIPVs) in residential housing is a fast growing technology. A number of studies on BIPV technology have been carried out in developing countries with the high potential of solar radiation. Haw et al. (2009) assessed the responses of Kuala Lumpur's residents to integration of photovoltaic system into their buildings. In spite of the great potential of solar energy in Malaysia and promising responses by households for adopting BIPV, the system is yet to penetrate into the local market. In many countries across the world, the advantages of solar energy have not been fully harnessed. James et al. (2011) proposed issues such as “declining module costs, growing consumer interest in solar energy and policy schemes” to increase the potential of PV market in residential housing. Eiffert (2003) claim that the technology would be accepted as cost effective if the payback period of investing in a BIPV system does not exceed its life cycle period. BIPVs provide advantages for households to generate their own electricity independently; however, the reliability of electricity in terms of power outages during winter and night times is important. The provision of feed-in tariff and subsidy can aid to promote the uptake of renewable energy in the small scale for the households, since currently the payback period for investing in PV system is not very much encouraging (Willis et al., 2011).

Moreover, the high cost of the initial investment also needs to be subsidized and reduced in price through financial incentives. Effective integration of solar systems in housing design has a higher potential for effective application if the system is integrated during the design of the house (Johnston, 2007). In addition, applying PV after the structure has been built would incur more cost and it sometimes leaves the building with a less pleasing appearance.

There are exhaustive studies that have been carried out to investigate public perceptions on BIPV application. However, fewer studies have considered solar technology as a part of the overall building in residential housing design (Haw et al., 2009; Malagueta et al., 2013; Makrides et al., 2010; Celiktas et al., 2009; Shi et al., 2013).

A number of questions from potential customers regarding BIPV systems can be addressed with the use of a virtual platform and 3D images. The potential users are able to build an ideological experience of what to expect if they accept to adopt the system in their housing design. The design of 3D image through Building Information Modeling (BIM) software makes the possibility of a good level of experience and also provides them with factual information for deciding on their willingness to pay. The economic concept of demand and consumer choice is fundamental for estimating consumer's willingness to pay and willingness to accept. Exploring the consumer's demand elasticity for utilization and purchasing the product is essential for utility estimation. A new product development can be managed by understanding the people's willingness to pay. Stated preference techniques can be used to estimate WTP for goods. Since the value of BIPV is not separately observed in the market, it can be measured through stated preference techniques.

The studies of Scarpa and Willis (2010) examine British, and Claudy et al. (2011) Irish households' willingness to pay for Renewable Energy (RE) microgeneration. Both studies found the high investment cost as a main obstacle, therefore government financial incentives and supports would be required to increase the dissemination of solar technology in the residential sector. The cost effectiveness of the system determines the willingness of people to invest in BIPV systems. Households are one of the major targets for developing BIPVS with the aim of producing electricity for their own usage and also to sell the excess generated electricity to the grid. It is generally accepted that people do not respond truthfully, unless certain incentive measures are adopted (Carson and Groves, 2007). In this study, a framework for appraising the households' maximum willingness to pay for integration of PV into the building at the initial design stage has been proposed. In addition, the study assesses households' minimum WTA compensation for the sale of electricity, generated by the integration of PV design in the building, to the national grid. A case study has been carried out in rural and urban area of Northern Cyprus in order to elaborate the framework.

2. Material and methods

There is a fast growth rate of electricity demand in Northern Cyprus. Cyprus is an island located in the Mediterranean Sea with the total surface of 9250 km^2. According to the World Bank 2012 data, Cyprus' Gross Domestic Product (GDP) per capita is US Dollar 22,767. Based on the 2006 census, total population of Cyprus was approximated to be slightly over 1 million (the Turkish Cypriot population was estimated at 265,100). In 2009, the GDP per capita of North Cyprus was approximately US Dollar 13,354. Recently, small Islands with similar conditions as Cyprus are targeting investing in the existing sources of renewable energy. The purpose is to be independent or at least less dependent on importing high cost fuels and oil as well as leading the community towards green and friendly environment. (van Alphen et al., 2008; Shirley and Kammen, 2013). As an Island located within the Sunbelt region of the Mediterranean, its geothermal and solar energy are great potentials for renewable and sustainable energy sources. Integration and application of PV technology in Cyprus provides various potentials for advancing the technology. Cyprus records one of the highest solar irradiation amongst European countries. Solar irradiation in Cyprus is at an average of 2000 kWh/m^2 yearly on a surface inclined at 27.5°, and about 300 days of sunny weather (Makrides et al., 2010). Using Solar Irradiation Software (SIS), December is the period with the lowest solar irradiation in Nicosia, Cyprus. The average solar irradiation in December was calculated as 2.1 /day when PV panels are tilted at 55° South (Fig. 1). Moreover, North Cyprus is reliant on imported fuels and its natural source of energy has been underutilized. Over the past 40 years, solar irradiance has only been exploited for production of hot water. Accordingly, the application of solar panels for electricity generation in North Cyprus is very low though the potential of utilization is high.

Building Information Modeling (BIM) is an approach to design and construction which provides a systematic way of solving problems. Through this medium, construction companies and potential house users can outline their objectives in key areas before the actual construction of a building. Such objectives include energy efficiency, on-site renewable energy, grid-supplied renewable energy (Barista et al., 2008). BIM provides a comprehensively advanced way of studying building structures from the conceptual stage to the construction period and the eventual lifecycle of the building. The most important part of the BIM system is the “I”, which stands for several layers of INFORMATION. The information that is fed into the virtual application determines the outcome of the final model. There are several softwares for BIM applications. They include Revit, Archicad, Autocad, Navisworks, ECOTECT

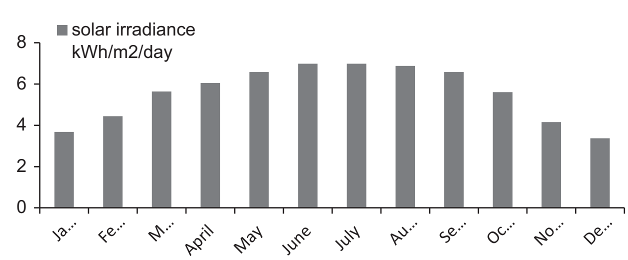

Fig. 1. Estimated solar irradiation for Cyprus (solar collectors tilted at 55° South).