CLOSUP Student Working Paper Series
Number 62

April 2020

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Evan Stanton, University of Michigan

This paper is available online at http://closup.umich.edu

Center for Local, State, and Urban Policy
Gerald R. Ford School of Public Policy
University of Michigan

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Evan Stanton

April 23, 2020

1 Abstract

This paper inventories American and European implementations of extended producer responsibility (EPR) solar waste management programs in order to understand the factors responsible for effective waste collection and successful collection financing by producers. Analysis of the legislation reveals that American solar waste policy places almost all of the onus of waste collection on producers, while European countries more tightly integrate collection with existing municipal systems. Earlier research has shown that the integrative approach is associated with collection efficacy, while the producer approach better shifts costs onto producers. These results suggest a similar split in outcomes might emerge from the differences between the European and American policy implementations; policymakers introducing solar waste management ought to consider which outcome is preferred and apply the corresponding European or American system as a model to guide legislation. In addition, the findings show generally more comprehensive regulations from the European policies, including guidelines on product design and consumer protections

not found in American policy.

2 Introduction

Production and deployment of photovoltaic (PV) panels has increased year-over-year as countries increase their renewable energy production capacities. Future production is predicted to continue to grow rapidly in the coming decades, with major producers in Asia projected to scale from 280 gigawatts (GW) in 2018 to over 4800 GW by 2050 (IRENA, 2016). The increased number of PV panels in use will pose a recycling challenge as installed panels reach the end of their roughly 25 year lifespans. Solar waste is not suitable for landfill disposal; panels have been shown to leach hazardous amounts of lead and cadmium in landfill conditions (Ramos-Ruiz et al., 2017). Moreover, due to the low value of recyclable components, manufacturers have little incentive to recycle decommissioned panels.

For many products lacking recycling incentives, recycling markets are created or supported by However, due to the relative novelty of PV panels, few policies exist regulating their recycling. The European Union broadened its directive on waste, electrical, and electronic equipment (WEEE or e-waste) collection to cover PV panels in 2012, with member states transposing the directive into national legislation by 2014 (European Commission, 2019). In the United States, while many states have legislative plans to increase solar capacity, only Washington, California, and New York have began to govern the disposal of solar waste. Leading Asian solar producers are similarly unregulated. None of Japan, China, Korea, or Singapore mandate PV recycling (IRENA, 2016).

This study explores which differences between leading EU solar recyclers and the more fledgling legislative landscape in American states promote waste collection and extended producer responsibility (EPR) schemes by inventorying each region's solar waste management plans along key areas such as collection, financing, and education.

3 Literature Review

Given the immaturity of solar waste regulation, little research exists analyzing specific policy implementations. However, we can gain a thorough understanding of solar waste policy by both examining stakeholder opinions about possible solar waste policies, and by drawing on the more robust literature about general WEEE recycling strategies. EPR and product stewardship (PS) frameworks, in which producers of products bear responsibility for their end-of-life waste management, have been implemented at various levels of government in the EU, China, and Australia to regulate e-waste collection, and the surrounding research offers insights about potential solar waste policies. The literature review is split into two sections: stakeholder opinion surveys and comparable waste policies.

3.1 Stakeholder Surveys

Much of the stakeholder opinion research comes from Australia, a country with an interest in solar production, and therefore, solar waste, as one of the sunniest developed nations in the world. However, Australia has not yet regulated the collection of solar waste. Morris and Metternicht (2016) conducted a case study, stakeholder interviews, comparative analysis against Japan and Switzerland, and a survey of local government officials evaluating the efficacy of Australian WEEE management policies. The researchers concluded that Australian policy was ineffective at even hindering, let alone reversing the increasing growth of WEEE. Though they could not recommend the Japanese or Swiss policies be implemented directly in Australia, they identified auditing measures and consumer education as a driving force behind increased WEEE recycling in the other countries, and analysis of the New South Wales survey data also recommended a push for consumer-focused WEEE efforts.

A survey of Australian PV industry stakeholders by Salim et al. (2019) corroborated

the dearth of effective Australian policies. Stakeholders identified the regulatory gap as an issue in effective PV waste management, as well as the lack of product stewardship programs and circular (i.e. trade-in or take-back) business models. In the aggregate, stakeholders ranked policy issues as the top 3 barriers to PV waste management and policy solutions as the top 3 enablers of effective waste management, implying that the implementation of PV waste regulation is urgently needed.

Davis and Herat's 2008 survey of Queensland local council officials provides further endorse the hypothesis that regulatory issues hamstring e-waste collection. Although they found widespread support for EPR and other legislation governing WEEE collection, the study revealed few measures concerning the auditing of data or reporting e-waste streams, as well as a lack of local facilities for WEEE recycling.

3.2 Comparable Waste Policy

There is much research about broader waste collection policies targeting e-waste in general or implementing EPR frameworks. Johansson and Corvellec (2018) compared general European and Swedish waste management plans in order to categorize the types of plans and gauge their ability to prevent waste generation versus simply managing the handling of created waste. As regards WEEE, they found that almost no measures focused on curbing WEEE production, but instead the majority focused on end-of-life management, reuse, and managing existing waste. This ran in stark contrast to food waste objectives, which holistically targeted the entire chain of food waste production with more preventative measures.

With respect to EPR, several analyses have looked into EPR measures across the globe. In South America, Ribeiro and Kruglianskas (2020) conducted a case study of Brazilian and Portuguese EPR implementations. Covering a period of about 7 years, the analysis revealed that the greatest obstacle to regulation was the regulation itself, but that change followed quickly after overcoming that barrier. Beyond that, a lack of incentives and free-

rider / participation problems were the greatest obstacles to the policy implementation.

Other studies have focused more on the apparent efficacy of EPR schemes than their path toward implementation. Lodhia, Martin, and Rice (2017) examined Australia's National Television and Computer Recycling Scheme (NTCRS), an EPR effort to reduce e-waste, and concluded that the NTCRS both met its waste collection goals and outperformed comparable implementations in Asia and the USA, as well as finding no specific groups that were advantaged by the implementation of the regulation. Wang et al. (2018) reported a similar success story with EPR implementation in China. The researchers performed a quantitative analysis of over 100 e-waste recycling facilities scattered across 31 Chinese provinces and cities over a 2.5 year period after an EPR policy was enacted. Their data showed significant increases (in the 5-15x range) in the quantity of each measured material: plastic, glass, aluminum, iron, and copper. The policy greatly increased the revenue and profit generated by recycling entities, transforming many from significantly costly enterprises to profitable ones. In addition, the time period saw policy compliance rise from roughly 84% to 99.7%.

Lastly, Corsini, Rizzi, and Frey (2017) also quantitatively analyzed EPR, with a focus on WEEE collection in EU member states. Specific EPR implementation varied significantly between countries. While the countries which integrated WEEE collection with existing waste systems achieved more collection, they failed to shift the cost burden onto producers, a core goal of EPR systems. On the other hand, the countries which did shift costs onto producers did not meet WEEE collection standards, suggesting that a more nuanced and harmonious implementation is needed to accomplish waste management goals.

However, there is a significant dearth of research studying solar waste policy and the various formulations of extended producer responsibility implemented in the world today, especially as regards the divergence of American policies from the prototypical framework introduced by the EU's 2012 WEEE directive. This research aims to understand the differences between American and European solar waste policies most relevant in influencing their ability to both effect waste collection compliance and ensure that producers fund

collection programs.

4 Method

This paper inventories solar waste legislation from EU member states, Washington, and New York. The stateside policies, S2837B in New York and SB5939 in Washington, are taken directly from local legislatures (NY State Senate, 2018, and Washington State Legislature, 2017). Note that while California classifies solar panels as hazardous waste, there are no specific directions to producers regarding the collection, recycling, or reuse of solar panels, so the state is not included in this inventory. The information regarding each EU member state's transposition of the 2012 updated WEEE directive is sourced from the EU's Final Implementation Report on the 2012 directive, which collected the specific implementations of each member state via surveying legislative officials (European Commission, 2018). While PV regulations are starting to develop in Asian and Oceanic countries like China and Australia, this study limits its focus to the EU and US due to the maturity of legislation in the two regions; the EU has the most comprehensive solar waste regulation in the world, with only some US states following behind (IRENA, 2016).

There is a significant imbalance in the geographical distribution of cases. 24 out of the 28 EU member states are inventoried (Malta, Romania, Greece, and Hungary did not respond to the European Commission's survey) compared to just 2 US states. However, as this study aims to specifically examine novel US legislation in contrast to mature European policy instead of drawing general conclusions, this sampling discrepancy does not skew any calculations. Note also that when the implementation report was written, the United Kingdom was a member of the EU. Thus, it is also included in the results.

4.1 Analytical Framework

This study examines each case in five areas, constructed from the European Commission report and listed in Table 1:

Table 1: Areas of measures

#	Category
1	Product design
2	Collection
3	Recycling
4	Financing
5	Education

Every area is then analyzed with four categories, drawn from the categories of Johannson and Corvellec (2018) with several adaptations. The categories, questions, and variables, all shown below in Table 2, were modified inductively after observing the policies themselves. In general, the bolded forward slash symbol **/** is used whenever the information for a non-binary variable (such as actors, or effect) is unclear or not specified in the text. For binary variables (such as presence/absence variables), if the information is unspecified, the variable is assumed to be negative.

Table 2: Categories

#	Category	Question	Variable
1	Effect	What aspect of waste management is targeted by the measure?	Waste quantity (**Q**), Health and safety (**H**), Environmental hazards (**E**)
2	Actors	Which actors are targeted by the measure?	Producer (**P**), Municipality (**M**), Importer (**Imp**), Non-producer industry (**Ind**), Distributor (**D**)
3	Character	How is the objective formulated?	Qualitative (**QL**), Quantitative with specific targets (**QU**)
4	Quantitative measures	If the measure is quantitative, what are the quantitative targets?	Textual Description

This framework does not include the *focus area* category from Johannson and Corvellec (2018) which classified prevention versus management efforts, as solar waste is nearly entirely focused on the management of solar panels, with special attention given to pre-existing installations which will be decommissioned after the legislation is enacted. The framework also omits the *waste type*, *type of measure*, and *character of measure* categories. The former is made irrelevant as the study only looks at solar waste, while the latter two are encoded in the first-pass areas listed in Table 1.

The included categories are semantically unchanged with the exception of *(2) actors*, which draws on the conclusions of Corsini, Rissi, and Frey (2017) that the 2002 WEEE directive collection rates varied based on whether a member state assigned financial and physical collection responsibility to the producers or to the distributors and municipalities. The category also makes a distinction between importers and distributors, as the updated WEEE directive does.

In addition to the four standard categories of Effect, Actors, Character, and Quantitative Measures, in the five areas inventoried, unique recurring themes are tracked via area-specific categories detailed as follows:

Table 3: Category-specific variables

1.8

Area	Category	Question	Variable
Product design	Right-to-repair	Are producers barred from interfering with a consumer's right to repair their products?	Yes (**Y**), No (**N**)
Collection	Means of collection	By which means is waste collected?	Municipal (**M**), Individual producer solutions (**P**), Collective schemes (**CS**)
Collection	Trade-in	Can customers trade in used products when buying a good of like kind?	Yes (**Y**), No (**N**)
Collection	Non-household waste	Are producers required to collect non-household waste?	Yes (**Y**), No (**N**)
Recycling	Mandatory Reporting	Are recyclers required to report the quantity of WEEE recycled?	Yes (**Y**), No (**N**)
Financing	Fee disclosure	Must producers disclose whatever extra fees or portion of product price is used to finance collection?	Yes (**Y**), No (**N**)
Education	Information method	By which methods are producers supposed to educate consumers and distributors about collection?	Mixed media campaigns (**MM**), Point-of-sale information and signage (**PS**), Website (**W**), Not specified (**/**)

Critically, for all categories, a result is recorded if and only if explicit mention of the variable in question is made. For example, a measure may affect distributors via

downstream effects or some other causal chain, but if either the text of the bill (in the case of the U.S. states) or the European Commission survey response (in the case of EU member states) does not explicitly mention distributors, then distributors will not be recorded as an affected actor.

5 Results

The results of the inventory are split according to the specified areas. For brevity, the tables presented in this section contain only the most notable variables; the full table containing the inventory results is attached in the Appendix, split according to area. For example, to find the full results for Section 5.3, Recycling, see Appendix 8.3.

5.1 Product Design

As shown in the Appendix, neither Washington nor New York mentioned product design in their legislation, while every EU member state was required to include measures related to product design by the 2012 directive. Moreover, 4 of the 28 member states mentioned qualitative measures in addition to qualitative ones: France, Malta, The Netherlands, and Sweden. Only two measures, those of Croatia and Spain, targeted hazardous waste as an additional goal; every other member state focused on only the environmental impacts of waste.

That product designs should not interfere with a consumer's right to repair or reuse the product was a frequent theme in the European Commission's implementation report, though it was not a specific question in the implementation survey filled out by member states. Of the 28 member states, 13 explicitly mentioned measures protecting a consumer's right to repair electronic goods; see Table 4.

Table 4: Right to repair by territory

Territory	Right to repair		Territory	Right to repair
Washington	N		Ireland	Y
New York	N		Italy	N
Austria	Y		Latvia	Y
Belgium	N		Lithuania	N
Bulgaria	N		Luxembourg	N
Croatia	Y		Malta	N
Cyprus	N		The Netherlands	N
Czechia	N		Poland	Y
Denmark	N		Portugal	Y
Estonia	N		Romania	Y
Finland	N		Slovakia	Y
France	N		Slovenia	Y
Germany	Y		Spain	Y
Greece	N		Sweden	Y
Hungary	N		United Kingdom	Y

5.2 Collection

As per the EU directive's mandate, every member state's measures include quantitative targets building on prior directive targets, scaling from 45% of WEEE by weight put on the market to either 65% of WEEE weight or 85% of WEEE generated within the member state. New York has no such quantitative goals, while Washington aims to collect 85% of solar panels by weight of materials. Considering involved actors, 75% of EU member states target producers, municipalities, and distributors via municipal collection and distributor trade-in programs, while New York's law directly mentions producers and consumers, and Washington's only consumers.

The European Commission report specifically asked member states whether they required producers and distributors to allow consumers to trade in used WEEE when purchasing a like item, and whether they required producers to collect non-household WEEE. While neither U.S. state guarantees trade-in at purchase, their broad collection plans cover non-household waste. In the EU, only Sweden does not explicitly mention a trade-in program, and only 29% of member states do not require producers to also guarantee collection of non-household waste in some way; see Table 5.

Table 5: Trade-in and non-household waste policy

Territory	Trade-in	Non-Household		Territory	Trade-in	Non-Household
Washington	N	Y		Ireland	Y	N
New York	N	Y		Italy	Y	Y
Austra	Y	Y		Latvia	Y	Y
Belgium	Y	N		Lithuania	Y	Y
Bulgaria	Y	Y		Luxembourg	Y	Y
Croatia	Y	N		Malta	Y	N
Cyprus	Y	Y		Netherlands	Y	N
Czechia	Y	N		Poland	Y	Y
Denmark	Y	Y		Portugal	Y	Y
Estonia	Y	Y		Romania	Y	Y
Finland	Y	Y		Slovakia	Y	Y
France	Y	Y		Slovenia	Y	Y
Germany	Y	N		Spain	Y	Y
Greece	Y	N		Sweden	N	Y
Hungary	Y	Y		UK	Y	Y

5.3 Recycling

Recycling and recovery measures were homogeneous in implementation among European countries, with almost every country closely following the guidelines outlined in the directive apart from the actors mentioned in the Commission's report. 14 out of the 28 European territories explicitly mentioned non-producer industry as a concerned actor in the context of mandatory reporting requirements for recycling centers. That is, independent recyclers must prepare reports on the quantity and kind of WEEE processed in their facilities. The rest only mention industry in passing while describing their recycling system in response to the Commission's prompt, while New York bars transporters of solar waste from knowingly mixing it with other waste or delivering it to incinerators or landfills. The full list of actors affected is detailed in Table 6. There is also a larger contrast between the whole of the EU and Washington/New York, as the directive outlines requirements for recyclers to obtain permits certifying their ability to properly handle WEEE, while the U.S. states defined no such process.

Table 6: Recycling actors

Territory	Actors		Territory	Actors
Washington	**P**		Ireland	**P**, **Ind**
New York	**Ind**		Italy	**P**, **Ind**
Austria	**P**, **Ind**		Latvia	**P**
Belgium	**P**, **M**, **Ind**		Lithuania	**P**
Bulgaria	**P**, **Imp**, **Ind**		Luxembourg	**P**
Croatia	**P**		Malta	**P**
Cyprus	**P**, **Ind**		Netherlands	**P**
Czechia	**P**, **Ind**		Poland	**P**
Denmark	**P**, **Ind**		Portugal	**P**, **Ind**
Estonia	**P**, **Imp**, **Ind**		Romania	**P**, **Ind**
Finland	**P**		Slovakia	**P**, **Ind**
France	**P**, **Ind**		Slovenia	**P**
Germany	**P**, **Ind**		Spain	**P**
Greece	**P**, **Ind**		Sweden	**P**, **Ind**, **M**
Hungary	**P**, **Ind**		UK	**P**, **Ind**

P, **M**, **Ind**, and **Imp** stand for producers, municipalities, non-producer industry, and importers, respectively.

5.4 Financing

Almost all European member states explicitly require that producers finance WEEE collection in accordance to the amount that they place on the market, while a select few have municipal fees for collection. Similarly, both NY and WA require that producers finance collection efforts. Though all territories required that producers help finance collection, they were divided on whether producers must disclose whatever additional fee or portion of the product's price is allocated for collection financing; see Table 7.

Table 7: Mandatory fee disclosure

Territory	Fee disclosure		Territory	Fee disclosure
Washington	N		Ireland	Y
New York	N		Italy	N
Austria	N		Latvia	N
Belgium	Y		Lithuania	N
Bulgaria	N		Luxembourg	Y
Croatia	N		Malta	N
Cyprus	N		Netherlands	Y
Czechia	N		Poland	Y
Denmark	Y		Portugal	N
Estonia	N		Romania	N
Finland	N		Slovakia	Y
France	Y		Slovenia	N
Germany	Y		Spain	N
Greece	N		Sweden	N
Hungary	N		UK	N

5.5 Education

The EU and both U.S. states require that producers provide information to consumers and/or other stakeholders about the end-of-life management of solar panels. The only difference among them is the methods by which producers are required to inform stakeholders; such methods are described in Table 8.

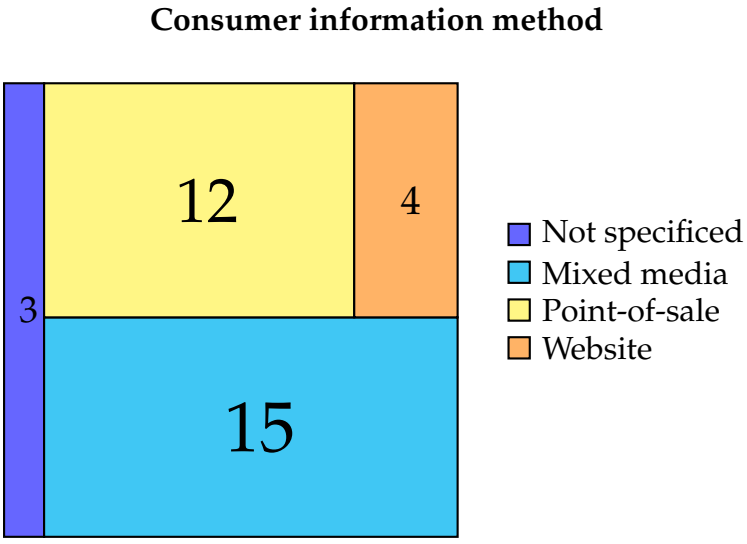
Table 8: Producer Education Methods

Territory	Methods		Territory	Methods
Washington	**/**		Ireland	**PS**
New York	**MM**,**PS**,**W**		Italy	**PS**
Austria	**W**		Latvia	**PS**
Belgium	**PS**		Lithuania	**PS**
Bulgaria	**PS**		Luxembourg	**/**
Croatia	**MM**,**W**		Malta	**/**
Cyprus	**MM**		Netherlands	**MM**
Czechia	**MM**,**PS**		Poland	**MM**
Denmark	**PS**		Portugal	**MM**
Estonia	**MM**		Romania	**MM**
Finland	**W**		Slovakia	**PS**
France	**MM**		Slovenia	**MM**,**PS**
Germany	**MM**		Spain	**MM**
Greece	**W**		Sweden	**PS**
Hungary	**/**		UK	**MM**

MM, **PS**, and **W** stand for mixed media campaigns, point-of-sale signage or labeling, and websites, respectively. Note that all territories require some producer education; **/** implies that no specific methods were given in the measure.

The methods for enforcing producer education programs are split mostly between mixed-media campaigns and point-of-sale information/instructions, as shown in Figure 1.

Figure 1: Producer education methods



6 Analysis

6.1 European Union

While this paper focuses primarily on comparison between the novel American legislation governing solar waste and the existing EU directive implementations, it must be remarked that the EU cannot be regarded as an e-waste monolith. The implementation of the directive varied between member states with respect to important categories, most significantly in the areas of product design and collection. Several countries like Czechia or Greece appear to have implemented the bare-minimum standards of the directive. Others like Denmark, Spain, or Lithuania have created funded eco-design initiatives to coordinate workshops with producers, recyclers, and distributors about environmentally sound design principles; France and Malta created financial incentive and fee structures based on the environmental toxicity or concentration of hazardous substances in a product's design.

As regards collection, the European countries split on which actor ought to control the means of collection. A small majority opted for a combination of integration with

municipal waste collection systems and collective schemes organized by producers. One such country, Czechia, noted that 9 of its 16 collective schemes operated solely for collecting solar waste. However, some member states chose to employ solely municipal systems or collective schemes; Belgium tackled the problem by founding a non-profit for the express purpose of collecting e-waste. States almost unanimously instituted trade-in programs at distributors, but as shown in the results, were split evenly on the existence of non-household waste collection plans.

In the other subcategories of recycling, financing, and education, European measures were more homogeneous, though differences were found in whether recyclers were required to report quantities of waste processed, whether collection fees should be visible to consumers, and what method to educate stakeholders about collection programs. Nonetheless, the range of responses was more tightly grouped.

The EU members also differed in their attitude towards aspects of the directive. The European Commission's report requested feedback on the states' experiences implementing each portion of the directive and received mixed feedback. Several states reported total satisfaction, while others cited administrative costs and ineffectuality of national-level (as opposed to EU-level) legislation. In particular, smaller member states like Luxembourg and several members in the Balkans remarked that they had little to no domestic WEEE producers, thus making much of the legislation pointless and administratively burdensome (European Commission, 2018).

6.2 Continental Differences

Though many of the tables presented earlier portray the EU directive as more thorough and comprehensive than its American counterparts, it remains to be seen whether those differences will in fact produce a true EPR system. As noticed by Corsini, Rizzi, and Frey

(2017), the EU countries most effective at increasing WEEE collection were those which did not sufficiently cast the cost burden of collection and recycling onto producers. As described above, the majority of the EU member states are integrating collection systems with existing municipal ones, and in some cases extracting a fee from local citizens in order to fund such programs. They also put significant demands on distributors to collect WEEE from mandatory trade-in programs. While some countries did alleviate the cost burden of smaller producers by alleviating the trade-in requirement for stores of a sufficiently small footprint, such stores likely make up a minority of WEEE purchases (and thus trade-ins) overall, and distributors will still incur a significant burden in collecting WEEE and playing their role in the recycling ecosystem.

In comparison, the guidelines set forth by the state governments of Washington and New York are much more open-ended, holding producers overwhelmingly responsible for creating and facilitating collection and recycling programs. Both states also bar producers from imposing a collection fee on top of current product prices, suggesting that they aim to fully shift the cost burden onto producers and away from consumers. Following Corsini's (2017) analysis, this producer-focused approach, in contrast to the holistic integration employed by the majority of the EU, might result in a more ideologically pure EPR structure, but may fail to achieve similar levels of collection and recovery efficacy, especially with respect to the relatively aggressive 85% of material weight target posited by Washington.

But while EU legislation is in many ways more thorough and comprehensive than its stateside counterparts, the broad scope of the WEEE directive may make it less effective for specifically targeting solar waste. The directive tries to provide granular targets by eventually requiring 85% recovery of the category "consumer equipment and photovoltaic panels", but such a category is large enough that producers might be able to meet recovery targets by recycling other forms of consumer equipment with more easily recoverable and valuable components. In contrast, Washington's recovery target measures only recycled panels, restricting the ability for producers to cleverly skirt requirements. In addition, Washington's law makes specific mention of the rare earth elements and heavy metals com-

monly used in panel construction, while the EU directive can only make vague mention of "hazardous substances" in order to be sufficiently inclusive of various WEEE categories.

But the EU directive's scope offers many advantages. Most notably, the requirement of environmentally sound product design targets an area of the waste cycle totally ignored by Washington and New York. This inclusion rectifies a former oversight from earlier EU waste policies, pointed out by Johansson and Corvellec (2018), that WEEE policies overemphasized end-of-life management and mitigating the effects of existing waste instead of preventing the initial creation of waste. While end-of-life management is still crucial for solar waste, as current panel installations already pose a waste management challenge, product design improvements may help facilitate the reduction of future solar waste, especially with respect to the amount of toxic metals like cadmium and lead, which have the potential to leach into groundwater, used in panel construction.

Moreover, the European solution addresses many of the concerns raised in the Australian stakeholder surveys conducted by Salim et al. (2019) and Davis and Herat (2008). These surveys showed a want of circular trade-in/take-back product lifecycles as well as a dearth of WEEE collection auditing, data reporting, and local facilities, areas in which the EU directive has prescribed significant measures. With that being said, both New York and Washington have also prescribed measures for auditing and reporting, though the proximity of collection facilities remains an unanswered question as these developing programs mature and take shape.

7 Conclusion

Though this inventory is a preliminary look at the key differences between European and American solar waste legislation, it faces several major limitations. Most significantly, due to the lack of available English translations of national laws from European countries, data collection was limited to the European Commission report, which likely produces a systematic underreporting of the scope and specificity of the European waste measures.

Further region-specific research may help better illuminate the details of European policies.

Also limiting this research is the novelty of the solar waste legislative landscape. The two American bills are the first solar waste policies enacted in the U.S., and are too recent to allow for longitudinal policy analysis. Even the European directive is relatively young; there does not yet exist a sufficient quantity of data from the reporting of e-waste streams in EU member states to allow for statistical analysis, as Corsini (2017) was able to do with the earlier EU WEEE directive. In a broader sense, the topics of extended producer responsibility and product stewardship are relatively underresearched, with limited case studies serving as models but limited generalized policy theory. More research is needed as solar waste management and product stewardship policies continue to mature.

Though this research faces limitations, policymakers can still glean important insights from it. The policies in NY and WA stand as useful examples of targeted solar waste legislation that places the responsibility on producers to manage the collection of their products, while the comprehensiveness of European waste management policy can serve as a model for a holistic integration at all stages in the waste management process, enabling circular economies and closed loop product life cycles. Moreover, the EU directive itself can also be a standard for policymakers looking to not only address solar waste concerns but also conduct sweeping reform of WEEE collection to combat the looming issue of e-waste; the diverse range of implementation choices by EU member states provides a wealth of case studies for policymakers to study when constructing the finer points of solar waste legislation.

8 Appendix

The appendix is split according to the 5 key areas inventoried.

8.1 Product Design

Territory	Effect	Actors	Character	Quantitative Measures	Right to Repair
New York	/	/	/	/	N
Washington	/	/	/	/	N
Austria	E	P	QL	/	Y
Belgium	/	/	/	/	N
Bulgaria	E	P, Ind	QL	/	N
Croatia	H	P	QL	/	Y
Cyprus	/	/	/	/	N
Czechia	E	P	QL	/	N
Denmark	E	P	QL	/	N
Estonia	E	P	QL	/	N
Finland	E	P	QL	/	N
France	E	P	QL,Q+	Fines for 6 product tiers	N
Germany	E	P	QL	/	Y
Greece	E	P	QL	/	N
Hungary	E	P	QL	/	N
Ireland	E	P	QL	/	Y
Italy	E	P	QL,Q+	"Differentiated fees"	N
Latvia	E	P	QL	/	Y
Lithuania	E	P	QL	/	N
Luxembourg	E	P	QL	/	Y
Malta	E	P	QL,Q+	Maximum toxic substance quantities	Y
Netherlands	E	P	QL,Q+	Subsidies	Y
Poland	E	P	QL	/	Y
Portugal	E	P	QL	/	Y
Romania	E	P	QL	/	Y
Slovakia	E	P	QL	/	Y
Slovenia	E	P	QL	/	Y
Spain	E	P	QL	/	Y
Sweden	E	P	QL,Q+	Financial incentives	Y
UK	E	P	QL	/	Y

8.2 Collection

Territory	Effect	Actors	Character	Quantitative Measures	Means of Collection	Trade-in	Non-household
New York	**Q**	**P**	**QL**	**/**	**P**	**N**	**N**
Washington	**Q**	**P**	**Q+**	85% of weight	**P**	**N**	**N**
Austria	**Q**	**P, M,D**	**QL,Q+**	Scaling[1]	**M**	**Y**	**Y**
Belgium	**Q**	**P, M,D**	**QL,Q+**	Scaling	**M**	**Y**	**N**
Bulgaria	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M**	**Y**	**Y**
Croatia	**Q**	**P,D**	**QL,Q+**	Scaling	**/**	**Y**	**N**
Cyprus	**Q**	**P,D**	**QL,Q+**	Scaling	**/**	**Y**	**Y**
Czechia	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**N**
Denmark	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**
Estonia	**Q**	**P,D**	**QL,Q+**	Scaling	**CS**	**Y**	**Y**
Finland	**Q**	**P,D**	**QL,Q+**	Scaling	**CS**	**Y**	**Y**
France	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**
Germany	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M**	**Y**	**N**
Greece	**Q**	**P,D**	**QL,Q+**	Scaling	**CS**	**Y**	**N**
Hungary	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**
Ireland	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M**	**Y**	**N**
Italy	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**
Latvia	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M**	**Y**	**Y**
Lithuania	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M**	**Y**	**Y**
Luxembourg	**Q**	**P,D**	**QL,Q+**	Scaling	**CS**	**Y**	**Y**
Malta	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M**	**Y**	**N**
Netherlands	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**N**
Poland	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**
Portugal	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**
Romania	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**
Slovakia	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**
Slovenia	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**
Spain	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**
Sweden	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**
UK	**Q**	**P,M,D**	**QL,Q+**	Scaling	**M,CS**	**Y**	**Y**

[1]Starts at 45% by weight for 2016, scaling to 65% by 2019; holds for all EU member states.

8.3 Recycling

Territory	Effect	Actors	Character	Quantitative Measures	Mandatory Reporting
New York	**H**	**Ind**	**QL**	/	**Y**
Washington	**Q,H,E**	**P,Ind**	**QL**	/	**Y**
Austria	**Q,H,E**	**P, Ind**	**QL,Q+**	80% recovered, 70% recycled[2]	**Y**
Belgium	**Q,H,E**	**P,Imp,Ind**	**QL,Q+**	80%/70%	**N**
Bulgaria	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**N**
Croatia	**Q,H,E**	**P**	**QL,Q+**	80%/70%	**N**
Cyprus	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**N**
Czechia	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**N**
Denmark	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**Y**
Estonia	**Q,H,E**	**P,Imp,Ind**	**QL,Q+**	80%/70%	**Y**
Finland	**Q,H,E**	**P**	**QL,Q+**	80%/70%	**N**
France	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**N**
Germany	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**N**
Greece	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**N**
Hungary	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**Y**
Ireland	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**N**
Italy	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**Y**
Latvia	**Q,H,E**	**P**	**QL,Q+**	80%/70%	**Y**
Lithuania	**Q,H,E**	**P**	**QL,Q+**	80%/70%	**Y**
Luxembourg	**Q,H,E**	**P**	**QL,Q+**	80%/70%	**Y**
Malta	**Q,H,E**	**P**	**QL,Q+**	80%/70%	**N**
Netherlands	**Q,H,E**	**P**	**QL,Q+**	80%/70%	**Y**
Poland	**Q,H,E**	**P**	**QL,Q+**	80%/70%	**Y**
Portugal	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**Y**
Romania	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**Y**
Slovakia	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**N**
Slovenia	**Q,H,E**	**P**	**QL,Q+**	80%/70%	**N**
Spain	**Q,H,E**	**P**	**QL,Q+**	80%/70%	**N**
Sweden	**Q,H,E**	**P,M,Ind**	**QL,Q+**	80%/70%	**Y**
UK	**Q,H,E**	**P,Ind**	**QL,Q+**	80%/70%	**Y**

[2]These targets hold for all EU member states.

8.4 Financing

Territory	Effect	Actors	Character	Quantitative Measures	Fee Disclosure
New York	/	P	QL	/	N
Washington	/	P	QL	/	N
Austria	/	P	QL	/	N
Belgium	/	P,Imp	QL	/	Y
Bulgaria	/	P	QL	/	N
Croatia	/	P	QL	/	N
Cyprus	/	P	QL	/	N
Czechia	/	P	QL	/	N
Denmark	/	P,M	QL	/	Y
Estonia	/	P,Ind	QL	/	N
Finland	/	P	QL	/	N
France	/	P	QL	/	Y
Germany	/	P	QL	/	Y
Greece	/	P	QL	/	N
Hungary	/	P	QL	/	N
Ireland	/	P	QL	/	Y
Italy	/	P	QL	/	N
Latvia	/	P	QL	/	N
Lithuania	/	P,Imp	QL,Q+	Fines as penalties	N
Luxembourg	/	P	QL	/	Y
Malta	/	P	QL	/	N
Netherlands	/	P	QL	/	Y
Poland	/	P	QL	/	Y
Portugal	/	P	QL	/	N
Romania	/	P	QL	/	N
Slovakia	/	P	QL	/	Y
Slovenia	/	P	QL	/	N
Spain	/	P,Imp	QL	/	N
Sweden	/	P	QL	/	N
UK	/	P	QL	/	N

8.5 Education

Territory	Effect	Actors	Character	Quantitative Measures	Information Method
New York	/	P	QL	/	MM,PS,W
Washington	/	P	QL	/	/
Austria	/	P	QL	/	W
Belgium	/	P	QL	/	PS
Bulgaria	/	P	QL	/	PS
Croatia	/	P	QL	/	MM,W
Cyprus	/	P	QL	/	MM
Czechia	/	P	QL	/	MM,PS
Denmark	/	P	QL	/	PS
Estonia	/	P	QL	/	MM
Finland	/	P	QL	/	W
France	/	P	QL	/	MM
Germany	/	P	QL	/	MM
Greece	/	P	QL	/	W
Hungary	/	P	QL	/	/
Ireland	/	P	QL	/	PS
Italy	/	P	QL	/	PS
Latvia	/	P	QL	/	PS
Lithuania	/	P	QL	/	PS
Luxembourg	/	P	QL	/	/
Malta	/	P	QL	/	/
Netherlands	/	P	QL	/	MM
Poland	/	P	QL	/	MM
Portugal	/	P	QL	/	MM
Romania	/	P	QL	/	MM
Slovakia	/	P	QL	/	PS
Slovenia	/	P	QL	/	MM,PS
Spain	/	P	QL	/	MM
Sweden	/	P	QL	/	PS
UK	/	P	QL	/	MM

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