STRATEGIC RESEARCH AND INNOVATION ROADMAP

FOR THE SWEDISH MINING, MINERAL AND METAL PRODUCING INDUSTRY

The update of the strategic research and innovation roadmap for the Swedish mining, mineral and metal producing industry was implemented by Svemin within the framework of the Swedish strategic innovation program for the mining and metal producing industry (SIP STRIM) with contributions from and in collaboration with stakeholders (industry, academia, institutes, GOs and NGOs). SIP STRIM is part of a joint investment in strategic innovation areas by Vinnova, Formas and the Swedish Energy Agency.

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Introduction

A COMMON RESEARCH AND INNOVATION ROADMAP

Aitik mine, Gällivare. Photo: Mats Hillbom, Boliden AB

Swedish mining companies, technology providers, universities and research institutes have have jointly developed a common strategic research and innovation agenda that is revised every third year. The purpose of this national research and innovation agenda, which is the third consecutive agenda of its kind, is to bring research and innovation needs of the Swedish mineral and mining industry, the metal extraction industry and equipment suppliers to the fore. In the agenda, these industries are referred to collectively as the the mining and metal producing industry.

Sweden is one of the world's leading nations in mining innovation. The mining companies are world leading in terms of productivity, both underground and at the surface, thanks in large to strong providers of technology and systems. There is a longstanding tradition of collaboration between mining companies, technology and systems providers, research institutes and academia. This collaboration has laid the foundations for strong innovation and successful, internationally competitive companies.

The aim of this national research and innovation agenda is to jointly define the challenges, objectives and activities that are relevant and describe how research and innovation will strengthen the competitiveness of a sustainable and responsible mineral and metal-producing industry in Sweden.

"Sweden is one of the EU's leading ore and metal producers and world leader in mining equipment and mining technology"

INSTRUCTIONS TO THE READER

This Roadmap consist of two parts. In the first section the current status, a summary of world trends and future prospects for the Swedish mining, mineral and metal producing industry are described from a national and international perspective (pages 6–15). On pages 16–29 the industry's joint strategy for an internationally competitive and profitable sector is outlined, together with a vision statement, challenges and objectives for research and innovation. Pages 30–33 summarise collaboration and strategic alliances between companies, organisations and knowledge centres, both national and international. Pages 34–37 briefly describe the technological and non-technological areas within research and innovation that are covered by this agenda.

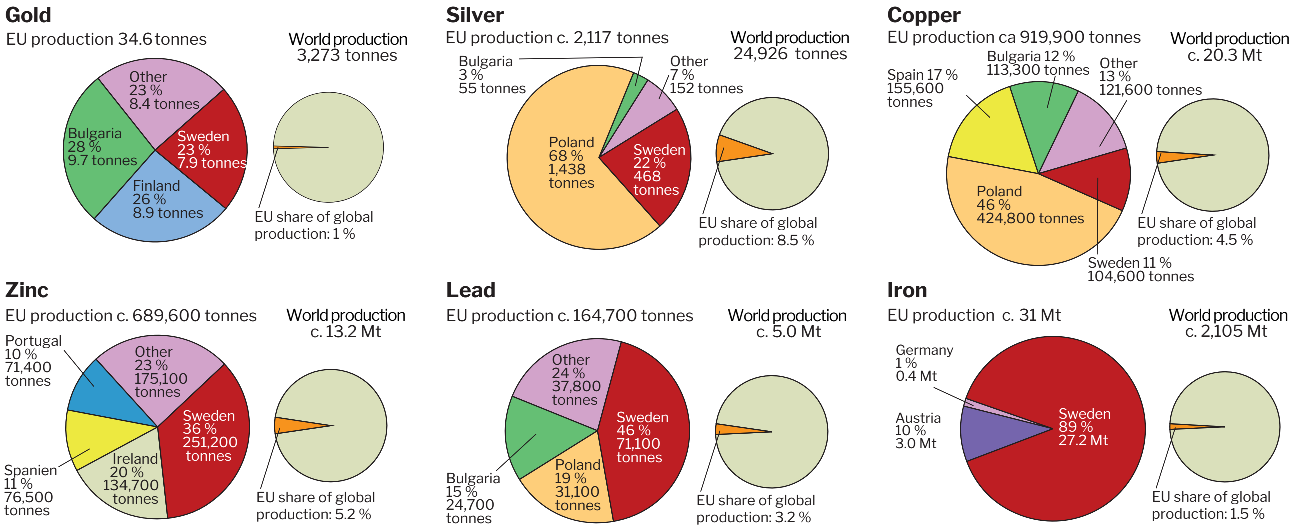
In the second section, indepth descriptions of the nine thematic research and innovation areas are given on pages 38–66, and the challenges, needs and measures over the short, medium and long terms, together with expected outcomes, are outlined. On pages 67–75 a summary of challenges, measures and expected outcomes is presented in table form.

Big data Photo: Shutterstock

Current status

THE BACKBONE OF A GLOBAL ECONOMY AND SUSTAINABLE SOCIETAL DEVELOPMENT

Luossavara, Kiruna Photo: Alm & ME, LKAB

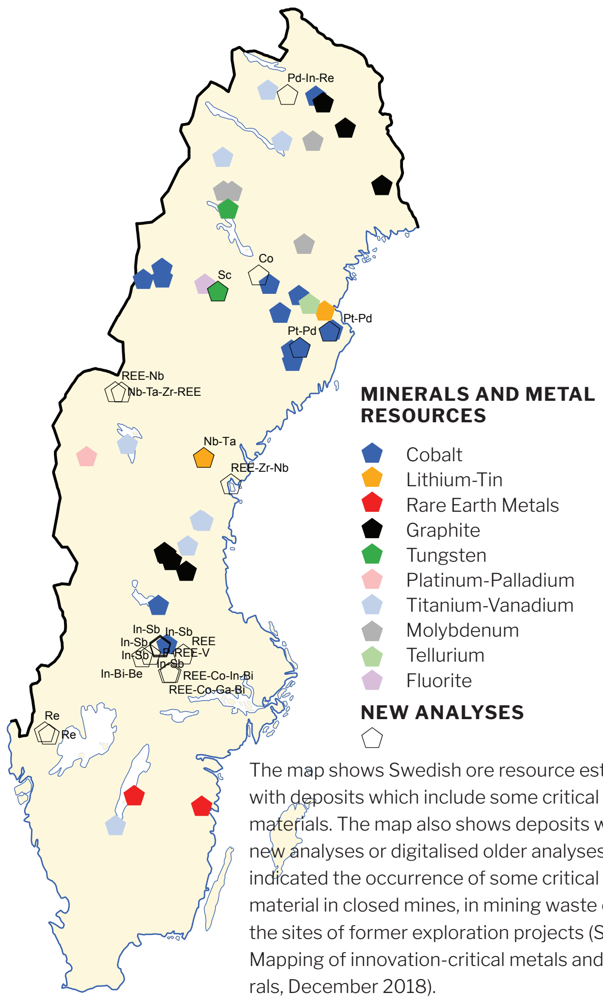


Sweden's mine production in 2017 in relation to the EU28 and the world. Source: SGU, Bergverksstatistik 2017.

Metals and minerals are the backbone of the modern society's economic growth and material development. Global growth in wealth brings increased demand for raw materials. According to the United Nations Environment Programme (UNEP), to meet the demands of a growing population, improved living standard and increased urbanisation, global metal needs will be three to nine times larger than all the metals currently used in the world. New industries, cities and infrastructure will be built, and the demand for capital goods and consumer goods will increase concurrently with the need for societal development that requires more efficient resources utilisation and less climate impact.

Population growth, economic growth and greater resource use place an ever greater burden of responsibility on countries and regions, and entail entirely new types of challenges for industry. Realisation of the global objectives depends entirely on new technologies and new products, and it also requires new raw materials in the industrial value chain. For example, a modern smartphone contains as many as 60 different basic elements and, in the transport sector, development of electric vehicles drives strong demand for metals such as cobalt, lithium, nickel and copper.

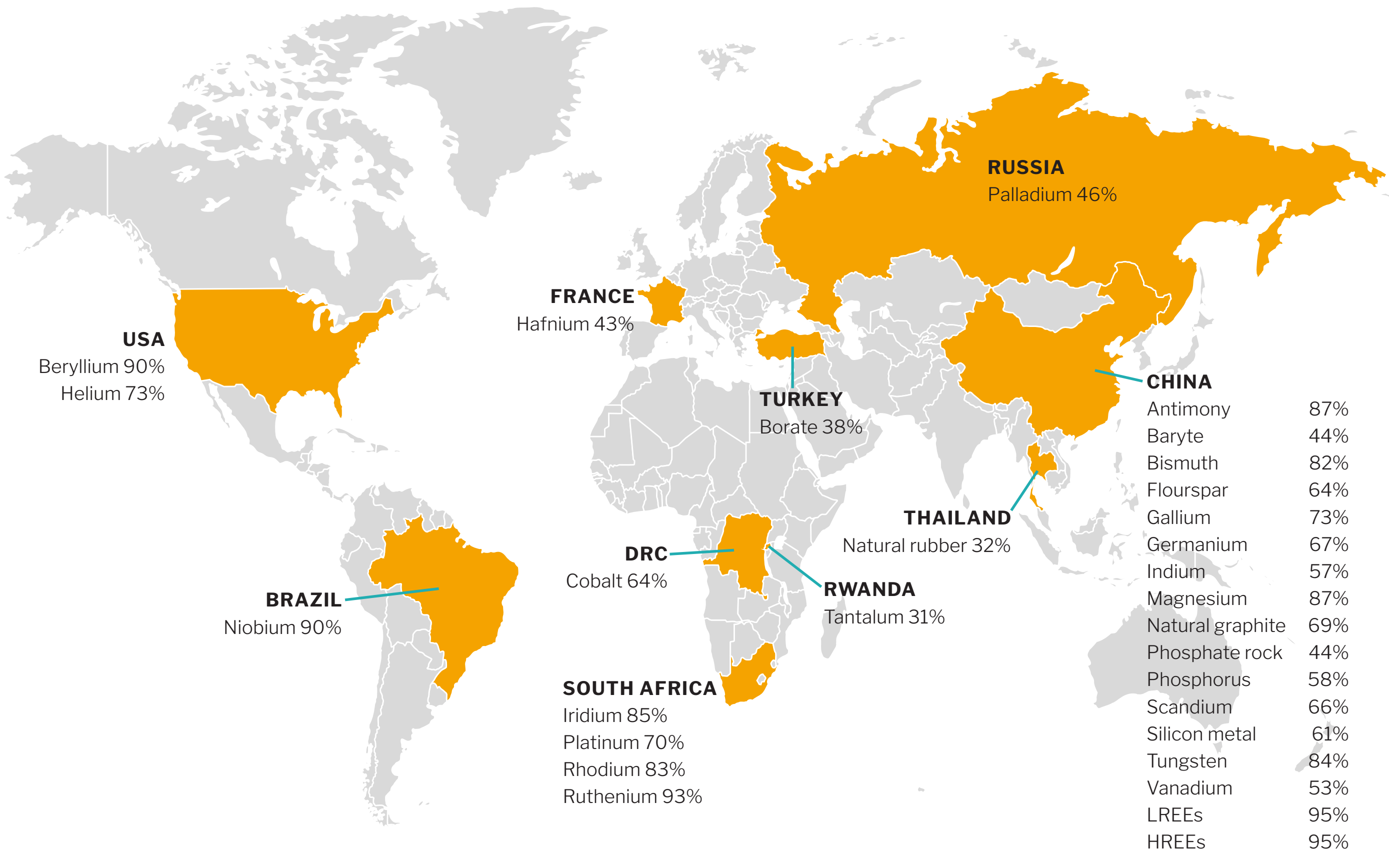
The EU countries now use about 20 percent of the world's metals and minerals, but produce only a mere four percent of them. Import dependency is second only to Japan.



The map shows Swedish ore resource estimates with deposits which include some critical raw materials. The map also shows deposits where new analyses or digitalised older analyses have indicated the occurrence of some critical raw material in closed mines, in mining waste or at the sites of former exploration projects (SGU, Mapping of innovation-critical metals and minerals, December 2018).

Access to raw materials is a major challenge for European industry and the EU member states have a great responsibility to meet the increasing demand and, in the best possible way, draw benefit from the knowledge, experience and geological potential that exist in our region. In Sweden there is good potential and knowledge of the reserves of many important metals and minerals, such as iron, zinc and lead, of which we, as a nation, are also the EU's largest producer.

However, knowledge is still lacking when it comes to the availability of what are known as innovation-critical metals and minerals. This refers to raw materials that are critical for industrial development of new technologies and environmental innovations, raw materials on which Europe is largely import-dependent. The Geological Survey of Sweden (Sveriges Geologiska Undersökning, SGU) has mapped the possibilities for extraction in Sweden of these metals and minerals. The final report, presented in December 2018, shows that there is geological potential in several deposits with ore resource estimates in which several innovation-critical raw materials are included.



THE WORLD'S LARGEST PRODUCER OF INNOVATION-CRITICAL RAW MATERIALS

The EU's industry and economy are dependent on international markets and import many essential raw materials. China is the largest global supplier of 30 of 43 innovation-critical raw materials (e.g., rare earth elements, magnesium, antimony, natural graphite, etc.). Brazil (niobium), USA (beryllium and helium), Russia (palladium) and South Africa (iridium, platinum, rhodium and ruthenium) are also significant producers of critical raw materials (Study on the review of the list of Critical Raw Material, June 2017).

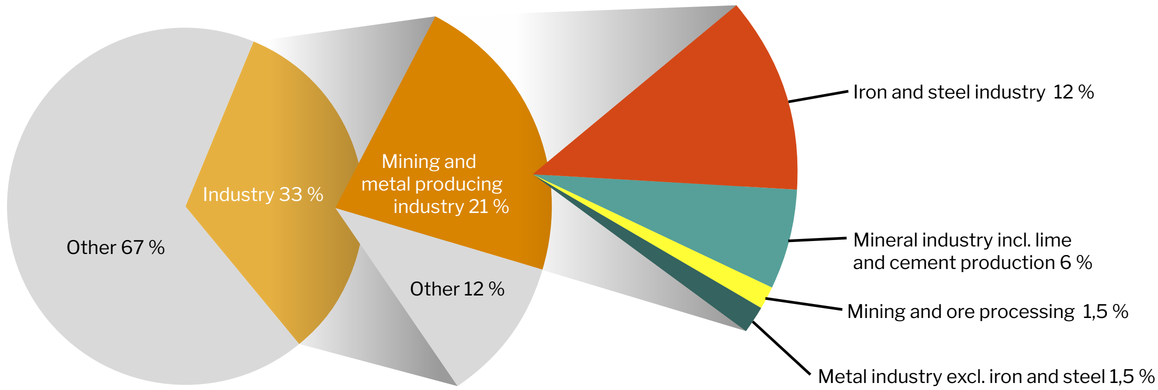
Silver Granules Photo: Boliden AB

AN ENABLER FOR REACHING THE UN'S SUSTAINABLE DEVELOPMENT GOALS

The UN's 17 sustainable development goals constitute the most ambitious agenda for sustainable development that has ever been adopted. The agenda has four main aims: to end extreme poverty, eliminate injustices and inequality, promote peace and justice, and address the climate crisis. Responsible production of metals and minerals is decisive for realising the global sustainability goals.

In many respects, the Swedish mining and metal producing industry is a responsible leader when it comes to mining minerals and extracting metals, as well as generating innovative climate-smart and environmentally sound solutions, products and equipment that create value in other sectors of society and are exported globally by Swedish companies.

Fossil fuels are used in many areas of the mining and metal producing industry's value chain. According to Sweden's National Inventory Report, NIR (2017), the mining and mineral producing industry and the metals, iron and steel industry account for about 21% of Sweden's total carbon dioxide emissions. To meet the challenge of a transition to fossil-free production, the mining and minerals sector must adopt a structured approach. In April 2018, via Svemin (the Swedish Mining Association), the industry presented a sub-report and roadmap for a competitive fossil-free mining and minerals industry in Sweden. The roadmap has been produced within the framework of the Fossil-Free Sweden initiative, a platform for dialogue and collaboration between companies, public-sector organisations and other stakeholders who share the vision of Sweden being one of the world's first fossil free welfare nations.



DISTRIBUTION OF GREENHOUSE GAS EMISSIONS BY SECTOR

Today, carbon dioxide emissions are generated within several areas of the value chain for the mining and metal producing industry. In 2017 the mining and metal producing industry accounted for about 21 % of Sweden's total carbon dioxide emission, corresponding to 11,090,000 tonnes of CO_2 equivalents. However, from a global perspective, emissions are at comparatively low levels (Swedish Greenhouse Gas Emission Inventories, National Inventory Report, NIR).

SIMS Zero family, electric mining vehicles Photo: Epiroc

THE HUB OF A CIRCULAR ECONOMY

Moving from a linear economy to a circular economy and sustainable consumption with more efficient utilisation of resources is a cornerstone for the transition to sustainable growth and realisation of the UN global goals.

Metals have high recycling potential and can, in principle, be reused indefinitely. The degree of recycling of conventional materials such as iron, base metals and precious metals in Sweden is now so high that it can only be increased marginally. When it comes to secondary sources there is a need for increased knowledge and new means of control to be able increase the degree of recycling. What can be recycled is determined largely by the composition of the products in which the materials are included. Therefore, recycling is not just a matter of technical solutions and infrastructure for handling and recirculating metals and minerals, it is also a question of new business models, products and production methods that make recycling technically and economically feasible.

A basic premise of the circular-economy philosophy is that residual products and waste should not arise, but should instead be part of a closed loop in which they can be utilised to create added value for society. Here, what is needed are innovative ideas, technologies and methods for developing new ways of transforming what was previously considered residual products and waste into value-adding products that bring benefit to society.

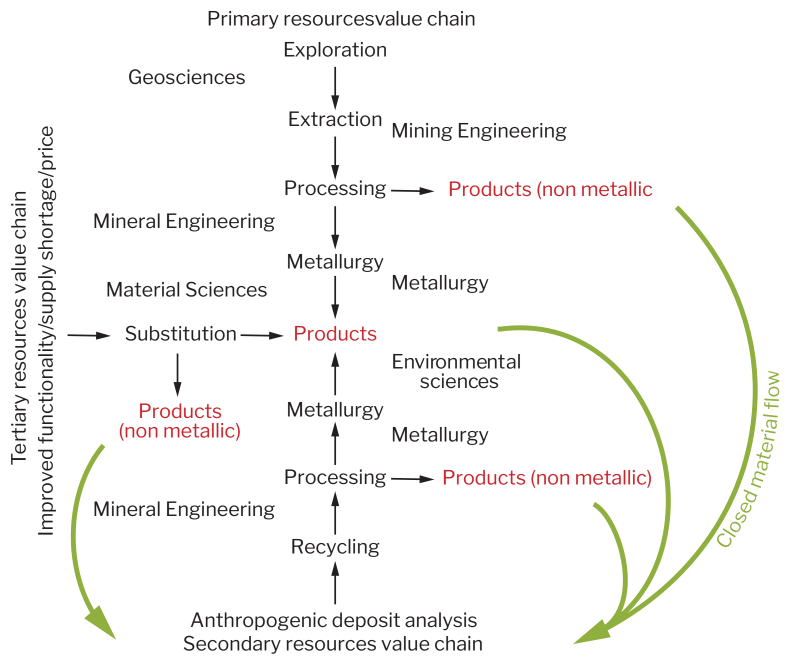
Residual products that are an inevitable consequence of the extraction of metals and mineral vary in nature. Some of them must be managed carefully to prevent undesirable environmental effects resulting from chemical processes that arise when different basic elements and chemical compounds come in contact with each other. Other residual products, such as waste rock and barren rock, are simply crushed stone and can often be used in, for example, concrete or as material in construction and roadbuilding. But, to effectively utilise the residual products that are generated by the industry, there must be consensus among politicians, public authorities, society, industry, academia and consumers as to what constitutes waste.

Sweden's use, mine production and recycling of metals. (WBMS April 2014, SGU 2014:3, UNCTAD 2013).

Metal	Use	Mine production	Recycling
Iron	4,326,000	27,285,000	2,032,000
Copper	121,800	82,760	65,300
Lead	17,000	59,466	49,300
Zinc	23,900	175,711	730
Aluminium	90,500	None	56,500
Nickel	25,000	None	14,610
Tin	70	None	None
Gold	2.6	6	10
Silver	35	340	27
Chromium	100,000	None	64,000
Magnesium	N/A	None	None
REE	500	None	None

“Recycling is important – but it is not enough”

Mikael Staffas, CEO Boliden



The raw materials chain. This research and innovation agenda addresses the primary and secondary resources value chains. The secondary resources value chain also contains mining wastes and residual products from metalworking. All value chains lead to products (red) that make use of research and innovation within the defined steps (black). The involved research subjects are expressed in black italic and the green arrows indicate the recirculation of raw materials to the value chain in a close-loop approach.

For consumers, a question of increasing importance has to do with a holistic view of how the metals in the products they purchase are produced. This means that, in addition to environment and climate, consideration is also given to requirements for ethical and social responsibility. Several years ago the OECD produced guidelines for so-called conflict minerals and, in the US, publicly listed companies are required to carry out due diligence on tin, tantalum, tungsten and gold. In the EU the Conflict Minerals Regulation, based on the OECD's guidelines will come into force in January 2021. The regulation requires EU companies in the supply chain to ensure they import these minerals and metals from responsible and conflict-free sources only. The Swedish mining industry is now considering the possibility of using digital means to trace the origins of metals and sustainably certification of metals and minerals. This could provide an international competitive advantage.

RECYCLING RATE (%)	CRITICAL RAW MATERIALS (EU 2017)
< 1	Be, B, Sc, V, Ga, Ge, In, Ta, Hf, Bi, Os, REE
1–10	Sb
> 10–25	W, Ru
> 25–50	Mg, Ir
> 50	Co, Nb, Pt, Pd, Rh

Functional recycling rate for critical raw materials. Data from UNEP (2013). Functional recycling means that the material's physical and chemical properties remain intact after recovery/recycling. For example, the metal in an end-of-life product is separated and sorted to obtain a recyclate that is recirculated to a production process to produce a given metal or alloy (Graedel et al. 2011).

SWEDEN – A SUSTAINABLE MINING NATION

Sweden is one of Europe's biggest mining nations and has good geological potential for mining and extracting minerals and metals. Here, there is well-developed and available infrastructure for transport and energy, as well as access to an internationally competitive and qualified labour force, all of which means lower capital expenditures and operating costs for new mine establishments. The fact that Sweden has a longstanding experience of mine operation, which in an international perspective is resource-efficient and has a low environmental impact, is safe and characterised by good interactions and relations with society and local communities, bodes well for more national mining initiatives. There are also good business opportunities for exporting our technology and experience and knowledge of environmentally sound, safe and resource-efficient mine operation to other countries. A stable and relatively sound socio-political and institutional framework also improves the attractiveness as a mining nation, even though there is room for improvement, unforeseeable permitting processes have affected the international ranking over the past decade.

THE SUCCESSFUL INNOVATION CLUSTER

In addition to mining companies, the Swedish mining cluster consists of a large number of industries that supply the mining industry with technology and companies that use the minerals from Swedish mines. Collaboration among these players has contributed, among other things, to increased productivity, thanks to collaboration across company boundaries, and where manufacturers have tested and developed their processes and products in Swedish mines. In many cases, this collaboration has been under way for more than 100 years. Recently, even large IT and telecoms companies have joined the mining cluster.

Longstanding, successful collaboration across company boundaries has helped to make Sweden one of the world's technologically leading industrial nations. That includes the development of successful and resource-efficient underground and surface mining operations, supplying equipment to the global mining industry and the residence of one of the world's leading recyclers of electronics scrap. Important contributors to the cluster are universities, institutes and other public-sector organisations that support the companies. Collaboration between academia and institutes in the mining sector has created one of the strongest raw-materials-related academic environments, and has led to an industrial environment with a high level of expertise and focus on research and development.

INCREASED DIGITALISATION AND ELECTRIFICATION

The industry faces ever increasing demands for greater production efficiency, optimised processes and working methods, and reduced climate and environmental impact. Digitalisation and the possibilities it presents are key factors for meeting these demands. Digitalisation is often associated with the term Industry 4.0, a term used in the German government's strategic initiative for the so-called fourth industrial revolution. Industry 4.0 refers to efficient production enabled by technologies such as the Internet of things, embedded systems, machine learning and real-time communication.

For the industry, this presents many opportunities for realising greater safety, improved production efficiency, reduced environmental impact and energy consumption, as well as lower costs. Developments within big data analytics, artificial intelligence, the Internet of things (IoT) and cyber-physical systems, and a high-performance communication infrastructure are critical enablers.

Electrification is a prerequisite for reducing the industry's environmental and climate impact. The development of machines, equipment and processes that enable fossil-free solutions is a top priority, as is the supply of innovation-critical minerals and metals that are needed for the new solutions.

Mining truck, Aitik, Gällivare Photo: Jonas Westling, Boliden AB

INNOVATION TRENDS IN THE MINING, MINERAL AND METAL PRODUCING INDUSTRY

Both nationally and globally, ever broadening and thoroughgoing business and sustainability challenges mean that the mining and metal producing industry must continue to develop and prepare to meet change. This concerns, for example, new technology, new working methods and new business models. Enabling this requires innovation.

An innovation is usually defined as a new idea or a new solution to a problem. The core of an innovation is the creation of business value – not the new technology, service, method or organisational solution in and of itself.

The logic behind innovation, how value is created, is about to change for many companies in the Swedish mineral and metal-extraction industry. Five trends are particularly significant:

- Increased digitalisation. Digitalisation presents great opportunities for creating increased value and new business models. The industry is collaborating with relevant partners to derive benefit from the opportunities that digitalisation presents; among other things, this has led to world-leading productivity. Continued development implies challenges in terms of working methods, ownership of data, systems integration and data security.
- Electrification. Minimising the use of fossil fuels is a key issue for the industry, and alternative solutions for reducing CO_2 emissions are essential. Mining companies and equipment and systems suppliers collaborate to develop and implement sustainable solutions.
- From product to advanced service solutions. There is an increasing tendency for equipment suppliers who develop process technology in various segments of the mining companies' value chain to package products and services, and sell a ”function” or ”result” to customers, rather than a technology or a product. Thereby, a unique customer offering is created. Standardisation among suppliers is important, and it is challenging to assume lifecycle responsibility for products while avoiding sub-optimisation and situations where services drive costs without generating income.
- Focus on open innovation. More companies in the industry are acquiring external technology and knowledge in cooperation with universities, colleges, other companies and organisations. Particularly evident is the use of technologies developed for other industries. Commercialisation of technology and intellectual property changes the logic behind the innovation process, as compared to traditional R&D.
- From linear to circular economy. Systematic and proactive improvement measures are a prerequisite for circular business models, which minimise environmental impact, optimise resource use and minimise systems risks. The circular business model cannot be realised by a single party, but requires major changes of all parties involved.

Innovation means doing things in new ways, and technological change without changes in working methods and organisation is impossible. For example, there is a direct need for technology and organisational issues to be combined in projects, and for strategy and research and innovation work to be formulated in a more cross-disciplinary and challenge-driven way.

Vision, challenges and objectives

Vision

A WORLD-LEADING MINING AND MINERAL PRODUCING INDUSTRY
– in harmony with the world around it

VISION AND OVERALL OBJECTIVES

The Swedish mining and metal producing industry has a common vision to generate profitability and sustainable growth through continuous improvement and a technological leap. The industry is working actively and conscientiously with sustainability issues to enable businesses to create value and increase social benefit.

OVERALL OBJECTIVES

With its vision, the mining and metal producing industry expresses clear overall objectives and assumes a globally leading position for the industry as a whole.

- We conduct mining operations with minimal impact on our surroundings, and our production is efficient and adapted to the climate and environment. Via an industry-wide transition to a carbon-dioxide-neutral energy mix we minimize our climate impact.
- Our industrial processes are competitive, resource-efficient, circular and release no environmentally hazardous discharges to water or emissions to air. Residual products from our operations are recycled. Through the entire process chain and in collaboration with other parties, we develop products, services and processes with recycling in mind.
- We strengthen our position with respect to innovation and technological development and efficient, responsible mining, and we export our technology and know-how to a global market.
- As a hub in a circular economy, the Swedish mining and metal producing industry contributes to a dramatic increase in value creation both locally and globally. We do this by creating growth and employment opportunities through economically, socially and environmentally sustainable mining, processing and recycling of minerals for maximum social benefit.
- The industry's vision and work culture, with opportunities for personal development and life-long learning, attracts diversified groups and makes the industry an attractive employer that attracts qualified personnel.
- We are internationally leading in work environment and occupational health and safety.
- Strong collaboration among industries, academia and society has produced synergies for knowledge and expertise, as well as strengthening the mining and metal producing industry's capacity to innovate.

Torneträsk, Kiruna Photo: Alm & ME, LKAB

CHALLENGES AND OBJECTIVES WITHIN THREE MAIN AREAS

Meeting the overall objectives requires research and innovation that contributes to economically, socially and environmentally sustainable and competitive mining and metal production.

The mining and metal producing industry's challenges can be divided into three areas: technological development, social benefit and acceptance, and access to qualified personnel. Within these three main areas there are challenges related to all dimensions of sustainability.

TECHNOLOGICAL DEVELOPMENT

The biggest, most tangible and most decisive challenges for the mining and metal producing industry are related to transition and to the necessity for new technology, new methods and new circular business models. While minerals and metals are an essential enabler for achieving many of the global sustainable development goals, reaching energy and climate targets and achieving sustainable production are major challenges for the industry as a whole.

Realising the green transition and the global goals is not just a question of technology, but the development of new technology, methods and infrastructure is decisive and is present in all areas of the work towards change within the mining and metal producing industry. Sweden is also one of the world's leading nations when it comes to collaboration within research and innovation for sustainable industrial development.

Within the area of technological development four decisive challenges for the Swedish industry have been identified.

- **Climate change increases demands on the industry and drives the technology shift**
  Both nationally and internationally, the mining and metal producing industry is an important player in the world's transition from fossil to renewable energy systems. However, while the mining industry extracts innovation-critical metals that will help to achieve the goal of a carbon-dioxide-neutral society, the industry must also reduce its own climate impact. Decisive factors for reduced climate impact are technology, methods and processes that support fossil-free solutions, access to a renewable, stable and competitive source of electricity, reduced energy demand (thanks to more efficient processes) and increased use of biofuels.

- **Increased business opportunities through technological development and changing demand for metals**
  The global sustainability goals drive and accelerate technological development in all industries. Rapid technological development poses a major challenge for the mining cluster's industrial processes. Furthermore, the transition to a sustainable society means that the advent of new technology and business models in other industries and contexts can rapidly change the demand for, and access to, metals. The geological potential in Europe is good and it is very important that the EU increases its self-sufficiency in metals and minerals. This requires effective, foreseeable and just permitting processes, as well as the development of new technologies for deep prospecting and ore modelling.

Mining automation, Renströmsgruvan Photo: Tomas Westermark, Boliden AB

- **Safe and resource-efficient production with reduced environmental impact**
  The mining and metal producing industry's operations must not only be sustainable, but also globally competitive. Profitable mining of low-grade and complex mineralisations and mining at greater depth with reduced environmental impact and a safe work environment are great challenges. This places demands on, for example, new process technology, increased automation and recycling and handling of waste and residual products. New technologies are needed to reduce emissions to air and discharges to water. An important area for innovation has to do with how waste and residual products can be upgraded to products that create value for companies, the environment and society.

- **Implementation and full utilisation of digitalisation and automation**
  Digitalisation and automation can give the mining and metal producing industry the means of addressing the challenges the industry now faces. This concerns e.g., cost-effectiveness, productivity and safety, prospecting, characterisation, process efficiency and quality. Important considerations are how new technology and new systems can be integrated with existing facilities at low cost, and how different parts of an operation can be coordinated and highly automated. Automation can also contribute to eliminating hazardous environments and injuries. The question as to how the digital tools should be integrated with the industrial processes, organisations and working methods is also a big challenge for the industry. Advanced digital solutions require a whole new type of knowledge and expertise among co-workers, and will entail considerable changes in the production apparatus.

OBJECTIVES FOR RESEARCH AND INNOVATION IN TECHNOLOGICAL DEVELOPMENT

The tables below summarise the research and innovation needs to meet identified challenges facing the industry with respect to technological development.

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
Mineral access, resource efficiency and circularity	Geophysical methods for exploration at depth, airborne observations and borehole observations, sensors and multi-dimensional modelling Drilling technology for deep boreholes and implemented MWD and AWD Genetic ore models with a focus on both iron and base metals as well as innovation-critical metals Geometallurgy as an approach for the entire value chain, from rock mass to product and tools for evaluating resource utilisation and sustainability assessment of both existing and planned mining operations More efficient and more selective separation processes for increased yield Adaptation of slag properties with respect to new and existing uses for slag products Increased utilisation of waste as a resource	Innovative technology for the exploration of deeper lying ore-bodies and complex ores Established process for better control of deposits and nationwide 3D model of bedrock Mineralogical and geochemical analysis in real time New process solutions and optimised water management in ore processing to extract minerals and metals and new products from by-products and waste streams for full utilisation of metals found in existing raw material flows Process for recycling of future-critical metals	Increased self-sufficiency and stable supply of minerals, base and innovation-critical metals for the Swedish and European markets High resource efficiency through efficient extraction of waste as secondary raw material with minimal water use Increased circulation of metals and industry-wide use of waste materials with new business models for circularity Optimised resource utilisation - utilisation of a larger proportion of mined material

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
Efficient and safe production	Equipment, processes and methods for efficient and continuous unit operations throughout the mining process Effective fragmentation process for great depths and methods for stabilising the rock that can guarantee safe conditions without unforeseen outcomes Semi-autonomous work processes and safer working methods Effective separation processes for the treatment of fine-grained, polymetallic ores and removal of impurities, both mineral and process metallurgical State-based and predictable maintenance of mobile and fixed installations Dam guidelines and improved dam construction and design with regard to waste properties, and adaptation for cold climate with technology for monitoring	Energy-efficient and environmentally friendly processes within the concept of geometallurgy and 4D geomodelling Continuous selective mining methods and processes for all types of orebodies Implemented methods and technologies for efficient fragmentation Mining methods/layouts and rock reinforcement methods that ensure production in order to minimise seismic events ”Zero-entry mine” where all machines are autonomous or remote-controlled Effective coarse and fine particle separation processes, both wet and dry	Resource-efficient production and reduced ore losses and waste rock mixing Cost-effective mining process with more efficient rock reinforcement and stable and safe conditions Improved and safe work environment and minimised presence of people at the production front Effective decomposition and separation processes reduced energy and production costs Dam safety and minimised risk both in the short and long term

”The mining industry is a key in every transition of society”

Mikael Staffas, CEO Boliden

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
Automation and digitalisation	Digital twins and process control systems that enable system optimisation New monitoring methods for rock mechanics, seismic and maintenance by adapting the use of sensor technologies Reliable IT infrastructure with real-time features - 100% coverage 24/7 Automated and smart mining equipment for all unit operations Digitalised processing plants with online analysis and characterisation, sensor technology and data analysis using AI New methods for monitoring and controlling the work environment and new iterative frameworks for planning attractive workplaces Environmental risk management through on-line environmental monitoring and data management systems	Overall system integration for systems and equipment throughout the mining production process 100% continuous on-line process control and control in Swedish mines Automated equipment that optimises process using AI Developed measurement technology and methods for processing large amounts of data linked to metallurgical reactions	Cost-efficient, resource-efficient and safe production through an optimised system-integrated mining production system Increased efficiency in production lines through new measurement technologies, process modelling and automation Good work environment and digitalisation with a human focus Minimised environmental impact through on-line monitoring systems
Reduced climate impact and increased electrification	Energy-efficient unit operations throughout the mining process with fossil-free mining machines Methods and procedures for safe implementation of fossil-free mining machines Introduction of new fossil-free (bio) fuels for heat and reduction in various processes Developed infrastructure that supports equipment powered by alternative power sources, e.g., electricity, battery, fuel cells	Fossil-free mining machines fully implemented Technology for CO2-neutral metal production	Cost-efficient and energy-efficient mining processes Reduced climate footprint and environmental impact through reduced CO2 emissions Improved work environment with electrified mining machines

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
Reduced environmental impact	Improved geochemical characterisation Fragmentation processes that lead to a minimum of undetonated explosives Minimised water consumption and pollutant emissions New and cost-effective cleaning technology Improved deposition techniques Developed methods for recovery and compensation Improved capacity to further reduce atmospheric emissions (SOx, NOx, fluorides and chlorides) Methods/measures that reduce dust Remediation for land use that creates added value	Optimised production processes that reduce emissions, waste amounts and consume minimal water Equipment, methods and models for predicting water chemistry and environmental impact Methods for quantifying, estimating and evaluating improvements in assessing biodiversity and ecological compensation Long-term safe, stable and cost-effective disposal of mining waste	Reduced emissions to air, soil and water Less water use Net positive impact on biodiversity Attractive remediated areas

"Meeting the highest environmental standards is a matter of survival for the Swedish mining sector"

Lars-Åke Lindahl, Director Environment Svemin

“Artificial Intelligence is key technology enabler for autonomous operations”

Jan Nyqvist,
Global Product Manager Mine Automation ABB

“Research and Innovation is an enabler for future sustainable raw material supply ”

Jenny Greberg, Program director SIP STRIM

LKAB research laboratory, Gällivare
Photo: Alm & ME, LKAB

SOCIAL BENEFIT AND SOCIAL ACCEPTANCE

Consensus and collaboration among politicians, society, academia and industry are essential for realising the UN's global sustainable development goals. This is such an important issue that Goal 17 specifically addresses the role of collaboration and partnerships for achieving the goals.

The Swedish mining and metal producing industry collaborates and interacts on a broad front to accelerate efforts aimed at greater sustainability to generate social benefit. As a complement to existing networks and channels, we must establish new networks and initiate dialogue and collaboration between industry and the research community at the local, regional, national and global levels. Political prioritisation and consensus among companies, local communities and public administrations are also needed, as are dialogue and understanding among the various stakeholders.

Within the area of social benefit and social acceptance two decisive challenges for the Swedish mining and metal producing industry have been identified.

- **Social acceptance and relations with the community**
  The Swedish mining and metal producing industry creates exceptional value as an employer, a customer, an investor and a developer of vital local communities, as well as in a national and international context. The industry works actively to promote environmental and climate awareness, and assumes social responsibility for both employees and those who live and work in the vicinity of its operations. Improving knowledge and awareness of the mining industry's economic and societal importance and how our industry creates value locally and globally is a challenge. Increased dialogue between the mining industry, society and other stakeholders is decisive. There are prerequisites for the companies to continue to develop in terms of long-term economic sustainability and competitive strength.

- **Improve the industry's investment climate**
  The Swedish mining and metal producing industry creates many jobs both directly and indirectly, and is a key player in the transition to fossil-free energy systems and transportation, climate-smart building construction and increased recycling. The Swedish mining cluster is already contributing to global climate benefit through exports in three dimensions: products, processes and equipment. For the industry to be able to continue to create value and contribute to economic growth there must be clear regulatory frameworks and efficient, transparent and foreseeable permitting processes. Long-drawn and unforeseeable permitting processes have a negative impact on the willingness to invest and, ultimately, on Swedish competitiveness. It is also of central importance that a long-range view is adopted in political decision-making and prioritisation if the industry is to be able to engage in long-term, competitive planning and investment.

"The mining and metal producing industry create great values for the local community and the Swedish export industry"

OBJECTIVES FOR RESEARCH AND INNOVATION - SOCIAL BENEFIT AND SOCIAL ACCEPTANCE

The tables below summarise the research and innovation needs to meet identified challenges facing the industry with respect to social benefit and social acceptance.

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
Contribute to a more sustainable society, through CSR and sustainable business	To develop strategic tools, guidelines and measurable indicators for more sustainable business	Strategic tools, guidelines and measurable indicators are integrated, implemented and demonstrated	A more sustainable, competitive and socially accepted mining and metal producing industry
Managing land use conflicts	Develop and test a social cost-benefit approach in the case of investments in the context of mining and metal producing industries	Complete a handbook for conducting cost-benefit analysis for mining development to support e.g., legal rulings	Conflicts related to indigenous rights, cultural heritage, diversity of lifestyles, etc. are clearly understood and dealt with in processes that are deemed by all involved as legitimate and efficient
Innovation management and systems	New methods, tools and techniques which allow companies to create new products, services and business models	Development of new innovation management frameworks to make companies “innovation leaders”	Companies in the mining and metals ecosystem are better settled to save costs and/or increase revenues by using new innovation methods and tools
Regional development	Review and evaluate existing methods used, in Sweden and internationally, to assess the regional-economic impacts of mining operations and the role of benefit-sharing	Develop and put into use new improved methodological approaches to assess the regional-economic impacts of mining operations, including impacts and trade-offs	The regional economic impacts of mining investments will be better assessed and will therefore support a more knowledge-based decision-making at different levels of society
Environmental regulation	Review and evaluate the decision-making processes that underlie the existing permitting conditions with respect to air and water pollution, including mining waste	Develop different regulatory approaches that can be used to improve the environmental performance without compromising fundamentally with the industry’s long-run competitiveness and demand for transparency	The environmental regulations and the industry’s management practices address land use conflicts and pollution concerns in an efficient and a legitimate manner, leading to a high standard of environmental commitment

ACCESS TO QUALIFIED PERSONNEL

Access to, and the development of, qualified personnel has always been decisive for the Swedish mining and metal producing industry's growth and competitiveness. In the rapid, ongoing transition and technological development towards a resource-efficient and circular economy, the need for qualified people is greater than ever. Here, the great challenge is to attract and recruit people to the industry in tough competition with other high-tech-driven industries.

While sustainability challenges and technological development bring about fundamental changes in industrial processes, the need for expertise and knowledge is also changing. This means that the industry must be able to attract men and women, in new occupational groups, with entirely new knowledge, at the same time as competition for qualified labour is increasing. The importance of broadening the recruitment base and of grasping, developing and maintaining business-critical know-how and expertise in the industry is increasingly evident. Modern management is essential, as is an inclusive culture in which personal development and career opportunities are based on equality, equal opportunity and equal treatment.

Where access to qualified personnel is concerned, three decisive challenges for the Swedish mining and metal producing industry have been identified.

- **Secure access to qualified personnel**

  Attracting both new employees and training existing co-workers to meet future needs and knowledge requirements. This is a priority issue for the industry. Naturally, an important reason for this is the development of, not least, technical innovations that the industry is now experiencing. Therefore, it is important to ensure access to the relevant higher education, increase the level of interaction between schools and the industry, offer alternative study programmes and develop the possibilities for regionally adapted education, company-specific training and continuing education.

- **The next-generation labour force – a shift in attitudes and values**

  Future personnel are not only looking for well-paid jobs – they are also placing demands on work, based on the values that characterise their generation. The industry must have knowledge of the prevailing attitudes and values among the various generations in the labour market. Increasingly, employers are expected to provide jobs that involve meaningful tasks, variation and challenges. It is important for the industry to present a different image and show that it offers jobs in occupations with good future prospects in a creative environment that demand advanced knowledge and international-calibre education.

- **Take advantage of untapped knowledge resources through increased equality and diversity**

  To be able to recruit the competencies that are required, the recruitment base must be broadened. Therefore, the mineral and metal-extracting industry is working conscientiously with issues concerning equality and diversity, and is positively disposed to initiatives that facilitate recruitment of employees among recent immigrants. This type of recruitment contributes in a very positive way to increased diversity in our workplaces.

OBJECTIVES FOR RESEARCH AND INNOVATION - ACCESS TO QUALIFIED PERSONNEL

The tables below summarise the research and innovation needs within the national agenda to meet identified challenges facing the industry with respect to access to qualified personnel.

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
Attract expertise for efficient, profitable and sustainable production	Qualified people are attracted by value-driven and sustainable business development and attractive workplaces that offer groundbreaking technology change and development of a new industry	To compete by offering attractive and equal workplaces for efficiency, productivity and innovation in a multicultural environment	Cost-effective and resource-efficient production with reduced environmental impact
New recruitment and company-internal skills development to meet future requirements	Identify future skills needs and education, as part of lifelong learning	New training programmes and courses for retraining and competency development of management and employees are implemented	Reduced costs by recruiting and retaining qualified miners and staff
Attracting labour from new generations	Communicate the image of the new mining industry that offers an interesting profession, personal and professional development as well as lifelong learning in a safe and healthy work environment	Attract and retain qualified people through responsible, value-driven and sustainable business, and pioneering technology development	Increased interest in the mining industry among young people, and contribution to the development of an attractive society
Take advantage of under-utilised knowledge resources	Create new conditions for increased equality and diversity and set up new knowledge and research on gender, diversity and gender equality in the mining industry that increases the attractiveness of the industry and facilitates recruitment	Production is designed to promote collaboration and creative problem solving in multi-competency teams characterised by openness and tolerance	The mine is considered as a workplace that respects ethics, ecology, gender equality and diversity

"I strongly believe that a company that doesn't seriously go into digital transformation today will not be in business 10 years from now."

— Industry insider & former CIO of two global companies, Mining Magazine and Rockwell Automation, 2019-05-01

National and international collaboration

The Swedish mining and metal producing industry is in many areas a world leader in innovation and resource-efficient production. Although Sweden is a small supplier of raw materials on the world market, as a supplier of technology and knowledge, we are a large and globally leading nation. Therefore, it is essential that the Swedish mining and metal producing industry initiates collaboration and strategic alliances outside of Europe and, in an international context, leverages the national initiatives in research, innovation and education.

It is important that the Swedish mining and metal producing cluster seeks to establish strategic alliances in international projects or research programmes that have strategic objectives similar to its own. Of particular interest is collaboration with companies, organisations and research centres in countries or regions that play a globally leading role in innovation and research related to mineral and metal production. Here, the importance of both national and international research and innovation programmes cannot be underestimated.

Luleå University of Technology Photo: Nicke Johansson, LTU

NATIONAL COLLABORATION

One of the most crucial funding mechanisms for realising this strategic research and innovation agenda is the 12-year participation of Vinnova, Formas and the Swedish Energy Agency's in the Strategic Innovation Programmes, SIP. These programmes number 17 in all, one of which is SIP STRIM, the strategic innovation programme for the mining and metal producing industry. Other SIPs which are relevant for the mining and metal producing industry are SIP PiiA (process-industry IT and automation), SIP Metallic Materials (metal industries), SIP Re:Source (recycling) and SIP Production 2030 (sustainable industrial production).

Sweden's Riksdag has set a target of zero net emissions of greenhouse gases by 2045. To support the transition in industry, the government has introduced a long-term programme known as Industriklivet (Industrial evolution). Via Industriklivet, support is given for feasibility studies, pilot and demonstration projects, detailed project planning studies and investments. The target group is industries with so-called process-related emissions, which includes the mining and metal producing industry.

To enable a strong innovation system a strong foundation in the form of applied research is required. During 2008/2009 the government established 23 so-called Strategic Research Areas (SFO). The aim was to develop internationally well-reputed knowledge centres to address long-term challenges facing society. One SFO was CAMM, the Centre for advanced Mining and Metallurgy at Luleå University of Technology, which has since become an important arena for applied research in the mining and metal producing industry in Sweden.

There is a longstanding tradition of collaboration among mining companies, technology providers, academia and institutes in the Swedish mining and metal producing sector. Among these actors there is a very high level of credibility and a good ability to collaborate. Together, they have initiated several programmes directed towards the mining and metal producing industry via the foundation Stiftelsen Bergforsk, which has functioned as a think tank. Since 2018, activities in Bergforsk have been integrated within the industry organisation Svemin.

”Luleå University of Technology is the largest Swedish arena for applied research in mining, mineral and metal extraction in Sweden”

INTERNATIONAL COLLABORATION

Within the EU there are several collaborative initiatives in the area of raw materials. In 2008 the EU adopted the *Raw Materials Initiative*, a strategic initiative of which the aim is to promote:

1. Fair and sustainable supply of raw materials from global markets
2. Sustainable supply of raw materials within the EU
3. Resource efficiency and supply of "secondary raw materials" through recycling

To advise the European Commission and oversee implementation of the raw materials initiative the Commission has appointed an expert group – *the Raw Materials Supply Group*, which includes representatives from the EU countries, European Economic Area countries, EU candidate countries and organisations representing stakeholders in industry, research and civil society.

The EU's revised Industrial Policy Strategy from 2017 highlights raw materials from a sector-specific perspective. Raw materials are considered strategically important for the EU's manufacturing industry, and the EU's climate strategy from 2018 states that raw materials are indispensable enablers for carbon-dioxide-neutral solutions within all sectors of the economy.

The European Commission launched *the European Battery Alliance* in October 2017. The alliance has adopted a strategy with concrete measures to develop and manufacture innovative, sustainable and competitive batteries in Europe. Sweden has an active role in the alliance, which gathers both public-sector and private-sector stakeholders. Among other things, the strategy is aimed at securing access to raw materials from resource-rich countries outside the EU, facilitating access to European sources of raw materials and improving access to secondary raw materials via recycling.

The European Innovation Partnership on Raw Materials (EIP RM) is an EU initiative of which the aim is to contribute to the long-term, secure and sustainable supply of raw materials to meet the fundamental needs of a modern, resource-efficient society. Sweden has an important role in realising the EIP's strategic plan, with measures that will be carried out within the EU's research and innovation programme, Horizon 2020.

An important platform for collaboration among raw-material stakeholders at the EU level is the *European Technology Platform for Sustainable Mineral Resources (ETP SMR)*, whose Swedish members include representatives from public administrations, universities and industry. In conjunction with the technology platform for the forest-based sector, ETP SMR has produced a European research and innovation agenda for raw materials, ”R&I Roadmap 2050 for the European Raw Materials”.

ERA-NET Cofund on Raw materials (ERA-MIN 2) is a public-public partnership based on the ERA-NET Cofund scheme under Horizon 2020. ERA-MIN 2 aims to implement a European-wide coordination of research and innovation programmes on raw materials to strengthen the industry, competitiveness and the shift to a circular economy.

EIT RawMaterials has been initiated and funded by EIT (European Institute of Innovation and Technology), an independent EU body and the world's largest consortium in the raw-materials sector. EIT's vision is to develop raw materials into a major strength for Europe through innovation, education and entrepreneurship. EIT RawMaterials consists of more than 120 partners from 22 European countries and is organised in six innovation hubs in Europe, one of which is based in Luleå, Sweden (Innovation Hub CLC North).

SPIRE is a public-private partnership within Horizon 2020 dedicated to improving process-industry resource and energy efficiency in the European mining, minerals and steel industries.

In the next framework programme for research and innovation in Horizon Europe (2021-2027) raw materials will be included in the theme ”circular industries”. The Swedish mining industry has been very successful in the framework programmes (FP7 and Horizon 2020) and has been an active partner and coordinator in several projects.

Sweden adopted an Arctic strategy in 2011 which was followed in 2016 by an integrated *EU policy for the Arctic*. The Swedish Arctic policy states that ”Swedish companies have extensive operations in the Arctic region. Ore and mineral extraction are now high on the global economic agenda, which has resulted in significant investment in the Swedish mining industry”.

In a global perspective *Business Sweden*, a Swedish state organisation which helps Swedish companies to succeed internationally, is an important actor. For several years the mining industry has been a focus area for Business Sweden, for example, via *the Swedish Mining Initiative*.

COLLABORATION IN EDUCATION

Access to qualified personnel and education are decisive for the raw-materials sector. Swedish stakeholders, such as industry, research institutes and academia, should be committed to education and collaboration that serves the industry's needs nationally and globally. This may involve the establishment of new MSc programmes, joint doctoral studies programmes, cooperation with relevant countries and activities within the area of life-long learning and broader social learning, where Swedish participants can play an import role. This can be accomplished through participation in the following initiatives:

MARIE SKŁODOWSKA-CURIE ACTIONS (MSCA)

Research networks (ITN): Support for Innovative Training Networks that develop new researchers. Individual fellowships (IF): Support for experienced researchers undertaking mobility between countries, optionally to the non-academic sector. International and inter-sectoral cooperation through the Research and Innovation Staff Exchanges (RISE). Co-funding of regional, national and international programmes that finance fellowships involving mobility to or from another country.

EIT RAWMATERIALS

Much of the EIT RawMaterials initiative has to do with education, broader social learning, life-long learning and MSc and PhD programmes. The Swedish mining and metal extracting cluster should take an active part in these activities and even function as a catalyst for involving the industry in these issues. Here, it is especially important to increase the degree of interaction between industry and academia.

Nine research and innovation areas

Gruvberget mine, Svappavaara Photo: Alm & ME, LKAB

The common national agenda covers the measures and activities in research and innovation that are needed to address the demand for resources and raw materials in the industrial value chain, and it includes the related technical and relevant non-technical areas. Research and Innovation areas 1–6 mainly have a bearing on the challenges associated with technological development, while area 8 is related to social benefit, and areas 7 and 9 concern access to qualified personnel.

These research and innovation areas have been identified to establish a clearly defined, common focus for important research. This division into separate R&I areas must be counterbalanced by coordinated, cross-functional and holistic raw-materials research and innovation that will lead to increased innovation throughout the entire value chain.

1. EXPLORATION

Europe must reduce its import dependency on a range of minerals and metals. The bedrock in Europe has good potential for new mineral finds, but large areas are under-explored and competition for land is a major concern for the extractive industry.

Future exploration will focus on finding deeper mineralisations and mineralisations containing critical metals. Exploration at depth requires better geological, geophysical, drilling and mineral-chemistry methods. With knowledge about the three-dimensional structure of the bedrock and with improved ore geology models, exploration targets will be easier to locate.

The aim of this thematic area is to provide Sweden with the technology and knowledge needed to find deeply located mineralisations. This should lead to a higher degree of self-sufficiency of metals and minerals, and at the same time reduce conflicts related to land use.

2. RESOURCE CHARACTERISATION

A sound knowledge of a mineral resource serves as a basis for effective extraction and increases the value of the orebody. Knowledge of the geometry of the orebody, the commodity grade and how it is affected by mining is important.

Development of existing analysis methods is necessary to achieve more resource-efficient mining, even in the case of complicated and low-grade mineralisations, with less environmental impact. There is also potential for identifying and extracting innovation-critical metals as by-products.

Overall objectives for this thematic area are improved data collection and development of smart, innovative production systems, so that more of the mineralisation can be extracted profitably with minimal environmental impact.

3. MINING

Mining, both underground and open-pit, involves complex systems where many interacting processes, such as drilling, blasting, fragmentation, loading, hauling, hoisting, rock reinforcement, ventilation and logistics, need to be coordinated.

All of these processes must be improved and optimised for resource-efficient processes and competitive production with minimal environmental impact. Mining at greater depth poses new challenges with respect to, for instance, fragmentation, rock support and logistics.

An overall objective for this thematic area is fully automated and integrated mine production. Automation contributes to increased safety, since fewer people are near the production face and more ore can be extracted with less energy consumption and less environmental impact.

4. MINERAL PROCESSING

To extract metals from the mined ore, the ore must first be crushed. This is the most energy-demanding part of the process, but it is also decisive for extracting the maximum amount of available metal. The challenge is to extract a larger number of minerals, even from complex ores, and to enable increased productivity and resource efficiency while reducing the volume of waste.

An overall objective for this thematic area is to develop intelligent and innovative production systems which better utilise natural resources by minimising losses during waste-rock separation in an optimised and energy-efficient process.

5. RECYCLING AND METALLURGY

Increased recycling of metals is a prerequisite for a circular economy. Sweden has in many respects very efficient systems for collecting and recycling metals, e.g., iron, copper and aluminium, while there is a relatively low degree of recycling of innovation-critical metals which are found in, for instance, electronic scrap/waste.

One challenge is to increase the degree of recovery and recycling of metals that are currently already recycled. Another is to recover additional elements contained in the material streams that are not extracted today but instead lost in by-products or waste streams. There are also large, known mineral deposits which are not currently viable because there are no good mineral processing methods to extract the metals present.

An overall objective for this thematic area is to develop resource-efficient processes for extracting more metals from complex ores, reclaimed material and waste, and thereby reduce the current import dependency.

6. REMEDIATION AND ENVIRONMENTAL PERFORMANCE

Although environmental impact from mining has decreased markedly in recent decades, the mining industry is a large consumer of electricity and fossil fuels, and nitrogen from undetonated explosives is discharged.

To minimise environmental impact from, for example, discharges of nitrogen and sulphides from process water, one challenge is to minimise the volume of waste and to develop methods for converting waste into products.

Overall objectives for this thematic area are to develop technology and methods that minimise the environmental impact of mining and to make mining sustainable and accepted by society. Operations should generate no harmful emissions and a large part of the residues from mining can be used as a value-creating resource. Remediation and rehabilitation of mine sites can contribute to increased biodiversity and create space for recreation.

7. ATTRACTIVE WORKPLACES

A key issue for the industry is to recruit and retain qualified personnel. There is a need to identify what kind of knowledge may be needed in the future, and to influence the available education and training, so that people with the right knowledge can be recruited.

Safety and reduced risk of accidents are decisive factors for the industry's attractiveness. There is also a need to improve the social environment and to ensure that work tasks are stimulating. Opportunities for development are also important. Increased digitalisation and automation can contribute to improved working conditions.

Overall objectives for this thematic area are to enable a well-planned, automated and remote-controlled mine in which the risk of accidents is reduced, and to improve the attractiveness of the occupation for women and men of all social groups.

8. CSR AND COMMUNITY RELATIONS

The mining and metal industry's contribution to sustainable development has major economic, social and environmental implications. Companies must consider the broader positive and negative effects their operations have at the local, regional, national and global levels.

Overall objectives for this thematic area are to contribute to the further development of constructive and mutually respectful relations with local communities and the wider society, and to increase the industry's contribution to the achievement of important social, economic and environmental goals at the local, regional, national and global levels.

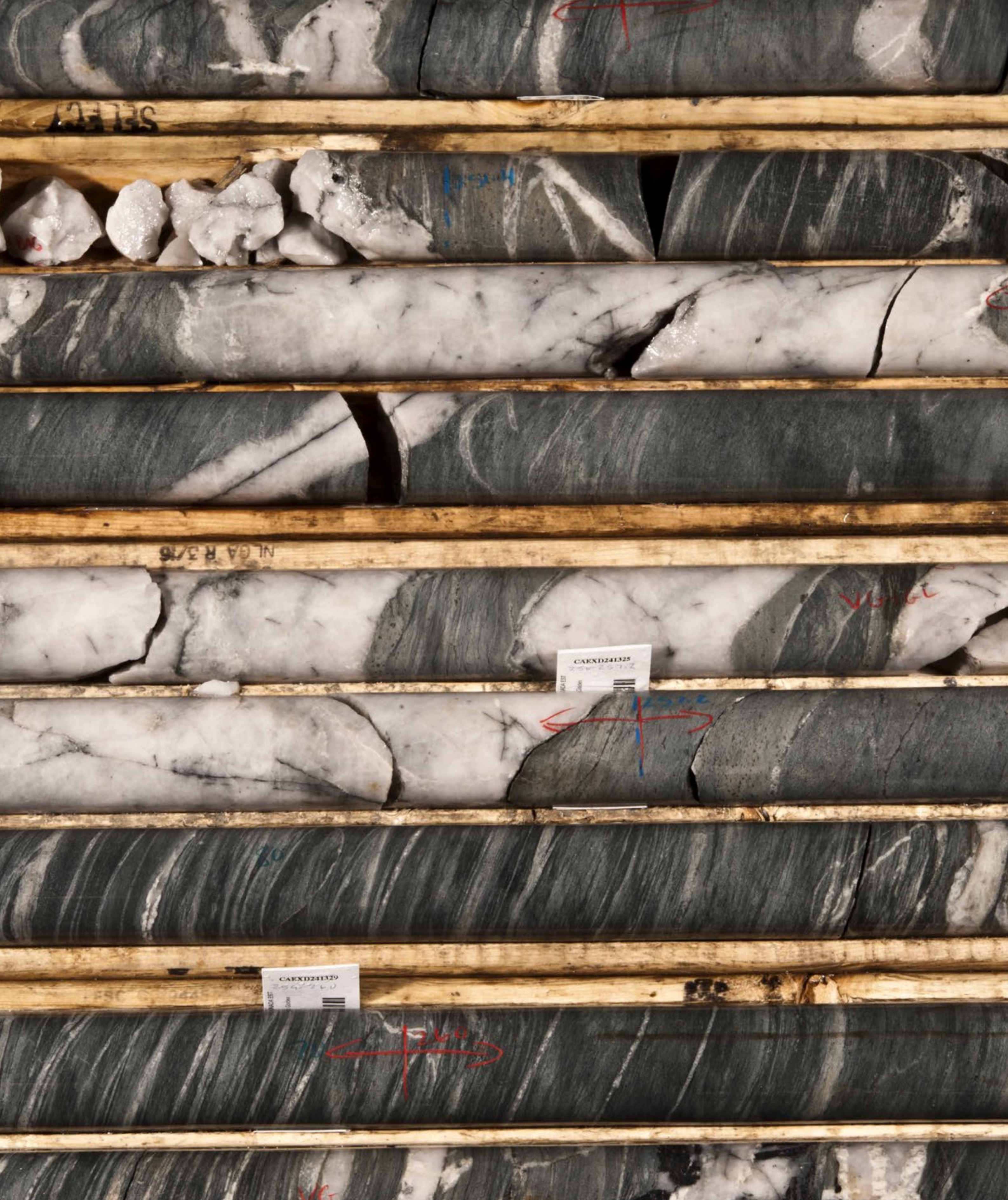
9. GENDER EQUALITY AND DIVERSITY

The mining industry has traditionally been a strongly male-dominated industry, but global competition, new technology and the demands for efficient and safe production mean that the mining industry must attract more people from a broader recruitment base to ensure a more innovative environment.

Issues of gender equality and diversity must also be addressed if the mining communities are to avoid a divided labour market. The migration of women from these communities today is high, which makes the communities vulnerable. One challenge is to attract a diverse group of young people to begin studies that can lead to jobs in the industry.

An overall objective for this thematic area is that the Swedish mining industry should be world-class when it comes to mining ore and changing gender and diversity patterns.

Sample drill cores from Meliadine, Nunavut Photo: Agnico Eagle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Section II

A DETAILED DESCRIPTION OF THE NINE RESEARCH AND INNOVATION AREAS


Bjørnfjell station, Narvik Photo: Alm & ME, LKAB

EXPLORATION

In any region, sustainable extraction is in the long run dependent on exploration. Since any one mineral deposit is by nature non-renewable, extraction without exploration will inevitably exhaust known mineral resources. Even if this is partly mitigated by increased recycling and substitution, urbanisation and population growth in the modern high-tech society will inevitably lead to the fact that if there is no exploration investment in a region, self-sufficiency will decrease instead of increase. A proposal is made for an Exploration agenda owing to the need to improve the required supply demand of primary mineral raw materials from domestic resources. Exploration should target ferrous, base, precious and critical commodities, bearing in mind that within the time frame of the project the criticality aspect for some currently critical materials may change. The Exploration agenda encompasses six main areas:

- Technology
  - Development of new drilling technology for deep (>1,000 m) drill holes.
  - Deep, >1,000 m diamond and percussion drill holes with master and daughter drill holes.
  - Fan or cone type drilling patterns at depth, developed and implemented MWD.

- Location
  - Development of 3D/4D geo-modelling of mineral resources.
  - Three-dimensional models of the Swedish bedrock in all areas of high potential for deep mineralisation with a target depth of 1–5 km, and for critical metal mineralisations.
  - Models of the evolution of geology and related mineral deposits over time: Four-dimensional modelling.

- Penetration
  - Development of new, deep penetrating geophysical techniques. Develop new electromagnetic and induced polarization methods with improved resolution at a range of depths, from shallow to below 1,000 m.
  - Develop new seismic techniques with data acquisition in 3D utilising three-dimensional infrastructure such as mines and drill holes. Target: good resolution in 3D in the top 5 km.
  - Development of improved and joint 3D modelling and inversion techniques for magnetic, gravimetric, electromagnetic, geoelectrical and seismic geophysical data. Fully integrated geophysical and geological modelling.

- Formation
  - Conceptual modelling of mineral deposit types.
  - Establish genetic and exploration models for major ore types in Sweden, including models for deposits containing critical raw materials with economic potential.
  - Define potential exploration targets, and the geological, geochemical, mineral chemical, and geophysical vectors to ore for the most pertinent ore types in Sweden. A major target is increased investment in deep exploration in Sweden.
  - Compare and contrast major Swedish ore deposits and mineral belts with equivalent deposits and belts internationally in order to better define and model mineral deposit systems, ore genesis and vectors to ore.

- Education
  - Building knowledge and developing skills in Europe.
  - Define a knowledge base of metals and minerals in Sweden. A target is to implement the teaching of economic geology and geophysics based on Swedish resources in Swedish universities.
  - Improving skills in the staffs of industry and survey organisations for future forefront predictive targeting of resources in Sweden.
  - Improving the awareness (public and government) of the need for minerals and metals for a sustainable and green society.

- Integration
  - Integration of data into real-time exploration and geometallurgical tools.
  - Developing tools for data collection while drilling:

Photo: Agnico Eagle

3D camera, geochemical assay while drilling (AWD), down hole geophysical measurements while drilling (GWD).
  - Integration of structural, mineralogical and geochemical data sets in one software system in real time.
  - Integration of early-stage exploration data in geometallurgical modelling.

OBJECTIVES

Deep exploration calls for interpretations based on improved drilling technology, more efficient depth penetration and resolution of geophysical data, advanced geochemical/mineral chemical techniques and utilization of machine learning, and more accurate targeting based on a three-dimensional knowledge base and a genetic concept of ore for- ming processes. The vision for these areas is expressed as established targets and Key Performance Indicators (KPIs) for 2030 and beyond:

- Reduction of energy in drilling
- Increase in resources base and commodity diversity focused on critical minerals
- Increased use of new deep drilling technology
- Improved ore genetic models for Swedish mineral resources
- Improved geophysical, geochemical and mineralogical targeting methods, sensor technology and multi-dimensional modelling
- Improved integrated interpretation of geochemical/geophysical data through machine learning
- Increased efficiency through applied real-time exploration
- Improved awareness of the need for minerals and metals for a sustainable and green society

RESEARCH AND INNOVATION NEEDS, STRATEGIES AND ACTIONS

SHORT TERM

Based on the results of recent exploration research projects, define similar projects in areas of Sweden offering a great potential for new discoveries.

- Start to develop the ore genetic models by defining deposit types in these areas with a focus on both main mined commodities and related critical minerals.
- Develop exploration models by defining the geological,

geochemical, mineral chemical, and geophysical vectors to ore at both the regional and local mine scale.

- Establish procedures for ensuring a fully integrated data and knowledge driven approach. Specifications for new efficient exploration technologies exist but the proposed methodologies need financial support in order to be implemented and developed further. Launch a technology-based project for new and innovative drilling, geophysical and geochemical techniques.
- Build visualisation centres and publish predictive 3D models for Sweden.
- Improve the awareness of the need for minerals and metals for a sustainable and green society, both publicly and throughout the whole of government – this is crucial for the objectives to be achievable.

MEDIUM TERM

Intensive fieldwork, pilot actions on new exploration techniques, feeding 3–4D models with data and further adjustment of acquisition parameters.

- Continue to develop genetic ore- and exploration models for Sweden's ore deposit types. Testing and validation of genetic- and exploration models with predictive models in pilot areas.
- Development of new geophysical methods for deep penetration from surface, airborne and borehole observations.
- Development of new geochemical and mineral chemical vectors to ore, through advanced microanalysis and data interpretation.
- Potential pilot-scale verification of 3D models, and new geophysical and geochemical equipment by deep drilling in test areas. Start to utilise results in training across Europe.

LONG TERM

Training of decision makers for better resource governance, and actively promoting results among exploration industry at large.

- Proven new deep drilling, deep geophysical, deep geochemical/mineral chemical techniques, and "real-time" mineralogical and geochemical analysis, as well as 3D structural modelling.

EXPECTED IMPACT

TECHNICAL

- Providing Sweden with innovative, world-class technology for minerals exploration of deeper-seated ore bodies and complex ores.
- Providing Sweden with a first nationwide 3D model of the bedrock down to several kilometres, to be used for decision making on land planning issues.

ECONOMICAL

- Deeply located deposits can be defined and economically evaluated.
- Improved self-sufficiency and a stable supply of base, critical and other metals for the Swedish and European economy.
- Foster the development of Swedish-based downstream industries on domestic mineral resources, e.g. battery manufacturing.
- Create wealth and growth in many less densely populated areas of Sweden.

ENVIRONMENTAL

- Definition of deeply buried resources to minimise the effect of mining.
- Define where the mining potential is in Sweden for the coming century to be used as a tool for decision making on land use, protection etc.

SOCIAL

- Fewer problems with access to land in densely populated areas. Exploring deeper and under cover may meet rising community and environmental concerns.
- An awareness of the need for minerals and metals for a sustainable and green society, both publicly and throughout the whole of government.
- Increased employment opportunities in less populated and rural regions of Sweden with a good potential for the extraction of minerals and metals.
- Training of decision makers on resource geography and potential and predictive models will lead to improved governance of Swedish resources.

RESOURCE CHARACTERISATION

A sound knowledge of a resource serves as a basis for effective extraction and utilisation of an ore body. Besides geological knowledge of geometry and commodity grade, spatial information should be available on how the rock unit (ore type, rock mass) behaves during mining production, minerals processing, and waste disposal/remediation.

This knowledge should preferably be acquired in an early stage of the primary mineral resource value chain.

Knowledge of the resources in mining operations is currently in many ways incomplete. Gaps exist in data collection, subjective characterisation and between different disciplines. Cross-thematic and multi-disciplinary usage of data is limited. For example, geological and rock mechanical models are separate and use very little data from each other. In addition, some of the relevant data is underused or is lost during data processing. In mining operations in general, the data collection and usage are ineffective and subjective. It is not uncommon for drill core logging to be done twice: first for geological purposes and then for rock mechanical measurements.

In order to avoid subjective characterisation, automatic, online and less time-consuming methods are needed in tunnel mapping and for characterisation of drill cores and chips. With our research, we aim to achieve:

- Resource characterisation that results in a mathematical and physical (property based) copy of the rock mass, i.e. a detailed description of all parameters (rock material, joints, faults, mineralogy, microstructure, geometallurgy etc.) of the rock mass.
- Resource characterisation that results in the detection of new value-added minerals, e.g. high-tech and critical raw materials.
- Resource characterisation that results in identification and quantification of minerals and elements of concern for environmental studies, as well as potential industrial minerals suitable for innovative products.
- A geometallurgical approach that captures variability within the ore body significant for mineral processing plants (e.g. mineralogy and ore textures implemented in comminution models) and production management (e.g. traceability of ore from mining face through concentrator).
- In-situ mining and process development aiming to zero footprint in future resource development.
- Energy-efficient and environmental-conscious process development in the concept of geometallurgy and 4D-geomodelling.

OBJECTIVES

For theresearch and innovation area Resource Characterisation, the long-term vision for 2030 and beyond is to improve the competitiveness of the Swedish mining companies with high-quality knowledge of ore bodies and rock mass, high resource efficiency and reliable systems for predicting and managing production from mine to mill. This will help to reach the goals for zero accidents, no human exposure at the production face, greater energy savings, reduced CO_2 emissions and lower ore losses, effective water and waste management. For these targets the following key performance indicators are defined:

- Increased use of automated and on-line systems
- Reduction of energy and related CO_2 emissions
- Reduction of ore losses
- Reduce dilution
- Increase of new value-added products from ore and waste
- Reduce the amount wastes by resource efficiency and development of innovative product
- Increase of water circulation

RESEARCH AND INNOVATION NEEDS, STRATEGIES AND ACTIONS

In order to mine Swedish deposits at increasing depths as well as near the surface with good resource efficiency, minimised environmental impact and increased productivity and safety, the research should be focused on optimising the methods providing reliable data in the design-, operational-, and closure stages, and optimising data handling and integration. The research should focus on the following main areas:

SHORT TO MEDIUM TERM

- Apply new and existing resource characterisation techniques for online and in-situ measurement of geological, mineralogical, rock mechanical and metallurgical properties.
- Facilitate the use of new monitoring methods for rock mechanics by adapting the use of existing sensor techniques.
- Develop new resource management tools, which enable real-time data integration, effective data visualisation, production planning and scenario analysis.
- Develop a tool for resource efficiency assessment and sustainability evaluation of existing and planned mining operations.

LONG TERM

- Facilitate the use of new online analysis tools, sensing methods and management tools, all integrated in a geometallurgical model and resource management system.
- Facilitate the use of micro-analytical tools for incorporating detailed resource information in long term production planning.
- Develop interdisciplinary tools for rock mass characterisation. A common visualisation platform based on an open source Virtual Reality technique could possibly be used.
- Develop and implement novel resource characterisation techniques and methodologies for identification of innovation-critical metals as by-products.
- Develop MWD and AWD (measurement while drilling and assay while drilling) technology to deliver data for online process design, optimisation, prediction and planning for ore delineation, rock mechanics, drilling, continuous mechanical excavation, blasting, crushing and grinding or milling.

EXPECTED IMPACT

TECHNICAL

- Increased resource efficiency by automation.
- Reduction of ore losses.
- Optimised mine-to-mill processes.
- Enhanced prediction of downstream processing performance.
- Effective mass handling and transport.

ECONOMICAL

- More cost-effective production.
- New value-added products.
- Providing income to local communities.
- Providing information for a net present value (NPV) optimized mine.
- Promoting environmental mindfulness through early-stage rehabilitation programs.
- Generating revenue for the local government thereby directly contributing to its economy.
- Promoting a more efficient use of energy.

ENVIRONMENTAL

- Reduced energy consumption.
- Reduction of the amount of wastes.
- Efficient use of wastes as secondary raw material.
- Decrease in harmful emissions.
- Reduced CO_2.

SOCIAL

- Improved working environment.
- Increased job satisfaction.
- Equal gender employment.
- Effective and systematic community engagement.
- Safe workplaces.
- Sustainable and suitable approach for community dislocation and amenity loss.

MINING

The mining industry is facing a number of important challenges in the future, such as increasing variation of the available mineral deposits, from spatial characteristics to mining depth (a large number of mines are moving towards greater depths). This may increase unforeseen mining challenges such as adaptive mining, ground control, and hot working conditions, which threaten the safety and the equipment as well as result in reduced production capacities. The demands on the mining industry in near and far future are high efficiency and productivity, minimum environmental impact, a safe working environment with a minimum of human injuries and zero fatalities. The societal pressure on the industry to reduce emissions of CO_2 and nitrogen, the amount of deposited waste rock, the mining-induced subsidence and the vibrations from blasts and seismic events will require research, development, demonstration and implementation of new technologies. The fragmentation processes have to be developed to obtain optimum fragmentation, a minimum of blast damage, undetonated explosives and dilution and a maximum of ore recovery. The CO_2 will be reduced by deploying equipment powered by non-fossil-fuel sources. The safety will be achieved by automation, improved ground control practices and reduced exposure of human beings at mining faces. This will require the development of new mining methods, and remote-controlled and/or autonomous mining equipment. Furthermore, mining in the near and far future will comprise conventional (manual) as well as remote-controlled and autonomous mining equipment, and have solutions for mixed traffic scenarios, i.e., interaction between autonomous machines and people. Since fewer humans will be in the mines, reliable and cost-effective methods for surface detection, positioning of equipment, rock mass investigation, rock support, fallout detection/observation and mining equipment monitoring have to be developed. To reduce the nitrogen emissions and to be able to use remote-controlled and/or autonomous equipment mining methods that can be selective and effective in different types mining environments, continuous excavation methods have to be developed. In the future mine fleets will be highly automated, which requires reliable communication networks with real-time capabilities that include localisation and navigation systems enabling automation and integrated process control.

OBJECTIVES

The long-term vision for 2030 and beyond is to improve the competitiveness of the Swedish mining industry with more efficient and highly competitive and environmentally sustainable mining processes, equipment and methods for underground as well as open pit extraction, more energy-efficient extraction and improved safety. In order for this to be achieved the following objectives are stated:

Drifting in a underground mine Photo: Epiroc

- No fatalities.
- Minimized Loss Tinme Injuries (LTI).
- Minimize waste and/or all waste into "products".
- No CO2-emission from mining equipment.
- Air quality and temperature in accordance with Swedish regulations.
- Energy-effective mining processes.
- Mine process systems in cooperation with mining machines (of varying brands) that can handle mixed traffic scenarios i.e, interaction between automatic/autonomous machines and/or interaction between automatic/autonomous machines and manually driven machines and/or people.
- Improved mining methods/layouts that ensure safe mining conditions.
- Continuous excavation methods that can be used in most mines.
- Fragmentation processes that gives an optimum fragmentation and a minimum of undetonated explosives and no spillage.
- Improved ore recovery and a minimum of dilution
- Ground control measures that can ensure safe conditions with no unforeseen fallouts.
- Reliable communication networks with real-time capabilities - 100% coverage 24/7.
- 100% continuous/on-line process control and dispatch in 100% of the mine.
- Reliable monitoring systems for production and rock mechanics purposes (e.g., positioning, surface detection, rock fall detection, deformation and seismicity).

RESEARCH AND INNOVATION NEEDS, STRATEGIES AND ACTIONS

In order to mine Swedish deposits both at increasing depths and near the surface with minimised environmental impact and increased productivity and safety, the research should be focused on optimising the mining processes and methods. The research activities should aim at improving and optimising all separate parts of the production process, as well as finding solutions that enable an optimisation of the complete process. The research should focus on the following areas:

SHORT TO MEDIUM TERM

- Infrastructure that support equipment driven by alternative power sources e.g., electric, battery, fuel cells.
- Remote-controlled charging and connection to the firing station.
- Digital twins of unit operations that enable optimization of the complete mining process.
- Methods to handle big data collected from various instruments.

SHORT TO LONG TERM

- Develop
  - Fossil free mining equipment to reduce the environmental impact.
  - Transport systems of ore, air water etc. to reduce the overall energy consumption.
  - Reliable remote-controlled and autonomous systems which enable continuous mining, which is a key issue to increase the efficiency, and/or reduce exposure of human beings at mining faces.
  - Autonomous mining machines which can handle mixed traffic.
  - Mining methods, for deep mining conditions (down to at least 2 km depth).
  - Operator training and procedures.
  - The drilling, charging and blasting process to optimise the use of explosives and minimize the emission of nitrogen from undetonated explosives.
  - Reliable communication networks with real-time capabilities that include localisation and navigation systems enabling automation and integrated process control in real time.
  - Production prediction systems, calculation and prediction of KPIs in real time.
  - Operator training and support systems based on augmented reality to increase the work understanding an job satisfaction for operators.
  - Condition-based and predictive maintenance of mining equipment and systems, ore passes, ventilation shafts and rock support.
  - Mining methods or mining sequences in present methods to mitigate seismic hazards and to achieve stable and safe conditions.

- Rock support, pre-conditioning, close and reentry systems, that improves ground stability and safety.
- The next generation of continuous extraction methods for Swedish conditions.

- Implement available cutting-edge technology and lead the development of future technology for surface detection, positioning of equipment, mining equipment monitoring, rock mass data collection, rock mass - rock support monitoring, rock fallout detection/ observation.
- Reduce waste by selective mining methods and develop products based on waste rock.
- Improve and develop ventilation and air conditioning by employing battery powered machineries, controlled partial recirculation, ventilation on demand, and natural-assisted cooling techniques.

LONG TERM

- Develop:
  - Infrastructure that support equipment driven by alternative power sources e.g., electric, battery, fuel cells.
  - Remote-controlled charging and connection to the firing station.
  - New continuous selective excavation methods for all types of orebodies (even large-scale), resulting in a minimum of human exposure and waste rock production.
  - Small mine machines using swarm technology enabling to control hundreds of small inexpensive units instead of a few big ones.
  - Monitoring instruments for data collection in a mine without human exposure by developing and using cutting-edge technology, i.e., replace the human senses, using the mine fleet, infrastructure, drones, drilling and scaling machines as well as remote controlled installed instruments (e.g., seismic system, stress monitoring).
  - Digital twins of unit operations that enable optimization of the complete mining process.
  - Surface support with high stiffness and ductile behaviour for deep mining conditions that replaces the combination shotcrete and weld mesh.
- Reduce the environmental impact by zero CO_2 and minimized nitrogen emissions.

EXPECTED IMPACT

TECHNICAL

- Optimised mining processes.
- Reduction of ore losses and dilution.
- Integrated process control and one control room.
- Minimised human exposure at the production face and safer mining with fewer accidents.
- More cost-effective mining process overall.

ECONOMICAL

- Reduction of cost per tonne.
- More cost-effective rock support.

ENVIRONMENTAL

- Reduced energy consumption.
- Reduced CO_2 and nitrogen emission.
- Reduced waste rock.
- Reduced mining induced vibrations.
- Reduced or no environmental impact from water used in the mines, both that re-circulated and that coming out from the mine.

SOCIAL

- Increased social acceptance.
- Increased job satisfaction.
- Increased holistic work understanding (from planning to performance) for all employees.
- Acts as a responsible and active partner in society.

HEALTH:

- Improved air quality.
- Increased safety.

MINERAL PROCESSING

The purpose of mineral processing is to treat ores by separating the valuable minerals from waste rock and gangue and by adjusting mineral grades and particle properties. It is usually the first step that ores undergo after mining in order to produce a concentrate for subsequent metallurgical extraction or an industrial mineral product, respectively. The main steps are usually comminution and classification, concentration and, in case of wet processing, dewatering.

Comminution is needed in order to liberate the minerals. This stage is usually not only the most energy-intensive step within mineral processing plants, but is also crucial for all subsequent steps in mineral beneficiation. Sufficient liberation of valuable minerals is the prerequisite for any downstream separation. However, selection and operation of comminution circuits are often not optimal due to limited ore characterisation and incorrect parameter settings. Steps have been taken during recent years to adapt e.g. high pressure grinding rolls or stirred media mills to ore comminution. In comminution modelling and simulation, the approaches used today still need to be extended in order to take into account mineralogy and ore texture.

Within ore concentration, the efficiency of separation processes needs to be further improved. For instance, flotation separation requires suitable particle size ranges as losses occur in the very fine and coarse fractions. Several principle approaches exist to adjust the flotation process to fine particle flotation, involving high intensity dispersion and mixing, while low intensity is generally intended for coarse particle flotation. Selective flotation of minerals requires suited and environmentally sound reagent schemes.

One possibility of reducing the amount of ore that needs to be processed downstream is by separating liberated gangue already at coarser particle sizes, e.g. by sensor-based sorting or physical separation. Although the benefits of pre-concentration are obvious, these technologies are currently used only at a few mining sites. Other approaches, as more efficient classification steps within comminution circuits or successive concentration and size reduction, have also not gained acceptance yet due to more complex flowsheets.

Grounding and concetration, Boliden Garpenberg Photo: Stefan Berg, Boliden AB

OBJECTIVES

The main objective for mineral processing research and development will be to significantly improve resource efficiency by 2045. This will result in added value from high quality products and new by-products, lower energy consumption as well as decreased metal losses, and from improved environmental performance with respect to reducing water consumption and emissions.

For these targets the following key performance indicators are defined:

- Reduction of energy consumption and related CO_2 emissions.
- Reduction of metal losses.
- Increase of by-products from processing rejects.
- Minimisation of water consumption and pollutant input.

RESEARCH AND INNOVATION NEEDS, STRATEGIES AND ACTIONS

In the long term, research and innovation on resource-efficient mineral processing is needed to develop and implement:

- Energy-efficient comminution processes.
- Efficient separation processes for treating fine-grained, polymetallic ores and removing impurities.
- Optimised beneficiation processes for reduction of waste rock and tailings (turning rejects into products), reduction of process water (dry processing).
- Suitable pre-treatment processes for separation of coarse material close to the mining production face (e.g. sensor-based bulk sorting).
- New processing routes for producing minerals and metals from by-product and reject streams from beneficiation and extraction plants.

RDI strategies are proposed in the fields of comminution and separation, as well as their combined consideration in a systems approach in order to optimise entire mineral processing chains. The research needs and suggested short-term and medium-term actions presented involve both fundamental and applied research.

COMMINUTION

For more efficient crushing and grinding, currently existing processes need to be optimised or novel technologies have to be provided:

- Enhance mineral liberation by adjusting breakage mechanism (comminution and assisting pre-weakening technologies) to ore properties.
- Improve comminution technologies and machinery for hard ore comminution with regard to energy for grinding and wear characteristics.
- Develop measurement technology and advanced models for optimising design and control of comminution circuits.
- Investigate alternative fragmentation methods and mill types for the efficient grinding of coarse and fine particles (considering dry and wet grinding).

SEPARATION

Improvements in separation technology are required particularly for coarse and very fine particle sizes, involving the investigation of:

- Processing routes for bulk sorting prior to the concentrator, considering separation at coarser particle sizes.
- Novel reagents, reagent schemes and hydrodynamic concepts for improved flotation of valuable minerals, particularly for very fine and coarse size fractions, and for flotation in cold climate.
- Stability and degradation of flotation reagents and their effect on downstream processing and water recirculation.
- Processing routes for separation of complex ores and removing impurities.
- Dry processing technologies particularly for finer size ranges (classification, sorting, magnetic, electro-static and gravity separation).

PROCESS DESIGN AND ANALYSIS

Improvements along the entire processing chain need to be investigated, involving the introduction of new and smart process designs and methods. Innovative process design and control optimisation of comminution and separation processes will lead to intelligent production systems.

- Hybrid flowsheets based on successive separation and size reduction for efficient comminution circuits.
- Optimised chain of ore fragmentation (from blasting to grinding) in combination with pre-concentration.
- Geometallurgical modelling together with innovative analytics for resource characterisation and ore traceability.
- Flexibility in plant operation for different ores types.
- Strategies and models for the efficient management and treatment of process water.
- Digitized processing plants using advanced online characterisation, sensor technology and data analytics.

EXPECTED IMPACT

TECHNICAL

- Availableness of energy-efficient comminution equipment and process designs.
- Reduced wear and enhanced mill control based on innovative measurement solutions and mill modelling.
- Provision of efficient coarse and fine particle separation processes, for wet and dry processing modes.

ECONOMICAL

- Reduced costs due to less energy consumption and wear in comminution.
- Higher revenue from increased recovery of valuable minerals and metals.
- Increased production due to reduced material amounts after pre-concentration.
- Increased revenue by producing by-products.

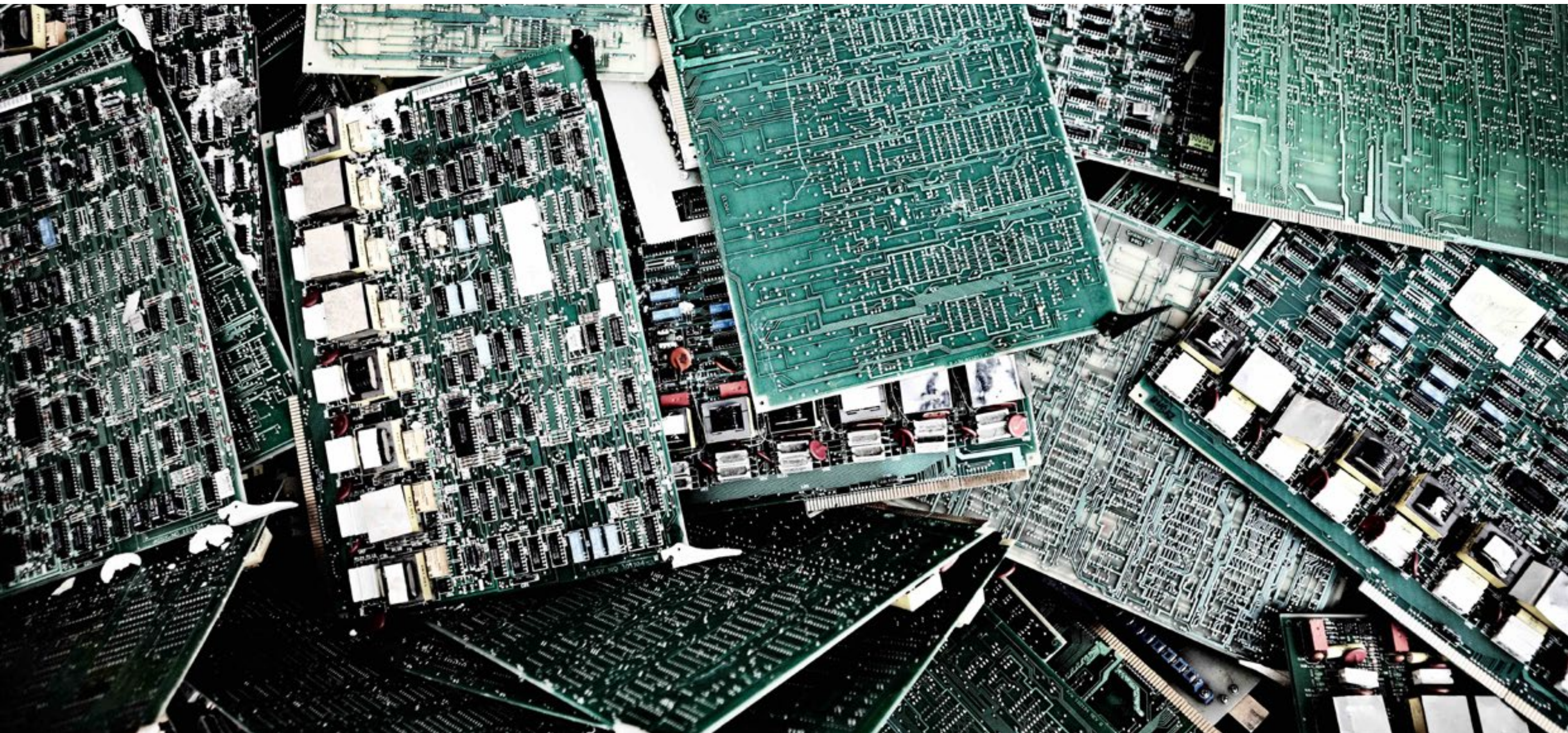
ENVIRONMENTAL

- Reduced CO_2 emissions due to decreased energy consumption.
- Less water usage due to more dry processing and reducing the tonnage in downstream processes.
- Less and coarser material to be deposited.
- Stabilised processing rejects with reduced hazards or harms.

SOCIAL

- Improved social acceptance of mineral processing plant operation due to higher resource efficiency and less emissions and waste.
- Increased awareness of civil society of how the mining industry can improve the quality of life in society.
- Generation of new knowledge through research to be included in educational programs and trainings.

Electronics recycling, Boliden Rönnskär Photo: Stefan Berg, Boliden AB



RECYCLING AND METALLURGY

Processes for metal extraction from raw materials as ore, scrap and metal containing residues have high demands on low emission levels and low energy consumption as well as being competitive, cost and resource efficient. The process steps for extracting metals from primary and secondary resources are for many metals highly interconnected. A thorough understanding of the involved processes as well as a holistic view on ore based metallurgy and recycling is needed to increase the yield in metal extraction.

A flexible use of existing process steps, together with improved pre-/post-treatment of scrap, ores and residues through hydrometallurgical or physical separation methods, could increase the capacity for recycled scrap and ability to manage more complex scrap and ores.

All metallurgical processes generate residue materials such as slag, dust and sludge. The largest in volume is usually slag, in many cases with excellent technical properties for a.o. construction applications. However, tightened environmental regulations connected to the environmental goals formulated by the government influence the requirements for by-products and the use of residue materials in applications outside the plant. There is need for increasing the knowledge regarding how to adapt a slag to both environmental requirements and technical demands connected to the intended application.

Minor elements with high vapour pressures are often enriched in dust and sludge from the cleaning of process gases. There are considerable amounts of metal and carbon units deposited that could contribute to higher raw material efficiency if ways to recycle these materials are developed.

Scattered process information (measurements, camera images, product analyses, thermodynamic data, flow dynamics etc) is available which creates an opportunity for the metal extraction and recycling industry to improve flexibility, efficiency and working environment by further implementing digitalization and automation. This would improve process control and ensure an attractive and secure working environment.

One key factor for a sustainable industrial sector is the availability of competence. New/adapted approaches for education is needed to attract next generation to the field and to ensure life-long learning for industry and society.

OBJECTIVES

To provide the society with materials required for a sustainable modern life.

- By combining novel pre-treatment and metallurgical operations to fully utilise ore concentrates, scrap and residues from ore and metal treating industries.
- Minimizing the environmental impact for the entire process chain.
- Being technologically in the forefront, having safe and healthy working environment ensuring future competence by attracting young employees.

To reach the objectives, development is needed in several areas:

- Metallurgical production routes in general.
- Recycling of metals from scrap and secondary sources.
- Recycling and utilization of industrial by-products.
- Improved process control (modification and development of measurement technology, methods to treat large amount of data connected to metallurgical reactions, technology for automation).

To meet future demands, the challenge is to increase the yield of recovered metals and extract additional elements contained in the material streams (ore, scrap and residues) not extracted today. The strive is to utilize all by-products, e.g. slag, dust and sludge, depending on their properties through recycling and recovery of elements, in external applications or as raw material in other industrial sectors.

RESEARCH AND INNOVATION NEEDS, STRATEGIES AND ACTIONS

To increase the metal recovery from ores and increase the recycling of metals it is necessary to have a holistic perspective where the whole processing and recycling chain is considered as well as the interaction with ore based metal production and the advantages from a combination of ore and scrap based production. Combination of suitable pre-treatment and post treatment methods, as e.g. bio- or hydrometallurgical processing, should be considered as a supplement to existing processes.

Research to utilise metal containing residue streams, understanding of their generation and how metal content can be enriched, should be encouraged. Examples are dust and sludge from gas cleaning that contain metals only in minor amount in the primary and secondary raw materials. Securing the quality of by-products such as slag requires research to assure environmental and technical properties of the material which may need modification in the extraction processes. This needs to be done without jeopardizing the overall outcome of the processes.

Models based on fundamental properties and chemistry of the materials, models that are also implemented in overall process models, will aid in optimising material, gas and energy utilisation, and predict consequences of e.g. changed material streams. Development of new process models should also be complemented with new innovative measurement techniques for online measurement of important process parameters and treatment of data.

Research and innovations will be needed within the following areas:

- Process development including pyro- and hydrometallurgical methods.
- Fundamental understanding of distribution of elements between different process streams and their capacity to accept different elements.
- Separation techniques or combinations of such to more efficiently separate the metals contained in complex material streams.
- Innovative techniques for carbon free or carbon neutral reduction processes.
- Innovative techniques to utilise waste streams from one industrial sector as raw material to another industry sector as for example carbon containing waste streams as reductant and energy carrier.
- Innovative measurement techniques and methods to evaluate large amount of data.

OBJECTIVES

- To fully utilise the material and energy content in raw materials through enhanced extraction of metals from complex scrap, ores and residues, including extraction of elements contained in existing material streams but so far not extracted as well as securing the quality of products and by-products and securing a viable use of the by-products.
- To fully utilize flexibility in processes through implementing new measurement technology and processing of data for on-line process models as well as new automation systems.
- Securing a minimal environmental impact by minimized emissions and transformation to carbon neutral processes.
- Securing the future competence and attractiveness through education and knowledge dissemination.

TECHNOLOGY

- Adapting processing of raw material for increased product quality and simultaneously optimised gas and energy utilisation for minimised emissions, based on fundamental knowledge coupled to the processing and implemented in process models (medium to long term).
- Develop and adopt measuring techniques for online measurements for enhanced process control (short to medium term).
- Develop and adopt automation systems (medium to long term).
- Develop knowledge and technology to use by-products such as slag products in new applications (short to medium term).
- Develop knowledge and technology to increase the yield in existing processes, considering the whole value chain for the raw materials (medium to long term).
- Develop the technology needed to extract more elements from material streams already processed (short to medium term).
- Develop technology for carbon neutral processing (medium to long term).

RESOURCE EFFICIENCY AND PROCESS CONTROL

- Optimise the existing process chains for simultaneous extraction of metals from ore concentrates and scrap, including the whole system from exploration, concentrating of ores and scrap, and processes for extraction of the metals, e.g. through improved process modelling (medium to long term).

- Develop methods to enhance the metal content in and secure the quality of all by-product streams to increase the possibility to extract more metals from the material streams (medium term).
- Dissipate knowledge about recycling possibilities and limitations to the designers of consumer products (design for recycling) (short to medium).
- Introduce new methods to more efficiently control the processes through new measurement techniques (medium to long term).
- Develop the knowledge necessary to secure the product quality of the slag produced at the same time as processing consequences of varying slag composition can be controlled or purposely adjusted (short to medium term).
- Develop methods to utilise waste materials from own processes or across business sectors to enhance effectiveness and the recovery of metals, e.g. the use of organic-containing waste materials as reductants or fuels in the extraction of metals (short to medium term).

EDUCATION

- Strengthen Swedish education of engineers and PhDs within all areas related to metallurgy and recycling.
- Carry out project assignments and thesis work in collaboration between universities and the companies connected to the research agenda.
- Introduce the knowledge gained within the research into the study materials at universities.

KNOWLEDGE DISSEMINATION

- Dissipate knowledge to increase the understanding of both benefits and limitations for recycling to plant people, designers, researchers and society.
- Dissipate knowledge about the need for metals, how they are produced and what the alternatives are.
- Exchange personnel between academy and industry.
- Collaborate and exchange with universities, research organisations and industries in other parts of the world.

EXPECTED IMPACT

Research within the given areas has the potential to have a large impact on a more efficient extraction of metals from ore concentrates, scrap, residues and waste, and result in increasingly environmentally safe use of generated residue materials.

TECHNICAL

- Optimised use of upgrading, pre-treatment and smelting operations.
- Advise for design of products to enhance recycling possibilities.
- Increased efficiency in process routes through new measurement techniques, process modelling and automation.
- New processing routes for complex ore and scrap materials.
- Adaption of slag properties with respect to new and existing uses for the slag products.

ECONOMICAL

- Improved competitiveness of the industry through more efficient use of existing process streams.
- Known and new mineralisations are turned into ores.
- New, so far unused process streams are becoming economically viable.
- A market for by-products and slag.

ENVIRONMENTAL

- Increased resource efficiency.
- Lower amount of materials deposited.
- Decreased dependency on raw material availability.
- More environmentally friendly residue streams.
- Decreased energy consumption.

SOCIAL

- Increased employment opportunities and attractive sector for career opportunities.
- Higher awareness of sustainability issues connected to metallurgy and recycling among plant people, designers, recycling industry and society as a whole.

ENVIRONMENTAL PERFORMANCE

Thanks to high ambitions and a strict environmental legislation the Swedish mining industry has a history of being in the international forefront of developing the environmental performance of mining. In the 1990's and early 2000 focus was on water and waste management leading to, among other improvements, a dramatic decrease of discharges to water and a development of closure strategies for mine waste deposits. However, public expectations as well as legal requirements are steadily increasing, and the mining industry will have to continue to improve its performance and to reduce its environmental footprint to be able to get public acceptance and permits to operate in the future.

Today the Swedish mining sector has the knowledge and technology to manage the more direct environmental effects, such as obvious negative impacts due to water discharges. However, other aspects are growing in importance, such as risk management (relating to dam safety and other risks), long term geochemical and geotechnical stability of closed facilities, loss of biodiversity and issues related to land use, resource use etc.

In many situations, the fact that Sweden is located in cold to arctic climate has implications for both potential environmental and ecological impacts as well as for possible technological or other means to meet those challenges. This means that in many cases it is not possible to "import" knowledge and solutions from international experience.

OBJECTIVES

The aim of this thematic area of the SIP STRIM agenda is to support the Swedish mining companies in their efforts to minimize their negative environmental impact. Specific areas and objectives are:

WATER MANAGEMENT

- New and cost-efficient treatment technologies.
- Better understanding of effects/impacts in receiving waters.
- Better capacity to predict water chemistry and environmental impacts.
- Optimized water management in the whole mining process.

WASTE MANAGEMENT

- Reduced risk through new deposition methods.
- Optimized resource use through waste minimization, separation and utilization.
- Long term safe, stable and cost-efficient storage of mine waste.
- Post-mining land-use with added value.

DAM SAFETY

- Minimized risk in both short and long term.
- Biodiversity.
- Long term positive impact on biodiversity.

RESEARCH AND INNOVATION NEEDS, STRATEGIES AND ACTIONS

WATER

- New and cost-efficient treatment technologies (short to medium term).

To be able to meet new and even more stringent legal requirements regarding specific elements, new treatment technologies will have to be developed. The treatment systems can be either passive or active.

Methodologies for holistic assessments of net environmental impact of new technologies should be developed including both positive and negative aspects.

- Better understanding of effects/impacts of mine effluents in receiving waters, and better capacity to predict water chemistry and environmental impacts (medium term).

Based on a better understanding of environmental impacts in realistic environmental conditions a methodology for development of site specific impact assessments should be developed. There is also a need for better geochemical and hydrodynamic modeling to make it possible to predict water chemistry in receiving waters.

This in turn will be facilitated by improved methods for mineralogical characterization.

Any methodology for long term predictions will have to consider the impact of climate change.

Water nitrogen measurement, Aitik, Gällivare Photo: LTU

- Optimized water management in the whole mining process (short to medium term).

Water needs to be carefully managed at all mine sites as water management is interlinked with all steps of the mining process, including mine site planning and closure. Starting with mine dewatering, collected waters within the footprint, water added in the mill/concentrator and pumped with the tailings to the tailings management facility (TMF). From the TMF water is often recycled to the process in which case it may have a negative impact on recoveries in the process due to an accumulation of conservative elements in the recycled water. Another example of dependencies is that the amount of water, and how it is managed, at the TMF may have an impact on dam safety. Implementation of a better integrated water management will require better systems for on-line monitoring and data management.

For research on a holistic water management all steps in the process chain, and throughout the mine life cycle, will have to work together. Finally, water management will have to consider and be adapted to climate change.

WASTE

- Reduced risk through new deposition methods (medium to long term).

Internationally there is consensus that the way to reduce the risks posed by TMFs is to reduce the amount of water stored in the facilities. A lot of work is done on thickened tailings disposal and dry stacking. However, there are still problems to be solved. Some remaining issues relate to geochemical aspects of the deposition technique and to upscaling as most of the work so far has been in pilot scale. What is even more relevant for us is how these technologies can be applied in a Nordic climate. Another aspect that need further development is related to back-up options when the thickener or the dewatering methodology does not work as intended. This area is closely linked to dam construction and water management.

- Optimized resource use through waste minimization, separation and utilization (short to long term).

Waste minimization is primarily an area that is relevant in the development of mining technology. If improved characterization methods could contribute to a better separation of waste from ore (less dilution) the amount of waste brought to surface may be reduced. Another way to reduce waste may be increased use of tailings and waste rock for backfilling (mainly related to mining technology).

Through improved characterization and separation of different mineral groups, more minerals and metals in the ore can be used rather than becoming waste.

The biggest potential by volume is the use of waste rock for construction purposes such as road/railroad construction and construction of dams. The limiting factor is in most cases the distance to potential markets. Such geo-resources need to be well characterized regarding short and long term geochemical and geotechnical behavior to meet product specifications.

Current waste at Swedish mines contain minerals, hosting metals and other elements that are not extracted today but could be a resource in the future. Examples are phosphorus in apatite, REE and Co. Improved mineralogical characterization is one key to potentially unlocking this potential. This work needs to go hand in hand with work on process development to assure that additional processes are both environmentally acceptable and economically competitive. Finally, by separating waste in reactive and non-reactive there is a potential to reduce the amount of waste that need a qualified storage and closure.

- Long term safe, stable and cost-efficient storage of mine waste and post-mining land-use with added value (short to long term).

In the foreseeable future there will always be a need for long term storage of waste. Both for non-reactive waste that could not "find a market" and for wastes that need to be safely stored to avoid contamination of the environment. For reactive wastes, the development of innovative cost-effective stabilization techniques, cover and encapsulation materials and systems need to continue. One important aspect is to evaluate the long-term performance and durability of any solution.

The main footprint of a mine site is related to the mine itself, in the case of open pit mining, and to waste deposits, i.e. waste rock dumps and TMFs. Work should be done on how to maximize the remaining value of those areas following closure. This relates to sustainable landscape design as well as to added values such as improved biodiversity and beneficial land use.

DAM SAFETY

- Minimized risk in both short and long term (short to medium term).

The risk of dam failure remains one of the most critical risks for the mining industry to manage. The Swedish mining sector is in the process of reviewing the national sector guidelines for dam safety. This review will be built upon international good practice.

However, there is still a need to adapt international good practice to our Nordic climate and to manage existing dams. One research area that will be important for the future is new tailings deposition techniques, these issues are included under "waste management" above. Some specific areas of interest are:

- dam design in cold climate.
- optimization of design with respect to waste properties (including susceptibility to liquefaction), local conditions and planned closure.
- investigations of foundation.
- monitoring.

BIODIVERSITY

- Long term positive impact on biodiversity (short term).

The Swedish mining industry is developing innovative and responsible solutions to include biodiversity and ecosystem services in their daily operations. Performing rehabilitation with social and ecological added value and ecological compensation, is becoming an established way to work. The scientific background and experience is however limited. To strengthen this work methodologies should be developed regarding e.g.:

- practical advice on how to work with ecological rehabilitation and compensation and how the quality of this work can be monitored and evaluated.
- how to identify, quantify, estimate and evaluate the benefits and improvement of biodiversity and ecological compensation.

EMISSIONS TO AIR

Dusting is the environmental aspect that receives most complaints from the neighboring stakeholders at almost all mine sites in Sweden. While dust from crushers and other point sources are controlled with well-established technologies, dust generated from diffuse sources within the mining operations and during loading, transport and handling of ore and waste can constitute a significant source of particles and lead to particle sedimentation close to the mine, exposure of workers as well as exceedances of ambient air quality levels in neighboring communities. Improved methods for characterization, prevention, monitoring and modelling of emissions and dispersion of particles should be developed as well as cost-effective measures to prevent dust generation (short term).

There is also a need to improve the capacity to treat air emissions from the processing of iron ores with respect to emissions of SOx, NOx, fluorides and chlorides (medium term).

Reduction of CO2 and other energy related emissions from processing and transportation are covered by other thematic areas in this agenda. Technology for Carbon Capture and Storage/Utilization (CCS/CCU) will also be important on the road to no climate impact.

However, these technologies will primarily be developed as part of other research initiatives (medium to long term).

MULTIDISCIPLINARY APPROACH:

As mentioned above, many of the research areas are interlinked. A sustainable waste and water management needs a holistic approach since changes regarding one will have consequences for the other. An assessment of these and other dependencies and consequences needs to be included in the management and risk analysis of changes to existing facilities as well as in the development of new systems and processes. Changes of processes may also have an impact on environmental performance, and these consequences need to be addressed before such changes take place.

To ensure that research results and conclusions are in fact considering all relevant aspects there is a need to include expertise from relevant thematic areas and to, as a rule, consider the value of multidisciplinary approaches to research areas identified (short to long term).

EXPECTED IMPACT

TECHNICAL

This research agenda has the potential to contribute to the development of new technologies and to the adaptation and implementation within the Swedish mining sector of internationally available technologies. E.g. within the areas of:

- Mineralogical and geochemical characterization.
- Waste management including waste minimization, separation, utilization, stabilization, dewatering, deposition and closure.
- Water management, impact assessments as well as treatment.
- Risk management including aspects such as deposition methods, on-line monitoring and data management systems.
- Tools for assessment of biodiversity and ecological compensation.

ECONOMICAL

The holistic approach is expected to lead to the development of technical solutions that are net-environmentally positive, cost effective and make it possible to meet increasing requirements and still stay competitive. It is even foreseen that a high standard of environmental performance will be a competitive advantage on the market in a not too distant future.

ENVIRONMENTAL

The overall aim of the thematic area "Environmental Performance" is to minimize the negative environmental impact (foot print) of the mining sector.

SOCIAL IMPACT

Meeting high (the highest) environmental standards will be a requirement for social acceptance of the existence of a Swedish mining sector. Given that the sector manages to meet those expectations it will manage to continue to contribute economic development in several regions and to Sweden as a nation.

By a successful implementation of "closure with added value" the sector will also contribute social and ecological values after closure of a mine.

ATTRACTIVE WORKPLACES

To cope with the future labour supply, the mining industry must change the image of mining work and increase the attractiveness of working in the sector, especially for young women and men. In the section Attractive workplaces, we describe a number of activities required in order to attract and keep skilled personnel in the mining industry in Sweden. To achieve this, the research agenda identifies five areas:

1. Digitalization opens up for new opportunities to create attractive workplaces in a safe environment, and jobs that provide space for the employee's full expertise and creativity. But there are also risks that need to be addressed, such as privacy issues, increased stress and work-life boundaries.
2. With the increased digitization, new qualifications are needed. These must be identified and programmes for reskilling and lifelong learning must be formed.
3. Research on health and safety has been successful, but the industry still needs innovative methods to control health and safety-related issues. To be perceived as a safe industry, a zero vision is required based on better proactive safety work.
4. Health and safety conditions for contractors must be explored and more inclusive safety cultures must be developed.
5. One overall thought in the agenda is to be proactive and to avoid creating problems in the first place. This is especially important in mining where initial mistakes can have consequences for a very long time.

Our ambition is to make the mining industry more prepared to meet the technological development on human terms. In a longer perspective, this can lead to the recognition of the mining industry as an ethical, ecological and diverse industry that can offer challenging jobs and attractive workplaces.

OBJECTIVES

The long-term vision (beyond 2045) is the zero-entry mine where all machines are self-regulated or remote-controlled from operations centres above ground. These centres are designed to promote co-operation and creative problem solving in multi-skilled teams of men and women. Basic safety level is not an issue anymore: dangerous work tasks are performed by robots.

In a shorter perspective, many workers remain underground. Here, there are new methods for iterative mine planning that take work environment and safety into account and reduce common initial design errors when mines are planned; production is organised through a holistic approach based on production teams and broad professional skills among management and miners; mining work has been transformed into being attractive to both women and men, not only because of the wages, but also because it is an interesting occupation with good potential for personal and professional development and lifelong learning in a safe and sound working environment. Still, a number of issues of attractive workplaces should be considered in future research and innovation as well; the most important are addressed below.

RESEARCH AND INNOVATION NEEDS, STRATEGIES AND ACTIONS

First, digitisation and its effects have an obvious place in a research agenda. Used correctly, digitalisation can create attractive jobs that provide space for the employee's full expertise and creativity. But there are also risks which need to be analysed and considered. Furthermore, competence development, learning at work etc. should be prioritized. These topics are vital in order to meet the demands of new technology and can guarantee flexibility for the company and development in one's professional role. Important focus areas for research are:

- How can the new roles of the operators (i.e. "Operator 4.0") meet the values and expectations that young women and men have when they enter work life?
- How can we increase safety by monitoring the operators in real time?
- How should digitised production systems address privacy issues?
- How to gain acceptance and avoid resistance for new technology?
- The identification of future skills requirements and education, as part of a lifelong learning.

- The development of new education programmes for reskilling and competence development of management and workers.

Health and safety at work must have top priority. Mechanisation, remote control and automation are efficient preventive safety measures. They are also appropriate for reducing workload to avoid musculoskeletal injuries and allow for recovery periods. Mining is characterised by huge investments and long-term operations. Thus, it is very important to have a well-designed physical production system. The personnel will have to live with the negative consequences of mistakes for many years. Improved safety is also a matter of a developed safety climate in the form of relevant education, rules and effective leadership, with safety prioritised in the day-to-day-work. In short, there is a need for further development of:

- New methods for monitoring and controlling the work environment.
- Efficient tools for proactive safety control, as well as broader analyses of the impact of digitalization on health and safety in general.
- New iterative frameworks for the planning of attractive workplaces.

Moreover, the increased number of contractors must be addressed. Focus should be on the benefits and potential problems that come from a workforce of in-house personnel and contractors. This includes strengthening both formal (e.g. implementing joint safety management practices) and informal (e.g. communication and interaction in the workplace) relations in multi-employer worksites. Important issues in this area include:

- Reviews of the health and safety conditions for contractors in mining.
- The development a safety culture that includes contractor.

Finally, although the traditional image of mining is not particularly attractive and the industry still has health and safety issues that need to be considered, we think that it is possible to create a new vision of future mining - a vision of a high technology industry that speaks to today's young people. Mining companies must more actively demonstrate their social responsibility. Employees want to feel proud to work in the company, which means that issues such as vision, mission and core values are important. If we manage these problems well, they can be turned into advantages that create new, attractive job roles. All these factors affect the company's image, and thus the possibility of recruiting young talented people to the industry. Overall, broader strategic research areas should include matters related to:

- The development of a holistic concept for the zero entry mine.
- The development of efficient programmes for development of attractive societies.
- The development of a model for an ethical, ecological and diverse workplace and recognised as a green branch.
- Give the industry a new image that can attract young people.

EXPECTED IMPACT

TECHNICAL

- Digitalisation on human terms.
- New methods for monitoring and controlling the work environment.

ECONOMICAL

- Reduced cost by keeping qualified miners and staff.
- Increased efficiency at work.

SOCIAL

- Increasing young people's interest in the mining industry.
- Contribute to the creation of an attractive society.
- Improved health and safety conditions in mining.
- A significant reduction in the number of severe and fatal accidents.
- A significant reduction in the number of occupational diseases.

ENVIRONMENTAL

- Recognition of mining as an ethical, ecological and diverse workplace.

CORPORATE SOCIAL RESPONSIBILITY AND SOCIETAL RELATIONS

The contribution of the mining and metal producing industry to sustainable development has broad environmental, economic and social dimensions. Industrial actors need to recognize the wider positive and negative impacts of their operations on society at the local, regional, national and global levels. The thematic area Corporate Social Responsibility and Societal Relations comprises research and innovation on the nature and significance of the industry's relations with local communities and the broader society. It also addresses the various management practices and institutional preconditions (e.g. legal rules, policy instruments, codes of conduct, etc.) that could help increase the industry's contribution to sustainable development, and assist in further developing constructive and mutually respectful relations with local communities and broader society.

Achieving this requires an increased understanding about the range of societal impacts, such as employment and income generation, innovation, entrepreneurship, distributional effects, land use conflicts, implementation of indigenous rights, demographics, cultural heritage, etc. While the thematic area addresses all three dimensions of sustainable development, it also recognizes important trade-offs and synergies among these. The trade-offs (e.g. stringent environmental regulations versus competitive strength) as well as synergies (e.g. different innovative industrial sectors jointly benefitting from mining operations), may differ in the short-run compared to the long-run (e.g. due to technological development), as well as across different geographical locations. A related issue concerns how the responsibilities for sustainable development could be shared between the industry and different public authorities.

The research and innovation strategies and actions in the thematic area focus on five main sub-areas: Corporate Social Responsibility (CSR) and sustainable business; Regional development; Innovation management and systems; Managing land-use conflicts; as well as Environmental regulations.

Kiirunavaara, Kiruna Photo: Alm & ME, LKAB

OBJECTIVES

The activities of the mining and metal producing industries should contribute to sustainable development through the development of constructive and mutually respectful relations with the broader society. Swedish companies should be role models for other countries that aim at enhancing the industry's contributions to important social, economic and environmental goals at the local, regional, national and global levels.

SHORT TO MEDIUM TERM

- Strong social science research environments addressing the industry's relationship with other societal actors, and its contributions to sustainable development, have been established.
- Sustainability criteria and measurable indicators addressing various community values have been developed and operationalised.
- Impact assessment tools, institutions and deliberative approaches that can support the various decision-making processes (e.g. the permitting of new mines) have been developed.

LONG TERM

- Sustainability criteria and indicators are adopted by the industry, and perceived legitimate by key stakeholders.
- Expedient stakeholder management tools have been fully integrated, and are perceived legitimate.
- Sustainability management systems (SMS) have been implemented and minerals and metals produced have a sustainability label.
- Social innovation is practiced and the industry is perceived as a value adding corporate citizen.
- Government decision-making at various geographical levels is perceived as legitimate by key actors and has the capacity to handle diverging interests and make trade-offs in legitimate and effective ways, e.g., through the use of comprehensive impact assessment tools.

RESEARCH AND INNOVATION NEEDS, STRATEGIES AND ACTIONS

CORPORATE SOCIAL RESPONSIBILITY AND SUSTAINABLE BUSINESS

Corporate Social Responsibility (CSR) and sustainable business involve the willingness of a company to incorporate social and environmental considerations in its decision-making, and be accountable for the impacts of its decisions and activities on the broader society. CSR can generate shared value through sustainable business models, by the integration of sustainability aspects into the entire value chain, and by identifying, assessing and involving stakeholders in decision-making. The integration of CSR is essential and implies improving existing operations and integrating sustainability aspects into daily activities, e.g. through SMSs. It also means to promote social responsibility along the value chain. In order to demonstrate responsibility in a transparent and accountable way, companies' use sustainability reporting or through certifying the company or the products in accordance with a social or environmental standard or label. Through social innovation, companies create new ideas that meet social needs, establish social relationships, and form new collaborations in order to be a value adding corporate citizen.

SHORT TO MEDIUM TERM

- The development of new business models to address various social or environmental problems or conflicts of interest.
- The identification and implementation of industry-wide sustainability criteria and measurable indicators and their applicability.
- The development of strategic tools and guidelines for improved stakeholder management, sustainable supply chain management, sustainability auditing, community development practices and social innovation.

LONG TERM

- The development of SMS by integrating and implementing sustainability criteria and indicators into existing operational management systems.
- The development of a method for traceability and a framework for sustainability labelling of metals and minerals.
- Social innovation through new collaborations, partnerships and practices to create environmental, social and economic benefits and build trust in society, including the local community.

INNOVATION MANAGEMENT AND SYSTEMS

Innovation management centre on management of innovation processes, and allow industrial companies to respond to external and internal opportunities by creating new ideas, products, services, or business models. The objective is to enhance knowledge about innovative work in mineral and metals industries, and how this work could be improved over time. Innovation management is of particular importance to extract commercial values out of new technologies. It can be firm-internal (e.g., within a company) but frequently occurs across companies, such as when mining companies and suppliers of process technologies create joint R&D projects and engage in open innovation across firm boundaries. At the macro level, innovation can also be studied as an "ecosystem", which stresses the flow of technology and information among key actors, firms and institutions that set the boundary conditions for new products or services (e.g., circular business models).

Innovation system analysis often focus on identifying system strengths or weaknesses and may be conducted at the national, regional, sectorial or technological level.

SHORT TO MEDIUM TERM

- New methods, tools and techniques, which allow companies to create new products, services and business models.
- Improved knowledge of innovation management "best practices", and adaptation of such best practices to fit the Swedish mining and metal producing sector.
- The identification of key system-level strengths and weaknesses to improve the mining ecosystem.

LONG TERM

- Build world-class innovative capabilities of companies in the mining and metals ecosystem.
- The development of new innovation management frameworks to make companies "innovation leaders".
- Remove bottlenecks and weaknesses in the mining ecosystem so that the whole system can be strengthened.

REGIONAL DEVELOPMENT: LABOUR MARKETS, MIGRATION AND BENEFIT-SHARING INSTRUMENTS

Improved knowledge about the impacts of mining operations in terms of migration and commuting patterns, job creation, and recruitment challenges, is needed, taking into account that labour market impacts of the industry are likely to change over time due to cyclical fluctuations and technological change. The identification and evaluation of different types of instruments that can be adopted to strengthen any positive impacts, e.g. so-called benefit-sharing, also represents an important research field. Finally, empirical research on the relationship between social sustainability, social cohesion and company workplace and practices, is essential.

SHORT TO MEDIUM TERM

- Review and investigate current and future needs of labour recruitment.
- Review and evaluate existing methods used, in Sweden and internationally, to assess the regional-economic impacts of mining operations and the role of benefit-sharing.
- Analyse the labour mobility and population changes in local and regional labour markets impacted by changes in the industry.
- Review and analyse important developments in social sustainability factors and their relationships in key Swedish mining communities, including also practices within the companies concerning recruitment and personnel.

LONG TERM

- Identify and evaluate management practices aiming at meeting future demands for the recruitment of qualified labour to the industry.
- Develop and put into use new improved methodological approaches to assess the regional-economic impacts of mining operations, including impacts and trade-offs associated with different types of benefit-sharing mechanisms.
- Identify and evaluate strategies on how to promote economic and social cooperation between the industry and the local communities and regions.

MANAGING LAND USE CONFLICTS: RIGHTS, POLICY, PLANNING AND DELIBERATION

Land use conflicts raise questions about the efficient use of scarce resources, but such conflicts also concern legal rights, values and ethical issues such as fairness and procedural justice. Mining development may sometimes be difficult to match with local aspirations, including indigenous rights. Any meaningful decision-making institution and process must therefore be able to articulate and handle such concerns. This calls for the use of a mix of methods to resolve, or handle, land use conflicts, including the recognition of rights, a legitimate institutional framework, efficient and legitimate decision-making procedures, as well as well-functioning deliberative practices. Still, due to a complex web of legislation at different levels, it is often unclear how the mineral interest interacts with other land-use interests, as well as how they are considered or valued in relation to each other as well as over time. Underlying many land use conflicts are conflicting values and aspirations that ought to be addressed in legitimate ways. This calls for research investigating tools to evaluate impacts and how the existing regulatory frameworks addresses the range of actors, interests, goals and practices, and how it is implemented in real-life cases, including the role of communication and local participation in planning processes.

SHORT TO MEDIUM TERM

- Identify causes and challenges in land-use conflicts with respect to current institutions and practices.
- Review existing regulatory and planning framework in relation to various types of mineral exploration and mining operations as well as experiences from other industries, not least how the views of different actors are evaluated and addressed.
- Review the current use of public consultations and environmental impact assessments, and how these could enhance the quality of interaction and relationships.
- International comparison of the strategies employed to permit indigenous rights and mining operations to co-exist.
- Develop and test a social cost-benefit approach in the case of investments in the context of mining and metal producing industries.

LONG TERM

- Identify and evaluate different types of strategies, practices and regulations that could improve the legitimacy and the efficiency of land use decision-making with respect to mining concessions, including mechanisms for public participation and involvement in the planning processes.
- Identify and evaluate various strategies, practices and regulations to address co-existence of different national interests in mining areas.
- Complete a handbook for conducting cost-benefit analysis for mining development to support, for instance, legal rulings.

ENVIRONMENTAL REGULATION, COMPLIANCE AND COMPETITIVENESS

Research is needed on how environmental regulations can be designed and implemented to promote continuous pollution reductions while at the same time taking into account the long-run industrial competitiveness. Future research endeavours could involve new and/or improved methods on how to evaluate the efficiency and the competitiveness impacts of different types of regulations in terms of design and implementation.

SHORT TO MEDIUM TERM

- Review and evaluate the decision-making processes that underlie the existing permitting conditions with respect to air and water pollution, including mining waste.
- International comparison of how other significant mining countries regulate, and have regulated, the environmental impacts of mines and metal smelters.

LONG TERM

- Develop different regulatory approaches that can be used to improve the environmental performance without compromising fundamentally with the industry's long-run competitiveness and demand for transparency.
- Develop different ways of regulating the rehabilitation of mining areas to secure that the necessary costs can be covered in an economically efficient manner.
- Analyse best-practice regulations (e.g., experiences from other countries and industries) from a societal efficiency point-of-view, and the development of cost-benefit tools to assist the permit decision-making process.

EXPECTED IMPACTS

ECONOMICAL

- The practice of CSR and more efficient institutional conditions contribute to the competitive strength of the industry.
- The regional economic impacts of mining investments will be better assessed and will therefore support a more knowledge-based decision-making at different levels of society.
- The industry provides more synergies and less conflict with other interests and business sectors, in turn leading to a greater acceptance for the industry in society.
- Companies in the mining and metals ecosystem are better settled to save costs and/or increase revenues by using new innovation methods and tools.

ENVIRONMENTAL

- The environmental regulations and the industry's management practices address land use conflicts and pollution concerns in an efficient and a legitimate manner leading to a high standard of environmental commitment.
- Future changes in the stringency, design and implementation of the environmental regulations are conducted based on a thorough understanding of how these affect both environmental and economic outcomes.
- Companies in the mining and metals industries can lower their environmental impact by implementing circular business models.

SOCIAL

- Better understanding and improved relations with a range of actors in local communities and among the general public in Sweden.
- Conflicts related to indigenous rights, cultural heritage, diversity of lifestyles etc. are clearly understood and dealt with in processes that are deemed by all involved as legitimate and efficient.

GENDER AND DIVERSITY IN MINING

The thematic area Gender and Diversity in Mining is based on gender theoretical research as well as research on diversity, to meet the future challenges of capacity building as well as productivity, for an internationally competitive and socially sustainable mining industry. The thematic area also establishes critical, multidisciplinary and applied gender and diversity research in the Swedish mining industry as a field of excellence. The aim is to form visions, policies and financing that enable research that can contribute to a more gender equal, diverse and socially sustainable development of the mining industry. In 2045, Swedish mining is well known for being world-class at breaking ore and gender patterns and for creating and sustaining gender equal organisations and workplace cultures based on diversity for efficiency, productivity and innovation as well as prosperous regions and attractive mine communities in collaboration with local actors in society.

Global competiveness, new technology, digitalisation and the implementation of effective, safe and sustainable mine production processes place the mining industry in need for skilled personnel and expertise, with wide and new type of skills and knowledges. A challenge for the future is to engage and retain new target groups in all social groups, especially young people and women, to education and jobs in the mining sector. For future capacity building, diversity and gender equality initiatives are a potential for additional global competitiveness, also in achieving a mining sector that is viable and sustainable for Sweden. Social sustainable development is about building technology, communities, organisations and clusters where humans are at the centre of development and innovation – where no groups are disadvantaged by formal and informal structures. Diversity and gender issues often focus on external solutions for the problems with under-representation, for example of women in mining. It is important that women in a better way be included, respected and valued.

Equally important is to understand and change the existing internal organisations, including the cultures and norms within the majority (for example the men in mining). Today the overall gender pattern of the mining sector is characterised, more or less, by male stereotypes – in all parts of the sector, in the mining companies, in related business clusters, in mining communities and overall society as well as in education, research and innovation. Changing the old "macho-culture" is one important step in creating safe and flexible workplaces – and attractive, sustainable and productive mining workplaces – better suited for the high-tech mining work of the future. From this point of view, a critical gender and diversity perspective on Swedish mining is central.

LKAB employees Photo: Alm & ME, LKAB

OBJECTIVES

In 2045 the Swedish mining sector is:

- World leading in mining and gender equality and diversity.
- Competing with attractive, gender equal and culturally diverse workplaces for efficiency, productivity and innovation.
- Generating a prosperous and sustainable mining sector and mine regions characterised by openness and tolerance for all women and men, in all ages.

The long-term goal for the Swedish mining industry is to be world leading in efficient and innovative organisations based on gender equality and diversity. Midterm goals are to attract competence through responsibility and value-driven business development aimed at sustainable development and increased attractiveness by offering disruptive technology change and the development of a new industry. The short-term goal is to create new conditions for increased equality and diversity as well as institute new knowledge and research on gender, diversity and gender equality in the mining sector that will facilitate the long- and mid-term goals. It involves theoretical deepening but also need-driven development of methodologies and evaluation of best practices. An interactive structure for knowledge exchange and collaboration for all actors of the mining sector is necessary for successful implementation.

RESEARCH AND INNOVATION NEEDS, STRATEGIES AND ACTIONS

The industry faces challenges not only regarding breaking ore but also breaking gender patterns. The Swedish mining industry has for a long time been centred on men and associated with male-dominated activities. If nothing is done also future innovation, research and development are most likely to be tapered similarly. In order to secure safe, flexible and innovative high-tech mining and attractive workplaces, there is a need for more research and solid understanding of what the gender structures looks like, how gender inequality operates, at what costs and, most importantly, how problematic and unequal gender positions and patterns can be challenged and changed – and how diversity and gender equality can be constructed. The research should draw on critical theories on gender, gender equality and diversity. Parts of the research need to be theoretical in order to fill the research gap. It is also important that large parts of this research is applied and is done in close collaboration with the mining companies as well as with other actors. In this way it could connect to ordinary technological and organisational development processes in the mining context.

Some suggested themes for research are:

- Methods for systematic gender equality and diversity measures including mapping, risk assessment, measures, control and learning.
- Good psychosocial work environment (including culture, norms, attitudes, behaviour, jargon) for all women and men.
- Versatile and gender and diversity aware strategic recruitment, promotion and retention practices in the mining industry.
- Gender equality, diversity and innovation capabilities in the mining sector.
- Gender equality and diversity among mining entrepreneur companies, temporary staff and similar.
- The effects of the digital transformation of mining work on gender equality, diversity, attractiveness, workplaces, work environment and work organisations.
- Gender equality and diversity in the global mining sector and the relations with the local workplaces and the local societies.

Along the line of research areas these support actions are suggested:

- Develop systematic gender divided statistics in industry, clusters, education and academia etc.
- Create a learning platform where the mining companies can evaluate their diversity and gender equality related activities – to support best practice and cooperation.
- Encourage collaboration between industry and society for attractive, diverse and gender equal mining communities that are also flexible to change.

EXPECTED IMPACT

Research and actions within the thematic area Gender and diversity in mining has potential for a large impact on the Swedish mining industry's global competitiveness and for a vital and socially sustainable mining work sector in Sweden. The research will also contribute to a general and deeper understanding of problematic structures, as gender patterns, in working life and how to change these.

TECHNICAL

- Improved implementation of new technology.
- Improved implementation of effective and safe production.
- Creativity and innovativeness in organisational and technological development.

ECONOMICAL

- Improved competitiveness through diverse capacity building.
- Flexibility to change and development within the industry.
- Flexibility to societal progression, locally and globally.
- Reduced vulnerability due to a gender-segregated economy and labour market.
- Sustainable economic growth in rural regions in Sweden.

SOCIAL

- Improved competence recruitment – thanks to possibilities to attract all sorts of skilled people to the industry, both men and women.
- Safe, healthy and attractive mining workplaces based on modern leadership and technology.
- Enable more women to stay in mining regions.
- Additional employment opportunities for men and women.
- Prevent fly-in-fly-out societies.
- Attractive, sustainable and creative mining communities for men and women.

> ***"I strongly believe that a company that doesn't seriously go into digital transformation today will not be in business 10 years from now."***
>
> **— Industry insider & former CIO of two global companies, Mining Magazine and Rockwell Automation, 2019-05-01**

SUMMARY – RESEARCH AND INNOVATION CHALLENGES, ACTIONS AND IMPACT

EXPLORATION

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
CLIMATE CHANGE (Innovation critical metals)	Establish genetic and exploration models for major ore types in Sweden, including models for deposits containing critical raw materials with economic potential	Continue to develop genetic ore- and exploration models for Sweden's ore deposit types	First nationwide 3D model of the bedrock down to several kilometres, to be used for decision making on land planning issues
COST-EFFICIENT PRODUCTION (Technology, penetration)	New drilling technology for deep (>1,000 m) drill holes, implemented MWD. New geophysical methods for deep penetration from surface, airborne and borehole observations	Proven new deep drilling, deep geophysical, deep geochemical/ mineral chemical techniques, and "real-time" mineralogical and geochemical analysis, as well as 3D structural modelling	Providing Sweden with innovative, world-class technology for minerals exploration of deeper-seated ore bodies and complex ores
RESOURCE EFFICIENT PRODUCTION (Increase of EU's supply of raw materials)	Ore genetic models by defining deposit types in areas of great potential with a focus on both main mined commodities and related critical minerals	Training of decision makers for better resource governance, and actively promoting results among exploration industry at large	Improved self-sufficiency and a stable supply of base, critical and other metals for the Swedish and European economy
EDUCATION (Increase the knowledge, public and government, about the need for metals for the green society)	Improve the awareness of the need for minerals and metals for a sustainable and green society	Build visualisation centres and publish predictive 3D models for Sweden	Defined mining potential in Sweden for the coming century to be used as a tool for decision-making on land use, protection, etc.

RESOURCE CHARACTERISATION

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
CLIMATE CHANGE (Innovation critical metals)	Detection of new value-added minerals, e.g. high-tech and critical raw materials	Implement novel resource characterisation techniques and methodologies for identification of innovation-critical metals as by-products	Reduced energy consumption and reduction of the amount of wastes New value-added products
COST-EFFICIENT PRODUCTION (Geometallurgical approach, description of all parameters of the rock mass)	New resource management tools, which enable real-time data integration, effective data visualisation, production planning and scenario analysis	MWD and AWD technology to deliver data for online process design, optimisation, prediction and planning for ore delineation, rock mechanics, drilling, continuous mechanical excavation, blasting, crushing and grinding	Providing information for a net present value (NPV) optimized mine and mine-to-mill processes
RESOURCE EFFICIENT PRODUCTION (Increase of by-products from processing rejects)	Tool for resource efficiency assessment and sustainability evaluation of existing and planned mining operations	Micro-analytical tools for incorporating detailed resource information in long term production planning	Increased resource efficiency by automation and efficient use of wastes as secondary raw material
SAFETY & MINIMAL ENVIRONMENTAL IMPACT	New monitoring methods for rock mechanics by adapting the use of existing sensor techniques	Energy-efficient and environmental-conscious process development in the concept of geometallurgy and 4D-geomodelling	Improved working environment

MINING

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
CLIMATE CHANGE (Energy-effective mining processes)	Develop energy efficient mining processes Develop fossil free mining equipment Secure infrastructure that support equipment driven by alternative power sources e.g. electric, battery, fuel cell	Energy efficient unit operations throughout the mining process implemented Implement fossil free mining equipment	Reduced CO2 and nitrogen emission with an improved air quality Reduced energy consumption
COST & RESOURCE EFFICIENT PRODUCTION	Develop tools and systems for improved process control and process optimization Fragmentation processes that gives an optimum fragmentation, improved ore recovery with a minimum of dilution, and a minimum of undetonated explosives Develop mining methods for deep mining conditions Reduce waste rock by developing efficient and selective mining methods	Digital twins and process control systems enable optimisation of the complete mining process Continuous selective excavation methods for all types of orebodies, resulting in a minimum of human exposure and waste rock production Efficient mining methods for mining at greater depths	Reduction of ore losses and dilution More cost-effective mining process overall
SAFETY	Ground control measures that can ensure safe conditions with no unforeseen fallouts	Improved mining methods/ layouts that ensure safe mining conditions to mitigate seismic hazards and to achieve stable and safe condition	Minimised human exposure at the production face and safer mining with fewer accidents
MINE AUTOMATION	Develop reliable remote controlled autonomous systems and equipment for all unit operations Reliable communication networks with real-time capabilities - 100% coverage 24/7	100% continuous/on-line process control and dispatch in 100% of the mines opens for reliable monitoring systems for production and rock mechanics purposes	Integrated process control and one control room Optimised mining processes

MINERAL PROCESSING

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
CLIMATE CHANGE (Reduction of energy consumption and related CO2 emissions)	Improved comminution technologies and machinery Optimised chain of ore fragmentation (from blasting to grinding) in combination with pre-concentration	Energy-efficient comminution processes are implemented	Availableness of energy-efficient comminution equipment and process designs
COST-EFFICIENT PRODUCTION	Suitable pre-treatment processes for coarse material separation close to the mining production face Efficient separation processes for treating fine-grained, polymetallic ores and removing impurities Flexibility in plant operation for different ores types Geometallurgical modelling together with innovative analytics for resource characterisation and ore traceability	Digitized processing plants using advanced online characterisation, sensor technology and data analytics (AI) for design and control are implemented	Provision of efficient coarse and fine particle separation processes, for wet and dry processing modes
RESOURCE EFFICIENT PRODUCTION (Increase of by-products from processing rejects)	Reduction of metal losses to tailings Increase of by-products from processing rejects Efficient separation of complex ores and removing impurities	New processing routes for producing minerals and metals from by-product and reject streams from beneficiation and extraction plants are implemented	Increased revenue by producing by-products
REDUCE ENVIRONMENTAL IMPACT	Minimisation of water consumption and pollutant input Efficient management and treatment of process water	Optimised beneficiation processes for reduction of waste rock and tailings, reduction of process water (or dry processing) are implemented	Less water usage due to more dry processing and reducing the tonnage in downstream processes

RECYCLING AND METALLURGY

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
CLIMATE CHANGE (Reduction of energy consumption and related CO2 emission)	Introduction of new fossil-free (bio) fuels for heat and reduction in different processes	Technology for carbon neutral processing	Minimised negative impact on climate change
COST-EFFICIENT PRODUCTION	Fully utilization of by-products such as slag-products in applications	Improved process control, modification and development of measurement technology, methods to treat large amount of data connected to metallurgical reactions, technology for automation	Increased efficiency in process routes through process control, new measurement techniques, process modelling and automation
RESOURCE EFFICIENT PRODUCTION (Increase of by-products from processing rejects)	Utilisation of waste materials across business sectors	Fully utilisation of metals contained in existing raw material streams. Design of products to enhance recycling possibilities	Adaption of slag properties with respect to new and existing uses for the slag products
REDUCE ENVIRONMENTAL IMPACT	Extraction of elements from complex raw materials, such as dust and sludges	Securing a minimal environmental impact by minimized emissions and transformation to carbon neutral processes	Products designed to enhance recycling possibilities

ENVIRONMENTAL PERFORMANCE

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
WATER MANAGEMENT	New and cost-efficient treatment technologies Better understanding of effects/impacts in receiving water	Capacity to predict water chemistry and environmental impact Optimized water management in the whole mining process	Water management, impact assessments as well as treatment
WASTE MANAGEMENT	New deposition method reduce risk with stored water Optimized resource use through waste minimization, separation and utilization	Long term safe, stable and cost-efficient storage of mine waste Post-mining land-use with added value	Waste management including waste minimization, separation, utilization, stabilization, dewatering, deposition and closure
DAM SAFETY	Minimized risk in both short and long term Adapt guidelines to Nordic climate and technology for monitoring	Dam design in cold climate and design with respect to waste properties	Risk management including aspects such as deposition methods, on-line monitoring and data management systems
BIODIVERSITY	Practical advice how to work with rehabilitation and compensation	Methods to quantify, estimate and evaluate benefits of improvements	Tools for assessment of biodiversity and ecological compensation
EMISSIONS TO AIR	Improve capacity to treat air emissions (SOx, NOx, fluorides and chlorides)	Reduction of CO_2	Minimize the negative environmental foot print of mining

ATTRACTIVE WORKPLACES

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
COST EFFECTIVE AND SAFE PRODUCTION	New methods for iterative mine planning that take work environment and safety into account is established Production is organized through a holistic approach based on production teams and broad professional skills among management and miners A safety culture that includes contractors is established	(Beyond 2045) is the zero-entry mine where all machines are self-regulated or remote-controlled from operations centres above ground Production centres are designed to promote co-operation and creative problem solving in multi-skilled teams of men and women Basic safety level is not an issue anymore as dangerous work tasks are performed by robots	Improved health and safety conditions in mining A significant reduction in the number of severe and fatal accidents A significant reduction in the number of occupational diseases Increased efficiency at work
ENSURE PROVISION OF COMPETENCE Both new personell and education of existing staff to meet future requirements **NEW GENERATION LABOUR – A SHIFT IN ATTITUDES AND VALUES**	Future skills requirements and education, as part of a lifelong learning, is identified New education programmes for reskilling and competence development of management and workers is implemented		Reduced cost by keeping qualified miners and staff Increasing young people's interest in the mining industry Contribute to the creation of an attractive society
UNEXPLOITED COMPETENCES – UTILIZE THROUGH INCREASED EQUALITY AND DIVERSITY	Mining work has been transformed into being attractive to both women and men		Recognition of mining as an ethical, ecological and diverse workplace
IMPLEMENTATION AND UTILIZATION OF DIGITALIZATION	New methods for monitoring and controlling the work environment has been developed New iterative frameworks for the planning of attractive workplaces is implemented		Digitalisation on human terms

CORPORATE SOCIAL RESPONSIBILITY AND SOCIETAL RELATIONS

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
THROUGH CSR AND SUSTAINABLE BUSINESS, (contribute to a more sustainable society)	To develop strategic tools, guidelines and measurable indicators for more sustainable business	Strategic tools, guidelines and measurable indicators are integrated, implemented and demonstrated	A more sustainable, competitive and socially accepted mining and metal producing industry
MANAGING LAND USE CONFLICTS (Rights, policy, planning and deliberation)	Develop and test a social cost-benefit approach in the case of investments in the context of mining and metal producing industries	Complete a handbook for conducting cost-benefit analysis for mining development to support, for instance, legal rulings	Conflicts related to indigenous rights, cultural heritage, diversity of lifestyles etc. are clearly understood and dealt with in processes that are deemed by all involved as legitimate and efficient
INNOVATION MANAGEMENT & SYSTEMS	New methods, tools and techniques, which allow companies to create new products, services and business models	Development of new innovation management frameworks to make companies "innovation leaders"	Companies in the mining and metals ecosystem are better settled to save costs and/or increase revenues by using new innovation methods and tools
REGIONAL DEVELOPMENT (Labour markets, migration and benefit-sharing instruments)	Review and evaluate existing methods used, in Sweden and internationally, to assess the regional-economic impacts of mining operations and the role of benefit-sharing	Develop and put into use new improved methodological approaches to assess the regional-economic impacts of mining operations, including impacts and trade-offs	The regional economic impacts of mining investments will be better assessed and will therefore support a more knowledge-based decision-making at different levels of society
ENVIRONMENTAL REGULATION	Review and evaluate the decision-making processes that underlie the existing permitting conditions with respect to air and water pollution, including mining waste	Develop different regulatory approaches that can be used to improve the environmental performance without compromising fundamentally with the industry's long-run competitiveness and demand for transparency	The environmental regulations and the industry's management practices address land use conflicts and pollution concerns in an efficient and a legitimate manner leading to a high standard of environmental commitment

GENDER AND DIVERSITY IN MINING

CHALLENGES	OBJECTIVES TO 2030	OBJECTIVES AFTER 2030	EXPECTED IMPACT
COST AND RESOURCE EFFECTIVE PRODUCTION WITH REDUCED IMPACT ON THE ENVIRONMENT	Competence is attracted through responsibility and value-driven business development aimed at sustainable development and increased attractiveness by offering disruptive technology change and the development of a new industry	Competing with attractive, gender equal and culturally diverse workplaces for efficiency, productivity and innovation	
UNEXPLOITED COMPETENCES – UTILIZE THROUGH INCREASED EQUALITY AND DIVERSITY	Create new conditions for increased equality and diversity as well as institute new knowledge and research on gender, diversity and gender equality in the mining sector that will facilitate the long- and mid-term goals. It involves theoretical deepening but also need-driven development of methodologies and evaluation of best practices	World leading in mining and gender equality and diversity Generating a prosperous and sustainable mining sector and mine regions characterised by openness and tolerance for all women and men, in all ages	

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