

# Tellurium—The Bright Future of Solar Energy

*As part of a broad mission to conduct research and provide information on nonfuel mineral resources, the U.S. Geological Survey (USGS) supports science to understand*

- How and where tellurium resources form and concentrate in the Earth's crust
- How tellurium resources interact with the environment to affect human and ecosystem health
- Trends in the supply of and demand for tellurium in the domestic and international markets
- Where undiscovered sources of tellurium might be found

*Why is this information important? Read on to learn about tellurium and the important role it plays in the national economy, in national security, and in the lives of Americans every day.*

Tellurium is one of the least common elements on Earth. Most rocks contain an average of about 3 parts per billion tellurium, making it rarer than the rare earth elements and eight times less abundant than gold. Grains of native tellurium appear in rocks as a brittle, silvery-white material, but tellurium more commonly occurs in telluride minerals that include varied quantities of gold, silver, or platinum. Tellurium is a metalloid, meaning it possesses the properties of both metals and nonmetals.

Tellurium was discovered within gold ores in the late 1780s in Transylvania, Romania. Fifteen years later, the element was isolated as a distinct substance and named tellurium, after the Latin word “tellus,” which means “fruit of the Earth.” Recovered tellurium has historically been used in metallurgy as an additive to stainless steel and in alloys made with copper, lead, and iron.

Because of its low abundance, little is known about environmental baseline concentrations for tellurium or its toxic effect on humans and ecosystems. Human exposure to tellurium can lead to a garlic odor on the breath, nausea, and eventual respiratory problems.

## How Do We Use Tellurium?

Tellurium's primary use is for manufacturing films essential to photovoltaic solar cells. When alloyed with other elements—such as cadmium—tellurium forms a compound that exhibits enhanced electrical conductivity. Therefore, a thin film can efficiently absorb sunlight and convert it into electricity. As an additive to steel, copper, and lead alloys, tellurium improves machine efficiency, specifically in thermoelectric cooling applications where it improves ductility and tensile strength, and helps prevent sulfuric acid corrosion. Together, the photovoltaic and thermoelectric applications account for more than two-thirds of global tellurium consumption.

Tellurium is used in copying machines and as a coloring agent in ceramics and glass, and as a vulcanizing agent in the chemical industry to make durable products, including an additive that improves rubber's heat resistance. Integrated circuits, laser diodes, and medical instrumentation, all of which have experienced robust manufacturing growth in recent years, contain tellurium. It can even be added to gasoline to prevent engine knocks in automobiles.

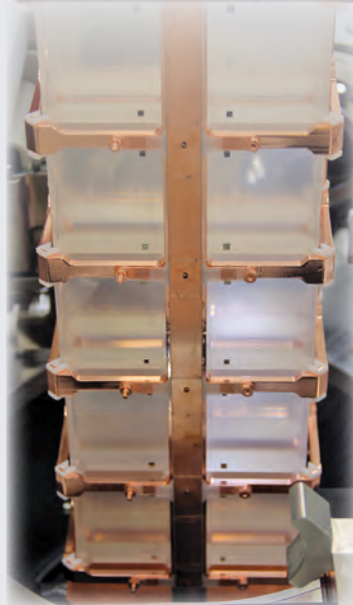
## Where Does Tellurium Come From?

Most tellurium used today is indirectly mined, as it is recovered as a byproduct of milled copper, iron, and other base-metal-rich ore bodies containing trace amounts of tellurium-bearing minerals. Globally, primary tellurium sources are large-tonnage, low-grade ores from copper and copper-gold porphyry-type deposits, as a byproduct of copper refining. Typically, concentrations of 1 to 4 percent tellurium are recovered from anode slimes at copper refineries. Seafloor volcanogenic massive sulfide (VMS) deposits can also yield significant amounts of byproduct tellurium; the large iron- and copper-rich ore bodies in the Ural Mountains of Russia are an important example.

Tellurium is concentrated in discrete telluride minerals and the structures of sulfide minerals in most gold deposits. Telluride minerals are significant gold sources in many giant gold deposits, such as Cripple Creek in Colorado and the Golden Mile in Western Australia, Australia. However, the overall tonnage of tellurium in the gold deposits is low compared to anode sludge recoveries from the milling of large-tonnage base-metal deposits. Because of this fact, gold deposits, despite containing high grades of tellurium, are rarely viewed as potential tellurium resources. Significant tellurium quantities are recovered as a primary ore from only two mining districts in the world: the adjacent epithermal gold-tellurium vein deposits at Dashuigou and Majiagou in southwestern China and the epithermal-like mineralization at the Kankberg deposit, Skellefte VMS district, Sweden. The deposits in these districts account for about 15 percent of annual tellurium production worldwide. In addition, minor amounts of tellurium were recovered from a small, epithermal gold deposit in northern Sonora, Mexico.



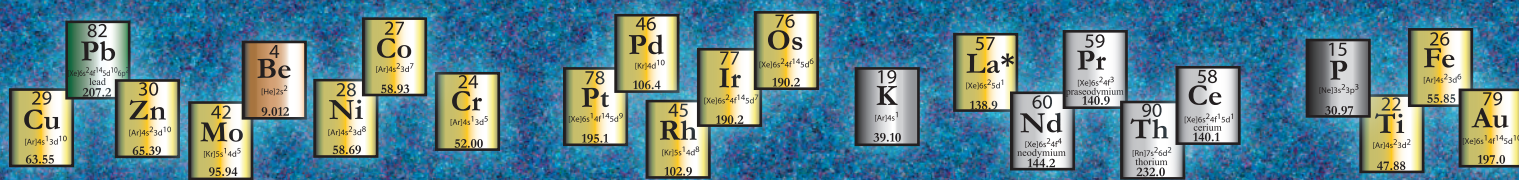
Tellurium is critical to efficient, thin-film photovoltaic cells that produce electricity from sunlight. A 2-megawatt, solar photovoltaic array occupies a former landfill at Fort Carson, Colo. Photograph from the U.S. Department of Energy Western Area Power Administration <http://usarmy.vo.llnwd.net/e2/c/images/2013/12/05/323603/original.jpg>.



Cryogenic Underground Observatory for Rare Events (CUORE) experiment uses towers of cubic tellurium oxide crystals (pictured) to try and detect a Majorana neutrino.

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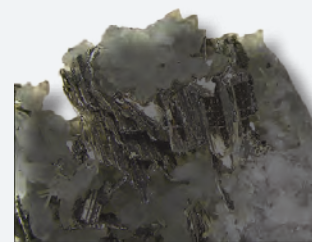




## Tellurium Supply and Demand Worldwide

Specific international and domestic tellurium sources are not well-known because tellurium is typically a byproduct recovered at refineries where base-metal-rich ores are received from multiple mine locations in many countries and treated collectively. The availability of economically recoverable tellurium depends on the demand for its parent metal, copper. Tellurium is typically extracted from copper refined by an electrolytic process, which is a cost effective technique applied to high-grade copper ores. In this process, tellurium and other impurities, such as gold, silver, and platinum, are concentrated onto, and then removed from, crude copper anodes. For refining lower grade copper ores, the most economical process is a solvent-leach refining process, which cannot extract tellurium. A global decrease in high-grade copper ores could therefore constrain tellurium recovery and increase the likelihood tellurium would be recovered from gold deposits.

In the United States, tellurium demand is met by domestic supply and importation. Nearly all domestic tellurium production comes from the Asarco copper refinery in Amarillo, Texas, where it is recovered as a byproduct of copper anode slimes and the skimming of lead refinery ores mined from deposits in the western United States. Whereas much of the data for domestic tellurium production are proprietary, estimates indicate that the United States imports about 50 percent of its tellurium. About 75 percent of imported tellurium is from China and Canada, with lesser amounts from refineries in the Philippines and Belgium. Globally, the primary producers of tellurium are Sweden, Japan, Russia, China, the United States, and Peru. Tellurium reserves in the United States are about 15 percent of the global total (24,000 metric tons) and equivalent to approximately eight times the global annual production total (450 metric tons of tellurium).



Calaverite, a gold-bearing telluride mineral, from the Cresson mine in the Cripple Creek deposit, Colorado. Photograph courtesy of irocks.com/ Arkenstone photo.

**Did you know...** Cadmium telluride photovoltaic cells for solar technology were first developed in the 1950s

## How Do We Ensure Adequate Supplies of Tellurium for the Future?

Current global tellurium demands are met through the recovery of tellurium from anode slimes during the electrolytic refinement of smelted copper. Geopolitical issues are unlikely to affect needed supplies because porphyry copper deposits, the main sources of most copper, are widely mined in the western United States and throughout the world. Regardless, demands for tellurium, particularly as the global carbon footprint is reduced and solar energy technology becomes more widespread, are predicted to increase steadily over the next 15 to 20 years. The main concern surrounding tellurium supply is the question of whether or not global copper production can meet the growth in tellurium demand.

To meet increased demand, more efficient tellurium extraction from copper slimes—above the present 30 to 40 percent level—may be critical. New copper recovery processes, different from traditional electrolytic refining, are being considered for implementation, but these methods do not recover tellurium. As a result, alternative sources for this critical element must be considered. Recycling solar cells may help, but tellurium-rich films have long lifespans and to date have not been extensively reused. It might become an economic necessity to extract tellurium directly from telluride minerals during gold mining in locations such as Cripple Creek, Colorado; the Sierra Foothills of California; and southeastern Alaska. In addition, although undersea mineral recovery is still in its infancy, tellurium is considered abundant in ferromanganese nodules on the ocean floor.



The Kankberg mine in Sweden produces ten percent of the world's tellurium from underground operations below this original pit and is one of the only deposits where tellurium is a direct product of mining activity. Photograph from [http://www.boliden.com/Global/Press photos/Gruvor/Bolidenomr det/Kankberg\\_Foto\\_Erica\\_Nilsson\\_fri\\_hi.jpg](http://www.boliden.com/Global/Press%20photos/Gruvor/Bolidenomr%C3%A4det/Kankberg_Foto_Erica_Nilsson_fri_hi.jpg).

**Did you know...** The Kankberg deposit in V sterbotten County, Sweden, originally mined for copper and zinc sulfide, now produces 10 percent of the world's tellurium and averages 186 grams of tellurium per tonne of ore

## For More Information

- On production and consumption of tellurium, as well as selenium, which is in the same chemical family:  
<http://minerals.usgs.gov/minerals/pubs/commodity/selenium/>
- On the use of tellurium for production of photovoltaic cells:  
<http://pubs.usgs.gov/circ/1365/>
- On historical statistics for tellurium in the United States:  
<http://minerals.usgs.gov/ds/2005/140/>

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The USGS Mineral Resources Program is the principal Federal provider of research and information on tellurium and other nonfuel mineral resources.

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