Resources, Conservation & Recycling 127 (2017) 29–41

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

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

Photovoltaic waste assessment in Mexico

Adriana Domínguez*, Roland Geyer

Bren School of Environmental Science and Management, University of California at Santa Barbara, Santa Barbara, CA 93106, United States

ARTICLE INFO

Keywords:
Photovoltaic
PV waste
Mexico
Solar energy
PV recycling

ABSTRACT

Large growth in renewable energy technology is required to combat climate change. Photovoltaic (PV) is the most promising technology with the largest potential, and Mexico has one of the best locations to exploit solar resources. During 2015, the Mexican government approved 7.8 GW of PV projects. This PV deployment is linked to a great generation of PV waste once the PV systems reach their end-of-life. Considering 30 years as average module lifetime, around 2045, Mexico will have 1.2 million mt of PV waste, 691 thousand mt of which are PV modules waste (31 millions PV modules). Since PV modules represent only 55% of the material contained in PV systems, this paper presents an assessment of the future PV-waste volumes in Mexico, including not only the PV modules but the balance of system (BOS). In total, near to 1 million mt of different metals will be contained in the PV-waste stream (42% Fe, 26% Al, 26% Si, 5% Cu). Fortunately, assuming the best available recycling technology, around 920 thousand mt of PV waste could be recycled. Precious and valuable metals (e.g. 271 mt of silver, 10 mt of gold, 17 mt of gallium, 10 mt of indium, 139 mt of cadmium and 100 mt of tellurium) can be recovered. This study analyzes the PV-waste generation under different scenarios such as: market share in PV modules technology, recycling yields for precious and critical metals, metal composition of transformers and thin film panel development.

1. Introduction

Photovoltaic energy is a reliable and sustainable source of electricity. This renewable energy allows the increasing demand for electricity to be satisfied worldwide, without generation of greenhouse gases during its operation. During 2015, photovoltaic solar energy experienced a 28% growth rate, the highest growth rate of renewable energy capacity, followed by wind energy at 17% (Lins, 2016). The total installed capacity of solar photovoltaic at the end of 2015 was 227 GW, or 1.3% of the world's electricity generation (Masson and Brunisholz, 2015). According to the International Renewable Energy Agency (IRENA), it is expected to reach 4500 GW by 2050. High cumulative deployment rates are anticipated for some countries: China (1731 GW), India (600 GW), the United States (600 GW), Japan (350 GW) and Germany (110 GW). Latin America is still far from these levels of development, however, during 2015 solar PV increased 166% in this part of the world. Chile and Honduras contributed with 78% of the new solar capacity installed in 2015 (see Fig. 1 (Weckend et al., 2016). Chile is leading PV in South America, although countries like Mexico, Brazil and Peru have adopted policies that could favor the development of PV in the forthcoming years (Masson et al., 2014).

The first PV projects development in Mexico were off-grid installations for rural electrification in the 1990s. Today, rooftop installations are being introduced in the commercial and residential sector. Distributed solar PV systems can yield energy cost-savings for commercial and residential sectors subjected to the DAC[1] tariff. An overview of the cumulative installed capacity of solar PV in Mexico is displayed in Fig. 2. According to the Mexican Energy Secretariat (SENER), the first solar PV installations in Mexico were used mainly for rural electrification, supply of energy in the residential sector, water pumping, and exterior lighting in the commercial and industrial sectors. The year 2013 saw the greatest growth in solar capacity, up to 82 MW, in large part due to the first large-scale solar power project, Aura solar I (39 MW) (SENER, 2015a).

The Energy Outlook published by SENER for the years 2015 to 2029 can be seen in Fig. 2. Although these are the best predictions available, there is a lack of data consistency. For instance, the energy outlook of 2015 shows 170 MW, however the cumulative installed capacity was 234 MW during 2015 (see Fig. 1). According to this document, Mexico has projected 1822 MW of additional solar PV projects in the public service and 1273 MW as distributed generation, by 2028 (SENER, 2015b). Furthermore, the survey Initiative for the Development of the Renewable Energy in Mexico performed by PricewaterhouseCoopers (PwC), estimates that starting in 2017, it will become economically

* Corresponding author.
E-mail address: adriana.dominguez@ucsb.edu (A. Domínguez).

[1] DAC (Doméstico de Alto Consumo) tariff is the highest electricity tariff paid in the residential sector. For those consumers with high electricity requirements.

http://dx.doi.org/10.1016/j.resconrec.2017.08.013
Received 3 February 2017; Received in revised form 11 August 2017; Accepted 13 August 2017
0921-3449/

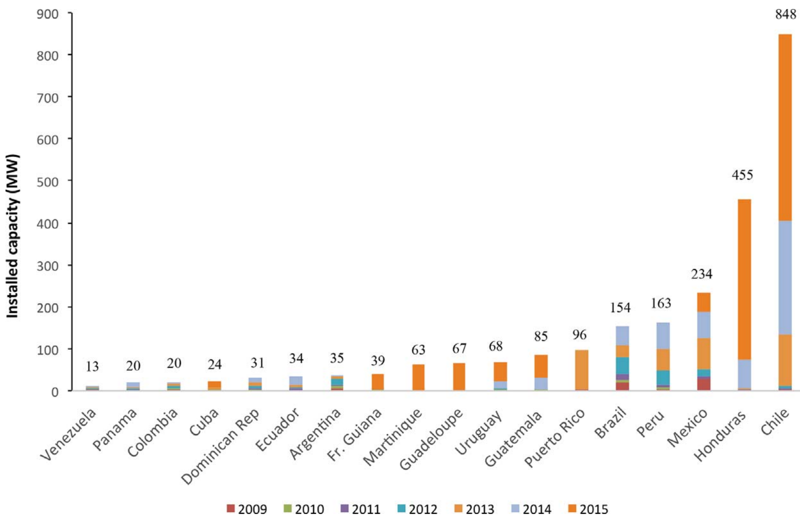

Fig. 1. Cumulative PV capacity installed in Latin America in 2015. Data from Whiteman and Esparrago (2016), Werner et al. (2015).

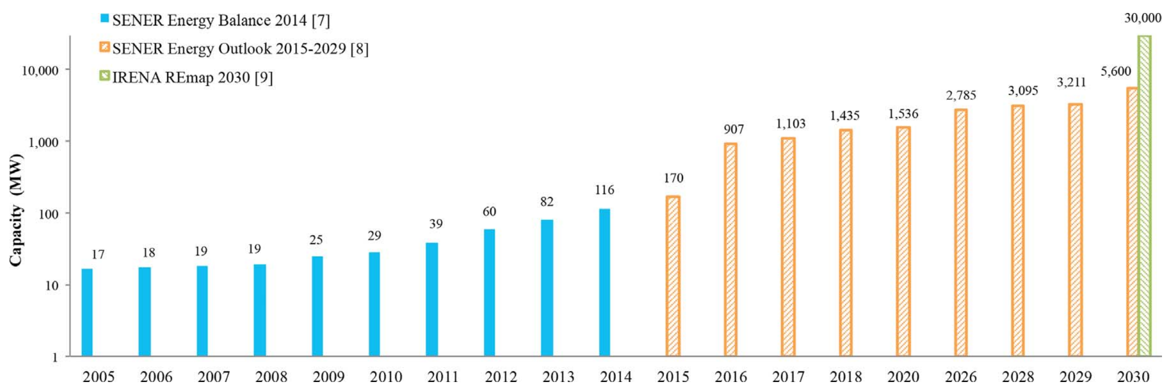

Fig. 2. Overview of the cumulative installed PV capacity in Mexico and projections 2016–2030.

feasible for the deployment of solar PV in residential rooftop, reaching 6.4 GW by 2020 (PwC, 2012). Moreover, by December 2015, the Energy Regulatory Commission of Mexico (CRE) had approved 275 projects distributed in 28 of the 31 states of the Mexican Republic, that together account for 7.8 GW. The projects under construction during 2016 account for 3.1 MW with the other 4.7 MW planned to begin construction between 2016 and 2018. This means that the target of 5.6 GW predicted by SENER by 2030 will be surpassed more than 10 years earlier.

Due to Mexico's great solar potential, PV could potentially contribute closer to 30 GW of power capacity in 2030, according to IRENA's Roadmap 2030 for a Renewable Energy Future (REmap). This means that solar PV energy predicted by SENER should be increased five times. This 30 GW scenario will include 60% utility-scale and 40% rooftop installations, and will require an average annual installation rate of 1.5 GW/year (IRENA, 2015). The REmap also envisions 860 MW of solar PV rural electrification systems, in order to provide electricity to households without access to grid power, street lighting, agricultural pumping, mobile phone towers, etcetera.

In an effort to reduce greenhouse gas emissions, Mexico is committed to achieve a target of 25% of renewable energy by 2018, 30% by 2021 and 35% by 2024. The development of solar PV in Mexico would contribute to the fulfillment of these targets. It is important to mention that Mexico has one of the best locations to exploit solar resources, with high solar irradiation levels, averaging 5.5 kWh/m^2 up to 10 kWh/m^2 per day, especially in the northwestern region during spring and summer (SENER, 2016). These levels are similar to the southwestern U.S. region, where many utility-scale solar projects are under construction (SEIA, 2016). However, the development of solar PV energy is linked to the generation of photovoltaic waste once the PV systems reach the end of their lifespan (25–30 years).

As PV installations increase, the PV waste will rise as well. Hence, it is important to draw up a plan for recycling future PV waste, since recycling has great benefits. The recovery and reuse of secondary materials has become an important issue due to the fact that PV modules use valuable metals (e.g. gold, silver, tellurium, indium, gallium, etc.) and other materials (e.g. glass) capable of being recovered, recycled and reused, sometimes within the same PV industry, contributing to the circular economy of this industry. Furthermore, recycling can lead to a decrease in resource depletion, a reduction of environmental impacts associated with mining and processing of valuable and limited virgin natural resources and energy savings.

The growth of PV is just beginning in Mexico as well as in Latin America, and there is no regulation in regards to the disposal and treatment of this kind of waste. As a result, it is necessary to look for solutions to the PV waste challenge ahead of us in the coming decades. By planning the management of PV waste, the exports of these kind of waste to developing countries could be lessened, thereby reducing the environmental and human health impacts derived from improper recycling. Additionally, the development of a new PV waste recycling industry will generate jobs and make a significant contribution towards a sustainable renewable-based energy future.

This paper aims to analyze the PV waste that will be generated in Mexico from end-of-life PV systems in the following years. It is very important to know the kind and amount of metals that are in the PV waste as well as other recoverable materials (e.g. glass), in order to propose a recycling plan that ensure that enough and the right type of recycling technology and capacity can be built. To accomplish the PV