

PV HEALTH AND SAFETY



PROVIDING THE LEADING ECO-EFFICIENT PV TECHNOLOGY



**SUPERIOR
ENERGY YIELD**



**COST
COMPETITIVE**



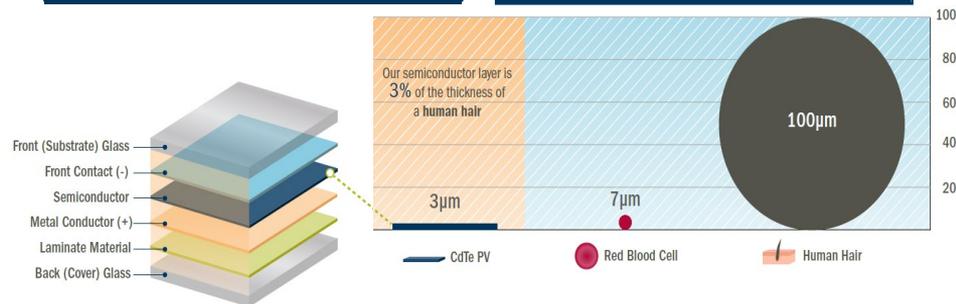
**LOWEST
ENVIRONMENTAL
IMPACT**

- Higher energy yields at a competitive cost
- Smallest carbon footprint and air pollutants
- Lowest life cycle water use
- Fastest energy payback time < 1 year
- Industry leading PV recycling program
- Validated by 3rd party research and global peer reviews

Creating more value with less environmental impact.

ENVIRONMENTAL PRODUCT SAFETY

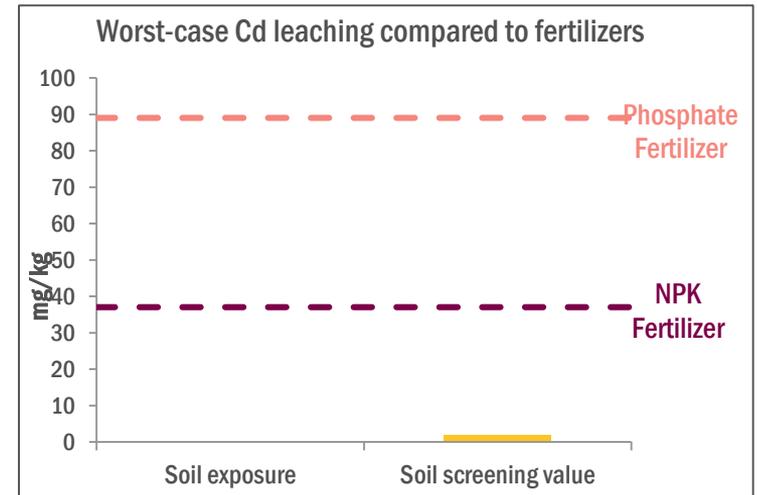
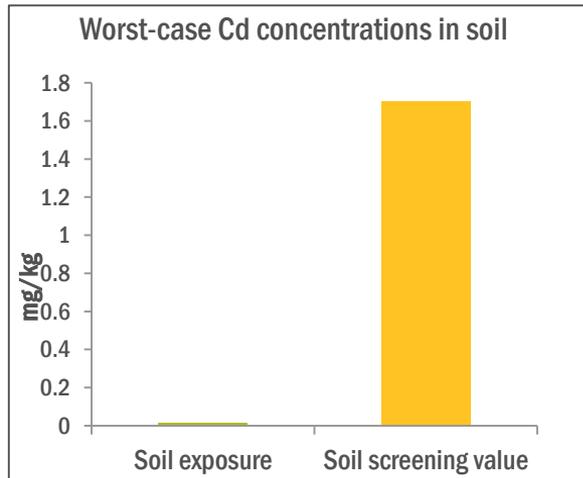
- CdTe is a stable compound that is insoluble in water and has high chemical and thermal stability
 - Strong bonding: >5 eV
 - High melting point: 1042°C (1908°F)
 - Low solubility: K_{sp} (solubility product) 9.5×10^{-35}
- Semiconductor layer is only a few microns thick ($\sim 3\%$ the thickness of a human hair) and encapsulated between two sheets of glass
- With over 200 million modules deployed, First Solar's PV technology has a proven safety track record
- At end-of-life, First Solar PV panels are non-hazardous according to the Method 1311 Toxicity Characteristic Leaching Procedure (TCLP).



“CdTe differs from elemental Cd due to **STRONG BONDING** that leads to an extremely **HIGH STABILITY**.”

WHAT COULD HAPPEN IF MODULES BREAK?

- Module **breakage rate is low**: ~0.04% per yr with over 1/3 occurring during shipping and installation
 - Most breakages are fractures, i.e. module remains bound together by industrial laminate
- CdTe's **insolubility in water** limits its ability to leach
- Potential Cd concentrations in **worst-case leaching** scenario are **1-5 orders of magnitude below** conservative human health screening levels in the U.S.
- Modelled worst-case leaching results are **3,000-7,000 times lower** than Cd concentrations in common fertilizers
- Routine inspections and power output monitoring identify broken modules for removal



CDTE PV SAFETY EVALUATED BY BNL/NREL AND NC STATE UNIVERSITY

CdTe PV: Real and Perceived EHS Risks

Professor **Vasilis Fthenakis**
National PV EHS Assistance Program



Ken **Zweibel**
National Renewable Energy Laboratory



Health and Safety Impacts of Solar Photovoltaics

- The **environmental risks from CdTe PV are minimal** and replacing coal generation with PV will **prevent Cd emissions** in addition to preventing **large quantities of CO₂, SO₂, NO_x, and particulate emissions**.
- CdTe is a **more stable and less soluble** compound than Cd...
- The vapor pressure of CdTe at ambient conditions is zero. Therefore, it is **impossible for any vapors or dust to be generated** when using PV modules.
- Research demonstrates that [CdTe PV modules] pose **negligible toxicity risk** to public health and safety while **significantly reducing the public's exposure to cadmium** by reducing coal emissions.
- All the approximately 7 grams of cadmium in one CdTe panel is in the form of a chemical compound cadmium telluride, which has 1/100th the toxicity of free cadmium.
- [CdTe] is a very stable compound that is non-volatile and non-soluble in water.

THE “SOLAR REEF” EFFECT OF UTILITY-SCALE PV POWER PROJECTS

- **Solar facilities create a variety of microclimates which promote botanical biodiversity**
 - Greater percentage of live cover, less bare ground and higher species diversity than surrounding land
 - Pollinators such as bees and butterflies have been found in greater abundance than control sites
 - PV projects offer shelter from predators and elements e.g. sun and wind
- **Best practice habitat protection measures further promote “solar reef” effect**
 - Siting on previously disturbed land
 - Vegetation management e.g. invasive species control and re-planting protected plants
 - Decommissioning and restoring land





END-OF-LIFE SYSTEM COMPONENTS

FIRST SOLAR RECYCLING TECHNOLOGY

- Technology based on crushing panels with shredder-hammermill and leaching with sulfuric acid and peroxide
- High yield (~90%) recovery of glass and semiconductor material for reuse in new glass and PV products and processing >20,000 metric tons per year
- Continuously improving processes and technology and reducing operational costs
- Cost-effective contracts with 2-year termed renewable pricing and no up-front fees: “pay as you go” model using later year project cash flows
- Easily integrated into O&M, EPC, PV project and module sales agreements
- Increased volumes and rising disposal costs will lead to recycling becoming a commercially attractive business



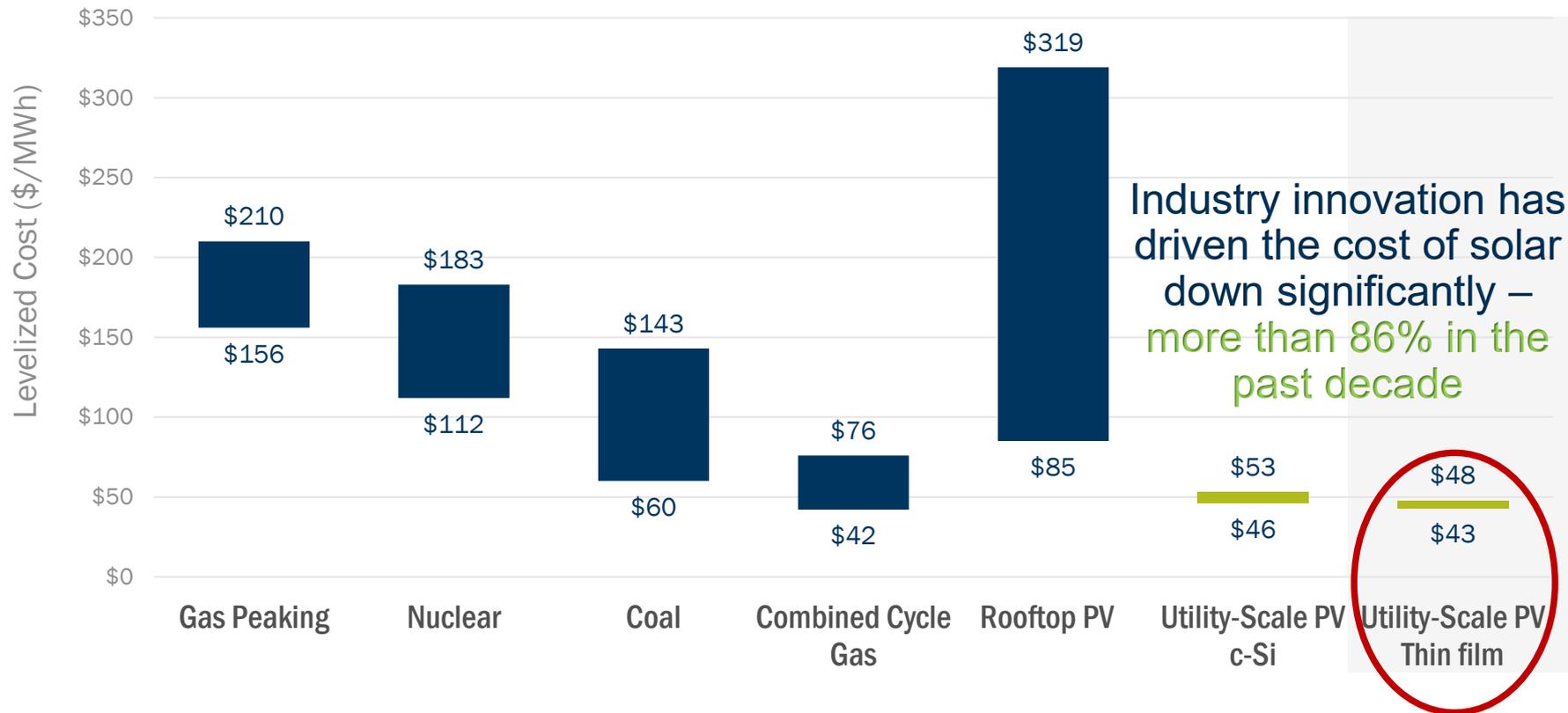
First Solar V3 Recycling Facility, Perrysburg, Ohio



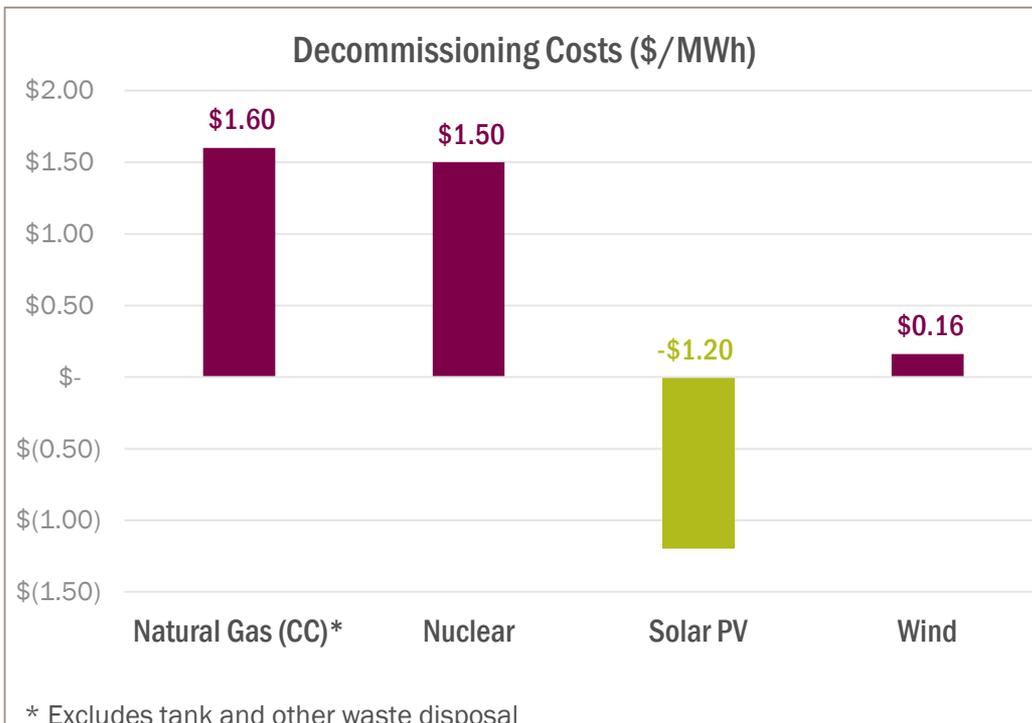
ECONOMICS

UTILITY-SCALE SOLAR IS NOW A LEAST COST ENERGY OPTION

Unsubsidized Levelized Cost of Energy Comparison in the U.S.



DECOMMISSIONING COST MODELING



Brown et al., Solid Waste from the Operation and Decommissioning of Power Plants, Oak Ridge National Laboratory, 2017. <https://www.osti.gov/scitech/biblio/1339360>

- PV has lowest decommissioning costs of all energy technologies
 - Recovery value of a PV system exceeds decommissioning costs
- Decommissioning cost models developed for First Solar projects
 - Columbia University: net revenue of up to \$ 1.58 per module area
 - ERM: 100% confidence of net profit from PV project decommissioning when land value was included, and up to 95% confidence in a net profit when land value was excluded