

Supporting Information for

“Control-Alt-Delete”: Rebooting Solutions for the E-waste Problem

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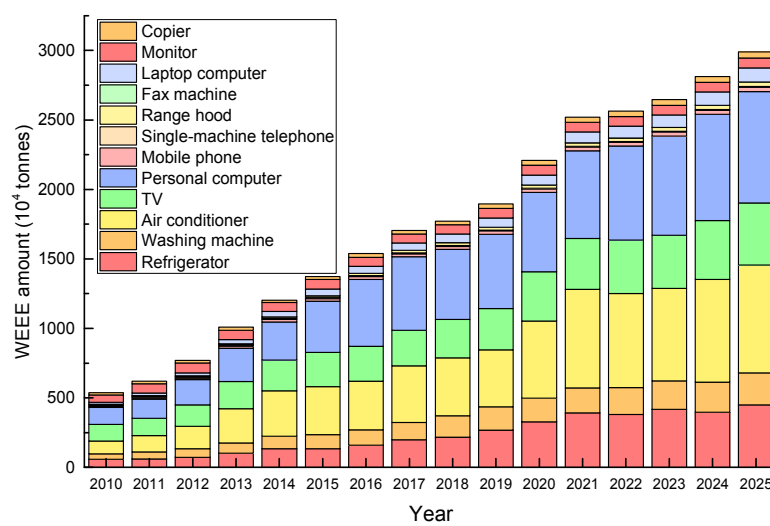
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Table S1 Available amount of e-waste generation published in the previous studies ¹⁻¹³

Countries or regions	Total e-waste (tonnes)	Year
Brazil	368,300	2005
Canada	67,000	2005
China Mainland*	6,410,000	2012
Colombia	36,100	2006
Denmark	118,000	1997
EU-27	8.3-9.1M	2007
Finland	120,000	2003
France	1.5M	2007
Germany	1.1M	2005
Ghana	13,000	2010
Hong Kong	80,443	2010
India	0.8M	2012
Japan	0.86M	2005
Kenya	7,350	2007
Korea	580,000	2010
Macau	10,000	2012
Malaysia	134,035.70	2009
Mexico	269,300	2006
Morocco	38,200	2007
Nigeria	60,000	2009
Norway	100,000	2003
Peru	24,420	2006
Philippines	58,000	2010
Senegal	3,730	2007
South Africa	59,650	2007
Sri Lanka	50,000	2005
Sweden	100,000	2003
Sweden	0.1M	2010
Switzerland	66,042	2003
Taiwan	14,036	2003
Thailand	0.1M	2007
Turkey	0.565M	2010
Uganda	4,390	2007
UK	1.2M	2010
USA	3.16M	2008
Global	~35M	2013

Note: N.A. no data; * predication based on China's new catalogue.



E-waste generation amount based on new catalogue in China. Prediction based on data source:
<http://data.stats.gov.cn/workspace/index?m=hgnd>.

Table S2 Critical Resource use in Electronics and Years of consumption remaining in global reserves¹⁴

Metal	Use	World mine production per year	Demand for electronics (%)	Years of reserves left	Consumption met by recycled materials (%)
Gold	Bonding wire, contacts, etc.	2,500 tonnes	12	45	43
Silver	Contacts, switches, lead-free solder, conductor, etc.	20,000 tonnes	30	29	16
Tin	Lead-free solder	275,000 tonnes	33	40	26
Copper	Cables, wires, connectors, PCBs, transformers	15 million tonnes	30	61	31
Indium	Flat screen displays, semiconductors	480	79	13	0

Table S3 Collection and dismantling of e-waste in 2009-2013

(A) Obsolete amount of e-waste in 2009-2013 (million unit)¹⁵

Year	TV	Refrigerator	Washing machine	Air conditioner	Microcomputer	Sum
2009	21.9804	5.4622	9.8136	0.9638	13.264	51.484
2010	23.7502	6.5425	10.5015	1.2206	16.5255	58.5403
2011	25.4804	7.4417	11.3052	0.9817	21.4982	66.7072
2012	27.7291	8.679	12.6358	1.5081	25.2981	75.8501
2013	32.0372	12.7857	12.6166	1.52995	37.0628	109.8018

(B) Dismantling amount of e-waste in 2012-2013 (million unit)

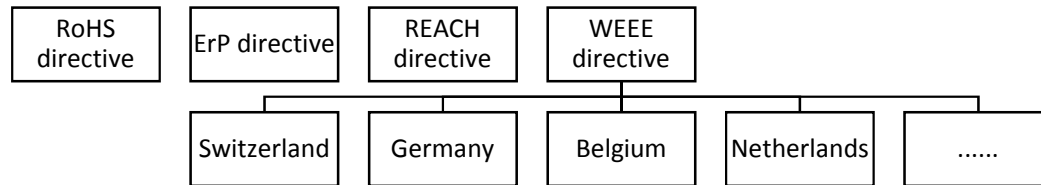
Year	TV	Refrigerator	Washing machine	Air conditioner	Microcomputer	Sum
2012	4.4993	0.2767	0.4024	0.0045	0.6641	12.4499
2013	38.9752	0.5848	1.7131	0.0085	1.3016	42.5832

(C) Dismantling rate of e-waste in 2012-2013 (%)

Year	TV	Refrigerator	Washing machine	Air conditioner	Microcomputer	Sum
2012	16.23	3.19	3.18	0.30	2.63	16.41
2013	121.66	4.57	13.58	0.06	3.51	28.78

Table S4 Legislation system and framework of e-waste management in typical countries and regions

(A) EU and typical countries¹⁶ⁱ

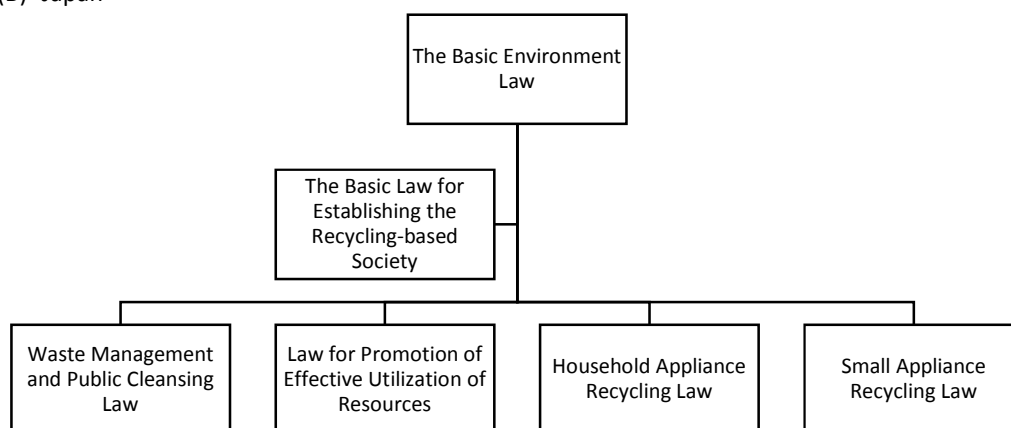


Note: RoHS directive: Restriction of Hazardous Substances Directive; ErP directive: Directive on Energy-related Products; REACH directive: Directive on Registration, Evaluation, Authorization and Restriction of Chemical Substances; WEEE directive: Directive on Waste Electrical & Electronic Equipment.

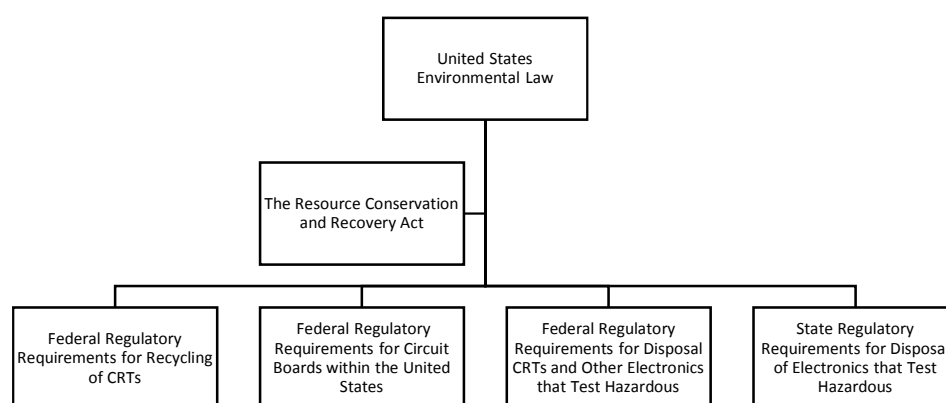
ⁱ http://ewasteguide.info/files/Kummer_2007_Legislation.pdf

	Switzerland	Germany	Belgium	Netherlands	EU requirements
Legal basis	Ordinance on Management of E-waste (ORDEA) and Guidelines issued by Federal Office for the Environment	Electrical and Electronic Equipment Act (ElektroG)	As the competence is at regional level, each of the 3 regions (Flanders, Wallonia, and Brussels Capital Region) has enacted its own decrees and ordinances. Regional Policy Agreements ensure coordination	Environmental Management Act; Electrical and Electronic Equipment (Management)	WEEE Directive (RoHS Directive)
Definition of wastes covered	1.consumer electronics equipment 2.office and ICT equipment 3.household appliances 4.lighting fixtures 5.lamps 6.tools 7.sports and leisure appliances 8.toys	As in WEEE Directive	As in WEEE Directive	1. Refrigerating and freezing equipment 2. heating equipment 3. hot-water equipment 4. washing and drying equipment 5. equipment for preparing food by heat 6. sound equipment 7. image receiving equipment 8. computers 9. paper printing equipment 10. telecommunications equipment 11. charging equipment, kitchen appliances 12. tools 13. other domestic appliances.	1.Large and small household appliances 2.ICT equipment 3.consumer equipment 4.lighting equipment, 5.tools 6.toys 7.leisure and sports equipment 8.medical devices 9.monitoring and control instruments 10. automatic dispensers
Responsibility for collection of WEEE	Producer, importer, distributor and retailer	Public waste management authorities and producer	Retailer and distributor (WEEE Directive)	Retailer and distributor (WEEE Directive); local authorities are responsible for collection of WEEE from private households	Retailer and distributor
Target quota for collection, recovery and re-use	Not addressed by the law	As in WEEE Directive	As in WEEE Directive	As in WEEE Directive	WEEE Directive: Collection: 4 kg per person/year from private households Recovery, reuse and recycling: different quota for different types of appliances
Operation of collection systems	Not explicitly addressed by the law. The system is operated under an industry agreement by 4 PROs (SWICO, SENS, BATREC and SLRS)	Organized by municipalities in cooperation with the Clearing House established by the industry pursuant to the law. Clearing House: Briefing of producers on placement of containers.	Organized by Recupel, a waste management organization founded by the industry in response to the legal obligations imposed on producers (operating in all 3 regions)	The modalities of collection from local authorities, repair companies and suppliers are organized by the manufacturers and importers in accordance with the legal provisions.	Not addressed; Member States are free to determine.
Modalities of collection	Consumers may return WEEE either to 1. producer 2. importer 3. distributor 4. retailer, 5. collection points (PRO owned) 6. public collection points	Private households: consumers to return to community collection points. Industrial: the producer is responsible for organizing collection.	Brussels-Capital: Retailers receive WEEE from consumers	Consumers may return WEEE either to 1. producer 2. retailer, 3. public collection points	Not addressed; Member States are free to determine
Financing	An advance recycling fee (ARF) is levied on sales under a voluntary industry agreement, not regulated by ORDEA. The Federal Government has the competence to introduce a compulsory ARF should this become necessary (e.g. if the voluntary system fails); this has not so far been the case.	Producer finances the transport and treatment of WEEE.	Brussels-Capital: producers have the responsibility to ensure financing. An advance recycling fee is levied on the sales of e-appliances	Producers or importers finance the cycle deficit from retailers, repair companies and collection points established by local authorities.	Financing is under the responsibility of the producer

(B) Japanⁱⁱ



(C) U.S.^{17, 18iii}



(D) China^{16, 19}

Type	Title	Permission party	Effective date
Comprehensive policies and regulations	Environmental Protection Law of the People's Republic of China	Standing Committee of the National People's Congress	January 1, 2015
	Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste	Standing Committee of the National People's Congress	April 1, 2005
	Law of the People's Republic of China on Circular Economy Promotion	Standing Committee of the National People's Congress	January 1, 2009
	Law of the People's Republic of China on Cleaner Production Promotion	Standing Committee of the National People's Congress	July 1, 2012
	Management Regulation on the Recycling of Waste Electrical and Electronic Products	the State Council	January 1, 2011
	Opinions on Strengthening the Prevention and Control of Pollution from E-waste	Ministry of Environmental Protection	December 31, 2012
	Administrative Measures for the State Environmental		February 1,

ⁱⁱ <http://hrd.apec.org/images/8/81/65.16.pdf>

ⁱⁱⁱ <http://www.epa.gov/epawaste/conserve/materials/ecycling/rules.htm>

	Prevention and Control of Environmental Pollution from E-waste	Protection Agency	2008	
Catalogue for recycling	Catalogue of WEEE Recycling (Batch 1) and Guideline for Formulating and Adjusting the Catalogue of WEEE Recycling	National Development and Reform Commission	January 1, 2011	
	Application of Customs Product Code (2010) from Catalogue of WEEE Recycling (Batch 1)	National Development and Reform Commission	January 1, 2011	
	Catalogue of WEEE Recycling (Batch 2)	Announce from National Development and Reform Commission	March 1, 2016	
Development plan	Guideline for preparing development plan of WEEE recycling	Ministry of Environmental Protection	November 15, 2010	
	Notice for preparing development plan of WEEE recycling (2011-2015)	Ministry of Environmental Protection	September 27, 2010	
Qualification licensing for recycling	Administrative Rules for License of WEEE Recycling	Ministry of Environmental Protection	January 1, 2011	
	Guideline for verifying the qualification and license of WEEE recycling enterprises	Ministry of Environmental Protection	December 9, 2010	
Management of recycling fund	Administrative Rules for License of WEEE Recycling	Ministry of Finance	July 1, 2012	
	Notice for verifying the situation of WEEE recycling	Ministry of Environmental Protection	September 3, 2012	
	Guideline for verifying the subsidy of WEEE recycling enterprises	Ministry of Environmental Protection	November 16, 2010	
	Notice for clarifying the types of EEE for fund levying	Ministry of Finance (2012)	July 1, 2012	
	Notice for completing the policy of WEEE recycling fund	Ministry of Finance (2013)	December 2, 2013	
Others	Technical specification for pollution control of WEEE recycling	Ministry of Environmental Protection	April 1, 2010	
	Technical policy for pollution prevention of WEEE	Ministry of Environmental Protection	April 27, 2006	
	Guideline for formal dismantling operation and production management of WEEE	Ministry of Environmental Protection	January 1, 2015	
	Administrative Rules for Regenerative Resources Recycling	Ministry of Commerce	May 1, 2007	

References

1. Kilic, H. S.; Cebeci, U.; Ayhan, M. B., Reverse logistics system design for the waste of electrical and electronic equipment (WEEE) in Turkey. *Resour. Conserv. Recy.* **2015**, *95*, (0), 120-132.
2. Song, Q.; Wang, Z.; Li, J., *E-waste Management and Assessment in Macau*. LAP LAMBERT Academic Publishing: Deutschland, Germany, 2014; p 176.
3. StEP StEP E-waste WorldMap. <http://www.step-initiative.org/index.php/WorldMap.html> (July 9, 2014),
4. Breivik, K.; Armitage, J. M.; Wania, F.; Jones, K. C., Tracking the Global Generation and Exports of e-Waste. Do Existing Estimates Add up? *Environ. Sci. Technol.* **2014**, *48*, (15), 8735-8743.
5. Robinson, B. H., E-waste: An assessment of global production and environmental impacts. *Sci. Total Environ.* **2009**, *408*, (2), 183-191.
6. Kahhat, R.; Williams, E., Product or waste? Importation and end-of-life processing of computers in Peru. *Environ. Sci. Technol.* **2009**, *43*, (15), 6010-6.
7. Müller, E.; Schluep, M.; Widmer, R.; Gottschalk, F.; Böni, H. In *Assessment of e-waste flows: a probabilistic approach to quantify e-waste based on world ICT and development indicators*, R'09 World Congress, 2009; 2009; pp 14-16.
8. Huisman, J.; Magalini, F. In *Where are WEEE now? Lessons from WEEE: Will EPR work for the US?*, Electronics & the Environment, Proceedings of the 2007 IEEE International Symposium on, 2007; IEEE: 2007; pp 149-154.
9. Cobbing, M., Toxic Tech: Not in Our Backyard. Uncovering the Hidden Flows of e-waste. Report from Greenpeace International. In 2008.
10. Agoramoorthy, G.; Chakraborty, C., Environment: Control electronic waste in India. *Nature* **2012**, *485*, (7398), 309-309.
11. Mmereki, D.; Li, B.; Li'ao, W., Waste electrical and electronic equipment management in Botswana: Prospects and challenges. *J. Air Waste Manage. Assoc.* **2014**, *65*, (1), 11-26.
12. Nnorom, I. C.; Osibanjo, O., Electronic waste (e-waste): Material flows and management practices in Nigeria. *Waste Manage. (Oxford)* **2008**, *28*, (8), 1472-1479.
13. Environment, M. o.; UNEP *WEEE/E-waste Management Report, Phnom Penh Municipality Kingdom of Cambodia*; 2009.
14. McCann, D.; Wittmann, A., *Solving the E-Waste Problem (Step) Green Paper: E-waste Prevention, Take-back System Design and Policy Approaches*. United Nations University/Step Initiative: 2015.
15. Guan, A.; Tang, A., Annual Report for Waste Electrical and Electronic Product Recycling Industry in 2013. In China Resource Recycling Association: Beijing, 2015; p 76.
16. Zeng, X.; Li, J.; Stevels, A. L. N.; Liu, L., Perspective of electronic waste management in China based on a legislation comparison between China and the EU. *J. Clean Prod.* **2013**, *51*, (0), 80-87.
17. Kahhat, R.; Kim, J.; Xu, M.; Allenby, B.; Williams, E.; Zhang, P., Exploring e-waste management systems in the United States. *Resour. Conserv. Recy.* **2008**, *52*, (7), 955-964.
18. USEPA Electronics Waste Management in the United States Through 2009. <http://www.epa.gov/osw/conserve/materials/eycycling/docs/fullbaselinereport2011.pdf> (EPA 530-R-11-002),
19. Zhang, B.; Cao, C., Four gaps in China's new environmental law. *Nature* **2015**, *517*, 433-434.