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INTERMIN

INTEGRATED COMPETENCY MODEL FOR EMPLOYMENT ACROSS THE RAW MATERIALS SECTOR

Deliverable 2.2

Horizon 2020

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Authors

Marco Konrat Martins, Balazs Bodo (LPRC); Amélie Vagner, Veronique Lamblin (BRGM)

La Palma Research Centre - LPRC

Rue Vautier 54 1050 Brussels, Belgium

www.lapalmacentre.eu

Project coordination

Manuel Regueiro and Luis Jordá

Spanish Geological Survey. Instituto Geológico y Minero de España- IGME

Calle Rios Rosas 23, 28003, Madrid, Spain

Phone: +34 – 913495700

www.igme.es

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Project partners

INSTITUTO GEOLÓGICO Y MINERO DE ESPAÑA	IGME	ES
EUROGEOSURVEYS	EGS	BE
BUREAU DE RECHERCHES GEOLOGIQUES ET MINIERES	BRGM	FR
ASOCIACIÓN DE SERVICIOS DE GEOLOGÍA Y MINERÍA IBEROAMERICANOS	ASGMI	ES
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Executive Summary

The 'Raw Materials sector skills, gaps and needs' work package looks into skills that employers are looking for and are likely to be in demand in the future. Gaps were identified in professional education and training against market demands assessed through three different timeframes (Deliverable 2.1). These results were compared with Work Package 1 to understand what is missing from present day education and how it should be tailored to meet employers' needs, in the different timeframes.

The first section of this report highlights the needs for adaptation and emergence of competencies in the three great areas of the raw materials sector

- Mineral exploration
- Mining & Processing
- Materials engineering and recycling

Most of the skills and competencies directly relate to the expected technological evolution and adoption across the different functions in raw materials professions as well as sustainability-related issues – managing social and environmental impacts.

Specific descriptions are given in the following section over potential needs for the most affected areas under the higher levels of qualification (Deliverable 3.1). Lower levels of qualifications are briefly considered as in how to adapt for the decreasing demand in more repetitive and mechanical tasks.

Such future considerations also depend on social and economic hypotheses. For that, four scenarios were developed in order to support the identification of the potential changes arising form the inherent uncertainties in how the future may unfold. The scenarios produced were named:

- Business as usual: assembly of main past trend hypotheses. Note that business as usual scenario is an easy reference (known past trends) but is not necessarily most probable in the future.
- Environmentally driven: responsibility of all stakeholders for the environment
- Fragmentation: a world of tensions and conflicts, companies tend to exploit new discoveries in difficult location (new frontiers); and
- Mining 5.0: scenario of radical innovation, new ways of mining in remote areas Invisible and profitable mining well accepted.

Finally, this report provides an overarching framework for competencies and skills in raw materials, supporting the creation of 'future-proof' agendas for raw materials skills provisioning.

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1. INTRODUCTION

The H2020-Project INTERMIN has started in February 2018 and will last a total of 36 months. Its goal is to create a feasible, long-lasting international network of technical and vocational training centres for mineral raw materials' professionals. Specific objectives of the project are to develop common metrics and reference points for quality assurance and recognition of training and to create a comprehensive competency model for employment across the primary and secondary raw materials sector. INTERMIN activities include:

a) To develop an international qualification framework for technical and vocational training programs on mineral raw materials' topics, based on present and future requirements by employers.
b) To foster joint international training programs by a merger of competences and scope of existing training programmes.
c) To optimise future interaction and collaboration in Europe and internationally.

The project activities require contact with people as well the collection, analysis, treatment and storage of primary data (data collected by the Consortium involved in INTERMIN) and secondary data (data collected by others and published or publicly available). INTERMIN also includes the development of a repository, which consists of a database of documents used and generated by the project.

The 'Raw Materials sector skills, gaps and needs' work package will look into skills that employers are looking for and are likely to be in demand in the future. Gaps will be identified in professional education and training against market demands assessed through three different timeframes and corresponding methods:

- Short-term (Horizon Europe): Desk research and interviews;
- Medium-term (2030): Focus Group;
- Long-term (2050): Delphi survey.

The results will be compared with Work Package 1 'Scoping & Mapping of educational-research programs' to build an integrated competency model for the raw materials sector. This will include the development of prospective scenarios and a roadmap of implementation.

This deliverable includes a Competency Model and corresponding recommendations for the development of future training agendas and curricula on raw materials in Europe and world-wide.

Future needs depend on social and economic hypotheses shaped by key drivers of change e.g. geopolitical orientations, circular economy, resource consumption patterns etc. Scenarios will be developed about such variables considering different hypotheses over a approximate 15 years timeframe. The current speed of social, economic, geopolitical change and transitions are so fast that scenarios over a longer timeframe do not seem appropriate in our case.

2. CONTENT AND SCOPE

One of the goals of the INTERMIN project is to effectively integrate a raw materials competency model to a qualifications framework (Deliverable 3.1). Skills gaps observed in the raw materials sector (Deliverable 2.1) provide the baseline for building up recommendations for future training agendas and curricula on raw materials programmes in Europe and world-wide.

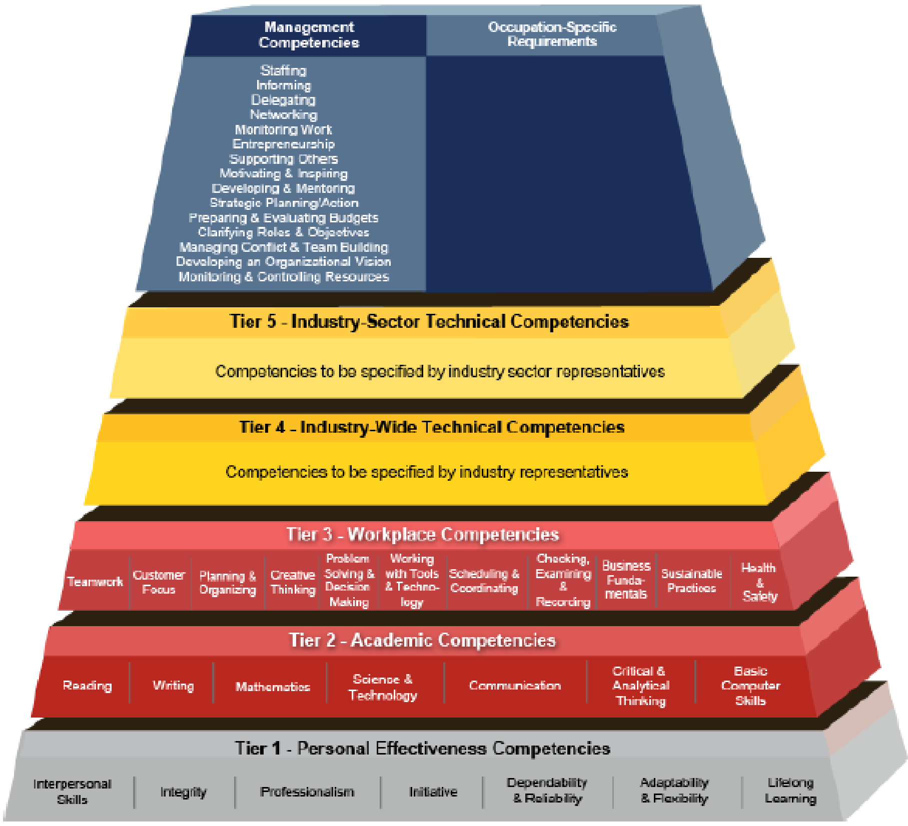


Figure 1 - Generic competency model (adapted from https://www.careeronestop.org/)

Based on the competence categories and the key competences defined by Work Package 3 (Deliverable 3.1) and the 'Skills Catalogue' (Deliverable 1.1), the identified Skills Gaps (Deliverable 2.1) are used to provide recommendations over projected needs for adaptation, the emergence of new competencies as well as providing a general overview on the impacts generated by expected future developments on the different professional levels (level descriptors 7 and 8 as per Deliverable 3.1). This process is supported by prospective scenarios analysis over a 5-15 years timeframe.

2.1 Needs for adaptation and emergence of competencies

The Skills Gaps review (Deliverable 2.1) provided the basis for understanding expected evolution of present-day trends and drivers as well as projected developments over longer time frames. This review stresses that there are two main sources of developments: socioenvironmental/Sustainability factors and technological developments. These in turn are likely to impact both the supply and demand sides of the raw materials sector.

Generic health and social tasks are expected to gain increasing importance across the raw materials value chain. That is, communication, creative thinking and problem-solving skills, sustainability and teamwork are job competencies that are becoming more important across different raw materials professions and organisations.

The following sections will examine in more detail professional areas that are likely to require adaptation and the potential emergency of new skills and competencies requirements.

2.1.1 Mineral Exploration

Increasing prospects of integrating and processing data from disparate and multi-datasets will enable improvements in many mineral exploration activities such as exploration targeting, sampling, orebody modelling and resources estimation. Techniques such as Machine Learning are expected to have increased applications integrated to more sophisticated 3D visualization software. These will be able to integrate data acquired with novel technologies such as hyper-spectral core imaging and autonomous drilling combined with improved remote sensing technologies.

2.1.2 Mineral Extraction and Processing

Data-rich environments such as mining operations will lever digital solutions that can combine Industrial Internet of Things concepts (Digital twins, 3D simulation and modelling, Machine Learning and AI) with more autonomous mining systems. This branches out in new decision-support systems and remote operating centres where a larger share of professionals are expected to work. A more autonomous, lifecycle-oriented systems design approach is likely to leverage on disciplines such as systems engineering for considering all systems requirement throughout the lifecycle of the project including decommissioning and mine closure/reclamation. Furthermore, operations will receive increasing attention on end-to-end productivity optimisation, with more integrated decision-making approaches with increased asset management applications.

2.1.3 Material engineering and recycling of waste

In addition to the previous section, efforts in increasing circularity are demanding more research and development skills for new materials applications, secondary processing techniques and technologies, new business models, policy and regulation analysis. It is perceived as a consensus that skills and competencies in those areas are likely to increase and gaps in professional training should be identified, monitored and tackled.

2.2 Lower level descriptors, disappearing qualifications and reorientation routes

INTERMIN Project puts stronger focus on higher qualification areas of raw materials training (Levels 7 and 8) and therefore this section does not intend to provide a sound review for 'Level 6' and below qualifications.

Recent assessments of skills need in raw materials sector agree that a decrease in physical and manual skills need is expected, whilst social and emotional skills and technological skills are expected to be demanded (Deliverable 2.1). This impacts more strongly lower level occupations and skills (Figure 2), as routine work demand is expected to decrease while higher level thinking to anticipate and plan activities is expected to increase.

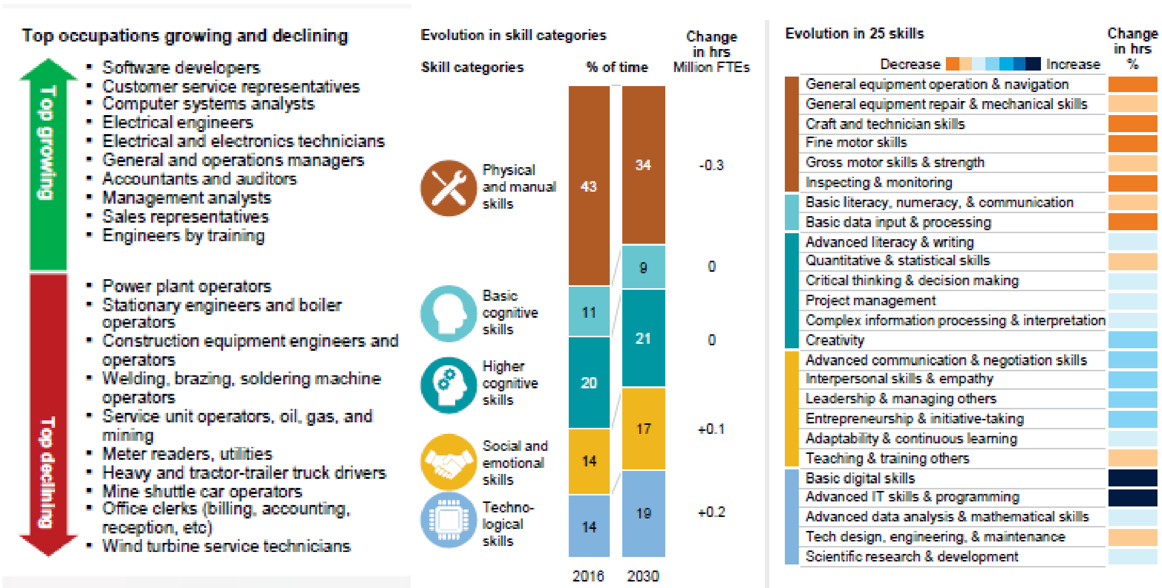


Figure 2 - Energy and Mining sector jobs and skills shift by 2030 (MGI, 2018)

Many specific occupations will then either disappear or be re-oriented to related activities. For instance:

- **Drilling:** more automated tasks, less demand for human operators
- **Ancillary fleet operators, logistics:** need adaptation for roles dealing with human-to-machine interfaces
- **Underground miners:** reduction in underground operators and increase in technology and system support staff.
- **Mineral processing staff**: managing increased information collection through the minerals processing flowsheets.

2.3 Higher level descriptors – most affected and potential adaptation needs

Higher level descriptors refer to specialised to most-specialised skills and techniques on a given subject. Professionals on that level are typically highly educated beyond undergraduate formation, with post-graduate level of studies in their field of work (Master, PhD) (Deliverable

3.1). There is a wide variety of programmes related to raw materials. Typical professions referred here are those that are traditionally employed in the raw materials sector e.g. Geoscientists[1], and Mining Engineers[2] and Metallurgical Engineers. The following sections are structured according to the main raw materials sector expertise domains and feature expectations on which areas are more likely to be impacted in the near to long-term future as well as what and where adaptation will be needed in terms of competences for employment in the sector.

2.3.1 Mineral Exploration

Level 7 and 8 – Mineral Exploration
Most affected areas • Targeting, identification and delineation of mineralisation • Exploration design • Field geology • Geo-spatial modelling
Potential adaptation needs • Advanced data analytics and simulation modelling in synergy with better understanding of orebody formation and geological processes in 4D. • Knowledge and application of principles of sustainable development • Social mechanisms of community engagement from exploration campaigns downstream. • Mineral exploration for new frontier mining e.g. deep sea and space resources.

2.3.2 Mineral Extraction and Processing

Level 7 and 8 – Mineral Extraction and Processing
Most affected areas • Drill & Blast processes, technical execution – more focus on decision support • Mining geology – less need for on-site presence • Deep rock engineering – more demand for geotechnical engineers and modellers • Mining systems – more autonomous systems will be designed and deployed • Asset management • Product marketing • Community engagement – towards embedded social responsibility in all mining extraction and processing activities.

[1] This can include exploration and mining geologists, geophysicists, geochemists, hydrogeologists among other.
[2] This can include geotechnical engineers, mineral processing engineers among other.

• Supply chain due diligence – Conflict minerals
Potential adaptation needs • Advanced/ predictive data analytics, digital twinning and simulation modelling – Remote operating centres • Systems engineering – managing increased complexity of planning, scheduling and advanced decision-making: complex system requirements definition, system design for life cycle, integration and decommissioning • Business and operating models: more customer-centric approaches, improved market forecasting and modelling, and blockchain embedded smart contracts application – increased need for integrated understanding of raw materials products development and customer demands. • Extreme environments: deeper underground mines will require a more complex combination of competencies in geotechnics, hydrogeology, mechatronics and automation. • Business management: deep understanding of 'social license to operate', how to implement environmental and social best practices as well as risk management strategies and plans. • Emerging techniques and technologies for extraction: increased demand in in-situ leaching specialists, biotechnology. Open-up of new fields such as nanotechnology. • Deep-water engineering skills for designing, implementing and operating deep sea mining projects. • Industrial ecology skills: understand the complex web of interactions raw materials are part of and is able to apply tools aligned with the optimisation of the total raw materials cycle, including resources, energy and capital requirements.

2.3.3 Material engineering and recycling of waste

Level 7 and 8 – Material engineering and recycling of waste
Most affected areas • Processing technologies
Potential adaptation needs • Investigation and development of new materials and processes • Strong understanding of circular economy principles and recycling markets. • Regulatory knowledge for secondary raw materials • Supervision and/or operation of recycling plants

2.4 Future scenarios for raw materials skills and competencies

The objective of future scenarios building is to provide a platform for thinking over contrasted hypotheses on possible futures of social, economic, political and technological aspects with the present-day trend (a business as usual scenario). These prospective scenarios will allow for considerations over the evolution of skills, knowledge and competencies needed in the raw materials professions under a 5-15 years timeframe into the future. Such exercise supports consensus building and the enhancement of anticipatory capacities on what types of skillsets are likely to be in demand and what types may no longer be needed or desirable.

2.4.1 Methodology

The chosen "Scenario" method is an assembly of engineering tools specific to foresight including both a rationale process and a common language that has to be shared between contributors. Such method requires creativity BUT limited by logic and rationale:
The foresight process and system definition towards a **prospective view of the Raw Materials Sector in the medium and long term** is based on the following 5 steps methodology.

- a) Identify *relevant* **main drivers** that will influence the future of mining and raw materials sector
- b) **grade/sort** the drivers (driving force, influence, uncertainty)
- c) for each driver, **building the *possible* hypotheses** based on past evolution, continuous trend or possible factors of discontinuities
- d) explore *possible* **evolutions** by assembling hypotheses
- e) structure at least **3 scenarios** built upon a selection of hypotheses, based on *consistent* links between drivers.

These steps are achieved with inputs based on expert elicitation and collaborative discussion among INTERMIN partners with the support of Prospective experts to animate meetings and provide a framework within the discussions.
The final scenarios will enable to better anchor the competency model in possible futures. And chosen horizon for this is 15 years: 2035 with a deployment to 2050.

2.4.2 From drivers to hypotheses

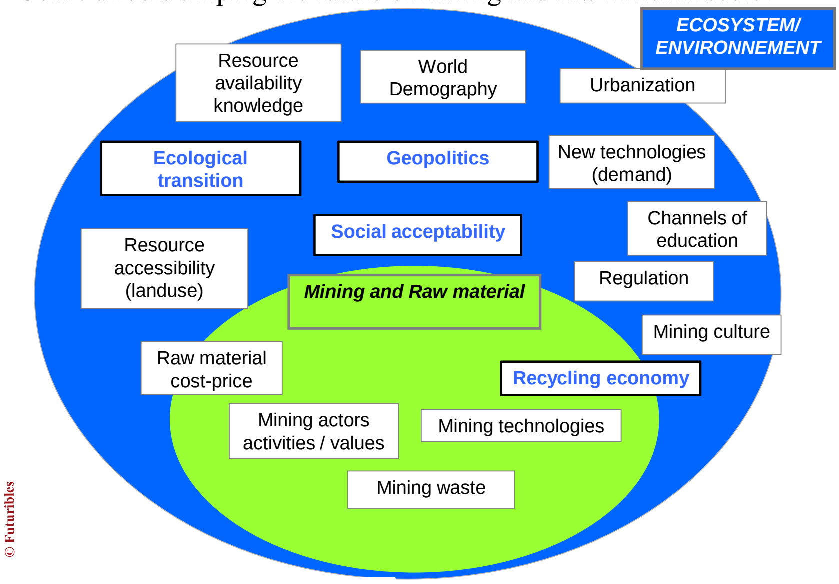
Drivers are the combination of factors and actors. Their identification can be done through different type of studies: experts elicitation, actors/stakeholders interviews, literature analysis, surveys or collective brainstorming.

Study duration is linked to the number of drivers: it is therefore limited to 6 to 8 drivers considering the time dedicated for such task in INTERMIN.

<u>Global identification of main drivers</u>

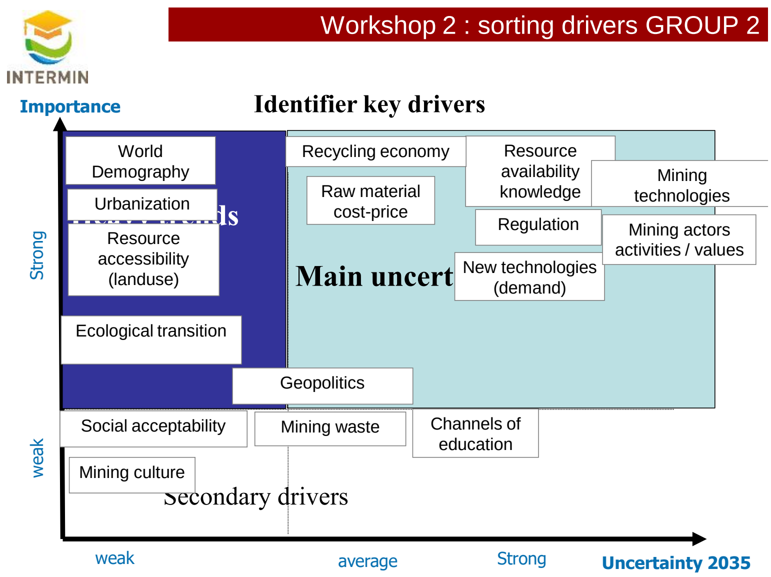
A first internal session was performed within BRGM in 25/01/2019. It gathered 8 researchers, engineers and experts in different fields of Raw Materials (primary resources, circular economy, exploration, European priorities, etc.) in order to brainstorm on the main factors and actors, which lead to 16 drivers listed, and among these 4 were considered as a priority:

Goal : drivers shaping the future of mining and raw material sector



Selection of 6-8 main drivers:

Based on this first rough approach, a second workshop was organised with partners during the Madrid meeting on 30/01/2019 in order to refine the identified drivers and set level of importance and degree of uncertainty for each of them. Discussion was organised in groups to sort drivers. As an example, the results of Group 2 is reproduced below:



Considering that world demography is always a heavy trend (just one hypothesis), and Mining culture is always a secondary driver, the following **8 drivers** have been to be documented:

Key drivers	Definition/rationale
1. Geopolitics	Geopolitical context of countries with resources, condition of access (from bribery, quotas, to sustainability labels)
2. Regulation /legislation	Environmental impact regulation, taxation, exploitation permits
3. Social acceptability	Environmental consciousness and acceptability bound to mining and material processing ("not in my backyard", acceptability of impact transfer to other countries….)
4. Recycling and circular economy	Waste treatment, recycling technologies or business models like service economy (rent a product instead of selling it)
5. Mining and processing actors and activities	Number of actors and strategy on the value chain (mining, processing, recycling) ; corporate social responsibility
6. Price and production cost of raw material	The profitability of raw material production is driving mining choices of companies
7. Companies technologies to find, access and process materials	Technological improvement in finding, accessing and processing raw material, including artificial intelligence
8. Channels of education including field experience	Channel to access knowledge and competencies especially about field experience (enhanced or virtual reality ?)

Building the drivers' hypotheses

For each driver an average of 2-3 clearly *independent* hypotheses of future evolution are identified. Past evolution (with relevant data and long-term time series) are described, hence building the initial hypothesis of continuous trend, then possible wild cards or factors of discontinuities are put forward for the description of other hypotheses.

Here is an example for *Driver 8 – Channels of education including field experience*. 3 identified hypotheses are:

Hypothesis 1 - The reality in the field at the heart of training *(continuous trend)*	Although digital learning reveals a multitude of concepts training, the mining industry and the raw materials sector only partially adopt it. Everyone learns differently, with its own pace, using adaptive or personalised approaches. The development of interactive videos in which the interaction of the learner is stimulated with a personal smart virtual assistant or chatbots, is in full swing. However, acquisition of hard skills of technicians and engineers in mineral resources industry (evaluation of the mining potential of a given region, the choice of targets for detailed studies, the estimation of discovered mineral resources…) can be only learned in real work situations, on the ground and by the return of experiences.
Hypothesis 2 - Virtual reality and Augmented Reality	Immersive training is expanding in the mining and raw materials sector, replacing the field experience. Technical means of virtual reality take learners to the field, where realistic situations are reproduced. With immersive virtual learning systems, staff is trained safely, with real-time interactions. But soft skills (project management, innovation…) still require field /group experience, human interactions.

Hypothesis 3 - Automated Learning	*Advances in brain imaging and knowledge of brain development and function have allowed to improve the learning process, to accelerate its learning capacity. The brain stimulation is well managed: the electro-stimulation of specific areas of the brain accelerate the creation of new neural connections corresponding to a specific skill.* *These techniques are beginning to offer new perspectives: the ability to transfer knowledge directly into the human brain, allowing instantaneous acquisition of new skills including soft skills*

The 8 drivers files with references can be found in Annex.

2.4.3 Future scenarios

With the established hypotheses, one dedicated online workshop was undertaken in order to:

- Review hypotheses in detail for each driver to keep meaning in mind. Some hypotheses are rephrased during the meeting
- As reviewing identify "main trend hypothesis", e.g. the one extrapolating past trend without (much) change
- Using the scenario table below: main trend scenario/reference scenario is assembling each main trend hypothesis
- Generate alternative scenarios: one hypothesis per driver (a scenario is a storyline).
    - Each participant (or by location) try to build 1 or 2 alternative scenarios on its own
    - To collect scenarios /name scenarios

During the workshop meeting the draft of the storyline has been described.

Following scenario storylines are following two rules:

- Consistency of the storyline: use the logical links and solve by explanation possible contradictions

2.4.3.1 SCENARIO 1 - BAU (Business As Usual)

World demand for raw material is still increasing but for many producing countries, resources extraction and trade become a political tool of foreign policy bargaining (quota, taxes, and export restrictions). Demand increases especially for small strategic metals that are often almost impossible to recycle and are produced as by-product of main regular metals. To meet this demand, mining companies reduce their costs with increased automation of processes (e.g. autonomous trucks) in the mine and by improving separation processes for some specific raw materials. Companies manage to improve their energy efficiency, though industry energy consumption still increases due to higher production of raw materials.

The profitability of mining companies tends to be lower for three reasons: taxes required by the countries owning the resources, the ores grades continue to decline often with more complex mineralogy requiring improved techniques and energy. Moreover, market price of main metals (copper, aluminium, iron) tend to be lower than their recycled counterpart. Recycling of easy to process material like copper, iron or aluminium has become usual in rich countries (OECD) since they have enough waste to process it into secondary raw materials and because the number of countries allowing waste importing is reducing. By 2030, countries like China recycle also the main and easy to recycle metals. But most small or by product metals are not recycled because it is not economically profitable. Low value waste is still sent or partly sent to poor countries but less and less countries accept it. Rich countries must develop specific recycling solutions for waste, but the last part of the waste, once sorted, is safely buried. Scandals may occur for the electronic waste between 2030 and 2050 for soil pollution.

For profitability reasons mergers and acquisition of large mining companies is still going on. It allows economy of scale for exploration and the mining landscape is dominated by mega-companies including Chinese ones. From 150 largest companies that produce 85% of the mineral production in 2017, only 100 large companies produce the same share of minerals in 2030.

This oligopoly has also more bargaining power with producing countries to acquire permits and negotiate taxes with countries. It is also easier for them to adapt the variety of regulation all over the world, EU included. Artisanal and small company mining is decreasing. But mining companies still have a despicable brand image for the media and most people: they exploit a non-renewable resource; the activity is often bound to bribery and corruption for mining rights. Mining is welcome only to communities who can work or benefit from it. Companies, to improve their image for investors, tend to show the good environmental and social mining experiments, but it is frequently just ‘green washing’.

Although digital learning reveals a multitude of concepts in training, the mining industry and the raw materials sector only partially adopt it. The general science (physics, chemistry) and typical example of mineral science be learned in a classroom or through e-learning. But practical leaning, hard skills like evaluation of the mining potential of a given region, the choice of targets for detailed studies, the estimation of discovered mineral resources still requires field experience.

2050

The oligopoly of very large mining companies is even smaller, around 80 companies. Among the top ten, three are Chinese (only one in 2017). The rate of recycling of the easy-to-process metals increases. Thus, the profitability of this metal production becomes lower and contributes only to 40% of the profits, 60% of the profits is earned by by-products. By-products seen as strategic raw materials are still very little recycled since the weight to recover is too small in most industrial products and the chemical composition changes quite often (not time to set up a new recycling process and value it). But some might be recycled in 2050. All the mining operations - from the mine to the processing plant – reaches high levels of automation. Exploration uses more data from all sources (3D seismic, satellite, UAV). Artificial intelligence, by analyzing quicker than man all past data, slowly helps evaluation of the mining potential of a given region, the choice of targets for detailed studies, the estimation of discovered mineral resources. Little or no mining in deep sea or poles, instead poorer ore is exploited.

2.4.3.2 SCENARIO 2 – Environmentally driven

Logic: responsibility of all stakeholders for the environment

2030

To improve their brand image toward investors, to attract the best engineers and geoscientists for hiring and to avoid demonstrations against mine exploitation, mining companies understand they have to take steps to improve their social and environmental behaviour. For investors, it became a necessity when the criteria to evaluate companies went beyond the financial performance and took into account impacts of the mining activity on society at large (e.g. social and environmental responsibility). International mining agreement arose in 2025 between big mining companies and most States owning mineral resources, to more common rules to access mineral endowments (permits, taxes, contracts, international exchange conditions) in exchange for minimum social and environmental standards. International organizations (UN, World Bank) have pushed this agreement to end corruption and the “resource curse” of many countries - mining should help the development of emerging countries instead of feeding bribery and corruption. Clean mine products are now certified by a label (“sustainable mine product”).

Big mining companies agree to set up minimum social and environmental standards at world level, concerning energy consumption, water use and pollution, mine waste management and workers welfare. They are also accountable for their sub-contractors behaviour since NGO’s may check local work conditions and publish which mining company partners with illegal ASM or ASM with poor environmental or social behaviour. Thus, illegal ASM decreases tremendously and mine exploitation is accepted by local communities since they benefit from it.

Some regions like Europe still ask mining companies for more severe standards than the world standards; for example, working hours must also comply with EU work standards, pollution requirement are more severe and remediation of the mining site at the end of the production is subject to more strict rules.

Moreover, mine product certification forces a transparent working process of the mining companies to allow accountability and actions and to show their activity benefits local communities.

The environmental issue is growing everywhere in the world with the occurrence of more extreme climate events, water scarcity and the pollution scandals (plastic waste in the ocean, polluted soils or rivers with heavy metals etc.) in news headlines. The energy transition, that has been going on since 2005 (Kyoto agreement), accelerate after 2020. It is more mineral intensive since people want the new appliance/vehicle that reduces the energy consumption. This trend boosts the mining sector, but the demand profile leans towards more for specialty strategic metals than for the main ones.

More and more countries ban waste imports in their countries (it started with China and Indonesia), and EU in 2025 bans waste exports. Citizens agree to sort for recycling and in rich countries people tend to rent some of their appliances (cars, electronics, dish or laundry washers) to the manufacturer instead of buying it if the manufacturer certifies it repairs and recycle the products while offering to consumer a product that is always up to date.

People agree to pay for recycling since an ‘ecotax’ is taken on all appliances. In Europe, where ecology and recycling is high in the political agenda, the ‘ecotax’ is modulated to promote objects built with secondary raw materials. Broad recycling of products as well as materials created millions of jobs in the EU and forces, on one hand, manufacturers to build objects easy to dismantle and, on the other hand, recycling companies to set up new processes to separate metals in complex materials. By 2030, some specialty strategic/by-product metals are recycled, the cost is paid by the ‘ecotax’.

There is a change in the profile of mining companies involved in mine production and processing – with new entrants, the ones who survive, take environmental issues into account and reduce drastically the energy and water consumption (water treatment to reuse process water) of the production and ore process. They engage into remediation of the mining site after exploitation first in OECD countries then Asia/latin america and in Africa after 2030. Their operations are more automated with the use of autonomous, electric trucks. The improvements in processes for ore processing and material separation in processing can sometime be adapted in the recycling industry.

Big companies re-position themselves as raw materials producers, increasing their focus in exploration and recycling. Exploration benefits from many new data sources helped by technology (e.g. seismic 3D, satellites, UAV…) and from data treatment with the help of artificial intelligence. Recycling becomes a real and profitable activity, innovating in the separation processes of complex materials benefiting from ore process progresses.

Mining engineering and technical education does not require any more much field experience. The transparency of the mining processes, required for certification, allow filming in the mine. Thus interactive course with immersive virtual training is expanding in the mining and raw materials sector, replacing the field experience. Virtual reality takes learners to the field with real-time interactions with his tutor, where realistic situations are reproduced. But soft skills (project management, stakeholder communication) still require field /group experience, human interactions.

2050

The issues of this scenario to 2050 are clearly first, the recyclability of specialty or by-product metals that are the most demanded and costly and second, the profitability of mining companies for main metals since secondary resources of main metals are favoured. Recycling has become a true profitable industry.

Finally, in 2050, recycling and material substitution competing with mining production tend to start reducing mined material demand. Moreover, the mining sector is expected to reduce its own carbon or pollutant emissions. The big companies and the small mining actors that are able to produce low-carbon premium minerals by using renewable energies for their process and recycle the water used for the process tend to dominate the market. This is pushed by a double trend, the labelling of low carbon and sustainably mined minerals and the increasing cost of fossil energy.

2.4.3.3 SCENARIO 3 – Fragmentation

Logic: in a world of tensions and conflicts, big companies tend to exploit new discoveries in difficult location like poles and deep sea.

2030

The control of major deposits in most countries generates tensions, corruption and conflicts. World countries compete for resource accessibility, thus mining permits are still often delivered through undercover bargaining in 2022. As a consequence, almost everywhere there is a strong local opposition to mining, especially when performed by multinational companies; not only because local communities do not benefit of this production source of bribery but also because the environmental impact of mining for communities. The environmental performance of companies is perceived to weaken with time since they have to dig deeper to access poorer ore, the social performance is not perceived since local communities do little work for the mine.

Mining countries, from 2020 to 2030, tend to regulate (permits, taxes, environmental mining conditions) better the mining activities including to favour local mining companies or to foster their creation. But regulation, legislation and its enforcement vary a lot from a country to another. Even in Europe, regulation still varies among Member States.

New challenges posed by this scenario come mainly from more disrupted trade flows of raw materials. Countries and economic blocks will regard as strategic their access to raw materials within their own boundaries – putting increasing emphasis on new frontiers for mineral exploration and exploitation as well as the recycling and re-use of local stocks..

Fortunately for main mining companies, quick automation of big data analysis adds new means of exploration - seismic 3D, satellites, marine ground mapping, UAV - bring new discoveries exploited as soon as 2025. They benefit from oil and gas exploitation process adaptation. The big mining companies tend to mine more in new location like arctic (thanks to climate change) and deep sea.

Circular economy and recycling stay as a motto for young urban rich and educated people, but the economic performance of recycling is not met and secondary raw materials are more costly than primary raw materials. Since most citizen are not willing to pay more for recycled materials, recycling targets in rich countries, like targets of EU directives, are not met. With the exception of easy to recycle materials, the waste of complex materials is still sent to the last countries that accept it in Asia and to African countries. Thus, the mining demand is high.

In this fragmented world, there is more automation and big technological improvement at all stages of the process for big companies. Improvement of the ASM process to more mechanized exploitation except where illegal mining is still blooming. Ore process to extract metals (main and by-products) improves in terms or energy consumption but it depends if it is managed by big companies or by small ones, big companies improve their process faster. Since there is very little recycling, profitability stays half due to main metals and half from by-products.

Digital learning is only adopted partially by the raw material sector. Hard skills of technicians and engineers in mineral resources industry depends so much of the company type (Big companies/ASM), the technology used and the location. Although the theoretical material background has to be the same, a greater variety of field situation and experience (Big companies, very high tech, specific locations/ASM low-medium tech and regular location) is needed to be fully experienced.

2050

For the 2030-2050 horizon, the mining value chain is very fragmented.

Big companies concentrate on exploration, exploitation of high-tech location (very deep deposits, offshore, and poles) with rich ore and improved processes

2.4.3.4 SCENARIO 4 – Industry 5.0

Logic: scenario of radical innovation, new ways of mining in remote areas. ‘Invisible’ and profitable mining well accepted.

The decision about mineral policies and rules and framework are proceeded at EU level around 2023 for permits and environmental procedure. Although enforcement and final negotiation is done at national level, increasing regulation all over the world with strong variation among countries lead the mining industry to sign a code of business conduct for responsible mining, sustainable exploitation and promote the development of emerging countries at international level. Policy and regulation secure mining investments as long as mining companies are allowed to participate political debates and regulation ensures a fair competition to mining permits.

At the same time, waste recycling and circular economy has become an important target in the political agenda. More and more countries, first in Asia, later in Africa, refuse to accept foreign waste, finally EU bans waste export. Hence governments and citizen become pro-active in sorting recycling and more often renting appliances to improve maintenance and object repair. People accept to pay for recycling through an ‘eco-tax’. Recycling becomes a valued activity area creating millions of extra-jobs in Europe.

In **2030**, main metals are generally recycled and only some specialty strategic metals are recycled with new processes to separate metals in complex objects. But the industry is always changing mineral composition of new alloys, thus it is impossible to recycle all metals and demand for specialty strategic metals is still high.

Fortunately, innovation, not only in exploration but also in exploitation allows to mine in new territories. Digitalized and automated mining has been developed by big international mining companies to mine in severe environments: poles but mainly deep sea where ore deposit are now richer than the ones found on land. Regions with vast maritime territories such as Europe are more competitive.

Most part of the process: exploration, exploitation, logistic and ore processing and separation are automated. Mining sites tend to use renewable energies for their need to produce low-carbon raw materials. But the mining process has to be clean, for example, deep sea mining is not performed by dredging anymore which destroys marine habitats ad impedes fish stock renewal. The automation of mining allows precision mining where ores are sucked on the off-shore platform with as little as possible disturbance of the surrounding sea floor. On land, clean mining avoiding air and water pollution takes up with large investments, but moderate operating cost at the end because of automation. Clean mining means also reversibility of mining impacts. To avoid this cost remote or deep-sea areas are often favoured. This remote mining also has an advantage, there is no local communities around, mining is invisible thus well accepted; acceptance is also bound to the miners’ code of conduct and clean mining technologies.

Immersive training is expanding in the mining and raw materials sector, replacing the field experience. Technical means of virtual reality like virtual masks take learners to the field, where realistic situations are reproduced.

With immersive virtual learning systems, staff is trained safely, with real-time interactions. But soft skills (e.g. project management, communication with stakeholders) still require field /group experience, human interactions.

2050

The logic of this scenario leads to more in-situ extraction techniques to recover only or mainly valuable by-products or specialty metals. Full automation in the mining process and exploitation of remote areas will take more than 10 years, thus the scenario described until 2030 would more realistically last until 2040.

2.4.4 Implications for raw materials professions, jobs, skills and competencies

In face of the uncertainties arising from the scoped drivers of change, the scenarios developed from the identified hypotheses can be used to test assumptions and projections of skills needed across a range of plausible futures. This assessment is of great importance for testing the robustness of any raw materials competence model and better orient strategies for implementation of an agenda that explicitly accounts for the different pathways the raw materials sector can take, how it can be monitored and successfully implemented. This section presents an overview on the implications that each scenario can have in terms of skills – technical and soft skills (Deliverable 2.1).

Business as usual	
Technical skills	- Confirming current projections, skills related to business management and mining equipment and systems are increasingly required. Current challenges such as 'Social License to Operate' and proficiency on designing, applying and managing more advanced mining systems (with greater levels of automation) are a mong the leading areas of professional demand in the sector. - Exploration requires specific skills of data acquisition (sensor positioning) requiring on site learning; but also big data analysis. Data acquisition with UAV and autonomous logistics requires pilots trained to remote control. Ore exploitation still requires training sessions in mine sites of the big companies. Ore exploitation and processing requires more energy efficiency thus energy engineering is valued to improve the mining overall process.
Soft Skills	Soft skills related to more sustainable operations and business models will continue to increase in demand. Bargaining (permit negotiation), project management and communication are required in this scenario and are almost more important than technical skills (technological improvement is limited in this scenario). It implies, for companies employees, to manage language and culture of the country in which they operate. Project management probably requires direct contact with local officials and communities as well as planning technics that can be learned at school. A key competency, in this scenario, is communication to let know as much as possible all environmental improvements and all benefits brought to local communities. Legal competencies are also very important considering the variety of world mining regulation.

Environmentally Driven	
Technical skills	- More transversal environmental sciences across all disciplines and professions related to the raw materials value chains. Professionals are increasingly demanded in skills and competencies related to compliance with stricter environmental regulations, certifications and requirements, stronger focus on waste, resource efficiency and industrial ecology. Principles of the 'Circular Economy' are well translated into the raw materials businesses; in the ability to investigate and develop new processes and materials, to manage waste and emissions and design and apply new technologies in line with the increasing of circularity across different raw materials value chains. - Exploration: data acquisition and management, artificial intelligence. Mineral targets will be explored not only for main metals, but also other resources that in the past would be considered waste. Remote Operating Centres for integrated operations. Recycling (raw material extraction from waste) with more emphasis than in the previous scenario. Mining processes (extraction + ore treatment) should be managed under stronger environmental regulations, not only for water and energy but also any kind of pollution and restoration plans after mine use is in the value chain. Mechanised, low consumption technologies for extraction that may use renewable energies. 'Sustainability labels' become the normal.
Soft Skills	Project management still exists but permanent employees are generally locally trained people. Foreign engineers and technicians visit the mine site just for short missions. Social performance professions become critical for successful operations, especially in communities strongly impacted environmentally and economically by nearby operations. Greater awareness and interest of general population on the environment increased the competence levels companies need to deploy in their business in order to successfully engage and communicate with a complex web of stakeholders.

Fragmentation	
Technical skills	- For big companies exploration requires specific skills of data acquisition (sensor positioning requiring on site learning; data acquisition by satellite or drones); but also big data analysis and artificial intelligence competencies. Robotic, new high tech production to drill deeper and in new environments and equipment management in these environments. At the same time, for ASM, regular mechanized mining technology training is required. Recycling training of ASM at the end. - New frontier exploration and unconventional mining methods will require specific training for developing skills in different environments and specific challenges posed by these types of operation.
Soft Skills	Creative thinking and problem-solving skills will be particularly important to come up with new solutions for developing mineral projects in new frontiers and with unconventional methods. Training to sustain extreme environments

Mining 5.0	
Technical skills	- Engineering skills. Robotic and remote control. Environmental engineering. Innovation. Very high emphasis on recycling thus on raw material extraction from different waste. Micro and nano metallurgy. Mining process (extraction + ore treatment) should also be environmentally managed, not only for water and energy but also any kind of pollution and restoration plans after mine use. Mine environmental management might require on site data collection and analysis (competencies close to the ones required for exploration). - Specific centre equipped with virtual reality for training; specific motion training is taught through equipment like a Wii console
Soft Skills	Soft skills are quite high in a scenario of such technical innovation. Because it means that mining companies allow their employees and sub-contractor to innovate, thus allow changes and experiments in the working process. It generally means that the company takes risks and has a strong trust culture. High levels of autonomy pushes companies to focus more on stakeholder management than technical personnel on-site.

2.5 Integrated competency model – towards a 'future-proof' agenda

As proposed in Deliverable 3.1, INTERMIN areas of competencies can be classified as per area in the value chain (mineral exploration, extraction and processing, material engineering and recycling) and by categories of competencies: raw materials specific, management competencies, conceptual competencies and implementation competencies.

In this sense, this report goes beyond in acknowledging existing gaps and future developments of the raw materials sector into the different areas and categories of competencies.

Table 1 - Integrated competency model

	Mineral exploration	**Mineral Extraction and processing**	**Material engineering and recycling**
Raw materials competencies	• Advanced data analytics and simulation modelling in synergy with orebody formation and geological processes in 4D. • Mineral exploration for new frontier	• Industrial ecology • Deep rock engineering/ Geomechanics • Advanced data analytics and simulation modelling • Responsible mining due diligence	• Investigation and development of new materials and processes • Advanced data analytics and simulation modelling

	mining e.g. deep sea and space resources.		
Management competencies	• Social mechanisms of community engagement from exploration campaigns downstream.	• Market forecasting and modelling • Blockchain embedded smart contracts • 'Deep social license to operate'	• Supervision and/or operation of recycling plants
Conceptual competencies	• Knowledge of principles of sustainable development		
	• Systems thinking	• Advanced/ predictive data analytics, digital twinning and simulation modelling • Systems engineering • Deep-water engineering	• Recycling markets and regulations
Implementation competencies	• Application of principles of sustainable development		
		• In-situ leaching, • Biotechnology • Nanotechnology. • Deep-water engineering • Electrometallurgy • Environmental and social best practices as well as risk management strategies and plans.	

3. CONCLUSIONS

Deliverable 2.1 provided the basis for locating the needs for adaptation in the different areas of the raw materials sector qualifications framework. Current needs were projected in the future accounting for the emergence of new ones, which in turn should be featured in the competence model in order to improve preparedness and anticipation capacities. This is supported by the creation of the scenarios – a process which identified relevant drivers of change as well as established hypotheses for each driver regarding the future. Such 'what-if' type of exercise widened the perspective on the potential needs for raw materials skills provisioning. It is clear that the sector is going through a global transformation in its activities, mainly through technological evolution and social expectations, however the rate of change, geographical aspects, among other uncertainties, are likely to pose different challenges across different regions and countries.

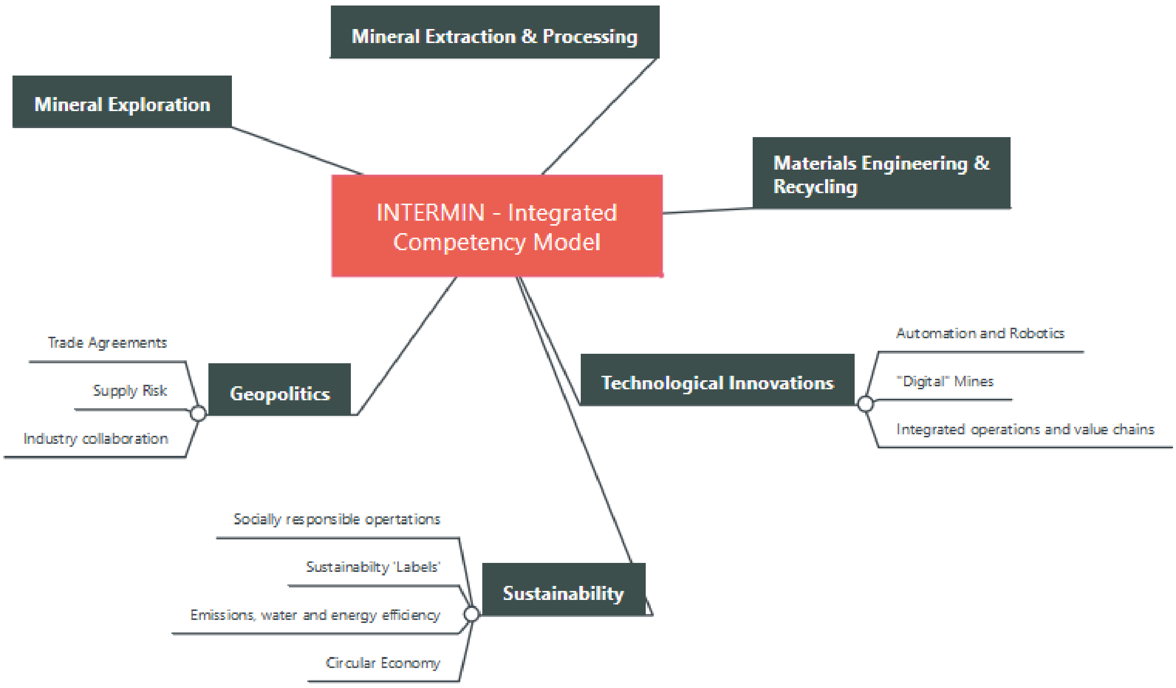


Figure 3 - Mind map of the competency model covered areas

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ANNEX A – SCENARIO DRIVER FILES

1. Geopolitics

Driver definition

Geopolitical context of countries in which major ore deposits are located represents a risk assessment for investors, mining operators and downstream industries transforming raw materials into various products.

Pertinent Indicators and past development

Scarcity of resources and conflicts

Industrial mineral and metallic ore deposits of the world are not equally distributed on Earth's surface. Their concentration depends on complex physical and chemical control parameters, as well as specific geodynamic conditions, that are relatively rare to meet together and finally reach the genesis of an economic deposit. Most of ore deposits are considered as non-renewable resources as the time necessary to form them is very long compare to human life.

Because of the scarcity of some specific resources (precious or rare with high value), disputes for the ownership and control of resources have been often the reason of social and political tensions along human history. Conflicts for mineral and metal resources have even be the starting point of major wars between ethnizes or nations. Most recent examples are the Persian Gulf and Iraq wars engendered for the control of oil fields or civil wars in Angola, Sierra Leone, Liberia and Ivory Coast causing bloody extermination for diamond or gold deposits possession. **At least 41% of total number of conflicts between 1946 and 2008 were related to contests for natural resources** (117 over 285 after Rustad and Binningsbø, 2012[3]). The environmental scarcity of mineral resources, the governance and the potential risk assessment of conflict generation are closely linked together (Figure 1).

[3] Rustad, S.A., Binningsbø, H.M. (2012) A Price Worth Fighting for? Natural Resources and Conflict Recurrence, Journal of Peace Research 49(4), p. 531-546.

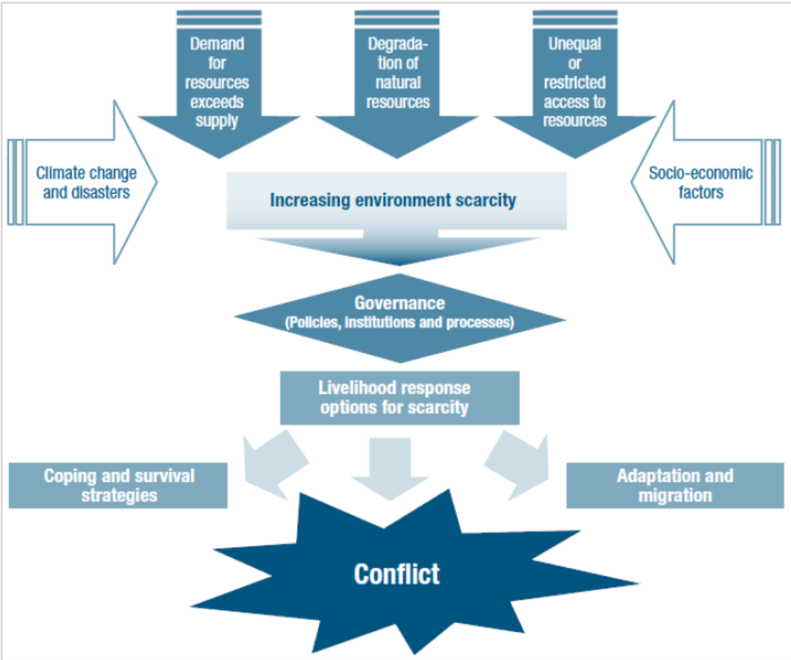
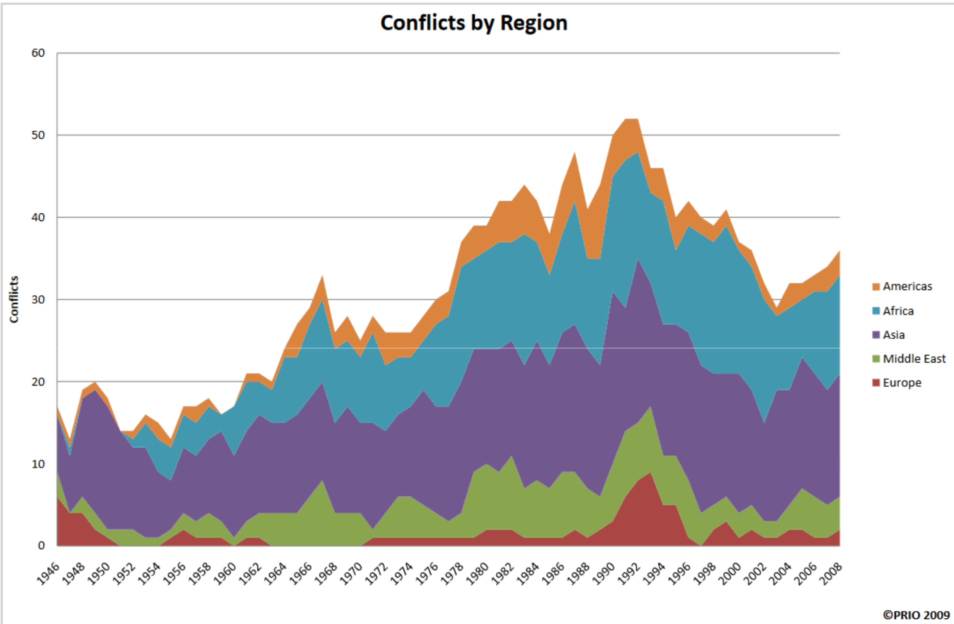


Figure 1. Links between environmental scarcity of natural resources, governance and potential conflicts (Source: UNEP[4]).

The Peace Research Institute Oslo (PRIO) database has numbered conflict episodes between 1946 and 2008. Number of conflicts by region and types are shown in Figure 2. Between 1960 and 1994, intrastate and internationalized conflicts are rising and dominant in comparison to interstate and extra systemic disorders. Conflicts are occurring more often in Americas, Asia and Africa compare to Europe and Middle East.



[4] UNEP, Guidance note for practitioners, The United Nations Interagency Framework Team for Preventive Action, 2010, p. 13.

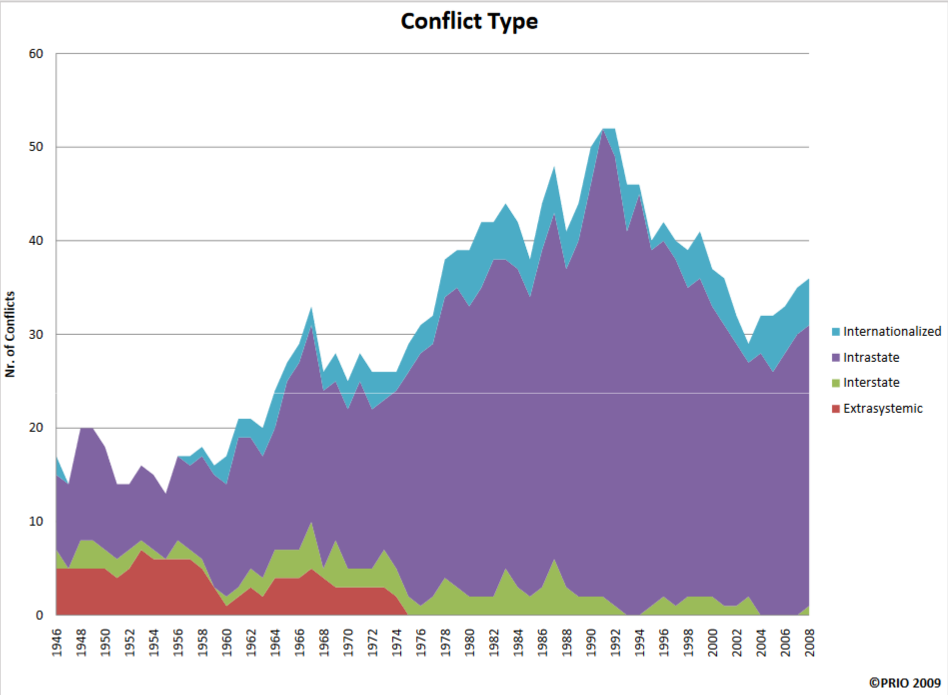


Figure 2. PRIO database showing number of conflicts by region and type (available at: http://www.prio.org/Data/Armed-Conflict/UCDP-PRIO/Armed-Conflicts-Version-X-2009/).

Through time, the number of conflicts on average increased in the past 30 years comparing with 1950-1980.

Geopolitical risk assessment

Social and political stability of countries in which raw material resources are located affects directly openness for investments, as well as the facility of exploration and mining project development. Major transnational mining companies and investors prefer capitalizing in countries where governments are reputed stable to maintain a high level of security for workers and their infrastructures or to avoid permits, regulation and taxation changes. Moreover, for downstream industries importing and transforming raw materials into various products, the geopolitical risk assessment is also of major importance to set the strategy of trades if commodities and market are concentrated in a specific area with high insecurity. Main considerations of geopolitical risk are corruption, criminality, terrorism, disrespect of human rights, labour law or intellectual and physical properties.

The different producer countries can be classified according to international standards considering in particular UNCTAD (U.N. organization dealing with trade, investment and development issues) and IIASA (International Institute for Applied Systems Analysis) classifications. Producer countries are still mainly unstable as shown in Figure 3 : more than 65% of producer countries are classified as unstable or highly unstable.

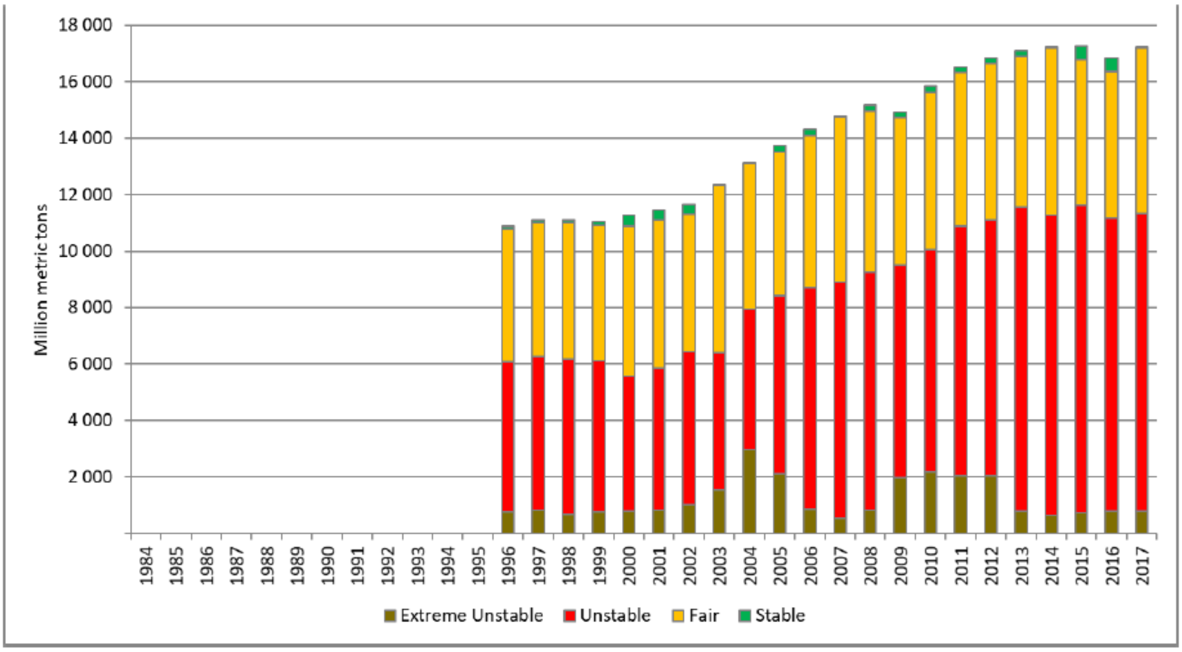


Fig. 6: World mining production 1984 - 2017 by political stability of the producer countries (without construction minerals, in Million metr. t)

Source : WMD 2019

Globally the political instability of producing countries increased through time in 1998-1999, around 54% of producing countries were unstable or highly unstable, around 60% in 2007 and 65% in 2017.

The “Freedom in the World Index” (FWI, 2018[5]), presented in Figure 4, assesses the condition of political rights and civil liberties around the world. Countries which are the least free (scoring close to 0) correspond to countries that encompass authoritarian rules (totalitarianism), public oppression or ethnic persecution, a hermetic policy, dictatorship or a civil war.

[5] https://freedomhouse.org/report/freedom-world/freedom-world-2018

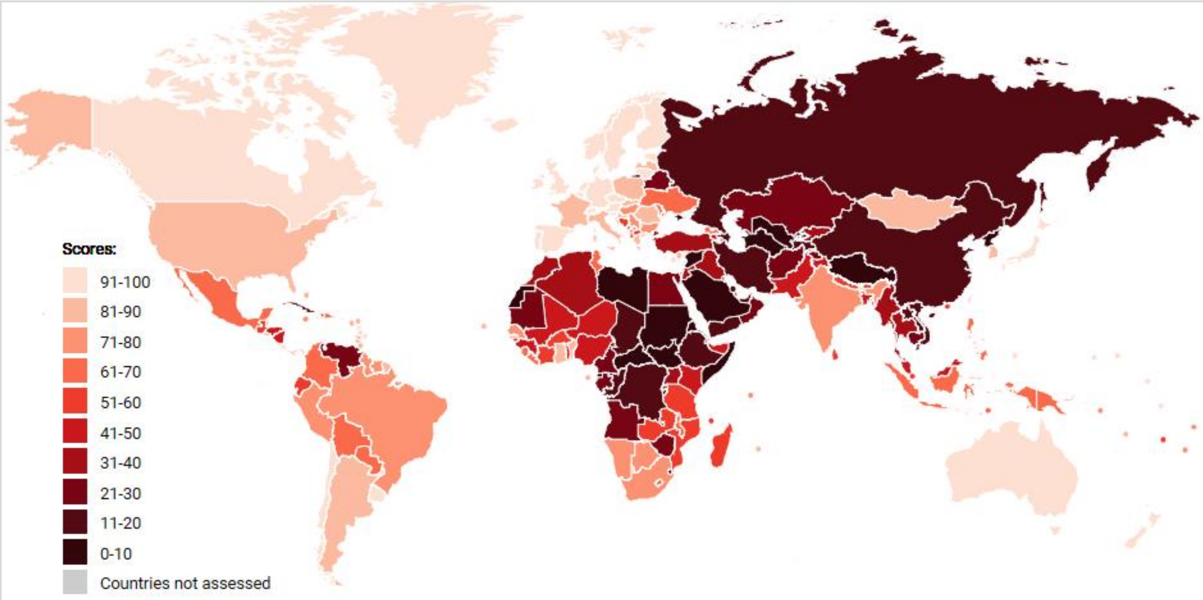


Figure 4. Map showing FWI[3] score ranking in the world by country for 2018 (Scores in a Likert scale ranging from 0 for least free countries to 100 most free).

The worldwide Governance Indicators rely on 31 data sources gathered from 25 different organizations around the world. A dynamic risk monitoring system based on worldwide governance indicators (WGI) that may change with time is available (methodology established by KAUFMANN, KRAAY and MASTRUZZI, 2010[6]). WGI able to evaluate the corruption perceptions of the public sector on a Likert scale of 0 (highly corrupt) to 100 (very clean). The World Bank continue to update each year the ranking of countries using WGI to assess transparency international, as illustrated on Figure 5 for the governance's effectiveness and political stability.

[6] Kaufmann, Daniel, Kraay, Aart and Mastruzzi, Massimo, The Worldwide Governance Indicators: Methodology and Analytical Issues (September 2010). World Bank Policy Research Working Paper No. 5430.

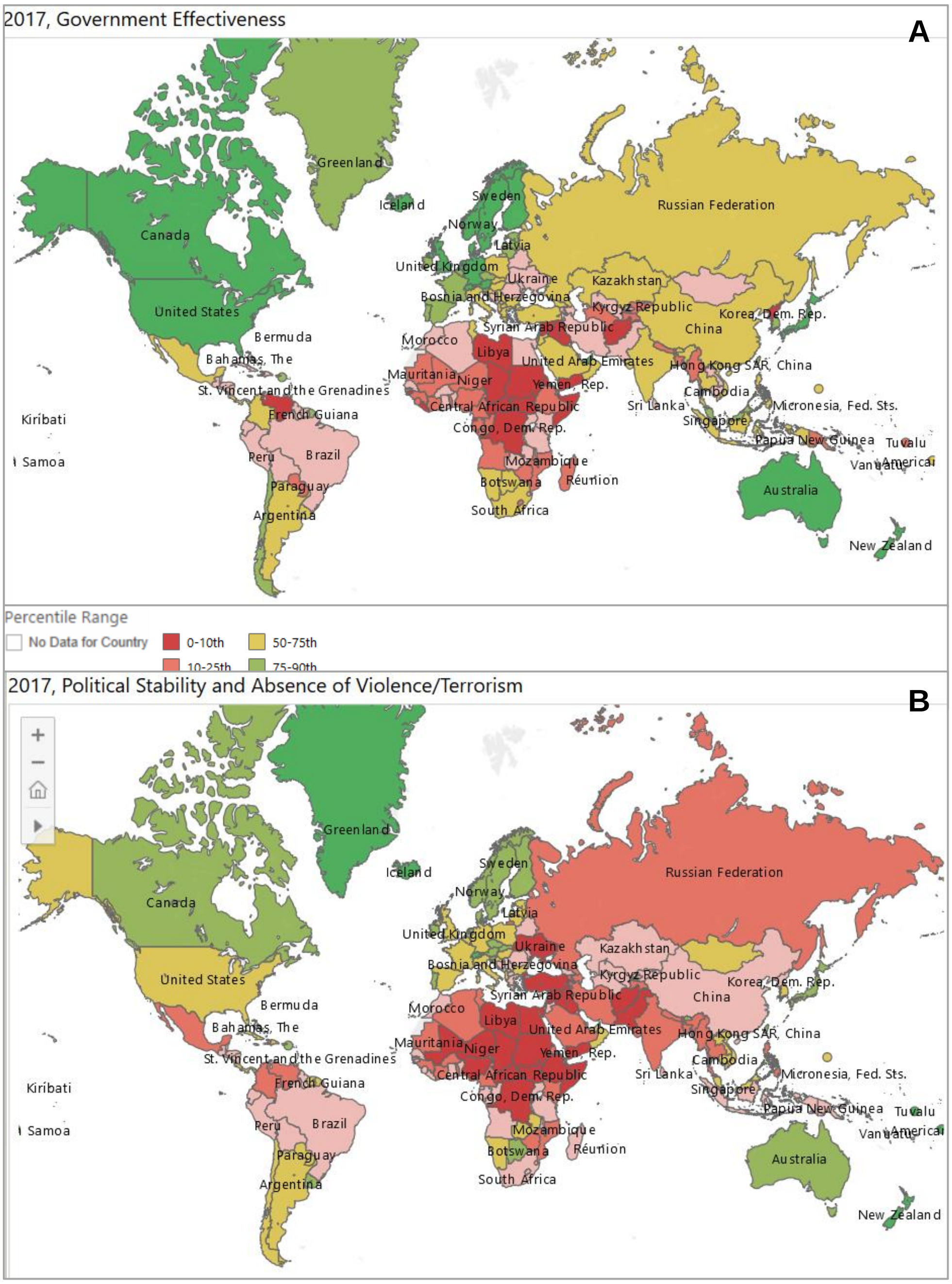


Figure 5. Maps representing government's effectiveness (A) and political stability (B) calculed from WGI indicators in 2017 (Source: http://info.worldbank.org/governance/wgi/index.aspx#reports)

However, not only the developing countries and emerging economies present a risk. The actual challenges within democratic states is also the rise of nationalism and protectionism which support anti-immigrant feeling and push gradually to limit fundamental civil and political liberties. EU faces also an actual risk of crises within the euro zone with Brexit and rise of nationalism during the past election of representatives in May 2019. Economic hostilities between US and Russia or China is also at high-level risks. Trump US government is seeking to protectionism ("America first") and scepticism toward the necessary international agreements on the environment.

Criticality assessment

The accessibility of raw material resources drastically influences the supply and worldwide prices of metal and mineral market. The historical consumption compared to projected applications and market demands suggests that there are not enough mineral reserves to meet worldwide metal demands.

A critical mineral or metal serves an essential function in the manufacturing of a product and common deposit types or sources are absent through domestic mining or reserves and thus its supply chain is vulnerable to disruption. Its absence would have significant consequences for the economic and national security of a country.

US and European countries depend mainly on foreign commodities. They have identified principal commodities that are critical for their industry and defence. US list published in 2018 pointed 35 critical minerals and 27 critical raw materials for EU in 2017. America and Europe are now compositing with the rise of these emerging countries and competing for the access of raw materials, which are not located in their territories (Figure 6). The rise of China has an important impact on global supply chains of raw materials as it provides many of global critical commodities.

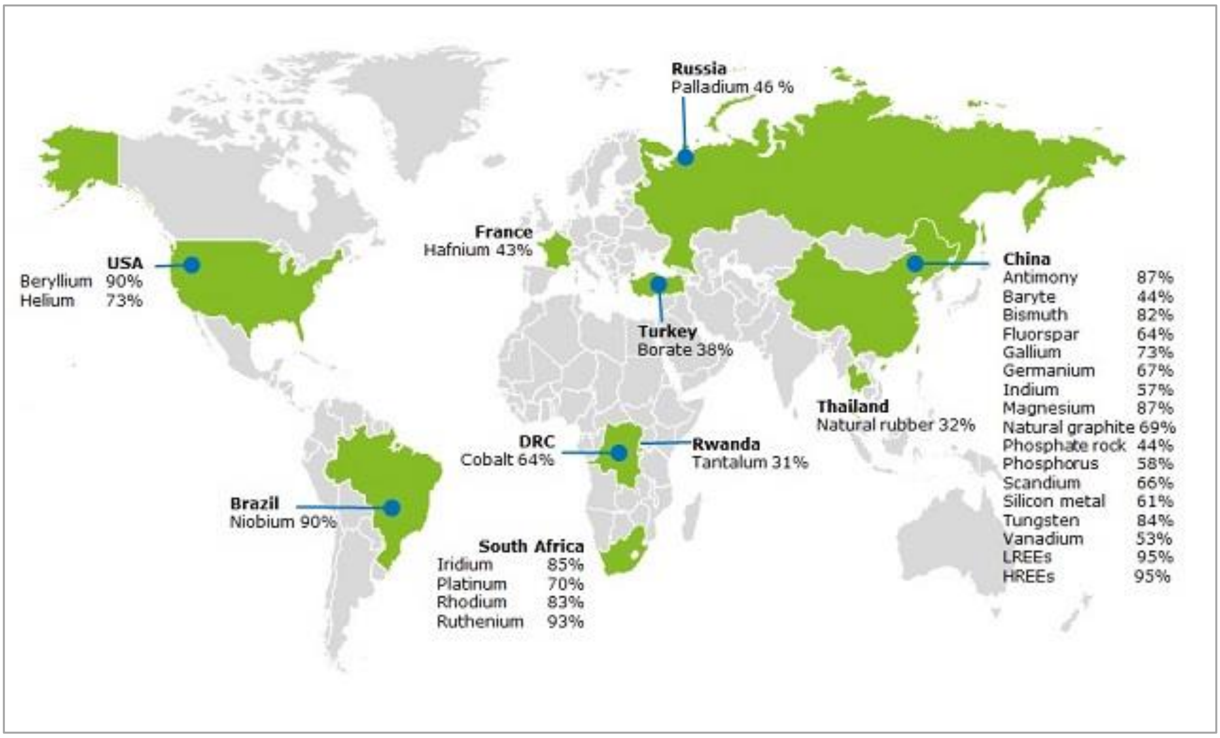


Figure 6. Countries accounting for largest share of global supply of critical raw materials (Source: https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en)

Internationalization of exchanges modifies drastically the metal market and capacity of develop countries. Globalization and the monopolistic control of resources lead to unstable supply situations. An example would be the disruption of REE supply chain observed in 2009 because of China market restriction. Another risk lies on 64% of cobalt resources of the world used in Li-ion electric batteries (used in smart phones and electric vehicles) or in additive metallurgy that are located in Democratic Republic of Congo, a highly unstable country.

Particularly the accessibility of critical raw materials has the capacity to push up or without to struggle the development capacity of the industry and therefore the entire economic system of a nation. Develop countries with high-level technologies is strongly dependant of the access to critical resources and trade with producers or cooperation with governments of producer countries. Therefore, criticality assessment for developed countries remains a major factor to estimate and compare with the governmental risk assessment of producer countries.

<u>Market pressure or export restrictions</u>

Producer countries of critical raw materials gain a power of negotiation because governments can give or not access to their resources by exploitation licenses, permits or authorization, or induce a certain pressure by taxation and fiscality. National politics on trade of raw materials imply taxation, royalties and exportation restriction.

OECD (Organisation for Economic Cooperation and Development) compares the different governmental measures that can restrict exportation of raw materials (tax, export prohibition, quotas, non-automatic licencing) and combines data with reserves and production rates for 66 commodities from USGS (US Geological Survey). This analyse able to elaborate a ranking of trade facilities for various countries illustrated on an interactive map (Figure 6) which shows that North America, Australia and Western Europe are facilitating trades compare to more restricting countries in Africa, South America and Asia.

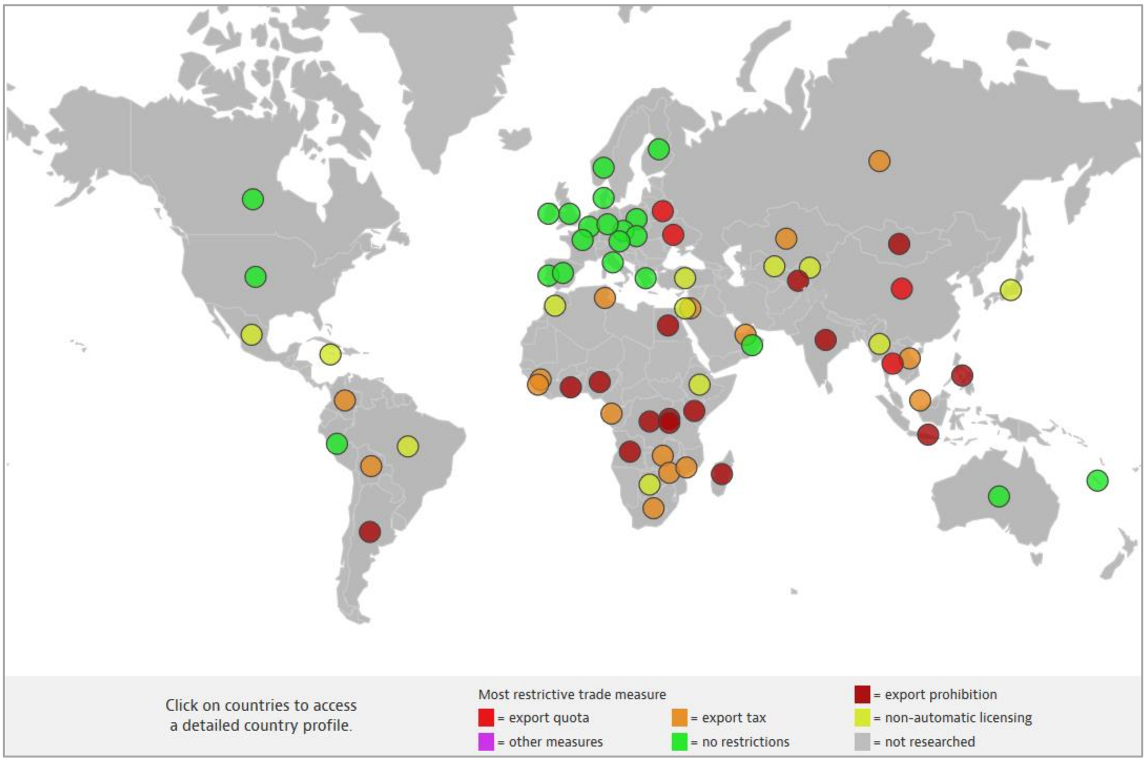


Figure 6. Ranking of restrictive trade measures by country (Source OCDE : http://www.compareyourcountry.org/trade-in-raw-materials?cr=oecd&lg=en&page=0&visited=1#)

Hypotheses

HYP-GEOPOL1	Global control of major deposits and world market by dominant countries; **Instability and conflicts**	Peace and international security breakdown between nations fighting for natural resource accessibility => economic war. Failure and lack of anticipation by governments and more political instability in mining countries -generating more widespread conflicts.
HYP-GEOPOL2	Development of international **cooperation to get a fair access on resources**	Governance is pushing due diligence of industries for responsible mining and sustainable development by applying new policies and more open exchanges to international market and promote development of emerging countries
HYP-GEOPOL3 (Current trend)	**Soft power of resources - Resource nationalism**	Mining resources and trade become a political tool of foreign policy bargaining (quota, taxes, export restrictions). Less conflicts bound to mining resources, increased political stability (including “strong” governments) in mining countries.

2. Regulation/Legislation

1. Driver definition

Mineral raw materials are the starting point of complex value-added chains. Raw materials are therefore of essential importance economies. In Europe, strong emphasis is given in the security of supply of raw materials generating implications at both EU and national levels with regards to accessibility of raw materials both internally and externally. The former requires appropriate regulation for exploration, environmental and legal restrictions and taxation. Legislation and regulation are part of a minerals policy framework, which in order to be effective should abide to certain principles (Table 1).

Table 2 - Principles for effective minerals policy framework (adapted from Falck et al. 2016)

	International	**European**	**National**	**Regional/Local**
Policies	Provide a Global Framework based on international cooperation which can ensure availability of minerals in resource deficit nations as well by encouraging favourable trade practices	Provide a level playing field based on secure access to minerals > Raw Material Initiative + follow-ups	- National minerals policy framework - Commitment to regulatory and knowledge framework	Identify and protect reserves of mineral resources

			- Incorporate minerals in land-use planning	
Intention	To Promote International Cooperation and Coordination of mineral resources	Consider minerals as key resource	Consider Public Interest, harmonizing sectoral policies	Autonomy from local political pressures Indicate time length to obtain a permit, or extension of existing permits
Implementation	Coordinate all country's NMPs; Ensure uniform policy standards	Monitor national minerals policies	- Focus on National interests, coordinate with regional policies. - Ensure international standard practices	Give certainty to operators
Impact	Better Resource utilisation at Global level. Supply of minerals to mineral deficit countries	Better Resource utilisation and coordination at EU level	Assess reserves of authorised available resources	Number of permit applications, refusals

In that sense, MIN-GUIDE summarises the minerals policies and legislation at EU level.. (Table 2).

Table 3 - EU mineral policies and legislation (MINGUIDE, 2016)

Policy Title	**Year and ID**	**Responsible for the design**	**Policy instrument type**
Council Directive concerning minimum requirements for improving the safety and health protection of workers in the extractive industries	Directive 92/91/EC	European Parliament, the European Council and the European Commission	Legislation
Directive on the management of waste from extractive industries	Directive 2006/21/EC	European Parliament, the European Council and the European Commission	Legislation

Council Directive on the minimum requirements for improving the safety and health protection of workers in surface and underground mineral-extracting industries	Council Directive 92/104/EEC	European Parliament, the European Council and the European Commission	Legislation
The European Innovation Partnership (EIP) on Raw Materials	2012	DG Growth – Internal Market, Industry, Entrepreneurship and SMEs	Committee or Network
Strategic Implementation Plan for the European Innovation Partnership (EIP) on Raw Materials	2013	DG Growth – Internal Market, Industry, Entrepreneurship and SMEs; The European Innovation Partnership (EIP) on Raw Materials	Policy Strategy
The raw materials initiative : meeting our critical needs for growth and jobs in Europe	COM/2008/ 0699 final	DG Growth – Internal Market, Industry, Entrepreneurship and SMEs	Policy Strategy
EU action plan for the Circular Economy	COM/2015/ 0614 final	European Commission, Secretariat-General	Policy Strategy
Directive on industrial emissions (integrated pollution prevention and control).	Directive 2010/75/EU	http://eur-lex.europa.eu /summary/EN/uriserv:ev0027	Legislation
Directive establishing a framework for Community action in the field of water policy (EU Water Framework Directive)	Directive 2000/60/EC	http://eur-lex.europa.eu/legal-content/ EN/LSU/?uri=CELEX:32000L0060	Legislation
Mediterranean Action Plan (MAP)	1975	http://www.unepmap.org /index.php	Policy Strategy
Directive on the conservation of wild birds (EU Birds Directive)	Directive 2009/ 147/EC	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri =CELEX:32009L0147&qid =1468329239134	Legislation
Council Directive on the conservation of natural habitats and of wild fauna and flora (EU Habitats Directive)	Council Directive 92/43/EEC	http://eur-lex.europa.eu/legal-content/EN/TXT/? uri=CELEX:31992L0043	Legislation
Directive on the assessment of the effects of certain public and private projects on the environment (EU Environmental Impact Assessment (EIA) Directive)	Directive 2014/ 52/EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri= CELEX:32011L0092	Legislation
Directive on the control of major-accident hazards involving dangerous substances	Directive 2012/ 18/EU	http://eur-lex.europa.eu/legal-content/EN/TXT/?uri= CELEX:32012L0018	Legislation

Directive relating to the assessment and management of environmental noise	Directive 2002/ 49/EC	http://eur-lex.europa.eu/legal-content/EN/LSU/ ?uri=celex:32002L0049	Legislation

2. **Pertinent indicators**

Policy Perception Index

Fraser Institute's Policy Perception Index (PPI) is used as a proxy for policy framework, through the perception of mining companies managers on various apsects of the jurisdictions where they operate. This particular index takes into account factors sch as burdensome regulations, regulatory duplication, uncertainty over current legislations, the legal system, disputed land claims and socioeconomic agreements, environmental regulation, taxation levels and the quality of infrastructure.

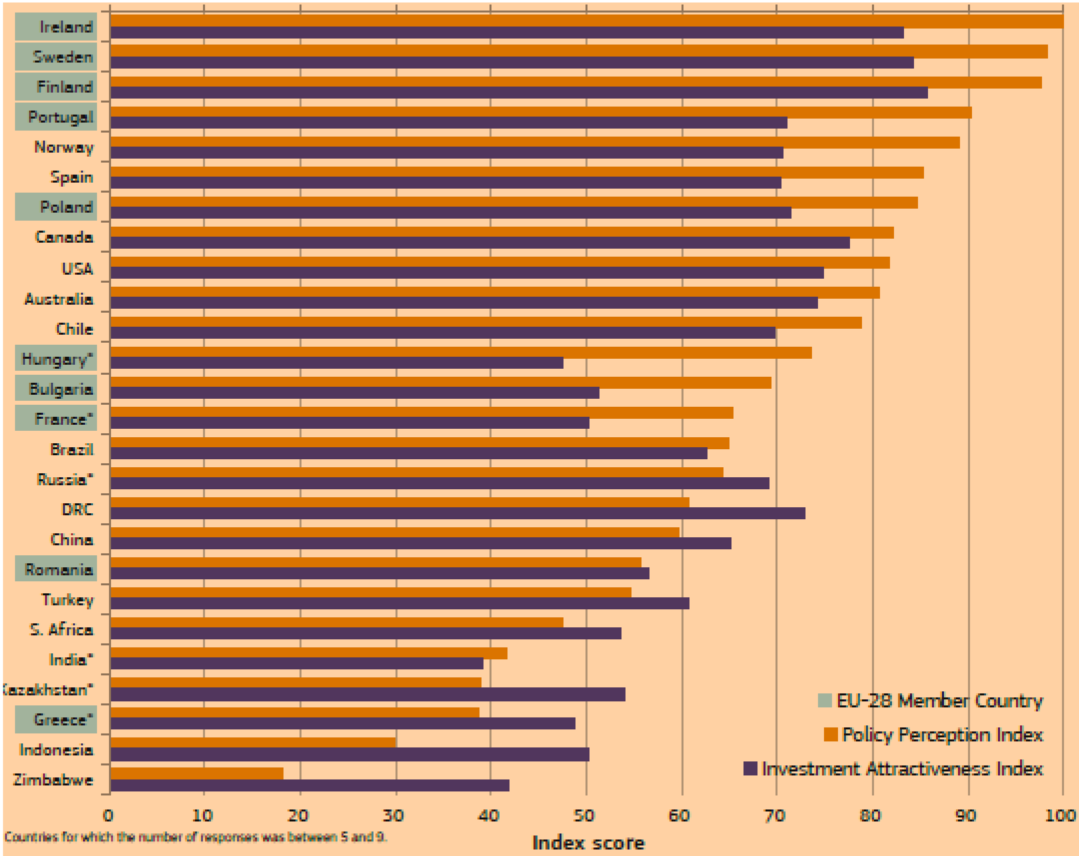


Figure 4 - Policy perception Index and Investment Attractiveness Index (Based on Fraser Institute Annual Survey of Mining Companies, 2016) (EC, 2018)

According to the EU Raw Materials Scoreboard (EC, 2018), the last five years have not seen significant change in the perception and attractiveness indexes of Ireland, Finland, Sweden, Bulgaria, Hungary, Greece and Norway. In turn, Portugal, Poland, Romania, Spain and Russia have seen an improve, whereas France and Turkey have seen a downward trend.

Mineral policy frameworks

On a global level, the IGF – Intergovernmental Forum on mining, minerals, metals and sustainable development[7] structures the mineral policy framework as follows (Table below):

Legal and policy framework	
Financial benefit maximization	Revenue generation (Taxation and royalties) Mining Policy Considerations
Socio-economic benefit maximization	Integration of community, regional and national issues Education Community health and safety Employment Business development Security Human rights, indigenous peoples and cultural heritage
Environmental Management	Water Biodiversity Mining wastes Emergency planning and preparations
Post-mining transition	Mine closure Financial assurances Orphaned and abandoned mines
Artisanal and Small-scale mining (ASM)	Integrating ASM into the legal system Integrating ASM into the formal economic system Reducing social and environmental impacts

According to Minlex, the minerals policy framework (complexity of relevant policy documents, legislation, fiscal instruments and permitting practices of EU Member States) differs significantly across the EU. Also, the lack of policies and complicated mining and/or environmental permitting procedures are limiting the access to minerals since many years (less permits, short duration of permits, expensive, time-consuming procedures for both operator and authorities). During the last 20 years the European Commission has received several complaints regarding the existing lack of transparency in the permitting and concessions procedures[8].

[7] https://www.igfmining.org/mining-policy-framework/framework/
[8] http://www.minlex.eu/index.html

Mineral resources and Land-use Planning

Mineral and other relevant (environmental, land use planning) policies have to be well integrated through high level land use planning activities and policies. In order for that to happen countries need to have well established mineral inventories, mineral potential assessments and stakeholder consultation. Once this is well established, appropriate mechanisms for safeguarding mineral potential supported by other legislations such as land use planning, mineral planning, sustainable development, environmental and waste management policies.

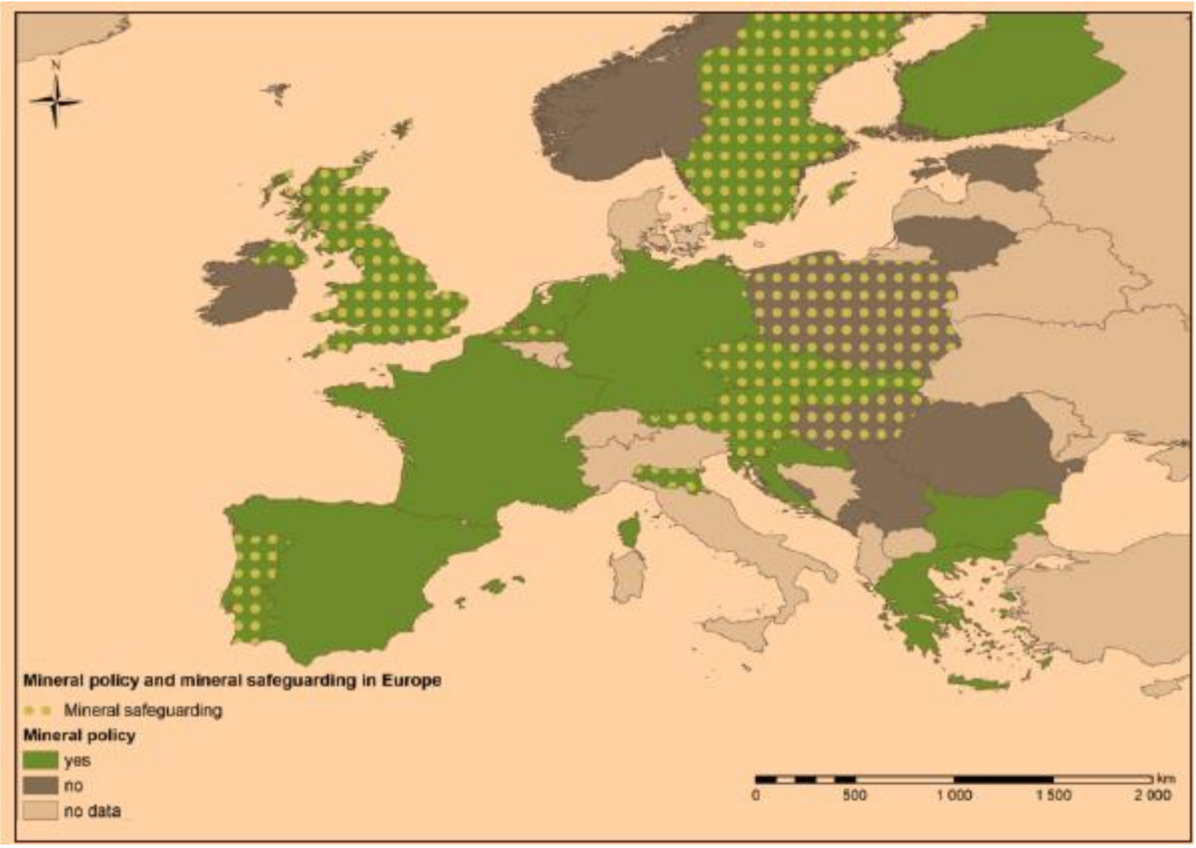


Figure 5 - mineral policy and mineral safeguarding in Europe (MINATURA Project, minatura2020.eu)

3. Past developments (20 years, what, how and who)

In 2008, the EU strategy on raw materials was published through the Raw Materials Initiative (RMI), a three-pillars strategy covering i) fair and sustainable supply of raw materials from international markets, promoting international cooperation with developed countries, ii) fostering sustainable supply of raw materials by increasing resource efficiency and promoting recycling (EC, 2010). This resulted in a list of 'Critical Raw Materials' that has been on ongoing update since then. This list aims to shed a light over raw materials that are economically important for the EU and at the same time have higher levels of supply risks and disruptions.

Since then, the EIP-RM (European Innovation Partnership on Raw Materials) and the Horizon2020 have provided the strategic implementation plan and funding tools, respectively, for supporting the achievement of the RMI objectives. The EIP-RM has established many targets, namely:

- Up to 10 innovative pilot actions
- Substitute for at least 3 applications of critical and scarce raw materials
- Framework conditions for primary raw materials
- Framework conditions for material efficiency and waste management
- European raw materials knowledge base
- Launch of knowledge and innovation community
- Pro-active international co-operation strategy.

HYP-REG1 (Current trend)	**Broad legislation and enforcement diversity**.	Legislation and regulation still vary across EU member States, some put more (e.g. environmental licenses) constraints on raw material mining than others. In non-EU countries regulation is more variable.
HYP-REG2	**EU common mining policy diversity everywhere else**.	Mineral policy rules and framework are now decided and negotiated at EU level.. Rules for permits, environmental procedures are the same within EU but negotiated with national countries. Other countries tend to increase their regulation but with strong variation across countries according to their economic needs and mining potential. EU common policy tend to secure mining investments in EU.
HYP-REG3	**World minimum standards accepted by all stakeholders**.	Minimum world standards are agreed at world level by the big mining companies (including to reduce share of legal ASM). EU policies are more severe than world standards and become more common across EU.

3. Social Acceptability

Driver definition

The stance individuals or groups of stakeholders take towards mining projects and the extractive industry in general[9].

Social acceptance is a contributing factor to the perception that the region is not ‘open for business’ to international mining investors[10]. It shall be distinguished from the social licence to

[9] INTRAW Descriptor catalogue, Scenarios: The world of raw materials 2050.
[10] Farooki et al. 2018, STRADE report : Supporting the EU Mineral Sector - Capitalising on EU strengths through an investment promotion strategy.

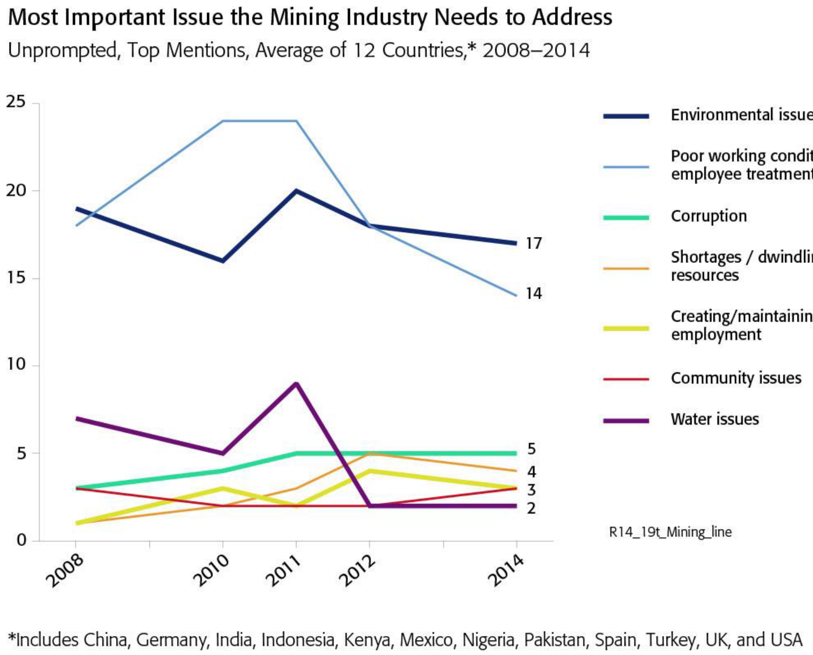
operate (SLO)[11] which is a concept focused on local stakeholders directly impacted by a mining project. Here the social attitude is much wider.

Pertinent Indicators and past development

Preliminary analysis of social media (twitter and blog posts) suggests that social un-acceptance takes its roots in the mining process itself. This latter is considered to cause environmental damage and the suppression of social and human rights that may result from mining company activities, particularly in third, non-EU countries[10].

Environmental issues are the main concern in public perception.

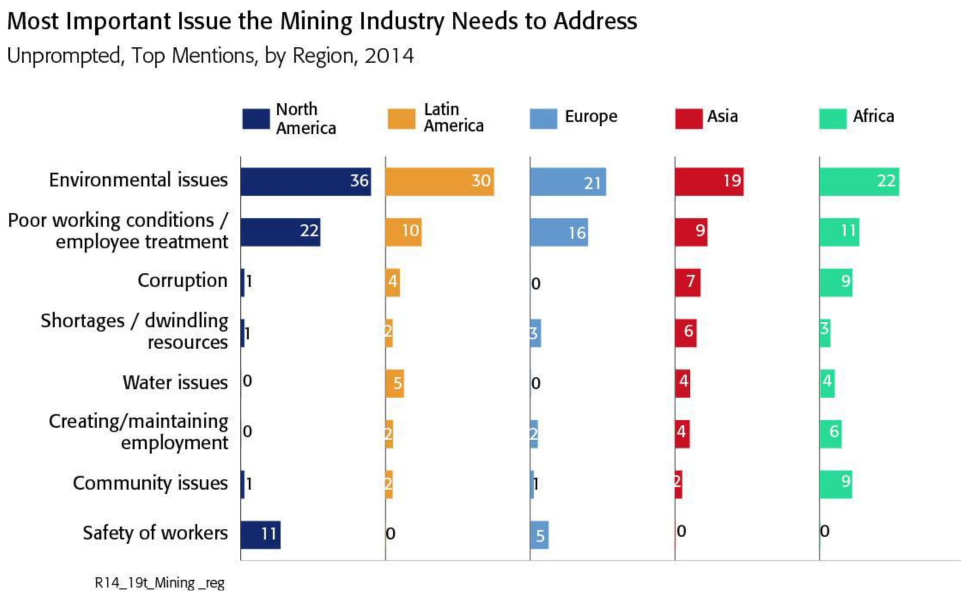
Indeed according to the respondents to a global reputation survey on Mining industry, environmental issues are now considered slightly more important than working conditions among the most important issues this industry needs to address[12] Working conditions have continued to decline in perceived importance since 2011.



Environmental issues are the greatest concern in all regions, but other issues may differ between regions, depending on their governance and economy maturity.

Note that through time, importance of environmental issues as well as poor working condition issues are decreasing but importance of corruption and to a lesser extend resource shortage issues are increasing.

[11] Boutilier, R. & Thomson, I., 2011. Modelling and Measuring the Social Licencense to Operate; Fruits of a Dialogue Between Theory and Practice, s.l.:s.n.
[12] GlobeScan Radar, Mining Industry Report 2014



<u>Stakeholders' expectations differ between developing and developed countries.</u>

At a local scale, near a possible mining project, the social attitude is mainly linked to the social licence to operate. It is to be noticed that expectations from the local stakeholders differ between developing countries and developed countries.[11]

While in developing countries, individual and groups expects mining companies to provide what their State cannot provide (e.g. infrastructures, health services and economic development initiatives), in the developed world stakeholders want mining sector to be active solutions providers to global issues they generate at the planet scale such as carbon emissions and climate change.

<u>The end of the social contract between mining companies and local inhabitants through employment.</u>

While looking at the potential benefits brought by the mining industry locally, mines can no longer employ large numbers of essentially manual labourer compared to 30-40 years ago[13]: due to a more mechanised and efficient production, the creation of employment is very limited today. And these new jobs require specific skills whereas training possibilities locally are not necessarily planned by companies. More generally, compared with 40 years ago, many communities today perceive their cost-benefit analyses with near zeros in the benefit balance, especially if the local economy is already well functioning.

<u>The development of the civic sector.</u>

[13] Boutilier, R. G., Black, L., & Thomson, I. 2012. From metaphor to management tool: How the social license to operate can stabilise the socio-political environment for business. International Mine Management 2012 Proceedings, 227-237. Melbourne, Australian Institute of Mining and Metallurgy.

The number of environmental groups, community health groups, neighbourhood groups, unions and rights advocacy groups that constitute the civic sector has grown heavily over the past 20 years[13]. These groups which can raise socio-political issues for mining companies are today more numerous, more qualified and more trusted with impacts both at local and global scales.

Raising role of social media and the paradigm of circular economy.

The world is more influenced by round the clock news and opinions released in the court of social media. These channels spread mistrust against several industries and among others the mining sector. Against this trend, only transparency campaigns can be a prerequisite for trust.

In this context, the first large communications campaigns on the circular economy concept with ultra-simplified schemes have raised negative attitude towards mining due to the misconception that it may no longer need mines anymore.[1]

Hypotheses

HYP-SOC1 **(Current trend)**	Strong opposition to mining	Environmental and social performance are perceived to weaken with time, hence raising a strong opposition that spread at a global scale also because of corruption bound to mining rights in some countries.
HYP-SOC2	Tolerance of mining but NIMBY[14]	Mining is understood as a necessity, especially in the context of a strong demand for new technologies and energy transition. Developed countries citizens accept the idea of mining as long as it is out of sight.
HYP-SOC3	Acceptance of mining	Mining companies develop radical transparency policies followed by tangible actions to enhance public accountability. This is the rise of social enterprises which are judged beyond financial performance and accepted on the basis of their impact on society at large[15,16] . Clean and social mining is a reality benefitting to local communities

4. Recycling and Circular Economy

Driver definition

Shifting from linear to circular economy.
The existing 'take-make-use-dispose' economy have detrimental consequences in human well-being and durability of the of the society considering the negative impacts it has on the planetary boundaries and the pressure on non-renewable resources.

[14] NIMBY: Not In My BackYard
[15] DELOITTE. Tracking the trends 2018 - The top 10 issues shaping mining in the year ahead
[16] DELOITTE. Tracking the trends 2019 - The top 10 issues shaping mining in the year ahead

These negative consequences of the linear economy have been brought to light 44 years ago in the Club of Rome's report "The Limits to Growth"[17].

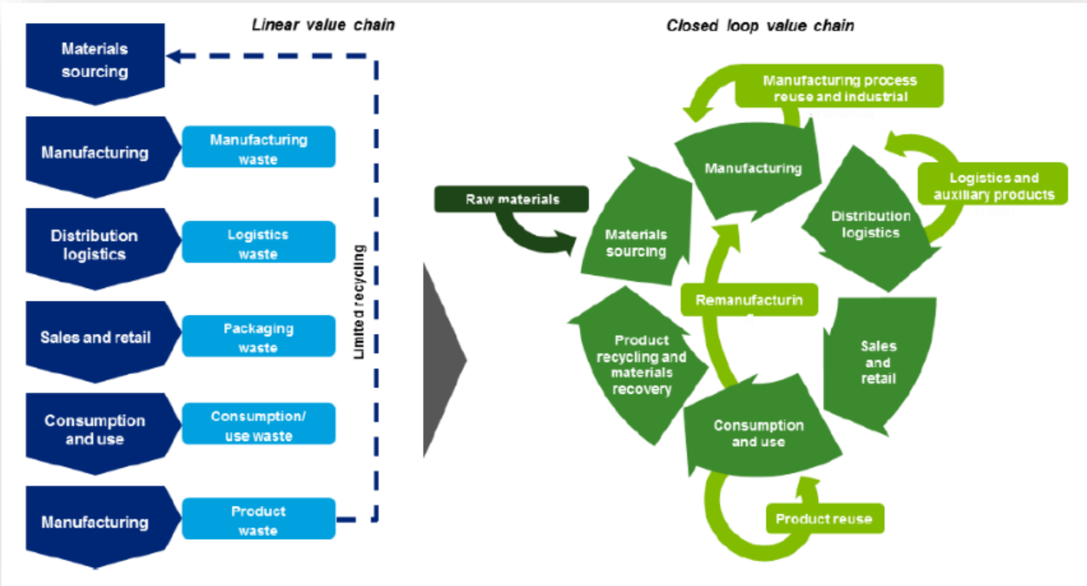


Figure 6 -Simplified illustration of a linear and a circular economy

The implementation of this transition requires technological, organisational and social innovations and the best pathway from a linear model to a circular model of the economy is still under construction.[18]

Any economy model cannot be self-sustainable and needs inputs of new raw materials.

Indicators and past development

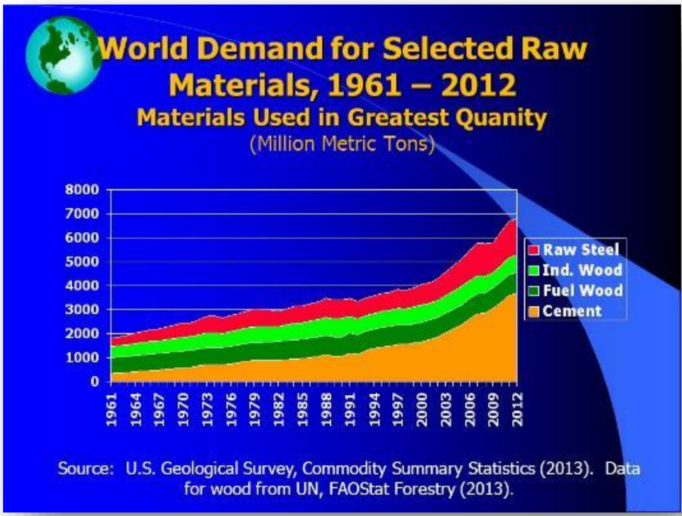
Global increasing of world resources consumption VS planet boundaries

As an example today worldwide metal production represents about 8% of the total global energy consumption, and a similar percentage of fossil-fuel-related CO_2 emissions.[20]

In the past decade the consumption of raw material showed a dramatic increase and the "Overshoot Day" is envisaged more and more earlier from year to year.

[17] Meadows, D., Meadows, D., Randers, J., Behrens III, W., 1972, The limits to growth: a report for the Club of Rome's Project on the Predicament of Mankind. Universe Books. URL : https://www.clubofrome.org/report/the-limits-to-growth/

[18] Deloitte Sustainability, November 2016: Circular economy potential for climate change mitigation



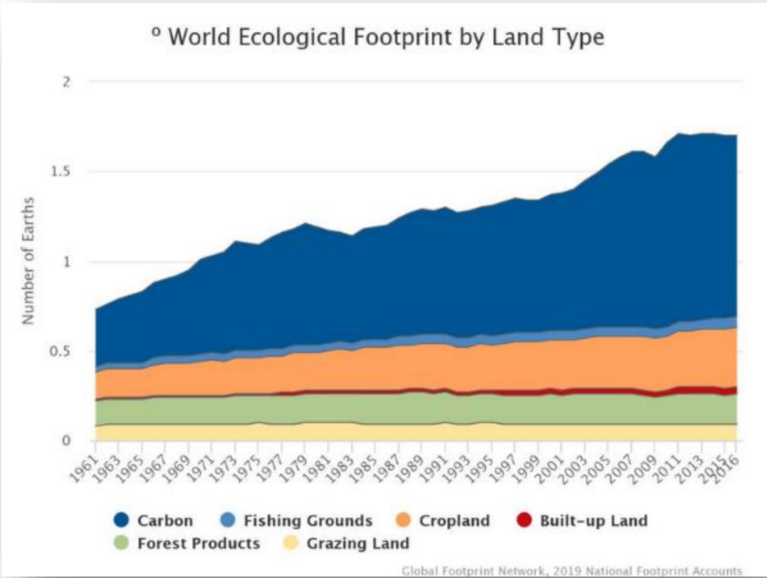


Figure 7 – source Global Footprint Network https://www.footprintnetwork.org/resources/data/

Declining ore grades

As global demand for many metals continues to rise, the potential metal deposits are deeper and the quality of ore decreases.

Thus depending on the metal concerned, the time span of discovery is delayed and about three times as much material needs to be moved for the same ore extraction as a century ago, with concomitant increases in land disruption, water use and pollution, and energy use[19].

Legal framework and legal target towards 2030 / 2050

Between 1994 and 2012, no less than 11 major European Directives were adopted on the theme of the circular economy, which were included in the various "articles" of the Environment Code. Subsequently, in 2015 a circular economy package was adopted by the European Commission and voted in 2018. It recaptures and amends most of the previous Directives with more ambitious targets and aims to "make the transition to a stronger and circular economy, in which resources are used in a more sustainable way."

Packaging Waste Directive, (94/62/EC)	Priority is given to the packaging waste reduction at its source, then by reusing or recycling them, with the global objective to valorise them
Landfill Directive (1999/31/EC)	Prevention and reduction of negative impacts of landfill waste on the environment, water, soil, air and at a global scale taking into account greenhouses gas effects and any other risk affecting human health over the whole duration of the landfill exploitation; major impacts on waste treatments and reduction
ELV Directive (2000/53/EC)	Organisation of the end of life vehicule (ELV) collection, recycling and transformation
RoHS Directive (2002/95/CE)	RoHS stands for Restriction of (6) Hazardous Substances : Pb, Hg, Cd, Cr^{VI}, polybromo-biphényles, polybromodiphényléthers
WEEE Directive, (2002/96/EC)	Towards a better recycling of EEE (electrical and electronic equipments)
Mining Waste Directive (2006/21/EC)	The first text on mine management providing restrictive measures about procedures and giving guidance to prevent or reduce as far as possible any adverse effects on the environment, in particular water, air, soil, fauna and flora and landscape, and any resultant risks to human health, brought about as a result of the management of waste from the extractive industries.
Battery Directive (2006/66/EC)	Text on the prohibition and the placement on the market of certain batteries and accumulators with a proportional mercury or cadmium content above a fixed threshold. Also promoting a high rate of collection and recycling of waste batteries and accumulators and the improvement in the environmental performance.
Waste Framework Directive (2008/98/EC)	Specify definitions for waste, valorisation and introduce the principle of life cycle of products; reinforce the principle of waste value

[19] UNEP. Recycling Rates of Metals – A status report, A report of the Working Group on the Global Metal Flows to the International Resource Panel, Graedel, T.E., Alwood, J., Birat, J.-P., Reck, B.K., Sibley, S.F., Sonnemann, G., Buchert, M., Hagelüken, C., 2011b.

Renewable Energy Directive (2009/28/EC)	Set up UE28 objectives in terms of % of renewables energies among the total energy demand ; Plan that mobility sector work with a minimum of 10% renewable energy sources
Energy Efficiency Directive (2012/27/EU)	Energy efficiency across the whole energy value chain, including its transformation, distribution and consumption.
EU's Energy Labelling Directive	Energy efficiency labels over new EEE
Bans/Interdictions	Forbid burial of plastics or recyclable materials as well as some toxic chemicals
EU Circular Economy Package : revised waste legislative framework	Some of the identified target: recycling 65% of municipal waste by 2035; recycling 70% of packaging waste by 2030; less than 10% of municipal waste buried in landfill by 2030.

These shall be declined at the national level for each Member states, hence leading to major legal incentive towards circular economy in Europe.

Recycling efficiency increasing

Despite there is huge variability among recycling rate for different materials, recycling technologies have improved over the last years and waste management have improved on the whole value chain with variable rates of implementation throughout the EC countries.

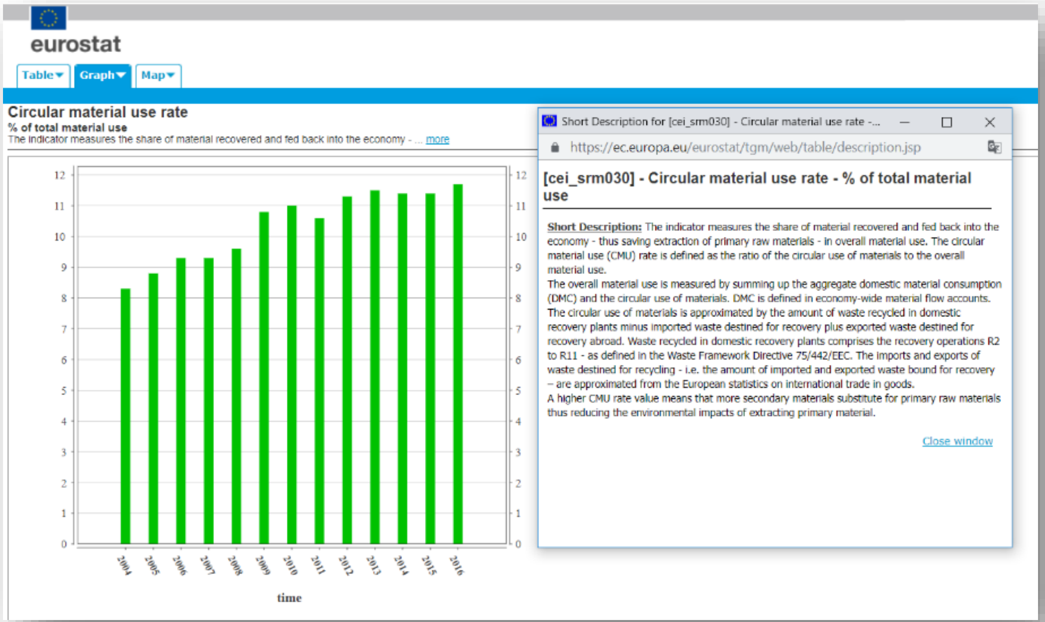


Figure 8- Circular material use rate between 2004 and 2016 among the EU28 (source Eurostat)

Towards more complex end-of-life products and more scattered elements

But recycling technologies face always new challenges posed by certain difficulties to separate waste type, such as in Electrical and Electronic Equipments (EEE) or in the Automotive industry. In such equipments, the recovery of metals from complex multi-layered end-of-life products can be of great difficulty. And such process is only economically viable if the final recycled materials price is lower than primary raw materials price, and guarantees the same high quality.

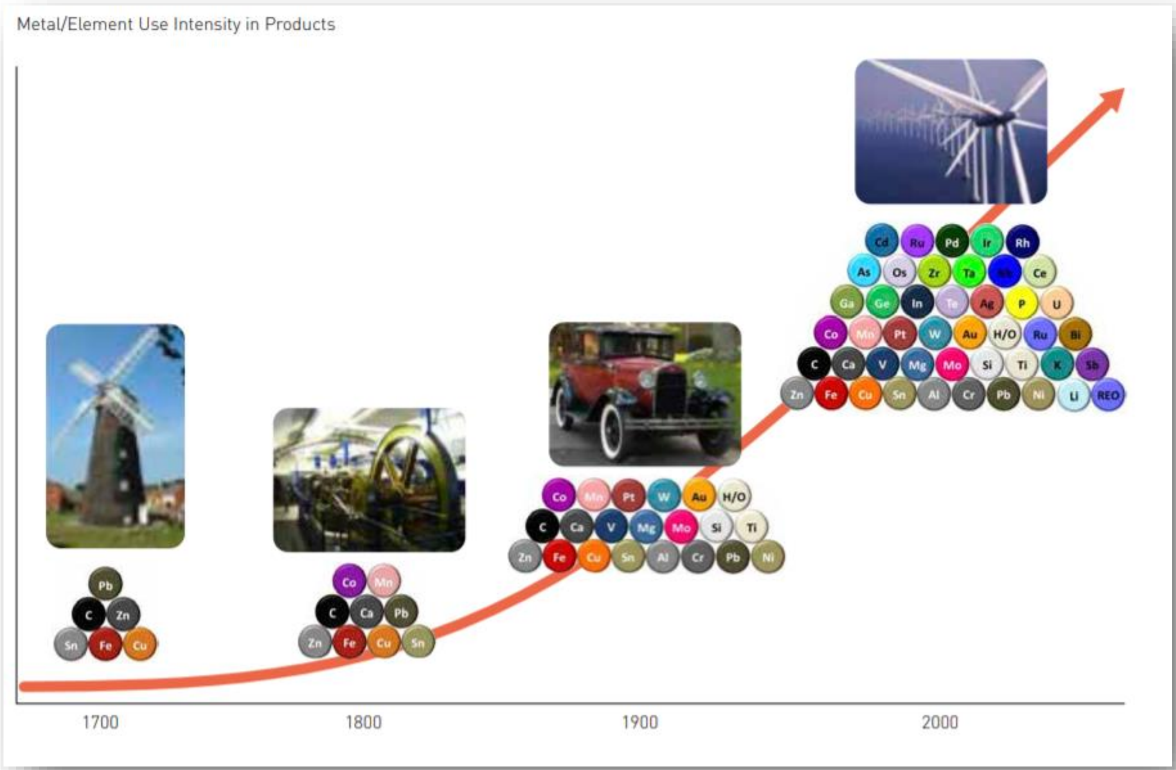


Figure 9- The ever increasing use of complex mixtures of metals in products has a key effect on the recyclability of metals (Adapted by Reuter from Achzet and Reller, 2011).[20]

In addition to this, the complex composition of EEE often goes with a size reduction of components, gathering infinitesimally small quantities of several components on semi-conductors and chips with thin films or mixed nanoparticles for examples. In addition, the decrease of the price related to the manufacturing performance tends to increase the market size and thus the dispersion of electronic compounds (i.e. the booming of LED). Such dispersion of materials over an increasing number of small devices leads to even more expensive recovery processes, which do not meet economic viability.

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[20] UNEP (2013) Metal Recycling: Opportunities, Limits, Infrastructure, A Report of the Working Group on the Global Metal Flows to the International Resource Panel. Reuter, M. A.; Hudson, C.; van Schaik, A.; Heiskanen, K.; Meskers, C.; Hagelüken, C.

Price of recycled materials VS primary raw materials

The value of the metals coming out of recycling depends upon their purity, which in turn – for reasons described above – is determined by design, material combinations, liberation and sorting efficiency, and recycling routes.

If the value of the recycled metal is too low due to low metal prices, recycling cannot come to its full fruition. Ultimately, metal price drives recycling: the higher the value, the higher its recycling potential. Unfortunately, commodity metal prices have decreased in real terms over the years. However, recent high prices of various metals – possibly indicating a paradigm shift towards higher metal prices – would generally have a positive effect on recycling.[20]

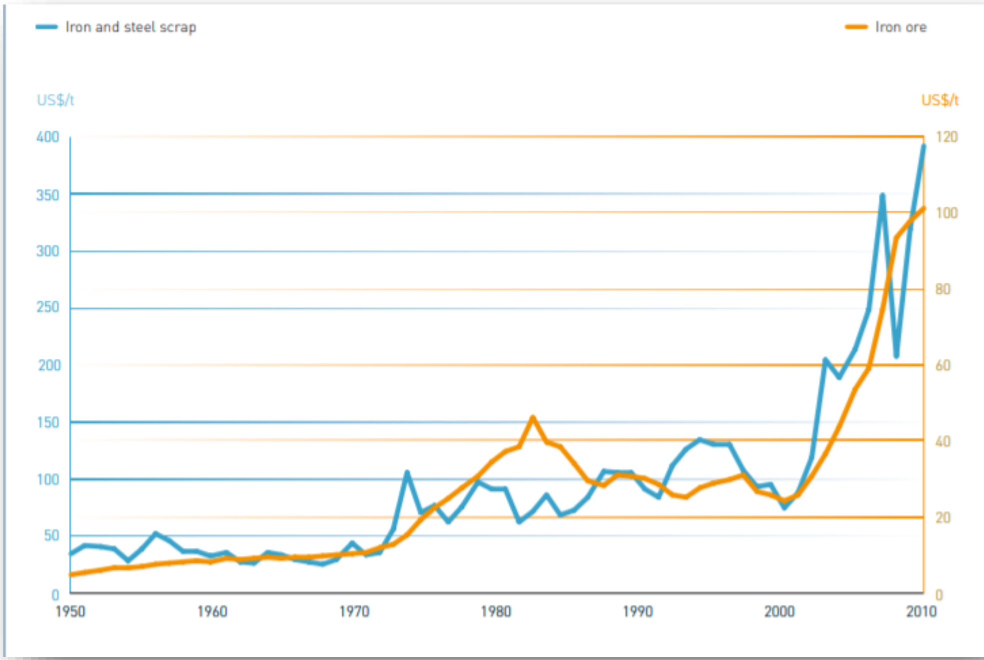


Figure 10 - Steel scrap prices following iron ore prices (USGS, 2011).[20]

Recycling rates

A survey done by UNEP about the recycling rates from worldwide data portrays a contrasted picture of recycling rates according the typology of uses. 60 metals were investigated. Due to incertitude of the data, five bins were created to show the main trends, which are also consistent with the recycling rates in Europe. The metals widely used are recycled with convenient rate: for steel is thought to be between 70% and 90%, while the equivalent for aluminium and most base metals is in the order of 50% to 70%. Recovery rates for a wide range of other less common metals, such as those in the REE group, are considered to be negligible except for platinum group elements, precious metals (Au, Ag) and some elements from specific technological niches (Nb, Re, Ti).

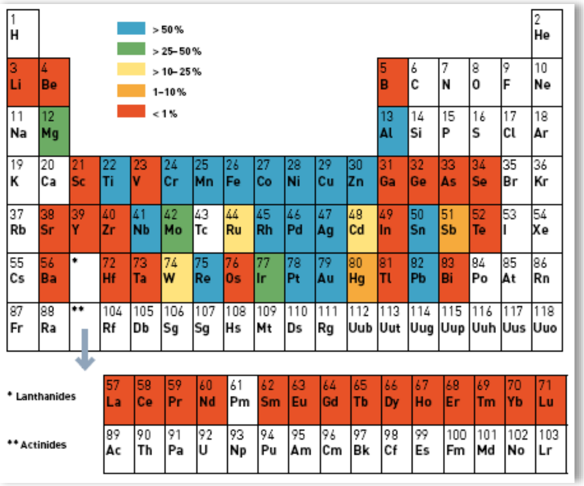


Figure 6 - Table of global average end-of-life functional recycling rates (EOL-RR = End Of Life products/Recycled EOL metals) for 60 metals, with the individual metals categorized into one of five ranges[21].

EU Exports/Imports

Scrap		2012	2013	2014	2015	2016
Imports	Unit					
Aluminium	t	322 509	322 642	361 778	357 767	404 188
Copper	t	496 075	480 212	477 551	466 551	414 210
Lead	t	29 680	35 568	34 551	35 957	45 291
Zinc_1	t	7 031	5 767	6 172	9 645	6 170
Nickel	t	11 096	11 575	12 275	13 302	16 497
Zinc_2	t	3 431	2 940	2 390	1 332	777
Magnesium	t	3 012	1 383	3 378	2 987	4 505
Steel	Mt	3 158	3 191	3 143	2 850	2 740
Exports						
Aluminium	t	1 083 630	922 653	974 415	858 272	940 992
Copper	t	1 231 043	1 076 232	1 063 654	1 007 775	985 785
Lead	t	34 300	37 971	42 943	29 929	39 086
Zinc_1	t	83 228	68 573	70 199	59 229	61 011
Nickel	t	34 126	20 318	20 260	15 489	15 624
Zinc_2	t	3 343	712	801	616	686
Magnesium	t	11 957	8 802	7 220	9 488	10 934
Steel	Mt	19 543	16 802	16 953	13 763	17 169

Table 1 – Data from Eurosat and EUWID calculation apart for Steel from EUROFER report 2018.

[21] USGS Staff -- Published Research. 596 (2011): What do we know about metal recycling rates? T. E. Graedel, Julian Allwood, Jean-Pierre Birat, Matthias Buchert, Christian Hagel¨uken, Barbara K. Reck, Scott F. Sibley, and Guido Sonnemann

Apart for lead, the main tendencies show that Europe exports more scraps than it imports. The following up of the ratio between import to export value through five years portrays weak but bearish tendencies for Al, Cu, Ni, Mg.

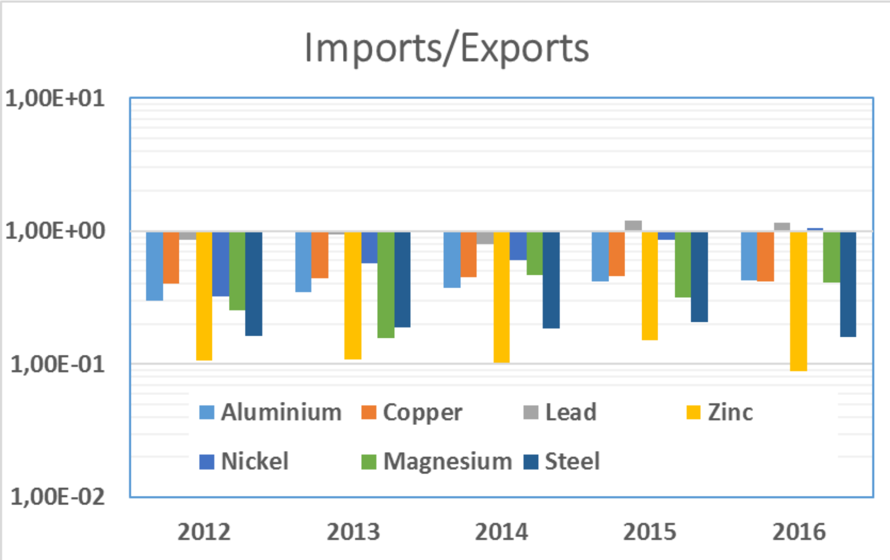


Figure 7 – Imports export ratio: follow up for five years for seven elements.

Emphasising on the main metals the country of destination classified by volume are:
a) For steel, Turkey, Egypt, Pakistan, USA, India, Switzerland, Morocco
b) For aluminium, China, India, Pakistan, Switzerland, South Korea
c) For copper, China, India, Pakistan, Japan

For the scrap metals, it is very difficult to portray a clear future scenario. The latter depends on many economic and policy factors: regulation, economic viability of the plants allowing the recycling and so on.

Waste export and ban

For years also, waste has been sent by rich countries to poorer countries for recycling. For example, until july 2017, when China banned this waste imports, China recycled up to 56% of the world plastic garbage. After China decision, Malaysia tripled it's plastic waste imports (source : https://www.dw.com/en/after-chinas-import-ban-where-to-with-the-worlds-waste/a-48213871)

China also announced a ban for all solid waste imports including metals for environmental reasons. From December 2018, China will ban imports of 16 types of solid waste including: steel slag, post-industrial plastics, compressed auto pieces, small electric motors and insulated wires, and vessels. By the end of 2019, a further 16 types of waste will be banned, including wood pellets, stainless steel scrap, and nonferrous scrap (meaning alloys not containing iron) excluding aluminum and copper. Source http://www.chinadaily.com.cn/a/201804/25/WS5adf5999a3105cdcf651a428.html

Social attitude towards recycling and waste management

Following two oil shock crises, people in developed countries have acquired a more responsible behaviour in the daily waste management, with the support of a wide public communication from authorities. And such trends is reinforced by recent global awareness of climate emergency.

Recently one-part consumers have started to adopt an attitude focused on the use and services provided by goods instead of the traditional ownership concept. These consumers are interested in the way a product is manufactured and what to do with it when it is worn. The eco-design principles make products more expensive when bought, but in return consumers are guaranteed to have the product repaired over a longer period, thus extending the life span of this product and its replacement. Over the full life cycle, consumers shall benefit from this additional initial investment.

Educating and changing the behaviour of individuals can thus lead to better recycling. One way is to encourage people to return their old products for recycling when they no longer need them. Currently, many consumers keep redundant products at home, or throw them into mixed waste. If more consumers would return their mobile phones for recycling, the increase from the current 2000 tonnes/year would amply drive the recycling system.

Many factors affect recycling behaviour, from personal attitudes and experiences to the quality of the existing recycling systems.

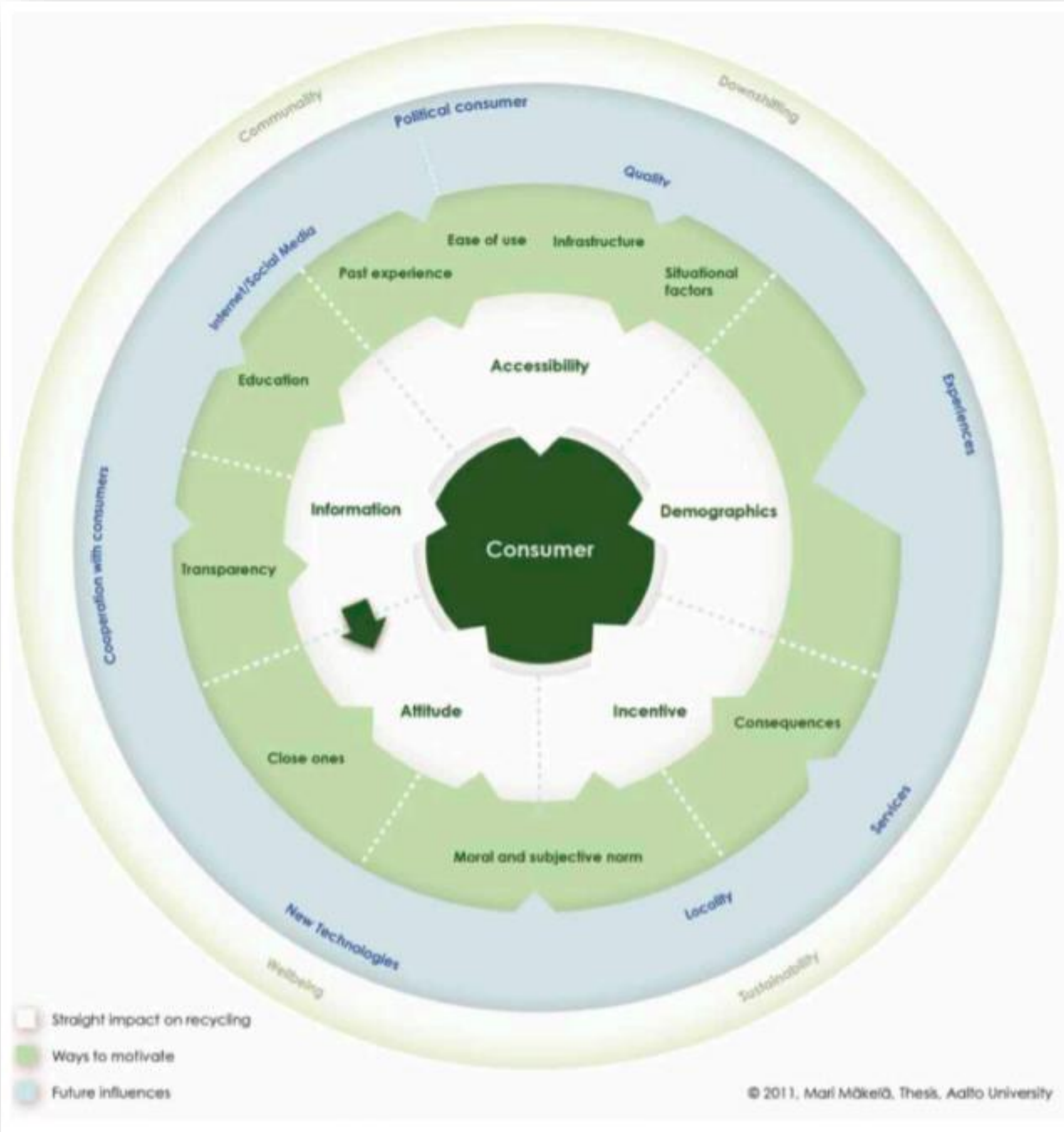


Figure 7 - Features affecting consumer recycling behaviour[22] .

The most important factors for enhancing recycling behaviour are convenience and awareness of where and how to recycle. Inhibiting factors are an emotional attachment to the old products perhaps more cost of collection and clean recycling cost. Making the consumer aware of the opportunities of recycling and changing his mindset and disposal habits are the true keys to any successful programme. Again, consumer education is of a vital importance.[20]

[22] Mäkelä, M. The Complexity of Mobile Phone Recycling, Developing user oriented design guidelines and future concepts for mobile phone Recycling, School of Art and Design, Aalto University, Helsinki (2011).

Hypotheses 2035 (and evolution to 2050)

HYP-CIRC1	No benefit, no economic viability	Targets set up in EU directives are difficult to be meet, especially considering the lack of willingness from citizen to pay more for recycled materials/objects than for new ones. Economic viability of recycling process is not met, since new processes are too expensive compared to the price of primary raw materials. Most waste is sent to countries in Asia and Africa.
HYP-CIRC2	Huge benefit	Strong change in global mindset, moving up the waste hierarchy with a pro-active roles of governments and citizen: sorting, recycling and even renting is considered across any step of the life cycle of a product, hence creating millions of extra jobs in EU. People agree to pay for recycling. All Waste export is banned in Europe.
HYP-CIRC3 (current trend)	Moderate benefit – benefit depends on the material	Local (in Europe) recycling of valued material, mainly metals with new processes to separate them in complex objects or equipment. But low value waste like plastics is sent abroad, in low cost countries, for burying or recycling.

5. Mining and Processing actors and activities

Driver definition

Mining and processing actors and activities are driven by innovation to rise production and develop activities to meet increasing competition from emerging industrializing countries (China and BRICS[23]) and meet society's expectations (social and environmental responsibilities).

Pertinent Indicators and past development

Producer countries, production and geographical trends

In 2017, world mining production of mineral raw materials rises 17,2 billion metric tons (Figure 1). Considering world population growth and urbanization, global extraction rate of mineral resources will triple by 2050.

China is actually the world largest producer for 31 commodities (iron, ferro-alloy metals, coal, further non-ferrous metals and industrial minerals). Asia is representing 57,9% of the total world production of the mining sector and its position is largely increasing in the global market since China has enter to the World Trade Organization in December 2001.

[23] BRICS countries are Brazil, Russia, India and Commonwealth of Independent States.

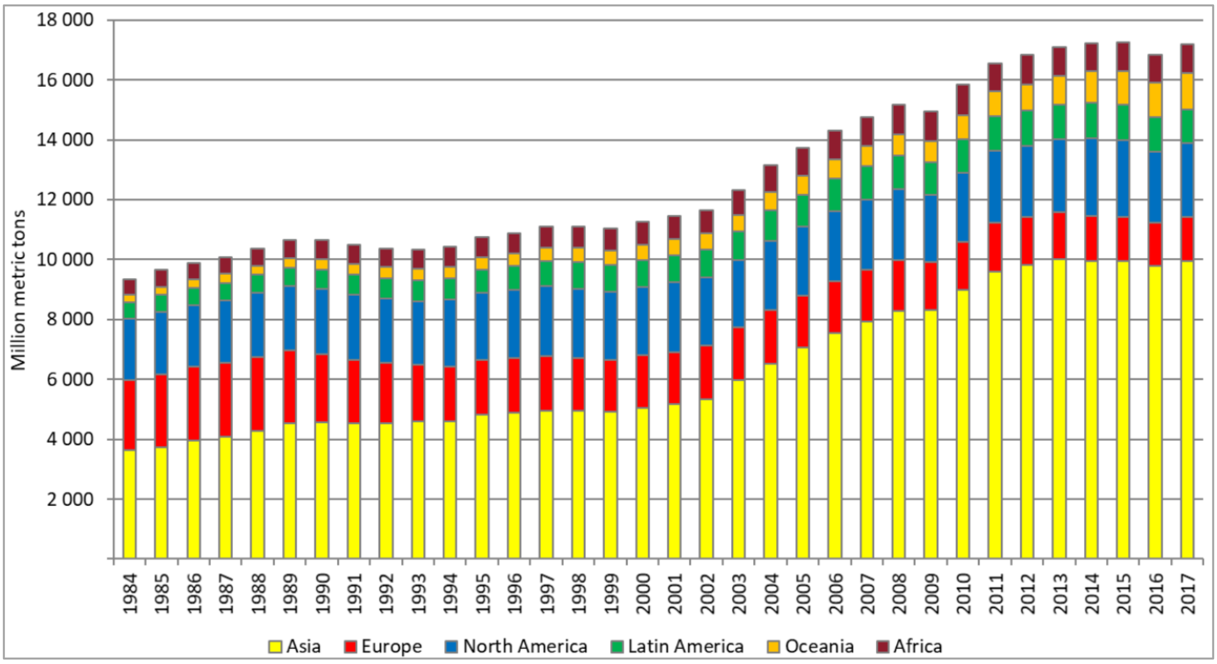


Figure 1. World mining production 1984 - 2017 by continents (without construction minerals) (Source: World Mining Data 2019 BNMT http://www.world-mining-data.info/wmd/downloads/PDF/WMD2019.pdf).

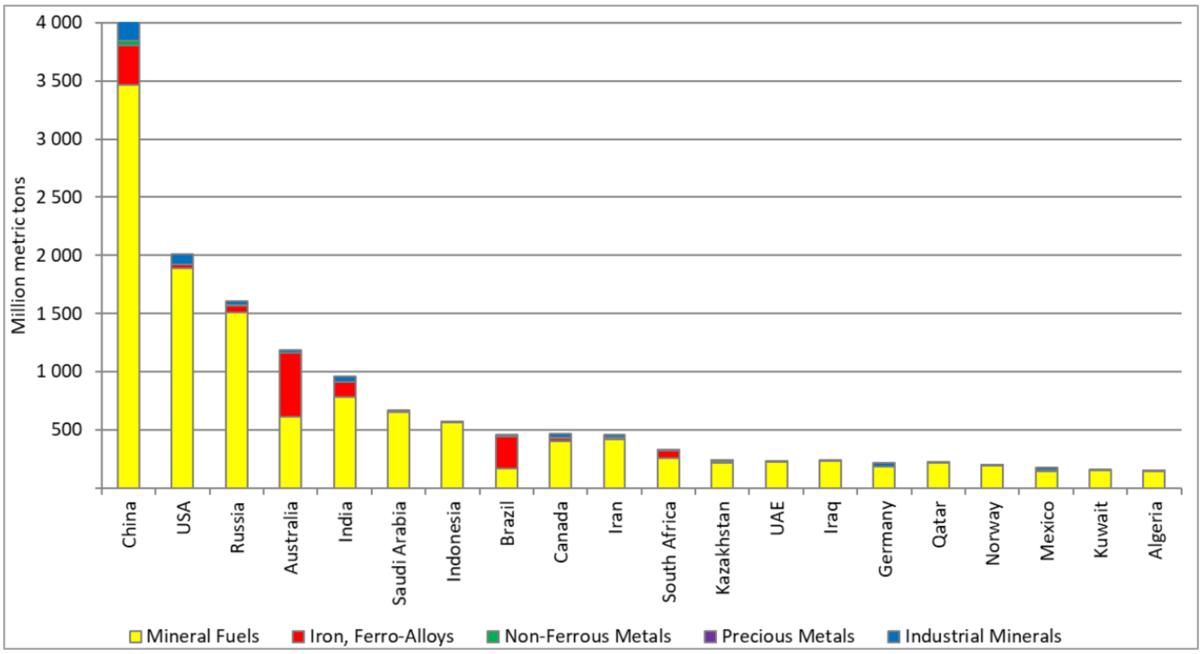


Figure 2. Twenty largest producer countries in 2017 (without construction minerals) in million metric tons (Source: World Mining Data 2019 BNMT http://www.world-mining-data.info/wmd/downloads/PDF/WMD2019.pdf).

Minerals and metals production rates are globally increasing, most rapidly in Asia, Oceania and to a lower extend in Africa and Americas; whereas in Europe the mining sector is declining since 2000 and it is the only continent with a decreasing global production rate during the last two decades (Figure 3).

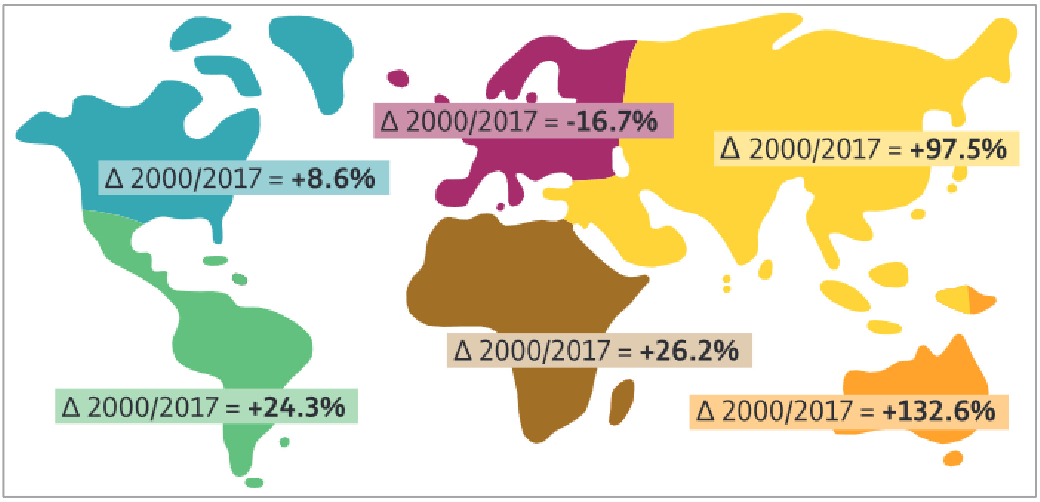


Figure 3. Delta of mining production by continents between 2000 and 2017 (Source: World Mining Data 2019 BNMT http://www.world-mining-data.info/wmd/downloads/PDF/WMD2019.pdf).

Mining companies and miners

The largest 150 companies control some 85% of the total global mineral production. Generally, developing countries are not in control of their mineral production (UNCTAD, 2007[24]). However, the structure of the global mining sector is slowly evolving with relocation of companies in developing and producer countries with emerging economies (Ericsson, 2012[25]) as China, India and South Americas.

According to market capitalisation in 2017, the top 10 of mining companies are: **Fresnillo** (Mexican company coated in London market, first producer of silver, and operating gold, zinc and lead), **Anglo American** (UK company, first producer of platinum and major producer of precious metals, nickel, iron ore, diamonds, coal and copper), **Newmont Goldcorp Corporation** (US company, second producer of gold, owning also mines of copper and silver), **Barrick Gold** (Canadian company, first gold producer of the world), **Coal India** (Indian state-controlled enterprise), **Vale** (Brazilian, world largest producer of nickel and iron), **Glenclore Xstrata** (Switzerland, zinc,nickel and ferroalloys), **China Shenhua Energy** (Chinese company, coal), **Rio Tinto** (Australian company, iron, uranium, copper, aluminium, diamonds and coal) and **BHP Billiton** (British-Australian company, potash, coal, copper, iron ore, nickel and uranium). Over the last 10 years major companies have merged and joined forces to face increasing extraction and production cost or diversify their commodities to assure less dependence of the fluctuation of prices (as examples: Glenclore and Xtrata, Anglo American and De Beers, Newmont and Goldcorp with possible joint venture with Barrick Gold). The rise of China and other developing countries will probably conduct to an upscaling of Chinese emerging companies in the top of largest mining operators in the next years.

[24] World Investment Report 2007 - Transnational corporations, extractive industries and development, United Nations, UNCTAD, 323 p.

[25] Ericsson, 2012, Mining industry corporate actors analysis POLINARES working paper n. 16, http://www.eisourcebook.org/cms/Mining%20industry%20corporate%20actors%20analysis.pdf

Around 2,500 mines produce metal ores using mechanised methods and only a hundred produce more than 10 Mt of metal ore per year. On the other hand, the Artisanal and Small-scale Mining (ASM) sector represents over 40 million of workers (after the World Bank DELVE database, Figure 4). ASM miners use manual operations to extract ores. Their main problems remain the respect of human rights (violence after woman and exploitation of children work, poor livelihood…) and the lack of financial facilities because of the contested ASM legitimacy that enable to develop and ameliorate business and working conditions (OECD Forum, 2019). As the extraction of mineral resources in developing countries is largely dominated by large-scale, capital-intensive investments, although artisanal and small-scale mining, to get access to modern infrastructures and increase productive capacity to enter global trade.

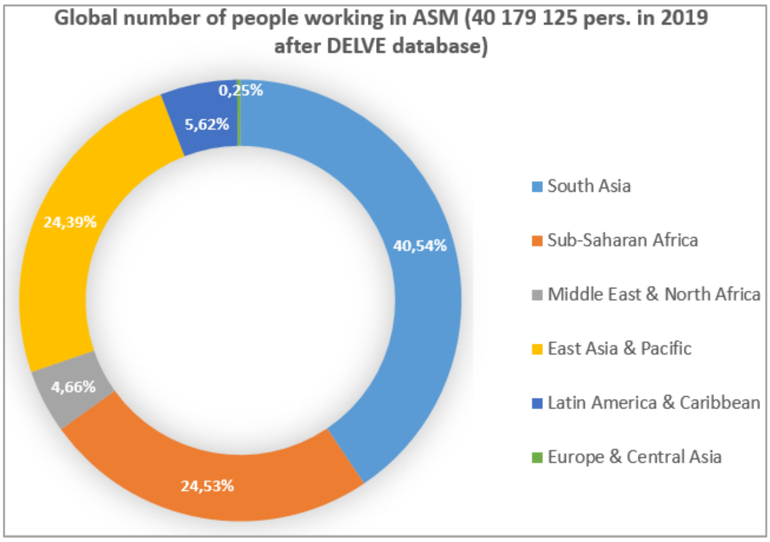


Figure 4. Distribution of artisanal and small-scale miners over regions (after data from https://beta.delvedatabase.org/).

Opportunities and characteristics of investments

The long-term nature of investment from exploration to discovery, economic and technical feasibility studies, up to the development of an operating mine can take between 15 to 20 years. Because near surface discoveries are becoming rare because of the finite nature of unrenewable mineral resources, investors are largely capitalizing in ongoing operational mines to extend the capacity of production in lower-grade ores or to find local extension of ore deposits. Fewer investments are engaged in new exploration campaigns that are characterized by high degree of uncertainty, turning out to unsuccessful projects after long periods of gestation.

In developed countries, effective management of new mining projects are faced with new challenges, which are the social acceptancy and environmental risk management with stronger legislation and regulation; moreover, it is getting extremely difficult and longer to get legal licences to operate. Investors and operating companies have to ensure sustainable development for the benefit of local communities and future generations respecting more drastic environmental norms and higher production costs.

In recent years, investments in the mining sector for exploration have taken place in Latin America, Africa and parts of Asia and these are likely to escalate in the next ten years. Moreover, if demand in raw materials continue to growth and new discoveries are not covering the gap, underexplored or large unexploited mineral reserves in specific geographic areas will gain attention for exploration, such as Artic region or Greenland.

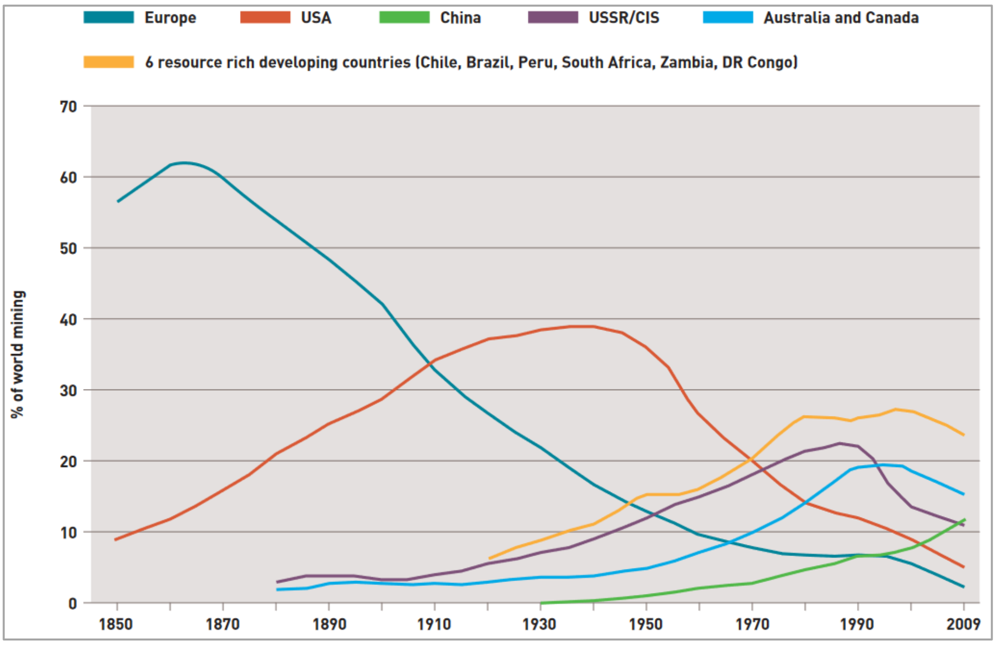


Figure 5. Location of world mining region from 1850 to 2009 (Source: Raw materials group, Stockolm, Sweden after ICMM 2012 report[26]). World mining is measured as the total value at the mine stage of all metals produced in all countries.

Deep exploration and mining: toward automation and digitalization

Extraction of natural resources has started by surficial deposits from soils and subsoils, but most of surficial deposits being discovered, reserves and ore grade progressively decrease and mining operation has to go deeper and deeper to continue supplying the demand. Mine production has undergone important changes during the 20th century with a shift from underground to open pit mining techniques (Figure 6). Early in the century, underground mining dominated in developed countries, and as mining evolved in emerging and developing countries, open-pit mining became more common because of the increase of extractive capacity of modern machinery. The mining industry is more and more focusing in deep and volume-increase technologies, undercover exploration or deep-sea polymetallic resource exploration. As security is becoming a more important issue for workers and risks increasing with depth or underwater conditions, automated technologies and digitalization are becoming also a new

[26] ICMM report 2012, Trends in the mining and metals industry, Mining's contribution to sustainable development, *available on http://www.ibram.org.br/sites/1300/1382/00002639.pdf.*

challenge. For resource and reserves evaluation, 3D modelling numerical tools are essential. Online and onsite rock analytical tools (chemistry and automated mineralogy) are also directly link to drilling techniques or used in front of open pit to minimize the time of operational and technical decisions. Important improvements have been done in sensor technologies (i.e. hyperspectral satellite, LIDAR, airborne geophysical survey, new UAV technologies, IA in autonomous extractive engines, sensors in drill holes to image the ground…) and associated digital tools for 3D modelling. Innovation should help geologist and miners to display of a better knowledge on ore deposits and therefore to remove less material and volumes of extracted rocks with a better selection of ores to optimize valorisation and lower wastes.

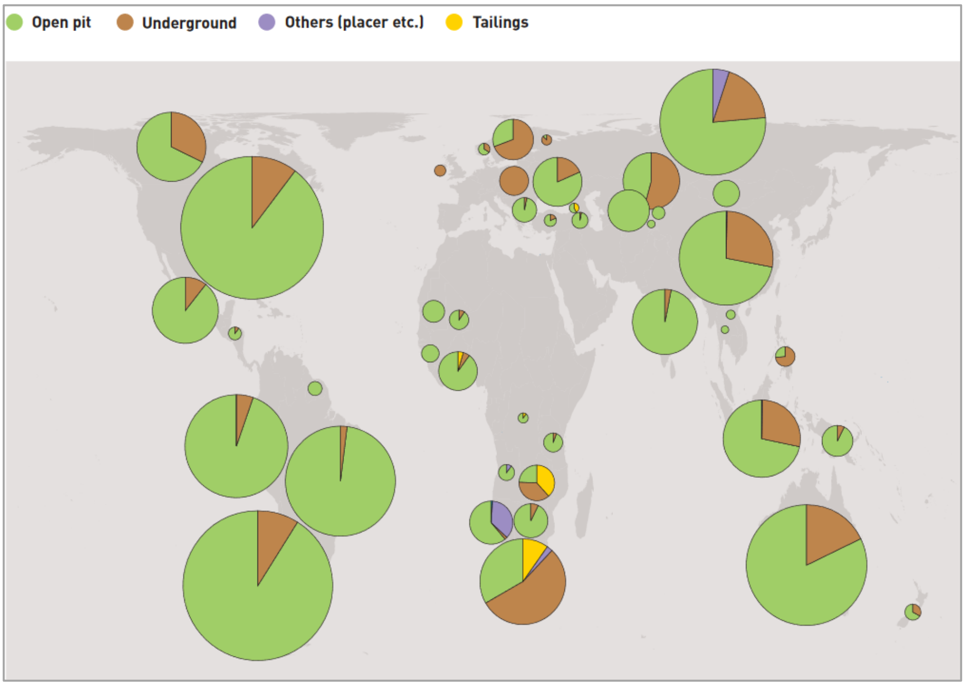


Figure 6. Production by mining method 2011 (Source: Raw materials group, Stockolm, Sweden after ICMM 2012 report[4]).

Investing in more efficient processing technologies and eco-friendly using green technologies

Stakeholders and civil society demand widely a total transparency on operational practices, which constrain companies to an exhaustive reporting of their activities in respect to high-level standards for health and safety routines but also including efforts to minor their social and environmental impacts.

Industrial efforts in R&D and innovation to improve ore treatment and processing are generally focusing to speed-up production, maximize valorisation of main commodities and co-products, or lowering water and energy consumption as well as limiting greenhouse gases emission.

Pyrometallurgy is still the common process encountered for iron, ferroalloys, aluminium and copper production but contributes to large amount of energy consumption, electric energy or fossil carbon energy (coal and coke). Smelter and refinery production remains located mainly in developed countries, although this balance has started to change during the last decades with the quick growth of Chinese production capacity. Improvement in pyrometallurgy processing is focusing on energy consumption management, heat energy optimization, capitation of gas and fine flying particles emission for reintroduction of dust back into the process. Valorisation of slags and metallic scraps is also a matter of possible innovation to find applications of these end-of life residues and minimize volume of industrial wastes.

Research is also focusing on evolution of processes that enable to extract more commodities from polymetallic deposits and especially scattered and low concentrations of rare and critical metals. Diversifying extracted commodities is directly related to sustainable development to longer life of operation and activities, but also conduct to greater profitability for the society. Hydrometallurgy and use of chemicals to treat polymetallic ores that contain disseminated multiple low-grade commodities are getting more common to dissolve metals into aqueous phase and after concentre by precipitation. Bioleaching using bacteria naturally activated under specific redox conditions constitutes suitable as an advance ecological technology. Efforts in the mining industry are also driven to generalize the use of electric vehicles to lower fuel consumption.

Concrete indicators of processing improvements could be on following:

- The level of concentration of worldwide production of raw materials, using the Herfindahl-Hirschman Index (HHI) which accounts for market competitiveness and production growth or evolution;
- numbers of new patents in ore processing;
- reduction of greenhouse gases emissions and other wastes, comparing each process for the same treated ores or type of deposits;
- life cycle costing or analyses on the value chain and mass balance of the workflow by commodities (LCC, LCA, MSA) ;
- reduction of water and energy consumption.

Hypotheses

HYP-MINACT1 (current trend)	Limited number of major mining companies which dominate the whole industrial sector	Merging and acquisitions of large companies get faster to constitute a small group of mega-companies dominated by Chinese organisations. Less importance of ASM. Slow improvement in processes (mainly for exploration).
HYP-MINACT2	Double effect of the low carbon industry	The energy transition will be more mineral–intensive than fuel-intensive, which will boost the mining sector. The latter will be also expected to reduce its own emissions. Actors who will manage such transformation based on renewables and circular economy will sell low-carbon premium minerals and dominate the market. This boosts ASM actors and some big companies working on a less energy intensive extraction.
HYP-MINACT3	Breakthrough innovations for future mining (deep sea, new territories)	The difficulty to access to resources will lead to develop radical innovations (automated and digitalised mining) to enable new forms of mining (e.g. deep-sea resources exploitation, In-situ extraction). This will shift boundaries in jurisdictions most appealing to mining

		ivestment. Less importance of ASM sectors and lead of the most high-tech and automated big mining companies.
HYP-MINACT4	Smaller scale production	Rise of artisanal and small-scale mining and illegal production and traffic. Big companies focus on recycling or exploration or sales; production is subcontracted to ASM.

6. Price and production cost of raw materials

Driver definition

The profitability of raw material (RM) production is driving mining choices of companies.

Different trends will have an impact on such choices. The need for new renewable energy sources is likely to increase global demand for base metals and their co-products, which will affect prices and the profitability of the operators. At the same time, the mining industry will inevitably have to adapt to higher energy costs of extraction.

Pertinent Indicators and past development

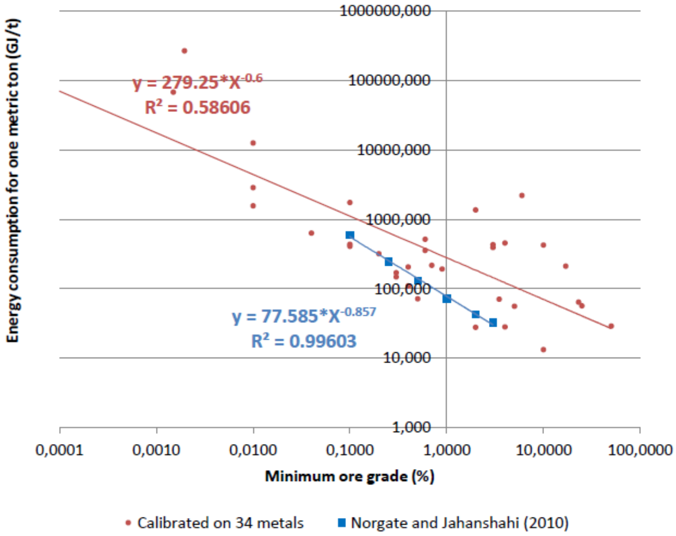
Profitability is the result of intra-project factors from geology and industrial processes (mineralogy & ore concentration/ coproducts / processing techniques / cost of reagents & energy, labor etc.) combined with external factors linked with market and macroeconomics (price evolution/global demand & supply situation). Even though each mining project is different from this regard, a few global indicators are pertinent to follow.

Cost of energy and EROI

Energy use in mining is crucial. Each step of mining lifecycle requires energy; from exploration drilling at the very beginning towards mine dewatering, ventilation and ore excavation, transportation, grinding, separation, concentration and land restoration. Energy is needed as electricity or different fuels. Many mining operations, especially on remote locations where on-grid power supply is not possible or too expensive, have installed their own power production facilities (diesel generators, hydropower, or increasingly solar, wind, or fuel cells).

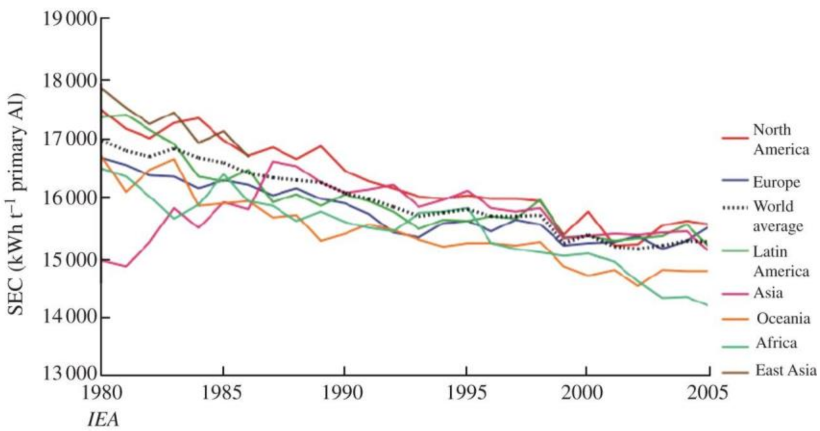
Two important trends are to be followed regarding energy consumption in mining and their impacts on costs. The first one is ore grade degradation over time for all major known deposits, which direct consequence is higher energy consumption to extract the same volume of ore[27].

[27] Court V., Fizaine F. (2015) Renewable electricity producing technologies and metal depletion: a sensitivity analysis using the EROI Ecological Economics, Volume 110, February 2015, Pages 106-118)



The second one is technological progress enabling to reduce the energy intensity required to produce RM. Many authors have worked on this topic[28].

In this article, authors estimate the possibility of reducing absolute material production energy by half, while doubling production of RM from 2013 to 2050. They conclude to gains of the order of a 50–56 per cent reduction in energy intensity. However, fundamental thermodynamic as well as practical constraints limit the ability to improve further the energy intensity of material production.



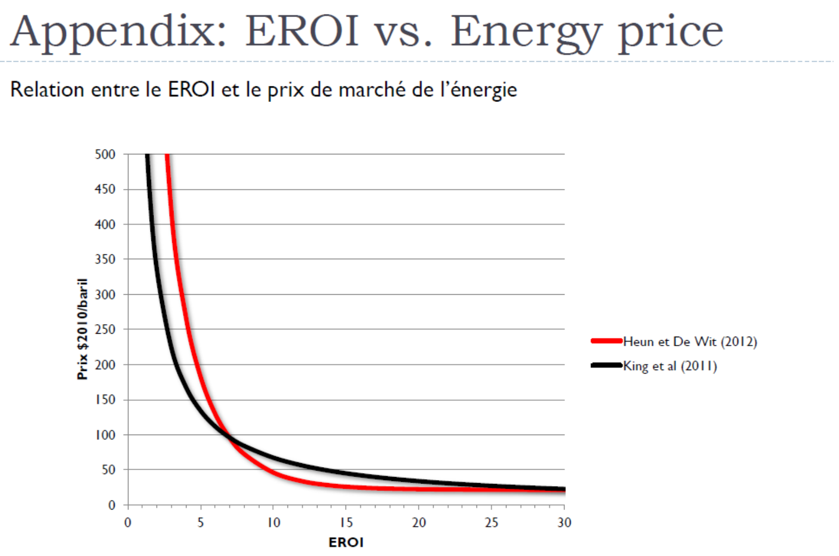
Historical regional data for the energy (electricity) intensity of aluminium smelting. SEC, specific energy consumption. Reproduced with permission from IEA [7]. Tracking industrial energy efficiency and CO_2 emissions OECD/IEA 2007, figure 8.1, page 211. (from Gutowski T. G. et al. (2013))

An appropriate indicator appears to be EROIE and its evolution with time, technology and energy prices. EROEI (Energy returned on energy invested or energy return on investment, EROI), is the ratio of the amount of usable energy delivered from a particular

[28] Gutowski T. G. et al. (2013) Energy required to produce materials: constraints on energy-intensity improvements, parameters of demand] Philosophical Transactions of the Royal Society, Volume 371, Issue 1986] https://doi.org/10.1098/rsta.2012.0003

energy resource to the amount of energy used to obtain that energy resource. For instance, the EROI of conventional fossil fuels currently stands at around 20 (which means 20 joules produced for an investment of 1 joule).

Some authors show an asymptotic relationship between Energy price and the evolution of EROI (Court&Fizaine, 2015)



In this graph, empirical evidences show that as long as energy is cheap enough (here < $50 per barrel of oil), the EROI can improve from 10 to 30. However, as soon as it is above $100, it appears almost impossible to increase the EROI.[29]

This indicator is likely to drive mining companies choices in the future. Indeed as many governments try to impose stricter standards for energy efficiency, the mining industry growingly seeks alternatives to achieve lower costs and better social acceptance of producing RM trying to adopt a 'material efficiency' strategy (i.e. providing more material-based products with less material and energy).

Share of by-product production in the profitability of operations

Metals prices demonstrate temporal cycles that have major impact on mining sector employment, investment, output, as well as exploration, mine startups and closures, and profitability of the operators. The repeated cycles of low & high prices driven by over & under supply of RM's are controlled by long mine development timescales, depletion of mines and economic fundamentals of high upfront mine capital investments.

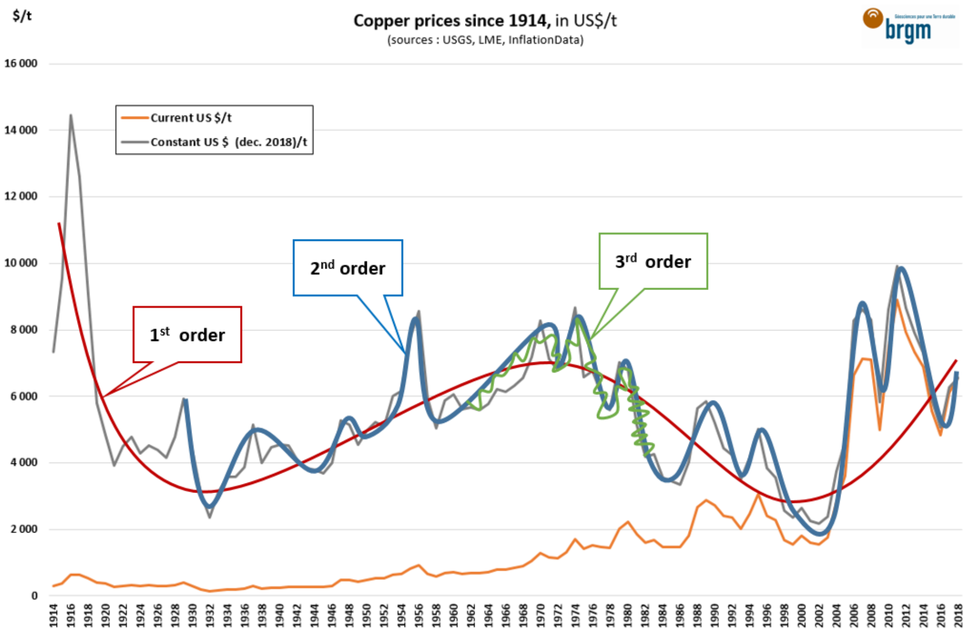
Nevertheless, new and other factors can come in line. Such cycles have traditionally been typically 8-15 years in length. More recently, the importance of by-production have risen and

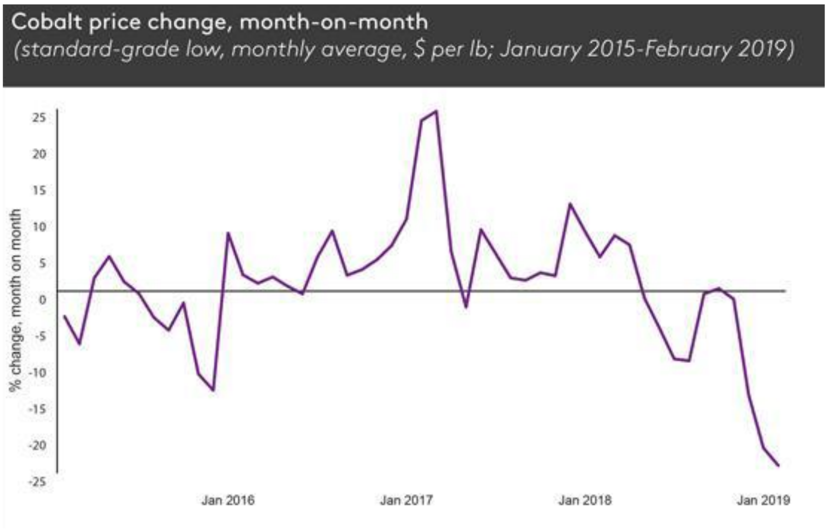
[29] Evolution of energy prices in the mining industry : Example of Canada 1990 to 2012 : Nyboer, J. & Bennett, M., 2014. Energy Use and Related Data: Canadian Mining and Metal Smelting and Refining Industries, 1990 to 2012. [Online] Available at: www.ceecthefuture.org/wp-content/uploads/2014/05/canada.pdf

can radically change supply-demand balances as well as considerations on profitability. Rare and precious metals, which are key to enable the development of new technologies for instance in the field of energy production and storage are in many cases recovered in the metallurgical process of other metals. As demand for rare metals is rising and their prices evolution can be much faster, they play a fundamental role in the new drivers of mining cycles and in the profitability of operations.

An example is cobalt, which has seen a dramatic increase in prices in 2017-2018 (from 30 000 $/t to 90 000 $/t in March 2018, LME prices). Some producers from the Copper Belt in Democratic Republic of Congo recovering cobalt as a by-product of copper had their income dominated by the sale of cobalt at this period despite much lower tonnages than copper. Cobalt thus became the main product of exploitation and highly beneficiated such producers, impacting their production and investments.

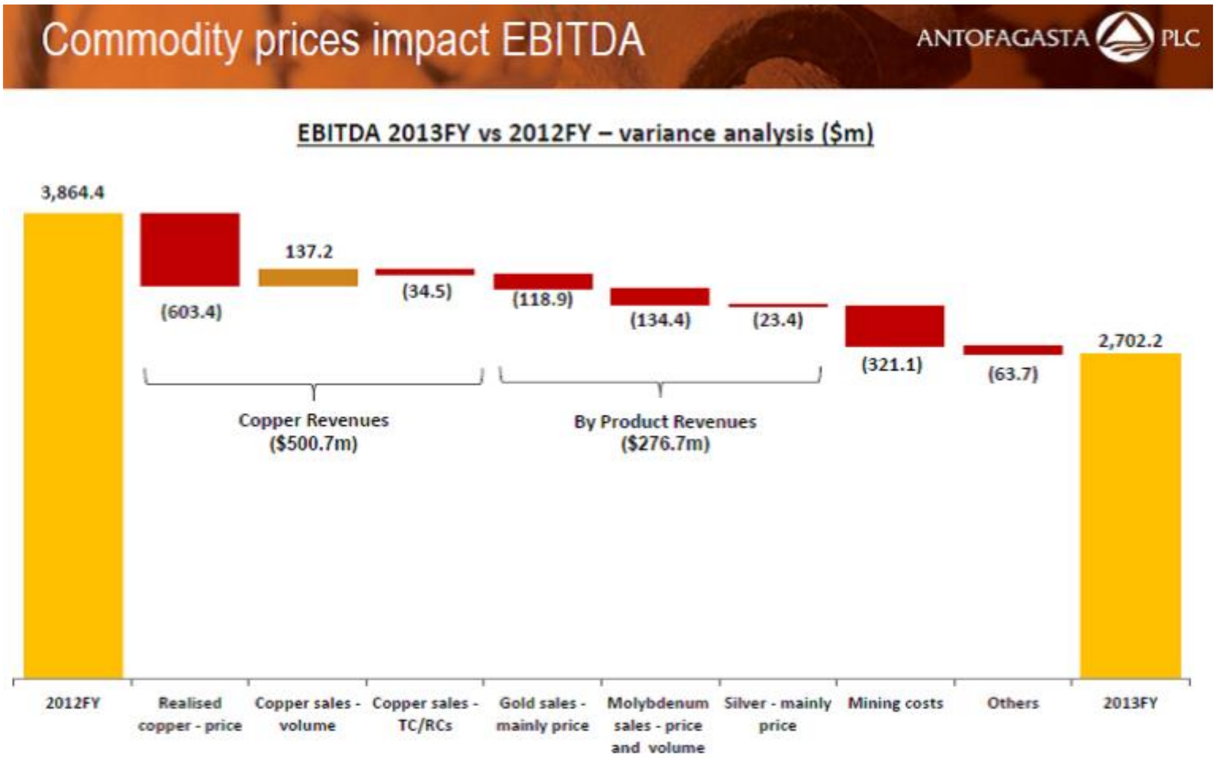
Illustration of metals prices cyclicity at different orders-timelines:





Source: LME, Fastmarkets

The following figure (source: Antofagasta Plc, Investors Presentation, 2014) also illustrates that in 2013, by-products (Gold, silver and molybdenum) weighed more than half of total revenues for the producer Antofagasta. Furthermore, revenues from their recovery covered almost entirely the company mining costs.



Therefore, *an* important indicator to follow and understand global mining choices is the respective weigh of *by-products in global mining operations and their respective prices evolution.*

Cost of primary production vs. cost of recycling

Another indicator can be the evolution in time of efficiency and cost gains in terms in RM recycling. It can be a huge incentive to produce less primary material, that will still be preferred as long as they can be obtained at much better prices and energy costs. Such competition is still a huge challenge as of 2019.

Hypotheses

HYP-COST1	Lower production costs and high prices of RM lead to higher production and lower energy consumption. **Profitability and higher production**	Thanks to technological breakthroughs, mining operations achieve lower energy consumption that allows higher production of RM in better conditions.
HYP-COST2 (Current trend)	**Higher production of RM despite high production costs (lower profitability)** and better energy intensity but higher overall energy consumption.	“Business as usual” scenario.
HYP-COST3	**High production costs leads to lower RM production** (and lower energy consumption)	Limits to the development of mining operations due to prohibitive production and energy costs. More local recycling and alternative materials competing with mining production

Complementary sources:

U.S. Department of Energy, 2007. Mining Industry Energy bandwidth Study. [Online] Available at: https://energy.gov/sites/prod/files/2013/11/f4/mining_bandwidth.pdf

Sims & Schock, 2014. Energy Supply Chapter 4. [Online] Available at: www. ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter4.pdf

Exxaro, 2008. Energy and Mining The Impact of One on the Other. [Online] Available at: http://www.exxaro.com/pdf/sanea_may_08.pdf

Ernst&Young, 2013. Mining: the growing role of renewable energy. [Online] Available at: http://www.ey.com/Publication/vwLUAssets/EY_-_Mining:_the_growing_role_of_renewable_energy/$FILE/EY-mining-the-growing-role-of-renewable-energy.pdf

F Fizaine, V Court (2015) Renewable electricity producing technologies and metal depletion: A sensitivity analysis using the EROI, Ecological Economics 110, 106-118

F Fizaine, V Court (2016) Energy expenditure, economic growth, and the minimum EROI of society, Energy Policy 95, 172-186

Fizaine F. (2014) Analyses de la disponibilité économique des métaux rares dans le cadre de la transition énergétique, Thèse de Université de Bourgogne,

Vidal O., Goffé B. Arndt N. (2013) Metals for a low-carbon society, Nature Geoscience 6(11):894-896

Ali S.H. et al. (2017) Mineral supply for sustainable development requires resource governance, *Nature* volume 543, pages 367–372

7. Technologies to find, access and process raw materials

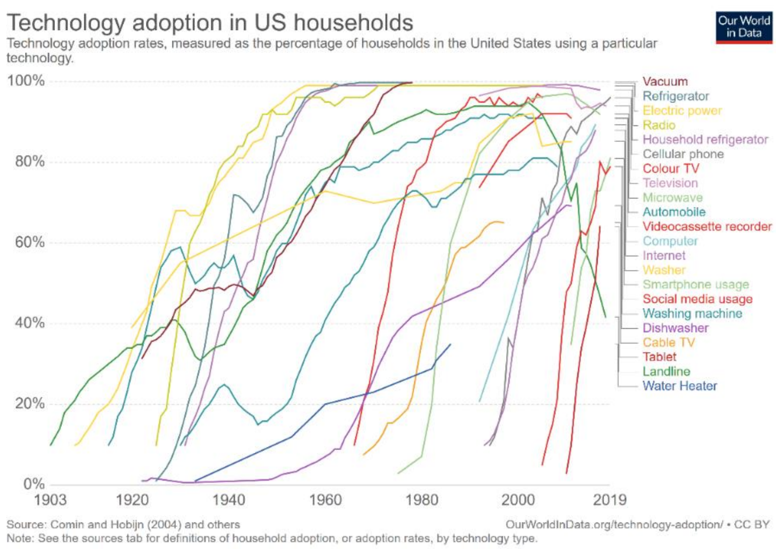
Definition: **Technological improvement in finding, accessing and processing raw material, including artificial intelligence**

1. Driver definition

Increasing mechanisation in mining is not new, however the rate of technological development and digital innovations currently seen is expected to have profound impact on a sectoral level and across value chains. Minerals companies are traditionally reluctant to adopt new technologies unless it can be done in an incremental way with minimum risks to production. However, current technological trends are said to be evolving at a faster rate than in the past. These include mainly automation and robotics, IT/OT convergence, advanced analytics and AI.

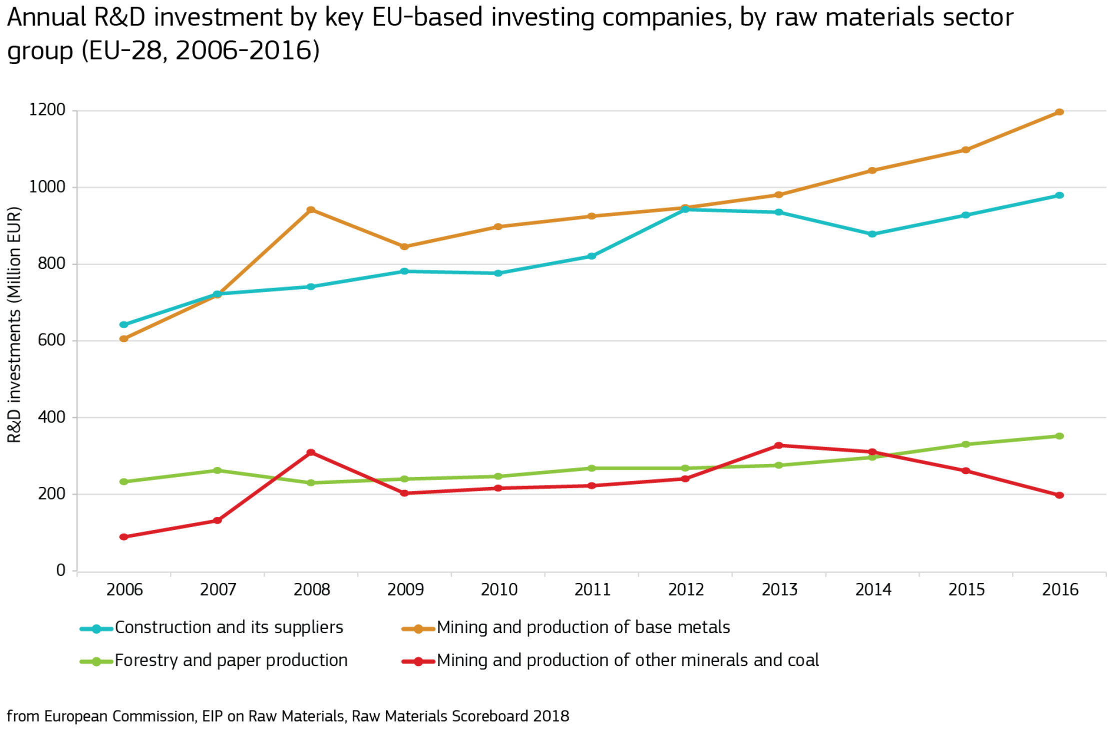
2. Pertinent indicators

Level and speed of adoption of new technologies



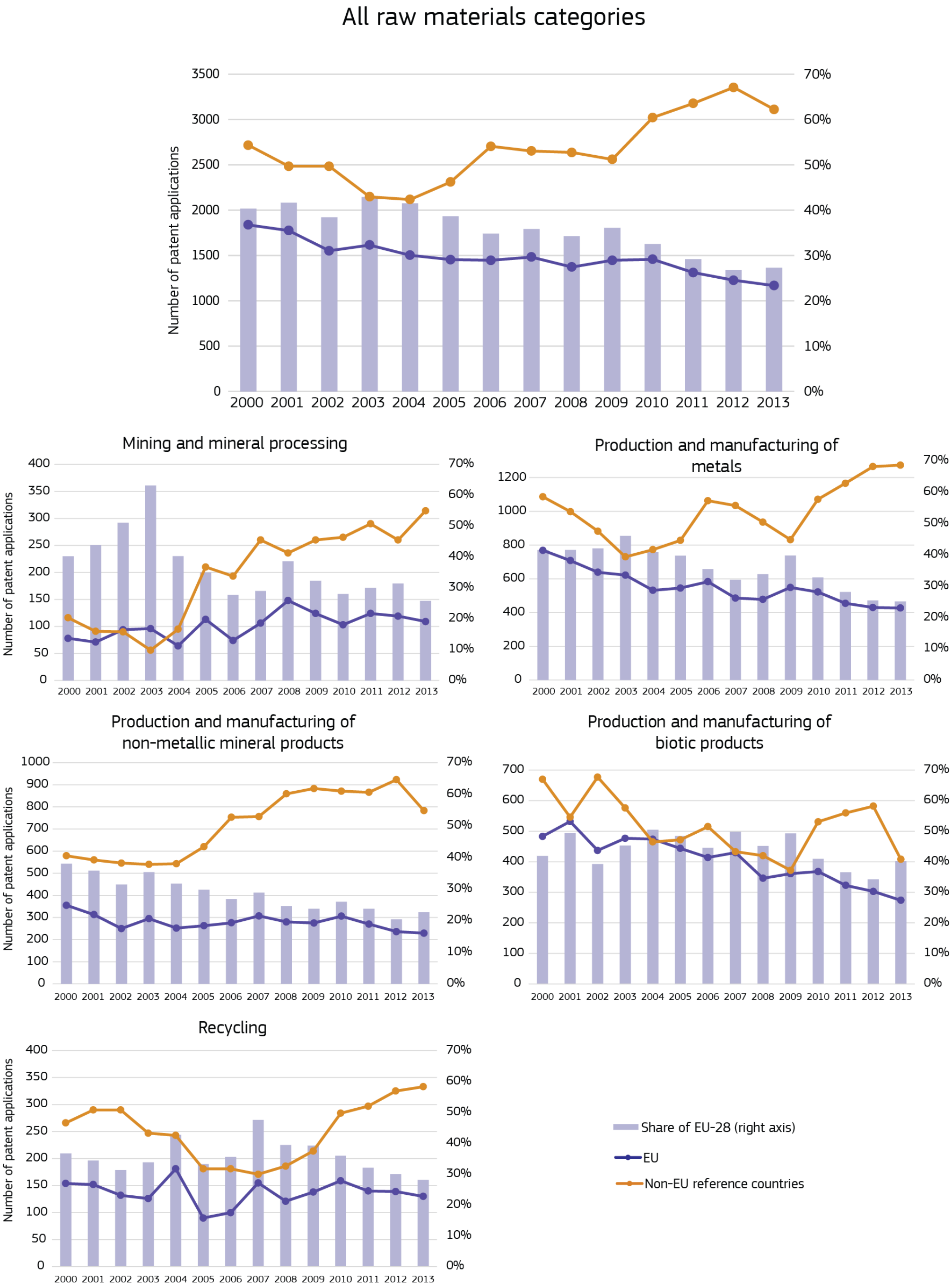
Recent innovation were very quickly adopted by the vast majority, such as digital innovation or internet. In the mining industry, however, it must be noted that innovation adoption tend to be limited by capital risks trade-off as mining operation legacy systems, which can last for decades, can outweigh the associated costs and risks of partially or completely revamping and refurbishing existing operations with new technologies.

Annual R&D investment by key EU-based investing companies



Patent applications by raw materials sector

Comparison of the number of patent applications by the raw materials sector and its five contributing categories (EU and selection of non-EU reference countries, 2000-2013). Lines refer to left axis, bars to right axis.



from European Commission, EIP on Raw Materials, Raw Materials Scoreboard 2018

Potential emerging technologies for radical change:

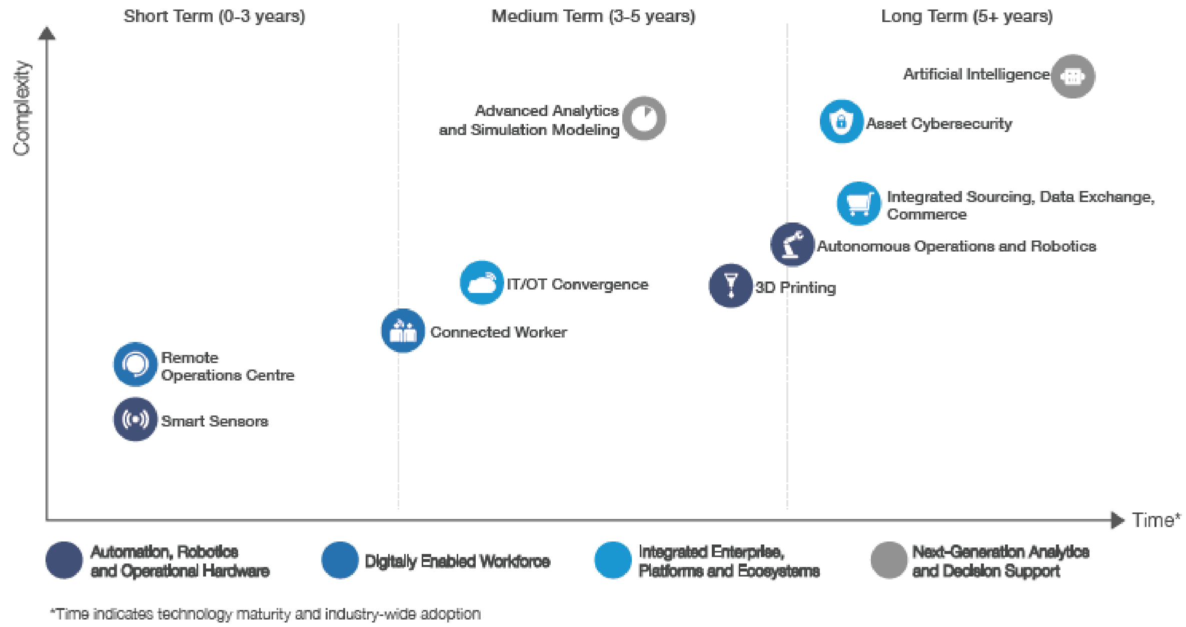


Figure 11 - Time and complexity for digital initiative to reach scale (WEF, 2017[30])

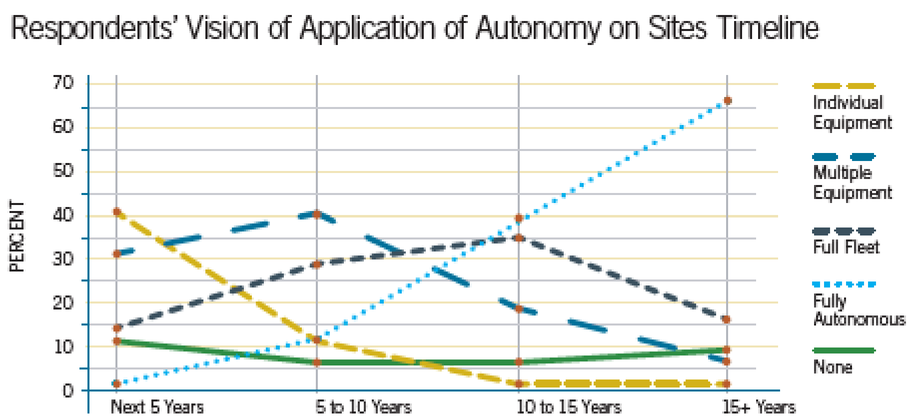


Figure 12 - GMG (2017)[31] Survey on the future levels of autonomy in mining operations

3. Past developments

Historically, the mining sector has been technology innovators in some areas and followers and late adopters in others. This is shaped by several factors, such as the capital availability, geographical dispersion of key operations, managerial conservatism and inherent complexity of some operations (WEF, 2017). It has been argued that pace and pervasiveness of

[30] WEF (2017). Digital Transformation Initiative: Mining and Metals Industry. White Paper. World Economic Forum. 36p.
[31] GMG, 2017. Building a Strategic Vision of Future Mining. Global Mining Standards Group. September 2017 Corporate Member Report.

technological change is expected to increase in comparison with previous decades. Mostly due to the falling cost of technology. For instance, costs per KWh of solar power dropped from $30 in 1984 to around $0.12 in 2016, cost of a drone in 2007 was nearly $100,000 and dropped to around $1,000 in 2018. Also, industrial robots would cost around $500,000 in 2007 and dropped to just $20,000 in 2014.

Technical change ultimately seeks to improve productivity of operations. As a cyclical industry, the raw materials sector typically feature two important behaviours: when the commodities prices are inflated, companies increase production for profitability, but lose productivity, conversely, when prices decline, companies re-center their focus on costs and productivity to remain competitive. Interestingly, critical inputs such as energy and water are becoming more expensive on their conventional forms of usage. More broadly, EY (2019) defines four categories on how technology can create value (Figure 3).

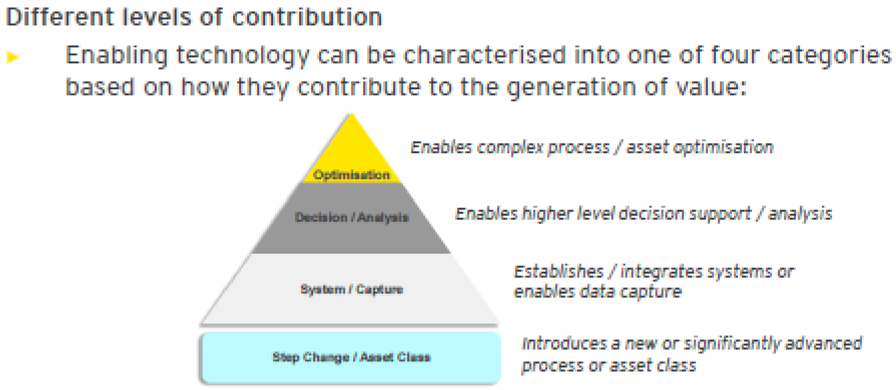


Figure 13 - Categories of technology contribution to create value (EY, 2019[32])

Over the past few decades, one important aspect has been the social and community acceptance of mining operations, challenging companies in how they operate. This has had impacts also on the research & development efforts of technologies that help companies not only to improve productivity and efficiencies, but also to improve their operations in terms of environmental impacts, safety and benefits to local communities. This trend is likely to continue.

Mining has steadily evolved over the last century in function of economies-of-scale, where incremental innovations were able to increase sizes of equipments and production capacities, while reducing unit costs of production. In mineral processing, this meant larger grinding mills, flotation cells, and furnaces, where the main drivers are lower ore grades and more complex mineralisations. This evolved together with an increase in computerization of processes, where most of plants now have central control rooms. In that sense, step-change technological innovations have been rare and might be specific to a particular type of ore/mineral commodity. According to Randolph (2009), hydrometallurgy has been increasingly displacing

[32] EY (2019). Future of work: The economic implications of technology and digital mining. A Report for the Minerals Council of Australia.

pyrometallurgy in the non-ferrous area and and larger share of leaching technologies application can be expected to develop.

Table 4 - Escondida mine expansion (Randolph, 2009[33])

Metric	1990	2008
Daily ore production, t/d	35.000	• 240.000 concentrator feed, • 60.000 oxide leach feed, • 300.000 sulfide leach feed
Total material moved, t/d	280.000	1.4 Million
Annual copper production ,t/yr	320.000 in concentrate	1.1 Milion in concenrate, 300.000 in cathodes
Average copper grade	2.9%	1.5%
Processing technology	Concentrate flotation	Flotation, oxide leach, sulfide leach, electrowinning
Mining technology	Drill, blast, truck and shovel	Drill, blast, truck, shovel, ore conveyors.

Mineral exploration technology has evolved from a reliance on simple observations of geologic features in the field to detection of hidden mineralization at increasing depths. Specially during the last 30 years, sattelite spectral scanners combined with faster computer processing capabilities meant that an individual geophysicist can now process complex input from a variety of sources, for defining topographies, structures and alteration just with a laptop computer (Randolph, 2009). More recently, developments on UAV's onboard technology are being increasingly used in remote sensing for mapping ground data with relative low costs. Also, such technology can aid resource modelling procedures for monitoring and calculation volumes of stockpiles and production. Trends point to UAV-based solutions to be increasingly deployed by mining companies.

HYP-TECH1 (Current trend)	**Increased automation and improved processes (for specific materials)**	More automated processes (e.g. drilling, loading, autonomous trucks), automation improvements in extraction still constrained by type of deposit. Improvement in material processing for specific raw materials.

[33] Randolph, M. (2009). Current Trends in Mining. In: SME Mining Engineering Handbook. Peter Darling (Ed). Society for Mining, Metallurgy and Exploration, Inc. ISBN: 978-0-87335-264-2.

HYP-TECH2	**H1 + Breakthrough in exploration**	Automation in logistics and improved processes Automation of exploration (satellite, UAV…) leads to new discoveries
HYP-TECH3	**Automation AND clean mining**	H1 for technologies + for mining acceptability (first in OECD, then Asia/latin america and in Africa after 2030) extraction must take environmental issues into account to be allow production and reversibility of the mining damage. Thus big improvement in "clean" mining to avoid air or water pollution.

8. Channels of education including field experience

Driver definition

Training programmes can be organised according to different pedagogical, separate or complementary channels:

- Face-to-face training, action training, alternating training: types of training giving specific place to professional situations.
- Tutoring, coaching, personalized coaching: integrating personalized support for learners.
- Exchange of practices, return of experiences
- Informal learning
- E-training / E-learning
- Open distance learning
- Use of standardized educational products (teaching suitcase, tutorials, etc.)

The implementation of training actions has always led to mobilize varied and complementary teaching methods, in order to be effective and to search for the closest answer that fits better to the needs.
New digital technologies, including information and communication technologies (ICTs), artificial intelligence and robotics, are reshaping the way people live, work and learn[34].

There is a real change in teaching methods and practices: knowledge sharing, collaborative interactions, co-construction are among the new components defining these new methods of learning, thus changing the traditional role, initially focused on trainer.
The digitalization of vocational training is susceptible to renew pedagogies and training courses, in line with the expectations of individual needs and companies. [35]

[34] *OECD Skills Outlook 2019 - Thriving in a Digital World*
[35] *IGAS report N°2016-055R - La transformation digitale de la formation professionnelle continue.*

In a digital age, training bodies are likely to face challenges in designing and implementing training programs taking into account the organization's requirements and new expectations of learners.

Literature and media regularly raise the concern of schools and businesses about the training, recruitment and retention of millennials – Gen Y (born between 1980 - 1995) - and Gen Zs (born after 1995).
Millennials, who are already emerging as leaders in technology and other industries and will comprise 75 % of the global workforce by 2025, want to work for organizations that foster innovative thinking, develop their skills, and make a positive contribution to society. Who will transmit them these skills is a source of some debate.
Millennials say business (30 %) has the greatest responsibility for preparing workers, followed by educational institutions (24 %) (Figure 1).
The two generations did agree that individuals— through self-education and ongoing professional development—came next, and that government bore the least responsibility for developing workers.[36]

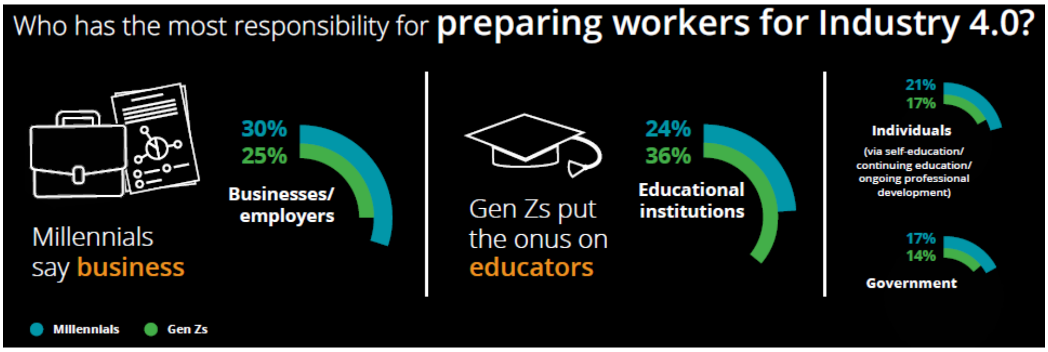


Figure 14: Who has the most responsibility for preparing workers for the changes that will result from Industry 4.0?

All millennials 13,416, all Gen Zs 3,009 - Deloitte Global Millennial Survey 2019

Indicators and past development

New communities of knowledge – A more active role for learners

In June 2007, a group of experts convened in Kronberg, at the invitation of UNESCO and the German Commission for UNESCO, discussed the future of knowledge acquisition and sharing in over the next 25 years. This event is widely considered as a major milestone in knowledge acquisition foresight.
Experts issued there a statement announcing profound changes in existing methods, and evoked a revolution in traditional educational processes, the formation of new communities of

[36] *The Deloitte Global Millennial Survey 2019, Societal discord and technological transformation create a "generation disrupted"*

knowledge and the increased importance of social skills and competences (networks, communities of practice): "Learners will play an increasingly active role in acquiring and sharing knowledge, including creating and distributing content".[37]

Emergence and key role of Digital Learning

With the introduction of computer and the Internet at the end of the 20th century, virtual learning environments have truly begun to flourish, people having access to a wealth of online information and learning opportunities.

On the technical side, the arrival of computer science has made it possible to develop new tools and software for geologists: modelling, digitization, collection of huge amount of data.

In the early 1990s, several schools were created to offer online courses only, taking advantage of the Internet and bringing education to people who would never have been able to attend a university because of geographical or temporal constraints. It was also a way for educational institutions to reduce the costs of distance education.

Another technical innovation of the decade: the webcam, that profoundly changes the nature of the relationship between teachers and students. Together with the increase of internet speed, the democratisation of the webcam allowed courses to be followed in real time, and facilitated dialogue and interactivity.

In the 2000s, thanks to the falling cost of computer equipment and the revolution of free software, distance learning became more and more popular.

In addition to the MOOCs[38] which is on front-page news often and rise the interest of the general public, e-learning is now spreading among the world of business. New and experienced workers now have the opportunity to improve their industry knowledge base and expand their skills.

Towards multi-modal offer

The range of digital training potential (e-learning, MOOC, COOC[39], SPOC[40], gamification, mobile learning, social learning, multimodal training / blended-learning), virtual reality) is in constant progression and renewal.

[37] *Unesco - Kronberg déclaration on the future of knowledge aquisistion and sharing, Germany*
[38] *Massive Open Online Course*
[39] *Corporate Online Open Course*
[40] *Small Private Online Courses*

E-learning already has a high level of diffusion, new, more targeted approaches are coming to the market (Figure 2).[41]

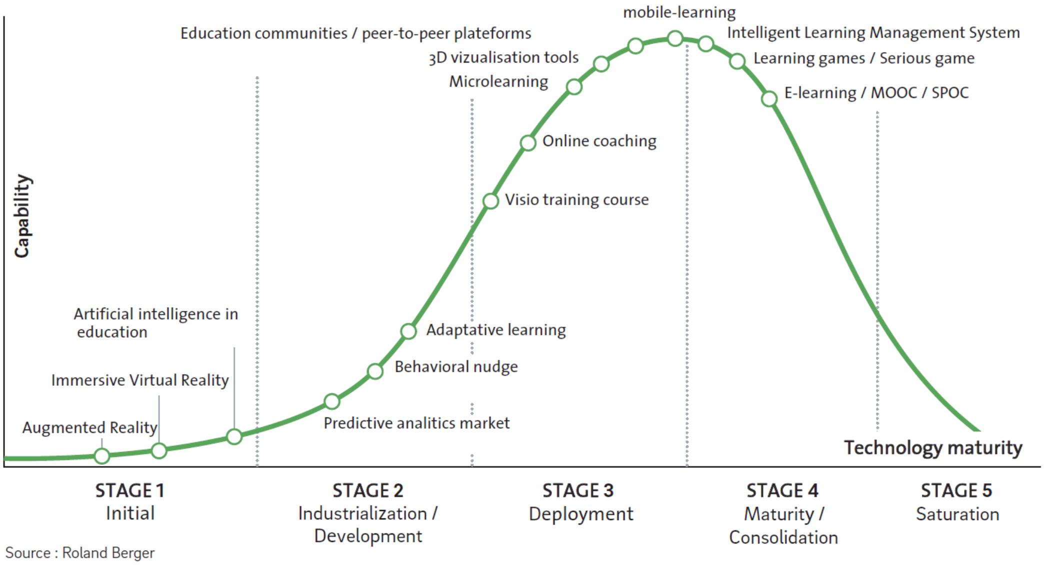


Figure 2: Positioning of technologies on the maturity curve [2016] – Roland BERGER

Digital training offers advantages for the accessibility, fluidity and personalization of training courses of facilitating entry into training, adapting courses to the prior positioning and pace of individuals, minimizing geographical and temporal constraints. However, up to now, different factors have hindered the diffusion of new modalities, such as still strong attachment to the classroom - pedagogical situations require "face-to-face" or a real scenario – or the magnitude of the human and financial challenge that represents the digitalization of training contents.[42]

The Cegos 2016 Barometer of Vocational Training in Europe highlights a strong increase in mixed and digital training in all the countries studied (France, Germany, Spain, Great Britain, Portugal and Italy).

In the 2018 survey, the Cegos barometer underlines that in terms of skills development, employees prefer face-to-face formats (training, coaching or peer-learning), where they can interact with other learners and where they are designed to work (Figure 3). Otherwise, their preference goes to solutions that enable them to learn when they need to, using online resources, for example. They appear to be more open to ATAWAD solutions ("anytime, anywhere, any device") than their HR & Learning Directors.[43]

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[41] *Report by Roland Berger / FFP - October 2017*
[42] *IGAS Report N° 2016-055R – La transformation digitale de la formation professionnelle continue, Nicolas AMAR, Anne BURSTIN*
[43] *Cegos 2018 European Research- Transformation, skills & learning (2,227 employees and 316 HR & Learning Directors polled, all working in private sector companies with 50+ employees in five countries: France, Germany, Italy, Spain and the UK)*

Figure 3: Transformation, skills & learning CEGOS, 2018 survey

Today, digitization has therefore not replaced face-to-face: they complete each other it in a multimodal offer. The market is actually moving towards a complementary integration of digital transactions. The training thus becomes "multi-modal" and relies on blended-learning which combines face-to-face and digital. This makes it possible to adapt the training paths for each profiles, answering to their expectations, their needs and their constraints. Thanks to this complementarity, training is becoming tailor-made. [44]
According to the European benchmarking of digital learning, produced by CrossKnowledge and Fefaur in 2015, 72% of the companies surveyed in seven European countries (France, Germany, England, Spain, Italy, Belgium and the Netherlands) intend to use more intensively blended-learning, over the next two years.

Companies and Human Resources vision

According to this same benchmark, for European companies, the rationalization and optimization of training costs are the primary expected benefit (68%) of the Digital Learning (Figure 4).

[44] *Report by Roland Berger / FFP - October 2017*

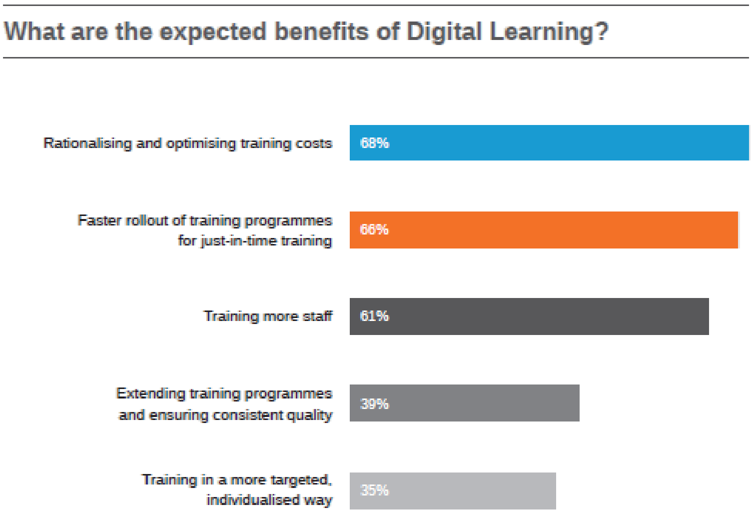

Figure 4: European Digital Learning Benchmark" CrossKnowledge and Fēfaur 2015

As for Human Resources (HR) department and managers, one of their Priorities in training is to provide employees with the means to learn at any time according to their needs.[45]

On a more practical level, when polled about how their training should develop, HR & Learning Directors emphasize on-the-job transfer and tailored learning paths:

- Workplace training and enforcement should be promoted (66%)
- Training courses and learning paths should be more individualised (57%)
- Devices should be more interactive and fun (42%)

One of the major challenges facing HR & Learning Directors today remain learner's involvement and commitment. For them, the three main drivers to ensure such commitment are to set the training in a real work situation, to make training content easy to access, and to provide support by a tutor or trainer.

The challenge of soft skills

The challenge for companies is now to recruit employees adaptable to the evolving environment, be able to innovate to stay ahead of the game and develop an attractive and productive corporate culture.

As a matter of fact, recruiters consider the hard skills as a lower priority. To be adaptable, autonomous, creative, to be able to learn things fast, to manage agile projects, to express a critical spirit, to collaborate, to work in a team, as much soft skills are becoming decisive factors of recruitment.

[45] *Cegos 2018 European Research - Transformation, skills & learning*

The importance of these soft skills is even more recognised in technology-intensive companies. And they allow any individual to adapt his behaviour to professional contexts and to various interlocutors. [46]

The Neuroeducation development (MBE : Mind, Brain and Education Science)

Research in cognitive neuroscience has been developing for some 30 years. They shed light on the development and functioning of the brain in adults and children. They rely on methods ranging from experimental psychology techniques to all those of brain imaging. Some discoveries have very concrete implications, particularly in the field of education.[47]
Four main factors have been identified to successfully a learning: attention, active engagement (a passive brain learns nothing), error (To be mistaken is essential to progress) and consolidation of gains.[48]

Thanks to new imaging techniques (for example, I.R.M. or magnetoencephalography), brain reactions linked to selected stimuli can be visualized. Advances in medical imaging allow us to observe the cognitive functions of the brain and to open up new perspectives at the crossroads of biology, genetics and technological innovations.[14]

Hypotheses

HYP-EDU1 (Current trend)	**Continued emphasis on practical experience**	Although digital learning reveals a multitude of concepts training, the mining industry and the raw materials sector only partially adopt it. Everyone learns differently, with its own pace, using adaptive or personalised approaches. The development of interactive videos in which the interaction of the learner is stimulated with a personal smart virtual assistant or chatbots, is in full swing. However, acquisition of hard skills of technicians and engineers in mineral resources industry (evaluation of the mining potential of a given region, the choice of targets for detailed studies, the estimation of discovered mineral resources…) can be only learned in real work situations, on the ground and by the return of experiences.
HYP-EDU2	**Virtual reality and Augmented Reality**	Immersive training is expanding in the mining and raw materials sector, replacing the field experience. Technical means of virtual reality take learners to the field, where realistic situations are reproduced. With immersive virtual learning systems, staff is trained safely, with real-time interactions. But soft skills (project management, innovation…) still require field /group experience, human interactions.

[46] *CEDIP 2019 Sheet n° 81-2*

[47] *Dr Laurent COHEN, professor of neurology at Salpêtrière Hospital, Team Leader "Neuropsychology and Neuroimaging" (ICM Research Center).*

[48] *Dr Stanislas Dehaene, neuroscientist, professor at the Collège de France, holds the Experimental Cognitive Psychology Chair, member of the Academy of Sciences, researcher at the NeuroSpin Center, President of the Scientific Council of National Education - Les quatre piliers de l'apprentissage, ou ce que nous disent les neurosciences (on November7th, 2013) - Apprendre ! Les talents du cerveau, le défi des machines (Odile Jacob, septembre 2018)*

HYP-EDU3	**Automated Learning**	Advances in brain imaging and knowledge of brain development and function have allowed to improve the learning process, to accelerate its learning capacity. The brain stimulation is well managed: the electro-stimulation of specific areas of the brain accelerate the creation of new neural connections corresponding to a specific skill. These techniques are beginning to offer new perspectives: the ability to transfer knowledge directly into the human brain, allowing instantaneous acquisition of new skills including soft skills