End of life of ICT

Anne-Laure Ligozat

Life cycle of an equipment

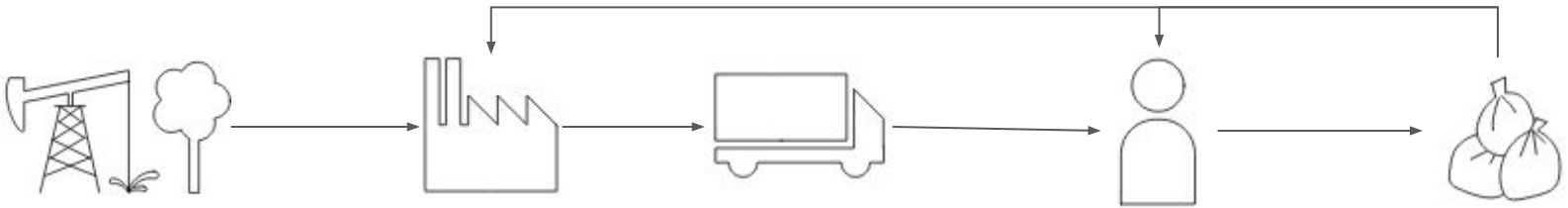


diagram taken from Jacques Combaz

Life cycle of an equipment

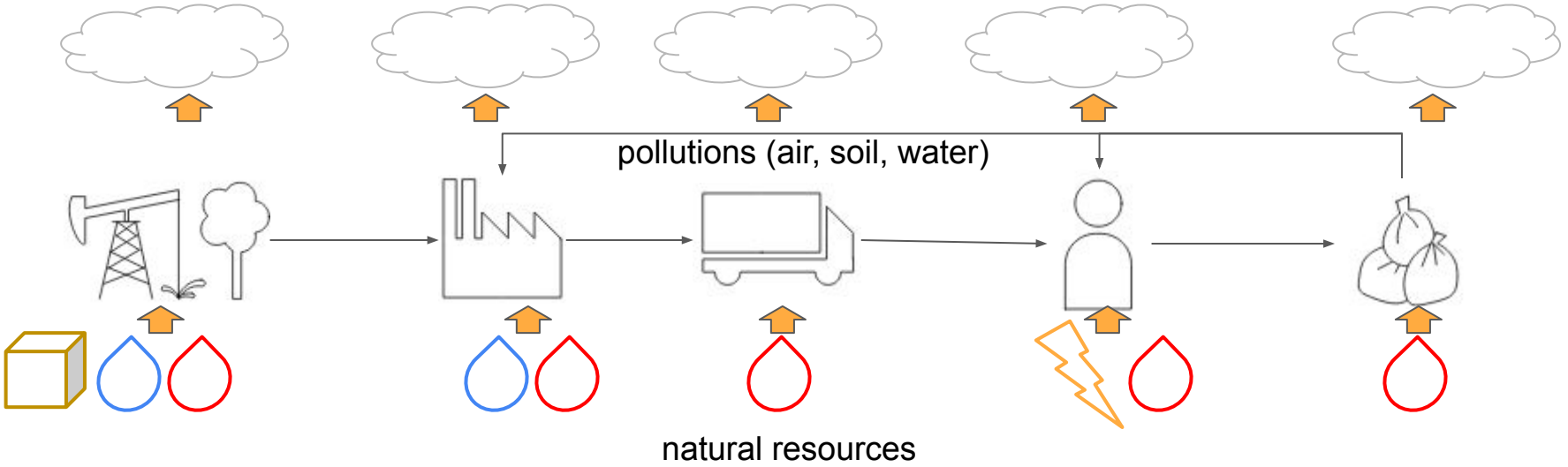
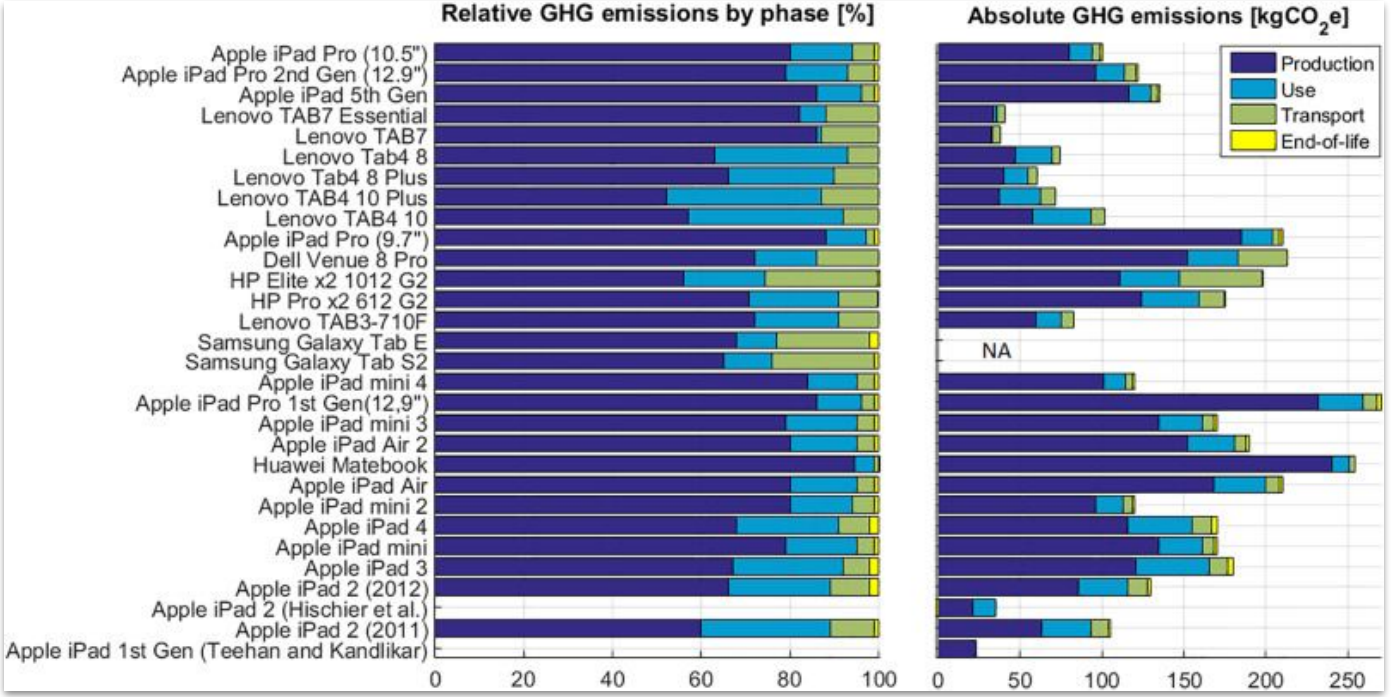


diagram taken from Jacques Combaz

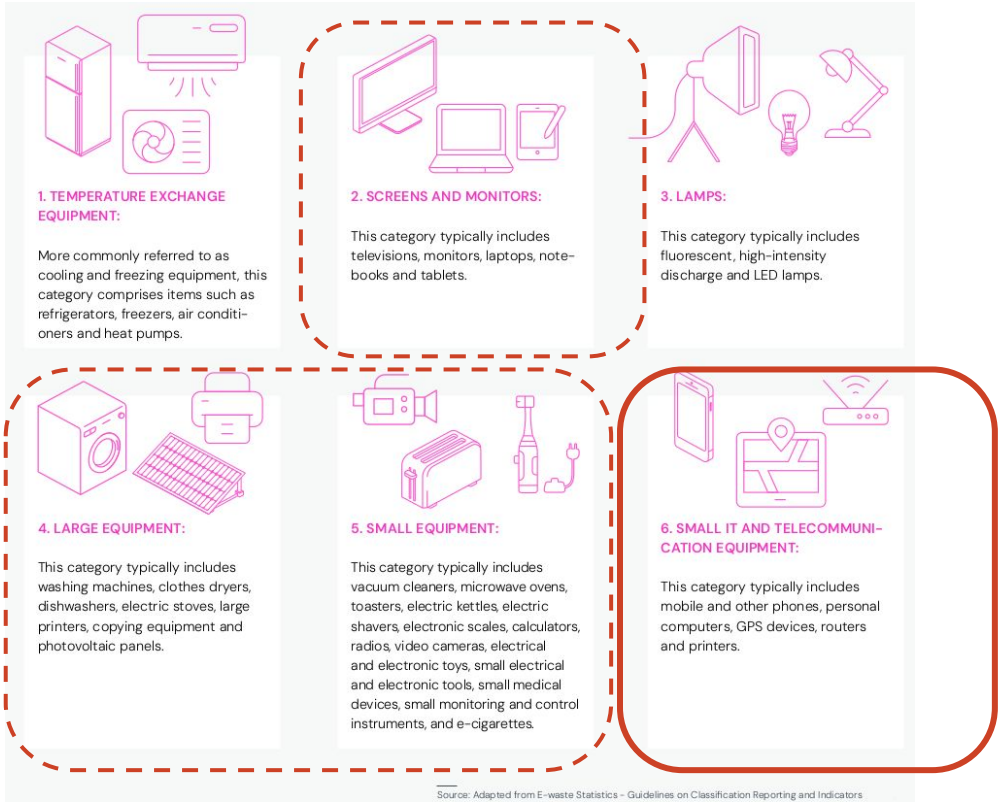
End-of-life is low in environmental evaluation of ICT?



source : [Clément, M.-P., Jacquemotte, Q. E., & Hilty, L. M. (2020). Sources of variation in life cycle assessments of smartphones and tablet computers. Environmental Impact Assessment Review, 84, 106416.]

E-waste ?

electrical and electronic equipment (EEE)



1. TEMPERATURE EXCHANGE EQUIPMENT:

More commonly referred to as cooling and freezing equipment, this category comprises items such as refrigerators, freezers, air conditioners and heat pumps.

2. SCREENS AND MONITORS:

This category typically includes televisions, monitors, laptops, notebooks and tablets.

3. LAMPS:

This category typically includes fluorescent, high-intensity discharge and LED lamps.

4. LARGE EQUIPMENT:

This category typically includes washing machines, clothes dryers, dishwashers, electric stoves, large printers, copying equipment and photovoltaic panels.

5. SMALL EQUIPMENT:

This category typically includes vacuum cleaners, microwave ovens, toasters, electric kettles, electric shavers, electronic scales, calculators, radios, video cameras, electrical and electronic toys, small electrical and electronic tools, small medical devices, small monitoring and control instruments, and e-cigarettes.

6. SMALL IT AND TELECOMMUNICATION EQUIPMENT:

This category typically includes mobile and other phones, personal computers, GPS devices, routers and printers.

Source: Adapted from E-waste Statistics - Guidelines on Classification Reporting and Indicators

source: [directive 2012/19/UE](#) on WEEE

Fine-grained product-centric categories

(54 in total)

Table A.1.1 UNU-KEYS and link to 6 e-waste categories

UNU KEY	DESCRIPTION	EU-6	EU-6PV
0001	Central Heating (household installed)	4	4a
0002	Photovoltaic Panels (incl. inverters)	4	4b
0101	Professional Heating & Ventilation (excl. cooling equipment)	4	4a
0102	Dishwashers	4	4a
0103	Kitchen Equipment (e.g., large furnaces, ovens, cooking equipment)	4	4a
0104	Washing Machines (incl. combined dryers)	4	4a
0105	Dryers (wash dryers, centrifuges)	4	4a
0106	Household Heating & Ventilation (e.g., hoods, ventilators, space heaters)	4	4a
0108	Fridges (incl. combi-fridges)	1	1
0109	Freezers	1	1
0111	Air Conditioners (household installed and portable)	1	1
0112	Other Cooling Equipment (e.g., dehumidifiers, heat pump dryers)	1	1
0113	Professional Cooling Equipment (e.g., large air conditioners, cooling displays)	1	1
0114	Microwaves (incl. combined, excl. grills)	5	5
0201	Other Small Household Equipment (e.g., small ventilators, irons, clocks, adapters)	5	5
0202	Equipment for Food Preparation (e.g. toaster, grills, food processing, frying pans)	5	5
0203	Small Household Equipment for Hot Water Preparation (e.g., coffee, tea, water cookers)	5	5
0204	Vacuum Cleaners (excl. professional)	5	5
0205	Personal Care Equipment (e.g. tooth brushes, hair dryers, razors)	5	5
0301	Small IT Equipment (e.g., routers, mice, keyboards, external drives & accessories)	6	6
0302	Desktop PCs (excl. monitors, accessories)	6	6
0303	Laptops (incl. tablets)	2	2
0304	Printers (e.g., scanners, multi functionals, faxes)	6	6
0305	Telecommunication Equipment (e.g. (cordless) phones, answering machines)	6	6
0306	Mobile Phones (incl. smartphones, pagers)	6	6
0307	Professional IT Equipment (e.g., servers, routers, data storage, copiers)	4	4a
0308	Cathode Ray Tube Monitors	2	2
0309	Flat Display Panel Monitors (LCD, LED)	2	2
0401	Small Consumer Electronics (e.g., headphones, remote controls)	5	5
0402	Portable Audio & Video (e.g., MP3, e-readers, car navigation)	5	5

E-waste generation

From EEE to WEEE

WEEE ?

equipment can be considered as waste

when its user wishes to dispose of it

without the intent of reuse,

even if it is functional or repairable

From EEE to WEEE

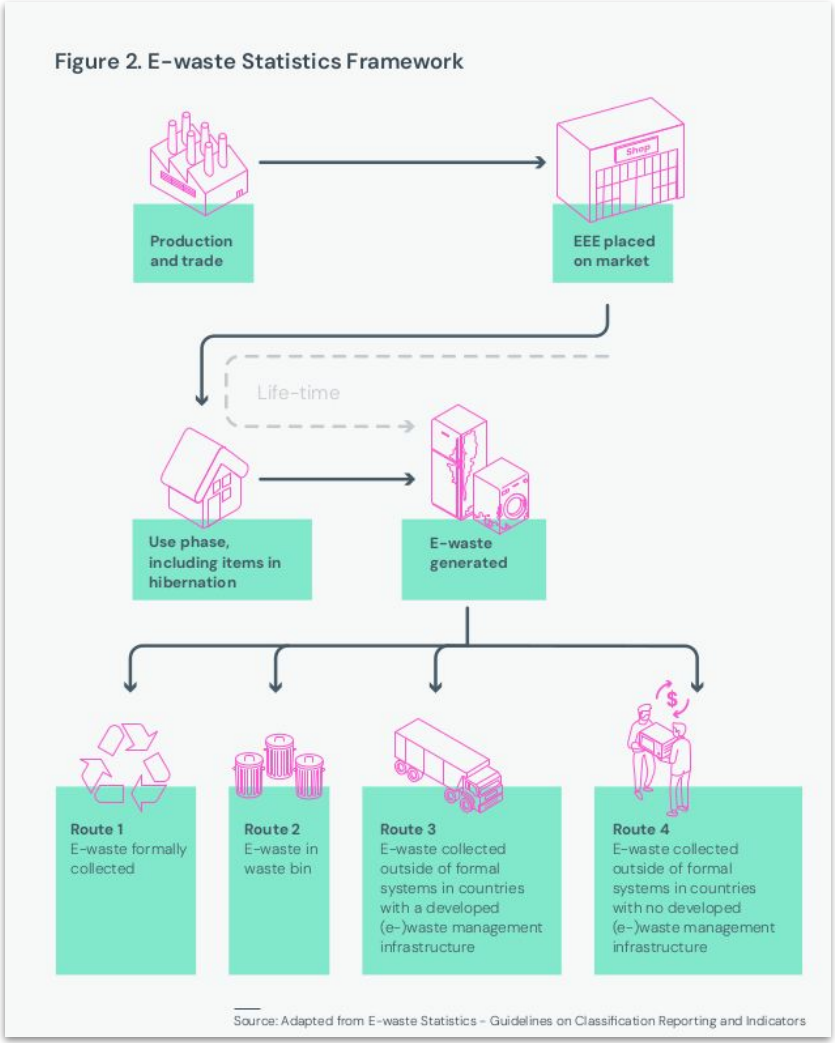
Obsolescence:

- by **incompatibility**: incompatible versions of software, supplies...
- **technical** or **functional**: cost of repair ≈ cost of replacement
- **psychological**: functionalities made indispensable...
- **ecological**: highlighting progress in the environmental impact of new products...

Measuring e-waste

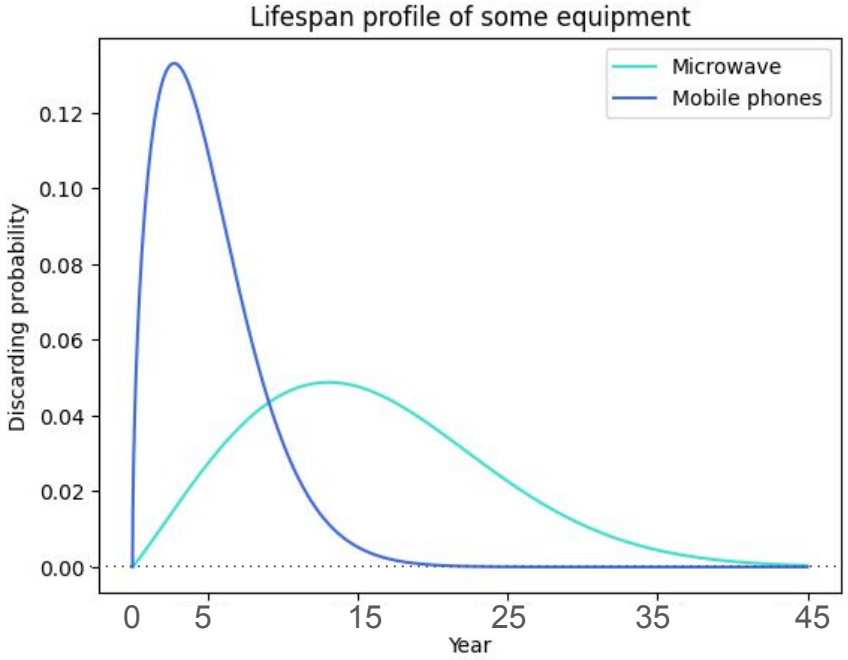
Since 2015, **standardized methodology for measuring e-waste**, updated in 2018 (UN+)

- harmonizes the measurement framework and indicators used for e-waste
- integrated as the common methodology for calculating the collection targets of the EU WEEE Directive



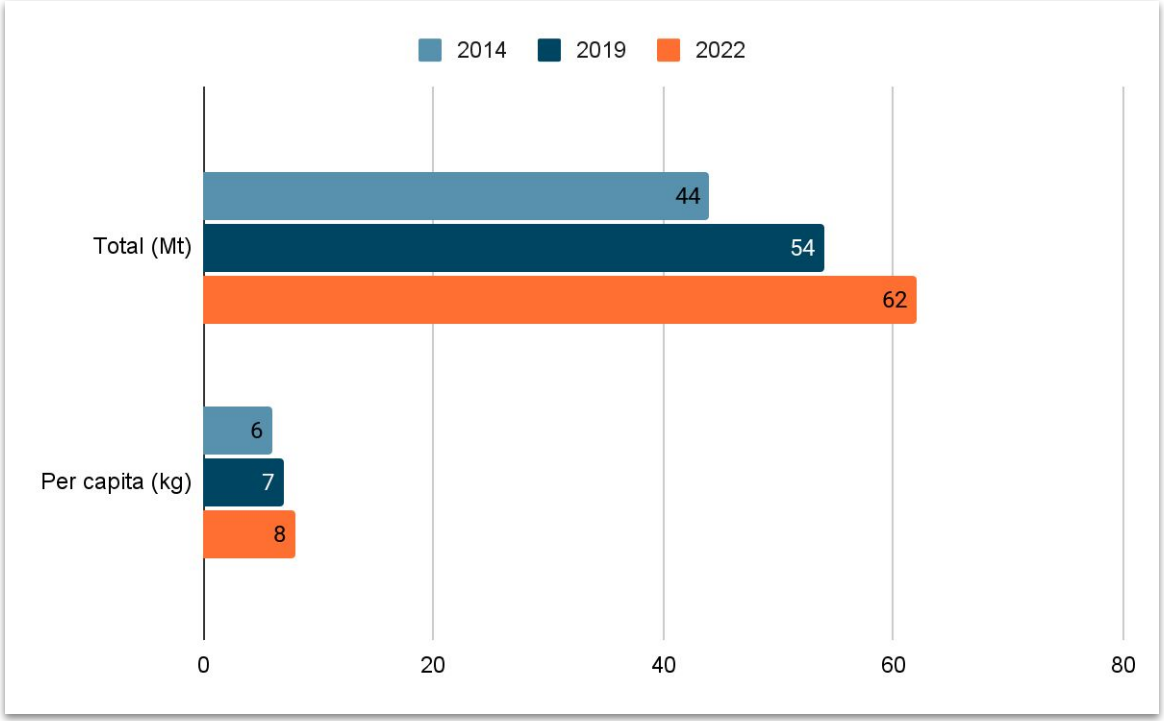
Measuring e-waste

from equipment placed on market (POM)



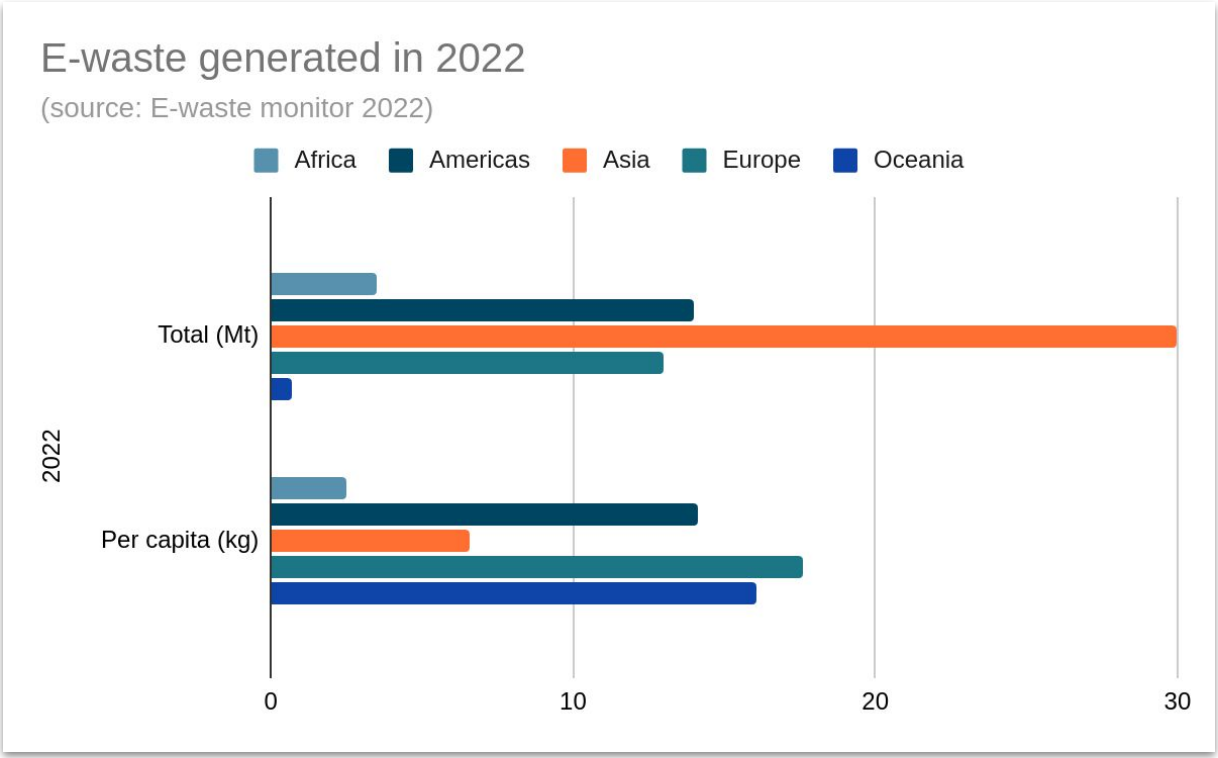
source: Borachhun You's report, 2023, based on [e-waste statistics guidelines]

WEEE generated (world)



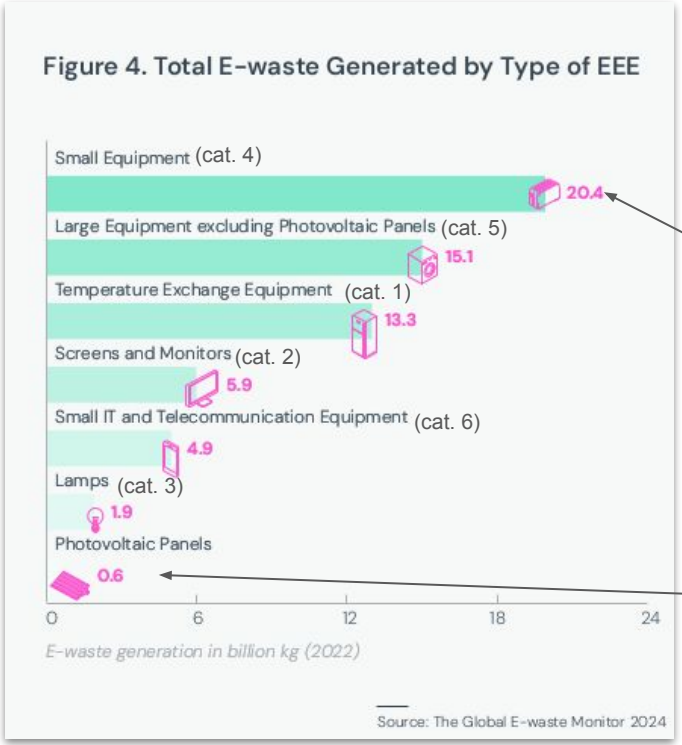
source: Global E-waste monitor 2024

WEEE generated (world, by continent)



source: Global E-waste monitor 2024

Categories of WEEE

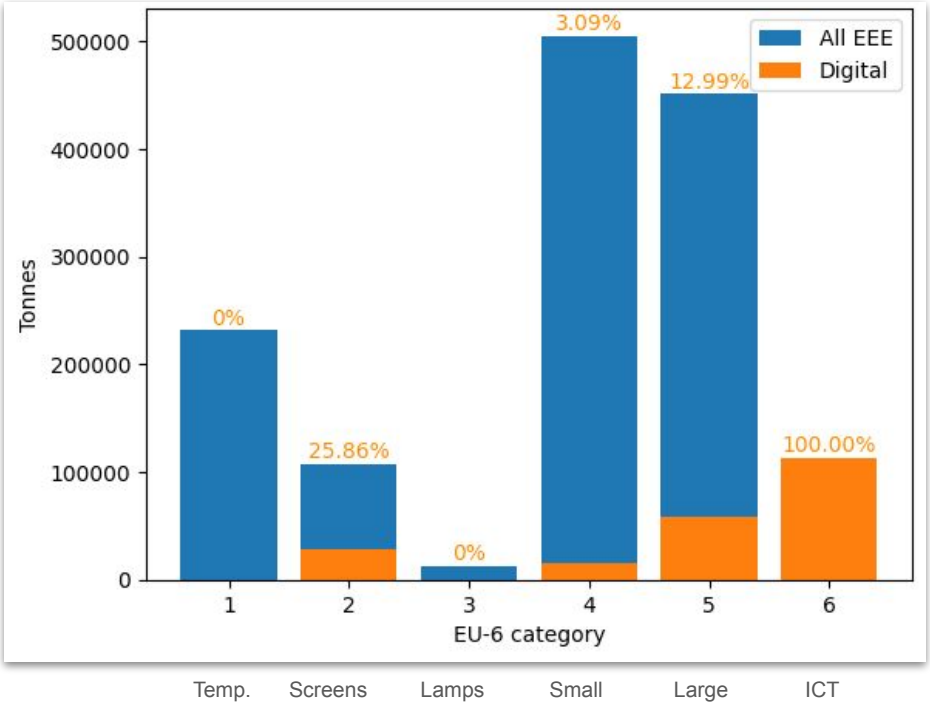


includes vaping equipment (flavored e-cigarettes): many are disposable and contain not only plastic but also lithium-ion batteries, a heating element and a circuit board

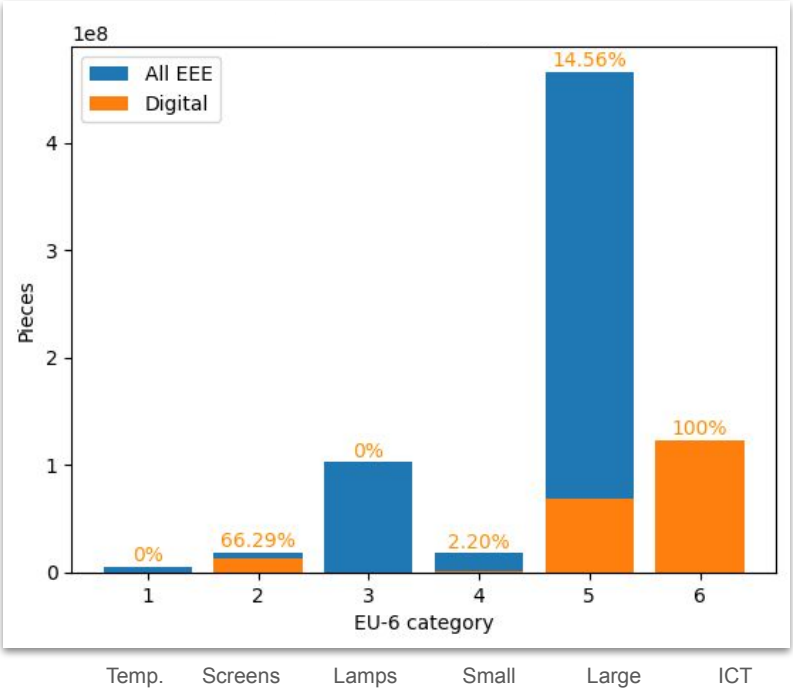
expected to quadruple between 2022 and 2030 due to green energy transition

Share of digital WEEE

WEEE generated in France in 2021 (metric tons)

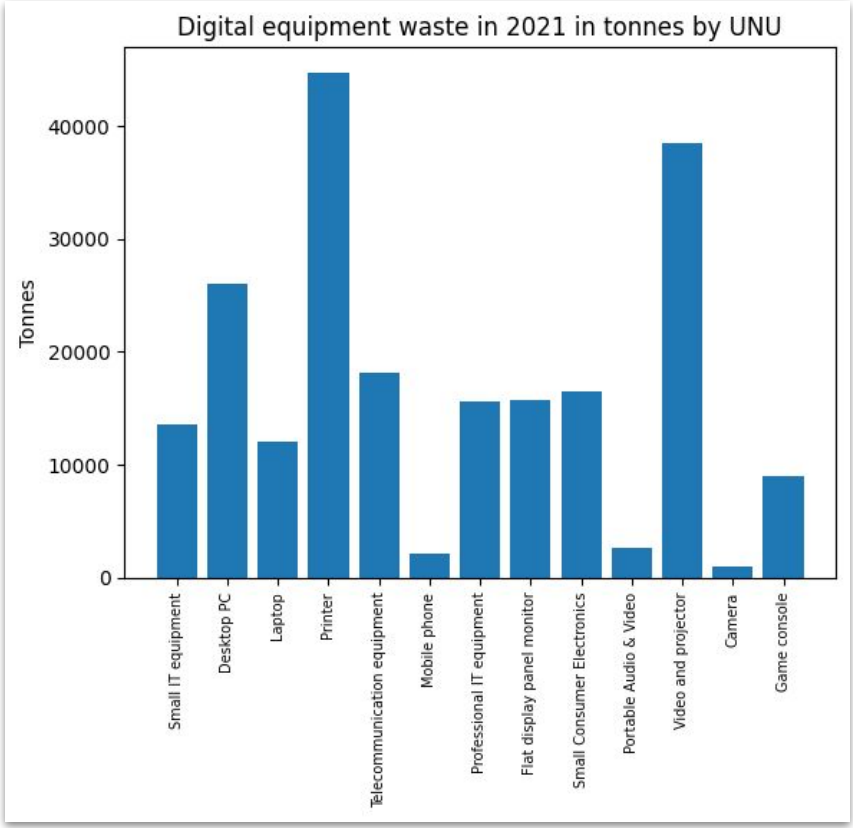


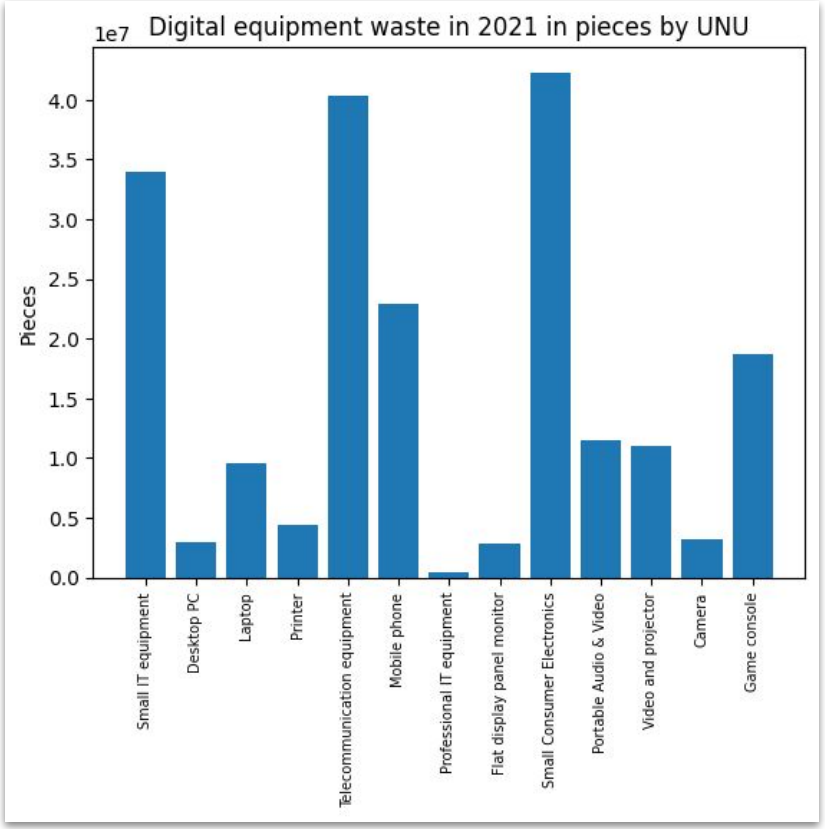
WEEE generated in France in 2021 (number)



source: Borachhun You's report, 2023

Digital WEEE categories

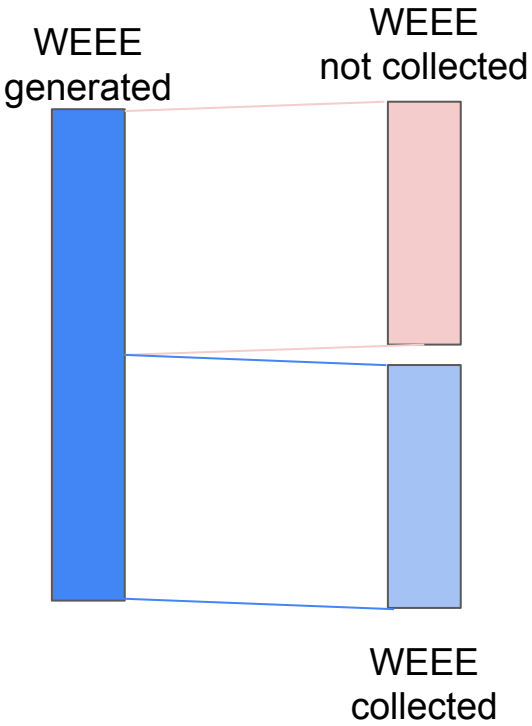




source: Borachhun You's report, 2023

E-waste collection (or not)

WEEE circuit



Collection rate

Method 1 - ‘EEE POM method’

$$\frac{\text{quantity of EEE collected in year N}}{\text{average POM (N-1, N-2, N-3)}}$$

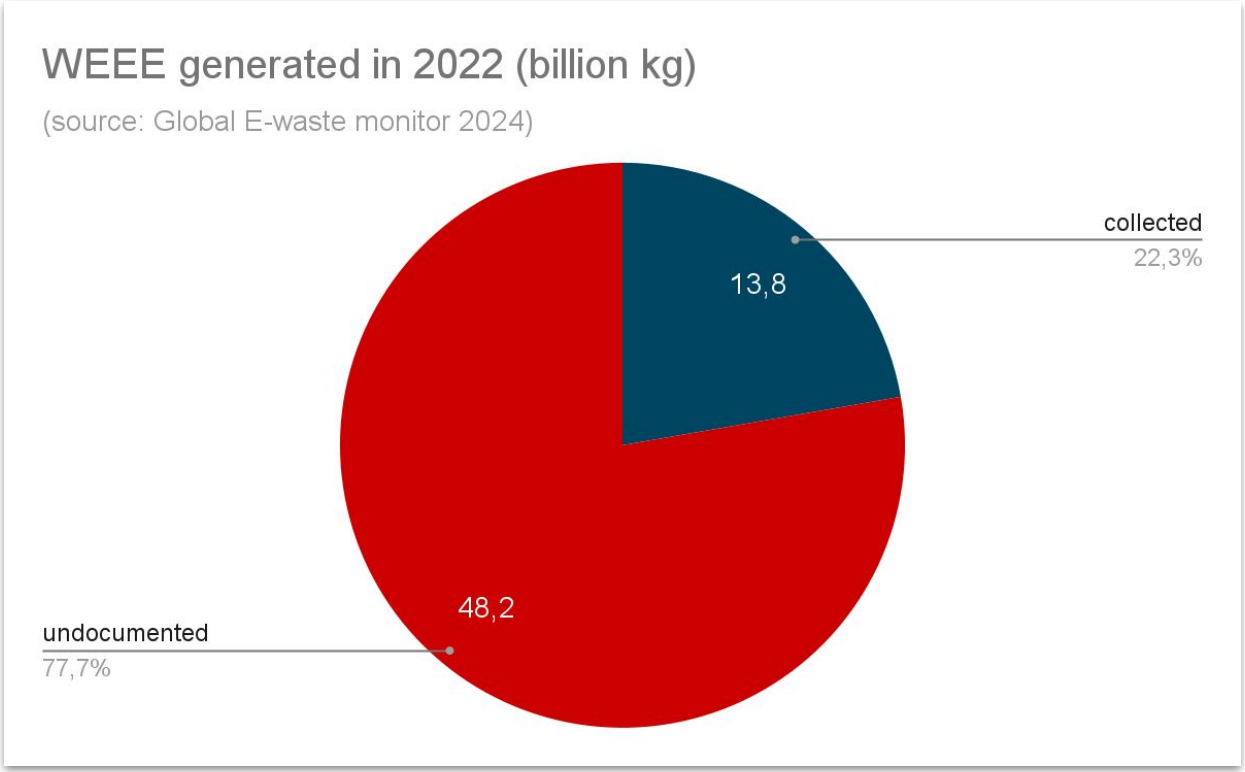
Objective: 65%

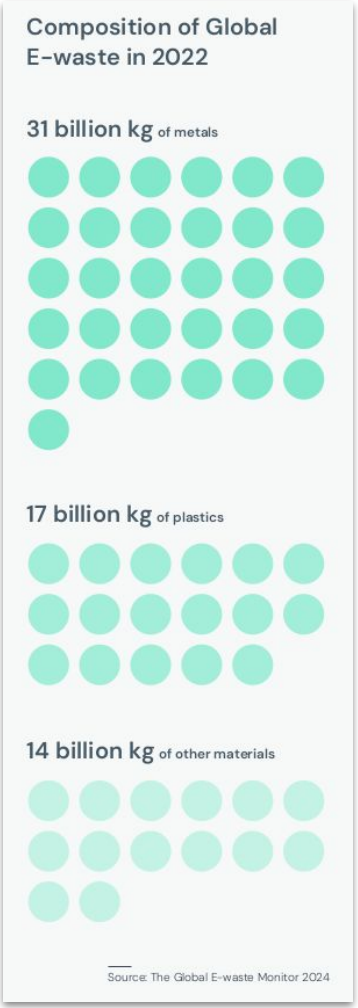
Method 2 - ‘WEEE Generated method’

$$\frac{\text{quantity of EEE collected in year N}}{\text{estimated EEE generated in year N}}$$

Objective: 85%

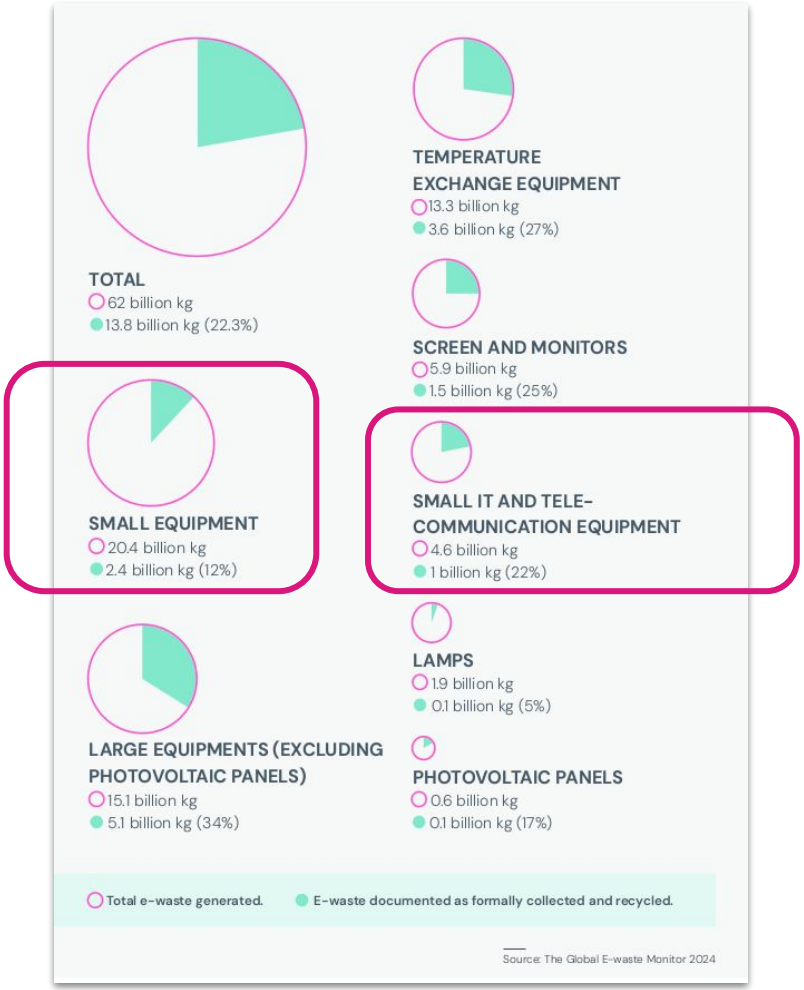
WEEE collected



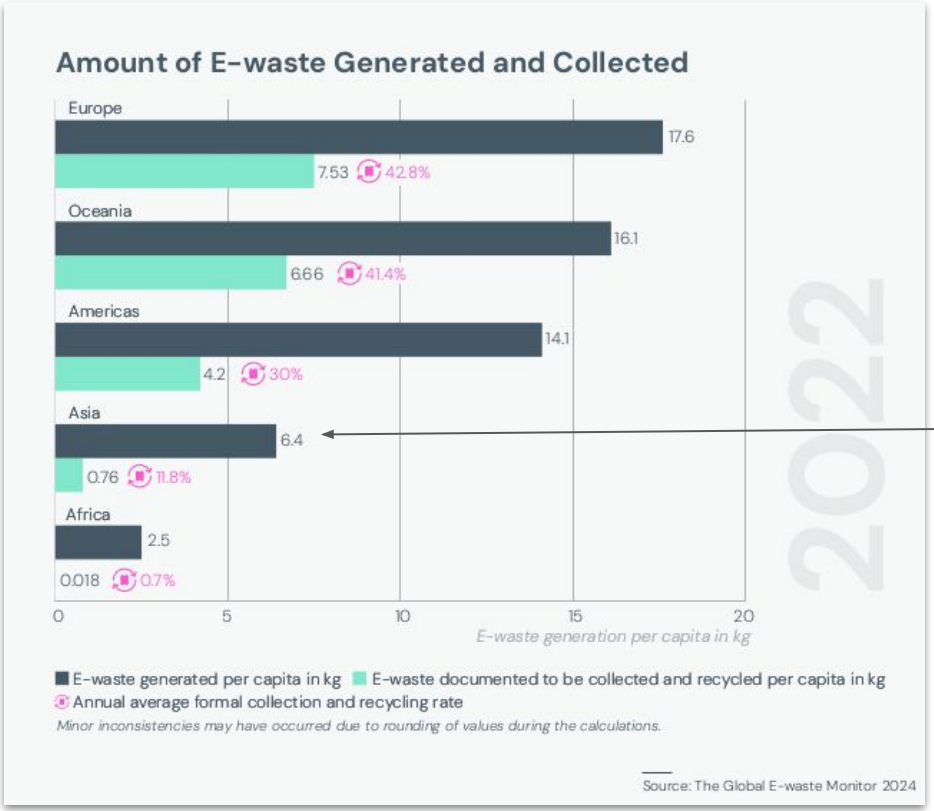


Varying collection rate

collection rates are highest for heavier and bulkier equipment categories



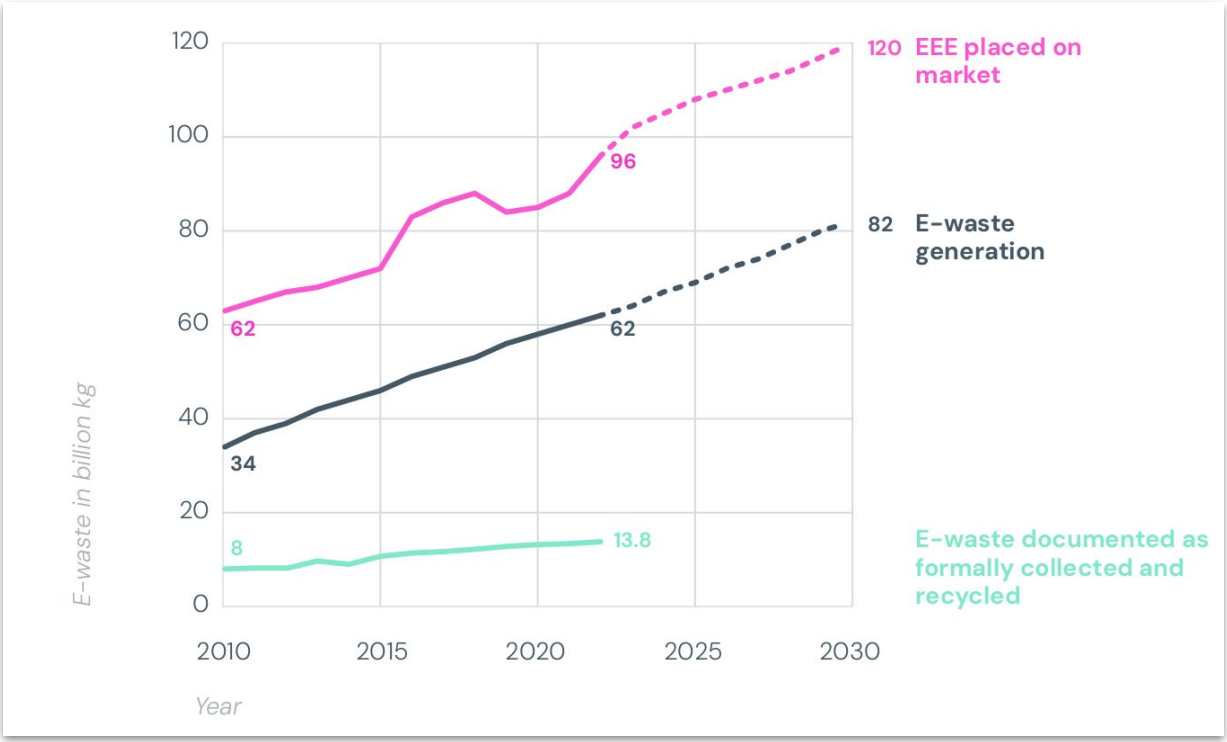
Collection rate



few countries have legislation and collection targets

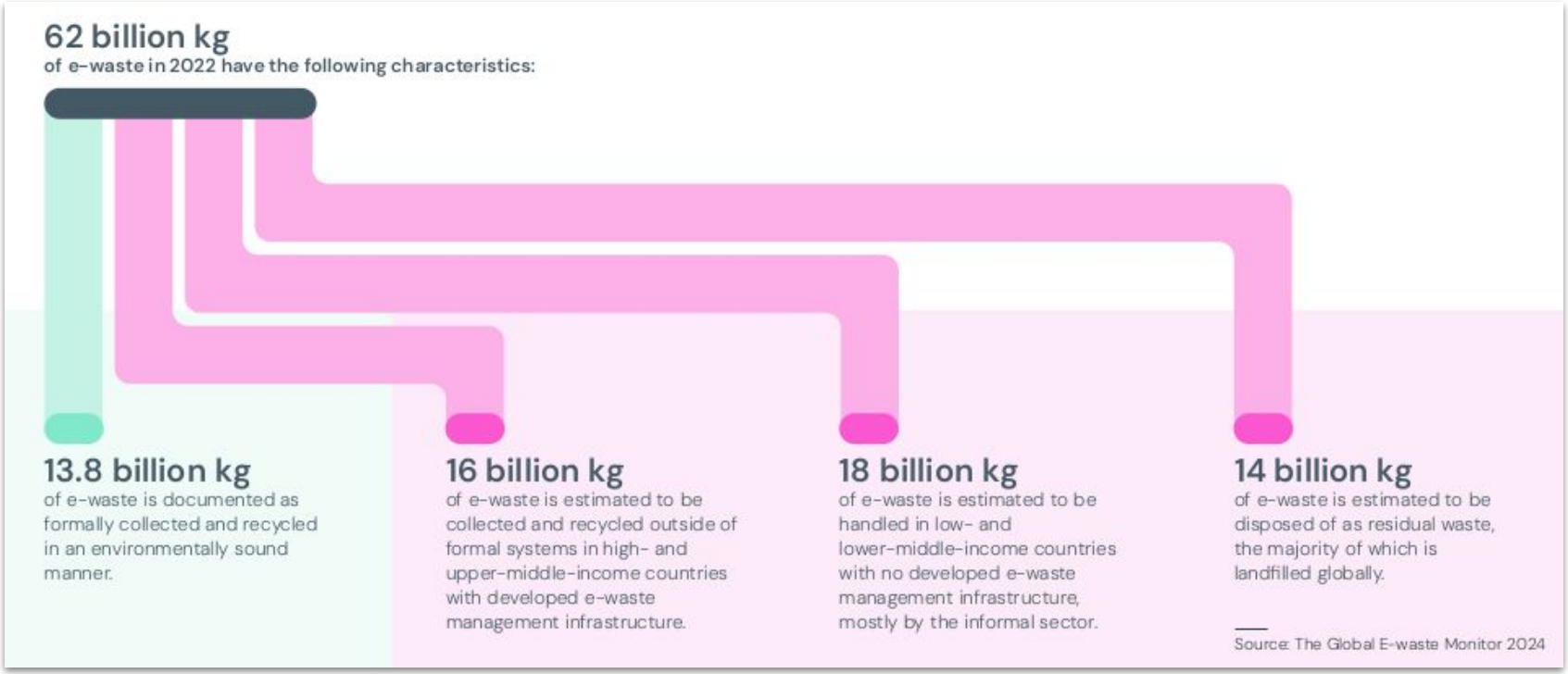
source: Global E-waste monitor 2024

Evolution of EEE and WEEE

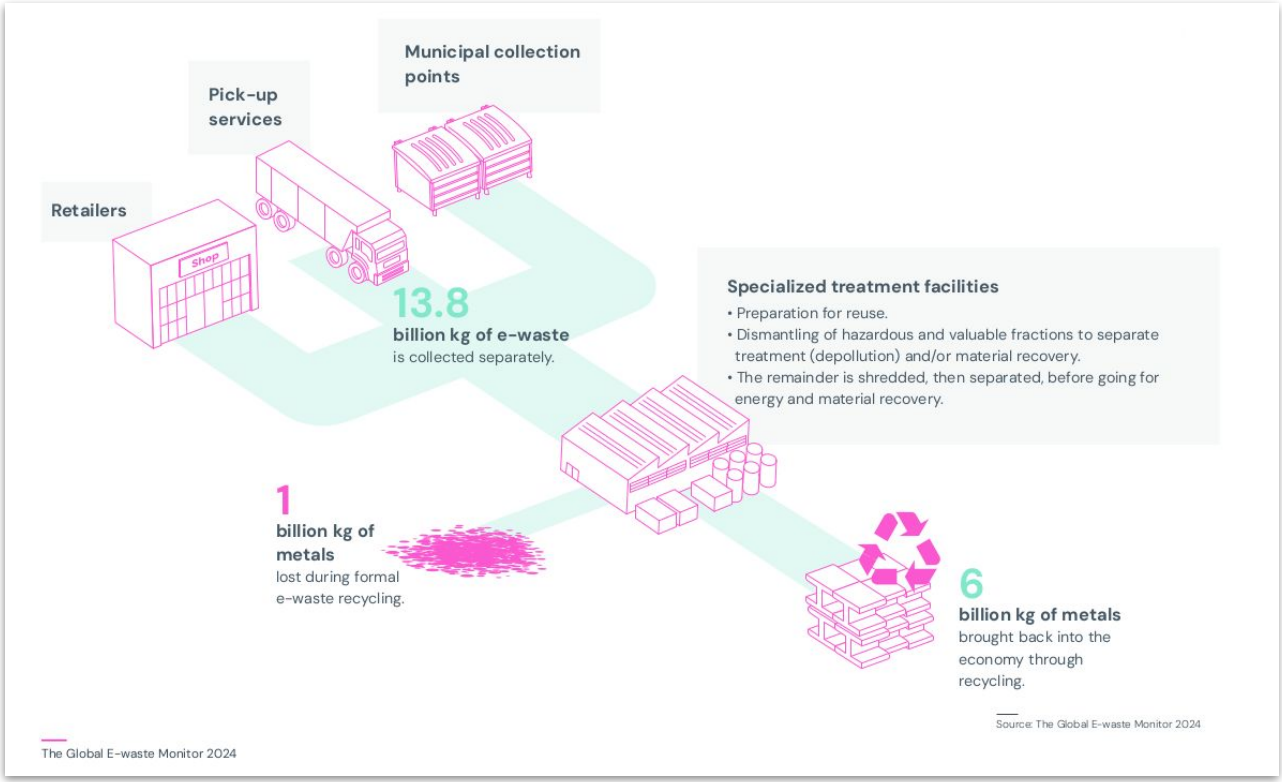


source: [E-waste monitor 2024]

Routes of e-waste

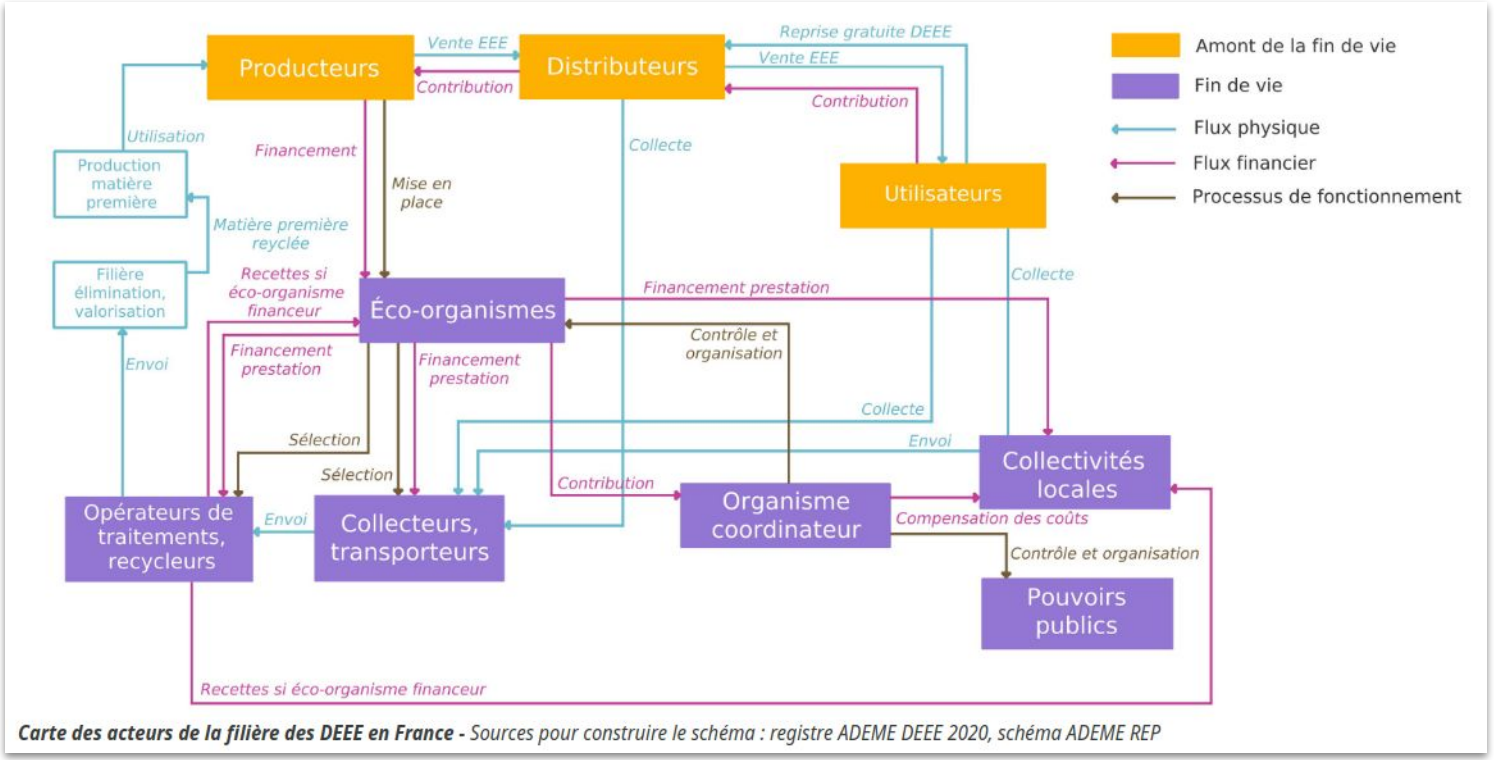


Formal e-waste collection



Who collects?

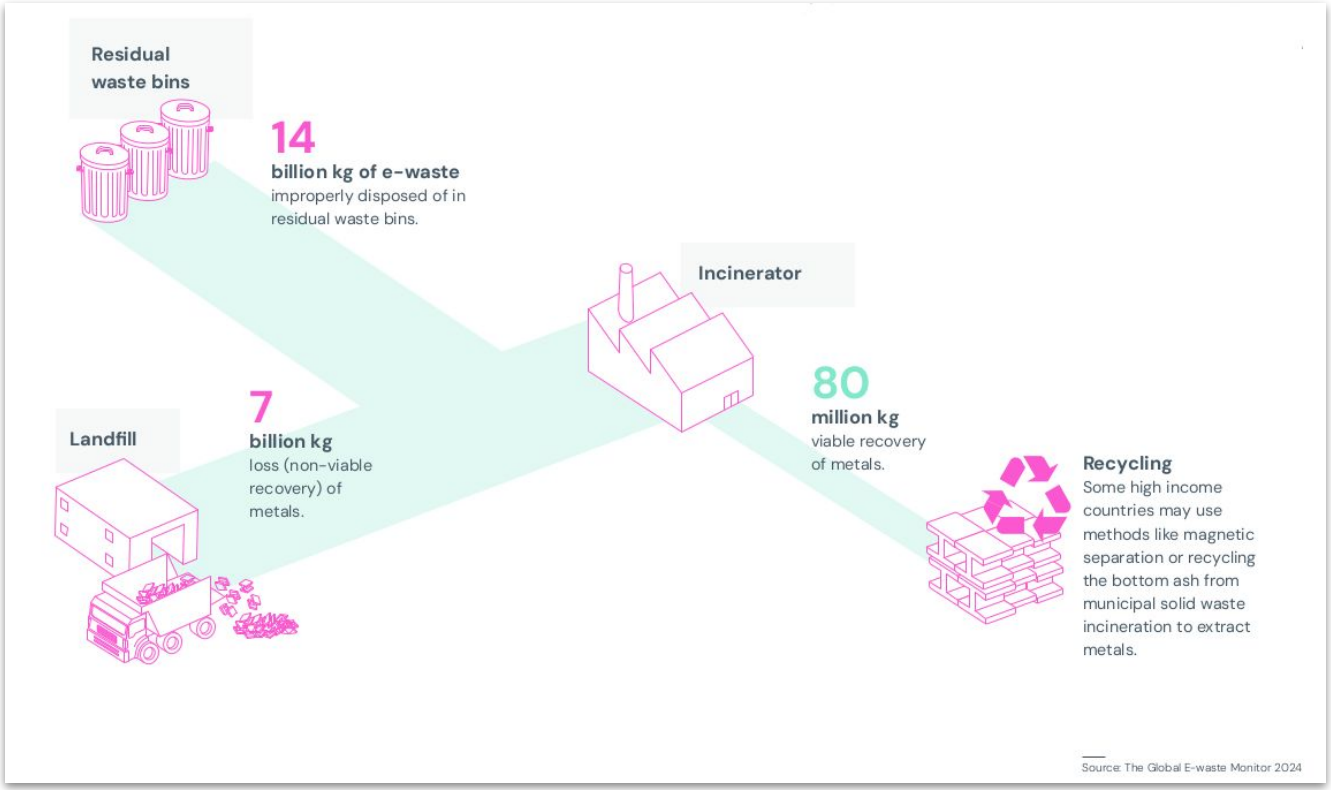
In France, Producers Responsibility Organisations (*éco-organismes*)



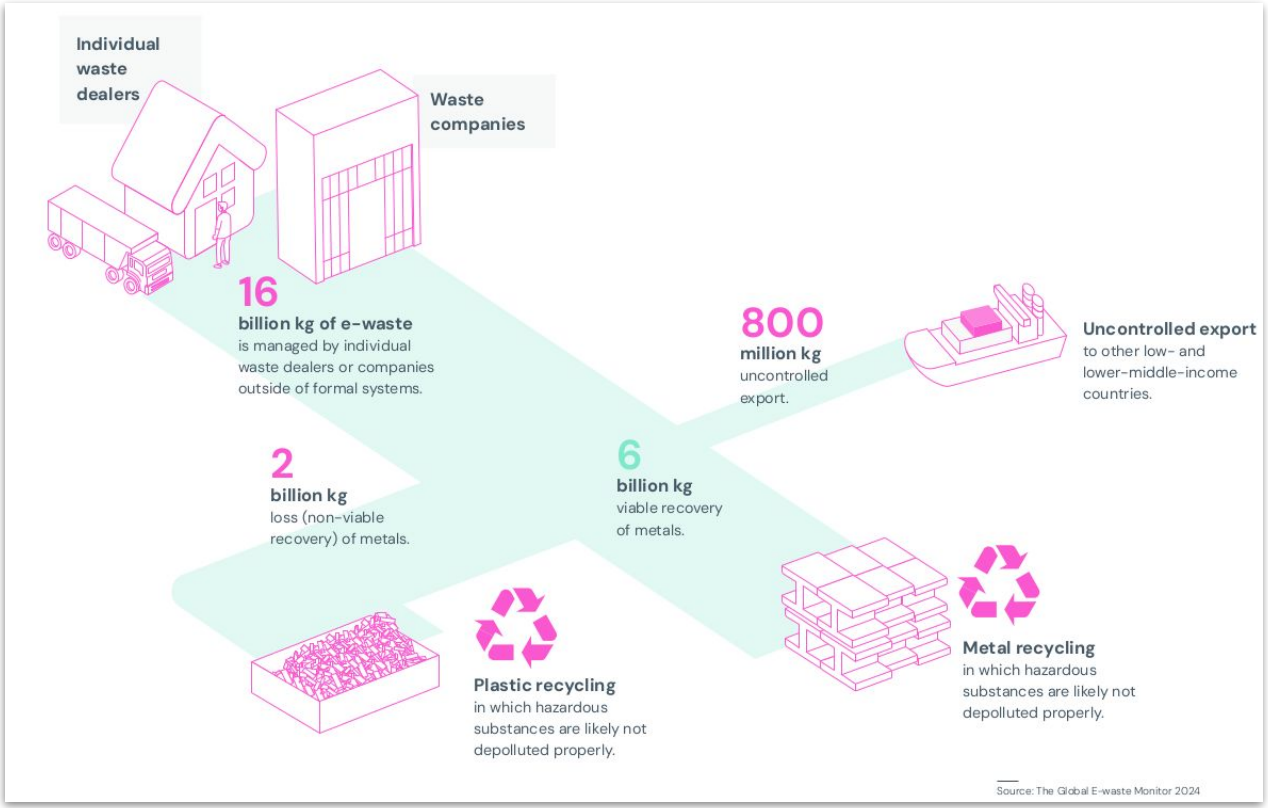
Carte des acteurs de la filière des DEEE en France *- Sources pour construire le schéma : registre ADEME DEEE 2020, schéma ADEME REP*

source: Marion Ficher

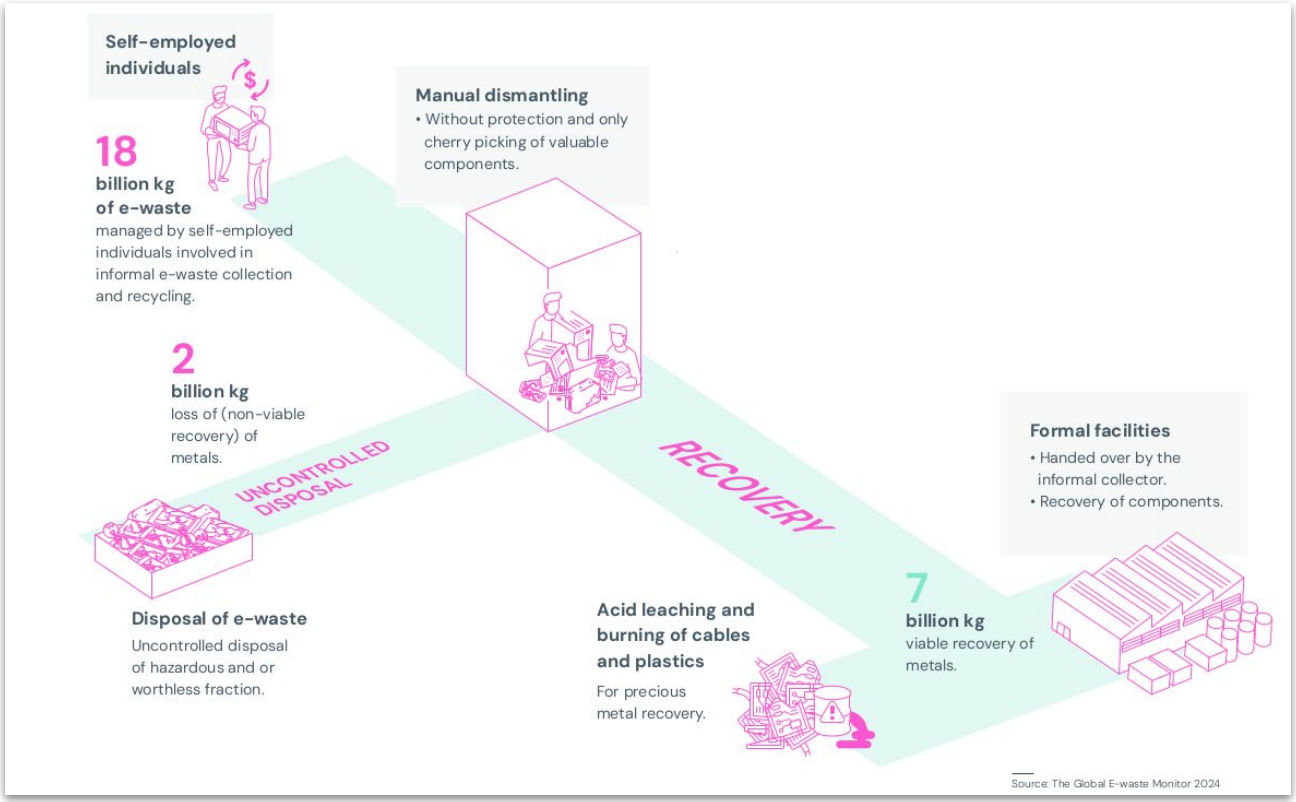
Disposing of E-waste in Residual Waste



Informal e-waste collection in countries with a developed (e-)waste management



Informal e-waste collection in countries with no (e-)waste management

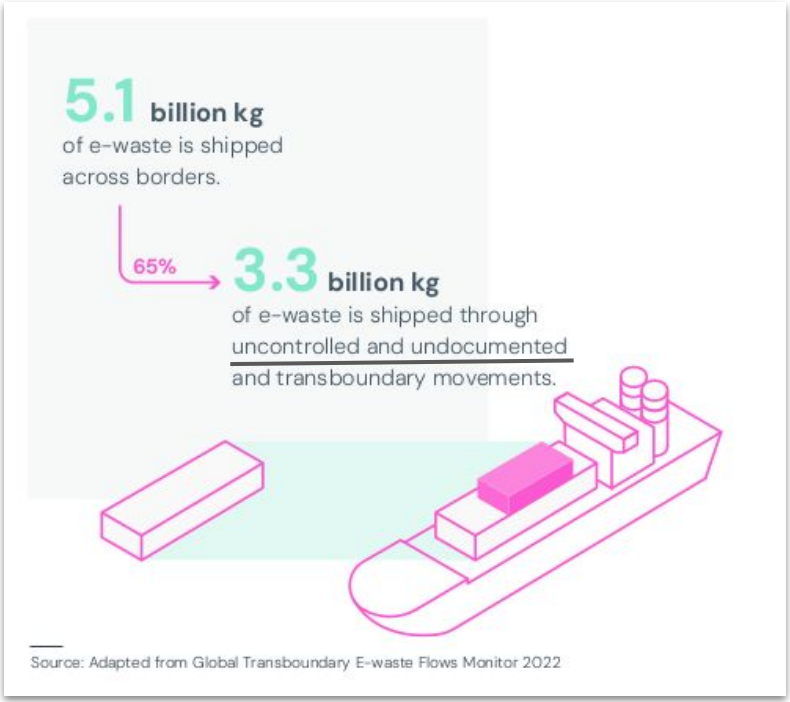


Informal recycling

Agbogbloshie landfill, Accra, Ghana

source: By Muntaka Chasant - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=81939788

Transboundary flows

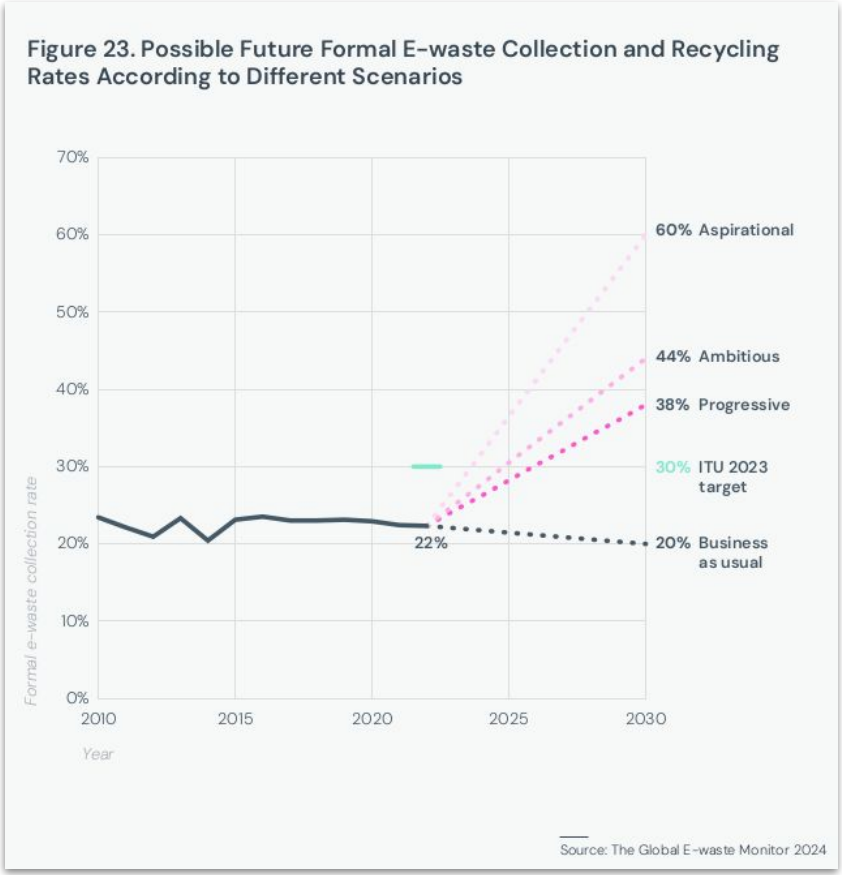


Most controlled transboundary flows take place within and into Europe and East Asia.

One of the primary challenges in controlling the transboundary movement of e-waste is distinguishing between waste and used EEE (international trade codes do not differentiate between new and used equipment).

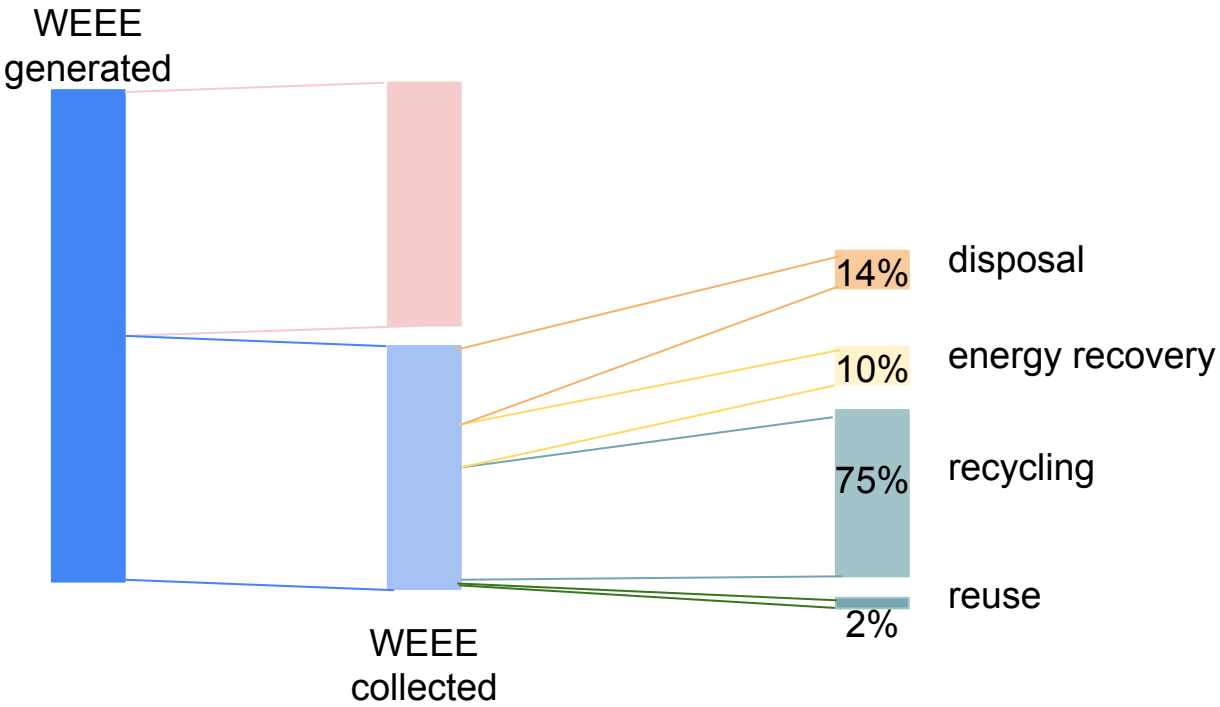
Evolution of e-waste collection

Business as usual : the rate of e-waste generation outpaces the improvements in e-waste management

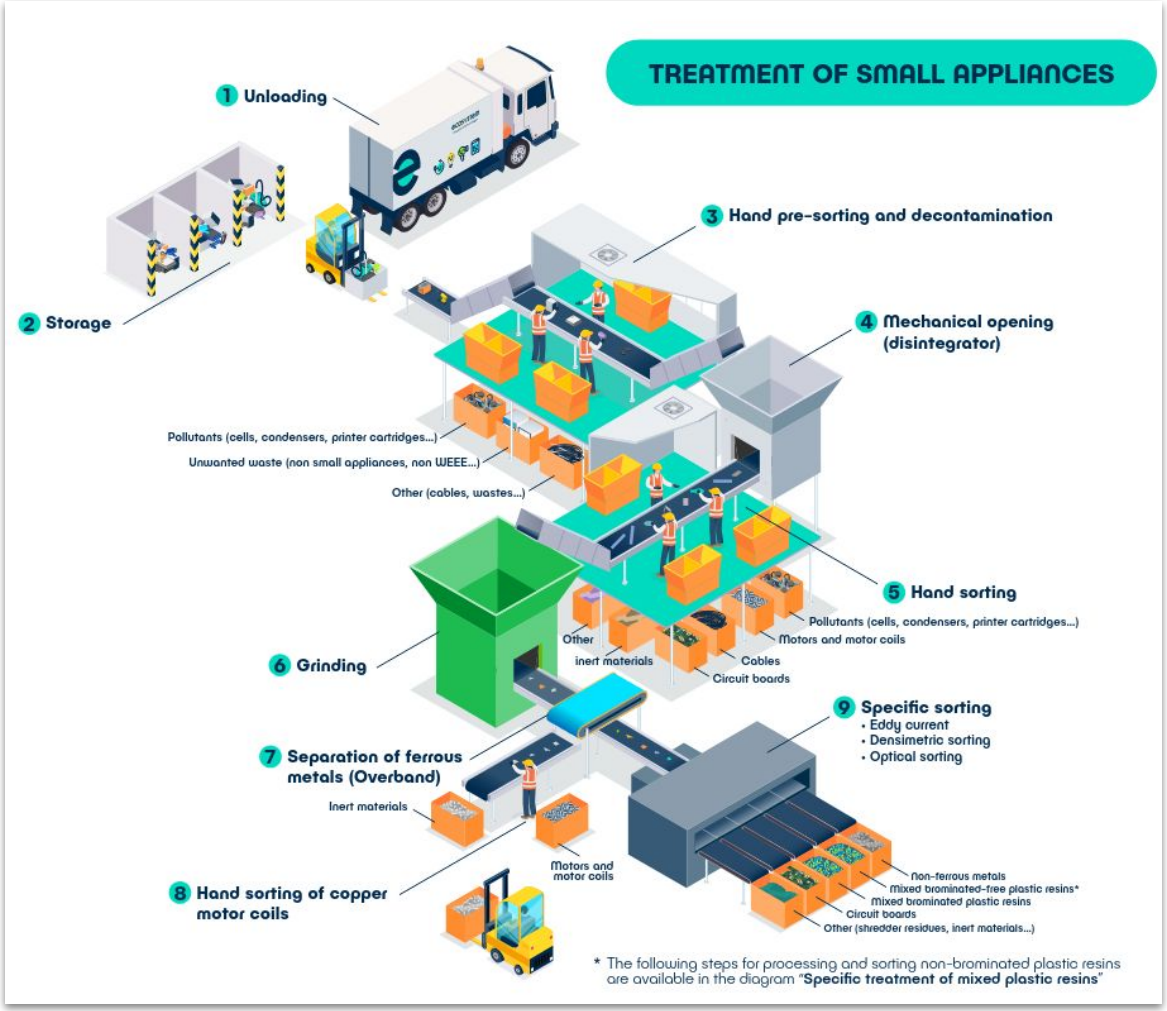


E-waste recycling

WEEE circuit (proportions: France 2019)

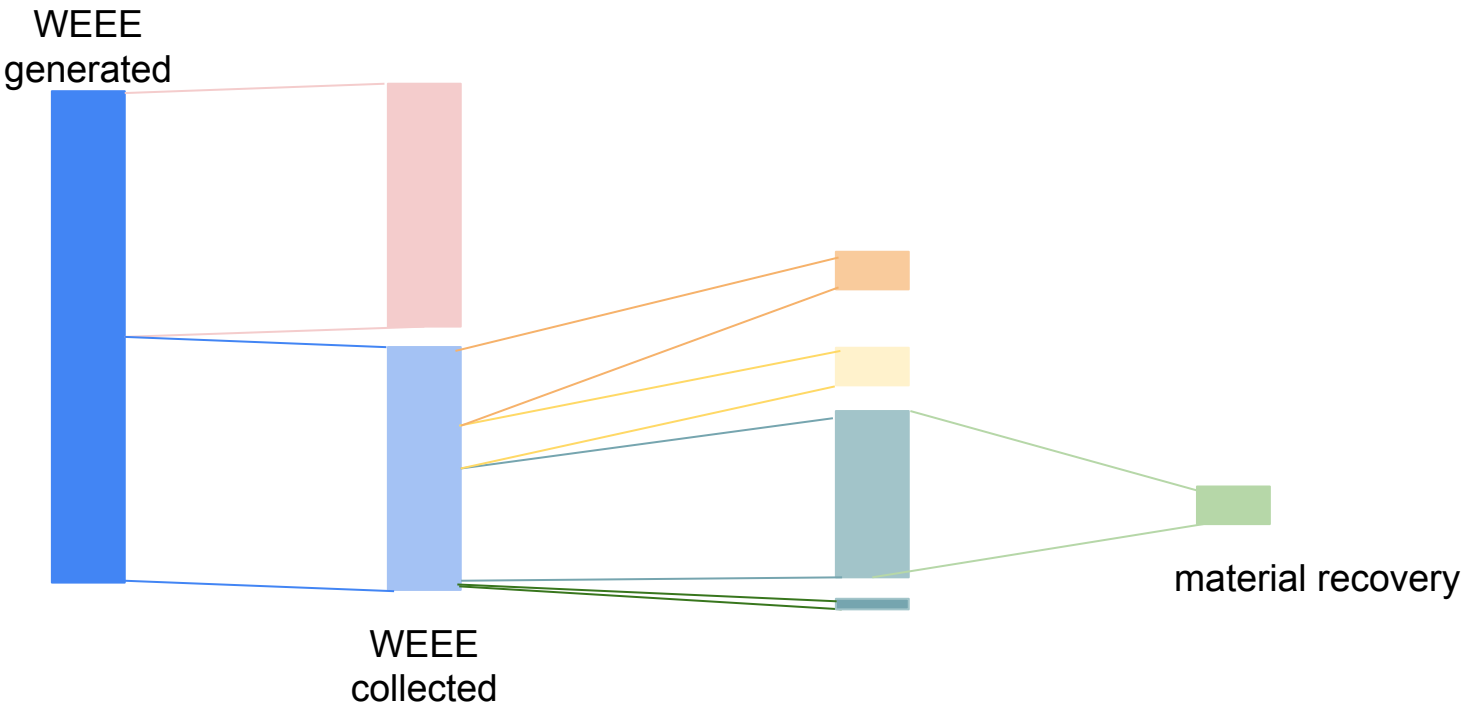


Treatment and recycling



Source: [ecosystem]

WEEE circuit

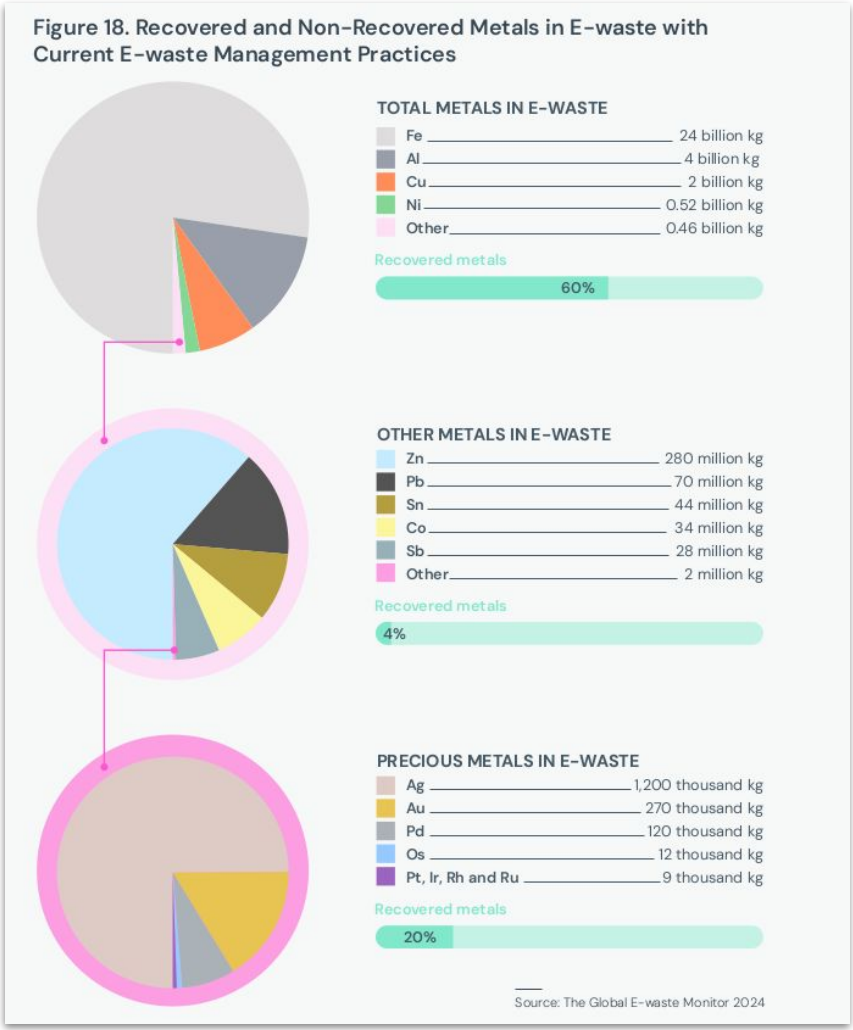


Material recovery

recycling challenges

- technical difficulties
- financial profitability
- sovereignty
- critical materials
    - avoiding supply disruptions

Metals in e-waste



Focus on Critical raw materials

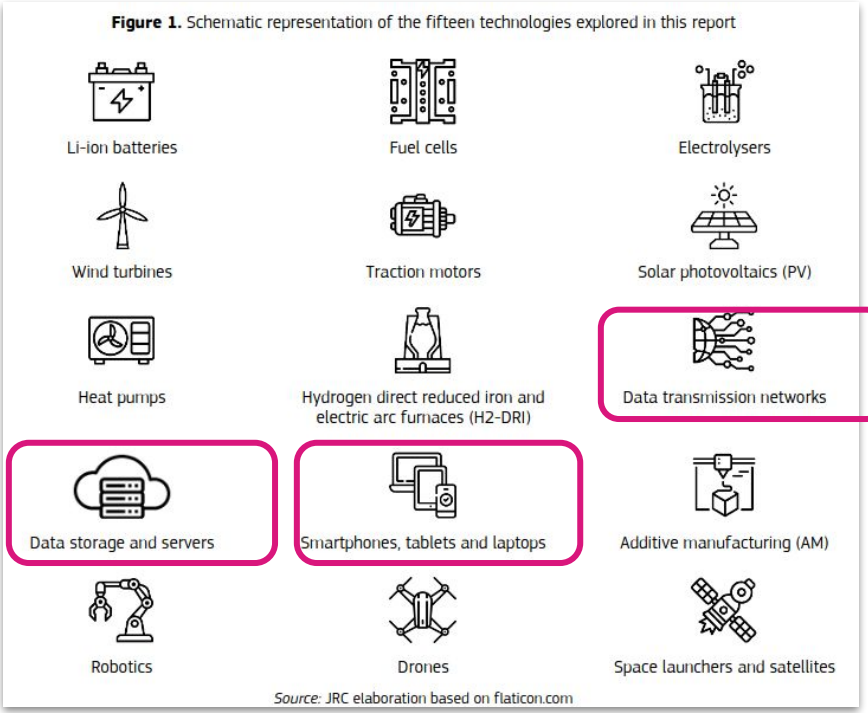
list created by the European Commission, with criteria:

- high importance to the EU economy (applications and value added)
  - Industry - non-energy raw materials are linked to all industries across all **supply chain** stages.
  - Modern technology - **technological progress** and quality of life rely on access to a growing number of raw materials. For example, a smartphone might contain up to 50 different kinds of metals, all of which contribute to its small size, light weight and functionality.
  - Environment – raw materials are considered as essential for the **energy transition**. They are irreplaceable in solar panels, wind turbines, electric vehicles, and energy-efficient lighting.
- high risk associated with their supply

source: EU 2024 regulation

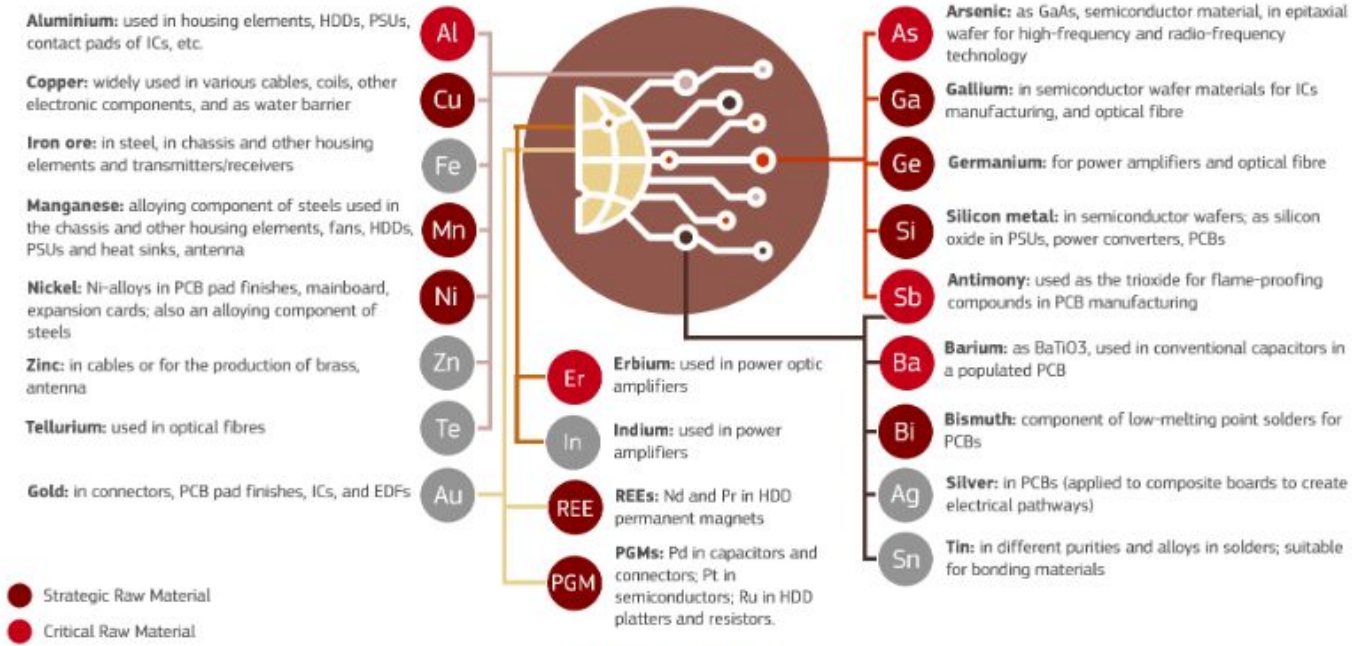
Strategic raw materials

- strategic =
  - importance for strategic areas (vs overall EU economy for CRM):
    - renewables
    - electric mobility
    - industry
    - ICT
    - aérospace & defence
  - projected demand growth relative to current supply (vs high risk of supply disruption)
  - difficulties of scaling up production



Raw materials for data transmission

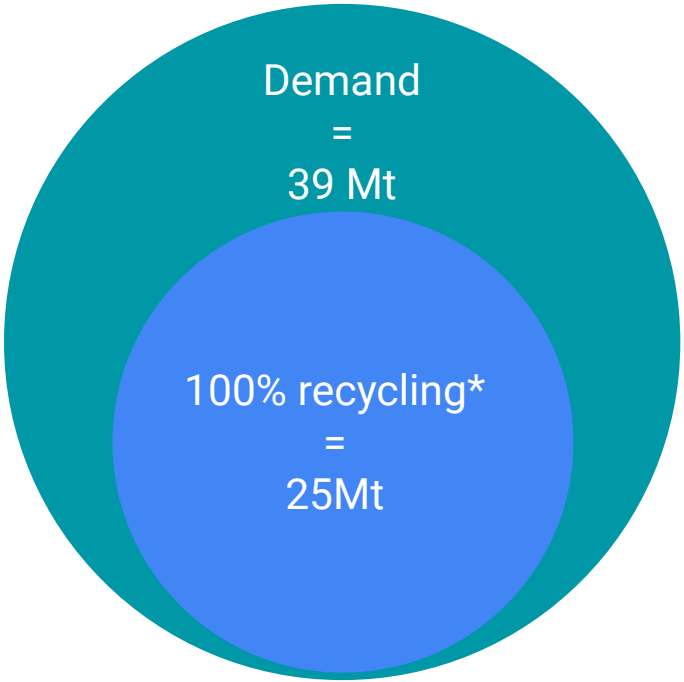
Figure 55. Selection of raw materials used in data transmission networks and their function



Source: JRC analysis.

Recycling vs demand

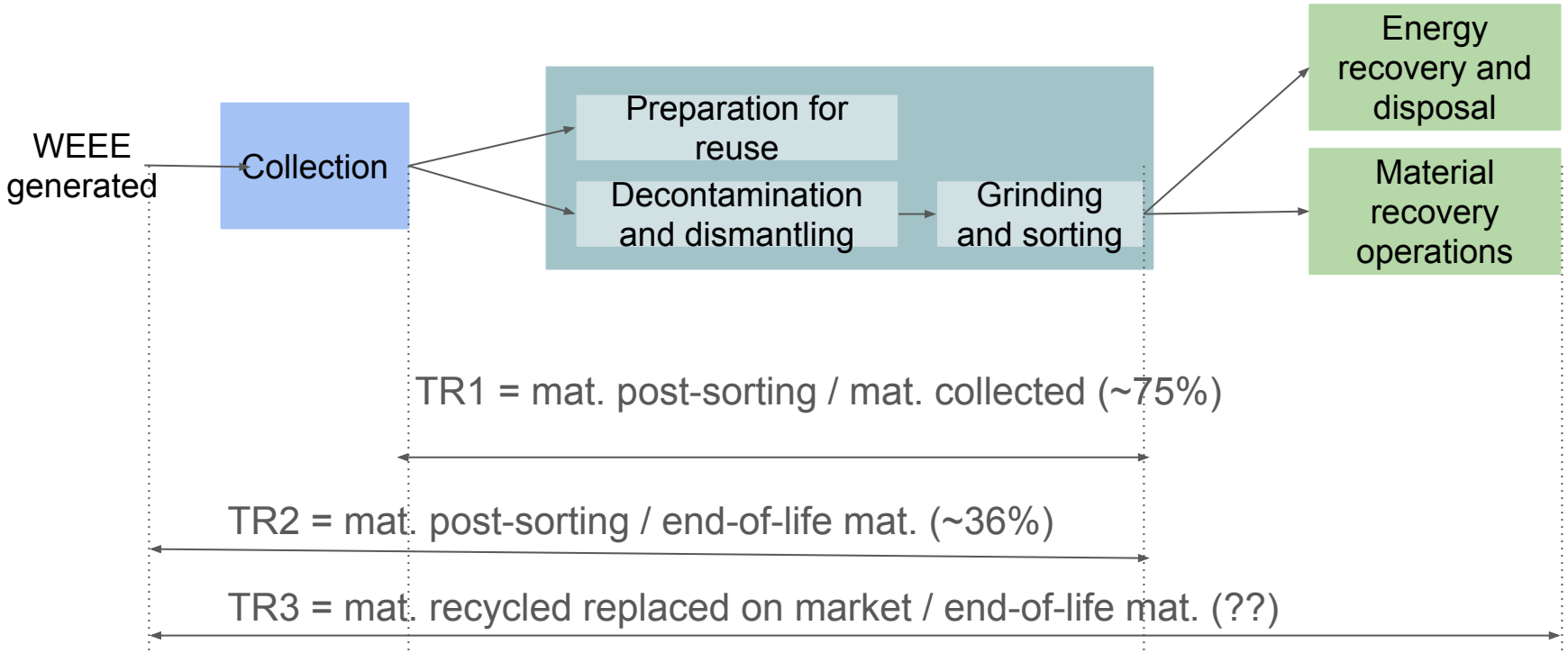
example of iron, aluminium and copper in 2019 (world)



* hypothetical

source: E-waste monitor 2020

Recycling rate?



Environmental impacts of e-waste

Impacts of non-compliant management of e-waste

- GHG emissions from refrigerants
  - in 2022, .25% of GHG emissions came from from mismanagement of refrigerants in e-waste
- pollutions
  - 58 thousand kg of mercury and 45 million kg of plastics containing brominated flame retardants are released into the environment every year

Avoided impacts from mining

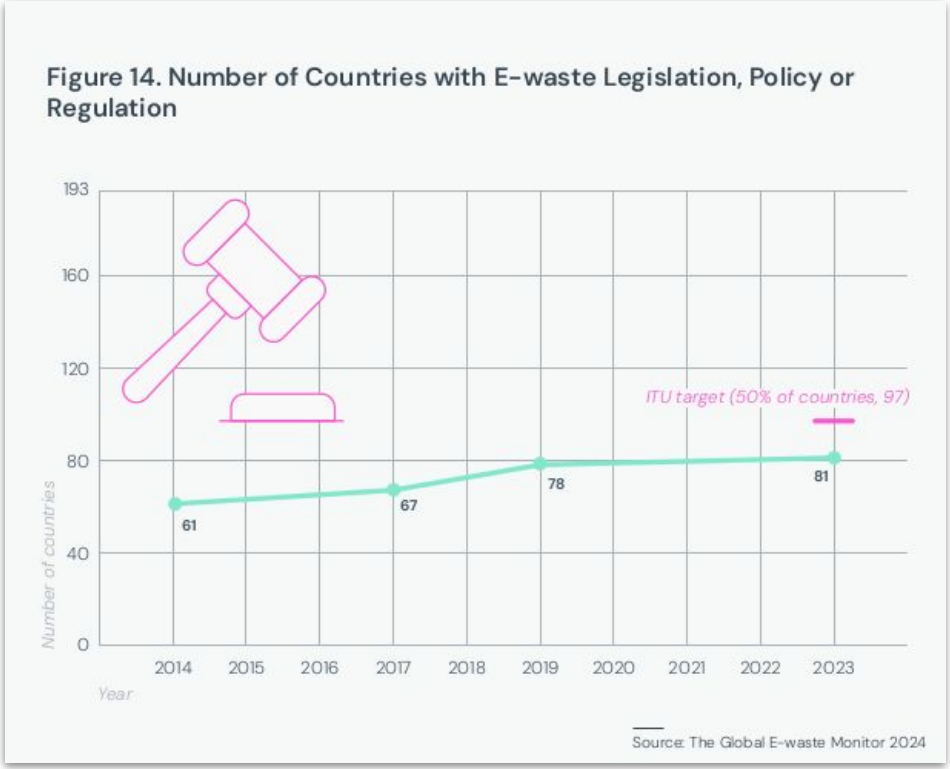
- no additional excavation of ore in primary mining
  - avoided GHG emissions, air and water pollution, damage to land and biodiversity loss, to human health

E-waste legislation and regulation

Legal instruments

In 2023

- 81 countries (42 % of countries) have adopted e-waste policies
  - covering 72% of the population
- 67 countries promote principle of extended producer responsibility (EPR)
- 46 countries have collection rate targets
- 36 have recycling rate targets



Types of legislations

Prevention preferred => targets on e-waste generated instead of EEE POM

Recycling: hardly any target for recovering critical raw materials

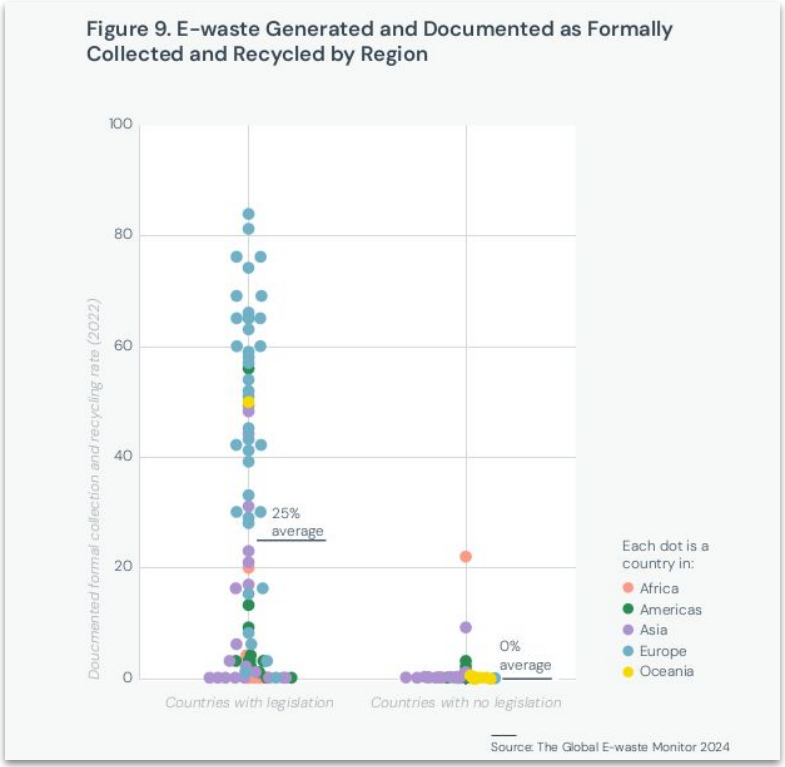
Enforcing legislation is a challenge: governments are under-resourced; online retailing may fail to comply requirements

source: Global E-waste Monitor 2024

E-waste legislation and regulation

Countries with e-waste legislation have higher collection rates

/!\ Informal e-waste collection can also be efficient



Focus on the European situation

- WEEE directive (inception in 2002, law since 2003)
  - sets collection, recycling and recovery targets for EEE
- Restriction of Hazardous Substances (RoHS) directive (2003)
  - limits the amount of hazardous chemicals in electronics

- Critical Raw Materials Act (2023)
  - safeguard the resources needed for technologies like renewable energy and battery power
  - step up domestic production and reduce its reliance on critical raw materials from non-EU/EFTA countries by 2030

Estimating EoL impacts for a product

ISO 14040:2006

Life cycle assessment

Life Cycle Assessment (LCA)

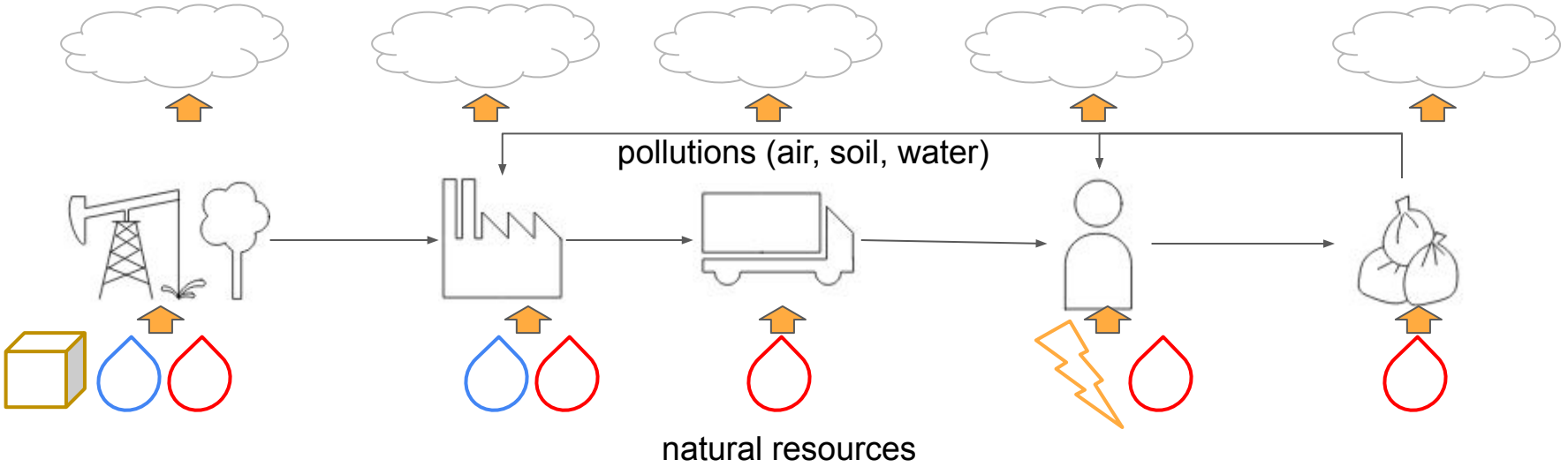
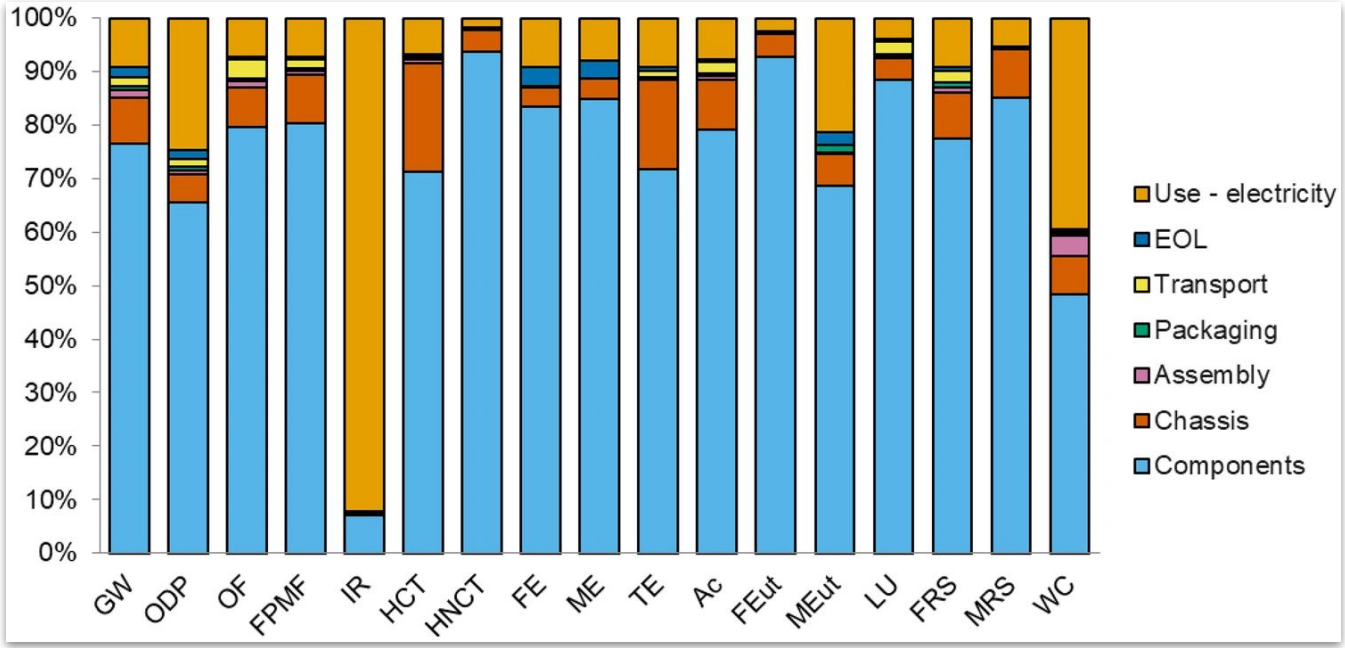


diagram taken from Jacques Combaz

Example of LCA



LCA of 600 desktop computers (Loubet et al., 2023)

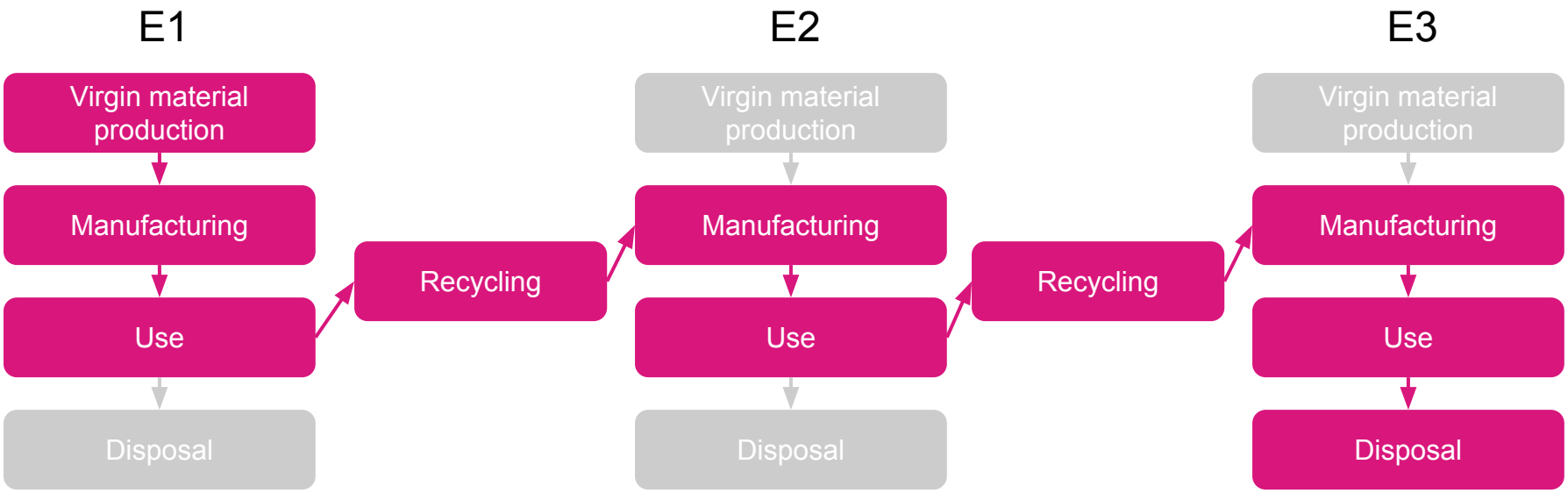
Modeling EoL in LCAs

Issue of recycling attribution:

equipment 1 → recycling→equipment 2

To which equipment are the burdens and benefits of recycling attributed?

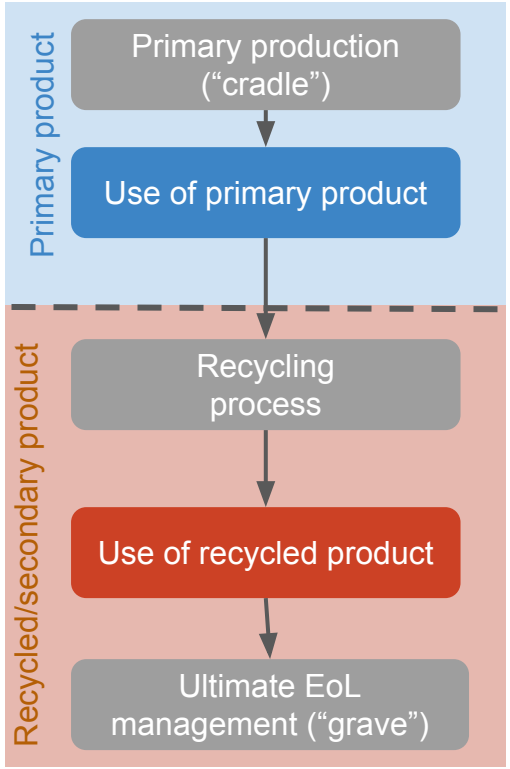
Modeling EoL in LCAs



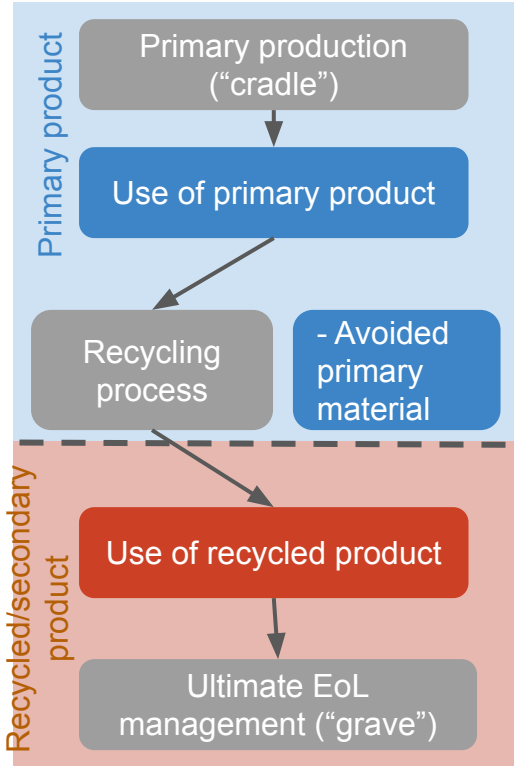
Source : [Modeling recycling in life cycle assessment]

Modeling EoL in LCAs

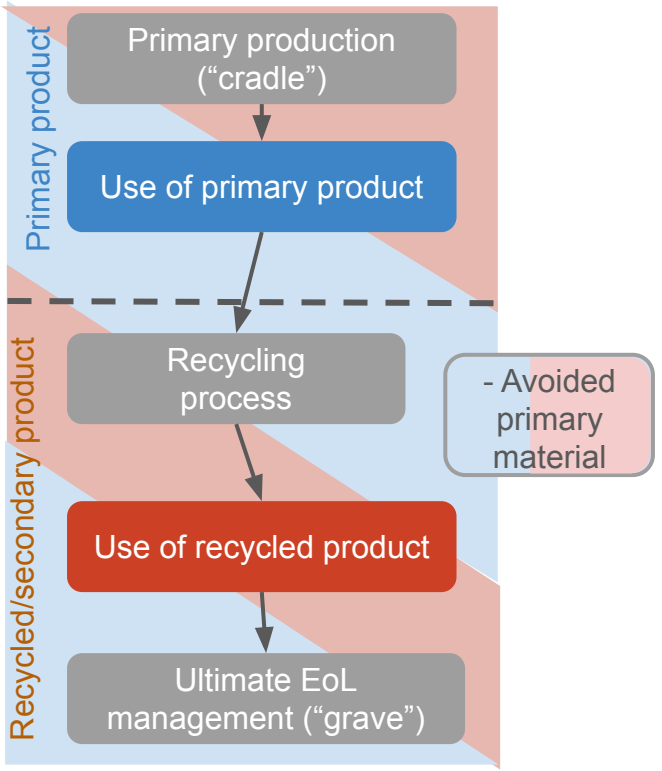
source: Corona, B., Shen, L., Reike, D., Carreón, J. R., & Worrell, E. (2019). Towards sustainable development through the circular economy—A review and critical assessment on current circularity metrics. Resources, Conservation and Recycling, 151, 104498.



100:0 or cut-off approach

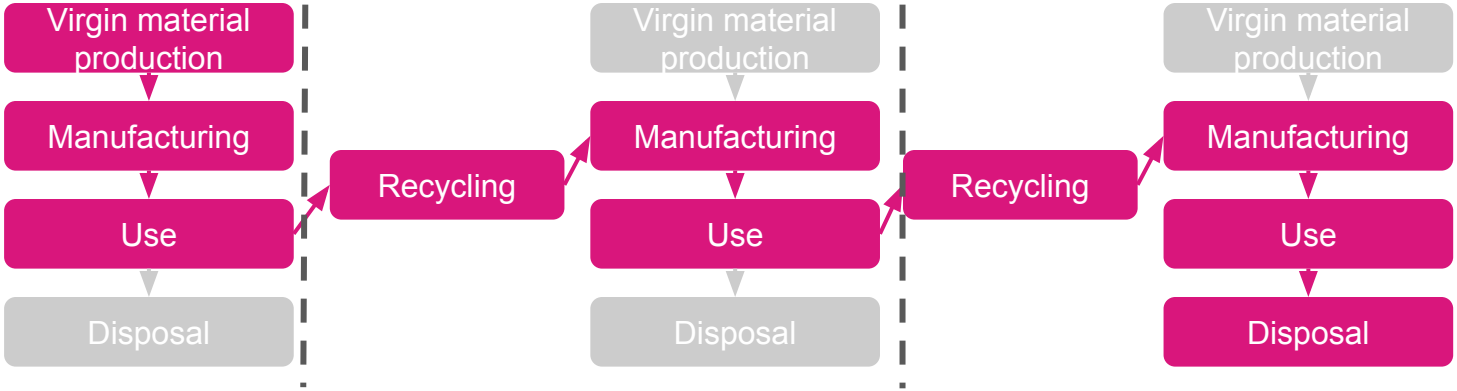


0:100 with substitution approach

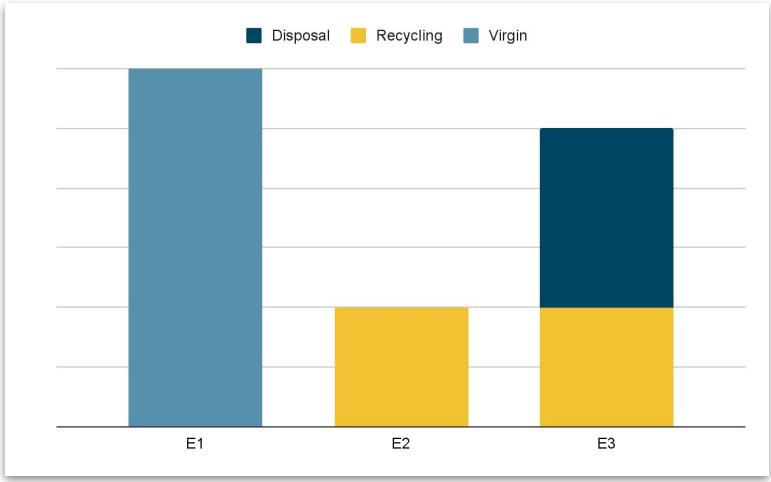


50:50, PEF

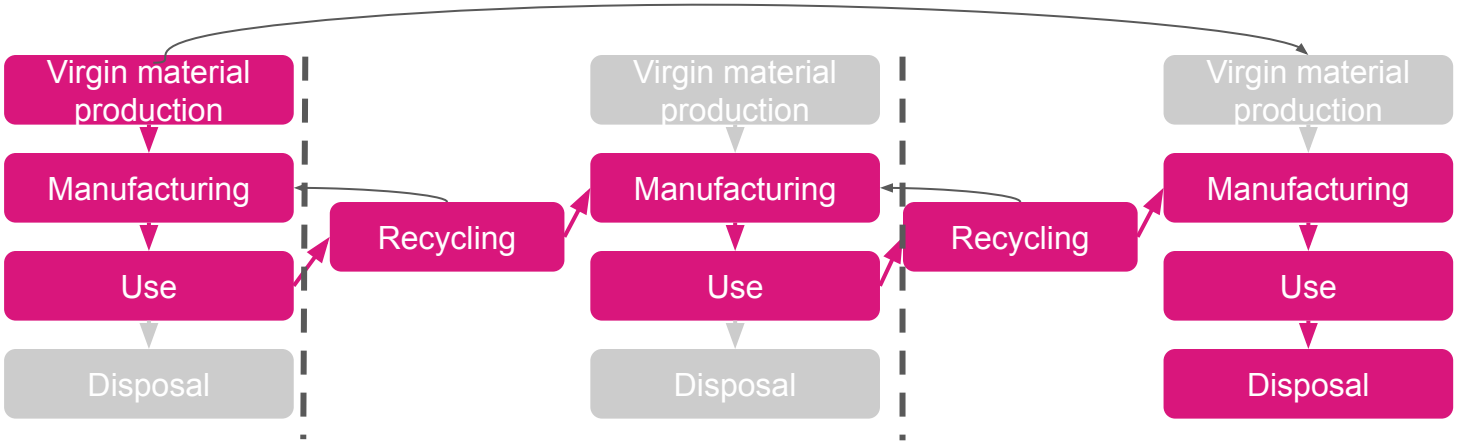
Modeling EoL in LCAs



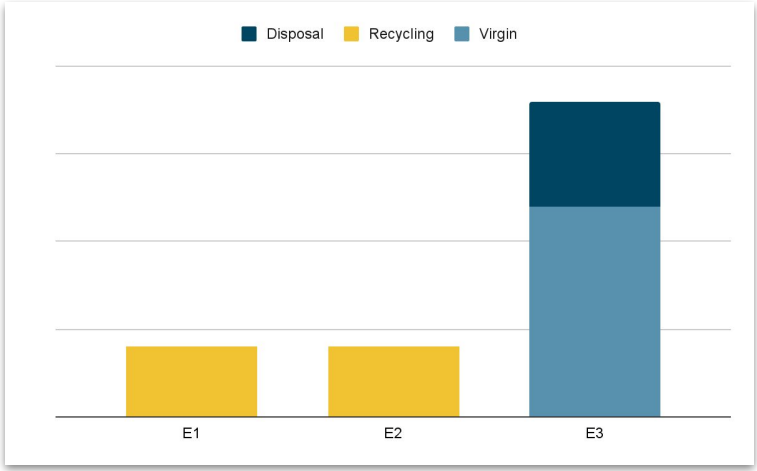
cut-off



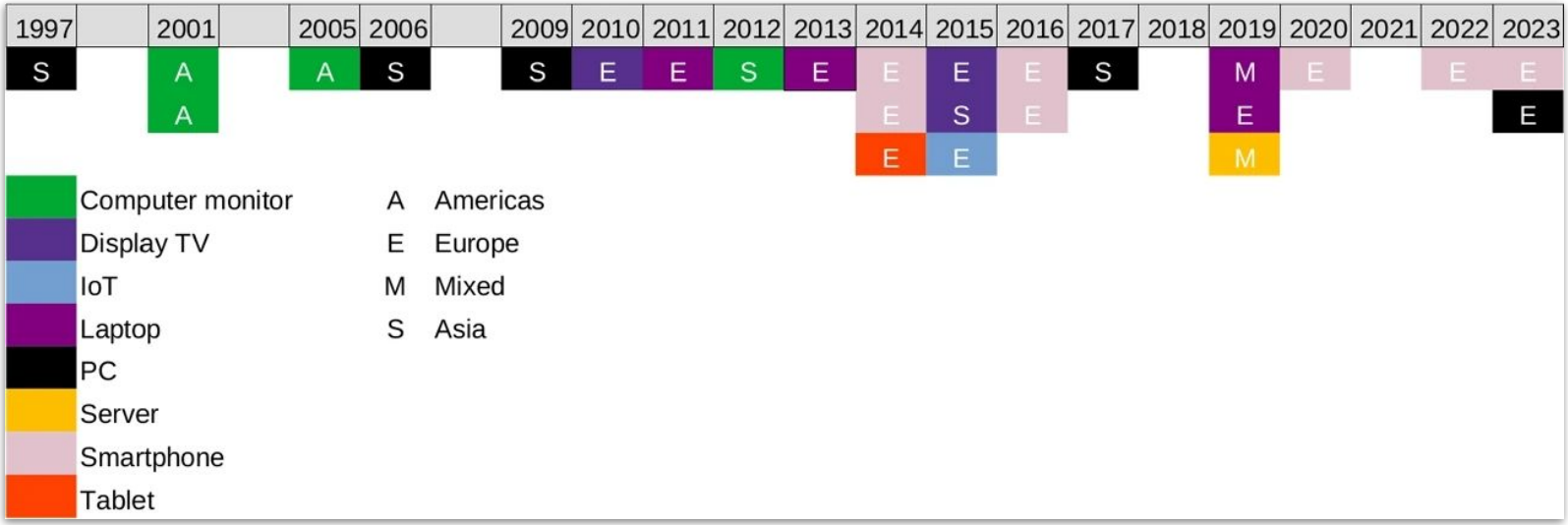
Modeling EoL in LCAs



closed-loop



LCAs of ICT equipment



source: Marion Ficher, Tom Bauer, Anne-Laure Ligozat. A comprehensive review of the end-of-life modeling in LCAs of digital equipment. 2024.

E-waste in higher education and research

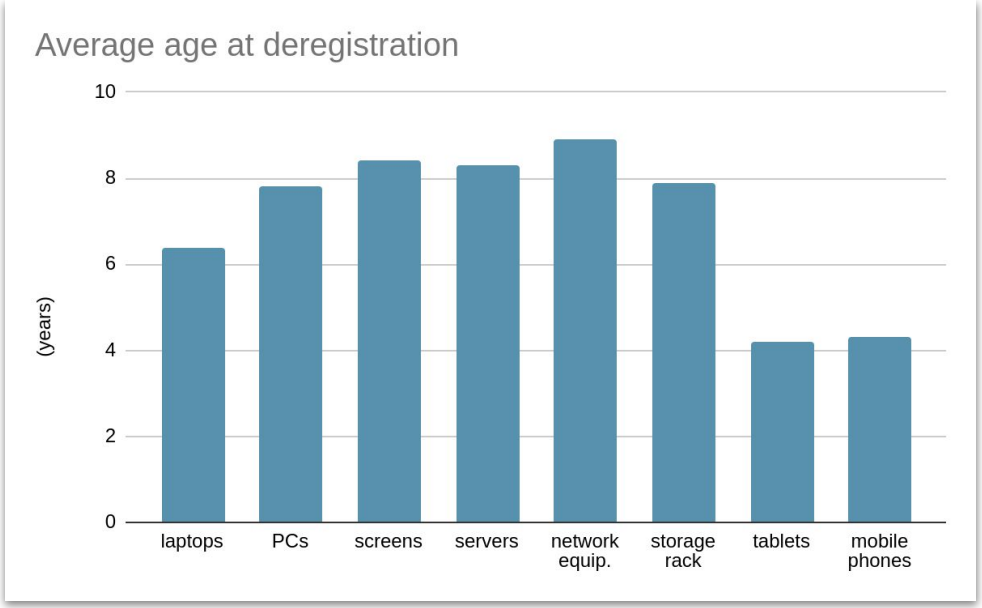
Disposal of WEEE in higher education and research

WEEE survey 2019

150 respondants

disposal of equipment :

- donations (staff, associations, schools)
- campus waste collection centers
- Paprec or Ecologic
- re-use service providers



Stakes for higher education and research

- **Environmental** impacts
  - environmental impacts of e-waste, although still poorly assessed
  - importance of recycling, especially as resources are limited, even if recycling is also costly and insufficient
- **Legal** impacts
  - establishments remain responsible for the fate of their WEEE until they relinquish this responsibility, for example by entrusting their WEEE to an eco-organization, or by donating the equipment via a transfer contract
  - need to erase data for certain structures
- **Financial** impacts
  - some laboratories currently pay to have their WEEE removed, as this requires handling

WEEE policy

First principle to apply: avoid producing this waste

- by limiting equipment renewal
  - increasing warranty periods
  - encouraging repair rather than renewal of equipment in the event of failure
  - using more energy-efficient software
- by encouraging re-use
  - in-house
  - via donations or reuse service providers

Second principle: reduce the impact of waste processing by using only (re-)known service providers

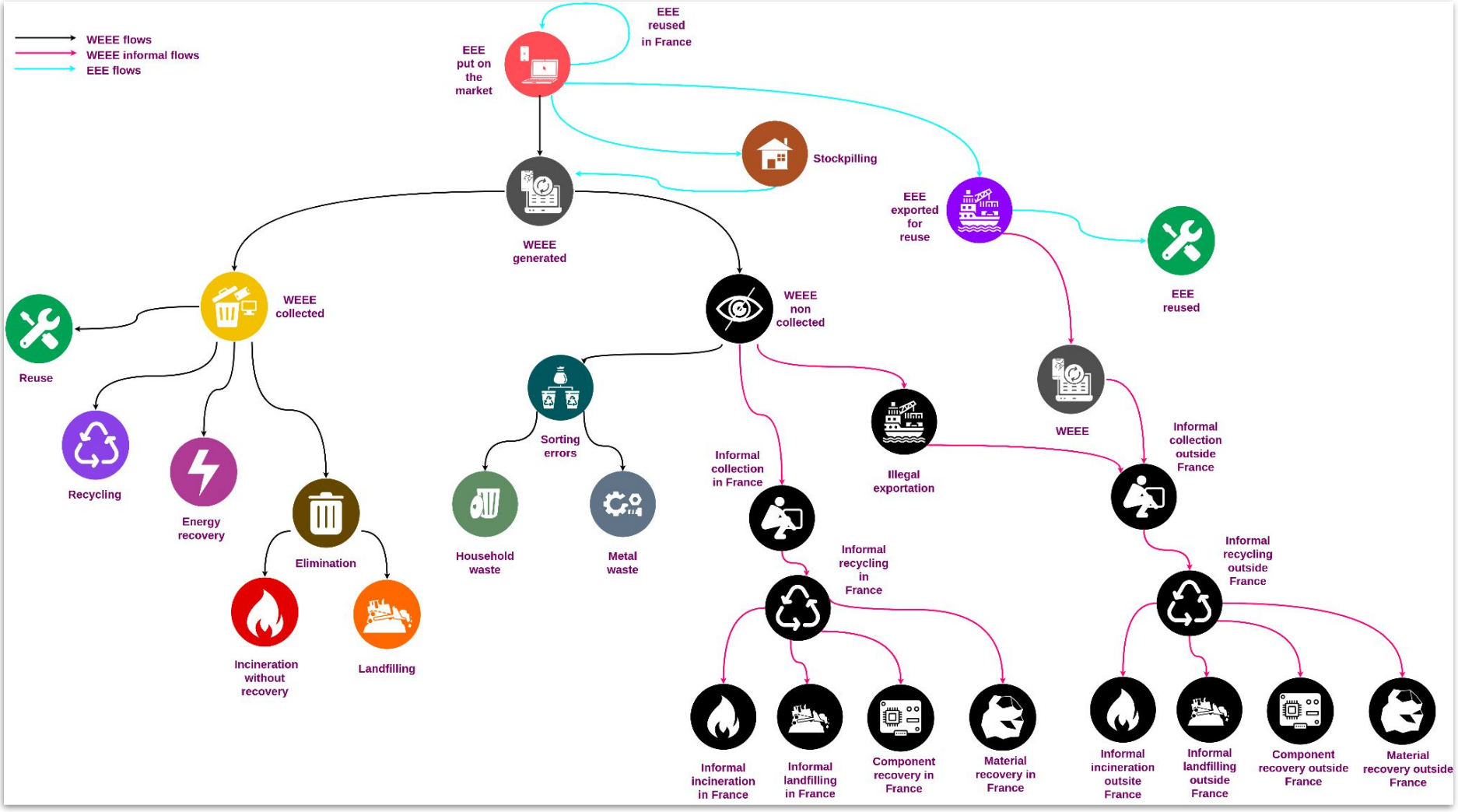
EcoInfo WEEE flyer 2023

References

- Marion Ficher, Tom Bauer, Anne-Laure Ligozat. Les DEEE numériques en France. 2023. ⟨hal-04098638⟩ (in French)
- The Global E-waste Monitor 2024 – https://ewastemonitor.info/the-global-e-waste-monitor-2024/
- Electrical and Electronic Equipment: data 2021, https://librairie.ademe.fr/dechets-economie-circulaire/6662-electrical-and-electronic-equipment-data-2021.html

Documentaries (in French)

- « Là où finissent nos déchets électroniques », https://www.arte.tv/fr/videos/111790-000-A/la-ou-finissent-nos-dechets-electroniques/
- «Déchets électroniques, le grand détournement», France 5 Le monde en face, https://youtu.be/uZI99xZDVkg?si=XtO2SpDU4sVeqNiK


WEEE flows
WEEE informal flows
EEE flows
EEE put on the market
EEE reused in France
Stockpilling
WEEE generated
EEE exported for reuse
EEE reused
WEEE collected
Reuse
Recycling
Energy recovery
Elimination
Incineration without recovery
Landfilling
WEEE non collected
Sorting errors
Household waste
Metal waste
Informal collection in France
Illegal exportation
WEEE
Informal collection outside France
Informal recycling in France
Informal recycling outside France
Informal incineration in France
Informal landfilling in France
Component recovery in France
Material recovery in France
Informal incineration outsite France
Informal landfilling outside France
Component recovery outside France
Material recovery outside France