



Determining the sustainability of large-scale photovoltaic solar power plants



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ABSTRACT

This paper highlights an evaluation of the potential level and nature of sustainability for large-scale photovoltaic (PV) solar power plants. This was achieved by applying a mathematical model of sustainability to the results of a qualitative-based environmental impact evaluation of the installation and operation of large-scale solar power plants.

The results from the model application indicated that large-scale PV solar power plants were conducive to achieving strong sustainability. This was because of the significant environmental benefits derived from PV solar power plants in respect to its construction and operation, as well as the minimum impacts derived from anthropogenic sources. This paper however notes that PV solar technology requires significant improvements in the conversion of sunlight to electric energy. This paper concludes that PV solar power plants offer a potentially significant and sustainable source of energy.

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1. Introduction

1.1. Purpose of paper

This paper continues our previous work on the quantitative evaluation of the sustainability and unsustainability of renewable energy by the application of a mathematical model. The mathematical model of sustainability and its application were first highlighted in respect to geothermal energy [1]. In this paper, we turn our focus to solar energy, and the sustainability of the installation and operation of large-scale photovoltaic (PV) solar power plants. This is based upon the work of Turney and Fthenakis [2]. In their paper, they conducted a qualitative-based assessment of the impacts derived from installing and operating large-scale PV solar power plants in the United States of America (U.S.A.). This was based on a comparison to traditional sources of electricity generation.

In this paper, we develop a quantitative scale to convert their original results into an appropriate numerical value for each category assessed. We then adopt these values to apply the model to determine, if appropriate, the level and nature of sustainability of large-scale PV solar power plants. The results should provide an indication as to whether large-scale PV solar power plants can be considered as sustainable or unsustainable.

1.2. The energy problem

During the last few decades, significant levels of demand for energy have become an increasing source of concern. This is because energy is essential to both socio-economic development and improving the quality of life in all countries [3]. The increased use of fossil fuels and other natural resources, on which humanity relies for their own survival and well-being, is the associated consequence of impacts upon the environment, specifically through damage to the air, climate, water, land and wildlife [4]. Consequently, if current energy approaches are considered as unsustainable in respect to environmental, economic and social considerations, then viable alternatives are required to meet the current and future global demand for energy. Because of the seriousness of the potential threat posed by global environmental change, strongly inferred to be predominantly anthropogenically induced, there is an increasing stress upon traditional sources of energy against the backdrop of increasing global demand, which has caused the pursuit of renewable sources of energy generation.

In the year 2000, renewable energy (e.g. biomass, hydroelectric, solar, wave, tidal, and wind) accounted for 14% of the current total global energy demand [5]. Renewable sources of energy are expected to increase significantly as humans attempt to avert the potentially catastrophic effects of global environmental change. According to Fridleifsson [6], energy generated by renewable sources is expected to significantly rise to 30–80% by 2100. Kralova and Sjobolm [7] highlighted significant increases to the use of global renewable energy by 2040 in their modelled scenario. This scenario in respect to energy consumption from solar energy technologies, all renewable sources, and all energy sources is shown in Fig. 1. Of all of the energy alternatives that have been suggested in the literature as a viable mass generation source of renewable energy, solar energy is repeatedly considered as such a source.

1.3. Sustainability and solar energy

1.3.1. Sustainable development and energy

Sustainable development has entered into the conscience of humanity during the last 25 years. The most well-known definition was stated by the World Commission on Environment and

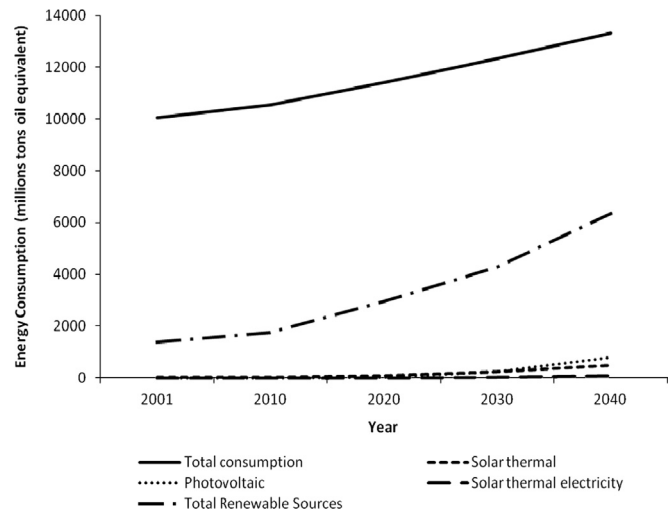


Fig. 1. Global renewable energy scenarios by 2040, after Kralova and Sjobolm [7], with specific focus on consumption from solar energy technologies compared to total consumption from all renewable sources and overall total energy consumption (renewable and non-renewable).

Development (WCED) which defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [8]. However, when the literature cites this definition, the two associated caveats are often not stated in conjunction with the WCED’s definition. The two caveats are both concerned with the limitations and ability of the environment to meet present and future needs in respect to the following: (1) The state of technology and (2) the social organisation [8]. These caveats and the definition provided were intended to address the concern at the time of the increasing needs of developing countries, such as India and China. This concern was in respect of such countries utilising their natural resources at a significantly increasing rate to achieve economic development, or developing countries where resources were limited and/or near to exhaustion against the backdrop of excessively rising populations and famine. So whilst the WCED report did engender a new spirit of global environmental conscience and action, there has been a growing concern that the goals of sustainable development to achieve a balanced approach towards environment, social and economic outcomes have been compromised [9].

The development of sustainable energy is one of the biggest challenges for humanity in the 21st century [10,11]. The significant economic expansion that has occurred since the Industrial Revolution has been strongly related to the use and production of energy [12]. The use of fossil fuels as the source of energy has driven this expansion [12]. However, as the IPCC [13] reported, this in turn has caused large-scale rises in emissions of greenhouse gases. As a direct consequence, this has caused significant environmental and economic impacts through climate change [13].

Therefore, the issue is how to produce cleaner and sustainable sources of energy for the future, particularly in rapidly economically expanding economies such as China and India, where the demand for energy currently is the greatest [12]. In part, this demand is greater in such countries because of their high levels of population and the consequential increasing expectations for improved living standards and quality of life. Consequently, finding clean and significant energy sources that are renewable has become an imperative and it is as one of the goals to achieve sustainable development. It was for this reason that research into developing solar energy as a mass source of energy generation has gathered pace.

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