

HISTORIC AND FUTURE FLOWS OF CRITICAL MATERIALS RESULTING FROM DEPLOYMENT OF PHOTOVOLTAICS

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Keywords: MFA; thin-film photovoltaic; secondary materials; material demand; recycling potential.

ABSTRACT

Within this study, the flows of indium, gallium, cadmium and tellurium used in CIGS, CdTe and a-Si cells are analyzed looking at historic installations and potential future developments. Additionally to the material demand, secondary material flows arising at the cells' end of life are quantified. The study shows that a significant growth in demand resulting from future photovoltaic installations is to be expected. Also, flows of secondary materials will develop to a significant scale showing the necessity of an efficient recycling infrastructure.

INTRODUCTION

Photovoltaic (PV) cells play a central part in most development strategies towards a more sustainable and climate-friendly energy system. Various scenarios regarding future installations of photovoltaic cells have been published in the past years predicting a constant growth of installed PV capacity (e.g., EPIA, 2011; EPIA, 2012; European Commission, 2010; Jäger-Waldau, 2011; Moss, Tzimas, Kara, & Kooroshy, 2011; U.S. Department of Energy, 2011). Among the different photovoltaic cell technologies thin-film cells are of growing importance (European Commission, 2010; Moss et al., 2011; U.S. Department of Energy, 2011). Due to their excellent properties compared to conventional silicon-based PV cells like temperature robustness, versatility and low costs they already gained a significant market share over the past years (El Chaar, lamont, & El Zein, 2011).

Examples for thin-film cells are copper-indium-gallium-(di)selenide (CIGS) cells, cadmium-telluride (CdTe) cells or amorphous silicon (a-Si) cells. These cell technologies require materials like indium, gallium, cadmium, and tellurium that have already been identified to be critical in various studies (e.g. Buchert, Schüler, & Bleher, 2009; European Commission, 2010; U.S. Department of Energy, 2011). These materials might prove to be potential bottlenecks for photovoltaic installations as it has for example been analyzed by Andersson (Andersson, 2000) or more recently by Zuser and Rechberger (Zuser & Rechberger, 2011). At the same time, anthropogenic stocks of these materials will develop and with some delay secondary materials in a significant scale will arise.

Against this background, future demands for critical materials, material flows into use and secondary material flows arising at the modules end-of-life have been analyzed in this study.

METHODOLOGICAL APPROACH AND DATA

The methodological approach centers around the material flows into and out of use. Those depend on the annual installations, the material intensity (critical materials embodied per MW) and the lifespan of the photovoltaic cells.

For the first parameter – annual installations of thin-film photovoltaics – scenarios from the European Photovoltaic Industry Association (EPIA) have been used and combined with historic data from (EPIA, 2012; Maycock, 2007; Maycock, 2005). In (EPIA, 2011) three different scenarios are distinguished: a moderate reference scenario, an accelerated scenario and a paradigm-shift scenario. Based on this, the amount of installed thin-film cells has been calculated using data from (EPIA, 2011; Moss et al., 2011; PHOTON, 2012).

Concerning the second parameter, the material intensity, i.e. the amount embodied in cells equivalent to 1 MW, a literature screening has been performed and completed with expert judgments and manufacturer data. As a result, the material intensity of each considered metal in each thin-film technology could be identified. The respective values are shown in the following table. Potential future developments have been considered, too.

		Lower bound	Mean value	Upper bound
CIGS	Indium	9.8	16.5	23.1
	Gallium	2.3	11.0	19.7
CdTe	Indium	15.4	16.9	18.3
	Cadmium	140.1	153.4	166.6
	Tellurium	93.3	137.7	182.0
a-Si	Indium	5.3	5.3	5.3

Table 1. Material intensity of thin-film technologies Data from experts, manufacturers and literature (Andersson, 2000; Moss et al., 2011; U.S. Department of Energy, 2011)

Regarding life span, it can be said that in LCA studies commonly a life span between 20 and 30 years is assumed (e.g., Azzopardi & Mutale, 2010; Berger, Simon, Weimann, & Alsema, 2010; Raugei & Fthenakis, 2010; Sherwani, Usmani, & Varun, 2010). Other studies indicate that a lifespan of over 25 years can be assumed for thin-film cells (Berger et al., 2010; EPIA, 2011; Kuitche, 2010; Kumar & Sarkan, 2013). Based on this, an average lifespan of 28 years is assumed here. Instead of assuming a simultaneous exit after 28 years, a lifetime distribution is used for analyzing the material flows. The Weibull distribution has been shown to give a good approximation and is most widely applied for such purposes (Cullen & Frey, 1999; Gößling-Reisemann, Knak, & Björn, 2009; Kumar & Sarkan, 2013; OECD, 2001; Oguchi, Kameya, Yagi, & Urano, 2008; Tasaki, Takasuga, Osako, & Sakai, 2004; Wilker, 2010, Wilker, 2010). Additional parameters required for applying the Weibull function in this study have been taken from (Kuitche, 2010).

RESULTS

Based on the approach and parameters described above, the material flows of indium, gallium, cadmium and tellurium connected with the deployment of CIGS, CdTe, and a-Si cells have been calculated. An overview of selected results is given in the following table.

Metal	Decade	Reference scenario			Accelerated scenario			Paradigm shift scenario		
		Flows into use [t]	Material demand [t]	Flows out of use [t]	Flows into use [t]	Material demand [t]	Flows out of use [t]	Flows into use [t]	Material demand [t]	Flows out of use [t]
In	'21-30	307	539	12	2,711	4,720	22	4,130	7,229	34
	'31-40	444	628	89	3,349	4,733	308	5,158	7,293	567
	'41-50	526	606	243	4,166	4,887	1,419	6,494	7,459	2,622
Ga	'21-30	115	211	2	1,005	1,825	6	1,544	2,820	10
	'31-40	158	229	27	1,211	1,755	103	1,866	2,705	193
	'41-50	193	224	91	1,517	1,759	518	2,362	2,733	955
Te	'21-30	747	1,180	50	6,633	10,416	83	9,993	15,740	119
	'31-40	1,168	1,559	279	8,505	11,347	863	13,994	17,472	1,550
	'41-50	1,307	1,479	568	10,515	11,877	3,494	16,416	18,537	6,487
Cd	'21-30	833	1,314	56	7,389	11,604	92	11,133	17,535	133
	'31-40	1,301	1,736	311	9,475	12,640	961	14,587	19,464	1,727
	'41-50	1,456	1,648	633	11,714	13,232	3,892	18,288	20,651	7,227

Table 2: Flows and demands of critical metals in different EPIA scenarios

CONCLUSIONS

It has been shown that a significant additional demand for critical metals will result from increased installations of thin-film photovoltaic cells. Even in the most conservative scenario (EPIA reference scenario) the maximum annual demand for tellurium amount to about 9 to 48 percent of the global 2012 production. In the other scenario the demand even amounts to 257 to 595 percent. A similar situation has been shown for indium where the maximum annual demand increases to – depending on the underlying scenario – between 98 and 231 percent of the global production of 2012.

At the same time a big potential for recovering secondary materials has been identified. Average secondary flows of tellurium between 2041 and 2050 amount to between 29 and 122 percent of the global production in 2012. In the same decade, indium secondary flows amount to between 29 and 122 percent of 2012's production. Gallium shows a similar situation. Given this, the necessity of an efficient and sustainable metals management becomes clearly evident. A working recycling infrastructure is strongly needed to recover and recycle these critical materials and hereby significantly reduce primary metal demand.

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