Swedish Mining Innovation baseline assessment and sustainability database

– Final report

SWEDISH
MINING
INNOVATION

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Swedish Mining Innovation, www.swedishmininginnovation.se

Content

Abbreviations

As – Arsenic
Au – Gold
Cd – Cadmium
CO_2 – Carbon dioxide
Cu – Copper
EUR – Euro
Fe – iron
FMG – Fortescue Metals Group Ltd
GDP – Gross Domestic Product
GoC – Government of Canada
GTK – Geological Survey of Finland
GWh – Gigawatt hours
ha – hectare
Hg – Mercury
ICMM – International Council on Mining and Metals
IFRS – International Financial Reporting Standards
IIRC – the International Integrated Reporting Council's
IOC – Iron ore company of Canada
JSE – Johannesburg Stock Exchange
King III – the King Code on Corporate Governance 2009
KPI – Key Performance Indicators
Kt – kilo tonnes
LKAB – Lousavaara Kirunavaara Aktie Bolag
LTIFR – Lost time injury frequency rate per million worked hours
MC – Mining Concession
Mt – Mega tonnes
N – Nitrogen
Ni – Nickel
P – Phosphorus
Pb – lead
R&D – Research and development
rhs – right hand side
SCB – Statistics Sweden
SEK – Swedish krona
SEPA – Swedish Environmental Protection Agency
SGU – Swedish Geological Survey
t – Tonnes
UNGC – the United Nations Global Compact
Zn – Zinc

1. Introduction

This is a report for a project that uses publicly available data to assess the environmental and overall sustainability performance of the Swedish mining and metals producing sector during the period 2013-2018. The work has been done as part of a strategic project within the framework of Swedish Mining Innovation (Strategic innovation programme for the Swedish mining and metal producing industry) which is funded by Vinnova, the Swedish Energy Agency and the Swedish Research Council FORMAS. The project work was conducted over the period October 2017 to December 2019, and it was done by an association comprising Swedish Geological AB and RMG Consulting. A Steering Committee with members from Swedish Mining Innovation and Svemin (the Swedish Mining Association) oversaw the implementation of the project.

The aims of the project were twofold, namely: (i) to develop and populate a database on sustainability aspects of the Swedish mining and minerals' cluster, using publicly available data; and (ii) to use this database to evaluate whether the goals of Swedish Mining Innovation, as presented in the Swedish Mining Innovation project document are being reached (c.f. Swedish Mining Innovation, 2016, and Figure 1.1).

Outcome (“direkta effektmål”)	**Impact** (“effektmål”)
More efficient and highly competitive processes, equipment & methods for the full value chain	A strong & competitive mining country based on innovations
Increased resource efficiency	Increased competitiveness
Increased energy efficiency	A more innovative and gender equal mining industry
Decreased environmental impact	Sustainable mining and metal production
Increased acceptance for the mining industry	Leading research & innovation eco-system (intern level)

Figure 1.1 Swedish Mining Innovation outcomes and impacts

The evaluations have been done against Key Performance Indicators (KPI's) that have been established within the project specifically to evaluate the performance of Swedish Mining Innovation (Appendix 1). A literature review was also completed in the early stages of the project. The review concluded that most of the similar and relevant initiatives that exist internationally rest on the assumption that the companies concerned will be prepared to allocate resources for measuring and following up on specified criteria. The approach used in this project, that is to only use existing data that companies and countries are already committed to collecting and disseminating, is therefore believed to be not only opportune but potentially both relevant and useful.

The evaluations of performance have been done on three main levels of organization and/or geographical foci, namely: (i) the national level; (ii) the corporate level; and (iii) the mine site or processing site level. The main sources of data that have been used are:

- Corporate reports, produced by the companies that operate mines and/or processing and smelting facilities.
- Annual environmental reports, submitted to the regulating authorities for mining, processing and smelting sites (e.g. the County Administrative Boards, and the Municipality of Skellefteå[1])
- Relevant data collected by Swedish central agencies (notably the Geological Survey of Sweden - SGU - and the Swedish Environmental Protection Agency - SEPA), other organisations (e.g. Statistics Sweden, SCB) and local government (municipalities and county administrative boards).

The Swedish data has further been benchmarked against international data, drawn from selected companies, countries and other relevant organisations.

Following this introduction is an account of the methodology used (Chapter 2). The results of the study are then presented, divided into five chapters that mirror each of the defined Swedish Mining Innovation outcomes (Chapters 3-7) as well as a chapter that considers performance related to Swedish Mining Innovation impacts (Chapter 8). The final Chapter 9 provides a summary and the conclusions of the report.

[1] The Municipality of Skellefteå is charged with supervising mining related operations within its boundaries. In the rest of Sweden, supervision and control is performed by the relevant County Administrative Board.

2. Methodology

The methodological approaches used in the study are outlined in the sections below. The bulk of the chapter is concerned with explaining how the data collection has been achieved.

2.1. Definition of Key Performance Indicators

The definition of Key Performance Indicators (KPIs) was done through an iterative process where a long list of possible indicators was assessed against the availability of public data that would enable evaluation. The work was led by the consultant, but extensive input was provided by the Steering Committee. The final list of KPIs was established following a Workshop conducted on 23 May 2018, and where participants included representatives of Swedish Mining Innovation, SGU, Svemin as well as the consultant (Appendix 1).

2.2. Database design and development

Data that is relevant to evaluate the KPI's were collected (c.f. sections below), and entered into standardised excel spread sheets. The excel sheets were then uploaded on a cloud-based software called PiNFO. PiNFO allows data that has some geographical property to be stored and displayed in a map format. A description of PiNFO is found in Appendix 2, and Figure 2.1 shows a selected screenshot of the project's PiNFO site.

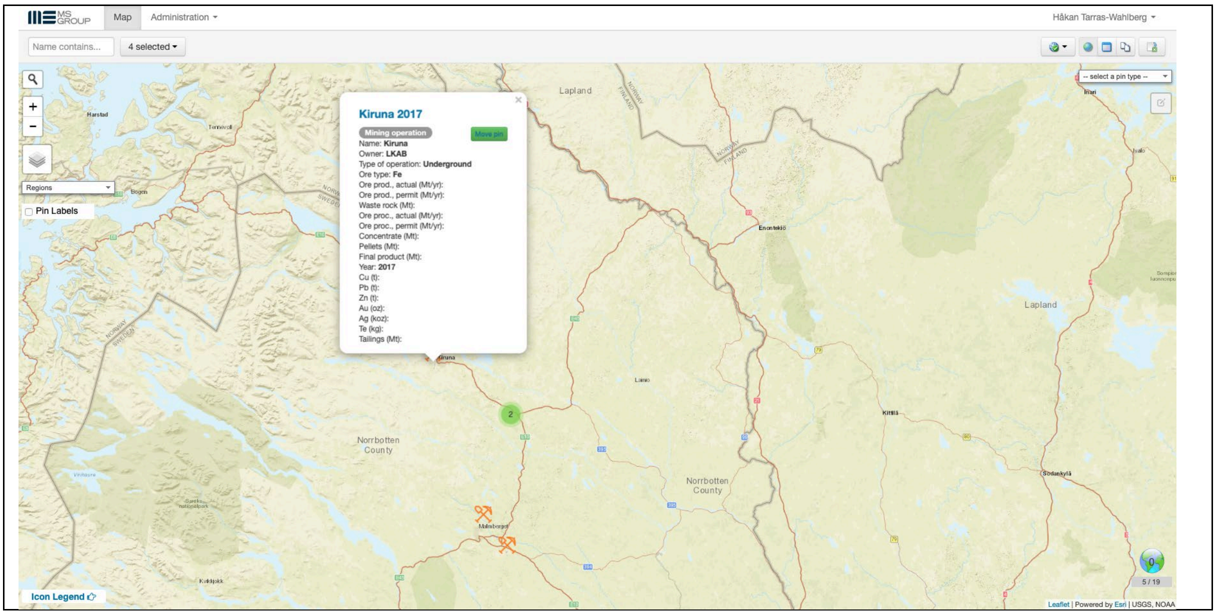

Figure 2.1 Screen shot of the project's PiNFO site.

2.3. Data collection – Sweden

National data for the Swedish mining sector was collected from publicly available reports and on-line databases such as SGU's Bergverksstatistik (yearly reports), Statistics Sweden (online database), Swedish Work Environment Authority (online database), Fraser Institute (yearly reports), and Universum's yearly reports. National data on discharges was estimated from data in site specific annual environmental reports. There is a near complete coverage of data for the period 2013-2018 with regards to the following types of data:

- Number and types of mines;
- Ore, concentrates, pellets, metals, waste rock and tailings production, subdivided into iron and non-iron metals;
- Work force with blue-collar, white-collar and gender subdivisions;
- Exploration permits and mining concessions, numbers and areas;

- Fraser Institute ranking;
- Work-related accidents and illness, with gender subdivision;
- Discharge to water of a number of elements and compounds;
- Emission to air of NOx, particles, SO_2 and CO_2;
- Financial data on sector turnover, exports and investments.

Universum's survey on most attractive employers is relatively new, and data is only available for 2016-2018. Table 2.1 below provides a summary of the types of data that was collected and their sources.

The corporations considered in the analysis below are the six Swedish companies that engaged in mineral extraction, processing and smelting during the study period, that is Boliden, LKAB, Lovisagruvan, Lundin Mining which operates Zinkgruvan, Kaunis Iron (2018 only) and Mandalay Resources which operates Björkdalsgruvan. Boliden and LKAB dominate the Swedish metals sector by being much larger corporations than the other three. In the analyses of data from the corporations, data from the two larger companies are therefore often shown and considered separately from the other three.

A total of 16 mining sites are considered, and of these five are iron ore mines, two are gold mines, and the remainder are base metal mines – one of which is very large (the Aitik copper mine). For ease of reading, the analyses treat the mines according to the following subdivision: (i) the iron ore mines, (ii) the base metal mines, and (iii) the gold mines. Aitik, given its large and dominant size, is often considered on its own.

The Rönnskär smelter and the Boliden Processing plant are also included in the analysis. Both are mature operations, owned by the Boliden Group. Rönnskär has existed since 1930, and processing activities at Boliden has existed in different guises since the 1920s.

Table 2.1 Summary of the types and sources of data on sustainability data were collected for the period 2013-2018.

Country level data (Sweden)	**Corporate level data**	**Site level data**
Data collected mainly from: • SGU (Bergverksstatistik) • Statistics Sweden (SCB)	Data extracted from corporate reporting from the following companies: • Boliden AB • Dannemora Mineral • Dragon Mining • Kaunis Iron (2017-2018) • LKAB • Lovisagruvan AB • Mandalay Resources • Northland Resources (2013-2017) • Zinkgruvan AB	Data collected from 19 sites, including: 16 mines with or without processing/pellets plants, two processing/pellets plants and one smelter: • Aitik • Bolidenverket • Björkdalsgruvan • Dannemora • Garpenberg • Gruvberget • Kankberg • Kaunisvaara • Kiruna • Kristineberg • Leveäniemi • Lovisagruvan • Malmberget • Maurliden • Mertainen • Renström

		• Rönnskär • Svappavaara • Zinkgruvan

2.4. Evaluation and international benchmarking

The data collected for the period 2013 to 2018 have been evaluated against the established KPIs. Since it may often be difficult to compare data collected by different organisations, considerations have also been made to elucidate any trends, that is changes with time, that would suggest that conditions are improving or, alternatively, worsening.

The data collected on the Swedish mining cluster was benchmarked based on comparisons with data collected by other corporations and/or nations. Table 2.2 presents the countries and corporations that have been selected as benchmarks.

Table 2.2 International benchmarks used for comparison with the sustainability data collected from Swedish companies and sites.

Benchmark – Countries/jurisdictions	Benchmark – Corporations
Finland Similar in terms of mining sector structure, climate, politics, geography. Good availability of data. **Canada** Similar in terms of mining, climate, and level of development. Widely seen as a good example in terms of management and control. Very good availability of data. ***British Colombia (Canada)*** See above. Metals mining sector partly similar to Sweden; British Colombia had eight base metal mines in 2017 (but no iron ore or gold mines). Very good availability of data. **Spain** ***Poland*** ***Chile*** ***South Australia*** ***Western Australia***	• **Kumba iron ore Ltd** (Kumba, South Africa), part of Anglo American group Iron ore producer with two mines (45Mt/yr; fines & lump ore). • **Fortescue Metals Group Ltd** (FMG, Australia) Iron ore producer with 4 mines (170Mt/yr; fines). • **Rio Tinto Group** (Rio Tinto, UK & Australia) Very large & diversified metal producer. • **Nyrstar NV** (Nyrstar; Belgium) Four base metal mines (Canada & USA) and four Pb/Zn smelters (Belgium, France, USA and Australia.

The benchmark companies were chosen based on a number of considerations, including the following: they should as far as possible be comparable with the Swedish mining companies; they must publish relevant and comparable data; and both large and medium sized companies should be represented. The requirements with regards to availability of data means that the companies selected for inclusion as benchmarks probably feature among the companies that have the best environmental and sustainability related performance. Thus, the end result is that the benchmarks selected are among the best performers, and probably not representative of the mining sector as a whole. An indication of the selected companies being comparatively more ambitious include that most of them report according to the GRI standards (Nyrstar does not) as well as a range of other standards[2].

The selected jurisdictions against which to benchmark Sweden include Canada and Canadian provinces (i.e. British Colombia) and Finland. Key data sources in this regard include several Canadian governmental sites that provide data on-line (e.g. Environment and Climate Change Canada, Natural Resources Canada – Mining, GoC – Pollutant Release and Transfer Data, Association of Workers' Compensation Boards of Canada, etc.), Eurostat – Mining and Quarrying Statistics, as well as Geological Survey of Finland (GTK) and Tukes (the Finnish Safety and Chemicals Agency) on-line information, and Statistics Finland.

In addition, various other relevant documents and data sources are used in some places to put issues in context, or to provide additional evaluations. In such case, explicit reference to the sources are provided.

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[2] Anglo American reporting is, for example, aligned with the AA1000 stakeholder engagement standard, the sustainable development principles and reporting framework of the International Council on Mining and Metals (ICMM), the United Nations Global Compact (UNGC), the International Financial Reporting Standards (IFRS), the International Integrated Reporting Council's (IIRC's) International Framework, the King Code on Corporate Governance 2009 (King III); and the Johannesburg Stock Exchange (JSE) Listings Requirements and the Companies Act, 71 of 2008).

3. Efficiency and competitiveness

Data that can support KPI's relevant to assessing efficiency and competitiveness include:

- Production (of ore, metal and waste products and related data on recovery, strip ratios)
- Productivity (per worker or other input)
- Revenues and costs (profits, cash cost)
- Health and safety data

3.1. Production

The number of mines decreased from 16 in 2013 to 13 in 2017 and increased to 14 in 2018 (Figure 3.1). The mines that closed and/or opened in the period 2014-2018 were however comparatively smaller mines, which means that the impact on total production and value of sales was correspondingly small. The total amount of material moved by the mines varied between 170Mt to 200Mt. The amount of iron ore extracted decreased somewhat over the period, whereas the production of other types of ore marginally increased (Figure 3.2). There was an overall decrease in the production of waste rock from 2014 to 2018, which is primarily due to a significant (16Mt) decrease in waste production at Aitik over this time, while there were no signs of the volume of tailings decreasing.

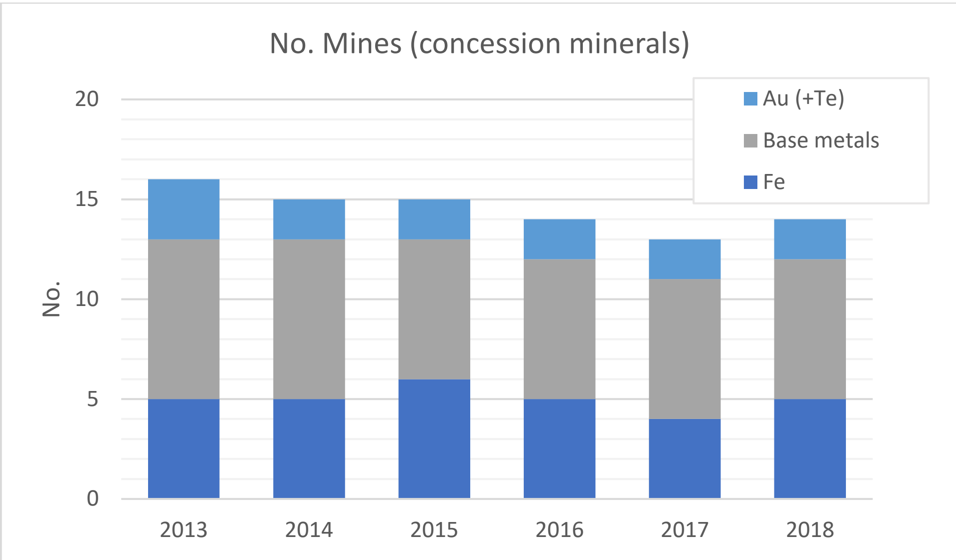

Figure 3.1. The no. of mines of different types in Sweden.

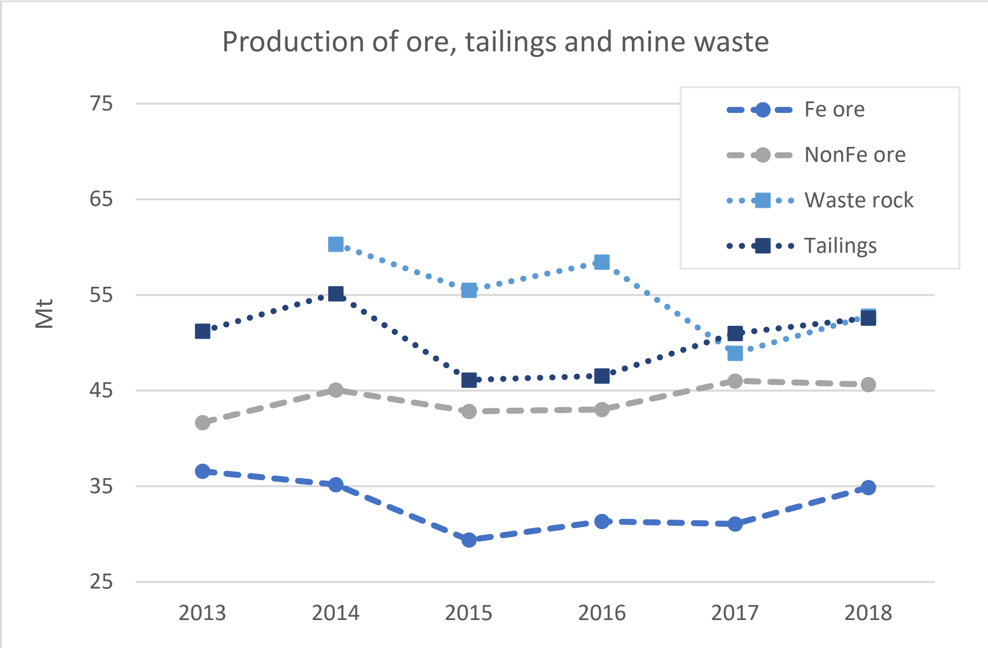

Figure 3.2. The amount of material moved and/or treated by the Swedish mines, by type.

Table 3.1 summarises metal production per company. Over the study period, metal production was fairly constant for Björkdalsgruvan, LKAB, Lovisagruvan and Zinkgruvan. In contrast, Boliden has increased its production markedly. This has been achieved through acquisitions in Finland (the Kylylahti gold mine, in 2014 and Kevitsa, a polymetallic mine, in 2016) and through increased production at the Aitik copper mine. As a result, Boliden's gold production has almost doubled in five years and its production of copper has increased by 80% during the same period (c.f. Figure 3.3).

Table 3.1 Mine production by company, 2013 & 2018 (most important metals)

		Gold (koz)	Silver (koz)	Copper (kt)	Lead (kt)	Zinc (kt)	Fe ore fines (Mt)	Fe ore pellets (Mt)
Björkdalsgruvan	2013	45						
	2018	51						
LKAB	2013						5	23
	2018						3	24
Lovisagruvan	2013				3	3		
	2018				3	4		
Boliden	2013	124	8,417	79	48	272		
	2018	247	12,936	140	55	290		
Zinkgruvan	2013		2,468	3.5	33	71		
	2018		2,155	1.4	25	77		

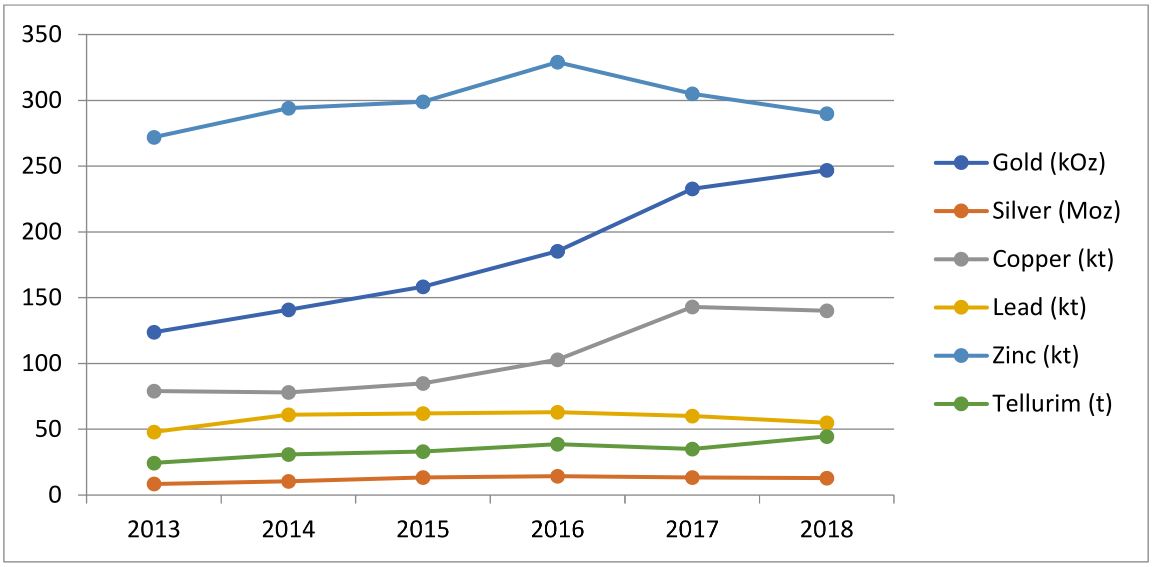

Figure 3.3. Boliden metal production (palladium and platinum not included).

The total material moved (ore and waste rock) by the companies increased significantly during the period of the study (Figure 3.4). Boliden is the company that moved the largest amounts of ore and waste rock and in 2018, it moved some 112 Mt, an increase of 34% compared to 2013. In the case of Boliden, the increase is mainly related to the acquisition of mines in Finland, and the expansion of the Aitik mine. At Björkdalsgruvan, the amount of material moved also increased, although the volumes are comparatively small. Most mines run by the studied companies have had stable strip ratios over the last few years. However, for Björkdalsgruvan, the strip ratio increased from 1:2 in 2013 to 1:7 in 2017 before coming down to 1:4 in 2018, which is likely related to different phases of expansion of the open pit and underground operations.

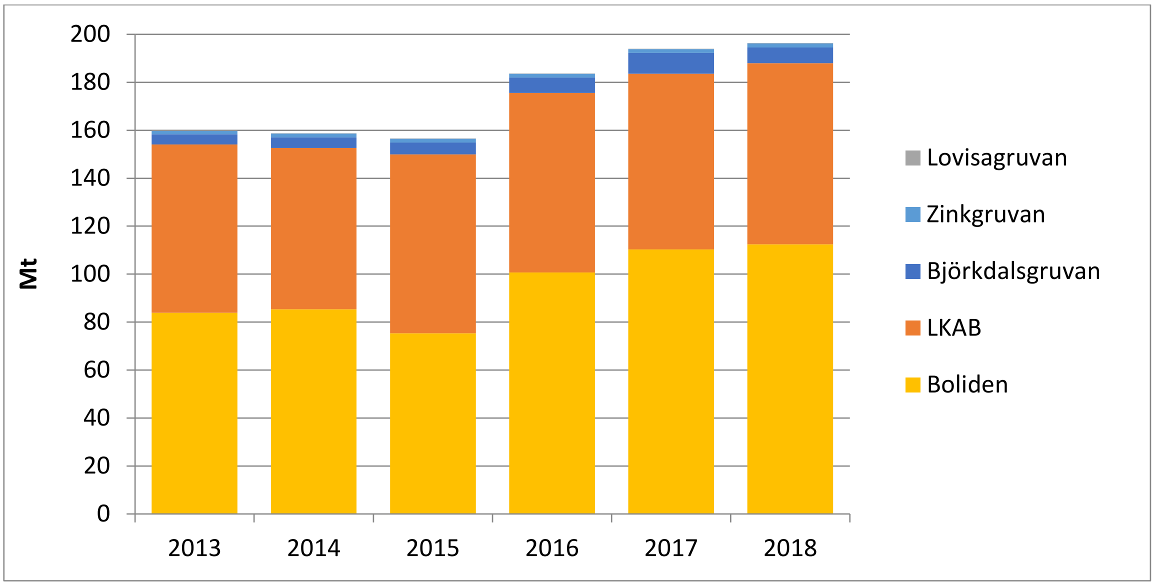

Figure 3.4. Total material moved, ore & waste rock

The amount of concentrate produced relative to the amount of ore processed increased at Aitik from 0,8% in 2013 to 1,05% in 2018 (Figure 3.5), which is significant bearing in mind the large mass of material moved at Aitik. At Bolidenverket, there has been an overall increase from 2013 to 2018 from 5,4% to 6,8%. These increases could indicate improved efficiency (either through more selective mining and/or through improved processing) or may have been caused by an intentional change in focus of type(s) of concentrate produced.

For Garpenberg and Zinkgruvan, the situation is the opposite with a decrease in the amount of concentrates produced relative to the amount of ore processed. At Garpenberg, the concentrate production increased by almost 50% over the study period while ore production increased at an even higher rate. At Zinkgruvan, the drop in the relative amount of concentrate produced is primarily related to a large decrease in Pb concentrate production (from about 33Mt to 26Mt).

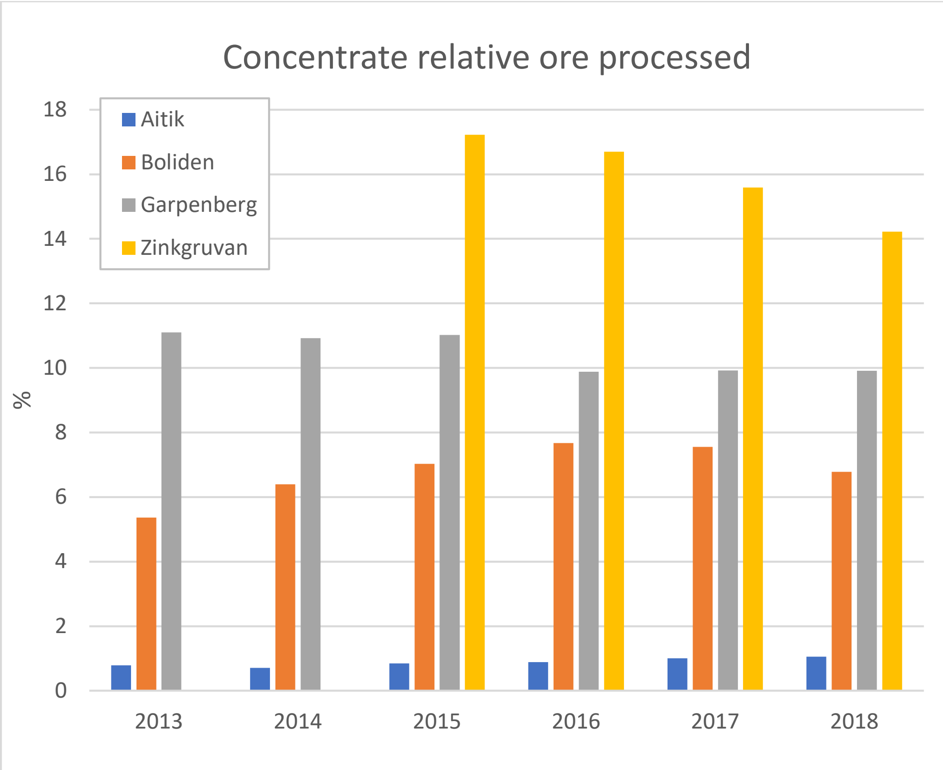

Figure 3.5. Weight of produced concentrates in proportion to the weight of processed ore for Bolidenverket, Garpenberg and Zinkgruvan (no data for Zinkgruvan 2013 & 2014).

With regards to the production of the economically most important metals at the various base metals (and gold) processing facilities, production has in general increased more or less continuously and in many cases significantly over the study period (Figure 3.6). Notable exceptions are the production of Pb at Garpenberg and Zn at Zinkgruvan, which have been more or less constant, and the production of Pb at Zinkgruvan, which decreased by some 25%.

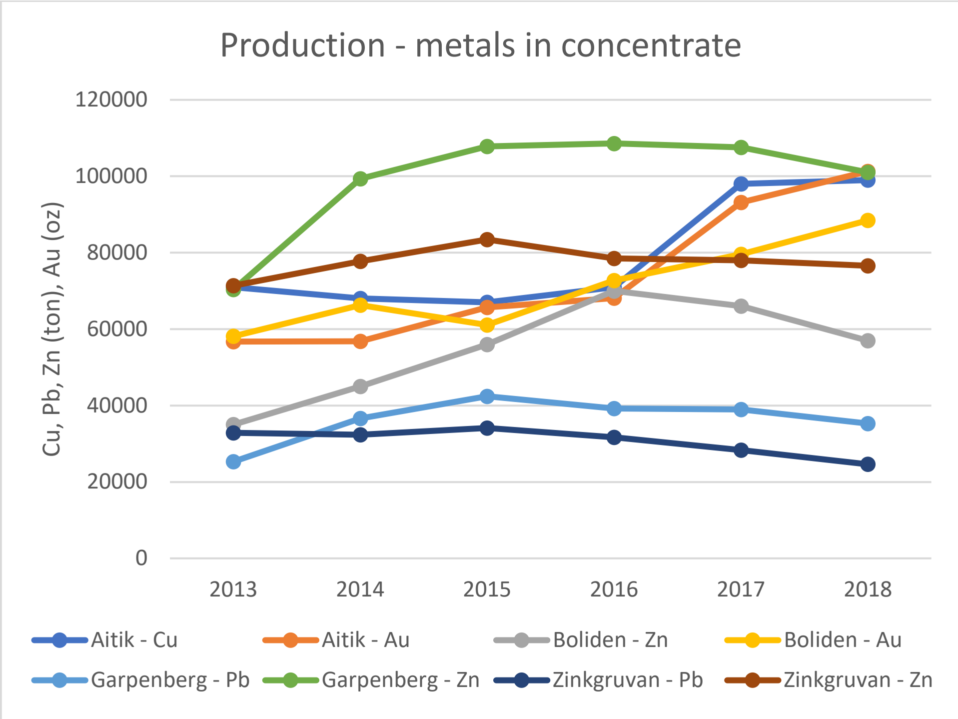

Figure 3.6. Production of the most important metals at base metals (and Au) processing plants.

At the Boliden plant, the production of a new metal concentrate, that is a Tellurium (Te) concentrate, was achieved for the first time in 2013. Since then, the production has increased steadily, from 24 tonnes in 2013 to 45 tonnes in 2017. This in itself represents a clear positive development in efficiency and competitiveness.

Data on metal recovery at mineral processing is shown in Figure 3.7. For the Boliden operations, data on recovery at mineral processing is not provided but has been calculated based on reported metal contents in concentrates, and tonnages and metal contents of processed material. The numbers thus obtained are not based on the mill feed but can still reveal some patterns that are of relevance. With regards to Zinkgruvan, Lundin Mining provide recovery data in their annual reports.

Notable trends include that the recovery of Au and Ag at Aitik has increased significantly (both by >20%). At Bolidenverket, the recovery of all metals with the exception of Cu has increased by between 9% (Te) and 116% (Pb). At Garpenberg, the recovery of the most important metals, Pb and Zn, has increased by some 4% and the recovery of Au and Ag has increased by some 10%. At Zinkgruvan, on the other hand, the recovery rates have remained stable or decreased (by 6% for Pb and 8% for Ag).

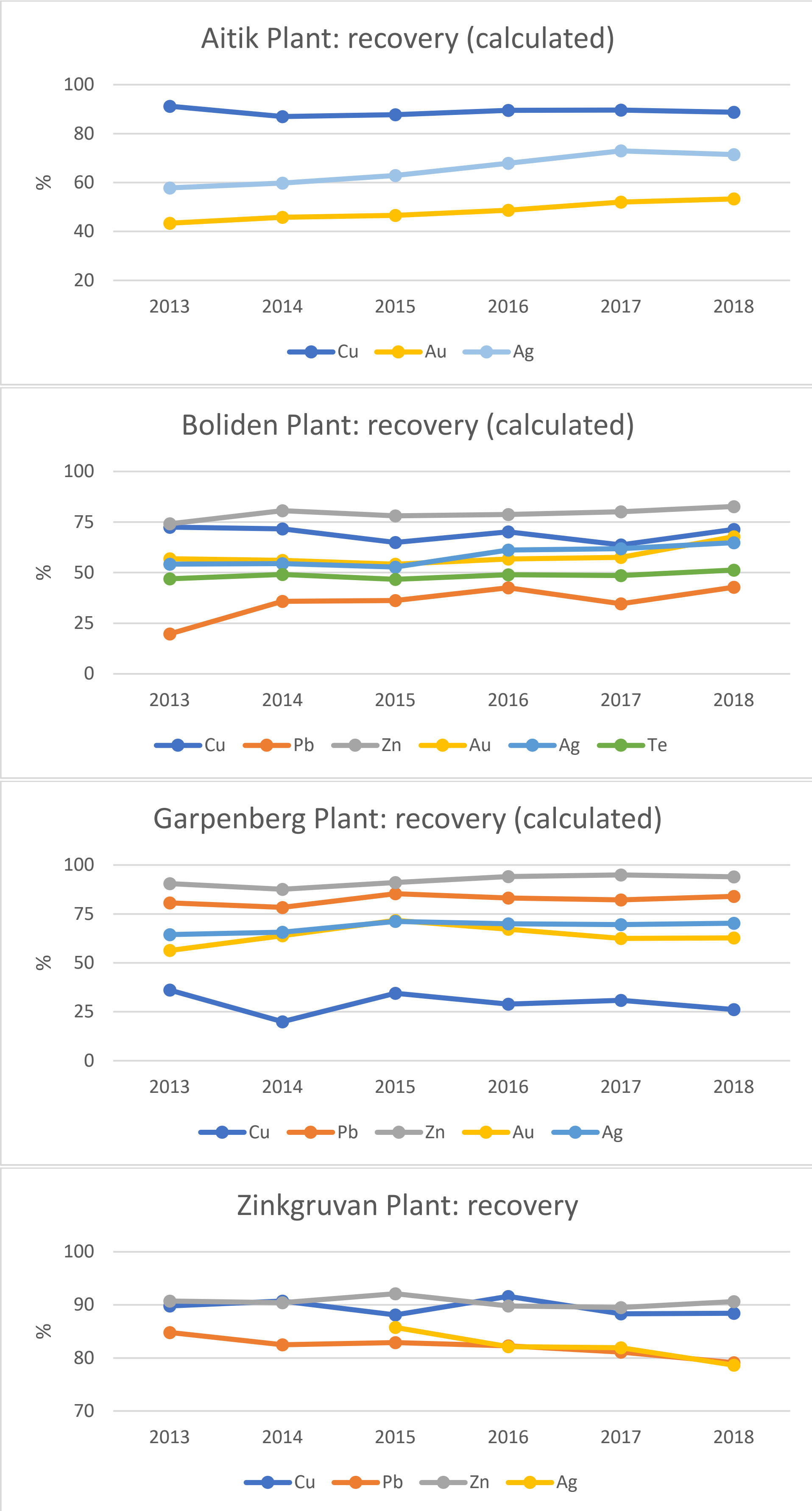

Figure 3.7. Metal recovery at processing plants (calculated for Boliden operations, see text, and as reported by the company for Zinkgruvan).

The generation of waste at Rönnskär, including hazardous waste specific for the smelter, general hazardous waste and non-hazardous waste, has varied over the period of the study but there was an overall decrease in the production of waste from 2013 to 2018 (Figure 3.8). The total volume of hazardous waste stored increased from about 408,000 tonnes in 2013 to 443,000 tonnes in 2018 (not shown in graph). Importantly, the iron sand produced (about 250,000 tonnes per annum), which was previously used as a construction material, is classified as hazardous waste since 2015. This represents a serious issue, as the volumes produced are large.

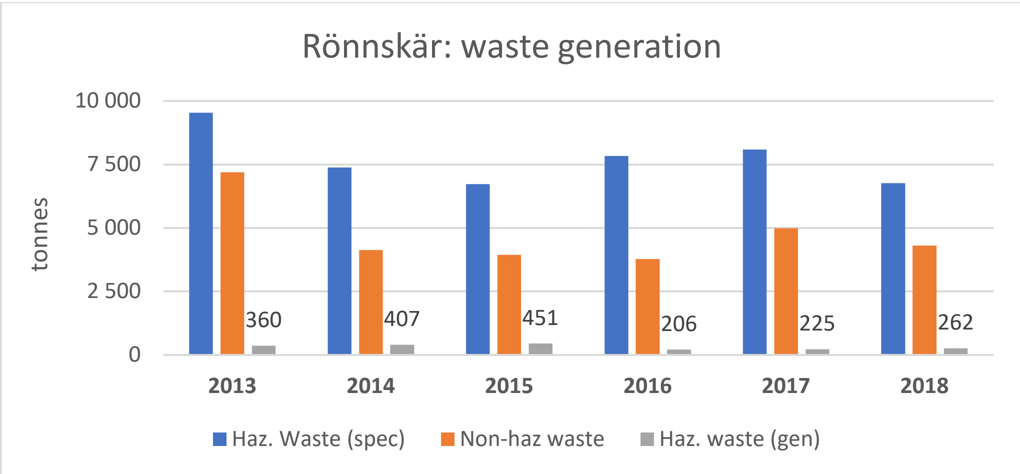

Figure 3.8. The generation of different types waste at the Rönnskär smelter. The hazardous waste that is specific for the Rönnskär smelter mainly includes captured dust and sludges.

3.2. Productivity

Figure 3.9, 3.10 and 3.11 illustrate selected measurements of productivity. Figure 3.9 shows the value created per employee of the companies, and the two largest corporations (Boliden and LKAB) are also the ones where the employees create the most value per person. The value created per employee at Boliden is more than twice the value created at the smaller corporations, and productivity in Boliden (as well as LKAB) increased even further during the last two years of the study[3].

[3] It should be noted that productivity as revenue per employee is influenced by metal prices, which means that it cannot be established from Figure 3.9 whether or not a company has become more productive.

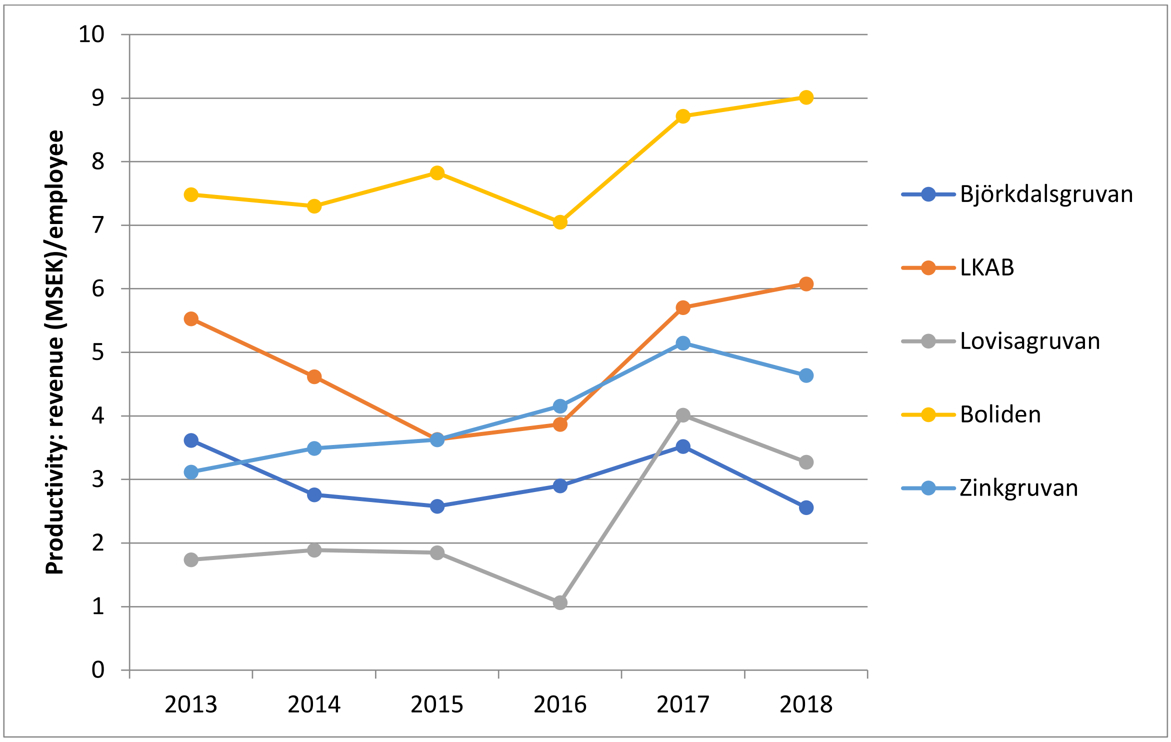

Figure 3.9. Productivity per employee at the Swedish mining companies (revenue per employee).

The amount of ore produced per employee is a more direct measure of changes in productivity as it only takes into account the company's performance (Figure 3.10). The larger mining companies, LKAB and Boliden, produce significantly more ore per employee than the other companies. Further, it is noticed that the production per employee has been fairly stable for most companies, although the productivity increased by some 10% at LKAB over the study period. At Björkdalsgruvan, however, the productivity about halved from 2013 to 2018. This decrease is due to a 100% increase in work force between 2013 and 2018, which has been required for mine expansion and more active exploration work to extend reserves.

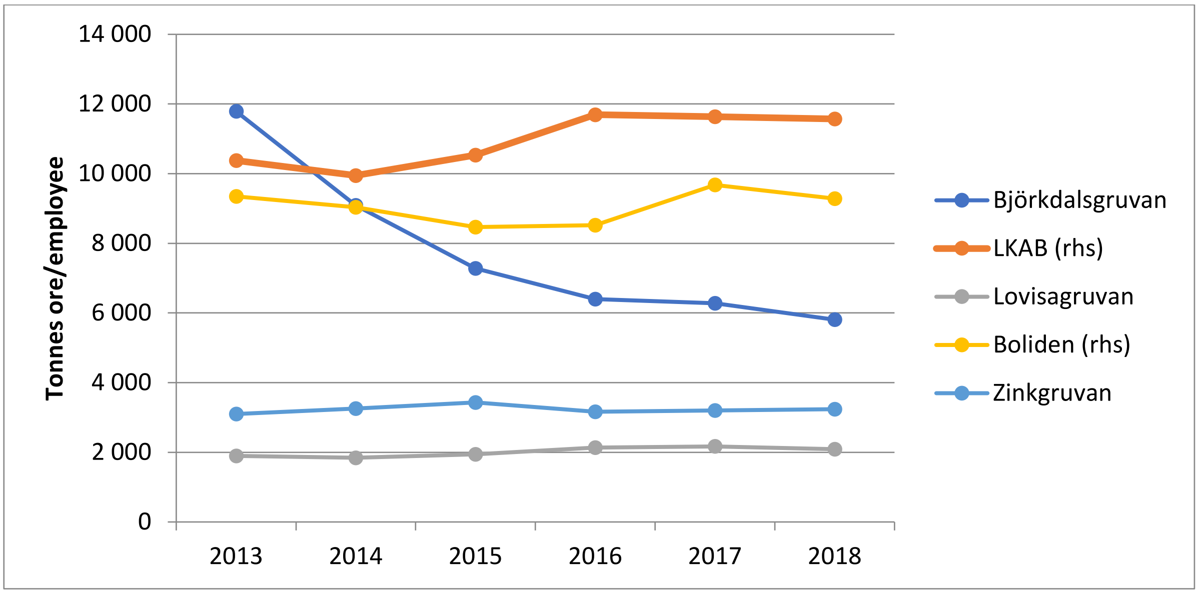

Figure 3.10. Productivity per employee at the Swedish mining companies (tonnes of ore produced per employee).

Figure 3.11 compares production volumes and productivity of the Swedish mining companies with international peers (for the year 2017). Boliden's productivity, calculated as value created per employee, compares well with the international mining companies – being better than Nyrstar and Rio Tinto in this regard. In contrast, the value created by the other Swedish mining corporations is below the international peers. Of the iron ore producers studied, Kumba and FMG are considerably more productive than LKAB.

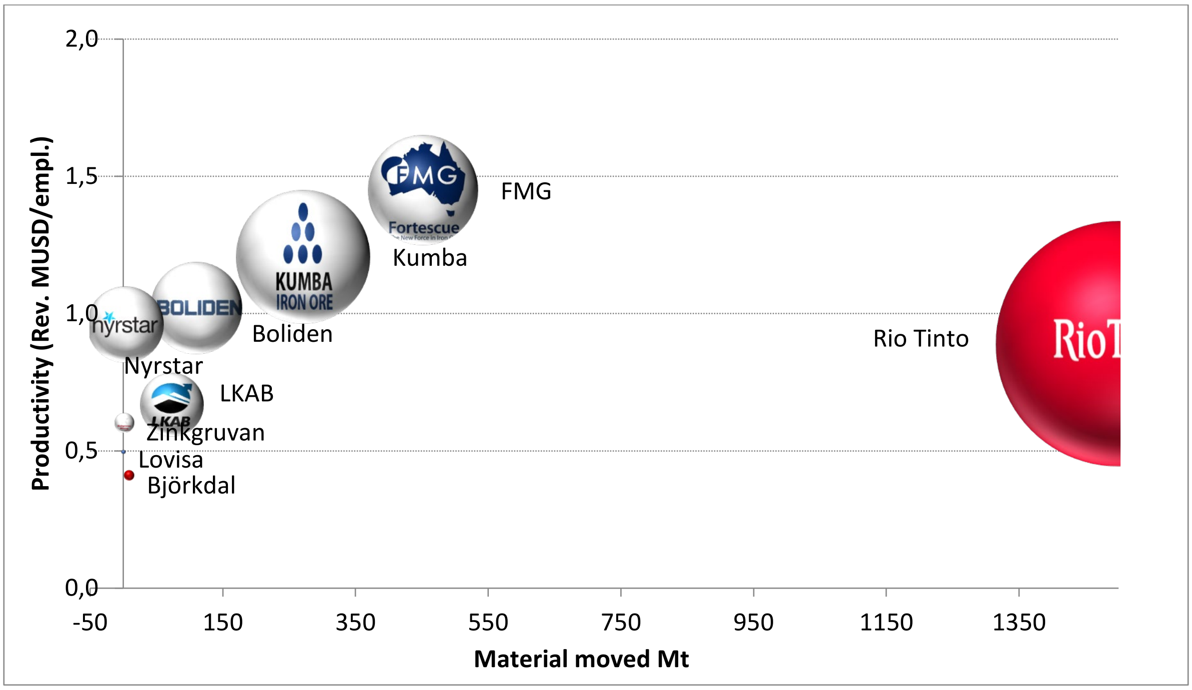

Figure 3.11. Comparison of productivity (as revenue per employee) and indicators for operation size (material moved and production volumes) of Swedish mining companies with international peers for the year 2017. The relative sizes of circles are proportional to revenue of each company.

The efficiency and competitiveness of any one mine site is the product of many factors, some of which are inherit (the nature of the deposit) whereas many other factors can be managed and improved through various means. It is relevant to consider the cash cost of production at mine sites, as this gives an indication of the potential for any one site to be profitably and efficiently run. Figures 3.12 to 3.14 show where some of the important Swedish mine sites are situated on the respective cost curves.

For zinc and copper, it can be seen that the Boliden mines in the Skellefte field fall towards the higher end of the cost curve, whereas Aitik and Zinkgruvan fall close to the median cash cost. Only Garpenberg feature in the lower end of the relevant cost curve.

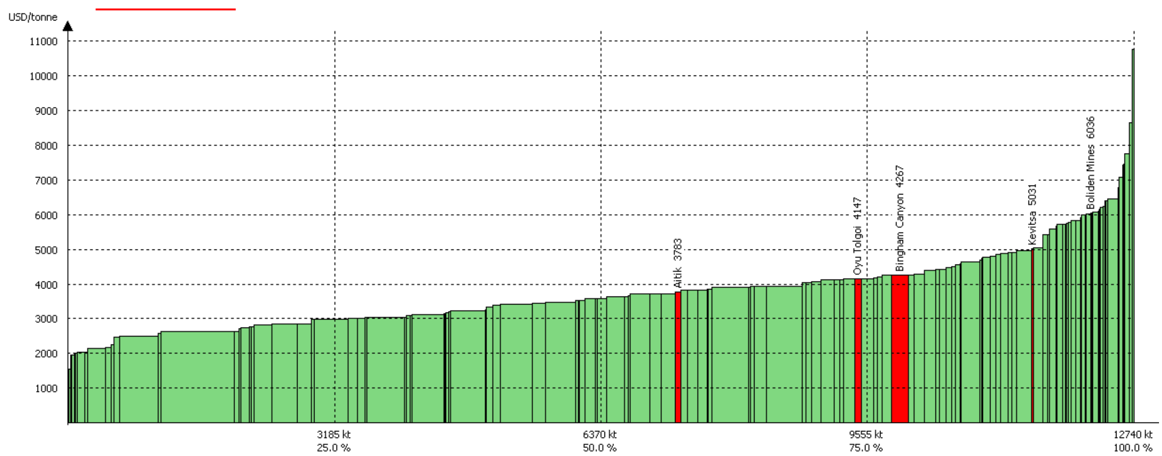

Figure 3.12. Cash cost curve for copper (2013). Aitik and some international peers are indicated in red (source: RMG data).

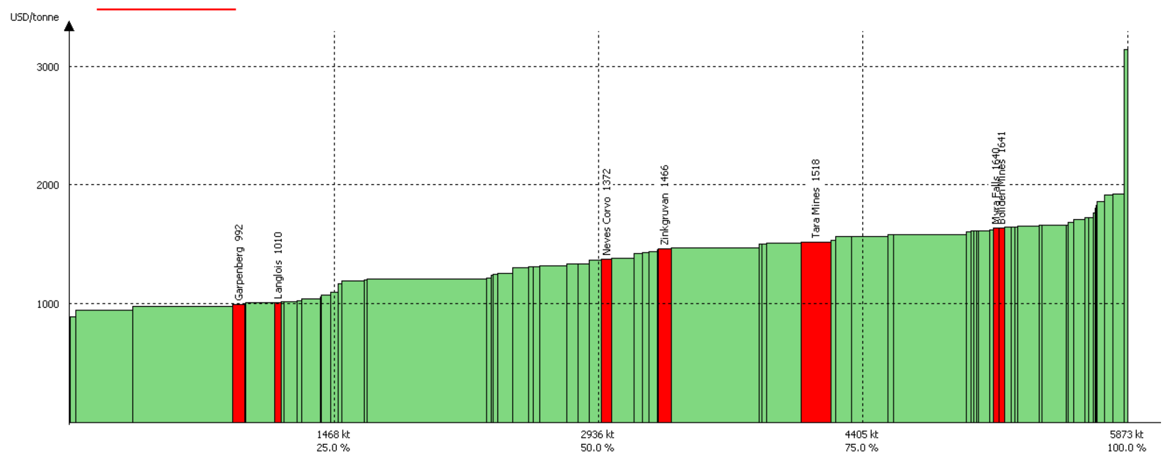

Figure 3.13. Cash cost curve for zinc (2013). Zinkgruvan, Garpenberg and some international peers are indicated in red (source: RMG data).

The cash costs for the LKAB's iron ore mines fall squarely towards the higher end of the spectrum that includes all producers and all products. If we consider only those operations that produce pellets, then LKAB fares much better. The difference here is the fact that while some products are less costly to produce, some products pay more than others. LKAB produce predominantly pellets which cost more to produce but sell for a higher price.

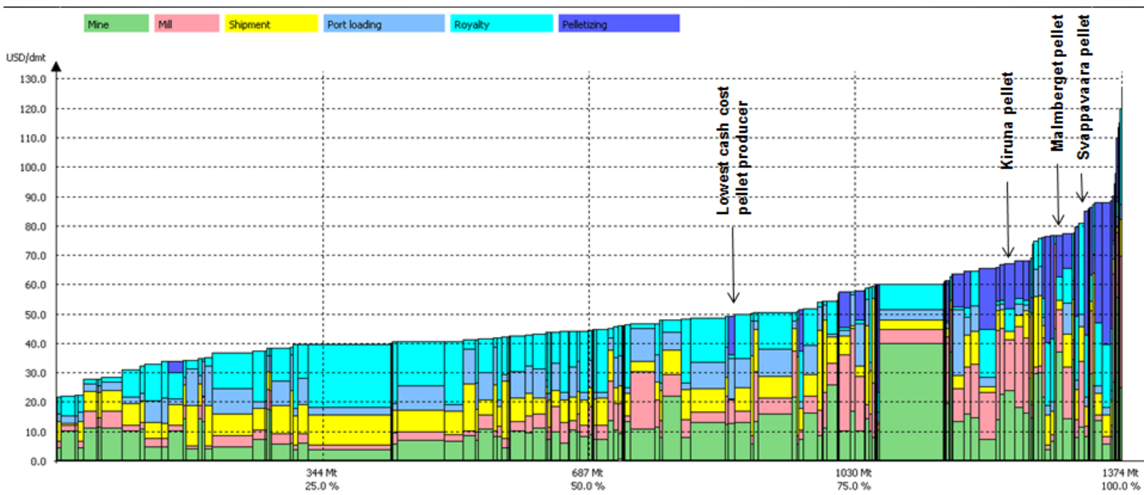

Figure 3.14. Cash cost curve for iron ore (2013; source: RMG data).

The fact that the Swedish mines tend to fall towards the higher end of the cost curves suggests that these mines must be efficiently run for them to remain profitable. Figures 3.15 shows some efficiency indicators for Boliden's Aitik and Garpenberg mines. The trend of production of metal per employee is clearly positive, whereas in terms of ore production it is positive for Garpenberg but slightly negative for Aitik.

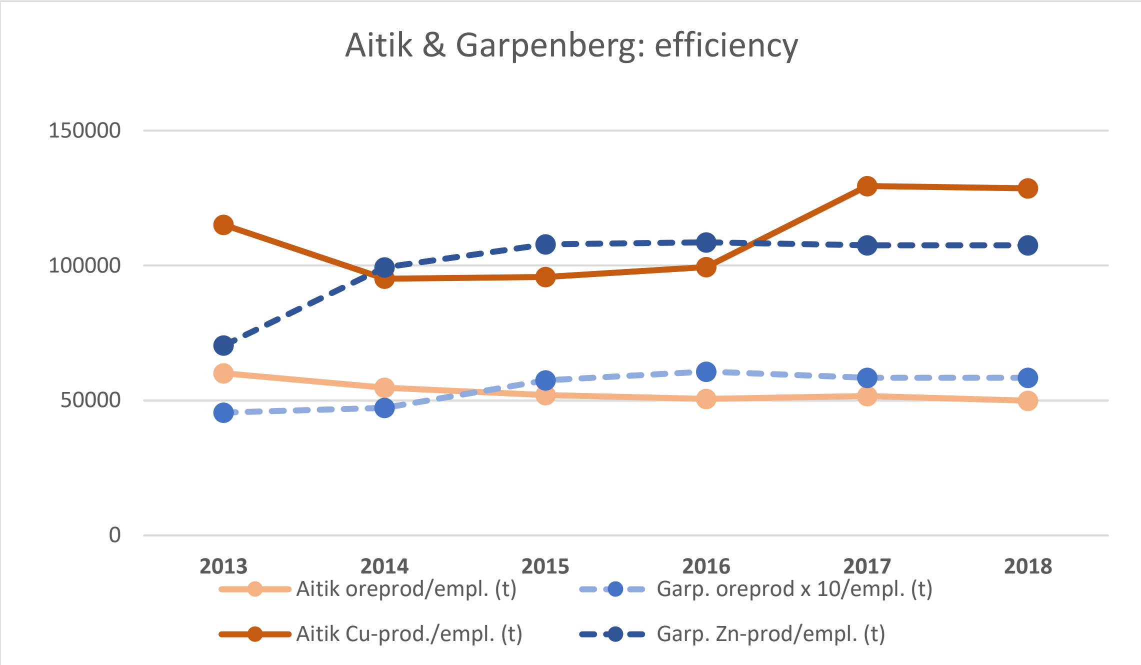

Figure 3.15. Ore production and metals in concentrate production per employee for the Aitik and Garpenberg mines and processing plants (both Boliden).

3.3. Revenues and costs

The decrease in the number of mines during the study period had no clear negative impact on the number of people employed, or the export value of sales from the sector. In fact, the number of people employed increased somewhat, as did the value of exports – with the latter closely following the commodity price cycles of the world market (Figure 3.16).

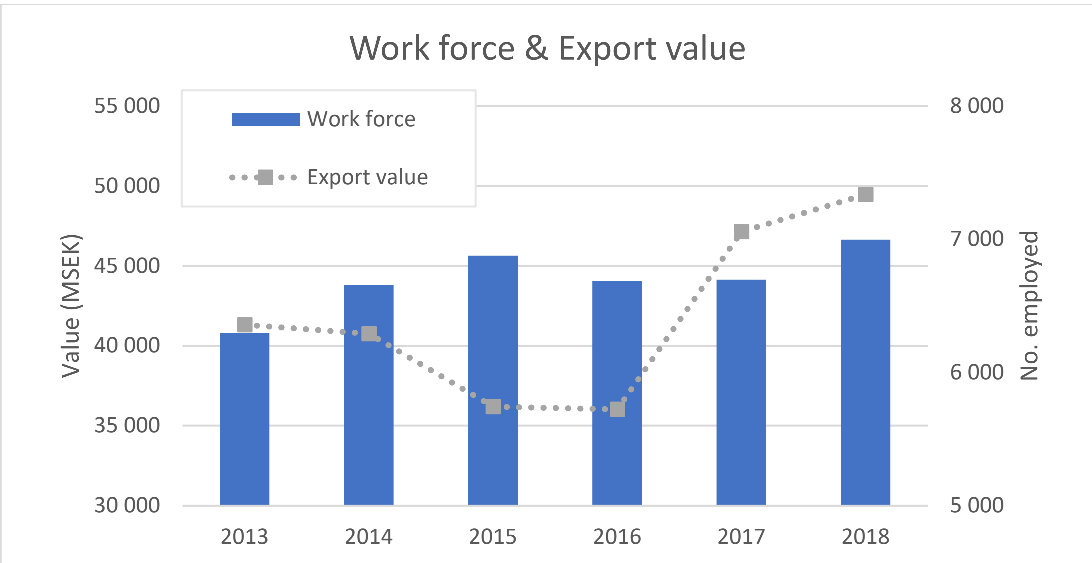

Figure 3.16. Work force in the mines and the value of exports (sources for export value is SCB)

Figures 3.17 and 3.18 show the profits made by the mining companies. The profitability is closely related to variations in metal prices. Metal prices as represented by an overall index reached a peak in 2011. Between 2011 and 2015 prices declined overall after which they have increased slightly. In terms of iron ore and copper, these two metals have developed in slightly different ways – iron ore prices recovered in 2016 while copper prices recovered some in 2017. These patterns are, in part, reflected in the profits of Boliden and LKAB, respectively (Figure 3.17). LKAB made a loss in both 2015 and 2016 but has shown a pre-tax profit since 2017. For Boliden, the profits have increased year by year over the period of the study as a combined result of increased production (acquisitions of new operations in Finland and expansions at Aitik), and increased metal prices. The sales and profit trends for Zinkgruvan were similar to those of Boliden, with increasing profits over the last few years (Figure 3.18). The pre-tax profit at Lovisagruvan was rather stable and positive in 2013-2016 followed by a 6-fold increase in 2017 and a 30% decrease in 2018. Profits at Björkdalsgruvan were less stable with negative results in both 2013 and 2018.

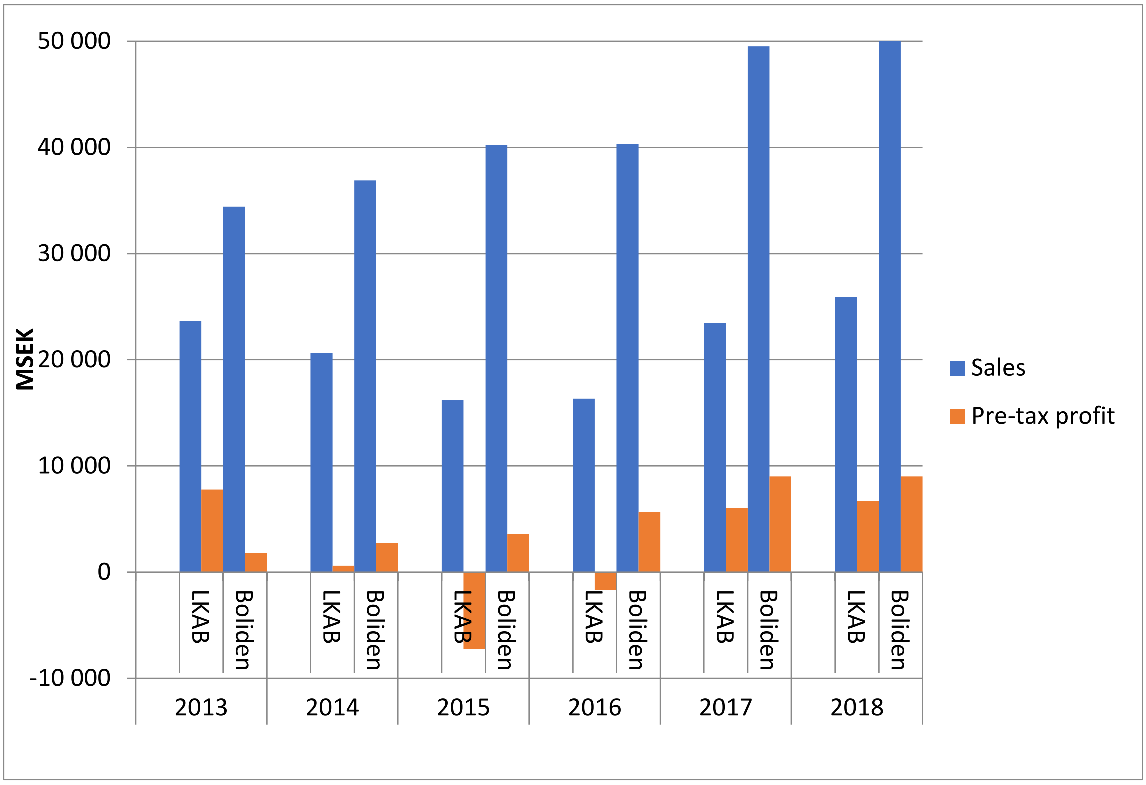

Figure 3.17. Sales and pre-tax profit for Boliden and LKAB (MSEK)

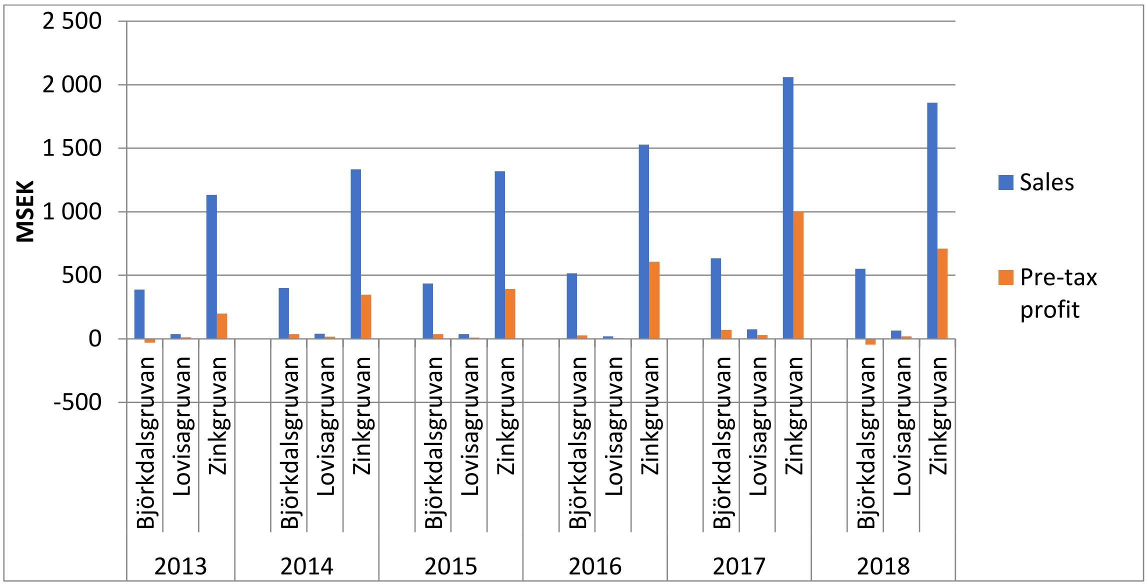

Figure 3.18. Sales and pre-tax profit for Björkdalsgruvan, Lovisagruvan and Zinkgruvan (MSEK).

Figure 3.19 compares profit rates (pre-tax profit divided by revenue) of the Swedish companies and selected international peers (Rio Tinto and Nyrstar), and some interesting patterns stand out. First, the smaller companies Lovisagruvan and Zinkgruvan generated the highest and most consistent relative profits. Further, both the iron ore producers LKAB and Rio Tinto did poorly in 2015. However, the fall in profit was much more severe for LKAB, probably because it relies on only one commodity, whereas Rio Tinto is a diversified producer. LKAB also had a generally lower profit rate than Rio Tinto over the study period. Boliden and Nyrstar are both mainly copper producers, and the two companies had similar profit rates during 2013-2015, but after that Boliden has increased its profit rate while Nyrstar has seen a decrease.

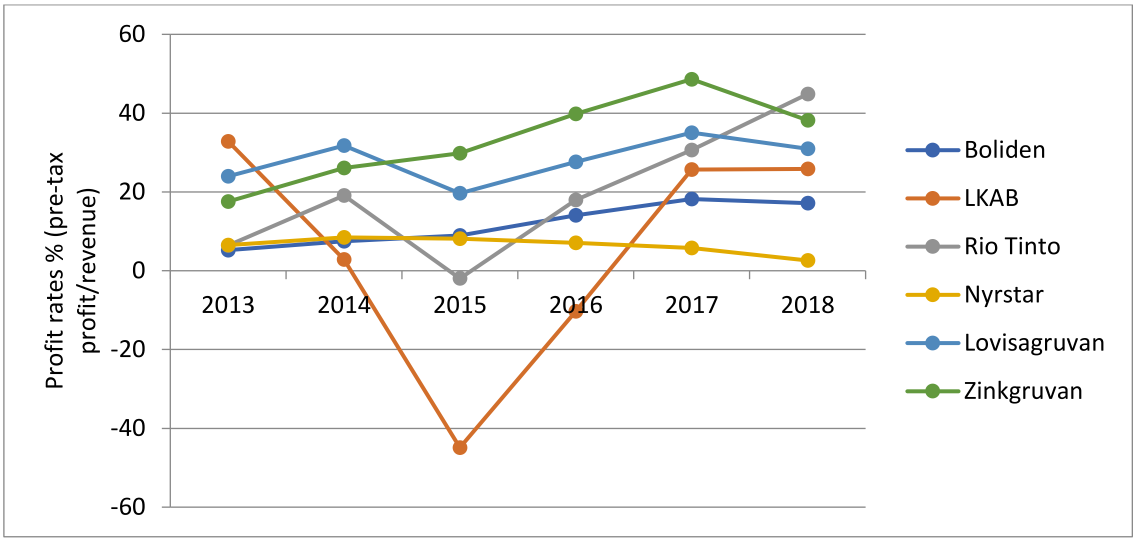

Figure 3.19. Profit rates (%) of Swedish mining companies, and those of selected benchmark companies.

Rönnskär had a good development in terms of both value of sales and pre-tax profits, with the value of sales 2018 being 50% higher than in 2013, and with profits mostly increasing (except for 2018) over the same period (Figure 3.20). During the same period, the volumes of material smelted as well as the metals produced were rather stable. The workforce contracted noticeably, from 866 in 2013 to 775 in 2016 (no data found for 2017 and 2018). This suggest that the positive results in terms of value of sales and profits were caused by a combination of increased commodity prices, and a lowering of staff costs, in turn made possible through overall improved efficiency.

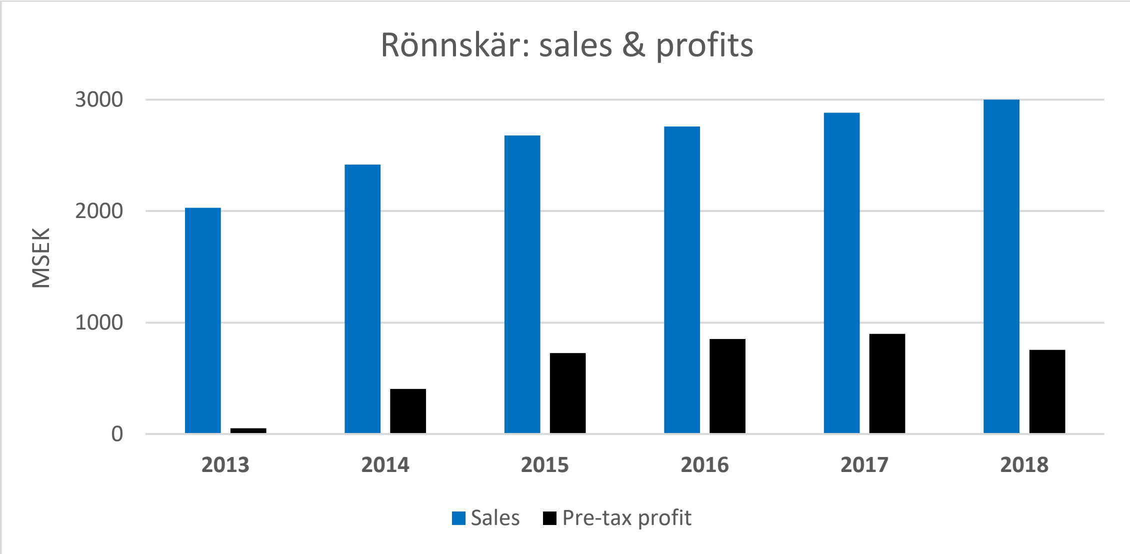

Figure 3.20. The values of sales and pre-tax profits for the Rönnskär smelter.

3.4. Health and safety

In terms of health and safety, data from the Swedish Work Environment Authority suggests a decrease in the total number of serious accidents over the period of study (Figure 3.21). With the exception of 2017, there is a clear indication that men are, overall, more accident-prone than women working in the sector. Looking at older data, it becomes clearer that true improvements have been made. For example, the total accident frequency (accidents per 1000 employees, men and women) averaged 12,7 over the period of this study, compared to an average frequency of 18 for the period 2006-2012 (Svemin, 2016).

Comparing work related accidents and illness data from different jurisdictions or sources is difficult, as there is very little information published at the required industry branch level, and measurements are often not made in the same way. However, comparing the Swedish metal mining sector with other sectors of the Swedish economy is possible and it can then be seen that working within the metal mining sector is comparatively more dangerous than most other sectors. The average frequency of accidents in metal mining is 13-15, whereas the Swedish average is 7. Other sectors that have similar accident frequencies as metal mining include construction (10-11) and manufacturing (12) sectors. Only the transport sector (14-15) has as high or higher accident rates than the metal mining sector. However, data collected and reported by the Swedish Work Environment Authority show that there are a fairly large number of occupations, with higher accident frequencies than that of mine workers, and these include: builders, carpenters, truckdrivers and process operators.

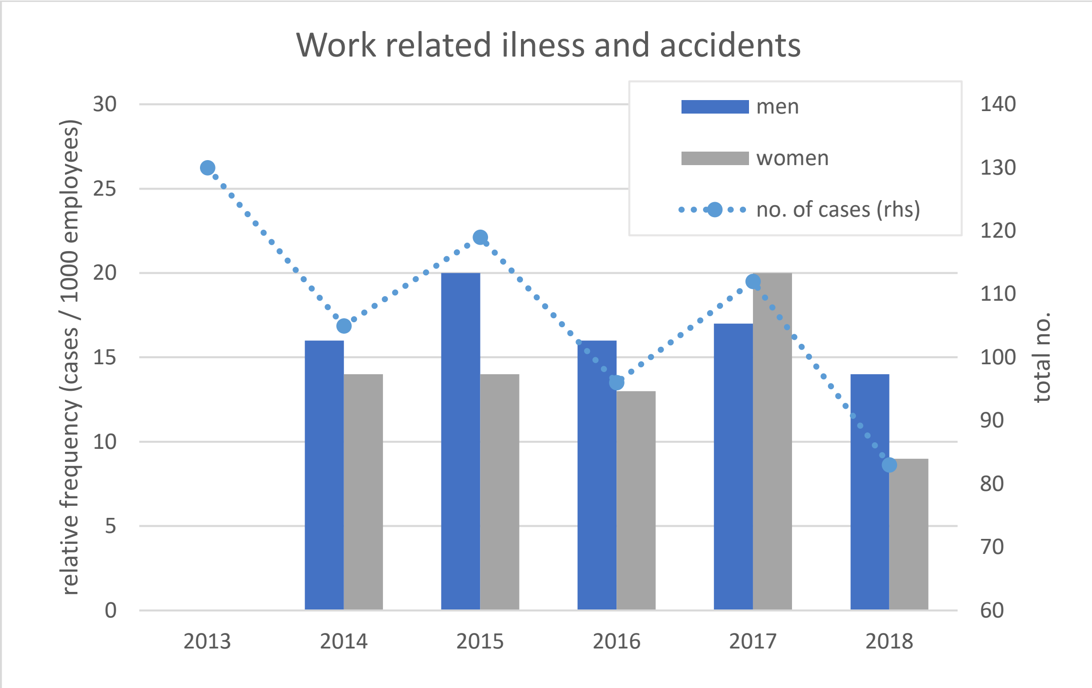

Figure 3.21. Frequency and total number of work related illness and accidents with associated lost work time in the metal mining sector (source: Swedish Work Environment Authority).

The safety record of LKAB and Boliden is compared with international mining companies in Figure 3.22. LKAB and Boliden have a much higher LTIFR than their international peers while the reason for this is not clear. The LTIFR of LKAB and Boliden is also considerably higher than statistics reported from Western Australia (2.3 in 2016; Department of Mines, Industry Regulation and Safety, 2018), or the average for the ICMM mining companies (4.4 in 2016; ICMM, 2016).

Boliden's LTIFR has decreased substantially from 2013 to 2018 (Figure 3.22). LKAB's LTIFR decreased from 2013 to 2015 but has since increased almost to the 2013 level, and significant improvements need to be made to reach the LTIFR target for 2021 of maximum 3.5. Björkdalsgruvan's reporting of LTIFR is incomplete (data exists for 2014-2017), and the LTIFR varies considerably, between zero and 11,2. Zinkgruvan (Lundin Mining) does not report LTIFR and their safety performance can thus not be directly compared with the other companies. They do, however, report on the total recordable injury frequency rate (TRIFR), which is the sum of the LTIFR and the medical aid frequency rate (MAF) and there has been a significant, and almost continuous, improvement in TRIFR from 2013 (17.5) to 2018 (5.8).

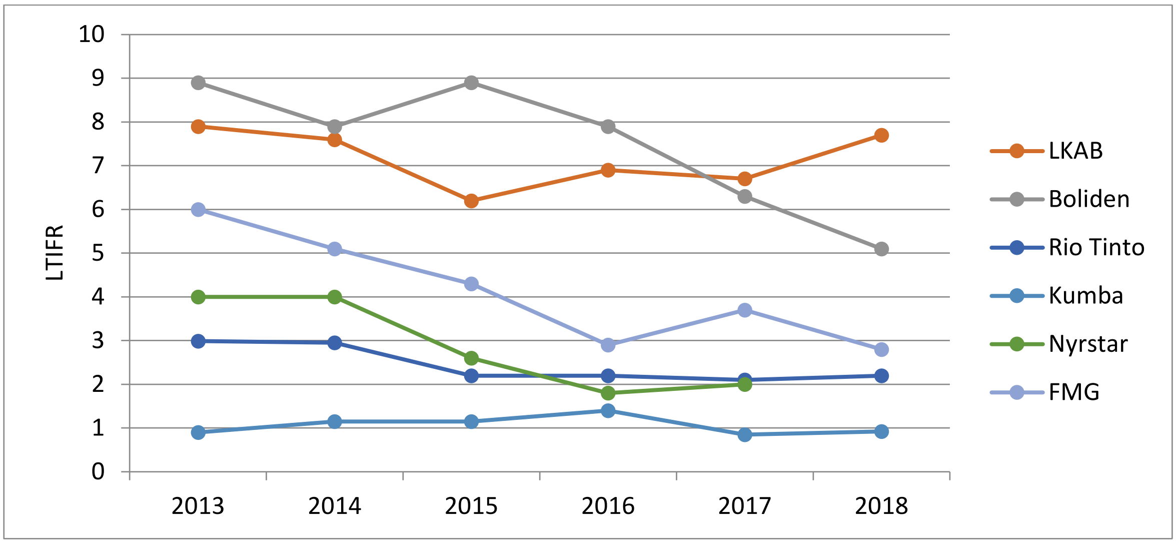

Figure 3.22. Comparison of lost time injury frequency rate (LTIFR) (number of lost time injuries occurring in one million hours of work).

Serious accidents have occurred during the study period. Thus, Boliden reported one fatality in 2016 in Finland. Another fatality occurred in 2017, at Rönnskär. LKAB had one fatality at the Svappavaara mine in 2018. As a comparison, Rio Tinto which has around 50,000 employees reported three fatalities in 2018, one in 2017 and four fatalities in 2015; and FMG with 5,000 employees had two fatalities in 2013.

4. Resource efficiency

Data that can provide KPI's relevant to assessing resource efficiency include:

- Metals produced through recycling
- Data on exploration (e.g. money spent, meters drilled)
- Resources and reserves
- Water usage
- Use of waste rock and tailings

4.1. Recycling

The recycling of iron scrap is a mature sector, and according to SGU (2014), the amount of steel produced from scrap in Sweden represent almost half of what is used. No other metal or other mined product come up in proportions of recycling that are even close to that of iron, and this in spite of Sweden, mainly through Rönnskär, being a world leader in this regard.

Boliden's recycling rate (Figure 4.1) shows the share of secondary materials in the total input to its smelters. Recycled materials include secondary materials from external sources such as electronic waste, and secondary materials from within Boliden. Boliden are among the world leaders in e-scrap recycling, and the Rönnskär smelter began using a new electronic scrap recycling facility in 2012. Boliden had a recycling rate of about 13% in 2013. The rate fell during the following two years and reached a low of around 11% in 2015. Since 2017 it has yet again come back up to the levels of 2013. None of the other mining companies use secondary materials in their process[4].

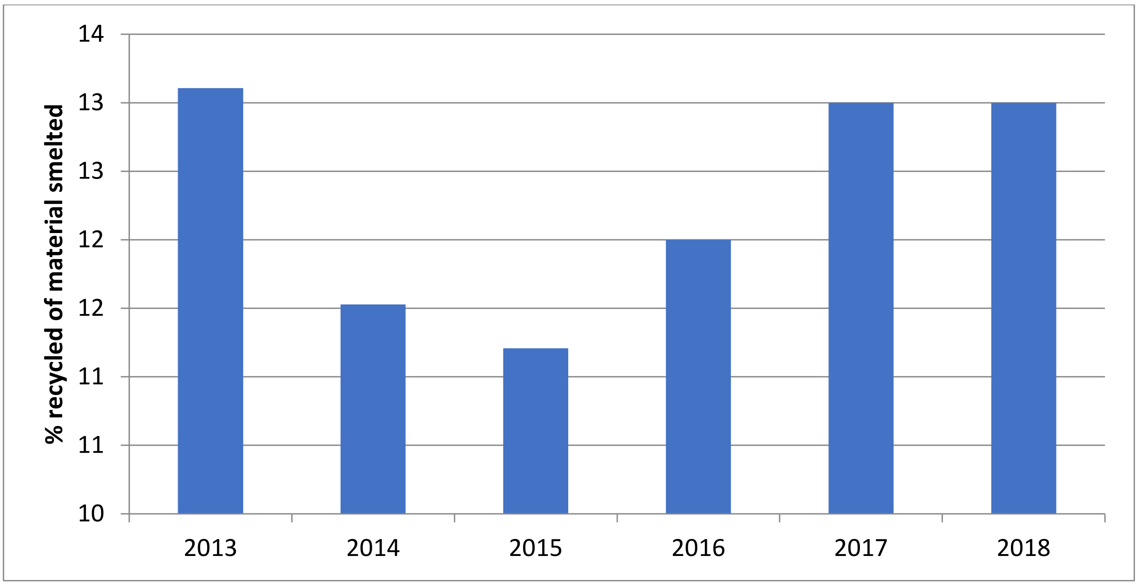

Figure 4.1 Boliden recycling rate.

4.2. Mineral reserves, resources and exploration

The majority of the metals and minerals commodities that are needed to sustain modern society, need to come from primary, mined material for a foreseeable period (e.g. see Ali et al., 2017). With this fact in mind, it is important that resources and reserves are established that can sustain such mining activities. Figure 4.2 illustrates the total proven reserves and

[4] To use scrap, a company needs to be involved in a process that allow for the use of scrap. In the iron ore industry, for example, this takes place at the steel plant. This is why most of the Swedish mining companies do not use scrap – they simply do not operate in that part of the value chain.

resources held by active Swedish mining companies during the study period. The resources have overall decreased, whereas reserves increased in 2014 mainly as a result of successful exploration work at Aitik, but thereafter they have remained steady. Although the overall pattern of how reserves and resources have developed hides a lot of detail in terms of different commodities, and different grade, it is still represents a situation which is not quite optimal and which suggests that overall, there is a need for further and more exploration work to be done.

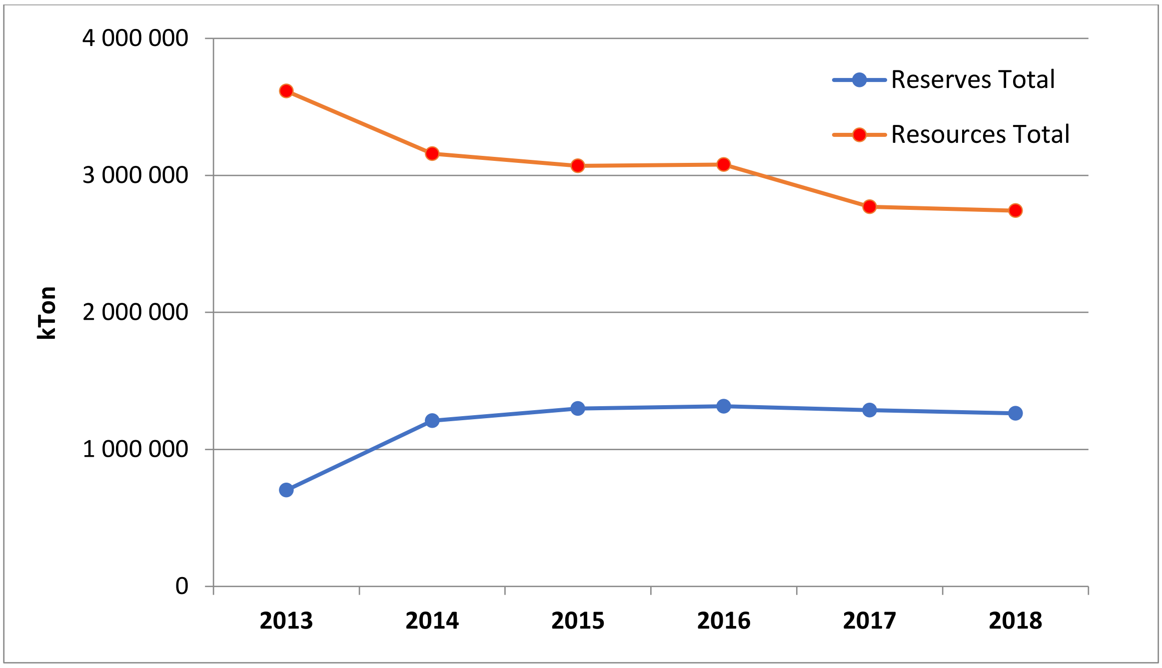

Figure 4.2 Total ore resources (measured, indicated and inferred) and reserves (proven and probable) in Sweden. The graph does not include Dannemora and Kaunis Iron, nor does it include resources/reserves held by pure exploration companies.

In 2013 the total exploration expenditure in Sweden, according to SGU, was SEK 550 million, and by 2018 it had increased to about SEK 772 million, which translates to SEK 16/ha total land area. This is on par with the exploration expenditures in Finland, which were about EUR 1.8/ha. In Canada, however, one of the world's top countries in terms of absolute amounts spent on exploration, they were significantly higher with about CAD 110/ha (Natural Resources Canada, 2019). In terms of exploration costs in relation to the total area permitted for exploration, these were some four times higher in Finland (ca. EUR 280/ha) than in Sweden (ca. SEK 650/ha) on average over the time period 2013-2018. Thus, from the perspective of exploration expenditure, it can be concluded that Sweden is not seen as one of the most attractive countries for investing in exploration, although there are other indicators pointing towards Sweden being a fairly attractive country for exploration and mining (c.f. Section 8.2).

Of the SEK 772 million spent on exploration in Sweden 2018, LKAB and Boliden accounted for 64% or SEK 494 million. Boliden spent SEK 520 million on exploration in 2018, but they do not report the share spent in Sweden. LKAB does not report how much is spent on exploration, but an estimate for 2013 suggests an exploration expenditure of around SEK 80 million per year (RMG data, 2013). This expenditure has probably increased during the last few years, since LKAB has communicated that they will spend more time and resources on exploration and that the exploration division is being expanded with a number of additional employees. The number above suggest that Boliden and LKAB spend about 1 and 0.4% of revenues on exploration, respectively. This is in the same range as the benchmark companies (Rio Tinto, 1.1%; FMG 0.4%; Nyrstar 0.5%; and Kumba 0.9%).

Exploration at Aitik has led to an almost doubling of the total reserves base (proven and probable) over the study period, from 633 Mt in 2013 to 1,148 Mt in 2018. LKAB's reserves also increased, from 958 Mt in 2013 to 1,151 Mt in 2018. The reserve base in relation to production at LKAB is rather large compared with other major iron ore producers. Rio Tinto, for example, had a reserve base of 5,524 Mt but produces ten times more iron ore than LKAB annually. However, there is a big difference when comparing resources; Rio Tinto has 25 billion tonnes in total mineral resources while LKAB has a modest 1 billion tonnes.

Looking at proven reserves only for selected Swedish mines (Figure 4.3), these have increased at Aitik and Garpenberg over the study period, and in 2018 they represented 20 and 10 years of production, respectively. Proven reserves at Zinkgruvan decreased somewhat during the same period, and represented about 5 years production in 2018. The Kristineberg mine decreased markedly over the period, and this mine is somewhat representative of the situation at the smaller Boliden mines where proven reserves tend to be close to mined out. With regards to the iron ore mines, the proven reserves at both Kiruna at Malmberget increased slightly, and represented in excess of 20 years of production at both mines in 2018 (Figure 4.4).

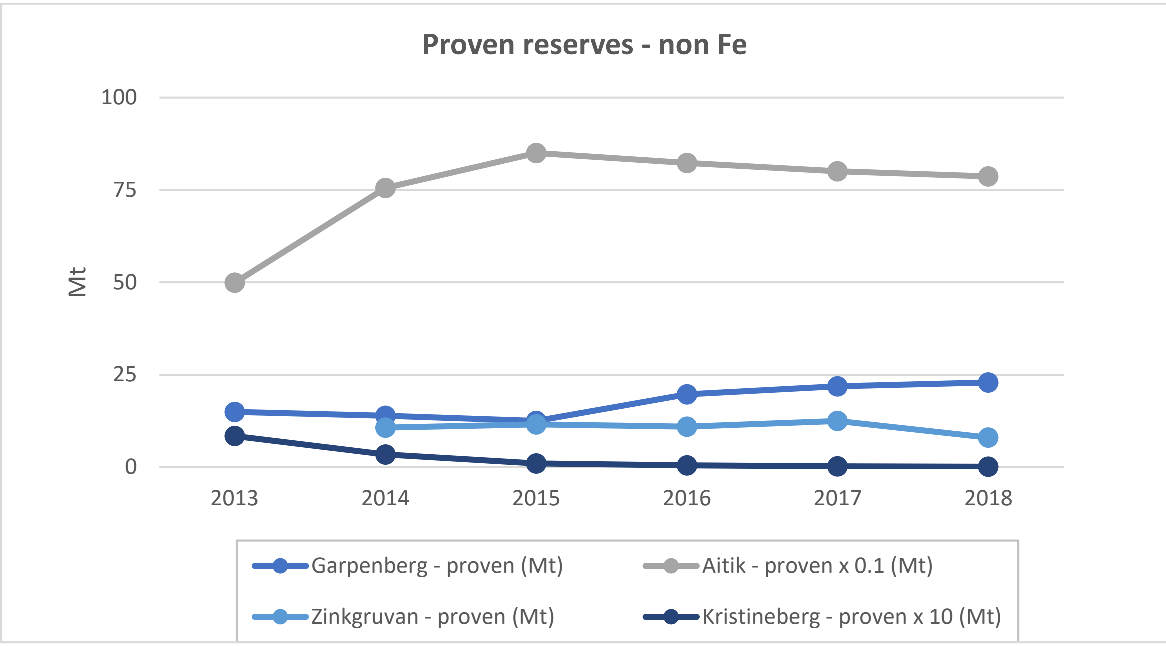

Figure 4.3 Proven ore reserves at selected metal mines.

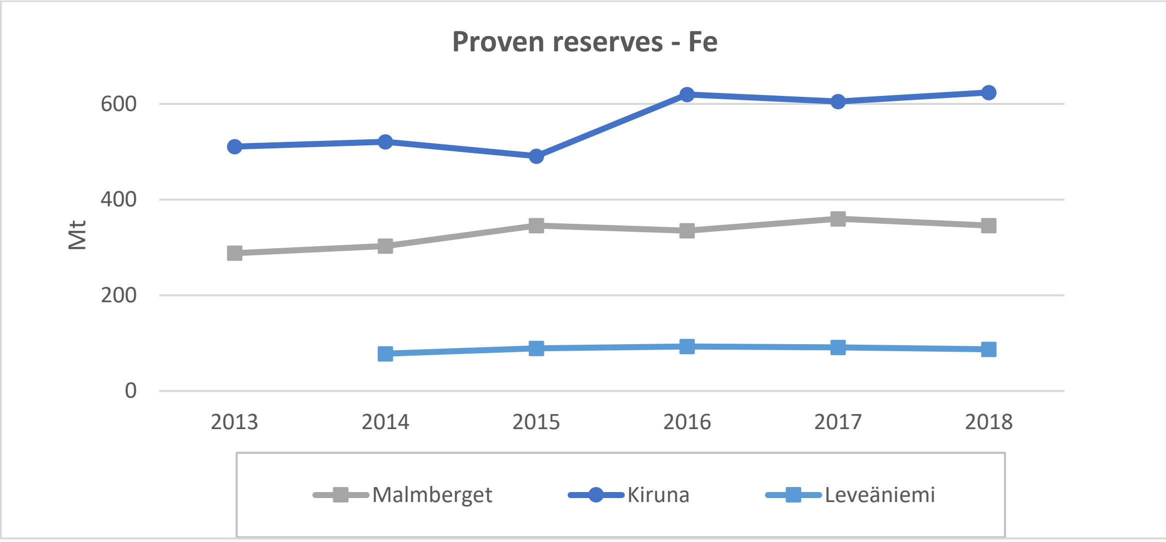

Figure 4.4 Proven ore reserves at Sweden's largest iron ore mines.

4.3. Water use

The use of fresh water at Aitik was significantly reduced over the study period: in 2013, over 2 million cubic meters was used, whereas in the period 2016-2018 the amount used was 100,000 cubic meters or less per annum (Figure 4.5). This is a result of increased recycling of water from the clearing pond, which means that essentially all the processing water at Aitik (40-45 Mm^3/year) now comes from recycled water. At Zinkgruvan, the amount of freshwater used has also decreased substantially, by some 35%, from 2013 to 2018. In this case, however, it is largely a result of a decreased water intensity in mineral processing, while the recycling rate has been fairly constant at about 50-65% over the period of the study. Freshwater use at other sites has been relatively stable, or increased over the last few years. This is valid also for the Boliden plant (not shown in graph), which uses significantly more freshwater than the other sites, about 4.6-4.7 Mm^3 annually, as only some 4% of the water used is recycled.

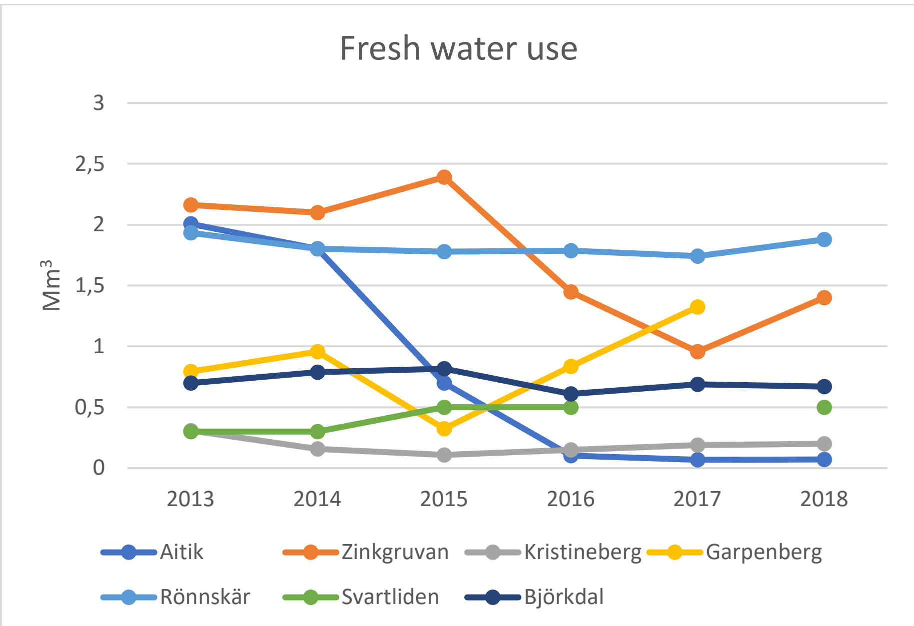

Figure 4.5 Freshwater used in industry processes at mining/processing sites and Rönnskär. Bolidenverket not included in figure for clarity, see text.

5. Energy efficiency

Data that can provide KPI's relevant to assessing energy efficiency include:

- Energy, fuel and electricity consumption and savings
- Renewable/non-renewable sourcing of energy
- CO_2 emissions
- Energy savings

5.1. Energy consumption

The metals and mining industry uses large amounts of energy, corresponding to almost 2% of the total energy use in Sweden. The high energy consumption is primarily related to energy demands in mineral processing - according to one estimate[5], around 50% of the energy in a mine is used to break rocks apart and grinding them. The total use of energy in mining, mineral processing and smelting in Sweden, and the proportion of electricity use, has remained rather steady over the period of the study (Figure 5.1).

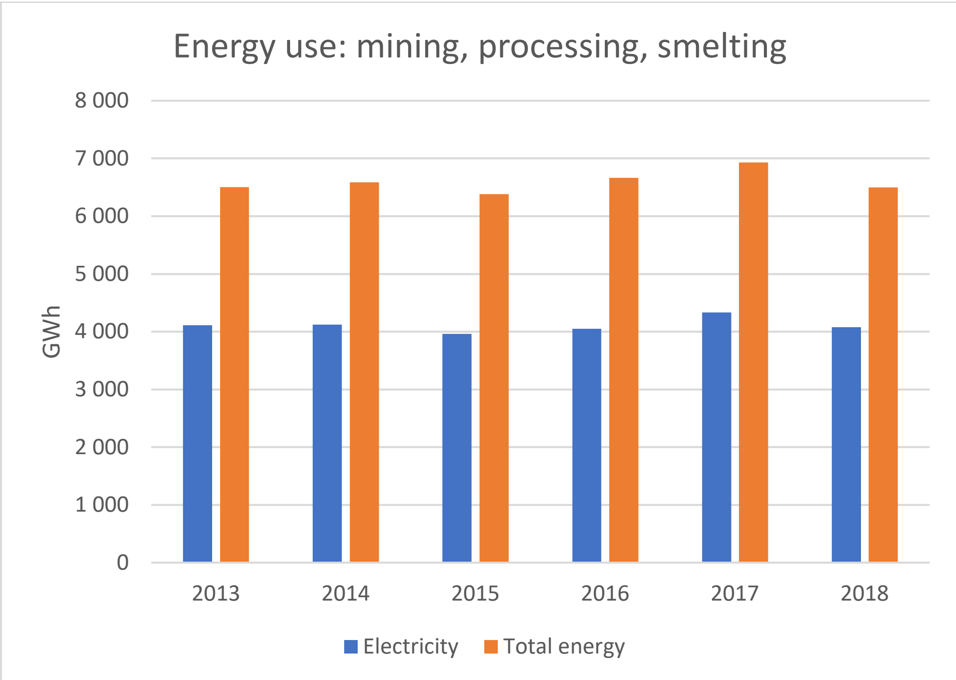

Figure 5.1. Amount of electricity and total energy used in mining, mineral processing and smelting in Sweden. The data sources include mainly site-specific annual environmental reports, and company annual reports.

LKAB and Boliden are responsible for the bulk (nearly all) of the energy use in the Swedish metals and mineral sector, with LKAB using about twice as much energy as Boliden. The high energy consumption at LKAB is in large part related to the production pellets, which requires more energy than for example the production of direct shipping ore[6]. With regards to Boliden, about one quarter of the energy is used at the Rönnskär smelter.
The energy intensities (energy used in relation to final products) at the corporate level for Boliden and LKAB have been rather stable over the period of the study (Table 5.1)

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[5] Presentation by Anglo American at Svemin's "Höstmöte" 2018.
[6] Direct Shipping Ore refers to iron ore that can be used in the blast furnace with minimal upgrading i.e. fines and lump.

Table 5.1 Energy intensity (energy used in relation to final products) *at the Boliden and LKAB corporate levels.*

	2013	2014	2015	2016	2017	2018
Boliden kWh/t	3 550	3 528	3 394	3 658	3 719	3 619
LKAB kWh/t	167	163	163	160	164	161

However, looking at individual operations, Aitik has lowered its energy consumption in relation to produced tonnage of concentrate markedly, and Malmberget, Kiruna and Rönnskär have also become somewhat more energy efficient since 2015 (Figure 5.2). At Svappavaara, the energy efficiency worsened significantly in 2017 due to a much higher energy consumption at a fairly constant pellets production, while the reason for this is unknown. In 2018, the production decreased by more than 30% at Svappavaara but the energy use decreased even more so that the energy efficiency moved closer to pre-2017 levels.

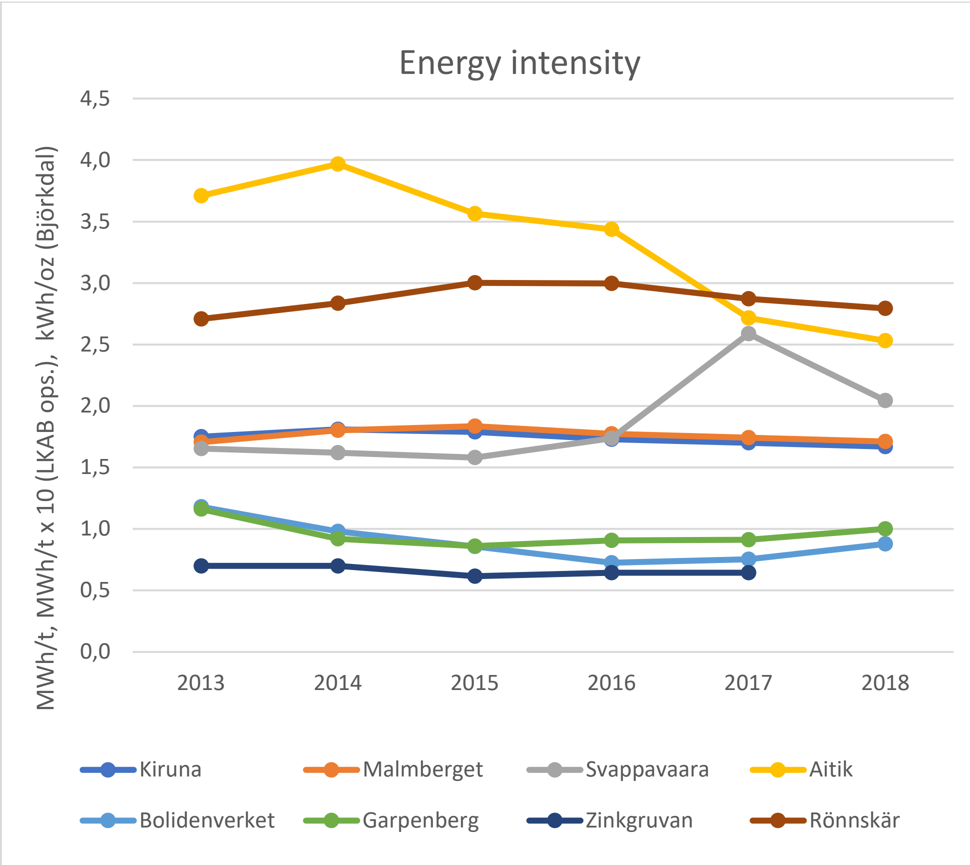

Figure 5.2. Total energy consumption per produced ton final product for selected sites (final products include pellets for the LKAB operations, metal concentrates for the base metal mines and Bolidenverket, and Cu cathode for Rönnskär; the consumption of coal and coke at the Rönnskär smelter is not included in the estimated energy use as they are used as reducing agents rather than energy source).

5.2. Energy sourcing and CO_2

The metal mining industry accounts for about 5% of Sweden's electricity consumption and most of that (98%) is used by LKAB and Boliden. The relative amounts of different energy sources used by Boliden and LKAB changed very little during the study period (Figure 5.3) and the electricity share of has remained constant at around 55% and 75%, respectively for LKAB and Boliden. For LKAB, the use of non-renewable sources of energy (diesel, oil and coal) decreased by 2%, and for Boliden it increased by 2% during the study period.

Rönnskär uses mostly (>80%) hydropower generated electricity and at the Boliden plant, nearly all of the energy (ca. 98%) comes from hydropower.

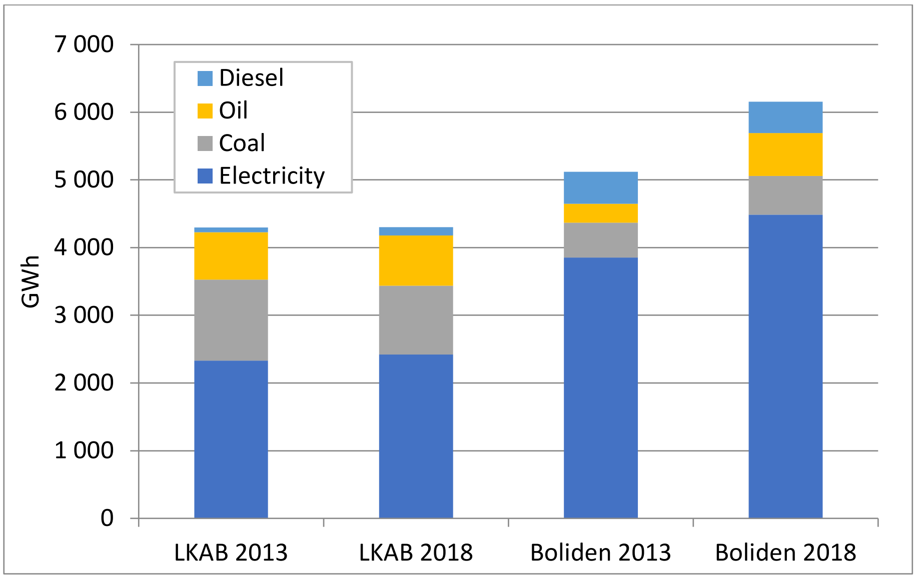

Figure 5.3 Energy by source for Boliden and LKAB.

Sweden is overall in a comparatively good situation in terms of the supply of energy, specifically as the electricity to a significant extent is generated through renewable sources - in 2018, SCB reports that 40% and 11% of the Swedish electricity was generated through hydro- and wind power respectively. Current Swedish government policy is further to have no net emission of greenhouse gases by 2045 and to thus become one of the world's first fossil-free welfare nations. The metal and mineral sector is to a significant extent able to use this fact to lower its carbon dioxide emissions. However, the emissions of CO_2 remain significant at 1.06-1.12 Mt annually, in turn representing 1.95-2.14% of the Swedish total during the study period (Figure 5.4). There were, furthermore, no sign of these emissions being lowered during the study period. Most of these emissions derive from LKAB (62-65%; mainly from coal used in pelletising) and the Rönnskär smelter (24-27%; mainly from the adding of carbon in the smelting process).

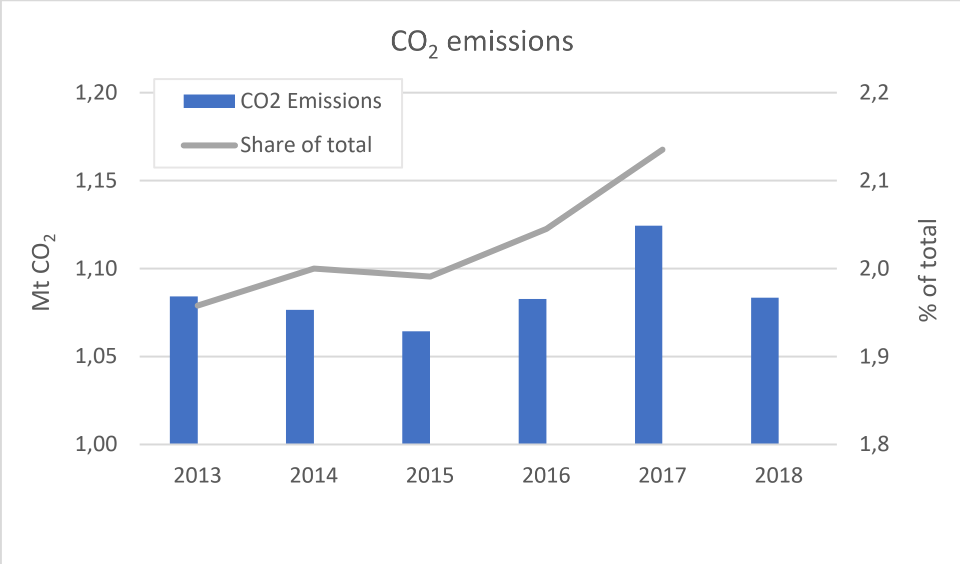

Figure 5.4. CO_2 emissions in the Swedish mining and metals producing sector – in absolute amounts and as a share of Sweden's total.

Table 5.2 shows CO_2 intensities for Boliden and LKAB at the corporate level. At Boliden, the CO_2 intensity decreased during the study period while it remained constant for LKAB.

Table 5.2. CO_2 intensity for Boliden and LKAB.

	2013	2014	2015	2016	2017	2018
Boliden CO_2/kt	780	740	650	730	690	640
LKAB CO_2/kt	27	27	26	26	27	26

Comparing CO_2 emissions per tonnes of product between base metals or more diversified companies is difficult because both end products and reporting practices differ, and there is also a lack of transparency in how calculations are performed. Boliden reports CO_2 intensity on the whole cycle from mine to finished product (mining and smelting with scrap included, and including all different metals, gold, copper, zinc, lead etc).

With regards to iron ore producers, CO_2 intensity data exists that allows for a comparison between LKAB and other iron ore pellet producing companies and it is clear that LKAB performs very well compared to international peers (Figure 5.5). The Ukrainian Ferrexpo releases almost ten times more CO_2 per ton pellets than does LKAB, the IOC (Iron Ore Company of Canada) almost twice as much, and Samarco around three times as much.

It is also interesting to note that LKAB's CO_2 intensity is similar to that of Kumba Iron Ore, a South African company that produces fines and lumps, i.e. direct shipping ore. Iron ore fines need to be agglomerated in a sinter oven prior to entering the blast furnace a process that will cause CO_2 emissions. The fact that LKAB can produce an agglomerated product emitting the same amount of CO_2 as a non-agglomerated product represents an actual and overall CO_2 emission reduction when pellets from LKAB is used in comparison to the use of fines from Kumba.

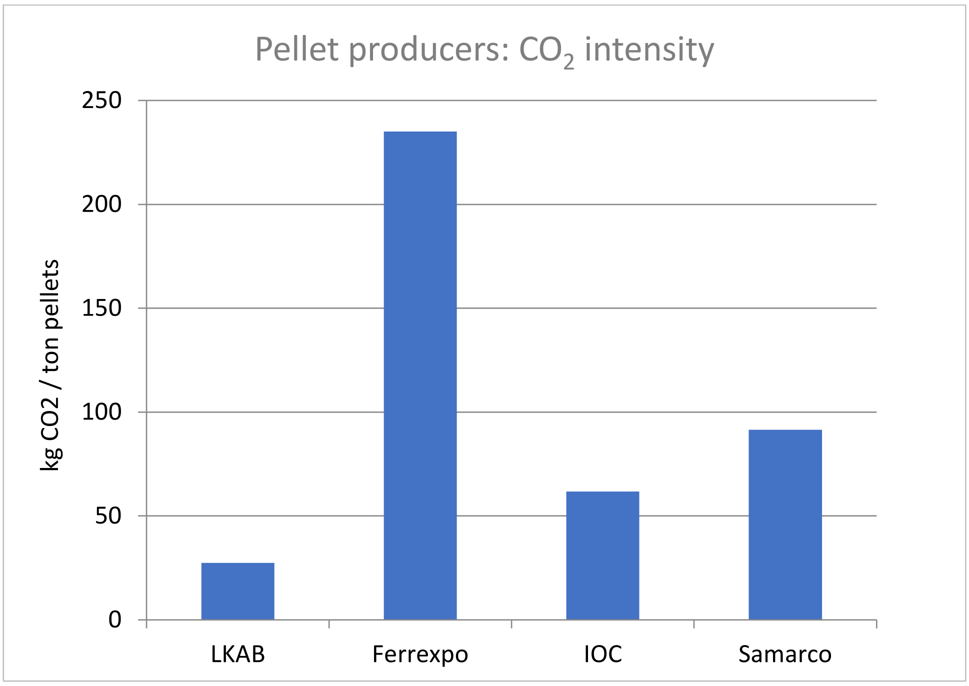

Figure 5.5. Comparison of CO_2 intensity for iron ore pellet producers in 2018 (Samarco 2016, no production in 2017-2018).

In terms of individual mining and mineral processing operations, there were notable reductions in CO_2 emissions and gains in CO_2 intensity at Aitik over the period of the study (Figure 5.6). Garpenberg and Rönnskär, two other Boliden operations, also lowered their CO_2 emissions and intensity over the study period (not shown in graph), albeit to lesser degrees and with less consistent year-on-year trends. Bolidenverket, on the other hand, shows no clear overall trend of either increasing or decreasing CO_2 emissions or intensity (Figure 5.7).

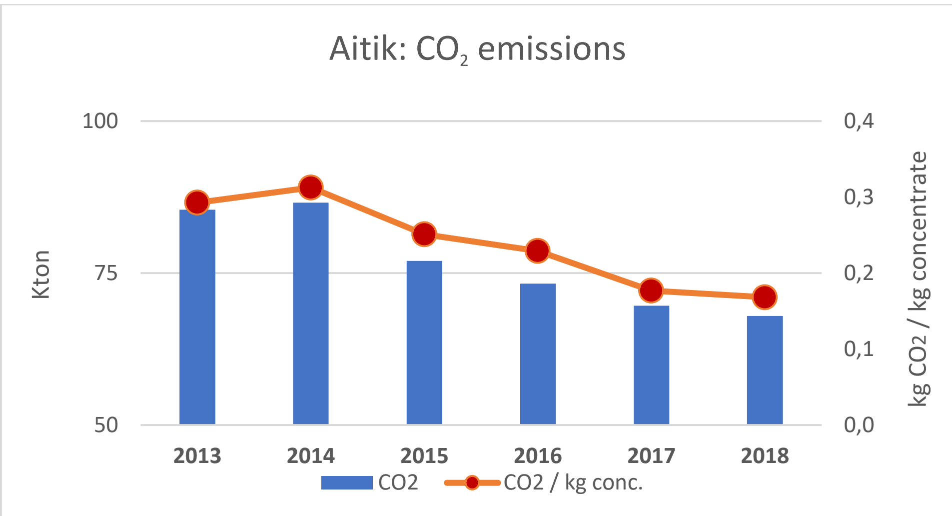

Figure 5.6. CO_2 emissions at Aitik – total and divided by weight of mass of concentrate produced.

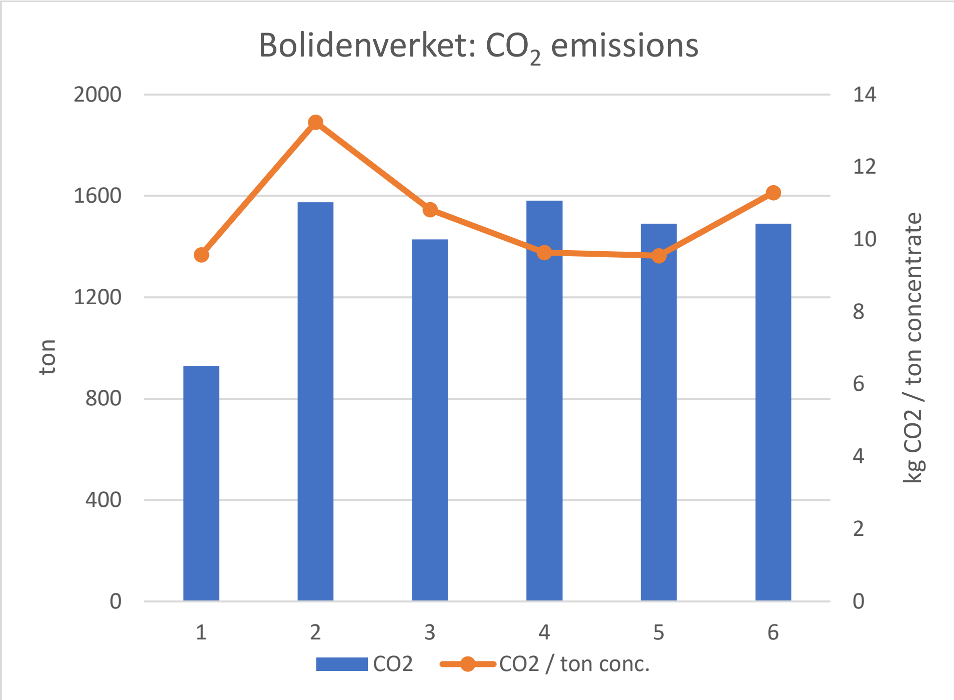

Figure 5.7. CO_2 emissions at Bolidenverket – total and divided by weight of mass of concentrate produced.

With regards to the LKAB operations, Kiruna and Malmberget govern the CO_2 intensity for the company as a whole (cf. Table 5.2) and both the CO_2 emissions and intensities for these sites have been more or less constant during the study period.

5.3. Energy savings

A large amount of heat energy is generated in the processes at Rönnskär, and this heat is to a significant extent reused with 98-116 GWh being used inside the smelter itself, and another 35-40 GWh used for heating the town of Skellefteå. LKAB is developing a similar plan where Kiruna will be heated by excess heat generated at the LKAB pelletizing plants.

6. Environmental impacts

Available data that can provide KPI's relevant to assessing environmental impacts include:

- Presence/absence of environmental management systems
- Discharges to water and emissions to air
- Reported environmental incidences
- Water usage
- Production of waste
- Land take & rehabilitation of sites
- Ecological compensation

6.1. Environmental management

All companies studied except Lovisagruvan have introduced some sort of Environmental Management Systems and also report the number of environmental incidents (Table 6.1.). Unsurprisingly, the larger companies report comparatively more incidents. Further, the number of incidents reported increased significantly for both LKAB and Boliden over the study period, which could suggest either a worsening environmental performance or alternatively, changes in reporting procedures. Boliden has acquired new mines during this period, which is likely to be part of the reason for the increase in reported incidents for that company. No similar reason can be seen for LKAB.

Table 6.1. Environmental incidents reported (source: site-specific environmental reports; for LKAB and Boliden, incidents reported for individual operations have been added together).

	2013	2014	2015	2016	2017	2018
Boliden	6	12	15	17	22	36
LKAB			9	17	21	25
Björkdalsgruvan	0	0	1	3	1	1
Zinkgruvan	2	1	1	1	0	4

6.2. Discharges to water

Considerable work has been done to limit discharges deriving from the minerals sector. The amount of metals discharged into downstream waterbodies is nowadays generally counted in kilos and are often contributing only small amounts when compared to the natural transport of metals in rivers and streams (e.g. Landner & Lindeström, 1999; SMHI/SMED, 2012). Data that show the relative success of work to limit discharges can best be seen at the corporate and site levels (see below). Data that has been aggregated at the national level show that significant improvements have continued to be made, also during the period of study, and then especially with regards to lowering metal discharges to water from the mines (Figure 6.1). Thus, significant reductions were made in the discharges of a range of metals, including Cd, Pb and Zn, over the study period while the large increase in the discharge of Pb and Zn in 2018 is related to problems experienced at the Zinkgruvan mine (see below). Cu discharges also show a decreasing trend, albeit with an important exception in 2014 when discharges were larger than the years before or after, and this was in turn caused by problems experienced at the Aitik mine (see below).

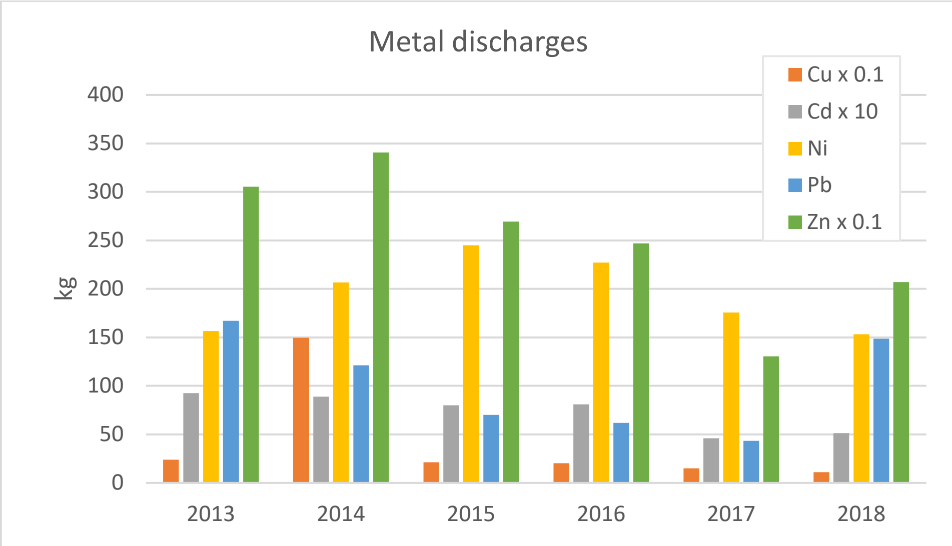

Figure 6.1. Metal discharges to water from the Swedish mining and metals producing sector, excluding the Rönnskär smelter, which is a significant source of such discharges, c.f. Section 6.4.

Similar successes in limiting discharges of nitrogen and phosphorus to water have not been achieved. On the contrary, aggregated data suggest that such discharges are overall on the increase over the period of the study (Figure 6.2). Though, the decrease in the discharge of phosphorous over the last two years and the steady discharge of nitrogen over the period 2015-2017 followed by a decrease in 2018 may suggest that challenges are being addressed.

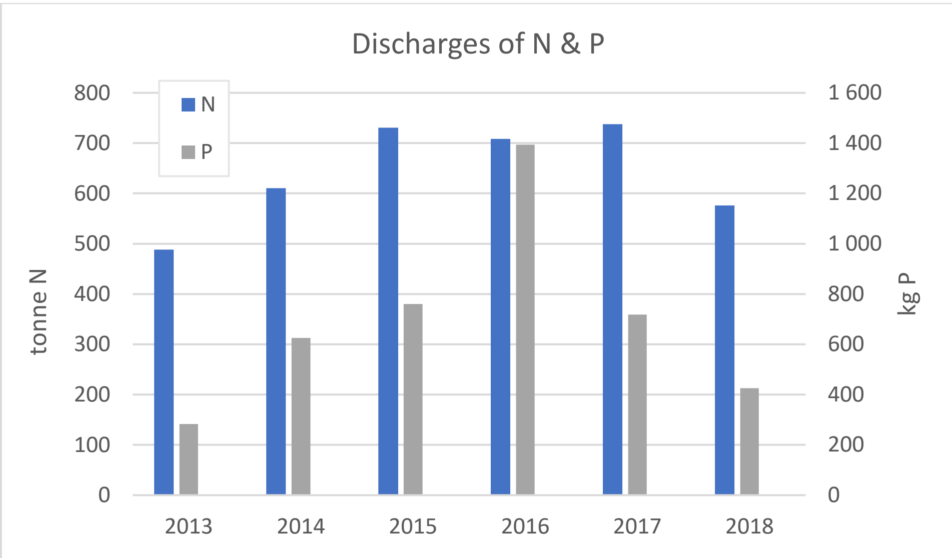

Figure 6.2. Discharges of nitrogen and phosphorous to water from the Swedish mining and metals producing sector.

Overall discharges of metals to water are reported to have decreased significantly at the corporate level. Figure 6.3 shows the total discharge of metals to water for Boliden, Zinkgruvan, LKAB and Lovisagruvan, and the overall decreases suggest an improving environmental performance.

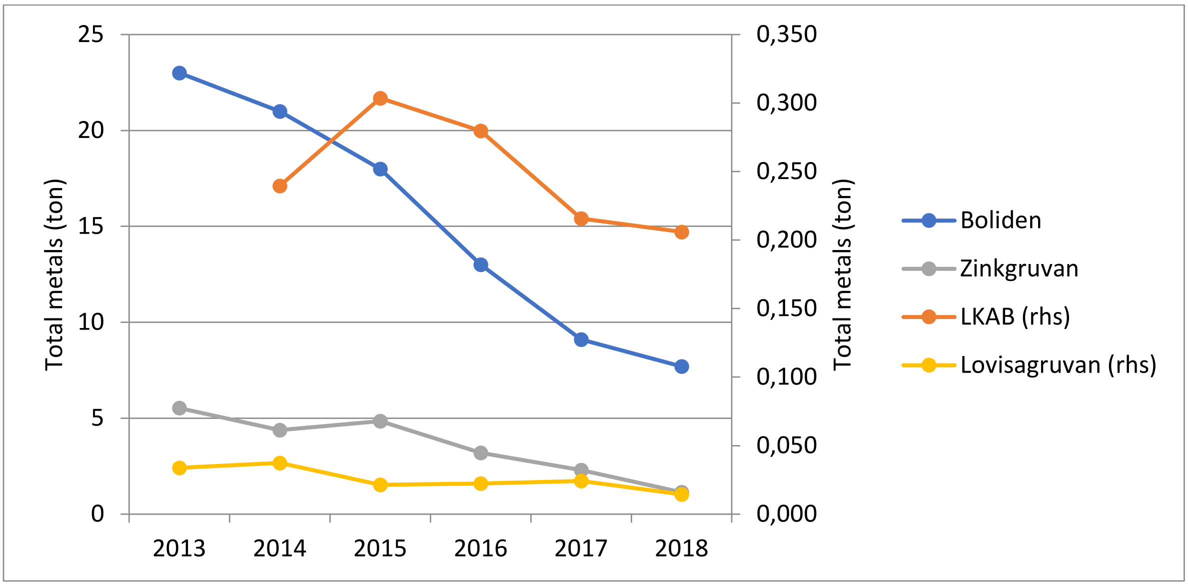

Figure 6.3. Metal discharges to water by company 2013-2018 (tonnes metal).

Improvements at the site level are in particular impressive in the case of Aitik over the last three years of the study period (Figure 6.4). The much lower levels of metals in 2018 are likely caused mainly by improved water processing.

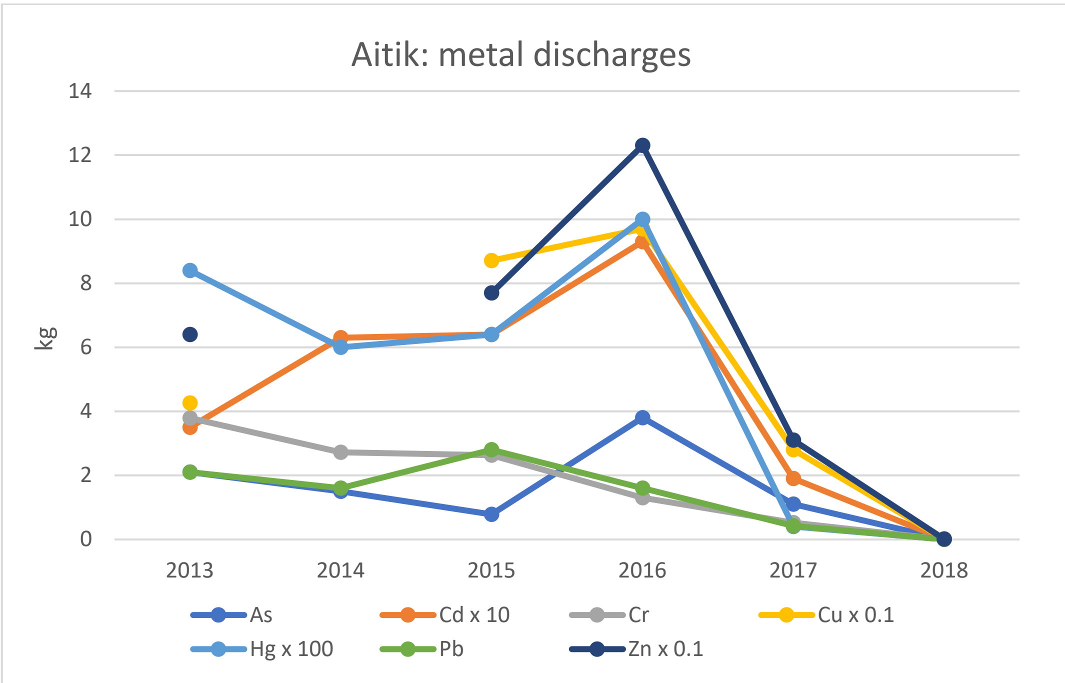

Figure 6.4. Estimated metal discharges to water at Aitik (the anomalously high levels of Cu and Zn in 2014 have been omitted for clarity).

The investments made at Rönnskär for environmental purposes during the study period amount to about SEK 1 billion, and data show that significant improvements have been made with regards to lowering metal discharges to water as a result (Figure 6.5).

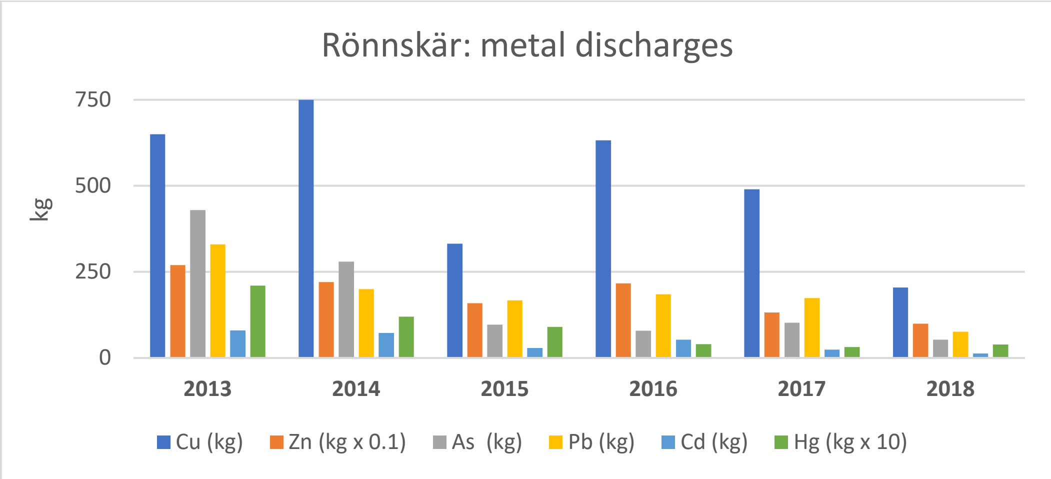

Figure 6.5. Estimated metal discharges to water from the Rönnskär smelter.

The Boliden plant is compared to Rönnskär a much less significant discharger of contaminants to water. Nevertheless, there are no signs that discharges to water decreased over the period of study (Figure 6.6).

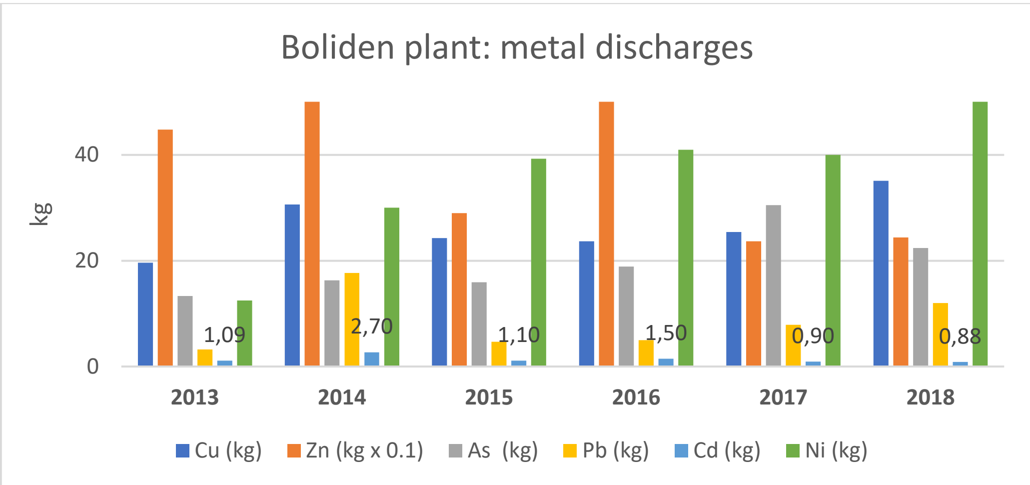

Figure 6.6. Estimated metal discharges to water from the Boliden processing plant.

As inferred from the national data (above), the discharge of nitrogen to water at the site level has not improved in the same way as the metals discharges. Issues of eutrophication and the need to control the release of nitrogen and phosphorous are well known, and the industry is working continuously to develop more efficient blasting methods. However, there are few clear trends of consistent improvements with regards to achieving a decrease in nitrogen released to water per tonnage of rock volumes that are mined Figure 6.7).

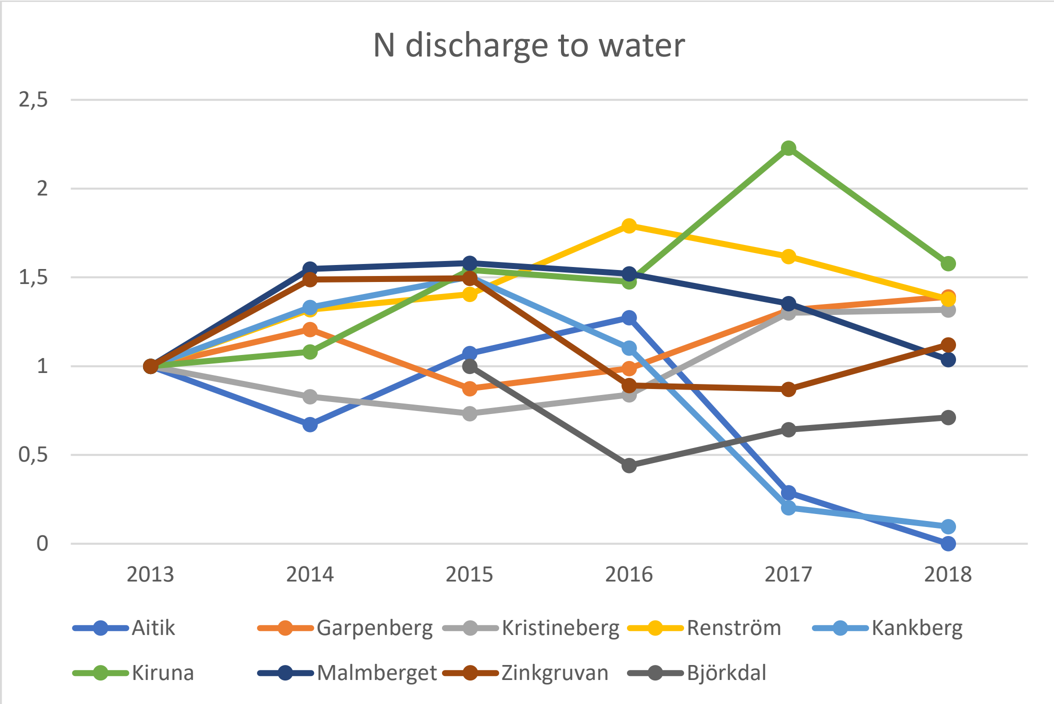

Figure 6.7. Indexed discharge of total nitrogen to water per weight unit material mined (ore and waste).

6.3. Emissions to air

Similar improvements that are seen above with regards to metal discharges, are not as clear when looking at emissions to air, although there are some clear and promising trends.

LKAB's operations emits, by far, more SO_2 and NOx to air than any other mineral sector operation in Sweden. Thus, LKAB is responsible for more than 90% of the NOx emissions and more than 99% of the SO_2 emissions. While the SO_2 emissions from the LKAB operations decreased substantially over the period of the study, the NOx emissions have increased somewhat (Figure 6.8)

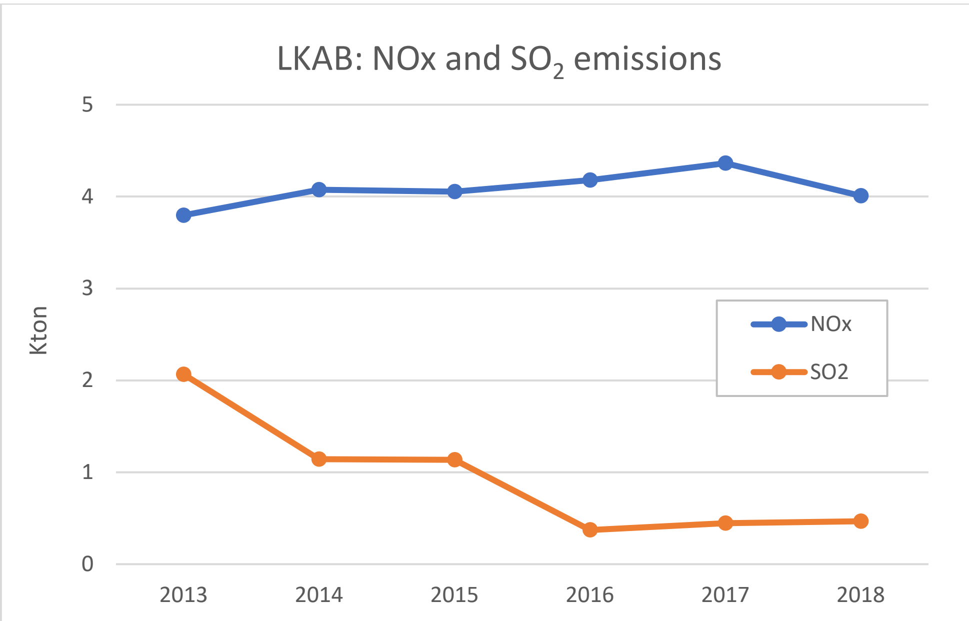

Figure 6.8. Combined emissions of NOx and SO_2 from Kiruna, Malmberget and Svappavaara.

While Boliden's contribution to the total NOx and SO_2 emissions from the minerals sector is comparatively small, efforts are made to reduce emissions (Figure 6.9). Aitik and Rönnskär are together responsible for more than 90% of Boliden's SO_2 emissions and more than 95% of the NOx emissions. Of the NOx emissions, more than 80% come from Rönnskär alone. Thus, the trend of decreasing NOx between 2013 and 2018 is solely related to improved control of NOx emission at Rönnskär. With regards to SO_2, there was a significant reduction in emission at Aitik, by some 7 tons, between 2013 and 2015, while the SO_2 emission at Rönnskär has increased somewhat since 2015.

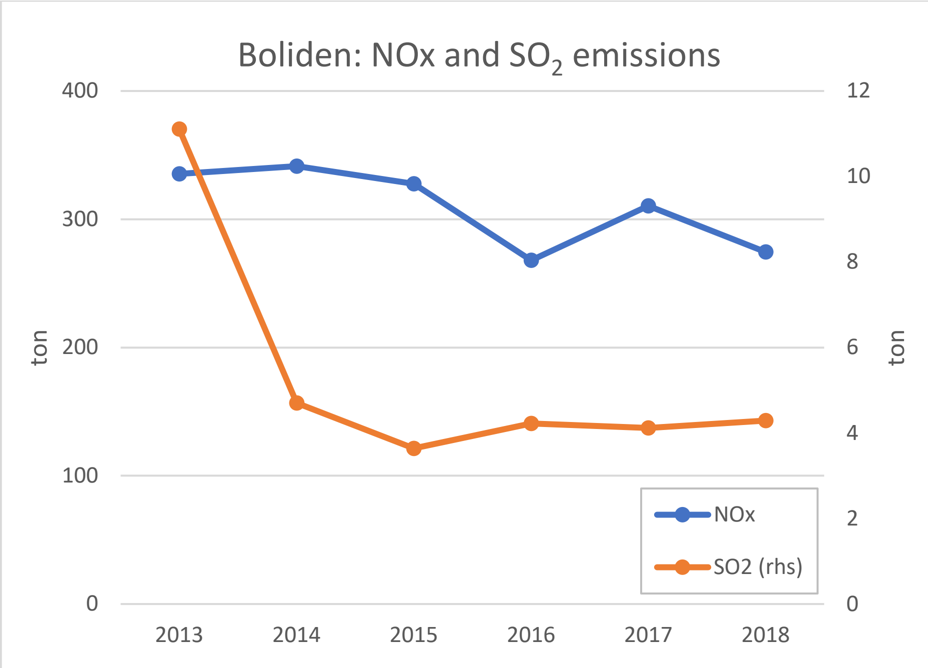

Figure 6.9. Combined emissions of NOx and SO_2 from the Boliden operations.

Improvements have overall not been achieved at Rönnskär with regards to metal emissions to air (Figure 6.10). Thus, the amounts of NOx, dust, SO_2 and CO_2 emitted remained rather stable over the period. The emissions of Hg decreased considerably though, from 35 kg in 2013 to 20 kg in 2018.

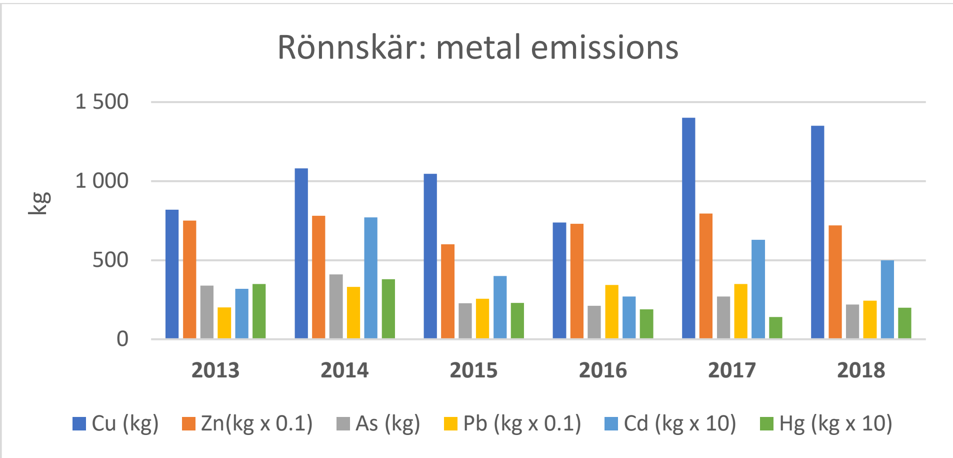

Figure 6.10. Estimated metal emissions to air from Rönnskär.

6.4. Land take & rehabilitation

In terms of land use, the total land covered by mining concessions is small when compared to most other land uses. The number of valid mining concessions increased somewhat over the period of study – from 151 in 2013 to 166 in 2018[7]. In 2018, the total area covered by mining concession was 130 km², representing 0.03% of Sweden's total land area. In terms of the total land allocated to the mines that operated in 2018 – that is the area of the actual mining concessions and additional land used for related activities - then the area taken up by mining activities was 197 km². To give an indication of the size of this total area, it is about 2% of the area that is currently allocated to windfarms (9,000 km², existing or under implementation; c.f. www.vindlov.se) and about half the area that taken up by to ski lifts and golf courses (377 km²; SCB, 2017).

Table 6.2. Total areas covered by mining concessions, and the total land take of active mines in 2018.

	Area (km²)
Areas covered by valid mining concessions (166)	130
Allocated land use for operating mines (concessions and related land use rights – "markanvisning")	197

Although the areas covered by mining are small, there is exist since 2008 a strict legal requirement that funds – so called environmental bonds (see below) for post mining rehabilitation - exist (see below) with the dual purpose that the land area may have other use post mining, and that any environmental impacts that are caused should be adequately managed. These legal requirements are, however, rather recent when compared to the time period during which mining activities have occurred in Sweden. As a result, there exist sizeable areas where previous mining has occurred, and where today there are in places severe problems related both to ongoing environmental impacts that needs to be remediated, and to the fact that the land cannot be used for other purposes. In 2019, SEPA lists about 330 "abandoned mines", most of which are small and rather insignificant. However, some sites will require substantial funds to be rehabilitated, and in the last few years such work performed at the relatively recently abandoned Svarträskgruvan and Blaiken (in 2007, both in the county of Västerbotten) represent substantial rehabilitation costs.

In 2013, the total of environmental bonds lodged for mining and processing sites amounted to about SEK 890 million, with a dominant bond of 660 million being for Aitik (Table 6.3). By 2018, the amount was SEK 2.8 billion, with the largest individual bonds being for Aitik (1.819 billion), and the Rönnskär smelter (760 million). This increase reflects the argument that environmental bonds have been too low in the past (e.g. SOU, 2018). The amount of the bond normally increases in response to mine development/expansion projects, with new estimates being based on updated environmental management and mine closure plans. They may also decrease if, for example, rehabilitation of mined out areas is undertaken concurrently with the ongoing operations. There are a few rulings and petitions, however, that point in the direction of that bonds may be required to increase even in the future. Thus, in the case of Aitik, MMD has ruled (in 2018) for a total bond of MSEK2,857, which has been appealed by Boliden. On the other hand, Boliden has themselves proposed an increase of the bond for Garpenberg from the current MSEK95 to MSEK490. In 2018, there was also an MMD ruling for a total bond of MSEK43 for Björkdalsgruvan, related to an approved mine

[7] The number of mining concessions will drop markedly in 2024, when 64 concessions expires that were granted the month before the enactment of the Environmental Act in 1999; c.f. Tarras-Wahlberg, 2014).

expansion plan. Furthermore, in the on-going (2019) environmental permit process for the Tapuli mine, the county administration board of Norrbotten advocates for an increase of the bond to MSEK155.

With regards to LKAB, SOU (2018) refers to data from Svemin and reports a total bond of MSEK300 by the end of 2017. Pledged collaterals and contingent liabilities in LKAB's annual financial report that are directly related to eventual needs for environmental rehabilitation, however, amount to far less than that (Table 6.3)[8]. In any case, the level of the bond appears rather low in the light of the size of their operations.

Table 6.3. Level of environmental bond (million SEK) for some companies and operations (sources: site-specific annual environmental reports, company annual reports, SOU (2018); for LKAB, the data includes the following annual financial posts: Pledged assets - Deposits of cash and cash equivalents that are intended to cover future expenditures for remediation measures and other restoration measures at mines after mining activities cease, and Contingent liabilities – collateral, remediation.

	2013	2014	2015	2016	2017	2018
Kaunis Iron AB	19	29	29	29		
Aitik	660	660	1 819	1 819	1 819	1 819
Garpenberg						95
Kankberg	6	6	6	6	6	6
Renström				20	20	20
Svartliden	31				33	
Björkdal	16	16	16	16	16	16
Zinkgruvan			162		162	
Rönnskär			0	0	760	760
LKAB	158	181	213	168	169	167

6.5. Tailings and waste rock deposits

Issues related to mining waste and specifically tailings dam safety have attracted widespread attention and concern internationally in later years, as a result of several well-known catastrophic dam failures (most recently in Brazil and Canada). Thus, a worldwide and important initiative to develop a "Global Tailings Standard" is underway, with the purpose to minimise the risk for accidents. Boliden has had first-hand experience of such a catastrophic dam failure in 1998 (Aprisa dam in Spain), and the Swedish mining industry has since developed a system for improving dam safety termed Gruv Ridas. All the Swedish mining companies follow Gruv Ridas, and this entails regular follow up and monitoring of risks. The companies are also required to report specifically on dam safety to the authorities. The reports in this regard are, however, not rich in information or data, and essentially consist of an account of whether all work that should have been done has been done. There is, for example, no data on volumes, on heights of dams, or on the construction methods used.

Svemin has recently begun publishing data that are relevant to dams and safety (dammregistret.se). Although the initiative is laudable, the information contained is rather modest, and incomplete and falls well short of what is achieved in some countries, for example in Chile (Consejo Minero). We used Svemin's data, information provided in Ramböll

[8] The amounts given for LKAB in Table 6.3 derive from their annual financial reports and include: Pledged assets - Deposits of cash and cash equivalents that are intended to cover future expenditures for remediation measures and other restoration measures at mines after mining activities cease, and Contingent liabilities – collateral, remediation.

and Ecoloop (2018), as referred to in SOU (2018) and communication from relevant company staff as sources for data on the extent of tailings and waste rock deposits (Table 6.4). There are some discrepancies between Svemin data and SOU (2018) data, which means that for some dams a range is provided. In 2018, the total area covered by tailings dams and clearing ponds is reported to be in the region 31 - 39 km².

Table 6.4. Approximate data on area of tailings dams at mining/processing sites.

	Clearing ponds (ha)	Tailings pond (ha)	Total (ha)
Aitik[1,2]			900 - 1460
Björkdalsgruvan[3]	12	171	183
Garpenberg[1,2]			116 - 130
Gillervattnet (Bolidenverket)[3]			230
Hötjärn (Bolidenverket)[3]	32	185	217
Kaunisvaara (Tapuli)[1,2]			200 - 300
Kiruna[1,2]			520 - 650
Kringelgruvan (Woxna)[1,2]			15
Kristineberg[1,2]			70-74
Malmberget[1,2]			200 - 212
Stekenjokk[1,2]			100
Svappavaara[1,2]			160 - 200
Svartliden[3]	35	42	77
Zinkgruvan[3]	102	13	115
			Total: 3 103 – 3 963

sources:
[1] Svemin's tailings dams register, dammregistret.se
[2] Ramböll & Ecoloop, 2018, as referred to in SOU, 2018
[3] Relevant company staff

The only source identified that provides the extent of waste rock deposits is Ramböll & Ecoloop (2018), as referred to in SOU (2018). There are uncertainties in the information, and the data need further assessment and corroboration. The data, nevertheless, indicate that a large portion of the waste rock stored at mine sites is potentially acid generating.

Table 6.5. Waste coverage at Swedish mine sites (source Ramböll & Ecoloop, 2018 as referred to in SOU (2018). Waste rock, "inert" refers to the Swedish term miljögråberg and PAG refers to potentially acid generating.

	Waste rock, "inert" (ha)	Waste rock, PAG (ha)
Kiruna	430	
Mertainen	290	
Svappavaara	290	
Malmberget	65	
Tapuli		44
Aitik	290	595
Kristineberg		6,3
Maurliden	4	16
Maurliden Östra		2,6
Renström	0,5	
Kankberg		3
Bolidenverket		12
Zinkgruvan		2
Svartliden	28	2,6
Björkdalsgruvan	120	
	1 518	684

7. Social acceptance

Specific data on the social acceptance of the mining and metals sector hard to come by, so we must look at other, indirect evidence. Available data that can provide KPI's relevant to assessing social acceptance include:

- No. of licenses for exploration and mining, no. of applications for such licenses and no. of appeals against decisions made
- No. of reported grievances at mine/processing sites
- Results of stakeholder surveys conducted by companies and/or others

7.1. Appeals

Relevant data in this regard relates to appeals against decisions made by the Mining Inspectorate regarding licenses for exploration and mining. Such data exist for the years 2016 - 2018 (Table 7.1). The numbers of appeals against granted exploration permits have been increasing significantly during the study period, in turn suggesting that there may be an increasing distrust towards the sector on part of the public. Although no data is readily available on who is appealing the decisions, a review of the relevant literature (e.g. Tarras-Wahlberg, 2014; Lawrence & Klöcker Larsen, 2016) suggest that a considerable portion of the appeals are likely related to appeals by reindeer herders and Sami representatives on the ground of land use, as well as from organisations and/or individuals concerned with environmental issues (including the Swedish EPA).

Table 7.1. No. of appeals against decisions made by the Mining Inspectorate.

	2013	2014	2015	2016	2017	2018
Appeals against Exploration permits	nd	nd	nd	16	42	49
Appeals against Mining concessions	nd	nd	nd	2	5	2

7.2. Reported grievances

The number of grievances and formal complaints reported against companies or specific operations provide some indirect indication of the level of acceptance by neighbouring communities/persons of specific mining operations.

All the Swedish companies now report the number of grievances annually, although the coverage is not complete for the study period (see Table 7.2). The smaller companies report very few grievances whereas LKAB and Boliden apparently receive quite a few complaints each year. At Boliden, the numbers decreased very significantly during the last two years of the study period, which may suggest that the definition of what constitutes a grievance might have changed. Further, whilst LKAB and Boliden are reporting according to the GRI standard on grievances (on environmental, labour practice, and human rights issues) Zinkgruvan does not.

Table 7.2. Number of reported grievances.

	2013	2014	2015	2016	2017	2018
Boliden			49	119	16	19
LKAB			104	97	78	117
Björkdal	0	1	2	1	0	0
Zinkgruvan	1	0	0	0	0	5
Lovisagruvan	1	1	1	1	1	0

Grievances are also reported at the site levels, in the environmental reports. However, reporting in these seems inconsistent between sites for those companies that operate more than one site (LKAB and Boliden), and in several other cases it is incomplete and/or completely missing. Overall, the number of grievances reported are few. In terms of the mining sites, Aitik reports the largest numbers but even here, the numbers are small (varying from none to 7 per year). At Rönnskär, the grievances reported were likewise few, with no more than three such complaints being reported in any one year. Only one grievance was were reported on for the Boliden plant.

7.3. Attractiveness of sector

While social acceptance is hard to measure directly, there are some indirect indicators that can be used. One such indicator is the "Most attractive workplaces in Sweden" survey which is done annually by the international market branding company Universum. Thus, the survey measures how students rank prospective employers, and a high ranking may suggest that the company has high degree of social acceptance. Table 7.3. shows the ranking of Boliden and LKAB (the two only mining companies that feature in the top 100) for Engineers with a MSc degree. LKAB featured among the top 100 companies in all surveys conducted in the study period, while Boliden featured in two out of 4 years. Given that both companies feature among the 100 most important employers in Sweden, the results of the survey suggest that the large mining companies do have a reputation as fairly attractive employers which, in turn, should indicate a certain social acceptance / license to operate.

Table 7.3. Most attractive workplaces for graduates (MSc Engineering).

	2016	2017	2018
LKAB (99th largest employer 2017)	75	92	82
Boliden (76th largest employer 2017)	98	>100	94

Source: Universum

8. Other impacts

Available data that can provide KPI's relevant to assessing the impacts of Swedish Mining Innovation are to a significant extent similar to the data used in the above section to assess outcomes. Additional data that are used below include:

- Data on employment and the economic contribution of the sector to national and local economies
- Data on relative attractiveness and competitiveness of the sector in the international perspective
- Data on gender

8.1. Economic contribution

Figure 8.1 illustrates the economic importance of the mining sector over the period of the study. The share of national GDP is fairly stable at around 0.5%. However, the importance of the sector is greater if one considers its share of all investments made (varying from 0.6% to 1.4%), and it is even greater when looking at its contribution to exports (3-4%).

In Section 6.2, it is shown that mining activities occur over comparatively small land areas. At the same time, the sector generates large values from these areas. In table 8.1, the GDP (production side GDP – that is value added) and exports generated by mining per unit land area used is compared to agriculture and forestry. It is shown that mining (not including downstream smelting), generates some 130 and 925 times as much value as does agriculture and forestry respectively per unit area. It is similarly shown that the mining sector generates much larger export values per unit area, compared to the forestry sector (by a factor of 1 232). In addition, it should be remembered that the Swedish mining sector also supports the existence of a world leading cluster for mining equipment (with Epiroc and Sandvik being the most important companies in this regard).

Table 8.1. Comparisons of GDP (2017, production side) and export values (2018) generated by mining, forestry and agriculture per unit area.

	Area (km^2)	GDP 2017 (MSEK)	GDP / km^2 (MSEK)	Export 2018 (MSEK)	Export /km^2 (MSEK)
Mining (permitted land use, active mines)	197[1]	25 523	130	135 977[3]	690
Forestry	235 030[2]	33 940	0.14	132 071[4]	0.56
Agriculture (incl. pastures)	30 399[2]	31 406	1.03	n.d.	n.d.

Sources: SCB and Bergsstaten

[1] land use 2018; [2] land use 2015

[3] excluding steel; [4] timber, paper & pulp

In terms of the sector's relative importance to the national economy there are, however, signs of a decrease. Thus, the share of GDP has decreased continuously over the study period by totally 13%, whereas the sector's share of investments decreased continuously 2013-2017, followed by a slight increase in 2018, resulting in an overall decrease of 47%. For the share of exports there is no clear trend while its share of the total was 10% lower in 2018 compared to 2013.

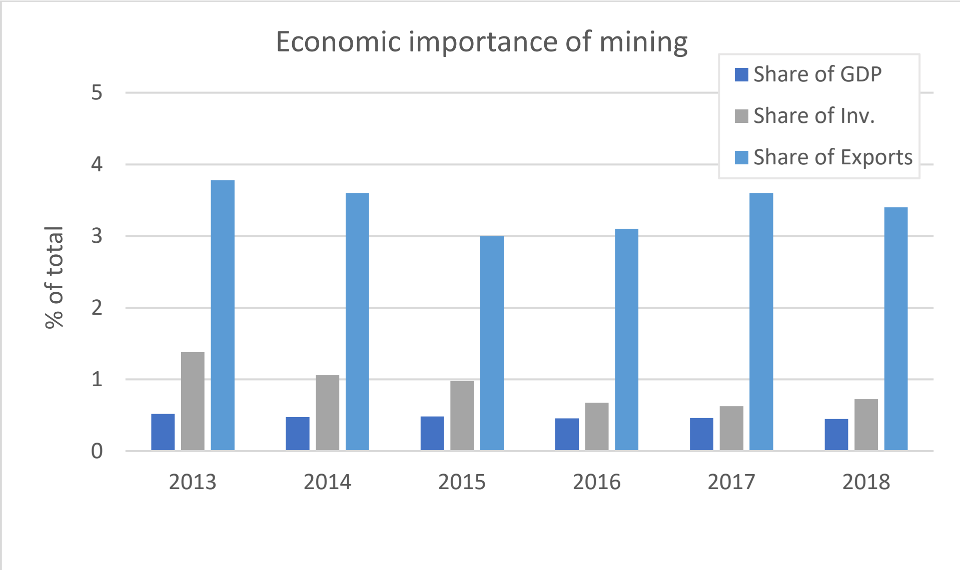

Figure 8.1. The economic importance of the mining sector in Sweden (source: SCB).

Comparing mining's contribution to GDP of some different countries, it is apparent that the importance of the mining sector is rather low in well developed countries with a diverse economy (Figure 8.2). Thus, even in Canada, one of the world's most important mineral producers, mining contributes only some 2% to GDP, and Sweden is on par with Finland at around 0.5-1%. In Chile, one of the world's top producers of copper, mining is significantly more important to the national economy and in Poland, mining's share of GDP is about twice that of Sweden.

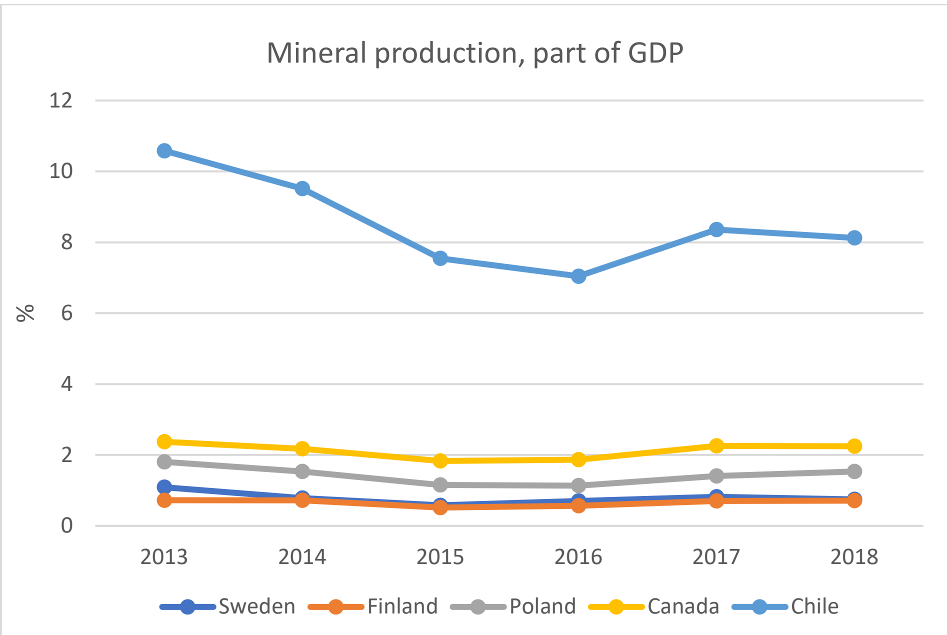

Figure 8.2. Mining's contribution to GDP of some selected countries (source: RMG Consulting).

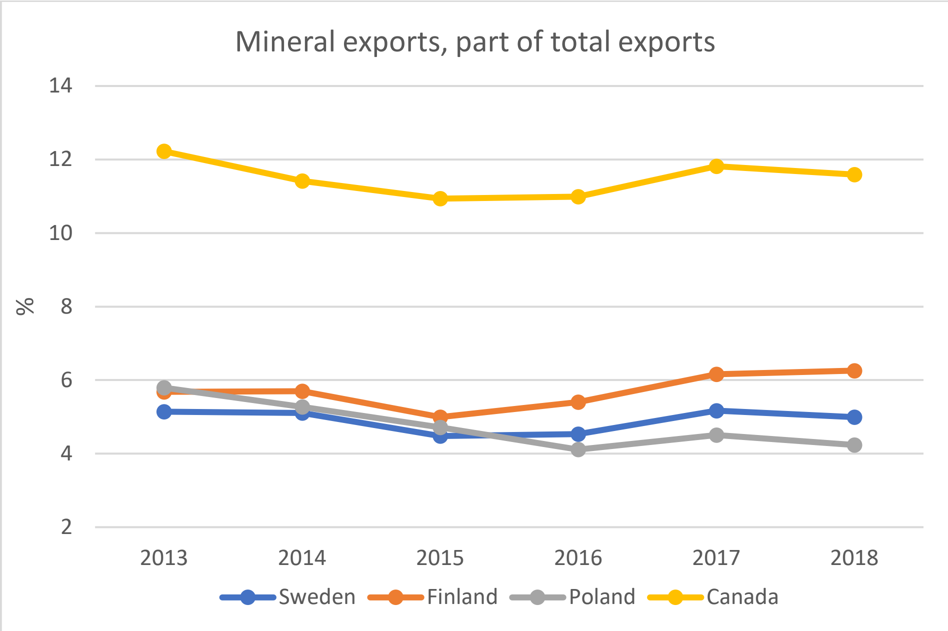

Figure 8.3. Mining sector's part of national exports for some selected countries (source: RMG Consulting).

There are no royalties payable to the state for mineral extraction in Sweden. In this, Sweden is rather unique (along with the other Nordic countries) as few other mining countries have a similar set up (of the important mining nations, only Mexico had no royalty – although that changed in 2014). In Sweden, there is however a so-called mineral fee payable, in cases when mining occurs on private land. The mineral fee is 0.2% of the value of the minerals extracted, with 0.15% of the value of minerals being payable to the landowner and 0.05% to the state. The annual mineral fees are rather small sums and during the study period, they increased from a total of about SEK4 million in 2013 to SEK12 million in 2017 (data on mineral fees for 2018 not available yet).

At the end of 2018 Boliden had 5,819 employees, which represented an increase by about 1,000 since 2013. LKAB reduced its employees with a couple of hundred between 2013 and 2017 but at the end of 2018, with 4,259 employees, the company employed more or less the same number of workers as in 2013.

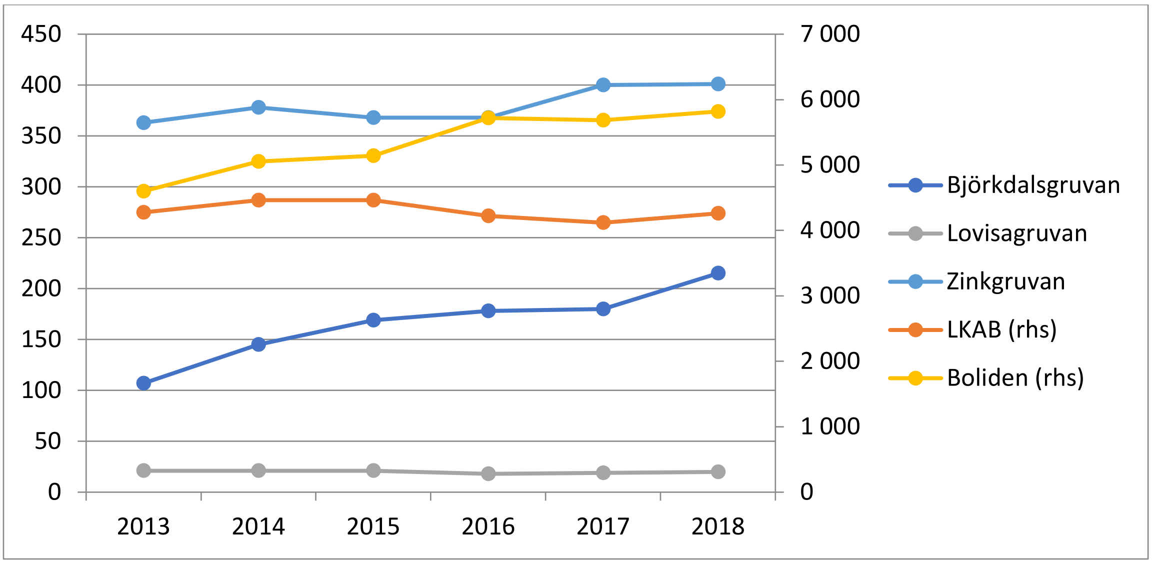

Figure 8.4. Employment in Swedish mining companies.

The mining industry is especially important in areas of the country where other employment is relatively scarcer. Thus, Boliden is the largest private company employer in the counties of Västerbotten (1,725 employees) and Norrbotten (675 employees). LKAB is an even more important employer in the Norrbotten county (3,475 employees).

Similarly, Rönnskär employs over 800 people, and is the largest private company employer and second most important employer overall in Skelleftea (second to the Municipality, that employs some 8,000). The Boliden processing plant has an all dominant position in Boliden town. By considering data on the regional average GDP per capita in Västerbotten (SEK 372,000 in 2017) and the population estimates for Skellefteå municipality, and Västerbotten as a whole, one may deduce that the turnover of Rönnskär represents some 3% of the county's GDP, and around 20% of the GDP generated in the Skellefteå municipality.

8.2. Attractiveness and competitiveness

The number of mining concessions applied for and granted provides an indication if Sweden is a globally attractive and competitive country for mining related investments. The results of the yearly Fraser Institute survey provide a similar gauge of how Sweden compares internationally as being prospective for mining related investments. Thus, Figure 8.5 illustrates that a total of 29 (2-9 yearly) applications for mining concessions were submitted during the period of study. Given that over the past few years, there were some 150 valid such concessions, this suggest that there is considerable interest in investing in mining in Sweden. Sweden also ranks relatively high in the Investment Attractiveness index of the Fraser Institute, although the trend in this regard has been negative in the last few years, with Sweden slipping from being ranked no. 6 in 2013 to no. 21 in the last survey. One possible reason for this slide may be the lengthy periods for administrating applications for mining concessions. Thus, in Table 8.1 it is show that whilst administration times for exploration permits have been rather steady or decreased during the study period, the time it takes to administrate an application for a mining concession has increased rather dramatically. Given that the number of applications for mining concessions are few (between 2-6 during the study period), it is reasonable to believe that it is not the number of applications that is the problem. Rather, there are specific issues, and these appear to relate to resistance from stakeholders, notably reindeer herders and Sami representatives, as well as uncertainties that have developed regarding how applications should be evaluated, and what the exact requirements should be.

Minehutte (www.minehutte.com) regularly ranks countries in terms of relative regulatory risk. In 2019, Sweden scores 67 (out of 100) which is in the "low risk" category and this may be compared with Finland (62, moderate risk), Spain (52, substantial risk) and British Columbia (85, minimal risk).

Table 8.2. Mean administration time for application to the Mining Inspectorate.

Days	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Expl. permits appl., administration time	119	104	82	78	86	99
Mining concessions appl., administration time	550	825	941	453	1,080	957

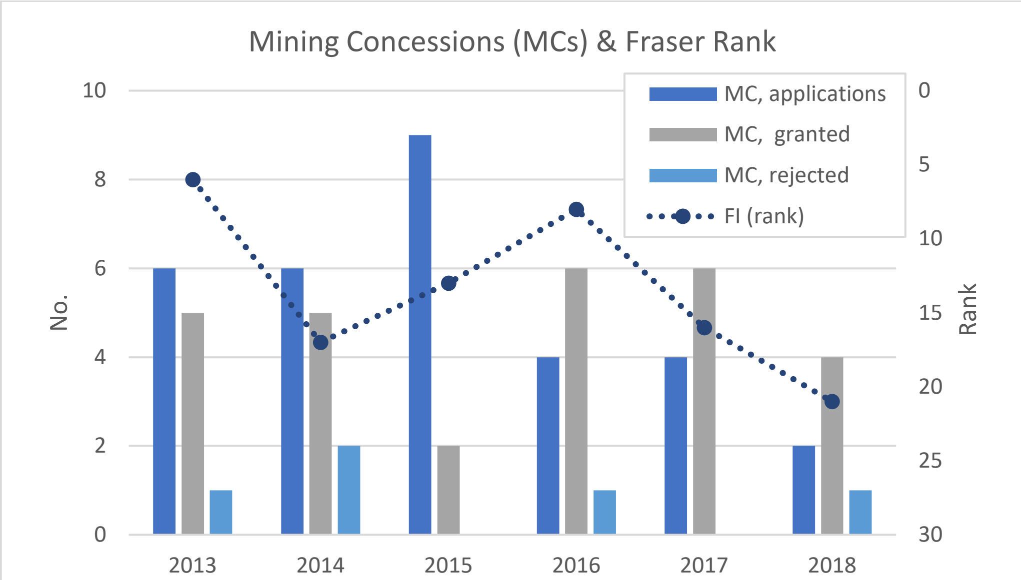

Figure 8.5. Data on mining concession applications in Sweden, and the country´s overall ranking on the Fraser Index (sources: SGU, Bergverksstatistik and Fraser Institute).

The number of valid and granted exploration permits, and the relative land covered by such licenses are shown in Figure 8.6. The land covered varied rather widely, between 1.5-3% of Sweden's total land area (including lakes, protected areas and other areas where exploration is either impossible or restricted). This may be compared to other countries and/or territories such as South Australia where close to 25% of the territory was under exploration licenses in mid 2019.

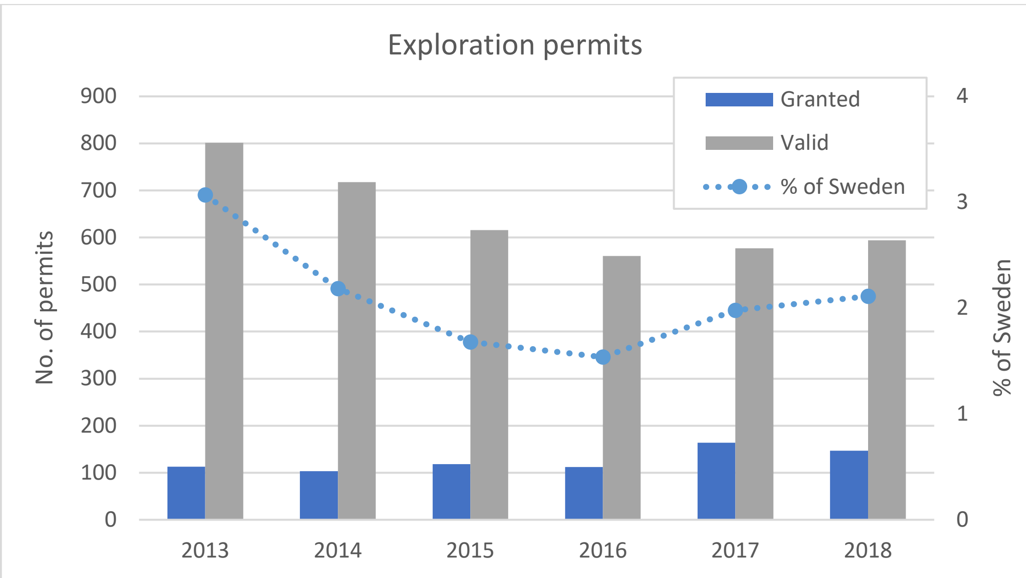

Figure 8.6 Exploration permits in Sweden (source: SGU, Bergverksstatistik).

8.3. Gender aspects

The Swedish metals and mining industry is making continued progress towards becoming a more gender equal sector, albeit from a low base. Thus, Figure 8.7 shows that the proportion females is increasing year to year, both with regards to "blue" and "white" collar positions.

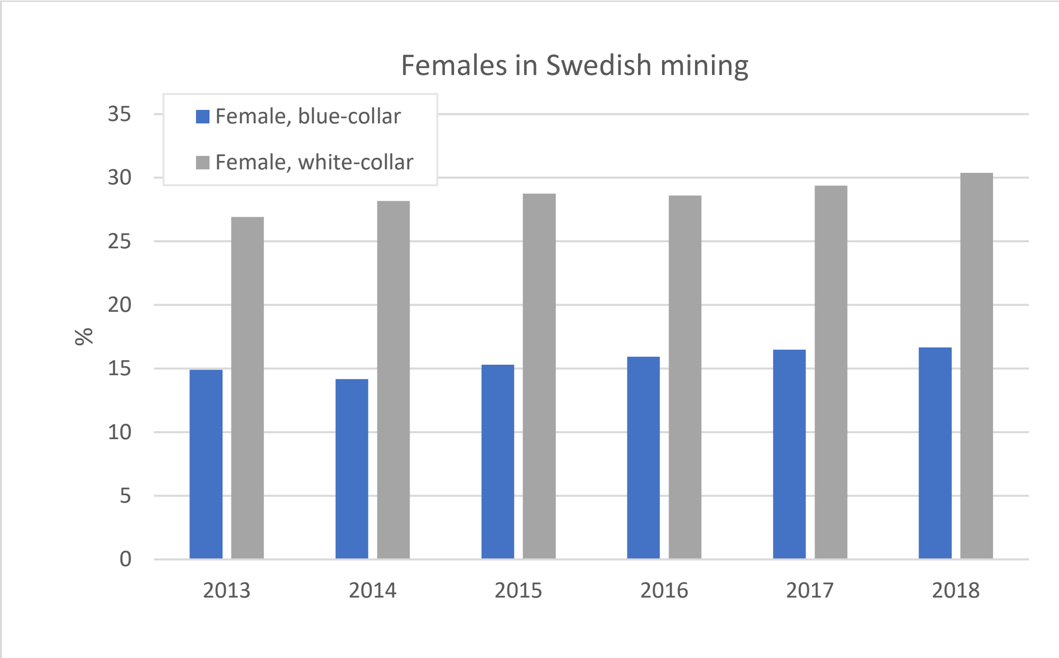

Figure 8.7. Data on the share of females in the Swedish mining sector.

The share of women in mining companies increased during study period (Figure 8.8). LKAB has the highest proportion of women employed at 22% (2018), a marked increase from 18% in 2013. For Boliden, the share of female employees increased from 16.5% in 2013 to 18 % in 2014 and has been more or less at that level since then. At Zinkgruvan, the female share of staff was between 17-18% over the study period. Björkdalsgruvan did not report the female share of total staff, and Lovisagruvan has two female employees out of twenty in 2018.

The share of managers that are women has been steady at around 20% for both LKAB and Boliden over the study period. The share of female board members in the Swedish mining companies have increased during the period of the study, but women are still underrepresented (Figure 8.9).

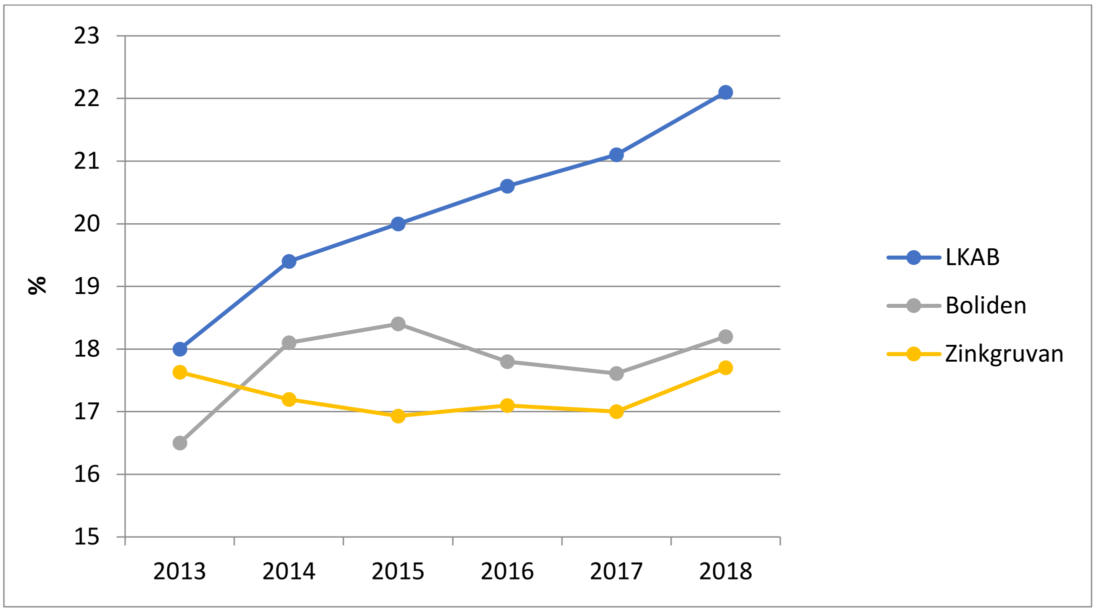

Figure 8.8. Share of female workers in Swedish mining companies.

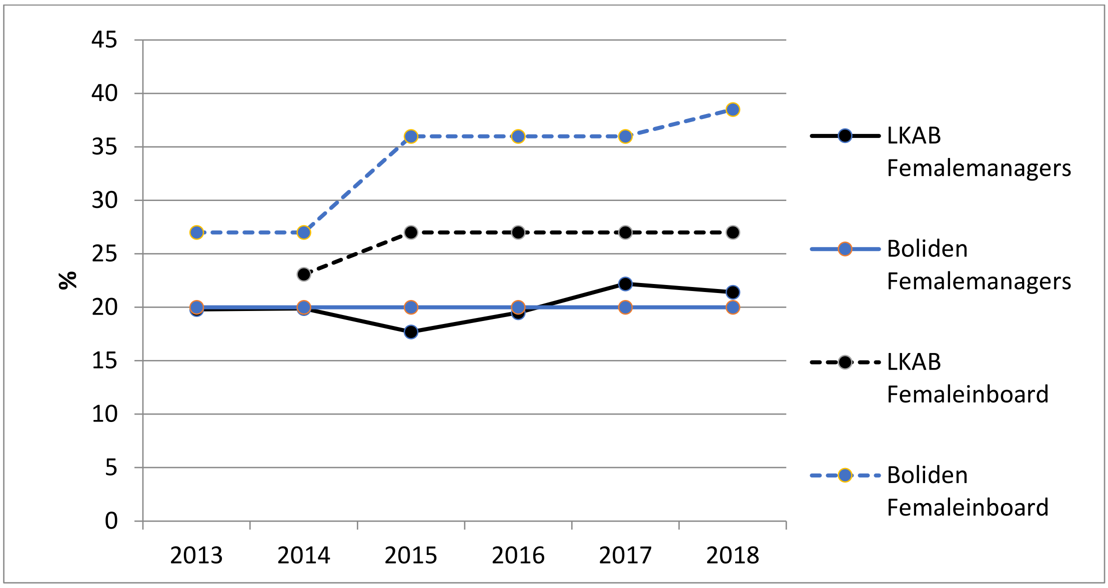

Figure 8.9. Share of female managers and on the boards of Swedish mining companies.

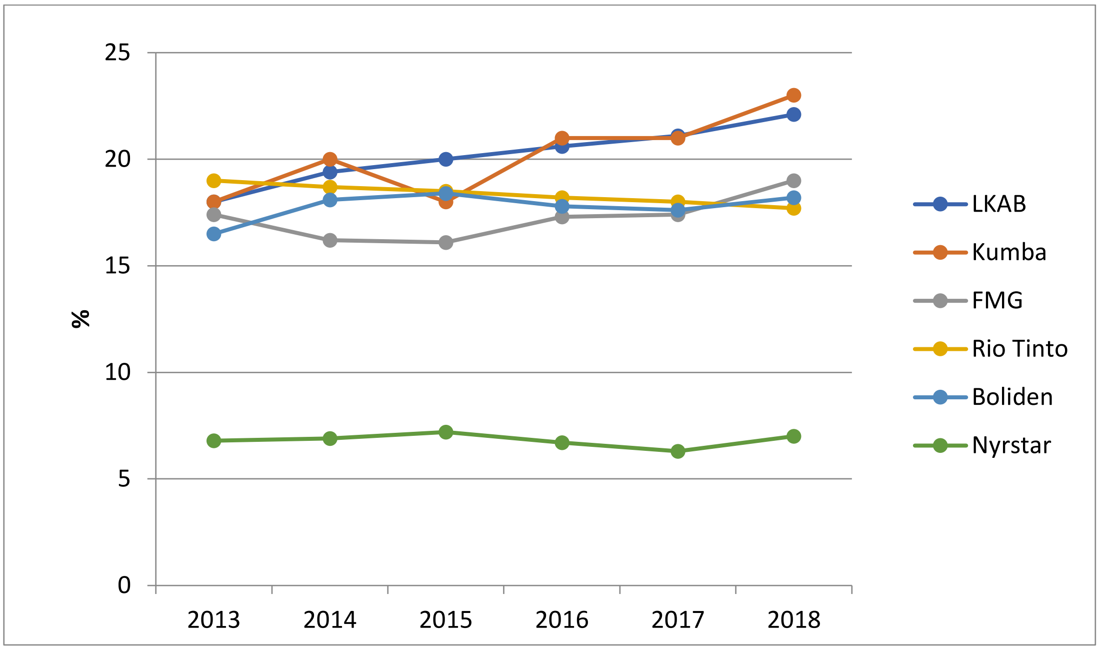

Figure 8.10. Share of female workers in Swedish and selected international benchmark mining companies.

When benchmarking the share of female employees in Swedish companies, it is shown that they feature among the top companies but that they are not outstanding. LKAB and Kumba has the same share of female employees and Boliden's numbers are similar to those of Rio Tinto and FMG. But there are still companies like Nyrstar with a share of female workers at very low levels only around 6-7% of total workforce (Figure 8.10).

9. Summary and conclusions

Sections 9.1 – 9.7 below summarise the results of the study, and based on these results, Section 9.8 considers the overall development of the Swedish metals and mining sector during the study period.

9.1. Observations on method and approach

The data and findings presented in this report confirm the assertion that it is possible to make useful analyses of sustainability performances in the metals and mining sector by using public data. To our knowledge, the work presented here is pioneering in that it includes data and evaluation on all components of sustainability in the metals and mining sector of one country (social, economic and environmental). The fundamental reason why this is possible is that relevant data is available and deemed to be trustworthy and of adequate quality. The database that has been built up in this regard is, consequently, a useful tool that may be used for a wide range of different purposes. From this follows that it would be valuable if the database could be updated regularly. This is especially relevant since the metals and mining sector is a capital-intensive sector where changes often occur more slowly and gradually than what is the case in many other sectors. This, in turn, also implies that the five years studied in this report may in some cases be on the short side when it comes to ascertaining changes that occur in the sector.

There are also other limitations in terms of the data and of the approach used. Thus, whereas data coverage for many aspects is good (e.g. financial and production data), moderately good for others (e.g. environmental impacts, such as discharges and emissions), it is patchy or even rather poor for other aspects (e.g. social acceptance and tailings dam safety) that we have sought to evaluate. In attempting to benchmark the performance of the Swedish metals and mining sector it also becomes clear that there exist substantial obstacles. These include that it is mainly countries and/or companies that have comparatively higher ambitions in terms of sustainability that tend to report relevant data and, thus, that the benchmarking that can be made is not representative but is mainly concerned with those that are "best in class". Data are also often collected in ways that make direct comparisons difficult or even impossible. For the larger corporations, much of the sustainability data are reported in compliance with the GRI standard which overall facilitates comparisons. However, some data that is seen as important in one jurisdiction or context is less important in another. For example, it is internationally common to include data on how many indigenous people and/or local people are employed (e.g. in Australian or South Africa). In Sweden, it is not even legal to keep such records (i.e. records based on ethnicity). Another sustainability indicator that is clearly stated in international companies is community investments. This is not reported on in Sweden, as mining companies are not generally seen to have a special role or responsibility in this regard (c.f. Tarras-Wahlberg et al., 2017). Taxes paid is also much more clearly stated by international companies, compared to those operating in Sweden. In many countries, companies report what share of procurement is local. None of the Swedish mining companies report such numbers.

Finally, it should be noted that whereas the current project is concerned with primarily assessing the outcomes and impacts of SIP-STRIM, the approach used is really more suited to assessing wider issues within the metals and mining sector and these may have relatively little to do with the various initiatives and projects that are undertaken within Swedish Mining Innovation.

9.2. Efficiency and competitiveness

The number of mines in Sweden decreased from 16 to 14 in the study period, whilst production levels remained stable. There were significant improvements in the mineral processing efficiency at Boliden's operations at Aitik, Boliden and Garpenberg. This is overall a continuation of a longer term trend of fewer, more efficient and productive mining operations. The number of people employed in the sector did, however, not decrease. In terms of the companies, Boliden expanded considerably, mainly due to acquisitions in Finland, although to some extent due to increased production at Aitik and Garpenberg. In terms of profits made, Boliden stands out as the best performer.

The production cost – cash costs of producing a unit of product – of the Swedish mines generally fall towards the higher end of the spectrum. Only Garpenberg is a low cost producer, whereas Aitik and Zinkgruvan fall close to the median cash cost. Given this, most Swedish mines must be highly efficient to stay competitive. The LKAB mines are in an international context very high cost producers, but these mines are made competitive through processing, creating a higher value product (pellets). In terms of efficiency overall, the larger companies – Boliden especially but also LKAB - created considerably more value per person employed, than the smaller companies. When compared to international peers, only Boliden compares favourably in this regard over the period of study. Boliden's Rönnskär smelter increased production, efficiency and profitability during the study period.

In terms of health and safety, the metals and mining sector is more accident prone than most other sectors of the economy, although similar to construction and building and significantly less dangerous than the transport sector. The trend over the study period was slightly positive, with decreasing numbers of accidents. When compared, data from the Swedish operators compares rather poorly with international peers.

9.3. Resource efficiency

The proven and probable reserves of the mines increased considerably over the study period, although the positive developments were concentrated to a small number of mines. Thus, Aitik and the LKAB underground mines had established about 20 years of proven reserves by 2018, and Garpenberg and Zinkgruvan had 10 and 5 years respectively. The other mines, especially the Boliden mines in the Skellefte field, generally have small reserves only. In terms of resources (less well-defined), the amount that LKAB hold in comparison to production is small compared to international benchmarks, which represents a significant longer term concern.

In terms of exploration, the amount spent on finding and defining new resources and reserves increased significantly over the study period. The amount of money spent in Sweden was on a per ha basis similar to Finland, although in Finland the amounts spent were more concentrated on fewer and smaller areas. In comparison to Canada, the amount spent on exploration per unit land area in Sweden was about 7 times less (in spite of Canada's enormous and partly very remote territory), showing that although somewhat attractive, there are territories that are better than Sweden in attracting exploration expenditure.

Boliden is the only sizeable metals and mining company that performs recycling/reuse of metals to any significant degree. Rönnskär is a world leader in this regard, and the production of metals from e-scrap represents about 1/10th of Boliden's entire production. Another improvement during the study period was that Boliden developed a method to extract Tellurium, a new product, from the Kankberg mine's ore.

There were noticeable reductions in the use of fresh water. This was most clearly seen at Aitik, where essentially all the processing water now is recycled, and only some 100,000 cubic meters or less per annum of fresh water is abstracted. The amount of water used at some other operations also decreased, largely as a result of a decreased water intensity in mineral processing. The Boliden plant uses significantly more freshwater than the other sites and uses only very limited recycled water.

9.4. Energy efficiency

The metals and mining sector is a substantial user of energy. Over the study period, there was no sign of any overall reduction in energy use, nor of a significant shift to non-fossil fuels. Further, as other sectors of Sweden's economy managed to reduce fossil fuels dependence somewhat, the metals and mining sector's share of the total fossil fuel consumption increased, with the largest contributors being LKAB followed by Rönnskär. However, although a large emitter domestically, LKAB is in an international comparison with other pellets producers, a low emitter.

Aitik represented a clear exception however as the increase in production was achieved with a concomitant shift towards higher overall energy efficiency and a relative lowered dependence on fossil fuels. The Kiruna mine and the Rönnskär smelter also become somewhat more energy efficient since 2015. At Rönnskär specifically, a substantial part of the energy used is being re-used to heat the city of Skellefteå[9].

9.5. Environmental impacts

Mining is a comparatively insignificant user of land, with all current mining concession (151 to 166 during the study period, with about a tenth of those being active) covering no more than 130km^2 (0.03% of Sweden's land area). Of more interest than actual land take is therefore to what extent the active mines are able to ensure that land and water outside the perimeters are not impacted. Swedish mining companies have made, and are making, considerable efforts to reduce environmental impacts. Data from the study period show that positive results of these efforts are achieved. Thus, there were significant reductions in both discharges and emission of contaminants, most notably metals to water. Today, the annual discharges of metals from mines are generally counted in kilograms and are often contributing comparatively small amounts when compared to the natural transport of metals in rivers and streams. The improvements have been achieved due to a mix of improved management and the installation of new environmental technology during the study period, most notably at Aitik, Rönnskär and at the Svappavaara pelletising plant. Similar successes in limiting discharges of nitrogen and phosphorous to water have not been achieved, and aggregated data suggest that such discharges are overall on the increase.

The mechanisms which require environmental bonds for mining and related operations began to develop at the turn of the millennium, and the current framework was established in 2008, which was somewhat late in an international comparison. By 2018 some SEK2.8 Billion was lodged in such bonds, with more than half being lodged for Aitik, and nearly 25% for Rönnskär. The exact nature, and size, of environmental bonds is still a comparatively recent and undeveloped field, and discussions are ongoing on the need for refining and/or strengthening the relevant legal and administrative frameworks.

Issues related to mining waste and specifically tailings dam safety is attracting widespread attention and concern internationally. In Sweden, companies are required to follow specific dam safety guidelines, and to report performance to the authorities. In 2018, the total area covered by tailings dams and clearing ponds is reported to be in the region 31 to 39 km^2. There are discrepancies in data as well as a dearth of available data that allow assessment of performance and risks. Given international events (e.g. the ongoing Global Tailings Review), improvements in this regard are required, and a similar case can be made for waste rock deposits.

9.6. Improved acceptance

Specific data on the acceptance of the mining and metals sector are hard to come by, but there is indirect evidence, which may be used. The numbers of appeals against exploration

[9] Similar plans exist in term of using heat from the LKAB pelletising plants in Kiruna.

permits increased significantly during the study period, in turn suggesting an increasing opposition to the sector on part of at least some stakeholders, notably the reindeer herding Sami and some environmental groups. The number of grievances and formal complaints reported against companies or specific operations does not provide any clear trend, whilst this may in part depend on a lack of well-defined criteria for registering grievances and complaints. Another indirect indicator is how students rank prospective employers, and the results of such surveys suggest that at least LKAB and Boliden have a reputation as fairly attractive employers which, in turn, should indicate a certain social acceptance / license to operate.

9.7. Other impacts

One Swedish Mining Innovation objective is to ensure that Sweden is a strong and competitive mining country. The metals and mining sector share of the GDP over the study period was stable at 0.5%, but the sector was more important in terms of investments made (0.6-1.4%), and even more important in terms of export (3-4% of total). One characteristic of the metals and mining sector is the ability to generate large values, from comparatively small areas. Thus, the currently active mines cover only about 190km², but generates values in the same order of magnitude as does the agricultural and the forestry sector, which use about 150 and 1,200 times as much land, respectively.

The relative importance of the contribution of the metals and mining sector to the national economy are similar to that of Finland, although in Finland the sector is growing whereas in Sweden the sector decreased slightly in importance over the study period. Other developed and diversified countries where the mining sector make a comparatively more important contribution to the economy include Canada and Poland.

In terms of being attractive for exploration, the area covered by exploration licenses varied between 1.5-3% of Sweden's land area which is rather low by international comparison. Sweden's rank in the Frazer index - concerned with ranking countries attractiveness for investments in mining and exploration – fell from 6th to 21st during the study period, suggesting that Sweden is losing ground in this regard. One reason is for this include the doubling of the average time to administrate applications for mining permits during the study period. This, in turn, appear to be related to combination of increased resistance from stakeholders, notably reindeer herders and Sami representatives, as well as uncertainties that have developed regarding how applications should be evaluated, and what the exact requirements should be.

The metals and mining sector is especially important in certain regions and mining companies are the most important private sector employers in the counties of Norrbotten (LKAB followed by Boliden) and Västerbotten (Boliden). Further, the mine and processing sites are more often than not the most important employer in the municipalities in which they are situated.

Female participation in the sector is growing, albeit from a low base. Among the companies, LKAB is doing best and as such feature high among international peers, although not at the very top. Boliden and LKAB spend 1.3 to 1.7% of turnover on Research and Development respectively, and this is more than their international peers.

9.8. Concluding remarks

The Swedish metals and mining sector is a minor user of land, but it generates values and contributions to the economy that are similar in size to other natural resource based sectors that require much larger areas (e.g. forestry and agriculture). It is furthermore a sector which is especially important and vital to the economy of northern Sweden, and which is completely dominated by two companies (LKAB and Boliden) and a small number of larger operations (Kiruna, Malmberget, Aitik and the Rönnskär smelter). However, the sector's relative contribution to the national economy was stagnant during the study period, although underneath this pattern is hidden some positive developments related to improved efficiency and competitiveness, especially at Boliden's operations at Aitik, Garpenberg and Rönnskär.

The overall picture in terms of mineral reserves improved somewhat during the study period, although mainly caused by exploration successes at Aitik. At other sites, the situation is less favourable. The lack of larger mineral resources is a considerable medium term concern for LKAB's mines, and a rather urgent concern for some of the smaller mines in the Skellefte field. Overall, the longer term survival and sustainability of the sector requires more resources and reserves to be established which, in turn, requires more exploration to be performed.

In terms of exploration, Sweden remains fairly attractive although less so than Finland, and much less so than a top mining and exploration destination such as Canada. In spite of the relatively modest level of exploration activity, and the low number of operating mines, there are clear signs of the sector meeting an increased "resistance" as shown by an increasing number of appeals against mining and exploration ventures. This suggests that the sector is struggling to maintain support from at least some sectors of society, notably reindeer herders and Sami representative, and environmental conservation groups.

Although mining is a long term business, with long time horizons, the report shows that it is still possible to achieve major and rapid improvements in sustainability related aspects. Thus, there were impressive improvements made in terms of reducing discharges and emissions to the environment during the study period. The Swedish metals and mining sector benefits from the energy mix supplied, which includes a considerable part of renewable sources. However, the sector is still not able to reduce its overall CO_2 footprint to any significant degree, although there have been some significant gains made in terms of energy efficiency.

When compared to international peers, Boliden especially perform well in terms of profitability and efficiency. LKAB is also doing well, especially when compared to producer of pellets. Overall, the sector is improving in terms of gender related aspects, and is doing rather well in an international comparison. Areas where the Swedish metals and mining sector fares less well include health and safety issues, and public disclosure of risks and issues related to the management of mine and processing waste.

Overall, the study has not been able to evaluate the specific performance of Swedish Mining Innovation, but it has identified serious and wider issues of concern within the metals and mining sector that must be addressed, with the most serious being: a relatively low level of exploration activity and success; increasing distrust of the sector on part of certain stakeholders; and limited progress in terms of minimising the sector's contribution to climate change.

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Appendix 1 – List of data and KPI's

Swedish Mining Innovation outcomes

More efficient and highly competitive processes, equipment & methods for the full value chain	
Data / KPI	**Datasource / Notes**
Metal production	Company reports, Env. reports, Bergverksstatistik
Ore production underground	
Ore production open pit	
Average production per worker and working hours, iron ore mines	Bergverksstatistik
Average production per worker and working hours, non-iron ore mines	Bergverksstatistik
Waste rock	Company reports, Env. reports, Bergverksstatistik
ROM	Company reports
Tailings	Company reports, Env. reports, Bergverksstatistik
Assets	Company reports
Revenue	
Pre-tax profit	
Net-profit	
Capex	Company reports, SCB
Cash cost	Company reports
Strip ratio	Company reports, Env. reports, Bergverksstatistik
Recovery	Company reports, Bergverksstatistik
Health & safety	
Occupational health problems / 1 000 employees	Company reports, Bergverksstatistik
No. accidents – staff and contractors	Company reports
Fatal accidents - staff and contractors	
Occupational health problems / working hours	
Work days loss due to accidents/injuries	

Increased resource efficiency	
Data / KPI	**Datasource / Notes**
Water usage / recycling	Env. Reports
Metal produced though recycling	Company reports, UNCTAD, WBMS
Exploration, meters drilled	Company reports
Exploration, cost	Company reports, Bergverksstatistik
Resources/ reserves	Company reports, Bergverksstatistik
Cost per meter drilled	Company reports

Increased energy efficiency	
Data / KPI	**Datasource / Notes**
Energy consumption GWh	Company reports, Env. reports
Electricity consumption	

Fuel consumption	
Total renewable energy GJ	
Total non-renewable energy use GJ	
Energy consumption (kJ/tonne of products)	
Energy consumption (diesel)	Env. Reports
Carbon dioxide emissions per tonne of product (kg/tonne)	Company reports
Carbon dioxide emissions	Company reports, Env. reports
Energy saving through recycling	SGU, SEPA

Decreased environmental impact	
Data / KPI	**Datasource / Notes**
No. of environmental conditions	Env. Reports
Transgressions of environmental conditions	Env. Reports
Recycling	
Degree of recycling	SGU, SEPA
Metal usage	SGU, SEPA
Emission to air	
Particles (tonne)	
SO2 (tonne)	
F (tonne)	
HCl (tonne)	
Nox(tonne)	Company reports, Env. reports
Particles PM2, 5, 10	
NH3	
Mercury	
Discharges to water	
Nitrogen (tonne)	
Phosphorus (kg)	
Chrome (kg)	
Cadmium (kg)	
Copper (kg)	
Nickel (kg)	Company reports, Env. reports
Lead (kg)	
Zinc (kg)	
Arsenic (kg)	
Metal discharges to water, tonne	
Total water withdrawal in million m3	
Production of waste	
Hazardous waste	Env. Reports
Non-hazardous waste	Env. Reports
Waste rock / overburden sold	
Overburden used for refill	
Waste rock deposited in waste facilities	Env. reports, Bergverksstatistik (national level)
Tailings used for refill	
Tailings deposited in waste facilities	

Increased acceptance for the mining industry	
Data / KPI	**Datasource / Notes**
LKAB survey	LKAB
Svemin surveys	Svemin
Corporate surveys on popularity of companies	Universum
No. reported grievances at mine/processing sites	Env. Reports
No. licenses for exploration	Annual report from Bergstaten
No. applications for licenses for exploration	
Area of licenses for exploration (km2)	
No. persons holding licenses for exploration	
No. companies holding licenses for exploration	
No. applications for extensions of licenses for exploration	
No. applications for extensions of licenses for exploitation (granted/refused)	
No. appeals against decisions	

Swedish Mining Innovation impacts

A strong and competitive mining country based on innovations	
Data / KPI	**Datasource / Notes**
Patent, intellectual property in sector	
Equipment manufacturers - market shares, turnover	Company reports, RMG Consulting
National value of mining industry	RMG Consulting
Salary structure in mining districts	SCB
Educational structure in mining districts	SCB
Regional and local employment generated by mining industry	Company reports, SCB
Regional and local value/importance of mining industry	SCB, Municipal budgets

Increased competitiveness	
Data / KPI	**Datasource / Notes**
Fraser institute survey	Fraser institute
Mining Contribution Index	RMG Consulting
Mine Hutte	Regulatory risk assessment
Production	Company reports
Cash cost	
Profit ratio	
Level of investments	Company reports, SCB, RMG Consulting
Market shares for individual metals	BGS, WMD

A more innovative and gender equal mining industry	
Data / KPI	**Datasource / Notes**
Share – female/male employees	Company reports, Bergverksstatistik

Share - female in management	Company reports
Share - female in board	
Patents & intellectual property	
Total staff	Bergverksstatistik
Staff in Sweden	
Contractors – no.	
Population structure in mining districts	SCB
Education level in mining districts	SCB

Leading research & innovative eco-system	
Data / KPI	**Datasource / Notes**
R&D	Company reports
Research funds	Company reports, University records
Education	University records
Publications	University records
Patents	University records
Programs initiated	Vinnova, SIP-STRIM
SME who participate in projects	SIP-STRIM
No. of SME in sector	Vinnova

Appendix 2 – PiNFO

The data collected in the project will be stored in a software called PiNFO. PiNFO has been developed by a sister company to Swedish Geological AB, and it has previously been used in similar projects. PiNFO allows data that in some way is spatially organised to be stored, displayed and searched visually. PiNFO is web-based and the data entered is stored in a "cloud", which enables access from any computer that have internet access and a browser. The data and documents entered into PiNFO are stored on a secure server and remains the property of the account holder.

PiNFO's main strength is its ease of use, which means that although it contains some key functionalities found in more complex GIS software, it can be operated by practically anyone, after only a few hours (or less) of training. Multiple users can access PiNFO and these users may be designated with variable user rights. An (or several) account administrator invite new users to access the system, and the administrator can configure whether this new user can create new objects, moderate changes or simply search and view existing data. The administrators act as "moderators", which means that they can locate data that has been added or updated to identify and review changes made and either accept or reject these changes. Changes and additions become visible to other users only once released by a moderator. Multiple users can capture and edit data simultaneously in PiNFO. All data and files entered into PiNFO can readily be exported into excel.