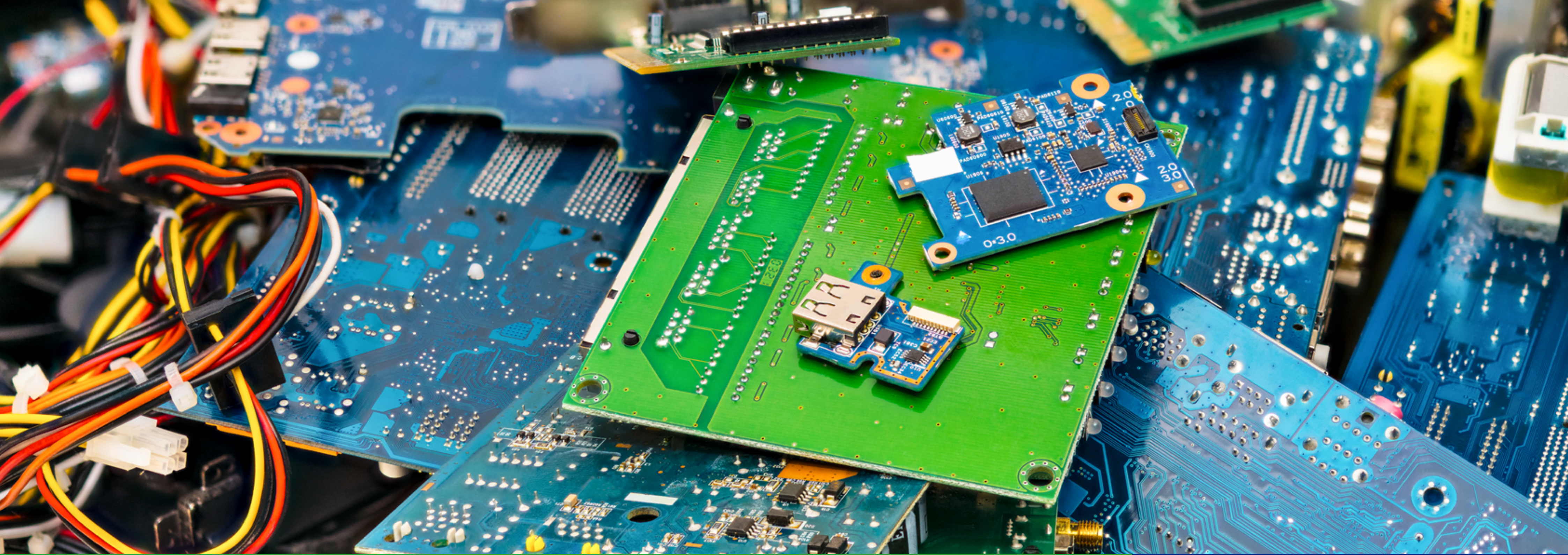
Whitepaper

# Activating Strategic Raw Materials Recovery:

## The case of waste electrical and electronic equipment



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# Executive summary

The EU faces increasing pressure on vital resources due to geopolitical pressures and the transition to climate neutrality, especially for critical raw materials (CRM) and strategic raw materials (SRM). The Critical Raw Materials Act sets benchmarks for EU extraction (10%), processing (40%), and recycling (25%) for meeting the EU's annual needs for SRMs by 2030. This white paper outlines possibilities to recover SRMs from waste electrical and electronic equipment (WEEE). A waste stream that holds many SRMs, of which few are currently recovered. This paper is intended for policy-makers, waste management specialists, public authorities, research institutes and producer responsibility organisations within the EU. Using a case study of the Netherlands, we examine the current system for recovery of WEEE and the possibilities to increase SRM recovery. We argue that SRMs within WEEE have the potential to meet up to over 30% of the EU's current demand for specific materials. Realising this potential requires policy adjustments, improved data collection and management, enhanced collaboration among stakeholders and a technological push. The key bottlenecks and recommendations for the recovery of SRMs from WEEE are:

**WEEE collection levels and the collection of broken or unused products from households and businesses needs to increase:**

- In 2020, the Netherlands collected 44% of the available waste against a target of 65%. Most EU countries fail to meet their collection targets. Roughly 9% of all electronic products in households and businesses in the Netherlands are unused or broken.
- **Recommendation (policy/NL):** incentivise better disposal by consumers & businesses of household stock and collection of products that are currently lost, looking to front-running EU examples.

**Existing policy needs to be adapted to promote and incentivise the recovery of critical and strategic materials and transparency of recycled materials**

- The WEEE policy promotes the collection and recovery of WEEE based on mass, not specific materials, e.g., CRMs or SRMs
- **Recommendation (policy/EU and NL):** increase the incentives for better pre-separation, recovering smaller quantity materials and transparency in WEEE reporting.

**Greater collaboration between organisations and policy changes are needed to increase the knowledge of the composition of electronic products**

- The heterogeneous nature of WEEE makes estimating the material composition incredibly challenging without repeated testing. There is little to no transparency and information provided by producers of E-products in the Netherlands.
- Recommendation (policy/NL): every producer who brings an E-product to the Dutch market has to declare what CRMs and SRMs are in this product (following the example of France).
- **Recommendation (policy/NL):** better collaboration is needed between research organisations and PROs to share data and undertake lab testing to increase the knowledge of product compositions.

**A push is needed to businesses and research institutions to develop and deploy CRM recovery technologies**

- **Recommendation (Activity/NL/EU):** Companies and research institutions involved in the R&D and deployment of CRM & SRM recovery technologies should join forces to develop new projects.

**The Dutch government should develop a roadmap towards SRM recovery by 2030, which provides direction and boundary conditions for stakeholders**

- Numerous barriers exist for the stakeholders involved in the collection and recovery of SRMs from WEEE. Overcoming these barriers requires multiple parties to work together.
- **Recommendation (NL):** provide a coordinated roadmap that combines all the boundary conditions, R&D, value chain integration for the recovery of SRMs and market activation for their use in EU industry.

We identify 11 SRM hotspots in WEEE that provide the basis for technological and projects developments. We call on policymakers, public authorities, research institutes, PROs, and waste management companies to embrace these proposals and develop a roadmap for SRM recovery to meet the ambitions of the CRMA.

# Contents

# Europe's dependency on critical raw materials and the need for increasing recycling

## Introduction

The European Union (EU) faces increasing pressure on vital resources due to geopolitical pressures and the transition to climate neutrality. This surge in demand coupled with global competition highlights the importance of accessing critical raw materials (CRMs) and Strategic Raw Materials (SRMs) essential for renewable energy and digital technology industries. CRMs are those raw materials that are economically important and have a high supply risk, such as cobalt (used for batteries) and neodymium (used in permanent magnets). SRMs are designated CRMs whose volumes are expected to be grow particularly strong in the coming years. Given their economic importance for key EU industries copper and nickel are added as SRMs as well, despite not meeting criticality thresholds (European Commission, 2024). See Annex for a complete list of CRMs and SRMs.

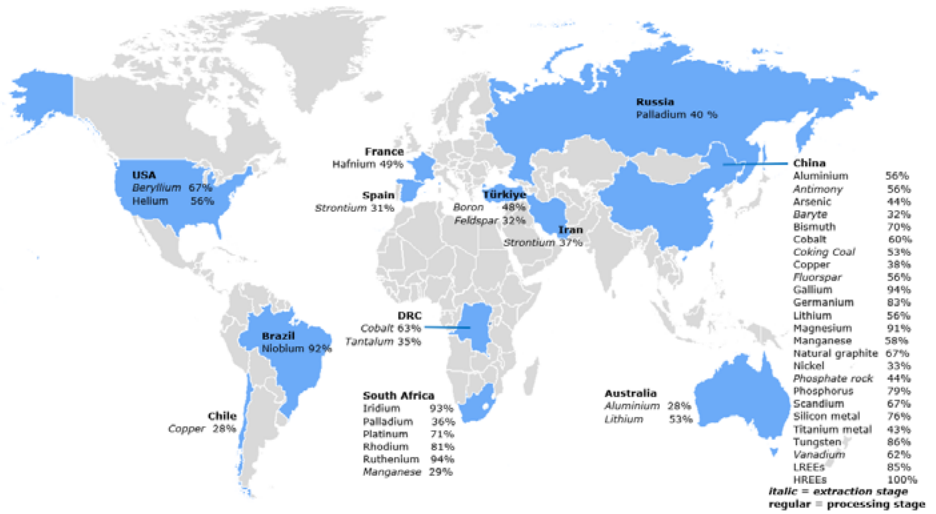
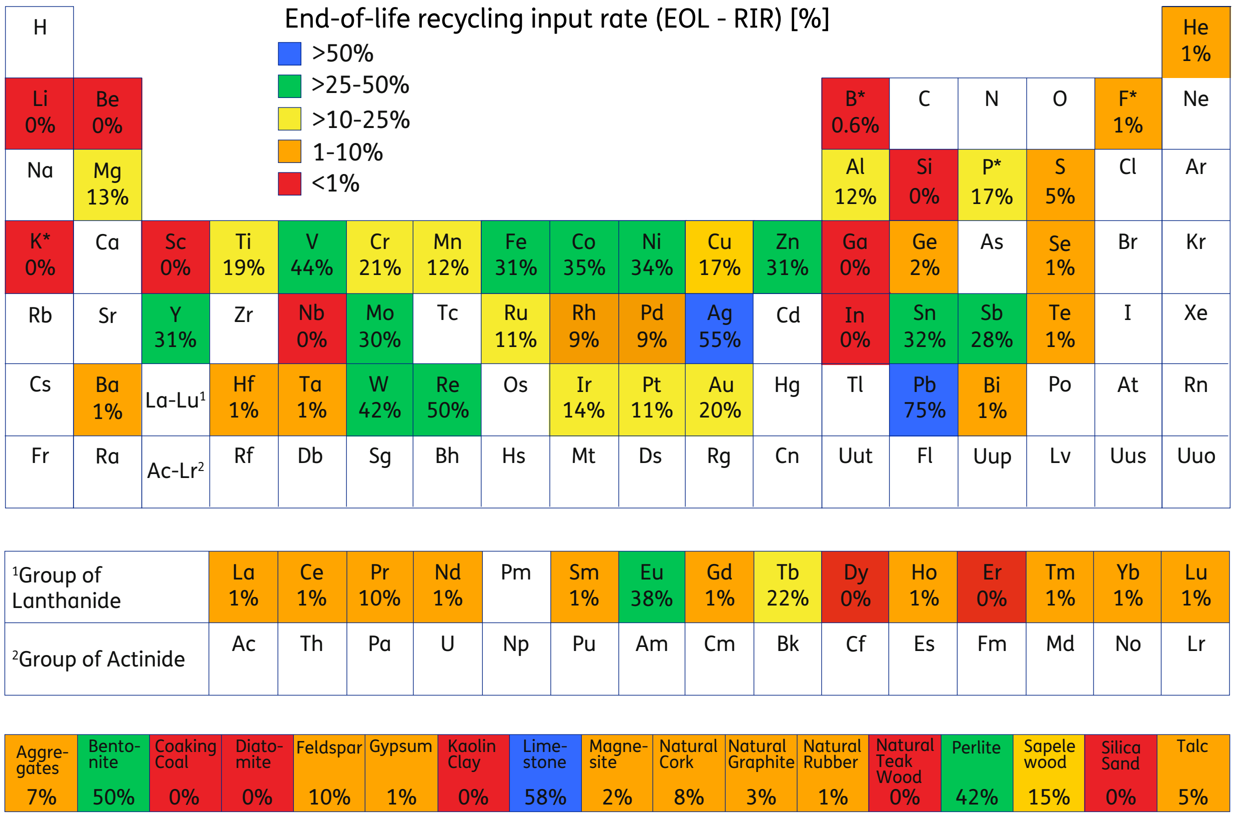



**Figure 1**: Countries accounting for largest share of global supply of CRMs (European Commission, 2020; SCRREEN, 2023)

Fig. 1 presents the main global CRM producers (European Commission, 2020; SCRREEN, 2023). The EU's dependency on other countries for CRMs is evident, with China emerging as the largest supplier for many key materials, such as rare earth elements (REE). Countries like Russia, South Africa, Australia, the USA, and Brazil also hold significant global shares for various CRMs.

The Critical Raw Materials Act (CRMA) outlined by the European Commission in 2023 strives for greater strategic autonomy for certain materials and to mitigate the material dependency outlined above. The CRMA sets benchmarks for EU extraction (10%), processing (40%) and recycling capacity (25%) to meetings the EU's annual consumption of raw materials. The recycling benchmark applies to SRMs. EU member states are required to report on their progress towards these percentages. In addition, member states are asked to report on components and materials containing CRMs and SRMs from waste electrical and electronic equipment (WEEE), where the systematic documentation across the EU is currently lacking. WEEE is estimated to contain various quantities of CRM and SRMs (Huisman et al., 2017). Promoting the recovery of SRMs from WEEE that can contribute to the EU's benchmarks is the focus of this white paper.

SRMs are currently recovered to varying levels from sectors and waste streams, which contribute to differing degrees to meeting the EU's current demands. Fig. 2 outlines the current European End-of-life recycling input rate, thus the degree to which current recycling of elements relates to EU demand. Several elements, such as copper and nickel, already have high recovery rates, while elements such as neodymium, gallium and dysprosium are much lower. Those elements, many with low overall recycling rates, that have potential from secondary resources require attention to activate technology development and processing capacity.




* F=Fluorspar; P=Phosphate rock; K=Potash; Si=Silicon metal; B=Borates.

**Figure 2**: The current end-of-life recycling input rate, e.g. the percentage that current recycling contributes to total demand for a specific element. Source (Bobba et al., 2018)

This white paper is intended for policy-makers, public authorities, waste management bodies, producer responsibility organisations (PROs) and research institutes working on increasing the recovery of SRMs. It provides a direction and motivation to realising the recycling potential of SRMs from WEEE. Using a case study of the Netherlands, we argue SRMs within WEEE could contribute up to over 30% of the EU's current needs for specific materials. The opportunity to realise this needs to be taken and requires changes in policy, data transparency and collaboration to unlock these, as yet, untapped sources.

## Reading guide

Part two outlines the quantities of WEEE in the Netherlands, and the current policy and organisational context.
Part three outlines the current material recovery value chain and practices around recovery.
Part four presents the quantities of CRMs within WEEE, and the degree they can contribute to EU demand.
The final part outlines the key recommendations for activating CRM recovery from WEEE.

# Waste from Electrical and Electronic Equipment

This section outlines the policy and organizational collection and recycling context for WEEE in the Netherlands. Our work shows that specific incentives to recover SRMs from WEEE are absent; nor is the reporting of SRMs from recycling transparent enough. Moreover, collection rates of WEEE are low in the Netherlands and across the EU, which reduces the potential source for raw materials. However, the collection and sorting facilities of the Netherlands provide a good example for separation and sorting. These provide a strong basis for increased recovery if SRM containing products and components can be identified.

### WEEE Provides a Strategic Opportunity for Recovering SRMs

As material technology progresses, the amount of WEEE is steadily rising, especially when it comes to smaller items of consumer products. Despite appearing small in mass compared to other waste streams such as construction and demolition waste, WEEE stands out as one of the EU's fastest-growing waste streams (EU Monitor, 2023). With other sectors already being addressed in revised regulations (such as construction waste, batteries, and vehicles), focusing on recovering SRMs from WEEE presents a strategic opportunity to tap into an untapped area of raw materials.

In the Netherlands, more than 750,000 tonnes of electrical devices are annually brought onto the market (roughly 44kg per capita). More than one billion devices are held in 'stock', either used, unused or broken by households and businesses (Stichting OPEN).[1] These electrical devices represent future sources of SRMs. In 2020, more than 200,000 tonnes of WEEE were collected, roughly 57% of the total quantity (excluding photovoltaic panels). This quantity represents the Netherlands' current source for CRM/SRMs (Fig. 3).

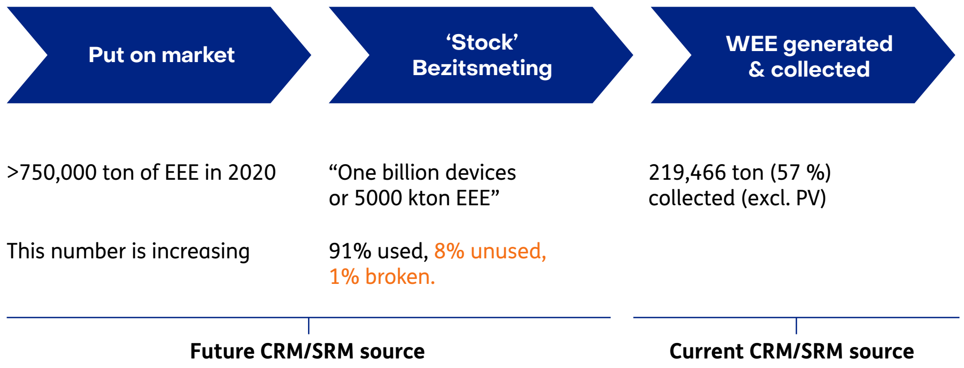



**Figure 3**: Dutch quantities of electronics and electronic waste. Sources Sichting OPEN by personal communication and (Nationaal (W)EEE Register Rapport 2020, 2021).

1 Via personal communication

## The Policy and Organisational Features of WEEE in the Netherlands Are Complex

The collection and recovery of WEEE in the Netherlands falls under the 2012 WEEE Directive. This directive deploys the principle of extended producer responsibility, where producers must organise the collection and recycling of WEEE up to 65% of the weight of products. Producers pay a fee, based on the weight of the product, to organize the collection and recycling of the waste product. Recovering SRMs specifically is not part of the WEEE Directive; however, it is now part of the critical raw materials act. This adds a vital policy driver. All the WEEE in the Netherlands is classified and reported following the six categories of the EU WEEE Directive as shown in Fig. 4.

In the Netherlands, a third party, Stiching OPEN, fulfils the responsibilities regarding the WEEE Directive on behalf of the producers, a definition that encompasses OEMs, distributors, and importers. Stichting OPEN was formed out of Wecycle, WNL, ZRN, PV Cycle, RTA, and Stibat with the aim to meet the EU WEEE Directive collection target of 65%. WEEE is collected at various collection points, such as retailers and municipal waste stations, transported and sorted into different categories and product groups. The collected WEEE is sent to various recyclers depending on the type of product and whether it is hazardous (e.g., mercury-containing lamps or products containing batteries, for which there is separate EU legislation).

Much of the end-processing, such as smelting, takes place outside the Netherlands, with the manual and mechanical processing predominantly happening inside. Mechanical processors are required to recover and recycle certain percentages from different product groups, e.g., 85% recovery and 80% recycling for large household appliances and 75% recovery and 55% recycling for lighting equipment. The final recycled percentages are also required to be reported by Stichting OPEN under the WEEE Directive. Presently, the WEEE Directive does not require mechanical and end-processors to communicate which SRMs they currently recover. This reduces knowledge of the state of SRMs recovery from WEEE. A selection of organisations involved in the collection and recovery of WEEE in the Netherlands are presented in Fig. 5.

**Temperature exchange equipment**
Refrigerators, Freezers, Air conditioning equipment,Dehumidifying equipment, Heat pumps

**Screens and monitors**
Screens, Televisions, LCD photo frames, Monitors, Laptops, Notebooks

**Large equipment**
Washing machines, Clothes dryers, Dish washing machines, Cookers, Electric stoves, Electric hot plates, Luminaires

**Small equipment**
Vacuum cleaners, Carpet sweepers, Appliances for sewing, Luminaires, Microwaves, Ventilation equipment, Irons, Toasters

**Lamps**
Straight fluorescent lamps, Compact fluorescent lamps, Fluorescent lamps, LED

**Small IT and Telecommunications**
Mobile phones, GPS, Pocket calculators, Routers, Personal computers, Printers, Telephones

**Figure 4**: The six WEEE reporting categories and quantities of WEEE. Source TNO

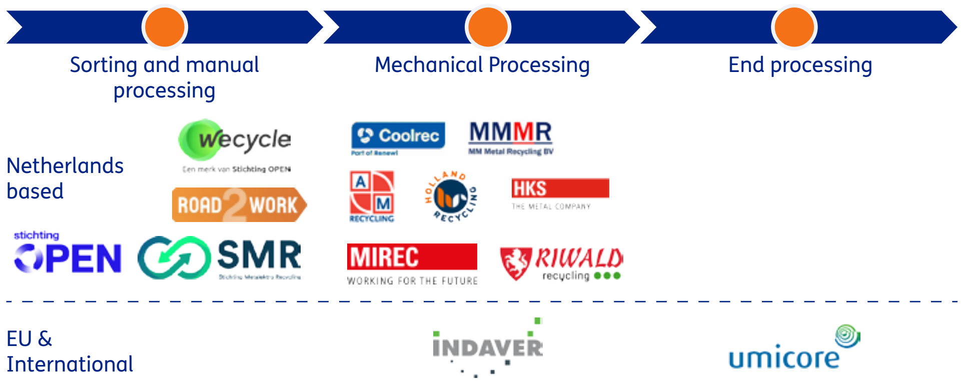



**Figure 5**: Overview of a selection key organisations involved in organising the collection and recovery of WEEE

## Collection Rates in the Netherlands and Across the EU Are Low and Need to Increase

In 2020, Dutch households and businesses held over a billion electrical devices that are in-use, unused or broken. The quantity collected in 2020 by Stichting OPEN corresponded to roughly 44% of the total quantity put on the market for the previous three years (57% without photovoltaic panels). Dutch collection levels are below the EU average, with most countries struggling to meet the 65% target (see Fig.6). Increasing the collection rate to level of a comparable counterpart (Belgium 51%) or collection leader (Bulgaria 91%) could see the Netherlands annually collect more than 35,000 and 235,000 tonnes respectively. Moreover, it is feared that the current lack of financial incentives and data prevents companies to improve these percentages in the coming years.

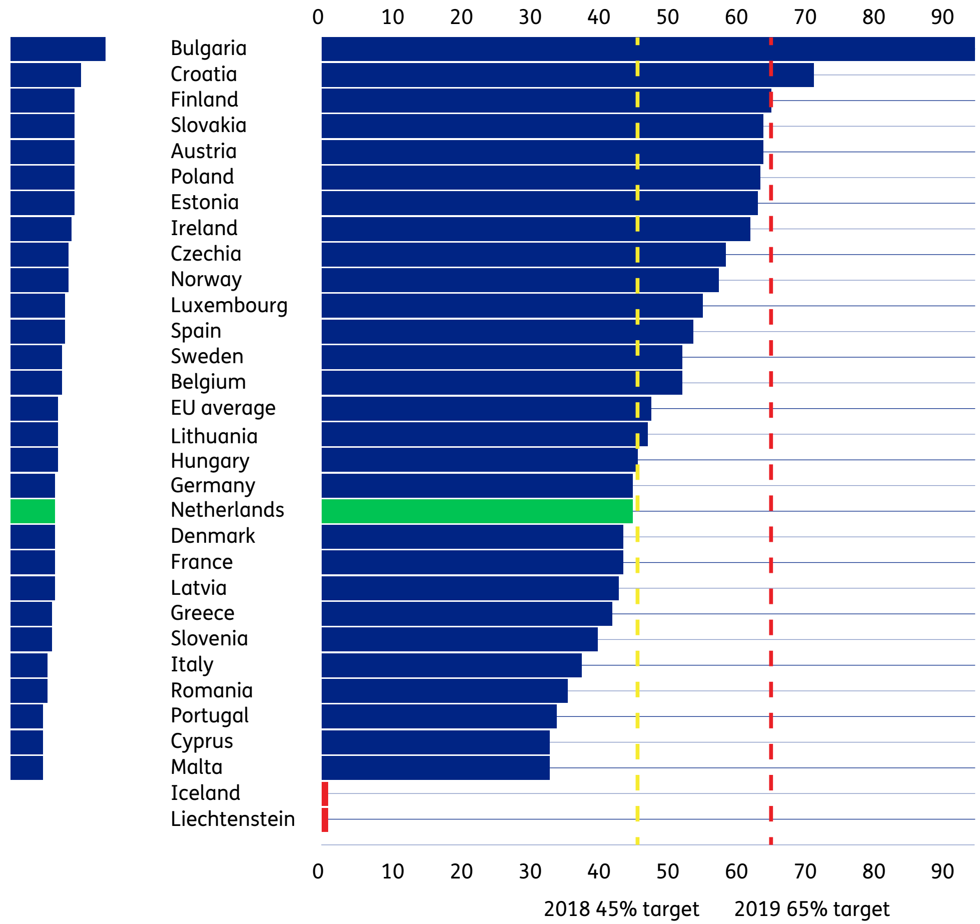



**Figure 6**: EU collection levels for WEEE in 2020. Source (Eurostat, 2020)

### The Collection and Sorting Infrastructure Around WEEE Provides an Opportunity to Support Better Pre-treatment and Overall Recovery

Stichting OPEN has a high level of data specificity on the product streams, gained via their contracted sorting facilities. With increased collection and the correct identification of products containing SRMs, these operations would greatly help in separating these products into more concentrated product streams that can be directed to appropriate mechanical or material recovery operations (Fig. 7).

**Figure 7:** Road2Work's sorting facility in Ede is a social enterprise, which supports people with a distance from the labour market into a job. The organisation sorts mixed electronic waste.

# Current Strategies and Raw Matrials Recovery practices from WEEE

This section outlines how SRMs are used within WEEE and the current barriers that inhibit greater recovery of them. It argues that the current policy promotes the recovery of bulk materials at the expense of smaller quantities of SRMs. Our work confirms that various socio-economic and technological barriers exist still, which must be overcome to make SRM recovery viable and feasible.

## SRM Uses and Concentrations Within WEEE are varied

SRMs are used within WEEE for different components and applications, as illustrated in Fig. 8 right. The diverse composition of electronics complicates recycling efforts. Printed circuit boards (PCBs) alone contain valuable metals like gold and copper, alongside semiconductors such as gallium. Other components like magnets and luminescent materials add elements like boron, neodymium,  and other rare earth elements (REEs) to the mix. This complexity reduces the recoverable quantity, given the wide array of elements used in different combinations.

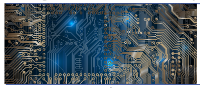
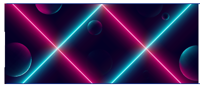
| | Component | Cu | Ga | Ai | Ti | Nd | Pr | Dy | B | Sm | Ce | Tb | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Cables | 29 Cu Copper 63.546 | | | | | | | | | | | |
|  | PCBs | 29 Cu Copper 63.546 | 31 Ga Gallium 69.723 | | 22 Ti Titanium 47.867 | | | | | | | | |
|  | Magnet | | | | | 60 Nd Neodymium 144.24 | 59 Pr Praseodymium 140.90766 | 66 Dy Dysprosium 162.500 | 5 B Boron 10.81 | | | | |
|  | Luminescent materials | | | | | | | | 5 B Boron 10.81 | 62 Sm Samarium 150.4 | 58 Ce Cerium 140.116 | 65 Tb Terbium 158.92535 | |
|  | Glass | | | | | | | | 5 B Boron 10.81 | | | | |
|  | Casing | | | 13 Al Aluminium 26.982 | | | | | | | | | 12 Mg Magnesium 24.305 |

**Figure 8**: SRMs and their varied uses in electrical products. Source TNO

### Typical Recycling Operations for WEEE Include Mechanical Processing, End-processing

Although WEEE streams are highly heterogeneous, the treatment processes are less so. The vast majority of WEEE products are not processed as an individual product stream, e.g. vacuum cleaners or hairdryers, but in aggregated product streams, e.g. small equipment. For example, while there are four different categories of lamps (compact fluorescent lamps, tube fluorescent lamps, special lamps, e.g. professional, small and large, and LED lamps), only the fluorescent tubes are treated separately because of the presence of mercury; all others are treated together. It would signal progress if, in the coming years, WEEE is increasingly pre-treated based on SRMs (not only hazardous chemicals) and recycling in separated streams is done as a result. An example of lamp recycling is given in Fig. 9. After pre-treatment including sorting and some disassembly, WEEE streams are mechanically processed into sub-streams or fractions. Treatment facilities focus on recovery of ferrous and non-ferrous fractions (aluminium, copper) and some plastics. All other materials end up in a mixed material stream that cannot be sorted and can only be treated through incineration with energy recovery. This practice is comparable to other WEEE product categories, which also focus on these main fractions.

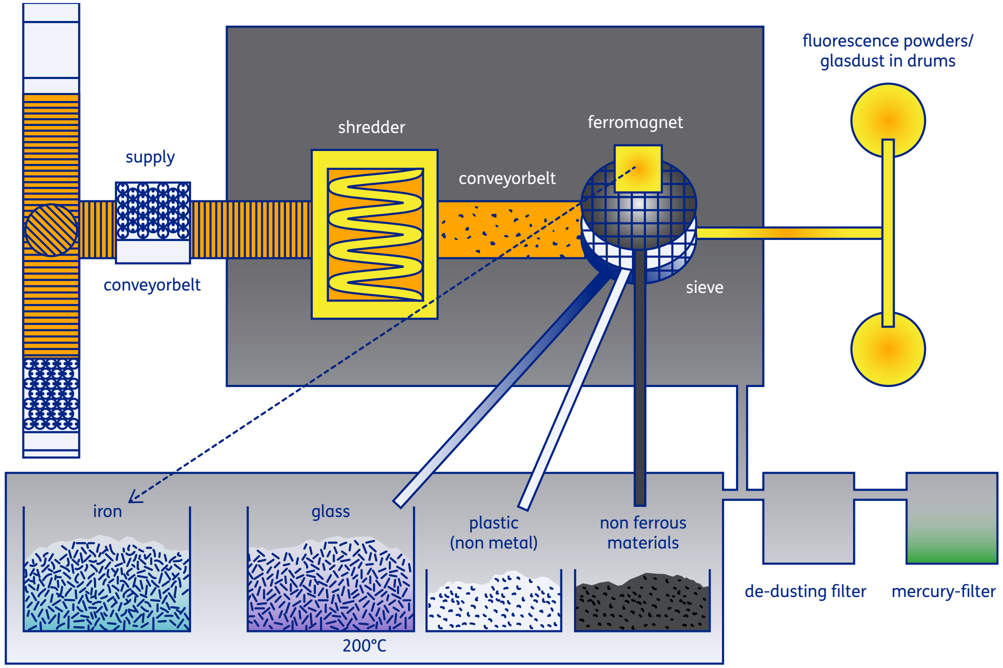



**Figure 9**: Treatment process for fluorescent lamps. Used with permission of Indaver N.V.

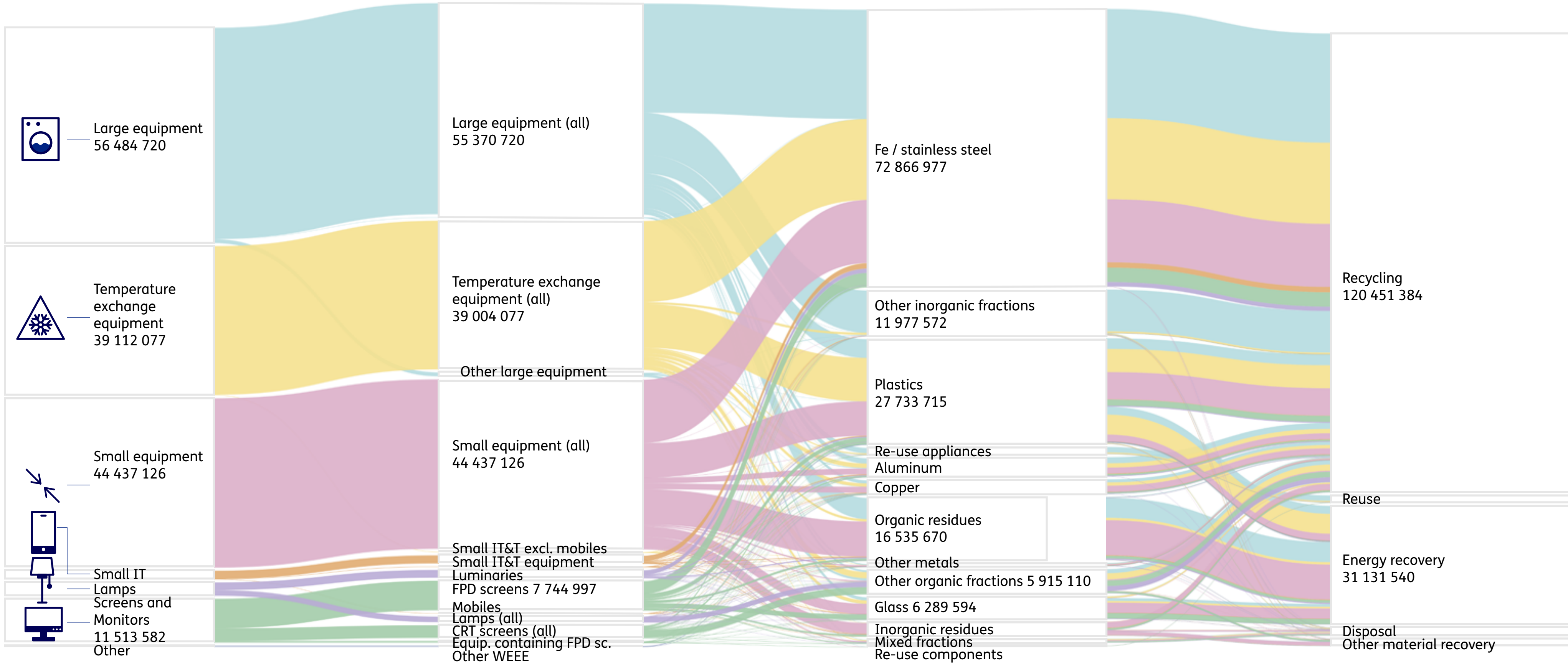



**Figure 10**: Sankey diagram of the sorting and processing of all collected WEEE in the Netherlands (2020). The weight is in kgs. Data provided by Stichting OPEN. Diagram made by TNO.

### The Current WEEE Policy Promotes Mass Recovery at the Expense of SRMs, While the Reporting of SRMs is Limited

Currently, the recovery of SRMs from WEEE largely depends on their application and economic value. Interviews with mechanical and end processors revealed that few SRMs are currently recovered from WEEE, such as copper, aluminium, antimony, nickel, and palladium from mixed WEEE fractions and PCBs. Additionally, even fewer SRMs are officially reported: SRMs that are currently recovered are not reflected in official statistics, making it difficult to quantify the exact quantities. See the Sankey diagram in Fig 10 which presents how collected WEEE is sorted, processed and then reported as monostreams such as copper and plastics.

The limited quantities of recovery and reporting today are explained by the lack of (mostly financial) incentives. WEEE policy promotes the recovery and reporting of materials based (65% collection target) on mass, i.e. bulk (see Figure 10). There is no incentive or mechanism within the policy to recover small yet critical quantities. Consequently, many SRMs, such as silicon, gallium, magnesium, and rare earth elements, are often lost in shredding residues or become diluted in other recycled fractions. A new direction is therefore needed.

### Crucial Barriers for Recyclers to Recovering SRMs from WEEE that Need to Be Overcome

Interviews with mechanical and end processors revealed the prevalent barriers to recovering SRMs from WEEE. These barriers must be overcome, either via better use of data, value chain coordination, policy incentives or technological developments, to initiate the recovery of SRMs. Table 1 below presents a non-exhaustive list of the key barriers.

**Table 1**: Key barriers to recovering SRMs as indicated by mechanical and end processors

| Socio-economic viability | Technological feasibility | Quantities present in WEEE |
|---|---|---|
| Economic costs of recycling SRMs vs virgin costs (no market for these SRMs)<br>Energy costs of recycling<br>Costs of manual disassembly.<br>There is no or limited market for these recycled SRMs (reyclate) | Lack of technology in place to decontaminate SRMs and waste streams<br>Lack of technology in place to recover them. | Low concentrations of SRMs<br>Hard to identify SRM fractions/ components<br>Phasing out of products containing SRMs, e.g., Cathode Ray Tubes. |

The combination of socio-economic, technological and quantity-related barriers presented above, coupled with the policy context, prioritises mass or bulk recovery while SRMs are predominantly lost in one of the main fractions.

# On the Quantities of Strategic Raw Materials Within WEEE, and How Much they Can Contribute to Meeting EU Demand

This section presents an analysis of the quantities of SRMs available in WEEE. WEEE is an incredibly heterogeneous and mixed waste stream. Thus, using and improving existing databases is needed to build up a clear perspective on the composition and possible focus areas for recyclers. Nevertheless, we argue that current quantities can provide up to over 30% of current EU demand. Keep in mind this percentage is a ratio, which can change in case the European industrial base grows. Therefore, there is no reason to be complacent as a result of this finding. We identify the main component and material SRM hotspots in WEEE.

### The complexity of characterizing WEEE composition and data limitations necessitates collaboration to increase the transparency of electronic products and waste

WEEE is an incredibly heterogeneous waste stream, comprising six broad product categories and 77 sub-categories. Thus, using and improving data is needed to build up a clear perspective on the composition of where to focus present and future recycling activities is needed.

Currently, estimating the quantities of these materials in WEEE is challenging due to the lack of comprehensive data. Public datasets on CRMs/SRMs within WEEE exists only on the product category or waste flow level, e.g., Large equipment, not for individual products and components (with such data being highly scattered or incomplete for many product groups). Reliable public data only extends to 2020, while better composition data on products is known only to a few. To effectively monitor stocks and flows of the materials and with that inform more specific policies and interventions by recyclers, more detailed data is required.

One of the reasons for the lack of reliable data is the lack of transparency in the value chain. Producer responsibility organisations and mechanical processors often don't know what the SRM content is of products they treat. Without this transparency in new products and within waste flows, it is highly complex to classify and estimate the amount of SRMs in specific products and brands. Fig 11 illustrates this complexity for the case of washing machines.

| Eu product categories | Sub categories |
|---|---|
| Screens and monitors | 6 |
| Lamps | 4 |
| Small equipment | 34 |
| Temperature exchange equipment | 7 |
| Small IT and telecommunications | 7 |
| Large equipment | 19 |
| Total | 77 |

**WEEE's heterogeneous nature makes it complex to examine**
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.

**Figure 11**: The heterogeneous nature of WEEE makes identifying specific SRMs and SRM components in products and specific brand complicated. The WEEE product categories, sub categories and a non-exhaustive list of washing machine brands is given above.

## Important datasets and legal developments to better understand the composition of WEEE

### The ProSUM Project

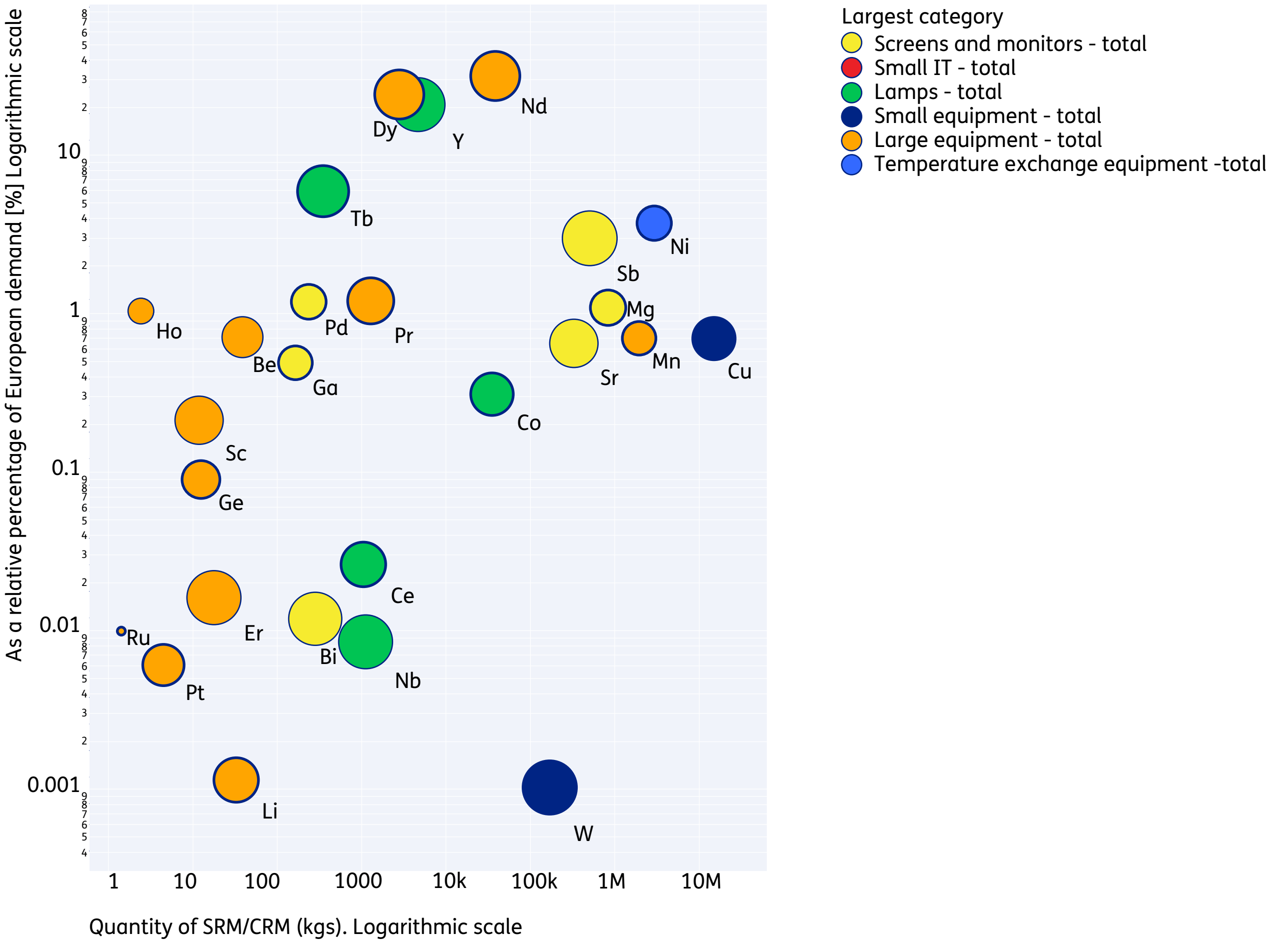
The ProSUM project, part of the EU Horizon 2020 initiative, ran from 2016 to 2018 and focused on estimating the historical elemental and material composition of electrical and electronic equipment (EEE), encompassing six categories of products, as well as batteries and electric vehicles (EVs) in the EU. The project relied on official reporting data to estimate the quantities of products put on the market, stocks, and waste generated. In addition to official reporting data, the ProSUM project combined multiple data sources, including literature reviews, product inventories, reporting data voluntarily collected by a French PRO on material composition, and laboratory testing, to estimate the composition of these products. This comprehensive approach provided the best public data available for the composition of WEEE products. This data extends up to the year 2020 and is managed by UNITAR.

### FutuRaM project

The FutuRaM project runs from 2022-2026 focuses on developing knowledge on the availability and recoverability of secondary raw materials within the EU. It has a special focus on CRMs from the present day to 2050. It focuses on batteries, WEEE, vehicles, slags and ashes, mining waste and construction and demolition waste, and classifies their recoverability according to a harmonized framework (the UN Framework Classification (UNFC)). This project currently has no public results.

### French law on reporting of CRMs within consumer products

Decree No. 2022-748 of April 29, 2022 relating to consumer information on the environmental qualities and characteristics of products generating waste (Décret n° 2022-748 du 29 avril 2022 relatif à l'information du consommateur sur les qualités et caractéristiques environnementales des produits générateurs de déchets), and Article L541-10-1 of the environmental Code (Article L541-10-1 Code de l'environnment) provide specifications on electrical products to indicate whether the product contains precious metals and some rare earth elements, e.g. scandium, yttrium, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium (more than 1 milligram). It further indicated if they are to be collected for reuse and end processing.




## SRMs Within WEEE Could Meet More than 30% of Current EU Demand

Despite the complexity of identifying where SRMs are, the data allows conclusions that seem plausible as an order of magnitude. We can thus claim that the estimated quantities indicate that efforts towards recovering them should be made. Fig. 12 outlines the quantities of SRMs within WEEE compared to current EU demand. SRMs neodymium (Nd), dysprosium (Dy), terbium (Tb) and yttrium (Y) stand out as elements within WEEE that can contribute significantly to EU current demand.

**Figure 12**: The position of the Netherlands for various CRMs/SRMs. The X-axis (logarithmic) indicates the quantity of a CRMs (kg). The Y-axis indicates the relevant percentage of that CRM to current EU primary demand (%). Materials with a black circle are strategic materials. The colour indicates the waste stream where the CRM is most highly concentrated. The darker black circles indicate in the material is a SRM. The size of the dots indicates the number of WEEE categories that this CRM has been found in. The smaller the dot, the more categories it can be found in. The bigger the dot the less categories the CRM is spread across. Sources Huisman et al., (2017), and SCRREEN, (2023). Figure TNO own creation. Note. This data figure does not include batteries that are included in WEEE. These are separated and treated differently according to separate legislation. Thus, Lithium quantity in WEEE is estimated to be low.

### A Way Forward... Key SRM Component and Material Hotspots in WEEE

The previous analysis demonstrated the sizable quantities for some SRMs within WEEE. However, not all these SRMs are currently being recovered. Focus and direction are needed. Table 2 outlines the main SRM hotspots within WEEE where practitioners should start focusing on, which were ascertained through triangulating expert interviews, online databases and scientific literature.

**Table 2**: SRMs with potential to contribute to the CRM Act recycling ambitions with identifiable components and material fractions.

| Product category | Identifiable fraction / component | SRMs present or highly suspected | Main global supplier / producer | Contribution to EU consumption (from all categories) | Current EU EoL recycling input rate From all EU waste streams | Product trend 2019-2023 | TRL (estimated) |
|---|---|---|---|---|---|---|---|
| Large equipment | Permanent magnets from automatic washing machines, tumble driers, dishwashers or e-bikes | Dy<br>Nd | China | 24%<br>31% | 0%<br>1% | + | 4-6 |
| | Aluminium fraction | Al | China | 0.4% | 12% | + | 9 |
| Lamps | Magnets / LEDs | Co | DRC | 0.3% | 35% | + | n.a. |
| | Fluorescent powders | Ce<br>Tb | China | 0.3%<br>6% | 1%<br>22% | -<br>- | 1-3 |
| Screens and Monitors | Aluminium fraction & FPD | Mg<br>Mn | China<br>China/SA | 1.1%<br>0.7% | 13%<br>12% | +<br>+ | n.a. |
| | LED | Ga | China | 0.5% | 0% | + | n.a. |
| Small IT | Hard disk drives & magnets | Pr (Dy & Nd) | China | 1.2% | 10% | - | 4-6 |
| | Copper fraction | Cu | Chili | 0.7% | 55% | + | 9 |
| Small Equipment | Permanent magnets from vacuum cleaners or microwaves | Dy<br>Nd | China | 24%<br>31% | 0%<br>1% | + | 4-6 |
| all (except lamps) | PCBs | Ga | China | 0.5% | 0% | + | 9 |

### The prize: better assessment of the many operational recycling business propositions for the European Urban Mine

As this whitepaper shows: current recycling practices in the Netherlands leave ample room for value retention but require a bit of a kickstart. Many metallurgical technologies are offered by start-up companies. These companies currently scout the European market for support in testing, permitting, infrastructure development and pre-treatment logistics. The propositions of these companies need to be assessed by public investment fund managers. The recommendations in this whitepaper mostly refer to policy drivers and data science technologies. These recommendations can be practical as well, as they can help decision makers make a better decision about which waste treatment proposition to support and focus on. For example, European regions (like Innovation Quarter in South-Holland, but also the members of EURADA in Europe) have to make decisions on a monthly basis on where to put subsidies, expedite legal processes and provide knowledge or other facilitation to help companies develop new business activities.

### Examples of metallurgical technology companies

Examples of metallurgical technologies are aimed at retention of toxic solvents, use of electrodialysis, use of redox technologies and organic solvents. The recommendations for post-consumer collection, pre-treatment and information management of waste streams could significantly boost efficiency and effectiveness of the metallurgical processes. Examples of such companies currently involved in the recycling of batteries are **Iondrive and Fortum**.

# Recommendations for Activating the Strategic Raw Materials Potential from WEEE

In the previous section, we have identified which SRMs have potential to add to the CRMA benchmarks, but also the varying barriers and challenges. To realise this potential, value chain coordination coupled with policy, technology changes and innovations are needed. The following recommendations are made:

**WEEE collection levels and the collection of broken or unused products from households and businesses need to increase:**

- Roughly 9% of all electronic products in households and businesses in the Netherlands are unused or broken.
- In 2020, the Netherlands collected 44% of the available waste against a target of 65%. Most EU countries fail to meet the collection targets.
- **Recommendation (policy/NL):** incentivise better disposal by consumers & businesses of household stock and collection of products that are currently lost, looking to front-running EU examples.

**Existing policy needs to be adapted to promote and incentivise the recovery of critical and strategic materials and transparency of recycled materials**

- The WEEE policy promotes the collection and recovery of WEEE based on mass, not specific materials.
- Only copper and aluminium are reported to be recovered from WEEE to Stichting OPEN. While additional SRMs, such antimony, palladium and nickel, are indicated to be recovered, the quantities are unknown.
- **Recommendation (policy/EU and NL):** increase the incentives for recovering smaller quantity materials.
- **Recommendation (policy/EU):** increase the transparency and level of detail of the reporting (both the quantity and location) all the way down to the smelters.
- **Recommendation (policy/NL):** incentive better pre-separation of products/ components containing SRMs for Stichting OPEN/EU PROs
- **Recommendation (Activity/NL/EU):** Stichting OPEN to collaborate with other European PROs, to combine quantities of SRM containing components into recoverable quantities.

**Greater collaboration between organisations and policy changes are needed to increase the knowledge of the composition of electronic products**

- The heterogeneous nature of WEEE makes estimating the material composition incredibly challenging without repeated testing. There is little to no transparency and information provided by producers of E-products in the Netherlands.
- Public databases exist which estimate the quantities of SRMs within WEEE, however, they only extend to 2020 and only extend to the product category or waste flow level, not to the specific product or component (information which is needed for better separation and pre-treatment).
- **Recommendation (policy/NL):** every producer who brings an E-product to the Dutch has to declare what SRMs are in this product (following the example of France).
- **Recommendation (policy/NL):** For public transparency: there needs to be better use of public databases for existing waste streams, such as the ProSuM and FutuRaM databases.
- **Recommendation (Activity/NL):** Stichting OPEN and/or mechanical processing companies should undertake systematic lab tests of products suspected to contain SRMs and their recovered fractions.
- With better knowledge on the composition of products, more immediate and long-term policymaking, such as incentives or recovery targets, can be made.
- Efforts should be made on a pan-European or regional basis to increase knowledge and use of data, including the use of the United Nations Framework Classification for Resources in secondary and anthropogenic resources to systematically categorise the maturity of CRM recovery projects.

**A push is needed to businesses and research institutions to develop and deploy SRM recovery technologies**

- European regions (like Innovation Quarter in South-Holland, but also the members of EURADA in Europe) have to make decisions on a monthly basis on where to put subsidies, expedite legal processes and provide knowledge or other facilitation to help companies develop new business activities.
- A starting area for the further exploration and valorisation of SRMs within WEEE is listed in Table 2
- **Recommendation (Activity/NL/EU):** Companies and research institutions involved in the R&D and deployment of SRM recovery technologies to join forces to develop new projects

**The Dutch government should develop a roadmap towards SRM recovery by 2030, which provides direction and boundary conditions for stakeholders**

- Numerous barriers exist for the stakeholders involved in the collection and recovery of SRMs from WEEE. Overcoming these barriers requires multiple parties to work together.
- **Recommendation (NL):** provide a coordinated roadmap that combines all the boundary conditions, R&D, value chain integration for the recovery of SRMs and market activation for their use in EU industry. This roadmap should include an outline for:
  - Knowledge and technology, which is focused on stimulating research and technological innovation for SRMs recovery;
  - Business case and supply chain integration, which is focused on actor collaboration (possibly beyond the Netherlands), necessary business cases and scaling up recycling operations;
  - Preconditions and market activation, which is focused on the wider market and regulatory system around SRM recovery and the uptake of recycled materials in Dutch/European industry.

We call on public authorities, policymakers, PROs, waste management bodies, research institutes and technology developers to embrace these proposals and take the next steps to meeting the goals of the critical raw materials act. The challenge is real, but the opportunity is waiting to be seized.

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# Annex

| Critical raw material name | Symbol element | SRM |
|---|---|---|
| Antimony | Sb | |
| Aluminium | Al | x |
| Beryllium | Be | |
| Bismuth | Bi | X |
| Boron | B | X |
| Cobalt | Co | X |
| Copper | Cu | X |
| Gallium | Ga | X |
| Germanium | Ge | X |
| Strontium | Sr | |
| Yttrium | Y | |
| Gadolinium | Gd | X |
| Terbium | Tb | X |
| Dysprosium | Dy | X |
| Holmium | Ho | |
| Erbium | Er | |
| Thulium | Tm | |
| Ytterbium | Yb | |
| Lutetium | Lu | |

| Critical raw material name | Symbol element | SRM |
|---|---|---|
| Scandium | Sc | |
| Lanthanum | La | |
| Cerium | Ce | X |
| Praseodymium | Pr | X |
| Neodymium | Nd | X |
| Promethium | Pm | |
| Samarium | Sm | X |
| Europium | Eu | |
| Lithium | Li | X |
| Magnesium | Mg | X |
| Manganese | Mn | X |
| Natural Graphite | C | X |
| Nickel (battery grade) | Ni | X |
| Niobium | Nb | |
| Ruthenium | Ru | X |
| Rhodium | Rh | X |
| Palladium | Pd | X |
| Platinum | Pt | X |
| Osmium | Os | X |

| Critical raw material name | Symbol element | SRM |
|---|---|---|
| Iridium | Ir | X |
| Silicon metal | Si | X |
| Tantalum | Ta | |
| Titanium metal | Ti | X |
| Tungsten | W | X |
| Vanadium | V | |

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