



Date: July, 22, 2022
To: Wareham Planning Board
Subject: CdTe PV safety

Dear Planning Board Members,

First Solar is [America's largest solar manufacturing company](#) and a leading solar panel technology supplier to project developers throughout the country. We are writing to offer some background on our company and to seek to address any concerns that you may have about our thin film cadmium telluride photovoltaic (CdTe PV) technology. CdTe PV is a mature technology and First Solar panels have been safely deployed for more than two decades.

Founded in Ohio in 1999, First Solar employs more than 2,000 U.S. associates, and is the only American solar manufacturer to have sold more than 40,000 megawatts of solar panels around the world (equivalent to more than 200 million solar panels) and are the only American company to rank among the world's ten largest solar manufacturers. Recognized as a trusted technology partner within the solar industry, approximately half of all utility-scale solar capacity in the U.S. in the past decade utilizes First Solar PV panels – a testament to our product and its track record. The strong demand for our products is reflected in our AA Bankability score from [PV ModuleTech](#) – among the highest in the industry. Our commitment to excellence through American manufacturing runs deep and we are currently constructing our third U.S. manufacturing facility in Northwest Ohio.

As one of the world's leading solar manufacturers, First Solar takes safety and environmental responsibility very seriously:

- Our modules are manufactured in facilities certified to globally recognized standards for quality, environmental management and occupational health and safety (ISO 9001, ISO 14001, ISO 45001).
- **Our U.S. manufacturing facilities have received the Ohio EPA's top environmental stewardship award- the [Encouraging Environmental Excellence Platinum Level Award](#)-** which recognizes an organization's exceptional achievements in environmental stewardship and contributions to the local community.
- **Our solar panels are the first and only solar products to be included in the [EPEAT registry for sustainable electronics](#), a globally recognized and independently validated ecolabel used by the U.S. federal government and other large purchasers.** EPEAT-registered products meet minimum performance standards in areas such as energy efficiency, toxicity reduction, recycling and material selection.
- **We are the only solar manufacturer with global in-house solar panel recycling capabilities** and we



have more than 15 years of experience operating high-value recycling facilities which can recycle our semiconductor material up to 41 times over for reuse in new First Solar modules. We established the industry's first global recycling program in 2005 and continue to demonstrate our commitment to product stewardship by offering industry-leading [PV recycling services](#).

- For more information about First Solar's sustainability practices and approach to Responsible Solar, please see our [corporate sustainability report](#).

More than 50 researchers from leading U.S. and international institutions (including MIT, Brookhaven National Lab, National Renewable Energy Laboratory, North Carolina State University and Virginia Tech) have confirmed the environmental benefits and safety of CdTe PV technology over its entire life cycle; during normal operation, exceptional accidents such as fire or module breakage, and through end-of-life recycling and disposal:

- In 2019, scientists from Virginia Tech investigated this topic in their report entitled "[Assessment of the Risks Associated with Thin Film Solar Panel Technology](#)." After reviewing experimental results, theoretical worst-case modeling, and observational data from historical events, they concluded that **CdTe PV installations "pose little to no risk under normal operating conditions and foreseeable accidents such as fire, breakage, and extreme weather events like tornadoes and hurricanes."**
- A 2020 [peer review](#) conducted by the Massachusetts Institute of Technology and Arizona State University concluded: "**Based on our review of competitiveness, safety, and life cycle environmental performance, CdTe photovoltaic technology is expected to make a valuable contribution to the U.S. energy transition.** These conclusions are drawn on the basis of eco-efficiency... the concept of creating more economic value with lower environmental impacts."
- A 2020 study by Columbia University entitled "[Sustainability evaluation of CdTe PV: An update](#)" evaluated conflicting leaching results and concluded that "**some studies alerting to cadmium leaching risks used completely invalid assumptions, e.g., grinded and/or un-encapsulated modules, whereas the most comprehensive studies showed absolutely no risks during normal conditions and insignificant risks during extreme conditions like major storm events.**" It is worth emphasizing that un-encapsulated CdTe solar technologies are not commercially produced and/or sold anywhere in the world and that First Solar's technology uses an industrial-strength adhesive to fully encapsulate the semiconductor material within the solar panel to eliminate any risk of exposure to the environment.
- While the above referenced leaching results were laboratory studies, Fraunhofer Institute conducted a field study entitled "[Health, Safety and Environmental Risks from the Operation of CdTe and CIS Thin-Film Modules](#)" of the fate of CdTe in broken solar module pieces. This study found no critical increase in soil Cd concentrations after 1 year of leaching in an outdoor experiment with actual rainwater.
- In their 2003 report entitled "[CdTe PV: Real and Perceived EHS Risks](#)", the U.S. National Renewable



Energy Laboratory and Brookhaven National Laboratory concluded that environmental risks from CdTe PV are minimal due to the use of stable materials in an encapsulated solid device.

In summary, First Solar's proven safety track record is based on the use of stable materials and thorough testing. First Solar panels have durable glass/glass construction and are subjected to rigorous [reliability testing](#) to meet national and international product safety standards from UL and IEC. With regard to weather impacts, First Solar PV modules are the only products in the industry warranted against cell cracking and micro-cracking which can be caused by excessive thermal and mechanical stress. This is particularly important in high wind and severe hail risk regions. First Solar modules consistently rank as "Top Performer" in PVEL's reliability scorecard which evaluates long-term durability and performance.

First Solar is also the only solar technology to meet the sustainability leadership standard (NSF/ANSI 457) through our products' inclusion in the EPEAT registry for green electronics, a globally recognized and independently validated ecolabel. As part of our EPEAT registration, the chemical composition of our products and manufacturing process are annually screened and contain no perfluoroalkyl substances (PFAS). In accordance with the U.S. federal waste characterization test (TCLP), First Solar warranty and end-of-life returns are characterized as a federal non-hazardous waste.

We recognize there is a lot of misinformation circulating about CdTe solar technology and would welcome the opportunity to speak with members of the Planning Board to share more information on our technology's safety track record and help address any concerns that you may have.

Sincerely,

A handwritten signature in black ink, appearing to read "P. Sinha".

Parikhit (Ricky) Sinha, Ph.D.

Sr. Scientist, Sustainability Research

Attachments

- First Solar Thin Film PV factsheet and FAQ



First Solar Thin Film PV.

Proven Benefits of CdTe Technology

CONVERTING WASTE BYPRODUCTS INTO A STABLE CdTe COMPOUND

CdTe is sustainably sourced from byproducts of the zinc and copper industries. Cadmium, a waste byproduct of zinc refining, and tellurium, a byproduct of copper refining, are converted into a stable CdTe compound. Once encapsulated in First Solar modules, CdTe produces clean, affordable energy for 30+ years.

“CdTe PV systems that use cadmium as a raw material should be considered as one of the solutions for a sustainable use of cadmium.”⁴



OPTIMAL SEMICONDUCTOR MATERIAL

First Solar’s cadmium telluride (CdTe) photovoltaic (PV) systems represent a breakthrough in large-scale renewable energy solutions. The thin layer of CdTe semiconductor material used in First Solar PV modules is optimal for absorbing and converting sunlight into useful electricity, enables high-volume manufacturing and has amongst the highest efficiency potential of all PV semiconductor materials.¹ In addition, First Solar thin film PV modules have a proven performance advantage over conventional silicon modules in harsh operating environments due to their superior spectral response and low temperature coefficient.

First Solar’s advanced thin film PV solutions are the industry’s leading eco-efficient technology due to their superior energy yield, competitive cost and lowest environmental impacts.² On a life cycle basis, First Solar modules have the smallest carbon footprint, lowest water use and fastest energy payback time of any solar technology on the market. First Solar fully integrated manufacturing process uses less energy, water and semiconductor material than conventional silicon modules. First Solar’s thin film PV solutions are designed to meet today’s global energy demands by generating clean and reliable electricity, minimizing fuel price volatility, and boosting energy and water security.

LEADING ECO-EFFICIENT PV TECHNOLOGY

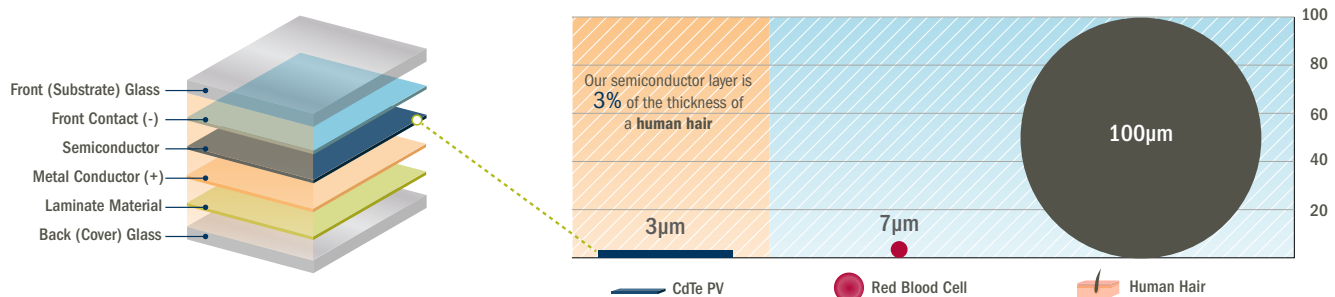
- Proven energy yield advantage over competing PV technologies in areas of high temperature and high humidity results in a lower levelized cost of electricity (LCOE)
- Cost competitive with conventional energy sources
- Fixed pricing and low operating costs reduces fuel price volatility risks and eliminates hedging costs
- Generates clean electricity for 30+ years with no carbon emissions or other air pollutants
- Requires no water to generate electricity and uses less water on a life cycle basis than other PV technologies (3X times less than crystalline silicon PV)
- Smallest carbon footprint and fastest energy payback time of all solar technologies on a life cycle basis

Energy payback time— is the amount of time a system must operate to recover the energy required to produce, install, operate and recycle it.

“CdTe PV technology can contribute to large-scale deployment of renewable energy solutions in an environmentally sustainable way addressing the increasing global demand for low-carbon energy.”³

DESIGNED FOR SAFETY AND DURABILITY

*"In the exceptional case that an accident like fire or breakage occurs, the emission of cadmium has been proven to be negligible and do not represent a potential risk for human health nor for the environment."*⁵



First Solar modules consist of a thin layer of CdTe, approximately 3 percent the thickness of a human hair or less than half the size of a red blood cell, that is encapsulated between two protective sheets of glass and sealed with an industrial laminate, resulting in a strongly bonded monolithic structure. The glass-on-glass design is more robust against fire and damage than the glass-on-backsheet design of other PV technologies.⁶ First Solar modules have been tested for safety during breakage, fire, flooding and hail storms and meet rigorous performance testing standards, demonstrating their long-term durability and reliability in real-world environments (UL 1703, IEC 61215, IEC 61730, Thresher test).

*"CdTe differs from elemental Cd and other Cd compounds due to strong bonding that leads to an extremely high chemical and thermal stability"*⁷

More than 50 researchers from leading international institutions have confirmed CdTe PV's safety over its entire life cycle during normal operation, foreseeable accidents such as fire or module breakage and through end-of-life recycling and disposal.

*"Replacing existing grid electricity with large-scale CdTe PV arrays would result in a reduction of greenhouse gases, criteria air pollutants, heavy metals and radioactive species by 89 to 98 percent."*⁸

COMMITMENT TO RESPONSIBLE LIFE CYCLE MANAGEMENT

Recycling is an integral part of responsible product life cycle management and is important to the whole PV sector as environmentally sensitive materials (e.g. lead, selenium, and cadmium compounds) are common in the industry.

First Solar provides a global industry-leading recycling service that recovers over 90% of the semiconductor material for reuse in new modules and ~90% of the glass for reuse in new glass products, setting the international standard for high-value recycling of PV panels. Our recycling facilities are scalable to accommodate high volume recycling as more modules reach the end of their 30+ year life.

¹ Shockley, W., & Queisser, H. J. (1961). Detailed balance limit of efficiency of p - n junction solar cells. Journal of applied physics, 32(3), 510-519.

² M. Seitz, M. Kroban, T. Pitschke, S. Kriebe, 2013, Eco-Efficiency Analysis of Photovoltaic Modules, Bifa Environmental Institute.

³ Study of the Environmental, Health, and Safety of Cadmium Telluride (CdTe) Photovoltaic Technology, King Saud University, Kuwait Institute for Scientific Research, Kuwait University, University of Jordan, King Abdullah University of Science and Technology, Masdar Institute of Science and Technology, 2012.

⁴ Scientific Review on the Environmental and Health Safety (EHS) aspects of CdTe photovoltaic (PV) systems over their entire life cycle, University of Tokyo and Yokohama National University, Japan, May 2012.

⁵ First Solar CdTe Photovoltaic Technology: Environmental, Health and Safety Assessment, National Renewable Energy Centre (CENER) and Fundación Chile, October 2013.

⁶ German Ministry of Economics and Technology, TÜV Rheinland, and Fraunhofer ISE, Assessment of the Fire Risk in Photovoltaic Systems and Elaboration of Safety Concepts for Minimization of Risks, March 2015.

⁷ Executive Summary, Study of the Environmental, Health, and Safety of Cadmium Telluride (CdTe) Photovoltaic Technology, IIT-Delhi, India, July 2012.

⁸ Fthenakis, V.M., Kim H.C., and Alsema, E. 2008. Emissions from Photovoltaic Life Cycles. Environ. Sci. Technol. 2008, 42, 2168–2174.



Q: WHAT MAKES FIRST SOLAR'S THIN FILM PV MODULES COMPETITIVE?

A: First Solar thin film modules are manufactured using a fully integrated and resource efficient process which enables affordable, high volume production with the lowest environmental impacts in the industry. In addition, First Solar's high efficiency thin film modules are proven to deliver more usable energy per watt than conventional silicon-based modules, resulting in a lower levelized cost of electricity (\$/MWh).

Source: Dirnberger et al., "On the impact of solar spectral irradiance on the yield of different PV technologies," *Solar Energy Materials & Solar Cells*, vol. 132 pp. 431-442, 2015.



Q: WHAT ARE THE ENVIRONMENTAL BENEFITS OF THIN FILM PV TECHNOLOGY?

A: First Solar's advanced thin film PV solutions are the industry's leading eco-efficient technology due to their superior energy yield, competitive cost and smallest life cycle environmental impacts. By using less grid electricity during manufacturing, First Solar modules have the smallest carbon footprint, fastest energy payback time and lowest life cycle water use and air pollutant emissions of any PV technology.

Sources: Louwen, Atse, Ruud E.I. Schropp, Wilfried G.J.H.M. van Sark, and André P.C. Faaij. "Geospatial Analysis of the Energy Yield and Environmental Footprint of Different Photovoltaic Module Technologies". *Solar Energy* 155 (October 2017): 1339-53. <https://doi.org/10.1016/j.solener.2017.07.056>.

Leccisi, Enrica, Marco Raugei, and Vasilis Fthenakis. "The Energy and Environmental Performance of Ground-Mounted Photovoltaic Systems—A Timely Update". *Energies* 9, Nr. 8 (08 August 2016): 622. <https://doi.org/10.3390/en9080622>.



Q: HOW DOES CDTE DIFFER FROM CADMIUM?

A: First Solar modules contain cadmium telluride (CdTe) which is a stable compound that is insoluble in water and has an extremely high chemical and thermal stability. These properties limit its bioavailability and potential for exposure. First Solar modules contain very little CdTe. The semiconductor layer in First Solar modules is a few microns thick, equivalent to 3% the thickness of a human hair. Additionally, the thin film semiconductor is encapsulated between two sheets of glass and sealed with an industrial amine, further limiting the potential for release into the environment in the event of fire or breakage.

Source: Kaczmar, "Evaluating the Read-Across Approach on CdTe Toxicity for CdTe Photovoltaics," in SETAC North America 32nd Annual Meeting, Boston, 2011..



Q: ARE THIN FILM MODULES DURABLE IN THE FIELD?

A: Yes. First Solar modules are tested for safety during breakage, fire, flooding and hail storms, and meet rigorous long-term durability and reliability testing standards. First Solar modules are the only PV module in the industry warranted against cell cracking and micro-cracking, which can be caused by excessive thermal and mechanical stress. First Solar modules have also consistently ranked as "Top Performer" in PVEL's reliability scorecard which evaluates long-term durability and performance.

Source: PVEL, *Cracking Down on PV Module Design: Results from Independent Testing*, 2020. https://www.pvel.com/wp-content/uploads/PVEL-White-Paper_Mechanical-Stress-Sequence_Cracking-Down-on-PV-Module-Design.pdf



Q: IS THIN FILM PV TECHNOLOGY SAFE FOR THE ENVIRONMENT?

A: Yes. More than 50 researchers from leading international institutions have confirmed the environmental benefits and safety of First Solar's thin film PV technology over its entire life cycle; during normal operation, exceptional accidents such as fire or module breakage, and through end-of-life recycling and disposal. First Solar provides the PV technology of choice for leading utilities and power buyers such as Southern Power Co., NRG Energy, and Capital Dynamics. With more than 40,000MW sold worldwide, First Solar modules have a proven record of safe and reliable performance.

Source: <http://www.firstsolar.com/Resources/Sustainability-Documents?ty=Peer+Reviews&re=&In=>



Q: CAN FIRST SOLAR MODULES BE RECYCLED AT END-OF-LIFE?

A: Yes. First Solar offers global, competitively-priced and flexible PV module recycling services. First Solar has a long-standing leadership position in PV recycling with more than 15 years of experience in operating high-value PV recycling facilities on a global and industrial scale. First Solar's high-value recycling process recovers more than 90% of a PV module for reuse in new modules and glass products.

Source: Sinha, Parikhit, Sukhwant Raju, Karen Drozdiak, and Andreas Wade. "Life cycle management and recycling of PV systems". *PV Tech*, 19 December 2017. <https://www.pv-tech.org/technical-papers/life-cycle-management-and-recycling-of-pv-systems>.