Minerals Policy Guidance for Europe

Innovative Processing

Deliverable 4.3

Final report including guidelines and recommendations for future policy development for innovation in mineral and metallurgical processing – Version 1, January 2018

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1 Executive Summary

This executive summary presents the objectives, methodology and principal findings of deliverable D4.3. Guidelines and recommendations for future policy development for innovation in mineral and metallurgical processing as a part of work package 4. Innovative processing.

Objectives

The aim of WP4 "Innovative Processing" is to elaborate how innovations in mineral and metallurgical processing are generated or taken up in different EU Member States and on EU-level and how this is either facilitated or inhibited by policies and legislation on national or European level. The purpose of the deliverable 4.3 is to complement the findings of D4.1 and D4.2 by carrying out additional interviews with representatives from different stakeholder groups (academia, industry, NGO's and policymakers). The topics and questions of the questionnaire addressed the respondents' perception of national and EU- and EU MS level mineral policies, gaps and needs with respect to innovation in mineral- and metallurgical processing. Questions for the questionnaire focus on previously identified innovations in mineral processing, metallurgical processing and metal recycling.

Based on the input both from previous deliverables and from findings through the additional interviews and innovation cases, an analysis of needs and gaps as well as a SWOT analysis has been conducted. Recommendations for future development of mineral and metallurgical processing sector were evaluated.

Main Findings

Conclusions and recommendations for future policy development for innovation in mineral and metallurgical processing were developed based on a survey and a SWOT analysis.

- Most of the mineral policies are addressing the entire mineral value chain. Several statutory provisions are related to mineral and metallurgical processing. National mineral policies are not very much addressing the mineral and metallurgical processing, while recycling is dislocated from mining/mineral legislation.
- The sentiment amongst policy makers towards the raw materials industry has improved on EU level through a number of strategic policy initiatives (e.g. the Strategic Implementation Plan for Raw materials, the revised EU Industrial Policy Strategy, the Raw Materials Initiative).
- The use of raw materials from secondary sources has been identified as being an integral part of the life cycle of materials.
- Innovations in mineral and metallurgical processing are not supported at strategic and economic/investment level. The policy is neutral or inhibiting through long and uncertain permitting procedure, or is indifferent to innovation as to mineral and metallurgical processing.
- The European knowledge and skills base in mineral and metallurgical processing has diminished during the past 20 years.

2 Introduction

The Horizon2020 project MIN-GUIDE aims at supporting a secure and sustainable supply of minerals in the EU, as discussed in the Strategic Implementation Plan for the European Innovation Partnership on Raw Materials. The challenges of raw material supply for Europe, along with challenges related to innovation in the raw materials sector, has been recognised both on EU level and in many of its Member States. The main focus of the project is on generating a database on mineral policy and legislation both on EU and national levels, and further to elucidate good practices in policymaking in terms of how innovation in the mining industry is facilitated or inhibited by these policies. For this purpose, the key objectives of the project are to:

1. Provide guidance for EU and EU Member state minerals policy
2. Facilitate minerals policy decision-making through knowledge co-production for transferability of best practice minerals policy
3. Foster community and network building for the co-management of an innovation-catalysing minerals policy framework

The project is divided into 8 work packages, see Table 1.

Table 1. MIN-GUIDE structure and work packages

Type	WP #	Description
Common Approach	WP1	Minerals policy guide development and conceptual basis
Core Content	WP2	Stock-taking of EU and EU MS mineral policy and legislation
	WP3	Innovative exploration and extraction
	WP4	Innovative mineral and metallurgical processing
	WP5	Innovative waste management and mine closure
	WP6	Raw materials knowledge and information base
Cross-cutting management and engagement	WP7	Stakeholder management, communication and dissemination
	WP8	Project management

WP1 is intended to provide background information and define a common approach for WP2-6, which provide the core content contribution to the project. These work packages focus on stocktaking of mineral policies and legislation both on EU and Member State level (WP2), value chain-specific investigation of innovations in industry and their connection to policymaking (WP3-WP5), and a review of the mineral data base and standardisation for systematic reporting (WP6). WP7 is devoted to stakeholder management including communication and dissemination actions and WP8 towards project management.

2.1 Scope of Work package 4

As part of the MIN-GUIDE project, the work package 4 is devoted towards studying the linkages between innovation, policy and legislative frameworks within EU Member States. The main inputs from other work packages include the conceptual basis and 'Minerals Policy Guide' developed in WP1 and the stocktaking of policies and legislation conducted within WP2.

The specific tasks within WP4 are directed towards studying how innovation is taking place within mining companies and metal producers in the context of mineral processing and metal production and to study which impact the policy and legislation framework has on these processes.

At first, this requires a detailed definition of the relevant value chain constituents and the related stakeholder network, followed by a discussion on the most relevant innovation types for both actors and this part of the value chain overall. Based on this, a number of concrete innovations are used as case studies in order to exemplify the links to various policies and qualitatively evaluating the roles of both policy and non-policy factors as barriers and enablers for innovation.

2.2 Objectives of Work package 4

The aim of WP4 "Innovative Processing" is to elucidate how innovations in mineral and metallurgical processing are generated or taken up in different EU Member States and on EU-level and how this is either facilitated or inhibited by policies and legislation on national or European level. The work within WP4 also fosters dissemination of identified good practices and the investigation of factors which can enhance the transferability of such practices across the EU.

The objectives of WP4 can, therefore, be summarised as follows:

- Identify existing innovation facilitating and inhibiting elements in policy and legislation for processing including permitting procedures.
- Exchanging of good practices for innovation in processing and facilitating their transferability.
- Exploring future policy developments in order to foster innovation in mineral and metallurgical processing.

The previous deliverables of WP4, D4.1 and D4.2 are provided as two separate but interlinked reports:

- D4.1 provides a topic overview of innovation case examples within minerals and metallurgical processing as well as a mapping of the relevant policy framework and an analysis of the impact on innovation. D4.1 is based mainly on literature surveys and preliminary case studies and analysis.
- D4.2 extends this approach through a more in-depth analysis of different innovation cases and their links to different policy and non-policy catalysing and inhibiting factors. In addition to further literature investigations, the work is complemented by interviews and questionnaires with industry representatives. A workshop (MIN-GUIDE Policy Laboratory 3) was held in Luleå, Sweden 18-19 May 2017, and attracted about 45 stakeholders from industry, policy-making and research organisations. Additional input obtained during that meeting was also used as background material for this deliverable.

The two previous deliverables are summarised in section 3 of this report.

2.3 The purpose of D4.3

The purpose of the deliverable D4.3 is to complement the preliminary findings of D4.1 and D4.2 by carrying out additional interviews with representatives from different stakeholder groups (academia, industry, NGO's and policymakers). For this purpose, a number of innovation cases have been selected as examples of good practice as specified in chapter 5. In the second stage, based on the input both from previous deliverables and from findings through the additional interviews and innovation case analyses, a SWOT analysis has been conducted.

3 Summary of other deliverables within the WP

WP4 aimed to investigate how innovation processes within the area of mineral and metallurgical processing are functioning in the different EU Member States and on the EU level, and how they are supported or inhibited by various national and European policy and legislation. The work in WP4 was split into 3 tasks:

- Identification of EU MS mineral policies and legislation relevant to innovation in mineral and metallurgical processing;
- Identification of catalysing and inhibiting elements for the implementation of innovative mineral and metallurgical processing solutions;
- Assessment of needs and gap analysis for aligning future policy developments/directions.

WP4 has so far resulted in two deliverables, D4.1 and D 4.2, which are provided as two parts of a coherent report on both (i) the policy and legislation framework and (ii) innovation promotion and inhibiting factors and examples of good practice. While D4.1 is a topic overview based on literature survey and preliminary case analysis, D4.2 is extended with more interviews and questionnaires to provide a more in-depth analysis of policy, legislation and innovation cases.

3.1 Summary of Deliverable D4.1

An identification of policies and legislation relevant to mineral and metallurgical processing was conducted based on the stocktaking of policy relevant information. This included EU level as well as Member State level mineral policy documents, for instance mineral strategies, and also a list of relevant legislation. From the data analysis it was clear that a hierarchical (i.e. vertical) structure of legislation existed when analysing the Member State level. Here, further distinctions could be made horizontally according to the issuing authorities, the part of the value chain, the type of raw materials, etc.

Besides mineral strategies that address sustainable supply with mineral resources and strengthening the competitiveness of the mining and minerals industry on a superior level, also other policies and legislation relevant to WP4 were identified. In the continuation, the overview of policies and

legislation was then divided into three main categories based on content, covering policies and legislation linked to (i) permitting procedures and social aspects, (ii) emissions and waste prevention and handling, and (iii) resources use (e.g. water, energy, land). Most of the policies were addressing the whole sector, i.e. out of the perspective of the MIN-GUIDE approach all parts of the mineral value chain were pertained in a similar way. Several statutory provisions were, however, related to process technology and production plants in general or even to mineral beneficiation and metallurgical processing in particular.

D4.1 also analysed an array of different innovation cases, i.e. significant and noteworthy innovations in mineral- and metallurgical processing, in order to identify and compare examples of good practice in fostering innovation.

From the analysis the following conclusions could be drawn:

- A general observation regarding policy initiatives related to mineral and metallurgical processing was that these are high up on the agenda of policy makers, and seem to have increased further in importance over the last 5-10 years. This is evident by looking at the EU level where a number of strategic policy initiatives supporting the industry in terms of recognizing the importance of a secure and safe supply of raw materials, produced in an environmentally responsible and sustainable manner, and also increasingly taken from domestic sources. Corresponding initiatives are also seen in many individual EU Member States.
- The use of raw materials from secondary sources has been identified as an intrinsic part of the life cycle of materials. Product and process innovations in mineral and metallurgical processing are frequently relevant to both primary and secondary materials.
- Innovation in all parts of the value chain is critical for success. These ambitions on the EU level are further reflected in many national and regional mineral and raw material strategies, which take into account industry-related prerequisites, challenges and opportunities specific to the national and regional context. To some extent, these are backed by other policy-type elements, as for instance research funding schemes, tax incitements, etc.
- Regarding legislation, the main contribution to support policy towards innovation is resulting from imposing various types of restrictions, which in turn might drive companies towards process improvement, more environmentally friendly production and operations, etc. Although this often has adverse effects on the economy of operations, the impact in terms of driving innovation in industry can still be net positive in the long run.
- The mere quantity of policy initiatives and legislation can act as a barrier to innovation. In particular, the multitude of policy and legislation leads to complicated and time-consuming permitting procedures, which may cause high economic barriers and time barriers for industry. This problem is further reinforced as there are interactions with related policies and legislation for which the industry is also accountable, and because policy is formulated and governed by a lot of different EU- and state level actors (i.e., different types of government agencies with different areas of responsibility).
- An overall conclusion is that the interaction with policies and legislation for most innovations are indirect, meaning that companies may respond to broader societal issues such as energy and resource efficiency, waste management, and hazardous substances. There are very few legislations (laws) that are targeted directly at the minerals- and metallurgical processing part of the value chain.

3.2 Summary of Deliverable D4.2

D4.2 involved a systematic analysis of innovation drivers and barriers related to mineral and metallurgical processing as well as an in-depth evaluation of several innovation cases. Besides the findings from literature surveys, interviews and questionnaires have been used to collect expert opinions.

Non-policy inhibiting and enabling factors that may cause or prohibit innovation were organized into four different levels: (i) external environment, (ii) organization, (iii) group and (iv) individual. There are multiple actors outside an organization that may influence its ability to innovate. These include actors in the value chain of a company in the mineral and metallurgical sector, such as suppliers or customers. These barriers may also refer to other actors in the broader ecosystem, such as suppliers of process equipment and technology who are critical to create innovation. Organisational barriers to innovation often focus on a lack of (or deficiencies in) capabilities at the organizational level. Barriers at the organizational level also centre on issues such as resources, learning, culture and structure. Barriers to innovation also exist at the group level. Groups are embedded in the larger organizational context, for example the cross-functional groups or teams that are used when firms try to create new processes or products. Finally, some barriers and enablers of innovation reside on the individual level, as innovation is largely contingent on abilities and attitudes of employees, e.g. managers' and employers' abilities and attitudes.

In addition, policy inhibiting and enabling factors for innovation were identified: i) regulatory instruments, ii) economic and financial instruments, and iii) soft instruments. Various levels of government (i.e. state, EU, etc.) are of course critical and should not be neglected. For example, the state may impose regulations and policy initiatives that either inhibit or catalyse innovation through e.g. regulatory frameworks. Innovation policy instruments are thus selected to influence innovation, e.g. process innovation, product innovation, or some other type. In doing so, they can inhibit or enable innovation.

- Regulatory instruments use legal tools where government defines framework conditions. These framework conditions set boundaries for what is allowed, and for what is not allowed. Measures are obligatory and backed by sanctions when firms fail to comply with whatever the instrument stipulates, e.g. laws, rules, directives and others. Sanctions may, for example, include fines, or temporary withdrawal of rights. For the mineral- and metallurgical processing sector, regulatory instruments may enable innovation by e.g. assuring intellectual property rights to innovators through patents, or through sector-specific regulations. Environmental regulation may e.g. act to spawn investments into better production processes (i.e. process innovation). However, they may also cause compliance costs and large transaction costs, which inhibit innovation, especially for newcomers who do not have the large resource pool of incumbent firms.
- Economic and financial instruments are used to incentivise (or discourage specific industry activities). For example, policy instruments could provide means in terms of money or in terms of in-kind, i.e. subsidies or cash transfer. One example is public support to universities and research organizations to spawn knowledge in basic R&D, product and process innovation, e.g. the Swedish initiative "Strategiskt gruvforskningsprogram".
- Soft instruments provide recommendations and make normative appeals or offer contractual agreements. Some examples include codes of conduct, governmental recommendations, voluntary agreements and public-private partnerships, which all may act to spawn

innovation. Soft instruments are often used in combination with policy initiatives from the two categories above in order to serve a common goal within a so-called "policy mix".

Using the above definitions and classifications, a number of recent innovation cases within minerals and metallurgical processing were analysed. Examples comprised recent innovations in the technological fields of comminution and separation processes, pyrometallurgy, hydrometallurgy, process systems analysis and control as well as environmental management. The following conclusions could be drawn from this case analyses:

- The main innovation drivers for the mineral metallurgical processing industry are related to increasing productivity and lowering costs. Process innovation (i.e. the implementation of a new or significantly improved production or delivery method) is consequently the prime innovation type critical to competitive advantage.
- Process innovation can also lead to sustainability outcomes in terms of improved resource efficiency. This refers to innovation drivers as the trend towards deposits with lower ore grades and more complicated mineralogy, the need for energy efficiency and reduction of related greenhouse gases, and/or efficient use of process water.
- The view on process innovation depends on which actors are asked. For service and equipment providers, the provision of novel process technology and equipment that supports process innovation in a company producing metals is typically seen as a product innovation from the manufacturers' perspective. A recipient firm (i.e. producing firm) typically thinks of such investments as process innovation.
- The study indicates that both policy-related and non-policy factors have an influence on innovation in the mineral and metallurgical processing sectors. The evaluation of these factors is, however, in some cases not straight forward, i.e. there might be factors that can be both catalysing and inhibiting depending on the case. Also, some factors can act as drivers in one part of the value chain, while being barriers in another.
- A critical obstacle, which can act as a barrier to industry innovation and development, achievement of strategic goals set by policy makers and economic development in general, is the mere quantity of policy initiatives and legislation. This leads to more complicated and time-consuming permitting procedures, lowers predictability, and in some cases causes unacceptably high economic commitments by industry. This not only concerns policies and legislation directly addressing the minerals and metals industry, but also the complex interaction with various less related policies and legislation for which the industry is also fully accountable.

4 Summary of Policy Laboratory 3

The 3rd MIN-GUIDE Policy Laboratory on "Innovations and supporting policies for mineral and metallurgical processing" took place in Luleå, Sweden, during May 18-19, 2017. The main objective of Policy Laboratory 3 was to provide an overview of, and reflect upon, innovation and supporting policies in mineral and metallurgical processing, including recycling. Therefore, the workshop had a twofold approach: informing participants about the most recent progress and steps in the

development of the MIN-GUIDE online Minerals Policy Guide, and to facilitate an exchange and learning on recent innovations and their link to policy in mineral and metallurgical processing.

A detailed documentation of the 3rd MIN-GUIDE Policy Laboratory, including the (i) Policy Laboratory Agenda; and (ii) the presentations given by the keynote speakers and the presenters from the Parallel Policy Laboratories, can be found on the MIN-GUIDE project website: http://www.min-guide.eu/content/policy-laboratory-3.

4.1 Policy and non-policy enabling and hindering factors

The following policy and non-policy enabling and hindering factors for implementing innovations in mineral and metallurgical processing were established through an intensive and interactive exchange in the three parallel policy laboratory sessions on "Mineral processing", "Metallurgical processing" and "Recycling of processing rejects":

Policy enabling factors

- The Raw Material Initiative (RMI) of the European Commission
- Public funding of RD&I and infrastructure for research in joint ventures between industry and academia
- Environmental policies and legislation (e.g. requirements with respect to reduced emissions, emission limits, and energy efficiency)
- Management of Waste from Extractive Industries, European Directive 2006/21/EC (prevention or minimisation of adverse effects on the environment and health arising from the management of waste from extractive industries)
- Legislation that regulates/defines use of standards, transparency, objectivity

Non-policy enabling factors

- Competition in the market leads to innovation
- Skilled and motivated staff: Talented humans with the ambition to provide smart product and solutions ("Thinking better")
- Strategic decision-making for long term mining project development (risk reduction, securing supply, ore assessment)
- Platforms of exchange for building trust between different stakeholder groups (engineering, technical, political, local interest groups)
- Public aspects: consideration of social acceptance, implementation of sustainability criteria

Factors hindering innovation

- Intrinsic difficulties in "translating" policies and following the policy-making process, resulting in a lack of transparency
- Tedious and time-consuming permitting procedures within mineral and metallurgical processing

- Conservative attitude of industry towards the implementation of new products and processes
- High investment costs of processing equipment and production plants combined with a long asset lifetime
- Missing deployment policies for effective scale-up of mineral and metallurgical processes, insufficient acceptance of modelling tools
- Lack of clearer rules and more transparent standards
- Silos in RD&I collaboration created by organisational or technical boundaries (departments, disciplines etc.)

4.2 Needs and gaps analysis from the workshops

One MIN-GUIDE Policy Laboratory 3 workshop session involved reflection on the needs, gaps and future pathways for innovation in mineral and metallurgical processing. The following needs and gaps were discussed during this session:

- The time frame for future development of policies and legislation needs to be more predictable (design of a “roadmap” for future development).
- Policy should focus on creating stable and transparent framework conditions. This also refers to consolidating legislation when several areas are involved (e.g. “one stop” shopping for permitting procedures).
- In order to define a market for by-products and secondary products from mineral and metallurgical processing more standardization is needed in terms of the products’ specifications.
- Test work on different scale, process design calculations, upscaling methods, estimation of the potential of process and product innovations should be improved by defining harmonized procedures.
- Faster permitting procedures are needed to expedite decision making pro innovative product and process solutions.
- Education in the field of mineral and metallurgical processing should follow common standards and alignment.

5 Evaluation of EU and Member State policies and legislation with respect to innovative mineral and metallurgical processing

5.1 Introduction

The extent of national mineral policies/strategies addressing issues related to mineral and metallurgical processing varies among the EU member states. EU Member States with a comprehensive and strategic approach have established the following types of policies/strategies: (1) a raw materials or minerals strategy, (2) a strategy for sustainable development, (3) a resource efficiency strategy (referring to raw materials and/or energy), (4) a waste management plan (usually including aspects of circular economy), (5) an environmental strategy (addressing climate, air, water, land, biodiversity), and (6) an innovation strategy. Table 2 showcases this structure showing the relevant policies and legislation in the case of Finland.

Table 2. Finland's policies and legislation related to innovation in minerals and metallurgical processing

Category	Description
Minerals strategy	Finland's Minerals Strategy
Strategy for sustainable development	National Strategy for Sustainable Development
Resource efficiency strategies	National Material Efficiency Programme
	Natural Resource Strategy for Finland
	Finland's Energy and Climate Strategy
Waste policies and legislation	National Waste Plan
	Government Decree on Extractive Waste
Environmental legislation incl. permitting	Environmental Protection Act
	Waste Act
	Water act
	Act on Environmental Impact Assessment Procedure
	Chemicals Act
	Finland's Product Safety Act
Innovation strategies	Finland's National Innovation Strategy
	Regional innovation strategies
Economic and financial instruments	Finnish Innovation Fund SITRA
	Finnish Innovation Agency Business Finland

The number of policies in each of these categories further depends on the EU Member State's governmental structure (complementing policies existing on national and federate state/province/regional level) and on the respective context (general industry-related policies, sector-specific policies etc.). The latter also applies to policy instruments like governmental innovation agencies and RD&I funding programmes. Policies and legislation for other EU Member States can be found in the MIN-GUIDE Online Policy Guide (www.min-guide.eu).

How these policies and legislation affect innovation within mineral and metallurgical processing in particular has been investigated by a survey involving experts from different stakeholder groups. The analysis of gathered data was mainly done by University of Zagreb, the Faculty for Mining, Geology and Petroleum Engineering, with contributions from researchers at Luleå University of Technology, Sweden.

5.2 Expert survey

The survey was conducted between October 2017 and January 2018, based on a questionnaire, by means of personal, video and telephone interviews. The topics and questions of the survey addressed the respondents' perception of national and EU-level mineral policies, gaps and needs with respect to innovation in mineral and metallurgical processing. The applied questionnaire is attached in appendix section 8.2.

The sample used for the survey consisted of contacts and organisations that work in the field of mineral and metallurgical processing. The contact list was created from the stakeholder database generated within this project, an additional internet search (involving national mining associations, members of Euromines etc.), and other individual contacts provided by University of Zagreb.

Due to the fact that the main drivers, providers and users of innovation are the industry sector and academia/research institutes, they were the main targets of this survey. Special attention was paid to include contacts from several EU member states. However, given the distribution of mineral raw materials and related industry in Europe, answers were mostly received from contacts in those countries that have an active mining industry as well as universities and research centres focusing on mineral production research. Furthermore, policy makers and NGOs were included into the survey as well, but with a modest response rate.

Considering the focus of the survey, a relatively small group of people is dedicated to this specific industry that also has good knowledge of national policies and relevant experiences. The number of contacts was 47 for the first round of the survey. The overall response rate was approximately 10%. The second round of search for interviews included 52 additional contacts (received from an EIT Raw Materials Workshop held in Budapest on December 7th 2017) and participants of the 2017 MIN-GUIDE Annual Conference held in Brussels. The contacts were mainly within research/academia and industry as depicted in Figures 1 and 2. The contacts from the EIT workshop were unresponsive, while in the Annual Conference the interview with three Polish representatives was taken.

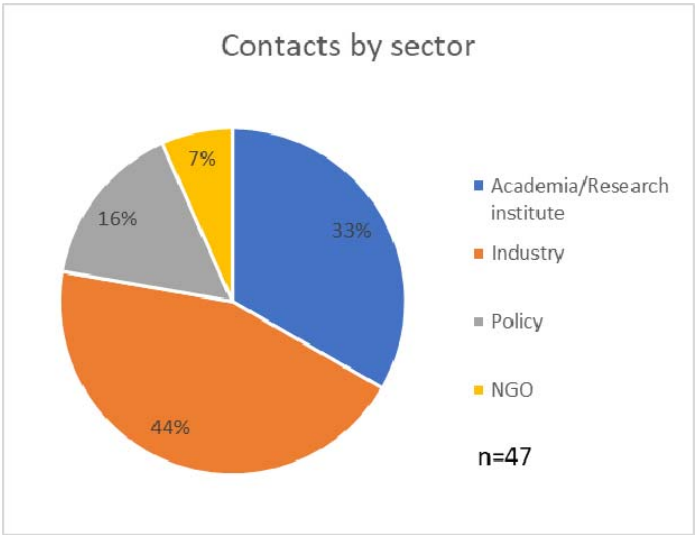

Figure 1. Structure of contacts by sector in the first round of surveying

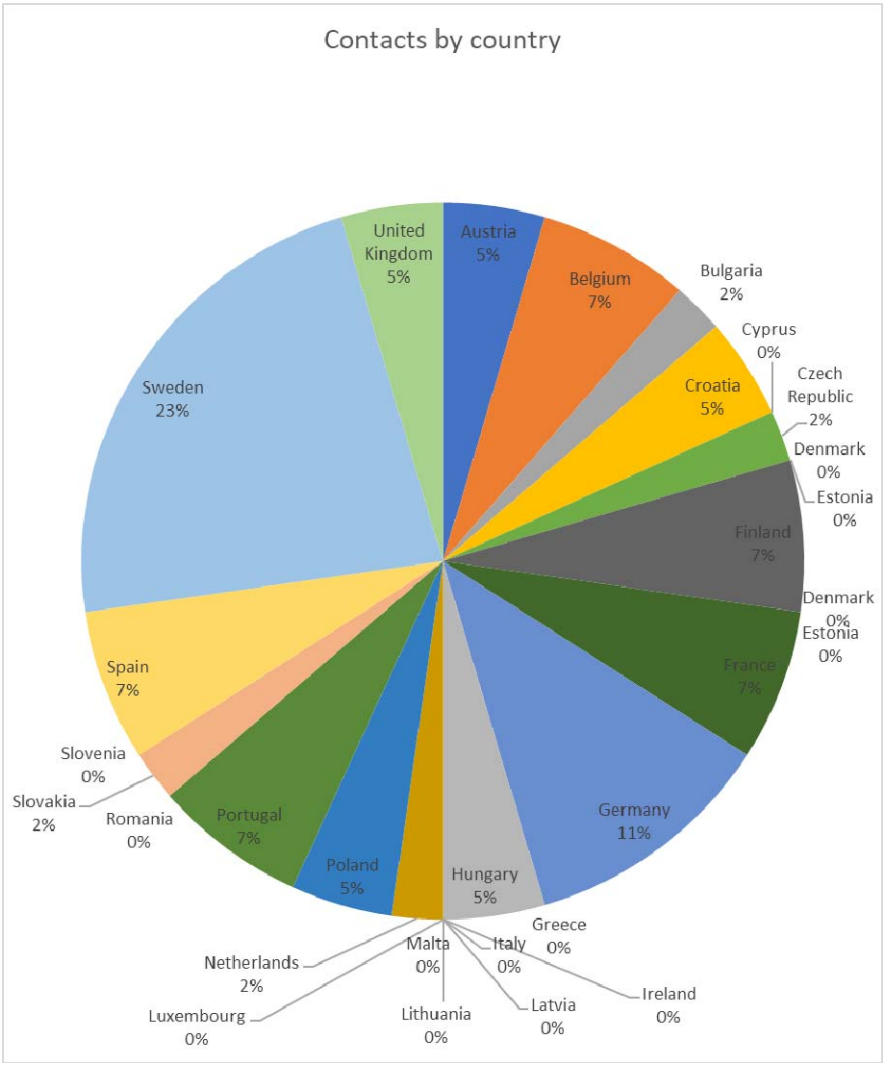

Figure 2. Structure of contacts by country in the first round of surveying

Questions for the survey (the interviews) focused on several previously identified innovations in mineral processing, metallurgical processing and metal recycling. These comprised:

- High pressure grinding rolls
- Novel flotation reagents, particularly for oxide mineral separation
- XRF online analysers for improved flotation process control
- Rare Earth dry magnetic separators with high magnetic flux
- Automated mineralogical systems
- Metallurgical processing and metal recycling:
- Alternative carbon sources (biomass, waste plastics) as reductant in iron-making
- Flash technology for copper smelting and conversion
- Bio-hydrometallurgical extraction, bio-leaching
- Precious metal leaching using thiosulphates
- Sensor-based sorting of metals (secondary materials) and minerals

The guiding questions for the interviews were as follows:

1. Is, in your view, the national mineral policy of your country stimulating or hindering the introduction of innovation in mineral and metallurgical processing?
2. What is your opinion: Is the national mineral policy stimulating or hindering mining and mineral production activities in general?
3. Is the governance authority responsible for mineral and metallurgical processing activities in your country well-structured and efficient?
4. Could you suggest some possible changes and improvements in national mineral policy (and other regulations affecting mineral- and metallurgical processing) to improve innovation (i.e. the implementation of novel technology)?
5. Could you specify some possible changes in national mining regulations/governance (and other regulations) that stimulate mining and mineral production activities in general?
6. Are there any gaps or needs in national policy that you are aware of, which affect innovation in mineral- and metallurgical processing?

Those expert respondents that replied in the interviews or by email contributed with high quality and well thought out answers addressing the questions of the survey. Some of the experts revealed issues that, at first glance, were unrelated with policies but have shown potential to provide policy-related solutions as described in the recommendations at the end of this chapter.

5.3 Policy impact (questions 1-3)

It turned out that the interviewed experts preferred to provide more general answers and comments on related policies and the perceived situation within the mineral and metallurgical processing sector, without specifically addressing the previously mentioned good practice examples of technological innovations.

Most of the interviewees agreed that the effect of policy is more neutral or that policy specific to mineral and metallurgical processing does not exist. It was pointed out that there are problems at national level with respect to the harmonisation between regions, between the regional level and national level as well as between different bodies. As to the gaps and needs, it was stressed that little attention is paid to the mineral processing and metallurgy segment in general, and that there is the need for establishing a development bank and investment in processing sector in order to overcome this situation.

The distribution of answers given to the first three questions is shown in Figure 3 below.

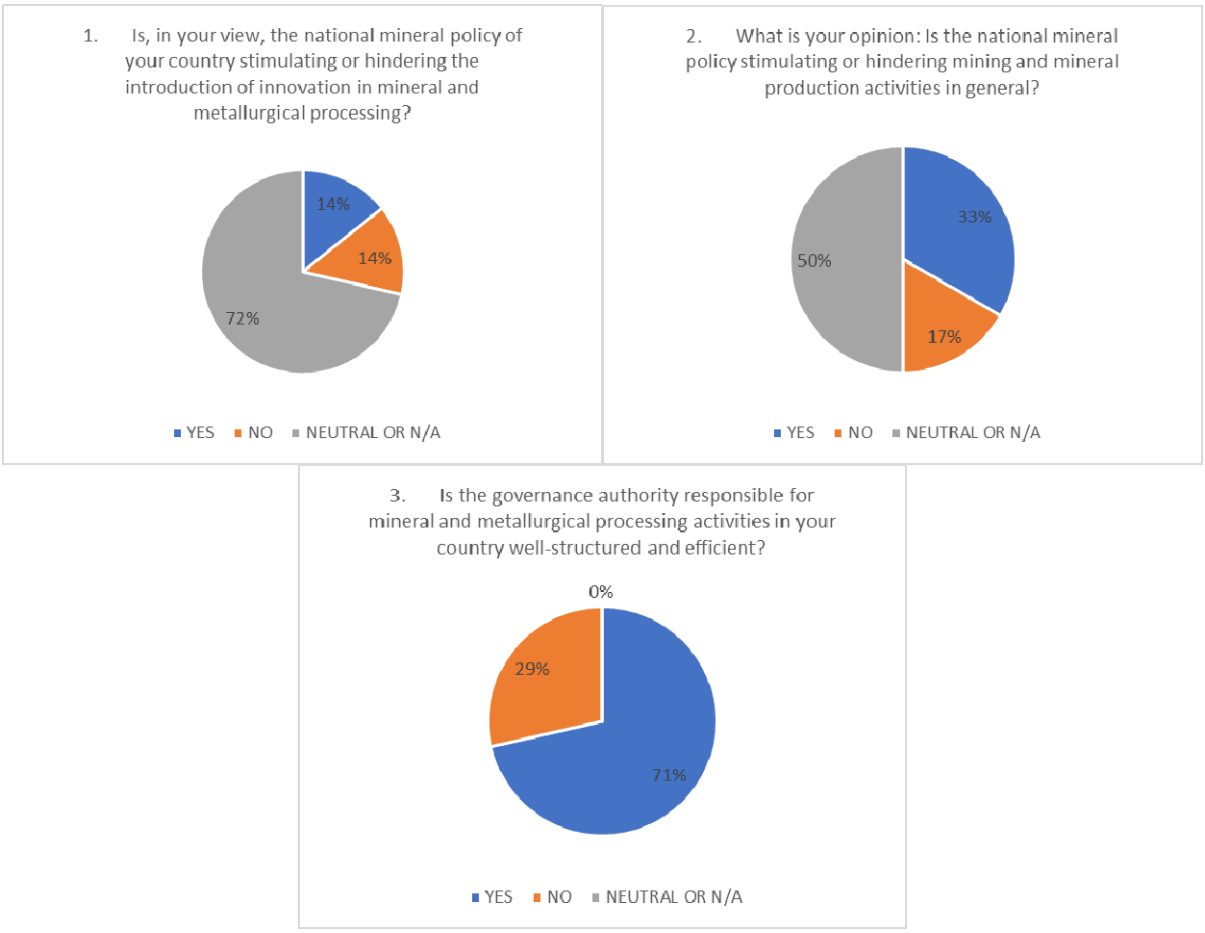

Figure 3. Distribution of answers to the questions related to policy impacts

5.4 Analysis of needs and gaps (questions 4-6)

The needs and gaps identified during the interviews can be linked to aspects and levels of national and EU policy and legislation, i.e. elements such as mineral legislation and regulatory procedure,

national and/or EU strategic level, education and networking, technologic innovations and economic/investment support. In the following a compilation of the received expert replies is provided.

Gaps in national mineral policy and other regulations affecting mineral and metallurgical processing to improve the introduction of innovation

- The lack of a national mining strategy able to align national and regional administration roadmaps together with mining industry and mining investors' interest. The lack of coordination between the National and Regional Administration.
- There is currently a gap within the mineral policy as the innovation part related to mineral and metallurgical processing is part of other policy programmes (Germany).
- Taking mineral and metallurgical processing from the agenda in times of low commodity prices.
- Some mining law is obsolete and is mainly devoted to permitting of mining rights, i.e. it is not focused on stimulating and facilitating mining development and implementation of innovation in mineral and metallurgical processing (Spain).

Lack of communication between mining authorities (governance) and mining companies

- One of the gaps mentioned by the experts is the missing dialogue between the mining governance authorities (different ministries responsible for mining activities) and mining companies in mining and metallurgical processing (Sweden). Also, the communication between different governance authorities is not satisfactory, they should agree to express a common approach.
- The mineral and metallurgy processing experts in governance authorities are missing.
- The overlapping of permitting procedures between different governance authorities is also identified as a significant hindrance.
- There is a shortage of skilled mineral and metallurgical processing engineers with mining experience, i.e. these competences are usually "imported" from countries outside Europe.
- National research facilities for mineral and metallurgical processing are disappearing or are underfinanced. In Western Europe the extractive metallurgy has diminished for at least 20 years. National research centres are left without funding and the base of knowledge has been lost.

Missing financial instruments to support the introduction of innovation

- The experts identify institutional risk for investment in mineral processing and metallurgy as very high and very dependent on EU environmental regulation. There is no existing access to funding for the development of new innovative technology.
- The banking sector treats investments into innovation in mineral and metallurgical processing as a "high risk" investment. Banks are not willing to finance the (innovative) technology unless its use is demonstrated and in wide use in the world.
- It is close to impossible to find a way (financial support) to develop pyrometallurgical processes. There are no financial incentives for innovation to the mineral and metallurgical processing companies, especially in Western Europe.

Technological innovations in mineral and metallurgical processing

- There is no economically viable and effective alternative for precious metal leaching by cyanidation yet. Alternative technologies for precious metal leaching have different environmental impacts as well.
- Use of waste energy from pyrometallurgical processing is identified as a significant area for innovation towards a zero-waste economy.

The identified needs and gaps can be summarized as follows.

5.4.1 Identified needs

- Harmonisation of the work of regulatory bodies, e.g. on regional and national level, related to mineral, industrial and environmental and other relevant areas (idea of "one-stop shopping", for instance for permitting procedures)
- Policy incentives and support to foster investments in mineral and metallurgical process development, policy instruments for stability and risk mitigations
- Better communication between policy, industry and research in order to monitor and communicate needs between these parties, involvement of processing experts in relevant bodies
- Strategic funding for innovation in mineral and metallurgical process and product development
- National processing institutes (previously existed, but haven been downsized or closed due to a lack of systematic support and funding)
- Development of efficient alternative technologies for certain processes, e.g. precious metal leaching with acceptable environmental impacts (deep eutectic ionic solution for example).
- More efficient use of energy, e.g. from pyrometallurgy processing

5.4.2 Identified gaps

- National policy gaps – mineral and metallurgical processing is not explicitly addressed or is non-existent in national mineral policy
- Communication gaps between policy makers and industry
- Non-existent funding and policy support for financial instruments
- Knowledge base and national processing research centres/institutes are lost/do not have sufficient amounts of funding (in some countries)
- Shortage of domestic skilled engineers with relevant experience
- Umbrella organisation for mineral and metallurgical processing and recycling at national and EU level

6 Recommendations for future development

6.1 SWOT Analysis

SWOT analysis has been used to further investigate the role of policy and legislation with respect to the objective of "promoting innovation in mineral and metallurgical processing". In this case, the "internal" dimension covers EU-level or Member State policy making and legislation while the "external" factors are seen as global, geopolitical trends (which in turn influence EU and national policy making). The SWOT matrix has been derived from the interviews conducted by University of Zagreb, combined with findings from deliverables D4.1 and D4.2 as well as the Policy Laboratory 3.

Table 3. SWOT analysis (objective: promote innovation in mineral and metallurgical processing)

	Helpful in achieving objective	**Unfavourable to achieving the objective**
Internal origin (EU and EU MS)	STRENGTHS • Existing good practice innovation cases within minerals and metallurgical processing • Established sustainability targets (improved resource efficiency, reduction of GHG, efficient use of process water) and environmental policies and legislation as a driver • Regulatory instruments for assuring IPR to innovators through patents, or through sector-specific regulations • Strategic policy initiatives on EU level, e.g. the RMI, supporting industry by recognizing the importance of securing raw materials supply even from EU sources • Focus on raw materials from secondary sources as part of the life cycle including management of waste from extractive industries as a driver • Public funding of RD&I and research infrastructure, support of Public Private Partnerships (e.g. SPIRE) • Competition in the market for increasing productivity and lowering costs • Skilled and motivated staff: talented humans with the ambition to provide smart products and solutions • Platforms of exchange for building trust between different stakeholder groups (engineering, technical, local interest	WEAKNESSES • Governmental bodies at different levels or among regions are not communicating sufficiently or have differences in regulations. • Experts in mineral/metallurgical processing do not participate in the work of governmental bodies. • Mineral processing is missing in mining laws and regulations or is insufficiently recognized. • Loss of educational resources and skilled engineers with experience in mineral processing and metallurgy. • Loss of national bodies for mineral processing. • Lack of EU funding and investment in innovation in mineral and metallurgical processing. • Non-existence of EU development bank for the raw material sector. • Leaving waste processing (recycling) sector out of the scope of national or EU raw material strategy and legislation.

	groups)	
External origin (Global)	OPPORTUNITIES • China is becoming more environmentally conscious – opportunity for cooperation and exchange of knowledge and field practice • With the decrease of raw material quality, and need to go deeper or larger distances, the mineral processing is going to become a significant and more extensive step between mining and metallurgy. • Further adoption of cleaner production concepts into mineral and metallurgical processing • Strong financial and policy incentive for innovation. • Consumer awareness fostering cleaner production from EU sources and worldwide using European technology. • If innovation in mineral and metallurgical processing was of strategic interest for national and EU policies, Europe could become a leader in sustainable processing.	THREATS • Perception of the mining/mineral/metallurgical processing by banking (investment) sector as a risky business due to long and inefficient permitting and social licensing • Lack of policy instruments for investment risk mitigation • Bad image of the mineral sector in Europe due to environmental incidents in Europe and other parts of the world • Lack of corporate responsibility and dedication to environmental and occupational safety in mining in other parts of the world (spill over effect) especially in Latin America and Africa • Competition with countries of EU size or larger with strong and coherent mining laws, strategy and economic growth, but without much concerns for the environment

6.2 Recommendations

Based on the analysed survey and expert opinion from the MIN-GUIDE team, the future development of an innovation friendly policy framework for mineral and metallurgical processing should focus on the following:

Investment, finance and risk mitigation

- Policy instruments for investment risk mitigation, new policy incentives for development and application of innovative and emerging technologies, or inclusion of such technologies into existing funding schemes
- The Setup of development banks in order to support investment in mineral and metallurgical processing could facilitate investment in novel technology

Knowledge centres

- Strengthening and re-introduction of national research institutes for mineral and metallurgical processing and recycling, as well as support to national educational organisations
- National education programme for mineral processing and metallurgy must be strengthened and adopted to the particular national mineralogical situation
- Continued support to mineral and metallurgical processing education, community and infrastructure build-up and promotion through existing initiatives, e.g. through EIT Raw Materials

Improvement of EU Member State policies

- Harmonization of mineral policies at national level, improvements in national mineral policy and other regulations affecting mineral and metallurgical processing (e.g. environmental protection, permitting) in order to facilitate innovation.
- Clear commitment to metallurgical processing as part of the raw materials value chain and the circular economy. Commitment to the need to maintain physical capacities (smelters) and know-how, for strategic reasons and as a base for a more independent raw materials supply.
- Development of national mineral strategies for each EU Member State (countries where these are missing) according to the EU Strategic Implementation Plan for Raw Materials that explicitly include processing

Improvements of Member State mineral governance

- Communication and cooperation between mining authorities (governance) and companies of the processing value chain (mineral industry and suppliers) have to be improved. The communication between different governance authorities has to be improved too
- Politics should recommend to authorities responsible for mining that are superimposed to the processing sector (such as: geological survey, mining/processing, environmental, building, economy governance) to include processing experts in their work
- Mineral and metallurgical processing (and mining in general) should become part of existing policy incentives and investment support
- Stronger linkage between national and federal state (regional) mineral policies. e.g. in countries where governance is decentralized but the decisions of regional governments have to be confirmed at state level, the time and cost of the procedure can be detrimental for investment. That is especially difficult if the laws are not same at both levels, so the permitting documentation has to be prepared twofold
- Creation of a single entity responsible for the managing of mineral resources is considered more effective in promoting innovation and new technologies in mineral and metallurgical processing. Improvement and simplification of the administrative procedures and the permitting process

Transparency of environmental performance

- Award the voluntarily efforts of processing companies in making production “greener”, for stronger participation in circular economy and for disclosure of their environmental data to public

Awareness and public communication

- Continue with public funding for initiatives to raise social acceptance and awareness for the importance of raw material sector

7 Conclusions

Conclusions and recommendations for future policy development for innovation in mineral and metallurgical processing

From the analysis of EU and member state policies and legislation with respect to innovative mineral and metallurgical processing (based on the survey and the SWOT analysis conducted by University of Zagreb) the following conclusions can be drawn:

- A general observation regarding policy initiatives related to mineral and metallurgical processing has been that the focus on processing has diminished during the past 20 years. Most of the mineral policies are addressing the mineral value chain as a whole or focus on mining. Only a few statutory provisions are directly related to mineral and metallurgical processing.
- The recycling industry, which significantly developed during the past 20 years, has not entered the mineral legislation yet even though there is a strong link between processing of primary and secondary raw materials.
- The sentiment amongst policy makers towards the raw materials sector has improved on EU level through a number of strategic policy initiatives (The Strategic Implementation Plan for Raw materials, the revised EU Industrial Policy Strategy, the Raw Materials Initiative) followed by the EU funding schemes on innovation in mineral and metallurgical processing as two key elements for securing supply with mineral raw materials.
- The use of raw materials from secondary sources has been identified as an intrinsic part of the life cycle of materials.
- A European knowledge and skills base in mineral and metallurgical processing is partly lost. This is visible through the hiring of skilled engineers from other regions outside the EU, the underfinanced situation of national mineral processing centres (laboratories) and mineral/metallurgical processing associations as well as the lack of processing experts in mineral legislation bodies.

To increase the number of innovations in this part of the mineral raw material production value chain the following recommendations can be stated:

1. Further promotion of resource efficiency in mineral and metallurgical processing (energy efficiency, reduction of related greenhouse gases, efficient use of process water etc.)
2. Formation of single entities (authorities) that are responsible for the governance of mineral resource extraction as well for mineral and metallurgical processing in order to improve and simplify administration and permitting procedures
3. Improvement of communication and cooperation between authorities (governance) and companies in the field of mineral and metallurgical processing (this refers also to better coordination between the different national authorities on state and regional level).
4. Alignment between different types of regulations along the mining value chain including mineral and metallurgical processing, better representation of mineral and metallurgical processing in mining regulations, consideration of waste processing /recycling in national and/or EU mineral strategies and legislation.
5. Strengthening and re-introduction of national research institutes for mineral and metallurgical processing and recycling, support to national mineral and metallurgical

processing education centres through existing initiatives, inter alia through EIT Raw Materials strengthening of national education programmes for mineral processing and metallurgy

6. Mineral and metallurgical processing should become part of existing policy incentives and investment support, including strong financial and policy incentives for innovation.

8 Appendices

8.1 List of Abbreviations

AMD	Acid Mine Drainage
DEM	Discrete Element Method
EIA	Environmental Impact Assessment
EIP	European Innovation Partnership
ETS	Emission Trading System in the European Union (EU ETS)
GHG	Greenhouse Gases
HPGR	High Pressure Grinding Rolls
IEEE	Institute of Electrical and Electronics Engineers
IPR	Intellectual Property Rights
LKAB	Luossavaara-Kiirunavaara Aktiebolag (Swedish mining company)
MS	Member State
NPV	Net present value
PFE	Programme for energy effectivisation in energy intensive industry
PGE	Platinum Group Elements
R&D	Research and Development
RDI	Researcher Development Initiatives
RMI	Raw Materials Initiative
RE	Rare Earth
REE	Rare Earth Elements
RoHS	Restriction of Hazardous Substances (EU Directive)
SBS	Sensor Based Sorting
SIP	Strategic Implementation Plan
SME	Small and medium sized enterprises
SSAB	Svenskt Stål Aktiebolag (Swedish steelmaking company)
SSF	Stiftelsen för Strategisk Forskning (Foundation for Strategic Research)

TRL	Technology Readiness Level
UNEP	United Nations Environment Programme
WEEE	Waste Electric and Electronic Equipment
WP	Work Package
XRF	X-Ray Fluorescence

8.2 Questionnaire

Dear Expert,

Thank you for agreeing to support our MIN-GUIDE project by answering this questionnaire.

MIN-GUIDE (Minerals Policy Guidance for Europe) is a project funded under Horizon 2020, the EU Framework Programme for Research and Innovation. The project, coordinated by the Institute for Managing Sustainability at the Vienna University of Economics and Business, started in February 2016 and will run until January 2019. MIN-GUIDE's activities are targeted to foster a minerals policy framework that enables public as well as private sector decision-makers to implement innovative and sustainable approaches to tackle challenges throughout the mining value chain. It will do so by developing a Minerals Policy Guide, while fostering network-building for co-management and knowledge co-creation which will support the implementation of the EU Raw Materials Initiative, including the Strategic Implementation Plan of the European Innovation Partnership on Raw Materials. For further information, please visit the project's website at http://www.min-guide.eu/ .

Within one of the MIN-GUIDE work packages we are investigating the situation in the EU Member States regarding policy initiatives and their link to innovation in mineral- and metallurgical processing[1]. This involves questions as which national and EU-level policies affect innovation in mineral- and metallurgical processing and how policy initiatives may spawn innovation or act as a barrier to innovation.

To approach this topic, we would like to discuss around the 10 below-listed selected innovations in mineral- and metallurgical processing that had a significant impact on this part of the value chain and are judged to be important examples of process and product innovations:

[1] *Mineral and metallurgical processing describes that part of the chain that follows the mining extraction of mineral raw materials. With regard to the latter, a distinction can be made between (i) metallic ore processing that involves the concentration of the metal bearing minerals followed by metallurgical processing and (ii) industrial mineral and rock production where minerals themselves become a product after enrichment and beneficiation.*

Mineral processing:

- High pressure grinding rolls
- Novel flotation reagents, particularly for oxide mineral separation
- XRF online analysers for improved flotation process control
- Rare Earth dry magnetic separators with high magnetic flux
- Automated mineralogical systems

Metallurgical processing and metal recycling:

- Alternative carbon sources (biomass, waste plastics) as reductant in iron-making
- Flash technology for copper smelting and conversion
- Bio-hydrometallurgical extraction, bio-leaching
- Precious metal leaching using thiosulphates
- Sensor-based sorting of metals (and minerals)

Guiding questions:

The following questions will help us to provide recommendations for future policy development:

1) Is, in your view, the national mineral policy of your country stimulating or hindering the introduction of innovation in mineral and metallurgical processing?
2) What is your opinion: Is the national mineral policy stimulating or hindering mining and mineral production activities in general?
3) Is the governance authority responsible for mineral and metallurgical processing activities in your country well-structured and efficient?
4) Could you suggest some possible changes and improvements in national mineral policy (and other regulations affecting mineral- and metallurgical processing) to improve innovation (i.e. the implementation of novel technology)?
5) Could you specify some possible changes in national mining regulations/governance (and other regulations) that stimulate mining and mineral production activities in general?
6) Are there any gaps or needs in national policy that you are aware of, which affect innovation in mineral- and metallurgical processing?