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Value Chains based on Mineral Raw Materials

Challenges for European Policy and Industry

Aurélie Faure-Schuyer, Christian Egenhofer and Milan Elkerbout

Summary

This report is meant to provide background and serve as starting point for a series of stakeholder discussions on the future of the EU's value chains based on mineral raw materials It describes the transformation the industry is currently undergoing, identifies both the challenges and opportunities it faces.

This report is not intended to give a complete analysis or draw final conclusions, but to stimulate further discussion on the most relevant challenges. It attempts to describe the controversies and to identify different stakeholder positions.

Keywords: mineral raw materials, value chains, trade, Europe, skills, employment

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Introduction

Now that the global manufacturing industry has settled from the resources boom of the early 21st century, attention is turning to new challenges, notably the increasing demand for mineral raw materials stemming from the unfolding digital revolution and the transition to the low-carbon economy. The drive towards clean or 'green' technologies, e.g. fuels, products and processes, is partly the result of policy and partly market-driven; in the latter case a response to demand triggered by a new generation of young consumers. This transformation is affecting and transforming the value chain of mineral raw materials industries from the upstream to the downstream, e.g. from mining, products and processes along the value chain to end-consumer markets.

The resources intensity of our economy and society will remain significantly high. Increasing quantities of mineral raw materials – some of them described as "critical raw material"[1] – will be required to ensure the transformation to the low-carbon economy, both in the EU and globally[2] and to meet growing market demand. Some speak of a "new age for metals and minerals". Close to 60% of the demand for critical raw materials is associated with high-growth industries.[3]

The combined effect has been to trigger political interest in new materials, which in turn raises concerns over security – availability and costs – of mineral raw materials. Consider, for example, China's export restrictions on rare earth elements, plus tungsten and molybdenum or President Trump's Mineral Order to secure raw materials deemed critical to US industry and American economy. It is therefore legitimate to ask whether we are witnessing the beginning of a more security-driven approach to raw materials, minerals and metals.

At the same time, the raw materials industry is affected by EU and global climate and energy policies. While on the one hand it enjoys major growth prospects, on the other, there are fears

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[1] Deutsche Bank, "Welcome to the Lithium-ion Age", Markets Research, 9 May 2016.

[2] World Bank, "The Growing Role of Minerals and Metals for a Low Carbon Future", Washington, D.C., June 2017.

[3] See Stephen Freiman, "Minerals, Critical Minerals and the US Economy", testimony before the House Science and Technology Committee, Subcommittee on Investigations and Oversight, Hearing on Rare Earth Minerals and 21st Century Industry, US Congress, 16 March 2010; and Joint Research Centre (JRC), "Critical Metals in the Path towards the decarbonisation of the EU Energy Sector: Assessing Rare Metals as Supply-Chain Bottlenecks in Low-Carbon Energy Technologies", European Commission, 2013.

that obligations arising from compliance with climate policies will affect energy prices and costs, and therefore its global competitiveness.

Concepts like carbon footprinting or lifecycle product responsibility are increasingly being operationalised in order to guarantee (end) consumers that end products meet environmental, ethical and other standards. This development, alongside the digital and other technological transformations, can provide new opportunities for industry and create new value chains while possibly offering more sustainable production.

This report analyses the potential implications of this transformation in the context of four salient challenges facing industry in the EU today:

1. Building a strong innovation capability with the goal of supporting breakthrough market applications
2. Securing access to raw materials, including secondary raw materials (e.g. urban mining), and through external trade
3. Ensuring an affordable energy-cost base, while achieving EU and international climate objectives
4. Consolidating an EU social framework based on a strong skills and employment base

Challenge 1. Technological transformation and innovation: Evolution and disruption

Maintaining the EU position in the industry by building a strong RD&I capability

The mineral raw materials industry and its processes are undergoing rapid changes in response to the digital transformation.[4] This is true both for the industry and for the final products. Products required by the industries' consumers are designed and manufactured under what is called "Industry 4.0" (or the "4th industrial revolution").[5] Digitisation is also transforming the mining industry ("Mining 4.0") where for example sensors and knowledge tracking offer higher resource and energy efficiency. New materials, for example for digital devices, are becoming increasingly complex. These revolutions have transformational effects on organisational structures, as well as on the industry's standards and modes of operation and have indeed already led to the emergence of new industrial and businesses models.[6] Innovation therefore takes place at different levels, with product (e.g. smart products), process and systems innovation having equal potential to contribute to industrial transformation. This innovation is unfolding in cycles, which generally include a gap ('valley of death') between the initial stages

[4] See Jacques Pelkmans and Andrea Renda, "Does EU regulation hinder or stimulate innovation?", CEPS Special Report No. 96, CEPS, Brussels, November 2014; and IW Consult, "Potentiale des digitalen Wertschöpfungsnetzes Stahl", Köln, 2017.

[5] Hugh Durrant-Whyte, Ryan Geraghty, Ferran Pujol and Richard Sellschop, "How digital innovation can improve mining productivity", McKinsey, November 2015.

[6] These new business models are spawning a technological revolution that disrupts an existing market and/or value network, and its existing demand patterns, leading to the creation of new firms, networks, alliances.

of R&D&I and successful market uptake and commercialisation at a later date. The EU's experience suggests that a funding gap often emerges at the demonstration stage and sometimes, early deployment.

Innovation policy enables future market potential

Innovation policy is pertinent for the mineral raw materials industry first with respect to its output production, productivity and technological capabilities. The mineral raw materials industry is not only competing for deposits but also for new materials technologies and know-how and patents. The raw materials composition of a product and their assembly into intermediate or final products play an important role in the process of innovation. They will most likely be the most critical constituents of the EU's knowledge and scientific capability in the future, requiring more R&D in materials science, in general, and improvements in recycling processes, in combination with the development of competences and skills.

Innovation and technology development tend to take place where the market is, i.e. where current and future demand and growth are found. This also implies that there has to be a business case for continued investment, without which innovation does not take place. With the transformation of industries, equally driven by decarbonisation, digitisation and automation, new industrial clusters will inevitably develop. Where exactly these new clusters develop depends strongly on the interplay between innovation and industrial policies (as well as climate, energy and trade policy more broadly). The EU can significantly affect change in innovation policy through funding mechanisms, as well as through its regulatory competence, e.g. for products, processes, emissions, etc. The success of the EU in launching its industry on a low-emissions pathway depends in part on its innovation policies. Low- and zero-carbon technologies, capable of transforming industrial processes, will require public support and strategies focused on industrial clusters and the adaptation of value chains, both inside and outside its borders, but also assisting regions in managing the transition. Innovation policy also involves identifying the EU's strengths and weaknesses, the qualities of its industrial network and value chains (or its skills). From an investment perspective, this mix of innovation and industrial policies should ideally be predictable. While there are inherent political limits to how predictable a policy environment can be in a democratic and multi-level governance system, it does point towards the importance of reflecting innovation and industrial priorities in long-term strategic policies.

It is equally important that the fruits of innovation – whether publicly supported or not – further reinforce EU competitiveness, which requires the protection of intellectual property (IP) rights. The issue of IP rights is relevant both in the context of public innovation policies inside the EU, as well as externally in the context of trade agreements.

Impact of EU policy-making on industrial development

For firms in Europe, it is essential that they retain and, where possible, expand their capabilities to engage in research, development, and innovation (RD&I) activities as part of their day-today operations. Externalising such RD&I capability could be detrimental to long-term competitiveness as essential skills and knowledge might be lost. However, these activities can only be financed and supported on a sustainable basis if firms as a whole have access to sufficient levels of free cash flow. This pre-condition links back to the importance of ensuring that climate and energy regulations do not impose undue burdens on firms, and thereby erode their competitiveness. At the same time, the climate and energy policy framework needs to be sufficiently effective in order to also create a credible market for low-carbon products. Indeed, in the absence of a far-reaching climate policy framework, the contingent case for climate policy-induced industrial transformation and associated (innovation) policies disappears. Moreover, environmental regulations and policies can also support competitiveness by inducing process innovation, as per the Porter-hypothesis.[7]

As industrial policy is primarily the prerogative of member states, and only a supporting competence belonging to the EU, EU policies may be inherently limited in what they can achieve with regard to industrial policy objectives. This is notwithstanding the fact that most EU policies in the field of innovation, climate, environment and energy have strong industrial policy implications. This points to the importance of coordinating member state activity at the nexus of innovation and industrial policy. The local political economy again plays a key role here, because these policies can have strong distributional impacts.

Questions: Technology and innovation

- Is Europe and its industry innovative enough and able to maintain its competitiveness to manufacture the products of the future?
- How can innovation contribute to expand markets that will benefit European value chains? What is required to make this happen?
- Can policy-making processes (in fields of direct impact of the EU, e.g. energy, climate, etc.) be set up to cooperatively build an industry strategy?
- How might disruptive new technologies, such as in mobility and material science, affect EU value chains?

[7] S. Ambec, Mark A. Coheny, Stewart Elgiez and Paul Lanoie. (2013), “The Porter hypothesis at 20: can environmental regulation enhance innovation and competitiveness?”, *Review of Environmental Economics and Policy* 7(1) 2–22.

Challenge 2. Securing access to raw materials

Via self-sufficiency and/or access through trade

For those mineral raw materials where domestic production, i.e. mining, does not meet demand, stable trade rules have been a key strategy for securing access to mineral raw materials in the EU. In most cases, this is also true for exporters, which have an interest in stable export markets. Within the EU, trade is embedded in a European framework, including the internal market, and a host of other EU and national policies such as product standards, safety provisions or consumer protection in the case of final products.

To address trade in raw materials – at least partially – the EU attempts to introduce Raw Materials (and energy) chapters in trade agreements. Cooperation with Africa has been ongoing for some time under the EU's ACP programme involving 79 African, Caribbean and Pacific states). A trilateral dialogue between the EU, Japan and the US is devoted to materials substitutions for critical raw materials as part of the EU's and Japan's raw materials action plan.

Trade tensions

We should not, however, neglect the tensions that flare up from time to time between importers and exporters, as witnessed especially during the first decade of the 21st century. There has been talk of market manipulation at times when supply has fallen short. Among the best-documented disputes are the rare earth elements conflict in 2009 and the tungsten and molybdenum dispute of 2012, where export restrictions were imposed on these resources. The OECD inventory documents the numerous export restrictions[8] imposing unilateral or coordinated limitations on the export of materials. For resource importers, the WTO offers the possibility to introduce anti-dumping tariffs.[9] Both the Bush and Trump administrations have used this instrument to protect the domestic US industry.

Tensions in the trade regime are also being compounded by the repeated requests of China to receive 'market economy' status under the WTO regime – a request firmly opposed by both the EU and the US. Last December 2017, a Minerals Order from the Trump administration[10] reflected a firm stance on the protection of critical raw materials and a stated attempt to protect national resources, as promised during the US electoral campaign. There is evidence that China is dumping semi-finished and finished products on other (e.g. US, EU), which has triggered antidumping measures.

[8] See Jane Korinek and Jeonghoi Kim, "Export Restrictions on Strategic Raw Materials and Their Impact on Trade", OECD, Paris, 2010.

[9] See OECD, "Export Restrictions in Raw Material Trade: Facts, fallacies and better practices", Paris, 2014.

[10] US Department of the Interior, "Secretary Zinke Signs Order to Begin Process of Creating First Ever National Survey of Critical Minerals", Press Release of 21.12.2017.

China – Asia – Latin America

From 2000 to 2014, the industry has been faced with a boom cycle from emerging markets (China, Asia and Latin America), leading to a doubling of trade in these critical raw materials.[11] This demand cycle culminated in 2014, when China's demand for steel declined for the first time in a decade, as a result of the Chinese government's attempts to redirect the economy into higher added value products and services.

China's resource boom encompassed a wide range of minerals and metal products, but the authorities are now changing their trade policy approach. China announced that its manufacturing industry would be re-oriented towards the export of semi-finished and finished goods. Chinese authorities have announced mine closures and capacity limitations, most often on grounds of limiting air and other polluting emissions related to aluminium and steel production. There are diverging views on the impact of China's policy on global commodity markets.[12] Nevertheless, the patterns of China's commodity plateau and its recent entry into recycling[13] may signal a turning point for global commodity markets, for both supply and demand as well as for industrial production.

Access to critical raw materials

In 2009, the EU launched the Raw Materials Initiative[14] with the objective of fostering diversification of and access to raw materials used in its industries. Its strategy involves i) assessing the risk of shortage in the supply of critical raw materials, with a view to promoting diversification of the sources and imports of raw materials; ii) supporting R&D in products 'and processes' substitution efforts and iii) formulating European policy proposals in the framework of the European 2020 industrial and knowledge base economy.

Under this Initiative, the European Commission has drawn up a list of critical raw materials, which is subject to regular review and updated in light of the EU's existing primary raw materials production capacities, e.g. for copper, zinc or lead, as well as main external sources of supply. It applies the 'criticality' concept,[15] which focuses on both the scarcity of the geological resource in terms of its abundance and an assessment of the value chain's self-sufficiency and vulnerabilities, including transport, and the potential for finding effective alternatives in

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[11] "Commodity Special Feature", *World Economic Outlook*, IMF, Washington, D.C., October 2015.

[12] Ivan Roberts, Trent Saunders, Gareth Spence and Natasha Cassidy, "China's Evolving Demand for Commodities", Reserve Bank of Australia, Conference Volume, 2016.

[13] Jian Xiao, "Extended producer responsibility system in China improves e-waste recycling: Government policies, enterprise, and public awareness", Elsevier, 2016.

[14] COM (2008) 699 Final, "The raw materials initiative — meeting our critical needs for growth and jobs in Europe".

[15] M. Frenzel, J. Kullik, M.A. Reuter and J. Gutzmer, "Raw material 'criticality'—sense or nonsense?", *Journal of Physics D: Applied Physics*, Vol. 50, No. 12, 2017.

production processes or recycling.[16] The latest EU critical raw materials list[17] adds nine materials to the existing 27[18] with certain regions being designated areas where the concentration of supply poses a risk to the European Union; in particular China and the Democratic Republic of Congo.[19] Cobalt appears on the EU critical raw materials list, while lithium does not on the grounds that its supply is seen as less concentrated and its economic importance less than in the case of cobalt. Industry has voiced criticism that although the list of critical raw materials has become longer, the measures the European Commission envisages might not be sufficient to effectively address the risks.

Complementary initiatives are the Extractive Industries Transparency Initiative, which aims to set a standard for good governance of the extractive industry[20] and the EU Regulation on Conflict Minerals.[21] The Extractive Industries Transparency Initiative is currently discussing the possibility of refining the self-sufficiency indicator so that its weight is balanced with other indicators, such as the contribution of the value chain to the overarching security policy goal, together with global decarbonisation goals. Taking such a value chain approach has the advantage that it directs efforts towards technological priorities and specialisation strategies while, in parallel, adapting to changing external policies objectives, particularly where they require secured and sustainable access to raw materials.[22] On the product side, the concept of 'product stewardship'[23] can help with mitigating environmental impacts and improve resource efficiency throughout the lifetime of a product.

In addition, it suggests increased efforts towards recycling in the European Union, notably under the Circular Economy Framework objectives (see next section).

Questions: Access and trade

- **What relationship should the EU develop with resource-rich region such as China/Asia, Africa, and Latin America under the aspect of access to mineral raw materials?**

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[16] Matthias Buchert, Doris Schüler and Daniel Bleher, "Critical Metals for Future Sustainable Technologies and their Recycling Potential", UNEP, July 2009.

[17] See Communication from the Commission on the 2017 list of Critical Raw Materials for the EU, COM (2017)490-Final, 13 September 2017.

[18] CRM 2014 list: Barite, Bismuth, Hafnium, Helium, Natural rubber, Phosphorus, Scandium, Tantalum and Vanadium.

[19] T.E. Graedel, E.M. Harper, N.T. Nassar, Philip Nuss and Barbara K. Reck, "Criticality of metals and metalloids", *Proceedings of the National Academy of Sciences*, 2015.

[20] See The Extractive Industries Transparency Initiative - https://eiti.org/

[21] EU Regulation 2017/821; Marta Latek, "Conflict Minerals", EU Parliament, EPRS, Plenary March 2017.

[22] Alessandro Giovannini and Umberto Marengo, "Boosting TTIP Negotiations: A Value Chain Approach", Istituto Affari Internationali, Rome, 2014.

[23] Product stewardship is a concept which aims at taking into account environmental impacts and responsibility during product design and over the life cycle of a product

- Should minerals, raw materials and certain metals still be classified as commodities? If not, what would they be?
- What levels of self-sufficiency (or import dependence) for the different minerals and raw materials are appropriate to guarantee continued EU prosperity?
- What indicators can be used to measure 'secure access'? Should secondary materials, e.g. 'scrap materials, be considered in such indicators?
- What role will and can world trade and the WTO play in the future for minerals, raw materials and metals? What role should trade policy instruments play?

Challenge 3: Global and EU energy, climate and resource efficiency policy

Decarbonisation: Combining new market opportunities with the challenge to remain cost-competitive

Policies to meet the EU decarbonisation targets, as well as renewable energy, energy efficiency and other environmental goals, as part of the Energy Union strategy, are impacting the competitiveness of industry. But it would be wrong to say that Energy Union is only about decarbonisation. There are five so-called dimensions to the Energy Union, including competitiveness, with research and innovation seen as a safeguard of future industrial competitiveness. The energy security dimension of the Energy Union relates to the overarching aim of ensuring access to affordable energy for businesses and consumers alike. The other dimensions are energy efficiency, an integrated internal energy market, and decarbonising the economy.[24]

Decarbonisation goals as driving force and challenge to the energy system

For some time now, the European Union has advocated more ambitious global climate change targets. The Paris Agreement on climate change in late 2015 has given new impetus to the global decarbonisation agenda. By now, all countries in the UN have signed the Paris Agreement, although the US declared its intention to leave the Agreement when it is eligible to do so in 2020. Parties to the Paris Agreement will have to increase their ambition level as part of the first "global stocktake" by 2023.[25] The EU target of a GHG emissions reduction target of "at least 40%" by 2030 compared to 1990, formulated during the October 2014 European Council, is an indication of things to come.[26]

For the long-term, i.e. 2050, an EU target that is compatible with the Paris Agreement's level of ambition most likely will require meeting the upper band of the EU's greenhouse gas

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[24] European Commission: "Building the Energy Union". See: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/building-energy-union

[25] Article 14 Paris Agreement (http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf).

[26] European Council Conclusions of 23-24 October 2014 (http://data.consilium.europa.eu/doc/document/ST-169-2014-INIT/en/pdf).

emissions reduction target range of between 80-95%, i.e. near complete decarbonisation of the EU economy and the need for negative emissions thereafter. A 95% reduction target means an annual 'allowance' of just some 280 million tonnes of greenhouse gas emissions for the EU, compared to over 4 billion tonnes in 2016. Agriculture alone currently accounts for more than 400 million tonnes, meaning that all sectors in the economy should significantly, if not completely, reduce their emissions.[27]

Reducing emissions intensity through increased efficiency may be sufficient to achieve near- and mid-term emissions reduction objectives, such as the EU's 2020 goals. There are, however, inherent limits to efficiency improvements. The attainment of more stringent climate objectives in the future requires more transformational changes to the underlying products and production processes. It will also require significant quantities of renewable energy to be produced for both the electricity system as well as certain industrial processes.

The energy transition as a challenge

About four-fifths of EU GHG emissions come from energy use. Besides electricity generation, all the fuels currently used for industrial processes and heat will need to be addressed. This will dramatically increase demand for low-carbon energy – both electricity and hydrogen – not just for replacing current power demand but also for heating and cooling, transport and energy-intensive industries. It has been estimated that an ambitious decarbonisation scenario of the chemicals industry alone would require some 1.900 TWh of low-carbon electricity by 2050. This represents approximately three times the current German annual electricity consumption or 55% of what the International Energy Agency projects as European annual low-carbon generation in 2050.[28] Steel decarbonisation could add up to additional 500 TWh. Including fuels would further increase demand very considerably. This will require massive construction of new infrastructure, requiring more raw materials such as copper, aluminium, steel, construction materials and many others. While, in principle, this is good news for industry, the concern is that EU climate and energy policy will drive up costs for EU industry to the extent that a (major) share of this new market will go to competitors operating outside the EU. Economies are already now connected via global technology value chains, in which investment apply state-of-the-art technologies globally sourced.

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[27] Figures derived from EEA. (2017). Trends and Projections in Europe 2017 (https://www.eea.europa.eu/themes/climate/trends-and-projections-in-europe/trends-and-projections-in-europe-2017) and the EU's national inventory report (NIR) for 2017, submitted to the UNFCCC secretariat by the EEA (https://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2017).

[28] DECHEMA (German Society for Chemical Engineering and Biotechnology), "Low carbon energy and feedstock for the European chemical industry", Frankfurt am Main, July 2017. The DECHEMA study estimated demand for low-carbon power for a range of scenarios. The intermediate scenario, i.e. a moderate level of ambition depicts a bit less than 1.000 TWh, the ambitious scenario some 1.900 TWh while in the maximum scenario, i.e. the theoretical potential, demand would go up to 4.000 TWh.

The energy transition will challenge existing patterns of industrial localisation. Industrial sites will develop in locations where alternative fuels (e.g. low-carbon electricity and hydrogen) can be provided, where emissions can be captured and stored and where opportunities for symbiosis between different industrial processes exist. Local conditions and the political economy will affect how different regions adapt to, and benefit from, this industrial and economic transition.

Competitive energy prices will be a challenge

These dimensions taken together are relevant in the context of the energy prices faced by industry, where obligations arising from compliance with climate policies can affect energy costs and competitiveness. Increased electrification, as well as the (renewable) electricity that may be required for increased hydrogen production make electricity prices particularly relevant. At this moment, it is far from clear where and how this hydrogen could be produced.

There may indeed be limits to transforming industries so that they are compatible with a decarbonised economy: energy costs may get too high, solutions such as carbon capture and storage may run into public opposition, and access to requisite raw materials and metals may become too costly. To the extent that these limits would be commonly acknowledged, it would require more attention to climate adaptation. For industries that are dependent on access to rare raw materials, dealing with potential climate impacts may become more important over time.

Historically, EU energy prices have been among the highest in the world. At the same time, energy costs were comparable if not lower than those from competitors in many other parts of the world. This owes to European industry generally being among the most efficient.[29] This situation however might change with a higher CO_2 price in so far as the energy produced is subject to carbon constraints. While member states have the possibility to compensate electro-intensive industries, increasing CO_2 prices might make this option untenable from a political or fiscal point of view. A different picture emerges for natural gas. Comparing natural gas prices shows that American industry on average pays less than half compared to European competitors. However, gas prices are relatively little affected by EU policies and are (for now) more a function of regional commodity prices. The transformation of the gas industry towards more global competition offers prospects for globally converging gas prices. Gas could theoretically become a bridging fuel to hydrogen based steel making but to date is more expensive than coal/coking coal and therefore has cost implications.

Obligations arising from compliance with climate policies will affect energy prices and costs. This might erode competitiveness of the sector, unless there is a truly global agreement where competing industries are subject to equivalent carbon constraints, which could for example be

[29] European Commission, "Energy Economic Developments in Europe", *European Economy*, No. 1, Brussels, 2014. See also report prepared by CEPS for DG Grow of the European Commission, "Composition and drivers of energy prices", CEPS, Brussels, January 2017.

achieved through global carbon pricing, and in its absence, by carbon border measures, consumption-based GHG emissions accounting or global sectoral approaches, or other incentives.

Circular economy potential still to be seen

Potentially, new innovative solutions can be provided, for example, under the circular economy concept. The circular economy is based on methodologies evaluating the metals and minerals 'content' present in industry and society, mainly in the form of products, buildings or infrastructure.[30] It aims at ensuring that products are preserved rather than being discarded or dissipated over time, and that substances of very high concern are progressively eliminated to reduce pressures on the environment.[31]

Still, it will not be able to guarantee a secure source of supply for the industry, as there are technological and economic limitations to recycling. If demand for metal has been growing significantly on a long-term basis, then the volume of end-of-life products coming back on the market will see a delay equivalent to its life-use. That means that in a period of steadily increasing demand, the supply of metal available for recycling will not be able to cover the gap. Additional primary metal would still be needed to meet the growing demand. At this stage, while the circular economy offers new prospects, it remains uncertain what the exact contribution of the circular economy to secure raw materials will be.

However, the circular economy concept adds an important focus to the design phase of products (smart design). And in order to monitor progress towards circularity, monitoring of materials flows at specific points of the value chain will be required. Concepts of life cycle assessment (LCA)[32] and life cycle inventory (LCI) that track emissions and flows will become increasingly important.[33] Finally, taxation and accounting rules will greatly impact how circularity approaches will develop.[34]

Questions: Energy and environment

- **Will EU policy be able to ensure access to affordable and secure energy in the long run?**

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[30] See Markus Zils, "Towards a circular economy: Rethinking value chain to boost productivity", Brussels Environment, 2015; and Briefing, European Parliament, "Circular economy package Four legislative proposals on waste", January 2016.

[31] Christian Hagelüken, Ji Un Li Shin, Annick Carpentier and Chris Heron, "The EU Circular Economy and Its Relevance to Metal Recycling", *Recycling*, 2016.

[32] Life Cycle Assessment - IEC (ISO 14040:2006, definition 3.2).

[33] Elsa A. Olivetti, Gerbrand Ceder, Gabrielle S. Gaustad and Xinkai Fu, "Lithium-Ion Battery Supply Chain Considerations: Analysis of Potential Bottlenecks in Critical Metals", 2017.

[34] Vasileios Rizos, Arno Behrens, David Rinaldi and Eleanor Drabik, "The contribution G20 governments can make to the circular economy", G20 Insights, 2017.

- **Is EU climate and energy policy on track to accelerate the transformation of the EU industrial base to a low-carbon industrial base?**
- **Are there limits to the decarbonisation of sectors, e.g. scale, access to mineral raw materials, or cost competitiveness? If so, how can this be addressed while meeting EU and global climate targets?**

Challenge 4: Skills and employment

New skills for a new world

Skills and knowledge in general are an important pillar for competitiveness, growth and employment. For mining and processing, to serve as an example in this chapter, the European Commission notes that the sector "is reported to be characterised by a talent shortage".[35] It further records a decline of educational programmes although with a difference between those member states with a strong mining industry and those without one. Mineral processing graduates in Europe are negligible in a global comparison at around 1% of all graduates globally.

Jobs move with the territory

This might affect the future of the European mining equipment manufacturing industry, which – despite its low share of global raw materials production, has globally been competitive. Over the years, due to the increase in demand for metals and minerals, mine production has increasingly shifted to new regions, and mining equipment flows have followed; such a trend has been observed in other sectors too. Industry investment moves with growing markets. The EU is supporting the competitiveness of mining equipment manufacturing by a series of actions on innovative extraction and processing materials in the context of the European Innovation Partnership on Raw Materials. One of the objectives is to support the development of new techniques and technologies to open a path for new mining technologies to be commercialised. For example, automation of mines will allow access to mineral deposits in small quantities or those situated at greater depth. This might be able to slow the relative decline of EU mining manufacturing, but most likely it will not be able to reverse the trend in which mining equipment investment follows the mining activity.

Revolution along the value chain

The technological revolution of digital technology is affecting all stages and processes of the industrial value chain, from the upstream to the downstream. This digital revolution is bringing a new wave of process and product innovation. In processing activities, industry 4.0 already impacts on the reduction of downtime, through predictive maintenance and a smarter programming of maintenance cycles.[36] All these developments together are having

[35] European Commission, "Raw Material Scoreboard", Luxembourg, 2016, p. 47.

[36] Hanno Kempermann, "Potentiale des digitalen Wertschöpfungsnetzes Stahl", IW Consult, Köln, 2017.

transformational effects on the industry and on organisational structures, particularly on their modes of operations and on technical standards. And ultimately, they will require new ways of educating and training.

New skills required

Traditional jobs will disappear in all sectors, giving way to new opportunities in the new industries of the future.[37] The 'traditional' career, where people would train for a particular field seems to be gradually disappearing. In the age of automation and smart systems, employment and employability will no longer be based solely on specialist knowledge. Although knowledge will always be important, life-long career success will be based upon key transferable skills that can be leveraged to succeed in business and organisations that probably do not even exist today. Digitisation and increasing process automation requires a transition to new skills sets, a process that is often described as "from linear to holistic". For example, future qualification profiles are most likely be defined by a combination of both profound materials knowledge and IT skills. Traditional R&D work in laboratories is being replaced with increasing frequency by software-engineered simulations.

These developments pose huge challenges to traditional education, which in the past has contributed to the current levels of industrial evolution and technological development. It is far from certain that the higher education system as it is today will be able to continue to teach the right set of skills and knowledge required for future work. A first question therefore will be how higher educational institutes will be affected by this industrial transformation and how the delivery of education will be transformed, for example by the internet and more advanced digital knowledge.

Questions: Skills and employment

- **Will we still need people in the upstream industry? If yes, what skills are required?**
- **What is more important: materials science or digital skills?**
- **How can re-skilling be achieved? How can a sufficiently skilled workforce be found?**
- **How can regions that are affected by mine closures and the decline of the associated industrial value chain be assisted to manage the impacts?**

[37] World Economic Forum, "The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution", Global Challenge Insight Report, January 2016.

Conclusions

Mineral raw materials are increasingly becoming critical to our economies. They are crucial components of the EU's industrial base, producing a broad range of goods and applications used in everyday life and modern technologies, including sensitive technologies applied for example to military purposes.

In part, demand is driven by technological developments such as digitisation, smart materials or disruptive technologies. Mutually reinforcing technologies such as mobile technology, the Internet of Things and data analytics create new markets or transform existing ones. Increased connectivity of people and things through mobile devices has contributed to the proliferation of new services and sharing models. Disruptive technologies such as autonomous driving, 3D printing, drones and renewable energy are transforming industry sectors and value chains, which often are described as Industry 4.0.

Demand is also driven by policies to reduce greenhouse emissions in the EU and globally, for example by materials and energy efficiency, renewable energy and increasing electrification. This in turn will necessitate a massive construction of new infrastructure, requiring more materials such as copper, aluminium, steel, construction materials and many more.

The growth in demand for mineral raw materials increasingly raises concerns over security – availability and cost – of mineral raw materials. This emerging debate on the 'security' of raw materials supply is echoing concerns we have dealt with for a long time in the energy domain and associated worries about the security of energy commodities, notably oil and natural gas. The difference with energy, however, is that raw materials cover a far more diverse set of materials and metals, which in addition, are used in diverse applications and many different economic sectors within Europe and elsewhere. We are also witnessing fast-changing value chains on the back of technological disruptions.

Yet, this time round, governments seem to be taking a more assertive, and in some cases, pre-emptive stance. Witness, for example, China's disputes on rare earth elements or President Trump's Mineral Order at the end of 2017. This new attitude may pose new challenges for EU trade policy.

The future will provide new opportunities for industry, economic growth and jobs and will create new value chains. For EU industry – as well as the economy at large – being able to reap these benefits will require profound adjustment and intensified attention on the part of EU policy-makers to address the challenges of the transformation, as discussed in this report.

Annex 1: A note on terminology and a brief description of the mineral raw materials industry

Terminology. This report covers non-energy and non-agricultural raw materials used for industrial purposes, such as *non-ferrous metals* (e.g. aluminium, copper, zinc, tungsten); *ferrous metals* (iron ore-based metals), or industrial minerals (e.g. graphite, kaolin) and aggregates. *Mined ores* (e.g. iron ore, bauxite, tungsten) and concentrates constitute extracted primary resources. The report also includes *critical minerals*, such as rare earth elements, used in small quantities in electronics, chemicals, defence and low-carbon industries. Raw materials and minerals are processed into transformed materials and end-products.

The *value chain of mineral raw materials* operates together with downstream supply chains in such a manner that it can act as a source of supply, for example in the production of automobiles, aggregates used in the construction sector, paper products, plastics, glass or fertilizers.

Security of supply refers to the uninterrupted supply of raw materials over a specific period of time.

The industry. The mineral raw materials industry is immensely diverse. The term "raw materials" encompasses a wide variety of materials and metals used in many different applications and sectors, such as paper, automobile manufacturing, construction and fertilizer. In some cases, product and processes substitution is possible, although to a far lesser extent for critical raw materials.

Mined ores are being processed and/or transformed throughout the mineral raw materials value chain.[38] In these transformation processes, both intermediary and final products are being produced, including materials derived from recycling activities. The industrial value chain typically is separated into upstream, midstream and downstream phases. Each of these phases includes different production stages or activities, leading to product ranges, aimed at specific product uses in different sectors – whether transport, consumer goods, construction or other. Along the value chain, primary products and processed metals such as cobalt or scrap metals, are being transformed in multiple ways and are frequently recycled.

There is often a differentiation between primary and downstream products. Primary products typically have a large spectrum of end-uses, such as steel-casted products or aluminium-extruded products, which then are used in many applications, e.g. construction, vehicles, planes, ships or infrastructure. They are used in the global high-tech and eco-industries, such as wind turbines, solar panels, energy-efficient light bulbs, electric car batteries and biofuels.

In some cases, raw materials can account for a considerable share of the costs in the production process, depending on the industrial value chain. For example, iron and iron ore constitute some 55% of total unit costs for the average output of steel plants. For aluminium, the

[38] CSFB Equity Research, "Global Mining 2020 Capex", 3 March 2017.

corresponding figure is 40%.[39] In others, the quantities can be very small, yet they are critical and non-substitutable.

Raw-materials intensity – comparable to energy intensity – can be an important factor for differentiating within manufacturing industries. For mineral raw materials, the upstream processes, i.e. mining, are a critical part of the value chain, typically because of high energy intensity. To cite but one example, secondary aluminium activities consume on average 5%of the total amount of energy consumed in primary aluminium production.[40]This does not mean that in cases, downstream or recycling activities can also be energy-intensive.

The production and production capacities in the upstream processes often have a strong impact on midstream and downstream, depending on the sectors or value chains. When demand is high, market power shifts to the upstream relative to the rest of the value chain, leading to rising contract prices and in some cases, volume restrictions. This phenomenon has been reflected in the past through market squeezes in copper, iron ore or critical raw materials. In other cases, volume restrictions can be exogenous, e.g. resulting from government intervention in trade.

[39] Ecofys, CEPS and Economisti Associati, "Composition and drivers of energy prices and costs: case studies in selected energy-intensive industries", study commissioned by DG Grow, European Commission, June 2016.

[40] Joint Research Center, "Best Available Techniques – Reference Document for the non-ferrous metals industries", 2017.

Annex 2: Selected background facts and figures

Since the financial crisis, EU manufacturing value added – measured as a percentage of gross domestic product – has been recovering from a low of 14.7% in 2009 to 16% in 2016 (World Bank data, 2016). The EU manufacturing industry generates economic wealth creation in the European Union and employs 29 million workers (Eurostat data, 2016). The EU is a net exporter of goods outside of its territories, with €1,745 billion of manufactured goods exported worldwide (Eurostat, 2017). According to 2017 data of the World Steel Institute the EU is responsible for the equivalent of 10% of crude steel production globally (World Steel Institute, 2017). It imported 25 million tonnes of mineral raw materials (Country RME tool, October 2017).

Altogether, according to Indicator 7 of the 2016 Raw Materials Scoreboard, the mineral raw materials sectors are responsible for close to 40% of the value-added of the EU's manufacturing sector.

Import dependency

The European Union is self-sufficient[41] in construction materials – a group of materials referring to aggregates of sand, gravels, and stones – which are used in the European construction industry and largely traded on a regional basis. The situation is different for other raw materials, where import dependence exists.

EU-28 Import dependency indicators, by raw material, 2000-16

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Biomass	8.7	9.2	9.6	10.1	9.2	9.6	10.1	10.6	10.1	8.7	9.2	9.2	9.5	9.6	9.6	10.3	10.6
Metal ores	62.4	62.3	62.9	64.9	66.6	67.4	67.5	68.5	67.5	55.8	58.7	58.8	54.3	52.2	56.3	56.8	54.7
Non metallic minerals	2.1	2.1	2.3	2.4	2.5	2.4	2.4	2.5	2.3	2.0	2.5	2.5	2.4	2.4	2.5	2.5	2.7
Fossil energy materials	48.1	49.3	49.5	51.2	52.7	54.5	56.1	56.6	57.6	57.2	57.7	58.1	58.8	59.3	59.9	61.5	62.6
Total	18.5	19.0	19.4	20.5	20.6	20.8	21.0	20.7	20.7	19.9	21.6	21.2	22.1	22.3	22.3	23.1	23.3

Source: Eurostat.

Global Recycling Data

Base metals (aluminium, copper, nickel, lead, zinc) have high recycling rates. Some 60% of aluminium is recycled from packaging, as reflected in Eurometaux / Industry data. Steel is the most recycled material with a rate of around 85%, according to 2014 data from the Steel Recycling Institute.

Precious metals (silver, platinum, gold, platinum and rhodium) also have overall high recycling rates (+50%), as documented by the UNEP (UNEP – Recycling Rates: A status report, May 2011).

[41] The position of the EU's sourcing of materials vis-à-vis the rest of the world is measured by an indicator of import dependence, i.e. comparing its external trade relative to its 'apparent consumption'. Apparent consumption refers to the level of consumption that would be required to absorb domestic production + net external trade.

Critical raw materials: 34 out of 60 materials have recycling rates less than 1%. This includes several critical raw materials: gallium, germanium, indium, tantalum, beryllium, vanadium, rare earths.

EU Recycling Data

Up to 90-95% of base metals consumed in the EU for building/construction or automotive applications is being recycled. For automotive applications, this is accounting for Directive 2000/53/EC – also known as the "ELV Directive" and subsequent legislations; and this excludes end-products exported to third countries. Recycling rates for electronic wastes - wastes from electrical and electronic goods - stood at 34% as reported by Eurostat in 2014.

Annex 3: Products flows in raw materials – Metal ores and non-metallic minerals, 2008-15

Product Flows in Raw Materials Equivalents - RME	2008	2009	2010	2011	2012	2013	2014	2015
	Domestic Extraction (Mt RME)							
Total	445	388	379	396	369	373	350	346
Metal ores	0	0	0	0	0	0	0	0
Non-metallic minerals	445	388	379	396	369	372	349	346
	Imports (1000 t RME)							
Total	425	346	373	378	343	353	394	401
Metal ores	255	175	217	216	206	206	217	206
Non-metallic minerals	169	171	157	162	137	146	177	195
	Raw Material Input							
Total	870	734	752	774	712	725	744	747
Metal ores	255	175	217	216	206	206	217	206
Non-metallic minerals	614	559	536	558	506	519	526	541
	Exports (1000 t RME)							
Total	295	254	259	268	241	249	272	285
Metal ores	161	115	136	142	136	135	132	130
Non-metallic minerals	134	139	123	126	105	114	141	156
	Raw Material Consumption (1000 t RME)							
Total	575	480	493	506	470	476	471	462
Metal ores	95	60	80	74	70	71	86	77
Non-metallic minerals	480	420	413	432	400	404	386	385

Source: Eurostat's EU RME model – Scoreboard Indicators.

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