
END’25
électronique & numérique durables

Automated E-Waste Disassembly System for Component Recovery and Reuse

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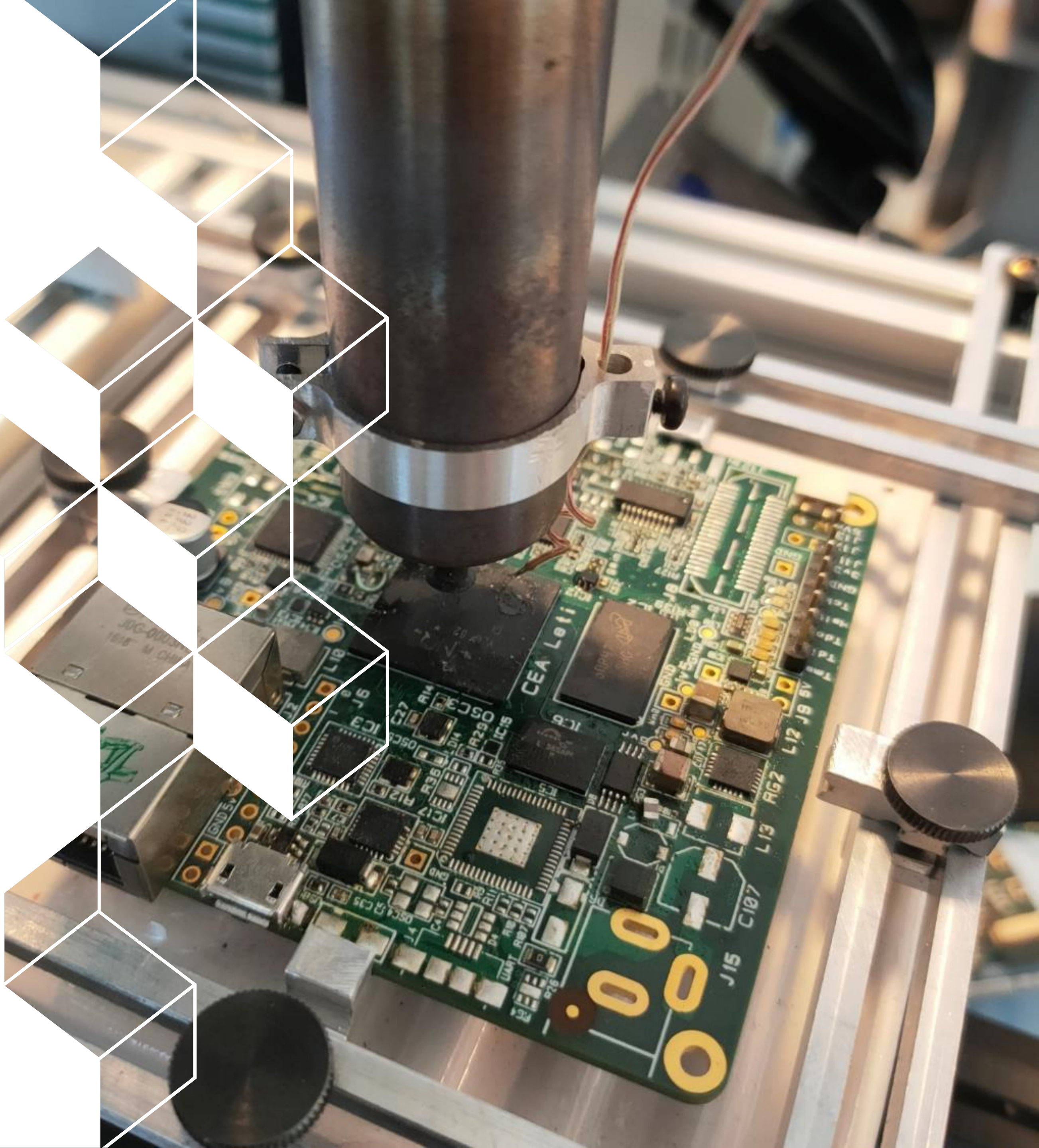

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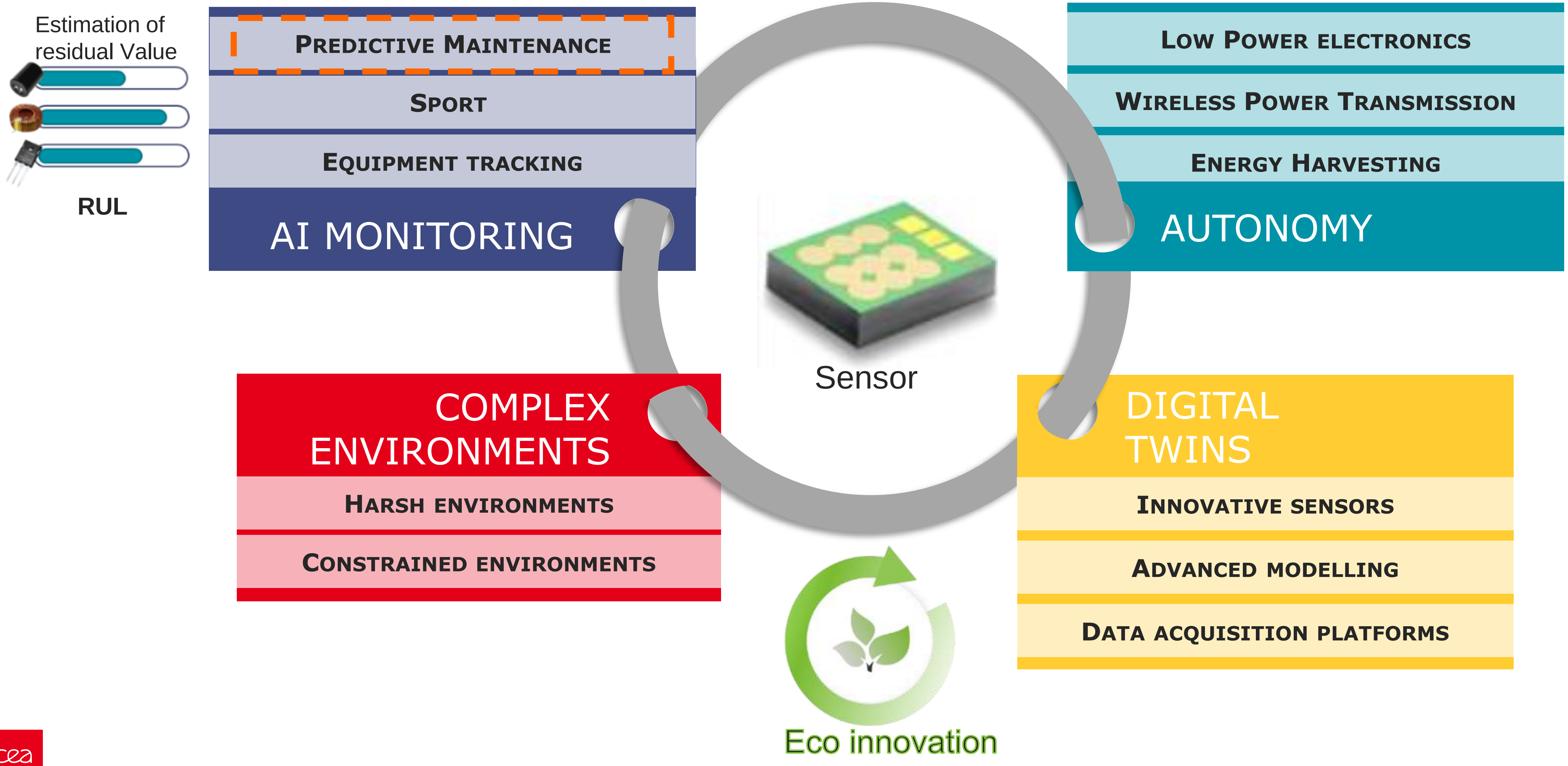


Outline

1. **Introduction**
   - Why E-Waste Matters
   - Brief Literature review
2. **The Pick and Remove System**
   - System overview and philosophy
   - Process Flow
3. **System Evaluation**
   - Experimental validation
   - Energy & Carbon Footprint
4. **Challenges and Next Steps**
5. **Conclusions**

1. Introduction

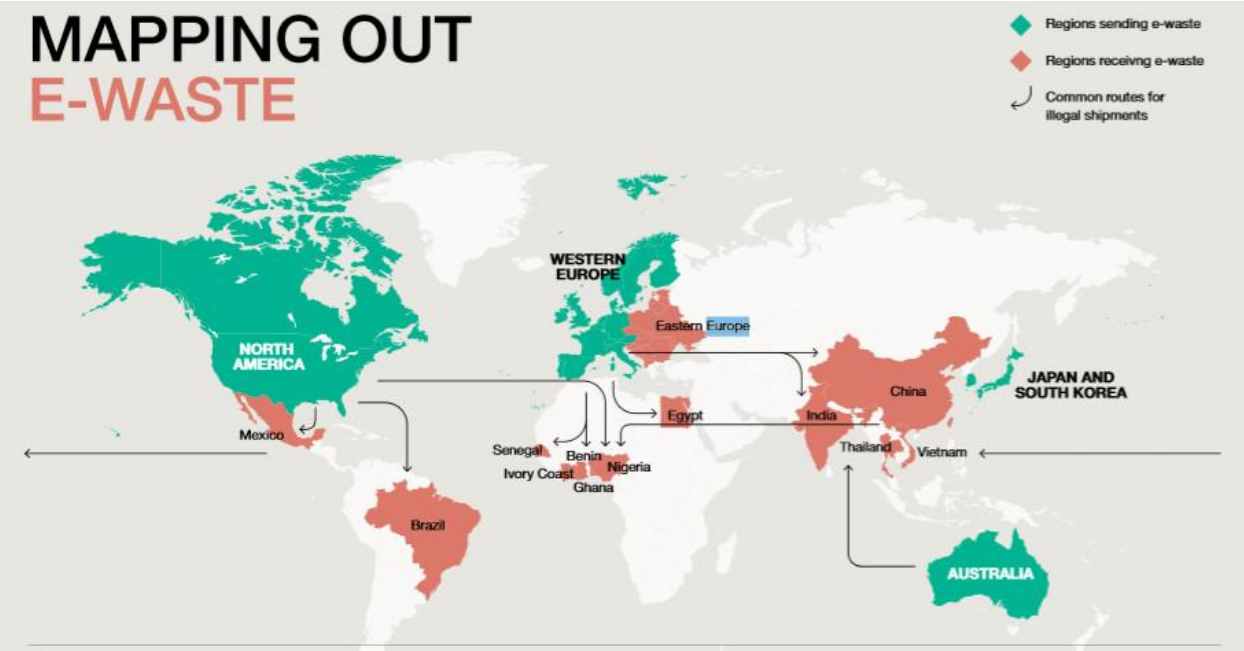
E-Waste : a pressing environmental challenge

Brief Literature review

E-Waste : a pressing environmental challenge

- 82 Mt of e-waste projected by 2030
- Only 22 % of e-waste is properly recycled

=> Need a shift toward a circular electronics industry with recycling and re-valorisation



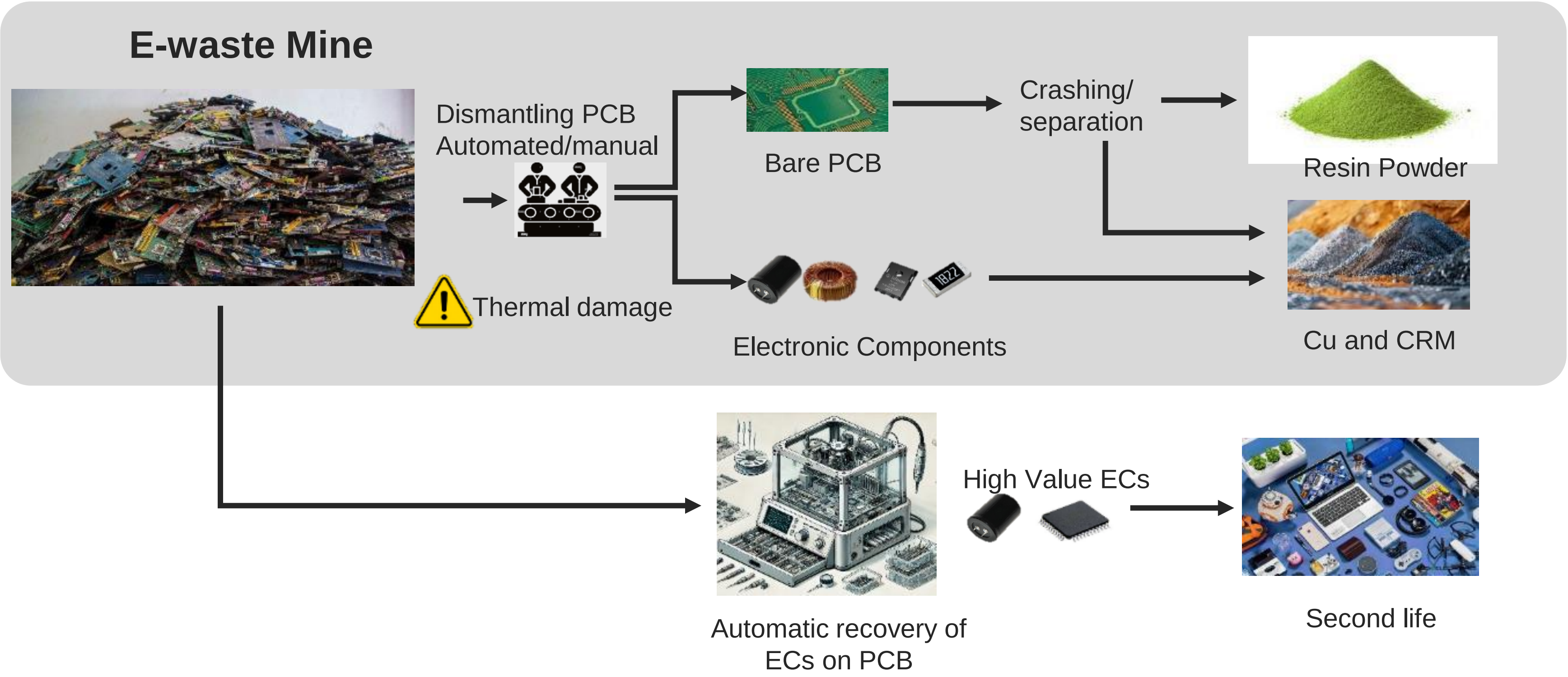
- > 95 % of electronic components discarded before end-of-life [1]

=> Need a solution to **recover valuable Electronic Components (EC)** to keep them functional to preserve added value

[1] C. P. Baldé, et al. "Global E-waste Monitor 2024", ITU and UNITAR, 2024.

E-Waste recovery : Brief Literature review

- Most of industrials and research teams are focusing on mass recycling of PCB and ECs to recover metals and Critical Raw Materials (CMR) [2]



- ECs recovery can be combined with conventional recycling to keep their added value and bring additional economic, social and environmental benefits [3]

[2] S. Gulliani, M. Volpe, A. Messineo, R. Volpe, "Recovery of metals and valuable chemicals from waste electric and electronic materials: a critical review of existing technologies". RSC Sustainability, 1(4), 2023, 590-627.

[3] Biswajit Debnath, Priyankar Roychowdhury, Rayan Kundu, "Electronic Components (EC) Reuse and Recycling – A New Approach towards WEEE Management", Procedia Environmental Sciences 35, 2016, p. 656-668

E-Waste recovery : which ECs ?

- Literature on EC recovery quite sparse [3]
- No guidelines to select valuable ECs
- Available data on common ECs from websites and datasheet

Component	Composition	Environmental Impact	Economic Value
Integrated Circuit	Au, Cu, REEs[1]	Energy-intensive, toxic	High, needs testing
Capacitor	Al, Zn, Ta, Nb	Ethical Ta extraction	High when scarce
Inductor	Cu, ferrite	Smelting, heat	Base-price of Cu
Transistor	Si, Ge, Ga, As	Toxic, energy	High resale for niche
Resistor	Cu, Sn, C	Low per unit	Low, bulk recovery

[1]REEs = "rare-earth elements"

- **Integrated Circuits (ICs) :** adapted size for recovery / economic and environmental benefits
- **Tantalum Capacitances:** high environmental benefits + easy testability
- **SMD packages** : most of new high-value components are manufactured in this format

2. The Pick and Remove System

System overview and philosophy

Process Flow

System overview and philosophy

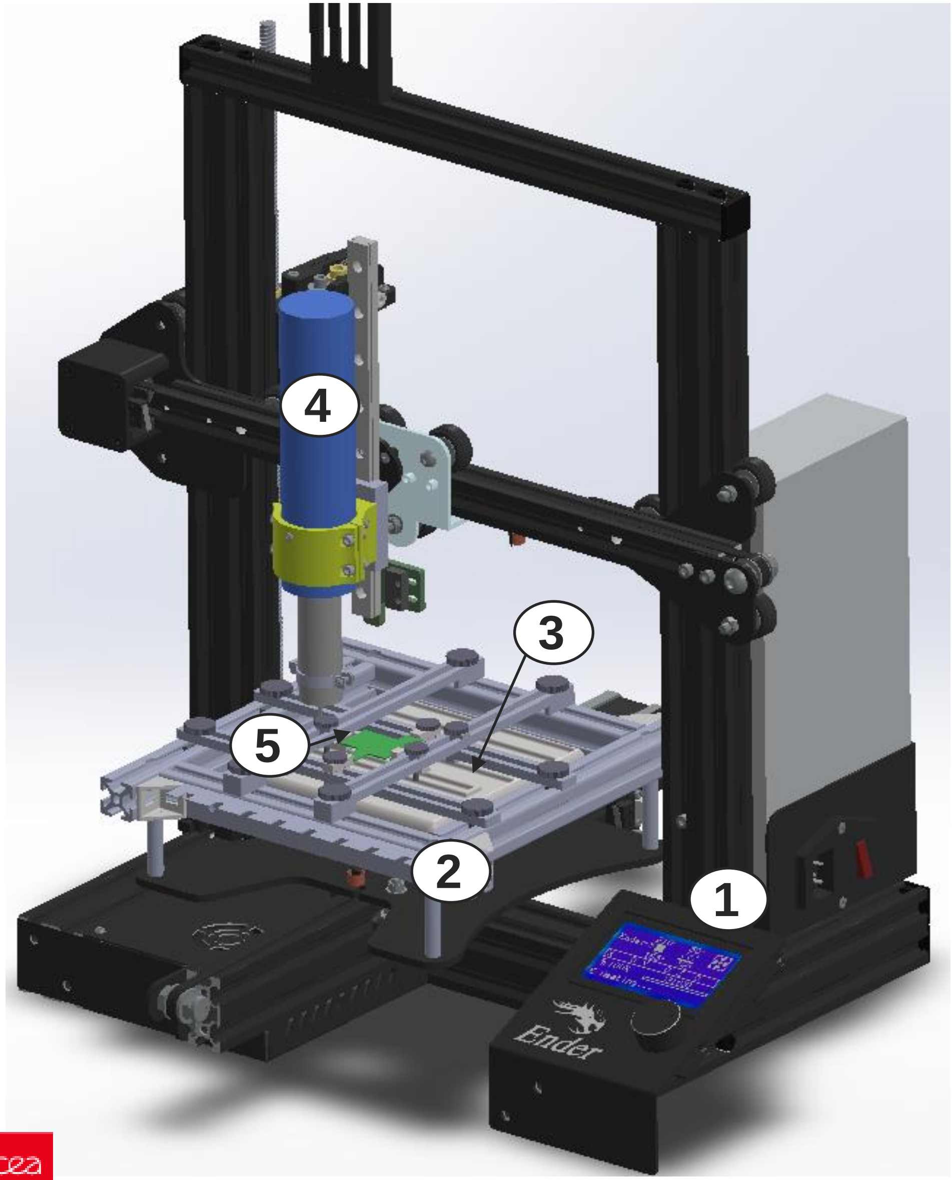
Philosophy:

- Make recovery of electronic components **accessible**
- Democratize ECs recovery in **academic** Labs and **FabLabs**
- All designs & code on GitHub (CERN-OHL license)

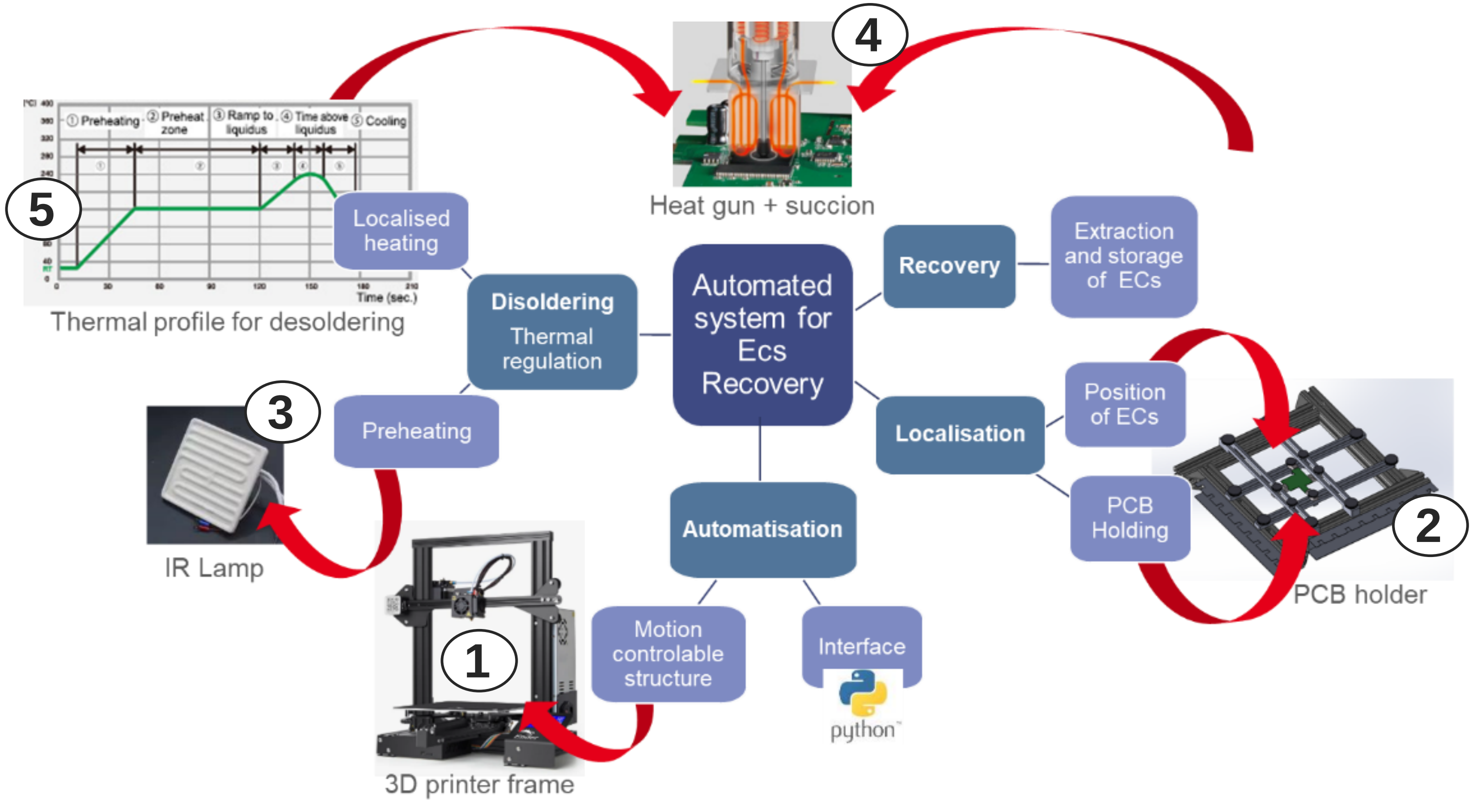
Functional analysis:

- **Identification** : x, y position of selected valuable ECs (no vision required)
- **Automation** : Autonomous displacement of desoldering system
- **Desoldering** : Temperature profile compatible with EC brasing
- **Recovery : **Remove EC and depose to a tray

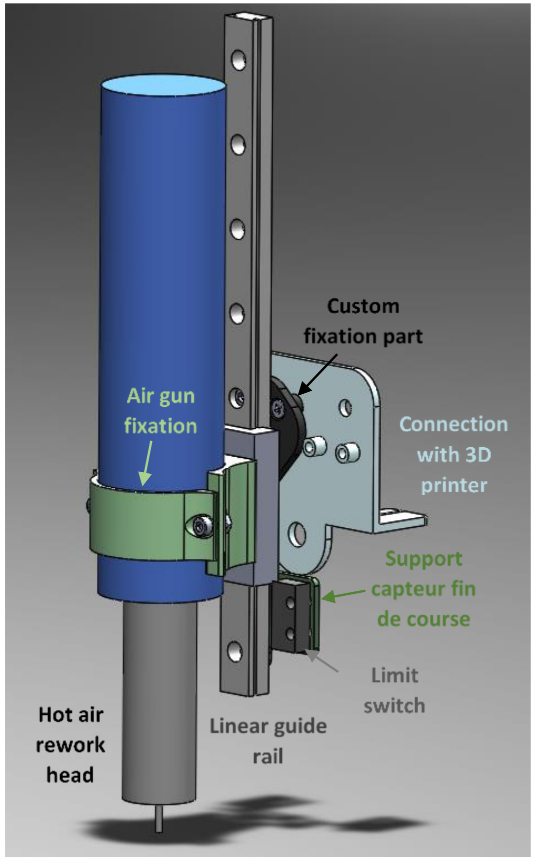
System overview



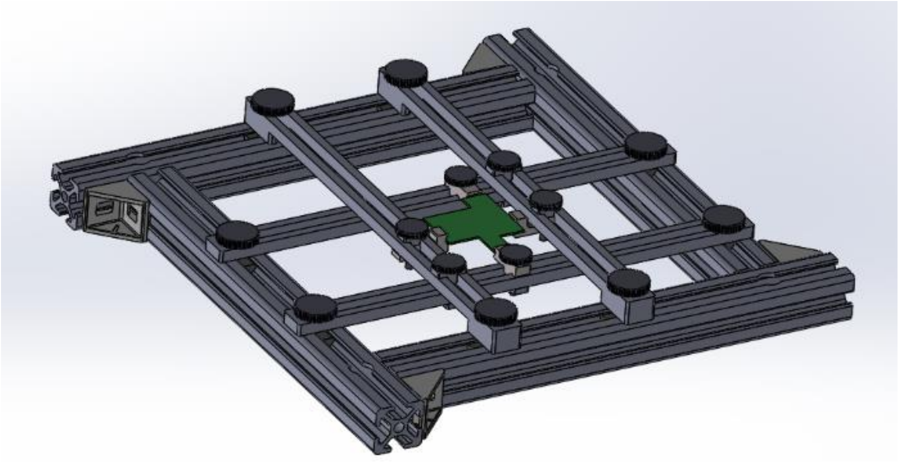
1. Repurposed Creality Ender-3 - 3D printer chassis
2. PCB Holder with tray
3. 120 × 120 mm IR ceramic heater (150 °C pre-heat)
4. HAKKO FR-811 hot-air station (250 °C + suction pad)
5. Thermocouple for controlled ramp



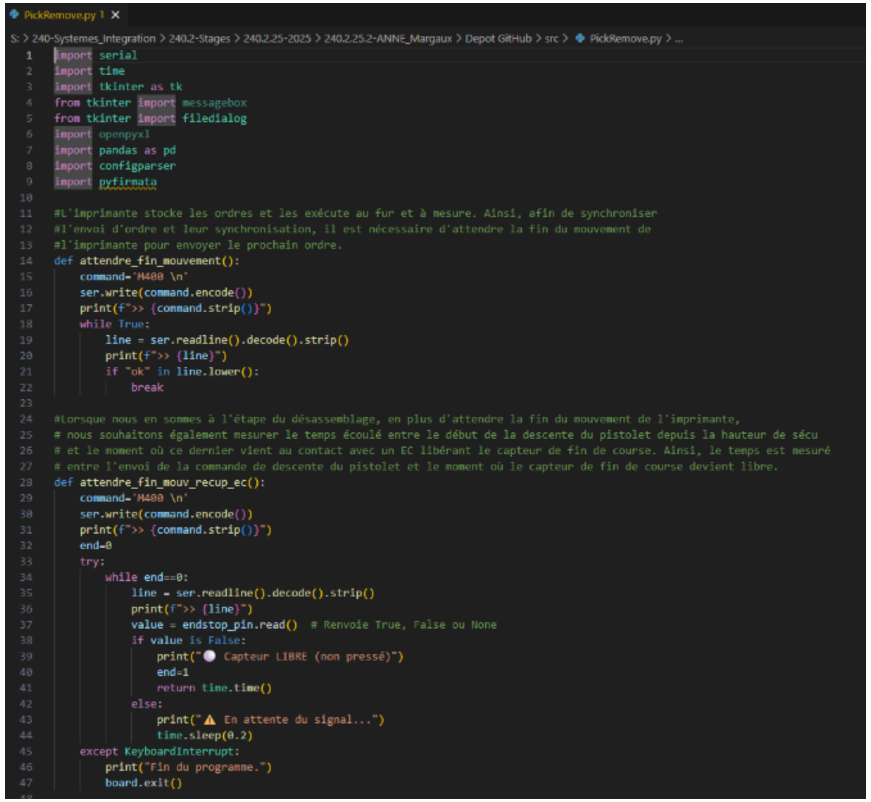
Design of specific parts



Reflow Head connexion



PCB and IR lamp holder



PickRemove.py 1

S: > 240-Systemes_Integration > 240.2-Stages > 240.2.25-2025 > 240.2.25.2-ANNE_Margaux > Depot GitHub > src > PickRemove.py > ...

```python
import serial
import time
import tkinter as tk
from tkinter import messagebox
from tkinter import filedialog
import openpyxl
import pandas as pd
import configparser
import pyfirmata

#L'imprimante stocke les ordres et les exécute au fur et à mesure. Ainsi, afin de synchroniser
#l'envoi d'ordre et leur synchronisation, il est nécessaire d'attendre la fin du mouvement de
#l'imprimante pour envoyer le prochain ordre.
def attendre_fin_mouvement():
    command='M400 \n'
    ser.write(command.encode())
    print(f">> {command.strip()}")
    while True:
        line = ser.readline().decode().strip()
        print(f">> {line}")
        if "ok" in line.lower():
            break

#Lorsque nous en sommes à l'étape du désassemblage, en plus d'attendre la fin du mouvement de l'imprimante,
# nous souhaitons également mesurer le temps écoulé entre le début de la descente du pistolet depuis la hauteur de sécu
# et le moment où ce dernier vient au contact avec un EC libérant le capteur de fin de course. Ainsi, le temps est mesuré
# entre l'envoi de la commande de descente du pistolet et le moment où le capteur de fin de course devient libre.
def attendre_fin_mouv_recup_ec():
    command='M400 \n'
    ser.write(command.encode())
    print(f">> {command.strip()}")
    end=0
    try:
        while end==0:
            line = ser.readline().decode().strip()
            print(f">> {line}")
            value = endstop_pin.read()  # Renvoie True, False ou None
            if value is False:
                print("⚪ Capteur LIBRE (non pressé)")
                end=1
                return time.time()
            else:
                print("⚠ En attente du signal...")
                time.sleep(0.2)
    except KeyboardInterrupt:
        print("Fin du programme.")
        board.exit()
```

HMI : python code for 3D printer driving (g-code), and temperature regulation

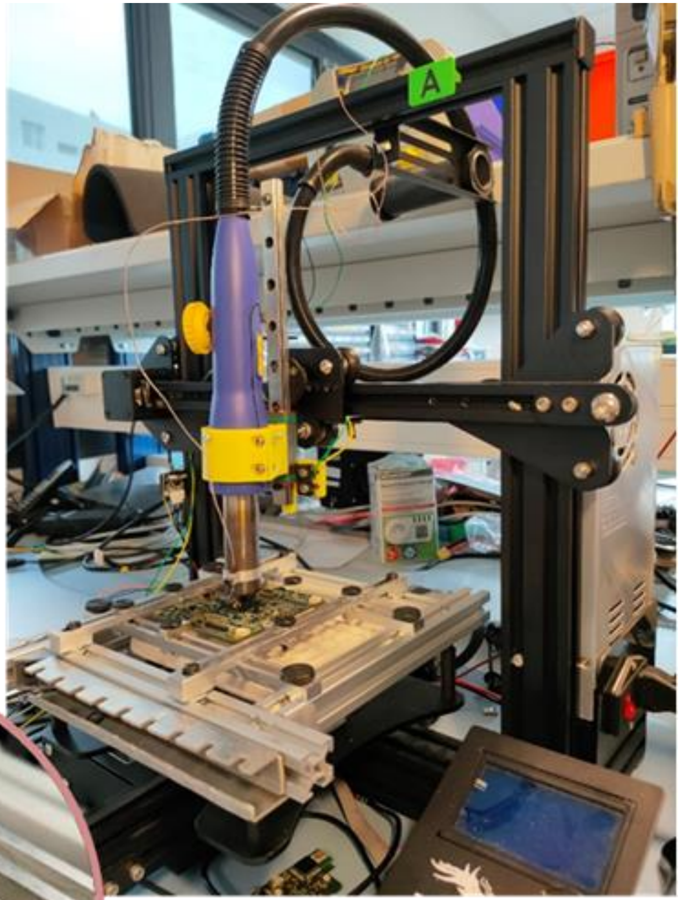
3. System Evaluation

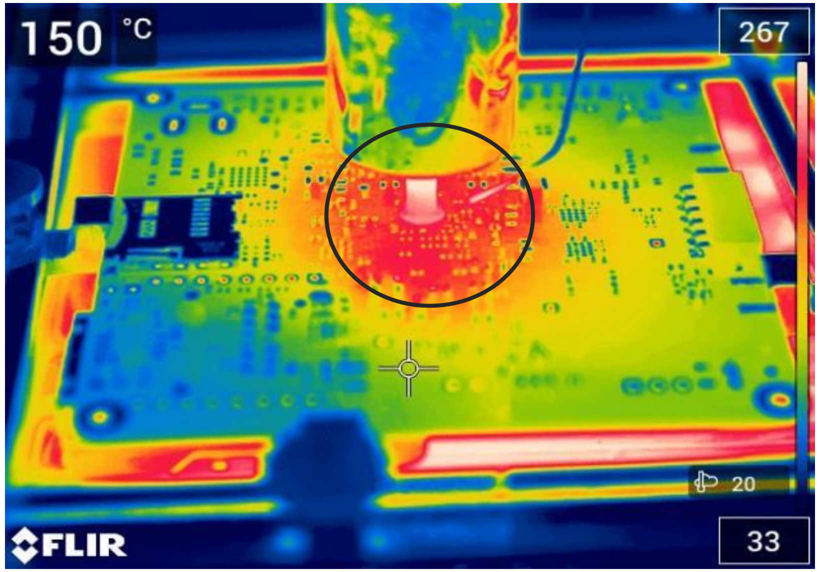
Experimental validation

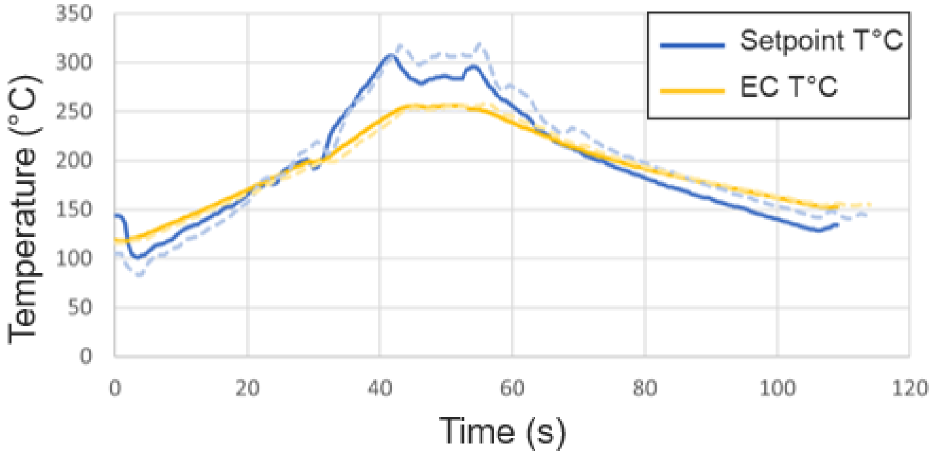
Energy & Carbon Footprint

Experimental validation

Experimental setup	
Preheating IR	150 °C
Local heating of EC	250 °C
Heating ramp up	< 3°/s
Dwell time	20 s
ECs	8 ICs and 4 cap.
No of PCB	5







Experimental Results

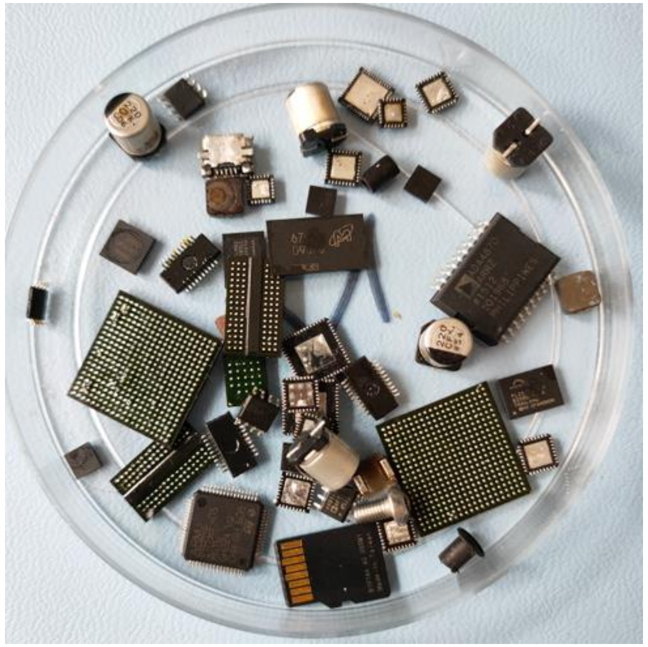
- During these tests, most of the ECs selected were successfully recovered without any damage

Ta-caps (4 / PCB):
- 100 % recovery
- No dielectric damage

ICs (8 / PCB):
- 75 – 91 % success
- All passed functional tests

Cycle time: 1 to 1.5 min / EC

Energy per cycle: 0.0345 kWh



Environmental impact of ECs recovery

- The environmental impact of EC recovery was evaluated by comparing the **cradle-to-gate carbon footprint of new devices** with the **energy-based footprint of the recovery cycle**

Footprint per pick-and-remove cycle

- 1.1 g CO_2 (French grid) | 8.3 g CO_2 (EU mix)

Manufacturing footprints [4][5]

- ICs: 35 - 50 kg CO_2 / 300 mm wafer

- Ta-caps: 97 - 312 kg CO_2 / kg

Recovery impact for IC and Ta-caps

- 0.4 – 52 % of manufacturing CO_2

Device	Cradle to Gate [gCO_2]	Relative carbon footprint for recovery	
		FR Energy mix	EU Energy mix
Large IC ǀ SoC - 20 x 20 mm²	280	0.4 %	3 %
Medium IC ǀ ST MCU [6]	120	1 %	7 %
Small IC ǀ MCU - 5 x 5 mm²	17	7 %	52 %
Large Ta. Cap. ǀ SMD - 250 mg	50	2 %	17 %
Medium Ta. Cap. ǀ 1210 SMD - 20 mg	4	28 %	n.a.

➢ EC recovery was evaluated and found to be a promising approach, both economically and environmentally.

[4] S. B. Boyd, “Life-Cycle Assessment of Semiconductors”. Ph.D. dissertation, University of California, Berkeley, CA, USA, 2011

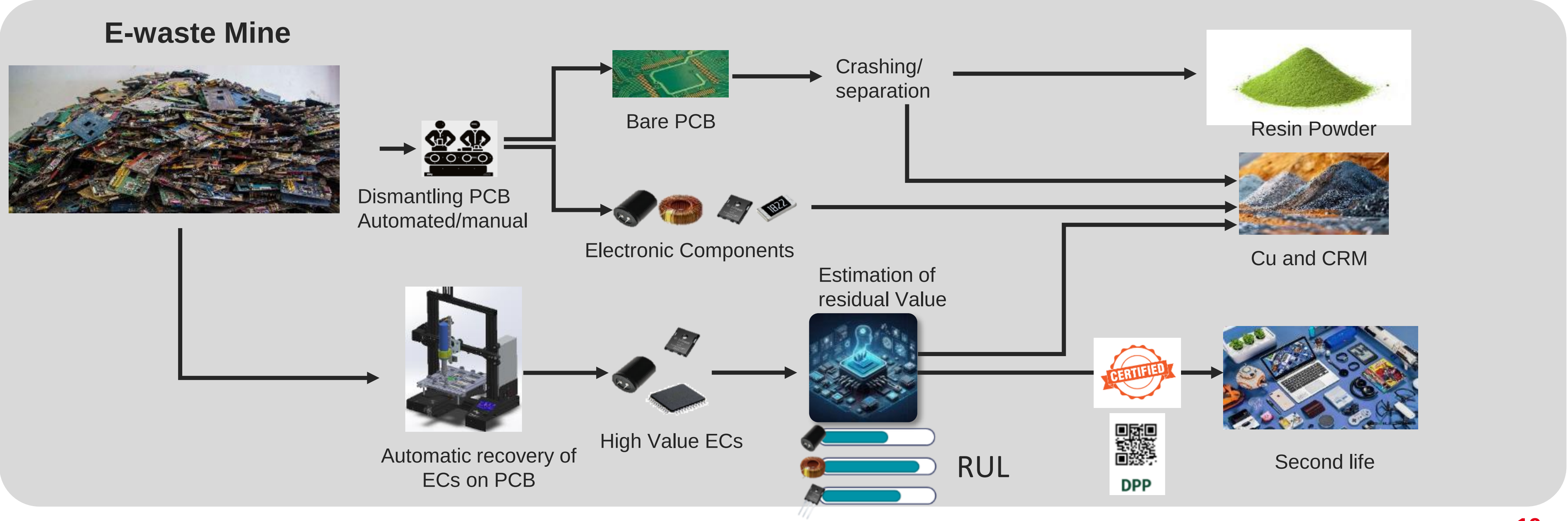
[5] Z. Elsayed, N. Elsayed, A. Abdelgawad, “Carbon Per Transistor (CPT): The Golden Formula for Green Computing Metrics”, 2025

[6] Footprint of an Ultra Low Power MCU, Available online: https://www.st.com/content/st_com/en/about/sustainability/sustainable-technology/environmental-footprint-of-an-ultra-low-power-mcu.html (accessed on 17th September 2025)

4. Challenges and Next Steps

Challenges and Next Steps

- The ECs recovery is a promising approach but it still faces several challenges to improve accessibility, efficiency and acceptability :
  - ❑ Automated EC identification (vision + AI)
  - ❑ Faster recovery (higher motor speeds, parallel arms)
  - ❑ Standardised testing & certification for recovered ECs
  - ❑ RUL prediction (physics-informed ML)
  - ❑ Digital Product Passports (DPP) for traceability

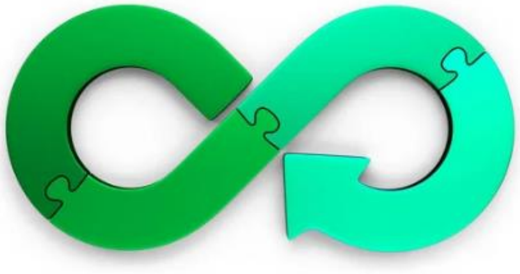


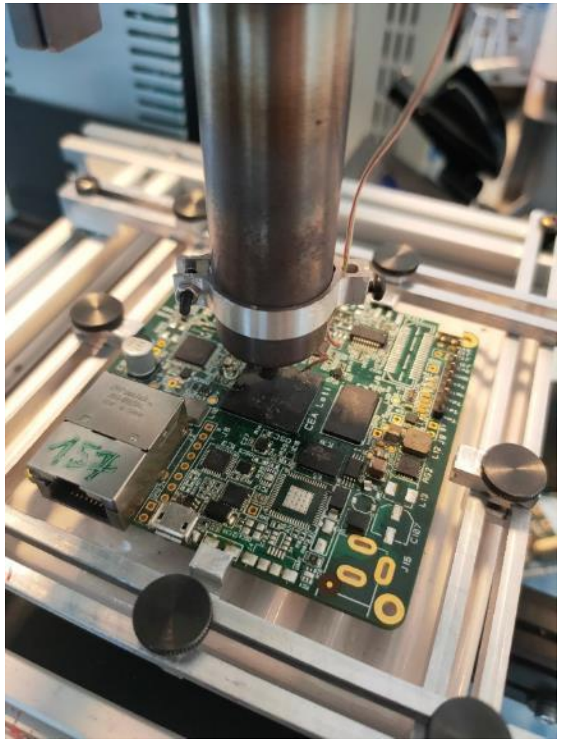
5. Conclusions

Conclusions

This work addresses the pressing issue of e-waste by developing an open-source system for automated recovery of high-value components from PCBs, enabling their reuse in a second life cycle.

- ✓ Accessible, low-cost system
- ✓ 75 – 100 % recovery, minimal thermal damage
- ✓ ≤ 10 - 20 % of manufacturing CO_2
- ✓ Open-source platform – invite labs, FabLabs, industry to adapt it





All designs & code on GitHub (CERN-OHL license)
https://github.com/CEA-Leti/Pick-Remove4Reuse

Many thanks for your attention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