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THE NOT-SO-GREEN RENEWABLE ENERGY: PREVENTING WASTE DISPOSAL OF SOLAR PHOTOVOLTAIC (PV) PANELS

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COMMENT

THE NOT-SO-GREEN RENEWABLE ENERGY: PREVENTING WASTE DISPOSAL OF SOLAR PHOTOVOLTAIC (PV) PANELS

I. INTRODUCTION

In October 2010, the Obama Administration announced plans to install solar photovoltaic (PV) panels atop the White House, to "lead by example" in building a clean energy economy.[1] One renewable-energy activist remarked that the Obama Administration's decision "could be a trigger for a wave of solar installations across the country and around the world."[2] If Americans follow the Administration's lead, potentially millions of panels will create green electricity.[3] But when these newly installed panels hit the end of their useful lives, they will become waste.[4] Like most trash, the panels will be abandoned in landfills, potentially

[1] Steven Chu, U.S. Sec'y of Energy, *The White House Goes Solar*, ENERGY BLOG (Oct. 5, 2010, 8:53 AM), blog.energy.gov/blog/2010/10/05/white-house-goes-solar; *see also* Carol Browner, *Solar Panels on the White House and in the Desert, 36 Billion Gallons of Biofuels, and Cleaner Trucks*, THE WHITE HOUSE BLOG (Oct. 29, 2010, 10:33 AM), www.whitehouse.gov/blog/2010/10/29/solar-panels-white-house-and-desert-36-billion-gallons-biofuels-and-cleaner-trucks.

[2] Wendy Koch, *Obama Will Soon Put Solar Panels Atop the White House*, USA TODAY (Oct. 5, 2010, 10:35 AM, updated 7:30 PM), content.usatoday.com/communities/greenhouse/post/2010/10/white-house-solar-panels/1 (quoting Bill McKibben, author and global warming activist).

[3] *See* Chu, *supra* note 1 (stating that the White House's solar installations "will show that American solar technology is available, reliable, and ready to install in homes throughout the country").

[4] V.M. Fthenakis, *Overview of Potential Hazards*, *in* PRACTICAL HANDBOOK OF PHOTOVOLTAICS: FUNDAMENTALS AND APPLICATIONS 11-12 (T. Markvart & L. Castaner eds., 2003), *available at* www.bnl.gov/pv/files/pdf/art_170.pdf.

causing pollution and contamination of environmental resources.[5]

Without effective regulation, landfill disposal of solar PV panels could cause an environmental tragedy.[6] Solar PV panels contain toxic materials that pose risks to human health and the environment.[7] However, most panels fail classification as "hazardous waste," so the panels circumvent laws designed to respond to the threat of dangerous wastes.[8] Even when deemed hazardous waste, the panels are discarded in landfills.[9]

However, this tragedy is not inevitable.[10] PV panels can be successfully recycled into other products or reused to make new panels, having a "double greening" benefit.[11] California is at the forefront of state lawmaking bodies developing alternative management regulations that foster recycling of hazardous waste PV panels.[12] To be sustainable and consistent with the core values of renewable energy, state policymakers throughout the United States need to sponsor legislation that reduces the volume of PV waste and ensures recycling of all PV panels.[13] The legislation needs to be structured in a way that will continue to promote the PV industry and not deter producers and

[5] *Id.*

[6] SILICON VALLEY TOXICS COAL., TOWARD A JUST AND SUSTAINABLE SOLAR ENERGY INDUSTRY 19 (Jan. 14, 2009), *available at* svtc.org/wp-content/uploads/Silicon_Valley_Toxics_Coalition_-_Toward_a_Just_and_Sust.pdf.

[7] Fthenakis, *supra* note 4, at 3.

[8] *See* discussion *infra* Part IV.

[9] *See* 40 C.F.R. § 268.40 (Westlaw 2011) (land disposal restrictions ensure that only the most toxic materials are treated to reduce their toxicity before they can be land-disposed); *see also* Fthenakis, *supra* note 4, at 12.

[10] *See* PV CYCLE, PRESENTATION: MAKING THE PHOTOVOLTAIC INDUSTRY "DOUBLE GREEN," *available at* www.pvcycle.org/fileadmin/pvcycle_docs/documents/membership/PVCYCLE_11_2010.pdf; Kari Larsen, *End-of-Life PV: Then What? Recycling Solar PV Panels*, RENEWABLEENERGYFOCUS.COM (Aug. 3, 2009), www.renewableenergyfocus.com/view/3005/endoflife-pv-then-what-recycling-solar-pv-panels/ (demonstrating that recycling of PV panels can be successfully implemented to reduce environmental impacts from PV waste).

[11] PV CYCLE, *supra* note 10.

[12] *See* CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, PROPOSED STANDARDS FOR MANAGEMENT OF WASTE SOLAR PANELS, No. R-2010-01, at 1 (July 28, 2010), *available at* www.dtsc.ca.gov/LawsRegsPolicies/Regs/upload/Solar-Panel-Draft-Reg-Text-for-July-Workshop.pdf (draft proposed regulations issued for discussion purposes only).

[13] *See* Letter from Jennifer Woolwich, PV Recycling, to Ellen L. Haertle, Cal. Dep't of Toxic Substances Control, with Comments on Proposed Standards for Management of Waste Solar Panels (Aug. 11, 2010), *available at* www.dtsc.ca.gov/LawsRegsPolicies/upload/PV-Recycling-Comments-on-Developmental-Solar-Panel-Regs.pdf; *see also* Letter from Sheila Davis & Dustin Mulvaney, Ph.D., Silicon Valley Toxics Coal., to Ellen L. Haertle, Cal. Dep't of Toxic Substances Control, on Solar Regulations Regarding the Exemption of Hazardous Panels (Aug. 11, 2010), *available at* www.dtsc.ca.gov/LawsRegsPolicies/upload/Silicon-Valley-Toxics-Coalition-Comments-on-Developmental-Solar-Panel-Regs.pdf.

consumers from investing in these important products.[14]

Part II of this Comment provides a background on solar power and PV technology, identifies the toxic components of PV products, and explains how disposal of PV waste poses a threat to the environment. Part II also illustrates how poor management of electronic waste (e-waste) in the United States has resulted in environmental pollution – a preventable consequence that can be avoided for the PV industry. Part III advocates a recycling and life-cycle-management approach to regulation because it provides a more sustainable future for the solar industry. Part IV discusses federal and state hazardous waste regulations and demonstrates how these laws are ineffective to regulate PV waste, primarily because they exclude most PV products from regulation and promote disposal over recycling. Part V discusses proposed regulations in California that would modify its hazardous waste program to allow alternative management options. It explains why California should proceed with its proposed regulations that foster reclamation and recycling of solar panels and aim to reduce the volume of hazardous waste entering landfills. Part VI describes how states should take the next step to prevent a future PV waste problem by enacting extended producer responsibility (EPR) laws that focus on the life cycle of PV products, and encourages states to subsidize these regimes. That Part also describes the European approach to PV waste management, which is based on a voluntary EPR system, and explains why mandatory EPR laws may be required for the United States.

II. PHOTOVOLTAIC TECHNOLOGY AND THE ENVIRONMENTAL RISK

The rising tide of PV technology poses a threat if these products are not managed responsibly when they become obsolete or reach their "end of life."[15] Regardless of the technology used, PV electricity generation is considered a zero-emissions process because it does not produce noise, toxic air pollutants, or greenhouse gases (GHGs).[16] However, once the clean power generation ends, the panels will be decommissioned and

[14] *See generally* V.M. Fthenakis & P.D. Moskowitz, *The Value and Feasibility of Proactive Recycling*, www.bnl.gov/pv/abs/abs_142.asp (last visited Mar. 7, 2011) (noting that economic incentives could be used to promote recycling of PV technology).

[15] Fthenakis, *supra* note 4, at 11; *see generally* U.S. ENVTL. PROT. AGENCY, EPA530-F-08-014, FACT SHEET: MANAGEMENT OF ELECTRONIC WASTE IN THE UNITED STATES 12 (Apr. 2007, revised July 2008), *available at* www.epa.gov/epawaste/conserve/materials/ecycling/manage.htm ("When a product is no longer used, stored, or reused, it has reached its end of life. The management options for a product at end of life include recycling or disposal.").

[16] *See* Fthenakis, *supra* note 4, at 11.

become waste.[17] Disposal of this waste, which contains hazardous substances, can leave lasting, damaging effects on the environment.[18]

A. RENEWABLE ENERGY AND THE GROWTH OF SOLAR POWER

PV technology harnesses solar power, a renewable energy.[19] Renewable energy comes from natural resources that constantly replenish such as from the sun, water, and wind.[20] The energy technology is considered clean and carbon-free because it does not directly emit GHGs.[21] Clean energy has less impact on the environment than energy from fossil fuels like oil and coal.[22] These fuels, when burned, discharge harmful carbon emissions into the atmosphere.[23]

PV technology is a growing sector of the U.S. renewable-energy movement.[24] The United States had the third-largest market in the world for PV products in 2009, a 36% growth from the previous year.[25] Between 2000 and 2009, annual domestic solar cell shipments increased thirtyfold.[26] High-profile solar power projects are helping to boost the industry.[27] For example, in October 2010, the U.S. Department of the Interior (DOI) approved the Blythe solar power project.[28] To date, this is

[17] *Id.*

[18] *See id.* at 11-12.

[19] *Id.*; Solar Energy Indus. Ass'n, *Solar Technology & Products*, SEIA.org, www.seia.org/cs/solar_technology_and_products (last visited Mar. 7, 2011). Other solar power technologies include solar thermal (heating and cooling), concentrating solar power, passive solar, solar ovens, and emerging technology. *Id.*

[20] U.S. Energy Info. Admin., *Energy Sources – Renewable*, EIA.DOE.GOV, www.eia.doe.gov/kids/energy.cfm?page=renewable_home-basics (last visited Mar. 7, 2011).

[21] *Id.*

[22] *Compare id. with* U.S. Energy Info. Admin., *Energy Sources – Coal*, EIA.DOE.GOV, www.eia.doe.gov/kids/energy.cfm?page=coal_home-basics (last visited Mar. 7, 2011).

[23] U.S. Energy Info. Admin., *Energy Sources – Oil/Petroleum*, EIA.DOE.GOV, www.eia.doe.gov/kids/energy.cfm?page=oil_home-basics#oil_environment-basics (last visited Mar. 7, 2011); U.S. Energy Info. Admin, *Energy Sources – Coal*, *supra* note 22.

[24] U.S. DEP'T OF ENERGY, DOE/GO-102010-3145, SOLAR: A CLEAN ENERGY SOURCE FOR UTILITIES (Sept. 2010), *available at* www1.eere.energy.gov/library/default.aspx?page=7.

[25] Solarbuzz, *United States PV Market*, SOLARBUZZ, www.solarbuzz.com/facts-and-figures/market-facts/regional-pv-markets-united-states (last visited Mar. 22, 2011) (the two largest PV markets in the world in 2009 were Germany and Italy).

[26] *See* U.S. Energy Info. Admin., *Solar Photovoltaic Cell/Panel Manufacturing Activities* tbl.3.2, EIA.DOE.GOV, www.eia.doe.gov/cneaf/solar.renewables/page/solarphotv/solarpv.html (last visited Mar. 17, 2011).

[27] *See* Press Release, U.S. Dep't of Interior, Salazar Approves Sixth and Largest Solar Project Ever on Public Lands (Oct. 25, 2010), *available at* www.doi.gov/news/pressreleases/Salazar-Approves-Sixth-and-Largest-Solar-Project-Ever-on-Public-Lands.cfm.

[28] *Id.*

the largest solar power plant project on public lands.[29] The Blythe facility will cover 6,000 acres of California's Riverside County and generate enough electricity to power 300,000 to 750,000 homes.[30] The approval of the Blythe project was one of six landmark decisions in 2010 by the DOI endorsing solar energy projects.[31] These endorsements are part of the Obama Administration's "effort to encourage a rapid and responsible move to large-scale production of renewable-energy projects on public lands."[32]

The booming pursuit of solar energy is largely driven by federal tax incentives and states' renewable portfolio standards and mandates.[33] The American Recovery and Reinvestment Act of 2009 includes funding of $16.8 billion to the U.S. Department of Energy (DOE) for renewable-energy programs and initiatives, of which $117.6 million is allocated to solar programs.[34] These grants have helped to accelerate production of wind, solar, and geothermal energy projects on public lands.[35] To stimulate the solar energy market on a state level, thirty-six states and the District of Columbia have adopted renewable portfolio standards or mandates.[36] California, which generates approximately 78% of the nation's solar energy,[37] administers the California Solar Initiative (CSI),[38] a $2.2 billion ratepayer-funded program to provide new grid-

[29] *Id.*

[30] *Id.*

[31] *Id.* Five other solar energy projects approved by the DOI in October 2010 are Imperial Valley Solar Project, Chevron Lucerne Valley Solar Project, Ivanpah Solar Electric Generating System, and the Calico Solar Project, all in California; and the Silver State North Solar Project in Nevada. *Id.*

[32] *Id.*

[33] *See* U.S. ENERGY INFO. ADMIN., RENEWABLE ENERGY TRENDS IN CONSUMPTION AND ELECTRICITY 2008 4 (Aug. 2010), *available at* www.eia.doe.gov/cneaf/solar.renewables /page/trends/trends.pdf (noting that the expansion of renewable energy is driven by states' renewable portfolio standards and mandates, federal tax credits, concerns over climate change, and reduced emissions compared with fossil fuels); *see also* U.S. Energy Info. Admin., *supra* note 20 (explaining that renewable-energy production has increased due to concern over higher prices for oil and natural gas and government incentives).

[34] American Recovery and Reinvestment Act of 2009, Pub. L. No. 111-5, div. A, tit. IV, 123 Stat. 115, 138; *see also* U.S. Dep't of Energy, *Solar Energy Technologies Program*, EERE.ENERGY.GOV, www1.eere.energy.gov/solar/recovery.html (last visited Mar. 31, 2011). Individuals are allowed a 30% tax credit on residential solar energy expenditures through the year 2016. 26 U.S.C.A. § 25D (Westlaw 2011).

[35] *See* Phil Taylor, *Obama Admin Says Initiatives Sparked Boom of Renewable Energy Projects on Public Land*, NYTIMES.COM (Feb. 9, 2011), www.nytimes.com/gwire/2011/02/09/09 greenwire-obama-admin-says-initiatives-sparked-boom-of-r-53819.html.

[36] U.S. ENERGY INFO. ADMIN., *supra* note 33, at 5.

[37] *See id.* at tbl.1.20 (figure based on year 2008).

[38] CAL. PUB. RES. CODE §§ 25780-25784 (Westlaw 2011).

connected solar energy.[39] The program provides incentive payments to state customers for PV energy purchases.[40] More than 45,000 solar projects have received, or are in the process of obtaining, CSI funding.[41]

The DOE predicts sustained growth for the PV industry.[42] The DOE provides funding to accelerate research, development, and installation of solar systems.[43] The Department's goal is for solar energy to cost-effectively compete with fossil fuels by 2015.[44] This is a win-win solution to address climate change, reduce the nation's reliance on fossil fuels, create green jobs, and boost the U.S. economy.[45]

B. PV TECHNOLOGY

PV technology absorbs energy from the sun and converts it into electricity.[46] Each PV panel or module is several square feet in area and composed of solar cells.[47] A solar cell ranges from less than one inch to several inches across and contains semiconductor material, a substrate, a protective layer, and wiring to conduct electricity.[48] The semiconductor material generates electricity by absorbing sunlight and releasing electrons that produce an electrical current.[49] The electricity output is

[39] Cal. Energy Comm'n & Cal. Pub. Utils. Comm'n, *About the California Solar Initiative (CSI)*, GOSOLARCALIFORNIA.CA.GOV, www.gosolarcalifornia.ca.gov/about/csi.php (last visited Mar. 17, 2011). The state has also adopted renewable portfolio standards for utility retailers, requiring them to procure at least 33% of their sales from renewable energy sources by 2020. Cal. Exec. Order No. S-14-08; *see also* CAL. PUB. RES. CODE §§ 25740-25751 (Westlaw 2011).

[40] Cal. Energy Comm'n & Cal. Pub. Utils. Comm'n, *supra* note 39.

[41] CAL. PUB. UTIL. COMM'N, DIV. OF RATEPAYER ADVOCS., CALIFORNIA'S SOLAR PV PARADOX: DECLINING CALIFORNIA SOLAR INITIATIVE PRICES AND RISING INVESTOR OWNED UTILITY BID PRICES 5 (Oct. 2010), *available at* www.dra.ca.gov/NR/rdonlyres/5A0E254D-47E0-4625-BACF-F1049CEAB924/0/ParadoxPaperFinal_v2.pdf.

[42] U.S. DEP'T OF ENERGY, *supra* note 24. Solarbuzz also reports that the U.S. solar market is projected to increase 30% annually on average until 2014. Solarbuzz, *supra* note 25.

[43] U.S. DEP'T OF ENERGY, *supra* note 24. The DOE funded $247 million in solar technology research in 2010. *Id.*

[44] *Id.*

[45] SILICON VALLEY TOXICS COAL., *supra* note 6, at 1.

[46] SOLAR ENERGY INDUS. ASS'N, PHOTOVOLTAIC SOLAR TECHNOLOGY, CREATING ELECTRICITY FROM SUNLIGHT (Mar. 15, 2010), *available at* www.seia.org/galleries/FactSheets/Factsheet_PV.pdf.

[47] SILICON VALLEY TOXICS COAL., *supra* note 6, at 6. The terms solar "cell," "panel," "module," and "system" are used interchangeably in this Comment, unless otherwise noted.

[48] *Id.* at 5; *see also* Nat'l Renewable Energy Lab., *Solar Photovoltaic Technology*, NREL.gov, www.nrel.gov/learning/re_photovoltaics.html (last visited Mar. 17, 2011). About forty cells are assembled into a panel. *Id.* Many solar panels are combined to create one solar array system. *Id.*

[49] SOLAR ENERGY INDUS. ASS'N, *supra* note 46.

greatest midday when the sun is at its highest point in the sky.[50]

Thousands of homes and businesses are powered with various PV array systems.[51] Developers can build large solar "farms" to provide electricity to utility customers.[52] These farms comprise hundreds of solar arrays whose energy is then funneled to commercial utility grid customers.[53] Homeowners can install PV panels to reduce or eliminate electricity bills by producing their own electricity instead of buying power off the regional grid.[54] About ten to twenty panels can power a home.[55] At the White House, about twenty-five to seventy-five panels may be required,[56] which will generate 19,700 kilowatts of electricity, more than twice the power needed by an average Washington, D.C., home.[57]

There are many PV technologies currently in use.[58] Beginning in the 1950s, solar cells were made with silicon.[59] The most common PV technology uses crystalline silicone.[60] Between 2007 and 2009, crystalline silicone panels accounted for 60% to 77% of PV shipments in the United States.[61] China is the world's leading producer of PV panels specializing in silicon-based models.[62]

"Thin-film" cells are the main focus of leading-edge PV systems in the United States because they are simpler and less costly to manufacture.[63] Thin-film cells use smaller amounts of semiconductor materials applied to inexpensive substrata such as glass, metal, and

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[50] *Id.*

[51] Nat'l Renewable Energy Lab., *supra* note 48.

[52] SOLAR ENERGY INDUS. ASS'N, *supra* note 46.

[53] Nat'l Renewable Energy Lab., *supra* note 48.

[54] SOLAR ENERGY INDUS. ASS'N, *supra* note 46.

[55] Nat'l Renewable Energy Lab., *supra* note 48. The average number of PV panels on a home varies depending on roof size and energy usage. Cal. Energy Comm'n & Cal. Pub. Utils. Comm'n, *Frequently Asked Questions About Solar Photovoltaic and Solar Thermal (Hot Water) Systems*, GOSOLARCALIFORNIA.CA.GOV, www.gosolarcalifornia.org/solar_basics/faqs.php (last visited Mar. 22, 2011).

[56] Dina Cappiello, *Solar Panels on White House: Obama to Install Solar Panels in 2011*, HUFFINGTONPOST.COM (Oct. 5, 2010, 12:15 PM), www.huffingtonpost.com/2010/10/05/solar-panels-on-white-hou_n_750525.html.

[57] Koch, *supra* note 2.

[58] SOLAR ENERGY INDUS. ASS'N, *supra* note 46. The various technologies are identified by their active semiconductor ingredients. *Id.*

[59] *Id.*

[60] U.S. Energy Info. Admin., *supra* note 26, at tbl.3.5.

[61] *Id.*

[62] CAL. PUB. UTIL. COMM'N, DIV. OF RATEPAYER ADVOCS., *supra* note 41, at 6.

[63] SOLAR ENERGY INDUS. ASS'N, *supra* note 46. However, the technology is less efficient than crystalline silicone models. *Id.*

plastic.[64] Cadmium telluride (CdTe), copper indium selenide, copper indium gallium diselenide, and amorphous silicon are used in thin-film technology.[65] Thin-film cells accounted for 21% to 39% of PV shipments in the United States between 2007 and 2009.[66]

"Multi-junction" panels are the highest-efficiency models, because they combine multiple semiconductor layers to more efficiently capture energy.[67] These cells use gallium arsenide combined with other thin-film materials.[68] Multi-junction technology can generate twice the power of silicon-based models.[69] However, because multi-junction panels are costly to manufacture,[70] they are limited in application to non-commercial sectors such as satellites, high-performance solar power vehicles, and military equipment.[71]

Because PV technology is in its infancy, new PV products are regularly being developed.[72] Emerging PV technology is assembled from a variety of materials, including inks, dyes, plastics, and mirrors.[73] To improve solar technology and produce micron-thin film to better absorb sunlight, manufacturers are now studying nanotechnology.[74]

C. THE THREAT OF PV WASTE

PV panels contain many toxic substances.[75] The active semiconductor materials in thin-film technology contain cadmium, telluride, and selenium.[76] Multi-junction panels contain arsenic

[64] *Id.*

[65] *Id.*

[66] U.S. Energy Info. Admin., *supra* note 26, at tbl.3.5. Recently, prices for silicon have been declining rapidly, intensifying competition between U.S. thin-film manufacturers and Chinese producers of crystalline silicone models. Todd Woody, *Silicon Valley's Solar Innovators Retool to Catch Up to China*, N.Y. TIMES, Oct. 13, 2010, at B1, *available at* www.nytimes.com/2010/10/13/business/energy-environment/13solar.html?_r=1&hp. This could hinder progress of the U.S. thin-film industry. *Id.*

[67] NATALYA V. YASTREBOVA, U. OTTAWA, HIGH EFFICIENCY MULTI-JUNCTION SOLAR CELLS: CURRENT STATUS AND FUTURE POTENTIAL 6 (Apr. 2007), *available at* sunlab.site.uottawa.ca/pdf/whitepapers/HiEfficMjSc-CurrStatus&FuturePotential.pdf.

[68] SILICON VALLEY TOXICS COAL., *supra* note 6, at 8.

[69] YASTREBOVA, *supra* note 67, at 3.

[70] *Multijunction Solar Cells*, POWEREDBYSOLARPANELS.COM, poweredbysolarpanels.com/multijunction-solar-cells/ (last visited Mar. 17, 2011).

[71] SOLAR ENERGY INDUS. ASS'N, *supra* note 46.

[72] *See* U.S. DEP'T OF ENERGY, *supra* note 24.

[73] Nat'l Renewable Energy Lab., *supra* note 48.

[74] *See* SILICON VALLEY TOXICS COAL., *supra* note 6, at 6. Nanotechnology examines opportunities based on chemical, physical, and electrical properties at a molecular scale. *Id.*

[75] Fthenakis, *supra* note 4, at 3.

[76] SOLAR ENERGY INDUS. ASS'N, *supra* note 46; Fthenakis, *supra* note 4, at 7-8.

compounds.[77] Components of PV panels – including circuit boards, invertors, and hardware – also contain hexavalent chromium, lead, copper, nickel, silver, aluminum, zinc, molybdenum, antimony, brominated flame retardants, polybrominated biphenyls, and polybrominated diphenylethers.[78] The Agency for Toxic Substances and Disease Registry (ATSDR)[79] ranks arsenic, lead, cadmium, and hexavalent chromium among the top 18 of 275 priority hazardous substances.[80] Cadmium is a highly toxic material that causes kidney disease, lung damage, fragile bones, and cancer.[81] Arsenic can cause death.[82] Potential hazards from some emerging PV technologies are not well understood and thus may pose new or unknown risks for the future.[83] For example, sparse data are available on the toxicity of CdTe,

[77] Fthenakis, *supra* note 4, at 3.

[78] SILICON VALLEY TOXICS COAL., *supra* note 6, at 20-23 (reporting that PV products contain hexavalent chromium, lead, copper, nickel, silver, aluminum, brominated flame retardants, polybrominated biphenyls, and polybrominated diphenylethers); NORWEGIAN GEOTECHNICAL INST., 20092155-00-5-R, ENVIRONMENTAL RISKS REGARDING THE USE AND FINAL DISPOSAL OF CDTE PV PANELS 17 (Apr. 16, 2010), *available at* www.dtsc.ca.gov/LawsRegsPolicies/upload/Norwegian-Geotechnical-Institute-Study.pdf (reporting that zinc, molybdenum, and antimony are found in CdTe panels). Additional toxic chemicals involved in the manufacturing processes of PV panels that are not a concern for disposal but present hazards to occupational workers are not discussed herein. For more on this subject, refer to SILICON VALLEY TOXICS COAL., *supra* note 6, at 9-18.

[79] The ATSDR, based in Atlanta, Georgia, is an agency of the U.S. Department of Health and Human Services. Agency for Toxic Substances & Disease Registry, *Agency for Toxic Substances and Disease Registry*, ATSDR.CDC.GOV, www.atsdr.cdc.gov/ (last visited Mar. 16, 2011). Congress has mandated ATSDR to perform functions concerning the effect of hazardous substances in the environment on public health. Agency for Toxic Substances & Disease Registry, *About ATSDR*, ATSDR.CDC.GOV, www.atsdr.cdc.gov/about/index.html (last visited Mar. 16, 2011). Such functions include public health assessments of waste sites, health consultations concerning specific hazardous substances, health surveillance and registries, response to emergency releases of hazardous substances, applied research in support of public health assessments, information development and dissemination, and education and training concerning hazardous substances. *Id.*

[80] AGENCY FOR TOXIC SUBSTANCES & DISEASE REGISTRY, 2007 PRIORITY LIST OF HAZARDOUS SUBSTANCES, *available at* www.atsdr.cdc.gov/cercla/07list.html. The ATSDR ranks substances, in order of priority, based on frequency at National Priority List facilities, toxicity, and potential for human exposure. *Id.* The list does not necessarily represent the most toxic compounds. *Id.* Rankings for chemicals in PV technology are as follows: arsenic – 1, lead – 2, cadmium – 7, hexavalent chromium – 18, nickel – 53, copper – 128, selenium – 147, aluminum – 187, and silver – 214. *Id.*

[81] Agency for Toxic Substances & Disease Registry, *ToxFAQs for Cadmium*, ATSDR.CDC.GOV, www.atsdr.cdc.gov/toxfaqs/tf.asp?id=47&tid=15 (last visited Mar. 17, 2011); *see also* Fthenakis, *supra* note 4, at 3.

[82] Agency for Toxic Substances & Disease Registry, *ToxFAQs for Arsenic*, ATSDR.CDC.GOV, www.atsdr.cdc.gov/toxfaqs/tf.asp?id=19&tid=3 (last visited Mar. 17, 2011).

[83] SILICON VALLEY TOXICS COAL., *supra* note 6, at 23; *see also* NORWEGIAN GEOTECHNICAL INST., *supra* note 78, at 14 (noting that CdTe is not expected to be more toxic than its parent compounds cadmium and tellurium).

which may not be as acute as that of elemental cadmium.[84]

Exposure by humans and other species to the toxic substances in intact panels is minimal, because the chemicals are encapsulated by other inert materials.[85] However, if PV products are disposed of on or in land, they can break and release toxic chemicals into soil and groundwater, potentially contaminating water supplies.[86] For example, heavy metals, such as cadmium in CdTe cells and lead in crystalline silicone panels, can filter out of the waste.[87] Studies have demonstrated that when thin-film cells containing CdTe are exposed to water, the CdTe dissolves, increasing the risk of leaching cadmium.[88] Tests have also shown lead to leach from crystalline silicone panels.[89] Once in soil and water, cadmium and lead can mobilize and spread beyond the dumping area.[90] The contaminants can then accumulate in plants and animals, the food supply.[91] Preventative measures taken at modern landfills, such as bottom/side sealing and containment of leachate,[92] help to reduce this hazard.[93] But these measures can fail and with high loadings of materials in landfills, the threat of leachate migration should be taken seriously.[94]

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[84] NORWEGIAN GEOTECHNICAL INST., *supra* note 78, at 4.

[85] *See* Fthenakis, *supra* note 4, at 12 (explaining that the PV layer is sandwiched between two layers of glass and reasonably isolated from the environment).

[86] *Id.*; s*ee also id.* at 11 ("If these modules end in a municipal waste incinerator (MWI), the heavy metals will gasify and a fraction of those will be released in the atmosphere.").

[87] *Id*. at 12.

[88] MATHIEU SAURAT & MICHAEL RITTHOFF, WUPPERTAL INST. FOR CLIMATE, ENVIRONMENT, & ENERGY, POSITION PAPER: PHOTOVOLTAICS AND THE ROHS DIRECTIVE 5 (May 2010), *available at* www.ntsa.eu/resources/Wuppertal+Institute+RoHS+position+paper$2C+May+2010+final.pdf.

[89] Fthenakis, *supra* note 4, at 12.

[90] NORWEGIAN GEOTECHNICAL INST., *supra* note 78, at 25.

[91] AGENCY FOR TOXIC SUBSTANCES & DISEASE REGISTRY, DRAFT TOXICOLOGICAL PROFILE FOR CADMIUM 11 (Sept. 2008), *available at* www.atsdr.cdc.gov/toxprofiles/TP.asp?id=48&tid=15 (follow "PDF version, 8.9 MB" link); AGENCY FOR TOXIC SUBSTANCES & DISEASE REGISTRY, TOXICOLOGICAL PROFILE FOR LEAD 4 (Aug. 2007), *available at* www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=96&tid=22 (follow "PDF version, 6.2 MB" link).

[92] Leachate is "any liquid, including any suspended components in the liquid, that has percolated through or drained from hazardous waste." 40 C.F.R. § 260.10 (Westlaw 2011).

[93] NORWEGIAN GEOTECHNICAL INST., *supra* note 78, at 22; *see also, e.g.*, CAL. STATE WATER RES. CONTROL BD., RESOLUTION NO. 93-62, POLICY FOR REGULATION OF DISCHARGES OF MUNICIPAL SOLID WASTE (July 21, 2005), *available at* www.swrcb.ca.gov/board_decisions/adopted_orders/resolutions/2005/rs2005-0058_rs93-62.pdf (providing liner requirements for California landfills to prevent leaching).

[94] *See* G. FRED LEE & ANNE JONES-LEE, SUPERFUND SITE REMEDIATION BY ON-SITE RCRA LANDFILLS: INADEQUACIES IN PROVIDING GROUNDWATER QUALITY PROTECTION (May 1996), *available at* www.gfredlee.com/HazChemSites/eia.htm (noting that landfill containment systems operate for a finite time period, after which leachate can pollute groundwater).

With sustained growth projected for the PV market,[95] the future volume of PV waste is a significant concern. One study predicts that by 2050, one third of cadmium use worldwide will be attributed to PV technology.[96] Most panels now in use have a life expectancy of twenty to thirty years.[97] The first wave of used panels is expected to hit the waste stream in five to ten years.[98]

D. LESSONS LEARNED FROM E-WASTE

The legacy of inadequate e-waste management in the United States provides a cautionary tale for controlling the future of PV waste.[99] Common electronic products, such as computers, televisions, and cell phones, that have become obsolete or hit the end of their useful lives are e-waste.[100] These products comprise many heavy metals and other toxic substances that are also present in PV systems.[101] Because wastes from electronic products were not specifically regulated while the industry developed, they were improperly disposed of, causing a significant strain on environmental resources.[102]

E-waste has been growing at an alarming rate – two to three times faster than other types of solid waste.[103] For years, e-waste was simply

[95] U.S. DEP'T OF ENERGY, *supra* note 24.

[96] NORWEGIAN GEOTECHNICAL INST., *supra* note 78, at 13 (citing M. Raugei, *Prospective Analysis of the Future Impact of CdTe PV in Terms of Cd Demand and Cd Emissions* 2584-2587 (Sept. 2008) (presented at 23d European PV solar energy conference, Valencia, Spain)).

[97] Fthenakis, *supra* note 4, at 11.

[98] ELLEN L. HAERTLE, CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, WORKSHOP FOR PROPOSED SOLAR PANEL REGULATIONS, REGULATORY EXEMPTION AND UNIVERSAL WASTE MANAGEMENT OPTIONS FOR END-OF-LIFE HAZARDOUS WASTE SOLAR PANELS 10 (July 28, 2010), *available at* www.dtsc.ca.gov/LawsRegsPolicies/Regs/upload/Workshop-Presentation.pdf (presentation slides for workshop to discuss the DTSC's proposed draft solar panel regulations).

[99] SILICON VALLEY TOXICS COAL., *supra* note 6.

[100] *See* Elecs. TakeBack Coal., *State Legislation*, ELECTRONICSTAKEBACK.COM, www.electronicstakeback.com/promote-good-laws/state-legislation/ (last visited Mar. 17, 2011). No state e-waste laws cover PV technology. S*ee* Elecs. TakeBack Coal., *Scope of Products in E-Waste Laws*, ELECTRONICSTAKEBACK.COM, www.electronicstakeback.com/wp-content/uploads/Scope_of_Product_in_Ewaste_Laws.pdf (last visited Mar. 17, 2011). Electronic products covered under e-waste laws vary by state. *Id.*

[101] *See* SILICON VALLEY TOXICS COAL., POISON PCS AND TOXIC TVS: CALIFORNIA'S BIGGEST ENVIRONMENTAL CRISIS THAT YOU'VE NEVER HEARD OF 10 (2004), *available at* svtc.org/wp-content/uploads/ppc-ttv1.pdf (explaining that e-waste contains lead, chromium, cadmium, selenium, arsenic, copper, nickel, silver, aluminum, and brominated flame retardants).

[102] *See* Elecs. TakeBack Coal., *The Problem with Electronics and E-Waste*, ELECTRONICSTAKEBACK.COM, www.electronicstakeback.com/problem/problem_index2.htm (last visited Mar. 17, 2011).

[103] U.S. Envtl. Prot. Agency, *Electronic Waste & eCycling*, EPA.GOV, epa.gov/region1/solidwaste/electronic/index.html (last visited Mar. 17, 2011).

discarded in landfills with other solid waste.[104] From 1999 through 2005, 85% of e-waste was land-disposed.[105] In 2007, 2.25 million tons of e-waste was generated, of which 1.84 million tons (or 82%) was land-disposed.[106] This uncontrolled disposal of e-waste may be responsible for 40% of lead and 70% of heavy metals in landfills.[107]

The current e-waste problem stems from a lack of early and effective regulatory oversight.[108] The United States has no national policy on household e-waste, leaving the solution up to the states.[109] By 2006, only four states had adopted e-waste regulations.[110] To date, twenty-four states have e-waste laws.[111] Even with these laws now in place, the overwhelming majority of e-waste is still dumped in landfills.[112] Worse, the majority of products ostensibly being recycled are shipped overseas where they are dismantled under unsafe conditions or improperly discarded.[113] Cleaning up e-waste is now one of the U.S. Environmental Protection Agency's (EPA's) top six international priorities.[114]

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[104] U.S. Envtl. Prot. Agency, *Statistics on the Management of Used and End-of-Life Electronics*, EPA.GOV, www.epa.gov/epawaste/conserve/materials/ecycling/manage.htm (last visited Mar. 17, 2011).

[105] *Id*.

[106] *Id*.

[107] SILICON VALLEY TOXICS COAL., *supra* note 101, at 3.

[108] *See* Elecs. TakeBack Coal., *supra* note 102.

[109] *See* Elecs. TakeBack Coal., *State Legislation*, *supra* note 100. For an analysis of state e-waste laws and recommendations for a national policy, see Jeremy Knee, *Guidance for the Awkward: Outgrowing the Adolescence of State Electronic Waste Laws*, 33 ENVIRONS ENVTL. L. & POL'Y J. 157 (2009); *see also* Phoenix Pak, Notes, *Haste Makes E-Waste: A Comparative Analysis of How the United States Should Approach the Growing E-Waste Threat*, 16 CARDOZO J. INT'L & COMP. L. 241 (2008); Valerie Eifert, Comment, *Collaboration Before Legislation: The Current State of E-Waste Laws and a Guide to Developing Common Threads for the State Patchwork Quilt*, 18 PENN ST. ENVTL. L. REV. 235 (2010).

[110] NAT'L CTR. FOR ELECS. RECYCLING, A STUDY OF THE STATE-BY-STATE E-WASTE PATCHWORK 6 (Oct. 2006), *available at* ecyclingresource.org/userdocuments/patchwork%20 study%20final.pdf (includes California, Maine, Maryland, and Washington).

[111] Elecs. TakeBack Coal., *State Legislation*, *supra* note 100.

[112] U.S. Envtl. Prot. Agency, *supra* note 104.

[113] U.S. Envtl. Prot. Agency, *EPA's International Priorities*, EPA.GOV, www.epa.gov/ international/topsix.html (last visited Mar. 17, 2011); *see also* Elecs. TakeBack Coal., *supra* note 102. The United States has not ratified the Basel Convention, a global agreement which bans the shipment of hazardous waste overseas without prior written consent by the receiving country. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, *opened for signature* Mar. 22, 1989, 28 I.L.M. 649. Export of hazardous waste is a federal jurisdictional issue and is not discussed herein. For more on this topic, see Manasvini Krishna & Pratiksha Kulshrestha, *The Toxic Belt: Perspectives on E-Waste Dumping in Developing Nations*, 15 U.C. DAVIS J. INT'L L. & POL'Y 71 (2008).

[114] U.S. Envtl. Prot. Agency, *supra* note 113. The EPA sets priorities to develop goals and visions for environmental progress on a global scale. *Id.* The EPA states that improper disposal of e-

To prevent a similar result for the PV industry, effective regulations for PV panels need to be adopted before the PV waste stream hits landfills.[115] Because the large volume of panels will not require disposal for another five years,[116] there is a window of opportunity open now for legislatures to enact regulations to thwart future PV waste problems.[117]

III. HOW TO APPROACH REGULATION OF PV WASTE – THE VALUE OF RECYCLING AND LIFE-CYCLE MANAGEMENT

PV energy is promoted as green, clean, and pollution-free,[118] but this can be true only if PV products do not pile up in landfills or leave other damaging footprints on the environment.[119] As policymakers look to enact laws to address the problem, they need to select an approach that will reduce, and eventually eliminate, the harmful side effects of PV technology.[120] Not only should laws require recycling and prevent land disposal, but they should consider the entire life cycle of products.[121]

Recycling of PV panels brings several advantages over disposal.[122] These benefits include reservation of landfill space, reduced emissions to the environment, and conservation of raw materials.[123] Public perception of the industry can also improve with recycling programs, attracting new buyers into the PV market.[124]

PV product recycling is technically feasible.[125] Components of PV panels, such as scrap metal, glass, and semiconductor material, can be recycled.[126] Better yet, entire PV panels can often be reused to make new

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waste is an urgent concern for the global environment and that the agency "will focus on ways to improve the design, production, handling, reuse, recycling, exporting, and disposal of electronics." *Id.*

[115] SILICON VALLEY TOXICS COAL., *supra* note 6.

[116] HAERTLE, *supra* note 98.

[117] *See* Fthenakis & Moskowitz, *supra* note 14 (commenting that due to this lag time, design of today's solar panels and materials used in them will likely "set a precedent for the future").

[118] *See* U.S. Energy Info. Admin., *supra* note 20.

[119] *See* Fthenakis, *supra* note 4.

[120] *See* SILICON VALLEY TOXICS COAL., *supra* note 6, at 27-28 (focusing on PV manufacturers as the responsible parties to take this action).

[121] *See* SILICON VALLEY TOXICS COAL., *supra* note 6, at 27-29 (focusing on the PV industry as the responsible party to take this action).

[122] *See* Fthenakis & Moskowitz, *supra* note 14.

[123] *See id.*

[124] *See id.*

[125] *See id.*

[126] HAERTLE, *supra* note 98, at 14; Videotape: Workshop for Proposed Solar Panel Regulations, Regulatory Exemption and Universal Waste Management Options for End-of-Life Hazardous Waste Solar Panels (Ellen L. Haertle, Cal. Dep't of Toxic Substances Control, July 28,

panels.[127] This has a "double greening" benefit: a green renewable-energy product is reused to create another renewable-energy product.[128]

To complement end-of-life recycling, legislation should also encompass the entire life cycle of PV products.[129] Extended producer responsibility (EPR), otherwise known as product stewardship, is a waste-reduction strategy that can achieve this goal.[130] The system places the costs and responsibility for product end-of-life management on the producer and others who make early design and marketing decisions.[131] "EPR is intended to reduce waste, boost recycling, and drive environmentally conscious design" by making producers accountable for the life cycle of their products.[132] Putting the onus on the product manufacturer fosters greener product design, which in turn reduces the hazards posed by the product's end of life.[133]

States will have the burden to regulate PV waste.[134] Except for hazardous waste, the federal government imposes minimal regulations and delegates authority for solid waste management to states.[135] Also, the federal government, through the EPA, does not mandate EPR, but only encourages it.[136] Thus, state governments have the onus to implement and support the programs.

In the following Parts, existing and proposed legal frameworks to manage PV waste are evaluated. The primary goals – to prevent releases of toxic substances, bar land disposal, reduce waste, promote recycling, and foster green design – are applied as benchmarks to evaluate the effectiveness and potential success of each regulatory scheme.

2010), *available at* www.dtsc.ca.gov/LawsRegsPolicies/Regs/Reg_Exempt_HW_Solar_Panels.cfm (follow "Workshop Video, July 28, 2010" link) [hereinafter Videotape].

[127] Videotape, *supra* note 126; PV CYCLE, *supra* note 10.

[128] PV CYCLE, *supra* note 10.

[129] Woolwich, *supra* note 13; Davis & Mulvaney, *supra* note 13.

[130] CalRecycle, *Product Stewardship and Extended Producer Responsibility (EPR)*, CALRECYCLE.CA.GOV, www.calrecycle.ca.gov/EPR/ (last visited Mar. 17, 2011).

[131] *Id.*

[132] U.S. ENVTL. PROT. AGENCY, EPA530-K-98-004, EXTENDED PRODUCT RESPONSIBILITY (Dec. 1998), *available at* www.epa.gov/osw/partnerships/stewardship/docs/eprbrochure.pdf.

[133] *Id.*

[134] *See* 42 U.S.C.A. §§ 6941-6948 (Westlaw 2011) (delegating authority for solid waste management to states).

[135] *Id.* For example, in California, the Department of Resources Recycling and Recovery (CalRecycle) regulates disposal and recycling of electronic products, tires, motor oil, and plastics. CAL. PUB. RES. CODE § 41780(a)(2) (Westlaw 2011) (making local governments and solid waste management agencies responsible to divert 50% of their solid waste "through source reduction, recycling, and composting activities").

[136] U.S. ENVTL. PROT. AGENCY, *supra* note 132.

IV. DISPOSAL OF PV PANELS AS HAZARDOUS WASTE

Federal and state hazardous waste laws provide mediocre safeguards to prevent environmental impacts from PV waste. Due to narrow definitions of hazardous waste, most panels are not regulated under the laws.[137] For the few that are regulated, the products are discarded in landfills.[138] Furthermore, exemptions allow homeowners to throw away hazardous waste panels with other household trash.[139] In the end, whether hazardous or not, the panels come to rest in landfills.

A. LIMITATIONS OF FEDERAL REGULATION UNDER RCRA

The EPA regulates hazardous waste, from its generation to disposal, under Subtitle C of the Resource Conservation and Recovery Act (RCRA).[140] This regulation is otherwise known as "cradle to grave" tracking of hazardous waste.[141] RCRA is the primary enforcement tool to properly and safely provide for end-of-life management of hazardous waste.[142] Despite its lofty purpose, however, RCRA has many shortcomings, including exclusive definitions of hazardous waste, exemptions, and allowances for disposal.[143] With these deficiencies, RCRA does not provide for sustainable control of PV waste.

RCRA is a rigorous statute that mandates a system of strict compliance for the management of hazardous waste.[144] Under RCRA, those who generate hazardous waste, "generators,"[145] must make certain that their waste ultimately ends up in treatment, storage, and disposal facilities that are designed to manage the waste long-term.[146] Generators are subject to stringent reporting and handling requirements at all stages of the waste's movement.[147] Generators who do not comply with RCRA

[137] *See infra* notes 150-160, 179-184 and accompanying text.

[138] *See* 40 C.F.R. § 268.40 (Westlaw 2011) (land disposal restrictions ensure that only the most toxic materials are treated to reduce their toxicity before they can be land-disposed); *see also* Fthenakis, *supra* note 4, at 12.

[139] *See infra* notes 162-165 and accompanying text.

[140] 42 U.S.C.A. §§ 6921-6934 (Westlaw 2011).

[141] City of Chicago v. Envtl. Def. Fund, 511 U.S. 328, 331-32 (1994).

[142] *See* 42 U.S.C.A. §§ 6921-6934 (Westlaw 2011).

[143] *See infra* notes 150-165 and accompanying text.

[144] *See infra* notes 145-148 and accompanying text.

[145] A generator is "any person, by site, whose act or process produces hazardous waste . . . or whose act first causes a hazardous waste to become subject to regulation." 40 C.F.R. § 260.10 (Westlaw 2011).

[146] *Id.* §§ 262.11(d), 264.

[147] *Id.* §§ 262.10-.44.

are subject to severe civil and criminal penalties.[148]

However, substances within PV panels generally do not meet the statutory definition of RCRA hazardous waste; therefore, they are not regulated as such.[149] The EPA defines hazardous waste as "solid waste" that is unsafe for humans or potentially harmful to the environment.[150] To be regulated as hazardous, solid waste must be listed by the EPA or exhibit certain characteristics of hazardous waste defined by regulations.[151] PV panels are not listed wastes because materials in PV panels are not among hazardous wastes on the EPA's lists.[152] A material is considered a characteristic waste if it exhibits one of four chemical characteristics – ignitability, corrosivity, reactivity, or toxicity.[153] Toxicity is determined using the toxicity characteristic leaching procedure (TCLP) analysis, which measures the leachability of a specific substance.[154] If the material fails the test by exhibiting a leaching potential over the TCLP threshold, it qualifies as characteristic hazardous waste.[155]

Each PV model containing a TCLP-regulated substance must undergo a TCLP analysis before disposal to determine if it is hazardous.[156] Very few PV models commercially available today fail the TCLP analysis.[157] The CdTe and copper indium selenide thin-film models are reportedly passing the test.[158] The amorphous silicon thin-

[148] 42 U.S.C.A. § 6928 (Westlaw 2011). Civil penalties range up to $25,000 per day per violation. *Id.* § 6928(g). Criminal acts not "placing another person in imminent danger of death or serious bodily injury" carry criminal penalties of $50,000 per day per violation and up to five years in jail. *Id.* § 6928(d)-(e).

[149] *See infra* notes 150-160 and accompanying text.

[150] U.S. Envtl. Prot. Agency, *Hazardous Waste Regulations*, EPA.GOV, www.epa.gov/osw/laws-regs/regs-haz.htm (last visited Mar. 17, 2011). A "solid waste" includes any "discarded material" that is "abandoned," "recycled," or "considered inherently waste-like." 40 C.F.R. § 261.2(a) (Westlaw 2011).

[151] 40 C.F.R. § 261.3(a) (Westlaw 2011).

[152] *See id.* §§ 261.31–.33. The four listed waste types are F-list, non-specific source wastes; K-list, source-specific wastes; and P-list and U-list, discarded commercial chemical products. *Id.*

[153] *Id.* §§ 261.21–.24.

[154] *Id.* § 261.24. TCLP limits are specific to each substance included in the regulation. *Id.*

[155] *Id.*

[156] *See id.* The TCLP analysis is a conservative test that mirrors harsh conditions in a landfill. Exova, *TTLC/STLC/TCLP*, www.exova.ca/index.php?option=com_content&view=article&id=1757&Itemid=&lang=en (last visited Feb. 13, 2011). The PV module is broken into small pieces for the test. Fthenakis, *supra* note 4, at 12. But if the module remains intact in a landfill, the substances are less likely to leach because they are sandwiched between layers of inert material, such as glass. *Id.*

[157] Fthenakis, *supra* note 4, at 12. *But see id.* (explaining that tests on non-commercial multi-junction modules containing gallium arsenide are not available).

[158] *Id.* (reporting early studies that showed CdTe panels to fail the TCLP criteria, but also

film models contain minor amounts of toxic substances, easily passing the test.[159] While some crystalline silicone models fail the analysis for lead, other manufacturers report that current modules are passing the TCLP threshold.[160]

Even for the few PV panels that qualify as hazardous wastes, homeowners and other residential entities can dump them with other household trash.[161] Hazardous wastes from households are exempt from RCRA Subtitle C regulation.[162] Under this exemption, wastes from single- and multiple-family dwellings, hotels, and other residential facilities are exempt.[163] Therefore, homeowners can dispose of their PV panels as solid waste without being subject to regulation.[164] Because the exemption applies to "household waste . . . derived from households," even if the owner hires a contractor to remove the panels, the waste is still exempt from regulation.[165]

Most manufacturers of PV panels, however, are not exempt when disposing of their waste.[166] Conditionally exempt small quantity generators (CESQGs) are exempt from regulation.[167] Only entities generating 100 kilograms or less of hazardous waste per month are CESQGs.[168] At approximately 40 pounds (or 18 kilograms) per panel,[169] PV manufacturers would not qualify as CESQGs.

Ultimately, RCRA is ill-suited to manage PV waste in an environmentally responsible manner. The very few panels that are subject to regulation are discarded in hazardous waste landfills.[170] While

more recent studies that report CdTe panels to pass the TCLP criteria); Nat'l Renewable Energy Lab., *Cadmium Use in Photovoltaics: The Perceived Risk and the Scientific Evidence*, NREL.GOV, www.nrel.gov/pv/cdte/cadmium_facts.html (last visited Mar. 17, 2011) (reporting that today's CdTe panels pass TCLP criteria); NORWEGIAN GEOTECHNICAL INST., *supra* note 78, at 14 (citing A.E. Baumann & K.M. Hynes et al., *An Investigation of Cadmium Telluride Thin-Film PV Modules by Impact Pathway Analysis*, 6(5-6) Renewable Energy 593-99 (1995)).

[159] Fthenakis, *supra* note 4, at 12.

[160] *Id.*

[161] *See infra* notes 162-165 and accompanying text.

[162] 40 C.F.R. § 261.4(b)(1) (Westlaw 2011).

[163] *Id.*; s*ee also* U.S. Envtl. Prot. Agency, *Solid Waste Laws and Regulations*, EPA.GOV, www.epa.gov/region9/waste/solid/laws.html (last visited Mar. 17, 2011).

[164] *See* U.S. Envtl. Prot. Agency, *supra* note 163.

[165] 40 C.F.R. § 261.4(b)(1) (Westlaw 2011).

[166] *See infra* notes 167-169 and accompanying text.

[167] 40 C.F.R. § 261.5 (Westlaw 2011).

[168] *Id.*

[169] WHOLESALE SOLAR, www.wholesalesolar.com/solar-panels.html (last visited Mar. 17, 2011).

[170] *See* 40 C.F.R. § 268.40 (Westlaw 2011) (land disposal restrictions ensure that only the most toxic materials are treated to reduce their toxicity before they can be land-disposed); *see also* Fthenakis, *supra* note 4, at 12.

this limits exposure to toxic constituents by containing the waste in a landfill, it does nothing to reduce the volume of waste produced or promote recycling. In fact, this "cradle to grave" tracking of hazardous waste actually hinders recycling – a system that can effectively eliminate the waste.[171]

B. WHY STATE HAZARDOUS WASTE LAWS ALSO FALL SHORT

State hazardous waste laws provide modest advantage over their federal counterpart for sustainable PV management. States can adopt more stringent requirements than RCRA's provisions for hazardous waste management.[172] For example, California does not exempt households from hazardous waste disposal regulation.[173] The state also has a broader definition of hazardous waste than RCRA, so PV panels can be regulated in California as non-RCRA hazardous waste.[174] However, state laws still suffer from the same weaknesses as RCRA – most panels are not regulated and, hazardous or not, panels are abandoned in landfills.[175]

Under California's Hazardous Waste Control Law,[176] tests for leachability are more conservative than the federal TCLP analysis.[177] Many of the materials in PV products, including arsenic, cadmium, hexavalent chromium, copper, lead, nickel, selenium, and silver, are "persistent and bioaccumulative toxic substances" under California regulations.[178] A PV panel containing at least one of these constituents qualifies as a hazardous waste if the total threshold limit concentration (TTLC) and soluble threshold limit concentration (STLC) exceed

[171] Videotape, *supra* note 126.

[172] 40 C.F.R. §§ 271.9–.16 (Westlaw 2011). The EPA authorizes states to manage their own hazardous waste programs under RCRA. *Id.* § 271.1. At a minimum, state programs must be at least as stringent as the federal requirements. *Id.* §§ 271.9–.16. For example, a state definition of hazardous waste cannot exclude listed and characteristic wastes under RCRA. *Id.* § 271.9. But it can include wastes in addition to those that are controlled as hazardous wastes under RCRA. *Id.*

[173] CAL. HEALTH & SAFETY CODE § 25218 (Westlaw 2011); *see also* CalRecycle, *Hazardous Waste and Universal Waste (U-Waste), Wastes Banned From the Trash*, CALRECYCLE.CA.GOV, www.calrecycle.ca.gov/HomeHazWaste/Info/ (last visited Mar. 17, 2011). *But see* CAL. HEALTH & SAFETY CODE § 25218.4 (Westlaw 2011) (any person who transports household hazardous waste is exempt from reporting and manifest requirements of the statute).

[174] *See infra* notes 176-184 and accompanying text.

[175] *See infra* notes 182-187 and accompanying text.

[176] CAL. HEALTH & SAFETY CODE §§ 25100-25258 (Westlaw 2011).

[177] *See* CAL. CODE REGS. tit. 22, § 66261.24(a)(2)(A) (Westlaw 2011); *see also* Videotape, *supra* note 126.

[178] CAL. CODE REGS. tit. 22, § 66261.24(a)(2)(A) (Westlaw 2011). See *supra* notes 76-78 and accompanying text for a description of materials in PV products.

regulatory standards.[179] If a PV panel is not hazardous under RCRA, but fails the state's TTLC and STLC limits, the panel is a non-RCRA hazardous waste and can then be disposed of only in specific landfills.[180]

Because they contain regulated substances, PV panels in California must undergo TTLC and STLC analyses to determine legal disposal of the products.[181] At present, only thin-film CdTe panels are failing TTLC and STLC tests due to their cadmium content.[182] The CdTe panels that fail the criteria are regulated as hazardous waste in the state.[183] Other models of PV products, including copper indium selenide and amorphous silicon, do not exceed California hazardous waste thresholds.[184]

While California law provides a more guarded approach to hazardous waste regulation than federal law, it is impaired by some of the same limitations as RCRA. Very few PV models are regulated as California hazardous waste.[185] Even when regulated as hazardous waste, the panels are discarded in landfills.[186] Panels that do not meet the statutory definition of hazardous waste are considered solid waste and can be disposed of with other trash.[187] These PV panels may have a lower potential to leach harmful contaminants into the environment.[188] Nevertheless, they contain many of the same toxic constituents as PV panels that have been designated hazardous waste, and they take up the same amount of space in landfills.[189]

States have an opportunity to solve the shortcomings of hazardous waste laws and attain responsible management of PV waste. First, for panels regulated as hazardous waste, states should establish alternative

[179] CAL. CODE REGS. tit. 22, § 66261.24(a)(2)(A) (Westlaw 2011).

[180] *Id.* § 66262.11(d); CAL. HEALTH & SAFETY CODE § 25189.5 (Westlaw 2011).

[181] *See* CAL. CODE REGS. tit. 22, § 66261.24(a)(2) (Westlaw 2011). See *supra* notes 76-78 and accompanying text for a description of materials in PV products.

[182] Letter from Richard K. Forsyth, Sierra Analytical Labs, Inc., to Mr. Hemme, The Non-Toxic Solar Alliance e.V. (July 22, 2010), *available at* www.dtsc.ca.gov/LawsRegs Policies/upload/Sierra-Analytical-Labs-Report.pdf (indicating that laboratory analyses of two CdTe solar panels failed the TTLC and STLC standards for cadmium); *see also* Davis & Mulvaney, *supra* note 13; Videotape, *supra* note 126 (emerging technologies are rapidly developing, and it is unknown if future PV models will pass hazardous waste criteria).

[183] *See* CAL. CODE REGS. tit. 22, § 66261.24(a)(2) (Westlaw 2011); *see also* Videotape, *supra* note 126.

[184] Videotape, *supra* note 126.

[185] *See supra* notes 182-184 and accompanying text.

[186] *See* Fthenakis, *supra* note 4, at 12; *see also* CAL. CODE REGS. tit. 22, §§ 66270.1-.73 (Westlaw 2011).

[187] *See* Fthenakis, *supra* note 4, at 12; s*ee also* 42 U.S.C.A. §§ 6941-6947 (Westlaw 2011).

[188] *See* Fthenakis, *supra* note 4.

[189] *See id.*; *see generally* Fthenakis & Moskowitz, *supra* note 14 (explaining that recycling of PV products would conserve landfill space).

reclamation and recycling options under existing laws.[190] Second, for all panels, including those that evade regulation, states should mandate EPR programs that require producers to take back and recycle PV products.[191] This is a "cradle to cradle" approach that avoids the improper disposal outcome advanced by RCRA under "cradle to grave" management.[192]

V. CALIFORNIA'S LEAD – MOVING TOWARD REUSE AND RECYCLING OF HAZARDOUS WASTE PV PANELS

California is taking valuable strides to modify its hazardous waste regulations to provide alternative management options for PV waste. The state Department of Toxic Substances Control (DTSC) is proposing regulations that would exempt solar panels from strict hazardous waste regulation and offer reclamation and recycling options.[193] This proposal marks the first step by a state to achieve responsible management of PV waste.

A. ELEMENTS OF CALIFORNIA'S PROPOSAL – RECLAMATION AND RECYCLING OR UNIVERSAL WASTE

In July 2010, the DTSC released proposed standards for management of hazardous waste solar panels to solicit comments before issuing formal public notice.[194] Under the proposed draft regulations, the DTSC offers two options for PV panels to avoid full regulation as hazardous waste: (1) a hazardous waste conditional exemption, and (2) a "universal waste" (u-waste) management option.[195]

Under the hazardous waste conditional exemption, generators could send their non-RCRA hazardous waste panels to reclamation and recycling[196] facilities operated by solar panel vendors in the United States.[197] Facilities in California would require a permit or other grant of

[190] *See, e.g.*, CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 12.

[191] *See* Woolwich, *supra* note 13; *see also* Davis & Mulvaney, *supra* note 13.

[192] CalRecycle, *supra* note 130.

[193] CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 12. The EPA is not considering options at a federal level, likely because PV panels do not fail the TCLP analysis and are not regulated as RCRA hazardous waste. Videotape, *supra* note 126.

[194] CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 12.

[195] *Id.* A PV waste generator could select either option to manage PV waste. *Id.* Absent the DTSC's proposed options, PV hazardous waste is subject to full regulation, including manifesting, reporting, and paying generator and disposal fees. *Id.*

[196] Videotape, *supra* note 126 (although often used interchangeably, "reclamation" is the process to recover useable product and "recycling" refers to reuse of materials).

[197] CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 12, at 3. The conditional

authorization from the DTSC to operate.[198]

Under the second option, PV panels would be designated as u-waste.[199] U-wastes are common hazardous wastes generated by households and small businesses.[200] Items managed as u-wastes are batteries, electronic devices, mercury-containing equipment, lamps, cathode-ray tubes (CRTs), CRT lamps, and non-empty aerosol cans.[201] These products are banned from regular trash.[202] However, households and other entities designated as "u-waste handlers" still benefit from the program because they can effectively and easily manage their hazardous wastes.[203] A u-waste handler is an individual, business, or other entity that generates u-waste, accepts u-waste from other generators at a facility, or accepts u-waste from generators and conducts treatment and recycling activities.[204] A handler must relinquish u-waste to an appropriate facility or program and cannot send it to a municipal landfill or non-hazardous waste recycling center.[205] The u-waste drop-off locations are convenient for the general public and include household hazardous waste facilities, curbside collection programs, special collection events, and retailers and manufacturers who accept products back from consumers.[206]

Typically, households and others generating less than 100 kilograms of hazardous waste per month, also known as "conditionally exempt small quantity u-waste generators," are exempt from handler reporting, recording, and labeling requirements of the program.[207] They are, however, still required to relinquish their waste to other handlers and not dispose of the waste with other household trash.[208] For PV panels, the DTSC is proposing not to give these limited exemptions to households

exemption applies only to non-RCRA hazardous waste. *Id.*

[198] *Id.*

[199] *Id.* at 6. The u-waste exemption for PV panels applies to both RCRA and non-RCRA hazardous wastes. *Id.* at 6.

[200] CalRecycle, *supra* note 173.

[201] CAL. CODE REGS. tit. 22, § 66261.9(a) (Westlaw 2011).

[202] CalRecycle, *supra* note 173.

[203] *See* U.S. ENVTL. PROT. AGENCY, EPA530-R-04-028, TRAINING PANEL: INTRODUCTION TO UNIVERSAL WASTE 4 (Sept. 2003), *available at* www.state.wv.us/swmb/rcra%20universal%20waste.pdf.

[204] CAL. CODE REGS. tit. 22, § 66273.9 (Westlaw 2011); CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, UNIVERSAL WASTE FACT SHEET 2 (Jan. 2010), *available at* www.dtsc.ca.gov/HazardousWaste/UniversalWaste/upload/UW_Factsheet1.pdf.

[205] CAL. CODE REGS. tit. 22, §§ 66273.30-.39 (Westlaw 2011); CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 204, at 4.

[206] CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 204, at 4.

[207] CAL. CODE REGS. tit. 22, § 66273.8 (Westlaw 2011).

[208] *Id.*

and small quantity generators.[209] The Department hopes that this will discourage do-it-yourselfers and instead induce home owners and small businesses to hire "qualified solar panel installers, repair persons, and others who are specifically trained to remove, package, and transport solar panels."[210]

B. THE DEBATE – WHY CALIFORNIA SHOULD MOVE AHEAD

The DTSC's proposal to give generators of hazardous PV waste a choice of sending their waste to reclamation and recycling centers, or of participating in a u-waste program, is a smart decision that advances environmental protection goals. Most importantly, the regulation encourages the public to recycle their products instead of discarding them.[211] If reclamation programs operated by solar-panel vendors were not available under the conditional-exemption option, the generator could still manage the waste as u-waste, a system that provides reuse alternatives.[212] Furthermore, the u-waste reporting requirements for small-quantity generators assure that the general public will handle and dispose of their products safely and within the confines of the law.[213]

While the DTSC's proposal is a major step in the right direction, many groups have been quick to point out its deficiencies.[214] One PV recycling business wants the DTSC to go further and require pre-financed, mandatory collection and recycling systems.[215] Public advocacy groups argue that California should not "deregulate" PV technology by allowing panels to evade strict regulation as hazardous waste, at least until programs are established to support the alternative

[209] CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 12, at 9.

[210] HAERTLE, *supra* note 98, at 20.

[211] *Id*. at 13.

[212] CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 12; *see* CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 204, at 4.

[213] *See* CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 204, at 4.

[214] *See, e.g.*, Davis & Mulvaney, *supra* note 13. For other comments from public advocacy groups, see Cal. Dep't of Toxic Substances Control, *Regulations in Development: Regulatory Exemptions for Hazardous Waste Solar Panels*, DTSC.CA.GOV, www.dtsc.ca.gov/LawsRegs Policies/Regs/Reg_Exempt_HW_Solar_Panels.cfm (last visited Mar. 17, 2011). As expected, the PV industry supports the proposal because it gives producers and their customers some relief and flexibility in managing their waste streams. *See* Letter from Sue Kateley, Cal. Solar Energy Industries Ass'n, Sara Birmingham, The Solar Alliance, and Rohne Resche, Solar Energy Industries Ass'n to Ellen L. Haertle, Cal. Dep't of Toxic Substances Control, Comments on DTSC Proposed Solar Panel Management Regulations (Aug. 11, 2010), *available at* www.dtsc.ca.gov/Laws RegsPolicies/upload/CAL-Solar-Energy-Industries-Assoc-Comments-on-Developmental-Solar-Panel-Regs.pdf.

[215] Woolwich, *supra* note 13.

management options.[216] Some groups contend that PV panels should not be exempted from hazardous waste regulation until a pre-financed, EPR program is in place to handle the volume of anticipated waste.[217]

These comments raise three limitations of DTSC's proposal: 1) capacity, 2) funding, and 3) most importantly, authority. The current recycling capacity may be far below what will be required to handle the large quantity of panels expected in the future.[218] With the current infrastructure, it could take 155 years to recycle the nation's thin-film CdTe panels.[219] Also, funding is not available to support new recycling centers to fill the void.[220] It is estimated that $800 million may be required to recycle California's total announced, planned, and installed PV products.[221] Thus, businesses may not have a financial incentive to voluntarily enact programs.[222]

The most serious restriction is the DTSC's lack of statutory authority.[223] An EPR program could address the financial and capacity concerns of the DTSC's proposal because the responsibility to manage PV waste would rest on PV manufacturers and other producers.[224] However, the DTSC does not have authority to require producer responsibility, because it cannot regulate PV products.[225] The DTSC's

[216] *See, e.g.*, Davis & Mulvaney, *supra* note 13. This group also expressed concerns of worker safety associated with handling end-of-life panels, which may trigger "environmental justice" considerations. *Id.* "Environmental justice" is defined by the DTSC as "equal application of environmental protection for all communities and citizens without regard to race, national origin or income." Cal. Dep't of Toxic Substances Control, *Environmental Justice and Tribal Program*, DTSC.CA.GOV, www.dtsc.ca.gov/GetInvolved/env_justice_policies.cfm (last visited Mar. 17, 2011).

[217] Woolwich, *supra* note 13; Davis & Mulvaney, *supra* note 13.

[218] Davis & Mulvaney, *supra* note 13. Reclamation and recycling programs operated by PV vendors in California are in various stages of development, some only at pilot or experimental phases, and others at full-scale operational levels. Videotape, *supra* note 126.

[219] Davis & Mulvaney, *supra* note 13.

[220] *Id.* (explaining that it may not be profitable to invest in PV recycling, thus ruling out private investors).

[221] *Id.*

[222] *See id.*

[223] *See* HAERTLE, *supra* note 98 (noting the DTSC's lack of statutory authority to implement EPR regimes for hazardous waste solar panels).

[224] *See* CalRecycle, *supra* note 130; *see also* U.S. ENVTL. PROT. AGENCY, *supra* note 132.

[225] *See* CAL. HEALTH & SAFETY CODE §§ 25150-25158 (Westlaw 2011) (the DTSC's authority to manage hazardous waste); *see also* HAERTLE, *supra* note 98. *But see* CAL. HEALTH & SAFETY CODE §§ 25251-25257.1 (Westlaw 2011). In 2008, the state legislature gave the DTSC statutory authority to implement the green chemistry initiative. *Id.* Under this initiative, the DTSC is developing regulations to identify and prioritize chemicals of concern in consumer products and evaluate safer alternatives for chemical components of the products. *Id.* § 25253; *see also* CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, CALIFORNIA GREEN CHEMISTRY INITIATIVE: FREQUENTLY ASKED QUESTIONS (Dec. 2008), *available at* www.dtsc.ca.gov/PollutionPrevention/GreenChemistryInitiative/upload/FAQs_greenchem.pdf. The DTSC's current recommendations under the

authority does not begin until a PV panel becomes a waste, that is, when the PV panel reaches the end of its life.[226] The DTSC is further inhibited by a lack of authority to administer or implement the reclamation and recycling centers that it advocates in its proposed standards.[227] Instead, there is an assumption that private entities would fill this void by participating voluntarily in recycling programs.[228] To bridge this gap, a mandatory producer responsibility program for PV waste needs to be addressed with separate, new legislation.

Despite these obstacles, the DTSC should move forward with its proposed regulations, because they would only decrease the amount of hazardous PV waste turning up in landfills. The capacity of recycling programs, while short, does not need to meet the full volume of PV waste at present, because the DTSC offers a choice to generators either to manage PV panels as hazardous waste or to recycle the products.[229] If recycling options are not available, a generator is still legally required to comply with hazardous waste regulations.[230]

The proposed regulations also encourage recycling of PV panels that are not hazardous. At this time, only cadmium-based panels are failing hazardous waste criteria under state law.[231] PV panels that are not hazardous waste continue to go unregulated and are discarded in landfills as solid waste.[232] Even without a complementary EPR system, the PV industry and recycling businesses would be incentivized to invest in reclamation and recycling programs if they are available for all types of panels, not just those deemed non-hazardous.

VI. THE NEXT STEP – EXTENDED PRODUCER RESPONSIBILITY

To achieve full, responsible, management of PV waste, state policymakers need to sponsor legislation that supports producer

green chemistry initiative include motivating manufacturers to supply a "green scorecard" to inform retailers of the chemical ingredients and potential hazards of their products. *Id.* Retailers would then develop targets for safer and more sustainable inventories. *Id.* With enabling legislation, the DTSC could regulate this process. *Id.*

[226] Videotape, *supra* note 126.

[227] HAERTLE, *supra* note 98; Videotape, *supra* note 126.

[228] *See* Videotape, *supra* note 126. *But see* Davis & Mulvaney, *supra* note 13 (noting that without assurances of financial gain or state monies to fund the program, participation by private investment may be a very large assumption).

[229] *See* CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 12.

[230] *Id*.

[231] *See supra* notes 181-184 and accompanying text.

[232] *See* 40 C.F.R. § 261.2(a) (Westlaw 2011).

responsibility programs.[233] In California, the DTSC is proposing to allow recycling of hazardous waste PV panels but is limited by a lack of authority and a lack in funding.[234] Because of these limitations, the DTSC's program will not be as effective as it should be. Further, there is no legislation to effectively regulate non-hazardous PV panels, which account for the overwhelming majority of PV waste volume.[235] State-sponsored EPR programs could ensure responsible recycling of all PV panels.[236]

A. EPR BASICS

EPR, or product stewardship, makes producers responsible for products when they hit the end of their useful lives.[237] Producers include suppliers, designers, manufacturers, and distributors of products.[238] EPR typically operates in the form of "takeback" programs, whereby retailers and other producers accept products back from consumers and are responsible for treatment, disposal, or recycling of the products.[239] EPR is based on the theory that producers are in the best position to reduce toxicity and waste because they are in direct control of design and marketing of products.[240] Holding producers accountable for end-of-life management encourages greener design and thereby reduces waste.[241]

Of the twenty-four states with e-waste laws, twenty-three use EPR-based systems.[242] These programs are preferred to models in which the

[233] *See* Woolwich, *supra* note 13; *see also* Davis & Mulvaney, *supra* note 13.

[234] *See supra* notes 220-228 and accompanying text.

[235] *See supra* notes 156-160, 181-184 and accompanying text (explaining that only some thin-film CdTe panels are currently regulated as hazardous waste). Thin-film technology only constitutes 21% to 39% of the industry. U.S. Energy Info. Admin., *supra* note 26, at tbl.3.5.

[236] *See* Woolwich, *supra* note 13; *see also* Davis & Mulvaney, *supra* note 13.

[237] CalRecycle, *supra* note 130; U.S. ENVTL. PROT. AGENCY, *supra* note 132.

[238] *See* CalRecycle, *supra* note 130. At a federal level, the EPA advocates a slightly different approach – extended product responsibility – which targets actors within the entire product supply chain. U.S. ENVTL. PROT. AGENCY, *supra* note 132. This approach includes "suppliers, designers, manufacturers, and distributors to customers, recyclers, remanufacturers, and disposers" who all have an opportunity to impact the product life cycle. *Id.* However, in reality, the burden typically lies on producers and those early in the supply chain. All of the EPA's examples for successful programs are the result of effort by producers – Xerox Corporation, DuPont, Hewlett Packard, Interface Flooring Systems, and Frigidaire. *Id.*

[239] CalRecycle, *supra* note 130; U.S. ENVTL. PROT. AGENCY, *supra* note 132.

[240] U.S. ENVTL. PROT. AGENCY, *supra* note 132.

[241] CalRecycle, *supra* note 130.

[242] Elecs. TakeBack Coal., *State Legislation*, *supra* note 100. The twenty-three states with EPR-based laws for e-waste are Connecticut, Hawaii, Illinois, Indiana, Maine, Maryland, Michigan, Minnesota, Missouri, New Jersey, New York, North Carolina, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Texas, Vermont, Virginia, Washington, West Virginia, and

consumer directly pays recycling fees, because they encourage manufacturers to develop greener products.[243] Further, EPR-based systems do not burden the taxpayer with finding a solution to the e-waste problem.[244] California applies a consumer fee model under which consumers of products are required to pay fees for end-of-life management when purchasing an electronic device.[245] However, the state recently adopted a strategic directive to seek statutory authority for EPR.[246]

Recycling goals under e-waste EPR programs vary among states.[247] Some states ban certain products from disposal.[248] Other states establish adjustable binding or non-binding recycling targets.[249] Further, states apply various forms of EPR to allocate responsibility between manufacturers, recyclers, and the state.[250] Under state-organized programs, local governments coordinate e-waste collections.[251] Other states put the onus on manufacturers and require them to administer their own recycling programs or use third-party recyclers.[252] Under a hybrid approach, some states allow manufacturers to either set up their own collection and recycling programs or pay the state to use a state-organized program.[253] Under these regimes, manufacturers are responsible for collection and recycling costs.[254]

There are no federal mandates in the United States for EPR.[255] The

Wisconsin. *Id.*

[243] CalRecycle, *supra* note 130; U.S. ENVTL. PROT. AGENCY, *supra* note 132.

[244] CalRecycle, *supra* note 130; U.S. ENVTL. PROT. AGENCY, *supra* note 132.

[245] CAL. PUB. RES. CODE § 42464 (Westlaw 2011).

[246] CAL. INTEGRATED WASTE MGMT. BD., BOARD GOVERNANCE POLICIES, STRATEGIC DIRECTIVES (Mar. 24, 2009), *available at* www.calrecycle.ca.gov/Archive/IWMBPlans /2007/DirRevise309.pdf (EPR is Strategic Directive 5).

[247] Elecs. TakeBack Coal., *Brief Comparison of State Laws on Electronics Recycling*, www.electronicstakeback.com/wp-content/uploads/Compare_state_laws_chart.pdf (last visited Mar. 17, 2011). The ability of each state to set robust recycling goals is likely a reflection of politics. *See generally* Noah Sachs, *Planning the Funeral at the Birth: Extended Producer Responsibility in the European Union and the United States*, 30 HARV. ENVTL. L. REV. 51, 53 (2007) (noting that conservative parties have hindered e-waste legislation in the United States).

[248] *See, e.g.*, CONN. GEN. STAT. ANN. § 22a-636 (Westlaw 2011); OR. REV. STAT. ANN. § 459.247(1)(f) (Westlaw 2011).

[249] *See, e.g.*, MINN. STAT. ANN. § 115A.1314(1)(b)(2) (Westlaw 2011). Manufacturers in Minnesota must recycle 60% of covered e-waste sold during the first year of the program and 80% during subsequent years. *Id.*

[250] Elecs. TakeBack Coal., *supra* note 247.

[251] *See, e.g.*, ME. REV. STAT. ANN. tit. 38, § 1610(5)(A) (Westlaw 2011).

[252] *See, e.g.*, WASH. REV. CODE ANN. § 70.95N.050 (Westlaw 2011).

[253] *See, e.g.*, CONN. GEN. STAT. ANN. § 22a-631(b) (Westlaw 2011).

[254] *Id.*

[255] U.S. ENVTL. PROT. AGENCY, *supra* note 132.

federal government, through the EPA, encourages a voluntary approach because it "achieves environmental improvement at less cost than mandates."[256] However, states with e-waste laws mandate takeback programs,[257] likely because they recognize that manufacturers are often unwilling to expend the resources to implement programs voluntarily.

B. THE EUROPEAN SOLUTION FOR PV WASTE – A SUCCESSFUL VOLUNTARY APPROACH TO EPR

The European PV industry has pioneered a successful voluntary EPR program administered by an association called PV Cycle.[258] Membership, which represents almost 90% of the European PV market, includes a range of interests from manufacturers to retailers of PV products.[259] Through the initiative of PV Cycle, leading manufacturers in the European Union (EU) have begun voluntarily taking back and recycling PV panels.[260] PV Cycle aims to have a producer-financed program fully implemented by the year 2015 to accommodate the high volume of PV panels that are expected to become obsolete by that date.[261]

PV Cycle has demonstrated that recycling of PV products is technically feasible and initial recycling targets can be set at high levels.[262] The association reports that from the dismantling of one large utility-scale generator, approximately 85% of the PV materials were recycled.[263] Even at an early operational stage, PV Cycle is targeting 65% collection industry-wide, of which 85% should be recycled.[264] This is a superior standard to the dismal recycling collection rate of e-waste in

[256] *Id.*

[257] *See* Elecs. TakeBack Coal., *State Legislation*, *supra* note 100 (summarizing state e-waste laws currently enacted).

[258] PV Cycle, *Making Photovoltaics "Double Green"*, PVCYCLE.ORG, www.pvcycle.org/ (last visited Mar. 17, 2011). The PV industry established PV Cycle in July 2007. PV CYCLE, *supra* note 10.

[259] PV CYCLE, *supra* note 10. PV Cycle has 107 members consisting of all manufacturers, all importers, companies reselling under their names, and companies that trademark PV panels manufactured by other suppliers. *Id.* Associate members, totaling sixteen, consist of all associations, all research institutes, all wholesalers, all system integrators, all electrical installation contractors, and all cell manufacturers. *Id.*

[260] *See* PV CYCLE, *supra* note 10.

[261] PV Cycle, *A Voluntary End-of-Life Take-Back and Recycling Programme*, PVCYCLE.ORG, www.pvcycle.org/index.php?id=5 (last visited Mar. 17, 2011).

[262] PV CYCLE, *supra* note 10.

[263] *Id.* (from dismantling and recycling of the Chevetogne PV generator).

[264] *Id.*

the United States, which was only at 18% in 2007.[265]

The voluntary efforts of PV Cycle have been so successful that PV products are excluded from regulation under the Restriction on Hazardous Substances Directive (RoHS)[266] and the Waste Electrical and Electronic Equipment Directive (WEEE).[267] RoHS bans from land disposal certain hazardous substances commonly found in e-waste, including lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ethers.[268] WEEE requires producers of electronics to finance the collection, treatment, recovery, and disposal of e-waste.[269] The legislation targets 70% to 80% collection, and 50% to 75% recycling, of e-waste.[270] In comparison, PV Cycle has set a minimum recycling target of 85% by December 2015,[271] which meets the WEEE goals. Because PV Cycle is proactively addressing the threat of PV waste, the government in turn has provided some leniency from regulation.[272]

C. WHY MANDATORY EPR REGULATIONS MAY BE NECESSARY FOR THE UNITED STATES

Whether manufacturers in the United States will follow the EU's

[265] *See* U.S. Envtl. Prot. Agency, *supra* note 104 (statistic based on an estimate of 2.25 million tons of televisions, cell phones, and computer products ready for end-of-life management, of which only 18% (414,000 tons) was collected for recycling and 82% (1.84 million tons) was disposed of, primarily in landfills).

[266] European Parliament and Council Directive 2002/95/EC, 2003 O.J. (L 37) 19 (on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment). PV products are exempt from RoHS for four years. Press Release, European Parliament, MEPs Flag Potentially Hazardous Substances in Electrical and Electronic Equipment (June 2, 2010), *available at* www.europarl.europa.eu/en/pressroom/content/20100531IPR75278/html/Potentially-hazardous-substances-in-electrical-and-electronic-equipment. To win this exemption, PV Cycle argued that PV products should not be regulated under RoHS because it could stunt the growth of innovative PV products and put the renewable-energy sector at a competitive disadvantage with fossil fuels which are not regulated under RoHS. EUROPEAN PHOTOVOLTAIC INDUSTRY ASS'N & PV CYCLE, RECAST OF THE ROHS DIRECTIVE – JOINT POSITION PAPER OF EPIA AND PV CYCLE 1 (Feb. 5, 2010), *available at* www.unendlich-viel-energie.de/uploads/media/EPIA-PVCyclepositionpaper_RoHSrecast_100205_final.pdf (providing comments to the European Parliament on increased PV regulation in Europe).

[267] European Parliament and Council Directive 2002/96/EC, 2003 O.J. (L 37) 24 (on Waste Electrical and Electronic Equipment).

[268] European Parliament and Council Directive, *supra* note 266.

[269] European Parliament and Council Directive, *supra* note 267.

[270] *Id.* Recycling targets depend on the product. *Id.*

[271] EUROPEAN PHOTOVOLTAIC INDUSTRY ASS'N & PV CYCLE, *supra* note 266.

[272] *See id.* The European PV industry successfully argued a four-year exemption from RoHS. *Id.*

lead is doubtful.[273] Although some PV producers in the United States have taken initial steps to enact responsible recycling schemes, the industry is far behind Europe.[274]

One advocacy group, the Silicon Valley Toxics Coalition (SVTC), is lobbying the California Legislature to enact EPR-based regulations for the PV industry.[275] As part of these efforts, the SVTC provides a "Solar Scorecard" survey of the PV industry.[276] In October 2009, the SVTC sent the survey to 227 U.S. solar companies.[277] The SVTC asked them to self-report on green factors, including whether they provide product takeback and recycling services, whether they provide green jobs, how they manage chemical use and life cycle of products, and how well they disclose product risks.[278] Of the fourteen companies responding, six have set aside funds to finance takeback and recycling programs, while seven provide free recycling to customers.[279] Companies that responded to the survey represent just 24% of the PV market share.[280]

Given the lack of movement by American manufacturers, it is unlikely that they will mobilize in time to proactively manage the future PV waste stream. In the past year, the PV industry has been vastly expanding, and solar companies have been hiring consultants to evaluate their potential for future waste.[281] The DOE is also exploring recycling techniques.[282] However, these are individual efforts. There is no trade association similar to PV Cycle in the United States that has initiated an

[273] *See generally* Fthenakis & Moskowitz, *supra* note 14 (noting that while recycling of PV products is technically feasible, economic incentives are lacking for the industry to voluntarily recycle).

[274] Davis & Mulvaney, *supra* note 13. The U.S. solar industry may be stalling from a lack of clear vision for the future. Currently, the volume of PV panels hitting the end of their useful lives is low. HAERTLE, *supra* note 98. Models in use will have long, productive lives and will not hit the waste stream for another five to ten years. *Id.* Primarily, factory scrap and broken or failed panels are being recycled now. Erica Geiss, *Solar Waste Recycling: Can the Industry Stay Green?*, SF PUBLIC PRESS (Aug. 9, 2010), sfpublicpress.org/news/2010-08/solar-waste-recycling-can-the-industry-stay-green.

[275] Davis & Mulvaney, *supra* note 13; *see also* Silicon Valley Toxics Coal., *Towards a Just and Sustainable Solar Industry*, SVTC.ORG, svtc.org/our-work/solar/ (last visited Mar. 22, 2011).

[276] Silicon Valley Toxics Coal., *Solar Scorecard 2010*, SOLARSCORECARD.COM, www.solarscorecard.com/ (last visited Mar. 17, 2011).

[277] Silicon Valley Toxics Coal., *Solar Scorecard 2010 – Research Methods*, SOLARSCORECARD.COM, www.solarscorecard.com/tab_approach.htm (last visited Mar. 17, 2011) (reporting that the 227 companies were selected from industry association directories, tradeshow materials, and web sites).

[278] Silicon Valley Toxics Coal., *supra* note 276.

[279] *Id*.

[280] *Id*.

[281] Geiss, *supra* note 274.

[282] *See* Fthenakis & Moskowitz, *supra* note 14 (prepared under contract to the DOE).

industry-wide system.[283] PV Cycle was implemented only after five years of careful collaborating, planning, testing, development, and resource allocation[284] – something that is lacking in the United States.

D. THE FINANCIAL BURDEN

The economic toll on the PV industry is a hurdle for EPR.[285] Significant time and resources are required for producers to prepare for, develop, test, and implement successful EPR programs.[286] The burden of paying for these programs, however, ultimately rests with the consumers.[287] Thus, states should consider subsidizing the industry to offset the economic hardships of EPR.[288]

In theory, while producers are initially burdened with the cost of implementing EPR programs, consumers end up paying for the programs.[289] Manufacturers incorporate their expenses into the total price of the product that consumers pay.[290] If EPR laws were implemented for the PV market, it would "level the playing field" among manufacturers and other producers.[291] All PV producers would charge an additional cost to their customers.[292] This would remove the competitive advantage that one company has over another in a voluntary system.[293] Producers would instead have an incentive to lower cost by streamlining their EPR programs.[294]

However, passing the excess EPR costs to consumers can stunt the PV industry because consumers are often unwilling to expend short-term

[283] Davis & Mulvaney, *supra* note 13.

[284] PV Cycle, *Our History*, PVCYCLE.ORG, www.pvcycle.org/index.php?id=24 (last visited Mar. 17, 2011). PV Cycle was first initiated in 2005 and has taken over five years to conduct tests and workshops, develop statutes, draft business plans, build membership, and implement programs to become a working association. *Id.*

[285] *See* Davis & Mulvaney, *supra* note 13 (estimating that $800 million will be required to recycle PV products in California).

[286] *See* PV Cycle, *supra* note 284.

[287] *See* CalRecycle, *supra* note 130.

[288] *See generally* Fthenakis & Moskowitz, *supra* note 14 (noting that economic incentives may be required for the PV industry to adopt voluntary recycling programs).

[289] *See* CalRecycle, *supra* note 130.

[290] *See id.*

[291] Woolwich, *supra* note 13.

[292] *Id.*

[293] *See id.*

[294] *See* CalRecycle, *supra* note 130 (explaining that EPR "creates a setting for markets to emerge that truly reflect the environmental impacts of a product, and to which producers and consumers respond").

resources despite long-term savings.[295] For example, after rebates, a residential solar system in California can cost $11,000.[296] To cover the cost of recycling under EPR, the consumer could also be required to pay a markup of $200 to $240 at the time of purchase.[297] This is a considerable cost considering the entire solar system might save $507 annually on average in electricity bills.[298] In comparison, disposal of the PV system in a non-hazardous landfill could be $20, about a tenth of the cost of recycling.[299] Without financial incentives, mandatory recycling fees could prevent the consumer from investing in the energy source altogether.[300]

Because EPR regulations would impose significant additional costs on consumers, states should consider subsidizing EPR programs for the PV industry. Subsidies are economic incentives provided by the government to encourage consumers to engage in environmentally positive activities.[301] For example, under California's CSI program, the state provides rebates to customers for PV energy purchases.[302] The federal tax credit for residential solar systems is 30% of the total system cost.[303] These programs have been successful in growing the solar industry. Nine large solar power plants are being developed in California in anticipation of receiving federal stimulus money.[304] According to one

[295] *See* Stephen M. Johnson, *Is Religion the Environment's Last Best Hope? Targeting Change in Individual Behavior Through Personal Norm Activation*, 24 J. ENVTL. L. & LITIG. 119, 131 (2009).

[296] U.S. DEP'T OF ENERGY, DOE/GO-102008-2555, PLANNING FOR PV: THE VALUE AND COST OF SOLAR ELECTRICITY (Jan. 2008), *available at* www1.eere.energy.gov/solar/pdfs/planning_for_pv.pdf (estimate based on a home in San Diego, California, with a two-kilowatt system).

[297] *See* Fthenakis & Moskowitz, *supra* note 14 (estimate calculated based on a two-kilowatt system and a $0.10 to $0.12 per watt cost of recycling thin-film panels from dispersed locations).

[298] U.S. DEP'T OF ENERGY, *supra* note 296 (estimate based on average annual utility savings of $507 for a home in San Diego, California, with a two-kilowatt system).

[299] *See* Fthenakis & Moskowitz, *supra* note 14 (estimate calculated based on a two-kilowatt system and a disposal fee of $0.01 per watt in a non-regulated landfill). Disposal in a hazardous waste landfill would increase to $700, based on a disposal fee of $0.35 per watt. *Id.*

[300] *See generally id.* (noting that economic incentives may be required for the PV industry to adopt voluntary recycling programs).

[301] Johnson, *supra* note 295.

[302] CAL. PUB. RES. CODE § 25782 (Westlaw 2011). The rebates vary depending on the size of the system, customer type, and performance and installation factors. Cal. Energy Comm'n & Cal. Pub. Utils. Comm'n, *California Solar Initiative Rebates*, GOSOLARCALIFORNIA.CA.GOV, www.gosolarcalifornia.ca.gov/csi/rebates.php (last visited Mar. 17, 2011).

[303] 26 U.S.C.A. § 25D (Westlaw 2011).

[304] Will Kane, *Turtles Last Hurdle for Huge Blythe Solar Project*, SFGATE, Oct. 26, 2010, articles.sfgate.com/2010-10-26/business/24221843_1_solar-power-plant-desert-tortoises-electricity-from-renewable-sources.

scholar, most homeowners would not buy solar panels without the tax incentives.[305]

The use of subsidies can be limited because the state may lack necessary funding.[306] Even with available funding, subsidies can be politically unpopular.[307] However, with mounting public concern over GHGs and pollution, the future outlook for economic incentives to promote greener energy is favorable.[308]

VII. CONCLUSION

Solar PV energy offers a solution to relieve the nation's dependence on dirty fossil fuels and achieve green energy.[309] PV panels on the White House will serve as a symbol of "America's commitment to a clean energy future."[310] Yet, the looming threat of PV waste, if not controlled, can tarnish this promising future.[311] PV technology has the potential for the same fate as e-waste.[312] State regulators were slow to react to the growing e-waste stream, which has become a global crisis.[313] This shameful result should prompt regulators into early action – a proactive, not reactive response – to avoid a similar outcome for the PV industry.

State and federal hazardous waste laws are ill-equipped to handle PV waste. California, at the forefront of the nation's PV industry, is taking valuable steps to modify its hazardous waste program to encourage recycling of hazardous PV panels.[314] State legislatures need to follow California's lead and enact producer responsibility regulations that manage the entire lifecycle of all PV products and reduce the volume of PV waste generated.[315]

State policymakers also have a choice to permit disposal of PV panels or mandate their recycling. When discarded, PV panels will amass

[305] Koch, *supra* note 2 (quoting David Kreutzer, energy and environment scholar at the Heritage Foundation).

[306] Johnson, *supra* note 295.

[307] *Id.*

[308] *See generally* Fthenakis & Moskowitz, *supra* note 14 (stating that economic incentives are currently inadequate to propel the PV industry to voluntarily recycle, but this could change in the future).

[309] *See* U.S. Energy Info. Admin., *supra* note 20.

[310] Chu, *supra* note 1.

[311] *See* SILICON VALLEY TOXICS COAL., *supra* note 6.

[312] *Id.*

[313] U.S. Envtl. Prot. Agency, *supra* note 113 (listing e-waste cleanup as one of the EPA's top six environmental priorities).

[314] *See* CAL. DEP'T OF TOXIC SUBSTANCES CONTROL, *supra* note 12.

[315] *See* Woolwich, *supra* note 13; *see also* Davis & Mulvaney, *supra* note 13.

on land and create a toxic waste problem.[316] Instead of allowing disposal, regulators should require recycling of panels. Recycling, together with producer responsibility, would stop PV panels from entering landfills, avoid releases of toxic substances into the environment, reduce waste, and foster greener design. This is a sustainable approach that advances renewable-energy goals and gives PV technology a lasting future in clean energy.

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[316] *See* SILICON VALLEY TOXICS COAL., *supra* note 6.

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