

Life Cycle Management of Critical Materials

Parikhit Sinha, Ph.D.

First Solar®

First Solar at a Glance



Over 6GW installed worldwide and ~3GW power plant pipeline



Cost competitive with conventional energy sources today



Delivering utility-grade PV energy solutions to global power buyers



Driving innovation across entire value chain and plant solution



Fully integrated PV solutions optimized for project specific economics



Founded in 1999 and publicly traded on NASDAQ (FSLR)

Premiere Provider of PV Energy Solutions

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Site	Agua Caliente, AZ, USA
System Size	290MW
Owners	NRG Energy & MidAmerican Solar



Site	Greenough River, WA, Australia
System Size	10MW
Owners	Verve Energy & GE Energy Financial Services



Site	Dhursar Solar Power Plant, Rajasthan, India
System Size	40MW
Owner	Reliance Power

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Representative Projects

Cadmium Telluride Photovoltaics

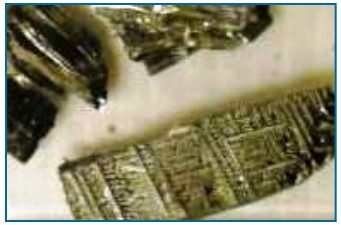
Cd



Cadmium (Cd) is a metal byproduct of zinc refining

+

Te



Tellurium (Te) is a semi-metal byproduct of copper refining

=

CdTe



Cadmium telluride (CdTe) is a semiconductor compound

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Critical Material – Tellurium (Te)

- *Where does Tellurium come from?*
  - Tellurium is abundantly present in the earth's crust. It tends to mainly exist in metallic sulfide deposits.
- *How is Tellurium obtained?*
  - Te is currently obtained almost exclusively through recovery as a by-product of refining copper. Reserve estimates are uncertain and an increased definition of reserves would be motivated by the economics of materials extraction.
- *What is Te currently used for?*
  - Te is primarily used as a machining additive to steel. It is also used for thermoelectric devices (coolers, thermal detectors, electrical generators) and Infra-Red Detectors (IR astronomy, research telescopes, military applications, night visions and heat seeking devices)
- *How much Te is currently being produced?*
  - Current world production is 500 – 1500 metric tons/ year and typically increases by 3-5%/year due to increase in copper production. Supply could be expanded at short notice by simply recovering more Tellurium from the anode slimes generated while electro-refining copper
- *What is the PV industry's demand for Te?*
  - approximately 90-130 metric tons Te/GW

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Recent Papers on Tellurium Supply

How PV can scale from GW to TW

1. **The Impact of Tellurium Supply on Cadmium Telluride Photovoltaics** (*Zweibel; 2010*)
2. **Is Indium and Tellurium Availability a Real Concern for CdTe And CIGS Technologies?** (*Candelise, Winskel, Gross; 2011*)
3. **Perspectives on the pathways for cadmium telluride photovoltaic module manufacturers to address expected increase in the price for tellurium** *(Woodhouse et.al., 2012)*
4. **Sustainability metrics for extending thin-film photovoltaics to terawatt levels** *(Fthenakis, 2012)*
5. **Future recycling flows of tellurium from cadmium telluride photovoltaic waste** *(Marwede and Reller, 2012)*

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Life Cycle Management



- First Solar is committed to responsible life cycle management of end-of-life modules and BOS products
- First Solar's state-of-the-art recycling recovers up to 90% of glass and 95 % of valuable semiconductor material
- Continuous investments into recycling technology: to offer competitively priced solution and maximize recycling

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Life Cycle Management of Tellurium

Demand Side Management

Supply Side Management

Product Design

- Decrease semiconductor layer thickness
- Increase module efficiency
- Increase energy output with tracking systems

Material Sourcing

- Te supply proportional to Cu production
- Increase Te recovery from 55 to 80%
- Obtain Te from Pb by-product
- Direct Te mining

Manufacturing

- Recycle overspray
- Recycle scrap

End-of-Life

- Collection and Recycling
- Semiconductor Refining

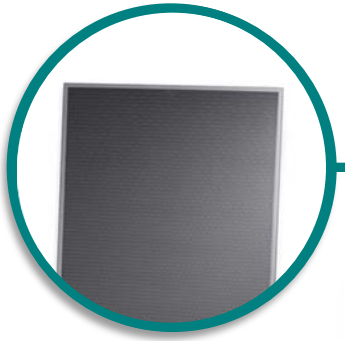
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First Solar's Module Recycling

~ 95% recycling of semiconductor material
~ 90% recycling of glass

IN

Warranty/End-of-Life Modules and Manufacturing Scrap





Shredder



Hammermill

Dry Process



Film Removal and Washing

Precipitation



Dewatering



Unrefined Semiconductor Material



Cullet de-watering



Glass-Laminate Material Separation



Laminate Material



Clean Glass Cullet

Wet Process

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Addressing Critical Materials through Recycling

- *How are you addressing the availability of Tellurium?*
  - High recycled semiconductor content contributes to long-term security of Te supply and reduced life cycle Cd emissions. Currently 95% of CdTe is recovered during recycling of manufacturing scrap and end-of-life modules.
  - Because current recycling volumes are low, this recycled semiconductor content accounts for a small fraction (**~6%**) of the total CdTe needed in the production of new modules.
  - Based on market projections from EPIA/Greenpeace[1] and IEA[2], in 2050, the quantity of annual CdTe PV waste (in MWp) is projected to be **~81%** of the newly installed CdTe PV capacity.
  - 81% waste content × 85% collection rate × 95% recycling rate × 97% refining rate: **over 60% recycled semiconductor content by 2050**.[1]

- *Is there any concern about future stocks of Cd in the future?*
  - An oversupply of Cd projected as current demand for Cd decreases. Sustainable use for Cd is needed (e.g., CdTe PV systems).[2]

[1] Sinha, P., M. Cossette, and J.-F. Ménard. 2012. End-of-Life CdTe PV Recycling with Semiconductor Refining. 27th EU PVSEC, Frankfurt, Germany, pp. 4653 – 4656.
[2] Matsuno, Y., T. Hur, and V. Fthenakis. 2012. Dynamic modeling of cadmium substance flow with zinc and steel demand in Japan. Resources, Conservation and Recycling, 61: 83– 90

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Global.