

# Knappheiten und Ressourcen von Rohstoffen

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# Materials critical to the energy industry. An introduction

## Materials critical to the energy industry An introduction

The world's energy systems rely on a wide range of materials with specific properties. A secure energy future depends on sustainable supplies of those materials.

A University of Augsburg publication, supported by BP as part of the multi-partner Energy Sustainability Challenge, which explores the implications for the energy industry of competing demands for water, land and minerals.



Materials critical to the energy industry. An introduction

UNA

## Materials critical to the energy industry An introduction

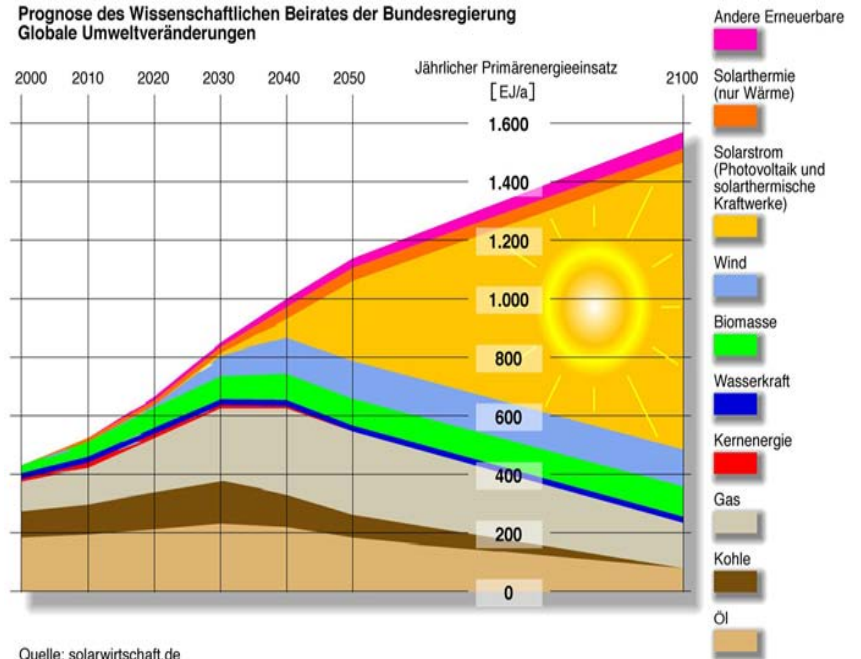
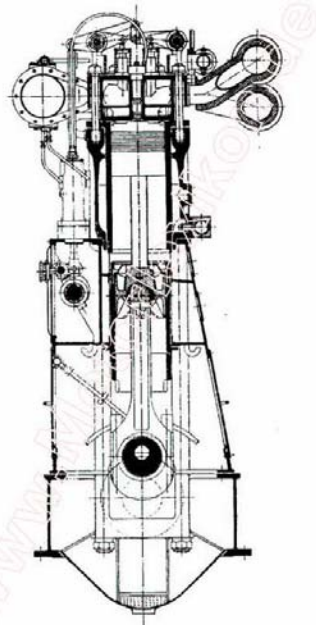
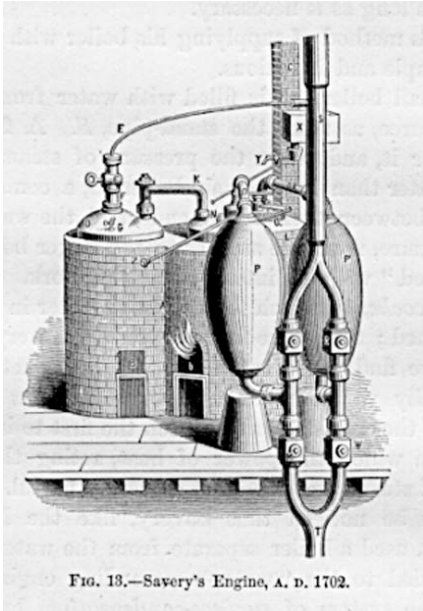


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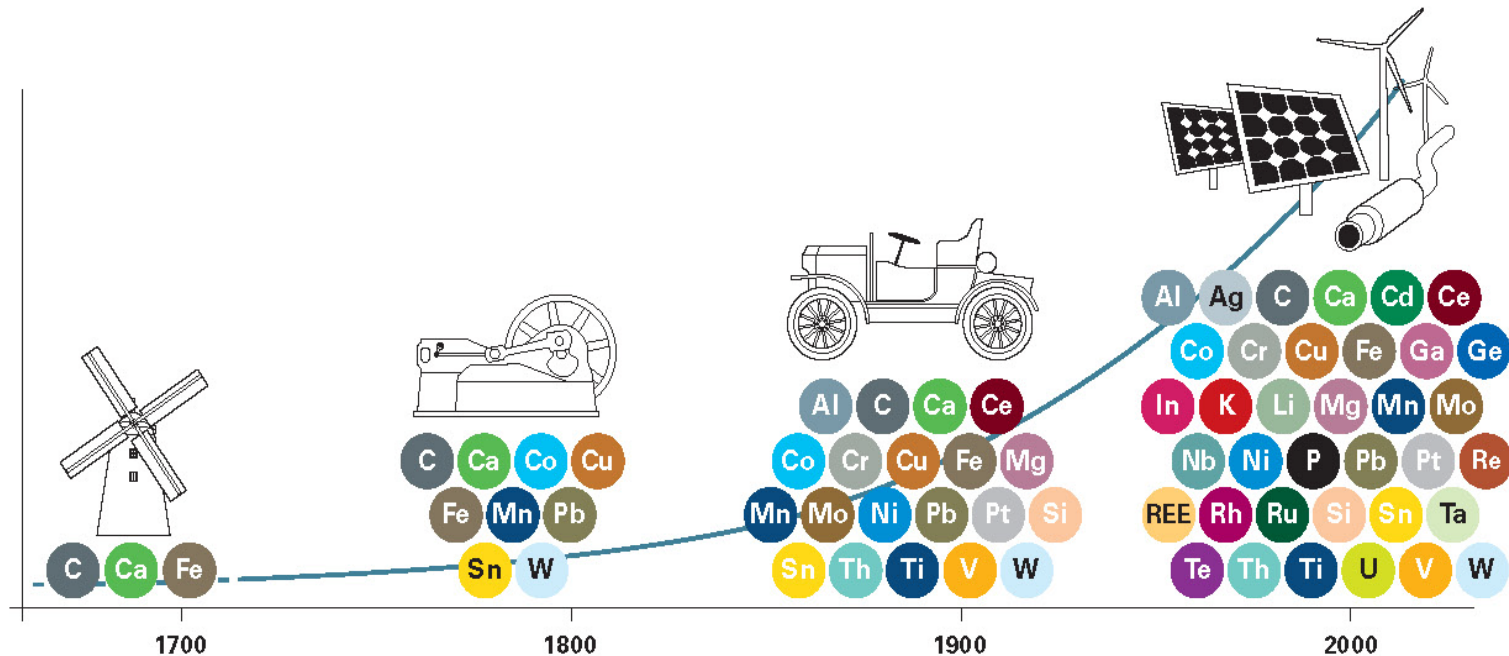
Verschiedene **Energiezeitalter** und deren Einfluss auf den Rohstoffbedarf

Die Rolle von: **Seltenen Erden** im Energiesektor.

# Energiezeitalter

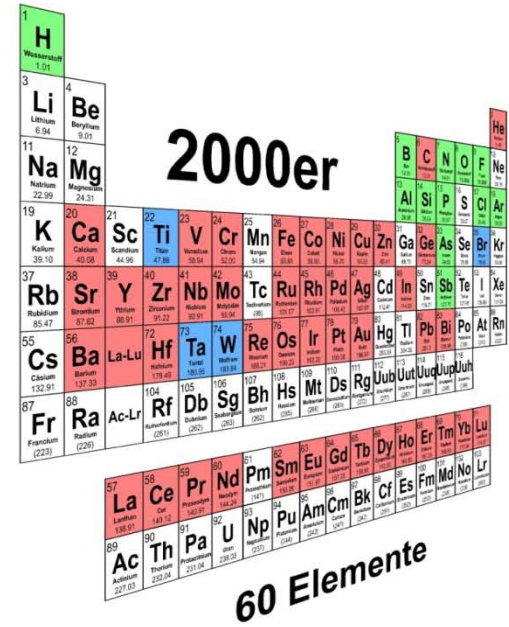
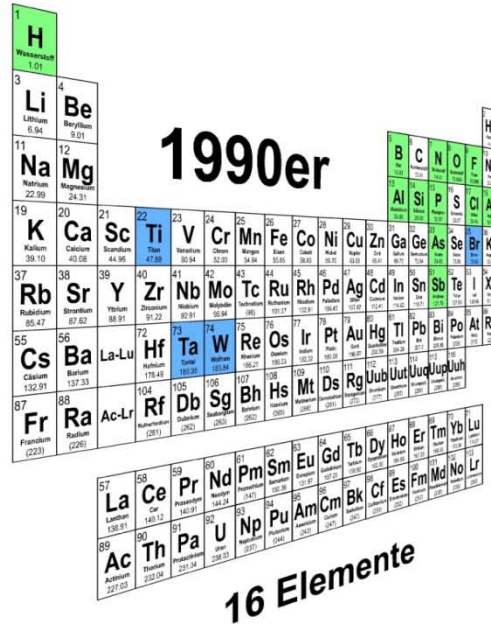
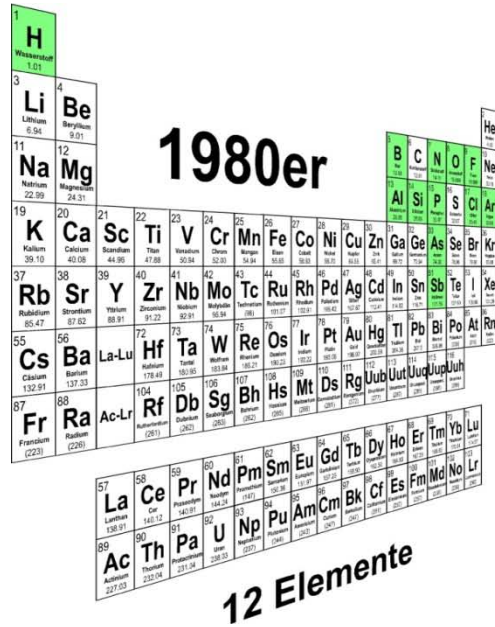


# Intensiv genutzte Elemente im Energiesystem

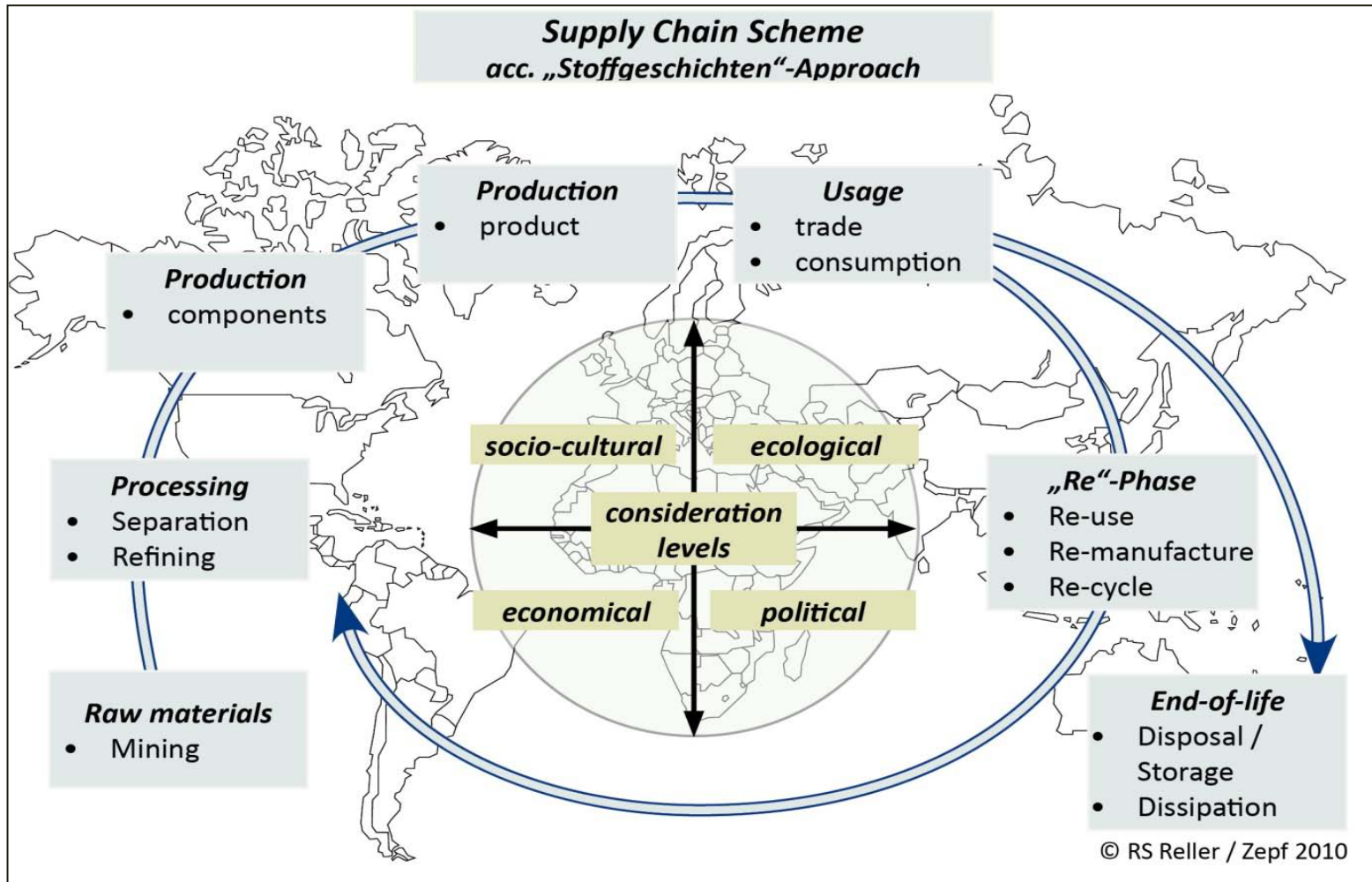


Elements widely used in Energy Pathways

# Materialdiversität in der Mikroelektronik



# Vorgehensweise



# Vorgehensweise

### Sustainability

**Co 27**

**Reserves** H  
Manganese has the only deposits where cobalt is mined as a by-product of copper and nickel mining. By far the largest reserves, some 10% of the world's total, are found in the sedimentary rocks of the Central African copper belt in Zambia and the Democratic Republic of the Congo, where grades generally run between 1.7% and 2.1% cobalt. A geological setting with regular stripes, the Kupferberg, opens from northern England, across Germany and into Poland. This deposit has been extensively mined in the past and gave rise to much of the metallurgical history of Europe. In addition to the Russian and South African magmatic deposits mentioned above, this type of mineralization led to major deposits in Safford in Canada and Kamohai in Australia, both mined primarily by nickel.

**Trade** H  
With most half of the world's production coming from a country devastated by war in recent years, continuity of supply is always in doubt. China is also in a semi-monopolistic position, as it is the world's leading producer of refined cobalt. This results from domestic mine production and the import of suboptimal quantities of ore through life-of-mine contracts with Australia and the DR Congo. World production is growing as many new projects come on stream, surprisingly a fair number in the DR Congo. Cobalt is traded on the London Metal Exchange.

**Ecological impact** L  
As an element vital for health, it is to be expected that plants and animals can tolerate reasonable concentrations. Cobalt is not known as biomorphic up the food chain. However, with rare mining and refining facilities that contain very high amounts of cobalt, so that the operator by animals through eating plants can cause detrimental health effects.

**Sustainability indicators**

**Reserves** H  
**Trade** H  
**Ecological impact** L  
**Processing** L  
**Substitutability** M  
**Recyclability** L  
**Reserves-to-production ratio** B3

**Processing** L  
As most cobalt is a by-product, the primary processing techniques will be employed for the main metal. Cobalt is normally extracted from the processing stream by hydro- and pyrometallurgical processes. Unlike many materials, a large percentage of cobalt concentrates are shipped internationally for smelting, with China leading this trend.

**Substitutability** M  
Scarcity and price drive the search for substitutes. In however, cobalt use has decreased with the introduction of newer alloys. Two in road alloys, cobalt's unique properties are not matched by alternatives and performance ratios. Ceramics have replaced some of the high-temperature, high-hardness materials that rely on cobalt, and various iron, lead, magnesium and vanadium alloys can, in some degree, replace cobalt in pigments.

**Recyclability** L  
Because of the high price of cobalt and its unpredictable supply, recycling has reached high levels, meeting approximately 15% of world demand. Also, the desire to reduce environmental impacts of cobalt has led to initiatives that have encouraged more to recycle, especially in countries where legislation has helped. Alloy manufacturers are also developing components, such as carbon blacks, one to method and the other without separating the individual metals.

### Copper Cu 29

**Without copper, there would be virtually no electrical appliances and certainly no electricity to power them.**

**Architecture and consumer goods 30%**  
**Water supply 15%**  
**Mechanical components 9%**  
**Electronic circuit heat conduction 3%**  
**Car wiring 1%**

**Electric energy generation 20%**  
**Electric motors 12%**  
**Traction motor 9%**  
**Household heating appliances 8%**  
**Data transfer communication 5%**

**Uses in the energy sector**  
Copper is at the heart of all generating equipment, in power in nearly all transmission circuits, both high and low voltage, in every home and office as wiring, in the wiring looms of every road vehicle, and in an essential component of the power circuits of virtually all electrical appliances.  
In addition to the use of copper for propulsion in electric vehicles, many automotive components are made of copper, especially as cars contain an ever-growing array of electrically driven ones, windows, fans and more.

**Uses outside the energy sector**  
As a heavy metal and displaying a strong colour, copper was obvious to early civilisations and was one of the first metals to be used to make an alloy as brass. Initially for ornamental and some tools, including of copper ores is thought to date back to 1000 BC and allowing with its product the harder metal, bronze, can be traced to 3000 BC.

**Properties and origins**  
Melting point 1083°C  
Density 8.96 g/cm<sup>3</sup>  
Thermal conductivity 39.8 x 10<sup>3</sup> W/m  
Copper, with a warm pinkish colour, is one of only three elemental metals not to be grey or silvery. It is soft, highly ductile and ductile, allowing to be easily worked. It has the second highest electrical and thermal conductivity of all pure metals, after silver, and the second to lowest and forms a wide range of compounds.

**Production and price**  
Annual production 18,100,000 tonnes

Country	2018	2019	%	Reserves	A/P
Chile	5,520,000	24		192,000,000	27
Peru	1,291,000	5		90,000,000	30
China	1,110,000	7		20,000,000	26
Congo	825,000	31		80,000,000	44
<b>World</b>	<b>10,236,000</b>			<b>420,000,000</b>	<b>20</b>

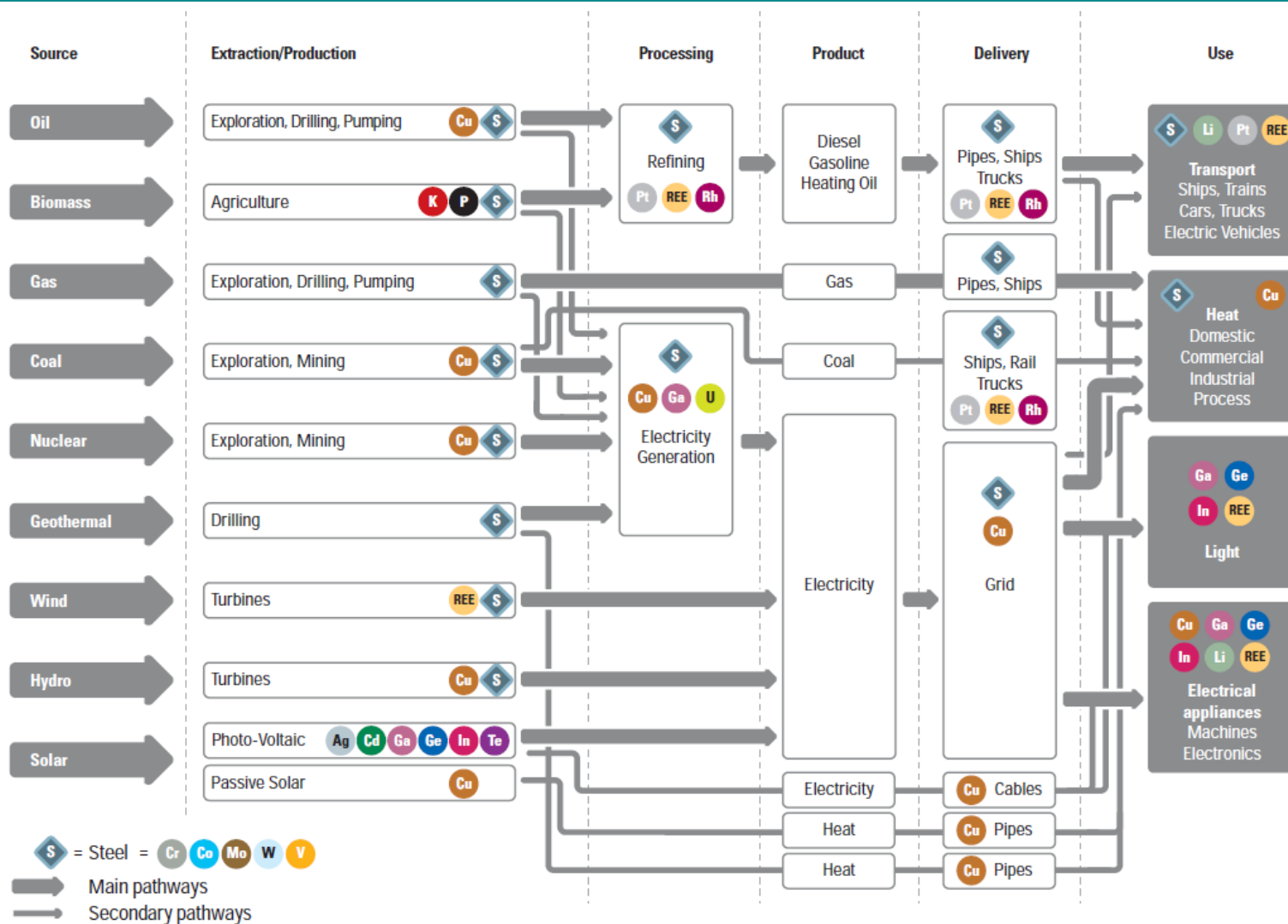
**Company**

Company	2018	2019	%	A/P
Copper Mountain (an Xstrata subsidiary)	1,056,100	11		4%
Freeport-McMoRan	1,125,000	10		4%
Copper & Gold Inc.	1,120,400	7		4%
BHP Billiton Group				

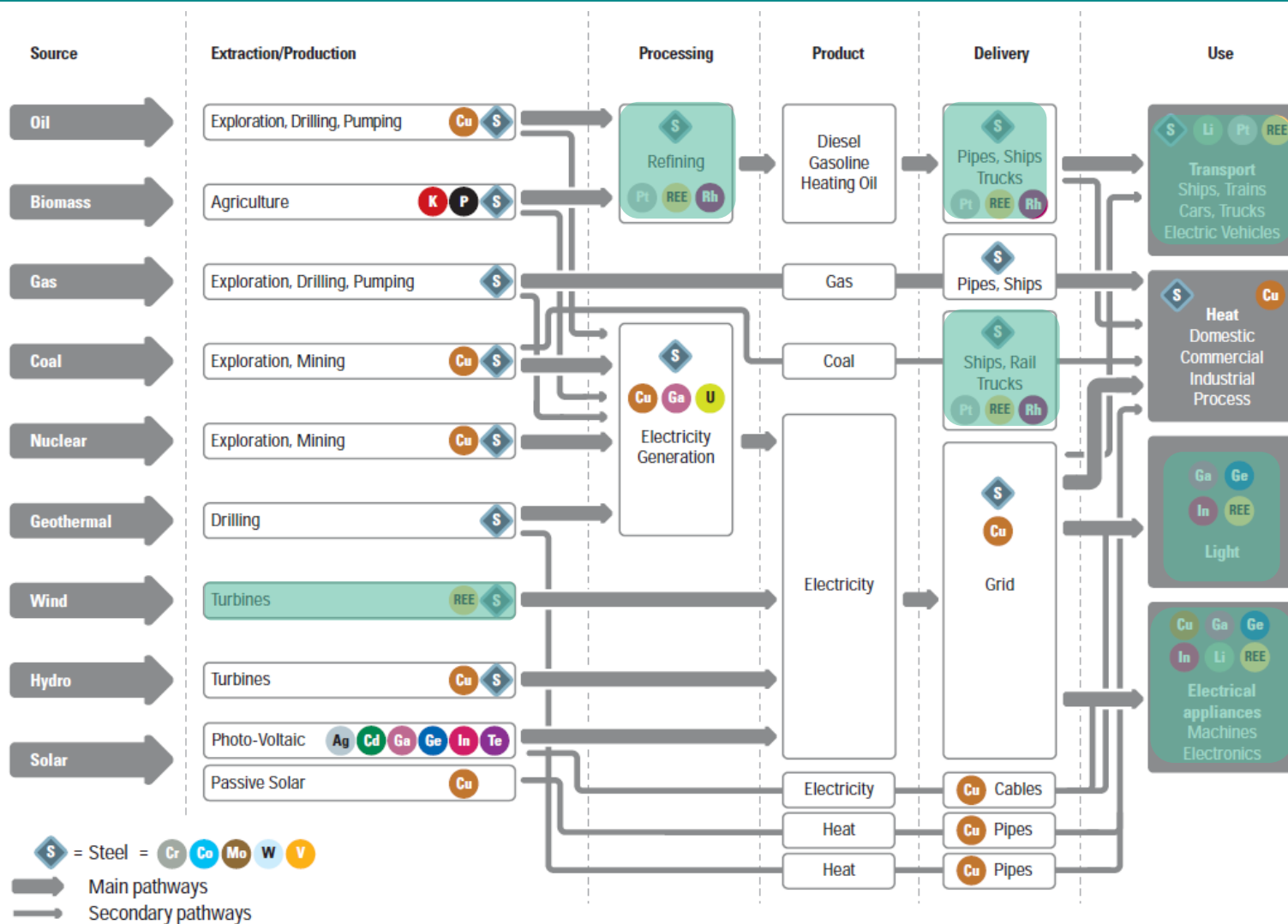
- Reserve
- Processing
- Trade
- Substitutability
- Recycling
- Ecological Impact



# 19 kritische Rohstoffe im Energiesystem



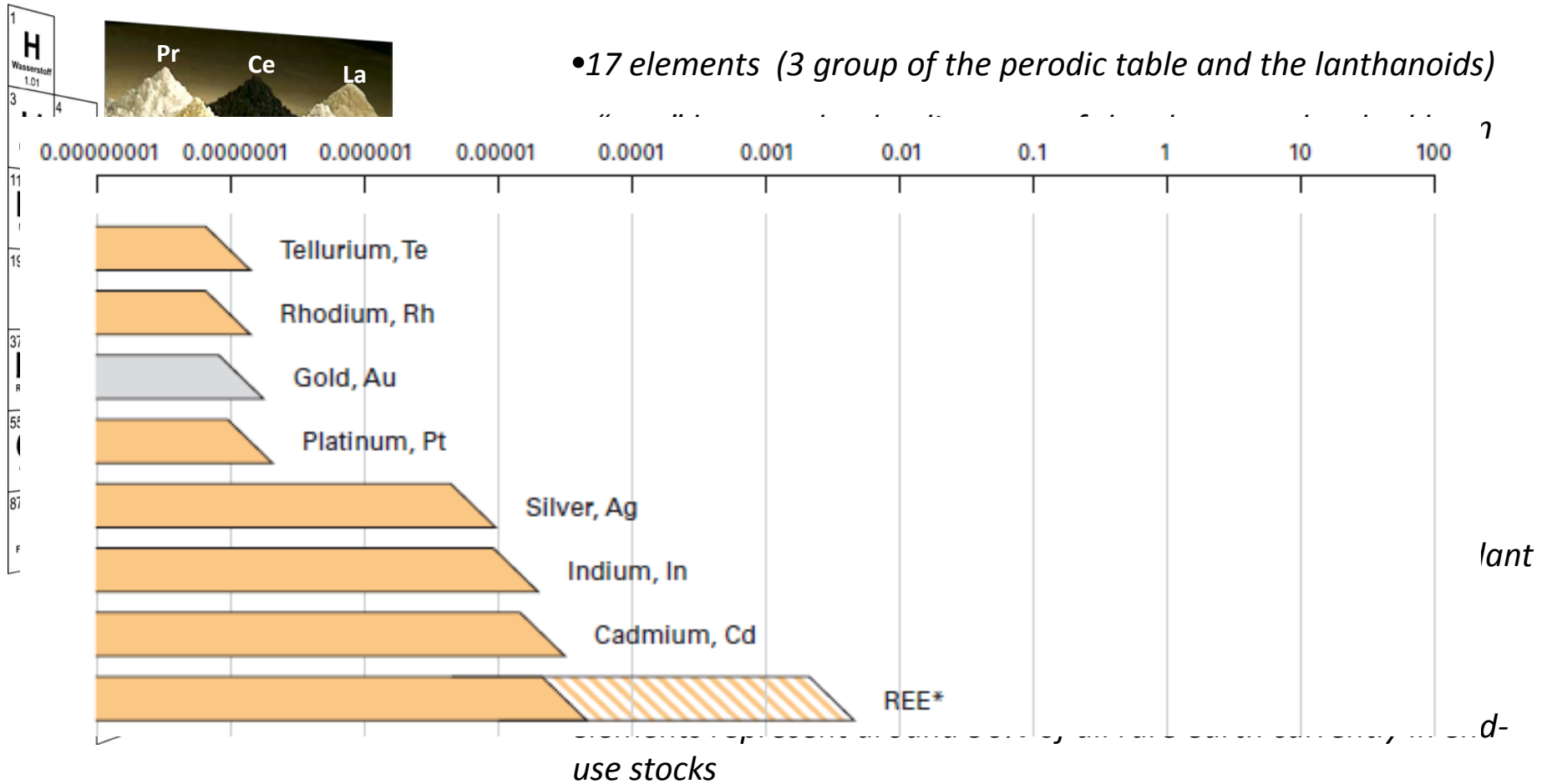
# Seltene Erden (REE) im Energiesektor



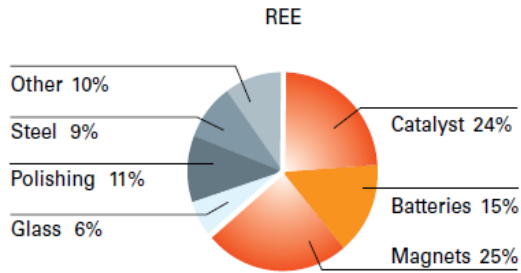
# Definition “Seltene” und “Erden”

## Rare earth:

- 17 elements (3 group of the periodic table and the lanthanoids)



# Anwendung von REE



## Effizienter Einsatz von Energie geringer Verbrauch



- Kompakt-Leuchtstofflampen
- Hybrid-Fahrzeuge
- Gewichtsreduktion im Automobilbau

## Umweltschutz geringe Emissionen



- Windräder (Generatoren)
- Abgaskatalysatoren
- Diesel-Additive

## Digitaltechnologie Kleiner, Leistungsfähiger



- Flat Panel Displays
- Digital Kameras
- Festplatten



## Medizintechnik



- Magnetic Resonance Imaging (MRI)
- Röntgenapparate
- Nuklearmedizin
- Additive für Medikamente
- Laser

## Militärische Anwendungen



- Permanentmagnete für Antriebssysteme, Sensoren und Lenkeinheiten
- Energiespeicher (Batterien)
- Elektromotoren (Kampfflugzeuge, Panzer, Schiffe)

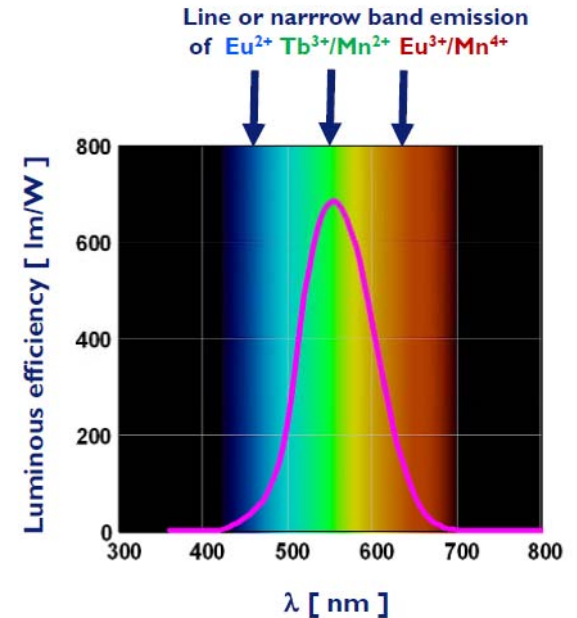
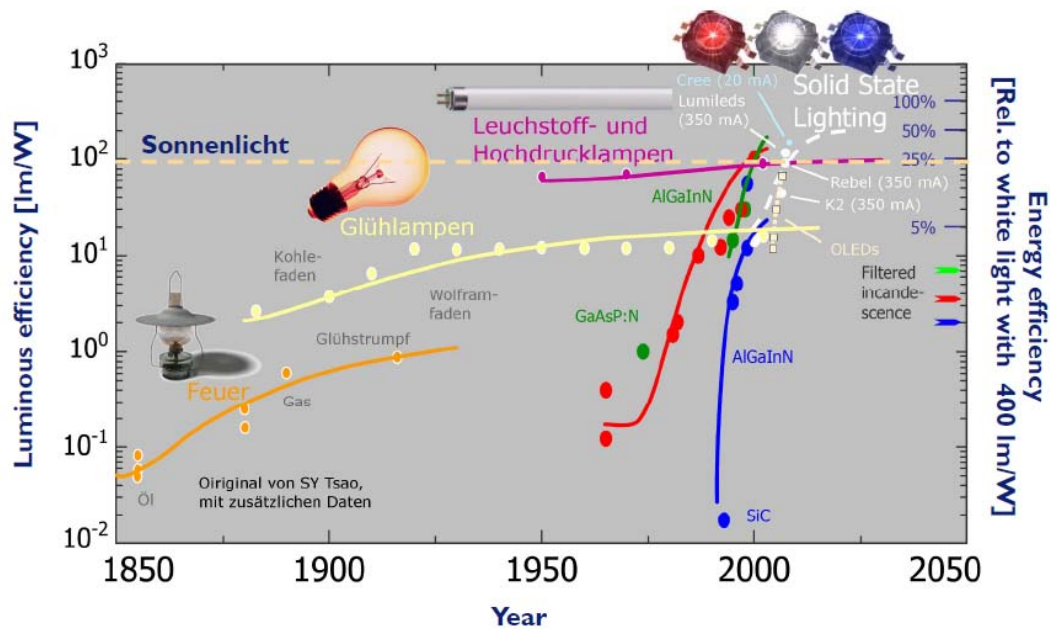
## Weitere Anwendungen

- Laser-Schneidwerkzeuge (YAG-Laser)
- Glasfaser-Signalverstärker
- Superconductors
- Neutronenabsorber
- Anwendung in Siedewasserreaktoren
- Algenwachstumskontrolle
- Wasseraufbereitung

Quellen: RWTH Aachen; USAF; Roekill 2007, Lynas 2010,

© RS Reller / Zepf 2010

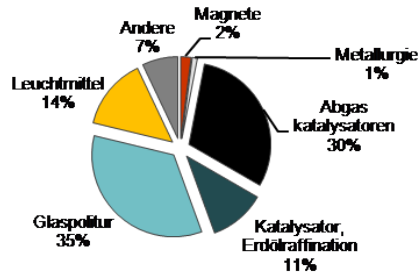
# LED technology and REE



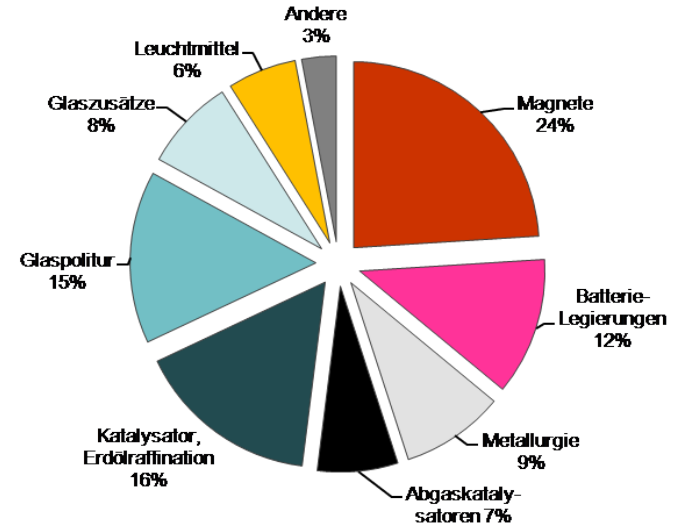
Rare Earth elements are the “vitamine” for efficient lighting and clean lamp technologies

# REE – Trends in End-Use Sectors

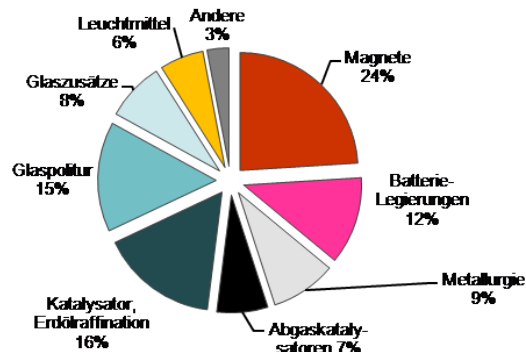
**2007**  
**124.000 t**



**2014**  
**182.000 t**



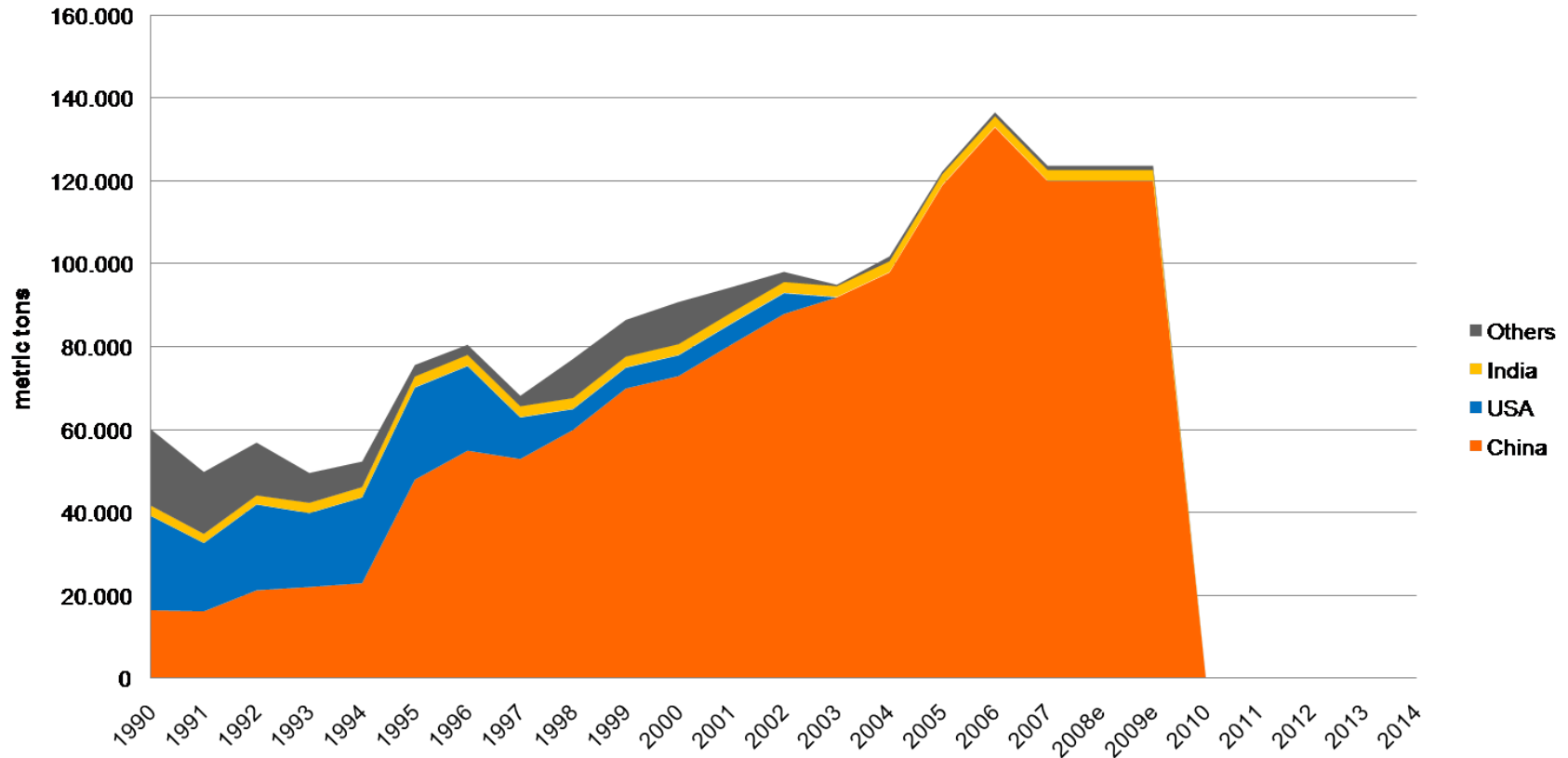
**2010**  
**134.000 t**



Quellen: USGS 2010, Lynas 2010  
© RS Reller / Zepf 2010

# REE – World Production

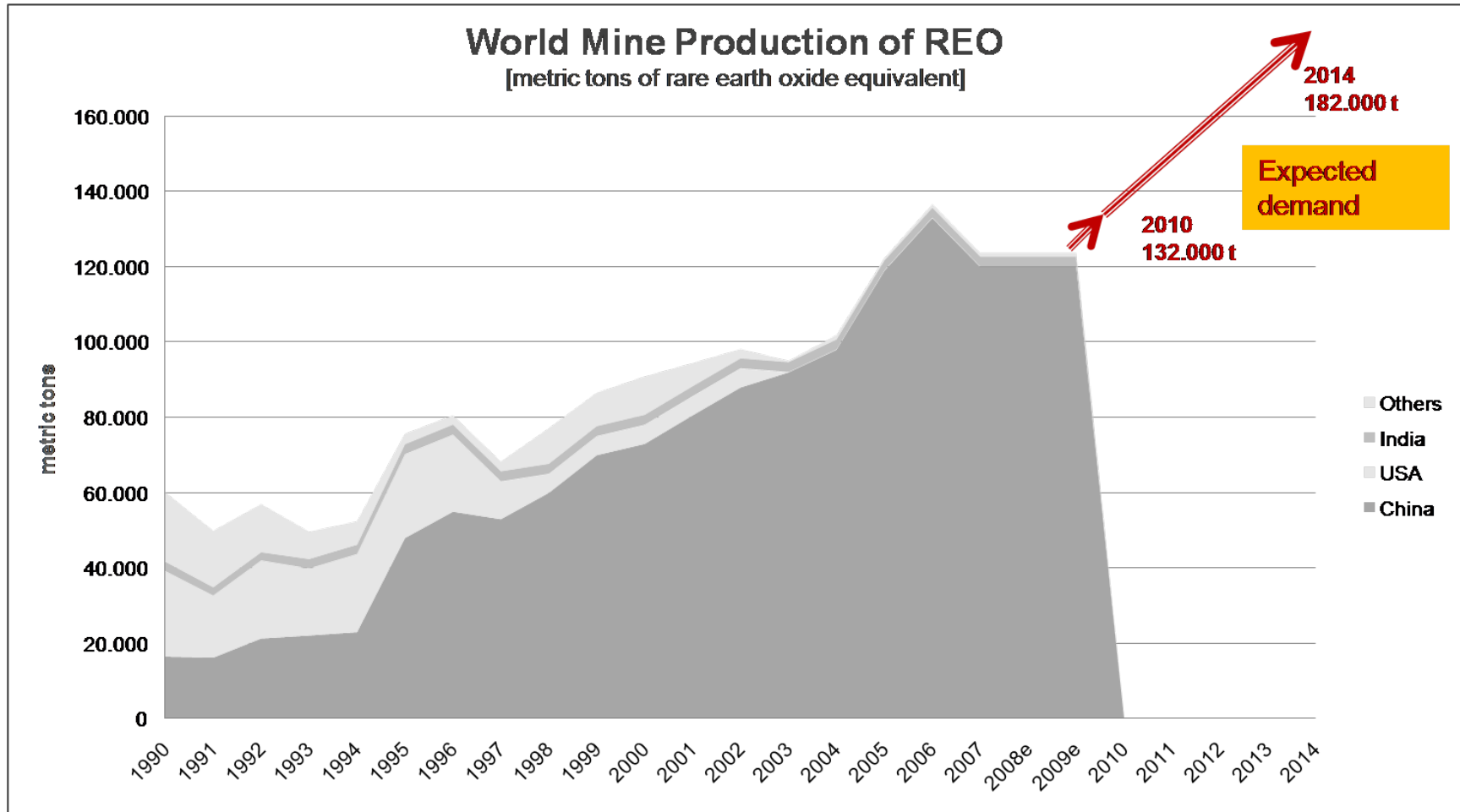
**World Mine Production of REO**  
[metric tons of rare earth oxide equivalent]



Data Sources: USGS 1994 – 2010, Lynas 2010  
© RS Reller / Zepf 2010

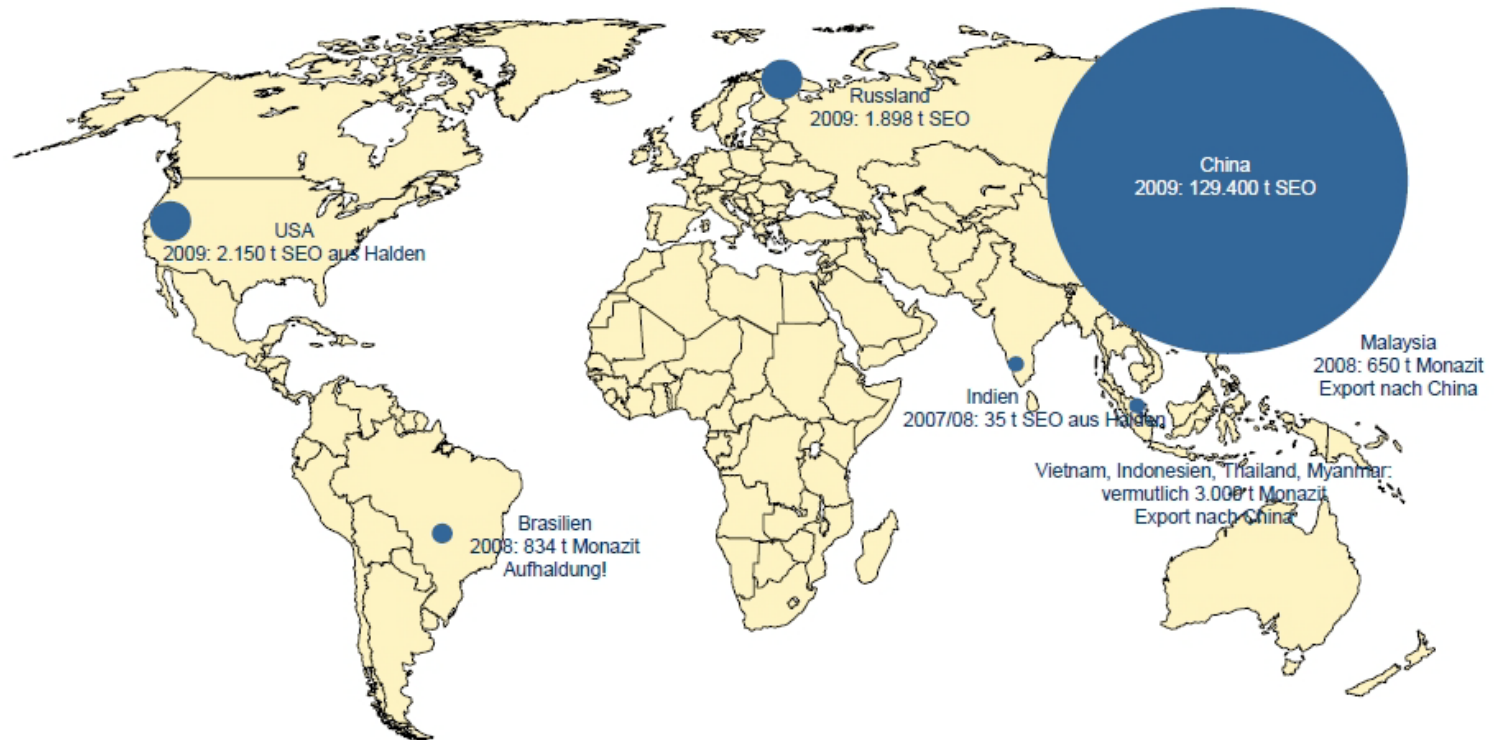


# REE – Production Trends



Data Sources: USGS 1994 – 2010, Lynas 2010  
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# REE production capacity

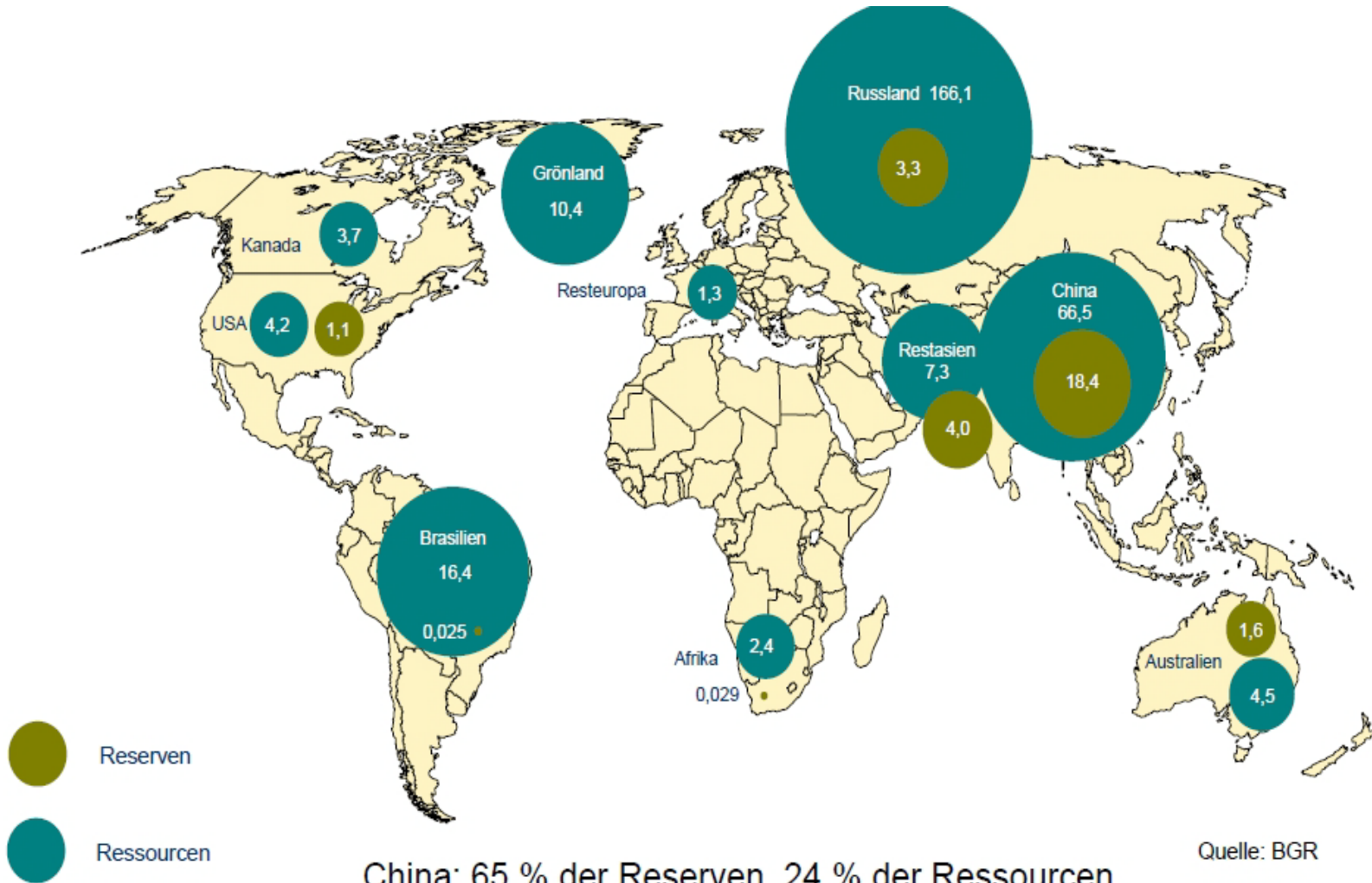


Produktion 2009: ca. 133.500 t SEO

China: 97,0 %, USA: 1,6 %, Russland: 1,4 %, Indien: <0,1 %

Quelle: BGR

# REE reserve and resource distribution



# The current rush on REE

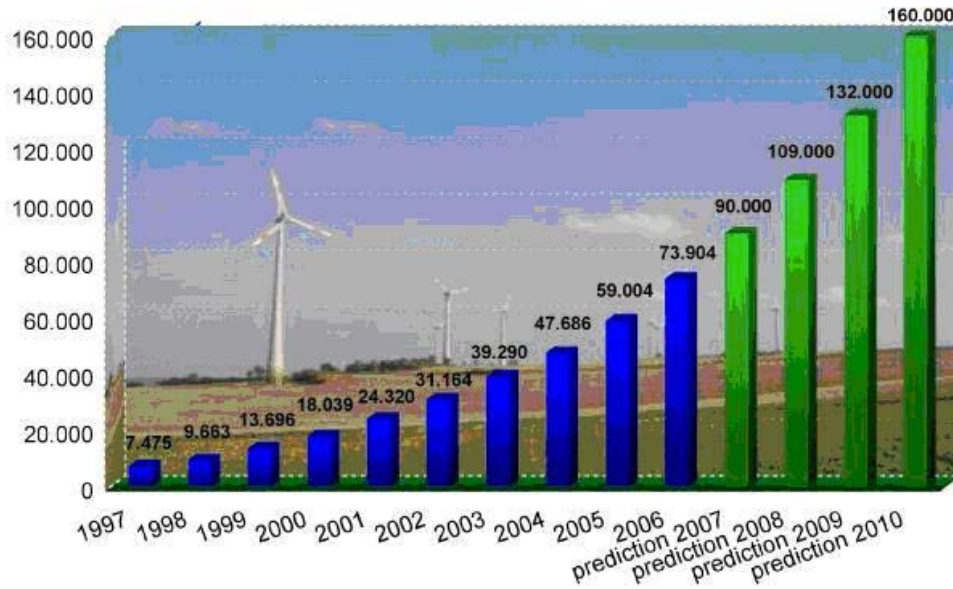


Anfang 2011: 270 Projekte durch 176 Firmen in 28 Ländern

Quelle: BGR

# REE – A “No Go” for the wind energy?

World Wind Energy - Total Installed Capacity (MW) and Prediction 1997-2010



- 0,5 tons/MW of NdFeB magnet ( or 0,2 tons/MW Nd) are need to build a permanent magnet direct drive wind turbine

- **It is possible to build wind turbines without permanent magnets!**

(wound field generator and permanent magnet generators)



- Only around 14% to 20% of all wind turbines do have a permanent magnet

# REE – Ein “No Go” für die Windenergie?

- Fiktive CAGR von 20% für Windenergie Nachfrage von 100% magnet angetriebenen Windturbinen



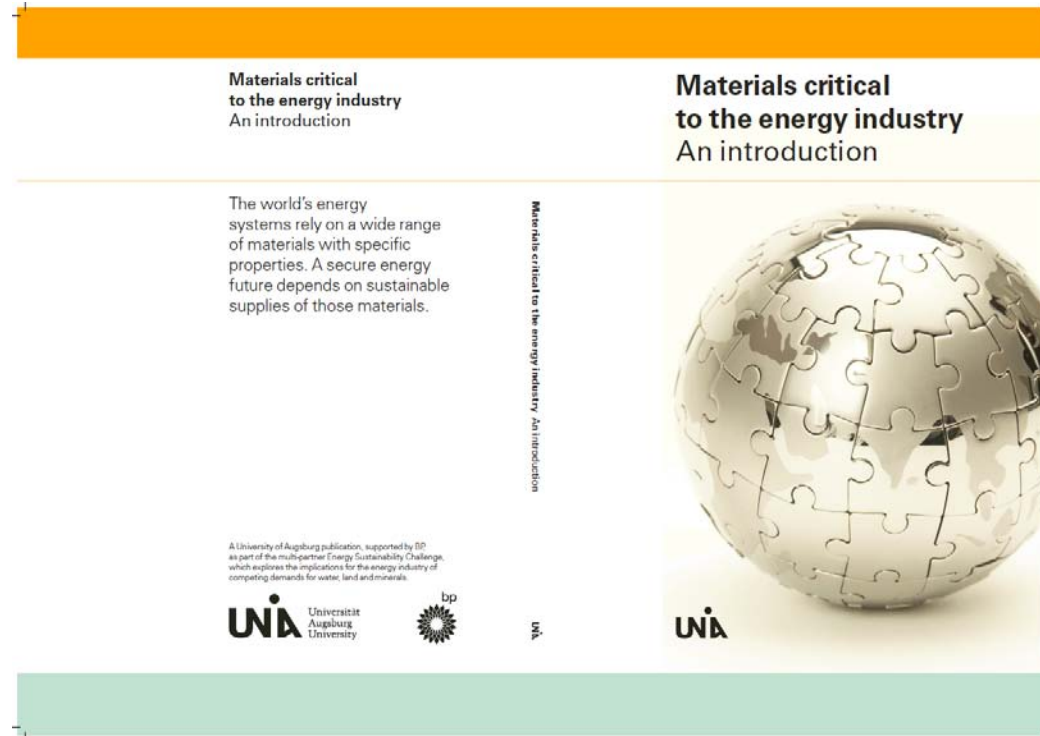
Nachfrage von **7000 Tonen/Jahr** Neodym.

- Die heutige Nd-Produktion liegt bei **11000 t/a** (Öko Institut)  
, **24400 t/a** (Lyans Corp.)
- est. **30000 t/a in 2014**

- Das fossile Energiezeitalter basierte auf ausreichend Metallen für Stahl bzw. Stahlveredler. Das post-fossile Energiesystem breite Basis von Edelmetallen, Halbmetallen und Selten Erdmetallen.
- Rohstoff Daten sind intransparent und basieren meist auf wenigen Quellen
- Eu, Tb, Dy sind wie die meisten kritischen Metalle multifunktional und besitzen eine geringe Nachfrageelastizität.



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**Bei Interesse bitte E-Mail an:**

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Metal Pages, <http://www.metal-pages.com/>

Bayron Capitals, The Rare Earth,  
[http://www.ggg.gl/userfiles/file/Broker\\_Research\\_Reports/Byron%20Capital%20Markets%20-%20Rare%20Earths%20Industry%20Report.pdf](http://www.ggg.gl/userfiles/file/Broker_Research_Reports/Byron%20Capital%20Markets%20-%20Rare%20Earths%20Industry%20Report.pdf)

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