



Providing metals and minerals
for carbon neutrality

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The mineral raw materials industry has radically progressed in productivity and energy efficiency and is still implementing new solutions aiming at further reducing the energy consumption/unit and improving carbon-intensive operations.

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Executive summary

The mineral raw materials industry and its raw materials are an integral part of any economy and society. Standing at the beginning of most value chains, the sector is a critical supplier of essential materials and products and therefore generates added value and growth through employment, economic growth, development, innovation and generating trade. To continue economic growth and demographic change as a modern society, extraction of commodities will remain essential.

Raw materials are indispensable enablers for carbon-neutral solutions in all sectors of the economy. Given the scale of fast growing material demand, primary raw materials will continue to provide a large part of the demand. (A Clean Planet for All, European Commission, November 2018).



In past years the mineral raw materials industry has radically progressed in productivity and energy efficiency and is still implementing new solutions aiming at further reducing the energy consumption/unit and improving carbon-intensive operations. As the world shifts to a low-carbon future, mining companies explore methods of decarbonisation in order to efficiently and effectively fulfil the continued increasing demand for resources.

Whilst globally and in Europe the forecasted energy demand is going to increase, the CO₂ emissions for Europe are forecasted to be reduced. However, it should be noted that for industrial supply chains, the overall energy/electricity input will have to rise.

The energy demand related to the access to raw materials and its higher quality products will rise due to four main factors:

- **deeper ore bodies which will require more energy to access and extract,**
- **lower grades of ore bodies which will require more processing,**
- **the full electrification of operations due to automation and digitalisation in order to reduce carbon footprint in comparison to the use of fossil fuels for haulage and transport and in order to reduce exposure of workers to fossil fuel related gases,**
- **the creation of higher value and refined products through transformation with higher energy input,**
- **new technologies to further reduce waste and waste water will require more energy.**

The global population is forecast to reach 9 billion by 2030, including 3 billion new middle-class consumers. This places unprecedented pressure on natural resources to meet future consumer demands. To meet the challenges caused by an increased, continuous demand for sustainably sourced raw materials, a shift towards more resource efficient production, increased recovery and reprocessing along the circular economy and sustainable development objectives is becoming more crucial than ever.

In November 2018 the European Commission - based on the Paris Agreement in 2016 - adopted a strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050 – A Clean Planet for all. This decarbonisation strategy shows how Europe may possibly lead the way to climate neutrality by investing into

realistic technological solutions, empowering citizens and aligning action in key areas such as industrial policy, finance or research – while ensuring social fairness for a just transition. The document covers nearly all EU policies and tries to align them with the Paris Agreement objective to keep temperature increase to well below 2°C and pursue efforts to keep it to 1.5°C. According to the Commission, the EU to lead the world towards climate neutrality means achieving it by 2050. However, many EU Member States will have to rely on fossil fuels such as hard coal, lignite and gas as well as imported hard coal and gas till 2040 resp. 2050.

The Commission's strategy clearly mentions the need to continue exploration and extraction in Europe. "Establishing European raw material sources: R&I is needed to map and explore available raw material resources in Europe and other world regions. To ensure sustainability while exploring new resources, development of efficient measurement criteria for assessing the environmental and societal impacts of mining activities could facilitate this process by accelerating the permission process essential for opening new mines. Outside the scope of R&I, EU diplomacy is an important aspect in securing the supply of raw materials."

The mining and metals sector play a critical role in underpinning global economic growth. The development of mineral resources is a pillar of many national economies, both in terms of contribution to gross domestic product and tax revenues, and also as an industry that directly employs millions of workers. The closely connected upstream supply sector of the mining and metals industry, which provides construction services, manufacturing, wholesale and retail trade, as well as technical, scientific and professional services, provides further employment and delivers significant additional economic benefit. The extraction and processing of minerals and metals has brought huge benefits to society, also by providing long-lasting infrastructure. These vital commodities are used to construct communication and transportation networks, consumer electronics, vehicles, buildings, and many other items that serve as a foundation for society's material quality of life. In particular metals form the basis for the energy transition as well as the decarbonisation process.

This document aims to contribute to the international and European collaborative effort among all stakeholders, and to be a source of inspiration for international and national policy makers to support decisions and regulations concerning the sustainable transition of the mineral raw materials industry. The objective of the publication is to demonstrate the technology solutions that the mineral raw materials industry implements to reduce greenhouse gas footprint.





Reducing the carbon footprint – towards carbon neutrality in the extraction of metals and minerals

As vital as this sector is for the European economy because it provides the base load for many metals and minerals for the EU downstream industries, its overall contribution in CO₂ on the scale of things is not enormous. On average 40% of metals are produced in the EU, in most industrial minerals and aggregates the EU is self-sufficient and in some cases even exports.

Definition of carbon neutrality Carbon neutrality, or having a net zero carbon footprint, refers to achieving net zero carbon emissions by balancing a measured amount of carbon released with an equivalent amount sequestered or offset, or buying enough carbon credits to make up the difference. It is used in the context of carbon dioxide releasing processes associated with transportation, energy production, and industrial processes such as production of carbon neutral fuel.

Whilst the mineral raw materials industry has been reducing and will continue to be able to reduce its CO₂ emissions from energy use, the removal of carbon dioxide from its processing emissions will not be possible due to the chemical compositions of some minerals and ores which release CO₂ during processing. For those emissions, only carbon capture and storage or utilisation will therefore be a solution for maintaining these resources in the economic cycles where they contribute considerably to a number of the objectives of the Circular Economy.

Amongst the 42 different metals and minerals being extracted and processed in the EU, the share of direct and indirect emissions intensity can vary considerably, for example for non-ferrous metals on average 130 kgCO₂/ton (direct) to 810 kgCO₂/ton (indirect). -15% direct and 85% indirect.

For an industrial mineral like magnesia, for example, the situation is very different: 1400 kg CO₂/ton (direct) to 96 kg CO₂/ton (indirect)¹ – 95% direct and 5% indirect. In addition to the big differences between direct and indirect emissions it is also important to consider the high contribution of the unavoidable process CO₂, which can exceed 60% of the total direct emissions in some sectors like magnesia.

It therefore becomes clear that the measures to be taken can and must vary considerably and will include a whole range of adapted measures. Existing operations and new operations have different options due to the technical conditions of existing mine working and future planning of new ones. Mines and quarries have long investment cycles and these need to be taken into account and will define the time scales on a site by site basis.

However, the following chapters will explain the various measures that have been taken in the past and are in the process of being taken for the coming years.

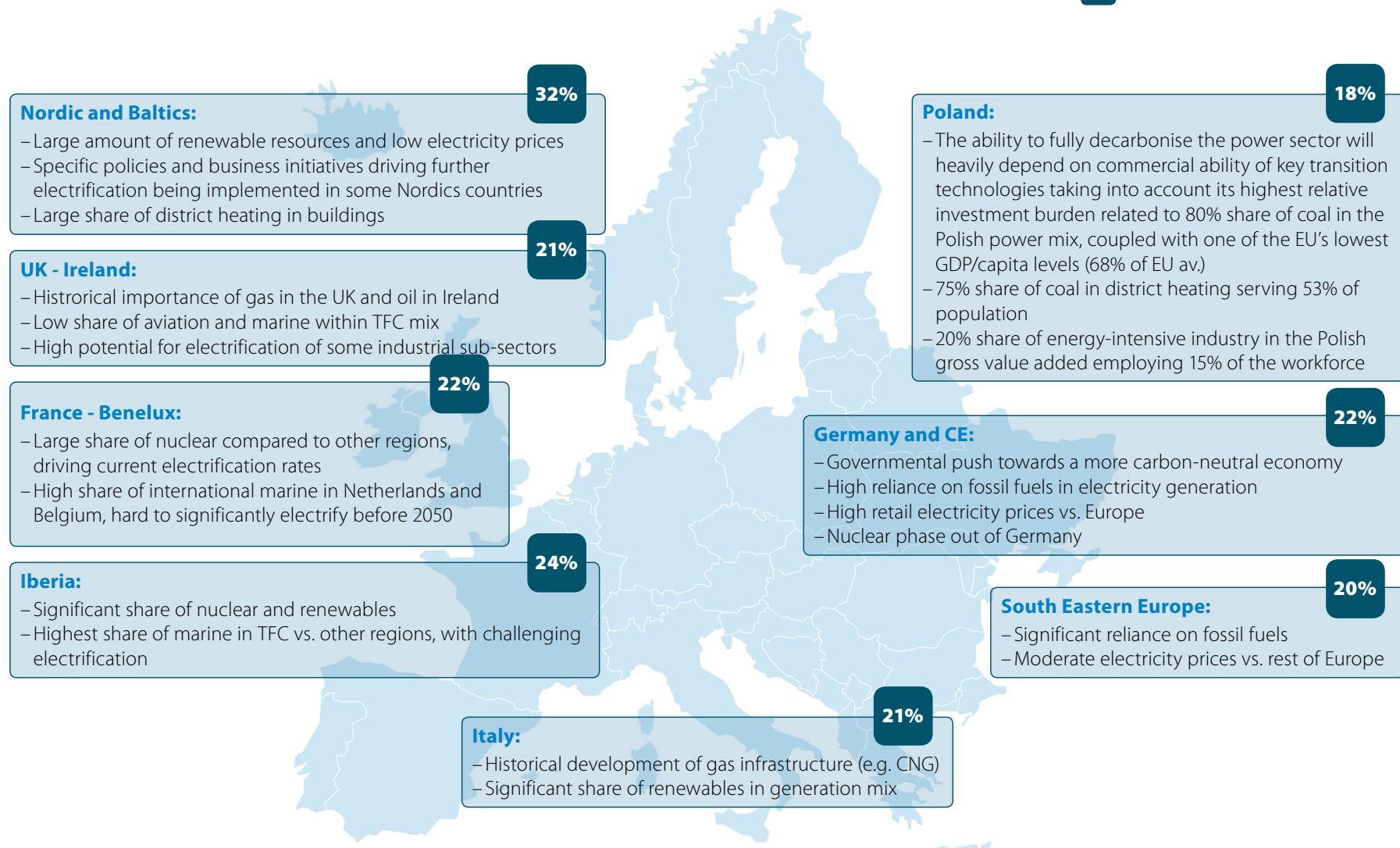
1.1 Switching to lower-carbon electricity

Most mines and quarries in the EU are dependent on the national grid for their electricity supply. This also means that their accounts of indirect CO₂ emissions depend largely on the company and entrepreneurial decisions of their suppliers, and since these are passing on the costs, this can have considerable impact on the mining industry's competitiveness.

¹ Source Ecofys, Towards competitive carbon and graphite and mining sectors in Europe, 2015.

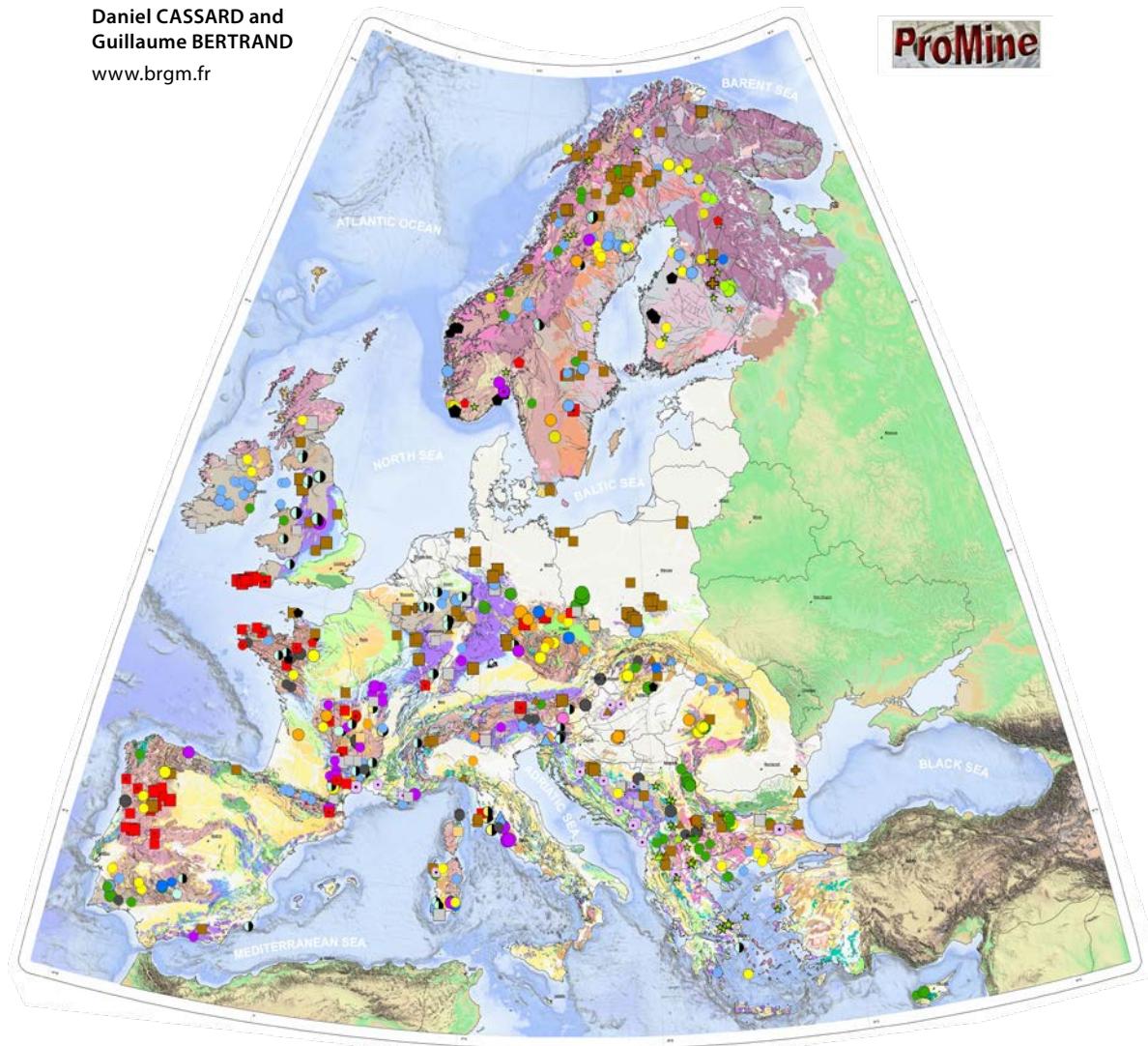
Different starting positions in the energy transition

 2015 baseline - direct electrification rate



Main Mineral Deposits of Europe

Scientific coordination
Daniel CASSARD and
Guillaume BERTRAND
www.brgm.fr



Source: Promine Project (2012)

Looking at the distribution of EU operations and deposits, it becomes clear that the carbon footprint of the mineral raw materials industry from any European mine will be impacted across Europe by any of the following changes:

- Any improvements in efficiency of existing power supply in current grids,
- Reduction on transmission losses,
- Future changes in the grid mix to low-carbon fuels,

At the heart of recent innovations in corporate mining energy strategies lie the construction and acquisition of renewable energy-generating assets, on- and off-site, and the direct contracting for renewable energy through power purchase agreements. Some companies have already opted for investing in their own alternative electricity generation and supply². Lundin Mining for example for its Zinkgruvan site has pro-actively switched to a 100% renewable energy source for its electricity supply, supported contractually by Guarantees of Origin³.

Example: Zinkgruvan, Sweden

In 2017, Zinkgruvan pro-actively switched to a 100% renewable energy source for its electricity supply, supported contractually by Guarantees of Origin.

Energy Mix 2017

Wind	100 %
Total Non-Renewable	0 %
Total Renewable	100 %

However, many EU Member States will have to rely on fossil fuels such as hard coal, lignite and gas as well as imported hard coal and gas till 2040 resp. 2050. Switching to lower-carbon electricity however strongly depends on adequate, national incentives and measures to increase the use of renewal energy.

2 Navigant Consulting, Inc: Renewable energy investment in the mining industry (base case, US\$m), world markets: 2013 and "Renewable Energy for the Mining Industry Revenue by Technology, Aggressive Investment Scenario, World Markets"

3 Source: Sustainability Report 2017, Lundin Mining https://lundinmining.com/site/assets/files/7311/lmc_csr2017_v10.pdf

1.2 Electrification – Powerful tool for decarbonisation

Energy costs already represent a significant part, 14% to 25%, of the operating costs of European mines, and as mines are beginning to extend to depths beyond current norms, their energy demand is growing even larger. Adding to these costs are the surplus costs due to ETS CO₂ costs and eventually tax regulations and the expected drastic change in status quo of underground mine ventilation upon recognition of diesel particulates as carcinogenic gases. With ever-growing environmental and health concerns associated with diesel consumption, the mining industry is actively seeking alternative energy solutions.

The first challenge arises from the fact that the majority of these operations rely on fossil fuels for material handling and heating, but mainly use electricity for hoisting, ventilation and mineral processing. This fossil fuel dependency is even greater in remote mining operations where reliance on diesel power dominates. To dilute and carry away diesel equipment exhaust gases, underground mines must be continuously ventilated with considerable amounts of fresh air; a typical underground metal mine is ventilated by 500 to 1,000 cubic meters per second of fresh air, depending on the ambient and operational conditions.

Switching to non-fossil fuels

The mineral raw materials industry depends to a high degree on fossil fuels when it comes to the actual extraction process and beneficiation process and the haulage of ores from underground mines to the surface or from the open pits to the processing plants, as well as of its product to the customer in the form of bulk haulage. For some mineral processing, the consumption of fossil fuel for the production of thermal energy is necessary. In this case energy efficiency measures and future research into alternatives are the solution. In other areas replacement of fossil-fuel-driven vehicles of all kinds wherever possible is therefore key in the context of CO₂ reduction, but also for achieving higher health and safety standards.

Therefore these processing and transportation steps are being scrutinised for increasing the electrification levels. Large European mines such as Boliden, K + S and KGHM Polska Miedz for example have to look at gradually replacing up to 1,000 vehicles, each of different size and functionality. Today such machinery is not available for all functions and in sufficient numbers. In addition, some of these machines are expensive and have a standard life time of up to 15 years with long investment cycles. Electric underground mining

fleets are still under development, however, their prospective economic, environmental and health benefits are promising.

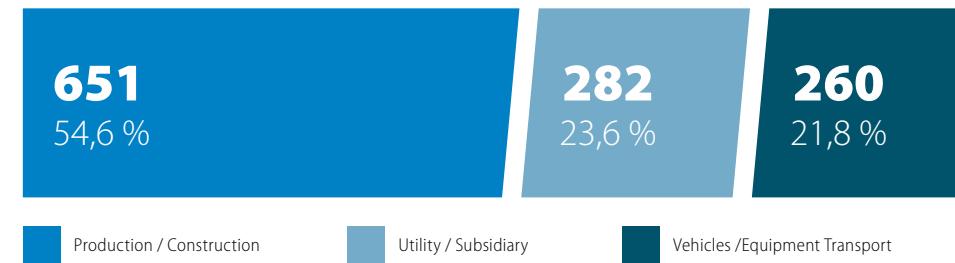
The market forecast for electric vehicles in mining shows that by 2028, it is expected that there would be over 30,000 units of electric vehicles (hybrid and pure electric) in global mining operations, with a market value of \$9 billion⁴.

Hence in the interim upgrading and refitting options are looked into.

Decoupling mines from diesel is not an easy task, mainly due to the diverse range of technical and financial challenges in mining various deposits which make a "one-size-fits-all" solution hard to find. For a number of the existing mines replacement by electric vehicles is not possible due to the lay-out and conditions of the mines. These are looking at other options.

Mobile machines underground in KGHM Mines in Poland as at 31. 12. 2015

Number of mobile machines (Total: 1193)



The cost versus benefits of phasing out diesel in a mine is heavily dependent on the characteristics of its operation. The electrification of mining equipment should result in reduced ventilation requirements (30–50% less) for gases and heat and reduced maintenance costs (some 25% fewer parts on EV propulsion vs. diesel propulsion rigs). However, in combination with the increasing depth of the ore deposits, the overall consumption of electricity consumption will increase.



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Whilst the mineral raw materials industry has been reducing and will continue to be able to reduce its CO₂ emissions from energy use, the removal of carbon dioxide from its processing emissions will not be possible due to the chemical compositions of some minerals and ores which release CO₂ during processing.

For an industrial mineral like magnesia only carbon capture and storage or utilisation will be a solution. Photo©RHI Magnesite

In Sweden it is intended to electrify the internal transportation, transport lines and machinery in mines. Increased electrification can be achieved by investments in battery technology, electric mine trucks, electric trolley lines and electric transport routes. In Sweden it is expected that electrification of machines and internal transports will require 0,2–0,3 TWh (corresponding to current production levels).

In light of additional demands the overall consumption is expected to result in an increased electricity demand of 0,3–0,5 TWh which is at the same level as current production levels in Sweden.

In Finland it is expected that, due to electrification, energy use will increase from 225 GWh/annum to 270 GWh/annum.

An increased demand for automated underground machinery with the possible implementation of tele-remote equipment operation, machine guidance and equipment automation is observed.

Zinkgruvan Mining (SE) is currently looking into the possibilities to replace the diesel driven lift tables with electric driven ones. The replacement of diesel driven company cars to

- Plug-In-Hybrid (electric and petrol driven) cars ,
- Future proposal to have 100% electric driven cars (all with an alcohol interlock).

However, the possibilities depend also on access to sufficient, reliable, competitive electricity:

1. For grid-connected mines: with access to additional grid capacity, it is conceivable to use electric-powered load, haul, dump machineries (LHDs) or electric haul trucks instead of heavy diesel equipment.
2. For off-grid mines: though replacing a diesel fleet with electric equipment will eliminate the diesel emissions in mine workings, it might not help with net carbon emissions or energy costs. That is because the electric power source is likely still to be fossil-based. An alternative solution can be sought in hybridizing a mine power system by integrating renewable energies into it. Worldwide, so far, concerns over load intermittency and cost of storage have kept the penetration rate of renewable energies somewhere between 15% and 20% of the baseload. However, this bottleneck is expected to be removed by continuous technological improvement and mass production of batteries and drive systems.

1.3 Electrification of heat for and from processing

Electrification of heat production may play an important role in decarbonising the industry. Some electrification measures are ready to implement such as hybrid or dual-fuel systems to generate medium temperature heat (100+ degrees Celsius). Other measures would benefit from targeted research and development or further commercialisation. These include the development of heat-pumps capable of producing medium temperature heat and development of electric furnaces to provide high temperature heat (400+ degrees Celsius), for example for refining.

- Electrification of pre-heating and heating processes and new furnace/kiln technology is implemented by the mines. There is ongoing research and development into new electric processes and the use of electricity for heating. Energy Use compared to current operations: Electricity for heating in refining processes is 1-1,5 TWh (corresponding current production levels).
- Water treatment heating to be changed to electric heating (power 500 kW enough) in Finland is under development.

Today in most high temperature thermal processes (including metals production and minerals processing), fuels are used to generate very high temperatures (>1200 °C). This is the case in many sectors : Cement (1500 °C), Lime (1200 °C), Dead Burnt Magnesia and Sintered Dolime (>1800 °C), Ceramics (1200–2000 °C), Glass (1400 °C), Steel (1600 °C). Currently existing processes and technologies for high temperature generation can not use electricity for the thermal treatment in the above mentioned sectors.

Therefore further development of electrothermal processes for high temperature heat-treatment is required. This is an important step for the electrification in many energy intensive industries requiring important R&I Actions at European level.

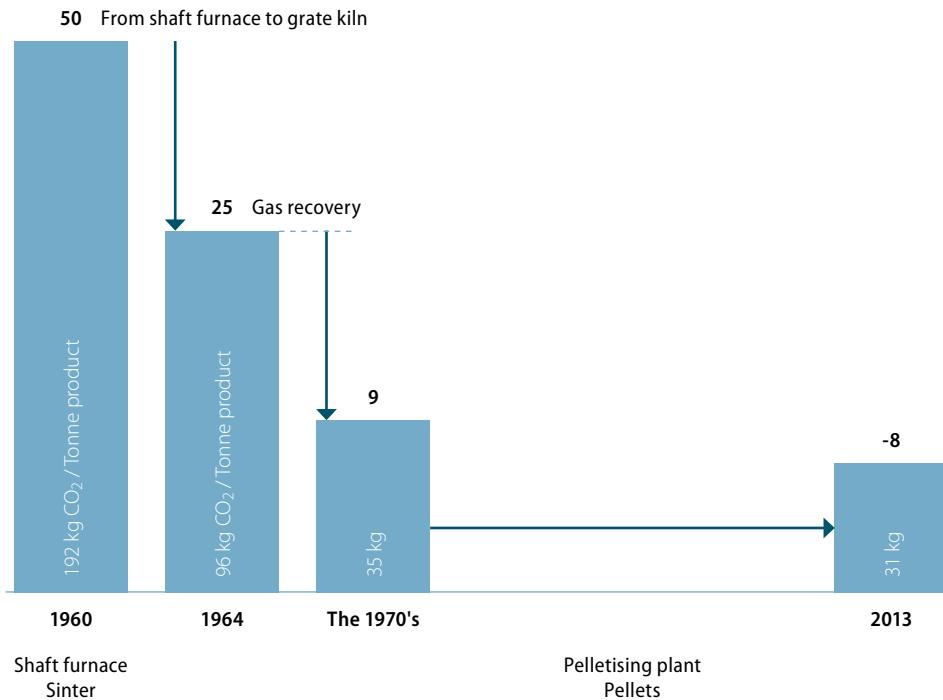
1.4 Energy efficiency in mining operations

We believe that a further energy efficiency of the mining industry is technically possible through a combination of new technical solutions and adaptation of newly emerging technologies. The optimum mix of such measures will however vary widely between regions and operations.

In the last two decades, significant reductions in energy efficiency and CO₂ reduction have already been made in the sector, and further efforts have to be made.

Over 50 years towards increased efficiency and reduced CO₂ emissions

Calculated from approximate oil equivalent litre per tonne product and energy use over time



Note: Calculation made with 2013 as base year. 1960 Shaft furnace to 1964 (KKI) grate kiln. Source: LKAB

However, in order to satisfy increasing demand existing mines have to expand their operations and extract deeper ore bodies. We have therefore seen in the last decade a number of major investments in Finland, Poland, Portugal, and Sweden and investments in new mines. For some this means that energy efficiency measures throughout the operations need to compensate for the increased energy consumption in order to stay competitive.

Example: Neves-Corvo has commenced the development of a significant extension to the mine, known as the "Zinc Expansion Project" (ZEP). New mine infrastructure for the ZEP includes a new crusher station, a conveyor system connecting this to the 700 shaft hoisting facilities, an upgrade to the main hoisting shaft together with extensions to the mine's ventilation, pumping and electrical distribution systems. Modifications to the existing zinc plant for the ZEP project include an expanded grinding circuit, expanded flotation capacity, expanded zinc and lead thickeners and filters and associated expansions and upgrades to ancillary services. It is anticipated that when the plant reaches full operating capacity in 2020, energy consumption is not likely to increase due to a number of efficiency initiatives and the altering of the work areas and vents raises required.

Existing mines

Establishing further energy saving programmes and Energy Management Systems

- Installing integrated Energy Management Systems throughout mines and processing plants
- Auditing of energy management systems

The range of measures on each site can include measures such as

- appointing a member of staff in charge of identifying energy savings,
- the identification and implementation of energy efficiency opportunities,
- assessment projects including potential for re-use of wood and residual oil and for installation of solar heating for dressing rooms,
- implementation of an energy/GHG emission reduction project comprising gradual replacement of lightning below and above ground,
- implementation of energy-saving projects across the mine and mill sites, including energy efficient lighting, modifications to improve efficiency of ceiling fans, modifications to the concentrate drying systems,
- Improvement of ore haulage loading efficiency to reduce the number of vehicle trips,
- implementation of energy/GHG emission reduction assessment projects continued, several retrofit projects in the processing plant such as power cables to improve efficiency,
- improvement of the regulation of heating in mine shafts,
- installation of lighting timers/movement detectors, roof insulation and improved sealing of buildings.

Replacing energy supply

- Wind power as an energy supply option: a study has been started.
- Underground mine battery operated machinery will be used to replace oil and diesel based machinery gradually.
- Conveyor belts powered by electricity present a possibility for efficiency and sustainability improvements.
- Replacing gas oil with biofuels for heating.

Replacing fuels with higher calorific values

- Energy-saving innovations and materials technology have focused mainly on replacing solid fuel with natural gas, scaling up and improving thus efficiency.

Process integration and automation

- Further process integration and automation can provide additional efficiencies. Examples can include:
 - Replacement of the existing belt drives by higher efficiency belt drives in 84 motors at the Zinc Plant; replacement of the existing belt drives by high efficiency belt drives in 71 motors at the Copper plant in Sweden.
 - Installation of auto-cleaning devices to avoid the use of compressed air to maintain a clear filter at the underground thickener in Portugal.
 - Implementation of tele-remote equipment operation, machine guidance and equipment automation (Portugal).
 - New heat exchangers in air shafts;
 - Change of regulation values for temperature in airshaft;
 - Improved sealing of buildings, such as roof insulation;
 - Change to LED-fittings above and below ground;
 - Installation of timers and movement detection for lighting.

Preheating ores and recycling heat

- Energy efficiency is being achieved in processing by preheating mineral ores before firing in kilns can improve overall energy efficiency and is increasingly used in the sector.
- Max utilisation of process based reaction heat to UGMine heating further – already decided for 2019 to replace 14 GWh/a fuel based heat with new heat recovery investment.

- Underground mine ventilation on demand improvements with a Mobilaris tracking system (safety and energy efficiency issue).
- Increased usage of waste heat flows in e.g. district heating systems in Sweden.
- Process heat already partly utilised for underground mine heating (21,3 GWh/a). Further plans to increase recovered energy usage on 2019 by 14 GWh/a and to minimise fossil fuel based energy usage in Finland.
- Other energy saving measures may include:
 - Automatic shutdown of the ventilation during the breaks underground.
 - On-going activities replacing the existing lighting to LED fittings.
 - Changing the controls of the primary crushers underground

New mines and new processing plants

- Introduction and investment into innovative mining methods including sole underground procession eliminating additional haulage and reducing machinery mileage.
- Adapting mine layouts to fully electrified and automated operations.
- New cement types with an increased carbon uptake in the cement structures are under development in Sweden. Innovation and research is required in order to develop new cement types with lower CO₂ emissions or with higher carbonisation quantities.

Higher quality products

Energy input as value added for quality of the product

- High iron content is in demand for better steelmaking. Using more highly upgraded input materials in steel mills enables more efficient processes, allowing steel companies to increase productivity, resulting in lower emissions. In China, the world's largest consumer of steel, the trend is clear. In 2017 a number of small, inefficient steel mills in the country with an estimated capacity of 100 million tonnes were forced to close down. A large proportion of these volumes have instead been taken over by larger Chinese steelmakers that demand highly upgraded iron ore products in order to satisfy environmental requirements and at the same time produce more steel in their existing furnaces⁵.

⁵ Source: Sustainability Report, LKAB, 2017, https://www.lkab.com/en/SysSiteAssets/documents/finansiell-information/en/annual-reports/lkab_2017_annual_and_sustainability_report.pdf

1.5 Higher valorisation of waste streams and materials efficiency

Higher valorisation of different types of waste streams and improved materials efficiency will be relevant across the metals and minerals industry including the mining part of the business.

New reduction technologies

Together with the downstream industry, the mining industry is investing in new and further research in developing a raw material feed that will allow reduction in carbon emissions in further processing.

LKAB for example has initiated research along with the international mining and steel industries for new reduction processes with reduced or no carbon emissions. In partnership with steel company SSAB and energy company Vattenfall, it is running the HYBRIT project with the aim of making steel with no carbon emissions whatsoever⁶.

Higher beneficiation in ore processing

Modern techniques based on physical and chemical properties of ores like photo camera and X-RD sorters have been developed in the last years. These techniques increase selectivity and recovery ratio with an overall energy efficiency increase in the mining industry.

In order to obtain higher yields from ore processing usually either different processing steps have to be added or processes have to be extended. Such additional processing can lead to the better processing of lower grade ores but it can also yield of a larger diversity of materials.

However, unless such processing is based on the use of other chemicals it will require more physical treatments which usually will demand higher amounts of energy, but will lead to less wasted resources.

Reprocessing of old mine tailings

Mobile processing units combining several separation and beneficiation techniques are used to increase recovery from old mine tailings. The use of mobile equipment helps to reduce energy consumption by limiting rejects transport. Grecian Magnesite is using this technique to recover 150.000 tons/year of raw magnesite from old mine tailings.

Such new processing technologies might also be used in reprocessing older tailings either for obtaining higher yields from ores which previously could not be treated with such high yields, or it will allow to reprocess old mine tailings to obtain with different technologies and methods materials which previously were uninteresting and therefore discarded. This would be beneficial for the overall supply of increasingly sophisticated materials as well as the reduction of waste and use of land and lead to the protection of the environment. However, such processing often requires energy input.

1.6 Carbon capture, storage and utilisation

The mining industry will not be able to eliminate all CO₂ emissions since not only will it not be possible to replace all fuel driven machinery in the foreseeable future, but there are also naturally occurring minerals that are being converted into high-value added products required for further downstream processing and recycling which are emitting CO₂ due to their chemical composition, not due to the use of any fuels.

For both cases the industry will have to rely to a certain degree on some form of carbon capture and storage (CCS) or utilisation (CCU).

On the one hand, at the capital investment costs which are currently associated with many decarbonisation measures, and more importantly with commodity prices (with electricity power being more expensive than gas), carbon capture and storage seems more economical than other alternatives for decarbonisation, such as sequestration.

Currently there are CCS/CCU plants for reducing CO₂ emissions from cement and lime production under way in Sweden. Current pilot plants are operated in Norway, but more demonstration and test plants are needed. Cost effectiveness and sustainability for large scale and big volume CO₂ emissions still has to be proven.

Any increase of shearing exploration will proportionally lead to higher use of electricity. Constant enlargement of mining area will also lead to a higher demand of electricity (mine ventilation, conveyor belts, etc). Expected rise cannot be quantified.

Due to higher demands in terms of product quality any potential increase in the future cannot be excluded.

⁶ Source: Sustainability Report, LKAB, 2017, https://www.lkab.com/en/SysSiteAssets/documents/finansiell-information/en/annual-reports/lkab_2017_annual_and_sustainability_report.pdf



Contributing to energy efficiency and carbon neutrality in downstream industries

In its report "Global Europe 2050"⁷ the Commission clearly identified industry, and in particular the manufacturing industry, as one of the key drivers of growth for the coming decades. In order to address the key drivers, but also the societal pressure points, the raw materials sector will have major challenges till 2030 and 2050.

The expected production growth rates for basic materials range from 14% to 178% from 2014 until 2050. Significant demand growth is expected for almost all transport modes. While air transport is expected to increase dramatically, it is not alone; transport demand for passenger cars and freight road may triple as well.

Raw Materials will be critical to building a future sustainable society that will rely heavily on new transport infrastructure as well as new green buildings. For many raw materials that means that the next 20 to 30 years will see an increase in material demands because of:

- the sheer numbers of human beings and their growing demands,
- large volumes of material have gone and will continue to go into infrastructure and housing which has an average lifetime of 30 to 100 years,
- new technologies are not necessarily material poorer; new technologies are going to support the aging population and hence this will result in more machinery/robots and therefore materials,
- the access to some materials for recycling will only be facilitated with the next generation of products.

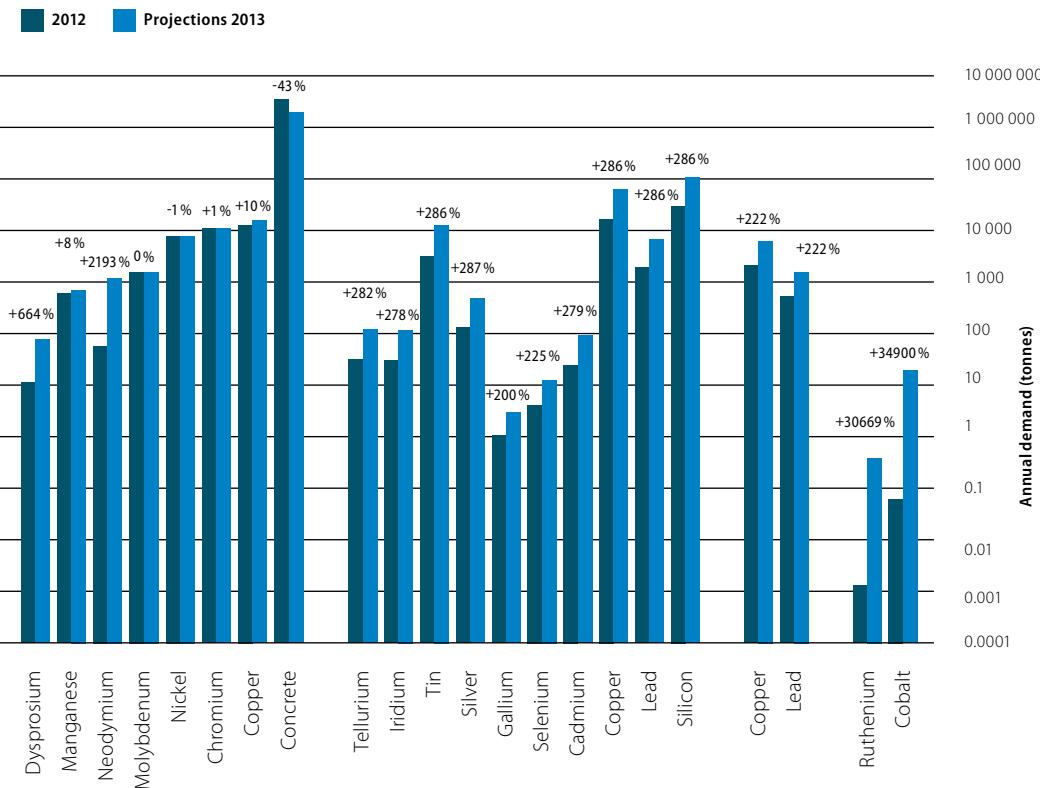
Not only do raw materials enable the European economy, but looking ahead, they are needed to enable a carbon neutral Europe and help address climate change adaptation. Alternative energy production will require considerable amounts of raw materials. Raw materials provide 97% of our current energy through fossil fuels, uranium and biomass. Global energy demand will also continue to rise. The infrastructure of the energy sector requires the massive use of metals and minerals, in particular steel for ships, pipelines, mining equipment, power plants, refineries and exploration activities, copper for the electricity grid, generators and electric motors, and aluminium, primarily for the electricity grid, and a host of other metals and minerals including phosphorous, potassium and nitrogen for biomass production.

The remainder of the energy is produced through hydropower, wind and sunlight – which need huge amounts of concrete, steel and specialty metals.

The EU's Raw Materials Scoreboard identified the various future demands per material for low-carbon technologies by 2030.⁸

2.1 Metal and mineral demand: Now and in the Future

Current (2012) and projected (2030) annual demand of raw materials used for selected low-carbon energy technologies. EC Scoreboard 2017



⁷ Global Europe 2050, European Commission 2012

⁸ EU Raw Materials Scoreboard, 2017

With the decarbonisation scenarios developed by ECOFYS, individual materials and sectors are expecting considerable growth rates.⁹

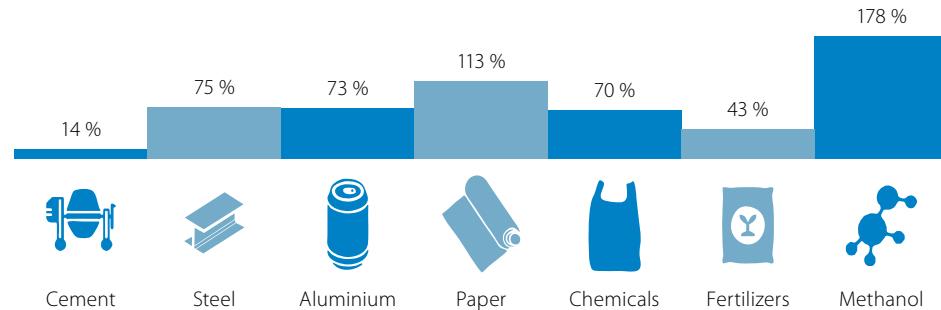


Figure 3. Expected demand development in the industry sector in our decarbonisation scenario

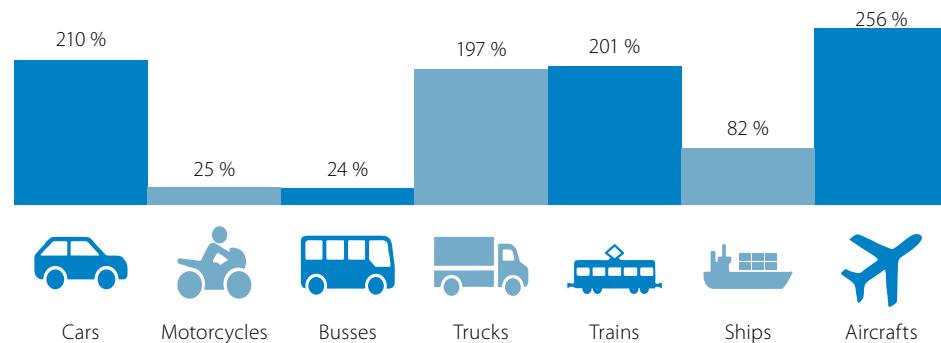


Figure 4. Expected demand development in the transport sector in our decarbonisation scenario

There are also mineral-based products that are widely used for equipment to produce renewable energy (e.g. wind energy). For example, sodium chloride produced from rock salt as a crude material for the electrolysis industry, graphite used for batteries or electrodes used for the recycling of steel.

Producing a 3-megawatt wind turbine requires 335 tonnes of steel, 4.7 tonnes of copper, 1,200 tonnes of concrete, 3 tonnes of aluminium, 2 tonnes of rare earth elements as well as zinc, which is really illustrative of the volume of raw materials we need for the green transition. (Maroš Šefčovič, the European Commission vice-president in charge of the energy union)

MOBILITY

Car

A new car today is 22% more efficient than in 2007, and metals as well as light-weight plastic materials help achieve this, together with high-performance lubricants and fuels. Lime helps produce high-strength steel for lighter cars, and ferro-alloys are essential to produce specialty steels. Specialised concrete highways reduce vehicles' fuel consumption by over 20%. As the number of Smart and self-driving vehicles on European roads increases, demand will also rise for high-tech materials.

Electric Vehicles (EVs)

EV technology is relevant for cars that average citizens may drive, as well as large vehicles in a variety of industries (mining included). Even public transport vehicles like city buses are becoming more eco-friendly. There's much debate over which materials are best for EV batteries, but future automobile manufacturing will certainly use at least some of the traditional raw materials used such as cobalt, lithium, graphite, nickel, zinc, magnesium, cadmium and manganese.

COMMUNICATION & DIGITISATION

Electronics

Printed circuit boards (PCBs) are the building blocks of all electronics, whether its smartphones and desktop computers or the small computers that now function in many machines we use in daily life from cars to washing machines. Copper is the main raw material used in PCBs but some also contain tin, nickel or gold depending on the conductivity needs of a device.

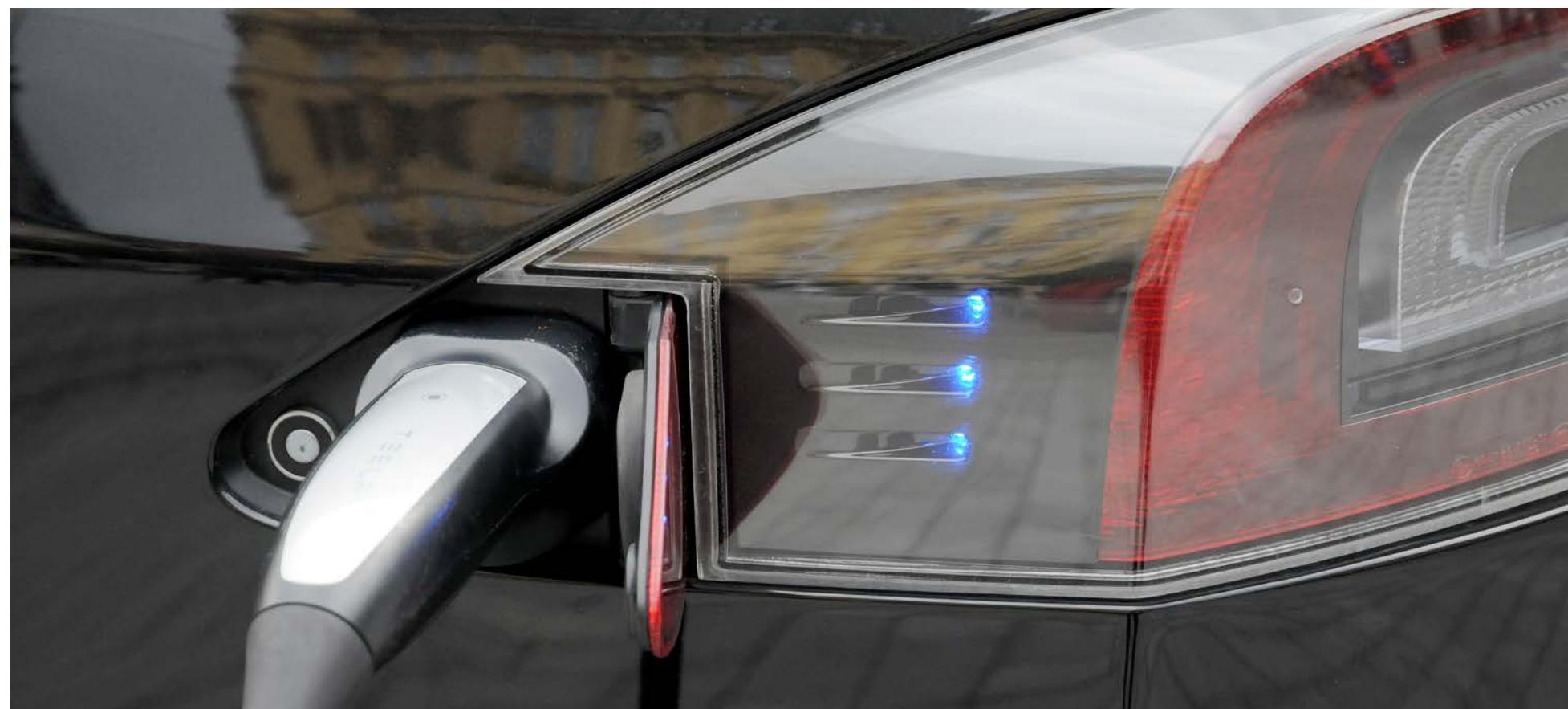
⁹ Source: ECOFYS, Energy Transition within 1.5C, A disruptive approach to 100% decarbonisation of the global energy system by 2050 (2018)

Mobile phones and tablets

Specifically, mobile phones and tablets require a massive range of raw materials. The average smartphone contains more than 50 different minerals and metals to achieve its communication and entertainment functions. Touch screen technology alone requires indium and yttrium. Speaker and microphone systems use neodymium and dysprosium and the printed wiring assembly requires a number of metals including copper, tantalum, tungsten, silver and gold among others. Based on current usage and complexity of these handheld devices, securing demand for the relevant raw materials is critical.

Computers and information technology

Pure silicon plays a significant role in computer chips, but they may also contain gold, phosphorus, boron, gallium, aluminium and quartz. Business and industry are on an exponential track of further digitisation and Industry 4.0, and a failure to secure the necessary materials needed to keep up with these global trends would make it impossible for European industry to maintain a competitive edge. All digital technology uses aluminium, magnesium, silicon and zinc.



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Raw materials are needed to enable a carbon neutral Europe and help address climate change adaptation. Alternative energy production will require considerable amounts of raw materials. Raw materials provide 97% of our current energy through fossil fuels, uranium and biomass.

Newer buildings also use more high-tech materials for additions such as solar panels.



CONSTRUCTION & INFRASTRUCTURE

Building

Building anything new requires basic construction materials such as aluminium, copper, feldspar, gypsum, iron ore, lead, manganese, tungsten, zinc and asphalt, just to name a few. But in striving for reducing carbon emissions, building materials need to be more energy-efficient, as well as more durable so they last longer and lessen the need for new resources. For example, lime helps produce high-performing construction materials such as high-strength cement and steel for sustainable housing and provides a longer life cycle to civil engineering applications such as asphalts. Developers are constantly working to achieve these goals, but the processes often increase the variety of raw materials needed. Newer buildings also use more high-tech materials for additions such as solar panels.

High-efficiency HVAC systems

Heating and cooling larger city buildings requires large amounts of energy, but great efforts are taking place to increase efficiency of HVAC (heating, ventilation and air conditioning) systems. Modern designs can now use solar energy for heating, powering natural ventilation and for the use of heat accumulation in the ceiling structures. Concrete thermal mass enables important HVAC savings, reducing hot island effect in cities. Insulation through the use of foam, stone or glass wool, coupled with high performance glazing in buildings has the potential to enable more than 80% energy savings from buildings.

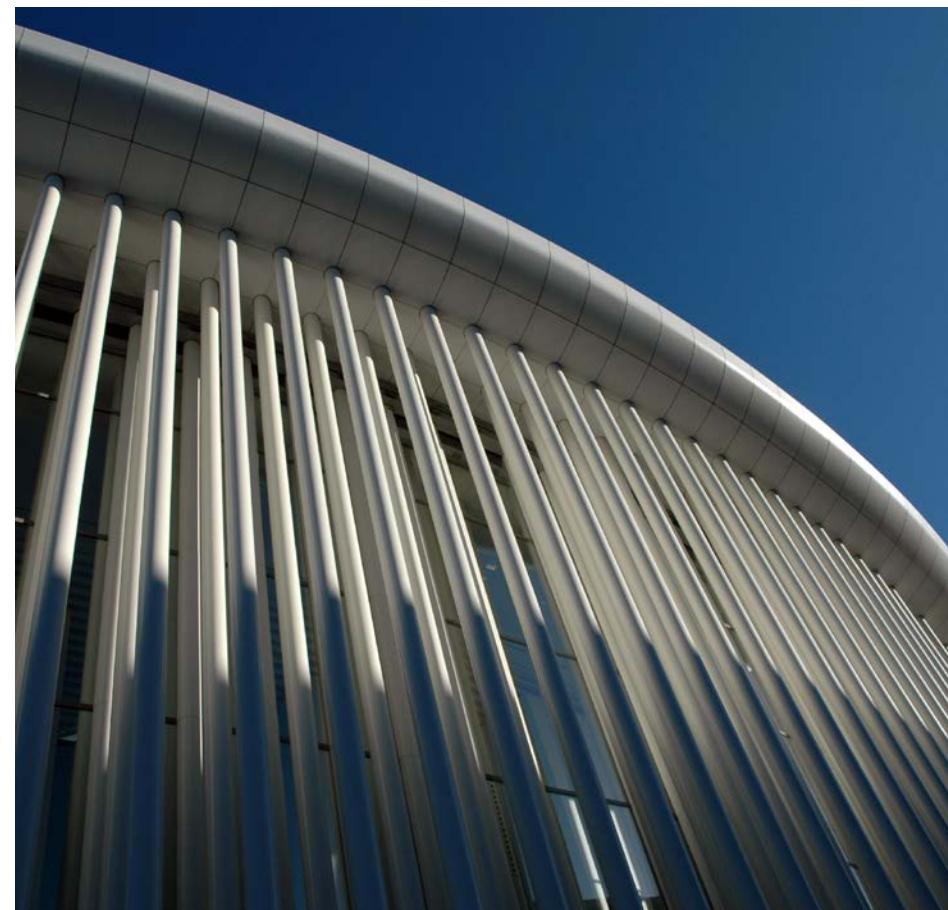
Efficient lighting

Energy-efficient LED bulbs use a combination of metals and plastics. LED lighting is critical to reducing energy consumption, but another significant reason to increase its usage is the long life of bulbs. Their service life lasts as much as 40 times longer than conventional light bulbs. LED bulbs use metals such as nickel and copper to make up the larger parts of the bulb, but the rare earth elements that make up less than 1% of a bulb are the most critical for making the LED functionality parts. The electronic LED driver uses an indium-gallium-nitride semiconductor.

Smart homes

A growing trend for reducing energy waste in individual homes across Europe is smart home devices. The Internet of Things refers to electronic devices that are connected to the Internet and often can communicate with users via smartphone applications. For example, a smart washing machine can send notifications to a smartphone when a load

is complete, and it can be set to automatically run when energy prices are lowest. Smart devices also reduce energy waste by enabling users to make changes to their homes when not there. If they forget to turn off lights when they leave for work, they can do so from a smartphone, reducing wasted energy. These products that reduce carbon impact will continue to require high-tech raw materials.



RENEWABLE ENERGY

Solar photovoltaic panels and thermal systems

These use a combination of up to 22 non-ferrous metals, silicon, chemicals (e.g. organic electrolytes) and a specific type of flat glass. Innovation in light-weight flexible photovoltaic films is also enabled by the development of advanced polymers. Improvements on solar energy cells are shifting some of the materials needed, and now include gallium arsenide, gallium indium phosphide and germanium. Besides these elements, solar panels may also contain molybdenum, zinc, cadmium, sulphur and aluminium.

Wind turbines

90% of a wind turbine's weight is comprised by metals components, and each wind turbine contains over 14 non-ferrous metals. Wind turbine towers exceeding a height of 80 meters are also increasingly fully made of concrete. Several hundred tons of steel as well as large amounts of copper may be used for a single turbine. Additionally, smaller amounts of other materials are often used, such as aluminium, cast iron, carbon steel and fibreglass.



ENERGY STORAGE

Batteries

Different kinds of batteries use different metals and alloys, as mentioned above. They also include various chemical materials such as electrodes, electrolytes, and membrane separators and battery trays which are all either oil based or mineral based.

Infrastructure development, power lines and energy storage

For all of these infrastructure developments for our communities, metals and mineral based products are required, whether that is steel, aluminium, copper, or specialised materials for future batteries. The extensions of Europe's electricity network to secure and extend access to electricity will require more aluminium and copper.

NUTRITION & AGRICULTURE

Food Production

As the population grows, Europe needs to be able to feed its citizens. Additionally, creating more green spaces aids in carbon capture. Phosphates and potash, which are used as fertilisers, are extracted directly from mineral sources. Phosphorus, mined from limestones and mudstones, is essential for the development of a plant's roots, flowers, fruits and seeds. Zinc can also make a significant impact on increasing crop yields. When zinc is added to soils, production is increased as well as the nutritional value of crops grown.

Nutrition

A larger population doesn't just need food, it needs nutrition. European mining produces salt, which is an essential nutrient that regulates muscle and nerve function. Lime is often added to animal feeds to help chickens produce healthy eggs and cows to keep the animals healthy and producing good milk. Additionally, metals are needed for the machinery used to process foods of all kinds and get them to consumers.



A photograph of a multi-lane highway stretching into the distance, framed by trees on both sides. The sky is blue with scattered clouds. A large, bold white number '3' is overlaid on the right side of the image, partially obscuring the highway.

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Conclusions – the way forward

In order to achieve the major pathways towards a more carbon-neutral mining industry in the next decade the sector needs a few prerequisites:

The need for a comprehensive EU industrial policy

The challenge of further significant greenhouse gas emission reductions across the metals and mineral value chain is substantial. Therefore, a new and integrated EU industrial strategy for energy intensive industries as part of a competitive low-CO₂ transition is needed. This must include:

- Securing access to substantially increased, reliable electricity supply at internationally competitive prices.
- Securing access to RTD support, including tax breaks for exploration and, in particular, RTD efforts going into technologies facilitating carbon neutrality.
- Securing competitive electricity prices in relation to other energy sources (fossil fuels: gas, coke etc.) to ensure incentives for electrification.
- Further development of electrothermal process for high temperatures heat-treatment.

Creating an enabling and stable level playing field

Most larger companies in the extractive sector operate with investment horizons of several decades. Securing the raw material base load supply from European resources will save CO₂ and other GHG in production and transport in uses in downstream industries. Decarbonisation policies should therefore be designed with care so as to protect the competitiveness of the European mining industry.

Electrical energy infrastructure

Achieving carbon neutrality will require improving infrastructure and cross-sectoral co-operation to achieve industrial symbiosis for overall CO₂ reduction and increased energy efficiency.

Mining investments are long-term investments. Mines that were designed twenty years ago seldom have optimal operations or efficient infrastructure today. The energy consumption of a mine is linked to the fixed energy-consuming infrastructure that forms part of the mine design, and most mines require large absolute volumes of energy and will require larger amounts of carbon-neutral electricity in the future.

Sensitivity for future electrical energy prices

Electrifying the mining sector—that is, replacing assets and updating processes to use electricity as an energy source instead of fossil fuels—is essential to reducing carbon emissions. Before companies commit to purchasing equipment and instituting practices that will lower GHG emissions, companies will want to have some assurance that regulations will favour the necessary investments and operational changes. Companies will also prefer to have some clarity about the future of electricity and CO₂ prices, since electrical energy as laid out is going to be an even increasingly more important factor in their operating costs. Hence, a reliable outlook on the availability of low-carbon energy also in remote areas and of the amount of electrical power in particular is essential.

The prospect of a stable, predictable future of the energy market is therefore needed as the basis for evaluating the operating costs of various solutions. Given the extent of the effect of lower electricity prices, competitively priced renewable electricity will be key in making this transition a success, both in national and international context.

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European mining equipment manufacturers are world leaders in quality equipment and new developments. Therefore, Europe will provide excellent opportunities for exporting such know-how and technologies, hence, contributing to addressing climate change contributions in other parts of the world.

Access to finance

A considerable decrease in specific energy consumption will only be achieved through major retrofits, which often have high investment costs that can be financially unviable, particularly for smaller operators.

The financing instruments at EU and Member State level should be present and accessible to facilitate investments. Investment costs can be significant and it would not be in the interest of the EU to have European companies relocating their headquarters and their stock exchange listing in order to access adequate finances and investments.

Public incentives: RTD and innovation

Industry is faced with uncertainty when considering the investments required for realising the lower carbon reduction targets. Public incentives can support in taking away some of this uncertainty.

It is important to put in place a R&D programme dedicated to the mineral raw materials industry low CO₂ technologies. Support for development, piloting and up-scaling of key innovative decarbonisation and energy efficiency technologies is needed.

In particular CCS and CCU will also be needed for a number of mineral processing since naturally occurring compounds will continue to emit CO₂ which ideally needs to be used, rather than emitted.

European mining equipment manufacturers are world leaders in quality equipment and new developments. Therefore, Europe will provide excellent opportunities for exporting such know-how and technologies, hence, contributing to addressing climate change contributions in other parts of the world.



Aitik, electric trolley. Photo: Mats Hillblom



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