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Rare materials for photovoltaics: Recent tellurium price fluctuations and availability from copper refining

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ABSTRACT

Of the materials of current research interest in thin-film photovoltaics, Ru and Te are amongst the nine rarest elements in the earth's crust, with In and Se in positions 11 and 14, raising the issue as to what constraints, if any, are placed on future thin-film photovoltaic manufacturing volumes by such scarcity. Te provides an interesting case study since more than 600 t has been incorporated into CdTe modules fielded to-date, with CdTe technology recently consolidating its position as the most successful commercial thin-film technology. The origin and impacts of recent fluctuating Te market conditions are discussed as are new insights into long-term supply from Cu refining.

1. Introduction

The low crustal abundance of several materials of present or potential interest for emerging technological applications and the increasing geopolitical concentration of their supply has stimulated several recent high level studies of material supply risks [1–5]. In and Te are materials of interest in photovoltaics featuring in these studies with both rated as “near critical” or higher in all, apart from a 2010 study by the European Commission [2]. This rated Te as “not critical”, but indicated Te would be rated as “critical” with a “slight change in the underlying variables”. One “underlying variable” was the assumption that Te demand in photovoltaics would decrease by 2% per year after 2015 due to “development of competing thin-film PV technologies”. Such a scenario now seems unlikely with CdTe recently consolidating its position as the leading commercial thin-film photovoltaic technology with steadily increasing demand past 2015 considered likely.

In studies specifically related to materials availability for photovoltaics, widely different answers have been forthcoming. In relation to whether there is enough Te to support the large-scale deployment of CdTe thin-film photovoltaics, Jaffe [6] has recently characterized a range of responses as “yes” [7], “probably” [8], “maybe” [9,10], “maybe not” [11,12], and “no” [13]. Subsequent studies [14–20] could also be slotted into various positions in this range. Reasons for such a wide range of opinion are discussed elsewhere [21].

Recent fluctuating photovoltaic market conditions with correspondingly widely fluctuating Te prices have given fresh insight into short-term supply issues and their impact that are discussed below, as are improved estimates for long-term Te supply from Cu refining.

2. Recent Te prices

The technology of CdTe cell and module manufacturing and the key present and potential manufacturing industry participants have been recently reviewed elsewhere [22,23]. At present, the CdTe module manufacturing industry is dominated by a single company, First Solar, one of the world's largest and most successful photovoltaic module manufacturers, with other companies (Abound Solar, Calyxo, and Primestar GE Solar) making recent attempts at market entry. The success of CdTe modules in the market has created a new demand for Te on a scale that has impacted spot market prices.

Fig. 1 shows a chart of the monthly average of technical grade Te prices over recent years annotated with the dates of events conjectured likely to have an impact on these prices. Also shown in the Commodity Metal Price Index (dotted line), which is the composite price of several metals (Cu, Fe, Al, Sn, Ni, Zn, Pb, U) normalized to the price over 2005 that is set equal to 100.

Historically, Te has been in oversupply as a by-product extracted from the slimes deposited during a final electrolytic step in mainstream Cu refining, with only a small fraction of the potential supply actually extracted. Market prices have fluctuated with imbalances in supply and demand with baseline costs only those of extracting of Te from these slimes. Prices dropped to as low as $22/kg annual average in the mid-1980s with production

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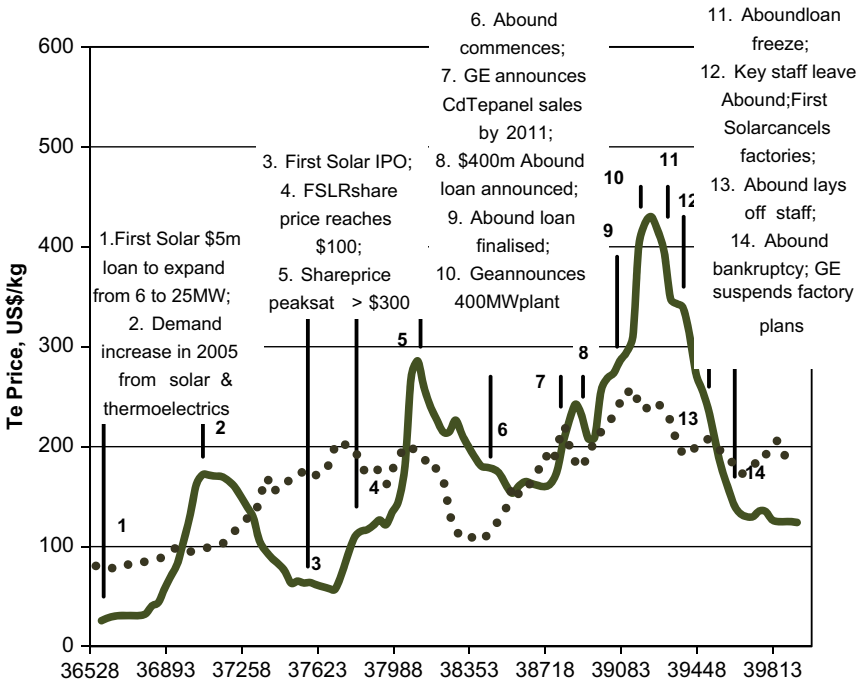

Fig. 1. Te spot market prices over the 2004–2013 period (solid line), showing the timing of events that may have influenced these (price data from www.metalprices.com). The dotted line shows the Commodity Metal Price Index over the same period (2005=100) (price data from www.indexmundi.com). References for events 1–14 are references [24–37], respectively.

around 100 t/year [38]. Production steadily increased to about 300 t/year by 2003 [39]. Since then, close to 600 t Te has been deployed in CdTe thin-film modules (about 6–10 g/m^2 [22,40] with close to 10 GW or 10^8 m^2 of CdTe modules now installed) with use in solar cells now forming the largest single use of Te [41]. This large new market demand is of a size where changes of the type shown might be expected to stimulate price fluctuations such as apparent in Fig. 1. The USGS (US Geological Survey) estimated the total refinery production of Te was 500–550 t in 2011 [38] of which 40% was used in solar cells, 30% in thermoelectrics, 15% in metallurgy, 5% in rubber formulation and 10% in other applications [38,41]. Production in 2012 is estimated as "slightly less" due to the decreasing solar demand [38] (as a result of the events documented in the final periods of Fig. 1).

From 2004, when First Solar first began rapidly expanding CdTe module production capacity, there have been three successive peaks in Te prices. The first in mid-2005 is attributed to emerging demand for thermoelectric coolers and for solar [25]. With 21 MW of CdTe panels produced in 2005, the solar demand would have been less than 10 t (250 t Te/GW output reported in 2007 [42]), making the direct impact of solar applications small and that assessment doubtful. It is conjectured that this peak in prices stimulated an increase in Te supply or a softening in demand for other applications due to the increased price, causing the subsequent price stabilization (opposite to the trend for the Commodity Metal Price Index).

First Solar listed on the stock exchange at the end of 2006, with its initial share price more than quadrupling over the following months, finally peaking several times higher again in May 2008. The company's module production doubled or tripled each year over this period with over 500 MW of product produced in 2008, requiring 50–100 t of Te, starting to contribute significantly to total demand. This undoubtedly was a factor in pushing up Te prices possibly compounded by the stock market fascination with solar stocks over this period with most solar share prices increasing rapidly. Speculative market manipulation may have also contributed to this second peak as has been postulated by a First Solar representative [43]. After May 2008, the interest in First Solar stocks declined as did the price of Te.

The third peak in mid-2011 appears to have arisen from the buoyancy of the solar market and the plans announced by several companies [29,30,33], notably General Electric, Abound Solar and Calyxo, to quickly ramp up production of thin-film CdTe modules. Although these plans were not fulfilled, these companies would have needed to demonstrate secure access to substantial quantities of Te to their investors/shareholders to ensure support for their proposals, likely to help push up Te prices. As a sign of this increasing demand, mining company Boliden announced in early 2011 re-opening of the Kankberg mine in Sweden, supported by an agreement with a solar manufacturer for sales of Te from the mine at a fixed price of $280/kg (until 2016) [44].

Oversupply in the PV market and rapidly reducing prices for c-Si modules upset most of this planning. The politically sensitive filing for bankruptcy protection by the thin-film CIGS company Solyndra in August 2011 undoubtedly put added pressure on Abound Solar, who had secured a similarly large loan guarantee from the US government. There was reportedly no funding drawn under the Abound loan after the Solyndra bankruptcy filing [45]. Several senior staff left Abound soon after, signaling something was amiss [35]. Almost at the same time, there was a change in senior staff at First Solar and the cancellation by the companyof plans for several new manufacturing facilities and a reduction in planned production volumes [46]. Te prices plummeted, with the drop likely reinforced by Abound soon after laying off staff and also announcing it would file for bankruptcy in June 2012 [37]. Within a week, General Electric also had lain off staff and suspended plans for the previously announced 400 MW facility. First Solar, although making impressive progress with module efficiency, announced closure of its German manufacturing facilities and also that it was operating its remaining lines at fractional capacity [46]. The consequent Te oversupply has seen prices stabilize since mid-2012 at pre-2008 levels.

Sufficient information is publicly available to allow investigation of the impact of these Te price excursions upon the reported