Renewable and Sustainable Energy Reviews 41 (2015) 1288–1297

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Economic analysis of the contribution of photovoltaics to the decarbonization of the power sector

J. Hernández-Moro [a], J.M. Martínez-Duart [b,*]

[a] Applied Physics Department (C-XII), Autónoma University of Madrid, Campus de Cantoblanco, E-28049 Madrid, Spain
[b] Applied Physics Department (C-XII) and N. Cabrera Materials Institute, Autónoma University of Madrid, Campus de Cantoblanco, E-28049 Madrid, Spain

ARTICLE INFO

Article history:
Received 15 April 2014
Received in revised form
17 August 2014
Accepted 17 September 2014

Keywords:
Photovoltaics
Decarbonization
Unit emissions costs

ABSTRACT

An analytical method has been developed for the calculation of the future (2013–2050) reduction of CO_2 emissions by the deployment of photovoltaic (PV) systems according to three Scenarios from the International Energy Agency (2DS, Roadmap and New Policies). Next, we have also evaluated the financial extra-costs incurred in the implementation of the PV systems which would replace the current traditional power generation systems, taking as reference four geographical areas: European Union, United States, China, and the world's average. The established method also allows the comparison of the influence on the extra-costs of the actual electricity mix, as well as the current electricity prices, corresponding to the above regional areas. In these calculations, we have taken into account several frequently ignored factors like solar-cell degradation, emissions attributed to the PV systems life-cycle, and the repowering due to the substitution of the systems after their life-time is reached. Finally, the results of this work can be of interest in energy planning policies related to the contribution of PV technologies for the decarbonization of the power generation system.
© 2014 Elsevier Ltd. All rights reserved.

Contents

1. Introduction

It is a well-known fact the impressive recent growth of renewable energies for power generation applications. This is especially true in the case of photovoltaics (PV), which with average annual growth rates of around 50% since 2005, has surpassed the most

* Corresponding author. Tel.: +34 660 446909; fax: +34 91 4973969.
E-mail addresses: jorgemoro85@gmail.com (J. Hernández-Moro), martinez.duart@uam.es (J.M. Martínez-Duart).

http://dx.doi.org/10.1016/j.rser.2014.09.025
1364-0321/© 2014 Elsevier Ltd. All rights reserved.

optimistic predictions [1]. At present, PV can be considered as a mature technology which in about two or three decades would probably move to the terawatt scale from the present more than 100 GW of global cumulative installed power [2]. Therefore, PV will become an important player in the electricity mix of many countries and is expected to contribute globally with percentages close to 10% by 2050 [3]. In addition, PV solar cells constitute probably the best example illustrating the technology-learning process characteristic of large-scale production economics, with a learning rate of 21% since the mid-seventies [4]. As a consequence, the solar module prices have at present plunged below $1 per peak watt, while some Chinese companies are already announcing prices of about half for 2015.

One of the main interests in the deployment of renewable energies in the power sector is related to the curtailment of CO_2 emissions. In effect, CO_2 and other greenhouse-gasses (GHGs) emissions, which in 2012 amounted to about 34 Gtonnes (Gt), are the main cause of global warming and climate change [5]. Evidently, if efficient measures are not taken during the next one or two decades, emissions will continue to rise at an annual rate of 2.5–3.0%, as a consequence of the continuous growth (close to 2%) of the world's primary energy demand [5]. Detailed studies by the Intergovernmental Panel on Climate Change (IPCC) indicate that, in order to avoid a global warming not greater than 2 °C by 2050, it would be necessary not to surpass the mark of 450 ppm in atmospheric C-concentration [6]. The IPCC document also indicates that this stabilization at 450 ppm would require that the peak in the annual emissions should occur within the next 10–15 years at the latest. This is a very challenging objective since we have already surpassed the 400 ppm mark in 2013 [7].

The object of this article is two-fold; first it consists in the development of an analytical method for the calculation of the avoided CO_2 forthcoming emissions by the deployment of photovoltaics in the power sector, and, second, in the calculation of the financial extra-costs incurred, both annually and totally, for any period of time considered, until 2050. Besides, we show in this work how the model can easily be applied to any geographic region and scenario considered for the PV deployment.

2. Present status and future scenarios of PV power generation

2.1. A short overview and present status of PV power generation

During the last two decades, the deployment of photovoltaic systems for the direct generation of electricity has been quite notable, due mainly to the exceptional decrease in prices and the continuous improvements in solar modules efficiency. The last decade has seen a real fall in the prices of solar cells after the 2003–2006 period, when a silicon shortage and large tariff incentives (cases of Germany and Spain) prevented effective pricing competition [3,8–10]. However, since 2008 there has been a continuous decrease in the price of purified silicon, along with significant cost reductions related to technology learning processes. Consequently, between 2010 and 2012, solar PV power generation costs have fallen around 44% [2,11]. In effect, Fig. 1 shows in a log–log space the cost (in constant 2012 US dollars) evolution of PV modules as a function of the cumulative installed capacity, which yields a learning rate of about 21% [3,4,12].

In Fig. 2 we represent the cumulative installed capacity and the annual electricity production for PV systems during the last decade [2,4,13–15]. It can be observed that the cumulative installed capacity has increased considerably during the last years, with average annual growth rates of 42% between 2000 and 2010 [11] and even 60% between 2007 and 2012 [2]. At the end of 2012 there were 100 GW installed in the whole world [2,3,13], most of them in Germany (32%), Italy (16%), USA (7.2%), China (7%), Japan (6.6%) and Spain (5.1%). However, Europe's leading role is fast diminishing, since its global market share has been reduced from 74% in 2011 to 55% in 2012 [13].

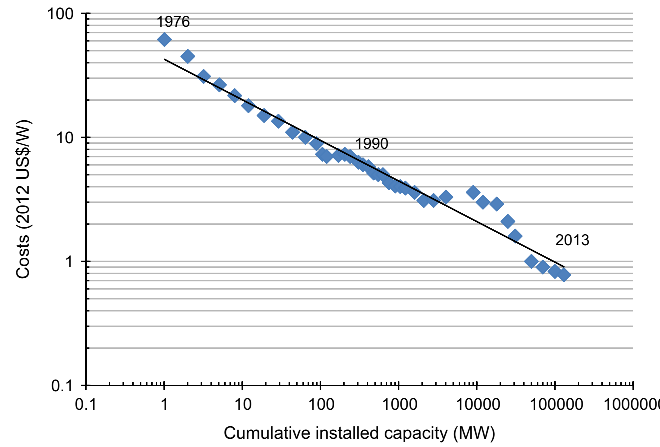

Fig. 1. Learning curve of the PV modules, showing in a log–log scale the cost of the PV modules (in constant 2012 dollars), between 1976 and the end of 2013, as a function of the PV cumulative installed capacity.

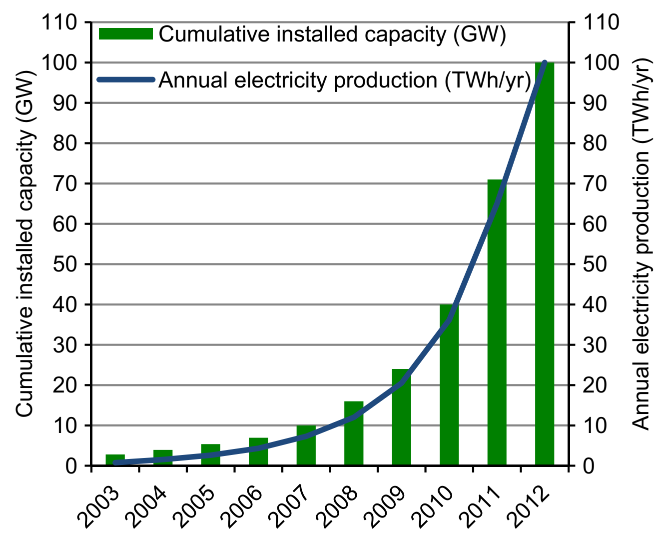

Fig. 2. PV cumulative installed capacity (GW) and annual electricity production (TWh/yr) between 2003 and 2012.

Annual PV electricity production (Fig. 2) has grown analogously to the cumulative installed capacity, reaching 100 TWh/yr during 2012 [11]. In 2011 PV electricity generation represented about 0.5% of the world electricity production [16], whilst for the European Union-27 (EU-27) was 2.6% in 2012 [13], with markedly high contributions in countries like Italy (6.7%), or Germany (5.6%) despite its low solar irradiation.

The PV industry is at present still predominantly based on crystalline silicon solar cells, followed by a share of about 16% of thin-film second generation (2G) cells with somewhat lower prices, as a consequence of the consumption of smaller amounts of materials, the use of large-area deposition techniques and low-cost substrates [3]. In addition, and in order to overcome the Shockley–Queisser limit [17] for single-junction devices, there is at present a large amount of research on third-generation (3G) cells. These cells, which are still under development, can make use of newly developed techniques such as quantum-size effects, two-step processes in intermediate bandgap semiconductors [18], etc.

Download English Version:

https://daneshyari.com/en/article/8118802

Download Persian Version:

https://daneshyari.com/article/8118802

Daneshyari.com