ERT

RAW MATERIALS IN THE INDUSTRIAL VALUE CHAIN

AN OVERVIEW

WHO IS ERT?

ERT is a forum bringing together around 50 chief executives and chairmen of major multinational companies of European parentage covering a wide range of industrial and technological sectors. Companies of ERT Members are widely situated across Europe, with sales in the EU exceeding EUR 1,000 billion, thereby sustaining directly and indirectly around 6.6 million jobs in the region.

Europe flourishes when its industrial companies can compete in the global economy. This capacity to compete depends on the health of the entire value chain. The economic and social policy framework is crucially important and must be able to adapt swiftly to changes in global conditions. ERT Member Companies are actively engaged in dialogue with policy makers and political leaders to identify and implement key enabling conditions which trigger innovation, create jobs and stimulate investment throughout the economy.

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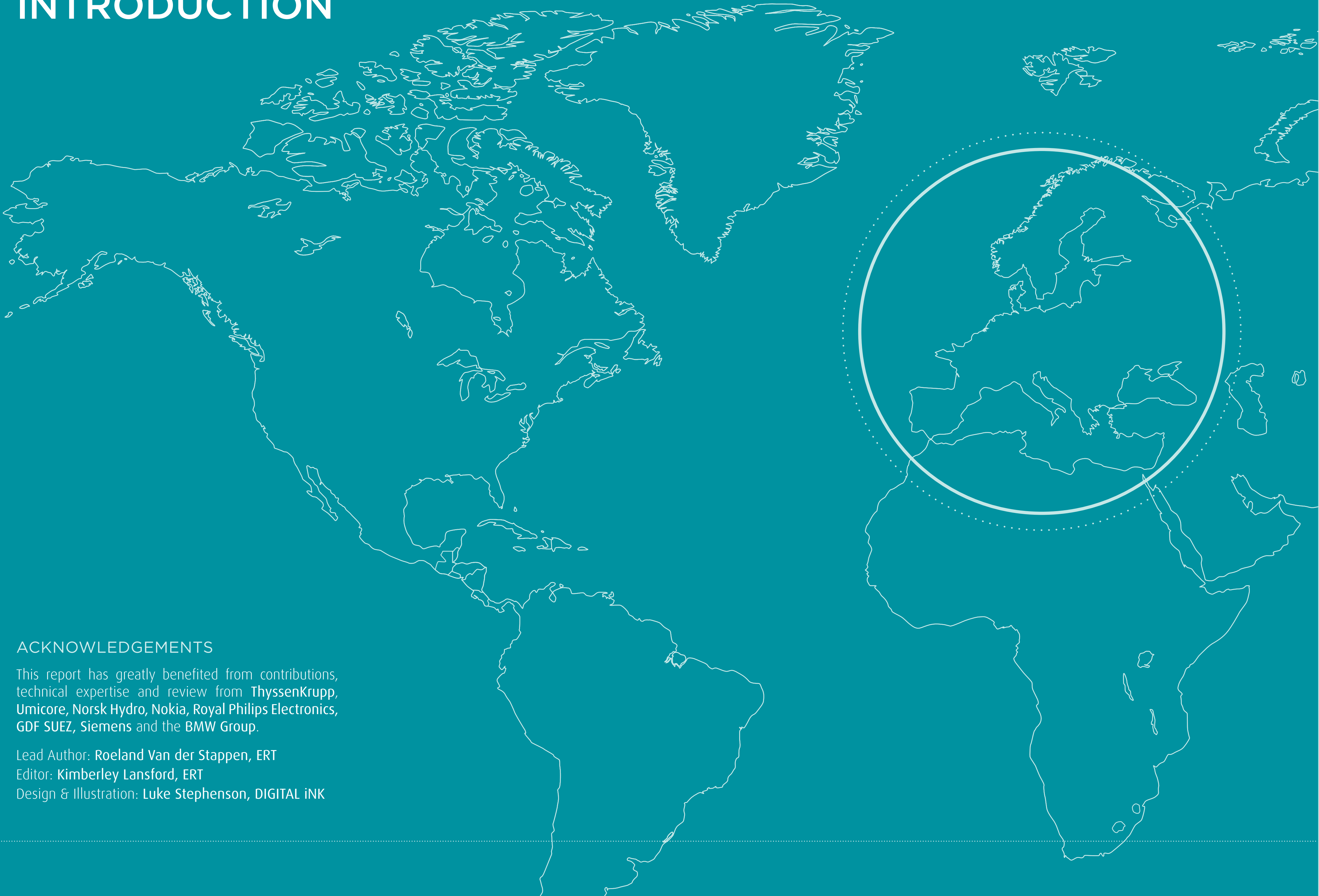
JANUARY 2013

A PDF version of this report is available at www.ert.eu

INTRODUCTION



ACKNOWLEDGEMENTS

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HOW THE EUROPEAN INDUSTRY MOVES INDUSTRIAL RAW MATERIALS UP THE VALUE CHAIN

We experience globalisation each and every day in our workplaces and homes. The integration of global economies is not new, but its pace and scale has increased substantially in the past years.

The industrial value chain is a substantial driver of this trend. The European industries represented at the European Round Table of Industrialists (ERT), can regard with satisfaction their track record of economic success that has contributed to the growth and prosperity for Europe's citizens. Europe is recognised for the innovation and quality of the wide range of goods we produce from materials to finished products as well as for its recycling technologies.

However, the supply of raw materials, the lifeblood of today's industry, poses increasing challenges for Europe which itself is relatively poor in resources. Political turmoil, price volatility, changes in markets and product applications and increased environmental protection are a few of the many aspects that influence the supply of raw materials. Megatrends such as demographic change, urbanisation and globalisation clearly demonstrate that continuous innovation is required to reduce the consumption of natural resources.

Significant efforts have been made by the EU institutions and in the Member States to bring forward initiatives to secure the supply of raw materials to European industry at competitive terms. ERT Members appreciate these initiatives and welcome the raw materials strategy proposed by the European Commission focusing on market access, indigenous production and recycling.

In parallel, leading European industry continues its long tradition in resource efficiency. Market forces, cost pressure and technical performance criteria are already integrated into the business models that drive our companies' efforts on sustainable solutions. Society's demand for goods, infrastructure, energy and raw materials is met by continually improved products and processes from industrial companies. Any new resource efficiency regulations must support these efforts without the risk of harming the global competitiveness of European industry.

This booklet provides an explanation about the importance of raw materials, for the European value chain by providing a view across industry sectors as well as a selection of individual applications. ERT hopes that the reader will gain a better understanding of the complexity of the issues and value chain involved in transforming raw materials into the products we all use in our daily lives.

It is of vital interest for the future of Europe that the growth and strengthening of European industrial competiveness remains at the heart of the political agenda both in Brussels and in Member State capitals. With the current political momentum, we see a window of opportunity to put the political initiatives into actions that will ensure Europe's future.

ERT Members are committed to continuing their leadership role.

Gerhard Cromme,
Chairman of ThyssenKrupp AG
Chairman of the ERT Raw Materials Working Group

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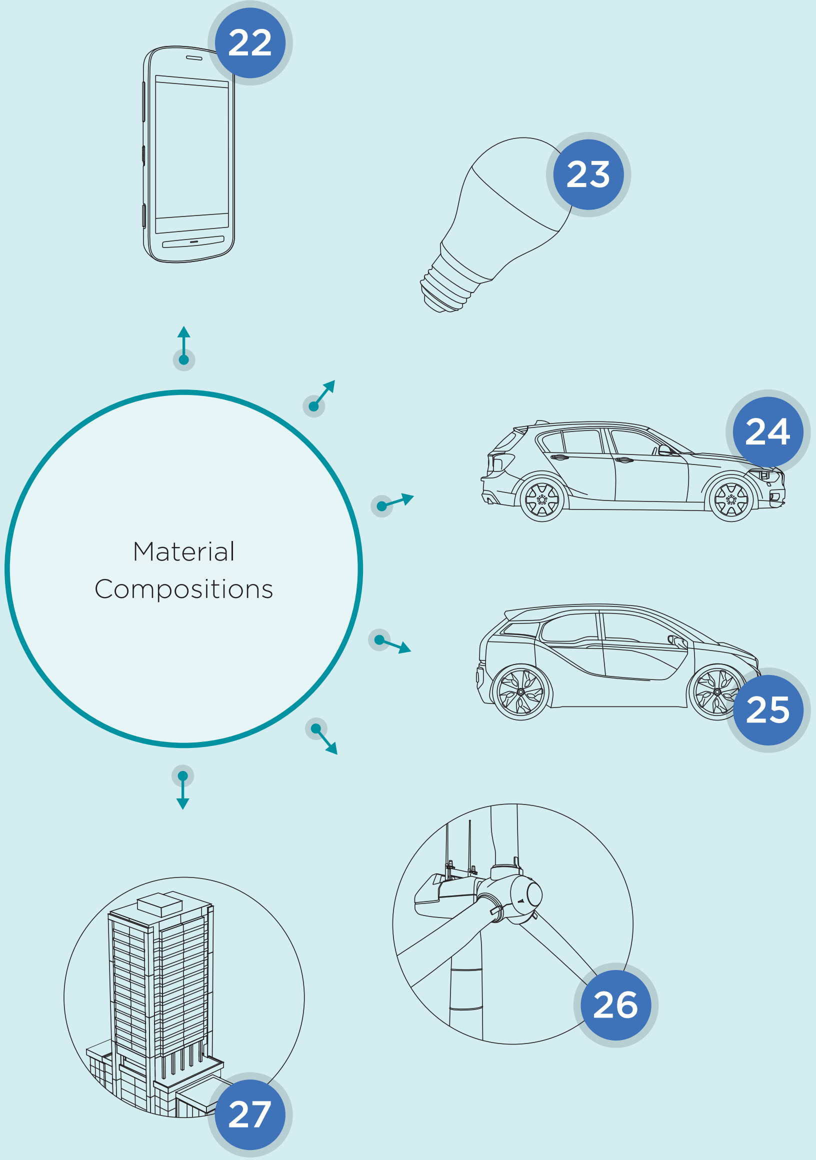
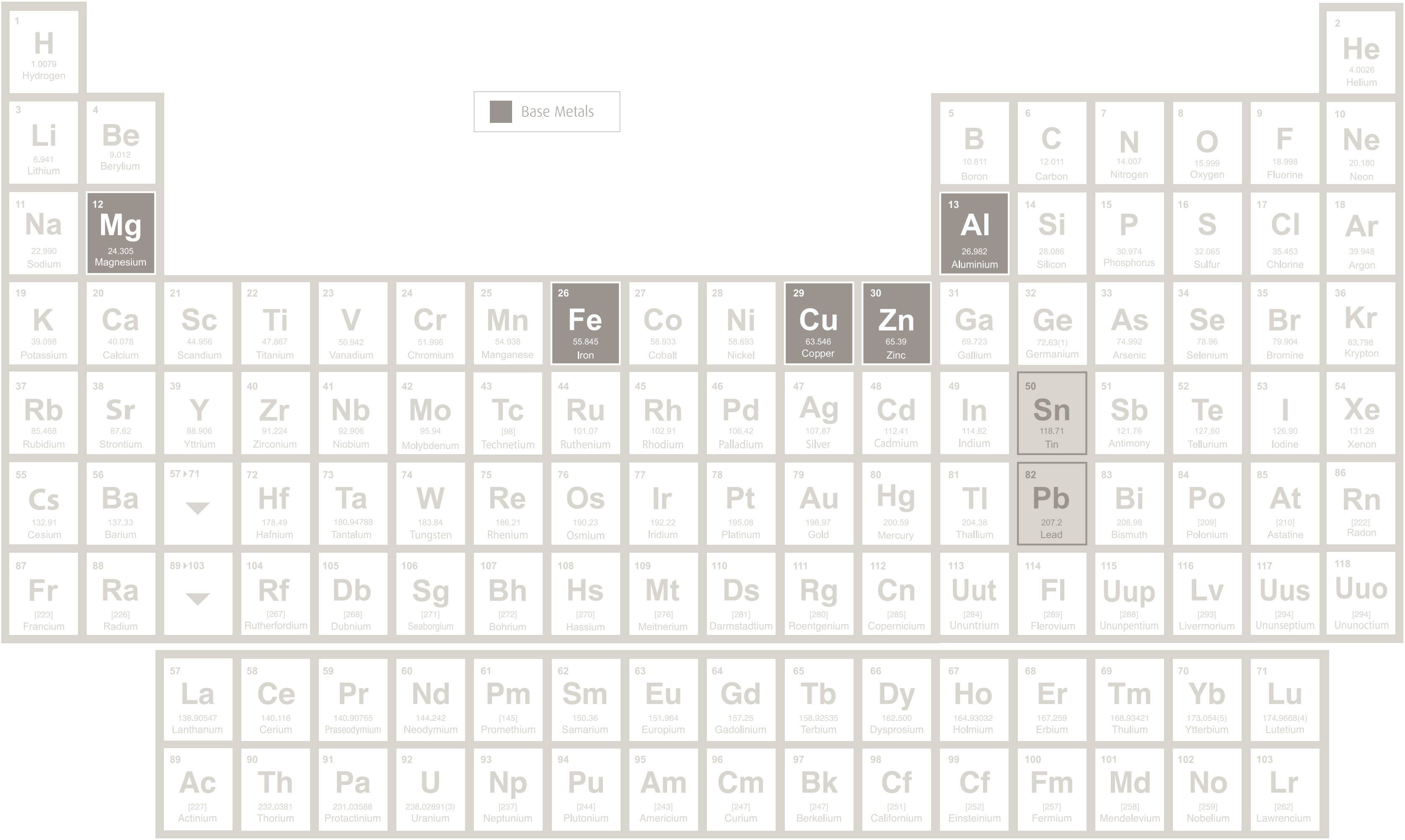


BASE METALS



Since the industrial revolution, the world's economy is dependent on a select number of base metals. They form the backbone for our economic infrastructure and products, and they are used in large and increasing quantities.

The base metals include iron, which when combined with carbon and minor amounts of other metals forms steel, copper that is mainly used in electrical wiring and heating pipes, tin that solders modern electronics, lead used in car batteries, and zinc that inhibits metal corrosion.

Moreover, steel and aluminium are often combined with manganese, magnesium and many other metals to create vast spectrum of metal products. These combinations differ so much in their properties such as strength, hardness, temperature resistance and formability that they can be used in a wide variety applications.

26
Fe
55.845
Iron

Iron is the most commonly used metal. The ease with which it can be cast, welded, machined, forged, cold-worked, tempered, hardened and shaped is unequalled by any other metal. It is mainly used to manufacture steel and other metal combinations in construction and manufacturing.

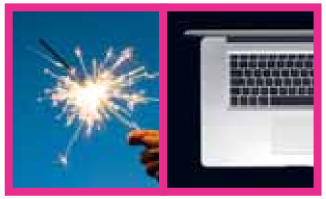
29
Cu
63.546
Copper

Copper is malleable and an excellent conductor of heat and electricity. Only silver has a higher electrical conductivity. Its main use is in electrical equipment such as wiring and motors. Because of its corrosion resistance, copper is also used in heating pipes, roofing, guttering and rainspouts on buildings.

13
Al
26.982
Aluminium

Aluminium is light and corrosion resistant. It is therefore used in an extensive range of products from beverage cans to window frames. Its malleability and high strength-to-weight ratio make it an interesting construction material for buildings and aircraft.

12
Mg
24.305
Magnesium

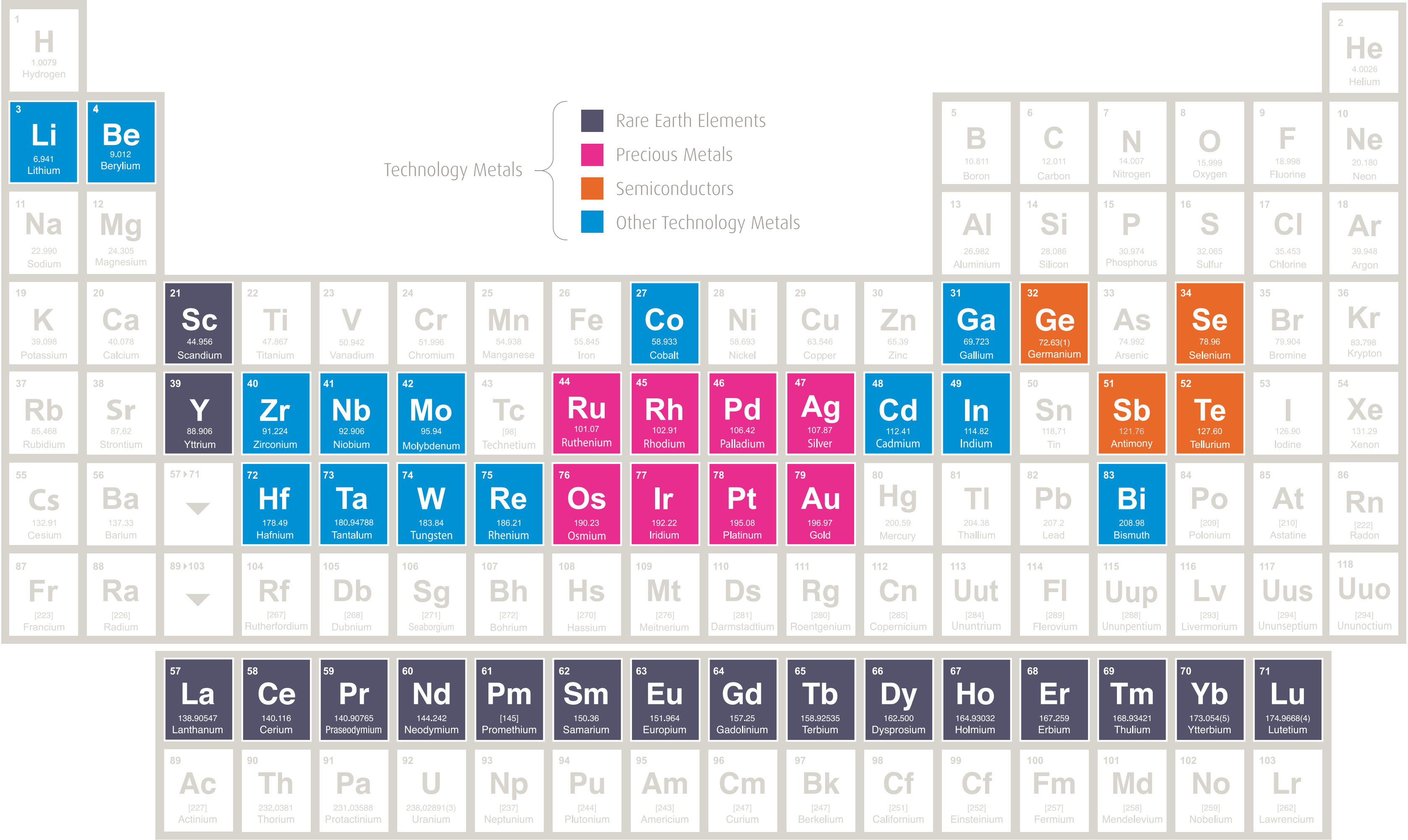


Magnesium is highly flammable and commonly used in fireworks. It is frequently used in the manufacturing of mobile phones, laptop computers and other consumer electronics as a result of its good high temperature mechanical properties.

30
Zn
65.39
Zinc

Zinc is used for the coating of steel to inhibit corrosion. It forms brass when combined with copper. Zinc oxide powder is used in sun block as the filters for harmful UV light.

TECHNOLOGY METALS



Our modern economy makes use of a wide spectrum of technology metals including precious metals, rare earth elements and semiconductors. High-technology products and green technology solutions are dependent on a large number of technology metals, even if used in only very small quantities. The availability of these metals is increasingly affected by growing demand pressure from emerging economies and global markets.

Technology metals are crucial for the characteristics and functionality of modern products which routinely employ dozens of different elements, each carefully chosen because of a specific physical or chemical property. Some have just the right conductivity for a specific purpose, others are chosen for their melting point, photon wavelength, magnetic and optical properties or their catalytic efficiency at high temperature.

3
Li
1.941
Lithium

Lithium is the least dense of metals and highly reactive. It is used in rechargeable lithium-ion batteries for consumer electronics, hybrid and electric vehicles. Lithium carbonate, which forms a colourless salt, is used in medical applications.

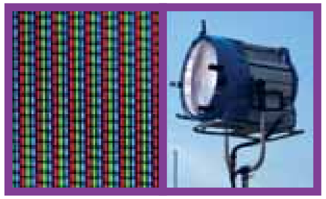
39
Y
88.906
Yttrium

Yttrium is predominantly used in making phosphors which provide the red colour in TV displays. Yttrium oxide is used to produce yttrium-iron-garnets which are effective microwave filters and essential to the operation of satellites. Yttrium barium copper oxide is a powder used for the development of high-temperature superconducting materials for the transmission of electricity.

46
Pd
106.42
Palladium

Palladium is widely used in catalytic converters for automobiles and as a catalyst for petroleum cracking. The metal is also used in jewellery, in particular as means to decolourise gold in the manufacturing of white gold.

58
Ce
140.12
Cerium



Cerium is used in carbon-arc lighting, which is used in the motion picture industry, given its good heat resistance. It is also used in phosphors for colour television screens and fluorescent lighting. Cerium oxide is used as a catalytic converter to reduce carbon monoxide emissions in the exhaust fumes from automobiles, as well as an additive to diesel fuel to reduce exhaust emissions.

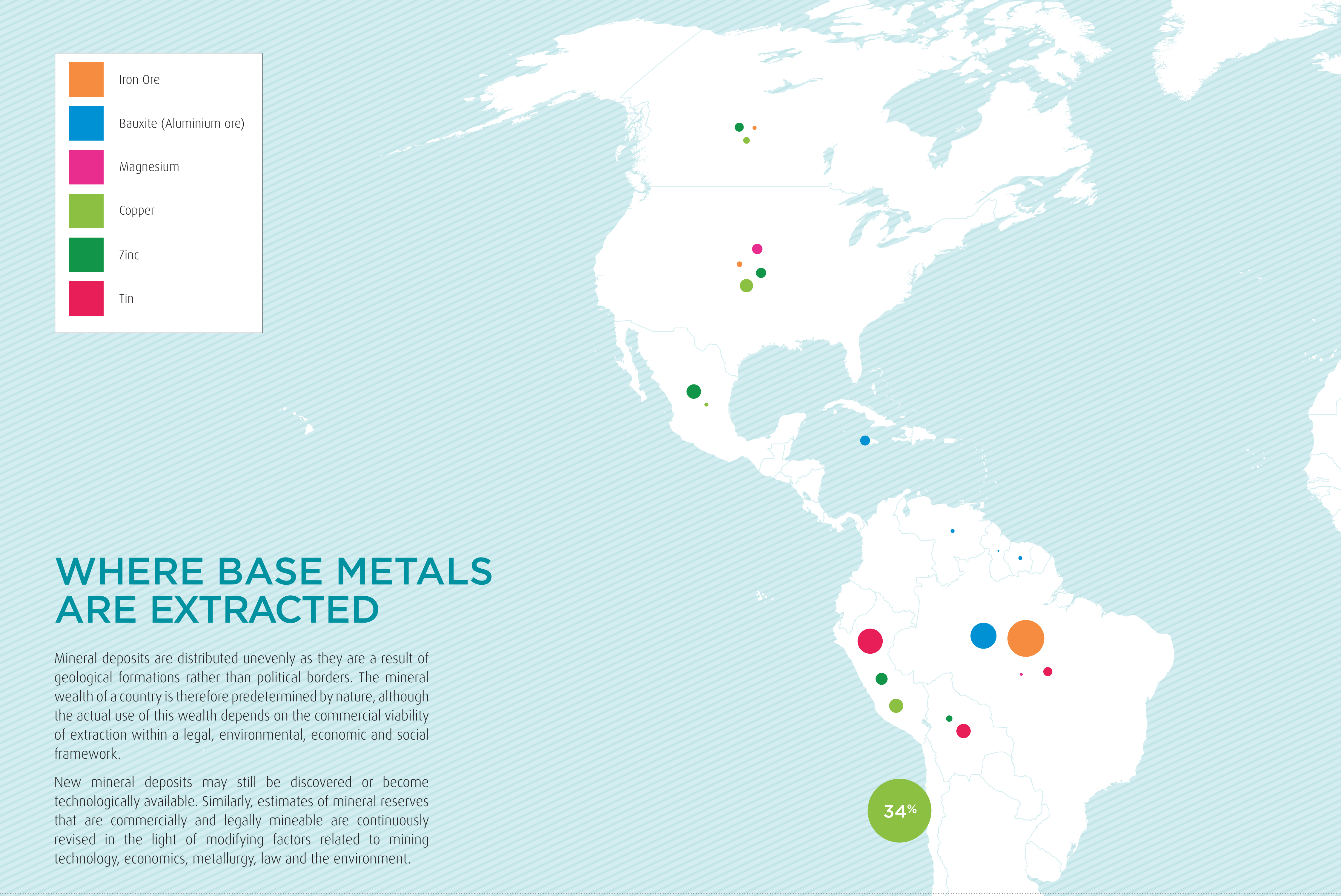
60
Nd
144.24
Neodymium

Neodymium is used with iron and boron to produce permanent magnets. These high technology magnets are necessary for use in electric motors, cell phones, medical equipment and audio systems. Neodymium is also used as a crystal in lasers with numerous applications including the treatment of skin cancer in medicine or the cutting and welding of steel in industry.

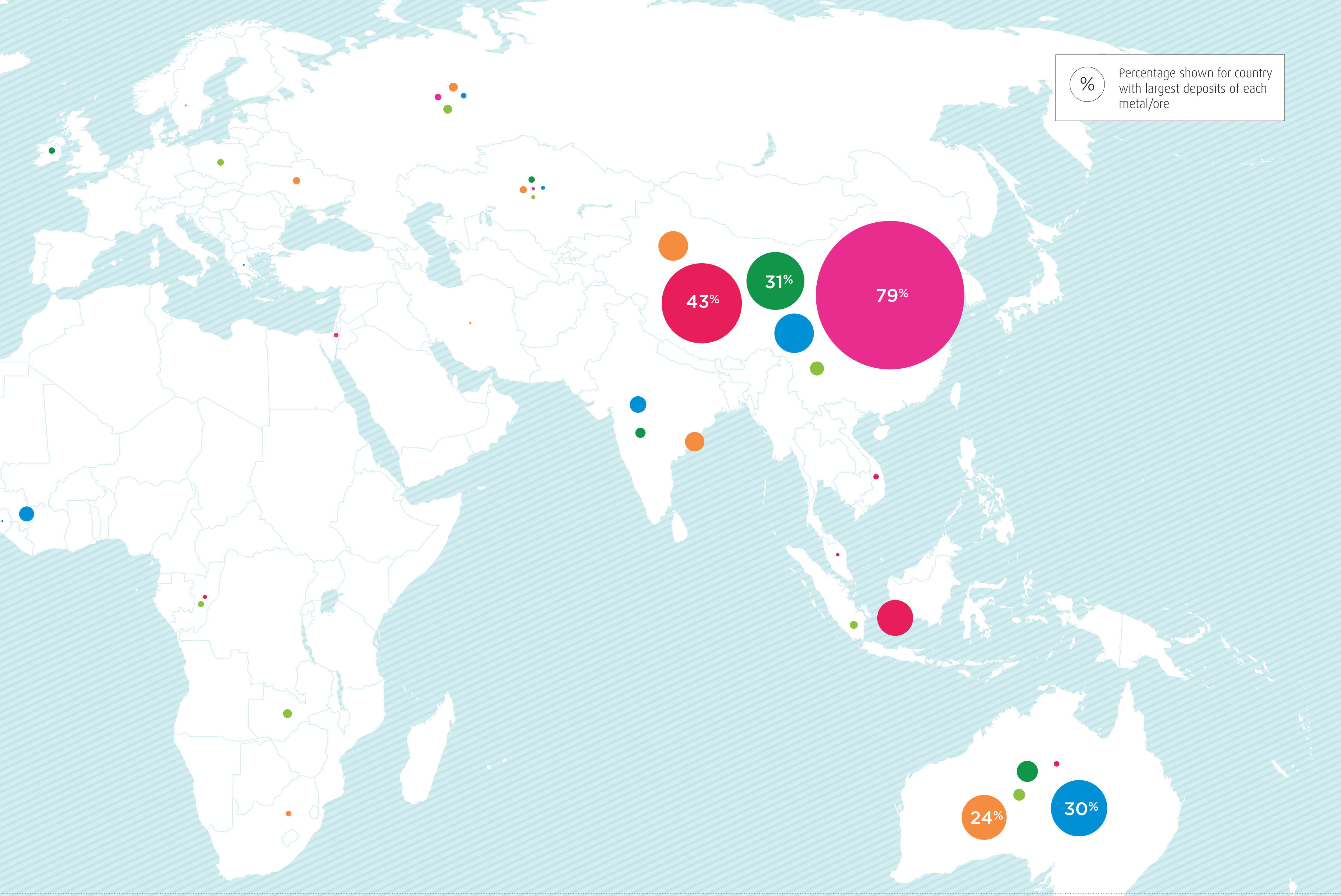
WHERE BASE METALS ARE EXTRACTED

Mineral deposits are distributed unevenly as they are a result of geological formations rather than political borders. The mineral wealth of a country is therefore predetermined by nature, although the actual use of this wealth depends on the commercial viability of extraction within a legal, environmental, economic and social framework.

New mineral deposits may still be discovered or become technologically available. Similarly, estimates of mineral reserves that are commercially and legally mineable are continuously revised in the light of modifying factors related to mining technology, economics, metallurgy, law and the environment.



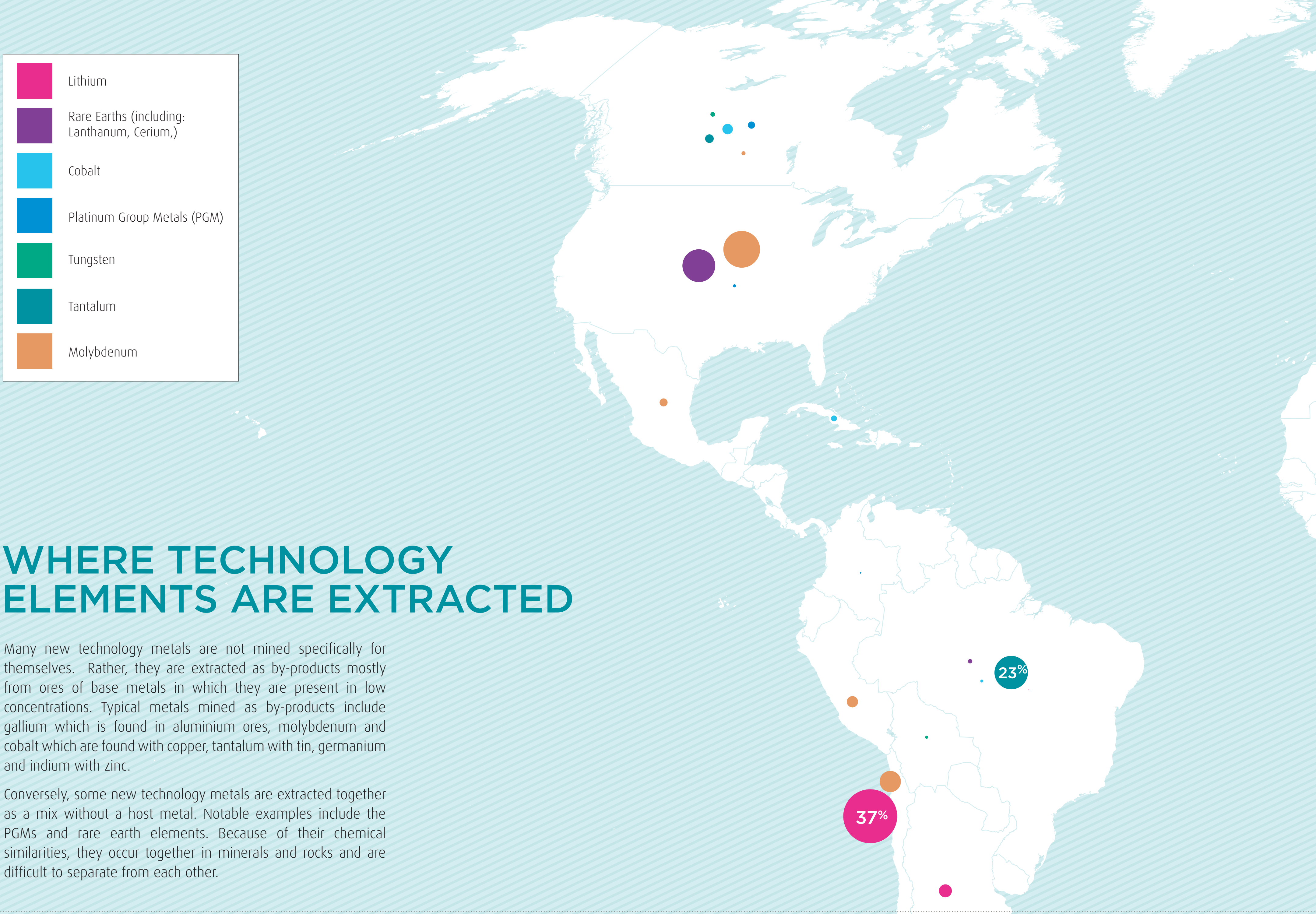
Source : U.S. Geological Survey, Mineral Commodity Summaries, January 2012 | UNCTAD


%
Percentage shown for country with largest deposits of each metal/ore
43%
31%
79%
24%
30%

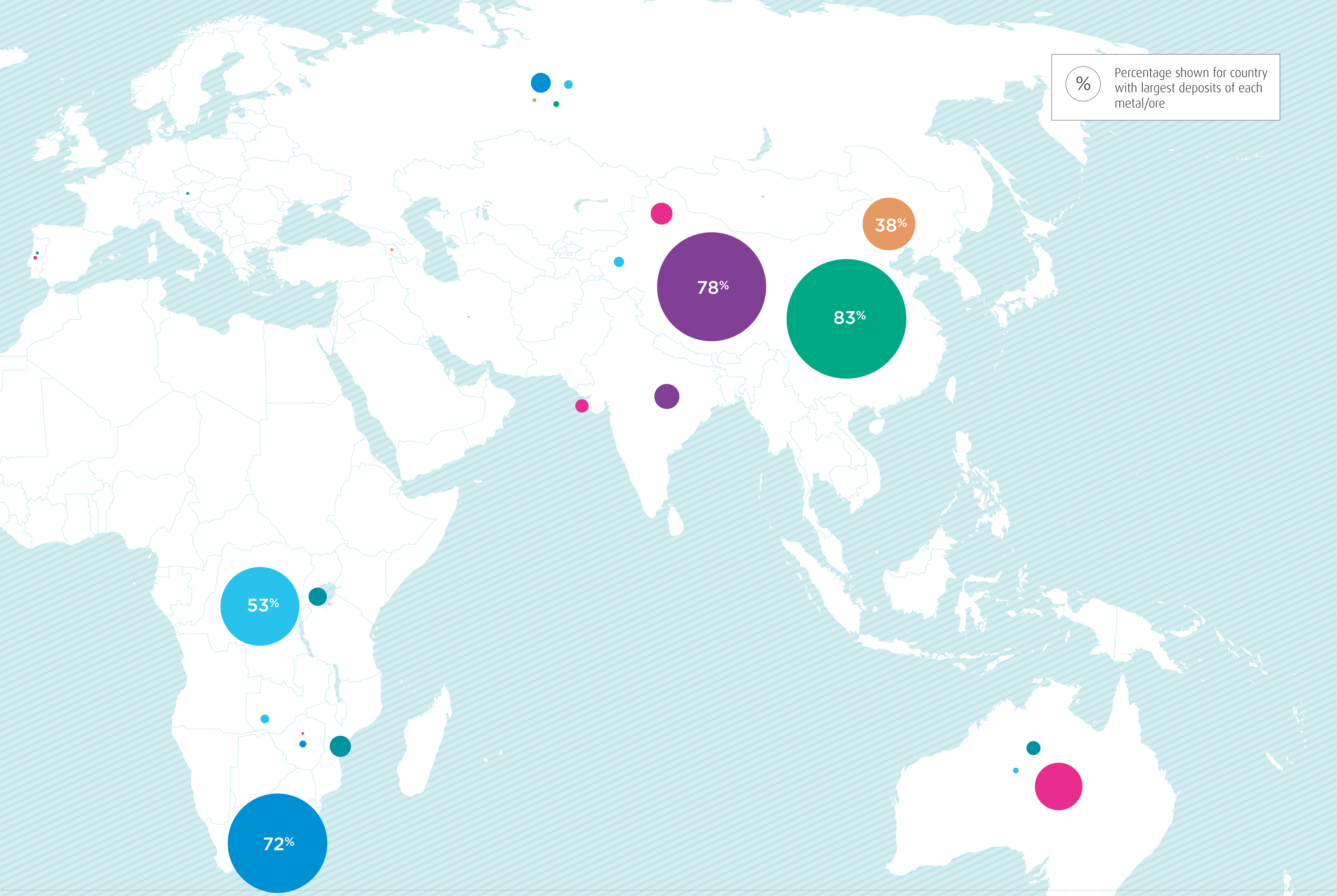
WHERE TECHNOLOGY ELEMENTS ARE EXTRACTED

Many new technology metals are not mined specifically for themselves. Rather, they are extracted as by-products mostly from ores of base metals in which they are present in low concentrations. Typical metals mined as by-products include gallium which is found in aluminium ores, molybdenum and cobalt which are found with copper, tantalum with tin, germanium and indium with zinc.

Conversely, some new technology metals are extracted together as a mix without a host metal. Notable examples include the PGMs and rare earth elements. Because of their chemical similarities, they occur together in minerals and rocks and are difficult to separate from each other.



Source : U.S. Geological Survey, Mineral Commodity Summaries, January 2012 | UNCTAD


%
Percentage shown for country with largest deposits of each metal/ore
38%
78%
83%
53%
72%

ISSUES RELATED TO EXTRACTION

ENVIRONMENTAL

The extraction of minerals invariably has an impact on the land were the operations are based. Most mines and quarries require the removal of surface features during the extraction process and need space for storage mounds, spoil tips, and lagoons as well for associated infrastructures including processing plants, waste treatment facilities and access roads. A sustainable approach is required to improve wildlife habitat and biodiversity during the project and at the end of the project life cycle, including through quarry and mine rehabilitation projects.

Increased demand for metal materials has made access to land for mineral extraction in the EU more important. While most metal minerals are sourced from outside of the EU, some can also be mined directly in Europe. Some of these resources are below of the surface of land within Natura 2000, the EU's network of protected natural areas. This network consists of nearly 26,000 sites and covers nearly 18% of the land in the EU.

Natura 2000 areas do not prohibit mineral extraction explicitly. However, differing regulation and permit procedures, planning processes, health and safety, and environmental protection rules have the potential to constrain mining activities or make them economically non-viable in the EU.

Therefore, strategic and centralised spatial planning, including the use of mineral resource maps, is needed to optimise the analysis of different land uses being considered across a broad geographic area. This would allow for a deeper reflection on economic development, dependence on imports, and the avoidance or reduction of potential negative impact on the natural environment while preserving the integrity of protected sites.

ECONOMICAL/TECHNOLOGICAL

The extraction of metal minerals can only occur in those locations where natural geological processes have concentrated them in sufficient quantities and in a suitable form to make their extraction and exploitation technically and economically viable.

The commercial viability of their extraction also depends on constantly modifying factors related to current and future market prices, regulatory regimes including environmental protection as well as improved technology for metal minerals extraction and chemical and mechanical processing.

This calculation becomes more complex for certain new technology metals which are extracted as by-products, mostly from ores from base metals in which they are present in low concentrations. Increased demand for such new technology metals can only be met if demand for the host base metals rises accordingly. Otherwise, there is a risk that an overproduction of the host metal would decrease its market price more than the additional value generated from the sale of its by-product metals.

Technological progress in exploring, mining and processing mineral raw materials has enabled supply to keep up with demand in the past. Mineral reserve estimates can increase with the discovery of new exploitable resources, which is dependent on both exploration and extraction technologies. This may occur in frontier areas such as the seafloor, extreme depths, deserts and the Arctic region, which may become technologically available in the near future. However, it may take 10 years or longer for new mining projects to go through all of the technical, financial, environmental and regulatory stages for approval.

POLITICAL

3.5 billion people live in countries rich in oil, gas and minerals. With good governance, the exploitation of these resources can generate large revenues to foster economic growth and reduce poverty. When governance is weak, extraction revenues are not always used to serve the interests of society and can even be at the core of political corruption and conflict.

For those reasons a coalition of the world's largest oil, gas and mining companies, governments and civil society have come together for the development of the Extractive Industries Transparency Initiative (EITI). This international voluntary standard aims to make visible the financial flows related to the extraction of natural resources from the awarding of concessions to the public spending of these revenues.

Transparency of payments is seen as a necessary step towards greater accountability in the use of extraction revenues. In countries participating in the EITI, companies are required to report the taxes, royalties or bonuses they pay to governments and the governments are required to publish what they receive from companies. These figures are then reconciled and published by an independent administrator.

The EITI process is overseen by a multi-stakeholder group in each country, including representatives from the civil society which can more effectively hold governments accountable for resource revenues. This oversight process entails a financial, physical and process audit of the entire oil, gas and mining industry. This is a massive undertaking given that many of the participating countries have little data available electronically, poor infrastructures, and insufficient historical record keeping, all of which necessitates investment for modernising the underlying infrastructure.

A number of countries are already well advanced in implementing the EITI. Certain countries have even incorporated resource revenues transparency into national legislation. The United States has recently joined. Its wider deployment is supported and encouraged by the G20, United Nations, and the African Union.

SOCIAL

Leading industrial companies and sector associations have come together to take continuous action to ensure appropriate social standards and reporting, not only in their own operations but also throughout their supply chain. The primary focus is to ensure that minerals from conflict areas do not enter the supply chain.

Conflict minerals, whether metal ores or refined metal minerals, are mineral resources whose sales revenues may finance military and guerrilla operations that contribute to human rights abuses. As an example, the sale of commodities such as gold, tantalum, tin and tungsten have helped fund armed conflict in Central Africa, and more specifically in the Eastern Provinces of the Democratic Republic of Congo.

These minerals are used by a wide range of industries including electronics, aerospace and automotive and the diversified manufacturing sector. Identifying the chain of ownership and origin of these minerals can be challenging. They move through a complex global supply chain, beginning from small scale producers to local consolidators, neighbouring countries and traders over the world, as well as smelters and other processors. In addition, the smelting and refining of minerals often combines ores from multiple sources, making it extremely difficult to trace their origin after refining occurs.

Therefore, industry has adopted a collaborative approach to supply chain tracking, tracing and due diligence, as developed by the Electronics Industry Citizenship Coalition (EICC) and the Global Sustainability Initiative (GeSI). This also includes the support of the 'Conflict-Free Smelters Program' which requires a third-party audit of the receiving and sourcing information of smelters' and refiners' incoming materials to ensure that the materials have been procured only from conflict-free sources. The EICC and GeSI's work has now been extended and coordinated with industries beyond the electronics sector to ensure an effective and reliable verification system from mine to market.

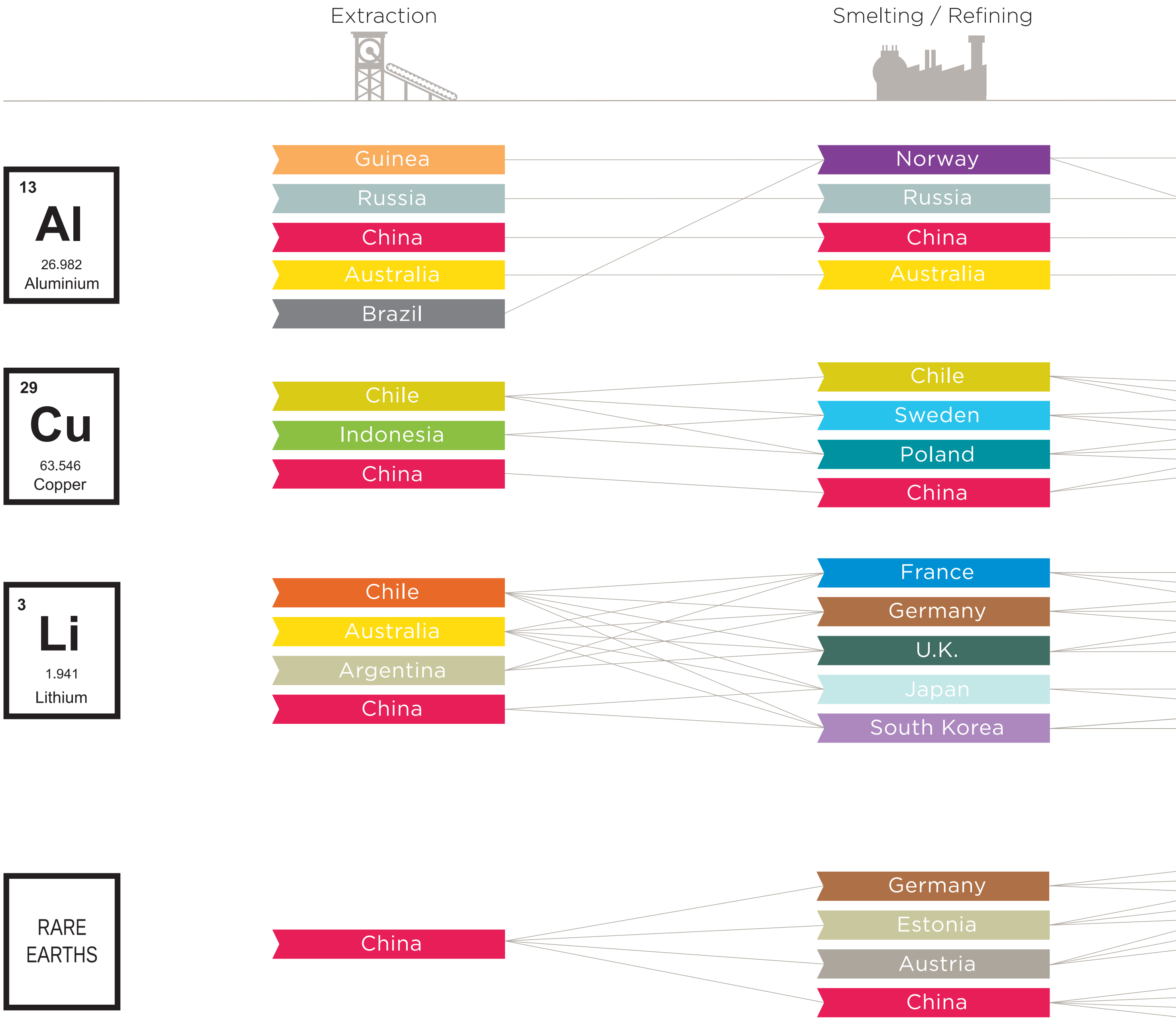
EXAMPLES OF TRADE FLOWS OF RAW MATERIALS

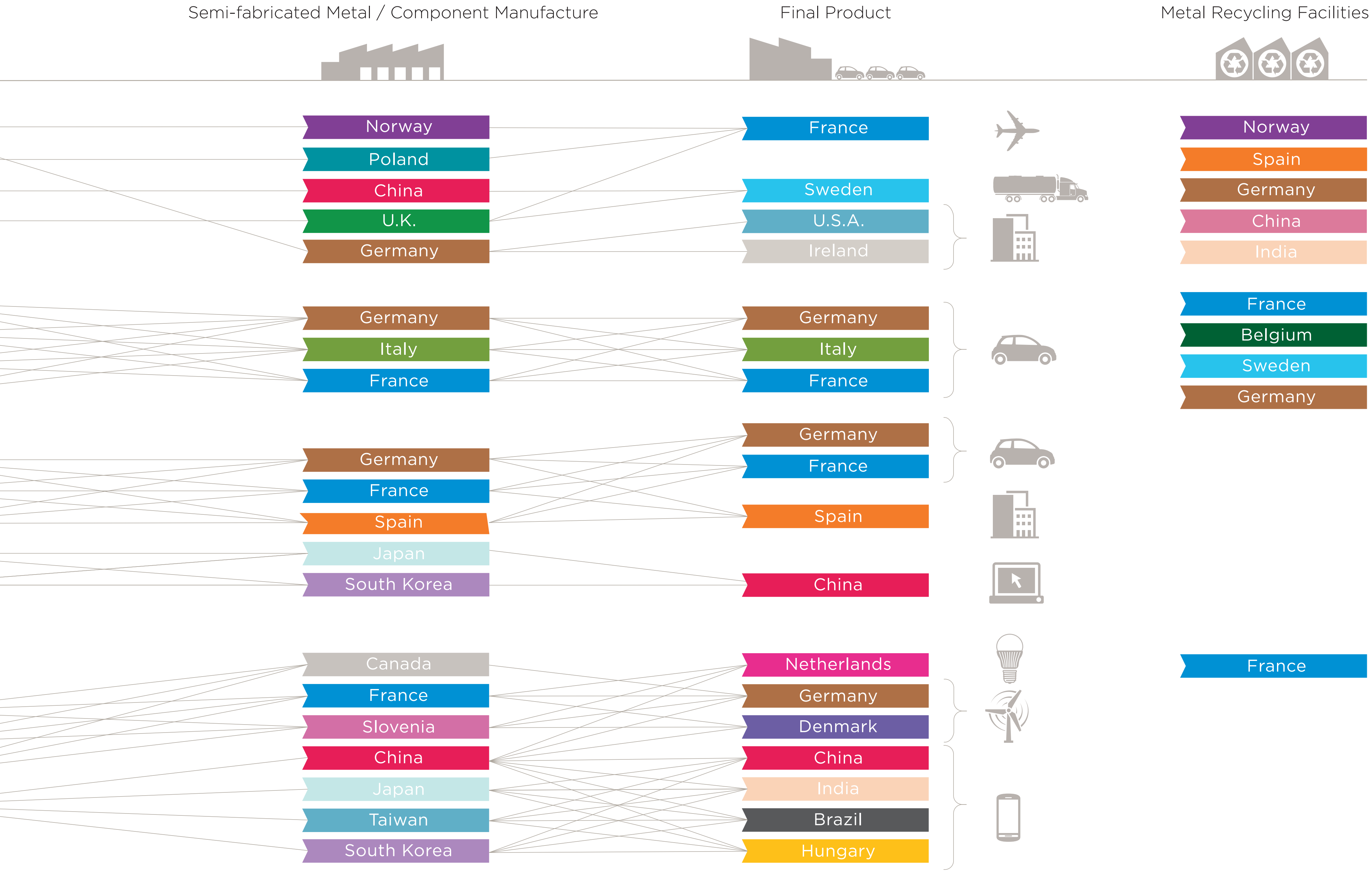
This picture illustrates the complex trade flows from extraction through refining for the manufacture of various metal-containing products. It shows how dependent European industries are on minerals - most of which come from sources outside of Europe. If we would be looking at the value chain, it would show that much of the added value, including that of R&D, is created in Europe by European companies.

Most of the base metals are appropriately recycled in many countries worldwide. Both the refining and recycling of certain technology metals require more complex processes and technologies which are less widespread. European companies encourage that recycling is done in an appropriate manner and that materials from their products are brought back into the raw material supply chain.

> *"As part of the European ICT industry, we need to be able to source raw materials freely on market terms. To be able to do this, we must work together to manage our global supply chain – to encourage diversity in the supply of metals, including extracting new resources across regions, and to recycle technology metals from electronic waste."*

Stephen Elop
President and CEO Nokia




Semi-fabricated Metal / Component Manufacture
Final Product
Metal Recycling Facilities
Norway
Poland
China
U.K.
Germany
France
Sweden
U.S.A.
Ireland
Norway
Spain
Germany
China
India
Germany
Italy
France
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China
Japan
Taiwan
South Korea
Netherlands
Germany
Denmark
China
India
Brazil
Hungary
France

RESOURCE EFFICIENCY OF RAW MATERIALS

Resource efficiency of raw materials involves the optimal use of materials across the product lifecycle and value chain, from raw material extraction and conversion, product design and manufacture, transportation, consumption and re-use, to recovery, disposal or recycling. The opportunities to improve the resource efficiency of a product are not limited to a specific stage of the lifecycle, and improvements at one stage can have a profound impact on another. By using less material resources and optimising their use, businesses and societies can reduce the risks linked with resources depletion, materials security and environmental impact.

Resource efficiency makes economic sense for industry, and it is also an essential factor in the transition towards a low-carbon economy. Depending upon the sector, average European manufacturing costs can be up to 40% for materials, with additional costs for energy and water and labour contributing around 20%. Due to high raw material and energy costs, companies already have a strong incentive to pursue resource efficient business strategies.

Resource efficiency is seen as a means to reduce costs, improve competitiveness and to even generate new commercial opportunities. A variety of innovative approaches are already employed by companies to reduce resource use and environmental impacts per unit of production of goods and materials at the level of the product, company or its value chain.

Manufacturing efficiency

Manufacturing processing transforms raw materials and other inputs into finished products. Energy and material efficiency improvements can be realised through improvements in quality control, the minimisation or elimination of waste and the recycling of waste. This often correlates with the deployment of advanced manufacturing technologies, but it can often be achieved by making changes in existing production lines.

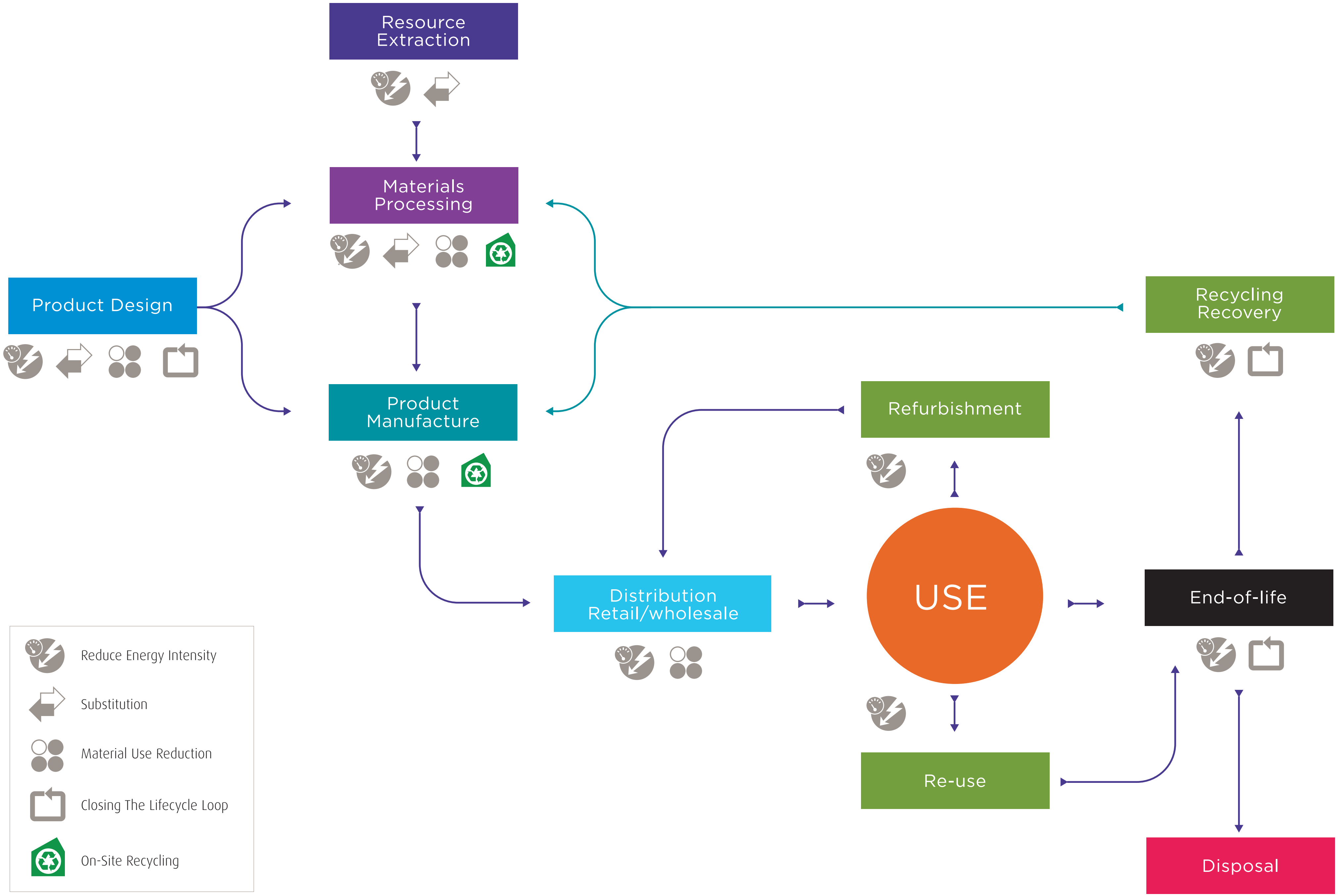
Resource-efficient product design

Products are designed to meet customer requirements, design functionality and regulatory requirements. The design of a product determines the impacts of its lifecycle, starting with the selection of materials and finishing with recyclability at end-of-life. Product design optimisation is typically achieved through the use of the following resource-efficient methods:

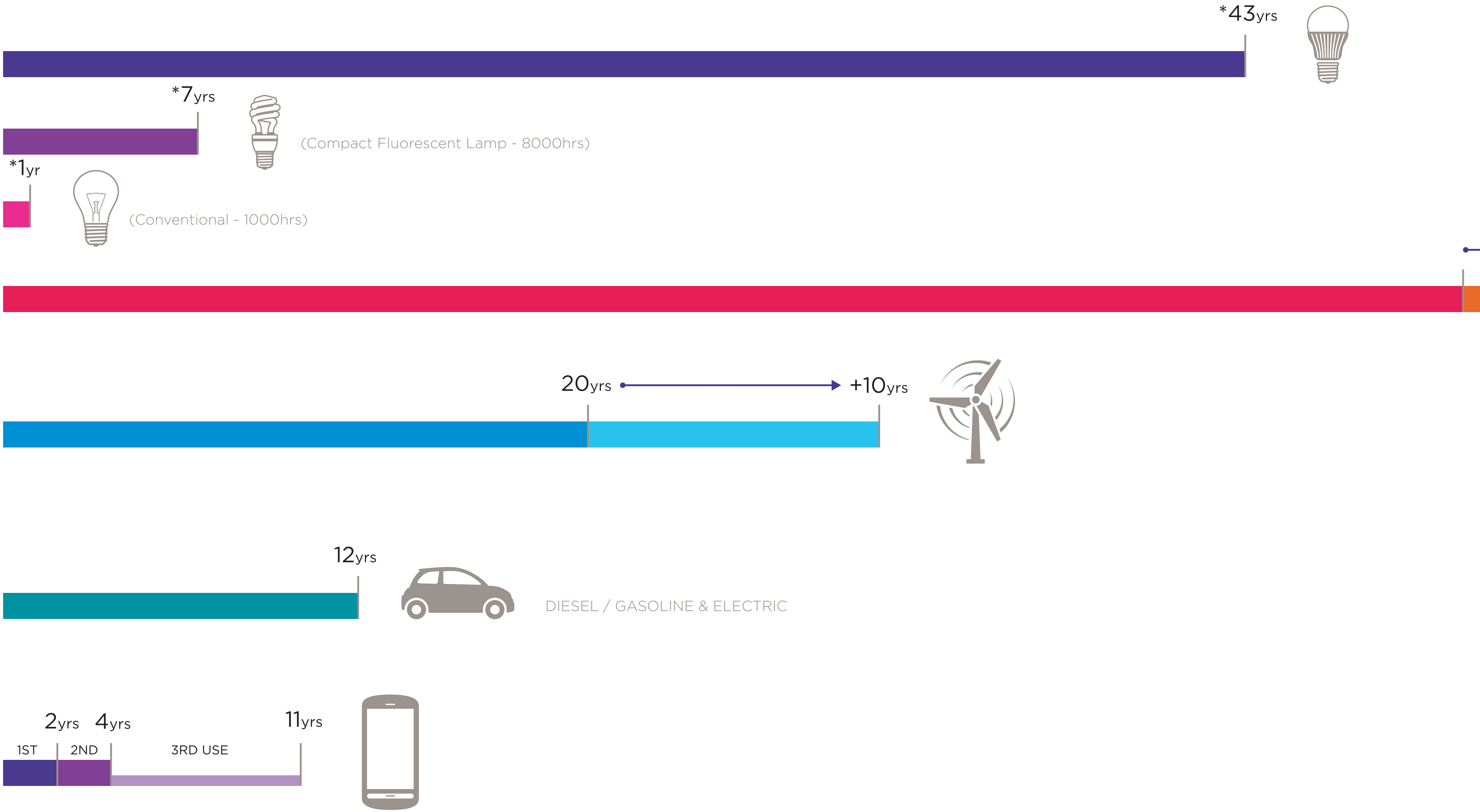
- **Substitution** – A material can sometimes be substituted by another one that may have a lower environmental impact over the entire lifecycle or have a lower supply risk. Substitution and materials innovation are part of the optimisation process to improve product function and performance, reduce cost, and address recycling concerns. New solutions may require changes in related technologies and processes.
- **Material use reduction** – Product design optimisation may enable the reduction of weight and components through the use of less or lighter materials. This can result in a reduction of the amount of waste and emissions but aspects such as product durability, longevity and functionality need to be considered.
- **Closing the lifecycle loop** – Product design optimisation can enable a high degree of recycling and re-use of materials, ease remanufacturing or repair of products. This allows for the same material to be used over multiple product lives and limit dispersive losses of material during the lifecycle. For example, innovative product design already facilitates the disassembly of products and reuse of materials by considering how compatible materials are with available recycling infrastructure and recovery practices.

Value chain optimisation

From resource extraction to a final product being sold to its end-of-life collection and recycling, there are many steps to be coordinated to ensure the efficiency of resource use. However, modern manufacturing companies are rarely vertically integrated throughout the complete production chain. One company's output is another's input, requiring a great deal of cooperation and communication across the value chain to optimise resource efficiency gains.


Resource Extraction
Materials Processing
Product Design
Product Manufacture
Recycling Recovery
Refurbishment
Distribution Retail/wholesale
USE
End-of-life
Re-use
Disposal
Reduce Energy Intensity
Substitution
Material Use Reduction
Closing The Lifecycle Loop
On-Site Recycling

EXAMPLES OF PRODUCTS' SERVICE LIFE



This data is based on best available experience and knowledge.

* Based on average usage of 3,13 hours per day

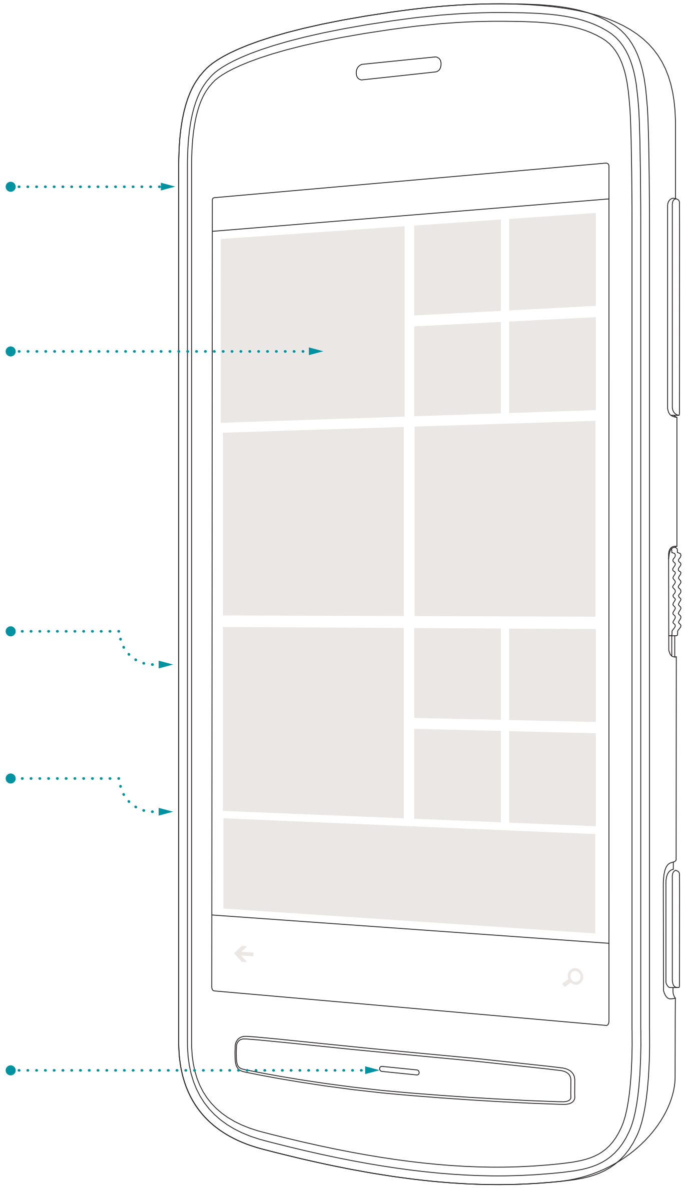
(Light-emitting Diode [LED] - 50000hrs)

A product’s service life is the backdrop against which companies conduct life cycle assessments to clarify the priorities for product improvement and environmental impact reduction measures. These assessments are specific to each individual product or product category as not only is service life different but also the material sourcing and composition, product assembly and transport, the product use phase, and product disposal and recycling possibilities vary widely.

Products are increasingly designed to have an optimised lifetime, which often means an extended lifetime. This can contribute to greater resource efficiency including the reduction of the environmental footprint. The continuing increase in demand for metals and the extended service life of many applications makes it important to increase in the recycling rate of metals in society. This is needed to ensure a sustainable supply of metals for future generations and to contribute to the transition to a low-carbon economy.

SMARTPHONE

MATERIAL COMPOSITION



29	3	60	49	66
Cu	**Li**	**Nd**	**In**	**Dy**
63.546	6.941	144.242	114.82	162.500
Copper	Lithium	Neodymium	Indium	Dysprosium

The ICT industry is a major consumer of metals, and consumption is growing as ICT solutions are increasingly integrated in medical, industrial and transportation applications. The ICT industry accounts for about one third of the demand for the world production of copper and silver which are needed for circuitry and electric wiring of various high-technology products, as well as tin to solder its electronic components.

The technology trend in the ICT sector has resulted in a significant increase in the variety of technology metals including rare earth elements used in products such as televisions, computers and mobile phones.

Today's smartphones may contain up to 50 different metals although used mostly in very small absolute quantities. They provide the user with additional functionalities with a comparatively low weight and small volume. Of the new technology metals, neodymium and dysprosium are used for powerful loudspeaker magnets, cobalt and lithium for the battery, indium for the LED display, and gallium for the processor.

Demand for these technology metals will continue to increase, while the possibility to substitute these metal minerals is limited. This raises concerns regarding the continuous supply and potential price increases of these metals, especially as the resources and production are concentrated in a few countries.

A diversification of supply of these metals is needed through the extraction of new resources across different regions, increasing the return of technology metals from recycled electronic waste to the supply stream, and further R&D to continue to reduce materials needed for the same or better performance.

LED LIGHTING

MATERIAL COMPOSITION

29	57	58	63	65
Cu	**La**	**Ce**	**Eu**	**Tb**
63.546	138.90547	140.116	151.964	158.92535
Copper	Lanthanum	Cerium	Europium	Terbium

Green technology solutions are largely dependent on a number of rare earth elements and technology metals. These metals are essential for our transition towards a low-carbon economy.

As an example, LED lamps use small quantities of rare earth powders as phosphors. These make up less than 1% of the overall weight, but are crucial for LED lamps' characteristics and functionality as the emission of light is created by electron excitation rather than heat generation.

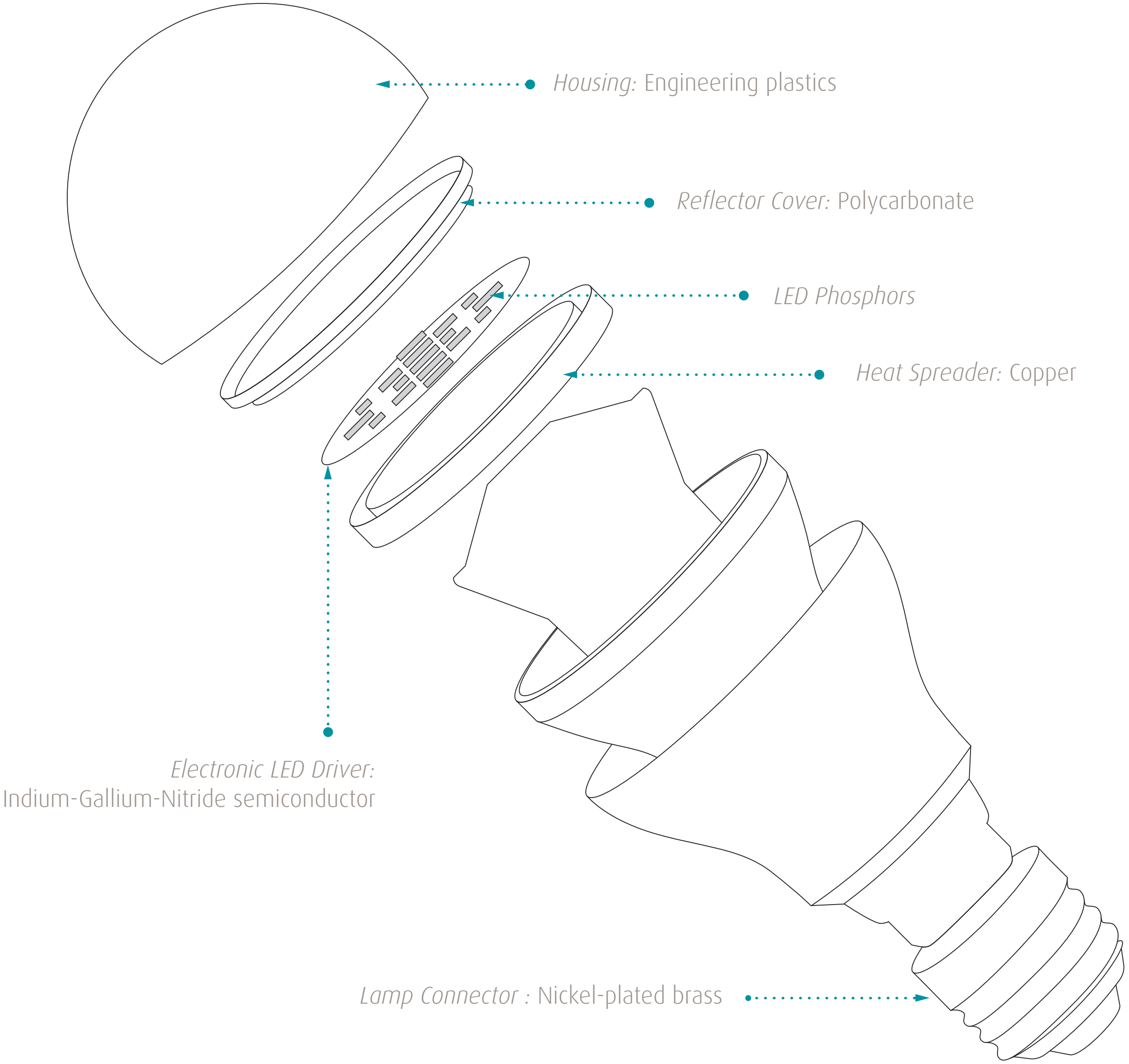
LED lamps and other forms of electronics largely use the same materials. However, LED lamps have up to 80-90% energy savings due to the fact that their service life is 5-40 times longer than that of conventional light bulbs.

Their longer service life also corresponds to a breakthrough in material consumption reduction including the overall amount of rare earth elements needed for lighting solutions.

This resource-efficient approach to product design must continue to make best use of these rare earth metals, to cut carbon emission and to meet climate change challenges. Ongoing product design innovation, including the development of rare earth substitutes, addresses both material supply risks and environmental challenges.

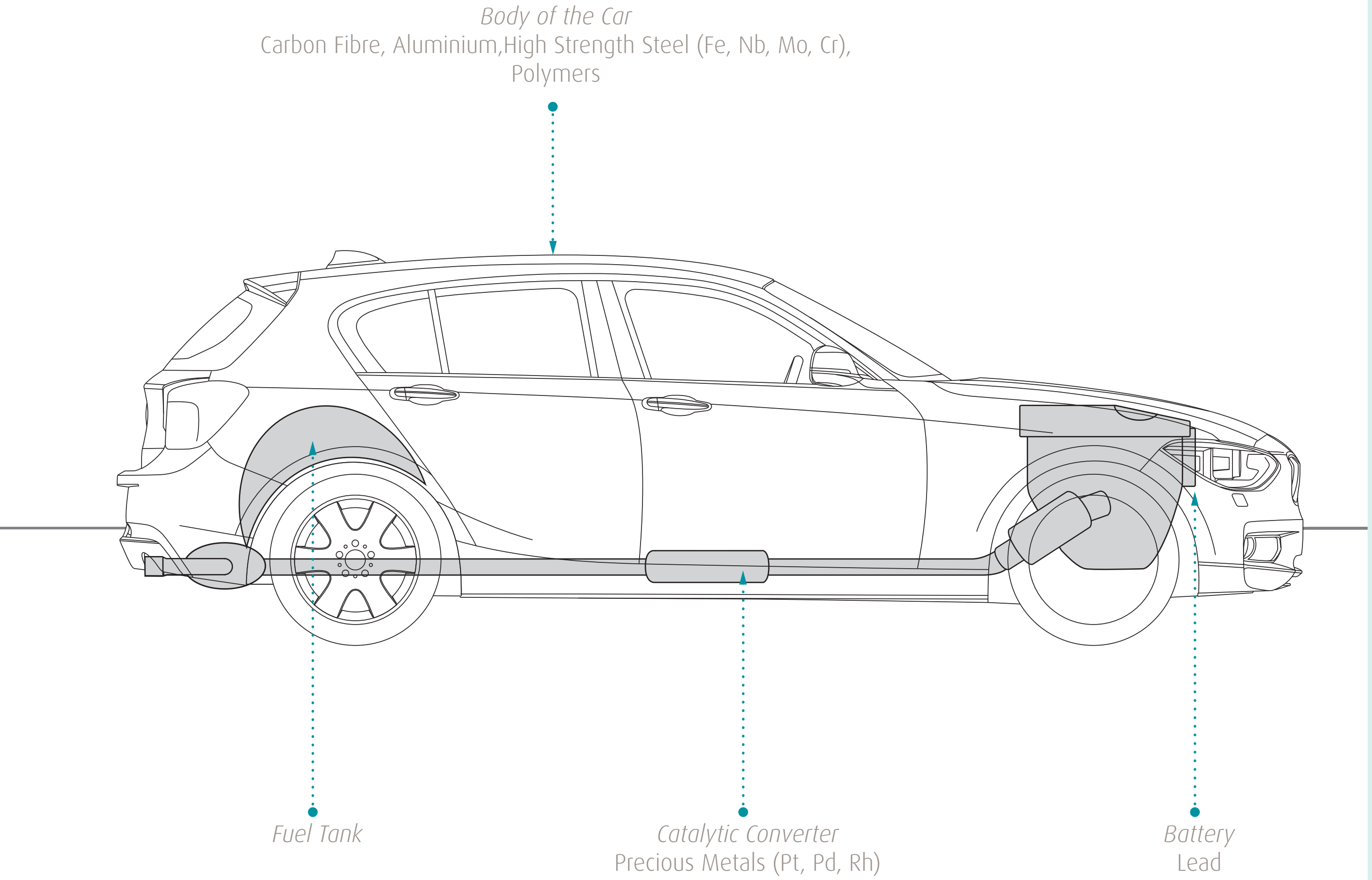
> *"The huge potential of LED lighting solutions is a good example of how concern for environmental issues like climate change drives innovation in European companies and advances exciting digital solutions to lighting control systems."*

Frans van Houten
President and CEO Royal Philips Electronics



CONVENTIONAL CAR

MATERIAL COMPOSITION



26 Fe	13 Al	78 Pt	46 Pd	45 Rh
55 845	26.982	195.08	106.42	102.91
Iron	Aluminium	Platinum	Palladium	Rhodium

The automotive industry continues to pave the way towards the decarbonisation of road transport producing more energy efficient and resource efficient vehicles.

Whether the vehicle has a conventional powertrain or is an electrified vehicle, one way to improve energy efficiency is to reduce the weight of the vehicle through its design and the use of light-weight materials. High-strength steel is used to improve crash protection of the vehicle while at the same time lower the weight. Other materials such as aluminium can be used, for example, for body panels, engine blocks, roofs and wheels and high-performance plastics for body panels and fuel tanks. Carbon fibre material is another key technology for weight reduction in body panels for all vehicles, but especially for electrified vehicles to increase the expected range. There is always an optimisation to be made between cost, performance, and recyclability.

There are differences in some of the critical raw materials used in conventional powertrain vehicles compared to the newer hybrid and electric vehicles. For example, catalytic converters have been used on conventional powertrains for a long time to reduce emissions. Catalytic converters require the use of precious metals such as platinum, palladium and rhodium which act as catalysts. These elements chemically convert the hot exhaust gases as they pass through the system nearly eliminating the concentrations of carbon monoxide and nitrogen oxides. Continuous research and innovation has substantially improved the performance of the catalysts while at the same time significantly reducing the amount of the precious metals needed.

Electrified vehicles, whether hybrids or full electric vehicles, use a different powertrain technology requiring different materials. The obvious example is the significantly larger batteries needed

26	13	3	29	60
Fe	Al	Li	Cu	Nd
55 845	26.982	6.941	63.546	144.242
Iron	Aluminium	Lithium	Copper	Neodymium

to store the electric power and which must maintain their performance through a large number of charging cycles over the life of the vehicle. The materials used in new battery technologies such as lithium-ion have been chosen due to their high energy density and performance over time in spite of their significant cost.

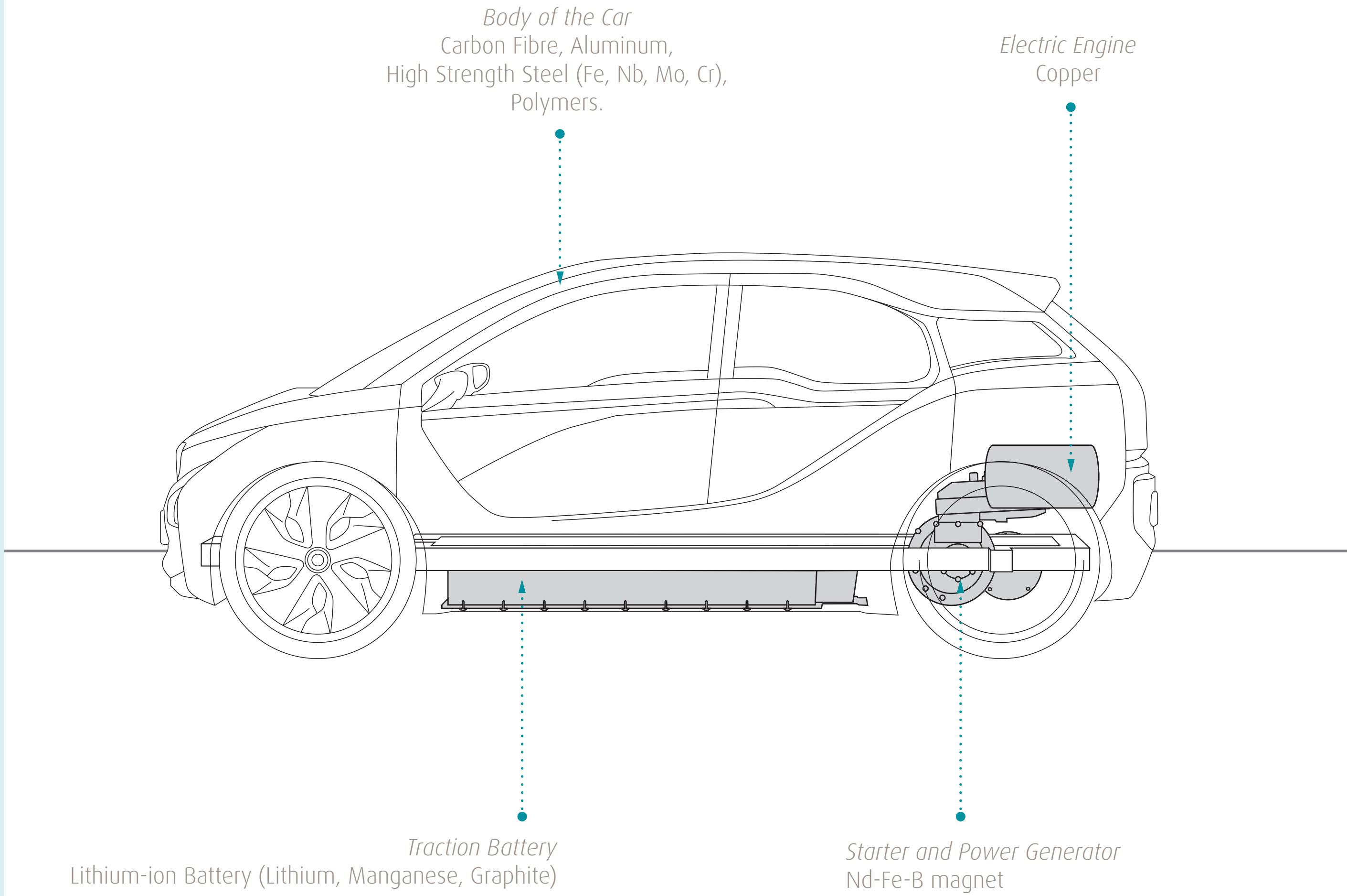
Several rare earth elements are essential for electrified vehicles. Elements such as neodymium, dysprosium and terbium are used in permanent magnets in electric motors and are critical to the performance of these components. Other rare earths such as cerium are used in catalytic converters of conventional powertrains and energy-efficient LED lights.

Copper is a metal commonly used in both conventional powertrain vehicles and electrified vehicles, but much more copper is used in electrified vehicles. The automotive industry's share of world copper demand, currently at around 6%, is likely to grow with rising market penetration of electrified powertrains.

Automotive manufacturers and their suppliers are concerned about both access to materials and significant price volatility. Additional funding for research and innovation is needed to reduce the amount of materials used and to find more reliable and cost effective substitutions.

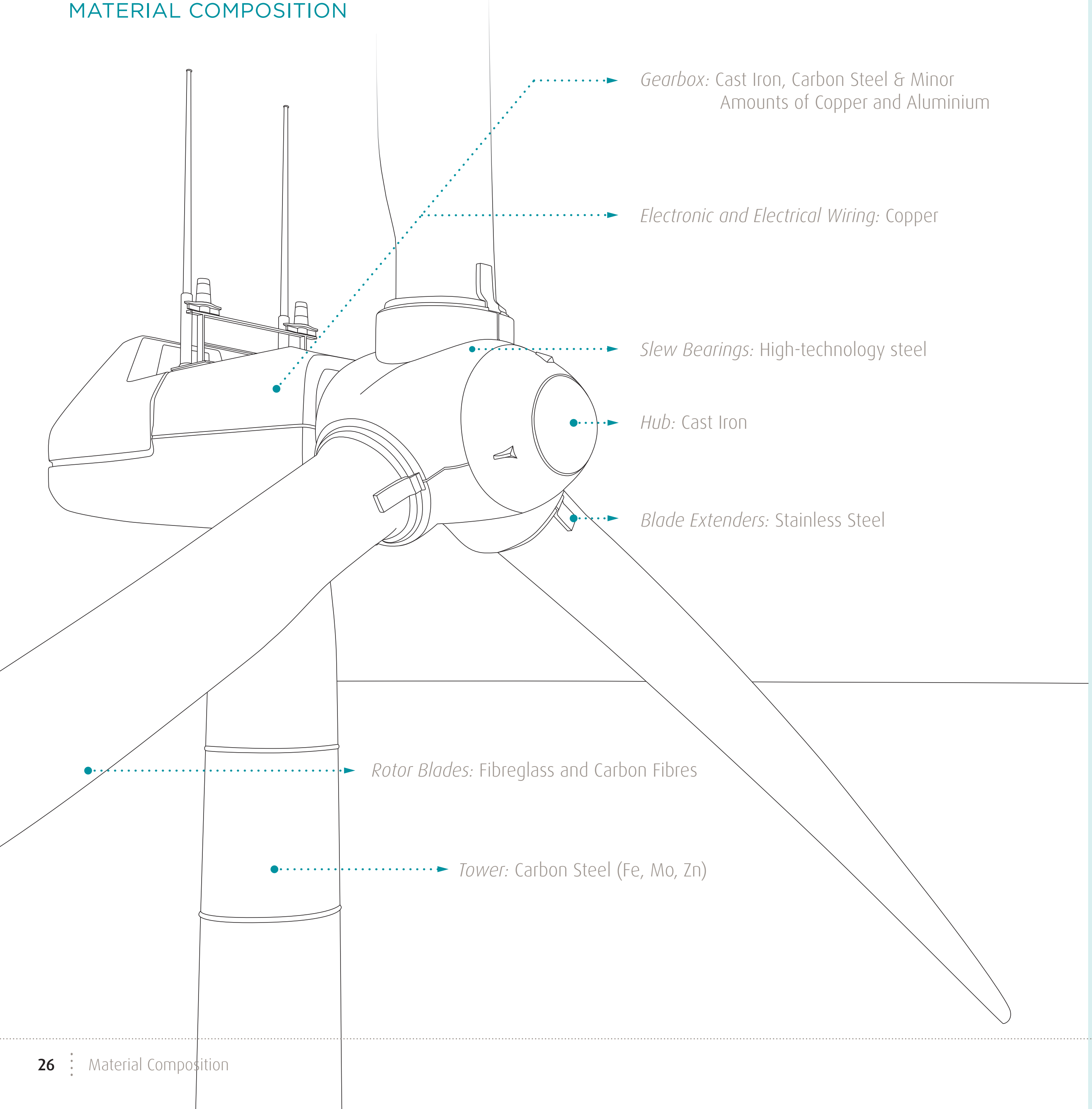
> *"For over a century, European automotive companies have been at the forefront of advancing vehicle safety, performance, and design through innovative material use. The future offers even greater opportunities as we expand our use of cutting-edge materials and develop new ways to approach existing challenges."*
>
> **Norbert Reithofer**
> Chairman of the Board of Management, BMW Group

ELECTRIC CAR
MATERIAL COMPOSITION



WIND TURBINES

MATERIAL COMPOSITION



26	13	30	42	29
Fe	**Al**	**Zn**	**Mo**	**Cu**
55 845	26.982	65.39	95.94	63.546
Iron	Aluminium	Zinc	Molybdenum	Copper

The transformation of our energy system through the expanded use of renewable energy sources including wind power is not possible without innovative metal materials. As an example, wind turbines largely depend on highly engineered steels, making it possible for the wind energy industry to meet the technical performance requirements of the turbines. This is an example of a green energy needed to address climate change that relies on a traditional industry with high-technology solutions.

Whilst the blades are often made of other materials, such as carbon fibre or fibreglass, steel holds the blades as they turn using a cast iron or forged steel rotor hub. Electrical steel is used in the machinery of the generator because it is tailored to produce the specific magnetic properties which optimally convert rotor motion into energy.

High-tech steel is used for slewing bearings and rings, which are important structural and connecting elements in wind turbines. These bearings are essential to the power control and safety of a wind turbine, in turn ensuring high performance, long-term reliability, and low maintenance and repair costs. The steel used in the tower is engineered to enhance its longevity and performance under wide-ranging weather conditions, onshore or offshore. This is achieved through the use of molybdenum to harden the steel and zinc for a corrosion-resistant coating.

In total, a single wind turbine can contain up to several hundreds of tons of steel, compared to several tons of copper and aluminium, as well as steel reinforced concrete for the base. The increasing demand for wind energy introduces a new demand on the supply chain. Furthermore, the steel used in wind turbines remains in place for a period of 30-40 years. Steel is, however, fully recyclable at the end of the service life of the application which reduces its environmental impact.

26	13	29	30	24
Fe	Al	Cu	Zn	Cr
55.845	26.982	63.546	65.39	51.996
Iron	Aluminium	Copper	Zinc	Chromium

There is a significant use of base metals in the building and construction sector as part of the ongoing trend towards greater urbanisation. These metals are a key feature of sustainable and high-performance building projects due to their technical performance in building applications, durability, and because these metals can be recycled without loss of quality.

Steel and aluminum alloys are created by adding small amounts of other metals such as copper, manganese, nickel, magnesium and zinc. They are used in building applications because they are weatherproof and corrosion-resistant and ensure optimal performance over many decades.

They can be tailor-made to specific performance criteria that are integrated into an entire systems design. They can also deliver efficiency gains for a building's overall resource and energy consumption. Their applications range from frames for high-rise buildings, roofing and cladding applications, window frames, and structural support for solar heating and cooling systems.

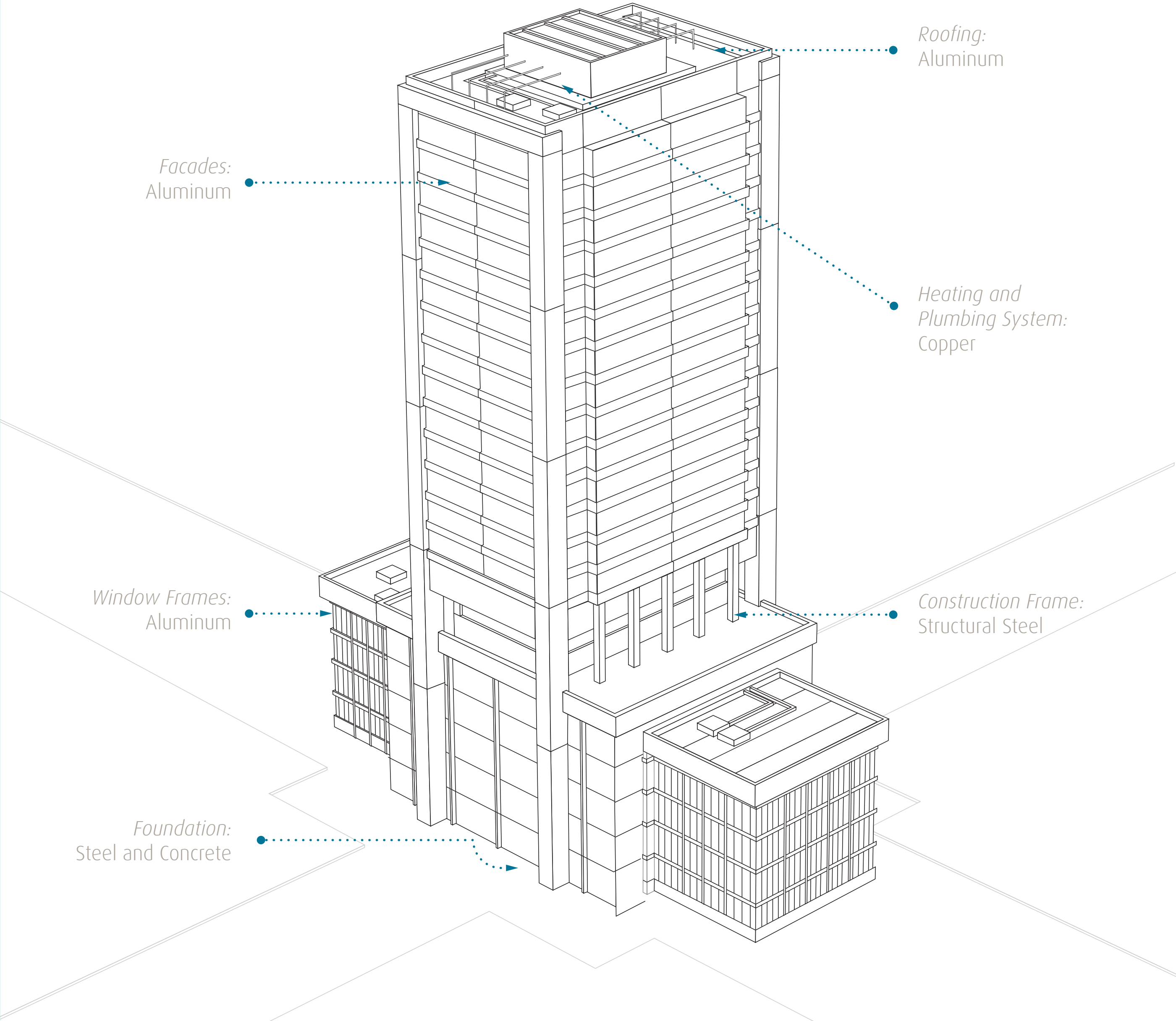
The trend towards increased urbanisation coupled with climate change challenges will lead to an increase in demand for these base metals for the construction of new more environmentally sustainable buildings. The recycling of metals used in buildings will contribute to reducing pressure on the supply.

> *"With continuous research and innovation, European base metals industries, like aluminium, provide new, high-performance solutions for the construction sector enabling Europe to reach its ambitious resource, energy and climate goals. The resource efficient future is already here today - using the capabilities of our metals together with advanced technologies, we create energy neutral buildings."*

Svein Richard Brandtzaeg
President and CEO of Norsk Hydro

COMMERCIAL BUILDING

MATERIAL COMPOSITION



Roofing:
Aluminum

Facades:
Aluminum

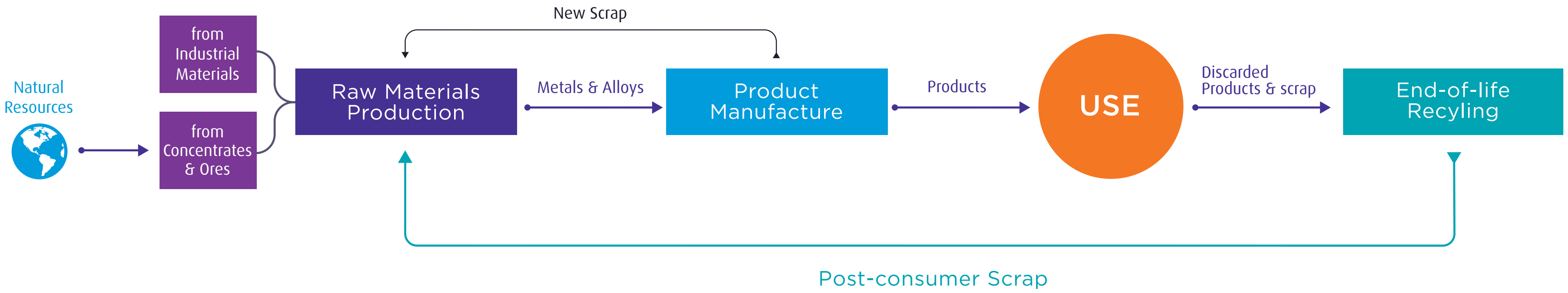
Heating and Plumbing System:
Copper

Window Frames:
Aluminum

Construction Frame:
Structural Steel

Foundation:
Steel and Concrete

RECYCLING CHALLENGES

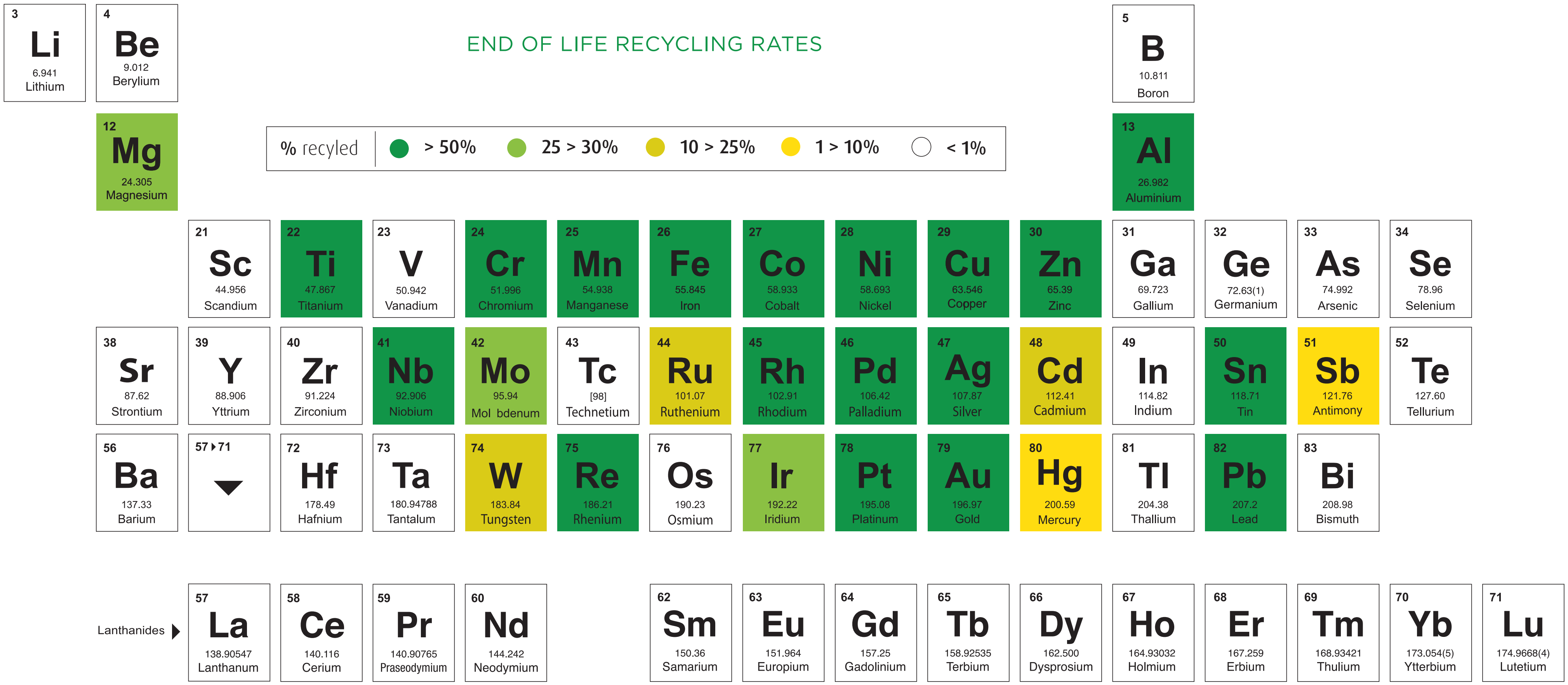


Metals have excellent properties for recycling. In principle, metals can be used over and over again, reducing the total volume needed from the mining and processing of new metals. In many cases this also leads to savings in energy and a reduction of environmental impacts.

Recycling also plays an important role in the management and mitigation of supply challenges. Even if recycling were to reach 100%, it cannot meet the entire demand for metals as global metals use continues to increase, and metals are used in products with extended lifetimes.

A product's life cycle encompasses a number of resource efficiency and recycling challenges. These range from the product design, technological and organisational set up including consumer awareness, to the technical, economic and environmental performance of a recycling operation. The biggest recycling challenges include:

- **Product design** – Choices made during the design phase have a lasting effect on the effectiveness of recycling the materials used at the end of the product life cycle. These choices include the type of materials chosen, how they will be used, how they will be joined, and the processes used in manufacturing. Leading industries are increasingly designing products for disassembly and for recycling which facilitates both the economics and technical feasibility of the recovery of metals and other materials.
- **Collection & Sorting** – A significant improvement in the collection of end-of life products is needed to maximise the re-use of already extracted metals. The cost of metal scrap collection and the net intrinsic value of the metal-bearing discarded product are determining factors in building a business case for recycling. Its biggest obstacles include high mobility of consumer products, generally low consumer awareness about the loss of these limited resources, illegal scrap exports and a lack of economic recycling incentives. Improving the overall collection rates of consumer products can be encouraged through many different initiatives ranging from increased consumer information to a variety of economic and legal incentives for returning products. These improvements would allow the recycling value chain to gain scale and would justify investments in larger, more streamlined collection facilities. This needs to be complemented with more semi-automated treatment systems to pre-sort metal materials and selected components prior to recycling.
- **Scraps recycling** – Pre-consumer scrap, which originates from the manufacturing process and is usually of high purity and value, is the easiest and economically most beneficial to recycle. Conversely, recycling of metal in end-of-life discarded consumer products often requires more effort, such as the need for a pre-treatment step because each specific metal is a small part of a complex product.
- **Recycling technology** – The practical and technical possibility to recycle and recover a metal is a basic requirement. New developments in technology are a constant challenge in the recycling industry. This involves the construction of better recycling processes, ensuring that metals are recovered efficiently, and that the re-entry on commodity markets of the end-of-life metals are ensured. Consequently, the metals of a discarded product must be separated or sorted in order to obtain recyclates that can be returned to raw material production processes. New technology is needed to create systems for economically viable recycling of minor constituent metals, particularly new technology metals, which are often a very minor part in an element-diverse and complex modern product.



STATE OF PLAY

An important parameter to measure the efficiency of an overall recycling system is the functional end-of-life (EOL) recycling rate. Only a select number of base metals, including aluminium, copper and iron have recycling and reuse rates that are above 50% at present. The reasons for this include the very long tradition of these metals in different applications with mature recycling systems, the large quantities of old and new scrap, and the well established recycling infrastructure in many countries.

The average recycling rates are also high for precious metals like gold, silver, platinum and palladium. However, this is not the case for precious metals used in electronics because of the inefficiencies along the current recycling chain, including consumer awareness. This is in spite of the high prices of these metals and the highly developed technical feasibility of recycling and recovery.

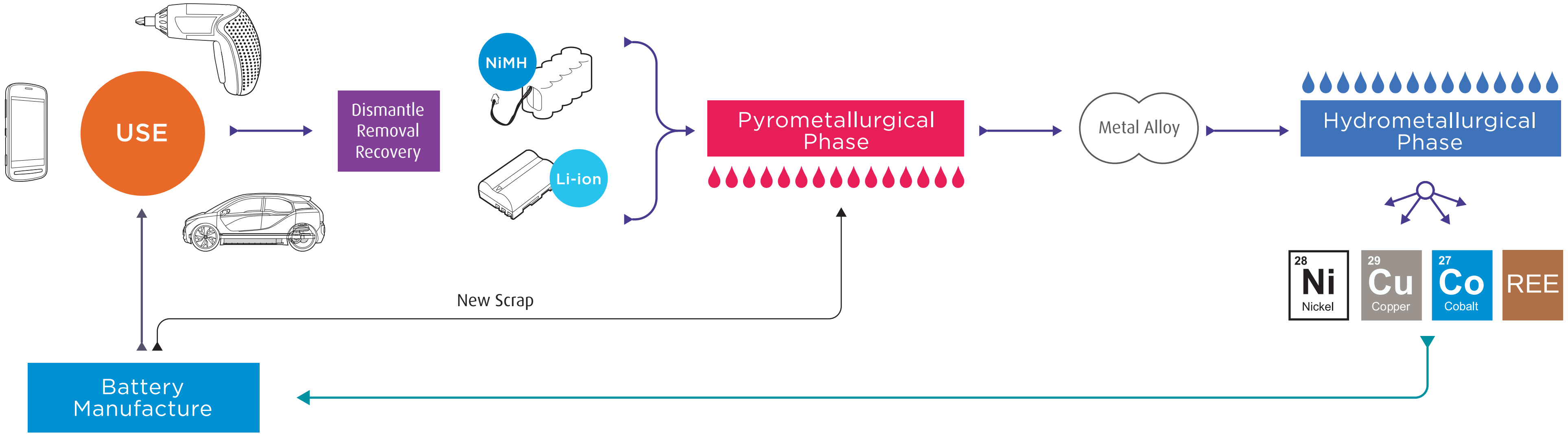
However, EOL recycling rates for many metals are very low, despite having excellent properties for recycling. This is a result of low efficiencies in the collection of most discarded metal-bearing consumer products, the lack of basic recycling infrastructure and the lack of modern recycling technologies in most countries outside of Europe. Because many primary materials are often perceived as being abundant and low-cost, the price of metal scrap is undervalued.

The EOL recycling of new technology metals is still in its infancy. These metals are used in small quantities as part of element-complex products or as a minor constituent in multi-component modern products. Their separation requires advanced and probably completely new recycling technologies and subsequent complex metallurgical processes. To date, almost no recycling infrastructure exists for these metals, requiring further research in this area.

Source: UNEP Metals Recycling Report, 2011

EXAMPLES OF RECYCLING CHALLENGES

UMICORE Case Study



A greener economy will require higher recycling rates for new technology metals including the ones used in rechargeable batteries. For example, cobalt and lithium which are key inputs in lithium-ion batteries and several rare earth elements used in nickel-metal hydride batteries.

These advanced rechargeable batteries increasingly act as key enablers for electric vehicles, large-capacity energy storage systems, cordless power tools and consumer electronics. They enhance the service life of equipment, and are optimised for product performance and designed for an efficient use of resources.

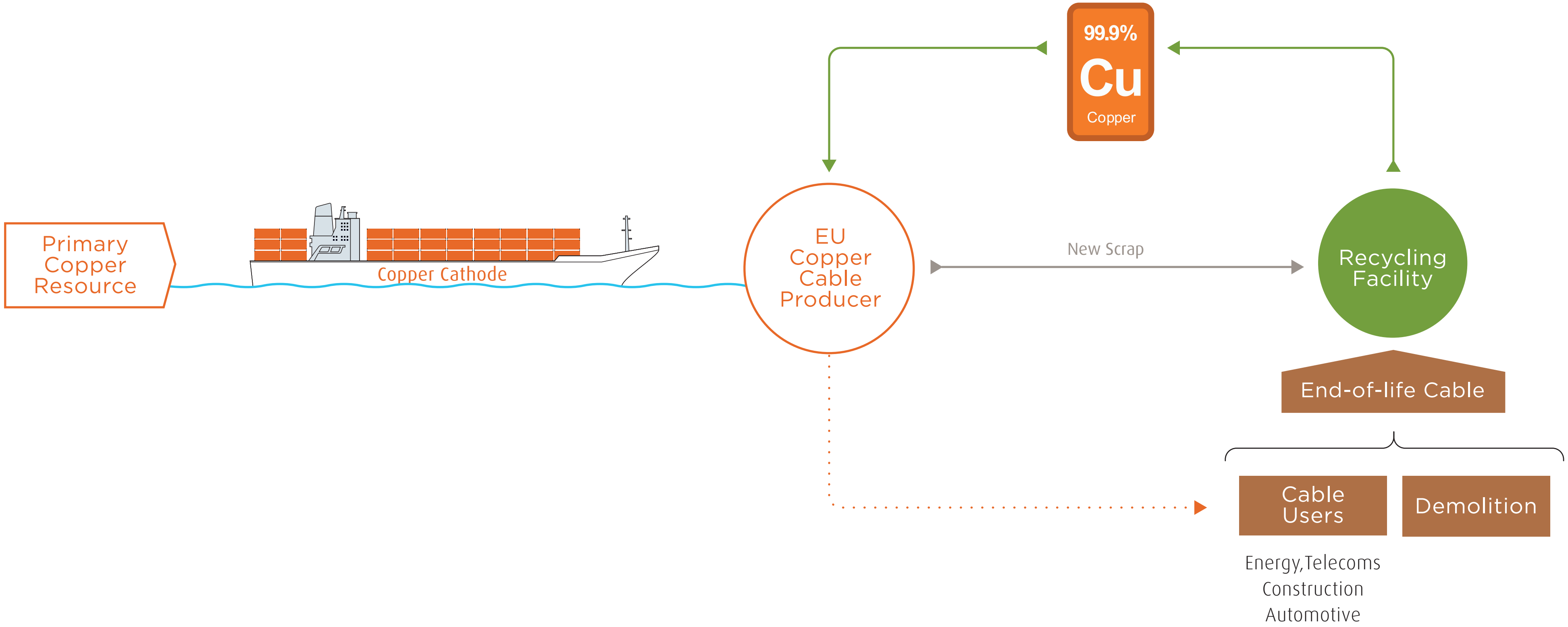
The growing increase in their applications has made recycling more important, especially in light of the wish to minimise constraints on their cost-effective supply to European manufacturers.

Advanced recycling technologies already allow processing of all types of advanced rechargeable batteries from single cell batteries for mobile phones to the battery packs of electric vehicles. Consequently, metals such as cobalt, nickel, copper and rare earth elements can be recovered and transformed into new battery materials or materials for other applications.

However, the collection of small, spent, rechargeable batteries in consumer products at end of life remains the primary bottleneck. It is estimated that only between 5 and 10 % of advanced rechargeable consumer batteries are collected and recycled. The rest are hoarded at home or are leaked out of the EU with illegal exports of electronic waste. This amounts to around 10,000 tonnes of valuable material that should be made available for collection in the EU recycling industry.

> *"Recycling will play an increasingly critical role in reducing pressure on sourcing new raw materials. Europe's technology leadership needs to be supported by more efficient collection and sound enforcement of existing legislation."*
>
> **Thomas Leysen**
> Chairman Umicore

GDF SUEZ Case Study



Copper is widely used for the production of electrical cables and wires used in the building and transportation sector, the circuitry of electronic equipment, and power cables for energy and telecom networks. Consequently, copper is an important contributor to both developed and developing economies.

Rapid growth in emerging markets, as well as the transformation of economies around the world, has led to a vast increase in the global demand for copper. One of the results is that the amount of copper to be found in post-consumer waste is expected to grow significantly. The expected high prices for copper will be a key driver behind further exploration, extraction from previously unprofitable sources, increased resource efficient product design, and the reuse and recycling of copper-containing products.

The urban mining of copper has already become a relevant solution for European companies that seek to secure a continuous supply of copper at an affordable price in addition to reducing their environmental footprint. As an example, European manufacturing and recycling companies are working together on the recovery of copper cable by-products and end-of-life copper cables to produce recycled copper. These tailor-made recycling processes ensure a fit-for-purpose, high-quality output at a purity of 99.9% of primary copper. This ensures that copper already extracted and refined stays in use, saves energy and creates new jobs in Europe.

"By working together with our partners in the European manufacturing sector, we have fundamentally transformed the services offered by the waste management and recycling sector. Through collaboration with our customers, we identify resource efficiency savings which are then locked in so that the customer can reap the benefits. Building long-term partnerships is critical to develop a common understanding of the manufacturing and recycling challenges, as well as a basis for sound investment decisions in a larger value chain perspective."

Gérard Mestrallet
Chairman and CEO GDF Suez
Chairman of the Board of Directors SUEZ ENVIRONMENT

FINANCIAL MARKETS

Metal exchanges bring together investors, metal producers, refiners and recyclers, and manufacturers who consume metals. They provide a platform for buyers and sellers worldwide to trade metals, to determine market prices and to allow metal producers and manufacturers to insure themselves against adverse price movements.

To date, metal exchanges predominantly trade base metals including aluminium, copper, tin, zinc, and lead as well as steel. In recent years, this has been extended to a select number of widely used technology metals including cobalt and molybdenum. However, the volumes of the few technology metals traded remains very small in comparison to base metals. Precious metals, including gold, silver, palladium and platinum are traded on specialised exchanges.

Metal exchanges are supported by international storage facilities which provide producers and consumers of metals with a physical market of last resort. Metal producers can sell excess stock in times of oversupply, whereas manufactures can use the exchanges as a source of material in times of extreme shortage. These metals must meet strict quality, shape and weight requirements before being approved for storage and subsequent trade on the metal exchange.

However, physical delivery only occurs in a minority of cases as most organisations use metal exchanges strictly to hedge against the risk of rising and falling world metal prices. Manufactures dependent on metals can attempt to reduce the risk of the metals becoming more or less expensive. Producers and refiners can insure themselves against the risk of falling or rising metal prices. And investors provide market liquidity in the hope of gaining a profit on the changes in the market.

The risk of price fluctuation between conclusion of a contract and physical delivery is usually managed through a futures or options contract. A metal futures contract is an agreement between a manufacturer or metal producer and a financial investor to buy or sell at a fixed price on a set date in the future. A metal options contract gives the right, but not the obligation, to buy or sell at a fixed price on a set date at a higher cost premium.

In the industrial metals market, metal exchanges do not only allow for price risk management but also act as a platform for price discovery. The prices determined in metal exchanges are used as a global benchmark for all metal prices used across the value chain. These prices are of essential importance for extraction companies, refiners, recycling companies and manufactures when negotiation physical contracts. These contracts will be concluded at a discount of the spot price, when the metal is of a lower grade than the respective metal exchange brand, or at premium for more processed or high-quality metal products.

The price discovery mechanism is also used for the valuation of portfolios of Metal Prices Index Funds and Metal Exchange Trade Funds (ETFs), which are traded on regular exchanges. These funds seek both to reflect the fluctuations of the spot and futures prices of the underlying metals. ETFs can also target the stock shares of companies that are involved in the mining, exploration or distribution of the metals. As a result, investors gain easier access to the benefits of industrial and precious metals markets without having to enter directly into the futures market.

Financial investment flows into the metals futures markets have grown significantly in recent years making metals increasingly more of an asset class. However, these financial flows need to take place in a regulated and transparent manner in order to avoid distorting the price discovery mechanism, which is essential to both financial and physical markets. An increase in the vertical integration of certain financial investors in the upstream production and refining assets risks to distort the transparency of the markets without proper and updated regulatory oversight.

PRICE RISK MANAGEMENT

1. Physical Purchase Contract

SELLER

Copper Producer

100
TONNES
COPPER
ON
1ST JAN
AT
MARKET PRICE

BUYER

Auto Manufacturer

Problem for Copper Buyer

=

Price Volatility on Market Price

(The uncertainty of the price at a fixed date in the future)

2. Futures Contract

THE INSURED

Auto Manufacturer

100
TONNES
COPPER
ON
1ST JAN
AT
FIXED PRICE

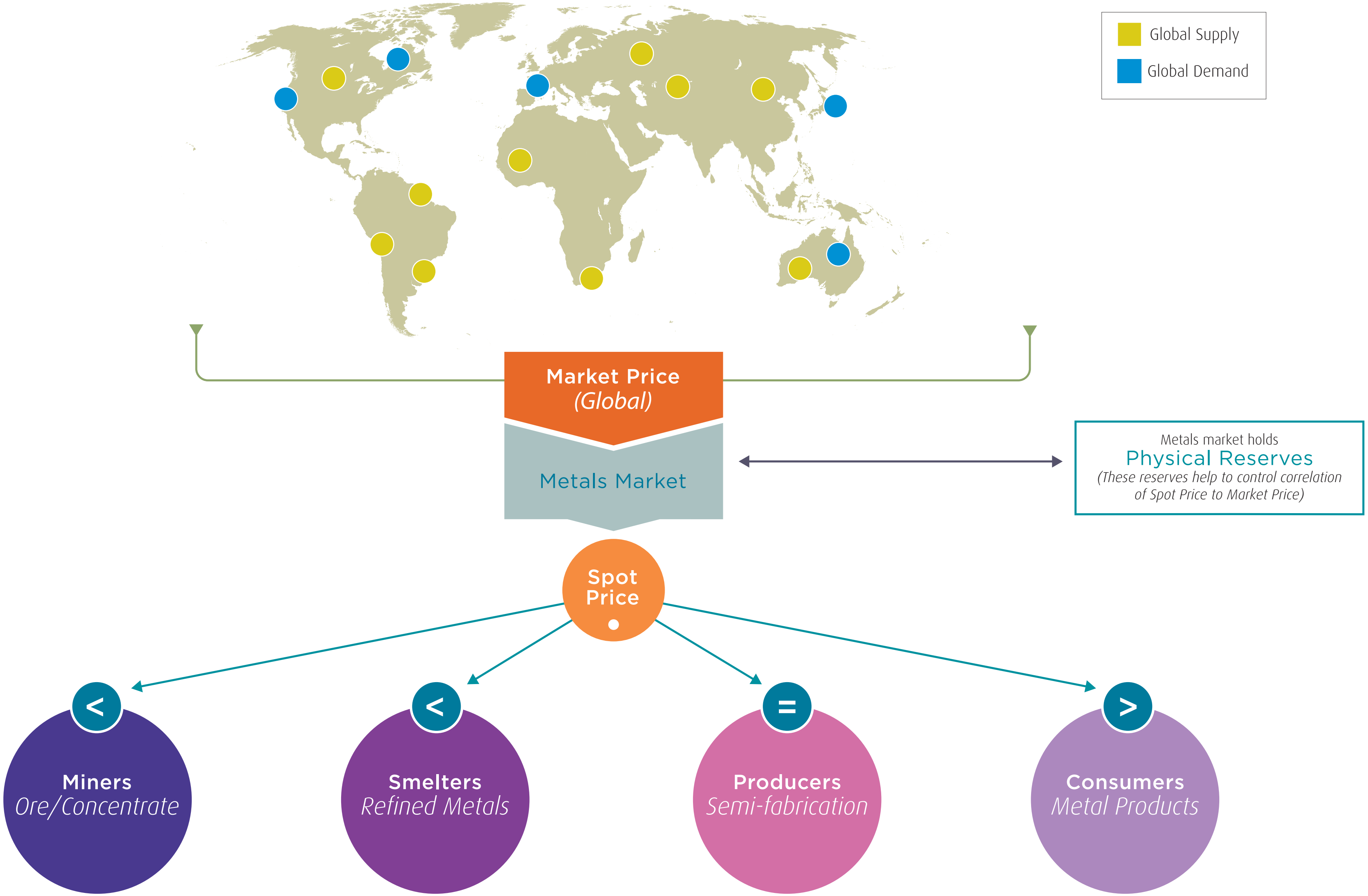
THE INVESTOR

Metal Market Facilitates Contract

3. Result

On January 1st the buyer pays for and receives 100 tonnes of copper at the market price on that date. The futures contract is settled as a financial transaction. If the price of copper has increased then the buyer benefits from the price increase. This benefit offsets the extra he has had to pay for the physical copper he ordered for manufacturing purposes.

PRICE DISCOVERY METALS



🟨 Global Supply

🟦 Global Demand

Market Price
(Global)

Metals Market

Metals market holds
Physical Reserves
(These reserves help to control correlation of Spot Price to Market Price)

Spot Price

Miners
Ore/Concentrate

Smelters
Refined Metals

Producers
Semi-fabrication

Consumers
Metal Products

All stages of the supply chain use the Spot Price from the metal markets as a trusted reference price

PHYSICAL MARKETS

Although financial markets can provide a physical market of last resort for most base and precious metals, as well as for a select number of new technology metals, most metals are sold directly under contract between producers, refiners, recyclers and manufacturers.

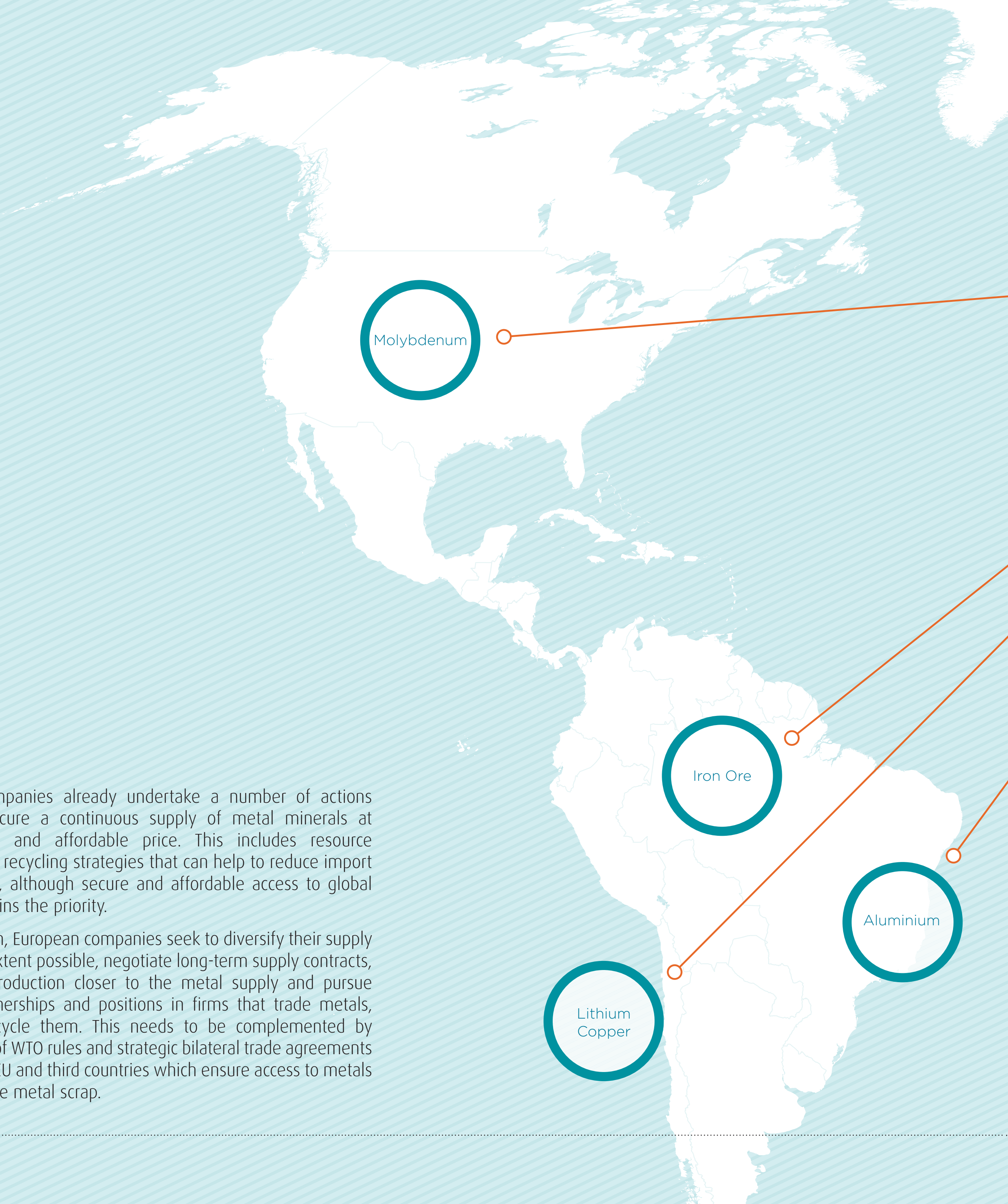
However, the majority of technology metals including rare earth elements can only be accessed on the basis of a physical contract. As a result, the market for these metals is less transparent and the volumes traded are smaller in comparison to exchange-traded metals. The market for non-exchange-traded metals is also less impacted by financial investors, and as a result, less volatile due to speculation.

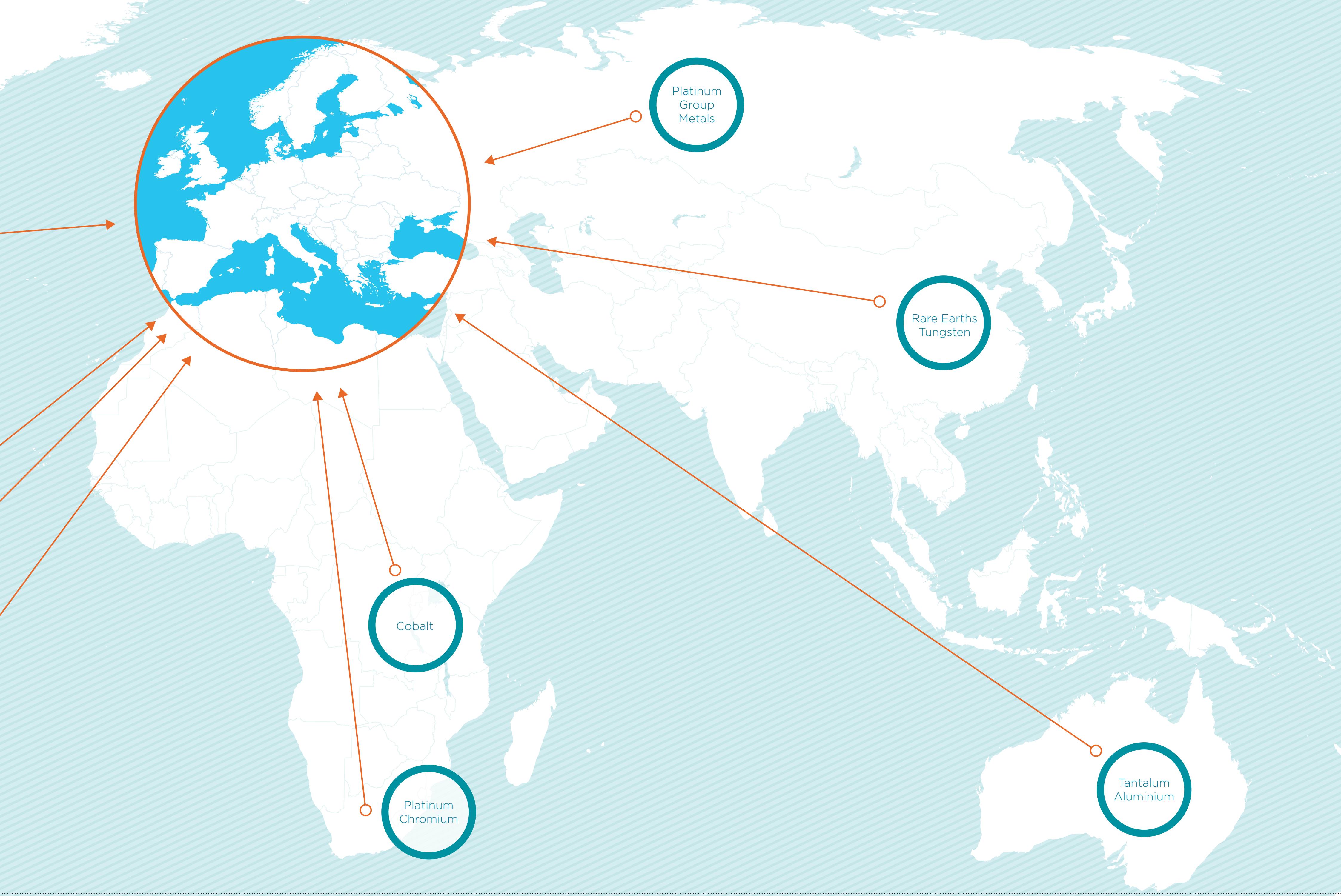
At the same time, the supply of these metals is often highly concentrated in a select number of countries, controlled by a select number of metal producing companies, and increasingly affected by growing demand pressure from both emerging economies and global markets.

Europe is in a particularly vulnerable position as it remains highly dependent on imports of many metal minerals. An increasing number of national policy measures taken by resource rich countries, including export taxes, disrupt the normal operation of global markets for technology metals and rare earth elements. This puts European companies at a competitive disadvantage as many high-technology products, new green technologies and the associated value-added jobs in Europe require these metals.

European companies already undertake a number of actions aiming to secure a continuous supply of metal minerals at a predictable and affordable price. This includes resource efficiency and recycling strategies that can help to reduce import dependencies, although secure and affordable access to global markets remains the priority.

For that reason, European companies seek to diversify their supply chain to the extent possible, negotiate long-term supply contracts, move their production closer to the metal supply and pursue strategic partnerships and positions in firms that trade metals, extract or recycle them. This needs to be complemented by enforcement of WTO rules and strategic bilateral trade agreements between the EU and third countries which ensure access to metals and to valuable metal scrap.




Platinum Group Metals
Rare Earths Tungsten
Cobalt
Platinum Chromium
Tantalum Aluminium

ACKNOWLEDGEMENTS & SOURCES

This report has greatly benefited from a number of public sources listed below as well as contributions, technical expertise and review from ThyssenKrupp, Umicore, Norsk Hydro, Nokia, Royal Philips Electronics, GDF SUEZ , Siemens and the BMW Group.

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UNEP, Metals Stocks in Society, 2010

UNCTAD Statistical Database

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Electronics Industry Citizenship Coalition, *www.eicc.info*

Global Sustainability Initiative, *www.gesi.org*

European Commission, Report on Data Needs for Full Raw Materials Flow Analysis, 2012

European Commission, Critical Raw materials for the EU, 2012

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