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A FRAMEWORK FOR RESPONSIBLE SOLAR PANEL WASTE MANAGEMENT IN THE UNITED STATES

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Abstract

Although solar panels are an effective alternative to greenhouse gas emitting energy sources, the panels themselves contain many hazardous substances. Therefore, at the end of a solar panel's life cycle, which is usually between twenty-five and thirty years, the panels become hazardous waste. Electronic waste, or "e-waste," is already a major problem worldwide, especially in developing countries that receive e-waste. Workers in these countries dismantle the e-waste to recover valuable materials, and they do not have proper safety equipment. Because of exposure to hazardous substances in the e-waste, these workers suffer health effects. The exponential growth of the solar panel industry has made solar panel waste a pressing issue due to the presence of substances that affect environmental quality and human health. This paper examines the European Waste Electrical Equipment Directive framework for solar panel waste, which is a program that uses extended producer responsibility to promote recycling of solar panels. A similar program should be implemented in the United States, because current laws are not sufficient in promoting the safe disposal and recycling of solar panels.

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I. Introduction

Climate change is one of the greatest challenges currently facing humanity. Not only has climate change already led to increased droughts, more powerful storms, and sea level rise, amongst other effects, but these effects will continue to escalate if the world does nothing to decrease carbon emissions.[1] In a report released in October of 2018, the Intergovernmental Panel on Climate Change ("IPCC") stated with high confidence that an average global temperature rise of 1.5 degrees Celsius above pre-industrial levels will lead to extreme temperatures, more frequent droughts and powerful storms, loss of biodiversity and ecosystems, and sea level rise that will drown cities, and in some cases, entire countries.[2] The world will reach 1.5 degrees Celsius above pre-industrial levels sometime between 2030 and 2052 if global carbon emissions continue at the current rate.[3]

Renewable energy has been especially important as the world attempts to mitigate and adapt to the effects of climate change. Currently, the most common energy sources are fossil fuels, which produce greenhouse gases when burned.[4] Anthropogenic greenhouse gas emissions contribute to climate change by trapping heat in the lower atmosphere and then re-emitting it back to the Earth.[5] Because energy is important in providing for human well-being and promoting economic development and the need for energy will increase with rising world populations and living standards, an alternative to greenhouse gas emitting forms of energy is necessary.[6]

In recent years, solar energy has become a promising avenue in green energy. The solar industry has grown rapidly within the past decade, bringing

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1. *See* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Summary for Policymakers*, *in* GLOBAL WARMING OF 1.5°C 7 (2018), https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf [hereinafter IPCC Special Report] (stating the effects on the world's climate of a 1.5 degree Celsius increase in temperatures from pre-industrial levels).

2. *Id.* at 7, 10.

3. *Id.* at 6.

4. *See* Nadarajah Kannan & Divagar Vakeesan, *Solar Energy for Future World: A Review*, 62 RENEWABLE AND SUSTAINABLE ENERGY REVS. 1092, 1093 (2016) (overviewing improvements in solar power and how solar power can be used in a changing climate).

5. *See* S.A. Montzka et al., *Non-CO2 Greenhouse Gases and Climate Change*, 476 NATURE 43, 43 (2011).

6. *See* Amir Shahsavari & Morteza Akbari, *Potential of Solar Energy in Developing Countries for Reducing Energy-Related Emissions*, 90 RENEWABLE & SUSTAINABLE ENERGY REVS. 275, 275 (2018) (stating how solar power can be used to ensure that developing countries have the energy they need without adding to the effects of climate change).

more well-paying jobs in addition to clean energy.[7] About 240,000 Americans worked in the solar industry in 2018, which is more than double the amount in 2012.[8] There has been an increase in solar panel use globally, especially in developing countries such as China.[9]

However, a little discussed element of solar panel use is what happens when the panels reach the end of their lives. Solar panels contain many hazardous chemicals that can leach into the environment.[10] Leaching can happen even if solar panels are disposed of in landfills that are compliant with United States regulations.[11] As the lifespan of most solar panels is about thirty years, solar panel disposal is beginning to become an issue for solar panels created and installed in the late 1980s and early 1990s.[12] Also, solar panel disposal will become an even larger issue when the solar panels now being installed en masse in countries such as China reach the end of their lives.[13]

This growing concern with solar panel waste is related to the global e-waste problem, which has become more prevalent as personal electronics become widely accessible.[14] The improper disposal of e-waste leads to health conditions and environmental degradation.[15] There has been a growing trend

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7. *See* James Hamilton, *Careers in Solar Power*, BUREAU OF LABOR STATISTICS, https://www.bls.gov/green/solar_power/ (last visited May 25, 2019).

8. *Solar Industry Research Data*, SOLAR ENERGY INDUSTRIES ASSOCIATION, https://www.seia.org/solar-industry-research-data (last visited May 25, 2019) (outlining the growth of the solar industry through 2018).

9. *See* Adam Vaughan, *Time to Shine: Solar Power is Fastest-Growing Source of New Energy*, THE GUARDIAN (Oct. 4, 2017), https://www.theguardian.com/environment/2017/oct/04/solar-power-renewables-international-energy-agency (outlining the growth of solar power throughout the world).

10. Michael Shellenberger, *If Solar Panels Are So Clean, Why Do They Produce So Much Toxic Waste?*, FORBES (May 23, 2018), https://www.forbes.com/sites/michaelshellenberger/2018/05/23/if-solar-panels-are-so-clean-why-do-they-produce-so-much-toxic-waste/#3e355219121c (analyzing the possible negative effects of widespread solar panel use).

11. *Id.*

12. INT'L RENEWABLE ENERGY AGENCY, END-OF-LIFE MANAGEMENT: SOLAR PHOTOVOLTAIC PANELS 19 (2016) (reporting on trends in solar panel disposal).

13. *See* Stephen Chen, *China's Ageing Solar Panels Are Going to Be a Big Environmental Problem*, S. CHINA MORNING POST (July 30, 2017), https://www.scmp.com/news/china/society/article/2104162/chinas-ageing-solar-panels-are-going-be-big-environmental-problem (discussing issues China may face as its solar panels reach the end of their lives).

14. *See* C.P. BALDE ET AL., THE GLOBAL E-WASTE MONITOR 2017: QUANTITIES, FLOWS, AND RESOURCES 4, 11 (2017) (reporting on how e-waste is handled throughout the world).

15. Phoenix Pak, *Haste Makes E-Waste: A Comparative Analysis of How the U.S. Should Approach the Growing E-Waste Threat* 16 CARDOZO J. INT'L & COMP. L. 241, 242-43 (2008)

of developed nations sending e-waste to developing countries, where poorly-paid workers are exposed to dangerous chemicals while taking apart the discarded electronics.[16] The world should acknowledge this global e-waste issue take it into consideration as solar panels become more prevalent.

In the United States, e-waste is a substantial problem without an effective solution. The average American family of four disposes of 176 pounds of e-waste each year.[17] Electronics are increasingly becoming integral to life in the United States, and by 2016, almost every American owned a cell phone.[18] Additionally, the prices of electronics have been decreasing over the years, making it more affordable for Americans to buy electronics and purchase new electronics as technology updates and improves.[19] It is difficult to know how much of America's e-waste is transported overseas to developing countries, but a 2016 study suggests that this is the fate of about a third of all e-waste generated in the United States.[20] The United States regulates the e-waste that remains in the country through the federal Resource Conservation and Recovery Act ("RCRA").[21] A variety of state regulations may apply as well.[22] However, this current framework of handling e-waste in the United States is insufficient because no federal law addresses e-waste and requires its recycling. This lack of a sufficient national standard will become problematic as the amount of decommissioned solar panels in the United States increases.

The European Union created a directive to address not just solar panel waste, but all e-waste.[23] This regulatory framework is called the European

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(analyzing the effects of the global e-waste problem and how the United States should respond).

16. *Id.* at 243–44.

17. Stephen Leahy, *Each U.S. Family Trashes 400 iPhones' Worth of E-Waste a Year*, NAT'L GEOGRAPHIC (Dec. 13, 2017), https://www.nationalgeographic.com/news/2017/12/e-waste-monitor-report-glut/ (describing the global e-waste problem and its economic implications).

18. BALDE ET AL., *supra* note 14, at 19.

19. *Id.* at 19–20.

20. Katie Campbell & Ken Christensen, *Where does America's e-waste end up? GPS tracker tells all*, PBS NEWS HOUR (May 10, 2016, 11:07 AM), https://www.pbs.org/newshour/science/america-e-waste-gps-tracker-tells-all-earthfix (reporting on the results of an investigation that tracked the location of 200 discarded electronic devices).

21. BALDE ET AL., *supra* note 14, at 11.

22. *See Map of States with Legislation*, ELECTRONICS RECYCLING COORDINATION CLEARINGHOUSE, https://www.ecycleclearinghouse.org/contentpage.aspx?pageid=10 (last visited May 25, 2019).

23. *FAQ*, SOLAR WASTE/EUROPEAN WEEE DIRECTIVE, http://www.solarwaste.eu/faq/ (last visited May 31, 2019) (providing basic information on the European WEEE Directive).

Waste Electrical and Electronic Equipment ("WEEE") Directive.[24] In 2012, The European Union created the WEEE Directive, which regulates the recycling of solar panels.[25] In the European Union, a directive is a legal order to member states that establishes a policy for all member states.[26] If a member of the European Union does not fulfill the requirements of a directive, the European Commission can commence a formal infringement procedure.[27] As part of the infringement procedure, the Commission sends the violating country a letter asking that country to comply with the directive.[28] If that country does not subsequently comply, the Commission can refer the issue to the Court of Justice, which can impose penalties on the offending country.[29]

The WEEE Directive could be a model for solar recycling regulations in the United States. The directive implements an "Extended Producers Responsibility" framework, where manufacturers must take back solar panels they have sold that have reached the end of their lifespan.[30] The collection of decommissioned solar panels is to be done at no additional cost to the consumer.[31] Although there are some concerns about the Extended Producers Responsibility framework, it could serve as a model for the responsible regulation of solar panel waste in the United States.

A program similar to the WEEE Directive in the United States would be the best way to handle solar panel waste because it would fill the gaps left by RCRA, state laws, and small recycling programs in the private sector. It would require recycling, and therefore solar panels would not end up in either conventional or hazardous landfills. Also, manufacturers would need to collect solar panels, either at local collection centers or directly from the consumer. This would make recycling easier on the consumer.

However, an extended producer responsibility model may discourage development and expansion of the solar energy industry because it places additional costs and responsibilities on the manufacturer. In order to offset

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24. *Id.*

25. *Id.*

26. *What is an EU Directive?*, EUROPEAN LAW MONITOR (Nov. 2, 2006), https://www.europeanlawmonitor.org/what-is-guide-to-key-eu-terms/eu-legislation-what-is-an-eu-directive.html.

27. *Infringement Procedure*, EUROPEAN COMMISSION, https://ec.europa.eu/info/law/law-making-process/applying-eu-law/infringement-procedure_en (last visited May 25, 2019).

28. *Id.*

29. *Id.*

30. *FAQ*, *supra* note 23.

31. *Id.*

any disincentive to the manufacturer that comes from an extended producer responsibility model, the federal government should provide tax credits to the solar industry. Alternatively, or in addition to tax credits, the federal government could invest in solar energy by building solar projects and adding solar panels to government buildings. The manufacturer may also increase the prices of their products in order to accommodate for the increased cost of an extended producer responsibility model. Therefore, in addition to tax credits and investments in the manufacturers, the federal government should continue to provide the current solar investment tax credit for both households and businesses that install solar panels.

This Article begins in Section II by addressing how solar panels work, what makes solar panels such an attractive option for combating climate change, and current trends in the solar industry. Section III examines the global e-waste problem and how solar panel waste fits into this problem currently and in the future. Section IV analyzes how e-waste and decommissioned solar panels are currently handled in the United States. In Section V, The European WEEE Directive and its effectiveness is discussed. Finally, in Section VI, it is determined that a framework similar to the European WEEE Directive should be adopted in the United States in order to properly handle solar panel waste. Current regulations in the United States that apply to solar panel waste, such as the federal Resource Conservation and Recovery Act and individual state initiatives do not provide an effective, consistent method for safely handling waste and encouraging the recycling of solar panels. Also, efforts of the private sector through the Solar Energy Industries Association to encourage recycling do not go far enough in requiring and enforcing the safe handling and recycling of solar panel waste.

II. Background on Solar Panels

The Photovoltaic ("PV") Effect, or the process by which sunlight produces energy was first discovered in 1839.[32] The PV effect occurs when certain materials absorb photons from light and release electrons.[33] These electrons can then be captured and used to produce electricity.[34] The first solar panel was not built until 1954.[35] Use of solar panels expanded in the 1960s, when

32. T.M. Razykov et al., *Solar Photovoltaic Electricity: Current Status and Future Prospects*, 85 SOLAR ENERGY 1580, 1580 (2011) (analyzing the status of the solar energy industry over time and how it is used today).

33. Gil Knier, *How do Photovoltaics Work?*, NASA SCI., https://science.nasa.gov/science-news/science-at-nasa/2002/solarcells (last visited May 25, 2019).

34. *Id.*

35. *Id.*

scientists began to use solar panels on space craft, and became even more prevalent during the 1970s.[36] The increased use of solar panels in the 1970s was due to the energy crisis of that decade, and the study of the use of solar panels for other purposes besides space exploration.[37]

In the 1980s, solar panel production and use dropped off in the United States due to dropping oil prices and the pro-fossil fuel policies of the Reagan Administration.[38] Solar panel use and production began to recover through the 2000s, partially after the 2005 passage of the Energy Policy Act.[39] The Energy Policy Act established a 30% investment tax credit for residential purchases of solar panels.[40] The Energy Policy Act also increased the credit for business purchases of solar panels from 10% to 30%.[41] In 2018, solar power made up 1.4% of total United States energy generation.[42] The solar industry is growing in both developed countries, such as the United States and members of the European Union, and in developing countries, such as China and India.[43] In the United States, the cost of solar energy decreased 82% between 2009 and 2015, and the cost of a solar module has decreased 99% from 1976.[44] Worldwide, solar energy has been the fastest growing form of renewable energy, with China being the leader in the expansion of solar power, followed by the United States.[45]

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36. *Id.*

37. *Id.*

38. DAVID HART & KURT BIRSON, DEPLOYMENT OF SOLAR PHOTOVOLTAIC GENERATION CAPACITY IN THE UNITED STATES 13 (2016) (reporting on the history of solar panel use in the United States).

39. *Id.* at 20.

40. *Id.*

41. *Id.*

42. *Frequently Asked Questions*, U.S. ENERGY INFO. ADMIN. (Oct. 25, 2019), https://www.eia.gov/tools/faqs/faq.php?id=427&t=3 (providing data on United States electricity generation by energy source).

43. *See* Daniela Sica et al., *Mgmt. of End-of-Life Photovoltaic Panels as a Step Toward a Circular Economy*, 82 RENEWABLE AND SUSTAINABLE ENERGY REVS. 2934, 2934 (2018) (analyzing the adoption of a circular economy in the solar panel industry).

44. P'SHIP FOR THE PUB. GOOD, BUFFALO NIAGARA AT THE CROSSROADS: HOW STATE ENERGY POLICIES CAN LEAD WESTERN NEW YORK TO A GREEN, PROSPEROUS, AND JUST FUTURE 1 (Mar. 16, 2016) (advocating for increased use of renewable energy in the Buffalo-Niagara region).

45. Vaughan, *supra* note 9.

Solar panels are made up of three parts, a solar cell, a photovoltaic module, and the semiconductor material.[46] Solar panels use semiconductor material in order to convert sunlight into electricity.[47] Silicon is often used as the semiconductor material.[48] The solar cell is made up of semiconductor material, and multiple solar cells are soldered together to make a photovoltaic module.[49] Solar panels can be set up in large solar farms, which are made up of hundreds of solar panels and can provide electricity to many consumers.[50] Solar panels can produce clean energy on a utility-scale basis, which means that the solar panel produces enough energy to have a power purchase agreement with a utility, and to be able to send out that on an electric transmission grid.[51] In addition to being used on a large scale, solar panels can also be installed by individual homeowners or businesses.[52]

Solar panel technology has had three generations.[53] The first generation panels are the most common, making up 90% of the market, and are crystalline silicon-based.[54] This generation is the oldest solar technology, and is highly efficient.[55] These panels are likely to continue to make up the majority of the market through 2030.[56] Second generation panels, also referred to as "thin-film technologies" make up about 9% of the market, and are largely phased out because of their low efficiency.[57] Second generation panels have lower efficiency, and lower production costs.[58] Finally, third generation panels are still in the pre-industrial stage, and consist of dye-

46. *Solar Panels Info. and FAQs*, CAL. DEPARTMENT OF TOXIC SUBSTANCES CONTROL, https://dtsc.ca.gov/solarpanels/ (last visited May 31, 2019) (providing background information on how solar panels work and how they are regulated in California).

47. Yan Xu et al., *Global Status of Recycling Waste Solar Panels: A Review*, 75 WASTE MGMT. 450, 451 (2018) (providing information on and support for solar panel recycling).

48. Kannan, *supra* note 4, at 1094.

49. *Id.*

50. Genevieve Coyle, *The Not-So-Green Renewable Energy: Preventing Waste Disposal of Solar Photovoltaic Panels*, 4 GOLDEN GATE U. ENVTL. L. J. 329, 335 (2011) (analyzing the best methods for handling solar panel waste).

51. Amy Morris et al., *Green Siting for Green Energy*, 5 GEO. WASH. J. ENERGY & ENVTL. L. 17, 18 (2013) (outlining best practices for siting solar panels).

52. *Id.*

53. Sica et al., *supra* note 43, at 2936.

54. *Id.*

55. MOHAMMAD TAWHEED KIBRIA ET AL., *A REVIEW: COMPARATIVE STUDIES ON DIFFERENT GENERATION SOLAR CELLS TECHNOLOGY* 51 (2014) (reviewing the different generations of solar panels).

56. Sica et al., *supra* note 43, at 2936-37.

57. *Id.*

58. KIBRIA ET AL., *supra* note 55, at 51.

sensitized technology and organic PV cells.[59] The organic PV cells are made of biodegradable materials.[60] Third generation panels are the most efficient.[61] Although the market share of third generation panels will grow, they will likely remain a small part of the market,[62] due to the higher cost of component materials.[63]

A. Trajectory of Solar Panel Use

In the United States, solar panel capacity will double within the next five years.[64] As of May 2019, there are two million solar panel installations in the United States, up from one million installations just three years prior.[65] California is the leading state in solar power, with nearly 17% of its electricity coming from solar energy.[66] Other states with high solar use include North Carolina, Arizona, Nevada, and Texas.[67] Nationally, the solar energy market is expected to increase in 2019-2020 with an increase in both residential and utility use.[68]

One program that will increase solar panel capacity in the United States is California's initiative that will require all new homes to use solar panels.[69] This initiative will go into effect in 2020, and will require builders to either build individual homes with solar panels or to build a shared-power system to be used by a group of homes.[70] Other states, including New Jersey and Massachusetts, and Washington D.C. have considered similar legislation.[71]

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59. Sica et al., *supra* note 43, at 2934.

60. KIBRIA ET AL., *supra* note 55, at 51.

61. *Id.*

62. Sica et al., *supra* note 43, at 2936.

63. KIBRIA ET AL., *supra* note 55, at 53.

64. SOLAR ENERGY INDUS. ASS'N, SOLAR MARKET INSIGHT REPORT 2018 Q4 5 (2018) (analyzing trends in the solar industry).

65. Anmar Frangoul, *Solar Installations in US Now Exceed 2 Million and Could Double by 2023, New Figures Show*, CNBC (May 9, 2019, 7:44 AM), https://www.cnbc.com/2019/05/09/solar-installations-in-us-exceed-2-million-and-could-double-by-2023.html (reporting an increase in solar panel usage in the United States).

66. Anmar Frangoul, *From California to Texas, These are the US States Leading the Way in Solar*, CNBC (Sep. 19, 2018, 4:45 AM), https://www.cnbc.com/2018/09/19/the-us-states-leading-the-way-in-solar.html (listing States with the greatest solar capacity).

67. *Id.*

68. *See* SOLAR ENERGY INDUS. ASS'N, *supra* note 63 at 15.

69. *See* Ivan Penn, *California Will Require Solar Power for New Homes*, N.Y. TIMES (May 9, 2018), https://www.nytimes.com/2018/05/09/business/energy-environment/california-solar-power.html.

70. *Id.*

71. *Id.*

This initiative in California will increase solar panel use in the United States, and if other states follow California's lead, solar capacity will increase even more.

China's total installed solar capacity is twice that of the United States.[72] In 2017, the country opened the largest floating solar farm in the world.[73] Additionally, China is the largest producer of solar panels, giving the country an economic incentive to increase its use of solar energy.[74] Although the Chinese government has cut subsidies for solar energy, the price of solar will continue to decrease because it will likely be inexpensive enough to build solar panels in China without subsidy in three to five years.[75] China is not the only country experiencing a steep growth in the construction of large solar farms.[76] Countries such as India, Egypt, the United Arab Emirates, Pakistan, and Mexico are also building large solar farms.[77] The majority of these large solar farms are in India.[78]

With this growth in the solar industry, solar panel waste will likely become a major issue worldwide in about thirty years.[79] The world must address and plan for this issue now. We need an appropriate framework for disposing of the waste we have today, and it is easier and more beneficial to create a solution before the issue becomes a crisis.[80] Also, the preventative principle of environmental law supports the proactive implementation of a framework to handle solar panel waste.[81] The preventative principle states that states have the "obligation to regulate, supervise, conduct environmental impact

72. Chen, *supra* note 13.

73. Sarah Zheng, *China Flips the Switch on World's Biggest Floating Solar Farm*, S. CHINA MORNING POST (June 2, 2017, 4:52 PM), https://www.scmp.com/news/china/society/article/2096667/china-flips-switch-worlds-biggest-floating-solar-farm.

74. *See* Chris Baraniuk, *How China's Giant Solar Farms Are Transforming World Energy*, BBC (Sept. 4, 2018), https://www.bbc.com/future/article/20180822-why-china-is-transforming-the-worlds-solar-energy (discussing China's large role in the production and use of solar energy).

75. *Id.*

76. *Id.*

77. *See* Sushma U N, *India is Beating China in the Race to Build Massive Solar Power Projects*, QUARTZ INDIA (May 22, 2018), https://qz.com/india/1283299/in-the-race-to-build-massive-solar-power-projects-india-is-poised-to-beat-china/ (providing a list of the world's ten largest solar parks).

78. *Id.*

79. Baraniuk, *supra* note 74.

80. *Id.*

81. *See* Angeliki Papantoniou, *Advisory Opinion on the Environment and Human Rights*, 112 AM. J. INT'L L. 460, 464 (2018) (reviewing an advisory opinion by the American Court of Human Rights on the right to a healthy environment).

assessments, establish contingency plans, and mitigate environmental damage."[82] The creation of such a framework would fulfill the obligations states have in respect to the prevention principle.

It is important that panels that have reached the end of their lifecycle are disposed of properly. Proper disposal is necessary due to concerns about the effects solar panel waste may have on the environment and human health. The ideal method for the disposal of solar panels is recycling. Two methods of recycling solar panels are available on an industrial scale: one by Deutsche Solar and another by First Solar.[83] The Deutsche Solar method involves using heat to separate the plastic parts of the panel manually to retrieve solar cells, glass, and metals or alloys.[84] The solar cells are then processed to make new solar wafers, and the other retrieved materials are sent to recycling and recovery operations.[85] The First Solar method has a two-stage crushing process which includes the breaking of panels to facilitate transportation and then the crushing of the glass.[86] Then, the semiconductor films from the panels are subject to a leaching procedure which is used to produce new thin-film panels.[87] The Deutsche Solar method has a recovery rate greater than 80%, and the First Solar method has an even greater recovery rates, 90% for glass and 95% for semiconductor material.[88] Additionally, more recycling methods are being developed.[89] These new methods seek to increase recycling and recovery rates and to improve the quality of reclaimed materials.[90]

B. Solar Panel Benefits and Drawbacks

Solar energy is the most abundant source of energy on Earth and it is non-exhaustible.[91] Solar energy is most efficient in areas of the world with intense solar radiation,[92] including the Middle East, the United States, Latin

82. *Id.*
83. Sica et al., *supra* note 43, at 2939.
84. *Id.*
85. *Id.*
86. *Id.*
87. *Id.*
88. *Id.*
89. *Id.*
90. KEIICHI KOMOTO & JIN-SEOK LEE, INT'L ENERGY AGENCY, END-OF-LIFE MANAGEMENT OF PHOTOVOLTAIC PANELS: TRENDS IN PV MODULE RECYCLING TECHNOLOGIES 46 (2018) (reporting on the current state of solar panel recycling).
91. Kannan, *supra* note 4, at 1093.
92. *Id.*

America, Africa, Australia, and many parts of Asia.[93] However, solar energy can still be harnessed in areas of the world that experience less solar radiation, such as Alaska, Canada, Russia, Northern Europe, Southeast China through tilting the panels towards the sun.[94]

Perhaps the greatest benefit of solar panels compared to conventional energy sources is that they are considered a "zero emissions" source of energy, in that they do not emit noise, toxic air pollutants, or greenhouse gases while producing energy.[95] Additionally, solar panels do not use water for dry-cooling systems, and only small amounts of water are needed to clean off the panels, which makes them sustainable in areas with water scarcity.[96]

Other benefits of solar panels include decreased energy costs and energy independence for homeowners who install panels on their homes.[97] Those who install and use solar panels no longer need to pay for electricity from a traditional grid, or they may just have to buy less electricity from a traditional grid.[98] Also, the expansion of solar panel use includes the reduction in electricity transmission lines, improvement in water resources due to the lack of pollutant emissions from the panels, increase in regional and national energy dependence, diversification and security of energy supply, and an avenue toward bringing electricity to rural communities in both developed and developing countries.[99]

However, high initial investment costs may be a barrier to some homeowners who would be interested in installing solar panels, but cannot afford the initial costs.[100] Some homeowners also are uncertain about solar panels, which may prevent them from investing in the technology.[101] This uncertainty can stem from solar power's status as an emerging technology

93. Shahsavari, *supra* note 6, at 279.

94. *Id.*

95. Coyle, *supra* note 50, at 331.

96. Shahsavari, *supra* note 6, at 282.

97. Jenny Palm, *Household Installation of Solar Panels – Motives and Barriers in a 10-Year Perspective*, 113 ENERGY POL'Y 1, 8 (2018) (analyzing the perceived benefits and drawbacks of homeowners using solar power in Sweden).

98. *Id*. at 5.

99. K.H. Solangi et al., *A Review on Global Solar Energy Policy*, 15 RENEWABLE & SUSTAINABLE ENERGY REVS. 2149, 2151 (2011).

100. Palm, *supra* note 97, at 6.

101. Monzur Alam Imteaz & Amimul Ahsan, *Solar Panels: Real Efficiencies, Potential Productions and Payback Periods for Major Australian Cities*, 25 SUSTAINABLE ENERGY TECHS. & ASSESSMENTS 119, 124 (2018) (analyzing the benefits of four Australian homes switching to using solar energy).

and inconsistent government solar energy policy.[102] Additionally, many potential customers have concerns about the intermittent nature of solar panels.[103] Not only do solar panels not produce any energy during the night, but the amount of energy may fluctuate during the day due to changing cloud cover.[104] This intermittency can be overcome by attaching many solar panels over a large geographic area to a single grid.[105] Additionally, solar energy storage technology is improving and becoming increasingly common.[106]

A potential drawback of solar panel use are the land use implications of having large solar farms. These solar farms can take up large amounts of land, which may not be possible in densely-populated areas.[107] Large solar farms raise other land use issues, such as having to significantly alter the surrounding ecosystems during the construction phase through grading and scraping, and also possible negative impacts on wildlife.[108] These impacts may include the displacement of species protected by federal conservation laws.[109] Large solar farms have been detrimental to certain bird species because of the "lake effect," where these birds mistake the reflective surfaces of the panels to be large bodies of water.[110] Through distributed generation or the widespread placement of smaller numbers of panels on existing structures can mitigate these drawbacks.[111] Existing structures can include rooftops, parking lots, and even on contaminated sites, such as former landfills, abandoned mine lands, and brownfields.[112] Distributed generation

102. L.H. Shih & T. Y. Chou, *Customer Concerns About Uncertainty and Willingness to Pay in Leasing Solar Power Systems*, 8 INT'L J. OF ENV'T SCI. & TECH. 523, 524 (2011), http://www.bioline.org.br/pdf?st11048.

103. *See* Morris et al., *supra* note 51, at 22.

104. Robert Fares, *Renewable Energy Intermittency Explained: Challenges, Solutions, and Opportunities*, SCI. AM.: PLUGGED IN (Mar. 11, 2015), https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/# (outlining the issues of solar energy intermittency and methods to improve on this challenge).

105. *Id.*

106. *See Solar + Storage*, SOLAR ENERGY INDUSTRIES ASS'N, https://www.seia.org/initiatives/solar-plus-storage (last visited May 12, 2019); *Powerwall*, TESLA, https://www.tesla.com/powerwall (last visited May 12, 2019) (providing information on Tesla's home solar energy storage device).

107. Shahsavari, *supra* note 6, at 282.

108. Morris et al., *supra* note 51, at 20.

109. *Id.*

110. John Upton, *Solar Farms Threaten Birds*, SCI. AM. (Aug. 27, 2014), https://www.scientificamerican.com/article/solar-farms-threaten-birds/.

111. Morris et al., *supra* note 51, at 21.

112. *Id.* at 17–25.

and siting on existing structures can protect wildlife, ecosystems, and bring solar energy to densely populated areas.

Another disadvantage of solar panels is that, if improperly disposed, in traditional landfills for example, they can cause environmental harm.[113] Some of these harms include the leaching of lead into the environment, the leaching of cadmium, the loss of recoverable resources (such as aluminum, silicon, and glass), and the loss of the recoverable rare metals (such as silver, indium, gallium, and germanium).[114] Solar panels also contain other toxic chemicals, but lead and cadmium produce the largest environmental harm of these chemicals.[115] Whereas, when solar panels are *properly* disposed, hazardous materials in the panels can be extracted and purified for reuse in the solar industry.[116]

III. The Global Electronic Waste ("E-Waste") Problem

Electronic waste, or "e-waste," is broadly defined as the byproducts of electronic and electrical devices and because much of it contains toxins and heavy metals, it poses a great harm to human health and the environment.[117] Waste from solar panels is considered e-waste. In 2016, the world produced 44.7 million metric tons of e-waste, or around 6.1 kilograms (about thirteen pounds) per inhabitant. This number is expected to rise to 52.2 million metric tons by 2021.[118] States properly recycled only about 20% of the e-waste collected in 2016 and threw 4% into residual waste.[119] It is unclear what happened to the remaining 76% of e-waste, but it was likely improperly dumped, traded, or recycled.[120] The majority of e-waste created in 2016 belonged to the small equipment category, and the second greatest category was large equipment, the category in which solar panels fall under.[121] Examples of products that are considered small equipment include vacuum

113. Shellenberger, *supra* note 10.

114. Xu et al., *supra* note 47, at 453.

115. *Id.*

116. INT'L ENERGY AGENCY, *supra* note 90, at 8.

117. Lucy McAllister et al., *Women, E-Waste, and Technological Solutions to Climate Change*, 16 HEALTH & HUM. RTS. 166, 170 (2014), https://cdn2.sph.harvard.edu/wp-content/uploads/sites/13/2014/06/McAllister1.pdf (discussing the disproportionate effects of e-waste on women and children in developing countries).

118. BALDE ET AL., *supra* note 14, at 38.

119. *Id.* at 39.

120. *Id.*

121. *Id.* at 11, 40.

cleaners and microwaves, and examples of large equipment include clothes washers, clothes dryers, and electric stoves.[122]

E-waste is a worldwide problem. Asia, which contains some of the countries with the fastest growing solar capacity, created the largest amount of e-waste in 2016.[123] The forty-nine countries in the region only collected 15% for proper recycling.[124] Europe was the second largest producer of e-waste in 2016, and those countries collected 35% of that waste for proper recycling, the highest recycling rate in the world.[125] The European countries with the best collection rates are Switzerland, Norway, Sweden, Finland, and Ireland.[126] Switzerland and Norway collect an impressive 74% of e-waste generated.[127] However, the Balkan region, including European Union members Bulgaria and Slovenia, struggles to collect its e-waste for proper recycling.[128] The Americas were the third largest producer of e-waste, with most of the waste coming from North America, and 17% was collected for proper recycling.[129]

The tech industry currently follows a "planned obsolescence" model, which means that companies are constantly turning out new products that quickly make older products outdated.[130] Besides creating new products, companies also develop new software updates that are incompatible with the existing hardware on older devices.[131] Even Apple, which has stated its dedication to environmental responsibility, admitted that it slows down the functioning speeds of older iPhones.[132] An Italian investigation also found that Samsung slows down the functioning speeds of its smartphone models.[133] Therefore, it is a business model that purposefully generates e-

122. *Id.* at 11.
123. *Id.* at 6.
124. BALDE ET AL., *supra* note 14, at 41.
125. *Id.*
126. *Id.* at 72.
127. *Id.*
128. *Id.* at 74.
129. *Id.* at 41.
130. *See* Brook Larmer, *E-Waste Offers and Economic Opportunity as Well as Toxicity*, N.Y. TIMES MAG. (July 5, 2018), https://www.nytimes.com/2018/07/05/magazine/e-waste-offers-an-economic-opportunity-as-well-as-toxicity.html (outlining the global e-waste issue and the possible economic benefits of reclaiming materials from e-waste).
131. *See* Rosie Spinks, *We're All Losers to a Gadget Industry Built on Planned Obsolescence*, GUARDIAN, Mar. 23, 2015 (discussing planned obsolescence and its role in the electronic market).
132. Samuel Gibbs, *Apple and Samsung Fined for Deliberately Slowing Down Phones*, GUARDIAN, Oct. 24, 2018.
133. *Id.*

waste. This business model would need to be revised to make a significant decrease in the accumulation of e-waste.

Unregulated and improper recycling of e-waste is damaging to both human health and the environment. A large portion of e-waste is recycled and reclaimed in the informal sector.[134] As a result of the lack of formal regulations, oftentimes those who work in the informal sector are subject to hazardous conditions that damage both their health and the environment.[135] Due to the unregulated and largely primitive methods used to recycle e-waste, heavy metals and other toxins have become pressing environmental and health issues in the developing countries where most recycling occurs.[136]

One of the most common of these unsafe recycling methods is the open burning of e-waste to extract metals.[137] The open burning of e-waste can cause air, soil, and water pollution.[138] In the informal e-waste recycling industry in China, e-waste processing sites are often located near agricultural fields, and as a result, heavy metals can pollute soil and crops and harm workers.[139] In the informal e-waste industry, most disassembling is done by hand without proper protective equipment, exposing workers to high levels of hazardous substances.[140] Exposure to the toxins in e-waste can lead to a multitude of health issues, including cancer, kidney and liver dysfunction, and hormonal imbalances.[141] Cadmium, a toxin found in many forms of e-waste, including solar panels, is a known carcinogen.[142]

The health effects from exposure to toxins in e-waste disproportionately affects women, in that more than half of the fourteen types of hazardous chemicals found in e-waste damage women's general reproductive and endocrine functions.[143] Another population greatly affected by e-waste toxins is children, who can suffer developmental difficulties from e-waste

134. BALDE ET AL., *supra* note 14, at 15, 32.

135. *Id.* at 15.

136. *See* Qingbin Song & Jinhui Li, *Environmental Effects of Heavy Metals Derived from the E-Waste Recycling Activities in China: A Systematic Review*, 34 WASTE MGMT. 2587, 2588 (2014).

137. BALDE ET AL., *supra* note 14, at 32.

138. McAllister et al., *supra* note 117, at 171.

139. Song, *supra* note 136, at 2588.

140. *Report of the Special Rapporteur on the Adverse Effects of the Movement and Dumping of Toxic and Dangerous Products and Wastes on the Enjoyment of Human Rights,* Okechukwu Ibeanu, ¶¶ 29–32, U.N. Doc. A/HRC/15/22 (July 5, 2010) (reporting on the status of human rights in the Indian e-waste reclamation industry).

141. *Id.*

142. McAllister et al., *supra* note 117, at 170.

143. *Id.* at 172.

exposure.[144] In certain countries, such as India, women are more likely to be exposed to the toxins in e-waste due as they are often forced to take the lowest-tier jobs, including e-waste collection.[145] Also, collecting e-waste is often an attractive job option to women due to its stability and flexible hours, which allow for women to care for their children.[146]

The greatest e-waste dumpsite, Agbogbloshie, is located outside of Accra, Ghana and is nicknamed "Sodom and Gomorrah" by locals.[147] There, children as young as seven mine e-waste for valuable components without any safety equipment.[148] They are continually exposed to hazardous chemicals, mostly through the burning of the e-waste.[149] Cadmium is especially present at the site.[150] Exposure to these substances cause health effects such as burns, lung problems, eye damage, chronic nausea, anorexia, headaches, and respiratory problems.[151] Dumping at the site is expected to double in 2020.[152]

Agbogbloshie is not the only e-waste dumpsite. Other similar sites are located in China, in towns such as Guiyu, Qingyuan, and Taizhou.[153] Additionally, large amounts of e-waste goes to large dumps in Hong Kong.[154] Since China banned the direct import of foreign e-waste in 2018, most of the e-waste that ends up in China travels through Hong Kong or remains in the toxic dumps of the city.[155] E-waste dumps are also found in India, which take in not only e-waste produced by Indians, but also e-waste from foreign

144. *Id.*

145. *Id.*

146. *Id.* at 173.

147. Kevin McElvaney, *Ghana's E-Waste Magnet*, AL JAZEERA (Feb. 12, 2014), https://www.aljazeera.com/indepth/inpictures/2014/01/pictures-ghana-e-waste-mecca-201413010474097522 3.html (reporting on the world's largest e-waste dump located in Ghana).

148. *Id.*

149. *Id.*

150. *Id.*

151. *Id.*

152. *Id.*

153. *See* David Lee et al., *Monitour: Tracking Global Routes of Electronic Waste*, 72 WASTE MGMT. 362, 362 (2018) (reporting the results of a study that tracked e-waste to its final destination using GPS units).

154. Natalie W. M. Wong, *Electronic Waste Governance under "One Country, Two Systems": Hong Kong and Mainland China*, 15 INT'L J. ENVTL. RES. & PUB. HEALTH 2347, 2348 (2018) (analyzing the relationship between Hong Kong and China in respect to e-waste disposal).

155. *Id.* at 2349.

countries.[156] Many of these toxic sites are found in Seelampur, a neighborhood of Delhi, where dangerous chemicals are dumped into the Yamuna River and children dismantle discarded electronics.[157]

In 1989 many countries throughout the world adopted the Basel Convention, which placed restrictions on the movement of e-waste and disposal of toxic wastes, including solar panel waste.[158] The convention addresses equity, health, and environmental issues that stem from the transfer of hazardous waste from developed countries to developing countries for disposal.[159] Although many parties desired a complete ban on the export of hazardous waste, the convention ended up taking the form of a "strictly controlled trading regime."[160] Countries that are a part of the agreement need to create and follow mechanisms for disposing of hazardous waste in an environmentally safe manner close to the origin of the waste.[161] It is important to dispose of waste close to its origin because transporting the waste long distances uses fossil fuels, which in turn contribute to climate change. Additionally, these State Parties are required to develop legislation to prevent and punish any illegal trading of hazardous waste.[162]

The convention calls for state parties to conform to a prior informed consent ("PIC") framework.[163] Under this PIC framework, state parties cannot export hazardous waste to another country unless that country has given written consent to the hazardous waste being taken into its borders.[164] Article VIII of the convention classifies e-waste as hazardous waste, and therefore it is subject to all of the requirements of the convention, including the PIC framework.[165] If a state party violates any part of the convention, the country that has improperly exported the waste is required to take back the

156. Amita Bhaduri, *What Happens to Your E-waste?*, INDIA WATER PORTAL, Aug. 5, 2017 (reporting on the informal e-waste reclamation economy in India).

157. *Id.*

158. McAllister et al., *supra* note 117, at 168.

159. *Id.*

160. Sabaa Ahmad Khan, *E-products, E-waste and the Basel Convention: Regulatory Challenges and Impossibilities of International Environmental Law* 25 REV. EUR. COMMUNITY & INT'L ENVTL. L. 248, 252 (2016) (outlining the Basel Convention and the effects it has had on the global e-waste problem).

161. *Id.*

162. *Id.*

163. *Id.* at 253.

164. *Id.*

165. *Id.*

waste.[166] If an importer of hazardous waste is found to be the perpetrator of the illegal act, that importer is responsible for the proper disposal of the waste.[167]

Despite the Basel Convention, around 60 to 90% of the world's e-waste was illegally traded or dumped in 2015.[168] This is due to shortcomings of the Basel Convention that allow for the improper transfer of hazardous waste.[169] Under Annex IX of the convention, used electronics intended for reuse are not considered hazardous waste.[170] The definition in Annex IX not only allows functioning used electronics to be imported for reuse, but also nonfunctioning electronics, which would otherwise be considered e-waste.[171] This was originally intended to increase developing countries' access to used electronics, but due to inadequate safeguards, shipments labeled for reuse sent to developing countries can actually contain hazardous waste that escapes the Basel Convention regulations.[172]

Additionally, the convention has no formal enforcement mechanism.[173] Instead, the convention mostly focuses on preventing the illegal trade of hazardous waste through providing guidance and training on what is hazardous waste and the proper way to dispose of hazardous waste.[174] If a state party is found to have broken the terms of the treaty, that state party would not face any severe legal consequences.[175] At the eleventh Conference of the Parties to the Convention, the state parties established the Environmental Network for Optimizing Regulatory Compliance on Illegal Traffic ("ENFORCE").[176] ENFORCE seeks to promote state party compliance with the Basel Convention through methods such as sharing and

166. Tseming Yang & C. Scott Fulton, *The Case for U.S. Ratification of the Basel Convention on Hazardous Wastes* 25 N.Y.U. ENVTL. L. J. 52, 63 (2017).

167. *Id.*

168. *Illegally Traded and Dumped E-Waste Worth up to $19 Billion Annually Poses Risks to Health, Deprives Countries of Resources, Says UNEP Report*, UN ENV'T (May 12, 2015), https://www.unenvironment.org/news-and-stories/press-release/illegally-traded-and-dumped-e-waste-worth-19-billion-annually-poses.

169. Khan, *supra* note 160, at 251.

170. *Id.* at 253.

171. *Id.*

172. BALDE ET AL., *supra* note 14, at 64.

173. Yang, *supra* note 166, at 83.

174. *Id.*

175. *Id.*

176. ENVIRONMENTAL NETWORK FOR OPTIMIZING REGULATORY COMPLIANCE ON ILLEGAL TRAFFIC (ENFORCE), TERMS OF REFERENCE FOR COOPERATIVE ARRANGEMENTS ON PREVENTING AND COMBATING ILLEGAL TRAFFIC 1 (2016) (outlining the goals and duties of ENFORCE).

developing training tools, hosting and organizing workshops, and periodic monitoring on the effectiveness of the developed training tools.[177] However, ENFORCE does not have any legally binding enforcement mechanisms.[178] Another weakness of the convention is that the United States has signed the Basel Convention, but has not ratified the agreement.[179] This is especially problematic due to the fact that the United States is the greatest producer of e-waste in North America, and also one of the greatest producers of e-waste worldwide.[180] All other major producers of e-waste, including all of Europe and China, are parties to the Basel Convention.[181]

Despite its flaws, the Basel Convention has seen some successes. One of the biggest successes includes the development of technical guidelines for certain types of waste that are covered under the convention.[182] Experts developed these guidelines and the guidelines are available not only to states, but also to other stakeholders.[183] The guidelines provide a widely accessible way for states and other stakeholders to ensure they are in compliance with the convention and are handling their waste in the most environmentally responsible way.[184] These guidelines provide information about what certain hazardous substances are used for, what types of waste contain these substances, and where these substances are produced.[185] Also, the guidelines state how these substances must be properly handled and disposed of according to the Convention.[186] Recently, at the 2019 Conference of the Parties to the Basel Convention, the state parties adopted technical guidelines that specifically address e-waste.[187] Also at the 2019 Conference of the

177. *Id.*

178. *Id.*

179. *See Parties to the Basel Convention and the Control of the Transboundary Movements of Hazardous Wastes and Their Disposal*, BASEL CONVENTION (2011), http://www.basel.int/Countries/StatusofRatifications/PartiesSignatories/tabid/4499/Default.aspx (listing the State Parties to the Basel Convention).

180. Balde et al., *supra* note 14, at 64; Kahn, *supra* note 161, at 251.

181. BASEL CONVENTION, *supra* note 179.

182. *See Milestones*, SECRETARIAT OF THE BASEL CONVENTION, http://www.basel.int/TheConvention/Overview/Milestones/tabid/2270/Default.aspx (last visited June 1, 2019) (outlining the accomplishments of the Basel Convention).

183. *Id.*

184. *Id.*

185. *See, e.g.,* UNEP, TECHNICAL GUIDELINES ON THE ENVIRONMENTALLY SOUND MANAGEMENT OF WASTES CONSISTING OF, CONTAINING, OR CONTAMINATED WITH PESTICIDES 9-24 (2015).

186. *Id.* at 24–34.

187. *2019 Meetings of the Conferences of the Parties to the Basel, Rotterdam and Stockholm Conventions*, IISD REPORTING SERVS., https://enb.iisd.org/chemical/cops/2019/

Parties, the state parties added most mixes of plastics to the Basel Convention, meaning that all of the convention's requirements apply to those mixes of plastics.[188] This is an important accomplishment in the face of a growing plastic crisis worldwide.[189]

IV. E-Waste and Solar Panels in the United States

At the end of a solar panel's lifecycle, it is e-waste. Solar panels contain toxic substances such as lead, cadmium, antimony, and sulphuric acid, which can be dangerous if not disposed of properly.[190] Steps must be taken to prevent solar panels from entering the global informal e-waste recycling sector, which is already a pressing issue, in respect to both the environment and human health. As the life of a solar panel is about thirty years, the issue of solar panels as e-waste will become more common as solar panel use increases.[191]

A more environmentally responsible alternative to landfill disposal of solar panels is recycling. Solar panels contain large amounts of aluminum and glass, both of which can be easily reclaimed.[192] Additionally, recycling solar panels prevents the loss of rare metals, such as indium, gallium, and germanium.[193] Recycling solar panels has potentially huge economic value, the International Renewable Energy Agency estimates that recoverable materials from decommissioned solar panels could be worth up to $450 million, and possibly $15 billion by 2050.[194] The possible expansion of solar panel recycling also presents a huge opportunity to create new jobs.[195]

Economic infeasibility makes it difficult to increase the use of solar panel recycling.[196] Oftentimes, today, the cost of recycling a decommissioned solar panel is more than the value of the recovered materials, which decreases the

(last visited June 1, 2019) (reporting on the results of the 2019 Conferences of the Parties to the Basel, Rotterdam, and Stockholm Conventions).

188. *See* Rob Picheta & Sarah Dean, *Over 180 Countries – Not Including the US – Agree to Restrict Global Plastic Waste Trade*, CNN, May 11, 2019 (reporting on the decision to add plastic to the Basel Convention).

189. *Id.*

190. Hong Yang et al., *Tackle Pollution from Solar Panels*, 509 NATURE 563, 563 (2014) (discussing the issue of solar panel waste in China).

191. Sica et al., *supra* note 43, at 2942.

192. Xu et al., *supra* note 47, at 451.

193. *Id.*

194. INT'L RENEWABLE ENERGY AGENCY, *supra* note 12, at 12.

195. *Id.* at 87.

196. Shellenberger, *supra* note 10.

incentive to recycle.[197] However, with the current and expected continued growth of the solar panel industry, an increased need for materials will drive the economy of recycling and the improve the methods used for recycling.[198]

A. Solar Panel Waste and Federal Law

In the United States, e-waste that is not shipped abroad and is determined to be hazardous must follow regulations under the Resource Conversation and Recovery Act ("RCRA").[199] The purpose of RCRA is to ensure that waste is properly managed in order to protect both the environment and human health.[200] Hazardous waste is specifically regulated by Subtitle C of RCRA.[201] RCRA defines hazardous waste as a "solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, may. . . cause, or significantly contribute to an increase in in mortality or an increase in serious, irreversible, or incapacitating reversible illness; or . . . pose a substantial present or potential hazardous to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed."[202]

RCRA is a cradle-to-grave approach to handling hazardous waste, which means that the status of hazardous waste is tracked from when it is created to when it is disposed of.[203] RCRA requires hazardous waste producers to comply with certain management standards to ensure the safe handling of hazardous waste.[204] RCRA also regulates transporters of hazardous waste, and Treatment, Storage, and Disposal Facilities ("TSDFs").[205] Treatment refers to the alteration of composition of hazardous wastes, storage refers to the temporary holding of hazardous wastes, and disposal refers to the permanently holding of hazardous wastes.[206]

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197. *Id.*

198. Sica et al., *supra* note 43, at 2942.

199. BALDE ET AL., *supra* note 14, at 11.

200. *See* ENVTL. PROT. AGENCY, RCRA ORIENTATION MANUAL I-2 (2003) (providing information on how RCRA works and its requirements).

201. *Id.*

202. 42 U.S.C. § 6903(5) (2014) (providing the definition of hazardous waste as it applies to RCRA).

203. ENVTL. PROT. AGENCY, HOW DOES RCRA WORK? 1 (2000) (summarizing RCRA's structure and requirements).

204. ENVTL. PROT. AGENCY, *supra* note 200, at III-2.

205. *Id.*

206. *Hazardous Waste Management Facilities and Units*, ENVTL. PROT. AGENCY, https://www.epa.gov/hwpermitting/hazardous-waste-management-facilities-and-units#unit

The regulations concerning TSDFs are designed to prevent fires, explosions, or unintentional release of hazardous substances, and may include requiring the TSDF to have an alarm system, the ability to promptly contact emergency services, and the equipment needed to extinguish a fire.[207] In addition to general regulations concerning TSDFs, there are special regulations for certain types of hazardous waste management units that are designed to ensure that hazardous wastes are not deposited into the soil, groundwater, or the air.[208] Examples of hazardous waste management units that a TSDF may use include tanks, drip pads, incinerators, hazardous waste landfills, and injection wells.[209]

A foundational part of RCRA is its requirement of manifests. Manifests are used to track the waste from its creation to its disposal.[210] Each party that comes in contact with the waste, including parties that just transport the waste from one location to another, need to log their activities on a manifest.[211] After the waste has completed its journey from where it was created to where it will be permanently disposed of, a copy of the manifest is sent to the original creator of the waste, so that this creator has confirmation and proof that the waste was handled according to RCRA regulations.[212]

In order to be considered hazardous, and therefore subject to RCRA regulations, the waste must be on one of the EPA's hazardous waste lists, and must have at least one of the four characteristics of hazardous waste.[213] Alternatively, if the waste is not specifically listed, it may still be subject to RCRA regulations if it has at least one of the four characteristics of hazardous waste.[214] The four characteristics of hazardous waste are ignitibility, corrosivity, reactivity, and toxicity.[215] A waste is ignitable if it can "readily catch fire and sustain combustion."[216] It is corrosive if it is acidic or alkaline,

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(last visited June 1, 2019) (providing a summary of hazardous waste management facilities and units that are covered by RCRA regulations).

207. ENVTL. PROT. AGENCY, INTRODUCTION TO RCRA TREATMENT, STORAGE, AND DISPOSAL FACILITIES 10 (2005) (summarizing RCRA regulations concerning treatment, storage, and disposal facilities).

208. ENVTL. PROT. AGENCY, *supra* note 200, at III-2.

209. ENVTL. PROT. AGENCY, *supra* note 203.

210. ENVTL. PROT. AGENCY, *supra* note 200, at III-43.

211. *Id.*

212. *Id.*

213. ENVTL. PROT. AGENCY, *supra* note 200, at III-21.

214. *Id.*

215. *Id.* at III-22.

216. *Id.*

and it is reactive if it may "readily explode or undergo violent reactions or react to release[d] toxic gases or fumes."[217]

The main concern about solar panel waste is its toxicity.[218] In order for a waste to be considered toxic, and therefore hazardous and subject to RCRA, it must fail a test called the Toxicity Characteristics Leaching Procedure ("TCLP").[219] To perform the TCLP, a liquid leachate is created from a sample of the hazardous waste to be tested.[220] Then it is determined if the leachate contains certain toxic substances.[221] If the leachate contains an amount of a toxic substance above a regulatory level, the waste fails the TCLP and is subject to RCRA.[222] Two of the hazardous substances found in solar panels, lead and cadmium, are tested for in a TCLP test.[223] When a TCLP test has been performed on solar panels, many have been shown to leach concerning levels of toxic substances, and therefore must be disposed of according to RCRA.[224]

RCRA is an insufficient vehicle for properly dealing with solar panel waste. First, household waste is exempted from RCRA regulations, and therefore individual homeowners could legally dispose of solar panels in the regular trash.[225] Additionally, solar panel waste that is subject to RCRA is likely to end up in hazardous waste landfills.[226] Although hazardous waste landfills would protect the leakage of the hazardous substances in solar panels into the surrounding environment, disposal in landfills is not as environmentally friendly or desirable as recycling solar panel waste.[227] The fact that solar panels would likely end up in landfills instead of being recycled make it an undesirable method of handling solar panel waste.

Another issue with RCRA is that if a certain type of solar panel was able to pass the Toxicity Characteristic Leaching Procedure, despite the presence of toxic substances, then that solar panel would not be subject to RCRA regulations.[228] Some types of thin-film panels have been shown to pass the

217. *Id.* at III-23.
218. *See* INT'L RENEWABLE ENERGY AGENCY, *supra* note 12, at 70.
219. 42 U.S.C. § 6903.
220. ENVTL. PROT. AGENCY, *supra* note 200, at III-23.
221. *Id.*
222. *Id.*
223. *Id.* at III-23.
224. 42 U.S.C. § 6903.
225. Coyle, *supra* note 50, at 345.
226. *Id.*
227. *Id.* at 341.
228. *Id.* at 345

TCLP test due to low levels of toxic substances.[229] However, these toxic substances are still present, and can cause environmental harm as well as human health issues associated with other forms of e-waste.

B. State Law

Besides RCRA, no national legislation specifically concerns the disposal of e-waste.[230] However, about 84% of the country is covered by hazardous waste laws through state legislation.[231] Today, twenty-five states have legislation that specifically addressing e-waste.[232] The provisions vary. For example, California's Electronic Waste Recycling Act of 2003 limits manufacturers limits the type of hazardous substances manufacturers can use in their electronic products.[233] The act also creates an electronic waste recycling fee at the point of retail sale of certain products, and it provides recovery and recycling payments to qualified collectors and recyclers to cover the average cost of collecting and recycling e-waste.[234] The law has some weaknesses, such as charging customers for the recycling fee, which places a financial burden on the consumer, and the fact that it only applies to televisions, laptops, and computer monitors.[235] Only covering television, laptops, and computer monitors leaves a lot of electronics used in daily modern life, such as cell phones, tablets, and smart watches. Despite these limitations, the law has been largely successful in California, which recycled about 1 billion pounds of e-waste by 2011.[236]

New York's Electronic Equipment Recycling and Reuse Act[237] establishes requirements for collective electronic waste acceptance programs, collection sites, consolidation facilities, recycling facilities, retailers, and waste haulers

229. *Id.*
230. *Id.*
231. *Id.*
232. ELECTRONICS RECYCLING COORDINATION CLEARINGHOUSE, *supra* note 22.
233. CAL. PUB. RES. CODE §§ 42460–42486 (West 2004); *Electronic Waste Recycling Act of 2003*, CALRECYCLE (Oct. 22, 2018), https://www.calrecycle.ca.gov/electronics/act2003/ (last visited June 1, 2019) (outlining the structure of the California Electronic Waste Recycling Act of 2003).
234. *Id.*
235. *See* Paul Rogers, *E-waste Law Reaches a Milestone: One Billion Pounds of Computer Junk Recycled in California*, L.A. TIMES (June 11, 2011), https://www.latimes.com/business/la-xpm-2011-jun-11-la-fi-ewaste-20110611-story.html (reporting on the successes and weakness of the California Electronic Waste Recycling Act).
236. *Id.*
237. N.Y. ENVTL. CONSERV. LAW §§ 27-2601 to -2621 (McKinney 2010).

and transporters of Covered Electronic Equipment ("CEE").[238] CEE refers to the types of electronics that are subject to the requirements of the act, which include computers, computer peripheral, small electronic equipment, small-scale servers, cathode ray tubes, or televisions.[239] Solar panels are not considered CEE.[240]

The law requires manufacturers to establish and run an electronic waste acceptance program, which provides for the collection and recycling of their used products at no cost to the consumer.[241] This includes providing a convenient way to collect and recycle used electronics in every municipality in New York that has a population of 10,000 or more residents.[242] The law also requires electronic waste collection sites, consolidation facilities, and recycling facilities to store waste according to specific regulations that are designed to protect human health and the environment.[243] The law implements a disposal ban which prevents both household and non-household electronic waste from being placed in a landfill or hazardous landfill.[244] This law has been successful in that just in the period of 2013-2015, the law prevented about 300 million pounds of e-waste from being disposed of in landfills.[245]

Even though states may have regulations stricter than the national RCRA framework and cannot have regulations less strict than RCRA, many current state e-waste regulations have their own weaknesses.[246] For example, in Virginia, the current e-waste law requires qualifying manufacturers to implement a recycling program for their used products at no cost to the consumer.[247] However, this act only applies to computer manufacturers that

238. *Id.*

239. N.Y. ENVTL. CONSERV. LAW § 27-2601(5) (McKinney 2010).

240. *Id.*

241. *Covered Electronic Equipment Manufacturer Requirements*, N.Y. STATE DEP'T OF ENVTL. CONSERVATION, https://www.dec.ny.gov/chemical/66845.html (last visited June 1, 2019) (outlining the requirements concerning covered electronic equipment in New York).

242. *Id.*

243. *See Electronic Waste Collection Site Requirements*, N.Y. STATE DEP'T OF ENVTL. CONSERVATION, https://www.dec.ny.gov/chemical/66957.html (last visited May 31, 2019); *Electronic Waste Consolidation Facility Requirements*, N.Y. STATE DEP'T OF ENVTL. CONSERVATION, https://www.dec.ny.gov/chemical/66947.html (last visited May 31, 2019); *Electronic Waste Recycling Facility Requirements,* N.Y. STATE DEP'T OF ENVTL. CONSERVATION, https://www.dec.ny.gov/chemical/66942.html (last visited May 31, 2019).

244. N.Y. ENVTL. CONSERV. LAW § 27-2611 (McKinney 2010).

245. N.Y. STATE DEP'T OF ENVTL. CONSERVATION, NYS E-WASTE RECYCLING & REUSE ACT: IMPLEMENTATION & RESULTS FOR 2013, 2014 & 2015 4 (2017).

246. Coyle, *supra* note 50, at 347.

247. *Id.*

produced more than 500 units sold in the state of Virginia., leaving out many different types of electronics, such as cell phones, televisions, and solar panels.[248] In Indiana, the regulations list specific products that cannot be regularly discarded by households, schools, municipalities, and businesses.[249] The electronics covered by the Indiana regulations include televisions, computer monitors, e-readers, and DVD players, amongst other products.[250] Solar panels are not covered by the Indiana regulations.[251] In Missouri, electronics from households can be disposed of in household trash, and the State simply "recommends" recycling or donating.[252] Additionally, twenty-five states have no e-waste regulations besides the federal RCRA regulations.[253] Some of the states without e-waste regulation have great potential for the use of solar energy, such as Arizona, Nevada, and New Mexico.[254]

Some states are beginning to take steps toward creating a framework for solar panel recycling. One state that has been progressive in creating solar panel waste regulations is California. In California, solar panels are considered hazardous waste, and there are proposed regulations to classify decommissioned solar panels as universal waste.[255] Universal waste is a category of hazardous waste that does not pose as much of a threat to the environment and human health, and is often produced by households and not industry.[256] Universal waste cannot be put in household trash, but must be

248. *See Virginia's Computer Recovery and Recycling Act (2008)*, VA. DEP'T OF ENVTL. QUALITY, https://www.deq.virginia.gov/Programs/LandProtectionRevitalization/RecyclingandLitterPreventionPrograms/ElectronicsRecycling/VirginiasComputerRecoveryandRecyclingAct.aspx (last visited May 31, 2019) (outlining the requirements of Virginia's Computer Recovery and Recycling Act).

249. *Electronic Waste*, IND. DEP'T OF ENVTL. MGMT., https://www.in.gov/idem/recycle/2352.htm (last visited May 31, 2019) (outlining the requirements of Indiana's e-waste regulations); 329 IND. ADMIN. CODE 16-2-36 (2013); 13 IND. CODE § 13-11-2-158 (2015).

250. *Electronic Waste*, IND. DEP'T OF ENVTL. MGMT., https://www.in.gov/idem/recycle/2352.htm (last visited May 31, 2019) (outlining the requirements of Indiana's e-waste regulations).

251. *See Id*.

252. *Electronic Waste*, MO. DEP'T OF NAT. RES. (Mar. 30, 2017), https://dnr.mo.gov/env/hwp/electronics/waste.htm (outlining the government of Missouri's requirements and recommendations for handling e-waste).

253. ELECTRONICS RECYCLING COORDINATION CLEARINGHOUSE, *supra* note 22.

254. *Id*.

255. *Photovoltaic Solar Panel Disposal in California*, NETWORK ENVTL. SYS. INC., https://www.nesglobal.net/photovoltaic-solar-panel-disposal-in-california/ (last visited May 30, 2019) (reviewing solar panel disposal policy in California).

256. *Id*.

brought to a facility that can recycle or otherwise dispose of the waste in a safe way.[257]

Classifying solar panels as hazardous waste, and therefore not allowing solar panels to be placed in household trash and end up in conventional landfills, is an improvement from the RCRA framework. This is because even if a solar panel could pass the TCLP or an equivalent, it would still be considered hazardous waste and cannot be placed in household trash. However, these California regulations do not go far enough. The California regulations do not require recycling, and therefore decommissioned solar panels could still end up in hazardous waste landfills. An environmentally responsible framework for handling solar panel waste would include mandatory recycling in order to preserve resources and prevent materials that could be reclaimed from filling landfills. Therefore, the California regulations are not sufficient.

Another state with a progressive solar panel waste law is Washington State.[258] In 2017, Washington passed a bill that in part requires solar panel manufacturers to pay for a take-back and recycling program.[259] Through this program, consumers can opt to send their decommissioned solar panels back to the manufacturer for recycling, all without any cost to the consumer.[260] This program is not fully operational yet, the current goal for full implementation of these take-back and recycling programs is January of 2021.[261] Final guidelines for approved recycling plans are to be published in July of 2019.[262] Although the mechanics of this program are yet to be established, there are elements to the program which indicate that it is not be the best method for handling solar panel waste. This is partially because the take back programs will only apply to solar panels purchased after July 1, 2017.[263] Also, under the current language of the bill, consumers are not required to recycle decommissioned solar panels, but manufacturers are only required to make take-back programs available.[264] Therefore, even if a

257. *Id*.

258. *See Solar Panels*, DEP'T OF ECOLOGY STATE OF WASH., https://ecology.wa.gov/Waste-Toxics/Reducing-recycling-waste/Solar-panels (last visited June 1, 2019) (outlining the State of Washington's 2017 bill concerning solar panel waste).

259. *Id*.

260. *Id*.

261. *See Timeline for Washington's Photovoltaic Module Stewardship Program*, DEP'T OF ECOLOGY STATE OF WASH., https://ecology.wa.gov/DOE/files/ec/ec664728-a4d5-45eb-87cc-7b3671e39b69.pdf (last visited May 30, 2019).

262. *Id*.

263. DEP'T OF ECOLOGY STATE OF WASH., *supra* note 258.

264. *See* WASH. REV. CODE § 70.355.010 (2017).

consumer has purchased a solar panel after July 1, 2017, and the manufacturer has a take-back program, the consumer could still choose to dispose of the solar panel in a landfill. Since a framework for handling solar panel waste should include all solar panels and make recycling mandatory, the Washington law is not sufficient.

C. The Private Sector

There has been a movement outside of the governmental sector to promote the recycling of solar panels.[265] The Solar Energy Industries Association ("SEIA") is the national trade association of the solar industry in the United States.[266] SEIA has developed a program called the National PV Recycling Program that aims to increase solar panel recycling by making it easier and more cost-effective for manufacturers.[267] The program does this by creating a list of Preferred Recycling Partners, and then offering benefits to member manufacturers through these partners.[268] These benefits include access to SEIA-approved recycling vendors and service providers, single point of contact for the recycling partners, exclusive pricing regardless of size or volume, amongst others.[269] Also through the program, SEIA is developing relationships with new recycling partners and helping them become capable of recycling solar panels.[270] However, this program is not widespread due to the fact that it is only available to SEIA members who have already implemented take-back and recycling programs for their products.[271]

If a similar framework were to be adopted in the United States, it would not provide the mandatory and effective method of regulation needed to address the issue of solar panel waste. If the government simply had "preferred recycling partners" and then offered incentives to those who use the preferred partners, this would not make recycling mandatory, but would only make it slightly more attractive. If recycling solar panels is not specifically required by law, a company may decide to not recycle, even if there are government-provided incentives to do so. The goal of the United

265. *SEIA National PV Recycling Program*, SOLAR ENERGY INDUSTRIES ASSOCIATION, https://www.seia.org/initiatives/seia-national-pv-recycling-program (last visited May 25, 2019) (outlining SEIA's program for solar panel recycling).

266. *About SEIA*, SOLAR ENERGY INDUSTRIES ASSOCIATION, https://www.seia.org/about (last visited May 25, 2019).

267. SEIA, *supra* note 222.

268. *Id.*

269. *Id.*

270. *Id.*

271. *Id.*

States should be a 100% recycling rate of solar panels, and this can only be achieved through making recycling mandatory by law.

In addition to this program created by SEIA, some companies are making individual efforts to reduce e-waste. Apple announced its goal of a closed-loop supply chain in 2017, but has given no deadline for implementing the program.[272] This would mean that the company would source most of their materials from recycled products or from renewable materials that are responsibly sourced, reduce the amount of material needed to make new products, and increase the durability of their products.[273] After producing their products, the company would put recycled, reclaimed, or renewable material back into the market supply.[274] Apple has started the process of moving toward this more sustainable model by decreasing the amount of aluminum used in its products, and it is also seeking to decrease the use of other materials, such as cobalt, copper, and plastic.[275] Additionally, to promote the durability of their products, Apple now provides repair services and parts for five years after the product ceases to be manufactured.[276]

V. European WEEE Initiative

The European Commission passed the Waste Electrical and Electronic Equipment ("WEEE") Directive in February of 2003.[277] The directive uses an extended producer responsibility model where consumers to return their e-waste to the producer at the end of the equipment's lifespan, free of charge.[278] The producer is then required to either recycle or reuse the decommissioned equipment.[279] The Directive also contains a requirement that states to collect information yearly on the amount of electronics put on their markets, and the amount of e-waste collected, prepared for re-use, recycled, recovered within the state, and the amount of e-waste sent overseas.[280] The WEEE Directive has been very successful, on average, EU

272. *See* APPLE, ENVIRONMENTAL RESPONSIBILITY REPORT 20 (2018) (including information on Apple's plan to achieve a close-loop supply chain).

273. *Id*. at 21–22.

274. *Id*. at 20.

275. *Id*. at 21.

276. *Id*. at 23.

277. *Waste Electrical & Electronic Equipment*, EUROPEAN COMMISSION (Feb. 22, 2019), http://ec.europa.eu/environment/waste/weee/index_en.htm (providing background on the European WEEE Directive).

278. *Id*.

279. *Id*.

280. 2012 O.J. (L 197) 38.

countries recycled 41% of their e-waste in 2016, up from 36% in 2015 and just 29% in 2012.[281]

In 2012, the European Commission expanded the WEEE Directive to include solar panel waste.[282] The WEEE Directive is the first comprehensive legal framework that addresses solar panel waste.[283] This expansion to solar panel waste uses an extended producers' responsibility method, which means that producers of solar panels are required to collect and dispose of the devices at the end of their lifecycles, with no additional cost to the consumer.[284] Under this directive, four categories of producers are subject to the extended producers responsibility: manufacturers, distributors or resellers, importers, and internet or distance sellers.[285]

The different countries that are part of the European Union ("EU") must make the directive national law and refine the rules of how the waste will be collected and recycled.[286] All twenty-eight members states of the EU have implemented the WEEE Directive through national legislation.[287] For example, in Ireland, the national e-waste regulations, which came into effect in 2014, allow, but do not require, producers to show an e-waste recycling fee as part of the product price at point of sale. The regulations also introduced the option of appointing an authorized representative.[288] Producers appoint an authorized representative to fulfill the producer's responsibilities under the regulations.[289] The regulations require distance sellers to display their "WEEE registration number" on their website, and requires distributors to retain records concerning the amount of e-waste taken back each year for two years.[290]

The WEEE Directive has led to the research and development of recycling methods for solar panels to decrease the cost of recycling and increase the

281. EUROSTAT, RECYCLING RATE OF E-WASTE (2019), https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=t2020_rt130 (last visited June 1, 2019).

282. SOLAR WASTE/EUROPEAN WEEE DIRECTIVE, *supra* note 23.

283. INT'L RENEWABLE ENERGY AGENCY, *supra* note 12, at 20.

284. European WEEE Directive, *supra* note 145.

285. *Id.*

286. *Id.*

287. INT'L ENERGY AGENCY, *supra* note 90, at 55.

288. *Ireland*, SOLAR WASTE/EUR. WEEE DIRECTIVE, http://www.solarwaste.eu/in-your-country/ireland/ (last visited May 25, 2019) (providing background on Ireland's implementation of the European WEEE Directive).

289. Eur. Union (Waste Electrical and Electronic Equipment) Regs. 2014 (SI 149/2014) (Ir.).

290. SOLAR WASTE/EUR. WEEE DIRECTIVE, *supra* note 23.

potential revenue of reclaimed materials.[291] In addition to benefits within Europe, the WEEE Directive also has benefits worldwide.[292] This is because any producer who wants to sell solar panels on the European market needs to comply with WEEE Directive requirements, even if that producer is not a European company and the panels are not produced within Europe.[293] Another benefit to the WEEE Directive is that it holds the producer accountable for the waste it creates at no cost to the consumer.[294] It also increases transparency in respect to e-waste, in that it places reporting requirements on producers, and informational requirements.[295] These informational requirements include informing consumers how the electronic equipment they are purchasing will be recycled at the end of its lifecycle, and also that collection for this recycling is free to the consumer.[296]

However, the WEEE Directive is imperfect. There are discrepancies in the definition of e-waste across EU member states.[297] This allows exporters of e-waste to choose to export their e-waste from a country that has more flexible definitions of e-waste, which may not classify the waste to be subject to WEEE Directive requirements.[298] Another issue with the Directive is that many countries do not provide guidelines to law enforcement agencies on how to differentiate e-waste from used electronics intended for reuse.[299] It can be difficult to differentiate the two different products, and some exporters may use this difficulty to masquerade e-waste for used electronics.[300]

VI. WEEE initiative as applied to the United States

WEEE Directive provides a more environmentally friendly model for solar panel recycling in the United States than RCRA and the current mismatching patchwork of state laws. The regulatory framework of RCRA focuses on tracking and appropriate disposal of waste, not recycling. The tracking of e-waste and ensuring its appropriate disposal is important, but the focus on the management of solar panel waste should be recycling. Recycling

291. INT'L ENERGY AGENCY, *supra* note 90, at 14.
292. *Id.* at 52.
293. *Id.*
294. *Id.*
295. *Id.*
296. *Id.*
297. SANGEETA MOHANTY ET AL., WEAKNESSES IN EUROPEAN E-WASTE MANAGEMENT 543 (2015) (reporting on the weaknesses of the European WEEE Directive).
298. *Id.*
299. *Id.* at 544.
300. *Id.*

prevents hazardous substances from endangering the environment and human health, and also allows for the reclamation of recoverable materials and prevents more waste from being sent to landfills. Another downfall to only using the RCRA model for solar panels is that not all solar panels will be covered by the regulations because of the RCRA exception for household waste.[301]

Implementing a program similar to the European Union's WEEE Directive for solar panels would address the weaknesses of applying RCRA to solar panels and depending upon inconsistent and often insufficient state laws. In order to do this, national legislation must be put in place that establishes an extended producer responsibility framework to e-waste. Under this, producers will have to cover the costs of collecting e-waste from consumers and properly disposing of that e-waste. E-waste can be brought by consumers to local collection centers, where the producers could pick up the e-waste, or hire a transporter to bring the e-waste to a recycling facility. Some producers may also offer to pick up e-waste directly from consumers, including both businesses and households. Some producers may choose to do this to make their products more attractive to consumers that may not want to travel to drop of their e-waste. Producers should also be subject to regular reporting requirements and disclosures to customers about how their e-waste will be disposed of.

Additionally, there should be a broad definition of e-waste that applies to the entire nation. The definition of e-waste should include all electronic and electronic equipment that the owner intends to discard, as this definition would include solar panels. Also, both household and non-household e-waste should be included in the definition of e-waste. The definition should not include a specific list of products considered e-waste. It is likely that by providing a specific list of products, some type of electronic or electronic equipment may be left out of the list and therefore not subject to e-waste regulations. Also, technology is constantly evolving and new products are being developed every few years. Therefore, new electronic products would not be subject to the regulations unless they are added to the list of products. The technology industry moves very quickly in its development, and having to add new products to the definition of e-waste would be time consuming and inefficient.

Under such a program, there should be a mandatory requirement for the recycling of solar panels. This mandatory requirement should be designed and implemented with the assistance of stakeholders and experts in both solar

301. Coyle, *supra* note 50, at 345.

energy and recycling. Stakeholders involved in this process should include SEIA, solar panel manufacturers, recycling facilities, and transporters of the decommissioned solar panels. The expertise of these stakeholders and experts will make the regulations to implement a mandatory recycling requirement more efficient and thorough.

A goal of the program would be to have e-waste, including solar panels, travel the minimum possible distance in order to be recycled. This is important because the e-waste will most likely be transported from collection centers or directly from the consumer to recycling centers via fossil fuel-powered vehicles, such as trucks, trains, or even airplanes. Having e-waste travel the minimum amount of distance to be recycled would decrease the amount of fossil fuels burned in the recycling process. If recycling is required by law, more e-waste recycling facilities will be built in order to handle the large amount of e-waste Americans produce. With more recycling facilities, e-waste would likely not have to travel very far to the nearest facility, no matter where in the country the e-waste is coming from.

Making the recycling of solar panels mandatory at the expense of the producer may discourage the development of solar technology. People and businesses who may be interested in entering the solar panel market may see the regulations and the increased costs that comes with the solar industry and not want to take the risk. In order to combat this, the federal government should offer tax breaks to businesses in the solar industry. Therefore, even though the solar industry would be required to pay for recycling, they would pay less in federal taxes. This decrease in tax revenue can be made up by increasing the taxes on fossil fuel companies. Not only would increasing taxes on fossil fuel companies increase tax revenue, but it would also make entering the fossil fuel industry less desirable.

Another method the federal government can use to encourage investment in the solar industry despite the costs of extended producer responsibility would be for the government to invest its own money in projects that use solar power. This could mean that the government builds more solar farms in areas with high solar potential, or installs solar panels on all newly built or renovated government buildings. Investing government money in solar would provide capital and stability to the industry. Also, private citizens may interpret the federal government investing so much in solar power to mean that investing in solar is a sound business decision, and may also choose to invest in solar energy.

A national framework like the WEEE Directive would be more effective than the current SEIA National PV Recycling Program. The SEIA program promotes solar panel recycling by creating a list of SEIA-approved Preferred

Recycling Partners, and then offers economic benefits to SEIA members that use these Preferred Recycling Partners.[302] However, the SEIA program does not apply to all solar panels, just solar panels created by manufacturers that are members of SEIA, a trade organization.[303] It is also not a mandatory program, and therefore even manufacturers that are members can refuse to participate in the program and choose to dispose of their solar panel waste in hazardous landfills. Also, the program does not require member manufacturers to have take-back programs, but only offers benefits to members that already have these programs in place.[304] A national program similar to WEEE would make solar panel recycling and take-back programs mandatory. Also, it would apply to all solar panel manufacturers and not just those that are members of SEIA. However, it would be beneficial to consult SEIA in the development of this national regulatory framework due to its expertise on solar panel recycling, solar panels in general, and any experiences they may have had related to their current take-back program.

A downside to the WEEE Directive and extended producer responsibility more generally is the financial burden that it presents on both manufacturers and consumers.[305] Establishing take-back programs poses increased costs to manufacturers who must obtain the e-waste from consumers, which may require travelling long distances. Producers would need to travel to collect the e-waste from consumers, and then these panels would need to travel to properly recycling facilities. This must be done with no additional cost to the consumer. Not charging the consumer would be consistent with the "producer pays principle," which states that the party that created the pollution needs to internalize the costs of their pollution.[306] Having polluters pay for the costs of their pollution incentivizes polluters to develop cleaner ways to make or use their product.[307] If the polluter was not held responsible for the environmental harm of their products, this harm would likely become an externality, which society as a whole would have to pay for. In the case of solar panels, forcing the manufacturers to pay for the cost of recycling would

302. SEIA, *supra* note 222.

303. *Id.*

304. *Id.*

305. Coyle, *supra* note 50, at 358.

306. *What is the Polluter Pays Principle?,* THE LONDON SCH. OF ECON. & POLITICAL SCI. (May 11, 2018), http://www.lse.ac.uk/GranthamInstitute/faqs/what-is-the-polluter-pays-principle/.

307. Mizan R. Khan, *Polluter-Pays-Principle: The Cardinal Instrument for Addressing Climate Change*, 4 LAWS 638, 640 (2015) (discussing the use of the polluter pays principle in combating climate change).

encourage these manufacturers to come up with cheaper and more efficient ways to recycle solar panels.

To offset this financial burden, manufacturers may incorporate the cost of take-back and recycling into the price of solar panels, which increases the price to the consumer.[308] With consumers already hesitant to switch to solar power due to the high upfront installation costs, this price increase may be problematic.[309] Financial burdens of extended producer responsibility can be offset by subsidies for solar power. These subsidies would be economic incentives designed to encourage solar energy despite the increased costs associated with extended producer responsibility.[310] An example of such subsidies are the California Solar Initiative ("CSI") rebates, which provides rebates for those who install solar power, based on system performance.[311] Under the CSI program, those who install solar units receive payment from the State, either in one lump sum, or in monthly installments.[312] The amount of these payments vary, depending upon utility territory, system size, customer class, and performance and installation factors.[313] Programs such as these can be very beneficial, as is illustrated by the fact that California is the nation's leader in solar energy usage.[314]

The federal government offers an investment tax credit ("ITC") to residences and businesses that use solar panels.[315] The solar industry has grown 5,000% since the ITC was implemented in 2006.[316] The current ITC system will be in place until the end of 2023, when it will have to be renewed to continue.[317] The ITC is a 30% tax credit for solar projects that begin construction through 2019 that can be applied to the income tax of the residential homeowner or the business.[318] The ITC decreases for solar

308. Coyle, *supra* note 50, at 358.

309. Palm, *supra* note 97, at 2.

310. Coyle, *supra* note 50, at 359.

311. *California Solar Initiative Rebates*, GO SOLAR CA., https://gosolarcalifornia.ca.gov/csi/rebates.php (last visited May 25, 2019) (reviewing rebates for solar panels offered by the State of California).

312. *Id.*

313. *Id.*

314. Frangoul, *supra* note 67.

315. *What Rebates and Incentives are Available for Solar Energy?*, SOLAR ENERGY INDUS. ASS'N, https://www.seia.org/initiatives/what-rebates-and-incentives-are-available-solar-energy (last visited June 1, 2019).

316. *Solar Investment Tax Credit (ITC)*, SOLAR ENERGY INDUS. ASS'N, https://www.seia.org/initiatives/solar-investment-tax-credit-itc (last visited June 1, 2019).

317. SOLAR ENERGY INDUS. ASS'N, *supra* note 315.

318. SOLAR ENERGY INDUS. ASS'N, *supra* note 316.

projects started after 2019.[319] Projects started during 2020 are eligible for a 26% tax credit, projects started during 2021 are eligible for a 22% tax credit, and projects started by businesses after 2021 are only eligible for a 10% tax credit.[320] After 2021, no residential projects will be eligible for the tax credit.[321] In order to offset any increase in the price of solar panels caused by the implementation of an extended producer responsibility framework, the federal government should continue to provide subsidies at least at the 30% rate. Also, this 30% rate should continue to apply to both homeowners and businesses.

VII. Conclusion

The threat of climate change has placed a responsibility on the world to reduce global carbon emissions. One way this can be done is by expanding the use of solar panels. Solar energy is the most abundant source of energy on Earth and it is inexhaustible.[322] Solar panels themselves are a "zero emissions" source of energy, in that they do not produce any pollution while creating energy.[323] A downside to solar panels in that they contain hazardous substances, such as lead and cadmium.[324] If solar panels are improperly disposed of, these substances can pollute the surrounding environment and become a danger to human health.[325]

In the United States there is no federal legislation that specifically regulates the disposal of solar panels. The federal government needs to regulate solar panel disposal for several reasons. One is that solar panel use in the United States is expected to double within the next five years.[326] As these solar panels reach the end of their lives, a federal regulatory framework is needed to prevent these decommissioned panels from being improperly disposed of, and thereby causing damage to the surrounding environment and human health. Another reason for federal regulation is that the world is already experiencing an e-waste crisis, which is exacerbated by the fact that a lot e-waste is shipped from the developed world to the developing world, where the waste is mined for valuable parts under unsafe conditions.[327]

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319. *Id.*
320. *Id.*
321. *Id.*
322. Kannan, *supra* note 4, at 1093.
323. Coyle, *supra* note 50, at 331.
324. Xu et al., *supra* note 47, at 453.
325. *Id.*
326. SOLAR ENERGY INDUSTRIES ASS'N, *supra* note 65.
327. Song, *supra* note 136, at 2588.

Currently, solar panel waste in the United States is regulated by RCRA, which is designed to deal with hazardous wastes more generally.[328] RCRA has shortcomings that make it not a desirable method for regulating solar panel disposal. For example, RCRA has an exception for household waste, and therefore homeowners with solar panels could legally send these panels to a conventional landfill, where the toxic substances would likely leak into the surrounding environment.[329] Additionally, RCRA focuses on ensuring that hazardous waste is disposed of in hazardous waste landfills.[330] A federal regulatory framework for handling the disposal of solar panels should require recycling for decommissioned panels.

In addition to RCRA, solar panel waste may be subject to various state e-waste laws.[331] Not all states have e-waste laws, and many of these state initiatives that do exist are not sufficient to properly handle solar panel waste. Amongst states that do not have e-waste regulation include Arizona, New Mexico, and Nevada, which have some of the greatest solar energy potential in the country.[332] Even if all states were to implement e-waste laws, a mismatched patchwork of laws and regulations across the country would not be an efficient way to handle solar panel waste in the most environmentally responsible way.

A model that the United States can look to in developing a national regulatory framework for solar panel waste is the European Union's WEEE Directive. The WEEE Directive uses an extended producer responsibility framework, which means that e-waste, including solar panels, is collected and properly disposed of by the producer at no cost to the consumer.[333] The WEEE Directive has been very successful in Europe, the recycling of all e-waste increased to 41% of all e-waste generated within the EU in 2016, compared to just 29% in 2012.[334] Some individual countries within the EU have seen an even greater increase in recycling rates.[335]

A regulatory framework in the United States based off of the WEEE Directive would ensure that solar panel waste is safely recycled within the country. Such a framework would include extended producer responsibility, in that producers would be required to collect solar panels at the end of their

328. BALDE ET AL., *supra* note 14, at 11.
329. Coyle, *supra* note 50, at 345.
330. *Id.* at 345.
331. ELECTRONICS RECYCLING COORDINATION CLEARINGHOUSE, *supra* note 22.
332. *Id.*
333. SOLAR WASTE/EUROPEAN WEEE DIRECTIVE, *supra* note 23.
334. EUROSTAT, *supra* note 238.
335. *Id.*

life cycles at no cost to the consumer. Additionally, this framework would require recycling of solar panels. Such a program may cause producers to increase the price of their products, so as to account for the extra costs associated with extended producer responsibility and required recycling the government can offer tax credits to manufacturers of solar panels and those who choose to use solar power. Appropriately managing solar panel waste will allow the United States to embrace an abundant clean energy source while also protecting human health and the environment worldwide.