

Performance analysis in terms of carbon credit earned on annualized uniform cost of glazed hybrid photovoltaic thermal air collector

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Received 26 April 2014; received in revised form 22 January 2015; accepted 4 February 2015

Available online 22 March 2015

Communicated by: Associate Editor Bibek Bandyopadhyay

Abstract

In this paper, the Performance analysis in terms of effect of carbon credit earned on annualized uniform cost of glazed hybrid photovoltaic thermal air collector on the basis of annual thermal energy and exergy have been analyzed for New Delhi climatic conditions. The effect of interest rates on annualized uniform cost has also been evaluated. For the lifetime (30 year) analysis, the carbon emission reduction comes to Rs 109,242 and Rs 25275.6 on the basis of overall thermal energy and exergy basis. It has also been observed that there is significant decrease in annualized uniform cost due to carbon credit earned.

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Keywords: Annualisation uniform cost; Energy pay back time; Electricity production factor; Carbon credits

1. Introduction

At first, the energy analysis of a PV module has been done by Slesser and Hounam (1976) and it has been reported that the energy payback time (EPBT) of a PV module is 40 years. A similar study has been conducted by Hunt (1976) and he has arrived at a value of 12 years for the energy payback time of a PV module. The result reported by Hunt (1976) has also in general agreement with those of Kato et al. (1998) for

crystalline silicon (c-Si) solar cell module. Aulich et al. (1986) have evaluated the EPBT for a crystalline silicon module and it has been concluded that the EPBT is 8 years; in this case plastic materials have been used for encapsulation for Siemens crystalline process. The EPBT for a crystalline silicon (c-Si) solar cell module under Indian climatic condition for annual peak load duration is about four years (Prakash and Bansal, 1995). Alsema and Nieuwlaar (2000) have attempted to forecast the EPBT for a mono-crystalline solar cell for the year 2020, taking into account the improved technology and the efficiency of the solar cell; it has been concluded that the present EPBT, which is 5–6 years, gets reduced to 1.5–2 years.

Keolein and Lewis (1997) have predicted the EPBT for an amorphous silicon (a-Si) solar cell module with efficiency of 5% as 7.4 years for the climatic conditions of

Abbreviations: CRF, Capital recovery factor; EPBT, Energy pay back time; EPF, energy production factor; FF, fill factor; LCCE, life cycle conversion efficiency; PVT, photovoltaic thermal; tCO₂e, tons of CO₂ equivalent; Unacost, annualized uniform cost.

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Detroit, USA; the EPBT gets reduced to 4.1 years with the increase in the efficiency of the module to 9%. [Srinivas et al. \(1992\)](#) have reported that the EPBT for an amorphous silicon (a-Si) solar cell module reduces to 2.6 years after considering gross energy requirement (GER) and the hidden energy. [Yamada et al. \(1995\)](#) have evaluated the EPBT for both polycrystalline and an amorphous silicon solar cell and reported that the EPBT for these cells are 5.7 and 6.3 years, respectively at the annual power production rate of 0.01 GW/y. [Battisti and Corrado \(2005\)](#) have investigated the EPBT for a conventional multi-crystalline building integrated system, retrofitted on a tilted roof, located in Rome (Italy) with the yearly global insolation on a horizontal plane has been taken as 1530 kW h/m² per year. They have concluded that the EPBT gets reduced from 3.3 years to 2.8 years. Based on the worldwide survey, [Gaiddon and Jedliczka \(2006\)](#) have presented the comparative assessment of selected environmental indicators of photovoltaic electricity in OECD cities. They found that the EPBT of a complete PV system was in the range of 1.6 to 3.3 years for a roof-mounted system and from 2.7 to 4.7 years for a PV-façade and energy return factor (ERF) is between 8 and 18 for roof-mounted systems and between 5.4 and 10 for PV façades considering 30 years long commercial life cycle. They have also found that the one single kWp of PV panels can avoid up to 40 tons of carbon dioxide (CO₂) during its whole commercial life and 23.5 tons of CO₂ per kWp for PV façades.

Life cycle assessment study of a 4.2 kW stand-alone photovoltaic system has been studied by [Valverde et al. \(2009\)](#) and they showed the CO₂ emission reduction potential of SAPV systems in southern European countries and point out the critical environmental issues in these systems. The study of the thermal performance, economics and environmental protection using thermosiphon solar water heating system has been presented by [Kalogirou \(2009\)](#). His finding shows that the system gives positive and very promising financial characteristics with payback time of 2.7 years and life cycle savings of € 2240 with electricity backup and payback time of 4.5 years and life cycle savings of € 1056 with diesel backup. In other words, the saving compared to a conventional system is about 70% for electricity or diesel backup. Life cycle analysis for future photovoltaic systems using hybrid solar cells has been discussed by [Azzopardi and Mutale \(2010\)](#) and they observed that comparable criteria for sustainability of electricity-generating systems namely net energy ratio (NER), energy pay-back time (EPBT) and CO₂ emissions per unit generated during life time are found to be lower than current commercially available PV modules. [Norton et al. \(2010\)](#) have given the solution to enhance the performance of building integrated photovoltaic. A case study on thermal vs photovoltaic electricity has been discussed by [Brown et al. \(2012\)](#) and they computed the Energy yield ration (EYR) including services are 6.8 for thermal electricity and 2.2 for PV electricity.

Carbon credit trading (Emission Trading) is an administrative approach used to control the pollution by providing economic incentives for achieving reductions in the emissions of pollutants. A credit means, owner have a right to emit one ton of carbon dioxide equivalent (1 credit = 1 tCO₂e). At present, our annual economic growth rate is 8–10% per annum. For energy, India depends on oil and gas imports, which accounts for over 65% of its consumption, it is likely to increase further considering the economic development, rise in the living condition of people and rising prices. India will exhaust its oil reserves in 22 years, its gas reserves in 30 years and its coal reserves in 80 years. More alarming, the coal reserves might disappear in less than 40 years if India continues to grow at 8% a year, [Kalshian \(2006\)](#).

Analysis of HPVT air collector, single and double pass, for different Indian climatic conditions of Jodhpur, Mumbai, Srinagar and Bangalore has been carried out by [Raman and Tiwari \(2008\)](#) and concluded that the cost/kW h for climatic (hot and dry) conditions of Jodhpur is most economical among others. [Tonui and Tripanagnostopoulos \(2008\)](#) have developed a low cost modification technique to enhance heat transfer to the air stream in the air. They have validated their results with experimental data for both glazed and unglazed PVT proto-type model. Climate change has been recognized as one of the greatest threats of the twenty-first century. Photovoltaic energy conversion is one of the technologies for which high expectations exist with regard to its potential for CO₂ mitigation. [Prabhakant and Tiwari \(2008\)](#) calculated the carbon credit earned by solar energy park, IIT Delhi including PVT system and recommended to develop such type of park in country to mitigate the carbon dioxide and earn the carbon credit. [Chaurey and Kandpal \(2009\)](#) have attempted to estimate the CO₂ mitigation potential of solar home system (SHS) in India by studying the potential for their diffusion and the appropriate baseline. They found that carbon finance could reduce the effective burden of SHS to the user by 19% if carbon prices are \$10/t CO₂ without transaction cost. [Purohit \(2009\)](#) has also attempted to estimate the CO₂ mitigation potential of solar home systems under the CDM in India. The theoretical potential number of solar home systems has been estimated to be 97 million. There are many parameters that affect the electrical efficiency of a hybrid PVT module air collector like thickness of the glass and Tedlar, temperature of the inlet flow, solar cell temperature and etc. Energy and Exergy analysis of hybrid photovoltaic system double pass air collector has been done by [Kamthania et al. \(2011\)](#) and concluded that double pass air collector gives better performance in comparison to single pass. All equations for solar cell and thermal collector have been derived in [Agrawal and Tiwari 2011](#) and comprehensive discussion and optimization design have been discussed. Hybrid photovoltaic/thermal collectors (PVT) consist of common photovoltaic modules

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