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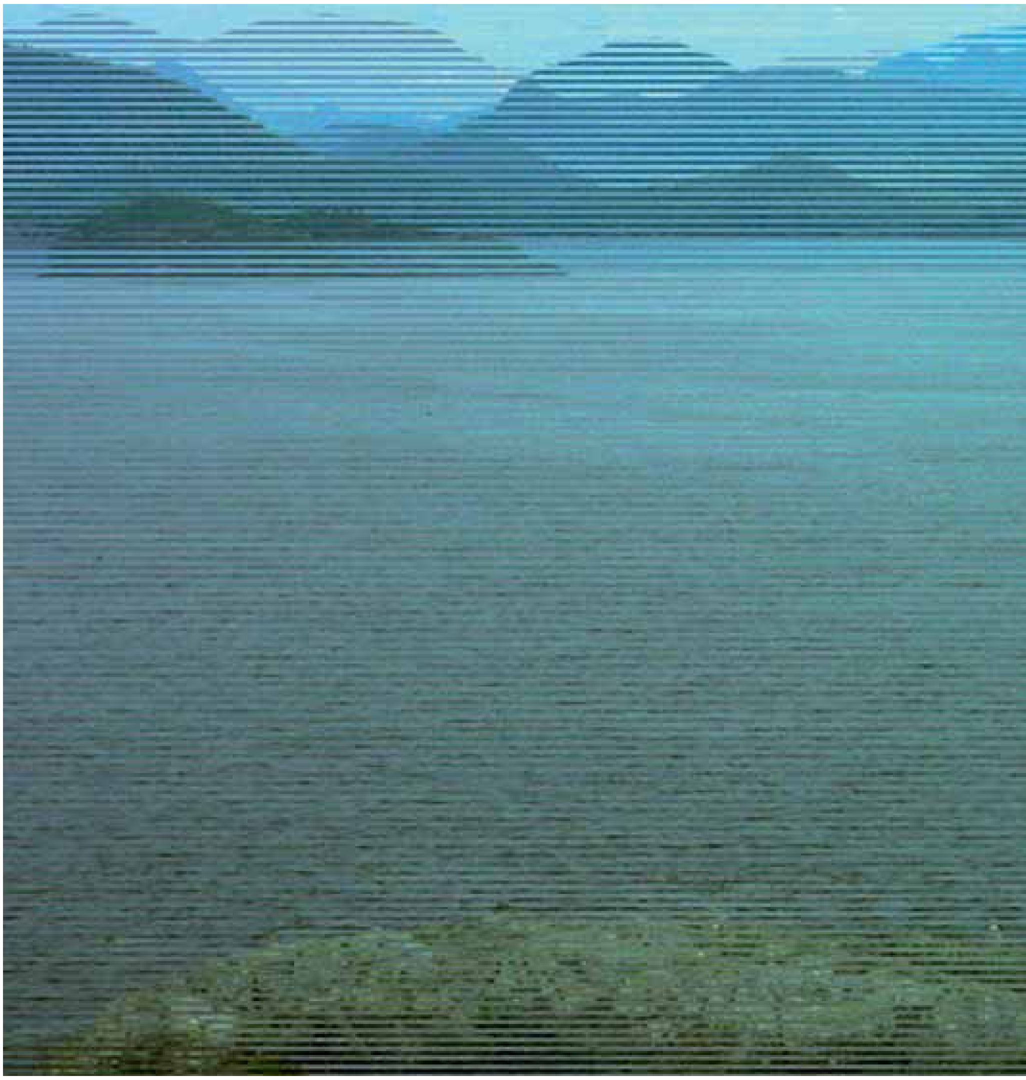

- FOCUS: COASTAL CHANGE AND MANAGEMENT
- FOCUS: SYSTEMIC RISKS, PART 2
- FINANZ- UND KLIMAKRISE

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The Mobile Phone: Powerful Communicator and Potential Metal Dissipator

The mobile phone boom: an unprecedented success. Yet which are the socioeconomic and ecological impacts of the cell phone life cycle? If phones end up as waste, we risk irretrievable dissipation of scarce but essential metals into the biosphere. This in turn provokes a systemic risk for the IT industry.

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Abstract

This article attempts to briefly evaluate the significance of mobile phones in the modern information and communication society. Furthermore, it shows the substantial success of the mobile phone industry in recent years by evaluating the increase in overall sales figures and the degree of mobile phone penetration in different societies. The study looks at the different materials, in particular rare metals, used in mobile phones. The dissipation of these materials is discussed as a consequence of the life cycle of mobile phones, especially of the after-use phase.
It is claimed that the dissipation and irretrievable loss of these materials could pose a severe risk to the industry. Moreover, we conclude that under the prevailing economic practices, the scarcity of strategic metals used for very specific purposes – often in small but critical amounts – could lead to shortage conflicts and economic drawbacks.

Keywords

dissipation of spice metals, information and communication society, mobile phone, raw materials use, systemic risk

The Rise of the Mobile Phone

More than any other device, the mobile phone – or cellular phone, or cell phone – has changed the world in the last 15 years. Virtually unknown and scarcely used only 15 years ago, it is now found in every corner of the world as the most important means of communication of almost every community. This is not to suggest that the mobile phone was an invention of the 1990s. It was the result of the evolution of a device that has been in existence for over 50 years. The German name of the mobile phone, "handy", hints to its origins: In the 1930s, the predecessor of the current conglomerate Motorola began producing the mobile radio device "SCR-536", the first hand-held radio communication device, in order to improve communication on the battlefield in World War II. The new radio communicator was soon dubbed the "handie talkie" in contrast to the "walkie talkie", which had to be worn as a backpack.

Some scientists predicted the importance of the invention at the very beginning. However, the mobile phone "revolution" was to take place only in the second half of the 1990s, even though commercial mobile phones had been available before the 1990s. The unprecedented boom at the time served – along with that of the computer and the Internet – to heavily influence the rapidly advancing "digital wave". With its ability to incorporate other digital technologies, the cellular phone increasingly seems to be at the centre of the digital wave: It provides not only communication, information, and knowledge exchange but also digital enter-

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tainment around the clock and around the world. We, the users, perceive the cell phone as almost limitless in a limitless world community. Mobile phones have become a vital part of our social life and provide the flexibility of staying connected virtually anywhere and at any time. They have become so indispensable that they are almost taken for granted.

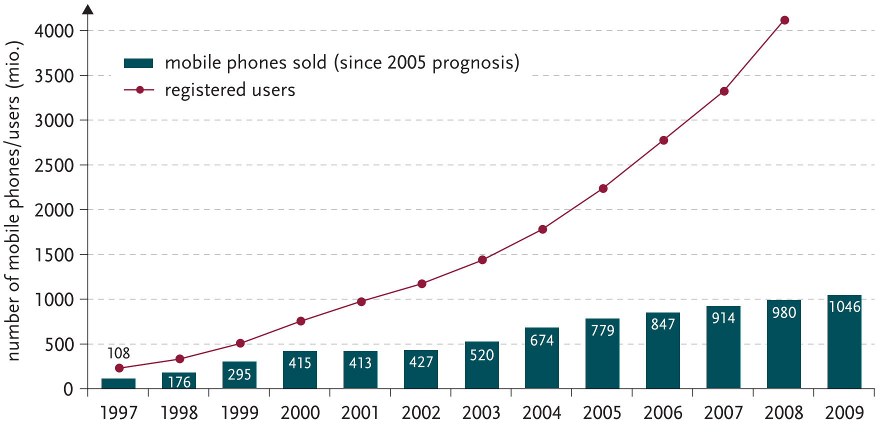

FIGURE 1: The rapid worldwide spread of the mobile phone is an unprecedented success story. The graphic shows the number of phones sold worldwide per year from 1997 to 2009 (extrapolated) and the total number of registered users worldwide from 1997 to 2008. Data based on Gartner Media Relations (2005), ITU (2009), and new own studies.

Modern information and communication technology devices, especially the mobile phone, digital camera, computer, and music player, are notable not just for their usefulness, but also for their complexity regarding chemical composition and production. The history of their development, distribution, and use is rarely broached as an issue. Even less common is the discussion of the resources and energy used by the devices, not to mention the spatial-temporal implications for our socio- and biosphere due to the rapid distribution and short lifespan of the products. Perhaps this lack of concern for the intrinsic risks (see, e. g., Renn and Keil 2008, Neitzke et al. 2008) is due to a belief that microelectronics products only use very small amounts of materials, or perhaps due to ignorance about the components used, especially the many metals which are critical and essential for certain functions.

The "material stories" (Huppenbauer and Reller 1996, Böschen et al. 2004) of all these metals reveal complex material cycles and provoke a number of important questions: How many persons use a cell phone (and how many cell phones are lying around unused)? What is the economic importance of the mobile phone industry? Which are the basic resources for the production of mobile phones? Is there a potential risk of dissipating metals into the biosphere that first came into use with modern microelectronic devices? These questions are inescapable when discussing the materials used for mobile phones. In this paper, we discuss some of the socioeconomic, cultural, and ecological impacts and risks of the cell phone.

The Historic Success of the Mobile Phone Industry

The balance sheets of the mobile phone industry of the last decade represent the impressive finances of an exceptional rise. In 2005, for instance, Gartner Media Relations, the worldwide provider of analysis in the information technology sector, extrapolated the sales numbers up to 2009, based on the yearly sales numbers from 1997 to 2005: While "only" about 100 million mobile phones were sold worldwide in 1997, yearly sales are nearing a billion little more than ten years later (figure 1). Altogether from 1997 to 2006, 4.6 billion cellular phones were sold, and by 2008, the six billion mark was passed. Hence, between 1997 and 2009, roughly one mobile phone was produced per person on earth, which is quite an historical milestone. Yet cell phone producers are currently complaining of a drop of the yearly growth rate from an average 22 percent in the period from 1997 to 2006 down to ten percent, a concern that is hard to sympathise with considered that most other sectors cannot dream of achieving two-digit growth rates at the moment. According to statistics of the International Telecommunication Union (ITU 2009), the number of registered mobile phone users surpassed four billion at the end of 2008, as compared to just 100 million in the mid-1990s.

The monetary figures also speak for themselves. In 2007, the average wholesale price of a mobile phone was at 174 USD and kept trending downward. By 2009, Gartner Media Relations estimates that it will "only" be 161 USD. Given the rising number of units produced, i. e., one billion units for 2009, the sales income for worldwide cell phone production amounts to a staggering 160 billion USD for 2009, which is about 50 percent higher than in the year 2004 (110 billion USD out of 647 million units sold). In other words, the yearly revenues from cell phone sales are on the same order as the recent gross domestic product of countries like the Czech Republic, Egypt, or Thailand. It needs to be taken into account that these revenues represent only a part of the cash flow that spurs the technology's rise: Not just the income from device sales, but also networks, energy supply, replacement parts and repairs, and above all usage contracts and fees, to name a few, yield large earnings for the sector.

These impressive but one-dimensional product-specific statistics are not sufficient to evaluate the effects of the mobile phone boom. The rise of the most important modern communication lifestyle accessory is connected with a value addition chain (figure 2) whose spatial, chronological, and socioeconomic dimensions have taken on unpredictable dynamics. This is due to the fact that a cell phone is a most complex technical device involving not only a complicated network of supplying and producing industries, but also a worldwide, fast-growing supercultural community of users.

In order to get a more detailed picture of the impact levels of the different value addition chains, one needs to investigate the various phases of the production process, use, and disposal of mobile phones. Figure 2 provides a schematic overview illustrating the typical life cycle of a cell phone.

As will be specified in the following chapter, statistical data on raw material extraction sites give a completely different picture than data on the production facilities or on global sales. Despite concentration in resource-rich countries like China, Russia, the USA, Canada, or Australia, the raw materials needed for mobile phones are mined all over the world. These materials then mainly concentrate at the supply chains and production sites of five market leading corporations supplying more than 80 percent of the world production, above all the Finnish company Nokia that has a share of more than 35 percent of the world market. These global players in turn sell their products in virtually every country on earth. The mobile phone boom has also reached the less developed parts of the world according to current statistics of the International Telecommunication Union (ITU 2008). In relation to population, the majority of cell phones are still sold in the western countries (defined here as Western Europe, North America, and Japan). The focus in these regions is on relatively new mobile phone functions such as cameras or MP3 players, as well as style. This trend is already noticeable in other regions as well. Latin America, Asia, Africa, and the Middle East currently show the highest growth rates of cell phone sales, especially in regard to new users.

The five large corporations mentioned above try to outperform their competitors by making their customers ever more dependent on product- or brand-specific parts. Historically, equal and mutual standards were internationally agreed upon in order to promote trade and distribution. Such standards were introduced particularly for technologies based on electricity, and later on also for complicated systems like telecommunication or audio systems. Today, however, individual supranational holdings seem to be striving for hegemony primarily through differentiated, brand-specific functional elements. Customers decide on a standardised product in regard to the main function, i. e., the use of the telephone. The very use and function, however, are almost always made brand-dependent through some peripheral but essential element.

The variety of information and communication products available, together with the focus on maximising profits, are currently advancing the global society like never before. This acceleration is reflected economically by the short product lifetimes. In the developed countries, mobile phones are especially short-lived, with contractually-bound product replacement generally every 18 to 24 months. For the developing countries, no reliable statistics are available so far. Technical advances, expanded functionality, and changing style trends further serve to entice frequent exchanges or new purchases (improved speaking quality rarely being an issue). In this way, the major companies can continue to increase sales not only in regions with yet poor market penetration, but even in seemingly saturated markets. The risks of

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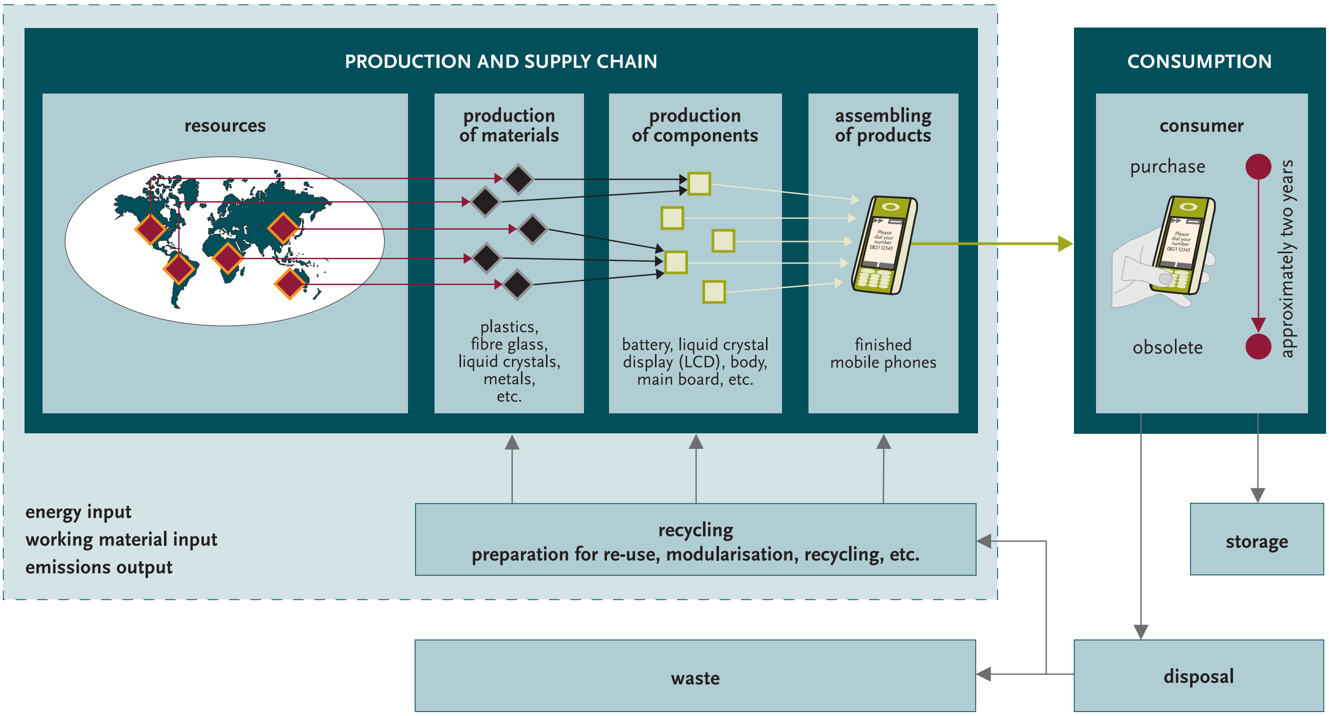

FIGURE 2: Flow of materials in the life cycle of a mobile phone. Today, only a small proportion of disused mobile phones is recycled although they contain valuable materials that could be re-used: Among other reasons, recycling seems not yet to be economically attractive. However, this could change as some of the rare trace metals essential for various high technology applications become scarce. Adapted from Bublies (2006).

accelerated development times are often ignored and may lead, for example, to recalls (Heuwinkel 2004, p. 34). Obviously, mobile phones are pervading our society more and more and are beginning to conquer other areas independent of their main function as a telephone. These general trends apply to most of the technically advanced, rich world regions. Yet, the greatest relative increase of sales, i. e., market penetration, is observed in Asia, where sales have reached staggering rates, but also in Africa, where the mobile phone's independence of conventional telephone infrastructure turns out to be the major driving force behind its rapid spread.

The success of the cellular phone is also due to its versatile functionality: In the past 15 years, since its early development, the mobile phone has proven to be the most agile product of the communication and information age, increasingly integrating computer, Internet, music, and camera technology. It has become the first ubiquitous all-around product to shape both our free time and our working lives. It might turn out to be a device that contributes – in an unforeseen, dynamic manner – to alphabetising global society, for without knowing Arabic numbers and the alphabet characters, a cell phone is rather unhandy. These developments unexpectedly overwhelmed the global society in the new millennium. Manuel Castells wrote about the role of modern information technology in regard to the rise of the "network society": "Presence or absence in a network and the dynamics of one network over another are the deciding points for domination and change of our society" (Castells 2004, p. 527).

The success of the cell phone provoked an additional phenomenal "story": Owing to its complex chemical composition, its production depends on complicated supply chains nourishing supplier companies, but also on enormous amounts of energy and mineral resources. Problems concerning resource supply – which would be reflected by price increases of the relevant raw materials – have so far hardly been observed in the world economy, least of all by the end consumer. We are experiencing an increasingly common phenomenon in the modern age: A loss of touch, i. e., a decreasing perception of our immediate environment, or a "loss of embeddedness", as Anthony Giddens puts it (Giddens 1995). Without a doubt, the success story of the cell phone entails substantial physical impacts and consequences. It is worthwhile to shed more light onto these interrelations and consequences in order to understand the far-reaching importance and relevance of this overwhelming socio-technological achievement.

What Materials Are Contained in a Mobile Phone?

Looking at the production chain with regard to the natural resources used, one realises that an immense global "resource chain" is connected to the mobile phone's rise. This resource chain begins with the extraction of the necessary raw materials from deposits and, unfortunately, it still ends far too often with the disposal of obsolete devices in landfills. A closed circuit of the raw materials does not seem to be economically and technically feasible at the moment. Various bottlenecks are found between the initial point and the endpoint of the life cycle. First, the necessary raw materials are sent to refineries and production facilities where the material is transformed. Output that needs to be further processed goes to the component producers, who in turn send their output to the producers of the final products. Finally, the finished products are sold to the users. After a certain usage life – for cell phones, an expected lifetime of only perhaps two years! – the outdated devices are either put away in storage or disposed of. Ideally, although seldom, they return to the production cycle through re-use or regeneration of materials through recycling. It needs to be mentioned that reliable statistics on recycling rates are very difficult to obtain. It is also unknown how many disused units are stored in households. In 2006, some data have been published for the United States: They show that although cell phone collection and recycling programmes have been implemented, these have had little impact on the total waste or dissipation stream (Sullivan 2006). This proves to be the present state of affairs. A recent estimate comes to the conclusion that in Switzerland alone eight million units that are still functioning are no longer in use. It is unclear where their life cycle will end. Obviously, recycling is not yet economically attractive and the collection logistics are not yet implemented, i. e., unknown secondary-use and end-of-use trajectories prevail.

Worldwide interdependencies result from these phases in the material flows, globalising the various and tightly-knit locations and regions where parts of the production, use, and end of use take place. At the same time, the life cycle and its bottlenecks must be investigated with regard to their influence on social, economic, ecological, as well as political-strategic relations.

In order to assess the spatial-temporal complexities of the material flows leading to the production of a mobile phone, it must be investigated what functional materials are used to manufacture cell phones as well as where these materials are found, produced, concentrated, and dissipated in their preparation and usage.

In a study conducted at the University of California in 2006 on *End-Life Management of Cell Phones* (Blass et al. 2006), a cell phone was disassembled and its component parts were analysed in detail. These essentially fell into four groups: The majority of the parts were plastics (60 percent), with a further 10.6 percent made from glass substrate. While these play a critical role, liquid crystals only account for 0.15 percent of the materials. For the resource scientist, the remaining third is the most interesting part: Just below 30 percent of the analysed cell phone's mass was comprised of metals. The UNEP released similar data in 2006 (UNEP 2006), which are partly represented in the table. The table shows the five most highly concentrated metals by weight found in a mobile phone, as well as the five most precious or valuable metals. Quantitatively, the most important metal for the mobile phone industry is copper: Assuming an average mass per modern cell phone of about 100 grams, about 15 grams of this high-demand metal are found in every device. For the approximately 600 000

TABLE: Percentage of selected strategic functional metallic elements in mobile phones and amount of those metals contained in one billion mobile phones (roughly the number of mobile phones sold worldwide in 2008), as compared to the world production of those metals in 2007. Data on percentage of weight are based on UNEP (2006); data on world production in 2007 and main production countries in 2007 are based on United States Geological Survey (2008) and British Geological Survey (2008).

metallic element	% of weight (average)	amount of metal in one billion cell phones (tonnes)	world production in 2007 (tonnes)	main production countries in 2007
copper	15	15 000	15 500 000	1. Chile (35.9 %), 2. Peru (7.7 %), 3. USA (7.6 %), 4. China (6.1 %), 5. Australia (5.6 %), 6. Indonesia (5.1 %), 7. Russia (4.5 %), 8. Canada (3.8 %), 9. Zambia (3.4 %), 10. Poland (2.9 %)
iron	3	3 000	2 043 000 000 (iron ore)	1. China (34.6 %), 2. Brazil (17.4 %), 3. Australia (14.6 %), 4. India (10.0 %), 5. Russia (5.1 %), 6. Ukraine (3.8 %), 7. USA (2.5 %), 8. South Africa (2.1 %), 9. Iran (1.7 %), 10. Canada (1.6 %)
aluminium			37 900 000	1. China (33.2 %), 2. Russia (10.4 %), 3. Canada (8.1 %), 4. USA (6.7 %), 5. Australia (5.2 %), 6. Brazil (4.2 %), 7. Norway (3.4 %), 8. India (3.2 %), 9. South Africa (2.4 %), 10. United Arab. Emirates (2.3 %)
nickel	2	2 000	1 600 000	1. Russia (16.9 %), 2. Canada (15.4 %), 3. Indonesia (13.8 %), 4. Australia (9.7 %), 5. New Caledonia (7.5 %), 6. Colombia (6.1 %), 7. China (5.1 %), 8. Philippines (4.8%), 9. Brazil (4.5 %), 10. Cuba (4.5 %)
tin	1	1 000	303 000	1. China (45.0 %), 2. Indonesia (21.8 %), 3. Peru (12.9 %), 4. Bolivia (5.3 %), 5. Brazil (4.2 %), 6. Congo (4.0 %), 7. Vietnam (1.8 %), 8. Rwanda (1.5 %), 9. Russia (0.9 %), 10. Nigeria (0.8 %)
silver	0.5	500	20 980	1. Peru (16.6 %), 2. Mexico (14.9 %), 3. China (12.9 %), 4. Chile (9.2 %), 5. Australia (9.0 %), 6. Poland (5.9 %), 7. Russia (5.7 %), 8. USA (5.6 %), 9. Canada (4.1 %), 10. Kazakhstan (3.4 %)
gold	< 0.1	< 100	2 340	1. China (11.6 %), 2. South Africa (10.8 %), 3. Australia (10.5 %), 4. USA (10.4 %), 5. Peru (7.3 %), 6. Russia (6.7 %), 7. Indonesia (5.0 %), 8. Canada (4.3 %), 9. Ghana (3.6 %), 10. Uzbekistan (3.1 %)
palladium	trace	approximately 15	221	1. Russia (43.9 %), 2. South Africa (39.2 %), 3. USA (5.8 %), 4. Canada (4.8 %), 5. Japan (2.5 %), 6. Zimbabwe (1.9 %), 7. Botswana (0.9 %), 8. Columbia (0.7 %), 9. Australia (0.3 %), 10. Poland (0.1 %)
tantalum	trace	approximately 4	816	1. Australia (53.3 %), 2. Brazil (22.1 %), 3. Ethiopia (9.4 %), 4. Canada (5.5 %), 5. Rwanda (5.1 %), 6. Mozambique (2.8 %), 7. Nigeria (1.2 %), 8. Burundi (0.4 %), 9. Congo (0.1 %), 10. Uganda (0.1 %)
indium	trace	approximately 2	553	1. China (57.8 %), 2. Japan (10.8 %), 3. Canada (9.0 %), 4. South Korea (9.0 %), 5. Belgium (5.4 %), 6. Russia (2.2 %), 7. Germany (1.8 %), 8. Peru (1.1 %), 9. Great Britain (0.9 %), 10. Netherlands (0.9 %)

tonnes of mobile phones produced in the last ten years, one can estimate that about 90 000 tonnes of copper had to be taken from mines all over the world, the main producer being Chile. Other metals with significant percentages are iron and aluminium. The cell phone industry plays only a secondary role in any strain on their supplies due to the massive yearly production volume of aluminium and iron.

The Crux of the Essential "Spice" Metals

Many rare strategic metals are needed for the production of mobile phones due to their specific properties. While these "spice metals"[1] make up only a small percentage of the total weight of a cell phone, vast quantities of these precious and/or scarce metals are necessary for cell phone production, given that the number of mobile phones produced each year is now surpassing one billion. The availability of many of these materials is limited, be it in terms of material and production time, be it in terms of unsafe geopolitical situations. These problems, combined with competition from other market sectors, could cause substantial price increases in an already uncertain market.

It also has to be mentioned that it proves to be rather difficult and tedious to get hold of reliable data concerning stocks and

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[1] The colloquial term "spice metal" – translated from the German term "Gewürzmetall" and for the first time used in this article – describes a metal that occurs in small amounts (in terms of geology a trace metal) and that due to its specific properties and functionality is essential for the technology of a device (e. g., mobile phone), like a specific spice for a special dish.

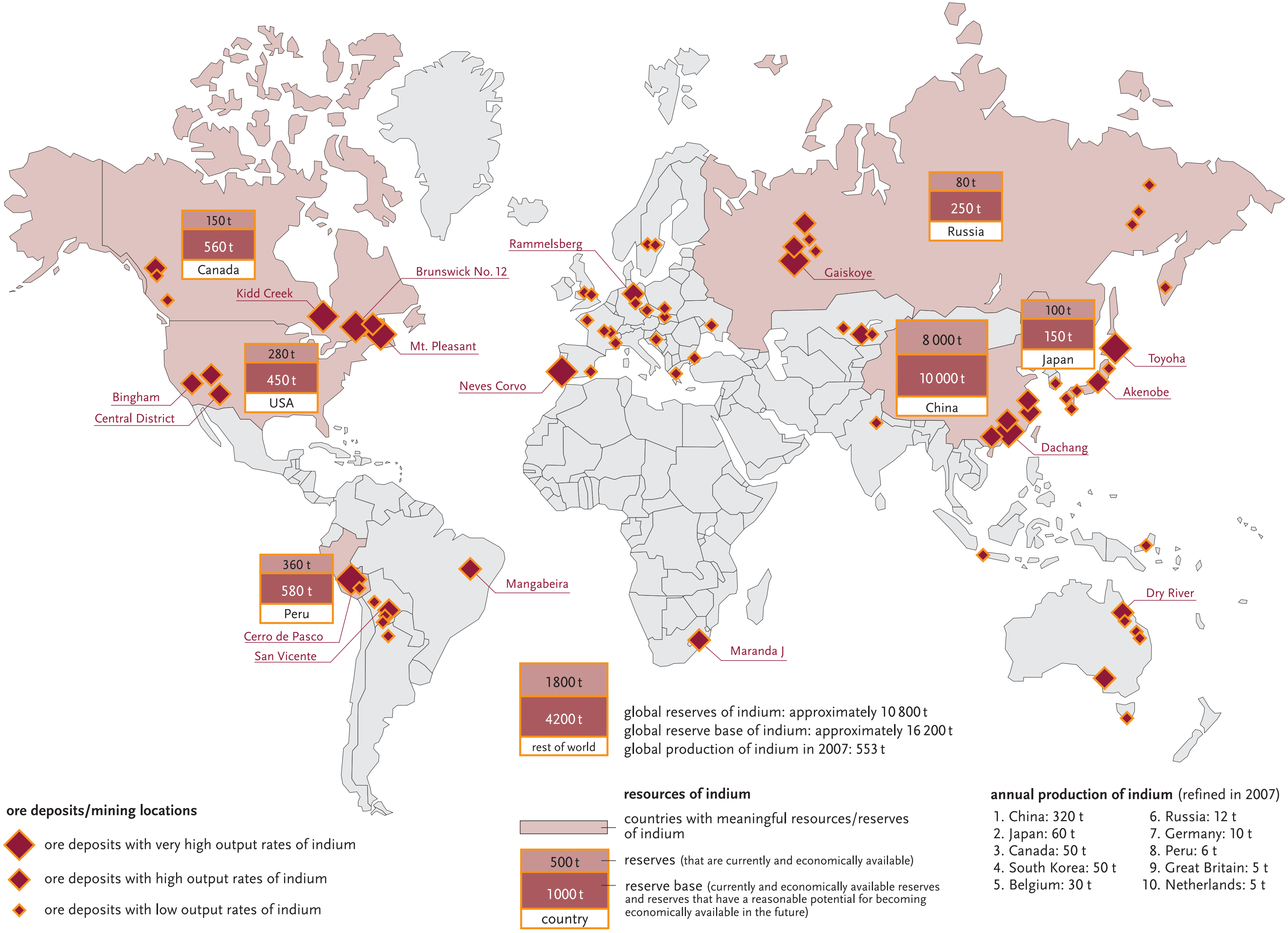

FIGURE 3: Global indium deposits. Indium has specific properties needed for various technological applications, for instance in mobile phones and, especially, photovoltaics. Its worldwide consumption rate has recently surpassed the production rate, resulting in a ten-fold price increase over the last three years. Data sources: Schwarz-Schampera (2004), Bublies (2006), United States Geological Survey (2008), Roskill Information Services (2003), Stevens (2007).

reserves of these spice metals. An example with a relatively clear data situation is palladium, used in mobile phones for contacts and as a gold substitute (palladium nickel alloy). According to the University of California study, the average cell phone is made of only 0.015 percent palladium. Nevertheless, about 15 tonnes of this very rare metal – only around 220 tonnes are produced worldwide per year, most of it mined in Russia and South Africa – are consumed by one year's cell phone production. This may mean serious competition for the leading user of palladium, the automotive industry, which uses palladium for the catalytic conversion of toxic exhaust gases.

Gold and silver are also found in cell phones – the gold that has been incorporated in cell phones in the last ten years is worth several billion US Dollars today.

Indium

Further metals that are exceptionally rare and hardly noticed by the users of mobile phones are found, for instance, in displays. One of these metals particularly worth mentioning is indium, used in the compound indium tin oxide as an essential transparent, conductive glass. Due to its very specific properties, indium is needed in various technologies, for example for the copper indium selenide semiconductor sheets in the latest generation of photovoltaic panels. Since indium has a worldwide yearly production of just above 550 tonnes, but an estimated overall yearly consumption of 800 tonnes (estimated data for the year 2008), it is not surprising that its price has risen by a factor of ten over the last three years. It is therefore important to get reliable data on where indium resources are localised and on how long reserve supplies last. According to our study (Bublies 2006), the indium resources can be quite well localised and quantified, as the map in figure 3 shows.

It is alarming that the strategic inventory of indium, essential to at least two key technologies (mobile phones and photovoltaics), could be exhausted within the coming two decades. Although China claims to have detected rather large new deposits in 2008, and a deposit of 1000 tonnes has been located in the Eiffel (Germany) in 2009, the global supply situation is critical. Optimists argue that there is still plenty of indium to be extracted from the earth's crust. But in most cases the concentration is so low – i. e., a few parts per million or less – that extracting these traces would not be cost-effective, even with another massive price rise. The mining would also have corresponding ecological implications. Others argue that an indium substitute will be found in time. However, the development and subsequent implementation of a substituting functional material takes its time. In other words, a very specific functional material like indium tin oxide or copper indium selenide as well as copper indium sulfide used in most current photovoltaic devices cannot be developed overnight. If a supply bottleneck is recognised too late and if research and development are not promoted actively, economic collapse and resource conflicts are foreseeable. Unfortunately, disregard for possible ecological risks is all too often a consequence of such situations.

Lithium

A separate examination is necessary for the most important secondary part of a mobile phone: the battery. Many of the materials used for a cell phone's power supply have been declared health risks in the past few years – above all, cadmium, which can account for up to 26 percent of nickel-cadmium (NiCd) batteries. Much has changed in this area over the last ten years, though. Lithium ion batteries are steadily pushing the more critical products out of the mobile phone market. And alternative energy sources like solar cells and fuel cells are being discussed to power mobile phones. Again, a crucial resource issue is involved: Owing to the fact that lithium accumulator technology is not only increasingly used in mobile phones but also starts to penetrate the automotive sector – current hybrid cars are equipped with lithium accumulators – a competitive stress is initiated. The most important lithium deposits, i. e., over 80 percent of the world production potentials, are found in Chile, Argentina, and Bolivia. In light of the recent foreign politics of Bolivia, for instance – its current president, Evo Morales, underlines the property rights of the indigenous population with regard to natural resources –, the political dependence of a potentially most essential emerging technology is obvious.

Limitation of Raw Materials

If the value of the many other strategic metals used in small amounts in cell phones and other high-tech products rises (as expected for the coming years), there will develop increasing pressure to recycle the devices. Already today, electronic waste is bought and laboriously disassembled by hand in China, India, and African countries. Special attention is paid to those spice metals that are not contained in chemical compounds or alloys, but can be directly taken out and collected. These recycling stations are the beginning of secondary deposits – "secondary mines", so to speak – of great strategic importance.

Many strategic materials are not being used in static everyday technology products, but in highly dynamic, constantly changing devices that are exceptionally variable through further developments. Up to now, serious concerns about the availability of the necessary resources, particularly the strategic and function-critical spice metals in emerging technologies, have rarely been issued. From an historical perspective, never before have so many metals been used in technical development. There has never been such a need to exploit the earth's mineral resources and mobilise them. In the past 20 years, the semiconductor industry has integrated into products and thereby in the value addition chain at least 30 metals that were previously thought interesting only by theoretical scientists. The economic and ecological effects of these advances in the coming years and decades are not foreseeable. But even the implications of the current prevalence of mobile phones for society and culture are not yet completely clear. A serious investigation of the relevant economic, ecological, and societal effects is of paramount importance.

An historical look at the development of materials for energy carriers is both helpful and deceptive. While the involved con-

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cepts promise theoretically unlimited reproduction of processes, facilities, and equipment, the basic raw materials needed are limited, especially the critical spice metals. So we find ourselves in an ambivalent situation: On the one hand, technological advancement promises complete emancipation of mankind from nature; on the other hand, technological advancement appears restricted, and therefore threatening, because of its material limitations. It is no longer guaranteed that the earth's resources can satisfy demand. A more precise understanding of worldwide material usage and material flows is needed.

Irretrievable Dissipation

The life cycle of a cell phone and of its constituents implies a global cascade of interactions. At its end, scarce raw materials may be irretrievably dissipated. Indium, for example, is a rather scarce metal which is mined together with aluminium or other base metals. It is then separated, refined, and reacted with tin oxide in order to fabricate indium tin oxide, the indispensable conducing but transparent oxide used as an essential functional material in the cell phone's display. After purchase and use, a mobile phone may be re-used by other users, put to oblivion, or dumped as electronic waste. Even if it undergoes a controlled recycling procedure, the indium contained in it cannot be retrieved easily because the amounts used are very small. Once diluted in the biosphere, indium will hardly ever be recoverable. This is an historic nuisance! By this effect called dissipation, functional spice metals most valuable for implementing strategic technologies are lost forever. Moreover, potential and unprecedented bioactivity could worsen the situation. Such situations are prototypical for many scarce metals being used in conventional, emerging, and possibly indispensable future technologies. These circumstances therefore may entail the most threatening, but most unperceived risks.

A Bright Future or a Miserable Collapse?

Opportunities and Cultural Impact

The information and communication sectors have allowed an historical advancement of the global economy in the last ten years. Mobile phones have reached the majority of people on the planet, regardless of geographical, political, or cultural borders. Oddly, these products seem to have changed our perceptions of time and space. The convenience offered by the technology promises a bright future without the boundaries that have hitherto existed. As mentioned before, the extraordinarily high pace of alphabetising the global society could turn out to be the mobile phone's most important, even historically unique cultural impact. The eagerly awaited combination of cell phone, camera, MP3 player, and laptop promises additional independence but hides the involved problems and uncertainties. Social structures are currently challenged by a compromised living space and a vast acceleration of pace. Anyone can be reached at any place or time. As for now, one can only hazard a guess about the ramifications of these new developments for the world's cultures (see also Beck 1986). Spatial and temporal "de-bedding" and "de-anchoring" (according to Giddens) promoted by the mobile phone technology change social structures, and it is not clear how well individuals can adapt to this change.

Risks

What can we learn from the histories of the various metals that make information technology possible? Above all, we need to be prepared for the following thought-provoking scenario: A new economic configuration has been established due to the use and the value added by a variety of metals that were, just a few years ago, only of relevance in chemistry and physics laboratories. On the one hand, the corporations that produce information technology devices are dependent on the above-mentioned strategic "spice metals". Should even one resource become scarce or unavailable out of economic or geopolitical reasons, these companies might go bankrupt. The argument that such functional materials can be substituted may be fair in many cases. In a highly dynamic development, however, such a substitute not arriving in time could easily lead to an economic collapse. In other words, this new economic configuration entails a systemic risk that should not be underrated.

An early clarification and understanding of the life cycles of the involved materials – focusing on the strategic metals – would lower the risk of such a severe outcome. Such an analysis also needs to address the appropriate research activities with regard to material circulation, especially planning and realising of logistics. At the moment, we are still quite far from this ecologically and economically essential approach. Not only are tonnes upon tonnes of metals like iron, copper, nickel, aluminium, zinc, and manganese mined each year, but extremely small amounts of indispensable spice metals like platinum, palladium, indium, germanium, gallium, and uranium are extracted too. The dilution of the latter metals in their respective ores is often in the order of $1:10^6$ to $1:10^8$. In other words: For every gram mined, between one and 100 tonnes of ore must be processed. But a profit can be realised as long as competitive functions or value can be derived from them. These metals, which are integrated in tiny amounts in various products, are often lost through or after use. They dissipate into the ecosphere, particularly in nanoscopic form, by wind and water, and are distributed and diluted so that they can never be regained. This is currently happening, for instance, with platinum and indium (Reller 2006, Bublies 2006).

Such new occurrences in technology and cultural history could lead to undoubtedly miserable, fatal consequences, if such finely distributed metals or metal compounds become bioactive. One more reason to better understand and manage the material flows and life cycles (Reller 2003, Staudinger 2005) of modern technological applications must be the goal of integrating economically strategic materials into manageable, ecologically innocuous recirculation. At the same time, one has to consider the resource consumption as well as the ecological effects of the production and the use of technical devices, focusing on their entire value addition chain as well as on their full life cycle. Without a doubt, this strategy can only be implemented if the global logistics for recirculation and re-use of valuable mineral resources and their derivatives, i.e., the functional materials, are guaranteed. This can only be achieved if the consumers of high-tech lifestyle accessories like the mobile phone understand the relevant time-spatial, socioeconomic, and ecological background and implications, i.e., the potentials and risks related to those accessories.

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