

Approach on material management and substitution – Case studies on certain CRM phase- outs

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Nokia's approach to materials management

Changes to materials management are initiated from

- Regulatory restrictions and requirements – RoHS, REACH, others
- Precautionary principle initiated voluntary restrictions and requirements

Nokia controls materials and substances in the Nokia Substance List (NSL)

- Updated on yearly basis
- Nokia brings out new substance requirement into Nokia Substance List first as *"Monitored substance"* and thereafter if/when substance is restricted it will be categorized as *"Restricted substance"*
- Part of Nokia's Standard Product Requirements and Purchase agreements

NSL initiates Nokia product level compliance verification

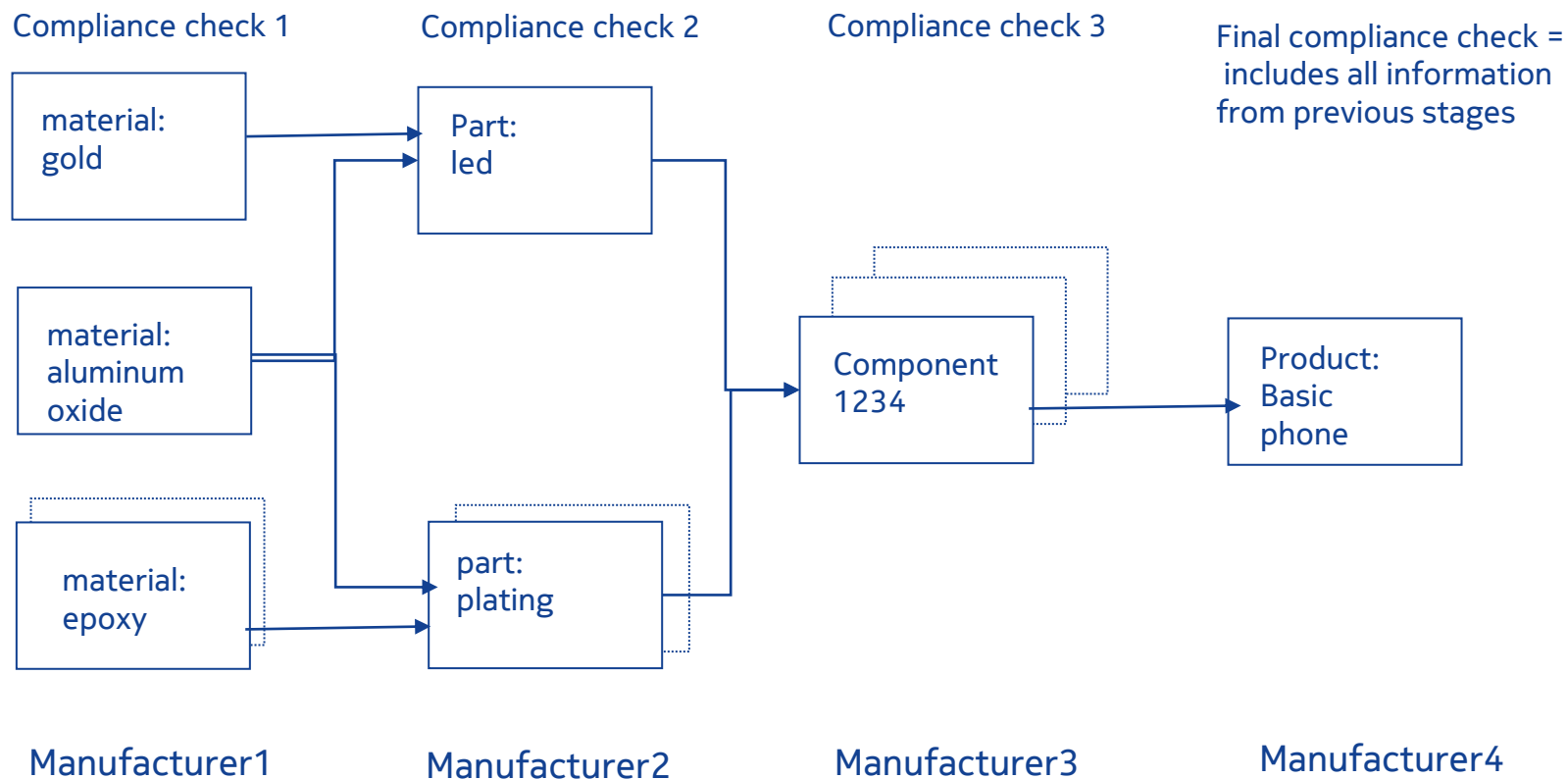
- Compliance verification is done for each product on full material declaration basis

More information found from

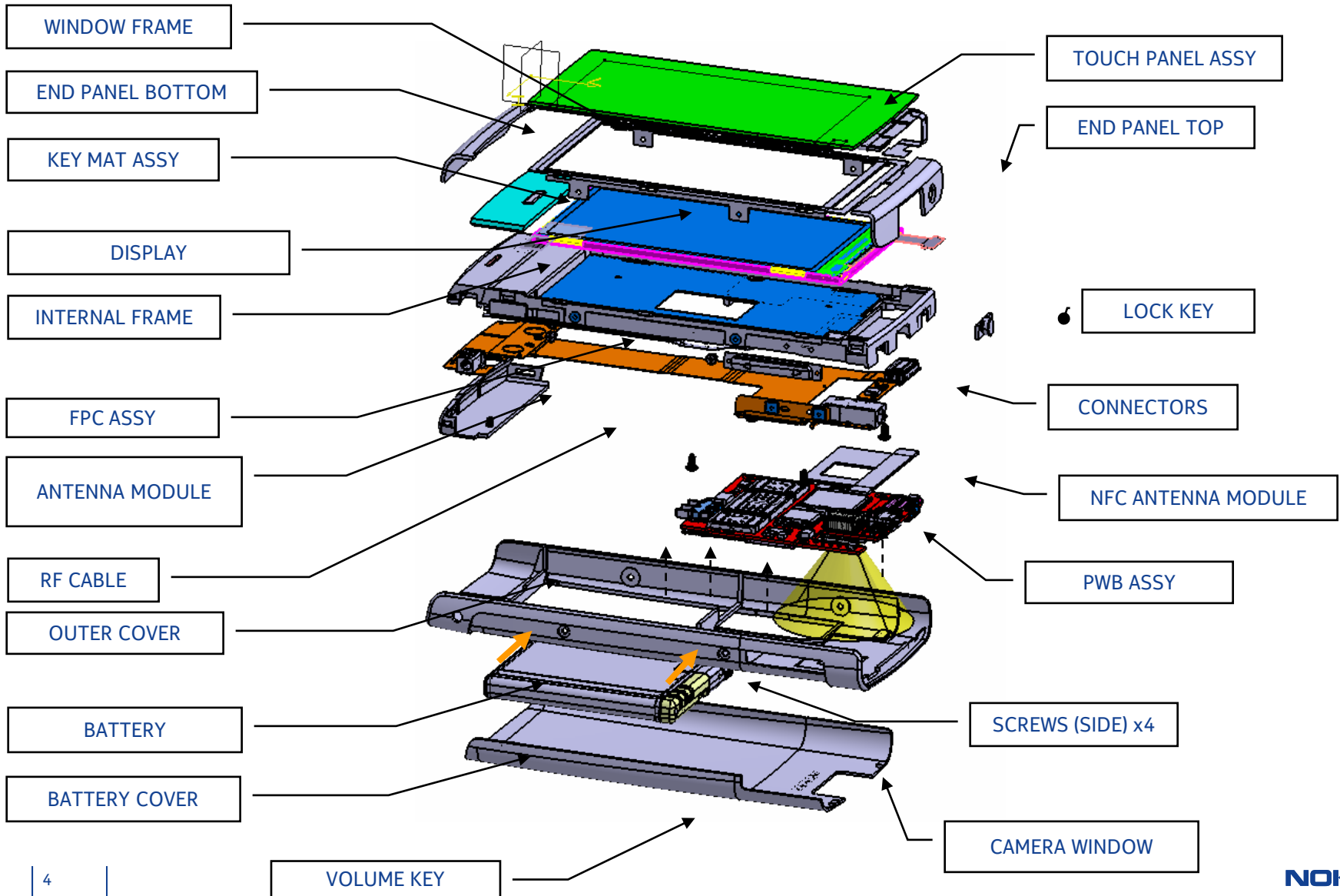
- <http://www.nokia.com/global/about-nokia/people-and-planet/strategy/management/substance-management/>

Full material declaration

- All the materials used in the components and, cumulatively, in mobile phones are declared by using the full material declarations through whole supply chain.
- Material declaration (on homogeneous material (=substance) level)) is required from every supplier through the entire supply chain and data is stored in the Material Data Management System.

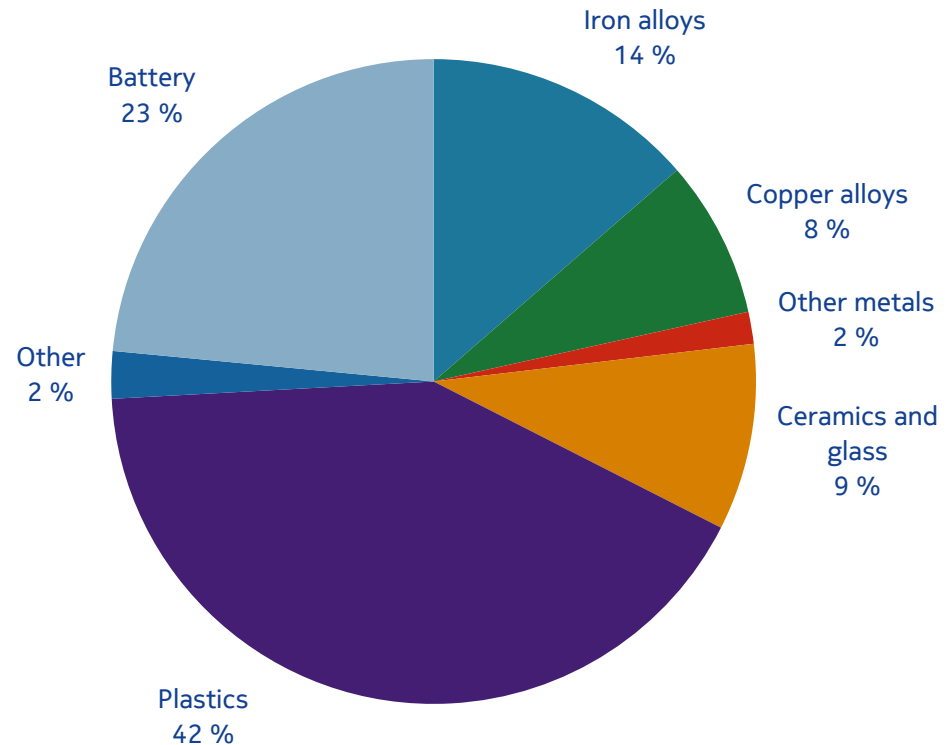


Example of Mobile Phone assembly



Material content of a mobile phone

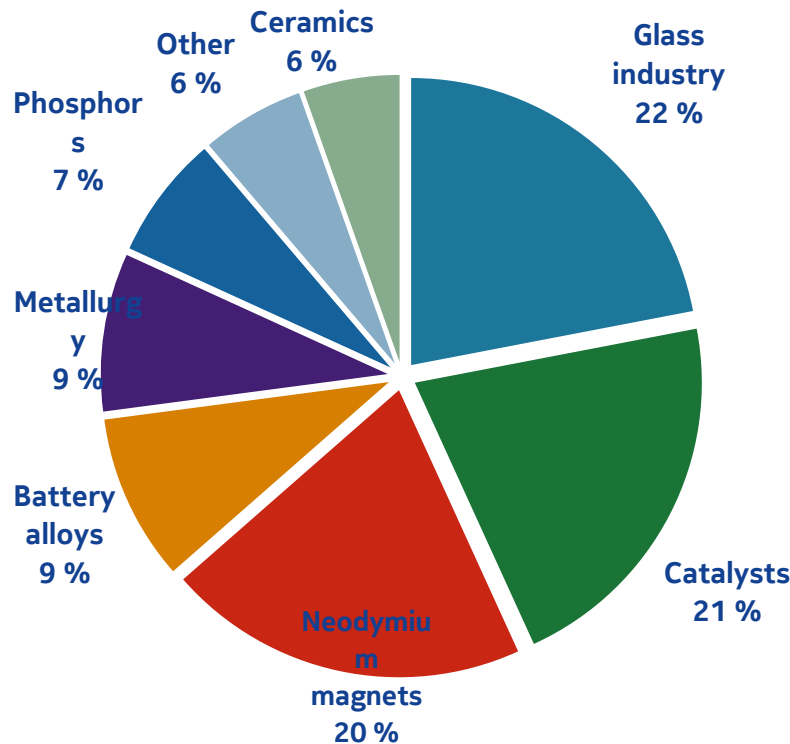
Nokia 2600 Classic



Other metals (2%) contains :

- precious metals,
- rare earth metals,
- tungsten, tin, nickel, chromium, titanium and zinc alloys
- (and other metal alloys with amounts less than 0.01g)

Rare earth elements: general information



Use of rare earth metals by market sector in 2008

Source: USGS - Rare Earth Elements - End Use and Recyclability (2011)

- High-technology applications of the rare earth metals (REM) have grown dramatically in diversity and importance over the past four decades
- As many of these applications are highly specific, rare earth metals have acquired a high level of technological significance.
- Global production for REMs in 2009 was 124 000 t (source: USGS)
- Nokia's volumes in 2009 (2012): 440 (335) million pieces
- Yearly REM use (rough estimate) around 106 t, which constitutes for 0.09% of global production
- If REM use per phone of all mobile phone is appr. the same, mobile phone sector's REM use would have been 290 tons (corresponding 0.25% of yearly REM production).

Elements typically used in a mobile devices

hydrogen 1 H 1.0079																	helium 2 He 4.0026						
lithium 3 Li 6.941	beryllium 4 Be 9.0122																	boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305																	aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.096	calcium 20 Ca 40.078	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 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80						
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	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						
caesium 55 Cs 132.91	barium 56 Ba 137.33	lanthanum 57 La 138.91	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]						
francium 87 Fr [223]	radium 88 Ra [226]	actinium 89 Ac [227]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	unnilium 110 Uun [271]	ununium 111 Uuu [272]	unbibium 112 Uub [277]			ununquadium 114 Uuq [289]									
		*lanthanoids																					
		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								
		**actinoids																					
		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]								

Key:

element name
atomic number
symbol
atomic weight (mean relative mass)

This periodic table does not take into account in what quantities and concentrations the elements have been used (only the smallest impurities are excluded). Neither does it take into account the form the element in question has been used in.

Rare earth metals in typical Nokia products

- Smartphones contain numerous metals, including many new technology metals
 - Mostly in very small absolute quantities and rarely as pure metals but more commonly as countless different compounds.
 - They provide the user with many additional applications, and all this with a comparatively low weight and volume.
- For example of the new technology metals, neodymium and dysprosium can be linked to the powerful loudspeaker magnets and passive components, cobalt and lithium to the battery, indium to the LEDs and displays and gallium to the processor.
 - The most used rare earth in Nokia products is **neodymium** (80-90% of all rare earths)
- Below is shown masses of rare earth metal (REM) use in two Nokia products (in all forms, not only in metallic forms)

Phone	Mass of the phone	Mass of REMs
Nokia 2600 Classic	73.2 g	0.11 g
Nokia 5530 XpressMusic	107 g	0.24 g

Example of CRM restriction in NSL

- Nokia fulfills all legal requirements, follow also precautionary principle
 - We aspire to go beyond legislation and compliance, and also restrict other materials and substances that have negative effects for human health or for the environment.
- No phase outs or restrictions have yet been made at Nokia because of a metal being classified as critical, but some of the critical metals defined by EU are restricted on Nokia Substance List for other reasons.
 - **Antimony:** antimony trioxide is banned in polymeric materials (max. concentration of Sb₂O₃ in polymeric materials shall be $\leq 0.09\%$ by weight of a homogeneous material.
 - **Beryllium:** Banned as intentionally introduced in all applications.
 - **Cobalt:** completely banned on product surfaces.
- All new material/substance restrictions are studied thoroughly beforehand with the impacted technology areas
 - Thorough studies are done to make sure that we are not substituting a material/substance with a worse alternative.

Substitution / phase-out ground rules

- "Time is of the essence"
- The proposals for substitution of CRMs should involve latest developments and allow innovation
- It also needs to be carefully assessed whether substitution or better recovery of a raw material is the more suitable alternative.
- It should also be taken into account that substitution can happen naturally, as part of product development, legislation is not necessarily required.
 - A good example of this is how the use of graphene can replace indium tin oxide (ITO) and in addition unlike ITO, graphene can be applied in flexible substrates.
- In Nokia a Business Impact Analysis is utilized as a methodology for material substitution from EHS / OHS point of view.

Business Impact Analysis as a Substitution methodology

- As new material/substance substitution need is identified, there are two methods in which Nokia proceeds:
 1. If initiated by the legislation, controlled substitution/phase-out is organized
 2. If initiated by the Nokia voluntary substitution/phase-out decision a Business Impact Analysis is performed
- Business impact analysis contains following issues:
 - Reason for proposed substitution: technical properties, EHS properties
 - Current usage status analysis
 - Life cycle impacts: impacts for material mfg, component mfg, Nokia assembly processes, (EOL) recycling
 - Socio-economic impact
 - Identification of alternative materials / substances
 - Effects on business: short term business effects: reliability, cost, yield etc. Long term business effects.
 - Market overview: raw material manufacturers, other business areas
 - Time required for the substitution in controlled method

Case examples: antimony trioxide substitution / phase-out

- Antimony
 - 2001 antimony trioxide Sb_2O_3 was introduced in NSL on 2001 v.2.0 as "Monitored substance"
 - *"Expected to be reduced or gradually phased out from Nokia applications, subject to the availability of technically, environmentally and economically sound alternatives"*
 - 2004 Sb_2O_3 was raised to "Restricted substance" category
 - *"Actions ongoing to reduce or gradually phase out Sb_2O_3 as a flame retardant in Nokia mobile terminal applications. For maximum allowable concentration value, the level of up to 0.1% by weight in resin shall be tolerated."*
 - 2005 was introduced more strict restriction for Sb_2O_3
 - *"All Nokia mobile terminal equipment (excluding car equipment): Banned as a flame retardant in components, parts and modules approved for production after 01.01.2007 and to be phased out from standard components by 30.6.2007. For maximum allowable concentration value, the level of up to 0.1% by weight in plastic (resin) shall be tolerated."*
 - 2010 Sb_2O_3 restriction was defined for all parts and components
 - *"For all new Nokia products: Sb_2O_3 is banned in polymeric materials in all parts and components. The concentration of Sb_2O_3 in polymeric materials shall be $\leq 0.09\%$ by weight of a homogeneous material"*
- Substitution /phase-out project was initiated by thorough Business Impact Analysis and phase-out of antimony trioxide was initiated on 2005.

Case examples: beryllium substitution

- Beryllium and compounds
 - 2001 beryllium introduced in NSL as monitored substance
 - *“Expected to be reduced or gradually phased out from Nokia applications, subject to the availability of technically, environmentally and economically sound alternatives”*
 - 2004 beryllium oxide was restricted, while beryllium compounds remained monitored
 - *“Banned as intentionally introduced in all applications.”*
 - 2009 beryllium and compounds were restricted
 - *“Banned in new parts and components, whose development starts from 1.1.2009 onwards. MCV shall be $\leq 0.1\%$ of homogeneous material”*
- Substitution /phase-out was initiated by thorough Business Impact Analysis and beryllium substitution with alternative material was started on 2009.
- Based on the substitution planning and alternative material implementation
 - *“All new products are free of beryllium compounds as defined in NSL.”*

Conclusion

- The main uses of critical raw materials in Nokia products are continuously assessed.
- As new alternative materials and technologies become available, material specific substitution /phase-out analysis shall be performed (Business Impact analysis)
 - Analysis should focus on specific applications of certain critical raw materials, take into account existing research initiatives and innovations. Life cycle impact needs to be part of the analysis
- Recycling of CRM of mobile phones is still difficult
 - The figures (Page 6) show clearly that the amounts of rare earths required to fulfill the needs of the industry cannot be met by simply focusing on recycling of mobile phones.
 - In recycling processes it is important to recycle all material or use material as energy for the processes. Recycling processes for complex products requires optimization of processes for specific critical materials.
 - More international research is required for the efficient recycling of specific CRMs.
- Substitution may be seen as more beneficial way to reduce dependency on CRM.
 - However, decision to substitute materials into less harmful materials need to be carefully analysed in order to control the life cycle impact of specific CRMS's.
 - Substitutes for at least three applications of critical raw materials (CRMs) are amongst the concrete targets of the European Innovation Partnership (EIP) on raw materials to be achieved by 2020

Thank you!