# Sustainable Prevention of Resource Conflicts: New Risks from Raw Materials for the Future? Case Study and Scenarios for China and Rare Earths

**Section report 3.4 (research project FKZ 370819 102)**

Lukas Rüttinger, Moira Feil

On behalf of Umwelt Bundes Amt for our Environment

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**Lukas Rüttinger**

Lukas Ruettinger works as a project manager for adelphi. His work mainly focuses on the fields of Energy and Climate as well as Resources and Governance.

ruettinger@adelphi.de

**Dr. Moira Feil**

Moira Feil works as a senior project manager for adelphi. Her research focuses on natural resource governance and its links to crises, conflicts and peacebuilding as well as Corporate Responsibility and sustainable entrepreneurship.

feil@adelphi.de

**adelphi**
Caspar-Theyss-Strasse 14a
14193 Berlin

T +49 (0)30-89 000 68-0
F +49 (0)30-89 000 68-10

office@adelphi.de
www.adelphi.de

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| | |
|---|---|
| **BGR** | German Federal Institute for Geosciences and Natural Resources |
| **GAO** | US Government Accountability Office |
| **NDRC** | Chinese National Development and Reform Commission |
| **ISI** | Fraunhofer Institute for System and Innovation Research |
| **IZT** | Futures Studies and Technology Assessment |
| **OECD** | Organisation for Economic Cooperation and Development |
| **USA** | United States of America |
| **USGS** | US Geographical Survey |

# 1 Introduction

"Rare earths are to China what oil is to the Middle East," stated Deng Xiaoping in 1992 (Wang 2007). China accounts for 97 percent of global rare earth production, and as such the world is more dependent on it than it is on oil from the Middle East. That situation is significant because rare earths, although usually used only in small amounts, are of great strategic relevance. They are not only key components of many military technologies, including guided missiles and radar; they are also to be found in many high-tech products which we use in our daily lives – primarily electronic devices such as computer hard disks, plasma screens and MP3 players. They also make alloys harder, and are used to grind precision lenses. Rare earths are of particular importance in the field of environmental technology however. They are key components of catalytic converters, wind turbines, energy-saving bulbs and electric motors – and new applications in the environmental field are emerging all the time. These technologies are increasing the importance of, and the demand for, rare earths.

As rare earths become ever more important, however, the question also arises as to the risks and opportunities they bring for consumers and producers. Consequently, this report (3.4) investigates those risks and opportunities, with a particular focus on China. Its analysis follows on from reports 1 and 2, illustrating and expanding upon their results. Likewise, this empirical case study will feed into the proposed solutions and recommended action to be set out in reports 4 and 5.

This report is divided into a case study and four scenarios. The case study serves as an analysis of the status quo. It sets out potential conflict risks and opportunities arising from the situation as it exists in 2010. The subsequent four scenarios depicted were devised in the course of a Scenario Workshop in conjunction with a group of experts. They make use of the case study to set forth a range of potential trends through to the year 2030. The opportunities and risks are summarised both according to the structuring of the case study and broken down by the individual scenarios depicted. The conclusions draw together the findings from the case study and scenarios to present the main conflict risks arising in relation to rare earths.

# 2 Case study: China and rare earths

This case study identifies risks and opportunities for consumers and producers relating to rare earths based on the status quo in the year 2010. In order to identify the strategic relevance of rare earths, their usage and potential substitution are first set out. The study then analyses rare earth reserves, market structures and demand, as well as projected future market trends, in order to identify supply risks and potential bottlenecks for consumers. It also considers the opportunities which might be presented by a diversification of producers.

The second part of the study investigates the conflict scenarios which might result from the use of rare earths, from trends in their supply and demand, and from their market structures. This section first sets out potential conflicts between China and the consumer countries. It then analyses risks and potential conflicts in the producer country China. It considers in detail China's environmental issues, as well as the increasing number of environmental protests being held in the country. Alongside these risks and potential conflicts, however, the report also identifies the development opportunities which China is able to exploit based on its monopoly position. The existing opportunities, risks and potential conflicts are appraised and summarised at the end of the subsection.

## 2.1 Resource type and strategic relevance

This section investigates rare earths as a raw material and in terms of their strategic relevance. The decisive factors in determining the strategic relevance of rare earths are their usage and potential substitution. Both are analysed in the following. Particular attention is devoted to the importance of rare earths to environmental technology. The study then analyses rare earth reserves, market structures and demand, as well as projected future market trends, in order to identify supply risks and potential supply bottlenecks. It also sets out the opportunities arising from the rising demand for rare earths with a view to a possible diversification of producers.

### Application and Substitution Options

Rare earths comprise 17 metals, including the lanthanide series and the elements of the first subgroup: scandium, yttrium and lanthanum (McGill 2007).[1] Thanks to their versatility and special properties, they are used in a wide variety of high-tech fields (Liedtke/Elsner 2009; Haxel et al. 2002).

[1] These are the elements numbered 58 to 71 of the periodic table: cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium.

Their range of usage is very broad. They are important as catalysts for emission control, such as in catalytic converters forming part of exhaust systems, and in petroleum and gasoline production. In the metallurgy field, they make alloys stronger and are a key component of nickel-metal hydride batteries. Virtually all high-grade glass products, such as precision lenses and mirrors, are burnished with them. As lighting products, they are basic components of energy-saving bulbs as well as of LCDs and plasma screens. In the electronics field, they are used, for example, in fibre-optic cables, lasers, ceramic capacitors and high-temperature superconductors. They have also made possible a new generation of high-performance permanent magnets, which are used in computer hard disks, DVD players and other electronic devices, as well as in the electric motors of electric-powered and hybrid vehicles and in the generators of wind turbines. Rare earths are also to be found in many military applications, such as in armour-plating, in missile guidance systems and satellites (Liedtke/Elsner 2009; Angerer et al. 2009; 2008; Haxel et al. 2002; GOA 2010).

Alongside the strategic significance of rare earths based on their use as raw materials for military applications, their importance to environmental technology must also be emphasised. Rare earths are particularly important in the fields of emissions control, electro-mobility and wind power, and for energy-saving bulbs. A hybrid vehicle, for example, contains as much as 12 kilograms of rare earths (Angerer et al. 2009), and the permanent magnets of wind turbines can use as much as two tonnes (Hilsum 2009b). Table 1 presents an overview of the various applications and their respective shares in the total consumption of rare earths.

**Table 1: Share in use of rare earths by application, 2006**

| Application | Percentage share, 2006 |
|---|---|
| **Catalysts (for petroleum and gasoline, and as components of car exhaust system catalytic converters and soot particle filters)** | 20.00 % |
| **Magnets** | 19.07 % |
| **Metallurgy** | 15.81 % |
| **Polishes** | 13.02 % |
| **Glasses** | 12.09 % |
| **Lighting** | 7.44 % |
| **Ceramics** | 5.12 % |
| **Other (e.g. lasers, medical applications, high-temperature superconductors)** | 7.44 % |

Source: according to Liedtke/Elsner 2009, 1

In order to assess the strategic importance of rare earths and the associated risks, a key factor in addition to their usage is the question of their potential substitution. In its comprehensive study "Minerals, critical minerals, and the U.S. economy", the US National Research Council reports that there are few known materials available as substitutes for rare earths, especially in relation to emissions control applications, for magnets and in the electronics field. Though electric motors and generators with permanent magnets could, in theory, be replaced by induction motors, such substitute solutions would be less efficient. In relation to the fields of metallurgy, ceramics and optics, the same report finds that there is insufficient information available to permit any definitive statement as to potential substitutes for rare earths. Where substitute materials are known, they are adjudged in any case to be less effective (National Research Council (U.S.) 2008; Hedrick 2010). Germany's Federal Institute for Geosciences and Natural Resources (BGR) concurs with the National Research Council that rare earths are today already of very high strategic significance, and indeed of critical importance, in many high-tech fields, especially in the environmental and military sectors, because few – if any – effective substitute materials exist (National Research Council (U.S.) 2008; Liedtke/Elsner 2009).

**Risks**

Rare earths are of extremely high strategic importance (cf. European Commission 2010) and very few substitute materials – if any at all – are available. This primarily entails risks to consumers due to supply bottlenecks, which might have major impact on high-tech industries.

### 2.1.1 Reserves and market structure

The risk of supply bottlenecks occurring can be judged in part from the existing levels of reserves and based on the market structure, both of which are analysed in the following. Firstly, with regard to reserves: Despite their name, rare earths are not rare in terms of their occurrence in the earth's crust. Copper, lead and tin, for example, are more rarely found than the most frequently occurring rare earths (Angerer et al. 2009). Thulium, the rarest of the rare earth metals, is still more commonly found than silver, platinum or gold (Angerer et al. 2009). However, concentrations of rare earths in deposits enabling mining of them exist in only a small number of locations around the world.

Rare earths can be recovered primarily from bastnaesite, monazite, xenotime and ion-absorbing clays. Deposits vary widely in terms of the rare earths they contain (Haxel et al. 2002). Since rare earths always occur together, however, they can only be mined together (Liedtke/Elsner 2009). This makes commercial mining difficult, as the quantities mined inevitably do not match the demand for them. Consequently, some 25 percent of rare earths mined remain unused (Angerer et al. 2009). Rare earths are produced, traded and used in the form of rare earth oxides or rare earth metals, and are available both as single metals and in combination (Angerer et al. 2009). The processing of rare earths is very complex and expensive (vbw 2009; Hurst 2010).

According to the latest estimates by the USGS, worldwide reserves[2] of rare earth oxides are around 99,000,000 tonnes (Hedrick 2010). The largest reserves are to be

[2] The term 'reserves' in this context refers to the amount of a mineral which it would be commercially and technically feasible to mine under current conditions.

found in China, the region of the former Soviet Union, the USA, Australia and India (for an overview see table 2). However, these estimates are based on past and current exploration by mining companies, which for the most part have a limited time horizon of around 20 to 30 years. Consequently, the discovery and exploitation of new deposits may result in new estimates.

**Table 2: Mine production and reserves of rare earths by country, 2009**

| Country | Mine production in t | Mine production as % | Reserves in t | Reserves as % |
|---|---|---|---|---|
| China | 120,000 | 97.0 | 36,000,000 | 36.52 |
| Former USSR | No data | No data | 19,000,000 | 19.27 |
| USA | 0 | 0.0 | 13,000,000 | 13.19 |
| India | 2,700 | 2.2 | 3,100,000 | 3.14 |
| Australia | 0 | 0.0 | 5,400,000 | 5.48 |
| Brazil | 650 | 0.5 | 48,000 | 0.05 |
| Malaysia | 380 | 0.3 | 30,000 | 0.03 |
| Other countries | No data | No data | 22,000,000 | 22.32 |
| Total | 123,730 | 100.00 | 98,578,000 | 100.0 |

Source: according to Hedrick 2010

Despite the widely varying applications of rare earths, the market in them is relatively small – with total sales of 1.25 billion US Dollars (2008) (Liedtke/Elsner 2009, 3). According to estimates by the USGS, global mining volumes have remained stable at around 123,000 - 124,000 tonnes since 2005 (Hedrick 2007, 2010). Of that total, 97 percent[3] originates from China, primarily from the bastnaesite deposits of Bayan Obo in Chinese Inner Mongolia and in the province of Sichuan, as well as from the deposits of ion-absorbing clays in southern China. Table 3 presents an overview of the spread of Chinese production. Smaller quantities of rare earths are also mined in India, Brazil and Malaysia. The processing of rare earths is even more heavily concentrated on China than their mining (King 2010). As a result, China enjoys a monopoly in the production of rare earths.

[3] Some analysts revise these figures downwards slightly, to 95 percent, based on their own estimates (VBV 2009).

**Table 3: Estimates of Chinese mining by region, drawn up by Kingsnorth for the year 2008, excluding illegal production**

| | Bayan Obo Bastnaesite | Sichuan Bastnaesite | Ion-absorbing clays | Other | Total |
|---|---|---|---|---|---|
| **in tonnes** | 60-70,000 | 10-15,000 | 45-55,000 | 8-12,000 | 125-140,000 |
| **as percent** | 48-50 | 8-11 | 36-39 | 6-9 | 100 |

Source: according to Cox 2010a

### Risks and opportunities

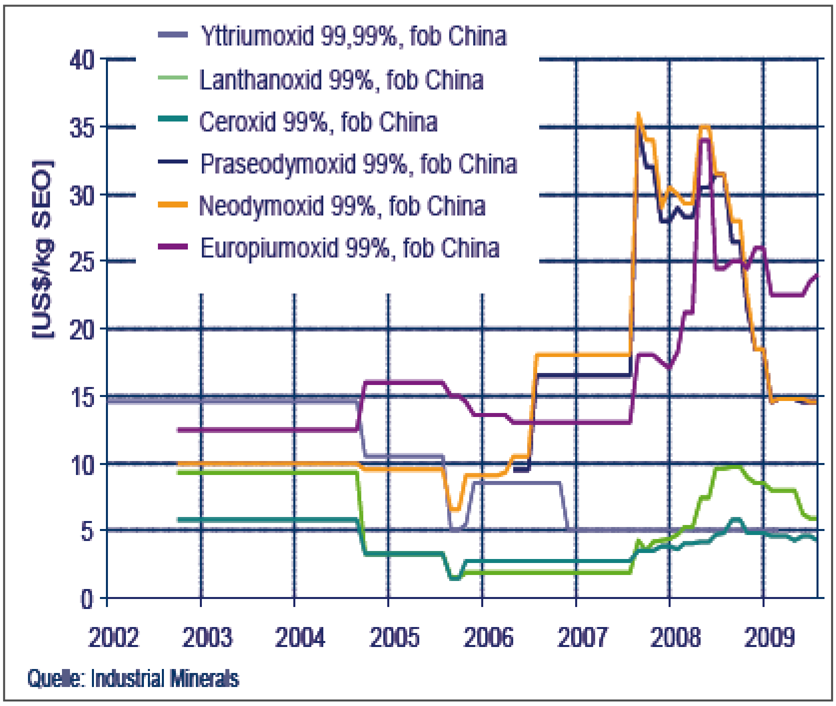
This monopoly entails an economic risk to consumer countries with regard to stable supplies of rare earths. Thanks to its market dominance, China can influence volumes and prices, for example by creating artificial shortages. Supply risks also arise from the fact that most of the global production of rare earths originates from a small number of regions in China. If production by just one of those regions were to be lost due to natural disaster or social unrest, it would have an immediate impact on world markets.

In view of the fact that some 63 percent of reserves are located outside of China, there is, however, an opportunity to develop alternative mining resources and slowly reduce China's monopoly. Nevertheless, China has the ability to keep competition off of the market, or squeeze existing competitors out of it, by creating artificially low prices ('predatory pricing') (Gillespie 2007). A potential counter-strategy to such moves might involve state subsidies.

## 2.1.2 Demand and future market trends

As well as the questions of reserves and market structure, the demand for rare earths and future market trends are essential to any estimation of supply risks. The demand for rare earths and the trends in their pricing have become considerably more dynamic since 2004: Driven primarily by the more widespread use of rare earths in lighting and in permanent magnets, the prices of selected rare earths, such as europium, terbium, dysprosium, neodymium and praseodymium, rose between 2004 and 2007. That trend intensified between 2007 and mid-2008, with the prices of almost all rare earths increasing (Liedtke/Elsner 2009). Demand for neodymium, dysprosium, europium and terbium rose to such an extent that it outstripped supply, resulting in bottlenecks (Hedrick 2009). When the global economic crisis hit, this trend was reversed; prices fell back and consumption declined. As one sign of that development, US imports of rare earths in 2009 were more than 45 percent down against 2008 levels (Hedrick 2010). According to estimates, worldwide demand fell from 124,000 to 80,000 - 85,000 tonnes between 2008 and 2009 (Cox 2010a). For an overview of price trends in selected rare earths from 2002 to 2009 see figure 1.

**Figure 1: Price trends in selected rare earths**




Source: Industrial Minerals according to Liedtke/Elsner 2009, 3[4]

However, most analysts and industry experts expect the market to recover rapidly and resume its steep growth. The background factors underlying those forecasts are long-term market trends. It is expected, for example, that the rising demand in the fields of emissions control, lighting, permanent magnets and accumulators seen in recent years will be continued. Those technologies are growing because they are being increasingly used in conventionally powered, electric and hybrid vehicles, as well as in computers and electronic devices (Hedrick 2009). They metals primarily being used are lanthanum, dysprosium, terbium, neodymium and europium (Liedtke/Elsner 2009). Based on those growth trends, it is estimated that between 2012 and 2014 demand will rise to 180,000 -190,000 tonnes (Arafura Resources Limited 2010; Tuer 2009; Liedtke/Elsner 2009). Roskill considers growth rates of 8-11 percent per year as a realistic prospect over the coming years (Roskill 2007).[5]

Those market trends are also expected to be sustained after 2012. The 15 percent growth rate in permanent magnets made using rare earths, for example, is likely to remain stable beyond 2012 (Hedrick 2009; Roskill 2007). Analysts additionally predict that the number of applications for rare earths will rise still further. Alongside existing applications, there is major potential for the wider use of rare earths in environmental

[4] 'fob' stands for Free on Board, meaning the price loaded on-board at the designated port of shipping; US$/kg SOE stands for US Dollars per kilogram of rare earth oxide.

[5] Although that estimate was published before the global economic crisis hit, it is cited here to illustrate the views of many analysts that the market will resume its prior steep rate of growth.

and energy technology in future. A study by the Institute for Futures Studies and Technology Assessment (IZT) and the Fraunhofer Institute for System and Innovation Research (ISI) on behalf of the German Federal Ministry of Economy identified a number of rare earths which are likely to be key in the environment and energy fields. Scandium, for example, was identified as a genuine 'enabler' of specific future technologies, in particular with regard to light-weight construction in civil aviation and to solid fuel cells, where it offers potential for major cost-cutting. The only limiting factor in this at present is the lack of availability of scandium. In the high-temperature superconductor field, which might play a key role in the Desertec project to transmit electric power over long distances for example, yttrium is likely to become more significant. Yttrium-barium-copper oxides are termed second-generation high-temperature superconductors by virtue of their low cost and potential performance advantages (Angerer et al. 2009). Moreover, rare earths might also lead to a breakthrough in magnetic cooling which would in turn render superfluous conventional cooling systems using fluorinated hydrocarbons, which are extremely harmful to our climate. The rare earth thorium might even replace uranium as an alternative nuclear fuel (Hedrick 2009).

So forecasts indicate a major growth in demand through to 2012 and beyond. Absolute shortages of rare earths may occur over the long term if that growth is not met by sufficient exploitable quantities. There are unfortunately no detailed long-term growth forecasts extending beyond 2012, so the question of absolute shortage is difficult to estimate. However, extrapolating from the existing forecasts of demand for rare earth oxides totalling approximately 180,000 tonnes in 2012 and a constant growth rate of 10 percent, the worldwide reserves of 99,000,000 tonnes would be used up in about 66 years. The resource levels taken as the basis for estimating the reserves plus the potential volumes which will be economically and technically feasible to mine in future amount to approximately 150,000,000 tonnes (Hedrick 2008).[6] This indicates a further relief of the strain on physical supply. However, figures for resources and reserves are of only limited informative value in terms of the physical finite nature of the raw material, as these estimates are based merely on existing exploration operations by mining companies and may change dramatically as exploration discovers new deposits.

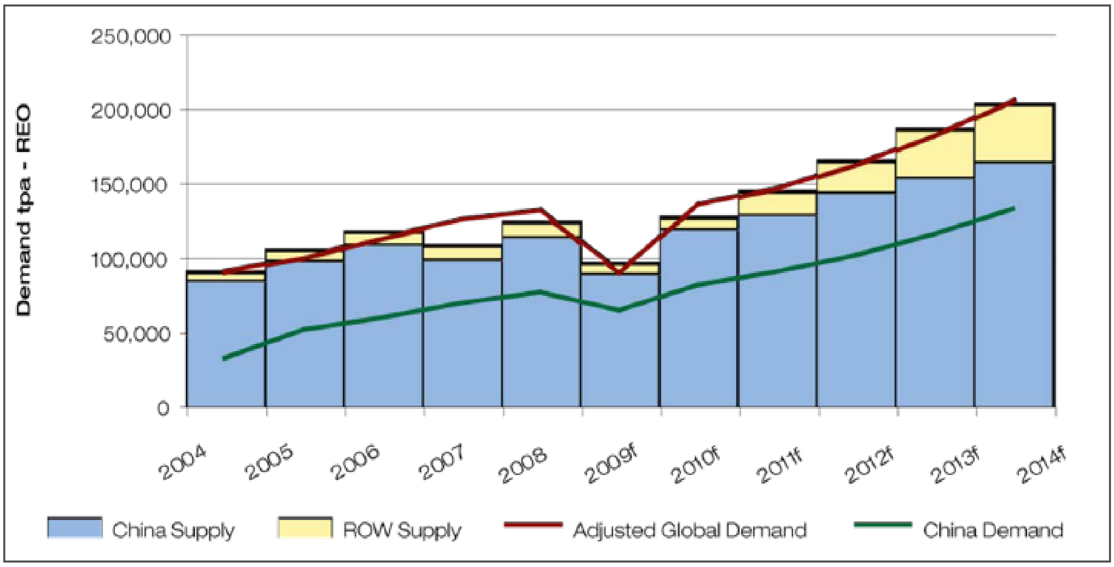
In the short term, many analysts see a supply problem arising as early as 2012. For that is when – at constant growth rates in Chinese mining capacity, and based on a conservative assumption of 8-11 percent growth in Chinese demand – China will have used up its entire production to meet its own consumption needs (Kingsnorth 2008). Thus, in order to meet its own needs and at the same time fulfill the rising demand from the rest of the world, China would have to massively expand its mining capacities. Such a massive increase in Chinese mining and production capacities is not likely, as China is at present more interested in consolidating the sector and in reducing the environmental impact from the mining and processing of rare earths (see chapter 3).

[6] The USGS has not published any estimates relating to the resource base since 2009.

The more likely outcome is that Chinese deposits might in the medium term produce fewer rare earths due to technical problems and physical limitations. In Bayan Obo, new deposits with lower concentrations of rare earths will need to be exploited in order to maintain existing production volumes over the medium term. New methods will also have to be devised for the extraction of rare earths from the waste water occurring in rare earth production, which has not been usable to date. There are also fears that Chinese reserves have already been largely used up (Kingsnorth 2008; Jiabao/Jie 2009). According to some estimates, deposits in southern China will have been completely mined-out in the next 15 years. All of China's reserves might have been exhausted with the next 20 to 30 years (Bradsher 2009b; Jiabao/Jie 2009).

Consequently, new production resources outside of China will need to be found and exploited in the short and medium term. Figure 2 shows the demand which will need to be met by deposits outside of China as "ROW Supply" (ROW standing for Rest of the World).

**Figure 2: Trend in supply and demand according to Kingsnorth**




Source: IMCOA according to Cox 2010a

But developing new deposits is expensive, and may take 7 to 15 years (Bird 2010; GOA 2010). Former USGS analyst James Hedrick stresses that, alongside the cost of developing new deposits, the cost of processing plants will pose a major hurdle to investors and producers (Hedrick nach Hsu 2010). The US Government Accountability Office (GAO) estimates that it could take up to 15 years to build up a complete supply chain in the USA (GOA 2010). The long lead time to develop new deposits means that in the short term supply can only be increased by mines which already are, or were in the past, active in producing rare earths. A number of promising projects exist: In the USA, Molycorp Minerals is working to restart production at what used to be the world's largest rare earth mine at Mountain Pass. Mining operations are scheduled to begin in 2010. The processing of rare earths from existing stocks began back in 2009 (Molycorp Minerals 2010). In Australia, Lynas Corp in Mt. Weld began a first phase mining rare earths as far back as 2007. There is a lack of processing plants to turn the rare earth ores mined there into oxides or metals (Hedrick 2010). Though relevant facilities are being developed in Malaysia (Cox 2010b). Australian corporation Arafura Resources is likewise working to commission into operation a mine and processing plant in Nolan, Australia. The facility is scheduled to begin production of rare earths in 2012. There are also a number of projects underway in the USA, Canada, India and Malawi (Liedtke/Elsner 2009; Hedrick 2010). Whether those projects will be able to start production soon enough, and in sufficient quantities, to close the gap between supply and demand remains uncertain – especially if demand turns out to be higher than forecast. An additional factor is that the financial and economic crisis has made it more difficult to attract investment in existing and new projects. Both Arafura Resources and Lynas Corp, for example, lost their financial backing in the course of the crisis and had to temporarily stop their mining and processing operations (Jubak 2009). So the possibility of a relative shortage as early as in the next few years cannot be excluded.

In addition to developing new deposits, it would also be possible to recycle rare earths as a means of building up secondary resource recovery systems and so increasing security of supply. Recycling is complicated, however, because rare earths are mostly used in only small quantities in a wide range of different applications. Consequently, recycling appears feasible primarily for lighting materials and permanent magnets, as they are used in sufficient quantities and in the same configuration, and/or contain larger amounts of rare earths (vbw 2009; National Research Council (U.S.) 2008).

### Risks and opportunities

There are therefore considerable short-term and medium-term supply risks for the consumer countries. From 2012 onwards, a relative shortage of rare earths might arise due to China's increasing domestic consumption, and if projects outside of China do not start producing in good time. In the medium term, relative shortages might arise if fears with regard to technical problems and physical constraints at Chinese mines and processing plants are confirmed and production has to be cut back as a result.

Opportunities will arise in relation to the development of new mines outside of China. This might not only safeguard China's reserves, but also slowly reduce its monopoly. Likewise, the establishment of recycling systems for rare earths might cut consumption.

## 2.2 Conflict scenarios

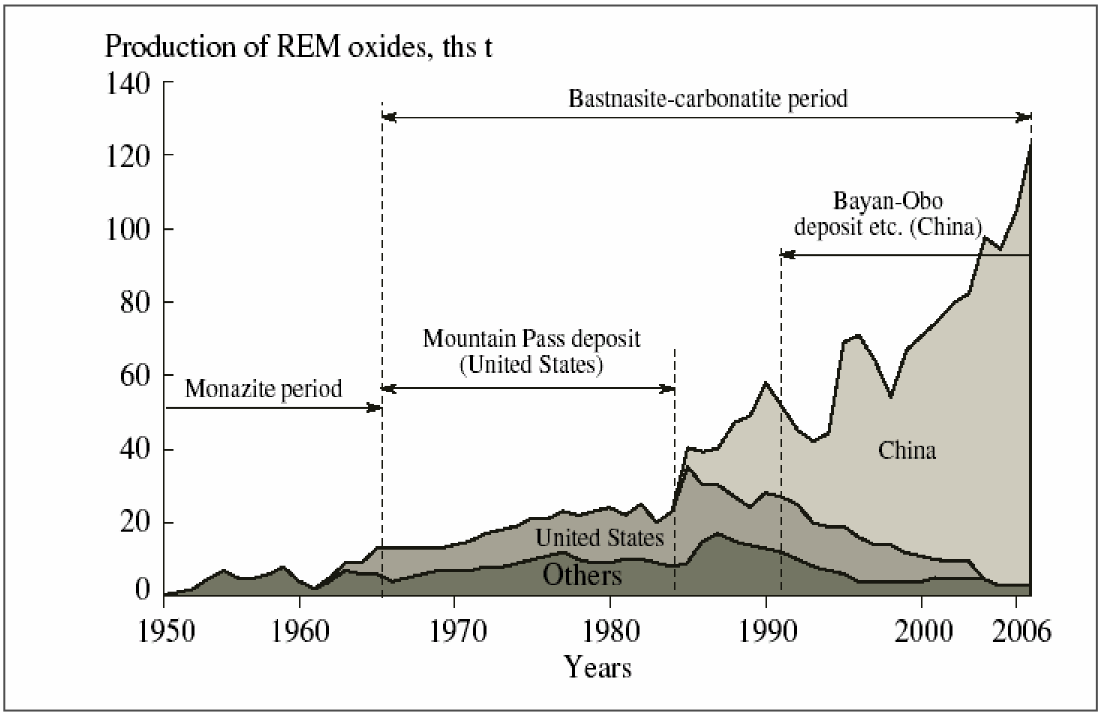
China's monopoly not only represents a supply risk to the consumer countries, however, it might potentially also lead to conflict between them and China. Moreover, the mining of rare earths and the associated environmental destruction poses a risk of potential conflict with the local populace in China. The following presents an analysis of both those potential conflicts and the associated risks. It also sets out the opportunities which rare earth mining offers for more sustainable development in China.

### 2.2.1 China's monopoly: Mineral policy as economic policy

China's monopoly is not a random occurrence. The Chinese government recognised the strategic potential of rare earths at an early stage. China began a process of continuously developing its rare earth production as far back as the mid-1980s. This broke the dominant market position of the USA, which had previously met most of the worldwide demand from the Mountain Pass mine.

From the mid-1990s, China began to exert massive pressure on rare earth prices. Rare earths were being produced in Bayan Obo as a by-product of iron ore mining, and lax environmental standards – or indeed a total lack of any such standards – meant that rare earth mining in China was many times more profitable (Cox 2009b). This enabled China to market rare earths at prices below US production cost. US production was no longer competitive and, after accidents involving radioactive waste water at the Mountain Pass processing plant, production at the facility was discontinued in 1998 (Haxel et al. 2002; Margonelli 2009). The question as to whether the low prices enforced by China represented the conscious implementation of a predatory pricing policy in order to establish a monopoly, as some analysts claim, cannot be definitively answered. For an overview of these trends see figure 3.

**Figure 3:** **Production of rare earths by origin, 1950 to 2006**




Source: Naumov according to Angerer et. al. 2009, 309

Today China enjoys an undisputed monopoly, and is aware of the powerful position it holds. As a consequence, it has begun to exploit that position for economic policy ends. Its aim is to promote and develop its own high-tech processing industries by attracting foreign firms to relocate their production to China (Stewart 2010). To achieve this, China first began reducing its rare earth export quotas year by year (Roskill 2007; Stewart 2010). China's exports of rare earth oxides in 2005 totalled 66,000 tonnes; by 2008 that figure had fallen to just 53,000 tonnes. The Beijing government also increased taxes on the export of rare earths by 15 to 25 percent (GOA 2010). This strategy proved successful, and manufacturers of high-tech magnets and motors and other leading-edge technologies relocated their production to China (Bradsher 2009a; Greenwire 2010). This trend was boosted by the guarantees provided by China to all manufacturers relocating there that they would be supplied with all the rare earths they needed (Cox 2009a). Near to the mines in Inner Mongolia, China has even begun developing a rare earth 'Silicon Valley' – a special economic zone named Baotou National Rare Earth High-Tech Industrial Development Zone, as a centre for high-tech processing industries (Hilsum 2009b).

The situation came to a head in August 2009 with the disclosure of parts of a draft resolution titled "Rare Earths Industry Development Plan 2009-2015" from China's Ministry of Industry and Information Technology. The document proposed a complete embargo on exports of the rare earths terbium, dysprosium, yttrium, thulium and lutetium. For other metals, such as neodymium, europium, cerium and lanthanum, it proposed introducing a combined export quota of 35,000 tonnes per year. That would have been less than the global demand for the metals in question (Evans-Pritchard 2009). However, shortly afterwards the Chinese government announced that it was not planning to impose an export embargo, but would be regulating the rare earths industry and its exports more closely. As well as consolidating the sector, the measure sought primarily to close down small, unregulated and environmentally harmful mines (Bradsher 2009a; Stewart 2010). These small, unregulated businesses are currently the lowest-cost producers in China, though they are causing major environmental pollution (see section 3.2). Moreover, they are often illegal, and some of their production bypasses China's official channels and is smuggled abroad (Bradsher 2009b). After having increased its export quotas by around 7,000 tonnes in March 2010, in July China then cut them back 72 percent compared to the previous year's levels (Reuters 2010; Chinaknowledge 2010).

China also attempted to broaden its influence on the rare earths market beyond its own borders too. When Arafura Resources and Lynas Corp lost their financial backing in the course of the economic crisis, Chinese state-owned firms came to their aid, acquiring a 25 percent share in Arafura Resources. However, their takeover of a majority share in Lynas Corp was blocked by the Australian government and the transaction did not go through (Bradsher 2009a; Keenan 2009).

Thus China can be seen to be deploying a number of economic and trade policy strategies – from export quotas and levies and the imposition of more stringent controls on unregulated mines, through supportive measures including the establishment of special economic zones and the provision of supply guarantees for domestic-based producers, to acquisitions of foreign firms – in order to attract high-tech businesses and their production to China and gain access to their technologies (Jubak 2009; Hilsum 2009b). Another objective behind the export quotas and levies, and the imposition of more stringent controls on unregulated mines, is to safeguard the country's own supplies of rare earths.

### Risks, potential conflicts and opportunities

Risks exist in this context with regard to conflicts between the producer China and the consumer countries, primarily Europe, the USA and Japan. The extreme concentration of mining resources in China and the high strategic importance of rare earths represents a potentially powerful tool for exerting pressure. At present, China is utilising its monopoly position as an instrument of economic policy to develop its own high-tech industries. Whether it is also willing to exploit it as a tool with which to exert pressure in the foreign policy sphere is difficult to judge. If other conflicts with China should intensify, the possibility can at least not be excluded.

China has to date shown itself to be pragmatic in terms of foreign policy, however, preferring to pursue a strategy of conflict avoidance (Zakaria 2009). Industry expert Dudley Kingsnorth additionally points out a number of risks with which China might be confronted if it chose this course of action (Kingsnorth 2008):

1. If rare earth prices rise, China's illegal mining sector will be boosted, resulting in falling prices, more environmental destruction, corruption, and a loss of government control.
2. More money would be invested in research into alternatives to rare earths, which would undermine the strategy of attracting foreign high-tech firms to China and weaken the Chinese rare earths industry in the long term.

3. China would be exposed to the risk of a dispute at WTO level.[7]

Whereas for the consumer countries China's monopoly primarily entails risks, for China it represents a development opportunity which it is understandably exploiting. As an emerging economy, China is confronted by twin challenges: The fact that much of its population still lives below the poverty line means that it has no alternative but to go for economic growth; yet that growth entails significant harm to the environment, and is consuming enormous amounts of resources. Consequently, developing the high-tech and environmental technology sectors is a priority for the Chinese government. Such a policy offers the opportunity to cut the link between ongoing economic growth and consumption of resources, and to minimise the major environmental impact which growth is exerting (see also section 3.2). However, in the medium to long term reducing China's environmental impact and resource consumption also represents an opportunity for the consumer countries, as without China global environmental problems such as climate change cannot be resolved.

### Responses of Japan, the USA and Europe

The USA, Japan and Europe have already begun responding to the risks arising from China's monopoly. In Japan, the powerful Ministry of Economy, Trade and Industry (METI) has adopted a "Strategy for Ensuring Stable Supplies of Rare Metals". The strategy paper does not explicitly name China, but it does make mention of the uncertainty of international supply. The strategy focuses on the following areas: Safeguarding supplies of foreign resources by intensifying economic and development policy engagement; recycling; research into alternative materials; and building up strategic reserves (Ministry of Economy, Trade and Industry 2009). According to the Financial Times, the country has already begun building up those reserves (Blas 2010).

In the USA, the 2010 National Defense Authorization Act called on the Department of Defense to investigate the use of rare earths in security-related fields and the consequences in terms of security policy of the high degree of dependency on China (McCarthy und Nye 2009). In March 2010 draft legislation was put before the House of Representatives incorporating measures to promote the development of a national rare earths supply chain and to create strategic reserves (Coffman 2010). In the same month, the US Department of Energy announced that it was preparing a strategy to safeguard supplies of rare earths (Greenwire 2010).

The European Commission has – as part of its Raw Materials Initiative – begun to develop an integrated strategy to safeguard supplies of critical raw materials to member-states. The Initiative also encompasses rare earths. In June 2010 an initial report containing a list of critical raw materials was published for the European Council. Rare earths are among the 14 metals which are subject to the greatest supply and environmental risks (European Commission 2008, 2010; EurActiv 2009; WBCSD 2009).

[7] According to an appraisal by US attorneys Stewart & Stewart, China's export levies on rare earths as they stand at present already infringe against WTO rules (Stewart 2010).

### 2.2.2 Environmental protests in China

In addition to the risks of conflict between the producer China and the consumer countries, there are also signs of potential conflicts with the local populace within China. The political, social and economic context underlying these conflicts is highly complex, and is influenced by a wide variety of quite ambivalent factors. In order to provide a better understanding of them, the following initially sets out the major environmental problems, conflicts and trends in China. It then specifically considers the mining and production of rare earths.

**Box 1: Assessment of the political, social and economic conditions in China by index**

Failed State Index 2009[8] Rank **57 of 177** States
Rank 1 = Most fragile state

The Worldwide Governance Indicators Project 2008[9]

- Voice and Accountability **5.8**
- Political Stability **33.5**
- Government Effectiveness **63.5**
- Regulatory Quality **46.4**
- Rule of Law **45.0**
- Control of Corruption **41.1**

Ratings in percent. 100% = Best rating

Freedom House 2010[10]

- Political Rights Score **7**
- Civil Liberties Score **6**
- Status **Not Free**

Score from 1-7. Score 1 = Highest level of freedom

Human Development Index 2009[11] Rank **92 of 182** States
Rank 1 = Highest development

Corruption Perceptions Index 2009[12] Rank **79 of 180** States
Rank 1 = Lowest corruption

Doing Business 2010[13] Rank **89 of 181** States

Rank 1 = Best business environment

Environmental destruction in China is having an enormous impact on its populace in terms of diseases, contaminated soils and polluted air and water. The statistics are

[8] Indicators: Social Indicators (Mounting Demographic Pressures, Massive Movement of Refugees or Internally Displaced Persons creating Complex Humanitarian Emergencies, Legacy of Vengeance-Seeking Group Grievance or Group Paranoia, Chronic and Sustained Human Flight); Economic Indicators (Uneven Economic Development along Group Lines, Sharp and/or Severe Economic Decline); Political Indicators (Criminalization and/or Delegitimization of the State, Progressive Deterioration of Public Services, Suspension or Arbitrary Application of the Rule of Law and Widespread, Violation of Human Rights, Security Apparatus Operates as a "State Within a State", Rise of Factionalized Elites, Intervention of Other States or External Political Actors) (Foreign Policy/ Fund for Peace 2009)

[9] See World Bank Group 2008

[10] Indicators: Political rights (Electoral Process, Political Pluralism and Participation, Functioning of Government); civil liberties (Freedom of Expression and Belief), Associational and Organizational Rights, Rule of Law, Personal Autonomy and Individual Rights) (Freedom House 2010).

[11] The rankings relate to data from 2007. Indicators: HDI value; Life expectancy at birth; Adult literacy rate; Combined primary; secondary and tertiary gross enrolment ratio; GDP per capita (UNDP 2008).

[12] See Tranparency International 2009

[13] Indicators: Starting a business; Dealing with construction permits; Employing workers; Registering property; Getting credit; Protecting investors; Paying taxes; Trading across borders; Enforcing contracts; Closing a business (International Bank for Reconstruction and Development / The World Bank 2010).

worrying: 10 percent of farm land is contaminated; 40 percent of river water is harmful to human health; and respiratory diseases resulting from air pollution are concidered by some the main cause of death (Economy 2007; WWF 2010).

China has recognised these problems however, and since the start of the 21st century has intensified its efforts in the environmental field many times over. For instance, the highest economic planning institution, the National Development and Reform Commission (NDRC), has undertaken extensive measures to make Chinese industry more energy-efficient and to reduce environmental pollution.[14] These measures have achieved their first successes: Thousands of small, heavily polluting factories and power stations have been closed. China's energy intensity – its energy consumption per unit of GDP – fell in the nine years from 1995 to 2004 by 30 percent, and in the two years between 2006 and 2008 even by 10 percent (Liu 2007b; Jigang/Chuhua 2008).

Yet despite these positive developments, and some ambitious initiatives from central government, at local level environmental protection is often treated with much less concern. This is in part a consequence of the conflict between economic development and environmental protection embodied in disputes between different sections of the central government. Where conflicts arise at local level, Party functionaries are more likely to focus on the incentives of economic growth rather than environmental protection (Economy 2007; Gang 2009; OECD 2005). Though economic growth and environmental protection can indeed go hand-in-hand – such as when improved resource efficiency results in cost savings – more stringent environmental standards do often initially entail higher levels of capital investment which impacts on short-term profit. For local Party functionaries, however, good (short-term) economic performance is vital. It dictates not only their own future career prospects, but also the revenues of the local administration and the material resources placed at the disposal of its public agencies (Zhong 2003; Gang 2009; OECD 2005). For these reasons, decisions by central government are often not implemented and funding actually intended for environmental protection is appropriated for other development projects (Economy 2007). This situation is exacerbated by the fact that the various provinces of China have to compete hard against each other, and businesses will relocate to a different province if regulation of them is too strict. Consequently, ground-breakers in implementing national standards are penalised. A further factor is that environmental legislation in China is very ineffective. It has many loopholes, and is highly complex. Moreover, when the relevant laws were drawn up it was assumed that the local authorities would adopt a cooperative attitude to their implementation (Gang 2009; OECD 2005,).

These problems are further exacerbated by widespread corruption and nepotism at local level (Gang 2009). Party functionaries often have close links to local industries, for example, and as such are even more directly interested in ensuring they remain as profitable as possible (Economy 2007; Larson 2009; OECD 2005). The judiciary is often

[14] In considering these measures, it needs to be remembered that China is still a planned economy, and the aforementioned body has enormous influence on the direction of economic development in China.

too weak to take action against corrupt local Party functionaries (Gang 2009; Economy 2007; OECD 2005).

These problem areas are mirrored by what is for China an extremely vibrant and active civil society with regard to the environment. Public awareness of environmental issues and the importance is comparable to that in western industrialised nations: According to the Pew Global Attitudes Project, over 80 percent of Chinese people believe that environmental protection is important, and some 70 percent regard air and water pollution as a major problem (PewResearchCenter 2008). This is reflected in a large number of environmental NGOs, and in regular media reporting on the issue (Liu 2007a). Furthermore, local environmental protests have been increasing in recent years – at a rate of 30 percent a year according to China's Environment Minister[15] (Blanchard/Laurence 2010; Jing 2003). In 2005 there were 51,000 environmental protests,[16] (Economy 2007), against just 10,000 protests of all kinds – not merely environmental ones – nine years previously (Zakaria 2009). These trends indicate that sections of the Chinese government consciously permit a greater degree of democratic freedom in environmental matters (Liu 2007b; Larson 2008). Pan Yue, Vice-Minister in China's Ministry of Environment[17], even goes a step further: For him, environmental protection in China is a political experiment (Liu 2007a).

Another explanation for the behaviour of the central government is that it is purposely exploiting the civil society to impose national objectives and mandates against the will of local Party functionaries and to control them more effectively (Bernstein und Lü 2003). For the Ministry of Environment this is particularly important, because it has little ability to enforce its policies otherwise at local level. This mechanism also operates in the other direction however: In some cases, the local populace purposely exploits these loopholes and contradictions in the system to impose its own interests (Jing 2003). Overall, however, the rising pressure from the civil society combined with pressure from Beijing does appear to be having some initial effects, and to be causing more and more local Party functionaries to rethink their attitudes (Liu 2007b). There are nevertheless also sections of the Chinese government which fear that these environmental protests might spill over into a wider protest movement, making demands for more far-reaching reforms (Economy 2007).

The ambitious initiatives of central government, the corruption and contradictory incentive systems at local level, as well as the active civil society and the increasing number of environmental protests indicate that in China the conflict between economic development and environmental protection is being played out on, and between, various levels and among a range of different players – resulting in quite ambivalent trends. The central government initiatives, for example, appear to be showing some initial signs of success, but are continually coming up against constraints at local level.

[15] The term 'environmental protests' refers to public protests concerning environmental issues.

[16] These figures are official data from the Chinese government. The actual number of protests is probably higher.

[17] China's Ministry of Environment did not yet exist in 2007. At that time Pan Yue was Vice-Minister of the predecessor institution, the State Environmental Protection Administration (SEPA).

At the same time, the population at large seems to be steadily losing patience with the government. The number of protests is rising, and if they have no effect, they sometimes also spill over into violence (Economy 2007; AFP 2007; Blanchard/ Laurence 2010). This was what happened in the spring of 2005, when two years of fruitless protests and petitions regarding contaminated farm land and polluted air in Zhejiang culminated in riots: 30,000 to 40,000 locals forced their way into 13 chemical factories, attacked local government representatives and destroyed windows, buses and police cars. The government deployed 10,000 troops to regain control of the situation (Economy 2007).

These trends and conflicts are also very much in evidence in relation to the mining of rare earths. In southern China, rare earths are mined at some 200 small and often temporary-style mines. Where the soil layers containing rare earths are close enough to the surface, they are scooped out directly and mixed together with acid in open pits. If the deposits are deeper down, acid is pumped into the soil layers containing them. Once the rare earths have been separated out, the acid is pumped back to the surface and the rare earths are extracted from it (Bradsher 2009b). These mining methods, and the lack of any environmental protection measures, are causing widespread environmental destruction. Local farmers complain of contaminated land, failed harvests and polluted rivers. The government resolved to close most of these mines, but many are still being run illegally. They are operated under armed guard, and with the collaboration of corrupt local Party functionaries linked to organised crime. Some of the rare earth mining operations in southern China appear to be firmly in the hands of such organised crime syndicates (Bradsher 2009b). This has already led to conflict with the local populace. In September 2009, angry locals in Pitou blocked trucks loaded with chemicals and protested in front of the local council building. Arrests were made (Hilsum 2009a).

In the extreme north of China too, in Inner Mongolia, there are reports of environmental problems relating to the processing of rare earths. Rare earths from the Bayan Obo mine are processed using highly toxic chemicals by workers wearing no protective clothing. In this process, the production of one tonne of rare earth oxide creates as much as 63,000 $m^3$ of exhaust gases containing sulphuric acid and hydrofluoric acid, 200 $m^3$ of acidic waste water and 1.4 tonnes of radioactive waste. In the industrial city of Baotou, where most of the rare earths from Bayan Obo are processed, chemical poisoning and respiratory disease are common among the workers. Moreover, at a location near Baotou water from tailings ponds used in rare earth production seeped out and contaminated the surrounding farm land, as well as drinking water supplies (Hilsum 2009a; Jiabao und Jie 2009). The waste water from the rare earths industry is also often discharged untreated into the Yellow River, entailing far-reaching impact on the local eco-system (Hurst 2010). There have been no reports of protests from the area to date. Nor could any detailed reports be found relating to the mining situation in Sichuan.

### Risks, potential conflicts and opportunities

Environmental problems in China and the unwillingness – or inability – of the government to take measures against them repeatedly lead to protests by locals, some of which spill over into violent confrontation. This is also the case with regard to the mining and production of rare earths and the resultant environmental destruction. If these problems are not resolved, it is probable that conflicts with the local populace will increase. This will most likely result in only short-term production outages however, as the Chinese government has to date in most cases responded rapidly, massively and firmly to such protests. If environmental protests generally become more militant, and spill over into a mass protest movement demanding far-reaching reforms, the government will probably respond with all the resources available to it.

The Chinese government has already begun taking action against the illegal, heavily polluting mine operations in southern China – primarily also because organised crime syndicates, in collaboration with corrupt Party functionaries, are smuggling rare earths past the government's controls and out of the country. If rare earth prices rise, however, the incentives for corrupt Party functionaries and organised crime syndicates to continue mining them will increase. Accordingly, it would then be more difficult for the central government to take action against those organisations. The environmental pollution would persist, or even become worse, and so increase the potential for conflict.

Opportunities exist at local level only if China's central government takes concerted action against environmental pollution caused by the mining and processing of rare earths.

## 2.3 Interim conclusion

Rare earths are of major strategic importance by virtue of their usage in high-tech fields, and particularly in environmental technology. The current lack of any potential substitute materials and the monopoly enjoyed by China in the production of rare earths make the supply situation more difficult.

Risks for the consumer countries arise, firstly, due to the extreme geographic concentration of global production in two mining territories. If natural disaster or social unrest should lead to a loss of production in those areas, it would have a catastrophic impact on the world market. Secondly, China might reduce its production or impose further export controls. This might happen in the short term as a result of a rise in China's domestic demand or, in the medium term, due to technical and physical constraints. More stringent environmental regulations might also lead to reduced production. This situation would become critical if alternative mine sites outside of China do not begin stable production in good time. Moreover, intensification of other conflicts between China and the consumer countries might cause China to exploit its monopoly position as an instrument of power.

For China, its monopoly represents an opportunity to develop its own domestic high-tech and environmental industries. The development of this sector is vital in view of the challenge confronting China to achieve ongoing economic growth without increasing resource consumption and causing environmental destruction. In the medium and long term, the consumer countries would also profit, as global environmental challenges cannot be met without greater commitment on China's part.

In China itself, environmental destruction and its impact on the local populace is regularly leading to protests, which sometimes spill over into violent confrontation. If the Chinese government is not able to protect the local populace from the most serious effects of rare earth production, or to provide them with appropriate compensation, existing conflicts – especially in southern China – may be intensified. Particularly in the event of rising global demand, entailing very high prices, the efforts of the Chinese government to close down the mines causing the worst of the environmental impact might be made more difficult. In such a case, there would be strong incentives for corrupt local Party functionaries to keep those mines running illegally.

The consumer countries appear to be increasingly aware of the risks entailed by their dependence on Chinese rare earths. This is demonstrated by early responses from Japan, the USA and Europe. Opportunities for the consumer countries to establish greater security of supply can be utilised by building up recycling systems. Such systems would only have an effect in the medium to long term at best, however. Another opportunity lies in the development of production resources outside of China. Whether the western industrialised nations will be able, or willing, to develop their own mines rapidly enough, however, remains open to question. Not least, the mining and processing of rare earths entails significant environmental impact. The dependence on China might thus be perceived as a small price to pay for externalising those costs. Such a short-term strategy would not increase security of supply however.

For China, too, the development of alternative mining and production facilities would be a positive move. Firstly, by reducing environmental damage within China; and secondly, by enabling China's reserves to last longer, thereby retaining the basis for its own rare earths industry in the medium term.

# 3 Scenarios for future mineral conflicts: China and rare earths

The following scenarios were drawn up on May 31, 2010 and June 1, 2010 in the course of a Scenario Workshop conducted by Adelphi and the Wuppertal Institute at the representative office of the German Society for Technical Cooperation (GTZ) in Berlin.

The following persons contributed to the devising of scenarios relating to China and rare earths: Benjamin Achzet (University of Augsburg), Dr. Doris Fischer (German Institute for Development Policy), Volker Handke (Institute for Future Studies and Technology Assessment), Dr. Eva Sternfeld (Technical University of Berlin). The Scenario Workshop on rare earths and China was moderated and summarised by Dr. Moira Feil (Adelphi) and Dr. Nikolaus Supersberger (Wuppertal Institute for Climate, Environment and Energy).

**Box 2: Scenario development**

**Scope and constraints of scenario development:**

The purpose of scenario development is not to predict the future as accurately as possible. Rather, it represents a method of managing the uncertainty of long-term forecasting. The starting point for scenario development is thus the insight that the future of complex systems is, as a matter of principle, almost impossible to predict. From the various directions in which certain critical trends and key factors may develop, intrinsically coherent and plausible narrative scenarios are devised. They describe specific possible states in the future, as well as setting out the trends, events and key players involved in attaining those states. All scenarios developed are equal; no probability is assigned to them (Schwarz 1996; Willmore 2001).

Each scenario describes a possible future development through to 2030, and begins with a description of the global trends exerting a major influence on rare earth supply and demand and on China. Then the specific trends in China are described. At the end of each case study, following the summary an info-box sets out key risks and conflict scenarios. These are based on the analysis matrix underlying the project, and represent links to reports 1, 4 and 5. These boxes also contain a number of pointers, indicating the direction in which the world is developing.

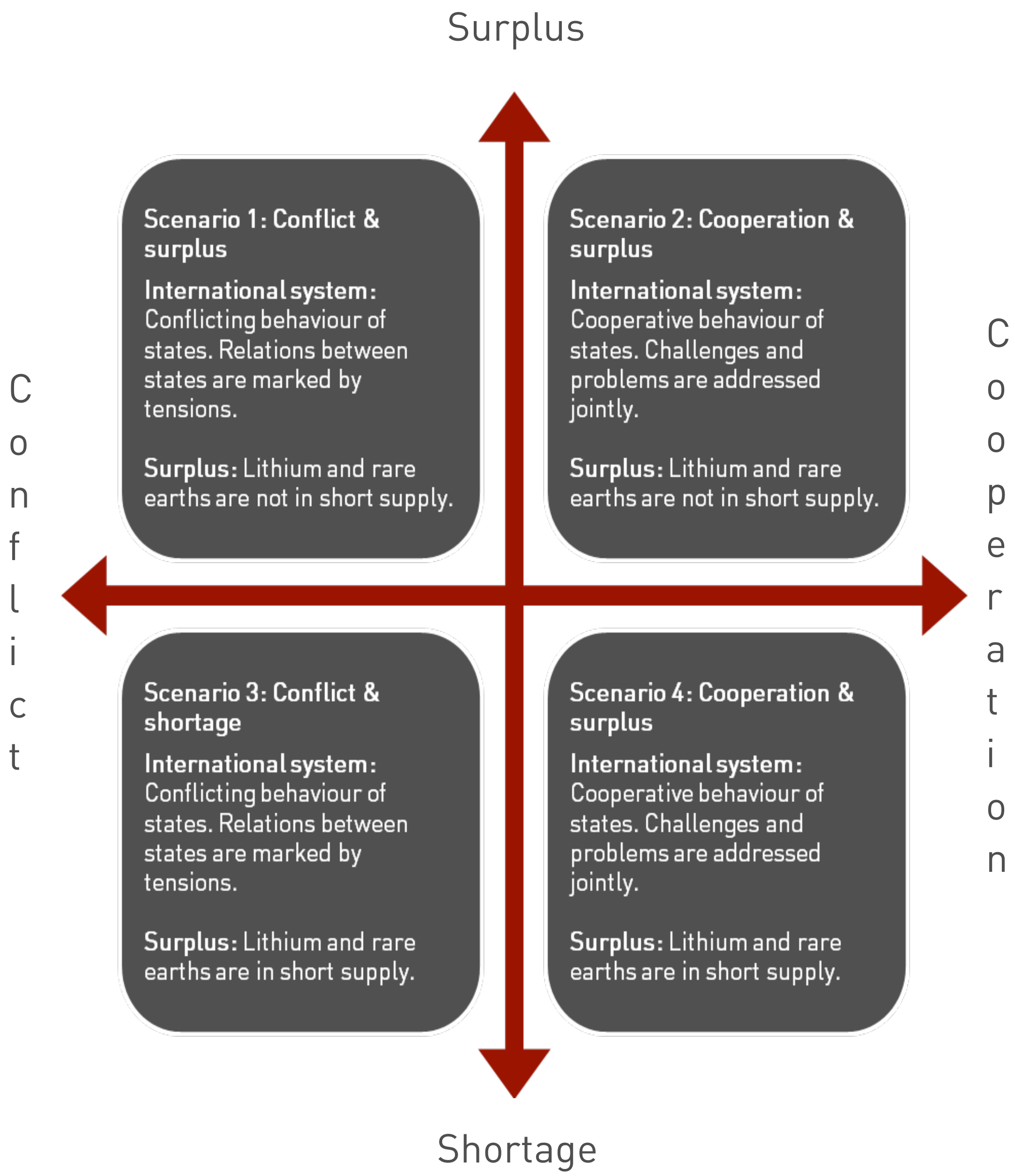
**Method:**

As an aid to orientation for the projection and analysis at the global level a coordinates system with two axes, encompassing four scenario spaces, was used. The axes were:

- cooperation-conflict and
- surplus-shortage.

These axes were identified in the course of the project. They formed the basic framework for development of the most closely targeted scenarios possible, which could subsequently serve as jumping-off points for conflict prevention measures and strategies. An important aspect is that these axes are merely basic alignments, into which the complex system of states can move. Trends within this system do not always progress in a linear manner; there are setbacks, opposing reactions, and transitions from one scenario space to another.

**Figure 4: Coordinates system for projection at global level**



The following trends and descriptors served as the basis for scenario development

**Global trends:**

1. **Economy: Economic growth and increasing energy consumption:**

    a. Growth rate
    b. Development of emerging economies
    c. Price rises in other resources, such as oil and gas
    d. Growth fluctuations

    This trend depicts global economic development and global energy consumption through to 2030. As well as the question of how strongly the economy will grow and how sharply energy consumption will rise, it also considers how these trends will impact on the emerging economies and whether this trend is subject to fluctuations in growth.

2. **Technology: Technological development possibilities:**

    e. Market penetration by key technologies, primarily green-tech
    f. Recycling rate, efficiency gains, substitution technologies
    g. Subsidies, regulation, etc.

    This trend depicts the extent to which key technologies for which rare earths are important raw materials will become established. It also considers the extent to which other technological trends influencing the consumption of those raw materials will develop: e.g. recycling, efficiency gains and substitution technologies. This is in most cases also subject to the influence of framework conditions such as subsidies and regulation.

3. **Socio-political framework: Global governance**

    h. Climate and biodiversity debate (development of standards, public opinion)
    i. International initiatives (e.g. WTO rules, standardisation for business, Kyoto Protocol, etc.)

    This trend depicts the development of standards and public opinion at global level in relation to key issues such as climate and biodiversity, as well as considering the extent to which international initiatives (e.g. WTO rules and the Kyoto Protocol) develop and have an effect.

4. **Raw material production: Change in global production**

    j. Investment
    k. Diversification of producers

    This trend relates *only* to the global mining/production of rare earths. It depicts the extent to which investments are being made globally in developing the mining/production of rare earths and whether this is leading to a diversification of producers.

**Descriptors at national level:**

1. **Change in extraction and/or production volume:**
   To what extent are investments being made *nationally* in mining and/or production capacities, and how are production and/or extraction volumes changing at national level?
2. **Corruption / Crime / Informality / Good governance:**
   To what extent is raw material production/mining characterised by corruption, crime, informality or good governance?
3. **Environmental changes with consequences for the local populace:**
   Does the mining/production of the raw material have negative effects on the environment, and does this have consequences for the local populace?
4. **State provision of safety, security, well-being and rule of law:**
   To what extent is the state fulfilling its basic functions?
5. **Economic development (growth, diversification, etc.)**
   How is the national economy developing? Alongside growth, aspects such as diversification of the economy, or 'Dutch disease', may also be of significance in this.
6. **Political freedoms / Democratisation / Autocratic trends:**
   In what direction is political freedom developing? Are there democratic or autocratic trends, and how are they affecting stability?
7. **Distribution of profits and losses (overall state level):**
   How are profits and losses from production/mining distributed at overall state level? Are certain social groupings/regions being neglected or favoured?
8. **Raw materials foreign policy**
   Is the country exploiting its position of power with regard to raw materials in order to impose its foreign policy interests?

## 3.1 Scenario 1: Disorderly damage limitation

The global economic has grown by 2030, but only at a low level compared to 2010. The reasons were severe fluctuations, particularly in raw material prices, which are characteristic of the overall economic system in 2030. Speculative short-term raw material funds were one of the main causes of the price fluctuations. State and private-sector investment in research and innovation mirrored those fluctuations: In times of high prices and revenues, investments were made, but programmes were postponed or shutdown when prices and exchange rates fell. There was a lack of long-term investment in, and state subsidy for, environmental technologies. Developmental activities are heavily influenced by national interests. There is strong competition for technology leadership and capital investment. The modest fluctuations in raw material prices provide little incentive for efficient use of raw material resources. There are few incentives to recycle or to use secondary raw materials. The relatively modest average prices make it difficult to make recycling pay. The depth of recycling, and investment in it, remain limited.

The volatility of the economic system also left its mark on the global governance structures: International initiatives to regulate the financial sector following the financial crisis of 2008-13, and also to establish a binding climate treaty after Copenhagen, failed. Disillusioned by the lack of success of multilateral regulation, and overshadowed by the general atmosphere of uncertainty and reaction, the EU and USA are unable, or unwilling, to assume a stabilising leadership role in the world. With no driving force, and with a lack of adequate capital investment, the green-tech boom which was still expected back in 2010 failed to materialise; green-tech developments are limited to highly segmented, short-term, national activities. The relatively narrow spread of environmental and efficiency technologies drove only weak additional demand, so there were adequate supplies of rare earth metals on the market to serve the existing production levels in those technologies.

Since it converted to a freely traded currency in 2020, China has been most particularly impacted by the volatility of international markets and price fluctuations. Rare earth production has not been driven by technology markets, but likewise by the price fluctuations and short-term investment. It is still unclear which environmental technologies will become established; the green-tech market is fragmented. Major rare earth producing companies responded to price drops by reducing their output and by closing down less profitable mines. They concentrated on production facilities operating to higher technological, social and environmental standards, in order also to export their commodities to markets where consumers demand such standards, so as to at least make some profit. The lower revenues have also reduced the incentives for corruption and illegal mining.

In times of high prices, however, mining is also transferred at short notice to other deposit locations and production facilities. At the same time, more entrepreneurs are being attracted to the business, some of whom are organising their mining and trading operations on an irregular basis. These activities profit from, and in turn promote, corruption, as well as low social and environmental standards. Working conditions, in particular, suffer as a result. Occupational health and safety and workers' rights are being eroded rapidly, and employment conditions are characterised by exposure to the random will of the employer, dependency and low pay. Accordingly, in times of such exploitative mining practices workers and the local populace are exposed to major health hazards and to environmental pollution, which are relieved somewhat as production volumes decline. Conflicts arise between the businesses which are on the market for the longer term and those committing all their resources to make a short-term profit. These conflicts are sometimes played out with the aid of legal recourse, but frequently also by means outside of the law. In some isolated cases, competitors are driven off, or disposed of, using violence.

This picture of the rare earths industry is characteristic of the political-economic leadership in China – namely, by speculators trying to get rich quick. They exploit loopholes in governance and utilise patronage as a means to gain advantage. The state has moved little over the last 20 years in terms of political freedoms and democracy. At the same time, the central governing party is no longer the actively controlling player. The state is fragmented, and its role has contracted to a reactive one. Nepotism and patronage are undermining the central governing party, which – though still enjoying some importance and formally holding power – has insufficient executive powers to assert and defend itself on a widespread basis. The party structures merely succeed in organising networks so as to prevent any one individual or group from exerting excessive power. As one illustration, between 2025 and 2030 four provincial governors and the state ombudsman were prosecuted on corruption charges and sentenced to lengthy prison terms. However, bloggers pointed out that the people concerned had been alienated too much from the Party and its networks, and so were 'cut off'. This example shows that there is still a process of brokerage in place between the party/state structures and networks based on personal relationships, without one form clearly dominating the other. The distribution of profits and losses from the raw materials sector, too, is brokered, and as such results in little transfer between the regions. The Chinese government is primarily engaged in maintaining the sensitive balance between parallel structures, instead of in active policy-making.

Also as a result of this self-obsession and its inward focus, China has not assumed any leading role in the global community. Consequently, no strategic foreign policy framing based on exploitation of raw material wealth is possible. Only in isolated cases – particularly when price rises are on the table – do new Chinese representatives, elevated to high office by their private networks attempt to exploit their major rare earth deposits within global forums. However, owing to the adequacy of global rare earth production volumes, this merely results in some diplomatic irritation.

The population at large accepts the existing power structures. On the one hand, the executive is still strong enough to counteract minor revolts and demonstrations, while at the same time the disorganised, multi-layered government administration also provides some room for development – even if in the informal way described above. The general standard of living has risen, though remains at a low level because of the country's volatile growth. This trend has gone hand-in-hand with a major wave of urbanisation. In 2030, 70 percent of the population live in cities, where they have better access to supplies and services.

### Summary

In this scenario, a global economy marked by fluctuation encounters a fragmenting China. The Chinese state has become increasingly weaker, and in 2030 is busy trying to keep its patronage-based parallel structures under control. As a result, China does not develop a decisive role in the foreign policy sphere. Domestically, there is no longer democracy, but thanks to the improved standard of living there has also been no decrease in stability. The country's own population exploits the freedom offered by the multi-layered governance structures, and regularly expresses its displeasure in the form of individual demonstrations and minor revolts.

*Risks in terms of:*

- Raw material supplies:
  Price fluctuations lead to concentration on small numbers of production facilities working to high standards and with irregular mining operations.
  (Time frame: long term; level: national)
- Crises and conflicts:
  The state structures are undermined by patronage and the creation of parallel structures by local power-brokers. (Time frame: medium to long term; level: national)
- Crises and conflicts:
  Conflicts between producer companies operating to high and low standards respectively, culminating in extreme cases in violence.
  (Time frame: medium to long term; level: national)
- Ecological impact:
  Severe environmental pollution due to irregular mining
  (Time frame: short, medium and long term; *level*: local)

*Conflicts and parties involved:*

Conflicts are restricted to those between players within China:

- Conflicts between producer companies operating to high and low standards respectively.
- Tensions between the centralised state and parallel structures alongside the state.

*Pointers:*

- Severe fluctuations in global economic growth and a lack of global regulation.
- China converts to a freely traded currency.
- The centralised state loses its executive powers at local level.

## 3.2 Scenario 2: Cooperative dictatorship

In 2025 a new global economic crisis occurred, which unfolded its full impact in 2027, and in the longer term resulted in lower economic growth. All states – industrialised nations, transforming and emerging economies alike – are affected equally. There are no winners in the crisis. As a consequence, overall global demand for raw material commodities and manufactured products is at a low level.

In order to cope with the crisis, a global will to cooperate emerges on many different levels and in a variety of fields, from technology to security. In this cooperative climate, previously liberated markets were gradually reined-in. New types of cooperation between producers and consumers of raw materials emerge. Their aim: to establish reliable framework conditions for markets and prices over the long term.

Prior to the 2025 economic crisis, however, there had previously been a boom in the renewable energy sector around 2020, at the turn of the new decade. This provided strong impetus to the development of alternative technologies. In the course of the global green-tech boom, there was also an increased awareness of the need to manage raw material resources with greater efficiency. Recycling, both in production and of end-of-life products, took a firm hold. Long-term, internationally coordinated development activities stimulated research and development leading to higher material yields, successful substitution of critical raw materials, and technological developments delivering lower raw material consumption. The insight that raw material resources needed to be managed with more care compensated for the lack of economic incentives to run businesses in a resource-efficient manner.

The wide spread of environmentally friendly technologies and the internationally coordinated regulation of mineral resources were the reasons why in 2030 demand for rare earths was heading towards a new low, which in absolute terms corresponds to the 2015 level. This level of demand is being sustained primarily by the use of rare earths in the automotive and electronics sectors. The low demand for rare earths is covered by means of efficiently operating regulated markets in 2030. Raw materials speculation is subject to very narrow constraints. As a result, no extreme price changes are to be expected; volatility seems to be under control.

The production of rare earths in China likewise falls, as there is no major demand globally. Consequently, China is not able to exploit its rare earths as an instrument of political power. For that reason among others, a cooperative approach to foreign policy matters at various political levels is of greater advantage to China. Another positive factor in this context is the cooperative spirit among the community of nations, which emerged from the successful demonstration of the various states' ability to act in concert and cooperate with each other in response to the crisis.

In China as elsewhere, economic growth is slow. Domestically, there is still significant demand for rare earths, though on that market, too, there are no critical developments in prospect on the resources side. Revenues from rare earths remain low however. The profits made are no longer sufficient to operate a patronage system. As a result, battles begin for appropriation of the declining profits. Analysts routinely describe this situation based on a metaphorical 'rare earths cake' which is getting smaller and smaller.

All in all, there are few opportunities to make money illegally from rare earths. The impact of this is felt all along the value creation chain. As a result, corruption, crime and informal mining operations decline. However, falling profits also mean increasing dissatisfaction among the local populace in the regions where rare earths are mined. In order to rein-in that dissatisfaction, the Chinese government exerts heavy pressure. Political freedoms remain restricted all across the country.

But declining rare earth production also has positive effects. Due to the lower production volumes and the decrease in informal mining, environmental destruction is reduced.

### Summary

The global economic crisis has strengthened the will of the international community to cooperate with each other, and the first initiatives to regulate markets are being implemented. China, too, is taking a correspondingly cooperative approach in its foreign relations. In terms of domestic politics, however, the collapse in demand for rare earths is leading to intensified distribution battles. Positive consequences, such as reductions in environmental destruction and corruption, remain random secondary symptoms. Dissatisfaction among the population at large is countered with autocratic means. The result in a mixed picture: Domestic policy trends fail to keep pace with positive developments globally.

*Risks in terms of:*

- Crises and conflicts:
  Decreasing revenues lead to intensified distribution battles.
  (Time frame: long term; *level*: national)

*Conflicts and parties involved:*

Conflicts are restricted to those between players within China, battling for the decreasing revenues from rare earths.

*Pointers:*

- New economic crisis results in will to cooperate and in closer regulation.
- China, too, takes a very cooperative approach in its foreign relations.
- Stagnating rare earth production.
- Decreasing environmental destruction due to rare earth production

## 3.3 Scenario 3: Dangerous green-tech boom

The global economy was generally marked by a period of high growth between 2010 and 2030. The emerging and developing economies, especially, enjoyed high growth rates. The growth was unevenly distributed however. As a result, the gulf between poor and rich countries widened.

As energy supply could barely keep pace with demand as this trend unfolded, energy prices are high. This encouraged the use of renewable energy, but on the other hand demand for fossil fuels remained strong. Traditional industries – heavy industries, chemicals, etc. – boomed. Demand is so high in 2030 that recycling and energy efficiency are inadequate tools to bring any marked relief to the strains on raw material markets.

Green-tech likewise boomed – to such an extent that bottlenecks in raw material supplies occurred. Consequently, green-tech growth was constrained by the availability of rare earths. Rare earths were also increasingly being used in other technologies, so creating demand from new markets. As demand outstripped supply, prices on markets rose strongly. While the high prices are proving powerful financial incentives to engage in recycling and to manage rare earth resources efficiently, the secondary raw material sources opened up in this way are not sufficient to bring supply up in line with demand.

The boom in demand was also stimulated by heavy subsidising of green-tech. The states are now confronted with the problem of not being able to cut back those subsidies rapidly enough, as a result of which demand is continuing to drive raw material prices strongly.

Shortages in many other raw materials, too, lead to blocks being formed, with producer and consumer countries allying themselves to create competing groups. In the face of such a global climate, governance structures are weak. Raw materials become instruments for exerting political power.

Potential producers of rare earths outside of China have failed to foresee the trend in demand, as a result of which China has retained its monopoly-like position. China is, as ever, very aware of the power of rare earths as a political instrument. This has enabled it to take a hard line in foreign policy, which has brought China a leadership role in the green-tech sector especially. The rare earths remained in the country, so green-tech companies were forced to establish production facilities inside China.

This outward appearance of an environmentally conscious China becomes rather less convincing on closer analysis however. Production was greatly increased. China sought to diversify and multiply its mining locations. When it was initially seen that the high prices were promoting the development of unregulated mines, after 2020 mining zones were defined in which all other economic activity was reduced to a minimum, to enable maximum concentration on rare earths. One element of this strategy is the uncaring forced resettlement of the local populace. Extensive areas of destroyed, pitted landscape are the consequence of this priority zoning policy; ecological standards are superfluous, as there is no way they can be met. In their place, the "rare earth barons", use some of their billions made from the rare earths business to establish model modern settlements, featuring extensive green zones.

The local rare earths boom took on a life of its own which had negative consequences for China's central government and the Communist Party. Gigantic mines encouraged the creation of regional monopolies. Wealthy mining elites were created who, in the early years, engaged in major power struggles until the strongest emerged victorious. In 2030, these new powerful figures are going so far as to protect themselves against external intervention by means of private armies. The authority of the central government and the leadership of the Party have been weakened, though not placed in question, as they have their own links with the new economic elites.

The central government has been weakened however. In 2030 it is unable to ensure security, well-being or the rule of law. In some areas of the country, the central government has been replaced by local figures who exercise the functions previously provided by the state as a means of safeguarding their own power base. The relations between such "states within the state" and the remaining official state representatives in the mining regions is heavily marked by corruption, criminality and informality. Good governance has no chance in such a climate.

Political freedom and democratisation are taboo subjects in the mining regions. Any efforts to make moves in that direction are strangled at birth by the holders of local power. A contradictory picture emerges within the mining regions: Profits from the mining operations flow primarily to the elites, but the regions as a whole also benefit. Their standard of living in terms of income rises, though their environments are totally destroyed.

For the holders of local power, the question then arises as to why they should continue to pay even a small portion of their revenues from sales of rare earths to the central government. Consequently, in January 2030 regional power-holder Uixi in Xinjiang declares the Independent Republic of Xinjiang, strengthens his army and convenes a puppet parliament. Uixi did not bank on such a move being utterly unacceptable to the now internally weakened Chinese state. His army is destroyed by a massive assault by government troops and state-of-the-art weaponry, and Uixi himself is executed.

It is not surprising that an attempted secession of this kind should have occurred. The Chinese government had for years pursued a half-hearted strategy of 'occasionally lopping off heads': Every now and again some overly troublesome individuals from the mid-range leadership level were removed off the elites, as a kind of warning to the actual leaders. They themselves remained untouched because they enjoyed close links with the central government and the Party, and were often related to senior figures.

### Summary

China exploited its monopoly position in rare earths and established a flourishing green-tech industry. However, this boom in raw materials stimulated widely varying trends in different regions, as a result of which rich and very poor regions were created. Combined with major governance problems which the central government is barely able to control, the regional disparity has triggered major tensions and secessionist tendencies in some regions. Even though the central government is able to reassert its strength by military force in 2030, the internal political situation remains unstable. In conjunction with the extensive environmental destruction, the outlook beyond 2030 is worrying.

*Risks in terms of:*

- *Raw material supplies:*
  China exploits its monopoly position and restricts exports of rare earths.
  (*Time frame*: short, medium to long term; *level*: international)
- *Crises and conflicts*:
  Widely varying regional trends, together with major governance problems which the central government is barely able to control, bring about conflicts between the central government and provinces, with some regions exhibiting secessionist tendencies.
  (*Time frame*: long term; *level*: national)
- *Ecological impact*:
  Major expansion of rare earth production in special zones, entailing catastrophic effects for the local populace.
  (*Time frame*: medium to long term; *level*: local)

*Conflicts and parties involved:*

- Conflicts between producers and consumers in China on the one hand and the other consumer countries on the other.
- Conflicts between regional power-holders among themselves and with the central government.

*Pointers:*

- Strong global economic growth, with increasing disparity between rich and poor countries.
- Active mineral-based foreign policy on China's part.
- Economic differences between the regions increase markedly.
- Corruption and governance problems increase markedly.

## 3.4 Scenario 4: Green democratisation

The Rio +20 environmental conference in 2012 had lasting effects. Green-tech and low-carbon technologies were provided with strong impetus, and boomed over the subsequent years – also driven by positive economic growth and the resultant high raw material prices. Despite the Rio Recycling Initiative, bottlenecks occurred in supplies of the essential raw materials, particularly metals. This led to a situation in which recycling and substitution were no longer adequate to meet the strong demand. The resultant 'rare earth rush' led to sporadic shortages of rare earth resources. The accelerated exploitation of global reserves, particularly in China, fed the fear that reserves might run out. So as not to lose this motor of the green-tech boom, and to reduce the environmental impact of the mining, China got together with other producer countries and in 2023 established the 'Organization of Rare Earth Metals Exporting Countries' (OREMEC). This initiative to stretch global reserves was welcomed. International cooperation between states is generally proving to be constructive and solution-oriented.

In China, the rapid rise in mining output of rare earth metals up to 2020 was also driven by domestic demand for green-tech. Economic growth went hand-in-hand with the increasing development of a middle class, with a keen awareness of sustainability and ecological issues, living in modern, 'green' urban conurbations, and helping to drive demand for electronic mobility, renewable energy and efficient use of energy and material resources.

The contradiction between low-carbon technologies and severe environmental pollution from rare earth metals production and use consequently led to protests. Alongside the shortage of reserves, these factors were key drivers in China's decision to cap production and to introduce mining quotas in conjunction with the other OREMEC producer countries. The positive consequences for the environment were quick seen at the production locations.

The strong public interest groups in the environmental sector also celebrated the quota controls as their own success. Their environmental reporting played a ground-breaking role, which has since led to greater political freedoms in other political areas to, especially with regard to freedom of speech and of the press. This gradual opening has resulted in wider monitoring of political action by the civil society as a whole, which is also reflected in improved state provision of fundamental functions (security, well-being and rule of law). There is also a certain transparency with regard to the distribution of profits and losses across the regions. The producer regions profit more, but are also subject to the most impact. While major players and elites still profit most, more people are able to share in the profits from the mining and use of raw material resources. Based on these successes, and the economic growth achieved, the one-party political system has been able to survive.

Externally too, the Chinese is confident and cooperative in its approach, such as in its collaboration with other producers in OREMEC, without exploiting the cartel as an instrument of power in relation to the USA, India or Europe.

## Summary

The shortage of rare earths is thus not leading to conflicts, but rather this challenge has been turned both internationally and nationally into an opportunity. Internationally, the rare earth producing countries agree on long-term strategies to sustain reserves and preserve the environment. Although OREMEC does offer the potential also to be deployed as an instrument of political power, this does not occur, because of the responsible approach adopted by the producer countries. Domestically, driven by an environmentally aware middle class and strong civil society, the issue of environmental protection is having undreamt-of effects, culminating in an opening-up of the political system and an improvement in state provision to its people. China can thus look to the future with confidence, even beyond 2030.

*Risks in terms of:*

- *Raw material supplies:*
  Rare earths cartel might be misused as an instrument of power.
  (*Time frame*: long term; *level*: international)
- *Ecological impact*:
  The major expansion of rare earths production results in severe environmental pollution.
  (*Time frame*: short, long and medium term; *level*: national)

*Conflicts and parties involved:*

Tensions between the populace, which is developing an increasing environmental awareness, and the government.

*Pointers:*

- Major progress thanks to global environmental treaties and ambitious national policy implementation measures.
- Demand for rare earths rising strongly.
- Cartel formation
- Environmental issues increasing in importance in China, and civil society is gaining in influence in the field.

# 4 Conclusions

Considering the case study and the scenarios together, two primary risks stand out: Firstly, the major ecological impact of rare earth mining and production. This was identified as a major challenge both in the case study and in all the scenarios in which rare earth production is expanded. In some of the scenarios, this ecological impact results in conflicts and protests by the local populace which are suppressed, or strangled at birth, by the holders of power (either locally or at central government level). Only in scenario 4 does a politically active middle class develop which utilises environmental issues as a resource for mobilising the wider civil society to fight for wider political influence as well as to resolve environmental problems. In this context, therefore, the social conflict created by the environmental impact is turned into an opportunity for greater political participation.

The second – and purely negative – projected conflict risk results from China's structural governance problems. These problems are identified in the case study, and in two scenarios exhibit a severely destabilising effect. In those scenarios the central government is only capable of controlling corruption and systems of patronage to a limited extent. Local elites gain increased power, undermine central authority and govern more strictly in line with their own interests.

Interestingly, the exploitation of the rare earth monopoly as an instrument of foreign policy is not a decisive issue in the scenarios. Whereas this aspect is currently central to the political debate surrounding China's rare earths monopoly[18] and is discussed as a primary risk in the case study, only in one scenario does China exploit its position of power for strategic purposes, though in that context, too, it allies itself with other rare earth producers. In the other scenarios, the main factor is either the will to cooperate (for quite pragmatic reasons, such as because the demand for rare earth metals is not as strong as originally assumed) or China is internally fragmented and unstable, so that externally it is not able to act coherently and strategically enough to exert international pressure.

So the risks identified here with regard to rare earths and China are initially of a mainly domestic nature. They are likewise closely linked to fundamental characteristics of the Chinese state. Firstly, in terms of the prevailing development principle of environmental destruction as a price worth paying for rapid industrialisation. Secondly, in terms of the governance problems faced by an autocratic political system undergoing economic liberalisation. The risks surrounding rare earths are thus a phenomenon within more profound development processes. How China controls those processes, and succeeds in engaging its population along the way, is likely to be the

[18] German Chancellor Angela Merkel expressed her concern regarding international access to China's rare earth reserves on her last visit to China in July 2010 http://af.reuters.com/article/metalsNews/idAFTOE66G00E20100717?pageNumber=2&virtualBrandChannel=0&sp=true, 19.07.2010).

key factor in determining whether, and how, China will utilise its monopoly position for foreign policy purposes in its relations with other consumer countries.

If the consumer countries wish to continue using China's rare earth metals, they will in any case have to integrate China into political processes and create incentives such as those set out in scenarios 2 and 4. How that integration should be shaped in order to help avoid international and internal conflicts relating to rare earth metals also depends on whether China remains internally stable and centrally controlled.

The case study, scenario analyses and considerations of existing risk reduction approaches (report 5) result in a number of recommendations for action in relation to China and rare earth metals:

- *Integrate China more into relevant dialogues.* For example, bodies in which China is already participating (such as the International Panel for Sustainable Resource Management) could be politically strengthened and their mandates upgraded so as to become a more stable platform for dialogue with China.
- *Enter into (environmental) technology cooperation agreements.* Based on genuine cooperation instead of unilateral technology transfer, Germany and Europe might well profit. In order to establish the relevant preconditions, the aforementioned dialogues are of particular importance. The environmental management experience and know-how of the mining sector should also be shared. To prevent 'clean energy' from being produced at the expense of severe local environmental impact, efficient, environmentally friendly production methods must be developed and environmental standards introduced.
- *Demand compliance with environmental standards in exploiting alternative sources.* In order to gain independence from China, good alternatives to China's rare earth metal production are being sought all over the world. There are also reserves in Outer Mongolia for example. The (re)start of production at facilities worldwide also represents an opportunity to deploy improved techniques and apply the latest environmental and social standards.
- *Make green-tech industries more aware of environmental impact and raw material conflict issues.* The question as to the environmental and social standards to be applied, and awareness of potential conflicts entailed by certain technologies and value creation processes, is of major importance in the green-tech field especially. It should have a particularly keen interest in avoiding damage to its image or reputation. Relevant standards should be drawn up in collaboration with the industry. Certification of mines and production facilities or awards for particularly environmentally friendly techniques/plants/manufacturers should also be introduced.

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