Diskusi *Urban Mining* dan *Circular Economy*

Prof M Akbar Rhamdhani
Department of Mechanical and Product Design Engineering

Universitas Sultan Ageng Tirtayasa
Monday, 22 March 2021

SWINBURNE UNIVERSITY OF TECHNOLOGY

Key References

- Mairizal, A.Q., Sembada, A.Y., Tse, K.M., Rhamdhani, M.A., 2021. Electronic waste generation, economic values, distribution map, and possible recycling system in Indonesia, *Journal of Cleaner Production*, Vol. 293 (Apr 2021), 126096
- Khaliq, A.; Rhamdhani, M.A., Brooks, G., Masood, S., 2014. Metal extraction processes for electronic waste and existing industrial routes: A review and Australian perspective, *Resources*, Vol. 3, no. 1 (Feb 2014), pp. 152-179

SWINBURNE UNIVERSITY OF TECHNOLOGY

ABOUT ME

Prof M Akbar Rhamdhani

- PhD (Materials Science and Engineering), McMaster University, Canada
- B.Eng (Cum Laude) (Materials Engineering), Institute of Technology Bandung, Indonesia
- GCLT, Swinburne University of Technology, Australia

Current appointments:

- Professor in Dept Mechanical and Product Design Engineering, Swinburne
- Director Fluid and Process Dynamics (FPD) Research Group, Swinburne
- Director (Academic) Curriculum and Quality, School of Engineering

Previous appointments:

- A research-academic at Institute of Technology Bandung (ITB); University of Queensland, Australia
- Visiting Professor at Katholieke Universiteit Leuven, Belgium; and at CSIRO (Commonwealth Scientific and Industrial Research Organisation), Australia

Key Expertise:

- High Temperature Materials, Metals and Chemical Processes
- Materials Engineering
- Thermodynamic and Kinetics of Processes
- Development of Novel Processes for Metals Production and Refining

Publications:

- **212** publications and reports **+ 2** patents

Awards:

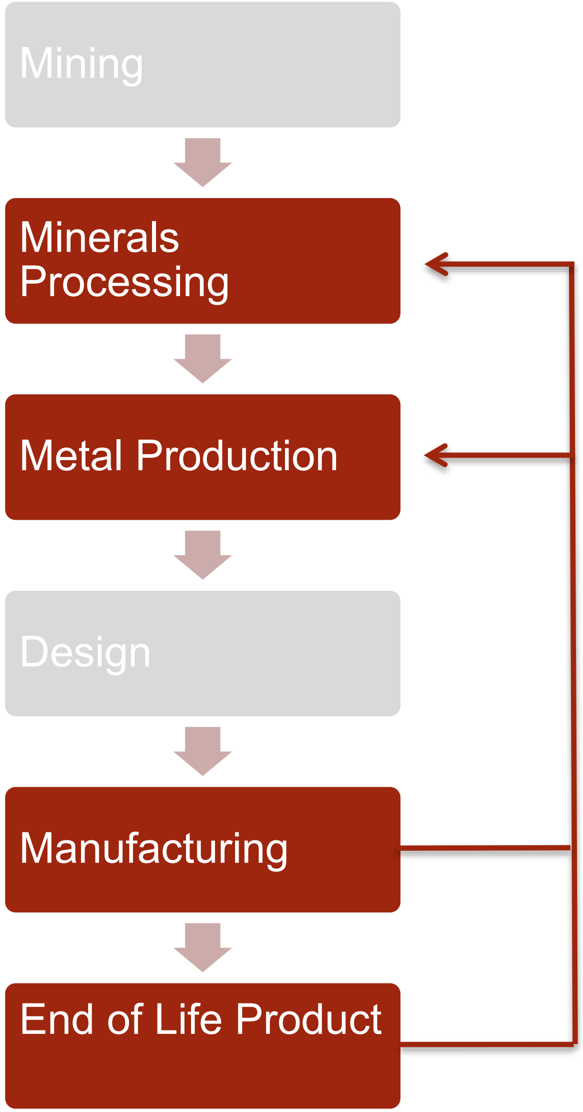
- 2020 Williams Award from IOM3 United Kingdom
- 2019 Kent D Peaslee Award from AIST USA
- 2018 World Class Professor and 2018 & 2019 World Class Scholar from the Ministry of Research, Technology and Higher Education, Republic of Indonesia.
- 2015 Mann Redmayne Medal from IOM3 United Kingdom
- 2015 Marcus Grossmann Medal from ASM International USA
- 2015 MetSoc Award from Metallurgical Society of Canada.

Current Research Focus / Context

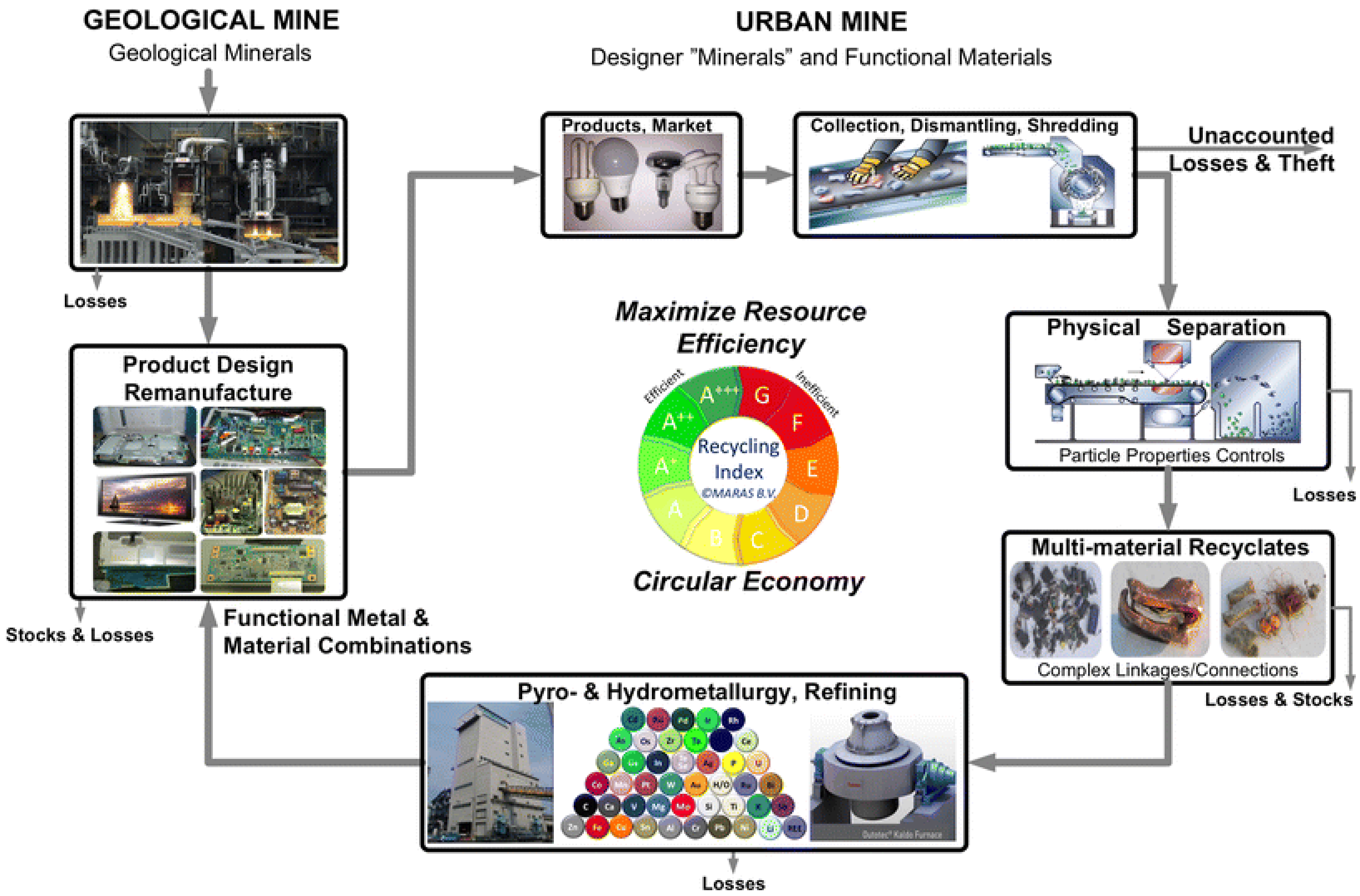
Prof M Akbar Rhamdhani
Director FPD (Fluid and Process Dynamics) Group
Director of Transport Innovation Centre
Advanced High Temp Refining and Impurities Removal, Processing of Secondary Resources, Metal Recycling

Extractive Metallurgy for Resource Efficiency and Circular Economy

- **Processing of Alternative Sources (Urban Ores; Low Grade Ores; Extra-terrestrial resources)**
- **Metals Recovery/Recycling from Wastes**
- **Advanced Refining and Extraction Process**
- **Impurities Removal and Ultrapure Materials**
- **New Processes with Low Carbon Footprint**



Circular Economy



- One of the key drivers of a Circular Economy is metallurgy and recycling
- Consumer products are complex, consisting of many technological and critical and functional materials/elements

Reuter, M.A. Digitalizing the Circular Economy. *Metall and Materi Trans B* **47,** 3194–3220 (2016). https://doi.org/10.1007/s11663-016-0735-5

SUSTAINABLE DEVELOPMENT GOALS

17 GOALS TO TRANSFORM OUR WORLD

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

ENSURE SUSTAINABLE CONSUMPTION AND PRODUCTION PATTERNS

BEFORE COVID-19

THE WORLD CONTINUES TO USE NATURAL RESOURCES **UNSUSTAINABLY**

2010
GLOBAL MATERIAL FOOTPRINT
73.2 BILLION METRIC TONS

2017
GLOBAL MATERIAL FOOTPRINT
85.9 BILLION METRIC TONS

COVID-19 IMPLICATIONS

THE PANDEMIC OFFERS AN OPPORTUNITY TO **DEVELOP RECOVERY PLANS** THAT BUILD A MORE SUSTAINABLE FUTURE

FROM 2017 TO 2019, 79 COUNTRIES AND THE EUROPEAN UNION REPORTED AT LEAST ONE POLICY TO PROMOTE SUSTAINABLE CONSUMPTION AND PRODUCTION

ELECTRONIC WASTE GREW BY 38%

BUT LESS THAN 20% **IS RECYCLED**

(2010–2019)

RISING **FOSSIL FUEL SUBSIDIES** ARE CONTRIBUTING TO THE CLIMATE CRISIS

$318 BILLION (2015)	$427 BILLION (2018)

HARVESTING → TRANSPORT → STORAGE → PROCESSING

13.8% OF FOOD IS LOST IN SUPPLY CHAINS (2016)

What is E-Waste

European WEEE Directive

“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.” [2, 3].

Basel Action Network

“E-waste encompasses a broad and growing range of electronic devices ranging from large household devices such as refrigerators, air conditioners, cell phones, personal stereos, and consumers electronics to computers which have been discarded by their users.”[4]

Resource Efficiency and Circular Economy Context

Swinburne

Lowering of the grade of ores around the world

Availability of alternative resources for metals

- Low grade/weathered ores
- Urban ores
    - Industrial Wastes
    - Consumer/household Wastes
    - Construction Wastes
    - End of Life Products
    - **Electronic wastes**

Electronic wastes

- 50 million tonnes+ are generated annually (global)
- Great challenges and also opportunities
- <u>Contain:</u> Precious, Platinum Group, Base, Hazardous, and Rare Metals

Alternative Metal Ore Resources

10-15 kg

=

Containing 2g Au

=

500 kg to 1,000 kg

1,000 kg

=

200g (Au)

3 kg (Ag)

100 kg (Cu)

100 g (Pd)

What is inside E-Waste

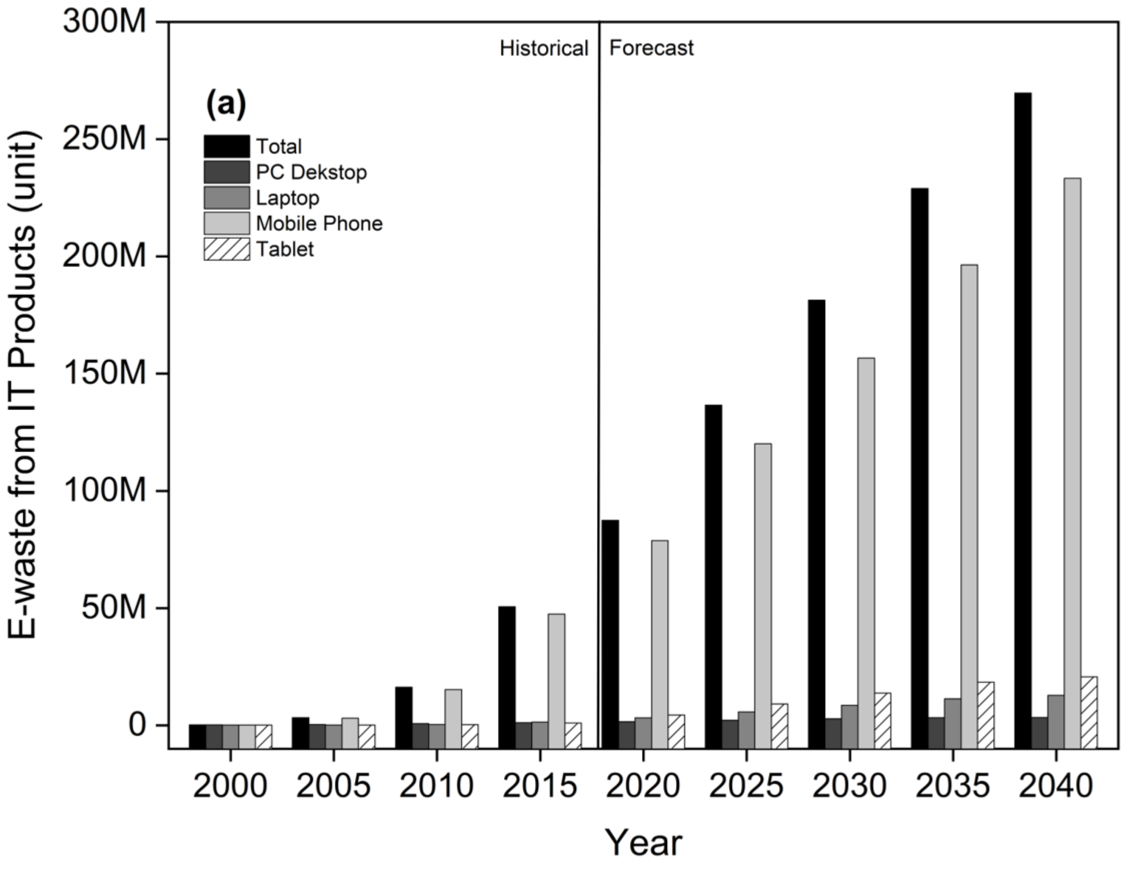
Weight versus value distribution in E-Waste

Weights %	Fe (wt %)	Al (wt %)	Cu (wt %)	Plastics (wt %)	Ag (ppm)	Au (ppm)	Pd (ppm)
TV-board	28%	10%	10%	28%	280	20	10
PC-board	7%	5%	20%	23%	1000	250	110
Mobile phone	**5%**	**1%**	**13%**	**56%**	**1380**	**350**	**210**
Portable audio	23%	1%	21%	47%	150	10	4
DVD-player	62%	2%	5%	24%	115	15	4
Calculator	4%	5%	3%	61%	260	50	5
Value-share	**Fe**	**Al**	**Cu**	**Sum Precious Metals**	**Ag**	**Au**	**Pd**
TV-board	4%	11%	42%	43%	8%	27%	8%
PC-board	0%	1%	14%	85%	5%	65%	15%
Mobile phone	**0%**	**0%**	**7%**	**93%**	**5%**	**67%**	**21%**
Portable audio	3%	1%	77%	19%	4%	13%	2%
DVD-player	13%	4%	36%	47%	5%	37%	5%
Calculator	0%	5%	11%	84%	7%	73%	4%

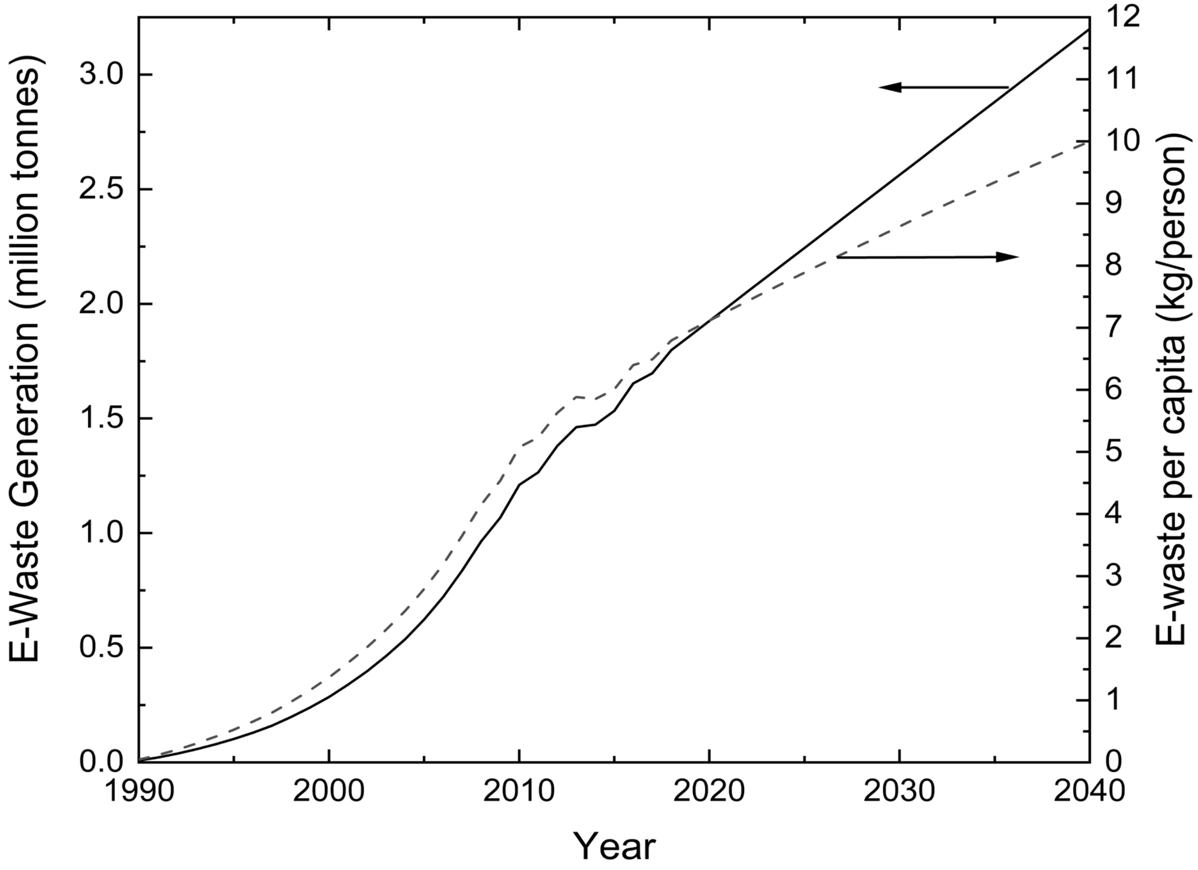
E-Waste in Indonesia

Mairizal, Sembada, Tse, Rhamdhani (2021), *Journal of Cleaner Production,* Vo. 293, April 2021, 126096

Ms Aulia Qisthi Mairizal
Mobile recycling facilities for urban ores (e-waste); E-Waste quantification in Indonesia



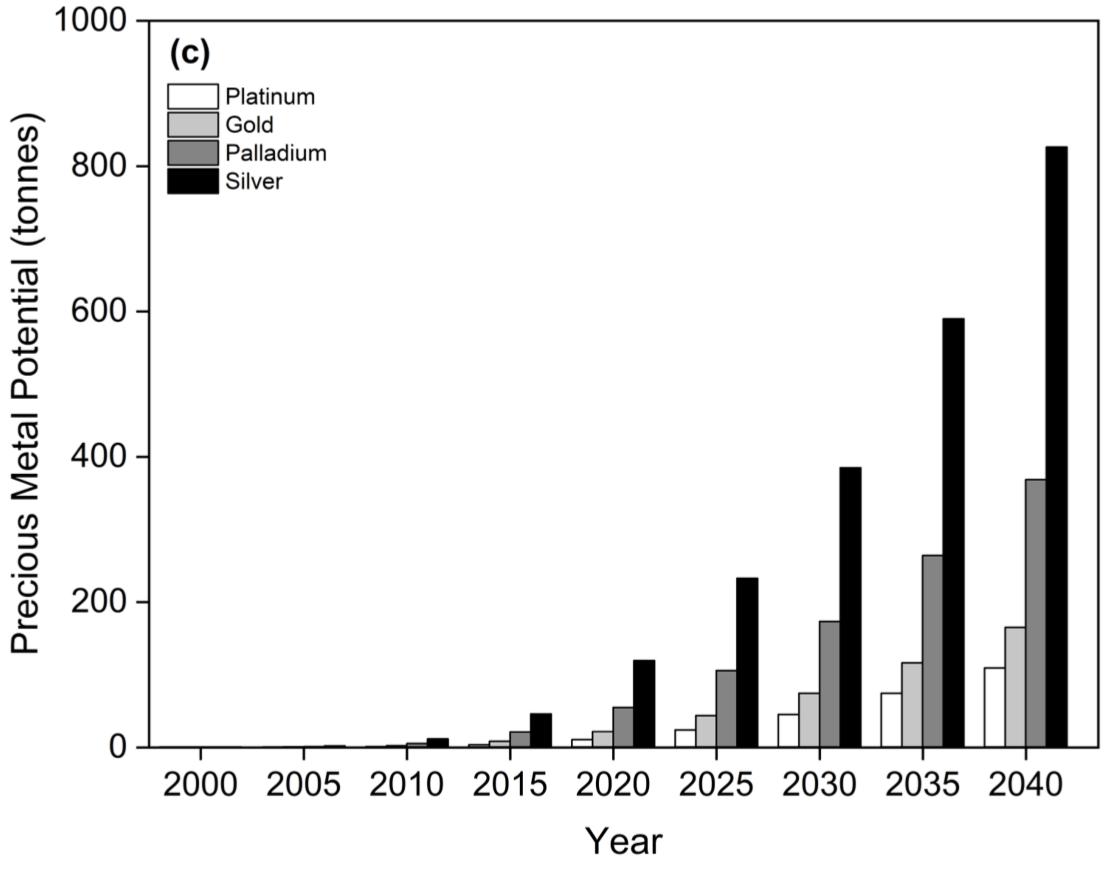
Estimated e-waste generation in Indonesia for IT products: mobile phone, laptop, desktop; in unit.



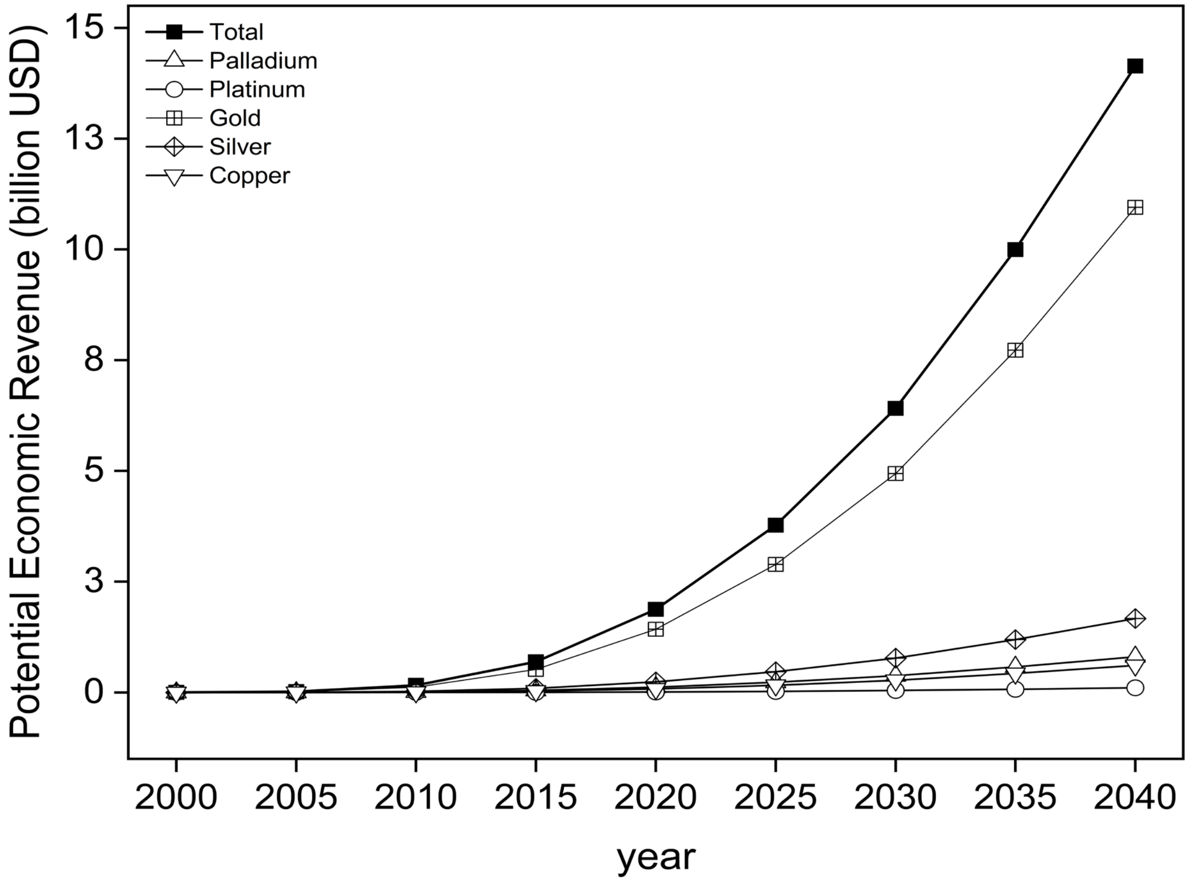
Estimated total e-waste generation in Indonesia from 1990 to 2040. (all types of categories)

E-Waste in Indonesia

Mairizal, Sembada, Tse, Rhamdhani (2021), *Journal of Cleaner Production,* Vo. 293, April 2021, 126096



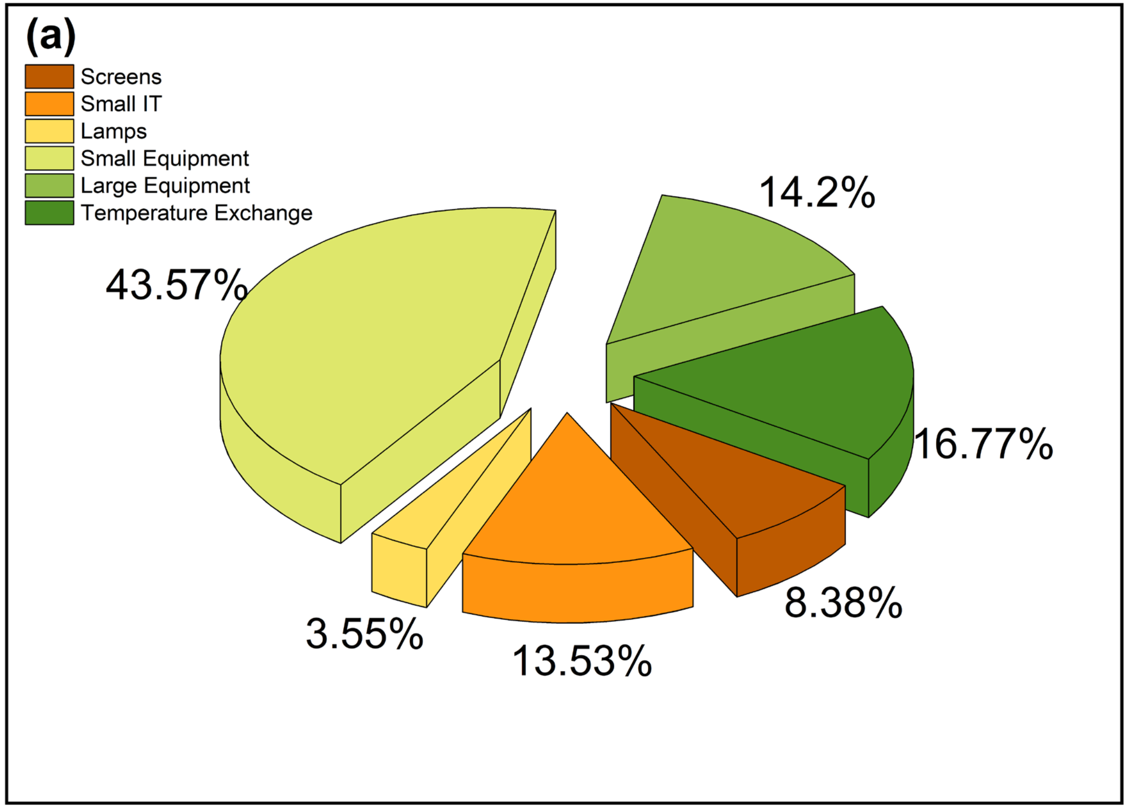
Estimated cumulative Au, Ag, Pt, Pd in the electronic waste (tonnes)



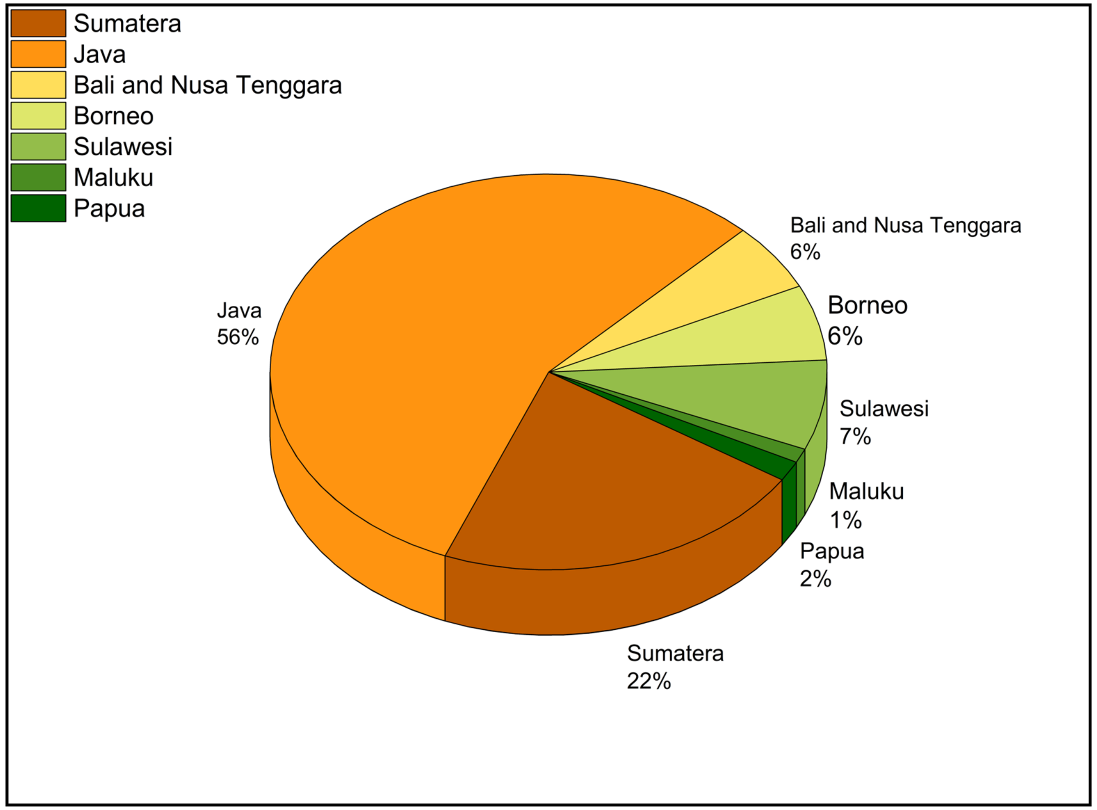
Potential Economic Revenue from Precious Metal in IT Products (2000-2040)

E-Waste in Indonesia

Mairizal, Sembada, Tse, Rhamdhani (2021), *Journal of Cleaner Production,* Vo. 293, April 2021, 126096



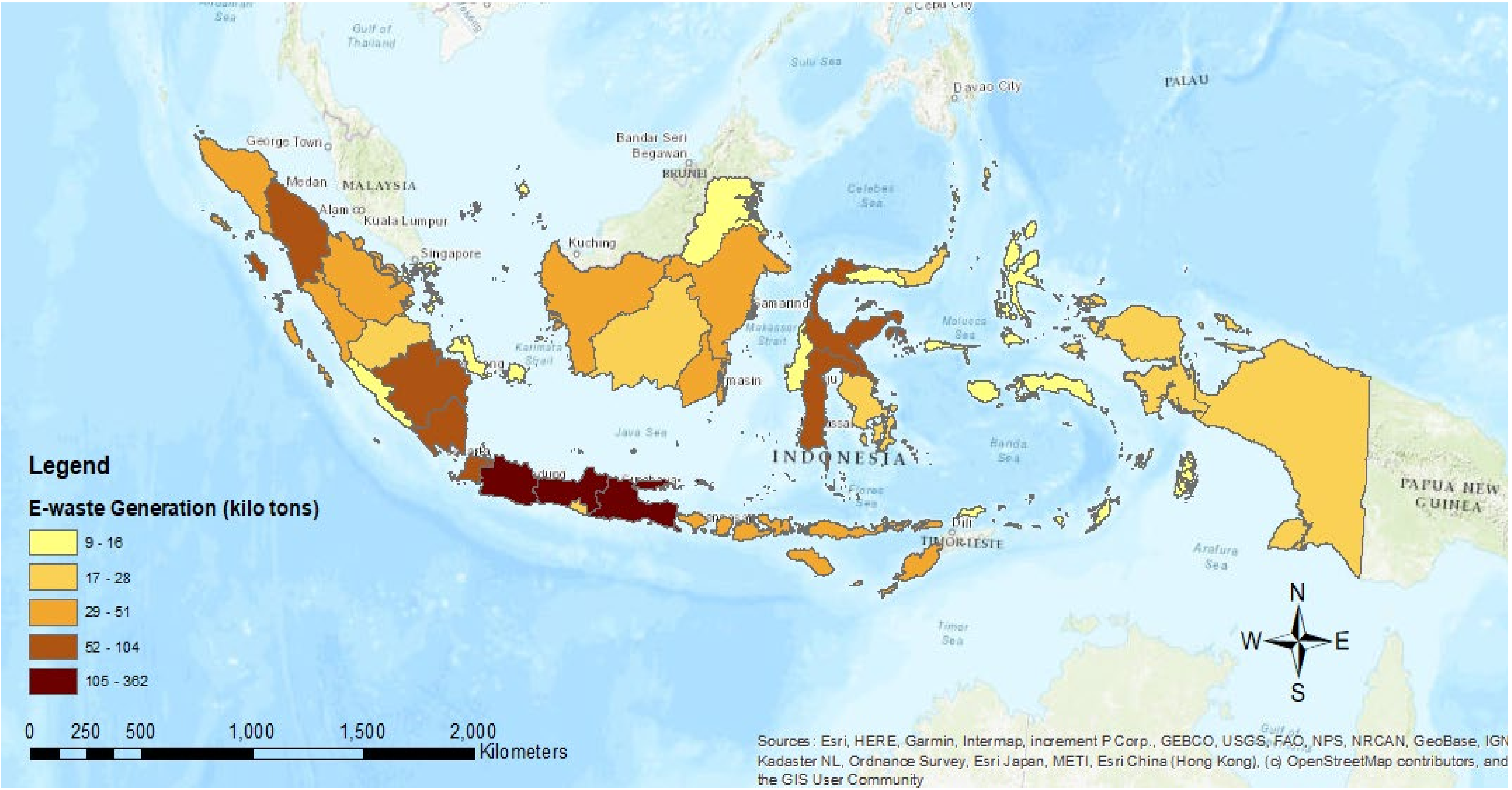
Estimated e-waste generation in Indonesia for:
(a) all types of e-waste category in 2020



Estimated e-waste generation distribution in major islands in Indonesia in 2020

E-Waste in Indonesia

Mairizal, Sembada, Tse, Rhamdhani (2021), *Journal of Cleaner Production,* Vo. 293, April 2021, 126096



Estimated E-waste Generation Distribution in Indonesia year 2021

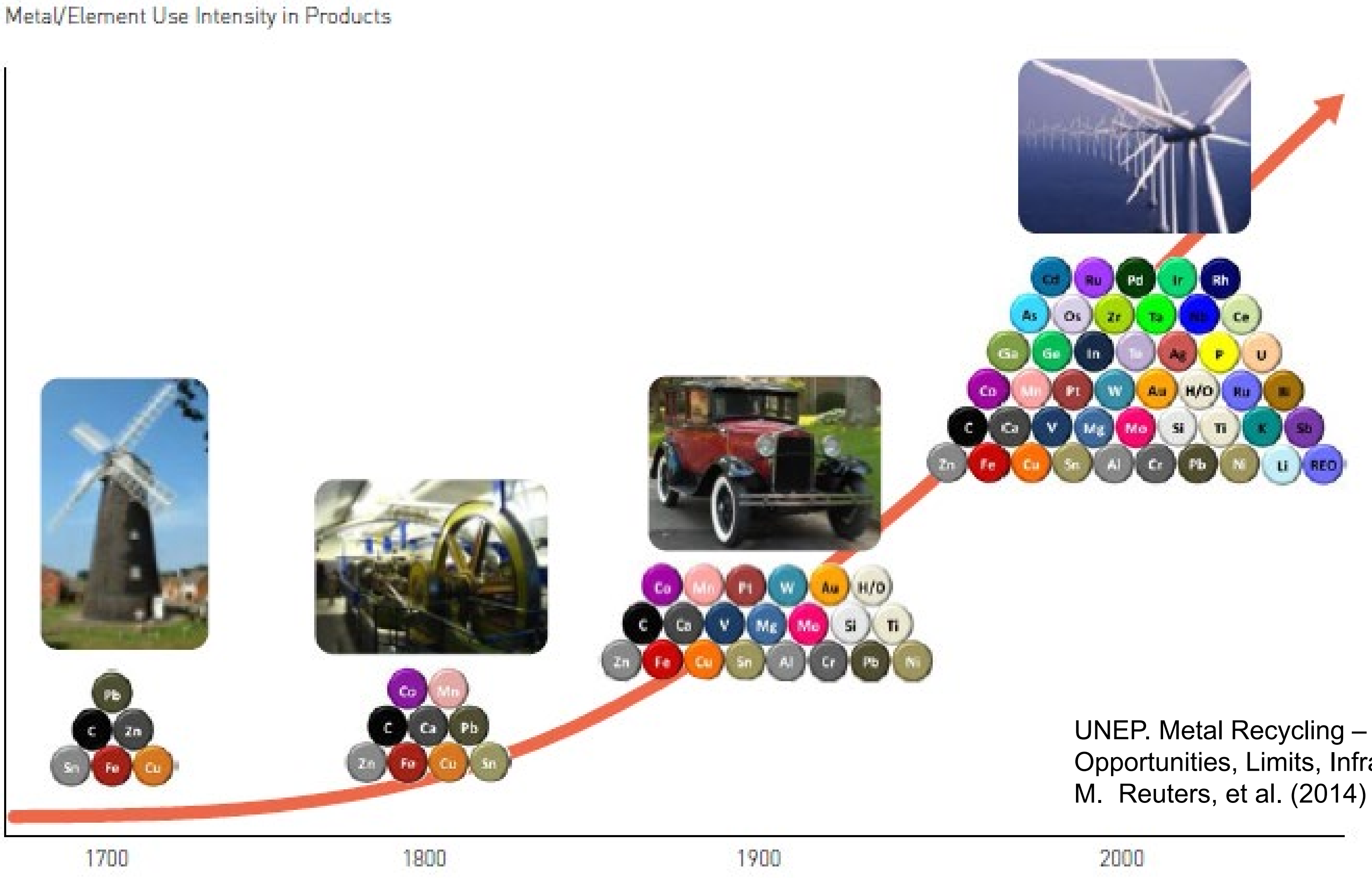
Complex microstructures

- **Contain remarkably different components**, e.g. plastics (hydrocarbons), glass (oxides), metals (ferrous and non-ferrous), and other components

Complex compositions

- The metals of interests are usually in **minor proportion (very low concentration)**
- They contain **large number of elements** (including valuable and hazardous substances), e.g. more than 40 metals on a cell phone
- Varies for different locations, products, and **time**

Increased Materials Complexity



UNEP. Metal Recycling –
Opportunities, Limits, Infrastructure,
M. Reuters, et al. (2014)

Fundamental knowledge

- A limited fundamental knowledge about this “new“ complex materials and how to effectively process them
  - **Thermodynamics, Kinetics, Separation, Refining, Extraction, and Materials etc**

Processing Technologies and Routes

- Extensive pre-processing and main extraction processes → longer overall process chains
- Development of new or modification of existing technologies and processes that is sustainable (economically and environmentally acceptable)
  - Systematic analyses of modified or new technologies and process routes, in terms of **techno-economic**, impact to environment (e.g. **life cycle assessment**), scale up from laboratory to full size plant, and feasibility, need to be considered

Overall economic of the process

- This often becomes the **main driving force**
- New and **innovative business models** may also need to be developed to shift towards more economical process

Infrastructure and logistics

- Facilities for **pre-processing**, in addition to the main extraction processes facilities
- A good **collection system**, e.g. the network of collection, transportation of the resources and associated costs
- Consideration of the **size of the facilities**, from a small scale city-based to a large scale integrated smelting-recycling plants

Government systems

- Governmental **policies** and **legislation** to promote and drive the market for processing towards the alternative resources
- Provide a **framework** for the development of innovative business models
- Government **incentives**

Social/socioeconomic challenges

- **Education** and **information** flow in the society about recycling and underlying wealth associated with the above ground “waste”
- Different **paradigms** and **cultures** within the society that can act as a barrier

General Steps in Processing of E-Waste

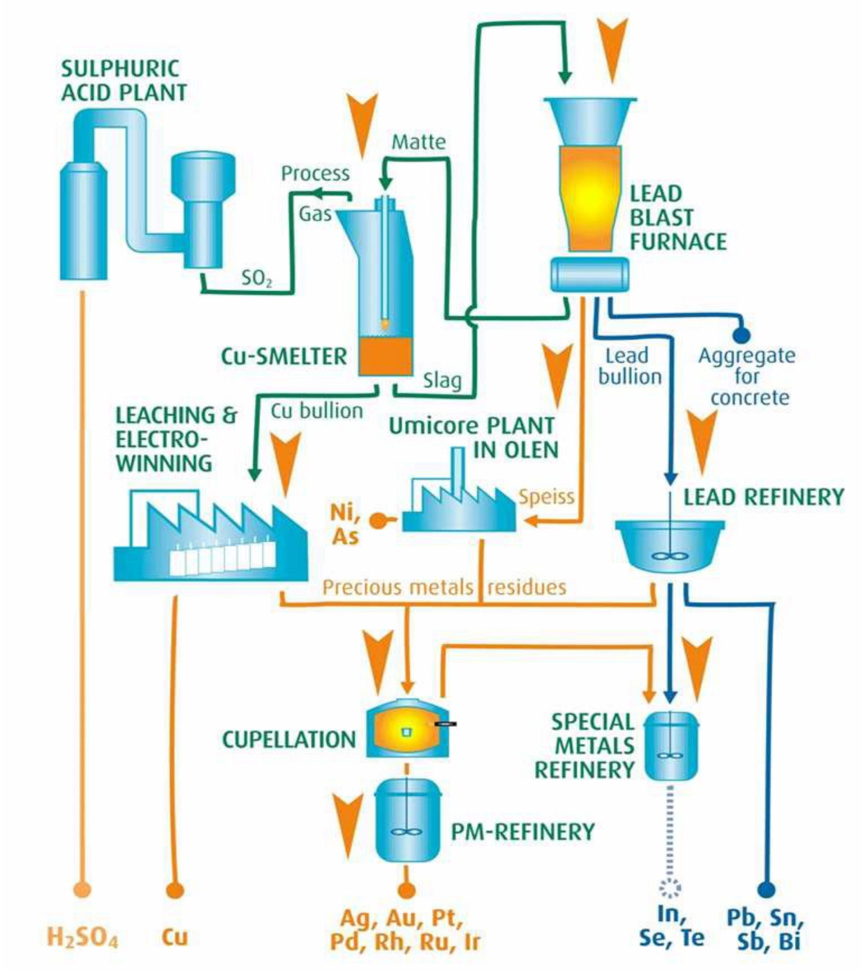
- **Collection**
  - Government policies
  - Public awareness
  - Easy access to collection facilities
- **Pre-processing**
  - Using similar method used in physical processing of ores
  - Sorting and dismantling (manual vs automatic)
  - Materials liberation (housing, wiring boards, drives)
  - Mechanical processing (shredder, hammer mills)
  - Separation of metals and non-metals (screening, magnetic, eddy current, density separation)
- **End-processing**
  - Further processing of non-metal and metal fractions
  - Metallurgical processes to recover metals (combination)

Copper Smelting Route

- Umicore integrate smelting and refining facility, Belgium
- Noranda process in Quebec, Canada
- Rönnskär smelters in Sweden
- Kosaka recycling plant in Japan
- Kayser recycling system KRS in Austria and Germany
- Metallo-Chimique N.V plants in Belgium and Spain

Integrated Smelting and Refining

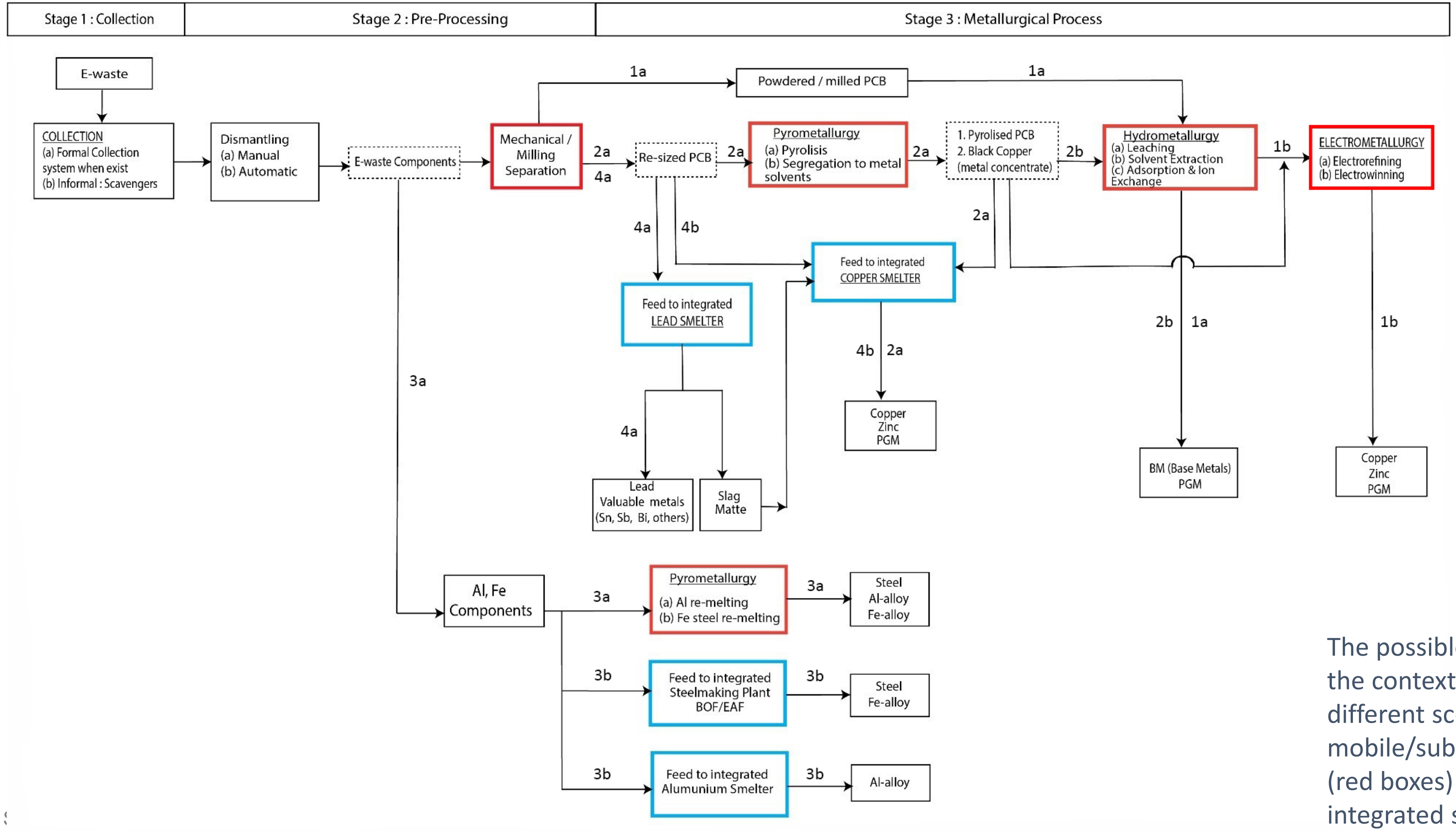
A flowsheet for Umicore's integrated metals smelter and refinery, Hageluken (2006)



Aerial view of Umicore plant at Hoboken/Antwerp, Hageluken and Corti (2010)

E-Waste in Indonesia

Mairizal, Sembada, Tse, Rhamdhani (2021), *Journal of Cleaner Production,* Vo. 293, April 2021, 126096



The possible e-waste processing routes in the context of Indonesia showing the different scenarios and the role of mobile/sub-station processing facilities (red boxes) in supporting the larger integrated smelters (blue boxes).

E-Waste in Indonesia

Mairizal, Sembada, Tse, Rhamdhani (2021), *Journal of Cleaner Production,* Vo. 293, April 2021, 126096

Indonesian Smelter Locations

The locations of major smelters Indonesia (for aluminium, iron and steel, lead, copper, zinc and nickel), data sourced from the Ministry of Energy and Mineral Resources.

Concluding Remarks

- Large potential for processing of **Urban Ores** to support circular economy
- There are **technical** and **non-technical** challenges for a sustainable processing of the alternative resources
- Need of a comprehensive approach addressing both of these challenges
  - Innovations in all sectors from **science**, **technology**, **social**, **governmental policy** to business will be vital in promoting the use of the alternative resources for maximized resource efficiency and wealth generation
  - **Need expertise from different disciplines!!!!!!**
- Optimised processing route will depend on a number of things that include the actual product, location, and other non technical aspects

Thank You

Prof M. Akbar Rhamdhani

ARhamdhani@swin.edu.au

SWINBURNE UNIVERSITY OF TECHNOLOGY