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Photovoltaic low power systems and their environmental impact: Yuma, Arizona, U.S.A. case study and projections for Mexicali, Mexico

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ABSTRACT

This article presents a proposal for the implementation of photovoltaic systems in homes located in Mexicali, Mexico. With exhibition of new insulation and different consumption characteristics. The photovoltaic low power system is proposed as a type of electrical supply that helps in reducing the environmental impact of generating energy by burning fossil fuels. A photovoltaic system installed in the city of Yuma, Arizona in the United States, which supplies the electrical needs to a building is selected as a reference for solar resource use. Energy use improvement and consumption costs are calculated, and the equivalent amounts of greenhouse gases, not generated since solar technologies were implemented are determined. Furthermore, comparisons of the solar potential between Yuma and Mexicali show that the Mexican city has a higher annual solar potential, so the applicability of this solar technology is too feasible in Mexicali.

Contents

1. Introduction

The world faces serious problems related to climate change. CO_2 is a major contributor to the global warming. Therefore, implementation of strategies to achieve a significant reduction in the global emissions is required [1]. A permanent increase in the overall electricity demand is a constant around the world. The availability, cost and sustainability of energy resources have caused instabilities in the supply and production of energy in

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recent years. Moreover, environmental damage has indicated the need for new energy models [2].

The climate scenarios generated by the Intergovernmental Panel on Climate Change [3,4] have exerted strong pressure on experts in the fields of electrical engineering, electronics and mechanics to develop systems using renewable energy resources, particularly solar and wind energy [5] and especially in developed countries [6]. The interest is due to the fact that these clean energy resources can lessen the effects of climate change caused by the use of energy based on fossil fuels, which produces pollutants such as CO_2, among others. Potential methods to address this global problem in the future include the use of photovoltaic and wind systems. In the long term, these systems will constitute a portion of the alternatives that will mitigate the amounts of CO_2 emissions [1,7,8,9,10]. In the past decade, only 13.61% of the worldwide energy demand was supplied by renewable resources [11]. Photovoltaic systems, especially those connected to a network, have experienced strong growth over the past five years, mainly in developed countries. In these countries during 2006, approximately 1.5 GW of photovoltaic capacity was installed, representing an increase of 34% over the previous year. In 2007, a 40% increase of the installed photovoltaic capacity resulted in a total capacity of 7.8 GW [12], indicating that there should be interest not only in renewable energy itself, but also in the related.

This installed systems contrasts with the global photovoltaic market produced which in 2007 produced 2392 MW and Europe accounted for 69% of this. By 2008 the market produced a total of 5559 MW, of which Europe accounted for 81%, though as a result of changes in the Korean and US markets the Asian and American markets also saw a large degree of growth, with the US accounting for 6.2% of the total global market. If these figures are broken down then it becomes clear that the majority of the global market is centered in Spain, Germany, the US and Korea, these four countries, while Belgium, the Czech Republic, Japan and Portugal are currently playing catch up. Globally accumulated PV installed capacity in 2008 has reached 15 GW and European countries accounted for 65% of this, more than 9 GW, while Japan and the US followed closely in 2nd and 3rd place (with Japan accounting for 15% or 2.1 GW and the US accounting for 8% or 1.2 GW) [13].

Urbanization has been the dominant global trend since the middle of the last century, resulting in cities exerting a polarizing effect, reflecting a social product where both poverty and wealth are found, in addition to economic, social and political opportunities [14]. In cities, energy dependence is directly proportional to quality of life. This concept has not always been well understood, as it is often based on distractors and satisfactors and therefore on a waste of energy [15]. It is no wonder, then, that the nations of the world, worried about a polluted environment and a society that has depended heavily on fossil fuels since the late 1880s, have proposed the concept of sustainability, which according to Bruntland [16], indicates that a sustainable society would be one that meets its present needs without compromising resources for future generations. It has been 25 years since this definition was provided, and the dialectical discussion about it continues today. Therefore, it appears the notion of sustainability is a long-term goal [17,18].

In Mexico, currently it is necessary to focus on the sustainable city concept, as it is imperative that we plan these types of cities. One of the essential questions that we must ask ourselves is whether we are able to reorient urban ecosystems that have been built haphazardly, and in a relatively short period of time progressively towards a stage characterized by health, order and energy efficiency. One of the key questions regarding reorienting a city toward sustainability is as follows: is electrical energy sufficient and used efficiently in a way that does not compromise future generations? Answering this question involves implementing strategies such as the proposed Net Zero Energy Buildings [19,20], which would generate as much energy as they consume, whether measured on an annual or monthly basis. The main idea behind this type of construction is that it can meet its energy needs with renewable, locally available and inexpensive sources, making it necessary to evaluate the energy potential of the source of interest in each region. One of the characteristics of Net Zero Energy Buildings is that these buildings both significantly reduce their energy needs and make adjustments for consumption to be reduced to a minimum, in addition to occasionally interacting with conventional supplies [21,22].

Another factor to be considered is construction materials. Todorovis [23] argues that construction should use materials found in the immediate environment, especially renewable urban materials that respect climate characteristics, making it necessary to develop energy efficient construction projects that meet high thermal standards and use eco-materials [24]. However, this is not currently the case in cities around the world, which further exacerbates the problem of supplying residential electricity. Residential areas are affected not only by the planning and design of constructions, but also by the density of the green canopy and the complex influence of anthropogenically generated heat [25]. Urbanization that is not linked to sustainability alters the native ground cover in a region and leads to a modified thermal climate. Different sets of micro- and meso-scale climates are therefore generated, giving rise to the well-known urban heat island (UHI) effect, which has been studied extensively in several cities around the world [26,27,28,29] and has practical implications for energy and water conservation, human health and comfort, pollutant dispersion and local air circulation [30,31]. All of these impacts on a city and its inhabitants can be mitigated by following proposals of power generation using natural resources, such as solar energy, which is the most abundant, inexhaustible and cleanest of all the renewable energy sources known to exist. The amount of solar power intercepted by the Earth is approximately 1.8×10^{11} MW, which exceeds the current rate of all energy consumption [32]. Moreover, covering 0.16% of the land on earth with solar conversion systems with a 10% efficiency would provide 20 TW of power, which is nearly twice the world consumption of fossil fuel-based energy [33].

Considering all of these factors, the present study was proposed with the following aims: (1) to evaluate the solar potential in the city of Mexicali, B.C., Mexico, using global solar radiation measurements; (2) to compare this potential with that of the city of Yuma, AZ, USA, where solar resources are currently used to power a building on the main Arizona Western College (AWC) campus; and (3) to conduct an analysis in terms of power consumption and economic and environmental impacts of the possible use of solar resources in Mexicali, B.C., and their relationship with respect to zero energy use compared with what actually occurs in the city of Yuma, AZ.

2. Methodology

The study was conducted in northwestern Mexico at the border with the United States using two cities, one in Mexico (Mexicali, B.C.) and the other in United States (Yuma, AZ), as a case study. The methodology employed in the study is presented in three sections: (1) Measurements of the solar resources in Mexicali, (2) Measurements of the solar resources in Yuma and (3) Analysis of the associated electricity demand, cost of household consumption and environmental benefits.

2.1. Measurements of the solar resources in Mexicali

This stage was developed based on radiometric measurements recorded in Mexicali through the weather station of the Institute