

Sustainability in the Global Photovoltaics Industry

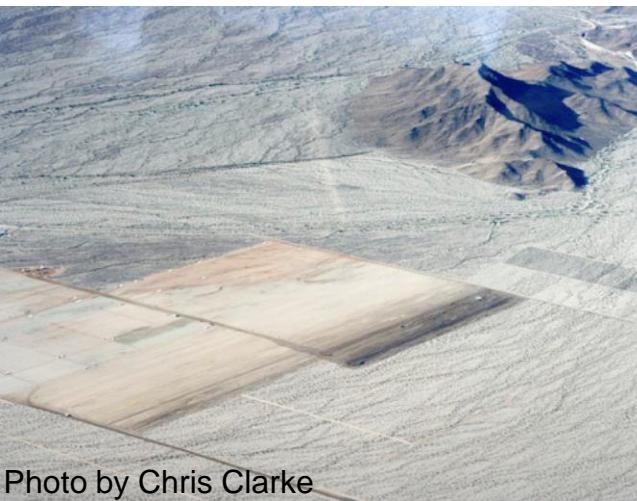


Photo by Chris Clarke



Solarhoney.co

Greenwashing vs. verifiable sustainability: What's the difference?

Dustin Mulvaney, Ph.D., Associate Professor



San José State
UNIVERSITY

DEPARTMENT OF
ENVIRONMENTAL STUDIES

Supply chains

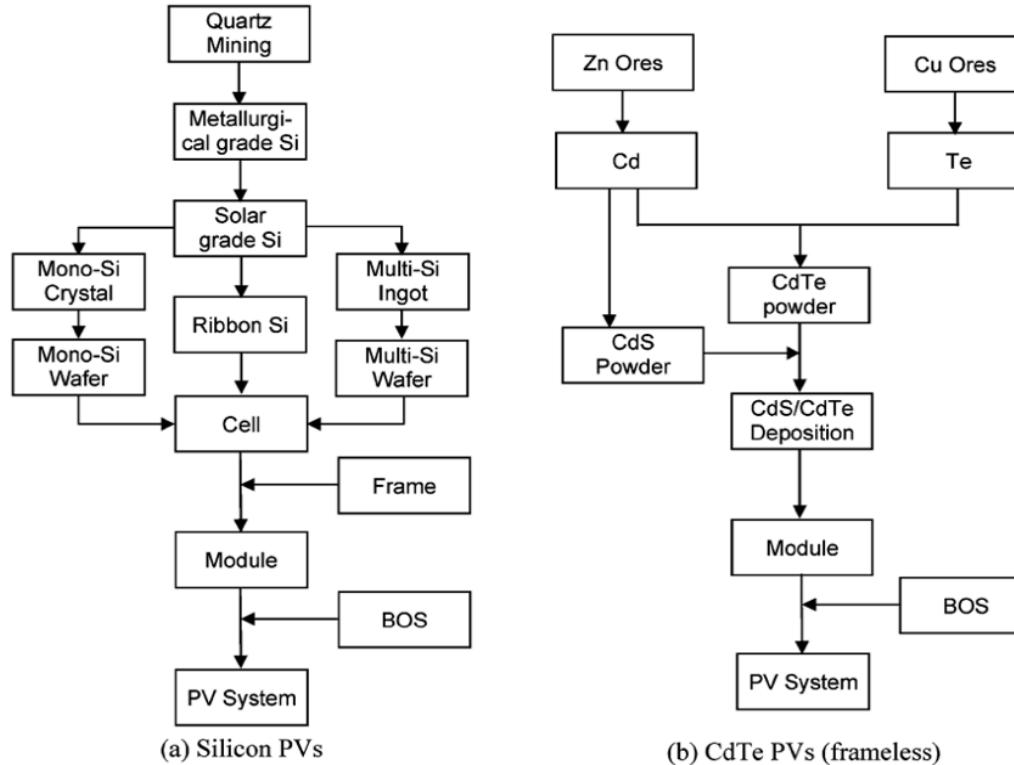
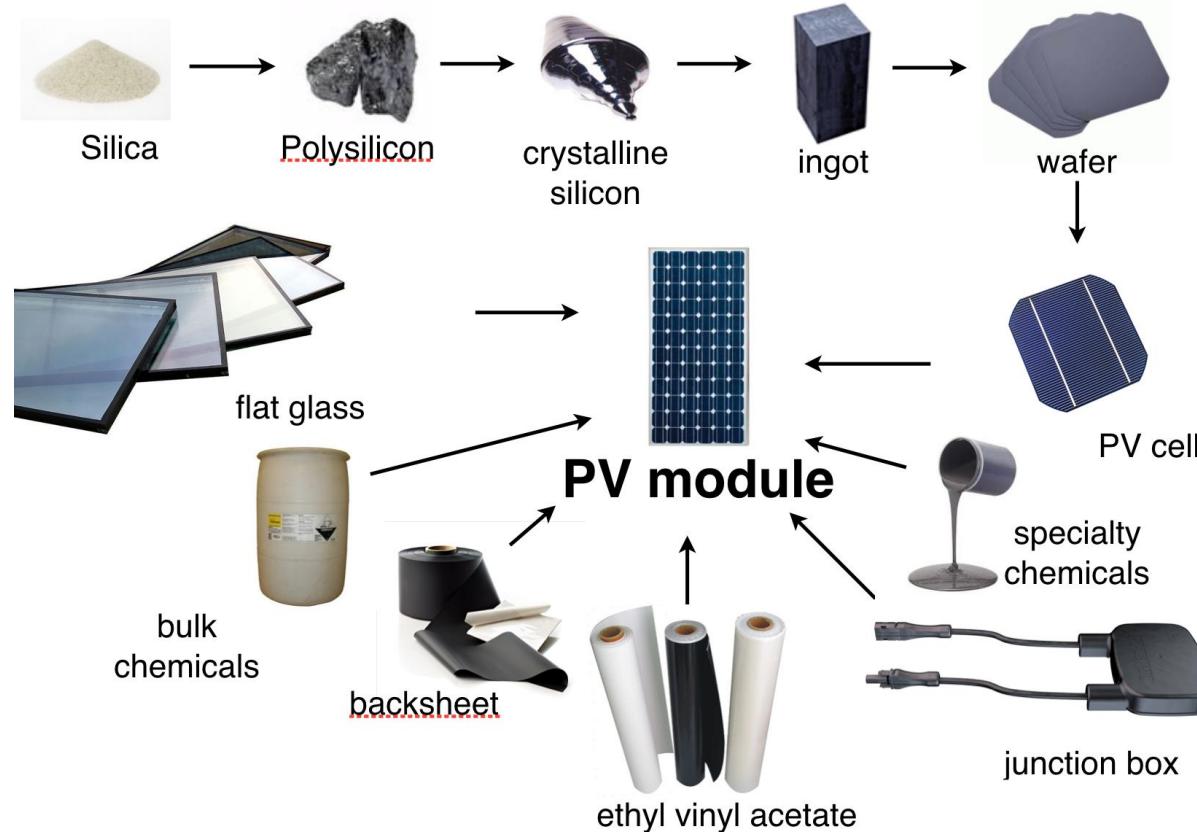


FIGURE 1. Simplified process-flow diagrams from mining to system manufacturing stages, namely cradle-to-gate for (a) mono-, ribbon-, and multi-Si PVs, and (b) thinfilm CdTe PVs. Detailed descriptions of the life cycles are available elsewhere (10, 12, 13).

Crystalline silicon photovoltaic (PV) supply chain





Solar Energy Firms Leave Waste Behind in China

By [Ariana Eunjung Cha](#)

Washington Post Foreign Service

Sunday, March 9, 2008; Page A01

GAOLONG, China -- The first time Li Gengxuan saw the dump trucks from the nearby factory pull into his village, he couldn't believe what happened. Stopping between the cornfields and the primary school playground, the workers dumped buckets of bubbling white liquid onto the ground. Then they turned around and drove right back through the gates of their compound without a word.

This ritual has been going on almost every day for nine months, Li and other villagers said.

SLIDE SHOW

[Previous](#) [Next](#)



"It's poison air. Sometimes it gets so bad you can't sit outside. You have to close all the doors and windows," says Qiao Shi Peng, 28, shown in front of a dumping site in his village, who worries about his 1-year-old son's health. (Zhang Quanfeng - Photo By Zhang Quanfeng)

19 September 2011 Last updated at 06:14 ET

105 [Share](#)

China solar panel factory shut after protests

A solar panel factory in eastern China has been shut down after protests by local residents over pollution fears.

Some 500 villagers staged a three-day protest following the death of large numbers of fish in a local river.

Some demonstrators broke into the plant in Zhejiang province, destroying offices and overturning company cars before being dispersed by riot police.



Riot police were brought in to remove protesters from outside the solar panel factory in Haining City

[Home](#) [Business](#) [Business & Markets](#)

Toxic waste casts cloud on Massachusetts solar co.

By Christine McConville

Friday, July 3, 2009 - Added 120d 12h ago

[E-mail](#) [Print](#) [\(6\) Comments](#) [Text size](#) [Share](#) [Buzz up!](#)

Evergreen Solar Inc., one of Massachusetts' rising green energy stars, is on its way to becoming one of the state's top producers of hazardous waste.

The company generated more than a million pounds of hazardous waste last year, according to a report filed this week with the state Department of Environmental Protection, even though its new \$450 million factory in Devens wasn't operating at full capacity.



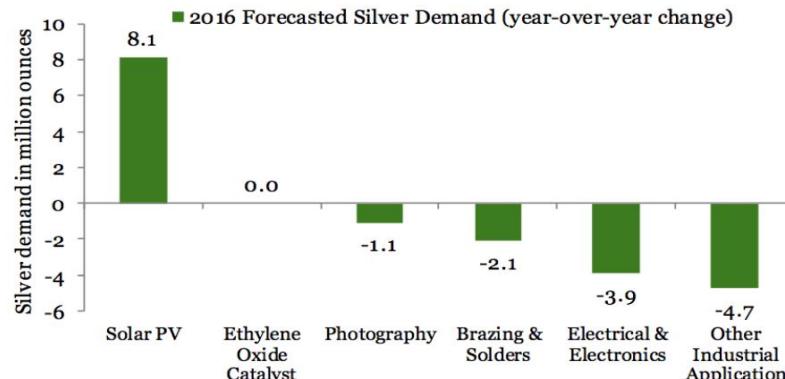
Photo by graphic by Sarah Kaempfe

Evergreen Solar wins praise from green-energy enthusiasts but the firm's solar panel-making process creates significant amounts of hazardous waste.

Silver mining



Exhibit 1: Silver demand for global solar PV remains a key growth segment of its industrial demand.



Source: GFMS Thomson Reuters, ETF Securities. Chart data as of 11/16/16

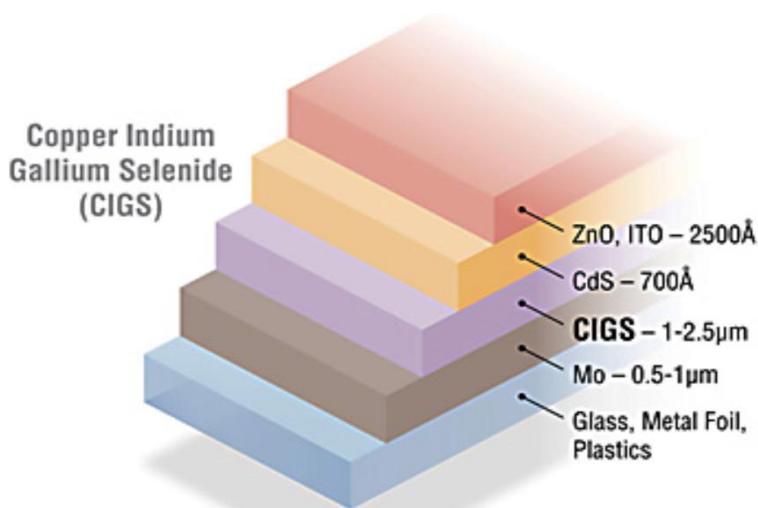
Quartz mining – semiconductor grade, glass quality



Rocks like these high-grade silica samples mined near Charlotte, North Carolina, are the basis for modern computer chips. CHARLES O'REAR/GETTY IMAGES

<https://www.wired.com/story/book-excerpt-science-of-ultra-pure-silicon/>

Indium and cadmium are by-products of zinc mining



Copper - tellurium, gallium...



Bauxite mining - aluminum frames - gallium



Manufacturing and Labor



We do more to ensure our panels are built as sustainably as the energy they produce.

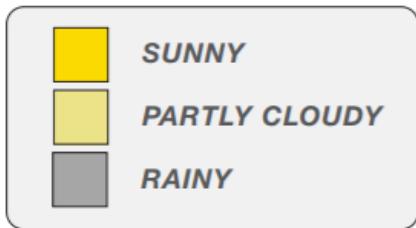
SunPower is the first solar company to achieve *Cradle to Cradle Certified™ Silver* designation.



CRADLE TO CRADLE MATERIAL HEALTH QUICK REFERENCE GUIDE

	v3 BASIC	v2 BRONZE	v2 SILVER	v3 SILVER	v2 & v3 GOLD	v2 & v3 PLATINUM
100% CHEMICAL DISCLOSURE					✓	✓
AT LEAST 95% CHEMICAL DISCLOSURE	✓		✓	✓	✓	✓
AT LEAST 75% CHEMICAL DISCLOSURE	✓	✓	✓	✓	✓	✓
CHEMICALS PROFILED FOR HAZARD AND EXPOSURE		✓	✓	✓	✓	✓
NO PVCs OR RELATED COMPOUNDS	✓	✓	✓	✓	✓	✓
NO C2C V3 BANNED LIST CHEMICALS	✓		✓	✓	✓	✓
NO CARCINOGENS, MUTAGENS, OR REPRODUCTIVE TOXINS				✓	✓	✓
ONLY POSITIVE CHEMISTRY				✓	✓	✓
RE-CERTIFIED EVERY TWO YEARS (MINIMUM)	✓	✓	✓	✓	✓	✓
DATA VERIFIED BY INDEPENDENT ASSESSOR	✓	✓	✓	✓	✓	✓

2016-17 SOLAR SCORECARD



Company		2016-17 Overall Score									
		Extended Producer Responsibility	Emissions Reporting	Worker Rights, Health and Safety	Supply Chains	Module Toxicity & Materials	Energy & GHGs	Conflict Minerals	Water		
2016-17 Leaders	Maximum Score	15	15	15	15	10	10	10	100		
	SunPower	15	15	15	15	10	8	10	10	98	
	SolarWorld	14	15	15	15	8	10	10	8	95	
	Trina	13	14	15	15	8	10	10	10	95	
	Aleo	12	14	15	15	8	8	10	10	92	
	Jinko	13	11	15	15	10	8	10	8	90	
	First Solar	15	11	15	11	2	10	10	8	82	
	Hanwha Q CELLS	8	11	15	15	0	8	10	10	77	
	Mitsubishi	3	11	9	11	8	10	10	10	72	

National Standards Foundation International

New ANSI standard: NSF 457 –

Sustainability Leadership
Standard for PV Module
Manufacturing



12 categories of sustainability
performance including **design for
the environment**, **responsible
EOL management**, and **conflict-
free mineral sourcing**



EPEAT registry for PV



Management of substances

List of declarable substances used in manufacturing

Disclosure of substances on the European Union REACH Regulation

Candidate List of Substances of Very High Concern

Avoidance or reduction of high global warming potential gas emissions

Conformance with provisions of EU RoHS Directive (inverters only)

Preferable materials use

Declaration of recycled content in product

Life cycle assessment

Conducting life cycle assessment

Energy efficiency & water use

Water inventory

End of life management & design for recycling

Product take-back service and processing requirements

Product packaging

Elimination of substances of concern in product packaging

Elimination of chlorine in processing packaging materials

Enhancing recyclability of packaging materials

Corporate responsibility

Environmental management system (EMS) certification

Manufacturer conformance with occupational health and safety performance

Reporting on Key Performance Indicators

Commitment to Environmental and Social Responsibility

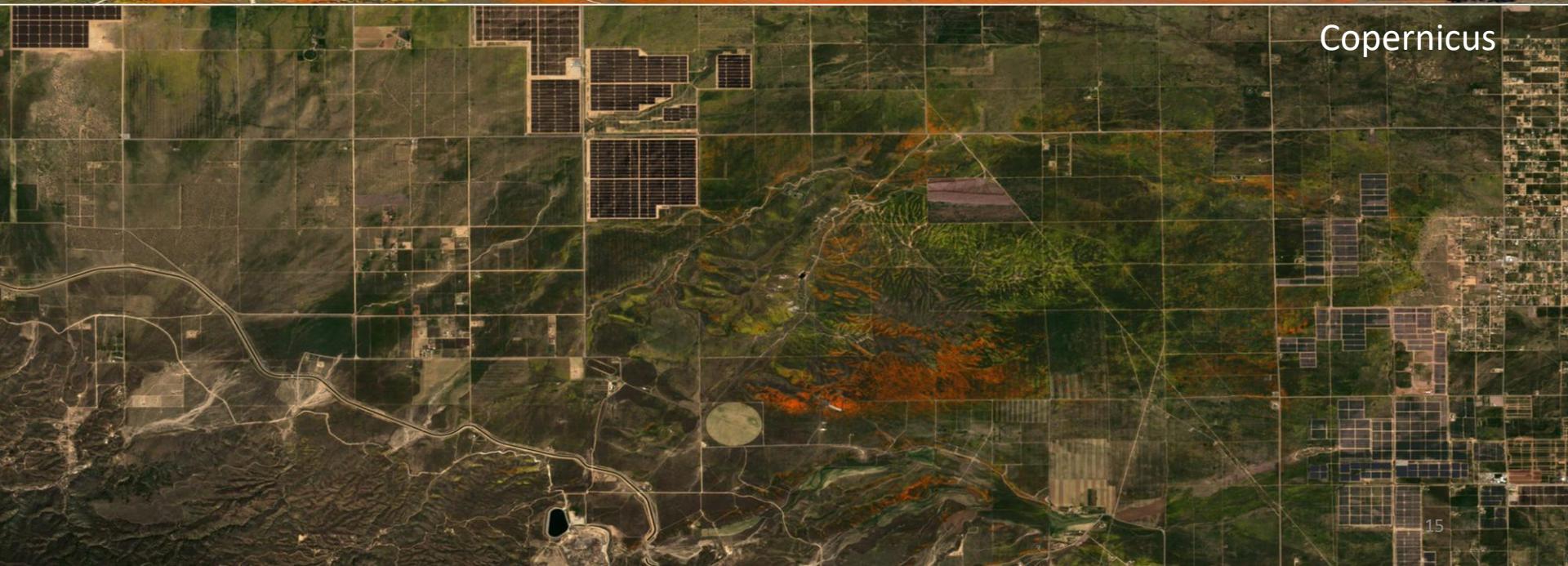
Public disclosure of use of conflict minerals in products

Land



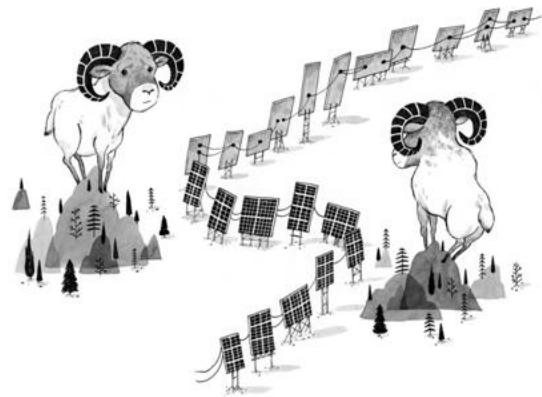
NASA Jim Ross

Copernicus



Sleeping Beauty Wilderness (Newberry Springs)





Cultural resources



Discovery of Indian artifacts complicates Genesis solar project

By [Louis Sahagun, Los Angeles Times](#)

APRIL 24, 2012



"...disrupted the peace of our ancestors and our relationship with the land. There is no mitigation for such a loss."

-Tribal leader quoted in LA Times



California Desert Kokopelli Intaglio: Blythe, CA 10.30.10
By PreservationNation ★ Favorite



Worker exposures to sources of Coccidioidomycosis or “Valley Fever”



Morbidity and Mortality Weekly Report

Coccidioidomycosis Outbreak Among Workers Constructing a Solar Power Farm — Monterey County, California, 2016–2017

Rebecca L. Laws, PhD^{1,2}; Gail Sondermeyer Cooksey, MPH²; Seema Jain, MD²; Jason Wilken, PhD^{2,3}; Jennifer McNary, MPH²; Edward Moreno, MD⁴; Kristy Michie, MS⁴; Christy Mulkerin, MD⁵; Ann McDowell, MPH⁵; Duc Vugia, MD²; Barbara Materna, PhD²

Coccidioidomycosis among Workers Constructing Solar Power Farms, California, USA, 2011–2014

Jason A. Wilken, Gail Sondermeyer, Dennis Shusterman, Jennifer McNary, Duc J. Vugia, Ann McDowell, Penny Borenstein, Debra Gilliss, Benedict Ancock, Janice Prudhomme,¹ Deborah Gold, Gayle C. Windham, Lauren Lee, Barbara L. Materna

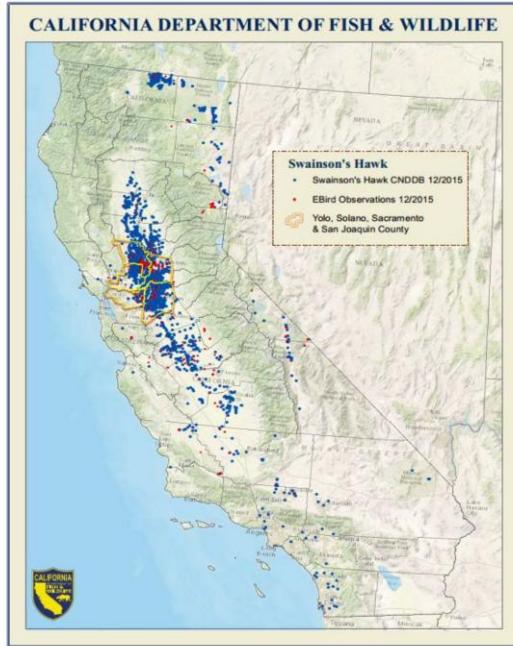


Figure 2. CNDB and eBird data for Swainson's Hawk in California (extracted from CNDB 12/1/2015 and eBird in 12/15/2016). The majority of the Central Valley's Swainson's Hawk population lies within an area that includes Sacramento, Yolo, Solano, and San Joaquin counties.



For Immediate Release, April 16, 2018

Contact: Aruna Prabhala, (510) 844-7122, aprabhala@biologicaldiversity.org
Gordon Nipp, Sierra Club, (661) 872-2432, gnipp@bak.rr.com

Lawsuit Confronts Kern County Over Broken Promise to Protect Imperiled Hawks, Important Farmland

Nearly \$3 Million Set Aside for Conservation Instead Transferred to General Fund

Western Solar Plan



California Energy Commission, California Department of Fish and Wildlife, Bureau of Land Management, & Fish & Wildlife Service.

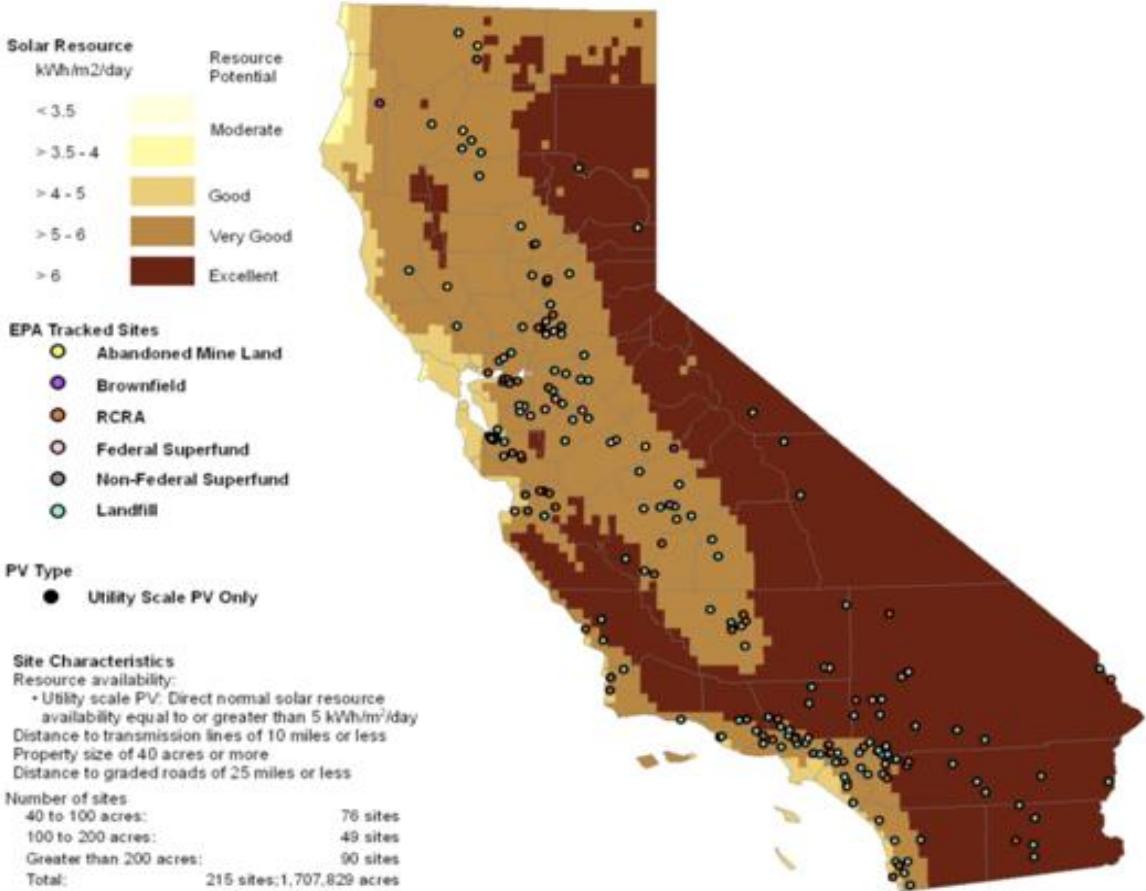
22 million acres studied
300,000 acres of **Solar Energy Zones** proposed

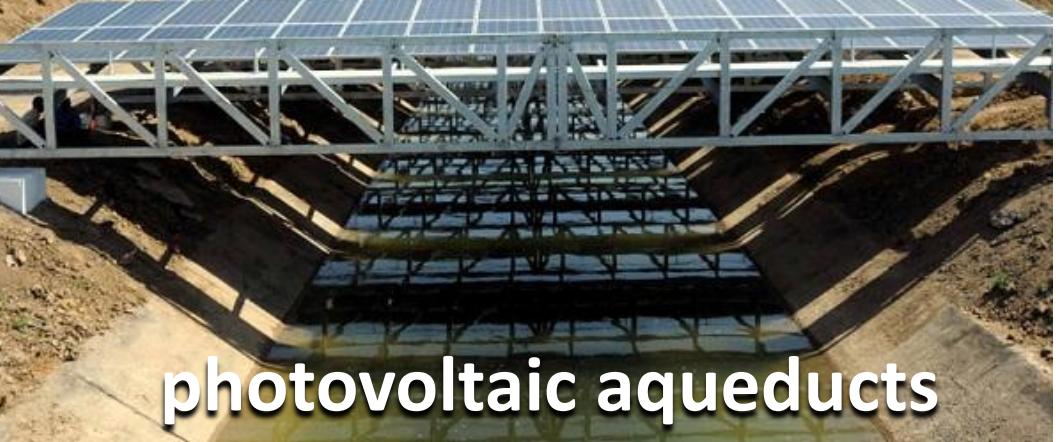
Table 1. Land Allocations in California's Desert Renewable Energy Conservation Plan across six western states: Arizona, California, Colorado, Nevada, New Mexico, Utah.

	Acres
Development Focus Areas	388,000
Variance Process Lands	40,000
Total BLM LUPA Conservation Designation	6,527,000
Recreation Management Areas	3,595,000
General Public Lands	419,000
Total	10,818,000

(Mulvaney, in review at the *Journal of Land Use Science*)

EPA Tracked Sites in California with Utility Scale Photovoltaic (PV) Solar Energy Generation Potential





photovoltaic aqueducts



float-o-voltaics

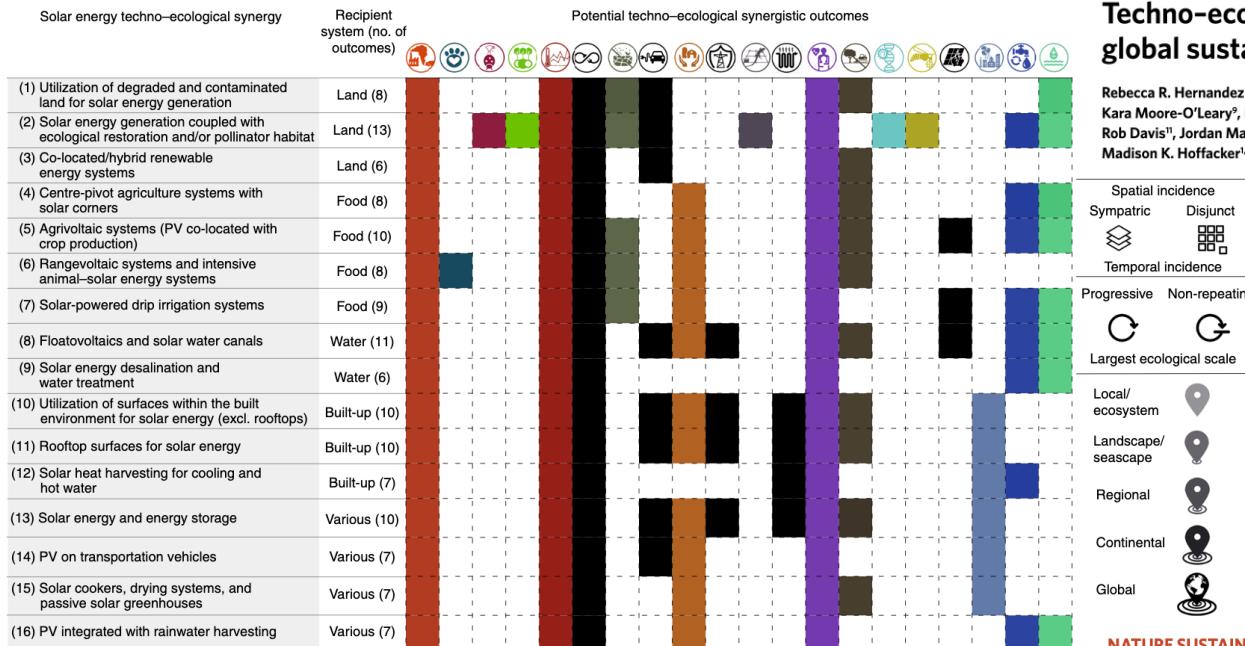
Techno-ecological synergies



pollinator enhancement

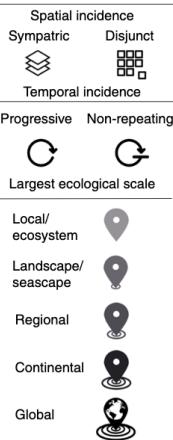


agri-voltaics

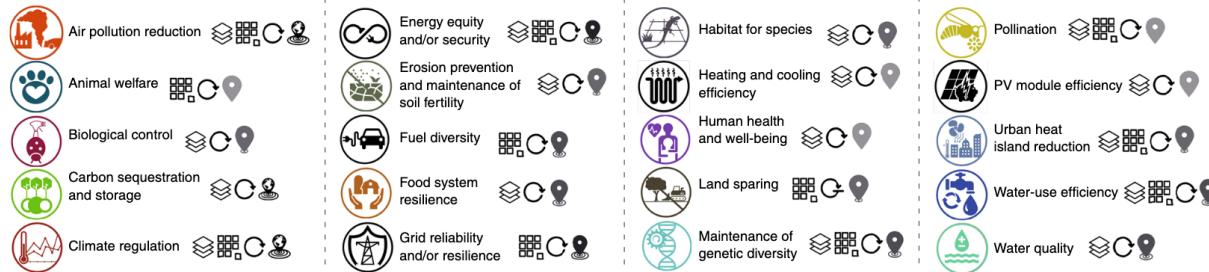


Techno-ecological synergies of solar energy for global sustainability

Rebecca R. Hernandez^{1,2,3,4*}, Alona Armstrong^{5,6}, Jennifer Burney⁷, Greer Ryan⁸, Kara Moore-O’Leary⁹, Ibrahima Diédiou¹⁰, Steven M. Grodsky¹², Leslie Saul-Gershenson², Rob Davis¹¹, Jordan Macknick¹², Dustin Mulvaney¹³, Garvin A. Heath¹², Shane B. Easter¹⁴, Madison K. Hoffacker^{1,2,3}, Michael F. Allen^{15,16} and Daniel M. Kammen^{1,3,7,18}



NATURE SUSTAINABILITY | VOL 2 | JULY 2019 | 560-568 | www.nature.com/natsustain

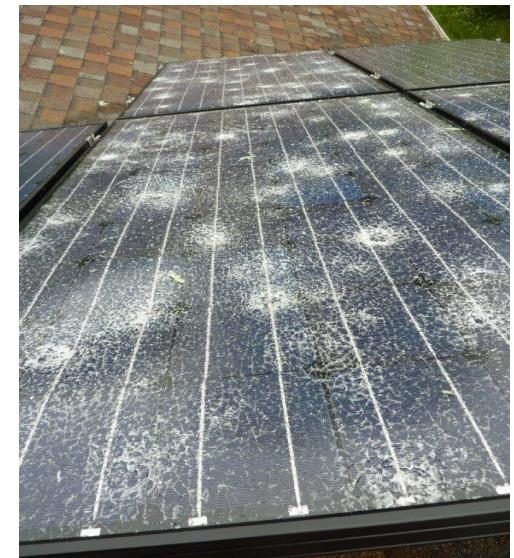


nature
sustainability

Waste

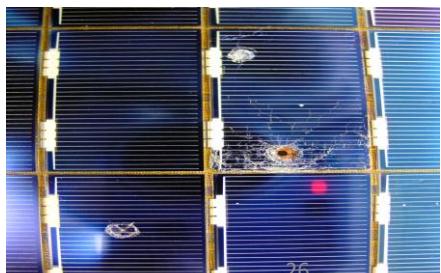
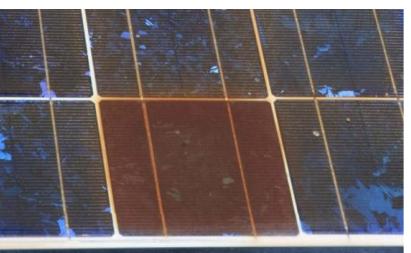
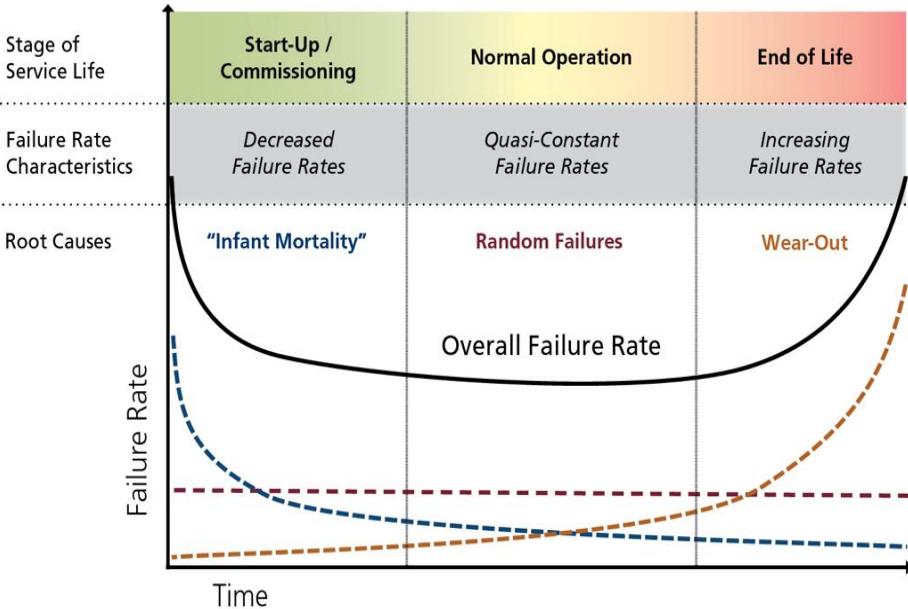


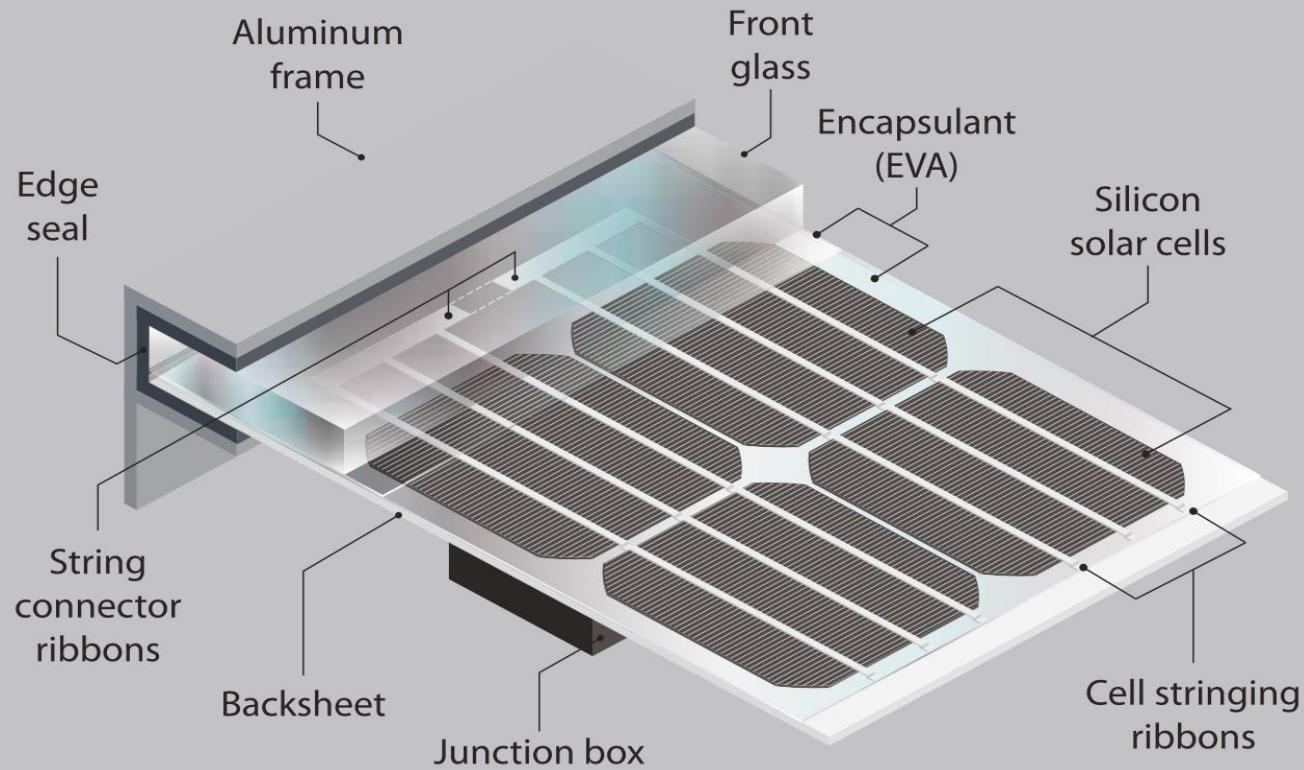
Photo by Kenneth Wilsey for FEMA - Humacao, Puerto Rico, Jan. 25, 2018



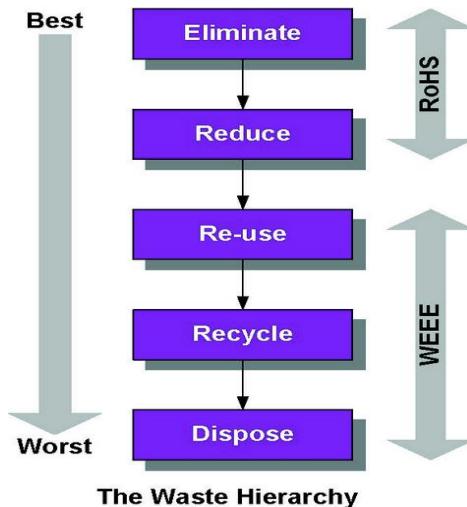
The "Bathtub Curve": When and Why Failures Occur in Solar Modules

FRAUNHOFER CENTER FOR SUSTAINABLE ENERGY SYSTEMS

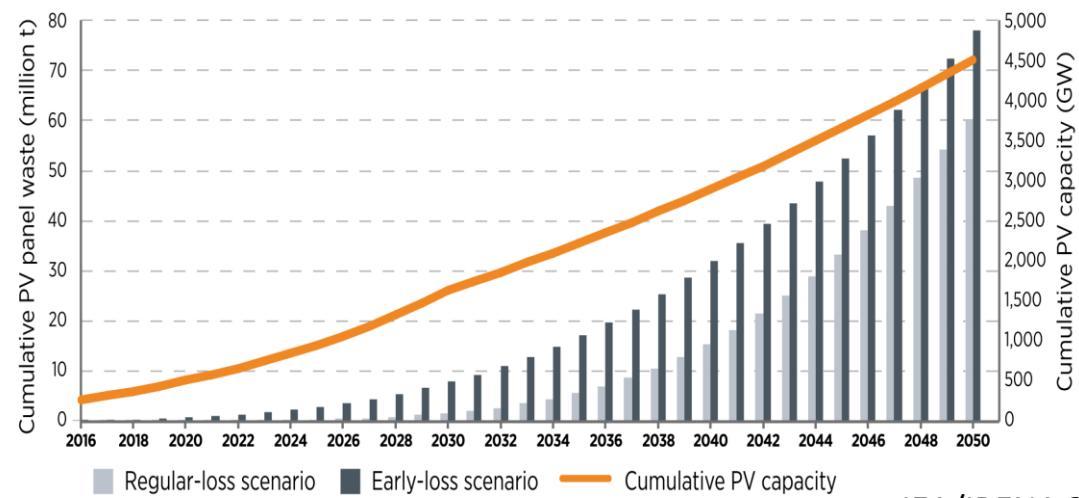
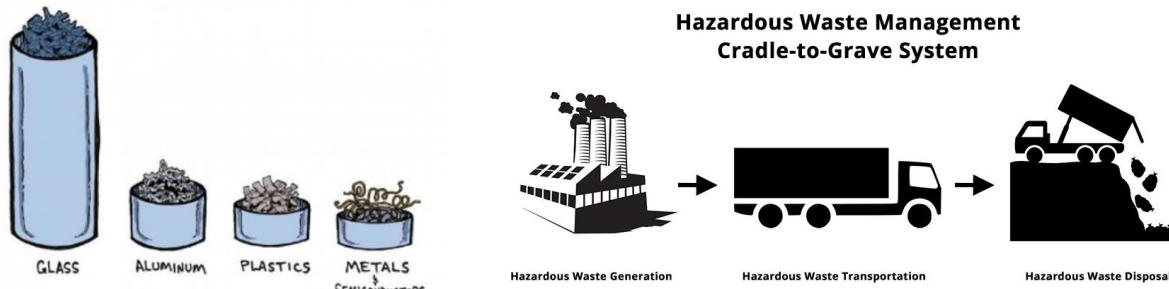




c-Si (monocrystalline) panel, National Renewable Energy Laboratory (NREL), 2016



Circular Economies



Shine on!

Dustin.Mulvaney@sjsu.edu



@DustinMulvaney



San José State
UNIVERSITY

DEPARTMENT OF
ENVIRONMENTAL STUDIES



STANFORD UNIVERSITY
THE BILL LANE CENTER
FOR THE AMERICAN WEST



UNIVERSITY OF
CALIFORNIA PRESS

