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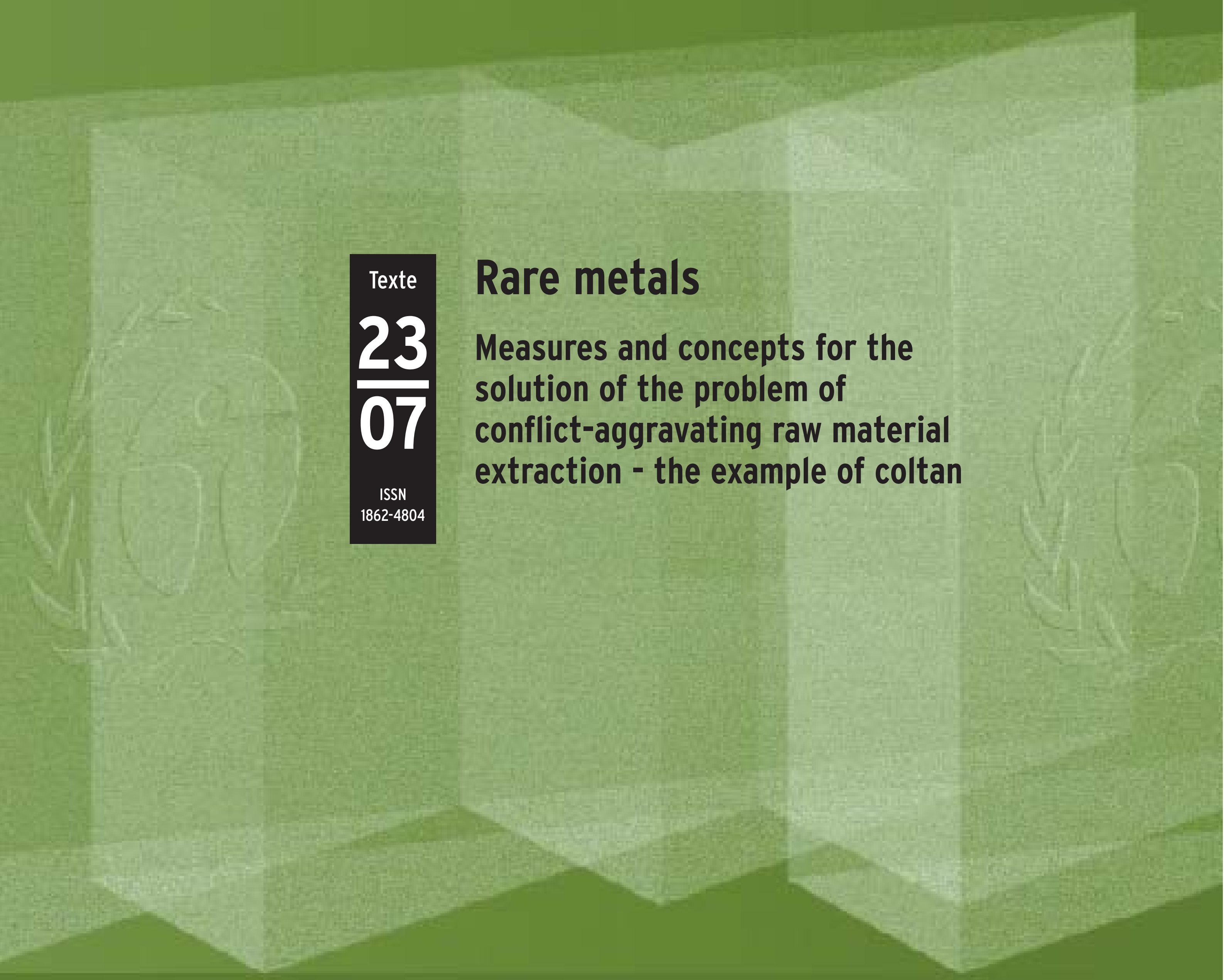

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Measures and concepts for the solution of the problem of conflict-aggravating raw material extraction – the example of coltan

by

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On behalf of the Federal Environmental Agency

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Contents

Summary

The scarcity of many raw materials holds significant conflict potentials as global demand increases rapidly. This does not only apply to fossil resources, focussed in the public debate, but also to many rare mineral resources. An important example is the ore coltan, from which tantalum is separated for the use as material or in the electronics industry. More specifically, tantalum is used in high performance capacitors, that are found for example in a broad range of information and communication technology appliances such as mobile phones and notebooks. Different interests in the exploitation and use of coltan aggravate violent conflicts in the Democratic Republic of Congo. The links between the increasing scarcity of minerals, conflict potentials and the resource management strategies of industrialised countries are obvious and raise additional questions:

- To what degree is the demand for rare minerals from industrialised countries (particularly in Europe) responsible for aggravating conflicts at the places of resource mining and processing?
- To what extent have initial political and corporate reactions been able to defuse the coltan problem? What lessons can be learned from the conflicts in the Democratic Republic of Congo?
- What influence do German and European companies have on resource mining and processing in developing countries?
- How can the difficulties of non-sustainable resource exploitation in countries outside Europe and the demand for them be integrated into the EU Resource Strategy and in EU and German policy generally?

These questions were addressed by the Institute for Futures Studies and Technology Assessment (IZT), Adelphi Research and the Wuppertal Institute for Climate, Environment and Energy in an expert report commissioned by the German Federal Environmental Agency. The report includes:

- a synopsis of the technical significance of rare minerals exemplarey for information and communication technology (IZT),
- an analysis of the importance of coltan extraction in the Democratic Republic of Congo and of the economic and political complexities of illegal coltan exploitation and use along the value chain (Wuppertal Institute),
- an appraisal of measures and concepts to solve the problem of conflict-aggravating resource extraction (Adelphi Research), and
- proposals for the improvement of German and European environmental policies.

The expert report was presented and discussed with representatives from business, companies, associations, governmental institutions, NGOs and research institutions at a workshop on 30 November 2006 in Berlin.

The following *key insights* have been gained and *recommendations* how to deal with the difficulties of non-sustainable resource exploitation have been derived.

Causes for the coltan conflict in the Democratic Republic of Congo

The particular problem about coltan extraction in the Democratic Republic of Congo (DRC) is that it is carried out illegally by different civil war parties and that this leads to considerable health problems

and ecological damage. The lack of effective administrative structures of the central government throughout huge parts of the DRC has enabled an uncontrolled extraction, which is protected by the duty to pay fees to civil war parties from the DRC or even from neighbouring countries. Coltan extraction also takes place in nature reserves with significant negative impact on flora und fauna.

Structures in the international raw material trade

The conflict surrounding illegal coltan extraction in Congo in 1999/2000 coincided with a period of high prices for tantalum. This period saw increased demand for coltan from the DRC on the global market. But the DRC's significance on the global market has never been particularly high and it has fallen again since 2000. The extraction of coltan did, however, intensify and extend the war in the DRC since, at various times and depending on the prevailing balance of power, it contributed to the funds of the respective governments, rebels and neighbouring countries. There were many reasons for the conflict and it went on to become a humanitarian crisis (around four million people died either directly or indirectly as a result of the war).

Altogether the coltan crisis has not been defused sufficiently in 2006. The situation in the DRC remains tense. The legal situation in the extraction areas is unclear and there is still no reliable information on direct investment, which is currently increasing. On the demand side, the role of new industrial consumers (e.g. optics industry) and the role of newly industrialising countries outside the OECD (e.g. China) should be viewed critically. High demand for raw materials has led to the creation of new structures and a redrawing of the geography of international trade in raw materials. The market is no longer dominated by OECD countries and the companies located there, but rather by countries like China, which are purchasing directly from raw material suppliers to secure their supply. Materials such as coltan from the DRC are processed in China and used in products from the optics industry, in PCs and other electronic products, which are then exported to the European Union. While German companies no longer acquire tantalum from critical regions directly, coltan and other tantalum ores from these regions are traded cheaply on international markets and are delivered to the European market in products indirectly.

The role of European companies

The reports of the UN Security Council provided information on the situation in the DRC and exposed links with foreign companies. The reports were criticised from various sides and may even have been unfounded in parts. Nevertheless, the discussion led European companies to take action to increase the transparency of the market. In the case of the German company H.C. Starck, its status as a subsidiary of stock exchange listed Bayer AG and as a supplier of other stock exchange listed telecommunication companies, which are more vulnerable to external criticism than other companies, prompted H.C. Starck to adopt countermeasures in order to restore its reputation. According to H.C. Starck, they do no longer get coltan from the DRC and they require from all suppliers a declaration that the coltan delivered does not come from illegal sources. The course of the conflict demonstrates that transparency can stem illegal trade in rare minerals and thereby reduce the conflict potential, but also that unclear property rights and shareholding structures exist which ask for further reform.

Transparency initiatives and certification systems

Transparency initiatives and certification systems are predominant approaches to deal with the problem of conflict-aggravating resource extraction. However, these approaches originate from certain resources (particularly oil and gas, as well as diamonds) and they are therefore in their structure not necessarily applicable to other resources and industries. Furthermore it turns out that, together with the (physical) characteristics of the raw material deposit, the local governance as well as industry-specific and company-specific characteristics play a major role in the escalation or de-escalation of conflicts. Nevertheless, the existing processes and systems provide experiences for the design of successful strategies. Especially transparency and inclusion of the relevant processes are decisive prerequisites for success. These experiences and scientific knowledge available in this field should be considered absolutely for the development of transparency or certification systems in the case of coltan. Because of the complexity of the links between resource extraction and violent conflicts, which connect (private) economic, political and resource specific dynamics, only multi-dimensional approaches promise success. Various companies and associations work on the development of control mechanisms for suppliers. Up to now, methods for questioning have been developed. It has to turn out, whether additional control mechanisms, which are currently worked out, have to be designed and realised according to region-specific conditions. Examples for evaluation mechanisms could be imported possibly from other industries such as forestry or the textile industry.

Dialogue on sustainable mining and use of resources

The current situation in the DRC after the democratic elections offers new opportunities for the resolution of conflicts surrounding resource mining. Formerly, Germany was an important trading partner for the DRC. In the revitalisation process of relations other minerals in the DRC should be considered, too. The formation of provincial governments in the DRC presents an opportunity to come to an agreement on regulations for the extraction of coltan and other resources. Dialogue on the sustainable mining and use of resources is therefore of central importance. In view of the (hoped for) end of the civil war, the German Federal Government could take the initiative for an international conference on the contribution of sustainable resource mining and use to the development of the DRC.

International panel on resources

An additional problem is represented by the fact that global competition makes it difficult to implement sustainable mining and trading practices. High demand for resources leads to various national strategies; some countries target investment in (foreign) mining (such as China), or build up reserves of resources. We advise the establishment of an "International Panel on the Sustainable Use of Natural Resources", similar to the IPCC, as proposed by the European Commission, to deal with the subject of mineral resources on a global level. This panel should also have competence in the areas of conflict and policy analysis.

Life-Cycle strategies for rare minerals of strategic importance

Apart from coltan other rare minerals are of strategic importance for different industrial sectors and technology fields. Above all, indium and antimony fall into this category. Both elements are indispensable for a multitude of modern technological applications. Indium is needed as a dopant material in the semiconductor industry, in flat panel displays, light diodes or solar cells. The scarcity of indium could limit the mass production of thin layer solar modules and become a bottleneck. Market growth and the development of new application fields (e.g. fuel cell) might aggravate the scarcity of resources. For a substitution it still lacks efficient alternatives. In principle, recycling of indium is technically feasible, but the high degree of dissipation is a problem. Dissipative uses of the material in a broad range of products (mobile phones, flat panel displays etc.) make recycling more difficult and allow the feed back into recycling systems only to a certain degree. It is also a fact that recycling opportunities still remain unexploited or are poorly developed. Only in Japan recycling of indium is realised on a larger scale. In view of the scarcity of indium recycling and substitution efforts should also be strengthened in Germany and the EU, as the existing legislative framework, such as the EuP-Directive, seems to be inadequate to address such rare strategic resources sufficiently.

European Resource Strategy

The subject ‘conflict-aggravating resources’ is mainly a matter of foreign and development policies, and still hardly treated from an environmental and resource policy perspective. The approach to shed also light on this subject from a strategic resource perspective would be new and could contribute to more efforts in other sectors (especially CSR initiatives and development policy measures on “good governance” in general). The European Union requires a resource strategy, that pays tribute to both: the supply of the European industry with rare minerals, and the problems in the mining and processing countries. As well as the environmental aspects emphasized by the EU Resource Strategy, attention should be paid to the socioeconomic aspects and criteria of fair trade.

1 What are rare metals?

1.1 Definition of terms[1]

This section starts with a definition of terms used. It goes on to discuss the use of metals in the information and communications technology sector. The following chapter discusses various criteria for defining “rare” and applies them to industrial metals in the periodic table. An interim conclusion on “rare metals in information and communications technology products” summarises the criteria discussed and the metals used in ICT products. The next chapter presents information on the use and production of tantalum. The appendix lists definitions of relevant terms and briefly describes the use of the metals in electrical and electronic equipment and in ICT products.

The call for proposals uses the term “rare minerals”. “Mineral” is used relatively uniformly in literature on the subject but refers to around 2,000 different substances. Of these, around 300 are regarded as common and the rest are considered rare (*Meyers Lexikon* 1983: “Mineralien”). However, minerals are rarely used in the manufacture of products[2], instead metallurgic processes or chemical reactions produce either pure forms of a substance, salts or alloys of that substance. The pure forms are usually indirectly used in intermediates such as wire, foil or alloys from copper ingots for use in production processes, whereas salts and alloys can either be used to create pure substances (e.g. silicon from silicon chloride) or can also be used to make intermediate products. The available data on mineral reserves and uses is still insufficient because substance lists and databases usually only refer to the pure forms of substances.

Conclusion: This paper will initially consider “rare metals” as opposed to “rare minerals”. The advantages of this are that it is easier to organise the substances and that more complete data is available.

1.2 Metals in electrical equipment, and in electronic products and components[3]

A screening of chemical databases (Rutherford), production statistics (USGS 2006), environmental performance evaluations of ICT products (Behrendt et al. 1998, Soldera 1995) and databases on electronic components (Elektro, Elko) and various scientific publications reveal that the electronics industry uses almost all stable metals in its products. In this first screening, only lanthanide, iridium, osmium, rhodium, ruthenium and vanadium were not identified in any electrical and electronic products or components. These metals are, however, probably also used within the electronics industry.

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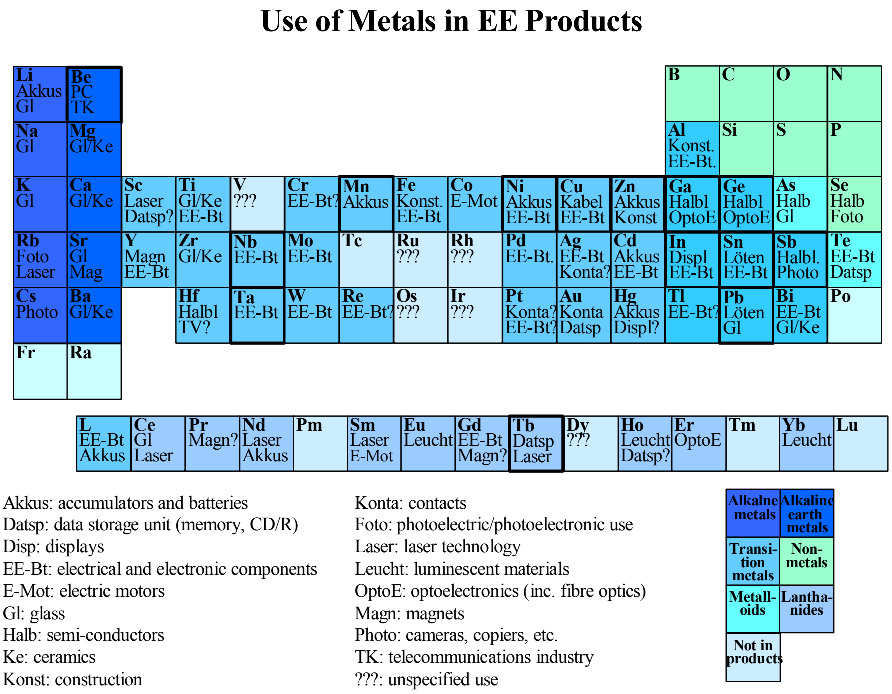
[1] For definitions of terms used frequently in this context see Appendix 1.

[2] One of the few examples is the use of cerium in abrasive polishing of glass.

[3] Cf. Appendix 2.

Figure 1: Use of metals in electrical and electronic products.



Akkus: accumulators and batteries
Datsp: data storage unit (memory, CD/R)
Disp: displays
EE-Bt: electrical and electronic components
E-Mot: electric motors
Gl: glass
Halb: semi-conductors
Ke: ceramics
Konst: construction

Konta: contacts
Foto: photoelectric/photoelectronic use
Laser: laser technology
Leucht: luminescent materials
OptoE: optoelectronics (inc. fibre optics)
Magn: magnets
Photo: cameras, copiers, etc.
TK: telecommunications industry
???: unspecified use

Source: own figure

It is not possible to designate specific metals as being either part of ICT products or part of EE products as it is difficult to draw this distinction. This becomes clear if we look at the example of dopants such as gallium, germanium, rubidium, scandium, yttrium and the rare earth metals in fibre optics and laser technologies. They are used in ICT products (such as CD and DVD players) as well as in optoelectronics, to run fibre-optic networks. Other examples of cases where it is hard to decide whether metals are primarily used in ICT products or in other EE products are the luminescent materials used in cathode ray tubes (europium oxide), materials used to make glass (barium oxide, litharge, boron, aluminium oxide, calcium oxide and potassium oxide) and the dopants used in semi-conductors (lanthanides, arsenic, antimony, germanium, gallium and indium).

Another difficulty which proved impossible to solve was establishing whether ICT products or EE products in general contain more or fewer key metals. The most commonly used metals in terms of volume are aluminium, iron, copper, nickel, zinc and the lead in cathode ray tubes in televisions and monitors. But other metals, only used in very small amounts, such as beryllium, europium, indium, tantalum and the platinum group are essential for today's ICT. As a consequence, and because of the limited amount of time available to work on this project, the application areas of all metals in the electronics industry were researched. The findings are shown in Appendix 2.

1.3 What are "rare" metals?

Things that are "rare" occur less frequently than other, similar things. "Rare" is therefore a relative concept. Yet this relative relationship must be considered differently depending on the specific matter at hand. "Rare" in the sense of "occurs less frequently" is a necessary part of the definition, but it is not adequate. For example, if one were to compare the reserves of different metals in the Earth's crust, the "rarest" stable metals would be tantalum, rhenium, uranium, indium and antimony, which each make up something between 10^{-7}% and 10^{-8}%. The next rarest are beryllium, boron, rhodium, silver, caesium, hafnium, tungsten, gold, mercury, thallium, bismuth, niobium, palladium, cadmium, iridium, osmium, ruthenium and tin, which each make up between 10^{-6}% to 10^{-7}%. Therefore the rare metals include key metals for the electrical and electronics industry such as antimony, indium, gold, platinum, selenium, silver and tantalum. Despite their rarity (in the Earth's crust), they are of integral importance for the manufacture of products. "Rarity" is thus a difficult term to define and requires more precise explication with regards to the topic of study. The following points thus test possible approaches to explaining the term.

1.3.1 Definition 1: Rare metals are those metals which are expensive or whose price has increased dramatically

Price reflects the relationship between supply and demand. High prices imply low supply accompanied by high demand. Higher prices are generally paid for rare things in high demand than for things which are readily available. Dramatically increasing prices point to an expansion of demand caused by, e.g., intensified production in current application areas or the use of the metal in a new area of application. Short-term or medium-term rarity can therefore also be signalled by increasing prices. The following table lists the prices of certain metals and the difference in price between 2001 and 2004[4]:

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[4] The metals selected were either significant in the production of electronic and electrical goods because of the amount used, such as copper and aluminium, or were metals with a low ratio of proven reserves to global consumption. Additional metals featured were those which were particularly expensive or experienced particularly high price increases between 2001 and 2004.

Table 1: Prices and price trends for key industrial metals

Metal	Price 2001 (US $ /kg)	Price 2004 (US $ /kg)	Price 2005 (estimate, US $ /kg)	Price increase 2001-2004 [%, calculation based on USGS data]	Notes
Aluminium	1.5	1.9	1.9	22	
Antimony	1.4	2.9	3.2	100	
Cadmium	0.5	1.2	3.3	140	
Caesium		14,890	14,890		a
Cobalt	24	53	35	118	
Copper	1.6	2.9	3.6	81	
Gallium	640	494	512	-23	
Germanium	890	600	610	-33	
Gold	8,745	13,214	14,147	51	
Hafnium	138	269	238	95	
Indium	120	643	810	463	
Iridium	13,343	5,948	5,144	-55	
Lead	0.5	0.9	0.9	90	
Manganese	0.2	0.3	0.5	18	b
Mercury	4	12	22	158	
Molybdenum	5	30	72	471	
Nickel	6	14	15	133	
Niobium	15.2	14.5	14.5	-5	
Palladium	19,612	7,491	6,109	-62	
Platinum	17,137	27,269	28,615	59	
Rhenium	910	1,090	1,170	20	
Rhodium	51,442	31,605	64,302	25	
Rubidium		10,850	10,850		
Ruthenium	4,180	2,058	2,251	-51	
Scandium	2,700	2,500	2,500	-7	c
Selenium	8	55	115	555	
Silver	141	215	230	52	
Strontium	0.63	0.53	0.57	-16	
Tantalum	82	68	76	-17	
Tellurium (t)	15	29	212	86	d
Thallium	1,295	1,600	1,900	24	
Tin	4.4	9.1	7.6	96	
Tungsten	6	5	14	-23	
Vanadium	5	12	39	258	
Zinc	1.0	1.1	1.4	18	

Sources: USGS 2006 and calculations based on USGS data. Prices for 2005 are USGS estimates, which is why these statistics are not made use of here.

Notes:

a) The price for ultra-pure caesium (99.98%)

b) Prices are based on an ore of around 47% manganese.

c) The price for tellurium with a purity of 99.95%

d) The values for scandium are based on an oxide with 99.99% purity.

The table makes it clear that some metals had very high absolute prices in 2004[5]. For example, prices in 2005 for palladium were around US$6,100 per kilogram, rubidium cost around $10,500, gold around $14,100, platinum around $28,600 and rhodium around $64,300. However, the absolute price does not automatically indicate that resources are scarce. Certain materials such as hafnium or rubidium are only extracted as a by-product as demand is not very high. Only extremely low volumes of these materials are used in products, meaning that they only have limited effect on the price of products. The same applies to some very expensive metals which are used in mass ICT products such

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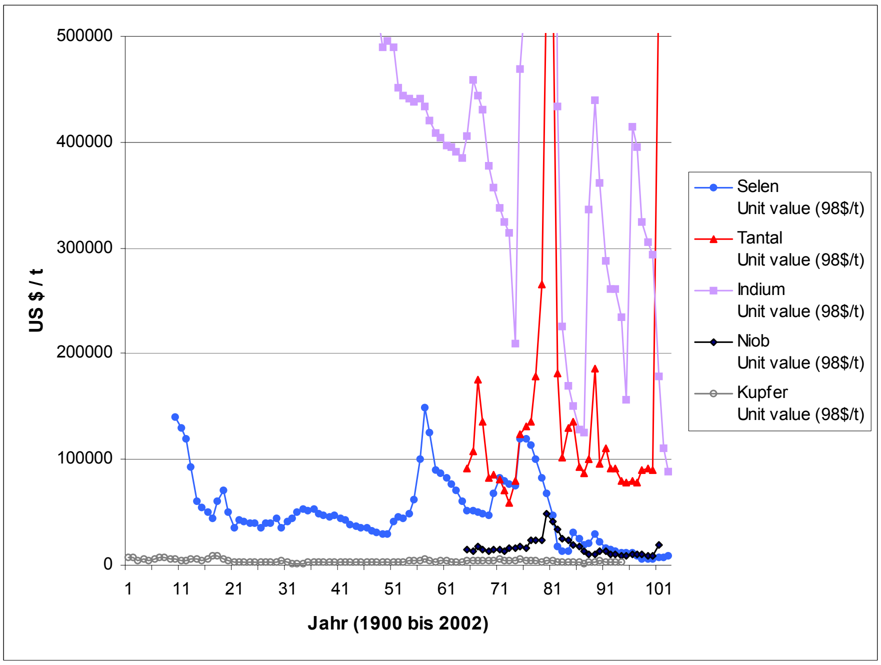
[5] This study considers the figures for 2004, since the available figures for 2005 are only USGS estimates. Various estimates for 2005 prices are available from various sources, but since these could be based on different methods of calculation, the study is based on the USGS data.

as mobile telephones (Sullivan 2006). A modern mobile phone was analysed for its noble-metal content and was revealed to contain around 0.35 g of silver, 0.034 g of gold, 0.015 g of palladium and 0.00034 g of platinum. The average mobile telephone in the mid-price range – average based on prices from 2002-2004 – contains US$0.06 worth of silver, $0.40 worth of gold, $0.13 of palladium and $0.01 worth of platinum. Therefore the average mobile phone contains precious metals to a total value of around 60 US cents, a very small proportion of the $200 to $600 which a modern mobile costs these days.

Metal prices in general have risen very sharply in recent years. The total price index for raw materials based on USD (2000=100) which averaged 90.1 in 2001 and 2002 increased to approximately 145 in 2005 for mineral raw materials (Bleischwitz 2006, p. 2). However, a look at long-term trends on the raw materials market reveals that some metals have fallen in price (Reynolds 1999 and Tilton 2003, see also Table 1 for gallium, germanium, indium, palladium, ruthenium and tungsten).

But metal prices are subject to large fluctuations in the short and medium term. There are many reasons for this. On the one hand, investment in mining is usually very high and characterized by long-term commitment, which is why mining companies work to very different time frames than product manufacturers. On the other hand, new findings in materials research can quickly lead to new application fields for metals in product manufacture. Some metals gain new markets (e.g. indium, due to its use in TFT screens) whereas others can lose their significance (e.g. diminishing demand for lead oxide in the wake of the popularity of flat screens). If items become mass consumer products because of societal trends (e.g. miniature mobiles with tantalum capacitors), supply and demand diverge, causing large price increases. The various methods used by stock market traders represent another important factor in determining price. Very often, stock market deals simply represent a type of gamble on price trends. Traders' perceptions are not always based on the real market conditions of direct buyer-seller relations. The targeted sale or purchase of stocks can more or less control price trends (cf. details on the Hunt brothers and "Silver Thursday", FAZ 2004). There is also another factor, not related to manufacturing, which affects prices in the mining industry. This is the phenomenon of future profits, gains which would be made if mineral prices were to increase in the future and the metals were not to be sold until later. A relatively complicated price formation process on the market means that predicted shortages in the future have an impact on current prices (Bleischwitz, p. 309). Another factor in price formation is that in some sectors of the metal market mine-owners and metal manufacturers have agreed fixed prices over a set period of time, so that prices on the spot market do not necessarily correspond to trading prices. This complex interplay of parameters and influencing factors results in price trends which are difficult to explain and almost impossible to predict, and which are only reflected in long-term overviews. The following graphs show the prices for some metals of current importance to the EE industry (selenium, tantalum, indium, niobium and copper). The prices are given in constant US dollars, base year 1998. Data on selenium and copper goes back as far as 1900, records for indium date from 1930 and those for tantalum and niobium date from 1964.

Figure 2: Price trends for selenium, indium, tantalum, niobium and copper over a century in constant US dollars (1998 = 100)



Source: Own graphic depiction of prices based on USGS data: Historical Statistics on Selenium (2004), Tantalum (2002), Indium (2004), Niobium (2002) and Copper (2004). Note: The prices are constant, base year 1998, and refer to the US market.

The graph shows that the copper price has remained very stable for almost a century. The selenium price has experienced extreme peaks but has fallen overall. The price of niobium peaked around 1980 but then dropped back to its medium-term level. In 2000, however, it briefly shot up to the level of tantalum, as niobium is also used in the manufacture of capacitors. According to the USGS data, tantalum and indium have experienced very erratic price trends. The reason for the tantalum price peak in 2000 was the heightened demand for tantalum capacitors coupled with supply difficulties (see Bleischwitz 2006).[6] Indium is important for the market because of its many applications such as in coatings for bearings, in vacuum seals, in smoke detectors, mercury-free medical thermometers, semi-conductors, solar technology and liquid crystal displays. Yet, indium is only obtained as a by-product from zinc, tin, lead and copper smelting. The difficulties of expanding supply linked to demand in many different application areas could have triggered the speculative price increase of indium.

Conclusion: In summary, it can be established that neither the absolute price of metal nor dramatic price increases over a limited period of time represent adequate criteria for defining rare metals. Price fluctuations over a longer period of time can be extreme. Yet prices can give indications as to the availability of a metal on the market or on market estimates as to its availability in the short term. So price, together with other criteria, could help to define “a rare metal” after all. The following metals cost around or above US$500 in 2004[7], according to USGS data (in ascending order): gallium ($494), germanium, indium, rhenium, thallium, ruthenium, scandium, iridium, palladium, rubidium, gold, caesium, platinum and rhodium ($31,605). USGS recorded a price increase of almost 100% and more between 2001 and 2004 for the following metals (in ascending order): hafnium (95%), tin (96%),

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[6] Part 2 of the paper on this project, by the Wuppertal Institute

[7] Unfortunately, the USGS does not have data on average prices for 2005. Status: October 2006.

antimony, cobalt, nickel, cadmium, mercury (all up to a maximum of 160%), vanadium (258%), indium (463%), molybdenum (471%) and selenium (555%). So, on the basis of these two criteria, only indium would be defined as "rare".

1.3.2 Definition 2: Rare metals are metals with a low current availability

The absolute availability of metals depends on their reserves and resources[8]. Reserves constitute the supplies from identified deposits which are recoverable under current technical and economic constraints. Resources are the deposits which will be accessible later given advances in mining technology and increasing prices. A distinction is often drawn between static availability and dynamic availability. Figures on static availability predict how many years reserves will last according to current consumption patterns. Figures on dynamic availability take economic growth and other possible changes into account. However, this is extremely complicated to calculate, which is why static availability figures based on realistic growth rates are normally used. The following table gives figures on static availability (not including growth rates) and the calculation basis for certain key industrial metals. All metals which, on the basis of known reserves, will last less than 50 years are listed here. Also listed are static availability figures calculated on the basis of reserves. The reserve base constitutes those resources which can fulfil minimum requirements as to grade, quality, seam thickness, etc., making them worth mining under current constraints.

Table 2: Figures on static availability of metals [a].

Metal	Production 2004 (USGS)	Production 2005 (USGS)	Reserves (USGS)	Reserve basis (USGS)	Years reserves can last (static availability)	Years reserve basis can last (static availability)	Notes
Antimony	113,000	117,000	1,800,000	3,900,000	15	33	
Barium	7,240,000	7,260,000	200,000,000	740,000,000	28	102	
Cadmium	18,800	18,000	600,000	1,800,000	33	100	
Chromium	17.500.000	18.000.000	475.000.000	800.000.000	26	44	e
Copper	14,600,000	14,900,000	470,000,000	940,000,000	32	63	f
Gold	2,430	2,450	42,000	90,000	17	37	
Indium	405	455	2,800	6,000	6	13	g
Lead	3,150,000	3,880,000	67,000,000	140,000,000	17	36	
Manganese	9,350,000	9,790,000	430,000,000	5,200,300,000	44	531	
Nickel	1,400,000	1,500,000	62,000,000	140,000,000	41	93	
Silver	19,700	20,300	270,000	570,000	13	28	
Strontium	551,000	520,000	6,800,000	12,000,000	13	23	h
Tantalum	1,540	1,910	43,000	150,000	23	79	f, i
Thallium	12	10	380	650	38	65	j
Tin	264,000	280,000	6,100,000	11,000,000	22	39	
Tungsten	73,700	76,500	2,900,000	6,200,000	38	81	
Zinc	9,600,000	10,100,000	220,000,000	460,000,000	22	46	
Zircon	850,000	870,000	38,000,000	72,000,000	44	83	k

Source: USGS 2006 and own calculations on the basis of USGS 2006.

Notes:

e) Reserves of chromium have not been adequately determined; resources are probably sufficient to supply humanity for centuries

f) Reserve basis is bigger than that claimed by USGS

g) Reserve estimate based on indium in zinc ore

h) Not including production from Kazakhstan

i) Reserves of tantalum have not been adequately determined, the static availability must be higher.

j) Production levels of thallium outside the United States

k) Reserves of zircon are based on zircon oxide reserves

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[8] For definitions see Appendix 1

Data given in literature on the subject are usually very disparate and often not comparable. Nevertheless, the table demonstrates that various metals crucial for electronic and electrical products will not be around much longer, given current availability of reserves. However, figures on static availability do not reflect potential for improved recycling, for new methods of metal extraction (urban mining, sea water extraction, or for new material science findings – substitutes). Furthermore, it cannot be said that humanity has prospected the entire globe for minerals; the oceans in particularly have remained largely unexplored (potential lies in manganese nodules and black smokers). Moreover, large price increases or new extraction processes (e.g. bacterial degradation of copper) trigger the exploitation of less concentrated ore deposits, as raw material extraction is in principle only limited by the energy input required.

In general, experts believe that current statistics on reserves and resources are of minor importance. In 1999, the German Ministry of Economics and Technology (BMWi) commissioned a study aimed at assessing the effects of global concentration of mining on the supply of raw materials to the German economy. The study considered various factors affecting ten metals including copper, niobium, tantalum and the rare earths. It came to the conclusion that "the analysis of ten selected raw materials markets revealed that there is currently no need to fear lasting supply problems on the global markets (deposits, production capacities)" (ibid. 1999, p. 24). A study by the German Institute for Economic Research (DIW) also found that shortages due to limited reserves and resources should not be feared. Matthes and Ziesing looked at the economically recoverable reserves of three groups of metals with different availability levels (ibid. p. 35). Metals which will last over another 100 years are considered "safe". It is expected that new technologies and higher prices will secure adequate supplies of accessible reserves of the group which have a static availability of 40 years and over, such as chromium, nickel, molybdenum, selenium and tungsten. However, for the group with a static availability of just 10 to 40 years (silver, gold, arsenic, boron, cadmium, copper, indium, manganese, lead, tin, strontium, tantalum, thorium and zinc) *it seems that it may be necessary to draw on additional resources, which will only be possible given significant technological innovations and at a much higher price. However, an actual physical shortage of reserves and resources is not foreseen for any of the resources described* (ibid. p. 36).

Conclusion: The supplementary criteria "availability" is not used consistently in the literature. However, the fourth management rule of the German Bundestag's Enquete-Kommission on "Schutz des Menschen und der Umwelt" (Protection for Humanity and the Environment) should be taken into account when considering the future of resource utilisation. The rule is based on the thoughts of Daly and states that "*non-renewable resources should only be used to the same extent as a physically and functionally equivalent replacement can be made available in the form of renewable resources or higher productivity of the renewable and the non-renewable resources is achieved*" (Enquete-Kommission 1994, p. 32). However, if one wishes to include this criterion of static availability, it should be used in conjunction with other criteria to define what makes a metal rare. The metals whose reserves are predicted to last under 25 years should be given special consideration. These are indium (six years), strontium, silver, antimony, gold, lead, tin, zinc and tantalum (23 years). The static availability of the reserve base for the following metals is under 50 years, a fact which should also receive special attention: indium (13 years), strontium, silver, antimony, lead, gold, tin and zinc (46 years). The metals specified in this case fulfil both criteria[9]. It must be remembered that for the platinum group, beryllium, germanium, gallium, scandium, hafnium, rubidium and caesium either no production data is available or the USGS does not have estimates on available reserves.

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[9] The researchers working on this study selected the time frames of 25 and 50 years.

1.3.3 Definition 3: rare metals are metals which are only extracted in a few countries

For some time, political and scientific discussions of resource policy have had an economic perspective as well as an environmental perspective. In 1999, the Federal Ministry of Economics and Technology (BMWi) commissioned a study aimed at assessing the effects of global concentration of mining on the supply of raw materials to the German economy (BMWi 1999). The report evaluates the risk of supply breakdown for ten metals according to political and economic as well as competitive criteria. Significant about the study, given that mining companies are largely market-oriented, is that the political situation in the countries where the metals are extracted was included in the evaluation. The following criteria for a risk of supply breakdown were used:

Table 3: Criteria for risk evaluation

Political and economic risk	Competitive risk
Concentration of stocks	Market structure
Concentration of exports	Competition/supply side (intensity, access barriers, flexibility of supply, pricing)
Concentration of production	Demand side (buyer power, possibility of substitution, price elasticity)
Share of secondary metal production (correction factor)	

Source: BMWi 1999, p. 29.

The results of a comparison of iron, manganese, copper, chromium, nickel, tantalum, titanium, vanadium, rare earths (REO) and tungsten showed that the greatest supply risks were for niobium, tungsten and vanadium (BMWi 1999, p. 27). In the case of tungsten and rare earths (REO), the risks are primarily on the supply side because these metals are mainly extracted in China, which has the largest proven reserves. At the time when the study was undertaken, a good three quarters of all niobium was being extracted by a single Brazilian company. Again, the majority of all known reserves are located in Brazil. The study assessed the political and economic situation in Brazil as problematic, meaning that niobium was classified as one of the elements at risk (ibid. p. 22).

A further study undertaken by the Federal Ministry of Economics and Labour (BMWA) investigated the economic situation of raw materials and resource policy options (ibid. 2005). Here, the main focus was again on the supply and value chains. Metals used for plating iron and steel, non-ferrous metals, noble metals, special metals and some non-metals were researched[10]. "Economic profiles" were prepared for each resource including use, supply, demand, price trends, recycling rate and substitution options[11] and, partially, supply and value chain sensitivity, strategic importance and other special problems (Federal Institute for Geosciences and Natural Resources 2005). The study reaches the conclusion that there are numerous sensitive areas in the supply and value chains which could affect German industry. The huge demand in China, India, Brazil and Russia for iron and steel plating materials, platinum metals, magnesium and zircon is an important factor. And production capacities are concentrated for the platinum metals, magnesium, niobium, tantalum and tungsten. However, the authors of the study came to the general conclusion that regional and corporate concentrations were no cause for concern with regard to supply security (BMWA 2005, p. 8).

By subjecting the metals considered in Appendix 2 to selected arguments (reserve distribution, countries of origin) from the above studies, whilst taking the USGS data on the distribution of reserves and the origin of metals (USGS 2006) into account, it can be seen that with 18 of the metals, all of which are used in the EE industry, predominantly in ICT products, different problems may arise with

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[10] The metals were silver, aluminium, gold, cadmium, cobalt, chromium, copper, iron, lead, lithium, magnesium, manganese, molybdenum, niobium, nickel, palladium, platinum, rhodium, tantalum, tin, titanium, tungsten, zinc and zircon.

[11] However, this data is not available on all the substances. Cf. BGR 2005.

regard to regional deposits and their market accessibility. Two different groups can be differentiated between:

- Metals whose largest known reserves are primarily located in one (> 50%) or two countries (> 65%) (reserve concentration criterion);[12]
- Metals for which the supply and value chain is highly concentrated, according to the BMWA 2005 (supply and value chain concentration criterion).

The BMWA only considered selected metals. However, as the investigation represents the most comprehensive study on the strategic significance of metals to date, its approach has been applied, in a greatly simplified form, to the remaining metals. All of the metals whose largest known reserves (> 65%) are located or extracted in countries which the BMWA study designated as having a special status with regards to resources (e.g. the problematic economic situation in Brazil, for example, or the implementation of protectionist measures on the metal market in China, Russia, India) are also assessed as worth investigating and have been marked "(X)"[13]. The result is the following classification of metals which have been assessed as worthy of investigation:

Table 4: Potentially strategic metals

Metal	**Production 2005 (USGS 2006) [10^3 t]**	**Reserves (USGS 2006) [10^3 t]**	**Reserve base (USGS) [10^3 t]**	**Availability of reserves (Reserves in t [t] or 1,000 t [tt])**	**Concentration of reserves**	**Concentration of supply and value chain**	**Notes**
Antimony	117	1,800	3,900	China 790 tt, Russia 350 tt, Bolivia 310 tt, US 80 tt, Tadjikistan 50 tt, other countries 150 tt		(X)	
Barium	7,240	200,000	740,000	China 62.000 tt, India 53.000 tt, US 25.000 tt, Marocco 10,000 tt, Thailand and Algeria 9,000 tt, other countries over 20,000 tt	X	(X)	
Beryllium	0.114		80	approx. 65% of resources are reckoned to be in the US	X		
Bismuth	5.2	330	680	China 240 tt, Bolivia 10 tt, Peru 11 tt, US 9 tt, other countries approx. 50 tt	X	(X)	
Chromium	18,000	475,000	800,000	Kazakhstan 250,000 tt, South Africa 160,000 tt, India 25,000 tt	X	X	1
Cobalt	52.4	7,000	13,000	Congo 3,400 tt, Australia 1,300 tt, Cuba 1,000 tt, Zambia 270 tt, Russia 250 tt, New Caledonia 230 tt, Canada 130 tt, other countries 250 tt	X	(X)	
Indium	0.45	2.8	6	Canada 1,000 t, US 300 t, China 280 t, Russia 200 t, Peru 100 t, Japan 100 t, other countries 800 t		(X)	m
Magnesium	610	Very	Very large	Magnesite: Russia 650,000 tt, North Korea 450,000 tt, China		(X)	

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[12] The authors of this study set the levels of 50% and 65%, not the authors of the BMWA and BGR studies.

[13] It is difficult to classify countries according to their political situation or adherence to trading standards. A possible classification could be countries which have joined the WTO and which actually stick to the trading rules. However, research findings of numerous studies (BMWi 1999, BMWA 2005) and publications (VWM 2005, UNICE no date) allude again and again to problems on the metal market, particularly in Russia, China, Ukraine, Pakistan and India. There was not enough time to research examples from the ore mining industry but the BMWA study clearly shows that countries like China have an inordinate amount of influence on imports and exports of, for example, non-ferrous metals and can therefore create competitive advantages for their own producers and consumers (ibid. p. 19 ff.). Even though the time available did not allow research into explicit examples where limiting exports of raw metals has led to an improved economic climate for domestic industry, we can see examples of where conflicts have arisen over other resources such as water from rivers which flow through several countries (the Euphrates, Jordan) and fuel supply (e.g. the conflict between Russia and Ukraine).

Metal	Production 2005 (USGS 2006) [10^3 t]	Reserves (USGS 2006) [10^3 t]	Reserve base (USGS) [10^3 t]	Availability of reserves (Reserves in t [t] or 1,000 t [tt])	Concentration of reserves	Concentration of supply and value chain	Notes
		large		380,000 tt, Australia 100,000 tt, other countries 615,000 tt			
Manganese	9,790	430,000	5,200,300	Ukraine 140,000 tt, India 93,000 tt, Australia 68,000 tt, China 40,000 tt, South Africa 32,000 tt, other countries 46,000 tt		X	n
Mercury	1.1	120	240	Spain 76 tt, Kyrgyzstan 7.5 tt, Algeria 2 tt, other countries 38 tt	X		
Niobium	33.9	4,400	5,200	Brazil 4,300 tt, Canada 110 tt, Australia 29 tt, reserves in other countries not known	X	X	o
Platinium group (Ru, Rh, Pd, Os, Ir, Pt)	> 0.43	71	80	PGM: South Africa 63 tt, Russia 6.2 tt, US 0.9 tt, Canada 0.3 tt, other countries 0.8 tt	X	X	p
Rare earth metals	105	88,000	150,000	REO: China 27,000 tt, Commonwealth of Independent States 19,000 tt, US 13,000 tt, Australia 5,200 tt, other countries 23,000 tt; approx. 95% of the rare earths are produced in China (USGS 96%, BMWi 1999: p.17: 65%)		(X)	
Scandium	50			Scandium oxide is only extracted as a by-product, mainly in China, Kazakhstan, Russia, Ukraine		(X)	
Tantalum	1.9	43	150	Australia 40 tt, Canada 3 tt, nothing is known about deposits in other countries except that the reserve base in Brazil is estimated to be around 73 tt. Mozambique probably has reserves too.	X	X	q
Tungsten	76.5	2,900	6,200	China 1,800 tt, Canada 250 tt, Russia 250 tt, US 140 tt, other countries 4,400 tt	X	X	r
Vanadium	42.5	13,000	38,000	China 5,000 tt, Russia 5,000 tt, South Africa 3,000 tt, US 0.45 tt, other countries: unknown		X	s
Yttrium	2.4	540	610	Yttrium oxide: China 220 tt, US 120 tt, Australia 100 tt, India 72 tt, other countries 32 tt. Almost 95% of yttrium oxide come from China.		(X)	
Zinc	10,100	220,000	460,000	China 33.000 tt, Australia 33.000 tt, US 30.000, Kazakhstan 30,000, Peru 16,000 tt, Canada 11,000 tt, other countries 67,000 tt		X	t
Zircon	870	38,000	72,000	Zircon oxide: South Afrika 14,000 tt Australia 9,100 tt, Ukraine 4,000 tt, US 3,400 tt, India 3,400 tt, other countries 3,600 tt	X	X	u

Source: Own table based on data from USGS 2006.

Notes: l) Increasing demand from BRIC (BGR 2005: chromium); m) Indium is mainly extracted from zinc ore, which is why China is the largest producer, with a market share of almost 60% (USGS 2006); n) high demand from China (BGR 2005: manganese); o) d BMWi allocates the metal a high strategic significance (BMWi 1999 p.27) and the supply chain exhibits a high level of concentration (BGR 2005: niobium); p) very few countries supply palladium, extraction of platinum and rhodium is limited to very few countries (BGR 2005: palladium, platinum and rhodium); q) high level of concentration in the supply chain (BGR 2005: tantalum); r) China virtually monopolises production (BGR 2005: tungsten); s) BMWi allocates vanadium a high strategic significance (BMWi 1999, p. 27) and BMWi allocates the metal a high strategic significance (BMWi 1999, p. 27), t) China is the largest producer (BGR 2005: zinc); u) demand outstrips supply (BGR 2005: zircon);.

Conclusion: A comparison of the geographical location of the reserves of various metals shows that many metals are found in a limited number of countries. This applies to reserves of metals in plentiful supply (chromium, manganese and zinc) as well as to metals with limited reserves (beryllium, indium, the platinum group, tantalum and yttrium). Many of the metals also indicate concentrated supply and value chains, or have reserves in countries which have yet to be investigated, as they were not included in the BMWA/BGR studies. However, it must be pointed out that the latter argument can only be used in a rough analogy to the BMWA study, and the BMWA itself does not believe that shortages of any of the metals it researched are really to be feared. But if one applies the arguments to the metals described in the table – as no information is available to the contrary – then bismuth, chromium, cobalt, niobium, the platinum group, tantalum, tungsten and zircon must all be considered as strategic metals, as they definitely ("X") or partly possibly doubly worth investigating ("X" and "(X)").

1.4 Initial conclusions

This investigation has analysed various arguments for the "rarity" of metals using the following criteria:

- Price: metal prices of almost US$500 per kilogram;
- Price increase: a rise in the price of metals in excess of 100% in the period from 2001 to 2004
- Scarcity of reserves: reserves lasting under 25 years, based on production figures for 2004;
- Scarcity of reserve bases: reserve bases lasting under 50 years, based on production figures for 2004;
- Concentration of reserves: concentration of known reserves primarily in one (> 50%) or two countries (> 65%,);
- Concentration in supply and value chain or high concentration of reserves: a high concentration in the supply and value chain, according to BMWA 2005, (concentration in supply and value chain, "X") and a high concentration of reserves (> 65%) in countries which can be analysed similarly to the countries in the BMWA study ("(X)").

A look at the findings of the above-mentioned supplementary criteria for determining what makes a metal rare reveals that different metals would have to be defined as rare depending on the criteria used. Beryllium, cadmium, caesium, gallium, germanium, hafnium, magnesium, manganese, molybdenum, nickel, rare earths, rubidium, selenium, thallium and yttrium fulfilled just one criterion. Barium, bismuth, chromium, lead, mercury, niobium, osmium, scandium, silver, strontium, tungsten, vanadium and zircon fulfilled two criteria. Gallium and germanium may also have to be included in this group as they are obtained as by-products of bauxite and zinc excavation. There is, however, insufficient information on the origin of these metals. It should be remembered that the USGS has either no production data or no reserves estimates for beryllium, germanium, gallium, scandium, hafnium, rubidium and caesium, meaning that they could actually fulfil more criteria.

Some metals could be identified as fulfilling three criteria, as shown in the following table. These are cobalt, gold, iridium, palladium, platinum, rhenium, rhodium, ruthenium, tin and zinc. It is, however, possible that some of the metals in the platinum group would also have to be classified as fulfilling an extra one or two criteria, as little is known about reserves for platinum metals. But they are only listed as a group here. The static availability of the platinum group as a whole is secure for a long time to come. The research did not reveal any applications of iridium, rhodium and ruthenium in ICT products.

Antimony and indium fulfilled the most criteria: 4 and 5 respectively. Both metals have diverse applications in EE and ICT products, with indium probably being of greater significance.

Table 5: Summary of evaluation results

Metal	Overall evaluation	ICT relevance[14]	Price > US$500 /kg	Price increase > 100 %	Static availability of reserves < 25 a	Static availability of reserve bases < 50 a	Concentration of reserves (>50% or >65%)	Concentration in the supply & value chain
Antimony	4	X		X	X	X		(X)
Cobalt	3	X		X			X	(X)
Gold	3	X	X		X	X		
Indium	5	X	X	X	X	X		(X)
Iridium	3	?	X				X	X
Palladium	3	X	X				X	X
Platinum	3	X	X				X	X
Rhenium	3	X	X				X	X
Rhodium	3	?	X				X	X
Ruthenium	3	?	X				X	X
Tantalum	3	X			X		X	X
Tin	3	X		X	X	X		
Zinc	3	X			X	x		X

Source: own table

To conclude, it should be noted that, firstly, the identification of rare metals is largely dependent on the criteria chosen, and secondly, there is not always sufficient data available for an adequate comparison of the metals. The method that has been used is, however, adequate for screening rare metals. It was possible to prove ICT product utilisation of all of the metals with the exceptions of cobalt, vanadium, dysprosium, thulium and lutetium and the platinum metals ruthenium, rhodium, osmium and iridium. It was not, however, always possible to provide information on the significance of the metals.

The criteria are oriented towards differing time frames. Whilst the reference to reserves reflects more of a medium-term perspective, concentrations in the supply chain, trade stability and an increase in prices are more short-term issues. At the same time, competition on the market should be taken into account. For instance, there is strong competition for noble metals between the automotive industry, the jewellery market and the dental sector. And in the medium-term future, fuel cell manufacturers will join in. All of these markets require substantially larger amounts of noble metals than the ICT industry and product prices are markedly higher, with the result that buyers in these industries are able to pay the higher prices. However, from a different point of view, high prices could benefit the electrical and electronic equipment industry. EE products only use very small quantities of the vast majority of the metals, with the result that metal prices have a minimal effect on product prices (cf. Sullivan 2006 on the amount of noble metal contained in mobile telephones). From this perspective, strong competition for tantalum between producers of special steels and producers of carbide cutting tools, for example, could be relativised. However, a shortage of the metals needed in larger amounts for EE products – such as tantalum, zinc and tin – could have grave consequences for the industry. A further criterion that would be worth investigating is the pattern of use of the metals. Some uses are highly dissipative (e.g. zinc and indium as coatings for steel or the inclusion of the rare dopants). Recycling is practically impossible in these cases, meaning that product life cycles cannot come full circle. And some metals such as indium, gallium and germanium are not extracted as raw materials but are obtained as by-products. The closure of ore mines could thus lead to a shortage of these metals.

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[14] X = certain, X? = probable, ? = uncertain

2 The example of tantalum: significance, conflicts and value chain

2.1 The metal tantalum

2.1.1 Tantalum, tantalite and coltan

Tantalum is an element in the fifth group and the sixth period. It mainly occurs in the form of tantalite $(Fe(TaO_3)_2$. Other important tantalum minerals, of which around 70 are known, are microlite and wodginite. Unlike other minerals, the ores are very heterogeneous. Different ores of tantalum are described under the umbrella term tantalite, even though tantalite is actually a mineral in itself. Coltan is a columbite-tantalite ore containing niobium and tantalum.

Tantalum is mainly acquired in the form of tantalite, microlite and wodginite. Tin slag also contains significant amounts of tantalum, although these have become less important (BMWi 1999 and USGS 2000: Tantalum). Tantalum ores are found mainly in Australia, Brazil, Canada and central Africa. Unlike other tantalite ores, coltan is predominantly found on river beds, in sedimentary deposits and within soft rock. Extraction is not particularly technically demanding.

Its chemical properties are as follows: It has a high melting point (2,996^{o} C), it is hard but malleable and ductile, it is resistant to all acids other than hydrofluoric acid, it is also resistant to alkalis and corrosion and is highly conductive of heat and electricity.

The ores are usually concentrated on site via physical processes. The concentrate is then treated with hydrofluoric and sulphuric acid to separate the tantalum and the niobium and to solubilise the oxides. This extracts complex metal fluorides that can be separated from metallic impurities using methyl isobuthyl ketone. Different procedures can be used to extract extremely pure tantalum and niobium solutions, from which potassium tantalum fluoride (K_2TaF_7) or tantalum pentoxide (Ta_2O_5) can be extracted by separating out Nb_2O_5. The potassium salt can then be used to create tantalum metal powder through (liquid) sodium reduction. The metal can be created from the oxide through reduction with carbon or aluminium. As well as the tantalum powder and tantalum compounds, the most important metal intermediate products are tantalum wire, plate, bars and alloys.

2.1.2 Reserves and resources

Not much is known about supplies of tantalum ores. Increasing prospecting has shown, however, that tantalum reserves are probably greater than was believed a few years ago. In 1992 and 1996, for example, the BMWi estimated reserves at around 21,800 tonnes (BMWi 1999, p. 19). Today, however, the USGS believes that the largest deposits are in Australia (40,000 t reserves, 73,000 t reserve base, estimated 50% of global reserves), Brazil (73,000 t reserve base) and Canada (3,000 t reserves). There are also believed to be large reserves in Congo and possibly other central African states. There may also be reserves in Ethiopia, southern African states, south-east Asia and China (approx. 12% of global reserves) (Mosheim 2003, Sons of Gwalia 2001, USDI/USGS 2006, p. 166).

The remaining reserves are difficult to estimate, as tantalum is in demand for growth markets such as electronics and telecommunications. Reserves of tantalum based on production figures for 2000 should be sufficient to supply industry over the next 15 to 25 years (Serjak et al. 2003, Delzeit and Bleischwitz 2005, p. 329). According to other estimates, there are sufficient tantalum resources to last 125 years: 41% in Australia, 22% in Asia, 16% in America, 13% in Africa and 8% in other countries. These resources are not extractable under current economic conditions, however (Serjak et al. 2003). Due to imprecise knowledge about reserves (cf. USGS 2006: Tantalum), it is very difficult to make a reliable estimate.

2.1.3 End consumption

Tantalum is used for the manufacture of capacitors (tantalum powder and foil), for steel alloys (high-strength and temperature-stable, as well as bioneutral tantalum alloys) and cutting tools (tantalum carbide). In the United States around 60% of tantalum consumption is for the manufacture of capacitors (USGS 2006); the TIC states that the manufacture of tantalum powder for capacitors accounts for around 50% of tantalum consumption (TIC, no year specification.). 15% is used to make foil and tantalum wire for manufacturing capacitors. Around 10% is used in the form of chemicals (fluoride, oxide) and another 10% as tantalum carbide. Around 9% is used in tantalum bars and around 8% in various other forms. Tantalum capacitors are small, have a long life span, low energy consumption and are resistant to temperature fluctuations The capacitors are mainly used in mobile phones, computers, digital cameras, hearing aids, cardiac pacemakers and automotive electronics (ABS, GPS, ignition systems). The increasing trend towards miniaturisation is another significant factor driving the heightened demand for tantalum. Tantalum is also used as a metal and in alloys in products that need its resistance to high temperature and corrosive substances, as well as its bioneutrality. These include surgical instruments, spinnerets, heating coils for corrosive substances, special apparatus for the chemicals industry, medical implants, special glass with a high index of refraction (camera lenses with tantalum oxide), X-ray film, surface treatment of corrosive-resistant steel (for bridges, water containers), as well as high-vacuum technologies. Tantalum-tungsten steels are used in turbines because of their toughness and temperature stability.

2.1.4 Recycling and substitutes

The BMWi estimates the proportion of recycled tantalum at between 10 and 20% (BMWi 1999, p. 20). The TIC estimates these values at 20 to 25% (TIC, no year specification.). The low figures are due to the fact that tantalum is mainly used in (steel) alloys and in dissipative applications (capacitors). This makes targeted recycling (as is the case for copper) much more difficult. Large quantities of recycling material flows back to intermediary producers from end product manufacturers and microelectronics manufacturers.

Scrap is divided into “old scrap” (scrap from consumer goods) and “new scrap” (from capacitor processors). The international market leader in recycling is H.C. Starck (H.C. Starck 2002). Worldwide, around 20% of tantalum is recovered from recycling. The proportion of this gained from old scrap is very low and this resource has not yet been fully exploited (USGS 2002, USDI/USGS 2006: 166, Hayes & Burge 2003). To date, 90% of electronic and electrical devices in the EU are not pre-processed before being dumped in a landfill or incinerated – although this will change as a result of the Waste Electrical and Electronic Equipment (WEEE) Directive. The amount of tantalum in electrical devices is negligible. The percentage of tantalum in a PC, for example, is 0.0157% of the total weight (ACCR, no year specification). Nevertheless, the recycling of tantalum plays an important role in the supply chain (ARCC 2003). Because electrical devices account for 68% of tantalum consumption, potential definitely exists for recycling old scrap. In practice, however, many electrical devices (including mobile phones) are broken up mechanically and the tantalum is either atomised or lost in other ways. Recycling would therefore require considerably improved precision engineering. In China – according to a statement made at the workshop on 30 November 2006 – better recycling rates are achieved using manual processing techniques.

Depending on usage, tantalum can be substituted with other metals, even if their specific properties are not exactly the same. It could be substituted with niobium for the manufacture of carbides (cutting tools), with niobium and aluminium to make capacitors, with niobium, platinum, titanium and zirconium in corrosion-resistant devices, and with niobium, hafnium, iridium, molybdenum, rhenium and tungsten in high-temperature applications (USGS 2006: Tantalum).

2.2 The tantalum and coltan value chain

The value chain for coltan, tantalite, microlite and wodginite begins with the extraction of tantalum by mining corporations, companies and other mining agents. They then sell the ore to intermediate product manufacturers. When the material has been processed to create intermediate products, it is mainly sold in the form of tantalum powder to capacitor manufacturers, who sell the finished tantalum capacitors to suppliers via intermediaries or subcontractors. Industrial demand comes mainly from the areas of automotive electronics, PCs, optics and telecommunications. Only a small proportion of the tantalum value chain comes from recycling of capacitor scrap by intermediate product manufacturers or suppliers (worldwide around 20%). The following sections will describe the relevant links in the value chain.

2.2.1 Supply and extraction of tantalum worldwide

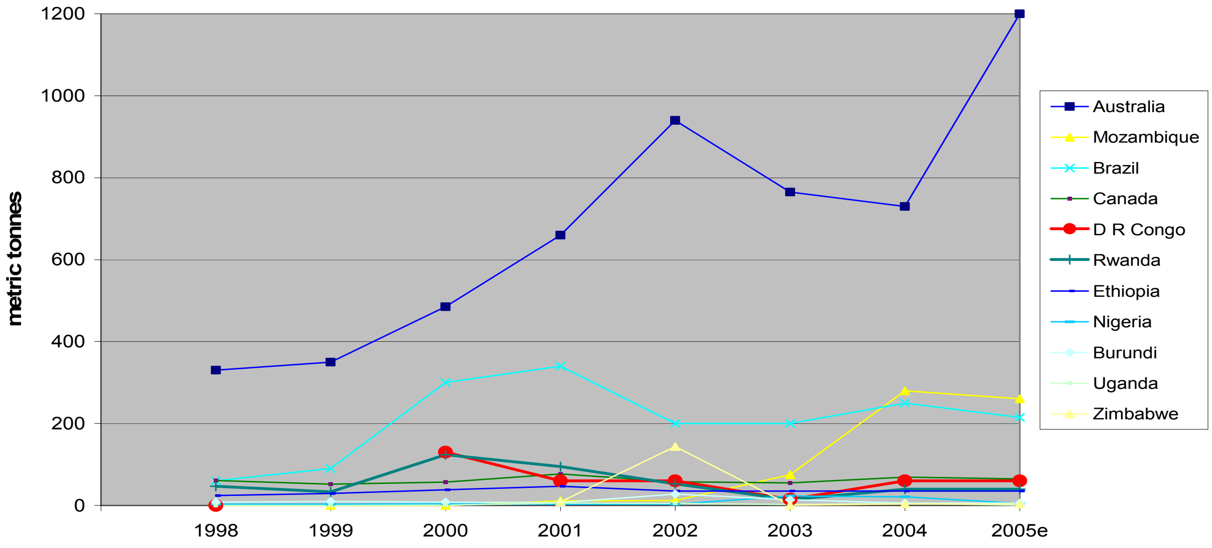
Mine production of tantalum has risen continuously in recent years. In 1996 production was 436 t (USGS 2000: Tantalum, p. 10), while in 2000 it was 1,070 t, and in 2004 it was 1,510 t (USGS 2000 and 2004: Tantalum, including columbite-tantalite and tantalite). According to the USGS, production for 2005 is estimated at 1,910 t (USGS 2006: Tantalum).

The tantalum market is very transparent as far as mining production and the manufacture of intermediate products is concerned. Mining is dominated by Sons of Gwalia (Australia), Cia. De Estanho Minas Brasil, Paranapanema Mineracao (both Brazil) and Tantalum Mining (Canada). In 2003, two Sons of Gwalia mines in Australia were responsible for around 50% of global production (TIC, no year specification). Since 1998, they have increased their production threefold. Estimates show that in 2005 around 63% of all tantalum came from the two Australian mines. With an 8% share of worldwide extraction in 2005, Brazil is the second largest production country and home to the third biggest mine (cf. Figure 3).

In 1997, China produced 9% of the tantalum extracted worldwide. In 2001 it produced 6%, of which a quarter was exported (Hayes & Burdge 2003). The production data for African countries show that the Democratic Republic of Congo had an 11.3% share of global tantalum production in 2000, making it the third biggest producer. The annual figures have pronounced fluctuations which reflect the impact of the wars and the supply gap. In 1998: 0 t; 1999: no data; 2000: 130 t; relatively stable since then at 60 t (cf.Figure 3). Since 2003, increased extraction quantities have been reported for Mozambique, which has now overtaken the Democratic Republic of Congo as a major producer. Total extraction in central Africa is slightly more than that in Brazil. It is difficult to gauge the reliability of the information from Africa. Due to small-scale mining conditions, open borders, war and poor transportation infrastructure, illegal trade cannot be ruled out.

Over the years, the origin of worldwide supply has shifted to smaller suppliers and between Brazil and Zimbabwe. Australia remains the most important producer of tantalum. It increased production of columbite-tantalite from 276 t in 1996 to 485 t in 2000 and 730 t in 2004. In 1996, Congo was the second largest producer with 130 t of columbite-tantalite mined, but production fell continuously until it hit 15 t in 2003, rising to 60 t again in 2004. Other important producers were Ethiopia (38 t of tantalite in 1996, 39 t in 2000 and 35 t in 2004), Brazil (90 t of columbite-tantalite in 1996, 190 in 2000 and 250 t in 2004), Canada (57 to 60 t of tantalite between 1996 and 2004) and Mozambique (180 t in 2002 and 280 t in 2004). Rwanda produced 26 t in 1996, 124 t in 2000 and 40 t in 2004. In summary, we can establish that Australia, Brazil and Mozambique are the largest producers of tantalite ores and that central African providers in general have a great significance. Small fluctuations in supply[15] have already had repercussions on the markets. Congo, Rwanda, Burundi and Uganda were particularly inconsistent. Their share of production was around 27% in 2000, yet only 7% in 2004. No data is available for Congo in 1996.

Figure 3: Tantalum extraction by country 1998-2005e



Source: U.S. Geological Survey, Niobium (Columbium) and Tantalum Statistics and Information 1997-2006

The price of tantalite has proved relatively unsteady over recent years (cf. Figure 2. In 1996, the price per lb of tantalite was US$28, rising only moderately until 1999 to US$34. In 2000, it reached an all-time high of US$220, dropping again quickly in the following years to just US$32 in 2004 (USGS 2000 and 2004: Tantalum). There have been three short-term peaks over the past 30 years. Apart from the peak in 2000, the price over the last decade has remained at around US$ 28 – 32 per lb.

2.2.2 The market for tantalum: development and trends

Fewer than 15 companies operate at the intermediate manufacturer level, manufacturing mainly tantalum oxide, tantalum metal (alloys, wire, plate, bars), tantalum carbide, tantalum powder for capacitors and potassium salts from tantalum. The intermediate manufacturer in Germany is HC Stark (largest manufacturer of intermediate products). H.C. Stark, a 100% subsidiary of Bayer AG until December 2006, has locations in Germany, the United States, Japan and Thailand. The No. 2 on the global market is Cabot Corporation, which has subsidiaries in the United States and Japan. Together, these two producers cover more than 80% of the market. Ningxia NFM is the third largest processing company and is based in China. According to *MiningNews 2002*, the company accounted for 18% of global tantalum powder production – 200 t every year and 40% of the tantalum wire (Tubby 2003). These three companies almost entirely cover the market. Some other traders also operate on the tantalum market. Traders had an important role during the period of steeply rising prices, when they bought up tantalum and speculated on rising prices. While their influence was not dominant, they did make it difficult to obtain a clear view of the market.

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[15] At the workshop in Berlin on 30 November 2006, a fluctuation rate of 5% was defined as “relevant”.

The tantalum market is not open. The most important producers of raw tantalum (mining) have long-term contracts with intermediate product manufacturers (Delzeit & Bleischwitz 2005). Only price and demand fluctuations are settled on the spot market. Tantalum production is thus characterised by the relationship between raw material producers and intermediate product manufacturers rather than by a true market based on supply and demand (Bleischwitz 2006, p. 311). These contracts also include manufacturers of final products who have agreed “take or pay” contracts with intermediate product manufacturers. The high price period in 1999/2000 created a strong incentive to agree long-term contracts. Overall, central Africa only supplies a small quantity of tantalum ore. Due to the insecure supply conditions, this is mainly sold on the spot market. It is possible that it comes from illegal extraction from Congo (TIC, no year specification).

Above all, the demand for coltan depends on demand from the electronics industry. Since 1992, demand for tantalum has grown annually at an average rate of 10%, with a peak in 2002 based on increased demand for products such as mobile phones and laptops. In 1999/2000, capacitor manufacturers were not able to meet demand for tantalum capacitors (Serjak, Seyeda & Cymorek 2002). This shortage was not caused by the ore supply gap, but by bottlenecks, media reports and the ensuing speculator rush (Delzeit & Bleischwitz 2005). At that time, the price of tantalum was still determined mainly on a transactional basis (Hunziker 2002). Double orders were placed and the market reacted with panic. Speculators were able to buy up tantalum, wait for higher prices, and then sell the tantalum again (Serjak, Seyeda, Cymorek 2002). During the high price phase of 1999/2000, the price per lb for tantalum increased six-fold from US$34 in 1998 and 1999 to US$220 in 2000. This price explosion can only be explained by speculation.

Capacitor manufacturers reacted to the price explosion by taking out long-term minimum purchase contracts with mining companies (Serjak, Seyeda, Cymorek 2003). After initial signs of relaxation, supplies were sold (e.g. US stockpiles), relaxing the market further. In the meantime the price has returned to $30 (USDI/USGS 2006).

The future tantalum market will also be determined by the growth of the electronics sector, as well as by the optics industry. Demand is still expected to increase, but as capacitors are becoming smaller, we can assume that the growth in tantalum consumption will be less than the growth in capacitor manufacture.

During the high price period from 1998 – 2000, smaller mines in Canada and the Democratic Republic of Congo (DRC) acted as a buffer for the global market (cf. Figure 3). In the DRC, this exacerbated the conflicts. Research continues into whether these conflicts are “wars over resources” and how significant a role resources play in the many years of conflict around the Great Lakes region of Central Africa (Billon 2004, Dunn 2005). These interrelationships are explained in greater detail in the following sections.

2.3 Coltan extraction in Congo

The Democratic Republic of Congo is a country rich in resources. It has significant reserves of cobalt and copper, among other materials. The Raw Materials Group, a major consultant in the field, ranks the DRC as the one of the six most resource-rich countries in the world[16]. Around 80% of Africa’s tantalum reserves can be found in the DRC, in the form of columbite-tantalite (coltan). Due to the relatively simple extraction conditions and geographical distribution, coltan is characterised as “easy” to extract (Billon 2004). Partly due to the richness of its resources in gold, diamonds, cobalt, coltan

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[16] Personal information from Magnus Ericsson, cf. Bleischwitz 2006, p. 305.

and wood, this politically unstable country has long been plagued by wars, depredation and illegal exploitation. There are several different explanations on the origins of the conflicts in the Great Lakes region (Dunn 2005). These will be looked at more closely within the context of coltan extraction.

When tantalum prices and therefore the price of coltan rose sharply, coltan was exported via neighbouring countries that were cooperating with rebel groups (United Nations 2001). In order to shed more light on the situation, we will first provide a brief overview of the political events in the DRC in order to subsequently analyse the global context and regional consequences of coltan extraction.

2.3.1 The political situation in Congo

The last “Congolese war” is closely tied to historical conflicts in the Great Lakes region. To describe its nature and origins, Dunn (2005) divides the conflict’s causes into two dynamics which operate at local, regional and global level:

- discursive (identity, power) and
- material (profits)

These dynamics are interwoven, making it impossible to name a single, separate reason for the conflict. One of the origins, the trade in coltan in the DRC, was and remains dependent upon the political situation. After gaining independence from Belgium in 1960, followed by five years of political unrest under the Marxists, the country was led by Joseph-Désiré Mobutu until 1997. He was finally overthrown by rebels from the east of the country, supported by Rwanda and Uganda. The leader of the rebels, Laurent-Désiré Kabila, declared himself president. He, in turn, was murdered in 2001, and his son became the new leader of a split government. After his first year in government, DRC’s relations cooled with the international community, as well as with its regional allies Rwanda and Uganda (Dunn 2005). There were also many social tensions and some hostility between different provinces. Allied with Angola, Namibia and Zimbabwe, the DRC fought against rebels supported by the governments of Rwanda, Burundi and Uganda. These countries have had a military presence on Congolese territory since 1998 and control large areas of the country (Speiser 2001). In March 2003 a ceasefire agreement was signed between rebel groups and the Congolese government (United Nations Security Council 2003).

The current situation, however, is extremely unstable. The first democratic elections for 40 years were conducted in August 2006 (the German army was involved in providing security for the elections). However, no presidential candidate achieved a majority. This led to a second ballot on 29 October 2006 between two candidates – the incumbent president Kabila (44.81%) and his vice president Bemba (20.03%) – which was won by Kabila (United Nations Security Council 2006, p. 4). Legal uncertainties about access to resources remain. Direct foreign investment (from China and other countries) has also increased.

2.3.2 Coltan extraction

The connection between the considerable price increase for tantalum and the Congolese conflict is described by E. Kennes as follows: “A temporary shortage of colombo-tantalite had to be filled by any means, including buying coltan from the network of artisanal diggers controlled by armed forces. Whenever the companies had the opportunity for a regular and steady flow of production elsewhere, they turned away from the Congo” (Kennes 2002, p. 605).

Illegal extraction of coltan

There is no reliable data on coltan extraction in the DRC. Because this study is based exclusively on literature, we have to rely on data and information from UN reports, statistics from the US Geological Survey or different NGO reports. Some of the mining areas in the DRC are in the rainforest region[17].

In the DRC, landowners are legally required to have a license to extract minerals. This law was broken during the wars, however (Redmond 2001). In some places, rebel groups issued licenses and profited from this (see below). In others, the legitimacy of the license issuing offices was unclear. These legal uncertainties have been a fount of illegal activity. Ross (2004) divides the conflicts (around coltan) in the DRC into two phases.

1. In the first phase, the AFDL (Alliance des Forces Démocratiques pour la Libération du Congo) under Kabila used money from the sale of future extraction and property rights to finance the overthrow of the Mobuto government in 1997, leading to a more rapid conclusion to the conflict. From the end of 1996, the AFDL rebel group, supported by Uganda and Rwanda, was also being aided by many foreign companies (Billon 2004).
2. By contrast, the second phase of the war from 1997/98 was extended and intensified by illegal exploitation by rebel groups and neighbouring enemy nations. Here, official administrative bodies that had been implemented by the Mobutu government were used to sell licenses and raise export taxes.

From 1998 to 2003 there were three separate areas which were controlled by the government of the DRC, Rwanda and Uganda (United Nations Security Council 2002). For example, the local Mayi-Mayi rebel group was able to transform itself from a self-defence paramilitary group into a self-serving criminal organisation (Billon 2004). In November 2000, the new company SOMGIL (Société Minière des Grands Lacs) was granted a monopoly from the RCD-Goma rebel group to regulate trade and maximise profits (Haynes 2002). The monopoly was kept in place until March 2001 and ended when the administration of RCD-Goma retained most of the profits. According to reports from the International Peace Information Service, it is possible that RCD-Goma earned US$2.35 million in these three months (Cuvelier & Raeymaekers 2002).

The data from the USGS show a significant increase in exports from Rwanda and the DRC during the high price period. However, there is no credible, precise data for this period. The expert panel of the UN Security Council has identified the following interrelationships:

Sixty to 70% of the coltan was exported under the supervision of the Rwandan Patriotic Army (RPA). *Comptoirs*, small traders based in Rwandan territory, exported 15-25% of the total coltan exported. They bought the ore from local *négoriants* (small-scale miners) or ran their own mines where miners worked in poor conditions. The smallest share of coltan exports came from Congolese *comptoirs*. There were very few left, as they could not compete with the mines owned by the RPA or Rwanda (United Nations Security Council 2002). Traditional traders such as MDM (Mudekereza-Defays-Minérais), at that time owned by a Congolese businessman and a Belgian expatriate, were driven out of the market.

The conflict has had far-reaching effects on the population, environment and structure of the country. The number of people killed during the conflict in the DRC from 1998 – 2004 is estimated at 3.9 million (Coghlan et al. 2006).

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[17] See below for information on the activities of the Dian Fossey Fund.

United Nations intervention

In February 2000, the United Nations Security Council used Resolution 1291 to form a peacekeeping force (MONUC) to observe the peace process after the second Congolese war. In June 2000, the Security Council established an expert panel on the illegal exploitation of natural resources and other riches in the DRC. The panel's purpose was to compile reports monitoring the situation and to gain information on all activities related to illegal exploitation. Another task was to research and analyse the links between the exploitation and the continuation of the conflict, in order to present the Security Council with recommendations.

From 2001-2003, the panel composed several reports and interim reports[18]. The first four came to the following conclusions:

- The conflict has a strong resource-driven element
- The extraction and trading of coltan was carried out illegally between neighbouring countries and allied rebel groups
- Trade relationships existed
- Eighty-five individuals and companies were accused of breaking OECD guidelines for multinational enterprises (report: October 2002)
- Seventy other individuals and companies were accused of breaking international ethical standards

The report from October 2002 was the subject of some controversy (Global Witness 2004). The final report of October 2003 thus dealt mostly with the reactions to the previous report, verifying, reinforcing and updating previous conclusions. Companies and individuals were divided into five groups according to level of awareness and handling of the accusations, effectively shifting the burden of proof to the national contact points for the OECD guidelines (Global Witness 2004, see Chapter 3.2.3).

Coltan extraction and German companies

The 2002 report accused the European states Belgium, France, Germany, the Netherlands, and the United Kingdom of breaking the OECD guidelines for multinational enterprises. Five German companies were named:

- Bayer AG
- H.C. Starck GmbH & Co KG
- KHA International AG
- Masingiro GmbH
- SLC GERMANY GmbH

Bayer AG, or rather its subsidiary, the capacitor manufacturer *H.C. Starck*, was accused of taking 15% of the coltan from the airline Eagle Wings. H.C. Starck denied these accusations and issued a press release to the effect that it had not accepted any coltan from central Africa since August 2001, stating that none of its resources came from "rural suppliers" or rebel groups (United Nations Security Council 2002, H.C Starck 2002). According to a statement at the workshop on 30 November 2006, the company had been surprised by the accusation and first had to verify whether materials had been sourced from this region. The panel's report also covered the falsification of documents from the

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[18] List of reports: Interim Report, 16 January 2001 (S/2001/49); Report, 12 April 2001 (S/2001/357); Addendum Report, 13 November 2001 (S/2001/1072); Interim Report, 22 May 2002 (S/2002/565); Report, 16 October 2002 (S/2002/1146); Addendum, 20 June 2003 (S/2002/1146/Add. I); Report, 23 October 2003 (S/2003/1027)

Mozambiquan Gemstone Company, which declared Rwandan coltan as coming from Mozambique, and then sold it to the H.C. Starck branch in Thailand via South Africa. The case was categorised in the report as "unresolved cases referred to NCP for updating or investigation" (United Nations Security Council 2003, Annex I). After inspection of documents and interviews, the allegations of the UN panel could no longer be maintained and the company was assigned to the group of solved cases (United Nations Security Council 2003). During the 44th session of the German parliamentary committee for human rights and humanitarian aid (Deutscher Bundestag 2004), the Starck case was discussed alongside the issue of lack of awareness about the conflict and the problem of transparency and tracking of coltan. There has been no inquiry validated by independent experts. According to a statement at the workshop on 30 November, HC Starck requires that all of its suppliers provide statutory declarations that they have not procured illegal coltan or coltan from the Democratic Republic of Congo. Because of fierce competition on the global market and the fact that Chinese providers, in particular, can import coltan from the DRC under favourable conditions, the company complains that it is suffering as a result of distorted competition.

KHA International AG is active in the area of mineral trading and extraction. Among others, it manages the company *Masingiro GmbH,* which has now declared itself bankrupt. The director Karl Heinz Albers[19] was the director of SOMIKIVU mine for several years, a company that was guarded by RCD-Goma rebels (Cuvelier & Raeymaekers 2002: 19) and – according to unconfirmed reports – he was formerly a geologist at H.C. Starck (Netzwerk Regenbogen 2003). The UN panel accuses the company of indulging in business for profit with no consideration of legal infringements (United Nations Security Council 2001, § 184 b and Annex 1). There have been various public reactions to the UN panel's allegations (RAID 2004, p. 11) and the manager Heinz Albers also made a statement to the *Financial Times Deutschland* (Förster 2001). He explained that he had delivered around 50 tonnes of coltan from the DRC per month to the three big processors (H.C. Starck, Cabot Corporation and Ningxia). He denied having received money from the German Embassy for the extension of SOMIKIVU activities, and claimed to have been close to the Kabila government (Förster 2001). The final report from the UN panel places the companies Masingiro GmbH and KHA International AG together in category III, "unsolved cases to be monitored and updated by the national contact points for the OECD guidelines". In Germany, this contact point is subordinate to the Federal Ministry of Economics and Technology. There is insufficient information on the contact point's approach to its monitoring function (cf. Chapters 3.2.3 and 3.2.4).

SLC Germany GmbH operated in the area of coltan transportation. The German subsidiary of Systems Lifecycle Pvt. Ltd. (SLC) GmbH was incorporated in November 2003 (SLC 2006). No information on SLC Germany before this time could be found. Systems Lifecycle Pvt. Ltd. (SLC) was founded in November 2001 and comprises software specialists from large corporations like Siemens, Xerox and

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[19] According to press reports (various issues of *die Tageszeitung (TAZ)*, 2006), Karl Heinz Albers has been active in Congo for years as a trader of raw materials. From 2000 to 2004 he owned a mine in Lueshe in eastern Congo. Exports were carried out via the trading company NMC (Niobium Mining Company), which also belonged to him. The mine had previously been run by the Nürnberger Gesellschaft für Elekrometallurgie (GfE) in a joint venture with the state of Zaire from 1983 until its closure in 1993. Heavily in debt, Mr. Albers resigned in 2004, spent a short period in prison in Goma and his whereabouts are currently unknown. He was charged in Germany with genocide by the Austrian construction magnate Michael Krall, who now has extraction rights. German shareholders are currently contesting ownership of the mine in Lueshe with Krall Metal Kongo (2006), as President Kabila had promised the mine to Krall in 1999.The rights were, however, assigned to SOMIKIVU by the all-party government in 2004, as contracts assigned during the war were declared invalid. In 2005, the rights were given to Krall again by the Ministry of Mining. The Ministry of Mining, however, claims that the decree is a forgery. It is unclear whether a share of 70% belongs to the GfE or to the federal government. According to *TAZ*, the Congolese government complains that it has no contact person in Germany. Recent press reports (September 2006) claim that Heinz Albers has formed a joint venture "Niobium Resources B.V" with the director of the Austrian company Treibacher Industrie AG, Dr. Reinhard Iro (*akin-Pressedienst* 2006, *KSV* 2006).

IBM (SLC 2006). The UN panel of experts has placed SLC Germany GmbH in category IV, “pending government investigation”. Public reactions are not known (Cuvelier & Raeymaekers 2002, p. 11).

Another German company that may have been involved in the Congolese conflict is named in *die tageszeitung* as Barter Trade Handels- und Seafood GmbH (Johnson 2001). It is alleged to have procured tantalum via its joint venture in the Ugandan fish sector, and then sold it in Germany (Johnson 2001).

2.4 Initial conclusions

The conflict surrounding illegal coltan extraction in Congo coincided with a phase of high prices and rising global demand for coltan from the DRC between 1999 and 2000. The role played by the DRC in global markets was never particularly large, and has further declined in significance since 2000. The rare metal tantalum, however, contributed to an intensification and extension of the conflict there. At various times and depending on the prevailing balance of power, it served to enrich the respective governments, rebels and neighbouring countries. Though the causes and effects of the conflict are manifold, resources are not themselves a cause but rather a catalyst.

Existing policies, international protest and a high level of public awareness have been unsuccessful in stopping illegal trade involving corporations from OECD countries. One German corporation involved (H.C. Starck) is a subsidiary of a stock-exchange-listed concern (Bayer AG) and a supplier to a stock-exchange-listed telecommunications firms. Companies listed on the stock exchange are more sensitive to external criticism, being obligated to deal immediately with reputational risks. In general, the case study indicated a need for action across the entire value chain:

a) The DRC is one of the six resource-richest developing countries in the world (in terms of mineral resource reserves, Bleischwitz 2006, p. 305). Dialogue on the sustainable extraction and utilisation of resources is thus of central importance. With the end of the war – hopefully– in sight, the federal government could take over leadership of an *initiative for an international conference* dedicated to the issue of sustainable extraction and use of resources for the economic future of the DRC. The Petersberg Conference on Afghanistan could serve as a model.

b) The international community and donor countries should assist the DRC in negotiating *fair agreements* on access to, extraction of and trade in its resources in order to:

   - curb and expose illegal mining activity, and
   - promote compliance with environmental and social standards

   thus promoting *capacity building*, which includes education as well as staff and organisational development. This may take the form of an international initiative to improve extraction and production conditions generally in similarly positioned LDCs. The exports of other African countries should be considered here.

c) Foreign investors (mining companies) are sometimes forced to operate in highly unstable “failing states”. The observance of laws and international standards *(corporate social responsibility, cf. Chapter 3.2.2)* should thus be a major priority. This includes combating corruption (*publish what you pay, extractive industries transparency initiative*) and compliance with environmental standards. The OECD guidelines for multinational enterprises and the Global Reporting initiative are key international policy elements, the enforcement and further enhancement of which are central international sustainability policy concerns.

d) Because illegal export and trade are impossible without the involvement of international corporations, dealers and transporters, the *conduct of such entities should be subject to scrutiny.*

Violations of international standards and agreements should be publicised and sanctioned. Dealers and intermediate goods manufacturers should feel responsible for creating better market transparency and information flows within the supply chain. Intermediate processors, of which there are a manageable number, should implement voluntary disclosure of information.

e) On an end-product level, the potential for introducing *certified products* ("fair trade", cf. Marine Stewardship Council, Forestry Stewardship Council) should be reviewed. Although it has not yet been possible to launch a "Durban Process" for coltan modelled after the Kimberley Process for diamond certification, this would be very helpful in increasing awareness and demand. As a primary product, rare metals require pre-processing. Additionally, the recyclability of rare metals should be considered in the light of the WEEE regulations.

UN Security Council reports have provided new information on the situation in Congo and on its relationships with foreign firms. Though sharp criticism of some companies was probably largely undeserved, the discussion has nonetheless led to action on the part of European firms to increase market transparency. The information centre TIC has become involved, albeit without taking an active role. These events have shown that transparency can help stem illegal trade with rare minerals, thus reducing the potential for conflicts.

At present it is still too early to speak of any resolution of the conflict, as the situation in the DRC remains tense. The legal situation in the mining territories is cloudy, and no reliable information is available on the amount of direct investment, which is currently increasing. The overall increase in mining and export activity among central African nations requires in-depth analysis. On the demand side, the role of new industrial buyers (optics industry) and non-OECD developing nations (China) must be regarded critically.

With some generalisation one may conclude that modern industries are dependent upon access to rare metals. Access is not solely a matter of geography and technology, but also of legal and political conditions. Another crisis could arise at any time, affecting global markets, exacerbating regional conflicts and directly or indirectly involving corporations from OECD countries.

3 Approaches and concepts for conflict avoiding resource extraction

3.1 Introduction: key concepts and approaches

Since the end of the 1990s, academic discussion and civil campaigns have focused on the economic dimensions of conflicts and the particular role played therein by large multinational mining concerns. The exploitation of natural resources, the basic line of argumentation goes, frequently serves to finance wars, corrupt regimes and military combatants as well as promoting illegal trade in the goods being fought over. In a study conducted for the World Bank, Paul Collier pointed out a connection between natural resource exploitation and the incidence of armed conflicts (Collier and Hoeffler 2001). Although "the precise relationship between resource extraction and the incidence of armed conflicts […] is not conclusively established" (Rittberger, 2004, p. 18), the latest research indicates that highly resource-dependent nations are at particularly high risk of armed conflicts. However, the risk of conflict is not identical for all resources. Resources such as diamonds or coltan, deposits of which can be "plundered" with little technological and logistical effort, are more associated with non-separatist conflicts and seem to extend the duration of existing conflicts. Rebel groups have less incentive to end conflicts due to the profitability of exploiting these resources. "Non-plunderable" resources such as oil and gas, on the other hand, are more associated with separatist conflicts, often caused by insufficient state distribution of extraction profits (cf. Ballentine and Sherman 2003;

Buhaug et al. 2003; Feil et al. 2005; Le Billion 2001 and 2003; Rittberger 2004; Renner 2002; Ross 2003).

Research thus far has indicated that the type of governance in countries where resources are located, industry-specific factors (Rader and Sabater, 2006) and company-specific factors (Ballentine and Nitschke, 2004) play an important role in the escalation or de-escalation of conflicts alongside the (physical) characteristics of resource deposits. It is thus only logical that concepts and measures to make resource extraction less likely to provoke conflict have thus far only been developed in relation to specific resources and industry and company-specific factors.

A brief presentation of a number of relevant measures and concepts addressing the problem of resource extraction and conflict escalation is provided below. It is not intended as an exhaustive discussion. In line with the submission guidelines of the German Federal Environment Agency (FKZ: Z 6 – 363 01 124), this chapter is organised to present approaches from the perspective of the various relevant players, namely the business sector, government, NGOs and academic research. The selection of approaches discussed conforms with the Federal Environment Agency's dual thematic focus on rare minerals in areas of conflict – particularly coltan from the Democratic Republic of Congo – and on the information and communications technology (ICT) industry. So far there have been no hard mechanisms or initiatives meeting all three criteria – addressing rare resources which are relevant to the ICT industry and come from conflict areas. This brief study of very limited scope approaches the topic from these three different angles, firstly by identifying ICT industry approaches to the coltan problem. There follows a presentation of a number of policies and initiatives addressing factors which are indirectly conflict-related (such as transparency) and a sketch of the role of the private sector in relation to coltan or to other resources and rare minerals. In the concluding section, a number of individual proposals are discussed that have not yet been concretely implemented, potentially offering a conceptual framework for concrete measures[20]. In this tri-perspectival approach we have selected those proposals coming closest to the crux of the issue. No claim is made to provide a comprehensive overview of the various initiatives or a systematic analysis of the potential effectiveness of these. As intended, this brief study is conducted on the exclusive basis of publicly accessible documents and information, including significant publications, position papers and potential solutions issued by governmental and private-sector organisations, NGOs and public-private initiatives.

3.2 Concepts and approaches advanced by various players

3.2.1 Public sector

The United Nations (UN)

The UN has contributed substantially toward achieving broad public awareness of the problem of illegal resource extraction in the Democratic Republic of Congo by appointing a panel of experts to investigate the role played by coltan extraction and trade in armed conflicts in eastern Congo. Over the years, Security Council experts have discussed a variety of positions and proposals, calling in 2001 for an embargo on coltan and other resources from the Democratic Republic of Congo, among other measures. Additionally, sanctions against individuals and companies involved in the exploitation of

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[20] For this brief study we have elected against providing a more detailed look at generalised approaches indirectly related to conflicts, such as corruption/transparency and human rights, for a number of reasons. Firstly, the idea was to maintain the thematic connection to the European Resource Strategy prescribed in the call for submissions, and secondly, opinions on the effectiveness of indirect approaches to reducing conflict vary widely. The impact of such approaches on the conflict may only be verifiable with regard to individual cases, if at all. Similarly, no legal discussion on conflicts is provided other than as directly pertains to flows of resources and materials. Le Billon et al. (2002) recently published an analysis of such thematically-related legal issues such as the prevalence of small firearms.

resources helped stem the unchecked plundering of Congolese resources (UN Security Council 2001). In the years following, OECD member states were called upon to implement OECD guidelines. The UN experts then called for the introduction of standards regulating the mining industry in the DRC. This shifted the focus to the regulation of resource extraction. Furthermore, high transparency standards and monitoring procedures (enhanced traceability systems) were designed to help regulate the trade in resources in the region (UN Security Council 2001-2004). The Security Council also recommended establishing a certification system for valuable minerals. These and other measures for stabilising the Democratic Republic of Congo and its neighbours are to be discussed at an international conference (UN Security Council 2006).

The Global Compact is an initiative created as part of the UN system for addressing the issues of the conflict-exacerbating effect of resource exploitation. It has potentially far-reaching impact but has only a very indirect effect in concrete cases[21]. The Global Compact was launched in 1999 in response to a speech by Kofi Annan at the Global Economic Forum in Davos. Forty corporations took part in the high-level meeting held on 26 July 2001 in New York. It included eight prominent German corporations operating multi-nationally. A tenth principle of transparency was later added to the original nine concerning the environment, human rights and minimum social standards. Now over 1,000 firms have joined the initiative, including Deutsche Telekom (since 2000), Bayer AG (2000), Siemens AG (2003) and Infineon Technologies AG (2004), along with numerous non-profitmaking organisations such as *Amnesty International*, *World Wide Fund for Nature* and the *International Confederation of Free Trade Unions*.

The UN Global Compact is a voluntary agreement binding upon all parties subscribing to it (primarily companies). Instead of a clear-cut system of monitoring and sanctions, the Global Compact functions by praising corporate best practices which fulfil the principles. Given the Global Compact's mission to be a platform for dialogue and a forum for learning, no concrete mechanisms will be forthcoming in the future. Global Compact signatories hold an annual discussion on a different topic each year. The German government nominated the initial policy dialogue topic, "The Role of Corporations in Conflict Areas" but this area is no longer being actively pursued by the Global Compact.

European Union (EU)

EU Commission

In 2001 the EU reviewed the results and proposals of the expert panel on the illegal exploitation of natural resources in the DRC (UN 2001) and announced its approval for extension of the mandate (EU 2001). However, that was all it did. While the EU Commission's DRC strategy paper for 2003 to 2007 mentioned that the panel's follow-up report presented in October of 2002 (UN 2002) provoked international reactions (EU 2003, p. 16), these were not referred to in a Council press release. Nor was there any mention of the recommended embargo against states implicated.

On balance, coltan did not play a major role in EU policy towards the DRC, being regarded as only one of many resources serving to finance the various different armed contingents (cf. EU 2006, 2003). The EU approach focused on restoring law and order, combating corruption and reforming the security sector. The plan was to thereby enable the DRC to fight illegal coltan mining over the medium term and deal with the consequences of doing so on its own.[22]

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[21] Feil et al. (2005) provide a more comprehensive view and analysis of the Global Compact.

[22] Interview with a representative of the European Commission Directorate General for Development, 10 November 2006, Brussels.

The strategy for the sustainable utilisation of natural resources (shortened: "Strategy", KOM (2005) 670) has not thus far directly dealt with the issue of the social and political impact of resource extraction in developing countries and fragile states. With an eye fixed firmly on sustainability, "the Strategy […] emphasises that environmental considerations must be incorporated into other political fields such as the exploitation of natural resources" (EU 2005, p. 4). The idea is thus to integrate environmental and sustainability objectives into other policy realms without advancing any specific approaches to resolving resource extraction and conflict escalation or other general socio-political problems in developing countries involved in resource extraction. The strategic goal of decoupling economic growth from the use of natural resources (see EU 2005, p. 7) could, however, have an indirect effect on EU demand for conflict-fuelling resources.

EU Parliament

In July 2001 the EU Parliament (EP) issued its first-ever joint resolution condemning the illegal use of natural resources in the Democratic Republic of Congo. In January 2003 the Parliament published its most detailed position paper on the topic to date, calling the fight over resources the main reason for the war in Congo. The EP stated that the exploitation of resources has had grave effects on the country's eco-system, accelerating deforestation, and that European corporations were involved in the exploitation of these resources. The Parliament pronounced itself in favour of the creation of a binding European legal framework regulating the responsibilities of European corporations operating in third countries. Member states were encouraged to implement legislation to penalise corporations involved in the exploitation of resources in Congo, and the EP called on the UN Security Council to bring sanctions against individuals and companies involved (EU Parliament 2001a/b, 2003). In the years following, the humanitarian situation, peacekeeping and deployment of EU troops in the Democratic Republic of Congo claimed the interest of the EU Parliament, forcing the topic of resource extraction temporarily into the background.

Organisation for Economic Cooperation and Development (OECD)

The OECD guidelines on multinational enterprises[23] represent a tool ostensibly designed to prevent OECD entities from involvement in conflict-exacerbating resource extraction. However, the UN panel of experts on Congo called attention to the poor level of implementation of the guidelines, pointing out guideline violations by 85 individuals and companies (cf. Chapter 2.3.2). As implementation of and compliance with guidelines is controlled by OECD member states, so-called "national contact points" (contact individuals)[24] address such violations, issuing statements as necessary. Austria, Belgium and France in particular have taken steps to target companies from their respective countries named in the UN report. In the case of one Belgian timber firm this involved the contact point issuing a press announcement (OECD 2006a, p. 15-16).[25] Issuing such press announcements is currently the only option contact points have for publicly responding to violations.

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[23] Cf. footnote 21.

[24] The German OECD contact is at the Federal Ministry of Economics and Technology and is part of a working group on OECD policy, collaborating with the Federal Foreign Office, the Federal Ministry of Justice, the Federal Ministry of Finance, the Federal Ministry for Economic Cooperation and Development, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety as well as with industry associations, unions and select non-governmental organisations (cf. OECD 2006a p.24).

[25] A mining-sector incident in the Democratic Republic of Congo in which a German company and another mining operator were involved was handled by the Austrian contact individual, thus far leading to no conclusive result (OECD 2006a pp. 15-16).

The OECD is now engaged in efforts to promote efficiency, transparency and on-time implementation of policies, convening a contact point meeting to this effect in September 2006 (OECD 2006a).[26] Also, in June 2006 the *OECD Risk Awareness Tool for Multinational Enterprises in Weak Governance Zones* was adopted, aimed at providing concrete operational assistance to businesses active in countries whose problematic governmental structures could pose ethical and other risks for companies operating there (OECD 2006b). OECD guidelines could substantially contribute towards neutralising the role resource extraction plays in conflicts, as they enjoy high public popularity and are international in scope. Opportunities for their implementation and their effectiveness will first have to be enhanced however, and OECD country contacts need to become more active.

National governments

German federal government[27]

The German government – in contrast to the governments of France and the UK – failed to obligate German companies implicated in the Security Council report to submit any special reports to the OECD contact point or to other bodies. In plenary sessions of the German Bundestag in 2001 and 2004, the government was asked what measures it was planning to take against the implicated German firms. In both plenary sessions, the state secretaries replied that - despite careful investigation and in-depth talks with UN Security Council experts, the companies accused and the National Contact Point for OECD Policies on Multinational Enterprises at the Federal Ministry of Economics and Labour - no corporate involvement in the illegal exploitation of resources in the Congo could be conclusively ascertained (Protocol 15/3253).

In addition to the implementation of OECD guidelines, the German government has a concrete approach to the problem of conflict-exacerbating resource exploitation in its Action Plan for Civil Crisis Prevention, Conflict Resolution and Peace Consolidation[28] adopted in 2004. In addition to scarcity of resources and wealth of resource as reasons for conflict, the Action Plan explicitly states: "In Africa in particular there is a clear relationship between resource wealth, the outbreak of armed conflicts, the emergence of economies of violence and insidious processes of state collapse. This requires the development of new political, financial and economic concepts and tools for addressing conflicts" (p. 50). Accordingly, in the Action Plan the German government calls on the private sector to "develop a greater sensitivity for conflict and to devise mechanisms for transparency and monitoring" (p. 50), providing for support of a "three-sided partnership between private enterprises, non-government organisations and government" (p. 51). As the first report on implementation of the Action Plan made clear, the German government has thus far primarily supported a voluntary approach to resolving the exacerbating role of resource extraction in armed conflicts, voluntary codes of conduct and voluntary monitoring regimes for promoting transparency.[29] In the second report on implementation of the G8 Africa Action Plan 2005, the German government announced its support for

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[26] Records on investigations by contacts reveal that the German contact has only addressed six cases since the year 2000 (OECD 2006a p.12).

[27] The publication *Inventory of Environment and Security Policies and Practices* (2006) issued by the Institute for Environmental Security provides an overview on pp. 57-62 of the German government's policies and projects relevant to "environment and security" (http://www.envirosecurity.org/ges/inventory/IESPP_Full_Report.pdf). This publication maps the activities of eight international organisations and 13 countries.

[28] www.auswaertiges-amt.de/diplo/de/Aussenpolitik/FriedenSicherheit/Krisenpraevention/Aktionsplan-Volltext.pdf

[29] Between 2002 and 2004 the GTZ supported the Observatoire Anti-Corruption (OAC), an established DRC anti-corruption NGO, which evidently had no direct connection to resources or the private economy (www.gtz.de/de/weltweit/afrika/kongo/16188.htm).

the Extractive Industries Transparency Initiative (see below) in the form of a contribution to the World Bank's EITI Trust Fund (p. 22).

In January 2006 the UN Security Council recommended establishing a certification system for the mining of and trade in valuable minerals from the Democratic Republic of Congo. In view of its G8 presidency and pending EU presidency, Germany was to play a leading role in the design and implementation of monitoring systems and in mediation between donor nations and the government of the Democratic Republic of Congo. Donor activities are to be coordinated with regional initiatives at a planned international conference of states bordering Africa's Great Lakes. The German Federal Ministry of Economics and Technology charged the Federal Institute for Geosciences and Natural Resources (BGR) with the development and execution of a pilot project on process verification in mining and resource refinement, in cooperation with business, government and civil entities. At the same time, the BGR is looking into ways to determine the origin of coltan ores through laboratory testing (Dow Jones 2006). Both projects appear to have a generally technical orientation. To increase the likelihood of success for the process verification project, prior experiences with and academic assessments of the political aspects (inclusiveness, transparency, legitimacy etc.) of such processes in relation to other types of resources should also be taken into account (cf. Chapter 3.2.4).

The United Kingdom

When the debate first arose on the extraction of coltan and other resources in 2001, the British government announced its readiness to investigate ways of countering the illegal mining of resources and conflicts arising in connection with it. The Department of International Development announced that international institutions should work to implement international standards on investment and transparency and to develop monitoring mechanisms. In the years following, the British government promoted the Extractive Industries Transparency Initiative.

The All-Party Parliamentary Group on the Great Lakes Region, an informational and advisory forum for British MPs and NGOs, has been studying political processes in the Democratic Republic of Congo since 1998. In 2002 the Group published a comprehensive research paper on the impact of the mining of coltan and other minerals. The Group observed that the one-sided focus on resource extraction was responsible for imbalanced settlement structures and land use. The Congolese national parks, it was noted, were threatened by the encroachment of resource hunters, refugees and militia.

In 2005 the Group released political action recommendations, calling for an expansion of the financial resources and authority of national OECD contact points for more effective implementation of the guidelines. Group MPs also formed a working group with businesses and NGOs for the formulation of OECD guidelines for corporations active in conflict regions.

Democratic Republic of Congo

The Democratic Republic of Congo is facing a number of structural problems. Disputes over land use rights, for example, have not been clearly resolved in many mining areas since the war years 1996-98. Nor has the government been very successful in attracting investors willing to put money into local infrastructures. The most critical concern for the international community is the low standards of transparency, which nurture corruption. Improved transparency is a precondition for the sustainable mining of resources. In 2002 an extractive industry code of conduct developed jointly by government, business and NGOs was released and adopted by the parliament. The code and other regulations stipulate high levels of corporate transparency and a fair public procurement process for government contracts. The mining of resources in ecologically at-risk areas and national parks was prohibited. Another law passed in 2003 developed this aspect further, providing that corporate taxes and mining permit fees be payable directly to local and regional authorities in the interests of regional development.

3.2.2 Private sector

Resource processing industry

Coltan refining companies have been a focus of public attention since the first UN reports on the impact of coltan extraction on the Democratic Republic of Congo came out in 2001, in which several firms were named and openly criticised. UN experts and public opinion were in favour of a coltan embargo from the Congo in 2001. HC Starck, a subsidiary of Bayer AG, stopped buying coltan from Central Africa in the face of public pressure. The company told the media its former Central African supplier had certified in writing that it did not procure resources from rebels. Then, in 2002, the company pointed out that various NGOs including *Fauna and Flora International* and the *Dian Fossey Gorilla Fund* had spoken out in favour of controlled, sustainable coltan mining in the Democratic Republic of Congo. The *Dian Fossey Fund* and others called on HC Starck to resume buying material from small mining operators to ensure them a means of subsistence outside national parks. HC Starck supported this organisation's research and sought dialogue. In July 2003 came the so-called *Durban Process* held in South Africa, a conference attended by the *Dian Fossey Fund*, HC Starck and a host of other players. Attendees expressed support for introducing a code for the mining industry and for more effective monitoring of national parks (HC Starck 2002a/b; Böge et al. 2005).[30]

Telecommunication and information technology industry

Companies

The resource refinement industry involves complex supplier chains in some cases, making monitoring difficult. The situation is even worse in the telecommunications industry, which forms the final link in long (sometimes very long) supply chains. Motorola, Vodafone, Samsung and Deutsche Telekom made a number of statements on the coltan problem in 2002 and 2003, demanding assurances from suppliers that the resources used were not derived from illegal mining in Congo. Spokespersons for Compac, Epcos, Intel, Nokia and Ericsson made similar pronouncements, although some - Nokia and Compaq for example – admitted seeing little prospect for monitoring suppliers (*The Industry Standard*, 11 June 2001). In 2003 Vodafone organised a workshop with suppliers and, like HC Starck, supported *Flora and Fauna International*'s study of the coltan problem and proposed solutions. The majority of relevant firms also expressed a willingness to replace coltan with other materials where possible.

Associations

In May 2006 the International Council on Mining and Metals (ICMM), an association of the 15 largest international and 24 largest national mining companies, adopted sustainability guidelines entitled the *Sustainable Development Framework*. In agreeing to comply with these guidelines, ICMM members expressed their commitment to sustainable development – ranging from improved labour conditions to preserving biodiversity to general environmental protection issues. The Council members furthermore declared their willingness to provide detailed reporting on their sustainability standards (ICMM online), in line with the criteria for the metals industry and mining companies developed by the Global Reporting Initiative (GRI).

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[30] The mining industry has been addressing the issue for some time, developing a range of concepts and approaches (see for example www.icmm.com) not discussed here, due to the focus on the information and communications industry and the limited scope of this study.

The *Tantalum-Niobium International Study Centre* (TIC), an association of tantalum producers and refiners, published a report in 2001 on the environmental and social impact of coltan extraction. The TIC particularly condemned the mining of coltan in DRC national parks (TIC 2001a/b). As a follow-up to its annual general meeting, the TIC emphatically exhorted its members not to purchase any materials from illegally mined resources. The TIC sees the solution of the problem in responsible trade on the part of individual firms; it views embargos as ineffective (T.I.C. 2001a).

The *Electronic, Assemblies & Materials Association* (ECA), a group of 2,100 US businesses, notified its membership in a 2001 press release that mining in Central Africa was jeopardising national parks. The association called upon its members not to buy or use ore from Central Africa (www.durbanprocess.net/en/). Like the TIC, the ECA is not in favour of regulation, instead promoting information and responsible trade on the part of businesses (FFI/ GeSI 2003).

Since 2003, the *Global e-Sustainability Initiative* (GeSI), launched by IT and telecommunications firms in cooperation with the UN Environment Programme (UNEP), has been supporting the research efforts of *Flora and Fauna International* (FFI) as co-publisher of its reports and proposals. The GeSI is dedicated to regulated and sustainable resource extraction. It promotes dialogue between stakeholder groups, integrating other initiatives such as, primarily, the Global Compact (FFI/GeSI 2003/2005). Alongside that, the GeSI formed the *Electronic Industry Code of Conduct Implementation Group* (EICC IG), devoted to establishing standards for supplier management. Following a study on current supplier management practices, a questionnaire was developed in 2005 for suppliers to provide information on their sustainability standards and on ecological and social risks. The next step is to improve communications between participating firms via an Internet platform and to ensure the more efficient distribution of relevant information (GeSI 2005). Also in development are tools for monitoring suppliers and assessing ecological and social risks (EICC IG online).

3.2.3 NGOs and researchers

The first reports on the impact of coltan extraction were published by non-governmental organisations concerned with environmental and endangered species protection. The scientific analyses and political action recommendations of such environmental NGOs are a central focus of this study commissioned by the German Federal Environment Agency.

The *World Wide Fund For Nature,* the *Diane Fossey Gorilla Fund* and the *World Conservation Union* (IUCN) reported in 2001 and 2002 on the devastating effect of resource mining in national parks in the Democratic Republic of Congo. The parks are a UNESCO World Heritage Site due to the great wealth of species inhabiting them. The organisations reported that miners were cutting down forests to obtain construction materials and extraction sites, that rivers were being polluted by mining processes and that gorillas and other rare species were under threat.

The *World Conservation Union* called on the responsible authorities to eject the miners from the parks. Businesses worldwide were asked not to buy resources from park areas. The WWF demanded mining in parks and protected areas (as defined in the IUCN *Guidelines for Protected Area Management Categories*) be banned. In addition the WWF demanded the protection of national parks as UNESCO World Heritage Sites, as laid down in the 1999 UNESCO Charter, calling for mining to be permitted only in approved areas where no serious risk would be posed to rare species, their habitats and their reproduction.

In 2001 the *Diane Fossey Fund* developed new solution proposals that were soon supported by other parties. Regional living conditions and incomes were to be stabilised to a point where the population would no longer be forced to turn to illegal mining in national parks. Agricultural subsidies and controlled resource extraction were to make this objective possible (DFGF 2001/2003). *Flora and Fauna International* took a similar position in 2003, contending that embargos cannot be enforced in practice. Restricting commercial activity through embargos exacerbates poverty, it was argued, thus increasing the incentive to engage in the poaching and plundering of resources. Seeing environmental protection as both an economic and a political challenge, *Flora and Fauna* thus sought dialogue with business and government (FFI 2003/2005). Numerous studies by NGOs and research institutes such as the POLE Institute have provided further support for a holistic concept of sustainable development and action proposals for governments and businesses.

3.2.4 Public-private partnerships for conflict-related resources

Anti-corruption and transparency initiatives represent an important approach to resolving the problem of resource extraction and conflict escalation. Governments and businesses – often with the involvement of NGOs – have formed several public-private partnerships. Below is a brief presentation of two prominent certification/transparency initiatives for the extractive industry alongside the Global Compact discussed above under 2.1. To date no other comparably established systems have been set up concerning the mining of or trade in coltan.

Kimberley Process

The Kimberley Process Certification Scheme is designed to certify the origin of diamonds to keep so-called “blood diamonds”, used to finance armed conflicts and weapons, off the legitimate international market. Representatives of interested governments, NGOs (notably Global Witness and Partnership Africa Canada) and of the diamond industry (notably DeBeers and the World Diamond Council) convened for the first time in 2000 in Kimberley, South Africa to agree on a certification system for diamonds, which became effective in January 2003. This system provides that participating states may only deal in certified raw diamonds, and exclusively with other states party to the Kimberley Process. Compliance with the Kimberley Process is monitored via peer review from the international trading regime imposed on all participating nations and industry self-regulation elements. Member states receive support in introducing the monitoring system and are sanctioned for non-compliance.[31] Although the Kimberley Process has not yet succeeded in completely eliminating trade in “blood diamonds”, it has succeeded in establishing a far-reaching regulatory regime. The market’s structure, involving few providers and buyers, is, however, substantially different that of other resources and industries (Böge et al. 2005; Schroeder-Wildberg and Carius 2003). The transferability of such a complex regulatory regime with regard to other resources would thus have to be reviewed.

Extractive Industries Transparency Initiative (EITI)

The EITI[32] was launched at the Global Summit on Sustainable Development in September 2002 by British Prime Minister Tony Blair, overseen by the UK government’s Department for International Development (DFID). The EITI is primarily directed towards extractive industry enterprises and governments of the countries where such firms operate or have their headquarters. Its membership now includes over 20 resource-rich countries including the Democratic Republic of Congo.

In October 2006, the International Advisory Group (IAG) submitted a report to the EITI with proposals for optimising the validation process. In its ten recommendations for the future evolution of the initiative, the IAG indicated that EITI would have to devote more attention to the specific

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[31] A state was excluded from the Kimberley Process for the first time in July 2004 - the Republic of Congo (Congo Brazzaville).

[32] www.eitransparency.org

environment of the mining sector, as it saw significant differences regarding the implementation of transparency initiatives for mineral mining and oil and gas extraction respectively. These differences will be outlined in greater detail in a subsequent report (Raber and Sabater, 2006) soon to be commissioned by the EITI Secretariat. Transparency regarding payment flows at national level in the mining industry is not a concern as the amounts are much smaller than in the oil and gas sector[33]. However, the societal impact of mining activities and conflicts arising in connection with them is generally manifested at sub-national level. It is thus important for the mining industry to achieve payment flow transparency at sub-national level. Despite this, however, good governance, ensuring the redistribution of mining wealth in addition to transparency, is also critical. Transparency in and of itself is of less interest for the mining industry than what it can contribute towards achieving sustainable development.

The mining industry has also formed its own CEO-level organisation, the International Council on Mining and Metals (ICMM; cf. Associations), enabling it to address the problematic role of resource extraction in heightening conflicts. The Global Reporting Initiative (GRI) has also adopted a new "mining supplement", obligating all participating mining enterprises to disclose any taxes paid to the governments of countries in which they operate, starting in 2007. These go beyond EITI requirements (Raber and Sabater, 2006, p. 15).

The report thus sees EITI as delivering added value for the mining sector only inasmuch as governments fail to achieve the broader objective of providing good governance. It simultaneously warns against exaggerated expectations of EITI's influence on the mining sector.

These reports make it clear that, while EITI is an effective system whose processes are being enhanced, it is still only in the beginning phase as relates to minerals. The final IAG report takes up a key recommendation of the Mineral Sector Report to establish a mining subgroup within the EITI to focus on industry-specific considerations. The current momentum behind this process may mean that the specific issue of the conflict-exacerbating role of mineral extraction, such as coltan mining in the DRC, may be put on the agenda.

3.3 Initial conclusions

Different approaches to solving the problem are being discussed by the parties involved in the coltan mining debate:

- Demands for a coltan embargo occupied the forefront of the early debate back in 2001. These demands had already subsided by the following year, however, as the effect of an embargo on the population and enforcement difficulties became evident.
- A majority were then in favour of regulating mining, taking up the UN Security Council experts' distinction between "illegal" and state-approved "legally mined" coltan.
- The public and the Security Council panel of experts became increasingly aware, however, that domestic government authorities could offer no solution to the problems facing the population and the environment due to the massive level of corruption. This led to a focus on measures for increasing transparency and reforming the public sector.
- At the same time corporations and private-sector associations were looking at developing monitoring mechanisms for suppliers. Thus far this has yielded a survey-based approach. It

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[33] According to an International Monetary Fund report (2005), oil and gas income accounted for an average 52.7% of total fiscal income of countries dependent on oil exports, as compared to a maximum 10% for the majority of countries with mining industries (www.imf.org/external/pubs/ft/grrt/eng/060705.pdf).

remains to be seen whether complementary monitoring mechanisms, already in the design phase, can be implemented and adapted to regional conditions. Possible evaluation methods could be ones borrowed from the timber, textile and other industries.

- Transparency initiatives and certification systems are the primary approaches for dealing with the problem of resource extraction and conflict escalation. However, existing approaches were originally derived in relation to specific resources (notably oil/gas and diamonds) and may not be structurally transferable to other resources and industries. But the processes and systems for these resources have provided examples of how to design effective and appropriate strategies, revealing that process transparency and inclusivity are key prerequisites for success (cf. Beisheim & Dingwerth, no year specification). Prior experience and academic research in this area should by all means be utilised for any transparency or certification system to be developed for coltan.
- As this overview has shown, a variety of different tools are available for helping resolve the problematic role resource extraction plays in conflicts. The complicated relationship between resource extraction and armed conflict, characterised by dynamic, interlocking private-sector, governmental/political and resource-specific factors, means that only an integrative approach can offer prospects for success (Le Billon et al., 2002, p. 34). The complexity of the issue, encompassing environmental, economic, foreign policy and development policy dimensions at multiple levels (UN, EU, the national level of donor/resource consumer states and the regional and national levels of resource-rich developing countries) demands a more comprehensive and detailed investigation of these tools and mechanisms in order to develop a holistic approach towards a solution.
- The issue of conflict resources has mainly been viewed as a matter of foreign and development policy. Incorporating environmental and resource policy considerations would provide a new perspective and would complement efforts in other areas (particularly CSR initiatives and development policy measures targeting good governance).

4 Conclusions and recommendations

Below is a summary presentation of the conclusions reached within the framework of the study and the workshop held in Berlin on 30 November 2006. It includes recommendations for further development of the topic.

4.1 Conclusions

Significance of rare metals for the information and communication technology

- Almost all metals of the periodic system are used in electronic products today. A distinction, whether metals are only used in ICT products or also in other electrical and electronical products cannot be made. It is impossible to select especially relevant metals as some are important quantitatively (e.g. copper, lead, zinc) and others are functionally essential (e.g. indium or tantalum).
- There is no coherent and systematic understanding up to date, which metals should be considered as strategic metals. In documents the term is used in different ways with regard to the supply and value chain or as a “key element” for the industry. A major aspect is the scarcity. Important criteria are:

  - Prices of almost US$500 per kilogram and more
  - Price increase of metals of almost 100% or more in the period from 2001 to 2004
  - Scarcity of the reserves, lasting less than 25 years based on production figures for 2004
  - Scarcity of the reserve bases lasting less than 50 years based on production figures for 2004
  - Concentration of known reserves primarily in one (> 50%) or two countries (> 65%)
  - Concentration in supply and value chain or high concentration of reserves of metals assessed according to a BMWA study and an analogous conclusion for metals that were not evaluated in this study

- The selected criteria were used in conjunction with the existing database to identify some rare metals. There are, however, other criteria that could be considered, such as pattern of use, ecological impact of the value chain, availability of substitutes or recycling rates. The use of these or other criteria would certainly also lead to the inclusion of other metals. Due to time restrictions for the study, however, other criteria could not be considered. Because of insufficient data, it was also not possible to adequately evaluate beryllium, scandium, gallium, germanium, the platinum group metals and some other metals. As they fulfilled the most criteria (four and five respectively), the study evaluated antimony and indium as the “rarest” metals. Both metals have many different applications in EE and ICT products, with indium probably being of greater economic significance.
- Alongside access (i.e. dependency on certain regions), the value chain is also a relevant factor in determining whether a metal is strategic. The value chain can become dependent on certain suppliers. Other problems can arise in the value chain with regards to occupational safety and job protection (e.g. mining personnel, conflicts between international mining corporations and the local population). The inclusion of criteria that take into account the ecological and social aspects of a metal’s entire life cycle would entail a completely new evaluation of “rare metals”.
- Because metals are sometimes used in ways not conducive to recycling or are used in a dissipative form, some metals cannot be included in existing recycling processes. Furthermore, in many cases metal recycling also entails downcycling. These patterns of use will aggravate the availability problem as long as no recycling processes or recycling-friendly manufacturing processes are implemented, using lower quantities of the relevant metals.
- Various metals (e.g. indium) have competing applications in important technology fields. Increased development (e.g. of renewable energies) is boosting demand for indium, which is also a key element for display devices. The highly-specific properties of metals and their compounds mean that they have now become essential for different products. A shortage in the availability of these materials would have serious economic consequences.

Significance of the coltan extraction in the Democratic Republic of Congo

- The extraction of coltan did intensify and extend the war in the DRC since, at various times and depending on the prevailing balance of power, it contributed to the funds of the respective governments, rebels and neighbouring countries. There were many reasons for the conflict and it went on to become a humanitarian crisis (around four million people died either directly or indirectly as a result of the war).
- The study also analysed the market for tantalum (coltan), the significance of the DRC for this market, as well as the extraction of coltan in the DRC. Tantalum is used in the manufacture of capacitors (tantalum powder and foil), steel alloys (high-strength and temperature stable as well as bioneutral tantalum alloys) and cutting tools (tantalum carbide). The capacitors are mainly used in

mobile phones, computers, digital cameras, hearing aids, cardiac pacemakers and automotive electronics (ABS, GPS, ignition systems). Industrial demand comes mainly from the automotive electronics, PC, optics and telecommunications sectors.

- Australia dominates mining. The second biggest producer is Brazil. The production data for African countries show that the DRC had an 11.3% share of global tantalum production in 2000, making it the third largest producer. Total extraction in central and southern Africa is slightly more than in Brazil. The conflict surrounding illegal coltan extraction in the DRC in 1999/2000 coincided with a period of high prices for tantalum. This period saw increased demand for coltan from the DRC on the global market.
- From 2001 to 2003, reports from expert panels to the UN Security Council provided information on the situation in the DRC and exposed links with foreign companies. The reports were criticised from various sides and may even have been unfounded in parts. Nevertheless, the discussion led European companies to take action to increase the transparency of the market and prompted at least one German company involved (HC Starck) to adopt countermeasures. The course of the conflict demonstrates that transparency can stem illegal trade in rare minerals and thereby reduce the potential for conflict, but also that unclear property rights and shareholding structures require further reform.
- At the end of 2006 there is still no confirmed solution to the conflict. The situation in the DRC remains tense. The legal situation in the extraction areas is unclear and there is still no reliable information on direct investment, which is currently increasing. The overall growth in extraction and export from countries in central Africa requires closer examination. On the demand side, the role of new industrial consumers (optics industry) and the role of newly industrialising countries outside the OECD (China) should be viewed critically.
- High demand for raw materials has led to the creation of new structures and a redrawing of the geography of international trade in raw materials. The market is no longer dominated by OECD countries and the companies located there, but rather by countries like China, which are purchasing directly from raw material suppliers to secure their supply. Materials such as coltan from the DRC are processed in China and used in products from the optics industry, in PCs and other electronic products, which are then exported to the European Union.

Measures and concepts for the solution of the problem of conflict-aggravating resource extraction

To be able to relate the case study ‘coltan’ to the discussion about a European Resource Strategy some relevant measures and concepts were examined as possible solutions to the problem of conflict-aggravating exploitation of raw materials from the perspective of various relevant players from business, politics, NGOs and research.

- One finding is that there are not yet any hard mechanisms or approaches that deal with rare resources relevant to the ICT sector that come from conflict areas.
- Furthermore, previous research shows that, as well as the physical characteristics of a resource and how it occurs, the governance of the country in which a resource is found also plays an important role in the escalation and de-escalation of conflicts, as do industry-specific and company-specific characteristics. For this reason, concepts and measures intended to solve conflict-aggravating resource exploitation will not necessarily be the same for all raw materials.
- Nevertheless, important experience can be gained from other resource areas (especially the Kimberley Process and the Extractives Industries Transparency Initiative) for the political

formation of such processes, which should also be taken into account when designing concrete measures for coltan extraction areas.

- The workshop was also presented with a current scheme from the Federal Institute for Geosciences and Natural Resources (BGR) which could serve as the technical basis for a transparency initiative for the coltan value chain. The BGR is running a pilot project on determining the precise origins of minerals using new analysis procedures. The project uses coltan as its test material. Possible techniques include a crystal structure analysis. Samples are currently being taken for comparison purposes. At the time of the workshop, the feasibility of a procedure of this kind was uncertain and some areas of industry were not expecting it to be helpful. In some areas, industry is looking into options for increasing transparency in the value chain. H.C. Stark, for example, is checking the origins of materials through their plausibility (e.g. "Does this mine exist?") or through confirmation from a reliable third party (e.g. embassies).

4.2 Recommendations

Based on the analysis of rare metals in ICT products, the value chain of tantalum and coltan, the approaches and concepts for conflict-defusing resource extraction as well as the discussion at the workshop on 30 November in Berlin some recommendations for environmental and development policies can be derived.

International panel on raw materials

Global competition makes it difficult to implement sustainable mining and trading practices. High demand for resources leads to various national strategies; some countries target investment in (foreign) mining (such as China), or build up reserves of raw materials. We advise the establishment of an "International Panel on the Sustainable Use of Natural Resources", similar to the IPCC, as proposed by the European Commission, to deal with the subject of mineral resources on a global level. This panel should also have competence in the areas of conflict and policy analysis.

Economic relations to the DRC

Formerly, Germany was a very important foreign trade partner for the DRC. The improved situation in the DRC since the democratic elections should revitalise relations. The revitalisation process should also consider other minerals in the DRC. The formation of provincial governments in the DRC presents an opportunity to come to an agreement on regulations for the extraction of tantalum and other raw materials. Dialogue on the sustainable supply and use of raw materials is therefore of central importance. With a view to the (hoped for) end of the civil war, the German Federal Government could take the initiative by organising an international conference on the potential contribution of sustainable supply and use of raw materials to a positive development in the Democratic Republic of Congo. When choosing industrial partners for this dialogue, it is important to remember that commercial companies are not tied to locations, and are therefore not particularly interested in medium-term commitments.

Consideration of small-scale mining in conflict prevention

Due to the special mining conditions for coltan, all approaches to conflict prevention must also take into account small-scale mining companies and operations. The ideal solution would be decentralised coordination, purchasing and processing bodies in the DRC itself. Within the framework of a policy aimed at development and cooperation, these bodies could provide support to individuals and operations (e.g. by providing equipment and training in occupational and environmental safety). Small loans could enable these miners to form cooperatives and small companies. It is also possible to safeguard against price fluctuations through insurance schemes or similar measures. Initiatives of this kind should be implemented in collaboration with the provincial governments, which will have a much more significant role to play in light of the new DRC constitution. The bodies will also be a good point from which to contact international companies and organise the legal framework. Otherwise an asymmetric relationship might develop between small mining companies and larger companies. Overall, bottom-up and top-down approaches should be combined.

Investment funds

Boycotting sources (e.g. due to the environmental impact of small-scale mining or because of regional crises) can be counterproductive. Falling sales potential for coltan from small-scale mining operations can, for example, lead to the exploitation of natural resources in nature reserves. It would make sense to investigate whether – due to the small value chain in the tantalum industry – regional investment funds could be set up to support small-scale mining while simultaneously promoting socially and environmentally sustainable practices. The aim of the funds would be to establish economic structures, environmental measures or diversification. Within the framework of development and cooperation these investment funds could also contribute to other goals in developmental aid policy (e.g. setting up processing plants in mining countries or agreeing long-term supply relationships with the relevant companies). The model for these funds would be the Norwegian oil fund. They would require reliable support from the new government, safeguards against corruption, overall independence and transparent structures. All this would take time to achieve, but valuable experiences from other countries (e.g. Botswana, Chile) could be made use of.

Validation and exchange of experiences of corporate activities to improve transparency in the value chain

Due to the complexity of value chains, product manufacturers can barely keep track of how different metals found their way into their products. The coltan example has demonstrated that problems can arise from this lack of knowledge and that risks can be involved which would not have been accepted with prior full knowledge of the situation. Greater transparency in the value chains for metals (e.g. by certification) would therefore be desirable. Labelling solutions have been implemented in other sectors. This possibility is currently being researched at other institutions (including the BGR). Certification, however, must also be practical for producers of metals and the product manufacturers as well as understandable for consumers / end customers. Case studies should therefore be carried out on selected metals to research how it might be possible to achieve transparency through various tools and how findings from different research projects could be combined. The solution should also look into how breaches of legal requirements can be determined and penalised (non-compliance, enforcement, accountability, liability, sanctions).

Integration of the "rare metal" concept into the European resources strategy

The study of strategic metals has provided initial indications that other nations are operating a strategic resources policy to secure their own industrial supply. These resource strategies and the actions of the corresponding national companies on the resources markets only meet European standards in part. For example, while German companies no longer acquire tantalum from crisis regions, tantalum ores from such regions continue to be traded on the market at considerably lower prices and end up on the European market in the form of products. This fuels social and environmental problems in the extraction countries while simultaneously creating competitive disadvantages for manufacturers that comply with tougher standards. Research is needed on a resource strategy that considers both the rare metals supply for European industry and the problems in the extraction and processing countries. As well as the environmental aspects emphasized by the EU Resource Strategy, attention should be paid to the socioeconomic aspects and criteria of fair trade. Currently, however, this area falls within the remit of the Federal Ministry for Economic Cooperation and Development.

Estimation of the consequences of indium and antimony as rare key elements for important technologies

The metals indium and antimony, included in the study, should be researched in greater detail. Both metals are extremely important for a large number of ICT and EE devices. Indium, in particular, is in demand for two important competing technologies – display devices and solar technology. This topic needs to be researched further with regard to the federal government's high-tech strategy.

Analysis of the environmental policy challenges resulting from the dissipative use of rare metals

Many rare metals are used dissipatively or in non-recyclable forms. Presented with this pattern of use and the fact that substitution is not currently possible in some cases, research is recommended on health and environmental impacts as well as into the options for improved usage, recycling and substitution.

Analysis of the problems of a modern closed loop economy of rare materials

The example of coltan (tantalum), and of other metals identified during the workshop, demonstrates that functional materials are hardly recycled today. The recycling is technically feasible in principle, but the high degree of dissipation is a problem. For example in the case of Indium dissipative uses in a multitude of products (mobile phones, plat panel displays etc.) make recycling more difficult and allow for the feed-back into recycling systems only to a certain degree. However, recycling opportunities in Europe are hardly used or are poorly developed. In contrast to Europe, there is a recycling of indium in Japan in larger quantities. Given the strategic importance of some of these materials and the fact that their extraction can have serious environmental consequences, we recommend research into how and the degree to which new methods can be introduced to the recycling systems and how existing elements can/need to be changed in order to meet growing requirements.

Ecodesign as a resource strategy element

Greater resource efficiency, particularly for rare materials for which recycling is naturally more complex, can be achieved through the right design. The tantalum example demonstrates that ecodesign and resource efficiency go hand in hand, as recycling of tantalum from miniature capacitors is not yet possible given current automatic recycling procedures. Based on the findings of the project, research would be better directed at the question of ecodesign requirements in fast-developing, dynamic product markets. From the very start, such research should consider the situation at both national and European level with a view to future policymaking.

Linking of departmental responsibilities in the further working on certain raw materials from conflict areas

The overview of existing approaches for dealing with conflict-aggravating resource extraction, as well as current activities by the Federal Ministry for Economic Cooperation and Development (BMZ) to deal with the topic of resource-related conflicts indicate that the BMZ is an important partner both in creating awareness of conflicts related to industrial processes and in establishing corresponding political processes in this region. The BMZ has experience of and responsibility for bottom-up processes (e.g. model solutions for small-scale mining) and top-down solutions (e.g. regional investment funds). With these measures, the BMZ can make important contributions to environmental and biodiversity protection in resource-rich countries. In cooperation with the BMZ as a development policy partner, it has been possible to devise environmental policy approaches that are able to integrate the European Resource Strategy as well as consider the socioeconomic consequences for resource-rich developing countries.

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Appendix 1: Definitions

The following chapter will provide various definitions for specific terms. In chemistry, the word ‘substance’ is generally used to subsume different forms of matter (Schröter 1987 p.23), making differentiation between elements, compounds, metals and salts necessary. In geology, however, the terms ores and minerals are also used. Moreover, the words reserves and resources are also used in different ways.

- **Elements**: An overview of the elements is provided by the Periodic Table of Elements. An element is characterised by the number of protons it contains.
- **Compounds**: Compounds are the combination of elements bound together in different ways (ionic, metallic, covalent / primary compounds or in complexes containing different modes of binding / higher order compounds.). There are organic compounds and inorganic compounds, as well as mixtures (usually in complexes, salts of organic compounds).
- **Metals**: Metals are metallic compounds. Here, valence electrons are usually delocalised.
- **Salts**: Salts contain ionic bonds. Here, electrons are transferred from the electropositive element (bond) to the electronegative element. There are simple salts, such as sodium chloride ($NaCl$), and complex salts, such as magnesium perchlorate ($Mg(ClO_4)_2$).
- **Minerals**: ‘Mineral’ is a collective term for all of the substances made of chemical elements, particularly inorganic elements, found in the Earth’s crust, its mantle, the planets and meteorites, (Meyers Lexicon 1983, vol. 9 p. 378). Minerals are chemically uniform, solid, naturally occurring substances (Schröter et al. 1987 p.201). There are 2,000 to 3,000 minerals, of which approx. 300 are common (Meyer vol. 9 p. 378). These usually have a crystalline structure, but may be amorphous or have an elementary structure. Minerals can be grouped according to their salt type (oxide, silicate, sulphide) or their most important constituent parts. The most important tantalum minerals are, for instance, tantalite $Fe(TaO_3)_2$ and columbite $Fe(Nb_2O_6)*(Mn,Fe)[(Nb,Ta)_2O_6]$, as a mixed salt.
- **Ores**: Ores are natural mixtures of minerals from which metal can be isolated on an industrial scale (Meyer vol. 4, p. 462)
- **Reserves**: That part of the reserve base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials; thus, terms such as ‘extractable reserves’ and ‘recoverable reserves’ are redundant and are not a part of this classification system (USGS 2006 Appendix C).
- **Reserve base**: that part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated (USGS 2006 Appendix C).
- **Resources**: a concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth’s crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible (USGS 2006 Appendix C).

Appendix 2: Metals in electrical equipment, electronic products and components

Aluminium Al: Aluminium is primarily used as a construction material, in its pure form or in alloys with copper, nickel and zinc. Its main applications are in building, vehicle construction and packaging (Rutherford: aluminium). Electrical equipment, such as televisions or computers, generally contains a large proportion of aluminium in the construction. Aluminium oxide is employed to produce the glass in cathode ray tubes (Behrendt 1998). Aluminium foil or oxide is often used in condensers or as material for cups (Elko: Condensers).

Antimony Sb: Antimony is mainly used as an alloying constituent for hardening metals, as an additive to natural rubber, as a flame retardant in synthetic materials and in paints and pigments (USGS: Antimony). Antimony oxide is added to cathode ray tube glass and is also used in semi-conductor technology and photocells (Kreibich 2004).

Arsenic As: This semi-metal is primarily used to harden steel and is still employed in pesticides around the world. It is utilised as a doping agent in semi-conductor production, e.g. in ICs, light-emitting diodes and photoconductors (Elko: LTR Photoconductors). It is also used as an alloy in lead-acid batteries. Arsenic oxide is added to cathode ray tube glass and luminescent materials. Arsenic doping can also produce semi-conductor properties in solar cells; these properties can then be made use of in tandem cells.

Barium Ba: The most important application of barium is as filler, as barium sulphate. A further application is in protective coating. Because of its density, it is able to absorb electron beams very well. Barium is employed as an oxide in glass and ceramics, e.g. for television screen glass.

Beryllium Be: Beryllium mainly serves a constituent of copper alloys, as it significantly increases the mechanical strength. These kinds of conductors are primarily used in areas where cables move or vibrate. Beryllium is also often used in reactor technology (neutron absorbers, Rutherford: Beryllium). On the US market, approx. 50% of beryllium is used in ICT products (computers, telecommunications) and other electric and electronic applications (USGS: Beryllium). Beryllium is also used in luminescent materials for television sets (Behrendt et al. 1998).

Bismuth Bi: Bismuth is mainly used on the US market for alloys with steels (46%), for the production of additives (29%), and for chemistry and pharmacy (24%) (USGS 2006: Bismuth). In information and communications products, it is also used as the oxide in ceramics or glasses. In EE components, it is used as a component of the alloy in chokes. Bismuth is also used in the fluorescent substances in television sets (Behrendt et al. 1998).

Cadmium Cd: Cadmium is still employed around the world to colour and stabilise synthetic materials. It is also used to make NiCd batteries (Rutherford: Cadmium). On the US market, approx. 80% of cadmium is utilised in batteries (USGS: Cadmium). A further occasional application is in electrical components for which high safety standards apply (railway engineering). Cadmium is also employed in fluorescent material for television sets (Behrendt et al. 1998). Moreover, cadmium is used in cadmium-telluride solar cells (Lauermann 1998). Photoconductors can contain CdS (Elko: LTR Photoconductors).

Calcium Ca: Calcium is chiefly used in glass and ceramics as an oxide, e.g. for television screen glass (Behrendt et al. 1998). However, this is a minor application compared to other uses of calcium (construction) (Rutherford: calcium).

Caesium Cs: The importance of caesium is that photons cause it to emit electrons. Because of this effect, caesium is used for night vision instruments and photoelectric cells (Rutherford: Caesium, USGS: Caesium). Caesium is also used in photocells, e.g. in television cameras (Kreibich 2004).

Cerium Ce: This metal is used to colour glass, as an alloy constituent and in reactor technology. The production volume is 9,400 t (Rutherford: Cerium). Cerium oxide is added to cathode ray tube glass and is also utilised in laser technology. See too Rare Earths.

Chromium Cr: Chromium is predominantly used to treat surfaces (chromium plating) and to produce ferrochromium steel. Further applications are pigments, tanning and catalysts (Rutherford: Chromium). Chromates are also employed in some production processes for PV cells. NTC thermistors (temperature-dependent semi-conductor resistors) contain chromates (Elko: NTC thermistors).

Cobalt Co: This metal is mainly used in steel alloys as it allows the production of temperature-resistant, ferromagnetic steel. Consequently, it is often utilised in generators and electric motors (Rutherford: Cobalt). On the US market, 65% is consumed for steels and other metallic uses, 9% for carbides (cutting tools) and 26% for chemical products (USGS: Cobalt). Cobalt is also employed in fluorescent material for television sets (Behrendt et al. 1998).

Copper Cu: The metal copper is by far the most important metal in the ICT industry, as copper has the best conductivity and plasticity properties. Aside from its uses in cables and conducting wires (e.g. for coils and chokes, transformers, electromotors and generators), there are also major uses in construction and in industry, including tubes and armatures. About 3% of the weight of televisions is made up by copper (Behrendt et al. 1998), 5% to 7% in computers and 8% in monitors (Soldera 1995). See under platinum for the quantitative use of copper in mobile telephones. In wired signal transmission in ICT, copper can be replaced by silicon dioxide (glass fibres).

Dysprosium Dy: This metal is only used to a small extent. Less than 100 t per year is produced. The metal is used in various alloys, in special magnets and in nuclear technology (Rutherford: dysprosium). See too Rare Earths.

Erbium Er: The metal is only used to a small extent. Less than 100 t per year is produced. The metal is used in nuclear technology, in titanium alloys and in dying glasses and enamel (Rutherford: erbium). Erbium is used as doping material for fibre enhancers in light wave conductors (electro: light wave conductors). See too Rare Earths.

Europium Eu: The metal is only used to a small extent. Less than 100 t per year is produced. It is used in extremely thin layers in superconductor alloys and as a neutron absorber in reactor technology (Rutherford: europium). Eu-doped Y_2O_2S is used as a fluorescent substance in television (Behrendt et al. 1998, Ruby, year not given). Eu-doped Y_2O_3 is used for energy-saving bulbs (Ruby, year not given). See too Rare Earths.

Gadolinium Gd: The metal is only used to a small extent. Less than 100 t per year is produced. Gadolinium is used in electronic components, magnets, magnetic optics and in neutron radiography (Rutherford: gadolinium). Tb-Gd_2O_2S is used as a green fluorescent substance in radar screens (Ruby, year not given). See too Rare Earths.

Gallium Ga: Gallium is mainly used in the production of various semiconductors (e.g. ICs with gallium arsenide phosphide and light-emitting diodes with gallium arsenide or phosphide) (Rutherford: gallium, Elko: LED). This makes up about 46% of the US market. It has also become an important component in optical electronics and in solar cells (USA: 36% of total consumption; UGSG 2006: gallium). Gallium arsenide solar cells exhibit high efficiency and are used in satellites, because of their resistance to radiation. They can also be used in the construction of tandem solar cells (double layer cells) (Lauermann 1998). Gallium is also used as doping material for semiconductors, e.g. in ICs.

Germanium Ge: Germanium is mainly used in semiconductor technology, for the manufacture of transistors, rectifiers, tunnel diodes and photoconductors (Rutherford: Gallium; Elko: Semiconductors, resistances). 24% of the germanium on the US market is used for glass fibre optical systems and 12% for infrared optics, electronics and photovoltaic equipment (UGSG: Germanium).

Gold Au: Gold is mainly used for producing jewellery and in gold reserves. Dentistry is also an important field of application. As the conductivity of gold is excellent, it is also found in contacts and in EE components. For the quantities used, see under platinum. Approx. 85% of the gold on the US market is used for making jewellery, 9% for dentistry and 6% for the electronics industry (USGS: Gold). Gold is also present in thin layers on CDRs (EUROMETEAUX, year not given).

Hafnium Hf: Hafnium is used for the production of special steels, used, for example, in reactor technology (Rutherford: Hafnium). Further areas of use include high pressure lamps, as hafnium nitride as an electrode in vacuum tubes and as hafnium oxide in semiconductor production (Electro: Hafnium).

Holmium Ho: The metal is only used to a small extent. Less than 100 t per year is produced (Rutherford: Holmium). The metal is used in various alloys for strong magnets. In ICT products, it is used as a fluorescent substance in colour televisions (Rutherford: Holmium). Holmium is also used in magnetic bubble memory and in fluorescent lamps. See too Rare Earths.

Indium In: Indium is used in a variety of ways in ICT products, e.g. for liquid crystal displays and flat screens. The reason for this is that indium tin oxide is transparent to light and a conductor, so that it can be used as a "conductor wire", without affecting visibility. This principle can also be applied to solar cells and LCDs. Other uses include high efficiency transistors (USGS: indium), ICs based on indium arsenide phosphide, in tunnel diodes and in light-emitting diodes (Al-Ga-In phosphate, In-Ga nitrogen, see Elko: semiconductors). Other uses include electroluminescent lamps, semiconductors for infrared detectors and photovoltaic cells. Approx. 70% of the indium on the US market is used for coating and 12% for electronic components (USGS: indium). Indium is used as doping material in semiconductor technology. For example, photoconductors contain InAs and field plates contain indium antimonide (Elko: LTR photoconductors, field plates). Indium is used in Hall probes to measure magnetic fields. It is used in solar cells as copper-indium diselenide thin layer cells (Lauermann 1998).

Iridium Ir: The metal hardens platinum and is often used in alloys (e.g. for the original metre). Because of its stability, it is also used in chemistry (laboratory equipment). Quantitatively, its most important use is as catalyst for purifying the exhaust gases of vehicles. Iridium is used in thermoelements at high temperatures (Electro: Thermoelements).

Iron Fe: Iron, in the form of steels, is primarily used for construction purposes. It is used in large quantities for these purposes in EE products, together with aluminium. Iron is also contained in transformers (mostly as ferrites) and in many other EE components (coils, relays) (Elko: coils). Iron oxide is used as an additive in cathode ray tube glass.

Lanthanum La: The metal is only used in small quantities, for example, as the oxide to dye glasses. Production is estimated at about 8,500 t (Rutherford: Lanthanum). See too Rare Earths. Lanthanum is used in thermistors to avoid overheating (Ruby, year not given). Lanthanum is also used in electrodes of Ni-metal hydride accumulators.

Lead Pb: Lead is mainly used in high-performance batteries. Lead oxide is used in glass and ceramics. Lead is also utilised as a coating for electric cables (Rutherford: lead). Relatively large amounts of lead oxide are employed in the glass of television screens (Behrendt et al. 1998). It is present in all electrical equipment as soldering tin (SbPb). An analysis of computers showed that approx. 30 g of lead is used in the hardware and approx. 17 g in screens (not including screen glass) (Soldera 1995). Photoconductors can contain PbS or PbSe (Elko: LTR photoconductors). As a result of the RoHS Directive (which took effect in July 2006), Kyocera introduced lead-free screens onto the market for its industrial customers as early as 2004.[34]

Lithium Li: Lithium is used for hardening lead (bearings). Lithium carbonate is used for glosses and as flux for enamels. It is also of enormous importance in organic synthesis (stearates). Low quantities of lithium oxide are present in the glass in cathode ray tubes. The most important use in ICT products is in accumulators containing Li ions, lithium polymers and lithium metal.

Magnesium Mg: The metal is used as reductant in the preparation of other metals. The most important uses are in corrosion-resistant alloys with other metals, such as aluminium. These alloys are used as low density materials in the construction of aeroplanes and vehicles. 59% of magnesium on the US market is used for shaped components, 29% as Mg-Al alloys in packaging and 7% to remove sulphur from iron. Magnesium oxide is used in cathode ray tubes.

Manganese Mn: The metal is mostly used in steel alloys. In the ICT industry, it is important in the production of dry batteries and accumulators (alkali-manganese cells).

Mercury Hg: The most important use of this metal is as amalgam (alloy with silver) in dentistry. Mercury vapour lamps are also used for illumination at high light intensities (Rutherford: mercury). Use of mercury in mercury button cells used to be important. Although these were prohibited in 2001, they are still produced throughout the world. The background illumination of the display in laptops is produced by cold cathode tubes (Wikipedia 2006: Mercury vapour lamp). Because of the RoHS Directive (in force from July 2006), Kyocera has brought mercury-free displays onto the market.[35]

Molybdenum Mo: The metal is mostly used in the production of high tensile and heat resistant steels (turbines). 75% of the molybdenum on the US market is used for these purposes (USGS: Molybdenum). It is used in lamp filaments and in catalysers (Rutherford: Molybdenum). It is used in electronic components in SMD diodes (Behrendt et al. 1998).

Neodymium Nd: Neodymium is used to colour glasses and enamels. It is used in neodymium lasers in special EE products. Production is estimated at 2,900 t (Rutherford: Neodymium, Ruby, year not given). Neodymium is also used as fluorescent material in colour television tubes and in fluorescent lamps. Neodymium is also used in Ni metal hydride accumulators. See too Rare Earths.

Nickel Ni: Nickel is mainly used in steel production (nickel silver, Monel metal). Nickel plating is used to protect steel products. Nickel alloys are often used in EE components. About 13% of the nickel on the US market is used for electric equipment (USGS: Nickel). In the ICT industry, it is

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[34] RoHS Directive: Restriction of the use of certain Hazardous Substances in electrical and electronic equipment. The directive restricts the use of specific hazardous substances and is part of the EU directive that makes it obligatory for car and electrical equipment manufacturers in the European Union (EU) to implement measures to protect the environment, such as the recycling of products. The directive restricts the use of five types of the six substances in electrical equipment that fulfil the provisions of Article 95 of the EC Treaty. These substances are heavy metals, such as lead, mercury, cadmium and hexavalent chromium, as well as brominated flame retardants, such as polybromo biphenyls (PBB) and polybromo diphenyl ethers (PBDE). By July 1, 2006, manufacturers are required to eliminate these substances from all their products, with the exception of mercury in compact fluorescent lamps, which may not exceed 5 mg per lamp, and some other cases. (Kyocera 2006).

[35] According to the directive, 5 mg per lamp would be permissible.

important in the production of accumulators. Ni-Cd accumulators are still used throughout the world for some high current applications (electric instruments); they are frequently more suitable than Ni-metal hydride accumulators (Elko: Nickel MH accumulators). In electronic components, nickel is present, for example, in SMD condensers (Behrendt et al. 1998)

Niobium Nb: Niobium is mainly used in corrosion-resistant steel. Almost 99% of the steel on the US market is used for steel production. (USGS: Niobium). It is used with germanium for the production of superconductors (Rutherford: Niobium). Uses in the ICT industry include the production of miniaturised high performance condensers (Behrendt et al. 1998).

Osmium Os: The metal is mainly used for hardening steel, for use in injection needles and fountain pens. It used to be used for lamp filaments (Rutherford: Osmium). A platinum-osmium alloy is used for implants and artificial heart valves.

Palladium Pd: The metal is used in dentistry as a silver alloy. It is still used as hydrogenation catalyst, as it readily forms hydrides with hydrogen (Rutherford: Palladium). Like most noble metals, it is used to purify exhaust gases from vehicles. In electronic components, it is used in SMD condensers (Behrendt et al. 1998). Its use in combustion cells may become important in future. See under Platinum, for the amounts used in mobile phones.

Platinum Pt: The metal is mainly used for making jewellery. Another important use is in catalysers to purify exhaust gases from vehicles. There are relatively high levels of platinum in mobile phones. A study of the content of noble metals in mobile phones (Sullivan 2006) found that the metal content is approx. 25%, even in modern mobile phones (without batteries or chargers). The main metals found in the instrument were copper, iron, nickel, silver and zinc, together with low levels of aluminium, gold, lead, manganese, palladium, platinum and tin. The following weights were found of the valuable metals: 16 g copper, 0.35 g silver, 0.034 g gold, 0.015 g palladium and 0.00034 g platinum. In spite of these very low weights, this adds up to very large quantities in this booming market. Based on the stock of approx. 630 million mobile phones in 2005, the quantities of valuable metals were approx. 10,000 t copper, 224 t silver, 20.9 t gold, 9.4 t palladium and 0.22 t platinum. On the basis of the mean prices over the period of use, the total value of the metals would come to just under $400 million. Thin layers of platinum improve the storage capacity of hard disks (EUROMETEAUX, no year given).

Potassium K: Potassium salts are used as fertilisers. Other uses of potassium are much less important. Potassium oxide is used in glass former in cathode ray tubes (Behrendt et al. 1998).

Praseodymium Pr: Uses of this metal include alloys in permanent magnets, gold colouration of glasses and enamels and in electrodes for light arc systems (Rutherford: Praseodymium). See too Rare Earths.

Promethium Pm: This metal is a member of the rare earths. It is only produced by fission of uranium. It is used in "atomic batteries" for satellites (Rutherford: Promethium).

Rare earths REO: The rare earths are also known as lanthanides or 4f elements. They are grouped together because of their very similar properties. This is the reason that they are very difficult to isolate in the pure form. The rare earths include cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, terbium, ytterbium and lutetium. The most important rare earth minerals are bastnaesite ($CeFCO_3$) and thortveitite: ($(Y,Sc)_2Si_2O_7$). They are only used in small quantities. The use on the US market is as follows: catalysers for vehicles, 32%; metallurgical additives and steels, 16%; glass polishes and ceramics, 12%; fluorescent substances for screens (televisions, computers, radars), illumination and X-ray films, 15%, permanent magnets (4%); catalysers for petrochemical processes, 4%; and miscellaneous 17% (USGS). Rare earths are also used in glass fibre technology and in superconductors. Rare earths are often used in fluorescent lamps. Probably the most important fluorescent substances are cerium, erbium and ytterbium (see Ruby, year not given). Lanthanum and neodymium are used in the electrodes of Ni-metal hydride accumulators.

Rhenium Re: Rhenium is used in catalysers (reforming) and steels. 40-50% of the rhenium on the US market is used for this purpose. In electrical products, it is used in electric contacts, electromagnets and in electron tubes (USGS: Rhenium). Other uses include filaments and thermo-components (Rutherford: Rhenium, USGS: Rhenium).

Rhodium Rh: The metal is mainly used in catalysers (purification of vehicle exhausts) and for highly reflecting mirrors (Rutherford: Rhodium).

Rubidium Rb: Rubidium is used in photocells (Rutherford: Rubidium). Other uses include laser and glass fibre technology and night vision instruments (USGS: Rubidium).

Ruthenium Ru: The metal is mostly used in catalysers (Rutherford: Ruthenium).

Samarium Sm: Samarium is used to dope laser crystals, to produce special glasses and ceramics and catalysers and as a neutron absorber in nuclear reactions (Rutherford: Samarium). Samarium is used in the form of intermetallic compounds with cobalt in permanent magnets, for example, in small motors. The annual global demand is approx. 2000 t (Ruby, year not given). See too Rare Earths.

Scandium Sc: Scandium is mostly used in alloys with aluminium, to produce highly stable sports instruments. But it is also used for highly intense halogen lamps and for magnetic memory and in laser technology (USGS: Scandium). The annual production is estimated at 50 t (Rutherford: Scandium)

Selenium Se: Selenium is only produced in small quantities and is mostly obtained from copper sludge. It is used in semiconductor technology and for solar cells. As it has good photoelectric properties, it is used in copying technology. Other uses are in vulcanisation, alloys and glass production.

Silver Ag: Silver is mainly used in jewellery and photochemicals. Silver in jewellery is now very often recycled (Rutherford: Silver). With the increasing use of digital photography and modern printing procedures, the use of photochemicals is expected to decrease. Silver is also used in batteries and EE components (SMD condensers). "Silver fingers" are used in PV cells, to ensure contact. (Solar Server, no year given). Silver is also used in fluorescent substances for television sets. In electronic components, it is used in SMD condensers (Behrendt et al. 1998). The section on Platinum contains information on the quantities in mobile phones. Silver is present as thin layers on CDRs (EUROMETEAUX, no year given).

Sodium Na: The most important sodium compound is sodium chloride, from which chlorine is manufactured. Other sodium compounds, such as the carbonate, sulfate, sulfite etc., are important agents used in chemical processes, cellulose production and in the use of soda in glass manufacture. Other uses of sodium are much less important. Sodium oxide is used as a glass former in cathode ray tubes (Behrendt et al. 1998)

Strontium Sr: Strontium is mainly used as the oxide in glasses and enamels, for example, in the screen glass in television sets. Approx. 68% of the glass on the US market is used for television glass and approx. 11% for ferrite magnets. Strontium is also used in pyrotechnology.

Tantalum Ta: Tantalum, in the form of carbides, is used for cutting tools in metal processing. Because of its lack of toxicity, it is also used in implants (Rutherford: Tantalum). Approx. 60% of the tantalum on the US market is used for the production of condensers (USGS: Tantalum)

Tellurium Te: The semimetal tellurium is mainly used as a component of steel, copper and lead alloys and as a catalyst in rubber production. As regards EE components, it is used in photocells and thermoelectric components. Small quantities of cadmium telluride are also used for solar cells (Lauermann 1998). It is also used for optical storage media (CD-RW). Tellurium can also be used in Peltier elements to cool ICs.

Terbium Tb: This metal is only used to a limited extent. Less than 100 t per year is produced. However, terbium is used in laser technology and as a fluorescent substance. Terbium is used as Tb-Fe-Co alloys for magneto-optic "mini-discs". In rewritable CDs, the magnetisation is extinguished by a laser, by exceeding the Curie temperature (see Ruby, year not given). See too Rare Earths.

Thallium Tl: Thallium is used in high temperature superconductors, in filters for wireless communication, in radiation gauges, in special glasses for infrared and for light refraction in acoustic optics. Thallium is also used in medical devices (USGS: Thallium).

Thulium Tm: This metal is only used to a limited extent. Less than 100 t per year is produced. It is only used in special areas, e.g. as a radiation source for transportable X-ray instruments (Rutherford: Thulium). See too Rare Earths.

Tin Sn: Tin is mostly used in the manufacture of tinplate (tins), bronze and stanniol. In ICT, it serves as solder (Rutherford: Tin). Of the tin on the US market, approx. 27%, is used for containers, approx. 23% for electric equipment, approx. 10% for construction and approx. 10% in transport (USGS: Tin).

Titanium Ti: Mainly because of its chemical, thermal and mechanical properties, titanium is used in alloys in many areas related to construction and traffic. Very large quantities are also used in dyes (titanium white). It is probably very rare in ICT products. Negative temperature coefficient semiconductors (Elko: NTC Hot Conductors) can contain zinc titanates and positive temperature coefficient titanium ceramics. Titanium oxide is used as an additive to cathode ray tube glass.

Tungsten W: Tungsten is mainly used in the form of carbides for the manufacture of cutting tools. About 50% of the tungsten on the US market is used for this purpose (USGS: Tungsten). Another important area of use is the manufacture of high tensile and heat resistant steels. Tungsten is also used for lamp filaments (Rutherford: Tungsten). Other uses are in electrodes, cables and electrical components (USGS: tungsten). Tungsten oxide is used as an additive in cathode ray tube glass.

Vanadium V: Vanadium is mainly used in the production of high tensile steels. approx. 94% of the vanadium on the US market is used for this purpose.

Ytterbium Yb: This metal is only used to a limited extent. Less than 100 t per year is produced. It is used in non-rusting steel (Rutherford: Ytterbium). Ytterbium is also used in fluorescent substances for television sets (Behrendt et al. 1998). See too Rare Earths.

Yttrium Y: Alloys of yttrium are very suitable for permanent magnets. Other uses of yttrium include oxygen sensors for vehicles, signal controls for microwave radars, lasers for digital communication and non-linear optics. Yttrium-containing materials exhibit superconductivity even at temperatures of -180°C (Rutherford: Yttrium). Eu-doped Y_2O_3 is used for low energy bulbs. Eu-doped Y_2O_2S is used as the red fluorescent substance in monitors and televisions (Ruby, year not given).

Zinc Zn: The metal is mainly used for electroplating the surface of iron. Brass (zinc-copper alloy) is widely used in machine and equipment construction, in vehicles and in fittings. Zinc-carbon batteries are important dry batteries (Rutherford: Zinc). 55% of the zinc on the US market is used for electroplating, 16% for zinc alloys, and 8% for brass and bronze. Zinc is very often present in electrical products and EE components and in relatively large quantities. Zinc oxide is used as an additive in cathode ray tubes and in fluorescent materials (Behrendt et al. 1998).

Zirconium Zr: The most important areas of use are jewellery, ceramics and fire-resistant products (USGS: Zirconium). Zirconium is mainly used in reactor technology (fuel rod coats). The metal is often used as alloy metal for corrosion-resistant steels. It is used with niobium for superconductors. It is present as filler in flashlights (Rutherford: Zirconium). It is used in television sets as the oxide in cathode ray tube glass.

Appendix 3: List of abbreviations

DRC	Democratic Republic of Congo
BGR	Federal Institute for Geosciences and Natural Resources
ECA	Electronic Components, Assemblies & Materials Association
EE	Electrical and electronic equipment
EITI	Extractive Industries Transparency Initiative
EICC IG	Electronic Industry Code of Conduct Implementation Group
EU	European Union
FFI	Flora and Fauna International
GeSI	Global e-Sustainability Initiative
IICM	International Council on Mining and Metals
IAG	International Advisory Group
ICT	Information and communications technology
IUCN	World Conservation Union
OECD	Organisation for Economic Cooperation and Development
T.I.C.	Tantalum-Niobium International Study Centre
UN	United Nations
WWF	World Wide Fund For Nature

Appendix 4: Participants

Workshop, 30.11.2006 in Berlin

Strategic Measures and concepts for the solution of the problem of conflict-aggravating raw material extraction – the example of coltan

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