

Dec 11th 2020

Jaarsymposium Circulaire Maakindustrie

[Workshop]

Building a resilient supply chain for Critical Raw Materials (CRMs) in the telecommunication sector

Energy Management & Circular Economy Team of KPN

Yeji Park – Researcher Circularity for Critical Raw Materials

Gloria Flik – Researcher Critical Raw Materials for Future Technologies

Introduction



Gloria Flik

Critical Raw Materials for
Future Technologies



Yeji Park

Circularity of Critical Raw Materials

Contents

I. Presentation

10:05 **Material Criticality for the core and future equipment**

Gloria Flik | Researcher Critical Raw Materials for future technologies

10:10 **Achieving a circular use of CRMs**

Yeji Park | Researcher Circularity of Critical Raw Materials

II. Workshop

10:15 **Brainstorming session on Miro**

10:35 **Discussion**

10:55 **Closing**



What are critical raw materials (CRMs)?

As defined by the European Union [1]



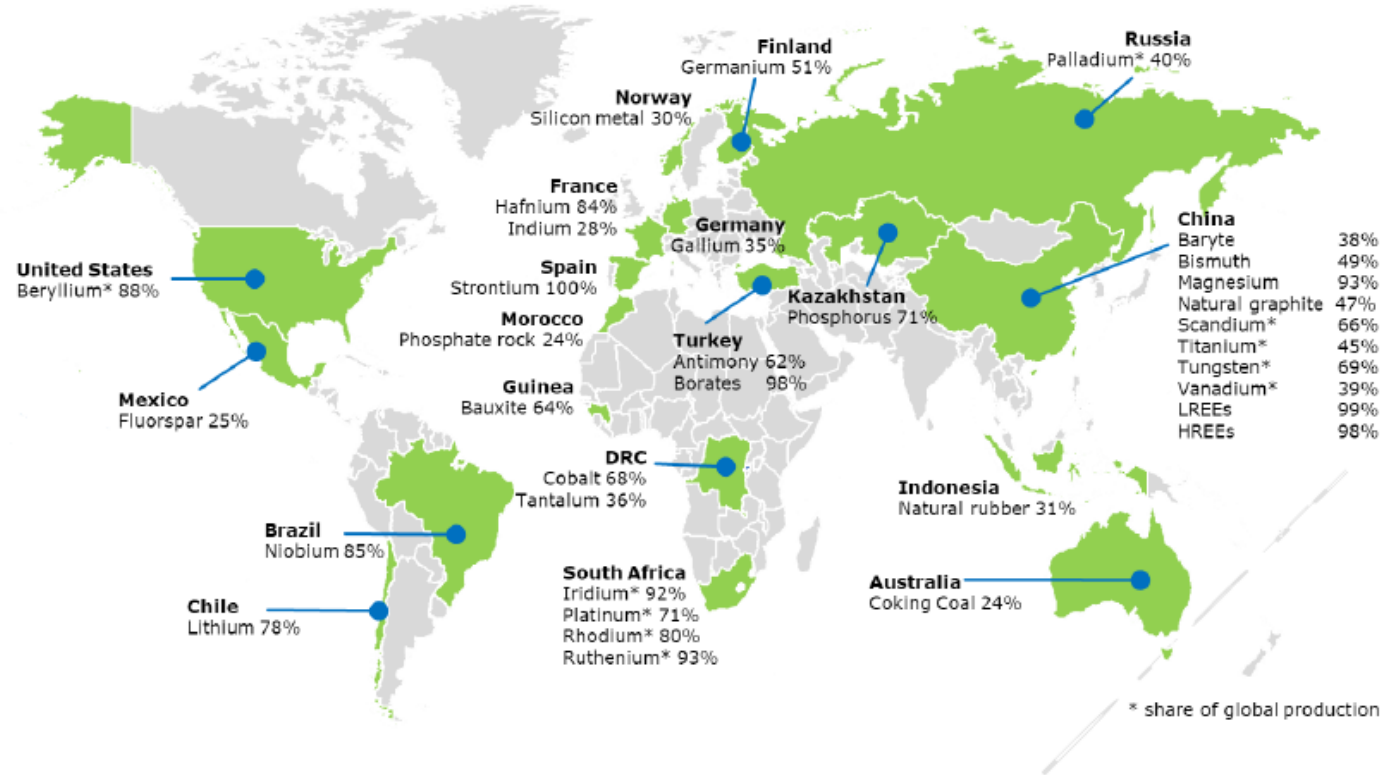
Critical raw materials

- Economic importance
- Supply risk

Reasons for material criticality [3]:

- Scarcity Risk
- Geopolitical Risk
- Demand Risk
- Environmental Risk
- Supply Chain Risk
- Market Risk
- Social Risk

Biggest supplier countries of CRMs in the EU



Source: European Commission report on the 2020 criticality assessment

[2]

How to start?

From the equipment to the mitigation strategy



Step 1
Identify Key Equipment

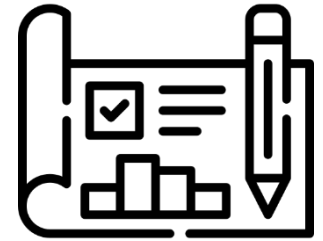
Step 2
Identifying Raw Material Content

Step 3
Conduct Criticality Assessment

Step 4
Determine Mitigation Strategies

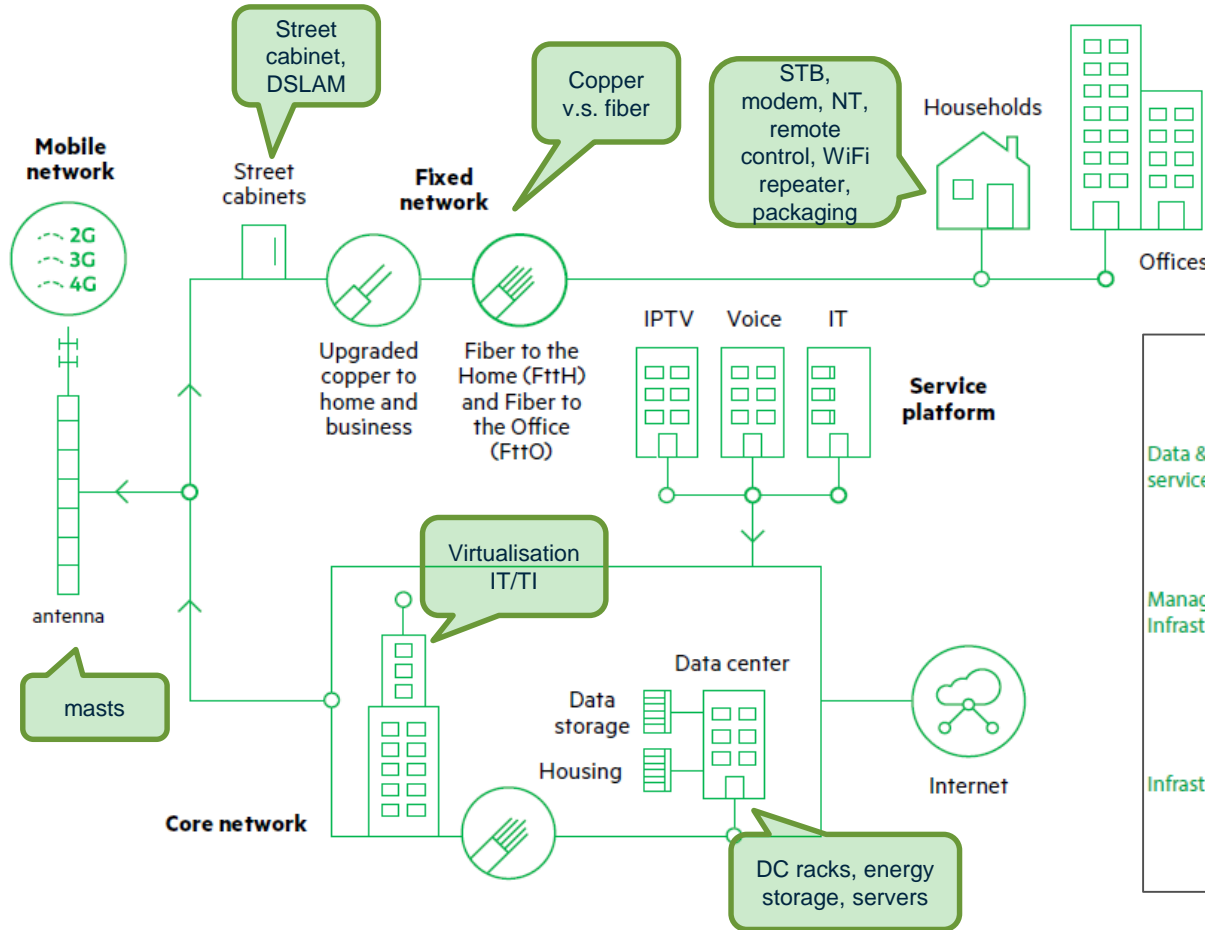


Hydrogen 1 H 1.00794																	Helium 2 He 4.002602
Lithium 3 Li 6.941	Beryllium 4 Be 9.012182											Boron 5 B 10.811	Carbon 6 C 12.011	Nitrogen 7 N 14.00643	Oxygen 8 O 15.999	Fluorine 9 F 18.9984032	Neon 10 Ne 20.1797
Sodium 11 Na 22.98976928	Magnesium 12 Mg 24.304											Aluminum 13 Al 26.9815386	Silicon 14 Si 28.0855	Phosphorus 15 P 30.973762	Sulfur 16 S 32.06	Chlorine 17 Cl 35.453	Argon 18 Ar 39.948
Potassium 19 K 39.0983	Calcium 20 Ca 40.078	Scandium 21 Sc 44.955912	Titanium 22 Ti 47.88	Vanadium 23 V 50.9415	Chromium 24 Cr 51.9961	Manganese 25 Mn 54.938045	Iron 26 Fe 55.845	Cobalt 27 Co 58.933195	Nickel 28 Ni 58.6934	Copper 29 Cu 63.546	Zinc 30 Zn 65.38	Gallium 31 Ga 69.723	Germanium 32 Ge 72.630	Arsenic 33 As 74.9216	Selenium 34 Se 78.96	Bromine 35 Br 79.904	Krypton 36 Kr 83.80
Rubidium 37 Rb 85.4678	Sr 38 Sr 87.62	Yttrium 39 Y 88.90584	Zirconium 40 Zr 91.224	Niobium 41 Nb 92.90638	Molybdenum 42 Mo 95.94	Technetium 43 Tc 98	Ruthenium 44 Ru 101.07	Rhodium 45 Rh 102.9055	Palladium 46 Pd 106.42	Silver 47 Ag 107.8682	Cadmium 48 Cd 112.411	Indium 49 In 114.818	Tin 50 Sn 118.710	Antimony 51 Sb 121.757	Tellurium 52 Te 127.6	Iodine 53 I 126.905	Xenon 54 Xe 131.29
Cesium 55 Cs 132.90545196	Barium 56 Ba 137.327	Lanthanum 57 La 138.90547	Hafnium 58 Hf 178.49	Tantalum 59 Ta 180.94788	Tungsten 60 W 183.84	Rhenium 61 Re 186.207	Osmium 62 Os 190.23	Iridium 63 Ir 192.222	Platinum 64 Pt 195.084	Gold 65 Au 196.966569	Mercury 66 Hg 200.59	Thallium 67 Tl 204.38	Lead 68 Pb 207.2	Bismuth 69 Bi 208.9804	Polonium 70 Po [209]	Astatine 71 At [210]	Radon 72 Rn [222]
Francium 87 Fr [223]	Radium 88 Ra [226]	* * [227]	Lr [260]	Rf [261]	Db [262]	Sg [263]	Bh [264]	Hs [265]	Mt [266]	Uun [288]	Uuu [289]	Uub [290]	Uuq [291]				
		Lanthanum 57 La 138.90547	Cerium 58 Ce 140.12	Praseodymium 59 Pr 140.90766	Nd 60 Nd 144.242	Europium 61 Eu 151.964	Gadolinium 62 Gd 157.25	Terbium 63 Tb 158.92535	Dysprosium 64 Dy 162.50015	Ho 65 Ho 164.93033	Erbium 66 Er 167.259	Thulium 67 Tm 168.93048	Ytterbium 68 Yb 173.05468				
		Actinium 89 Ac [227]	Thorium 90 Th 232.0377	Protactinium 91 Pa 231.03688	Uranium 92 U 238.02891	Np 93 [237]	Pu 94 [244]	Am 95 [243]	Cm 96 [247]	Bk 97 [247]	Cf 98 [251]	Es 99 [252]	Fm 100 [257]	Md 101 [258]	No 102 [259]		

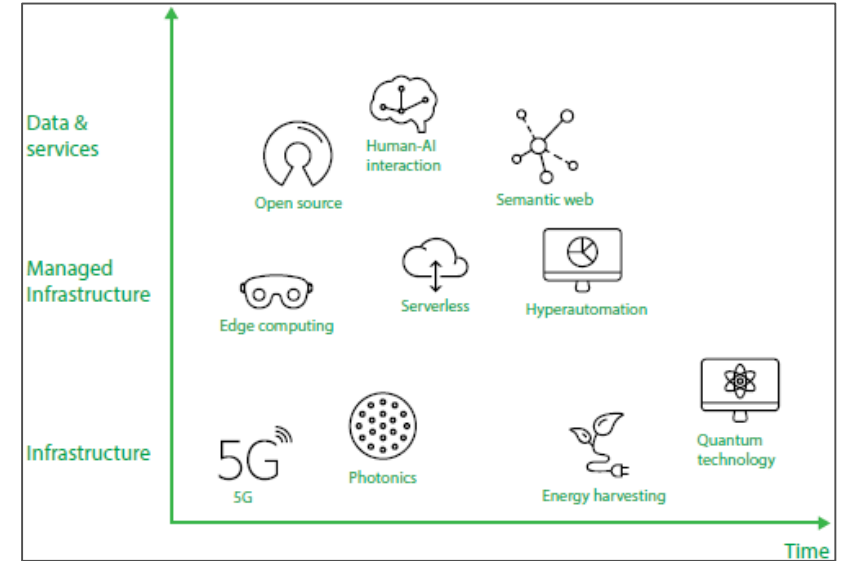


Step 1 + 2 : Identification of Core equipment & Raw Material Content

Close collaboration with suppliers necessary

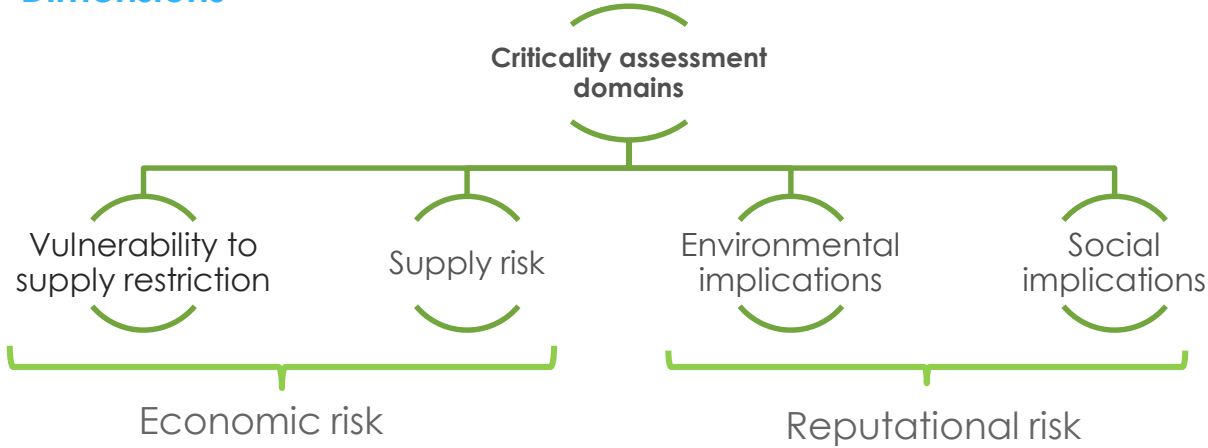


Future Research – Strategic Importance



Step 3: Criticality Assessment

Dimensions

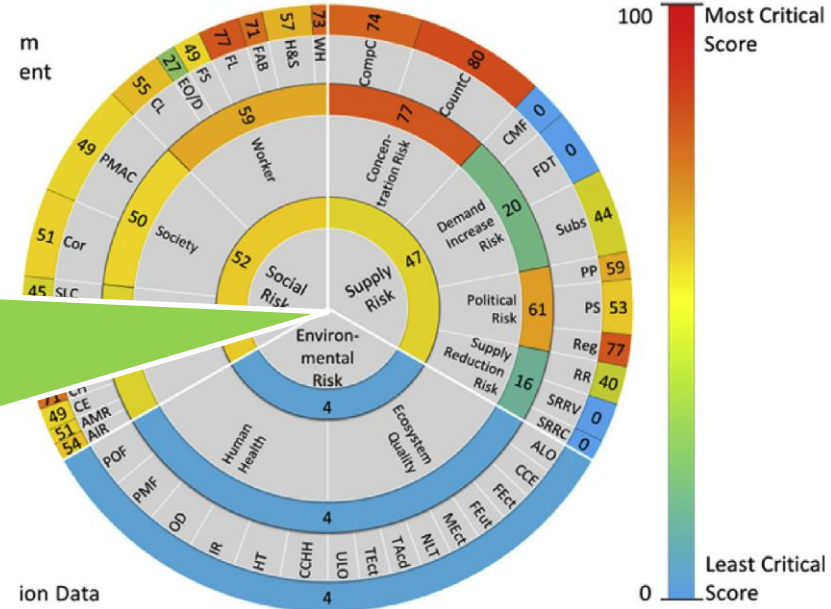


Which material should be prioritized?

Where may KPN encounter high risks?



Example of the Assessment of Aluminum (Kolotzek et al., 2018)



Step 3: Criticality Assessment

Examples based on literatures



1 Goal & Scope Definition

The system at risk

The objective of the assessment

Material focus

2 Quantified Risk

Vulnerability to Supply Restrictions

Potential damage from involuntarily reduced use of materials

Substitutability

Product value

Future demand

Strategic importance

Material value

Spread of utilization

Supply risk

Likelihood of supply disruption

Country concentration

Depletion time

Substitutability

Import dependence

Recyclability

Demand growth

Environmental implications

Damage caused by raw material extraction and likelihood of emerging reputational risk

Ecosystem Quality

Human Health

Social implications

Social hotspots on the country level.

Local Community

Society

Worker

Example Indicators

3 Source

Helbig et al. (2016) – How to evaluate raw material vulnerability – An Overview. [5]

Achzet et al. (2013) – How to evaluate raw material supply risk [6]

Graedel et al. (2011) – Methodology on Metal Criticality Determination [7]

Kolotzek et al. (2018) – A company-oriented model for assessment of raw material supply risks, environmental impacts and social implications [4]

Step 4: EU Critical materials in KPN products



Occurrence in KPN products

Data on 4 products

Number of products the material is contained in:



on EU list

hydrogen 1 H 1.0079																				helium 2 He 4.0026	
lithium 3 Li 6.941	beryllium 4 Be 9.0122																				
sodium 11 Na 22.990	magnesium 12 Mg 24.305																				
potassium 19 K 39.098	calcium 20 Ca 40.078																				
rubidium 37 Rb 85.468	strontium 38 Sr 87.62																				
cesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *																			
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *																			
			scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.64	arsenic 33 As 74.922	selecnium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80			
			yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29			
			lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]			

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

From simple PCBs

Modem

Core router

Blade Server

...to complex PCBs

Remote Control

Mitigation strategies

Example: Rhodium



Rhodium (Rh)



Function:

- Plating of electric contacts
- Constituent of capacitors and resistors

Mitigation strategy

Internal & External

- Design for reuse/refurbishment/recyclability
- Use secondary material source
- Substitution to non-critical materials

- Transparency
- Due diligence on suppliers
- Sourcing CERA (CERTification of RAW Materials) certified components/materials

Hotspots

Companion metal, hardly substitutable
Political stability/regulations
80% South Africa

Associated risk

● Economic risk

● Environmental risk

● Social risk

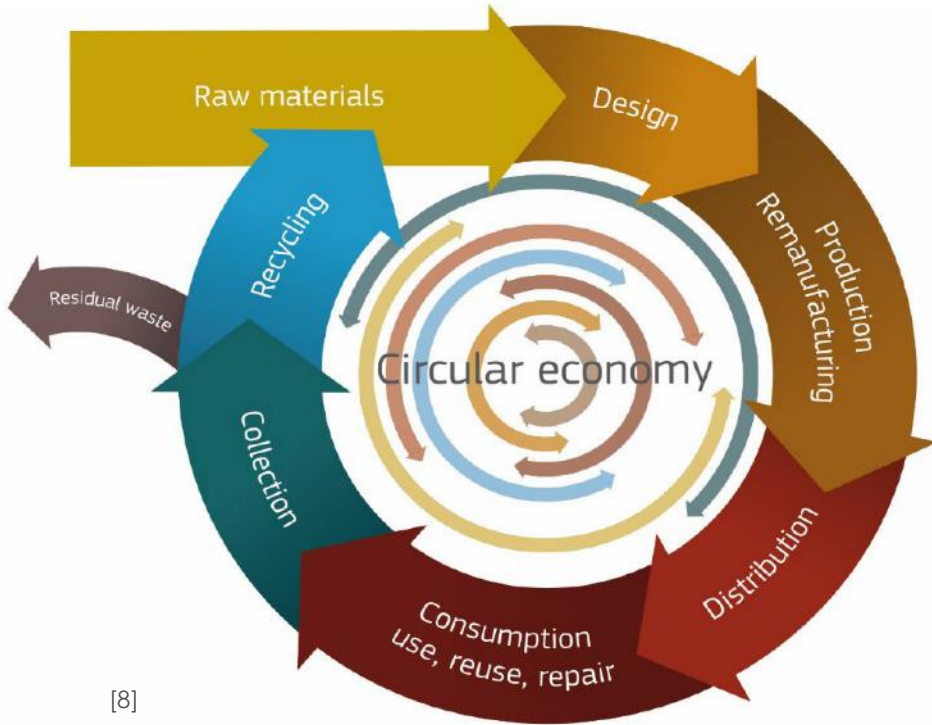
Systemic

- Demand-based recycling targets
- Research subsidies and standardization
- Trade agreements

- Translating externalities into pricing
- Trade agreements incl. social and environmental conditions for goods

Achieving the circular use of CRMs

Expansion of CE application from mass material to CRMs



Mass materials



Plastic



Aluminium



Copper



Printed Circuit Board (PCB)



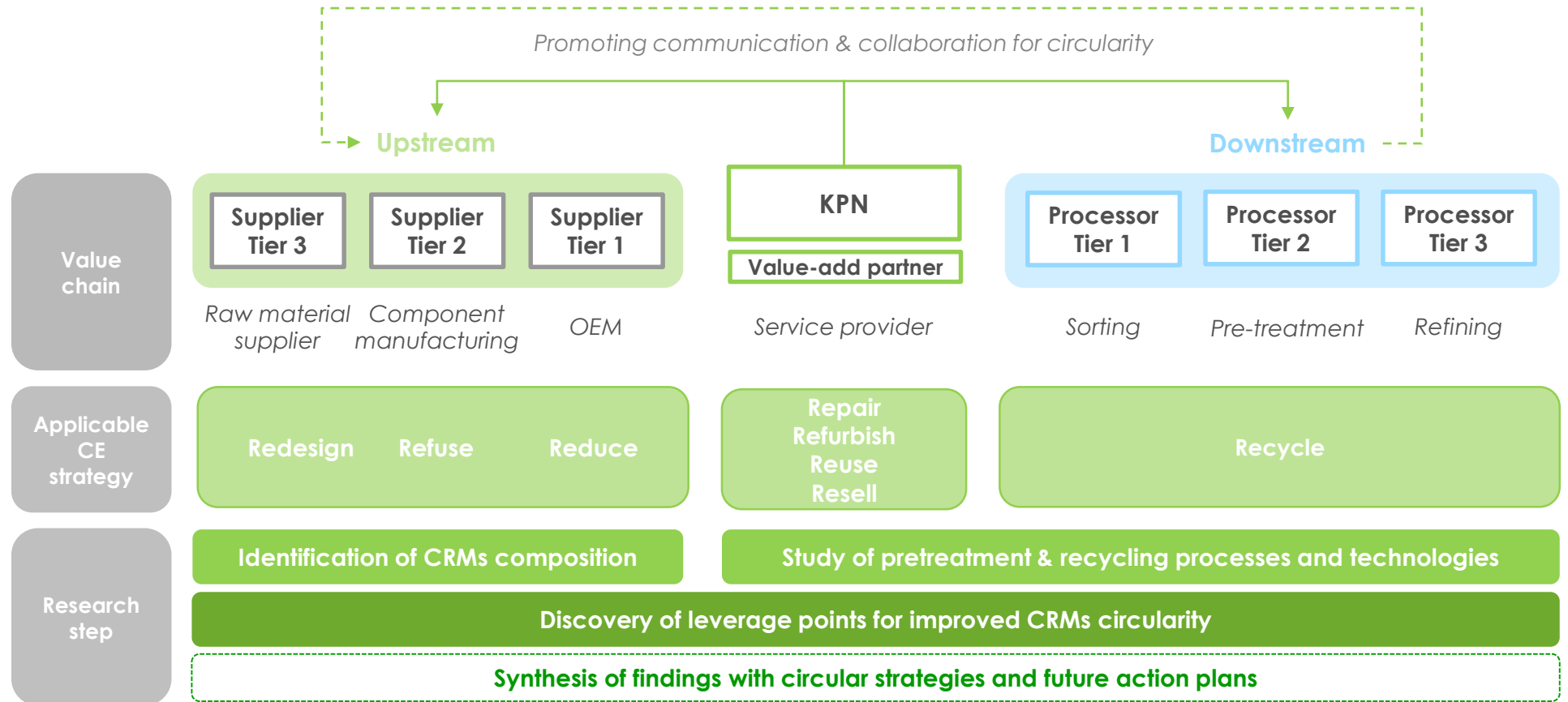
- Component - CRM

Critical raw materials

[8]

Improving the circularity of CRMs in KPN's equipment

Research plan and main concepts



Circular strategy for CRMs

Example of three CRMs commonly used in ICT device



Smartphone



Modem



46

Pd

Palladium

106.42



49

In

Indium

114.818



31

Ga

Gallium

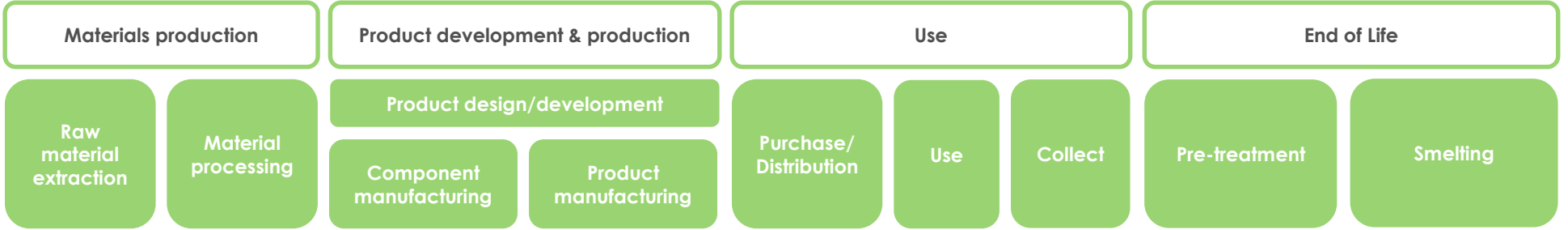
69.723

Case example: Circular strategy for three CRMs



Product value chain of ICT equipment

Cradle to grave value chain

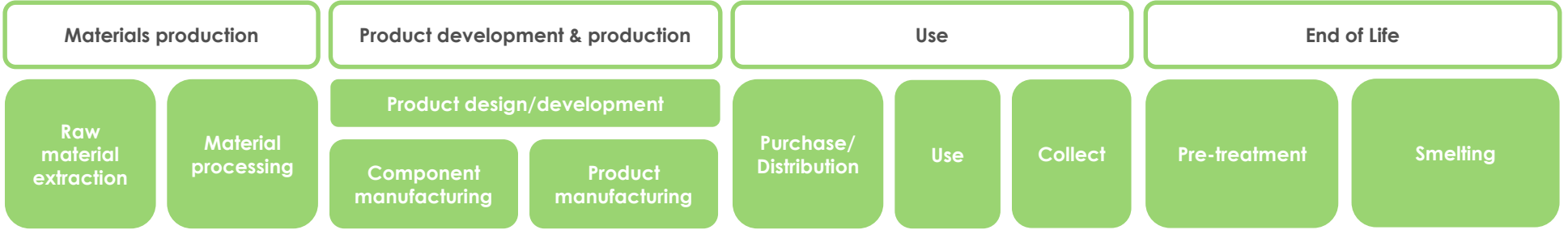


Case example: Circular strategy for three CRMs






Product value chain with specifications on CRM contents

Cradle to grave value chain



CRMs specifications

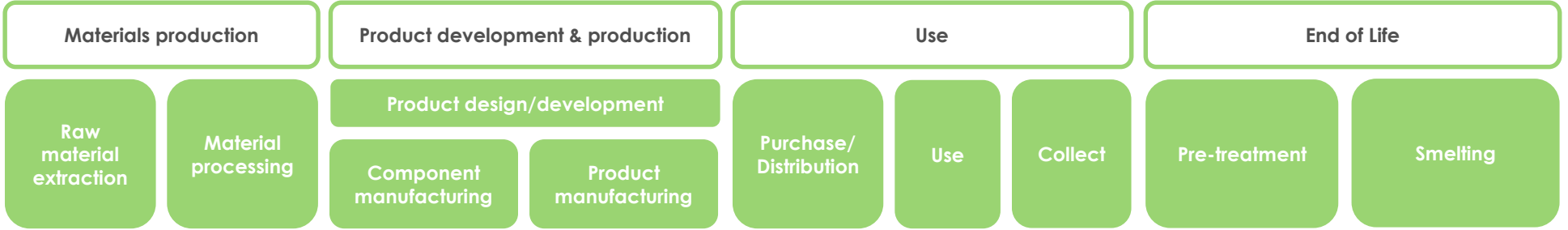
	Application	Concentration in WEEE [9]	EOL treatment (Recycling rate) [9]	
<div style="border: 1px solid blue; border-radius: 10px; padding: 5px; display: inline-block;">Pd</div> 	Capacitors, ICs, electrode, and etc.	30 – 200 ppm	Physical treatment	Pyrometallurgy (50%)
<div style="border: 1px solid blue; border-radius: 10px; padding: 5px; display: inline-block;">In</div> 	LCD panels, LEDs	0.05 – 1 %	Crushing & separation	Hydrometallurgy (<1%)
<div style="border: 1px solid blue; border-radius: 10px; padding: 5px; display: inline-block;">Ga</div> 	LEDs, ICs	2 – 140mg/kg(PCB)[10]	.	.

CRMs flow throughout product value chain

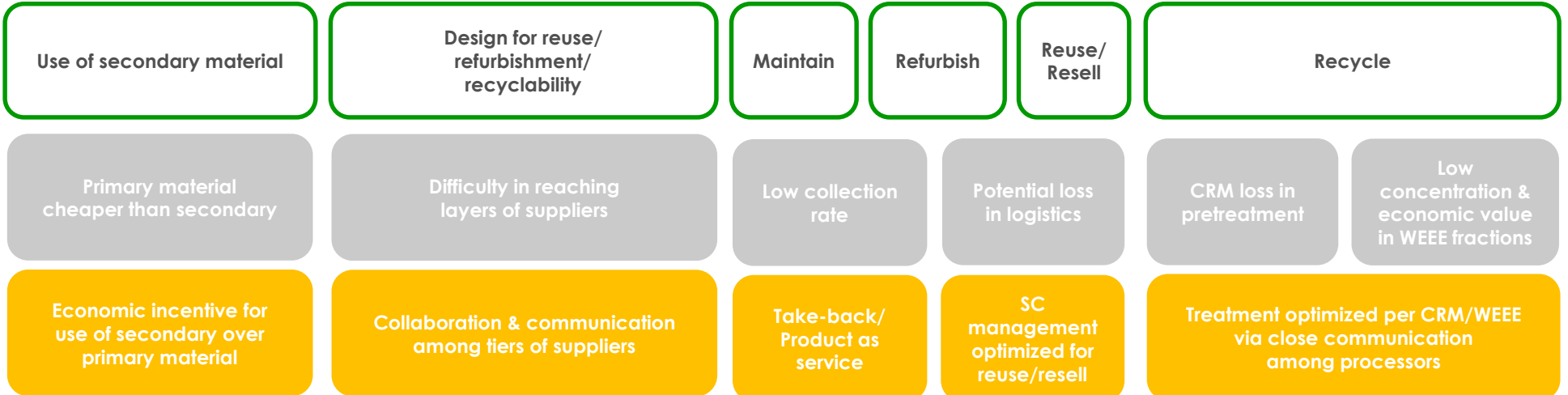


Case example of 3 CRMs

Cradle to grave value chain



Applicable CE strategy | Leverage points



CRMs application in other industries

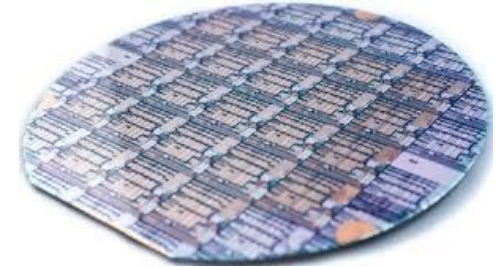
CRMs circularity: crucial topic to a wide range of industries



Auto catalyst



LCD



Semiconductor



Jewellery



Solar panel



Optoelectronic



46

Pd

Palladium

106.42



49

In

Indium

114.818



31

Ga

Gallium

69.723

Workshop

First please follow our instruction on the shared screen
And then enter the Miro link shared in the chat!

Discussion

Contact information



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- [1] British Geological Survey, Bureau de Recherches Géologiques et Minières, Deloitte Sustainability, European Commission, Directorate-General for Internal Market, I., Entrepreneurship and SMEs, & Toegepast natuurwetenschappelijk onderzoek. (2017). Study on the review of the list of critical raw materials: Final report. <http://dx.publications.europa.eu/10.2873/876644>
- [2] Gislef, M., Grohol, M., Mathieux, F., Ardente, F., Bobba, S., Nuss, P., Blengini, G. A., Dias, P. A., Blagoeva, D., Torres De Matos, C., Wittmer, D., Claudiu, P., Hamor, T., Saveyn, H., Gawlik, B., Orveillon, G., Huygens, D., Garbarino, E., Tzimas, E., ... Directorate-General for Internal Market, I., Entrepreneurship and SMEs. (2018). Report on critical raw materials and the circular economy. http://publications.europa.eu/publication/manifestation_identifier/PUB_ET0418836ENN
- [3] Griffin, G., Gaustad, G., & Badami, K. (2019). A framework for firm-level critical material supply management and mitigation. *Resources Policy*, 60, 262–276. <https://doi.org/10.1016/j.resourpol.2018.12.008>
- [4] Kolotzek, C., Helbig, C., Thorenz, A., Reller, A., & Tuma, A. (2018). A company-oriented model for the assessment of raw material supply risks, environmental impact and social implications. *Journal of Cleaner Production*, 176, 566–580. <https://doi.org/10.1016/j.jclepro.2017.12.162>
- [5] Helbig, C.; Wietschel, L.; Thorenz, A.; Tuma, A. (2016). How to evaluate raw material – An overview. *Resources Policy* 48, 13-24. <http://dx.doi.org/10.1016/j.resourpol.2016.02.003>.
- [6] Achzet, B.; Helbig, C. (2013). How to evaluate raw material supply risks – An overview. *Resources Policy*, 435-447. <http://dx.doi.org/10.1016/j.resourpol.2013.06.003>.
- [7] T. E. Graedel, Rachel Barr, Chelsea Chandler, Thomas Chase, Joanne Choi, Lee Christoffersen, Elizabeth Friedlander, Claire Henly, Christine Jun, Nedal T. Nassar,* Daniel Schechner, Simon Warren, Man-yu Yang, and Charles Zhu (2011). Methodology for Material Criticality Determination. Center for Industrial Ecology. *Environ. Sci. Technol.* 2012, 46, 1063 – 1070.
- [8] European Commission. (2018). Report on Critical Raw Materials in the Circular Economy. Retrieved from <https://op.europa.eu/en/publication-detail/-/publication/d1be1b43-e18f-11e8-b690-01aa75ed71a1/language-en/format-PDF/source-80004733>
- [9] Işıldar, A., Rene, E. R., van Hullebusch, E. D., & Lens, P. N. L. (2018). Electronic waste as a secondary source of critical metals: Management and recovery technologies. *Resources, Conservation and Recycling*, 135, 296–312. <https://doi.org/10.1016/j.resconrec.2017.07.031>
- [10] Chancerel, P., Rotter, V. S., Ueberschaar, M., Marwede, M., Nissen, N. F., & Lang, K.-D. (2013). Data availability and the need for research to localize, quantify and recycle critical metals in information technology, telecommunication and consumer equipment. *Waste Management & Research*, 31(10_suppl), 3–16. <https://doi.org/10.1177/0734242x13499814>