High-tech element availability for sustainable energy systems in the 21st century: The Iberian Pyrite Belt as a potential supplier

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Abstract: This work provides estimations on the future raw material demand for the thin-film photovoltaic (PV) elements indium, selenium, tellurium, germanium and gallium. Data calculation has been carried out on the basis of current energy and PV market outlooks. For indium, our calculation yields a maximum cumulative demand of 12 kilotons for the period from 2008 to 2030. The minimum demand for the same period is of 8 kilotons. Additionally, static depletion times for the elements in question have been determined. For indium, the static depletion time of 22 years shows that its supply is highly endangered, particularly if indium consumption for LCD and solar panel production stays on a high level or even increases. The situation for selenium, with a static depletion time of 53 years, is not much better.
Therefore, in addition to recycling, the fundamental way to enhance material supply is through intensified exploration for mineral deposits. Such exploration could focus in promising areas, where high-technology elements are already known to exist in sulphide ore deposits, e.g. the Iberian Pyrite Belt (IPB), a metallogenic province known for its massive sulphide ore resources.

Keywords: Thin-film PV elements, raw material demand, static depletion time, Iberian Pyrite Belt (IPB), sulphide ore

1 Introduction

Boosting electricity consumption, increasing costs of fossil fuel use and the need to reduce CO_2 emissions (UNFCCC 2008), will inevitably lead to a transformation of the energy system in the 21st century, requiring large-scale diffusion of a range of renewable energy technologies, including thin-film solar PV as a possible major component. Due to upgrading of cell technologies and improvement of production processes, thin-film solar PV transformed into a feasible electricity generation method. Modern thin-film PV cells are able to produce up to 30 times their production energy throughout an average module lifetime. But aside from being feasible electricity generators, solar PV technologies are invariably high-tech element specific. Hence, for large-scale implementation it is imperative to understand the raw material limitations related to the mass production of thin-film PV.

According to Andersson (2000), the material limitations are particularly strong for indium and tellurium, elements employed in copper indium (gallium) (di)selenide/sulfide (CI(G)S) and cadmium telluride (CdTe) thin-film photovoltaic cells. Therefore, the availability of raw material has to be assessed and sources of these elements have to be identified. When regarding future scenarios for PV market growth (EPIA 2008; Grama and Bradford 2008), it is likely that soon material demand may outstrip supply. In this case, the consequential resource scarcity constitutes a unique opportunity for mining companies and local communities to benefit from the discovery of new deposits that are rich in high-tech elements or from turning sub economic base metal deposits into profitable mines through high-tech element by-production.

2 Demand and Supply Scenarios

2.1 PV Growth Potential

The material demand calculations in this study are based on the 2008 European Photovoltaic Industries Association (EPIA) Advanced Scenario, whose values fit in with the average growth rate of the last decade, being of 47 %. The EPIA Advanced Scenario based PV growth rate extrapolation starts with the 2007 global PV production value of 4.3 GWp and yields future total PV cell production values of 11.7 GWp (for 2010), 139 GWp (for 2020) and 725 GWp (for 2030). The global production values for individual thin-film shares have been calculated assuming a thin-film PV share of 20 % by 2010 growing to 35 % until 2030 (Dhere 2007). When combined with the EPIA based total PV production values, this results in a thin-film PV production forecast of 2.4 GWp in 2010, 37 GWp in 2020 and 254 GWp in 2030.

2.2 Estimations of Material Demand

For converting the above calculated thin-film PV production values into metric material amounts, material consumption data per capacity unit (net element intensity) is needed. Net element intensities have been calculated on the basis of National Renewable Energy Laboratory (NREL) data (Keshner and Arya 2004) as well as with data provided by the German Zentrum Für Sonnenenergie- und Wasserstoff-Forschung Baden-Wuerttemberg (ZSW) (Table 1).

Table 1. Estimated cumulative material amounts, global reserve and global refinery data for 2007 and static depletion times (all data in metric tons). Reserve and Reserve Base data extracted from USGS Mineral Commodity Summaries (2008). SDT= static depletion time in years. (>1M = > 1000000 tons)

Advanced Scenario EPIA V; NREL; *ZSW*					**Period (years)**
Te	**Se**	**In**	**Ga**	**Ge**	
114	63 *(52)*	39 *(26)*	4	19	2008-2010
435	735 *(605)*	460 *(310)*	46	152	2008-2015
1659	3430 *(2830)*	2150 *(1440)*	210	680	2008-2020
14918	32660 *(26890)*	20420 *(13690)*	2025	6380	2008-2030
21000	82000	11000	>1M	>1M	Reserve
47000	170000	16000	>1M	>1M	Reserve Base
135	1550	510	103	100	Annual refinery
155	**53**	**22**	**9700**	**10000**	**S D T**

Individual thin-film shares for CI(G)S, CdTe and a-Si have been taken from a recent Prometheus Institute forecast (Grama and Bradford 2008). Table 1 shows the cumulative amounts of each element needed for thin-film PV production from 2008 until the years 2010, 2015, 2020 and 2030, respectively. Selenium and indium demand as calculated using ZSW data is significantly lower and shown in brackets. For indium, our calculation yields a maximum demand of 20 kilotons for the period from 2008 to 2030. The minimum demand for the same scenario and period is of 14 kilotons. When regarding the primary global indium reserves of currently 11 kilotons (USGS 2008), it is clear that CI(G)S thin-film module production in the GW range is highly dependent on the future development of the LCD and recycling market as well as on exploitation of additional indium deposits. For selenium, the calculation yields a maximum and minimum demand of 33 and 27 kilotons for the period from 2008 to 2030, respectively. The global primary reserves of selenium are currently estimated to be of 82 kilotons.

Regarding reserve data, it has to be kept in mind that any reserve calculation is dependent on a range of external factors. Such factors can modify quickly, e.g. due to changes of mining technology or raw material prices.

2.3 Static Depletion Time

The static depletion time calculation (reserve to current annual refinery ratio) gives another indication for the relative material constraints. For indium, the current static depletion time is 22 years. The situation for selenium, with a static depletion time of 53 years, is not much better. Tellurium may also be far from being abundant.

2.4 Material Supply

Increasing recycling of technical scrap will become important in the future, particularly if the LCD industry continues to grow. But difficulties arise due to the fine dispersion of the elements in technical devices and the complexity of many technical products, which can contain dozens of elements (Reiser 2008).

The LCD industry has been responsible for most of the industrial indium consumption during the last few years, using up to 70 % of the primary indium produced every year. Substitution and reduction of material usage (e.g. thinner absorber layers for PV) are other measures to extend material availability. But the fundamental way to enhance material supply is through intensified exploration for mineral deposits. Such exploration could focus in promising areas, where high-technology elements are already known to exist in ore deposits, e.g. the Iberian Pyrite Belt (IPB).

3 The Iberian Pyrite Belt as Potential Supplier

Located in the Iberian Pyrite Belt, the copper-rich Neves Corvo deposit (Fig. 1) is known for significant concentrations of some high-tech elements. In Neves Corvo, indium occurs especially in sphalerite and tennantite from MC3 (bornite-bearing massive copper sulphide) ore, but also in tin sulphide phases from MH (Cu-rich massive sulphides with Zn, Hg, Ag, As, Sb and Sn) and MS (massive sulphides with high Cu and Sn) ores (Gaspar 2002). Significant amounts of Se and Te were also identified in the same study. Benzaazoua et al. (2003) calculated that MS and MC ore types from Neves Corvo contain approximately 1.5 % stannite, which corresponds to a grade of approximately 200 ppm indium. They further estimated that even tailings can contain 20 ppm indium.

Additional deposits currently being investigated indicate that the presence of indium is not exclusive to the Neves Corvo deposit. Whole rock analyses of samples from the Lagoa Salgada deposit (NW IPB; Fig. 1) yield contents of up to 90 ppm In. Electron microprobe analysis shows indium in sphalerite with contents ranging from 0.02-0.5 wt%.

The Barrigão remobilised vein deposit, located SE of Neves Corvo (Fig. 1), presents lower indium contents than Lagoa Salgada but contrastingly shows high germanium contents up to 280 ppm in whole rock analysis.

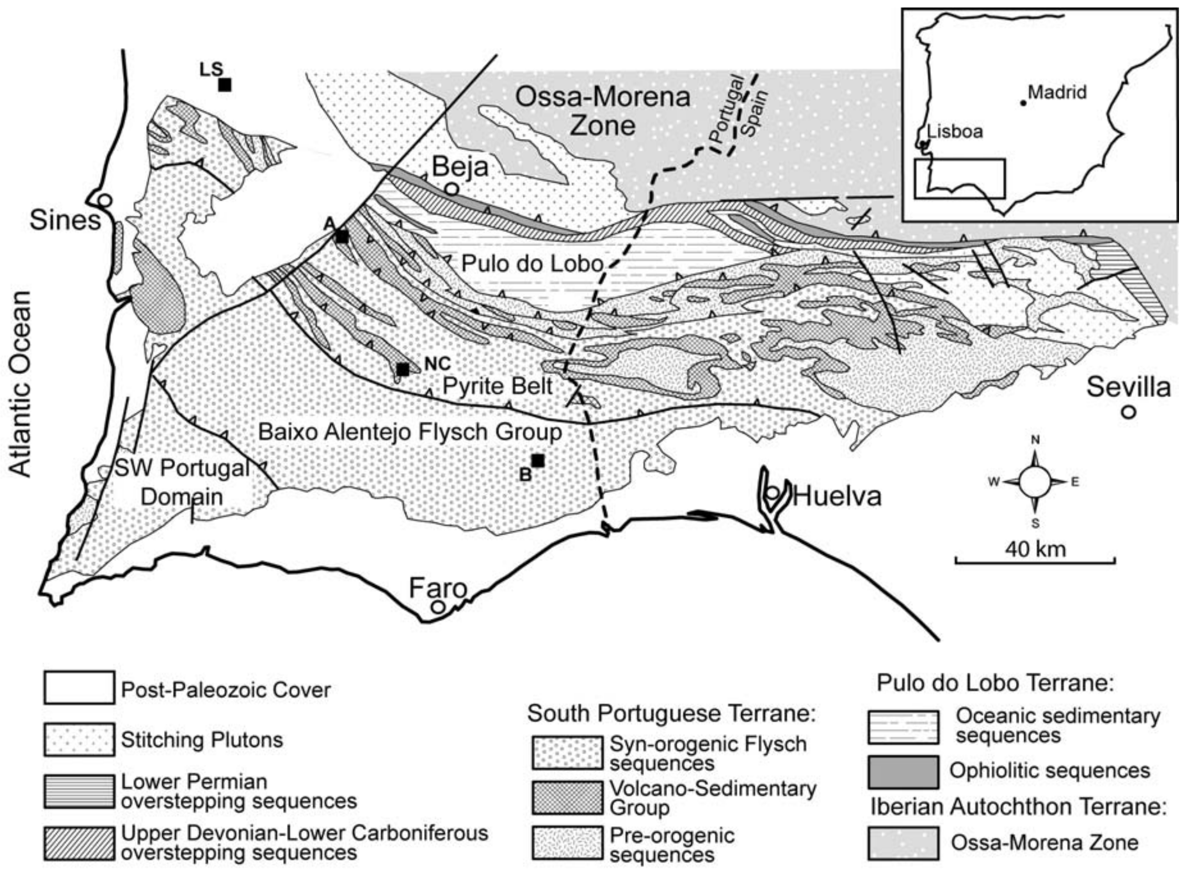

Figure 1. Geological setting of the Iberian Pyrite Belt (IPB) in the southernmost part of the Hercynian Iberian Massif. LS = Lagoa Salgada, A = Aljustrel, NC = Neves Corvo, B = Barrigão.

4 Conclusions

Serious raw material scarcity for indium and selenium, and to a less extend for tellurium, is confirmed in this study. The presented estimations show that until 2020, the material amounts needed for thin-film PV are quite manageable. But serious supply problems for at least some of the considered elements will arise from 2020 on. This is especially the case for indium, with a current static depletion time of 22 years. Therefore, to secure the supply of thin-film PV elements, exploration for new mineral deposits is essential. In the IPB, unexploited deposits such as the Lagoa Salgada massive sulphide deposit and the Barrigão remobilised vein deposit represent a promising target area. Investigation continues.

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