

# THE CASE OF ELECTRONIC WASTE



## HOW TO TRANSFORM AN ENVIRONMENT PROBLEM INTO AN ECONOMIC OPPORTUNITY?

## 1. Problem setting - From a global perspective on e-waste to the Italian case

“Electrical and electronic equipment” or “EEE” means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1000 volts for alternating current and 1500 volts for direct current (Source: Directive 2011/65/EU).

When Electrical and Electronic Equipment are disposed of because the owner discards them without the intent of reuse, the waste generated is known as “Waste from Electrical and Electronic Equipment” (WEEE). This category includes mobile phones, computers, televisions, fridges, household appliances, lamps but also medical devices and photovoltaic panels. In the identification of e-waste, two main issues occur:

- What is not EEE: Batteries and electricity storage devices, appliances specifically designed for and installed in the automotive sector and every electronic component related to national security and to space do not fall under EEE definition (mainly because they require a different processing);
- What is not waste: Appliances are considered waste when they are not actually reusable or repairable: obsolescence and reparability are fundamental in the classification of e-waste, increasing its amount.

Following the UNU-KEYs we can identify six macro categories of e-waste:

1. **Temperature exchange equipment** (e.g. refrigerators, freezers, air conditioners);
2. **Screen and monitors** with displays exceeding 100 cm<sup>2</sup> (e.g. televisions, monitors, laptops, note-books and tablets);
3. **Lamps** (e.g. fluorescent, high-intensity discharge and LED lamps);
4. **Large equipment** over 50 cm in size (e.g. washing machines, dishwashers, electric stoves, large printers, copying equipment and photovoltaic panels);
5. **Small equipment** under 50 cm (e.g. vacuum cleaners, microwave ovens, toasters);
6. **Small IT and telecommunication equipment** under 50 cm (e.g. mobile and other phones, personal computers, GPS devices, routers and printers).

The UNU-KEY framework is widely adopted as the international standard to categorize e-waste, ensuring consistency in measurement and reporting across different regions and countries. It allows for more accurate tracking of e-waste flows and supports efforts to increase recycling and recovery rates worldwide.

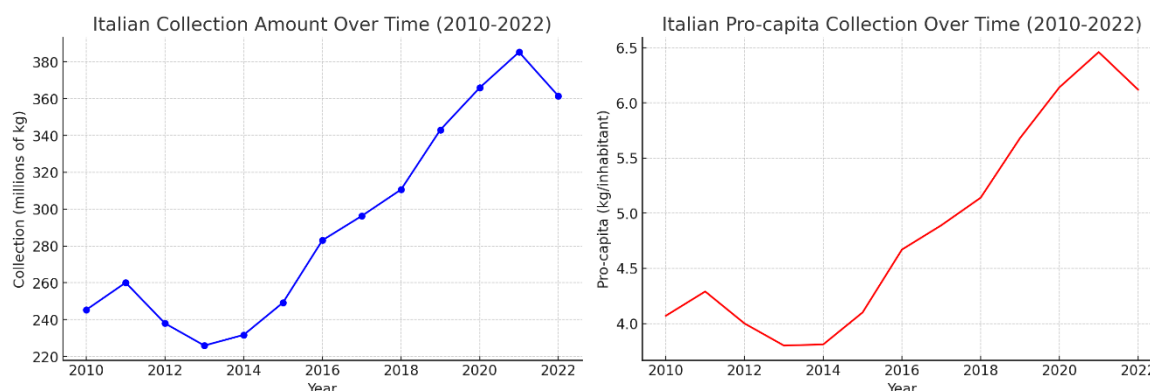
In parallel with the growth of electronic consumption, we have been witnessing a fast growth in electronic waste generation. Since 2010, it is estimated that the world production of e-waste has been increasing by around 2,3 billion kilograms per year. The rate of recycling has not been able to cover proportionally the rate of growth of the production of e-waste ([Table 1](#)). This could be due to technological progress, higher consumption, limited repair options, short product lifecycles, growing electrification and inadequate e-waste management infrastructure, as suggested by *The Global E-waste monitor 2024*.

As a result of the European regulation, Italy witnessed an overall improvement of the collection rate ([Table 2](#)). Nevertheless, the Italian scenario is not encouraging. After eight years of growing rates, starting from 2022 the amount of WEEE involved in the recycling process is decreasing. Forecasts suggest that this trend is consistent for the short-term projection. This may be due to WEEE dispersion because of incorrect classification, use of non-official channels, lack of disposal, low amount of purchased appliances (related to abnormal purchases during the pandemic), the extinction of the so called “Bonus TV”<sup>1</sup>, low number of collecting points in the Central and Southern Italy (which fostered the retail channel).

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<sup>1</sup> The initiative offered a discount of up to 20% at a maximum amount of 100€ if the purchase of a TV was combined with the disposal of the old one.

Another key aspect to consider is that WEEE contains critical raw materials (CRMs), vital for industries like renewable energy and digital technologies. Effective recycling could reduce Italy's reliance on foreign CRMs, but only 37% of WEEE is collected, compared to the EU target of 65%. Achieving this goal could recover 17,000 tons of CRMs by 2030, reducing Italy's dependence on imports.



## E-WASTE ISSUES

Addressing e-waste management is crucial to the severity of its impact on environmental, economic, and social issues.

Firstly, recycling WEEE, which has an estimated ecological footprint of around 0.023 Gha/ton per year, reduces the need for raw material extraction, thus mitigating the harmful effects of mining such as CO<sub>2</sub> emissions, pollution, biodiversity loss, and land degradation. Moreover, improper e-waste management leads to hazardous activities, especially in developing countries, where rudimentary methods of extracting valuable materials pose severe risks to both human and environmental health.

It is crucial to recover vital raw materials (CRMs) from WEEE, especially for economies like Italy and the EU as they depend heavily on foreign supplies, which could be risky from a geopolitical standpoint. Urban mining is a strategic solution to reduce reliance on imports. It is the process of recovering critical raw materials from waste of electrical and electronic equipment and has the potential to be a cornerstone in addressing the global challenge of critical raw material shortages. For instance, it allows the recovery of metals such as gold, copper, and palladium, which are increasingly rare in natural ore deposits.

Economically, The Global E-waste Monitor 2024 estimates that recovering materials from e-waste and avoiding greenhouse gas emissions could save around 28 and 23 billion USD, respectively. However, these benefits are outweighed by the long-term social and economic costs of GHG emissions and waste treatment, estimated at 59 and 10 billion USD. The current system thus incurs a net loss of 37 billion USD, emphasizing the urgent need to be reformed.

## 2. Institutional settings - EU legislation and Italian transposition

### INTERNATIONAL LEGISLATION

The **Basel Convention (1989)** governs the management of e-waste by classifying it as hazardous waste, requiring prior informed consent for transboundary movements, and providing technical guidelines for safe disposal. Additionally, it enhances the capacities of member states to manage e-waste in an environmentally sound manner, mitigating its adverse effects on human health and the environment.

### EU LEGISLATION

Efficient and effective regulation of e-waste is essential to limit the increasing undocumented flows of this waste stream. Europe provided two important legislative tools, then transposed in national systems:

- **WEEE DIRECTIVE (2012/19/EU)**

It is founded on the principle of *Extended Producer Responsibility* (EPR), according to which the Producer of EEE is responsible of its products not only during their lifecycle, but also when they become waste: its commitment is required both from the design point of view and from the managerial and economic one, by ensuring e-waste transport and treatment. For what concerns the design aspect, the reference is the Ecodesign for Sustainable Products Regulation (EU) 2024/1781, which improves product durability, repairability and recycling and introduces a Digital Product Passport to promote products' circularity.

Moreover, the Directive 2012/19/EU:

- requires the separate collection and proper treatment of WEEE and sets targets for their collection, recovery and recycling: among them, from 2019 all EU states must respect a new collection target, which is 65% of the average weight of EEE put in the market in the three previous years;
  - helps EU countries fight illegal waste exports more effectively by making it harder for exporters to disguise illegal shipments of WEEE;
  - reduces the administrative burden by calling for the harmonization of national EEE registers and of the reporting format.
- **ROHS DIRECTIVE (2011/65/EU)**

It aims to prevent the risks posed to human health and the environment related to the management of electronic and electrical waste. It does this by restricting the use of certain hazardous substances in EEE that can be substituted by safer alternatives. These restricted substances include heavy metals, flame retardants or plasticizers.

The Directive promotes the recyclability of EEE, as these products and their components that have become waste contain fewer hazardous substances. At the same time, it guarantees fair competition among manufacturers and importers of EEE within the European market.

The European Commission has mandated the European Standardization Organization (CENELEC) to develop standards for the collection, transport and treatment of waste for all products covered by the WEEE Directive. The standards also cover preparation for reuse.

The Commission has recently adopted a directive on common right-to-repair rules (**R2R Directive**), Directive (EU) 2024/1799: the aim is to prioritize repair over replacement to reduce waste and support the repair sector by making it easier and more cost-effective to repair goods. Manufacturers will be required to repair products which are technically repairable under EU law. Goods repaired under the warranty will benefit from an additional one-year extension of the legal guarantee and after the legal guarantee has expired, the manufacturer is still required to repair common household products.

## ITALIAN LEGISLATION

The key element of the Italian legislation on WEEE is represented by the **Legislative Decree 49/2014**, which arises from the transposition of Directive 2012/19/EU.

Its implementation aspects are defined by some Ministerial Decrees, including the following:

- **“One-for-Zero” Decree** (Ministerial Decree 121/2016): it regulates the take-back by distributors of small WEEE from households, free of charge and without the obligation to purchase an equivalent product;
- **“One-for-One” Decree** (Ministerial Decree 65/2010): it ensures the free take-back of WEEE coming from households by distributors and EEE installers when purchasing an equivalent product.

From 15 August 2018, the Decree has introduced a wider scope of application, called “*Open Scope*”: this has enlarged and eased the WEEE subjected to the legislation, establishing a new classification of EEE based on dimensional criteria, instead of EEE typology (see the 6 macro categories on page 1).

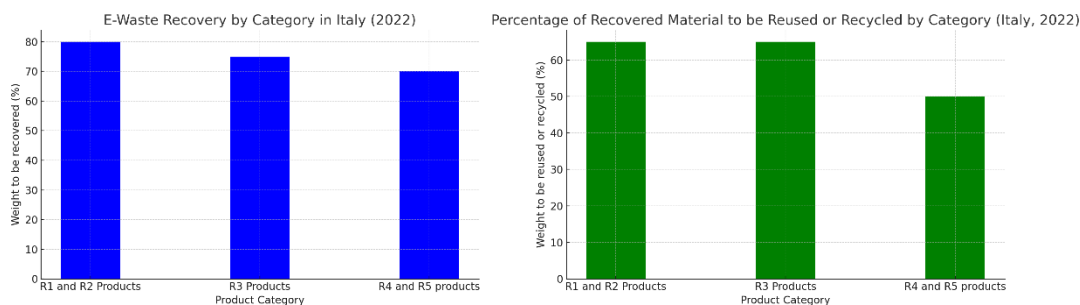
However, a widely adopted classification for domestic WEEE is still based on the type of EEE (**Ministerial Decree 40/2023**). It identifies five different classes of waste:

- R1: Temperature exchange equipment (refrigerators, freezers, air conditioners, driers, etc.)
- R2: “Others big white” (washing machines, dish washer, suction hood, ovens, etc.)
- R3: Tv and monitors (televisions and screens, tablets, electronics frames, etc.)

- R4: IT and consumer electronics, lighting appliances, PED and others (small home appliances, electronic or digital tools, lighting equipment, solar panels, etc.)
- R5: Light sources (EDL, fluorescent lamps, neon, LEDs, etc.)

Article 9 of **Legislative Decree 151/2005** addresses the implementation of European directives concerning the reduction of the use of hazardous substances in electrical and electronic equipment and the management of waste from such equipment. It also clearly defines the treatment phase of WEEE and establishes recovery and recycling percentages that must be achieved for each category of product. Recovery refers to the use of still functioning parts of the product as replacement components for another device. Where this is not possible, the product is disassembled with the intention of retrieving the recyclable material, generally glass, iron, copper. The recovered material can be used in the production cycle of other goods. In this case, it is considered recycling ([Table 3](#)).

Most policies and regulations focus on collection and recycling; hardly any include targets for recovering critical raw materials. As a result, the focus is on the process of recovering materials occurring in large quantities, such as steel, plastics, iron, copper, gold, silver, etc., to the detriment of CRM like rare earths elements. It is worth noticing that the recycling rate for rare earth elements contained in e-waste is only around 1%: the introduction of a specific recovering target could lead to a meaningful improvement.



### 3. Companies and market structure: the Italian system for WEEE's management

#### THE MULTI-CONSORTIUM SYSTEM

In Italy, e-waste is managed by a national multi-consortium system. The Coordination Center (*Centro di Coordinamento RAEE*, CdC) is the reference point of the system and regulates the activities of all the actors involved. Its fundamental role is considered an example of organizational setup within the waste management system at a European level. CdC is made of Collective Systems (*Sistemi Collettivi*), non-profit consortia founded by EEE's producers that take e-waste from collection sites and aggregation points across the national territory and transport it to specialized treatment facilities qualified for its recovery. These highly adapted plants carry out recycling activities and material valorization to obtain secondary raw materials to be reintroduced into new production processes.

The financing of WEEE management system comes indirectly from EEE producers that contribute proportionally to their market share. However, it would be more correct to say that consumers are the ones who bear the cost of the recycling system through the eco-contribution they pay when they purchase a new product.

Collective systems are legally required to join the CdC and, as of today, the CdC includes 14 consortia of domestic EEE producers and one consortium of professional EEE producers.

EEE producers, through Collective Systems, create Private Collection Centers (*Centri di Raccolta Privata*, CRP) to store waste from the voluntary collection activities carried out by EEE retailers. The minimum requirements to register a CRP on the CdC portal are the following:

- authorization of the CRP under Legislative Decree 152/2006;
- received WEEE is of exclusively domestic origin;
- the CRP is equipped with a scale to weigh the outgoing waste;
- WEEE is divided into one or more groups as indicated in Annex 1 of Ministerial Decree 40/2023: R1, R2, R3, R4, R5.



Next to the registration, the CdC assigns the designated categories of the CRP to the Collective Systems responsible for collection. The CRP must adhere to the general conditions for collecting and managing WEEE as defined in a specific regulation.

In terms of market share, Erion consortium owns the management of 60% of household waste. Of the remaining 40%, several smaller shares stand out: ERP Italia Consortium at 9%, Cobat RAEE with 7% and Ecolight Consortium contributing 5%. Although the regulation divides the market by allowing companies to enter with as little as 1% of the market, Erion retains significant market dominance due to the highly competitive contribution cost.

## HOUSEHOLD COLLECTION

Focusing on collection, there are two main collection channels for WEEE coming from households:

- **Centri di raccolta comunali (CdR):** fixed collection points set up by municipalities where citizens can dispose of their e-waste free of charge, sorted by categories. They are managed either by the municipalities themselves or by companies entrusted with waste collection, which can collect WEEE from citizens of one or more municipalities, depending on existing agreements. Each single city is managed differently from one another. The tender process is employed to outsource the service (for instance, AMSA operates in Milan and AMA in Rome).
- **Luoghi di raggruppamento (LdR):** sites set up by one or more EEE retailers that collect e-waste returned by customers through the "One-to-One" or "One-to-Zero" models. To benefit from the WEEE collection service coordinated by the CdC, retailers must adhere to the conditions established by the program agreement.

## TREATMENT

WEEE requires special handling aimed at minimizing the risk of environmental contamination and protecting public health, as well as enabling the recovery of raw materials contained within. For this reason, they can only be processed in facilities authorized for their recovery and recycling, in compliance with Italian and European regulations.

The Treatment Facilities (*Impianti di Trattamento*) are companies authorized to perform recycling and recovery activities for WEEE. According to Legislative Decree 49/2014, facilities that intend to treat domestic e-waste must register to the CdC RAEE and demonstrate that they meet the standards outlined in the program agreement for proper WEEE treatment. Registration to the WEEE Coordination Center's register is free and required also for facilities that only perform the movement and storage of electronic waste. Registration does also not depend on the WEEE's origin (domestic or professional).

When electronic waste reaches treatment facilities, it is meticulously stored in specific places to avoid environmental concerns and grouped in comparable categories. The first process requires carefully extracting dangerous compounds and components such as mercury, oils, and refrigerants, followed by physical disassembly to recover precious materials such as high-grade plastics.

After that, the waste is shredded to considerably reduce its size. Conveyor belts transport waste into shredding machines, producing bits typically only a few millimeters in size. Subsequent sorting procedures separate ferrous and non-ferrous metals, which are then processed into secondary raw materials. Dust created during sorting is immediately collected to preserve material integrity and prevent environmental pollution. The entire process is closely monitored by Quality Monitoring Systems for Treatment, which ensures strict adherence to expected treatment standards and performance benchmarks.

Glass, plastic and metals are the most economically beneficial materials due to relatively simple recycling processes. Common metals found in WEEE include iron, aluminum, copper and gold.

## 4. Innovative strategies for E-waste Reduction

### DEPOSIT RETURN SYSTEM

We believe that the most significant solution to be adopted is in the form of economic incentives on the model of **Deposit Return System (DRS)**. This is a collection system where the consumer pays a small deposit in addition to

the sales price of the product, which is fully refunded when the product is returned to a designated collection center. It incentivizes consumers to properly dispose of waste, as there is a direct financial return, and it is already used for plastic bottles and cans in over 50 countries around the world. In European countries with DRS, the average collection rate for this type of waste is 94%. In countries without it, the percentage peaks at 47%. One of the most virtuous examples in Europe is Germany, which in 2021 managed to collect 98% of single-use beverage packaging. In Berlin, the DPS for PET bottles was officially introduced in 2003 and further developed in 2006 and it is still a winning scheme.

It is possible to implement this solution to a specific type of electronic waste: small-sized products belonging to the R4 category such as toasters, hairdryers, electronic toys, or smartphones are ideal, as they are not often disposed properly due to their reduced size.

Once the consumers buy the product the deposit is included in the price and effectively disclaimed, this is necessary to inform and make them aware that once they decide to give the product back, they will be refunded. The proposed DRS system is not designed to provide an additional financial incentive to consumers but simply facilitates the return of the deposit originally paid at the time of purchase. Furthermore, the system does not disrupt the natural flow of the internal market but operates independently. When a consumer chooses to sell a product to another consumer, the resale price will reflect the inclusion of any unclaimed deposit. Products purchased before the deposit system implementation will not be eligible for deposit refunds, as the system's effects will only apply to products for which a deposit was actually paid at the time of purchase, having an *ex nunc* effect. Consequently, this mechanism will not encourage consumers to prematurely dispose of still-functioning devices. Our primary objective is to prevent electronic devices from remaining unused, thus allowing the recovery of critical raw materials, whose value often exceeds that of the deposit itself.

To make the system effective, collection points must be easily accessible. Many consumers are not informed about what a collection station is and often resort to improper disposal practices for WEEE. To greater awareness about waste trafficking and the environmental damage caused by improper disposal of e-waste, it's suggested to develop communication campaigns to educate end users on this new disposal method and conducting surveys to understand potential incentives.

In terms of placement, collaborations with supermarkets and shopping centers can be strategic, as these areas are frequently visited by most people. Likewise, collaborating with appliance manufacturers, local authorities, and environmental organizations would facilitate not only the program logistics, but also increase its visibility and legitimacy. In this sense, the criticality stands within the right economic incentive, to be found through practice. Differently from the PET bottles system, the technology to use a smart bin for e-waste is still not available. To avoid moral hazard, to teach consumers on the required process and to refund the right deposit to each device, a first implementation would lean on direct contact with an employee. This person should be instructed to safely withdraw and separate e-waste, and to correctly refund the user.

The system has wide growth opportunities, especially leveraging on a robust regulation and on the birth of the EU Digital Product Passport. On one side, the law should establish the right refunding amount for each sub-category of R4; on the other, the digital passport could be enriched with this information. In this way, through QR reading technology, a specific smart bin could be introduced to properly and autonomously manage e-waste and assign incentives.

Finally, implementing a system to monitor the effectiveness of the program and collect feedback from participants can help make continuous adjustments and improvements. This could include collecting data on the number of items returned and consumers' opinions on the process. Overall DRS seems a good choice as it leverages on a well-known system, already effective in other scopes of application (e.g. PET bottles); aligns stakeholders' interests in a win-win perspective; it does not require consistent adaptation on different city environments. It will be essential to ensure that the collection points are adequately equipped to safely handle such waste and that the staff is trained to manage the associated risk: the hazard of WEEE compared to more common waste is greater, since

these devices may contain toxic substances that are easily inflammable. In general, it is important to multiply the opportunities for e-waste recovery: the collection of WEEE, especially small electrical appliances (R4), is very complex and having a multitude of collection points increases the final output.

### **PARTNERSHIP WITH REPAIRMENT SHOPS**

To regulate also the old goods which are not under the DRS an innovative solution can be gifting rewards to users who dispose them correctly, by giving them to repairment centers. Authorized repairment centers would accept the waste and offer a repairment discount/vouchers for other products instead of a monetary reward. The vouchers are allocated by the specific shop that will repair or upgrade the good brought by the customer. This completely innovative initiative in the market would: facilitate the collection of old e-waste that is often abandoned in citizens' homes, extending the lifespan of products with free hardware or software upgrades and avoid the consumption of other goods preferring a circular approach.

It would contribute to increasing the percentage of e-waste collected in a responsible manner, complementing the DRS, while enhancing the sustainability of the overall system. The main threat of this new proposal would be the computation of the right value for each voucher, which can vary on the specific characteristics of the delivered product such as model, usage, conditions. To guarantee the same treatment, an unambiguous value must be established by an external authority under a devoted analysis of sector experts.

The EU, as stated before, published several directives to promote repair, which contributes to sustainable consumption. The right-to-repair directive is one of several laws aiming to increase the lifespan of consumer goods. In addition to requiring manufacturers to adhere to reparability standards, which are also part of the Ecodesign objective, it attempts to encourage customers to keep their repairable goods for a longer period. It requires that manufacturers provide information about their repair services, which is a crucial requirement in building stronger relationships between businesses and leads repairment services to provide better customer care.

In conclusion, the system can work only under governmental regulations within the manufacturer companies. Although the value of the good at the end of its life span is still positive, it might be economically unsustainable for the repairment shop to refurbish it. Therefore, governmental incentives must be allocated to compensate for the shop's loss. Funds might be collected by the EU through taxes or similar mechanisms imposed on the manufacturing company.

There are no other examples of a trade-in to repairment activity but examples of trade-in to money. Trading money instead of repairment vouchers wouldn't increase directly the lifespan of an existing project but would incentivize the purchase of another good. Amazon started on April a new campaign called "Amazon Trade-in", in which they refurbish or recycle old devices, and offer a digital gift card to be spent on its e-commerce. A similar activity is done by Currys a British electrical retailer and aftercare service provider which offers vouchers to be spent within the company in return for old devices. Although big e-commerces both in the USA and UK are pursuing these marketing strategies, those are not the best solution for pursuing a fully complete circular economy.

## **5. Conclusion**

In Italy, the current collection rate for WEEE is around 37%, still very far from the EU target of 65%. At this current rate, 280,000 tons of WEEE would not be recovered by 2025, with a yearly expected loss of 15,600 tons of CRM. Proposing a mix of solutions able to increase the touchpoints with the final user is mandatory. In this perspective, the Deposit Return System could be an interesting application as the economic incentive could be a key driver for better collection. Additionally, establishing partnerships with repair shops could play an important role in this process by acting as collection hubs and raising awareness about e-waste management, while also encouraging repairs over disposal.

The goal is that innovation and technology within cities' systems, along with strategic collaborations, can provide models able to guide a more responsible and effective e-waste management positively impacting our planet.



## ATTACHMENTS

Table 1. World e-waste production and recycling rates (source: The global e-waste monitor 2024)

Year	2010	2022
World e-waste production (kg)	34 billion	62 billion
Recycled world e-waste (kg)	8 billion	13,8 billion
Recycled world e-waste (%)	23,5	22,3

Table 2. Italian collection amount in kg (source: centro di coordinamento RAEE)

Year	Collection (millions of kg)	Pro-capita (kg/inhabitant)
2010	245.350	4,07
2011	260.090	4,29
2012	237.965	4,00
2013	225.931	3,80
2014	231.717	3,81
2015	249.254	4,10
2016	283.075	4,67
2017	296.274	4,89
2018	310.610	5,14
2019	343.069	5,68
2020	365.897	6,14
2021	385.258	6,46
2022	361.381	6,12

Table 3. Recovering, recycling and reusing for each category of e-waste in Italy – 2022

	Weight that must be recovered (%)	Of the recovered material, weight that must be reused or recycled (%)
R1 and R2 Products	80%	65%
R3 Products	75%	65%
R4 and R5 products	70%	50%

## REFERENCES

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- [Countering WEEE Illegal Trade Summary Report.](#)