

Dutch waste stream systems and potential for CRM recovery

A comprehensive evidence based analysis

**Volume II: Waste of Electrical and Electronic Equipment
(WEEE)**

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The NMO has made an effort to provide a complete picture of the extraction, processing and application of Dutch waste stream systems and potential for CRM recovery. At the same time, this is a living document, in which the NMO will incorporate new insights and updates in subsequent versions. If the reader sees errors or gaps, or has additional information that strengthens the document, the NMO is recommended to receive these comments in order to improve subsequent versions.

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The Netherlands Materials Observatory (NMO) collects, manages, and provides data, information, and knowledge about Critical Raw Materials (CRMs) and strategic supply chains. In doing so, the NMO contributes to a resilient and robust economy and society. The NMO works together with the Dutch national government, companies and research institutions in the Netherlands and abroad. The NMO provides insight into the supply and availability of these CRMs in the Netherlands and the European Union (EU). An enhanced understanding enables policymakers and businesses to respond more effectively to risks associated with supply chain disruptions.

The NMO collaborates with partners (e.g., industry) from the recycling value chain and the research community to analyse how the Netherlands (and neighbouring countries) can contribute to increasing recycling rates and, by extension, to meeting the Critical Raw Material Act (CRMA) benchmarks. To understand the potential material contributions to the CRMA recycling benchmarks from various waste streams, and the role of the recycling industry and circular strategies, it is important to examine the systems in place for recovering materials from specific waste streams, as well as the capabilities of these industries in the Netherlands.

Therefore, the NMO is conducting a series of case studies and activities to understand the context and background of different Dutch waste streams, end-of-life of product groups, secondary materials and the recycling industry. These efforts aim to support the Dutch ambitions and contributions to the CRMA benchmarks¹, as well as enhance supply resilience for the Dutch economy.

This report focuses on current activities aimed at recovering or disposing of specific waste streams, their connections to CRMs and the recycling systems (including collection, processing, etc.) and the industry landscape around them in the Netherlands. This work is an essential step in identifying and evaluating potential opportunities for material recovery and supporting decision-making related to promoting the recovery of CRM-containing waste streams.

¹ "Union recycling capacity, including for all intermediate recycling steps, is capable of producing at least 25 % of the Union's annual consumption of strategic raw materials and is capable of recycling significantly increasing amounts of each strategic raw material from waste." (European Commission, 2024)

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2. Volume II: Waste of Electrical and Electronic Equipment (WEEE)

2.1 Synthesis of observations

- Waste of Electrical or Electronic Equipment (WEEE) is a highly heterogeneous waste stream, covering multiple electrical products with different lifespans and material compositions. WEEE is divided into 72 categories within six main product groups: temperature exchange equipment, screens and monitors, lamps, large equipment, small equipment, Small IT and telecommunications. In 2024, approximately 168 kt of WEEE were collected in the Netherlands.
- WEEE consists of various materials such as glass, plastics, and a wide range of different metals. The waste stream contains varying quantities of all Critical Raw Materials (CRMs). Figure 1 represents the availability of elements (not limited to CRMs) present in the Dutch WEEE. Key components containing CRMs within Dutch WEEE include printed circuit boards (PCBs) and magnets (containing neodymium and dysprosium). Understanding and improving CRM recovery is a significant challenge, given that the composition of WEEE is constantly evolving over time, making it difficult to maintain accurate knowledge of material availability.
- The collection and recycling of WEEE is dictated by EU legislation, where producers (including importers and distributors) must organize the waste management activities. In the Netherlands, this is executed on behalf of the producers by Stichting OPEN. Producers must collect either 65% of WEEE (based on the volumes put on market) or 85% (based on the volumes of WEEE generated). Additionally, the voluntary European Committee for Electrotechnical Standardization (CENELEC) standard, which sets reporting and processing requirements, is mandatory for WEEE processors contracted by Stichting OPEN.
- The Netherlands and surrounding countries have not met EU collection targets for WEEE. The Netherlands' collection rate performance is lower than that of neighbouring countries, Germany and Belgium. In 2024, Stichting OPEN collected approximately 168 kt of WEEE; this collection amount corresponds to 64% of the waste generated in the country. Several studies indicate that significant quantities of WEEE are currently left unused at households, incorrectly disposed of, or exported (unadministered) abroad.
- There is a settled collection and pre-processing system of WEEE in the Netherlands, coordinated by Stichting OPEN, which follows the established CENELEC standard. The major base metals, precious metals and platinum metals present in the various WEEE fractions drive the recycling market, mainly outside the Netherlands, as

recovery within the country is minimal. The majority of Dutch WEEE-derived fractions are generally transported abroad to countries such as Japan (for precious metals) and Germany (for copper and aluminum).

- Material recovery by Dutch pre-processors is financially supported by prevailing market prices for metals such as aluminum, nickel, copper, ferrous/steel, and precious and platinum metals such as gold, silver, palladium, and platinum. In the case of non-economically recyclable materials, the process is supported through contracts with Stichting OPEN, which determines if a gate fee is paid for their services.

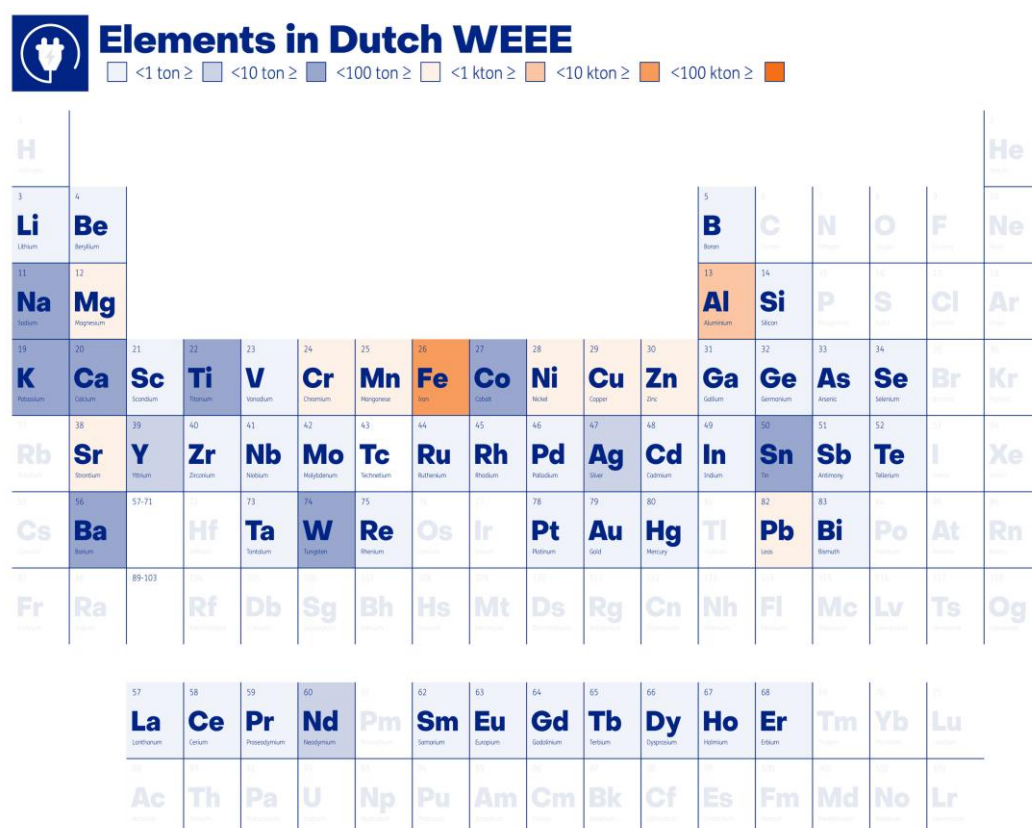


Figure 1. Elemental availability and quantity within Dutch WEEE in 2024. The color scheme represents the different elemental volumes present in WEEE not limited to CRMs.

2.2 Definition and characterization

WEEE and Electrical and Electronic Equipment (EEE) are defined in the WEEE directive as (European Parliament and the Council of the European Union, 2012):

- “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 1,000 volts for alternating current and 1,500 volts for direct current”.
- “‘waste electrical and electronic equipment’ or ‘WEEE’ means electrical or electronic equipment which is waste [...] including all components, sub-assemblies and consumables which are part of the product at the time of discarding”.

(W)EEE is classified into six major reporting categories (composed of 72 subcategories), which all member states have to report on (Table 1). Each category includes different products with varying lifespans. Waste products from industrial or commercial environments are also considered WEEE (Huisman et al., 2017). It is estimated that in the EU, 32.2 kg of new EEE per person were put on the market in 2023 (Eurostat, 2024).

Table 1. EU WEEE categories and specific products (European Parliament and the Council of the European Union, 2012)

Category	Examples
1. Temperature exchange equipment	Refrigerators, Freezers, Equipment which automatically delivers cold products, Air conditioning equipment, Dehumidifying equipment, Heat pumps, Radiators containing oil and other temperature exchange equipment using fluids other than water for the temperature exchange.
2. Screens and monitors	Screens, Televisions, LCD photo frames, Monitors, Laptops, Notebooks.
3. Lamps	Straight fluorescent lamps, Compact fluorescent lamps, Fluorescent lamps, High intensity discharge lamps - including pressure sodium lamps and metal halide lamps, Low pressure sodium lamps, LED.
4. Large equipment	Washing machines, Clothes dryers, Dish washing machines, Cookers, Electric stoves, Electric hot plates, Luminaires, Equipment reproducing sound or images, Musical equipment (excluding pipe organs installed in churches), Appliances for knitting and weaving, Large computer-mainframes, Large printing machines, Copying equipment, Large coin slot machines, Large medical devices, Large monitoring and control instruments, Large appliances which automatically deliver products and money, Photovoltaic panels.
5. Small equipment	Vacuum cleaners, Carpet sweepers, Appliances for sewing, Luminaires, Microwaves, Ventilation equipment, Irons, Toasters, Electric knives, Electric kettles, Clocks and Watches, Electric shavers, Scales, Appliances for hair and body care, Calculators, Radio sets, Video cameras, Video recorders, Hi-fi equipment, Musical instruments, Equipment reproducing sound or images, Electrical and electronic toys, Sports equipment, Computers for biking, diving, running, rowing, etc., Smoke detectors, Heating regulators, Thermostats, Small Electrical and electronic tools, Small medical devices, Small Monitoring and control instruments, Small Appliances which automatically deliver products, Small equipment with integrated photovoltaic panels.

6. Small IT	Mobile phones, GPS, Pocket calculators, Routers, Personal computers, Printers, Telephones.
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In 2024, approximately 168 kt of WEEE were collected in the Netherlands by the formal collection system (Stichting OPEN, 2025c). The largest amount in terms of mass came from temperature exchange equipment and large equipment (see Table 2).

Table 2. Weight of WEEE product categories collected in the Netherlands in 2024 (Stichting OPEN, 2025c).

Product category	Weight collected in 2024 (kt)
1. Temperature exchange equipment	39.7
2. Screen and monitors	11.7
3. Lamps	1.4
4. Large equipment	74.5
5. Small equipment	31.2
6. Small IT	9.5

Over the last few decades, electronics have undergone significant evolution in terms of function and material usage. For example, in the 1980s a mobile phone contained on average 12 elements, while currently it contains more than 60 (Meskers et al., 2023). The chemical composition and material mixes vary between products with different functions and also between products with the same function, such as those from different phone brands or refrigerators. Due to this complexity, the collection and recycling of WEEE have taken a Product Centric approach, rather than a materials-focused one (M. Reuter et al., 2013). The complex material compositions and combinations in modern electronics pose challenges for the complete recovery of elements using generalized recycling processes. To address this structural limitation, advanced dismantling and sorting techniques could be prioritized to ensure that distinct material fractions are routed to highly specialized end-of-life processing streams.

2.3 Composition and components of Dutch WEEE

Figure 2 shows the presence of CRMs in Dutch WEEE for 2024. This composition excludes batteries contained in EEE, as this waste flow is covered in a different volume. The largest amount of CRM present in Dutch WEEE is aluminum, with almost 4 kt per year, mainly present in the large equipment and small equipment categories. Copper is the second largest material found, with almost 0.8 kt per year, mainly within the large equipment category. Dutch WEEE also contains other CRMs such as neodymium (approximately 8.8 tonnes) and dysprosium (approximately 1 tonne), mainly in large equipment and small IT and telecommunications equipment.

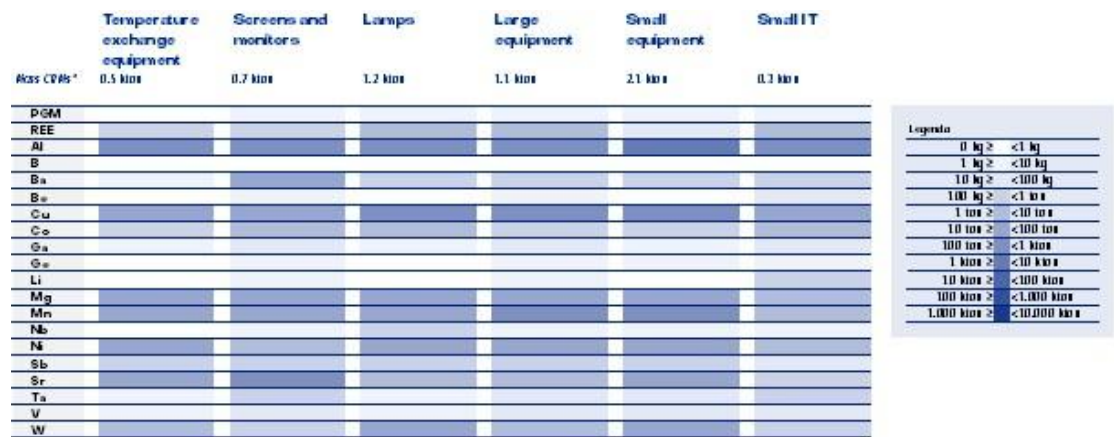


Figure 2. Elemental CRM composition of Dutch WEEE in 2024. Note that titanium and silicon on an elemental level are not included in this infographic, given that titanium metal and silicon metal are the ones classified as CRMs. For more information, see [Theoretical availability of CRMs in Dutch waste streams - Netherlands Materials Observatory](#). Note that this data is provided on an elemental level as a first step, and to understand the recyclability of CRMs and other materials, the chemical form is required. Note that data ta reflects total elemental mass; actual recoverability depends on the specific chemical compounds and material phases in which each element is bound.

The elemental composition of WEEE components

The availability of CRMS in WEEE does not necessarily signify that such flows are fully available for recycling or that it is even possible to recycle them (see Volume 1). Metals, such as aluminum or steel, can be recycled for various applications (depending on their quality), while other CRMs and specialized forms of aluminum and iron are embedded with complex alloys or composites. This creates a significant recovery challenge, as these materials are often used in trace amounts and specific chemical states. In addition, in some cases these materials will not end up in the appropriate recycling flows, due to their complex integration in the design. Consequently, recycling (if thermodynamically possible) them requires more energy and advanced (pre) processing than the techniques used for common, high-volume metals. Table 3 provides some examples of links between WEEE product categories, specific components (or metals) and associated CRMs. Note that, pinpointing which specific product type contains the relevant CRM component, such as those containing magnets, remains challenging.

Table 3. CRM content of different WEEE products and components. Note that this table is provided as an example, and further detailed research is required. This table is based on interviews with relevant stakeholders and literature to provide an overview (Arduin et al., 2020; Campbell-Johnston et al., 2024; Huisman et al., 2017; Meskers et al., 2023; Späth et al., 2022; Torrubia et al., 2023; Waste, 2021; Zeiler et al., 2021).

Product category	CRM	Suspected components/materials
All	Copper	Copper/cables
	Gallium, PGMs, gold (not a CRM but, due to value drives PCB recycling)	PCBs
	Aluminum	Aluminum alloys, metals
	Nickel	Nickel

	Vanadium, nickel, tungsten and iron	Steel alloys (varying types)/ ferrous fraction
Temperature exchange equipment	Neodymium, dysprosium	Permanent magnets, compressors from cooling systems
Screens and monitors	Cobalt, magnesium, (indium/tin oxides)	Display screens (plasma, LED, FPD)
	Neodymium, dysprosium	Hard disk drives / permanent magnets
Lamps	Cerium, lanthanum, yttrium, europium, terbium	Fluorescent powders
Large equipment	Neodymium, dysprosium	Permanent magnets
	Aluminum	PV frames
	Silicon	PV cells
Small equipment	Neodymium, dysprosium	Permanent magnets
	Tungsten	Drill bits
Small IT	Neodymium, dysprosium	Hard disk drives / permanent magnets

2.4 Legislation and standards

European and international WEEE legislation

Legislation is a significant driver of the collection and treatment of WEEE. Due to the hazardous properties of WEEE and the resulting threats to human health and the environment, the proper treatment and disposal of WEEE have been a global concern for many decades. Concerns about the illicit transport and dumping of hazardous waste, including WEEE, led to the agreement of the 1989 Basel Convention (Hilz & Radka, 1991). This convention requires "prior informed consent" for shipments, meaning that authorities in the exporting state must notify all prospective importing and transit states with detailed information on the intended movement. The waste shipment may only proceed after all states involved have given their written consent (Ahmed, 2019).

Within the EU, the management of WEEE has been overseen by the 2002 and 2012 WEEE Directives (European Parliament and the Council of the European Union, 2012). The extended producer responsibility (EPR) principle was introduced in these Directives. This legal principle builds upon the polluter-pays principle, meaning that those who cause pollution should be responsible for addressing it. In the WEEE Directive, producers are defined as "the actor who brings the final product onto the member states market for the first time" and are responsible for financing and organising the collection and recycling of their waste (European Parliament

and the Council of the European Union, 2012). This can be arranged individually or through a collective scheme, such as a Producer Responsibility Organisation (PRO). Producers (or their representative) are responsible for meeting one of two collection targets set by the EU.

Under the EU's WEEE Directive, member states are legally obliged to meet a minimum annual collection target, and they must choose one of two legally equivalent benchmarks to demonstrate compliance. The first target and most uniformly applied in the EU is the 'EEE put on market method', where producers must collect 65% (mass basis) of the average amount of EEE put on the market in the three preceding years. The second method, 'WEEE Generated', is calculated by dividing the mass of WEEE collected by the mass of WEEE generated in the same year, with a target of 85%. Almost all member states, including the Netherlands, chose the 'EEE put on the market' method, given that it is easier to track the EEE put on the market compared to calculating the total amount of WEEE generated in the country. PROs are required to report the volumes placed in the market, the collected quantities and percentages, and the waste management operations for each year. There are different recovery and recycling targets for the WEEE major categories defined in the WEEE directive, see Table 4.

Table 4. WEEE Directive recovery targets for major categories (European Parliament and the Council of the European Union, 2012).

WEEE category	Recovery target(s)
Temperature exchange equipment & Large equipment	85% recovered 80% prepared for reuse and recycling
Screens and monitors	80% recovered 70% prepared for recycling and reuse
Small equipment & Small IT and telecommunications equipment	75% recovered 55% prepared for reuse and recycling
Lamps	80% recycled

In addition to the WEEE Directives, the Restriction on Hazardous Substances (RoHS) legislation affects how WEEE can be treated (European Parliament and the Council of the European Union, 2011). Specifically, this legislation restricts the use of certain hazardous substances, such as cadmium, lead (previously used as a solder), and mercury, all of which were used in WEEE. Moreover, the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Directive provides a description of the substances found in electronic products (European Parliament and the Council of the European Union, 2006). Products containing these substances must undergo special treatments to prevent adverse impacts on human health and the environment.

Translation of EU legislation to the Netherlands

In the Netherlands, the WEEE Directive is translated to the national legislation as the "Regeling afgedankte elektrische en elektronische apparatuur", with a clear ban on landfilling (Ministerie van Infrastructuur en Milieu, 2014).

The recently introduced (2025) Circular Materials Plan (CMP) supports the transition to a circular economy through knowledge and frameworks for governments and companies. It is the successor to the National Waste Management Plan (LAP) and includes electronic devices as one focus area for CRM recovery (Ministerie van Infrastructuur en Waterstaat, 2025). The CMP main highlights are outlined as:

- Setting a minimum technical and environmental standards that operators must meet to obtain a processing permit.

- Establishing a cost threshold of 265 euros per tonne. If the cost to process one tonne of waste to the full standard (set in the CMP) exceeds this amount, for example, due to hazardous materials, the processor is allowed to use a lower standard method, such as incineration instead of recycling.
- CRMs are mentioned in the draft version of the CMP. No specific recovery, separation targets or recommendations are given. Instead, it outlines that *“Processors of waste can use this overview to make choices for developing the techniques within the Netherlands or, for example, choose to collaborate with countries within the EU that have experience with the technique and/or have capacity for recovering certain materials.”*
- Additional requirements include an Algemeen Verbindend Verklaring (AVV), which is in place until the end of 2025. This grants Stichting OPEN (see section below) the authority to fulfill the obligations as specified in the WEEE Directive and its Dutch equivalents.

WEEE recycling standards

WEEE is also covered by the CENELEC² and WEEE Label of Excellence (WEEELABEX)³ standards. CENELEC is a set of European quality standards for transporting, collecting, storing, and processing discarded appliances and lamps. To obtain the CENELEC certification, an independent auditor assesses whether a processor complies with these standards. WEEELABEX is a voluntary standard developed by EU PROs and the WEEE Forum, which provides the tools and guidelines for the collection, depollution and treatment process for treatment companies contracted by the PROs. It provides treatment benchmarks and indicates which output fractions should be monitored per product stream. The sampling and reporting requirements do not cover CRMs, except for copper and PCBs. This is mandatory for all contracted operators in the Netherlands (Stichting OPEN, 2025a). WEEELABEX certifies if a company is CENELEC compliant.

2.5 Organizational features: processing steps and key stakeholders

The system surrounding the collection and recycling of WEEE involves a diverse array of companies, including those involved in collection, transportation, and logistics. The waste management process for WEEE in the Netherlands consists of three steps: collection and transport, pre-processing, and (end-)processing (see Figure 3). Stichting OPEN⁴ is the designated representative for all electronics producers, importers and distributors and is the organization responsible for meeting the WEEE directive requirements. Stichting OPEN organizes and finances the collection system and holds contracts with licensed mechanical processors who treat the collected WEEE.

² For more information see [CEN-CENELEC - CEN-CENELEC](#)

³ For more information see [WEEELABEX ORGANISATION - Weelabex](#)

⁴ Stichting OPEN was formed out Wecycle, WNL, ARN, PV Cycle, RTA, Stibat with the aim to meet the EU WEEE Directive collection target of 65%. For more information see [Stichting OPEN - Stichting OPEN](#)

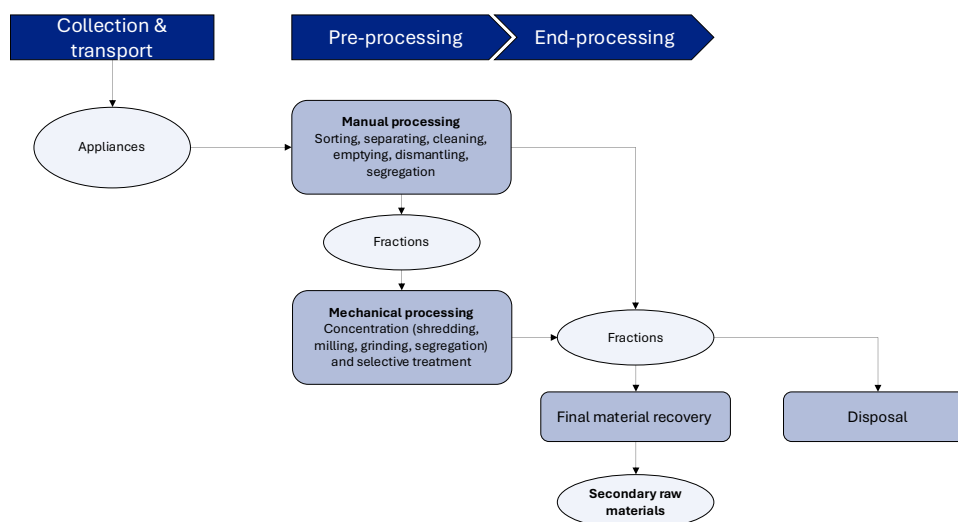


Figure 3. WEEE collection and recycling steps in the Netherlands, based on (Meskers et al., 2023).

Collection and transport:

The total volume of WEEE available for effective pre-processing is directly determined by the quantity captured through formal collection systems. In the Netherlands, there are over 10,000 collection points for consumers and businesses to dispose of their products. They are generally located at retail centers and civic amenity sites (Stichting OPEN, 2025b). Over one billion electronic devices (500 kt) are estimated to be in circulation, of which 91% are in use, 8% are unused, and 1% are broken (based on interviews). Once WEEE is collected, it is sent to specialized facilities for pre-processing.

It is essential to note that not all WEEE is collected through the formal collection system or treated in the Netherlands. Discarded EEE can be exported from the Netherlands legally to licensed processors or for reuse activities as second-hand products (e.g., via online sellers). Additionally, there are also illegal practices surrounding the final disposal of WEEE or its exports. To illustrate, (in 2018) it was estimated that approximately 33 kt of WEEE were collected in containers, 31 kt were exported for reuse, and between 20-40 kt could not be accounted for or were shipped abroad (Brink et al., 2021). Despite the Basel Convention, research has shown that large volumes of WEEE are leaked from the EU to non-OECD countries, particularly Nigeria, where the capacity to safely dispose of them is less assured than in the Netherlands (Puckett et al., 2018).

Pre-processing

Pre-processing is composed mainly of two steps, manual processing and mechanical processing. Note that pre-processing refers to the sequence of physical and mechanical operations performed prior to (metallurgical) recovery (see Volume 1).

Manual processing is the first step in preparing collected WEEE for proper treatment. In the Netherlands, WEEE is not separated at its source, so this manual stage is essential. At sorting facilities, workers separate the mixed WEEE into different product groups and remove items containing hazardous substances, such as mercury or cadmium. Stichting OPEN contracts seven social sorting centers to perform this work, where staff also check if products can be

repaired. This is also the stage where components, such as PCBs (which contain CRMs), can sometimes be manually removed.

Mechanical processing is the next step, which occurs on an industrial scale. It is designed to separate/concentrate recyclable materials into as pure fractions as possible and isolate hazardous substances. This is achieved through a sequence of physical processes, which typically includes crushing for liberation and size reduction (shredding, milling and dust removal), sizing (sieving, screening), and sorting (e.g., using magnetic, electric, density or sensor-based methods).

The CENELEC standard provides an overview of the requirements for the removal and separate treatment of substances, mixtures, and components with hazardous characteristics. This is a mandatory standard for recyclers contracted by Stichting OPEN. Key contracted partners in this step include HKS (and its subsidiary MIREC, both part of the Remondis group), Coolrec, A&M Recycling and Holland Recycling, among others (Stichting OPEN, 2025a).

End-processing

The recovered fractions from pre-processing require further processing/refinement and are sold as commodities to end-processors. The three main fractions are metals (ferrous/non-ferrous), glass and plastics. Most end processing/(actual) recycling of CRMs occurs outside the Netherlands. Note that WEEE is an attractive waste category due to the high concentration of Precious Metals (PMs) and Platinum Group Metals (PGMs) when compared to ores, offering a strong economic incentive for materials recycling. Additionally, the recovery of PMs and PGMs (for WEEE) is fundamentally connected to the metallurgical processing (and recovery) of base metals, primarily copper (and nickel), which is also notably found in this waste stream. This base metal is thermodynamically compatible with PMs and PGMs (“co-elements”) and provides the infrastructure necessary to physically capture and transport them for later recovery during refining stages. This thermodynamic affinity between elements and the specific combination of them present in WEEE explains why the industry relies on the copper pathway to recycle PMs and PGMs (present in WEEE) and avoids incompatible routes involving other base metals, mainly aluminum.

The recovery of PMs and PGMs, such as gold, silver, palladium, and platinum, and “carrier metals”, is carried out by specialist facilities. Umicore (Belgium) and Mitsubishi (Japan) are examples of companies that recover PM and PGMs through pyrometallurgical and hydrometallurgical processes. Elephant Refinery (the Netherlands) purifies PMs and PGMs from specific flows. Note that there are other facilities across the EU that focus more on the smelting and refining of large quantities of base metals as their core business, such as copper and aluminum, including those operated by Aurubis and Hydro. Most of the end-processing of WEEE to recover CRMs occurs outside the Netherlands.

2.6 Performance of collection and recycling rates

Collection rates

The EU sets specific collection and recovery targets for WEEE (see section Legislation & standards). Over the last decade, the collection rates in the EU have increased by 75% (Eurostat, 2025). Figure 4 illustrates the collection performance of the Netherlands for 2023, benchmarked against the other EU countries, following the ‘EEE put in the market’ approach. Few countries meet the 65% mark, with the Netherlands standing at 29%. Following the ‘WEEE Generated’ approach, estimated based on waste generated and waste collected over the same

year, the Netherlands collection rates stand at 57% for 2023. According to Stichting OPEN, this number has increased to 64% in 2024 (Stichting OPEN, 2025c). Note that the Netherlands is the country in the EU that puts the most electrical and electronic equipment per capita on the market (Eurostat, 2025).

In response to challenges in meeting the current 65% collection target, the Netherlands is actively researching and proposing alternative calculation methodologies⁵. The Dutch government and its producer responsibility organizations argue that the 'EEE put in the market' target is limited, given that it fails to account for different dynamics such as life spans of products and consumer behaviors. Therefore, the Netherlands is advocating for the 'WEEE Generated' approach with some refinements, mainly that collection targets should not account for WEEE fractions that are not accessible to the collection system.

Collection rates | WEEE | 2023

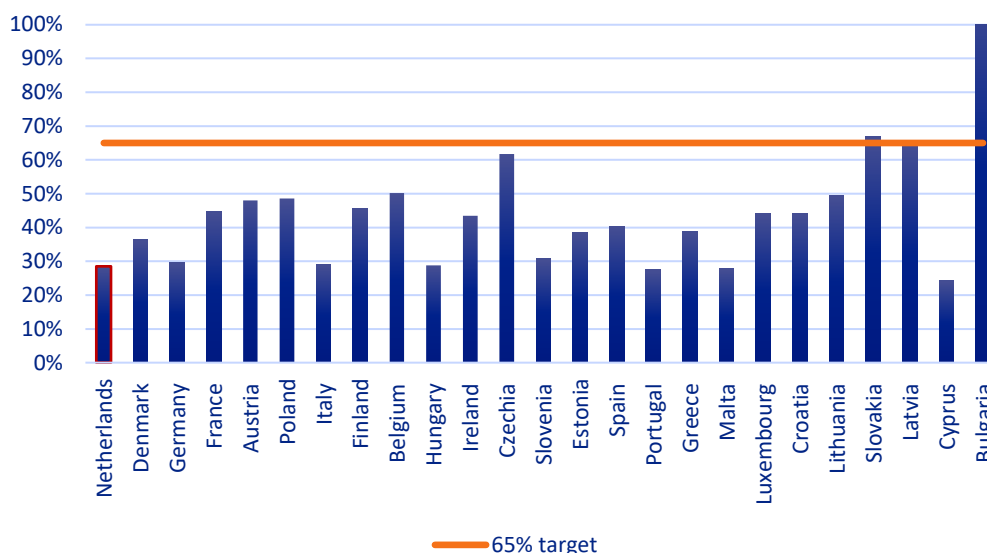


Figure 4. Collection rates based on the WEEE generated for 2023 following the 'EEE put on the market' approach (Eurostat, 2025).

Regardless of the collection target and calculation methods, the characteristics of EEE products, including life spans, consumer behaviors, and improper disposal, affect the overall collection system and ultimately the amount of CRMs that can be recovered in such a system. Therefore, strategies to increase collection rates of WEEE and their role related to CRM recovery are a focus improvement area.

Recovery and recycling rates

The EU's WEEE Directive sets specific recovery and recycling targets by major categories. The Netherlands has met the recovery and recycling targets for the amounts of WEEE that are successfully collected (see Table 5). Only the category screen and monitors with a 79.6% recovery rate are minimally below the 80%.

⁵ For more information see [Strenger toezicht op inzameling elektronisch afval • Recycling Magazine Benelux](#)

Table 5. Recovery and recycling rates for the Netherlands and neighbouring countries compared to the EU targets in 2023 (Eurostat, 2025). These are reported official statistics. However, note that cross country comparisons should be made with care due to differences in national reporting methods.

WEEE category	Recovery target(s)	Belgium	Germany	France	Luxembourg	Netherlands
Temperature exchange equipment	85% recovered	85.9	98.5	96	99.6	97.7
	80% prepared for reuse and recycling	78	86.2	81.6	86.	80.6
Screens and monitors	80% recovered	83.8	97.5	76.5	96	79.6
	70% prepared for recycling and reuse	73.8	88.6	60.9	92.8	60.4
Small equipment	75% recovered	73.7	98.5	90.3	93.8	94.1
	55% prepared for reuse and recycling	66.6	82.1	76.4	81.9	66.4
Lamps	80% recycled	89.9	93.8	61.5	80	100
Large equipment	85% recovered	85.4	98	88.9	91.8	85.7
	80% prepared for reuse and recycling	78.3	87.8	79.5	86	72.5
Small IT and telecommunications equipment	75% recovered	75.2	98.7	79.5	93.8	93.1
	55% prepared for reuse and recycling	65.7	83.3	69.1	81.9	74.7

2.7 Destinations of pre-processed WEEE

Table 6 shows the Harmonized System (HS) 6-digit codes for classifying traded products related to WEEE⁶. Note that WEEE is characterized by a complex mix of different materials. Once that WEEE is shredded and sorted, it becomes a wide range of marketable secondary feedstock, such as ferrous scrap, aluminum scrap, copper scrap, and sorted plastics. At this stage, these materials are not further characterized as WEEE and enter a new specific material stream traded under their own HS code, which is not specific to a WEEE origin. For example, the recovered copper in WEEE is traded under the copper waste and scrap HS code, which likely contains copper from different sources, such as construction and demolition, or the automotive sector.

The Netherlands is a net exporter of most waste relating to WEEE (see Figure 5). This means that the country's total exports exceed its total imports. In 2022, there was a trade of over 140 million USD of WEEE waste flows, primarily related to electrical and electronic assemblies and

⁶ The trade balance section is also corroborated with interviews to relevant stakeholders

printed circuit boards, other than those used primarily for the recovery of precious metals category. This trade flow has increased to almost 200 million in 2023.

Table 6. HS6 trade codes related to WEEE.

HS6 code	Description
854921	Electrical and electronic waste and scrap: of a kind used principally for the recovery of precious metal, containing primary cells and batteries, electric accumulators, mercury-switches, glass from cathode ray tubes or other activated glass, or electrical
854929	Waste and scrap: of a kind used principally for the recovery of precious metal n.e.c. in item no 8549.21 ⁷
854931	Electrical and electronic waste and scrap: electrical and electronic assemblies and printed circuit boards, other than those used principally for the recovery of precious metal, containing primary cells and batteries, electric accumulators, mercury-switch
854939	Waste and scrap: electrical and electronic assemblies and printed circuit boards, other than those used principally for the recovery of precious metal n.e.c. in item no 854931



Figure 5. Dutch HS6 WEEE related codes import/export for 2022 and 2023 in value (BACI – 2024, standard reference - Gaulier & Zignago, 2010).

Destinations of major bulk metals

The main fractions of bulk metals from WEEE and other sources (after pre-processing) are the ferrous fractions (including stainless steel) and aluminum and copper. The Netherlands exports these fractions to countries where they can potentially be utilized by the local industry and reintroduced into the production system. For example, the main destinations of such fractions are Turkey for ferrous waste and scrap, Finland for stainless steel scrap and Germany for aluminum and copper (see section Dutch waste trading data).

Destinations of precious metal fractions (e.g., PCBs)

The recovery of precious metals, including gold and silver, from PCBs is a driver for Dutch mechanical recyclers. Companies such as Elephant refinery process small quantities of Dutch waste PCBs, while Remondis PMR has a precious metal refinery linked with various scrap

⁷ Note: this HS code is used to illustrate what is evident regarding the trading of precious metals within E-waste, i.e. they are predominantly exported to Japan.

types, including catalysts. Overall, in 2022, the precious metal WEEE fraction (HS code 854929) trade balance in the Netherlands accounted for over 13% of the global trade (2 million USD), indicating that the Netherlands is a significant European hub for the trade in precious metal waste fractions (BACI – 2024, standard reference - Gaulier & Zignago, 2010). In 2022, there were more imports than exports, and the trend was reversed in 2023. Exports are carried out mainly to Japan, given the limited domestic capacity to process these precious metals effectively. Companies like Mitsubishi in the Port of Rotterdam operate facilities to test waste materials before exporting them, primarily back to Japan, for final processing. This is also evidenced by the fact that more than 90% of general precious metals waste (HS code 854929) is shipped to Japan. A similar destination is seen for waste categorized under HS code 854939, mainly exported to Singapore and Japan

Germany is the largest importer of WEEE fractions (HS code 854921), followed by Belgium, though to a considerably lower extent. Belgium and Portugal also import WEEE fractions under HS code 854931 from the Netherlands, representing just over two million dollars in trade. However, no additional information was found on these trade flows, either in interviews or in other sources.

2.8 Waste management fees and markets

A combination of waste management gate fees and material markets determines the financing for Dutch WEEE. All Dutch producers (including importers and distributors) are required to pay a fee per product to Stichting OPEN for the eventual waste management activities. In 2025, these fees were set either based on the weight of the product or a fixed fee per piece, ranging from 0.02 euros per kilogram to 1 euro per kilogram. Table 7 provides an indication of the evolution of the prices for the product category temperature exchange equipment.

Table 7. Waste management fees paid to Stichting OPEN 2023-2025 for the product category temperature exchange equipment (and sub categories).

Code (NL)	Description	Waste management fee 2023-2025
E1/01	Refrigeration and freezing equipment (domestic)	0.220/kg
E1/02	Tumble dryers (with heat pump)	0.045/kg
E1/03	Air conditioning equipment (separate)	0.170/kg
E1/04	Air conditioning equipment (built-in) and heat pumps	0.015/kg
E1/05	Refrigeration and freezing equipment (professional)	0.060/kg
E1/06	Automatic machines (cooled)	0.300/kg

The fee covers the activities of Stichting OPEN, and the processing of collected WEEE to the CENELEC standard. Currently, there are no specific requirements for the recovery of CRMs from WEEE, aside from large fractions such as copper and aluminum (which are reported to Stichting OPEN). The PRO is in the process of updating its contracts with operators to potentially include CRM requirements⁸. Stichting OPEN is financed by a combination of fees from producers (above) and the profits that contracted recyclers earn from selling key recycling streams for the main reported fractions, e.g., ferrous, non-ferrous, plastics, and glass. They

⁸ Personal communication

pay for the organisation of collection and logistics, as well as a gate fee for any collected products with a negative value, such as those containing hazardous substances.

Secondary materials markets

Metal markets are a significant driver of the operational activities of Dutch WEEE mechanical recyclers. Mechanical processors generate their revenue by selling secondary processed fractions to processors and smelters, such as those for copper and aluminum. PCBs are targeted by Dutch mechanical processors and are sold to precious metals smelters for the recovery of metals such as gold, silver, platinum and palladium. Mechanical recyclers are paid on the contents of “payables”, i.e., the quantity of materials (gold, copper, silver, platinum and/or palladium, and sometimes indium), minus the processing costs of the smelters. The gold composition of PCBs, which drives their separation and recovery, has steadily declined over the years, resulting in the price paid for PCBs decreasing⁹. Finally, smelters and precious metal refiners recover various metals, depending on their facilities. Different smelters and companies have varying rates for the material combinations they purchase, which are commercially sensitive and generally not disclosed to the public.

2.9 The Sherwood plot as an economic filter for further exploration

Figure 6 to Figure 11 show the Sherwood plots for the different WEEE categories. It is essential to note that these graphs do not represent the recycling efficiencies of each CRM, but rather observations linking an element's price to its dilution in a product or waste category. The dashed line (empirical boundary derived from commercial scale observations) represents the assumed recycling boundary, i.e., the boundary where an element's concentration dictates its economic attractiveness for recovery. The figures serve as proxy indicators to illustrate the economic threshold of whether an end-of-life material or waste stream (and its contained elements) justifies further inquiry for commercial recoverability opportunities. Note that these figures (a first step) consider waste at the point of generation, prior to any preprocessing. Materials can be redistributed across the graph after pre-processing activities, as these activities alter the dilution of materials.

Figure 6 shows the Sherwood plot for the temperature exchange equipment sub-WEEE category. Traditional base elements such as copper (Cu), aluminum (Al), and nickel (Ni) are positioned above the dashed line, showing that the recovery of these elements is a standard practice and connected to efficient large-scale pre-processing. This also suggests that the recovery of these materials is a mature and economically viable process, with prices tending to correlate with dilution. Other recovered elements above the line include PGMs such as palladium (Pd) and platinum (Pt). The latter indicates that the high price of these elements provides a strong economic incentive for their recovery, even when they are highly diluted, confirming the strong economic incentive for recycling these materials. Tungsten (W), cobalt (Co), and gallium (Ga) are also positioned above the line and not recovered, suggesting that the current market value exceeds the threshold dictated by their dilution, which might make recycling these materials feasible in the future. For the screens and monitors sub-WEEE category (Figure 7), the position of PGMs and base elements is rather similar to that of the temperature exchange equipment. In contrast, (non-recovered elements) only gallium (Ga) appears above the threshold line, with dysprosium (Dy), a Heavy Rare Earth element (HREE) and germanium (Ge) just on the threshold.

⁹ For more information see [PCB recycling - Holland Recycling in The Netherlands](#)

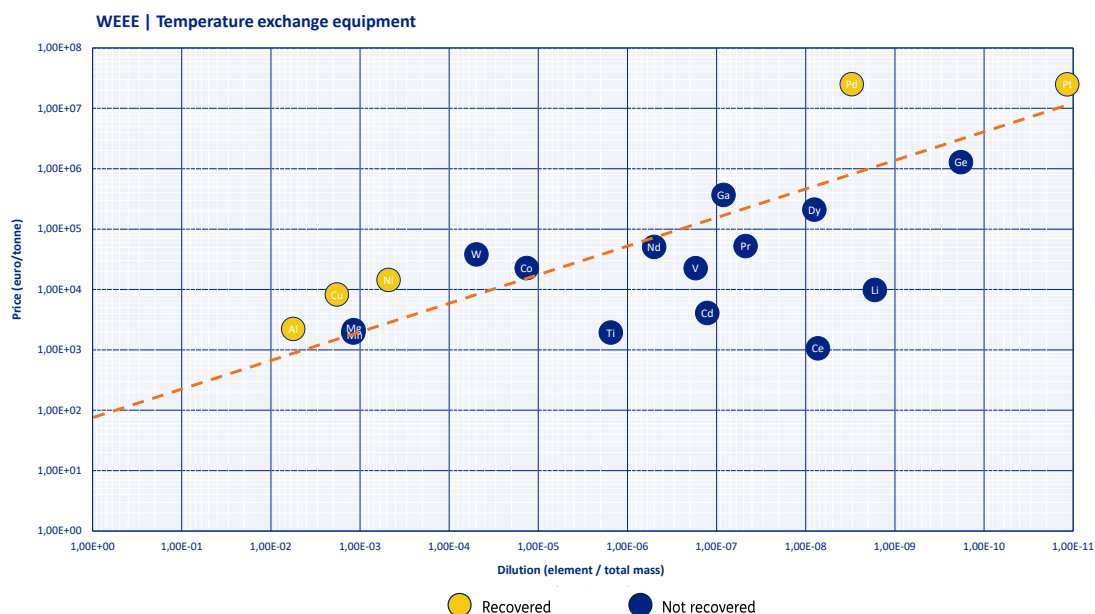


Figure 6. WEEE - Temperature exchange equipment Sherwood plot, limited to CRMs.

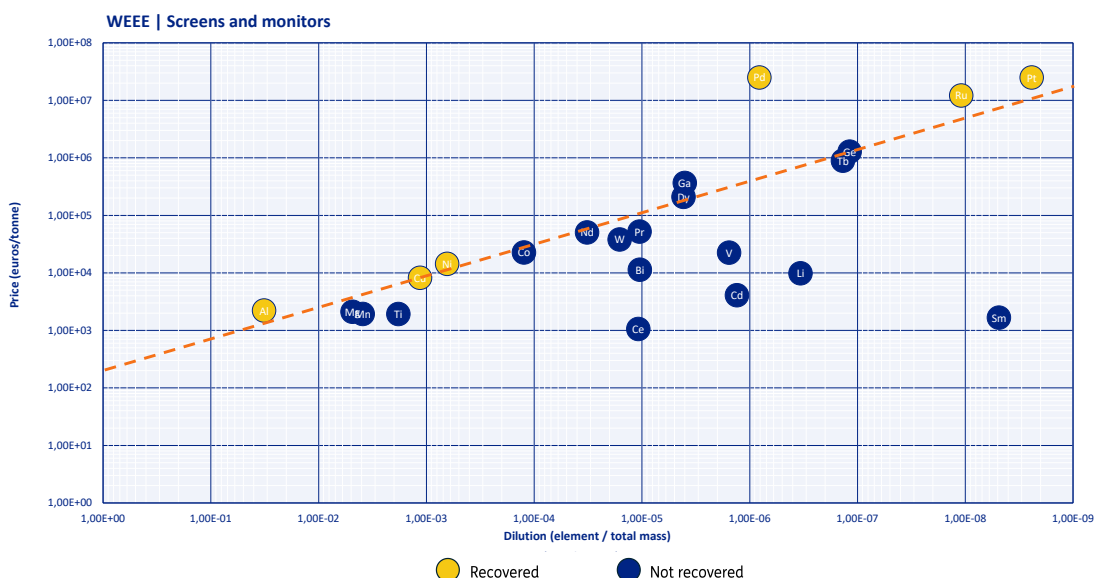


Figure 7. WEEE - Screen and monitors Sherwood plot, limited to CRMs.

Figure 8 shows the Sherwood plot for the lamps sub-WEEE category. Similar to other sub-WEEE categories, traditional elements and PGMs are recovered and positioned above the threshold line. Terbium, another HREE, is well-positioned above the threshold line, suggesting potential for economic recoverability based on its dilution. Tungsten (W) and cobalt (Co) are currently not recovered; however, similar to the temperature exchange equipment category, both indicate some economic potential for material recovery due to their dilution within the lamps category. For large and small equipment (Figure 9 and Figure 10) base elements and PGMs are positioned in the same region as with other sub-WEEE categories. For both categories, Tungsten (W) is not recovered and positioned well above the threshold line, while for large equipment, only dysprosium (Dy) and neodymium (Nd), a Light Rare Earth Element (LREE), are located above the threshold line. For large and small equipment, as well as for

most of the other sub-WEEE categories, elements such as lithium (Li), cerium (Ce) and samarium (Sm) are significant below the threshold line, suggesting that at the dilution found in these waste streams, recovery is not economically viable based on the current market price.

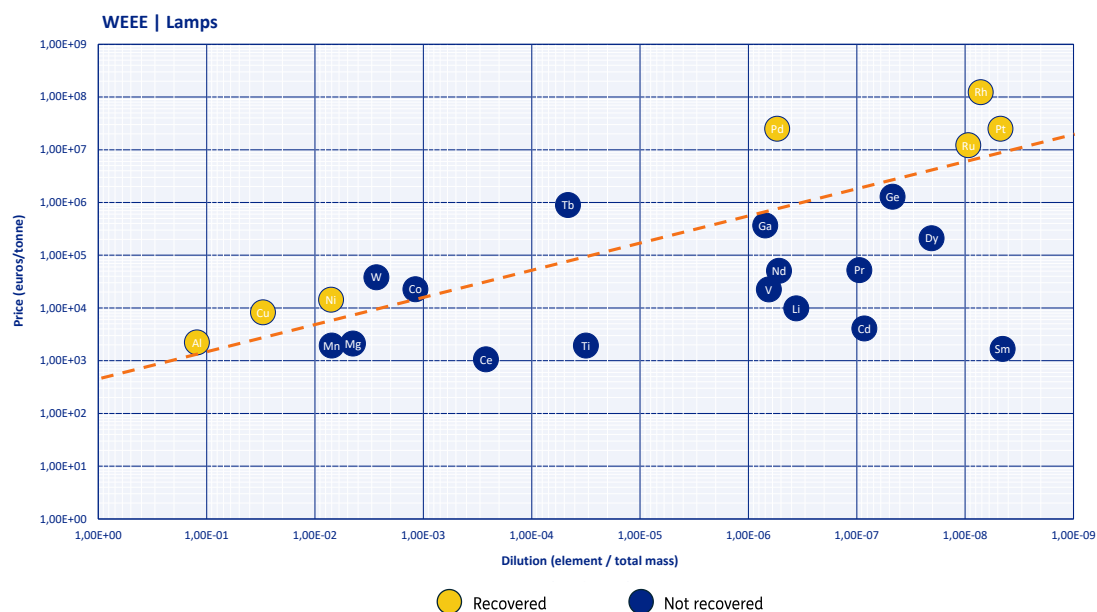


Figure 8. WEEE - Lamps Sherwood plot, limited to CRMs.

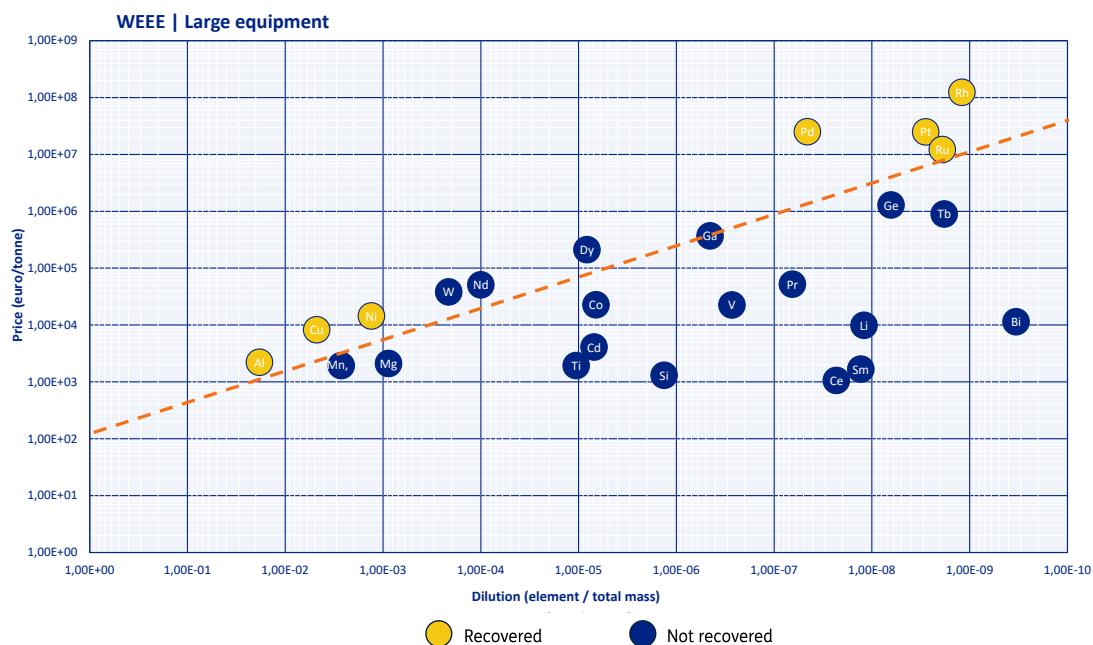


Figure 9. WEEE - Large equipment Sherwood plot, limited to CRMs.

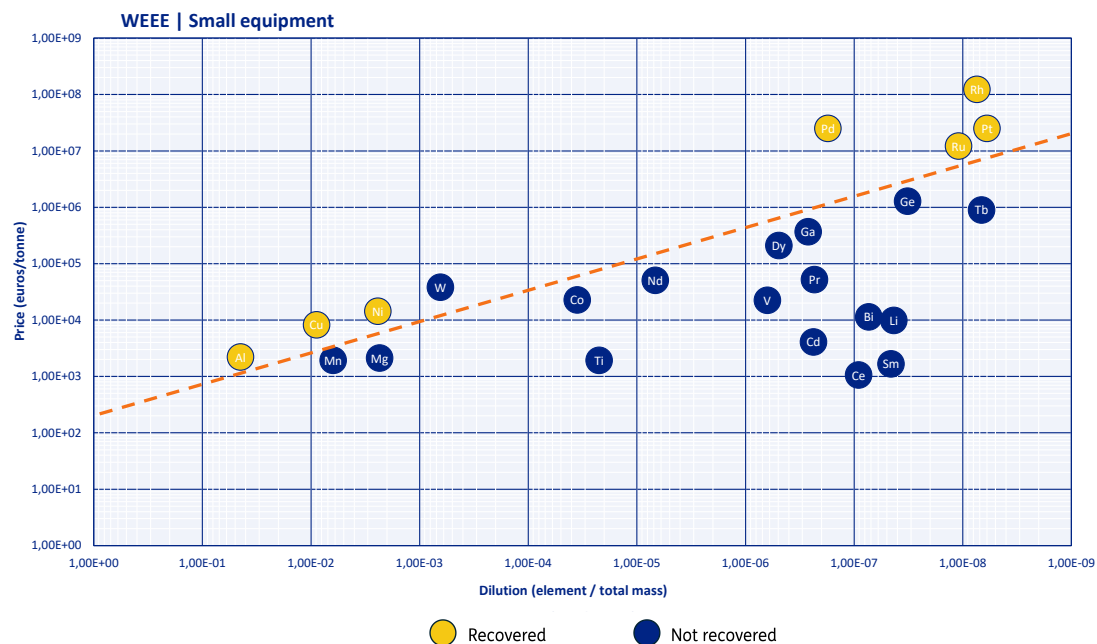


Figure 10. WEEE - Small equipment Sherwood plot, limited to CRMs.

Figure 11, shows the Sherwood plot for the small ICT sub-WEEE category. This category has the most (not recovered) elements above the threshold line, suggesting economic interest for further exploring the recovery of a wide range of elements. However, such diversity of elements that show economic interest for recovery can be a limitation, since it can create a chaotic matrix during extraction, where competing elements can act as contaminants to one another.

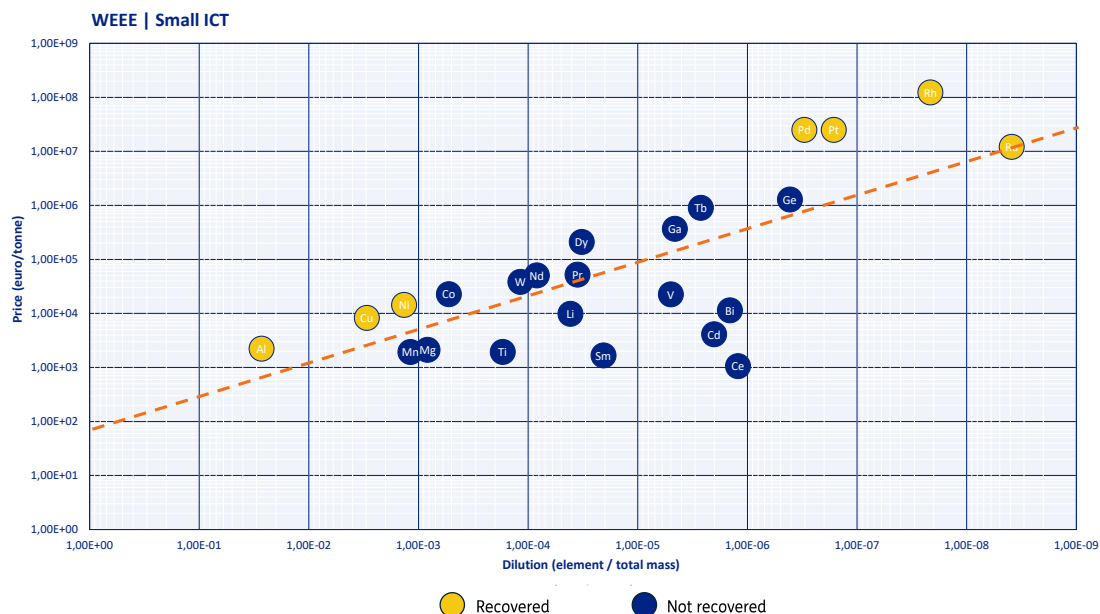


Figure 11. WEEE - Small ICT Sherwood plot, limited to CRMs.

2.10 WEEE considerations under the Metal Wheel framework

The possibility of recovering specific metals and CRMs will depend on the carrier metals in which they are embedded and the process to which they are subjected. Efficient connection between the segments of the Metal Wheel is required to ensure maximal economic recovery of the elements in WEEE. The Metal Wheel provides additional thermodynamic context for the observations presented in the Sherwood plot section, mainly with a focus on the elements above the threshold line and visualizing the complexity for policy.

For example, the recovery of PGMs via the copper pathway from WEEE is driven by the strong economic incentive to recover these materials, the thermodynamic compatibility of these elements and the product composition of this waste stream. Note, that while both copper and nickel are capable of acting as “metal carriers”, the physical composition of bulk pre-processed WEEE dictates the furnace dynamics. Generally, the copper content in electronic components exceeds that of nickel, and thus, copper becomes the primary “metal carrier” during the smelting process. Due to their thermodynamic properties, relatively noble¹⁰ PGMs dissolve into the more noble molten copper. When dissolving in liquid copper, these elements are later extracted and purified during refining. The copper route¹¹ is the main established metallurgical route for recovering PGMs because it connects to mature, scalable base-metal and efficient refining infrastructure. Note that any nickel present in the WEEE feedstock acts synergistically within this infrastructure, melting alongside the copper to form a unified liquid that carries PGMs (or PMs). Nickel as well as the elements show in the Metal Wheel are generally separated in further downstream processes, further maximizing the overall material yield and the economics of integrated smelting processes¹².

Historically, there has been a lack of economic incentive to recover REEs from WEEE, mainly due to the low costs of primary materials and the strong economic motivation to recover PGMs (and PMs), which has actually driven the economic incentive of WEEE recycling (Cui & Zhang, 2008; Dutta et al., 2023; Kaya, 2018). Consequently, losing these elements through incompatible routes was considered a necessary trade-off to maintain the profitable recovery of PGM (and PMs). Note that, for example, REEs are thermodynamically incompatible with the copper pathway due to their ignobility. Therefore, recovery should take place through hydrometallurgical and associated processes. REEs are highly reactive and oxidize when entering the furnace. Instead of dissolving in the molten copper for further recovery, they are rejected into the slag, where they become diluted and thermodynamically challenging to recover, making their processing economically unviable. Today, however, REEs are currently located above the threshold line for several WEEE sub-categories, indicating potential economic interest for element recovery. This is partly due to the high demand for REE-dependent technologies combined with critical geopolitical supply chain vulnerabilities, creating an economic and strategic incentive to recover these elements. However, as illustrated by the Metal Wheel, to successfully recover PGMs, PMs and REEs from the same WEEE stream, the industry needs to account for the fundamental opposed thermodynamic compatibilities. Therefore, REE-containing components require targeted dismantling and pre-processing to physically isolate them from the (pre-processed) bulk WEEE stream, ensuring they are diverted

¹⁰ Noble metals have a lower propensity to react with oxygen. At the other end of the scale are, for example, aluminum and magnesium, which react strongly with oxygen, a main limiting factor in their recycling.

¹¹ Its roots are in the processing of ores, which separates elements that have a geochemical association

¹² This capacity to simultaneously capture and separate multiple complex material streams is the defining characteristic of modern integrated multi-metal smelters such as the facilities from Umicore [Process | Umicore](#).

to their own specialized metallurgical recovery processes before the remaining materials are sent to an incompatible pathway.

Aluminum is another base metal that is observed to be recovered and appears above the threshold line in the Sherwood plots. Although its value is much lower than that of PGMs or PMs, aluminum is widely used as a bulk structural material in components such as frames and casings, making automated physical separation cost-effective (Bruch et al., 2022). This pre-processing step is also a metallurgical requirement due to aluminum's limited thermodynamic compatibility with other recovery routes, such as the common copper route for PGM and PMs recovery. If introduced into a copper smelter, aluminum oxidizes, forming aluminate slag that affects the furnace chemistry and metal recovery efficiency. Consequently, aluminum needs to be systematically extracted from WEEE during pre-processing and diverted entirely to its own dedicated (secondary) metallurgical recovery process. Of importance to always note with such ignoble metals such as aluminum, their oxidation must be controlled when remelting to ensure the dross formation (oxidic mixture) is minimized.

Tungsten is observed above the threshold line in most sub-WEEE categories. For electronics, tungsten use is characterized by extreme miniaturization and encapsulation. For example, tungsten is used inside smartphones' vibrators (Nissen et al., 2020) as an interconnect trace element for semiconductors (Ganesh & Gaidhane, 2020) and electrical contacts (Lungu & Barbu, 2022). Therefore, tungsten within the WEEE category exists in highly inaccessible forms, some of which are bonded at the microscopic level. This makes physical separation during standard WEEE pre-processing both technically challenging and economically unfeasible, leaving the tungsten trapped within the bulk feedstock. When the bulk feedstock is directed to a standard metallurgical process, such as copper smelting used to recover PGM and PMs, tungsten does not melt into the metal; instead, it stays solid, oxidizes, and is rejected to the slag, where it is permanently lost. Note that tungsten is a refractory metal with a high melting point, and it does not dissolve into the copper pyrometallurgical furnace's carrier matrix. While this thermodynamic incompatibility results in its permanent loss during typical (pre-processed) WEEE smelting, other industrial sectors have established recovery pathways. Tungsten is largely used for the production of cemented carbides and as an alloying element with iron to create high-speed tool steel; its recyclability in these two sectors is opposed. Tungsten is recycled from cemented carbides (as well as cobalt) (Katiyar & Randhawa, 2020) (via target extraction methods), while it remains permanently trapped and diluted when alloyed into the steel (recycling) loop. Note that tungsten is also rather reactive with oxygen and thus thermodynamically needs to be treated carefully; furthermore, any mixed-in metals must be properly managed so they do not degrade the quality of the final tungsten compounds or metal (Isocyanates, 1985).

Cobalt appears to be above the threshold line for three WEEE-sub categories, mainly lamps, temperature exchange equipment and small ICT. It is important to note that the purposes of cobalt use across these categories differ, and thus the considerations and routes for potential recovery vary under the Metal Wheel framework. For example, cobalt appears as a thermodynamically compatible element that can be recovered via the copper/nickel (or lead) smelting routes for (pre-processed) bulk WEEE. However, the location of the element in the middle ring means that, while these elements can dissolve "safely" with the main "metal carrier," they are also sensitive and can only be recovered through that pathway if the conditions along that route are properly managed (M. A. Reuter et al., 2019; M. A. Reuter & van Schaik, 2013). This implies that if cobalt (and, in general, other elements) is present at too low a concentration in a phase, it becomes a thermodynamic challenge to recover it, i.e., to unmix.

Modern integrated multi-metal smelters (e.g. Umicore¹³) could theoretically recover cobalt in a controlled, oxygen and sulphide atmosphere to prevent it from reacting. If such a process is not carefully implemented, cobalt's chemical affinity for oxygen causes it to oxidize, becoming incompatible with the molten "metal carrier" or mix of metal of "metal carriers" (mainly lead-copper-nickel) and partitioning into the slag. However, such specific conditions can conflict with the recovery of other, more valuable elements, which are the main economic driver of WEEE recycling and thus, cobalt recovery is not targeted within the bulk WEEE stream. In addition, note that the majority of cobalt present in electronics is concentrated in the battery components (Sommer et al., 2015), which follow a different recycling process

For cobalt in lamps, different considerations apply. The Metal Wheel framework precludes processing this waste through standard copper (or nickel) smelters, as the bulk glass (silica) matrix would generate large volumes of slag and potentially affect overall operations. Note that cobalt in lamps can be tightly bound with the silica matrices. Instead, the Metal Wheel dictates that this material should be routed exclusively to dedicated hydrometallurgical processes if technical and economic recovery allows for it, i.e., dismantling and mindful design for recycling. Given the technical and economic challenges of this process, the recovery has been carried out only on a lab scale, as in (Rocchetti et al., 2013). In addition, historically, the recycling infrastructure for end-of-life lamps has been designed to capture toxic mercury and to recover bulk materials such as aluminum, plastics, and glass (Subeshan et al., 2023). Therefore, the cobalt present as part of the pre-processed feedstock is generally downcycled into low-value applications such as aggregates for construction.

Gallium is another element that has been observed to be economically interesting for further exploration in three WEEE sub-streams. Gallium is generally used in the form of Gallium Arsenide (GaAs) or Gallium Nitride (GaN) for integrated circuits, semiconductor layers and other targeted applications (Lu et al., 2017). Gallium recovery from post-consumer feedstocks is extremely challenging because it's applied on a microscopic, very high-purity level (Guan et al., 2025). Gallium is incompatible with the current main copper-based metallurgical recovery route as it partitions mainly to slag as GaO for bulk pre-processed WEEE. Due to low concentrations it is a challenge to recover from slag. Note, however, it is also compatible with the lead and zinc processing routes. In summary, Gallium has a high affinity for oxygen and a strong tendency to partition into the slag, once again thermodynamics dictates the processing. Furthermore, even if trace quantities were captured, the high level of purity (99.9999%) required for semiconductor applications makes it extremely challenging to achieve using a heterogeneous recycled feedstock (Zheng et al., 2023). Consequently, gallium currently represents a total material loss in the WEEE recycling stream. To recover gallium and prevent it from being lost in incompatible metallurgical recovery pathways, it would be necessary to isolate gallium-containing components from the bulk WEEE pre-processed stream and send this fraction to a dedicated (hydro) metallurgical recovery process. However, this still does not overcome the major purity challenge for its reintroduction into specialized applications.

Germanium is another recovered element located in the middle (outer) ring under the Metal Wheel framework for copper/nickel and lead recovery routes. Additionally, according to Sherwood plots, further exploration to recover in the small ICT WEEE subcategory is potentially economically attractive. Nevertheless, germanium is volatile and, at high temperatures (in a smelter), vaporizes and is either trapped in the flue gas or lost in the slag. Note that this flue gas (with germanium traces) could theoretically be further processed via hydrometallurgical

¹³ Umicore is the only facility that uses Top Submerged Lance (TSL) technology on a large scale with such a variety of elements to inject enriched oxygen-enriched air and fuel in the molten bath. For more information see [Process | Umicore](#)

methods, but is considered economically unrecoverable from such a route (Meshram & Abhilash, 2022). Therefore, it is not intended to be recovered from bulk-processed WEEE via copper/nickel recovery routes. Germanium is mainly used in fiber-optic cables, infrared optics, and sensors, among other applications (Kamran Haghighi & Irannajad, 2022). Currently, most Germanium recycling is carried out on pre-consumer feedstock, given its known chemical origin, higher material concentrations and lower silica content. For example, Umicore facility in Olen recovers germanium via hydrometallurgical process from the waste stream of the zinc industry, and pre-consumer scrap from industries such as fiber optics, solar cells and infrared optics¹⁴

While this analysis has focused on an elemental level scoped by the economic interest from the Sherwood plots to provide fundamental chemical and thermodynamic limits of recovery based on the Metal Wheel, it is important to note that element recovery is additionally complicated by the fact that these elements do not exist in isolation and exist on a multi-material component level. Understanding how these elements combine within a single component is critical, as the physical bond between a "recoverable" element and an "incompatible" carrier often determines whether an element is or can be successfully recycled or becomes a permanent loss given thermodynamic incompatibility. Therefore, thermodynamics determines the solution chemistry and whether the elements are elemental, oxidic, sulphidic, volatile, etc. Optimal recycling requires unmixing a large number of elements and concentrating and refining these to produce high quality metals, alloys, materials and compounds while minimizing energy consumption and exergy dissipation.

2.11 Summary of key observations and next steps

- Currently, there is a discussion about the approaches used to calculate and report WEEE collection rates. The Netherlands advocated using the WEEE generated approach because it accounts for dynamics such as product lifespans and consumer behavior. Despite not achieving the 85% collection target (under the WEEE generated approach), the Netherlands has improved from 57% in 2023 to 64% in 2024. Furthermore, from the collected volumes, the Netherlands meets the recovery and recycling targets for all WEEE categories. This suggests that the system's capability to recover materials/resources once WEEE is collected is advanced and that the main challenges to increase collection rates rather arise from informal markets, consumer behavior and logistical issues to some extent.
- There are several elements located above the threshold line across different WEEE categories as presented in the Sherwood plots, suggesting that their market value theoretically justifies further inquiry for commercial recovery opportunities. This is observed for tungsten, gallium, cobalt, dysprosium, neodymium and terbium, among others. However, actual extraction (and costs) can be challenging given the thermodynamic dynamics of metallurgical processing, the complex physical interconnections among elements and components, and miniaturization. Once a pre-processed material mix enters processing, the thermodynamics dictate whether economically attractive "co elements" are recovered or lost, given an (in)compatible host metal matrix.
- To optimize overall material recovery, modern recycling strategies must be guided by a clear understanding of which thermodynamically incompatible materials should be

¹⁴ [EU's selection of Umicore's germanium projects underline leadership in germanium recycling | Umicore](#)

separated during the initial dismantling and liberation phases. As illustrated by the Metal Wheel concept, certain complex metal combinations cannot be co-processed without element losses, as described for REEs when routed via existing Best Available Techniques (BAT) base metal processing infrastructures, such as copper or lead pathways. Therefore, REE-containing components require targeted pre-processing to physically isolate them from the (pre-processed) bulk WEEE stream, ensuring they are diverted to their own specialized metallurgical recovery processes before the remaining materials are sent to an incompatible pathway. However, for REEs contained in electronic components, it is highly challenging given the connections and the nature of linkages/compounds in these parts/products.

- Separation in pre-processing stages is key to avoiding the loss of CRMs, which are increasingly interlinked within the same end-of-life products due to miniaturization and complex integration. However, more information is required to understand the feasibility of a specialized pre-processing and recycling ecosystem for the Netherlands that focuses on the liberation of targeted components (CRMs), including mapping where these components (CRMs) are located and how they are structurally integrated into products. The complexity of WEEE should be considered in terms of its actual functional material matrices rather than merely as isolated elements. Therefore, evaluating the technical¹⁵ and economic feasibility of physically isolating these components is key to enabling such a system. In addition, components related to feedstock volume requirements¹⁶, and domestic offtake are also relevant to be considered. **As a next step for WEEE, the NMO will conduct a deep dive into the pre-processing of REE-containing components as an enabler for material recovery, including the perspectives of recycling technologies and competition.**

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¹⁵ e.g., targeted pre-processing methods capable of breaking material bonds without degrading the target CRMs

¹⁶ Partly covered in [Theoretical availability of CRMs in Dutch waste streams - Netherlands Materials Observatory](#)

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