Asia-Pacific
Economic Cooperation

Advancing Free Trade
for Asia-Pacific Prosperity

# Mining Industry Competitiveness

## APEC Mining Task Force

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# Table of Contents

# Index of Tables



# Index of Figures

# 1. Executive summary

- When it comes to the ratio of produced metal over processed ore, Russia presents the highest figure for copper, likely explained by the fact that an important proportion of copper production is a by-product of nickel. Not surprisingly, Australia is #1 in iron ore and the Philippines in nickel. Chile and Peru are among the least productive in the copper industry – this may be related to the fact that a very large proportion of their production comes from large open pit mines whereas other economies (like Australia) present a relevant proportion of underground operations.
- Data suggests that labour productivity does not correlate with production levels in the copper and iron industries. In other words, economies of scale would not result in labour productivity gains as it might be intuitively expected.
- Peru seems to be highly productive in terms of electricity consumption across most of the commodities under analysis. China also ranks high in relevant industries such as iron ore, copper, nickel and bauxite. No clear differences can be observed between developed and developing economies in this field.
- The analysis of labour productivity yields some interesting results. The United States is ranked #1 in all the commodities where data has been obtained (the source of information is the U.S. Bureau of Labor Statistics). More broadly, developed economies (Australia, Canada, USA) tend to present better indices of labour productivity. This is one of the key findings of the study and certainly requires further research to be understood. Labour regulation, work practices and education are some of the areas which have an impact on labour productivity which may be addressed by future studies.
- Viet Nam, Russia and Canada are the three economies with the highest penetration of female employees which stands at ~20%. Chile and Peru are located on the opposite side of the spectrum with the lowest participation of women in the industry: 8% and 6% respectively. These percentages have not changed significantly in the last five years. In general terms, gender distribution has remained relatively stable among the economies under analysis.
- All the above conclusions need to be further analysed in subsequent studies, with the expansion and validation of the existing data set.
- The response rate from partner organisations has been relatively low. The depth and length of the questionnaire has been a deterrent for a number of organisations that, in principle, were interested in supporting the project.
- None of the organisations have been able to complete the questionnaire in full. Canada and Chile are the economies that provided more information – submitting data for 6 indicators (either partially or in full).

# 2. Introduction

## 2.1. About the project

One of the fundamental pillars of competitiveness is productivity. Since the economic downturn of 2008, mineral commodity prices have not fully recovered reducing companies operating margins and their contribution to tax revenues. This new economic environment requires companies to achieve greater production efficiencies, focusing their efforts on improving the use of resources, rather than just increasing the supply to market. Governments, companies and communities need reliable databases, populated with actual global mining industry experience, to provide transparent information about factors that influence productivity. With such tools, the investment and approval decision process, and the elaboration of guidelines, laws and public policies that promote and manage the mining industry, could be made easier.

A key development challenge for the Asia-Pacific Economic Cooperation (APEC) forum is to increase knowledge about leading policies and practices, including how input resources are utilized, such as energy, personnel, assets or commodities. Information from mining projects around the globe can be incorporated to close gaps between different economies and increase the contribution of economies to the industry's performance all over the region

**The main goal of this project is to develop a set of productivity indicators and to assess demand for data on productivity for the mining industry**, building upon existing commercial and public information. With better data systems, APEC economies will obtain reliable and transparent information about mineral production levels, and the economic factors that contribute to sustainable development of the mining industry.

## 2.2. Objectives and scope of the project

The main objective of this project is the dissemination of key industry information at economy level to increase the competitiveness of APEC economies due to the availability of a consistent productivity dataset. The longer term impact is to strengthen economic growth, investment, trade and business capacity, delivering development benefits for communities and resources for expanding industries. This objective is achieved by creating a sustainable and robust methodology for data collection along with completing a repository of information.

The scope of the study covered:

- The 21 APEC economies: Australia; Brunei Darussalam; Canada; Chile; China; Hong Kong, China; Indonesia; Japan; Korea; Malaysia; Mexico; New Zealand; Papua New Guinea; Peru; the Philippines; Russia; Singapore; Chinese Taipei; Thailand; the United States; and Viet Nam.

- Thirteen commodities: copper, zinc, lead, tin, nickel, aluminium, molybdenum, cobalt, iron ore, gold, silver, platinum and palladium.

It has to be noted that some of the APEC member economies have virtually no mining activity and offer very limited opportunities in this sector.

According to the Asia-Pacific mining sector study presented to APEC in November 2014, the following economies are assessed to have low mining potential:

| | | |
|---|---|---|
| • Brunei Darussalam | • Korea | • Singapore |
| • Hong Kong, China | • Malaysia | • Chinese Taipei |
| • Japan | • New Zealand | • Thailand |

After conducting further research on this particular list of economies, the project team still identified metal commodities production volumes in some of these jurisdictions. Anyhow, the outlook for mining production for the specific commodities assessed in this study is considerably poor for the listed economies, showing strongly decreasing trends in terms of mining output in the short and medium term future.

Considering this, priority will be placed in gathering robust information from the jurisdictions with high and medium mining potential: Australia; Canada; Chile; China; Indonesia; Mexico; Papua New Guinea; Peru; The Philippines; Russia; The United States and Viet Nam.

## 2.3. Structure of the report

This document commences with an Executive summary that presents the key findings and conclusions of the study. The main body of the work is divided in three main sections:

1. *Methodology*: provides a summary of the methodology and response rates of the primary and second-layer surveys that have been conducted during the course of the project.
2. *Projects results*: this section shows the results of the project, considering all the sources of information utilised during the execution of the study.
3. *Final analysis:* presents an overview of key findings in terms of productivity data.

The data shown in **Project results** chapter comprise three main sources of information:

1. A primary survey conducted with ‘partner’ organisations within APEC economies that have supported the execution of this project;
2. Estimations;
3. Second-layer survey conducted to complement a number of indicators where the initial two sources did not yield positive results.

# 3. Methodology

As mentioned before, the dataset was constructed based on three different sources:

1. A primary survey conducted with 'partner' organisations within APEC economies that have supported the execution of this project;
2. Second-layer survey conducted to complement a number of indicators where the initial two sources did not yield positive results;
3. Estimations

This chapter describes the methodology utilised for the primary and second-layer surveys.

## 3.1. Primary survey

The primary survey was conducted with the objective of populating and compiling a repository of information with all the information collected from APEC economies. A key assignment in this study was to find reputable public and/or private organizations at each APEC member economy that could consistently deliver the required information for maintaining the above-mentioned repository of information.

As such, fifty nine organisations across the twelve economies[1] included in this study were identified and contacted. In a first instance these organisations had been approached with the objective of introducing the project and obtaining a written confirmation of their willingness to participate in this study – at this stage 25 organisations confirmed their interest. An example of a written confirmation is shown at the right hand side of this page (**Figure 1**). As it can be noted in this example these confirmations were tailored to the language of the target organisations.

**Figure 1 Written confirmation example**


Asia-Pacific Economic Cooperation

CRU THE INDEPENDENT AUTHORITY MINING | METALS | FERTILIZERS

Form expressing interest to collaborate in providing available information to APEC for the study entitled "*Mining Industry Competitiveness: Improving Productivity and Data to Attract Investment*"

亚太经济合作组织《矿业行业竞争力：提高生产力和引进投资》调研同意书

Name of organisation: China Iron and Steel Association

机构名称：中国钢铁工业协会

China Iron and Steel Association agree provide available information published in "China Steel Yearbook" and "China Steel Statistics" to APEC for the latter's study entitled "*Mining Industry Competitiveness: Improving Productivity and Data to Attract Investment*".

中国钢铁工业协会同意向亚太经合组织提供《中国钢铁工业年鉴》和《中国钢铁统计》相关信息用于后者进行《矿业行业竞争力：提高生产力和引进投资》的研究。

Yes 同意 ☑ No 不同意 ☐

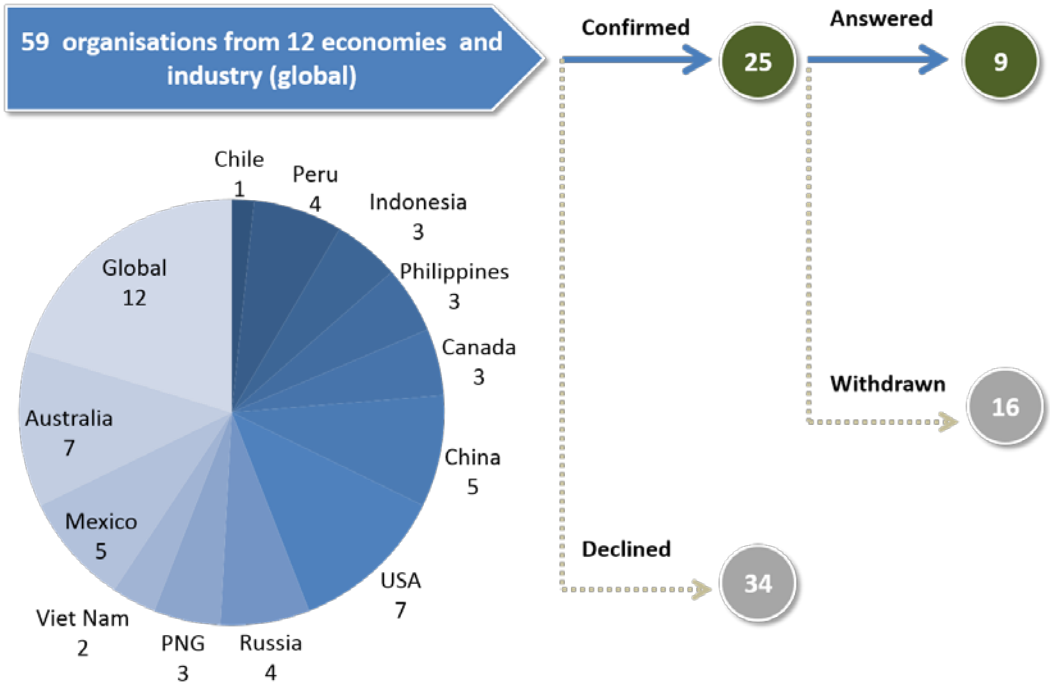
Name 姓名:

Date 日期: 2017.2.6

In a second instance the organisations which had previously demonstrated their interest in participating in the study received the survey via email. The survey consisted in a PDF file with a number of editable tables covering the information required to complete the seven indicators defined and agreed by the project team. The organisations were contacted via email and telephone, in regular intervals of 3-4 weeks

Almost all of the nine completed questionnaires were received during the first 2-3 months. Subsequent follow-up interactions did not trigger a significant share of answers. It was identified as a plausible explanation that the low response rate was not related to flaws in the methodology but rather to a lack of information from partner organisations. During this stage sixteen organisations withdrew from the process due to different reasons, although most of them claimed they were not able to gather/process the requested information or that the information was not available. As a result of the latter only nine organisations (shown in **Table 1**) successfully completed the survey. A summary of the outlined process is shown in **Figure 2**.

**Figure 2 Overview of the primary survey process**




Through the nine organisations that answered the survey the project team has been able to gather information for eight of the twelve economies under analysis: Australia; Canada; Chile; China; Indonesia; Peru; the Philippines and the United States. For the remaining economies, the dataset was complemented via estimations and secondary research.

The following table shows the organisations that completed the questionnaire.

**Table 1 List of respondent organisations**

| Engaged | Current status | Economy | Organisation |
|---|---|---|---|
| Yes | Answered | Australia | Department of Industry, Innovation and Science |
| | | Canada | Natural Resources Canada |
| | | Chile | Cochilco |
| | | China | China Nonferrous Metals Industry Association |
| | | Indonesia | General Directorate of Minerals and Coal |
| | | Peru | Ministerio de Mineria Peru |
| | | The Philippines | Chamber of Mines Philippines |
| | | | Mines and Geosciences Bureau |
| | | USA | USGS |

The extended survey period allowed us to draw a number of remarks about this process:

- The response rate has been relatively low. The depth and length of the questionnaire has been a deterrent for a number of organisations that, in principle, were interested in supporting the project.
- None of the organisations have been able to complete the questionnaire in full. Canada and Chile are the economies that provided more information – submitting data for 6 indicators (either partially or in full). On the other hand, Indonesia only shared information about production.
- “Non-current assets” was the most elusive indicator: only Canada provided information about it. On the other side, almost all economies submitted data about production by commodity.

## 3.2. Second-layer survey

The modest response rate from the primary survey created a need for additional efforts to enlarge the dataset. For this reason, a second-layer survey among top mining companies in selected economies was conducted. With the intention of achieving a higher response rate, the second-layer survey was limited to the two most relevant indicators: gender distribution and total hours worked.

This second-layer survey was focused on the two largest commodity industries in terms of market value in the analysed sample: iron ore and copper and consisted of a very short questionnaire comprising two questions.

The target sample was composed by a reduced number of mining companies operating in the copper and/or iron markets that account for a relevant proportion of the production in each economy. In case the response rate was high enough, the data provided would be considered an accurate reflexion of the indicators in each economy as a whole.

### 3.2.1. Target selection methodology

The first step of developing the second-layer survey is to determine the number of mines operating in each economy for the selected commodities. To do this, these steps were followed:

I. Identify mining operations for each commodity:

   For each economy, it has been determined which mining operations accounted for 80% of production of each commodity (iron ore and copper) taking into consideration output numbers from 2015 – this criteria was followed to select the most relevant operations today and to avoid considering operations that might have been relevant in the past but have lost their importance recently. It has to be noted that the surveyed companies have remained relevant in the respective APEC economies for many years.

II. Cross-check for repeated mining operations:

   Out of all the mining operations in the list, many of them produce two commodities or more. After cross checking for this factor, and considering both commodities under analysis in this second-layer survey, it has been concluded that a total of 171 mining operations comprise the full universe. However, this universe does not cover all operations in all economies. Therefore, there are some cases where it is not possible to identify the operations that represent 80% of production.

III. Limit the amount of economies to be surveyed:

   Given the large amount of operations that would be necessary to contact, if all of the information wanted to be recovered, it has been suggested to focus on the economies

with less than 30% of data completeness: Indonesia; Papua New Guinea; Russia; and Viet Nam. Only 18 iron ore and copper mining operations have been identified in these four economies.

In addition to this, the United States, Australia and Canada were added due to their relevance in the global mining sector. Data for these specific economies is of special interest to the users of this productivity assessment. This addition increased the number of mining operations surveyed from eighteen to sixty eight.

IV. Identify the operators of the sixty eight selected mining operations:

In an effort to further limit the amount of people to be contacted and make the second-layer survey more efficient, operators of each of the sixty eight selected mining operations were identified. Focusing on the company that operated each operation also increases the likelihood of reaching a relevant contact that might provide more high-level information.

V. Detailed prioritisation and selection of companies to contact:

For each company, it has been mapped the amount of mining operations under its control and how much production of each commodity they were responsible for the selected period. Based on this information, the project team short-listed the most relevant companies in each economy based on objective criteria on a case by case basis. The agreed indicators (workforce and gender diversity) have been researched for the period 2011-2015 for each of these selected companies.

Following the methodology described above, the following tables show all the companies selected by economy, as well as the percentage of production of each commodity they were responsible for in 2015. The same analysis has been conducted for 2011-2014. No companies have been selected in Viet Nam.

**Table 2 Companies selected to be contacted – Indonesia (% of production)**

| Company | Cu | Fe |
|---|---|---|
| Newmont Mining | 33% | |
| PT Freeport Indonesia | 53% | |
| **TOTAL - 2 companies** | 86% | |
| **TOTAL - selected companies** | 86% | |

| | |
|---|---|
| | Selected for survey |
| | No prod. |

**Table 3 Companies selected to be contacted – Russia (% of production)**

| Company | Cu | Fe |
|---|---|---|
| Aleksandrinsky Mining Co | 1% | |
| Evraz | | 11% |
| Lebedinsky GOK | | 23% |
| Mikhailovksy GOK | | 20% |
| Norilsk Nickel | 52% | |
| Russian Copper Company | 8% | |
| Severstal | | 12% |
| Stoilensky GOK | | 18% |
| UMMC | 22% | |
| **TOTAL - 9 companies** | 83% | 84% |
| **TOTAL - selected companies** | 74% | 84% |

Selected for survey
No production

**Table 4 Companies selected to be contacted – United States (% of production)**

| Company | Cu | Fe |
|---|---|---|
| Capstone Mining | 5% | |
| Cliffs Natural Resources | | 54% |
| Doe Run Co | 1% | |
| Eagle Mine LLC | 2% | |
| Freeport McMoRan | 68% | |
| Kennecott | 7% | |
| Montana Res | 3% | |
| U.S. Steel | | 28% |
| **TOTAL - 8 companies** | 85% | 82% |
| **TOTAL - selected companies** | 68% | 82% |

Selected for survey
No prod.

**Table 5 Companies selected to be contacted – Canada (% of production)**

| Company | Cu | Fe |
|---|---|---|
| ArcelorMittal | | 54% |
| Capstone Mining | 2% | |
| Copper Mountain Mining Corp | 5% | |
| Glencore | 13% | |
| Highland Valley | 22% | |
| HudBay Minerals | 6% | |
| IOC | | 37% |
| New Gold Inc | 6% | |
| Taseko Mines | 9% | |
| Teck | 1% | |
| Thompson Creek Metals | 5% | |
| Vale | 20% | |
| **TOTAL - 12 companies** | 88% | 91% |
| **TOTAL - selected companies** | 54% | 91% |

Selected for survey
No prod.

**Table 6 Companies selected to be contacted – Australia (% of production)**

| Company | Cu | Fe |
|---|---|---|
| Aditya Birla Minerals | 3% | |
| BHP Billiton | 13% | 33% |
| China Molybdenum | 5% | |
| Cobar Management | 5% | |
| FMG | | 20% |
| Glencore | 21% | |
| Hamersley Iron | | 19% |
| Newcrest | 8% | |
| Newmont Mining | 4% | |
| OZ Minerals | 13% | |
| Rio Tinto | | 4% |
| Robe River Iron Associates | | 7% |
| Sandfire Resources | 7% | |
| Straits Resources | 3% | |
| **TOTAL - 14 companies** | 82% | 83% |
| **TOTAL - selected companies** | 63% | 72% |

Selected for survey
No prod.

**Table 7 Companies selected to be contacted – PNG (% of production)**

| Company | Cu | Fe |
|---|---|---|
| Ok Tedi Mining | 100% | |
| **TOTAL - 1 company** | 100% | |
| **TOTAL - selected companies** | 100% | |

Selected for survey
No prod.

### 3.2.2. Success rate of the second-layer survey

Data for 48% of the total possible cases (considering the year 2015) was obtained through a combination of direct responses from participants and, in the majority of the cases, from CSR reports and other public sources. The completion rate decreases for previous years because the information is scarce. Naturally, the final dataset includes all the surveyed data for the period 2011-2015.

The success rate was significantly higher in the case of number of employees (77% of completeness) than in the case of % of women (23%). Responses by company and commodity are presented in the following tables (for 2015):

**Table 8 Second-layer survey, copper industry**

| Economy | Company | Response Workforce | Response Gender diversity |
|---|---|---|---|
| Australia | Newcrest | Yes | Yes |
| Australia | OZ Minerals | Yes | Yes |
| Australia | Sandfire Resources | Yes | Yes |
| Indonesia | PT Freeport Indonesia | Yes | Yes |
| PNG | Ok Tedi Mining | Yes | Yes |
| Australia | BHP Billiton | Yes | No |
| Australia | Glencore | Yes | No |
| Canada | Glencore | Yes | No |
| Indonesia | Newmont Mining | Yes | No |
| Canada | Highland Valley | No | No |
| Canada | Vale | No | No |
| Russia | Norilsk Nickel | No | No |
| Russia | UMMC | No | No |
| USA | Freeport McMoRan | No | No |

**Table 9 Second-layer survey, iron ore industry**

| Economy | Company | Response Workforce | Response Gender diversity |
|---|---|---|---|
| Australia | FMG | Yes | Yes |
| Australia | BHP Billiton | Yes | No |
| Canada | ArcelorMittal | Yes | No |
| Canada | IOC | Yes | No |
| Russia | Evraz | Yes | No |
| Russia | Lebedinsky GOK (Metalloinvest) | Yes | No |
| Russia | Mikhailovksy GOK (Metalloinvest) | Yes | No |
| Russia | Severstal | Yes | No |
| Russia | Stoilensky GOK (NLMK) | Yes | No |
| USA | Cliffs Natural Resources | Yes | No |
| USA | U.S. Steel | No | No |
| Australia | Hamersley Iron | No | No |

### 3.2.3. Extrapolation of results to economy level

The results from this survey have been considered a valid representation of an economy when the respondents accounted for more than 60% of the total copper or iron production of the said economy in a given year.

When that condition was met, the following assumptions have been taken:

- Total number of employees: has been estimated by using a simple linear extrapolation
- Percentage of women: has been assumed to be the same for the entire economy

Full details of these calculations are provided to APEC in a separate deliverable in Excel format.

## 3.3. Estimates

The third source of information corresponds to estimates that have been prepared utilising cost models widely adopted by the mining industry as a competitiveness analysis tool. As such, the estimates presented in this project are a reflection of information extracted from existing reports rather than a newly produced dataset.

These cost models contain production and cost data for a substantial proportion (>80%) of the global mine production for each of the twelve commodities under analysis. The key objective of these tools is to benchmark the competitiveness of mining operations and projects of a given industry on a normalised basis.

Cost estimates are calculated by mining operation based on a variety of technical inputs such as annual production, plant size, ore grade, recovery rate, stripping ratio, etc. Input data for the cost models is regularly collected through financial reports, telephone interviews and site visits (supported by robust methodologies for ensuring veracity and comparability).

Cost model data was aggregated at APEC at economy level and used for three indicators: annual production, processed ore and electricity consumption.

When available, this information was added to the project's dataset only in case of lack of results from the primary and second-layer surveys. As such, the estimates complement the other two sources but do not substitute them.

## 3.4. Methodological definitions and indicators

### 3.4.1. Assessment for primary production sector

The present study will exclusively assess primary production of metals, which is achieved through the mining activity. Mining is defined as the extraction of valuable minerals from the earth, commonly in the form of ore bodies with economically attractive concentrations of minerals of interest.

There are other types of metal production processes based on secondary production. Secondary production does not necessarily involve mining, since metal is produced through recycling. This type of metal production mostly processes and recovers metals from metal-containing end-use products after the end of their life cycle, generating production volumes without any mining activity. Therefore the analysis excludes secondary production of metals which are based on recycling of scrap.

### 3.4.2. Analysis and indicators focused on mining activity

The focus of the analysis will be on the mining sector and this excludes all downstream activity that processes output volumes being sold by mining operations as commercial products. Although downstream processing plants are fundamental to the mining activity, they do not necessarily involve the same context or framework observed at mine sites.

For those particular cases in which downstream plants are integrated with mining operations, then the mining side is the area subject of the study. The reason for this is that although an asset could operate as an integrated operation, in theory the mining area could still run without the existence of the downstream plant at site, and could potentially sell its commercial product to a downstream plant operated by a third party somewhere else.

### 3.4.3. Indicators

The study looks at a specific list of indicators that impact productivity of the mining sector, which in turn will be assessed by corresponding objective and quantitative metrics. The list of selected indicators is shown below:

**Table 10 List of indicators**

| Category | Indicator | Metric |
|---|---|---|
| **Mine production** | 1. Produced metal | Tons per year / ounces per year |
| | 2. Processed ore | Tons per year |
| **Energy** | 3. Electricity consumption | GWh |
| | 4. Fuel consumption | TJ |
| **Workforce** | 5. Total hours worked | Man hours |
| | 6. Gender distribution | % of women |
| **Non-current assets** | 7. Value of non-current assets | $ |

1. Produced metal:

This indicator refers to the volume of metal-containing product being produced from mining operations in a given economy. This metal-containing product is defined as a final or intermediate form in which the metal can be used for some commercial or industrial purpose.

It is important to note that the metal-containing product is not necessarily metal itself. The metal-containing product could be, for instance, a concentrate product that is a bulk material containing metal mixed with other materials (commonly considered as impurities). Although a concentrate product is not metal, it is still an intermediate form in which metal can be commercialised and exported as raw material for further downstream processing. Even in other cases, extracted ore without any downstream processing could be considered as metal-containing product, since its ore grade and consequent unit value reach a level at which a corresponding market can buy it as a commercial and exportable product.

For most of those cases of mining operations producing intermediate products (and not final products in form of pure metal), *produced metal* refers to the metal volume contained in the corresponding form of output. For instance, a mining operation producing and exporting 100 thousand tons of copper concentrates with 30% of contained copper, *produced metal* will be considered at 30 thousand tons for that specific year.

For other cases, however, of mining operations producing intermediate products (and not final products in form of pure metal), produced metal refers to the overall volume of concentrate or ore regardless of the share of contained metal. These are the cases of mining products that widely differ in form and quality, although contain the same metal. For instance, a mining operation producing and exporting 10 million tons of iron ore, which in turn are split into different types of products such as lump, pellets and pellet feed, all of them with different grades but averaging 65% iron grade, produced metal will be considered simply at 10 million tons for that specific year.

In the specific case of bauxite, produced metal is considered zero because 100% of its production is sold as Direct Shipping Ore to an alumina refinery so, in practice, all the extracted material is considered as “processed ore”.

2. Processed ore:

This indicator refers to the volume of ore being processed at mining operations in a given economy. The ore processed is defined as the extracted material coming from the mine, stocks or third parties that is processed at a beneficiation plant in the mine site for the first time, without previous beneficiation processes.

Beneficiation is defined, for the purposes of this study, as a process that improves metal content and unit value of the ore by removing material that is not valuable to the business (or impurities), resulting in an upgraded metal-containing product and a separate waste stream that contains impurities. Following this definition, processed ore is calculated at the first stage of beneficiation involving upgrades, with further downstream beneficiation not considered as processed ore. In general, in mining the first stage of beneficiation is located at the same mine site due to the high logistic costs that would be involved if large volumes of not-beneficiated ore (and with low metal grade) were transported from the mine to a beneficiation plant somewhere else.

3. Electricity consumption:

This indicator refers to the electricity being consumed at mining operations in a given economy. The electricity considered in this indicator is defined as the overall electrical consumption measured within the mine site, which is necessary to keep the whole mining operation producing and selling its corresponding commercial products.

For the sake of this study, electricity consumption at the mining operation is defined as the electrical consumption within the mine site until the last process strictly required to produce and to sell its corresponding commercial products.

This definition hence excludes electrical consumption at any downstream processing facility that is not strictly necessary to sell a commercial product.

4. Fuel consumption:

This indicator refers to the fuel being consumed at mining operations in a given economy. The fuel considered in this indicator is defined as the overall fuel consumption measured within the mine site, which is necessary to keep the whole mining operation producing and selling its corresponding commercial products.

For the purpose of this study, fuel consumption at the mining operation is defined as the fuel consumption within the mine site until the last process strictly required to produce and to sell its corresponding commercial products.

This definition hence excludes fuel consumption at any downstream processing facility that is not strictly necessary to sell a commercial product.

5. Total hours worked:

This indicator refers to the overall hours being worked at mining operations in a given economy. The hours worked considered in this indicator are defined as the overall working time accounted by internal and external workforce, including labour in exclusively operational tasks as well as labour with responsibilities in administrative and supporting areas required to keep the whole mining operation producing and selling its corresponding commercial products.

For the sake of this study, total hours worked at the mining operation is defined as the working time within the mine site until the last process strictly required to produce and to sell its corresponding commercial products.

This definition hence excludes work hours at any downstream processing facility that is not strictly necessary to sell a commercial product.

6. Gender distribution:

This indicator refers to the share of men and women working at mining operations in a given economy. The gender split considered in this indicator is defined as the fraction of overall working time accounted for men and women, considering internal and external workforce and including labour in exclusively operational tasks as well as labour with responsibilities in administrative and supporting areas required to keep the whole mining operation producing and selling its corresponding commercial products.

The gender distribution metric is entirely based on the total hours worked metric. Hence, the share of men and women working at the mining operation needs to be calculated on the basis of the indicator presenting total working time in man-hour (MH), which is taken from the total hours worked metric. All definitions related to the total hours worked indicator, which in turn provides the basis for the gender distribution indicator, must follow the same guidelines explained above.

7. Value of non-current assets:

This indicator refers to the value of assets that are not expected to be liquidated before one year at mining operations in a given economy. The assets considered in this indicator are those reported in balance sheets under the category of non-current assets, such as fixed assets, intangible assets, investments in other companies, inventories, financial assets, deferred taxes, goodwill, etc.

Within the category of non-current assets there are several types of assets considered as non-current assets, but are not necessarily linked directly to capital and furthermore will probably present very high variability across operations and commodities. This is the case of most items considered as non-current assets besides fixed assets – also known as property, plant and

equipment (PPE). Since the objective of the indicator is to represent capital expended in the mining sector, the value of non-current assets indicator will instead be represented exclusively by the value of fixed assets (or PPE), which is a considerably more representative index of tangible and physical assets at mining operations.

For the sake of this study, value of PPE at the mining operation is defined as the value of all assets considered as fixed and expected to generate economic benefits for a period of longer than one year within the mine site until the last process strictly required to produce and sell its corresponding commercial products.

This definition hence excludes PPE at any downstream processing facility that is not strictly necessary to sell a commercial product.

### 3.4.4. By-product output info and its use in productivity indicators

All productivity indicators, defined for this study specifically under a technical efficiency perspective (ratio of physical input to physical output), will only consider output for main mining products and will omit output for by-products.

It is important to consider that under the approach proposed in this study, the rest of the proposed indicators, which omit by-products data, will thus present null metrics.

As an example, if an economy presents relevant production volumes for a commodity entirely coming from by-product output, then produced metal for this commodity will naturally be greater than zero, but overall consumption (and consumption per unit of production) of a specific supply will be zero. In practice, this is not entirely true since by-product plants do consume supplies. However, most of the overall consumption will be allocated to the assets producing the main product(s), leaving nearly negligible consumption volumes to by-product assets. Hence, consumption metrics for by-products showing zero is a sensible approximation that applies logically to the scope of this analysis

# 4. Project results

## 4.1. Data completion

All the information related to data collection presented in this report should be considered final and is presented to APEC in a repository of information (Excel format) in line with the definitions presented in the Methodology Report submitted in January 2017.

The following tables show the level of completeness of each indicator and which are the sources of the obtained data.

**Table 11 Available data for Indicator 1 (Produced metal)**

| Economy | Cu | Ni | Fe | Al | Zn | Pb | Sn | Mo | Co | Au | Ag | Pt | Pd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chile | S | | S | | S | S | | S | | S | S | | |
| Peru | S | | S | | S | S | S | S | | S | S | | |
| Indonesia | Est | Est | S | | S | | S | | Est | S | S | | |
| Philippines | | Est | | | | | | | Est | S | S | | |
| Canada | S | S | S | | S | S | | S | S | S | S | Est | Est |
| China | S | S | Est | | S | S | S | S | S | Est | Est | Est | Est |
| USA | S | S | S | | S | Est | | S | S | S | S | S | S |
| Russia | Est | Est | Est | | Est | Est | | Est | Est | Est | Est | Est | Est |
| PNG | Est | Est | | | | | | | Est | Est | Est | | |
| Viet Nam | | Est | | | | Est | Est | | | | | | |
| Mexico | Est | | Est | | Est | Est | | Est | | Est | Est | | |
| Australia | S | S | S | | S | Est | S | | Est | S | S | | |

Est Estimated data  S Survey  No prod.  Prod. <0.5% of global output

**Table 12 Available data for Indicator 2 (Processed ore)**

| Economy | Cu | Ni | Fe | Al | Zn | Pb | Sn | Mo | Co | Au | Ag | Pt | Pd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chile | S | | Est | | Est | Est | | Est | | Est | | | |
| Peru | S | | S | | S | Est | S | Est | | S | | | |
| Indonesia | Est | Est | | Est | | | | | | | | | |
| Philippines | | Est | | | | | | | | | | | |
| Canada | Est | Est | Est | | Est | Est | | | | | | | |
| China | Est | Est | Est | Est | Est | Est | | | | | | | |
| USA | Est | Est | Est | | Est | Est | | | | | | | |
| Russia | Est | Est | Est | Est | Est | Est | | | | | | | |
| PNG | Est | Est | | | | | | | | | | | |
| Viet Nam | | Est | | Est | | | | | | | | | |
| Mexico | Est | | Est | | Est | Est | | | | | | | |
| Australia | Est | Est | Est | S | Est | Est | | | | | | | |

Est Estimated data  S Survey  No prod.  Prod. <0.5% of global output

## Table 13 Available data for Indicator 3 (Electricity consumption)

| Economy | Cu | Ni | Fe | Al | Zn | Pb | Sn | Mo | Co | Au | Ag | Pt | Pd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chile | S | | Est | | Est | Est | | Est | | Est | | | |
| Peru | S | | S | | Est | Est | S | Est | | S | S | | |
| Indonesia | Est | Est | | Est | | | | | | | | | |
| Philippines | | Est | | | | | | | | S | | | |
| Canada | Est | Est | S | | Est | Est | | | | S | | | |
| China | S | S | Est | S | S | Est | | S | | | S | | |
| USA | Est | Est | Est | | Est | Est | | | | | | | |
| Russia | Est | Est | Est | Est | Est | Est | | | | | | | |
| PNG | Est | Est | | | | | | | | | | | |
| Viet Nam | | Est | | Est | | | | | | | | | |
| Mexico | Est | | Est | | Est | Est | | | | | | | |
| Australia | Est | Est | Est | Est | Est | Est | | | | | | | |

Est Estimated data  S Survey  No prod.  Prod. <0.5% of global output

## Table 14 Available data for Indicator 4 (Fuel consumption)

| Economy | Cu | Ni | Fe | Al | Zn | Pb | Sn | Mo | Co | Au | Ag | Pt | Pd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chile | S | | | | | Est | | Est | | | | | |
| Peru | | | | | | Est | | Est | | | | | |
| Indonesia | | | | | | | | | | | | | |
| Philippines | | | | | | | | | | | | | |
| Canada | | | S | | | Est | | | | S | | | |
| China | S | S | | S | S | | | S | | | S | | |
| USA | | | | | | | | | | | | | |
| Russia | | | | | | | | | | | | | |
| PNG | | | | | | | | | | | | | |
| Viet Nam | | | | | | | | | | | | | |
| Mexico | | | | | | Est | | | | | | | |
| Australia | | | | | | | | | | | | | |

Est Estimated data  S Survey  No prod.  Prod. <0.5% of global output

## Table 15 Available data for Indicator 5 (Total hours worked)

| Economy | Cu | Ni | Fe | Al | Zn | Pb | Sn | Mo | Co | Au | Ag | Pt | Pd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chile | S | | Est | | | Est | | Est | | | | | |
| Peru | S | | S | | S | Est | S | Est | | S | S | | |
| Indonesia | Est | | | | | | | | | | | | |
| Philippines | | S | | | | | | | | S | | | |
| Canada | | | Est | | | | | | | | | | |
| China | | | | | | | | | | | | | |
| USA | S | S | S | | S | | | | | S | S | S | |
| Russia | | | Est | | | | | | | | | | |
| PNG | Est | | | | | | | | | | | | |
| Viet Nam | | | | | | | | | | | | | |
| Mexico | | | | | | Est | | | | | | | |
| Australia | Est | | | | | | | | | | | | |

Est Estimated data  S Survey  No prod.  Prod. <0.5% of global output

Data not available, but not strictly required

**Table 16 Available data for Indicator 6 (Gender distribution)**

| Economy | Cu | Ni | Fe | Al | Zn | Pb | Sn | Mo | Co | Au | Ag | Pt | Pd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chile | S | | | | | | | | | | | | |
| Peru | | | | | | | | | | | | | |
| Indonesia | | | | | | | | | | | | | |
| Philippines | | | | | | | | | | | | | |
| Canada | | | | | | | | | | | | | |
| China | | | | | | | | | | | | | |
| USA | | | | | | | | | | | | | |
| Russia | | | | | | | | | | | | | |
| PNG | Est | | | | | | | | | | | | |
| Viet Nam | | | | | | | | | | | | | |
| Mexico | | | | | | | | | | | | | |
| Australia | | | | | | | | | | | | | |

Est Estimated data  S Survey  No prod.  Prod. <0.5% of global output

Data not available, but not strictly required

**Table 17 Available data for Indicator 7 (Value of non-current assets (PPE)**

| Economy | Cu | Ni | Fe | Al | Zn | Pb | Sn | Mo | Co | Au | Ag | Pt | Pd |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chile | Est | | Est | | | Est | | Est | | Est | | | |
| Peru | | | | | | Est | | Est | | | | | |
| Indonesia | | | | | | | | | | | | | |
| Philippines | | | | | | | | | | | | | |
| Canada | S | | | | | Est | | | | | | | |
| China | | | | | | | | | | | | | |
| USA | | | | | | | | | | | | | |
| Russia | | | | | | | | | | | | | |
| PNG | | | | | | | | | | | | | |
| Viet Nam | | | | | | | | | | | | | |
| Mexico | | | | | | Est | | | | | | | |
| Australia | | | | | | | | | | | | | |

Est Estimated data  S Survey  No prod.  Prod. <0.5% of global output

Discarding the economies with no production or less than 0.5% of global production of a certain commodity[1] and considering aggregated data for Indicators 5 and 6 at economy level, the total number of possible responses is 606.

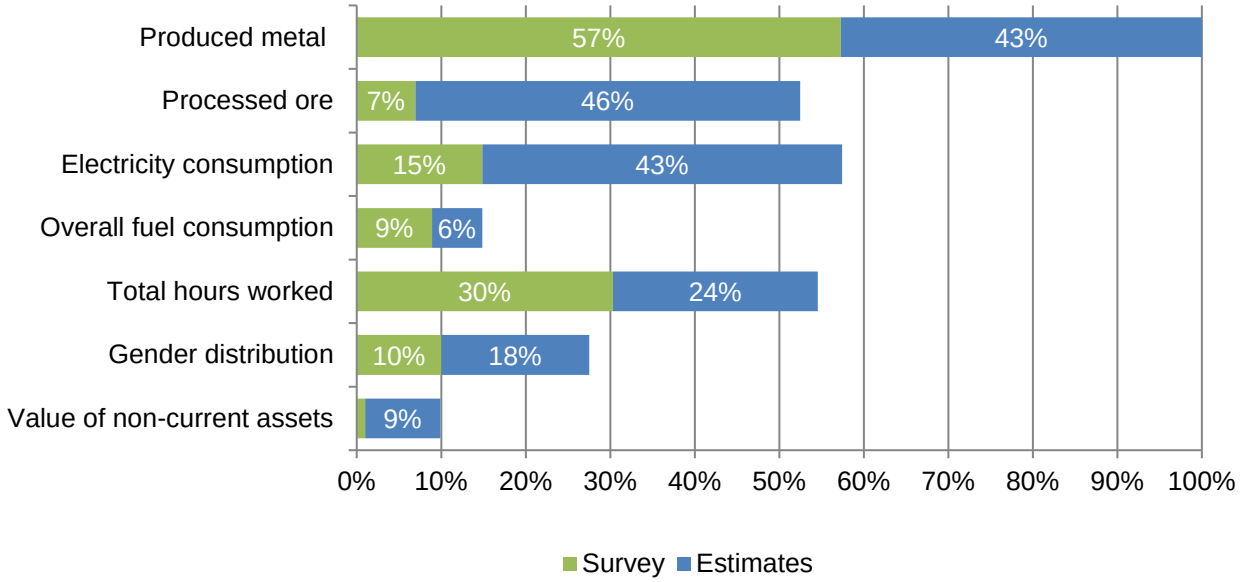
The final analysis of the results shows that 28% of data points (168) are filled with estimates, 18% with information from the survey (111) and 54% are missing (327).

[1] An exception was made for copper and silver production in PNG, both of which represent less than 0.5% of global production but were included due to the importance of these commodities in the economy's output.

### 4.1.1. Data completion by indicator

The following chart shows percentage data that has been obtained from the survey and estimates for each of the seven indicators:

**Figure 3 Data completion percentage by indicator**

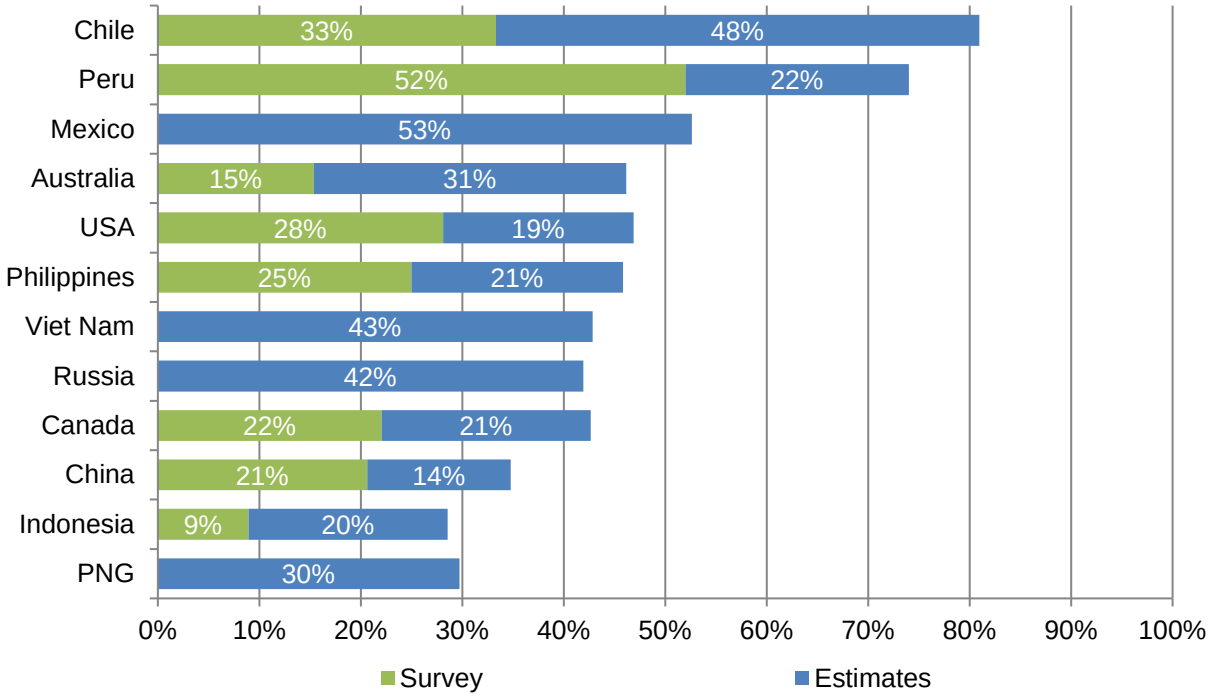



The “Produced metal” indicator has an almost complete set of information, and “Processed ore” and “Electricity consumption” present ~55% of completeness (including data from the survey and estimates). This allows for a good analysis regarding electric consumption productivity in different commodities. The survey also showed an acceptable level of completeness for Indicator 5 (total hours worked) in some commodities, used for labour productivity analysis.

### 4.1.2. Data completion by economy

The following chart shows percentage data that is taken from the survey and obtained from estimates for each of the twelve economies under analysis. It is important to mention that the number of data points varies from one economy to the next, depending on how many commodities it produces.

**Figure 4 Data completion percentage by economy**




The economies with the highest percentage of completeness are Chile, Peru, and Mexico, with 80%, 74% and 53% respectively. It is worth noticing that Mexico achieves this level using only estimated data. These economies are followed by Australia, United States, the Philippines, Russia, Viet Nam and Canada all with similar completion percentages of 43%- 47%. China has a percentage of completeness of 35%, and PNG and Indonesia are the only economies with a percentage of completeness below that number.

## 4.2. Indicators and productivity

This section presents a snapshot of the final results of the project. In the charts presented in this section, all data estimated is marked with an asterisk next to the economy name. Those economies with no production of the correspondent commodity are not shown in the charts and tables. The same applies for economies where no information was gathered.

The cumulative annual growth rate for the period 2011-2015 is indicated as a percentage number on top of each data series.

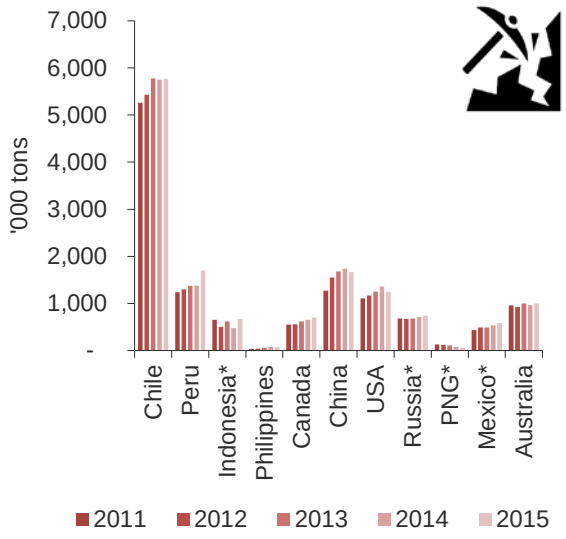
### 4.2.1. Produced metal and processed ore

This subsection shows produced metal and processed ore for each commodity, as well as the amount of produced metal per million tons of processed ore (Produced metal / processed ore). It is important to keep in mind that the amount of metal produced considers both the metal produced by mining operations with that commodity as their main product and operations that extract it as a by-product. This is not the case of ore, which is allocated only to the main extracted product.

Results are presented in the following pages; one commodity per page.

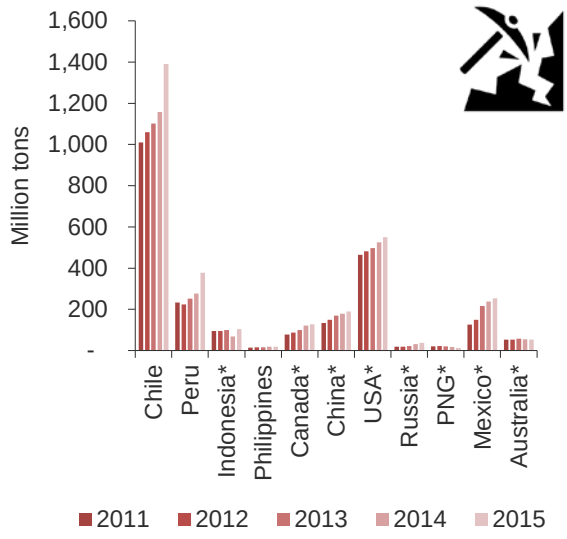
# Copper

**Figure 5 Produced metal, Copper (’000 t)**



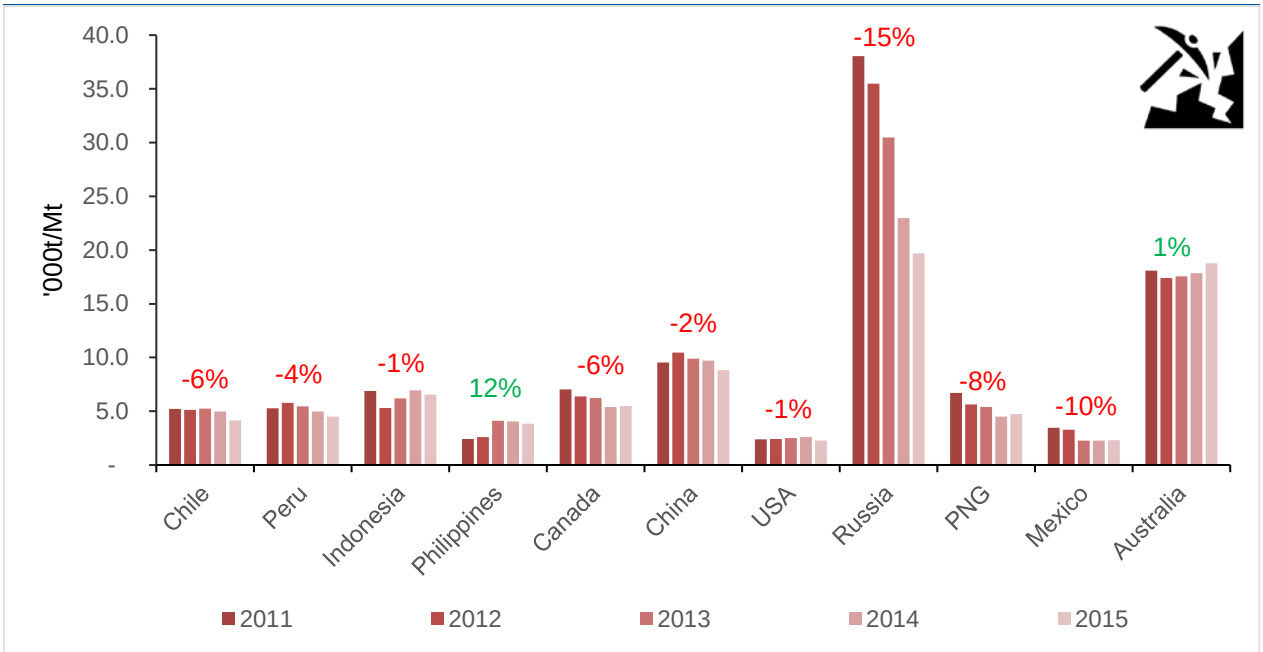

(*) Estimated data

**Figure 6 Processed ore, Copper (Mt)**



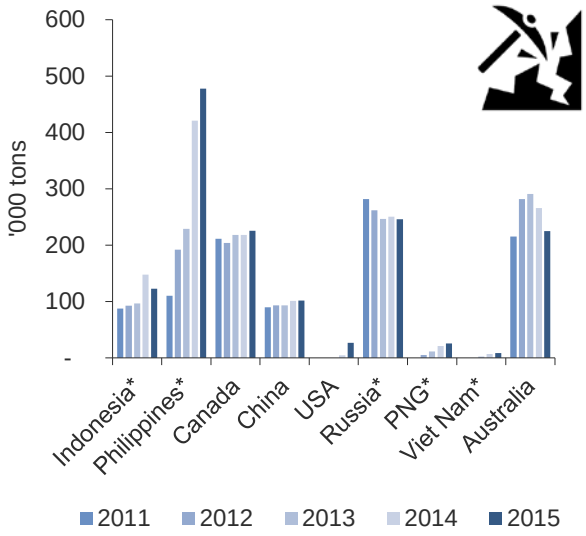

(*) Estimated data

**Figure 7 Productivity: Produced metal/ Processed ore, Copper (’000 t/Mt)**



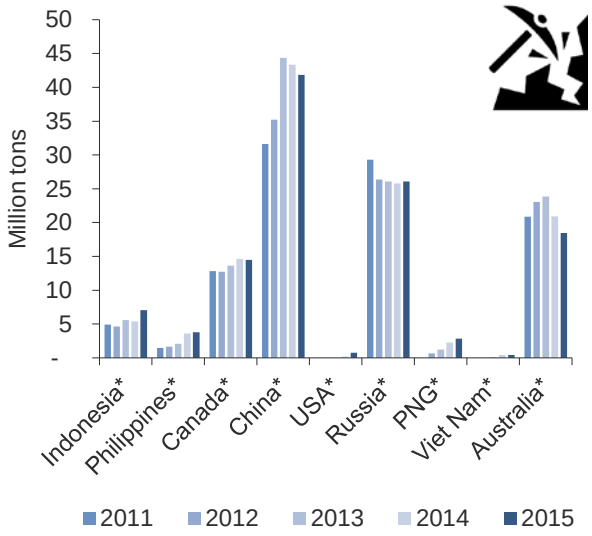
# Nickel

**Figure 8 Produced metal, Nickel (’000 t)**



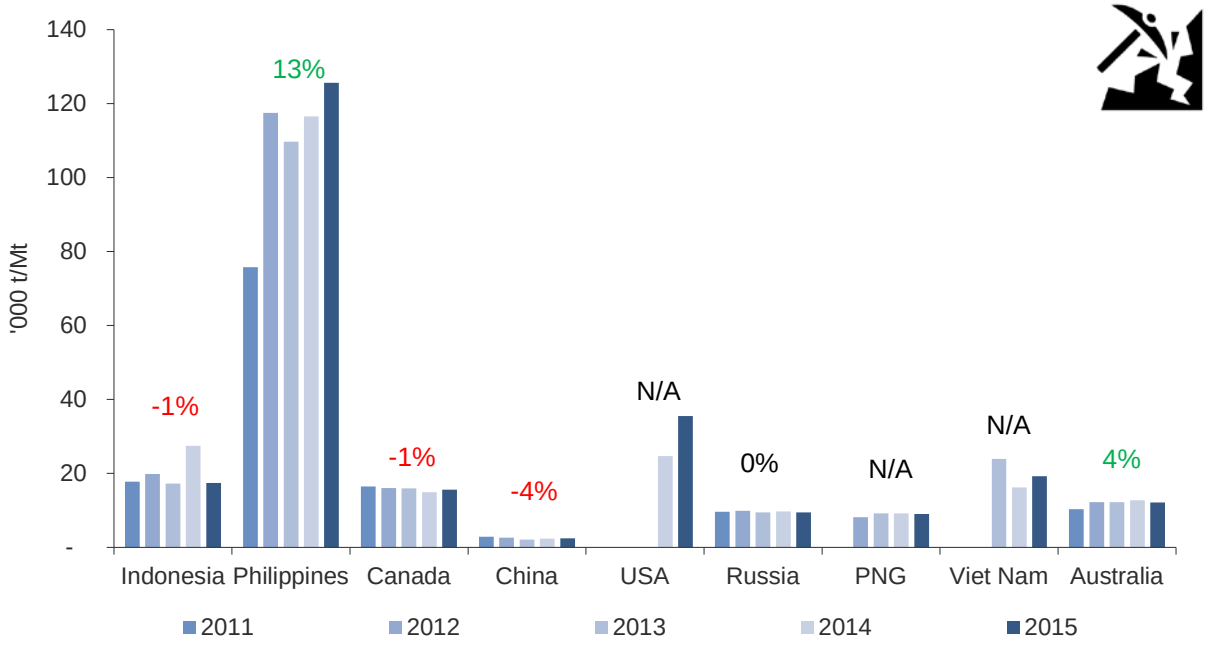

(*) Estimated data

**Figure 9 Processed ore, Nickel (Mt)**



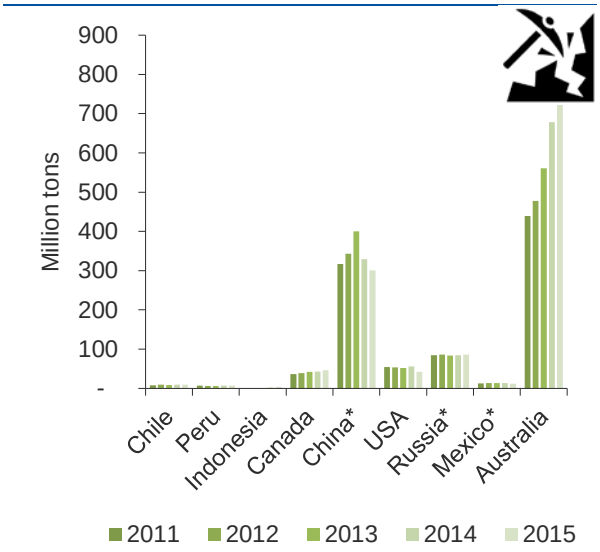

(*) Estimated data

**Figure 10 Productivity: Produced metal/ Processed ore, Nickel (’000 t/Mt)**



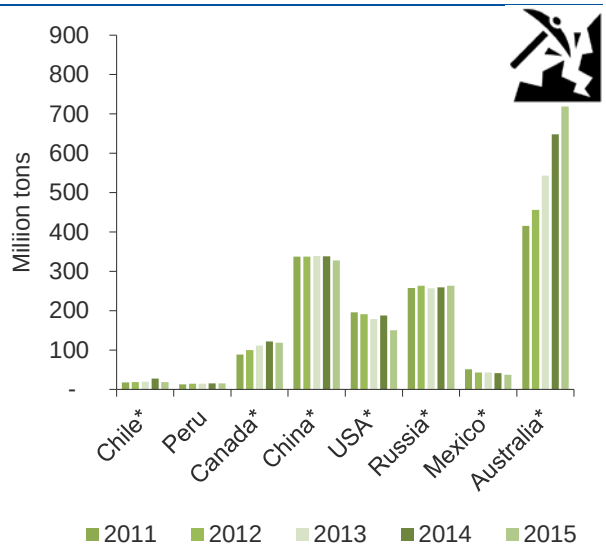
# Iron ore

**Figure 11 Produced metal, Iron ore (Mt)**



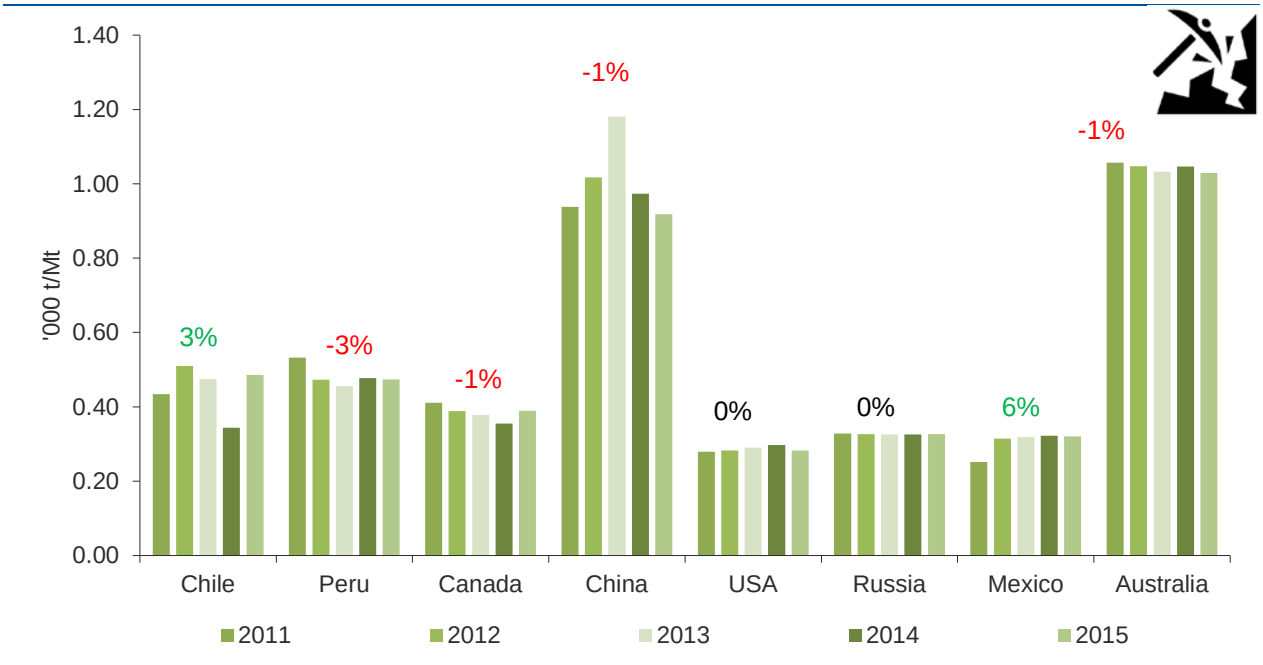

(*) Estimated data

**Figure 12 Processed ore, Iron ore (Mt)**




(*) Estimated data

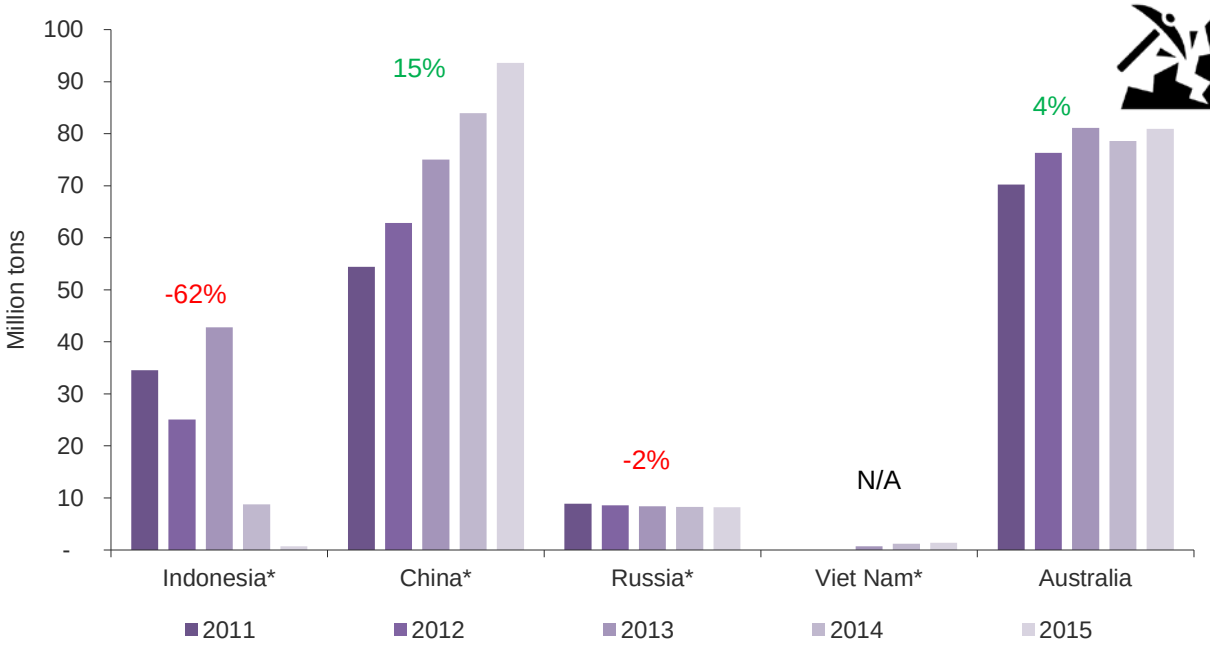
**Figure 13 Productivity: Produced metal/ Processed ore, Iron ore ('000 t/Mt)**



## Bauxite

Processed ore is the only metric under analysis in the case of bauxite because 100% of its production is DSO (direct shipping ore) so the definition of “produced metal” does not apply.

**Figure 14 Processed ore, Bauxite (Mt)**

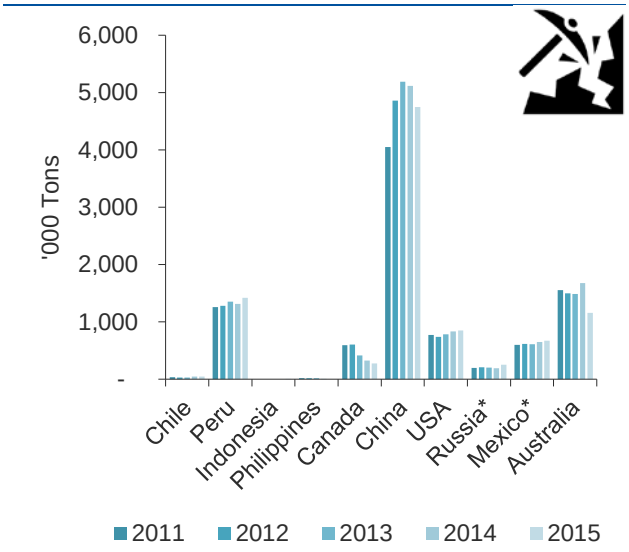



(*) Estimated data

## Zinc

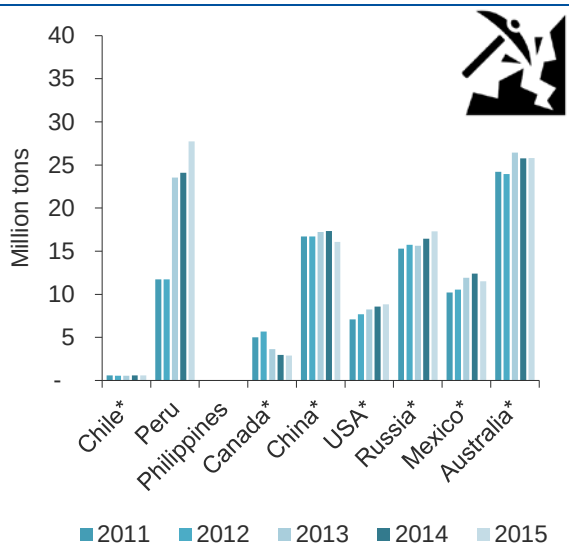
There is no information available on Indonesia's processed ore for zinc, and therefore it is not included in the following chart. The Philippines, on the other hand, do not have any ore processed mainly for zinc production – all zinc production comes in the form of by-product.

**Figure 15 Produced metal, Zinc ('000 t)**



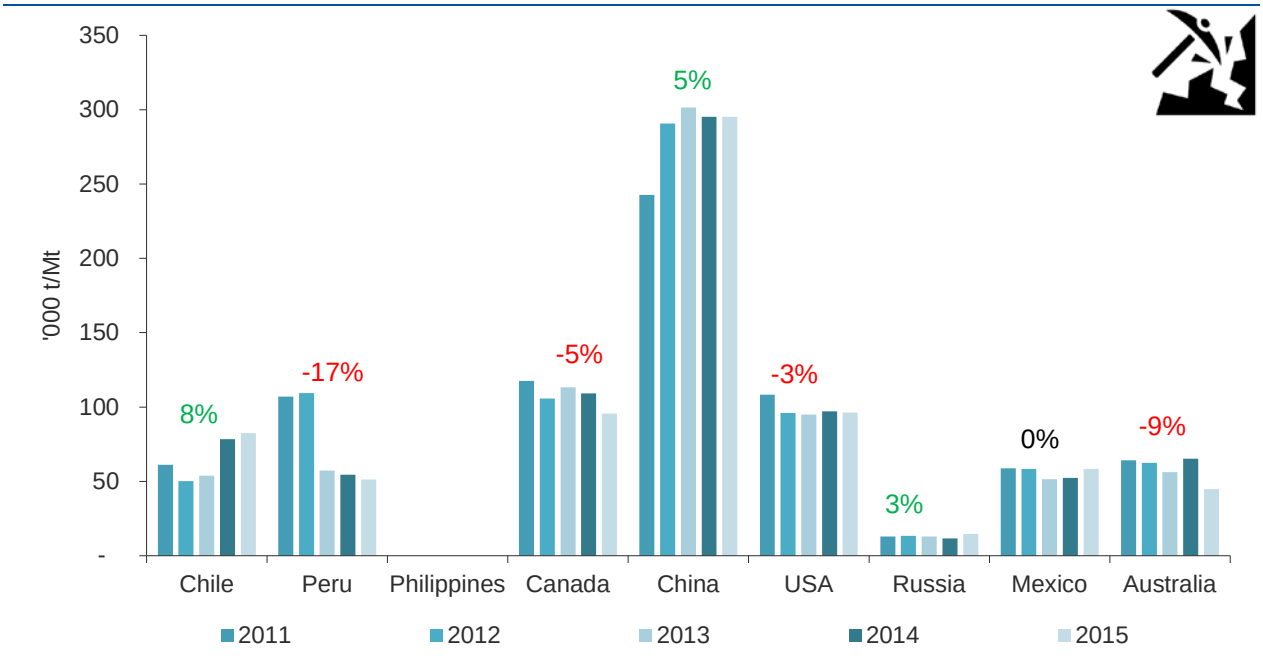

(*) Estimated data

**Figure 16 Processed ore, Zinc (Mt)**




(*) Estimated data

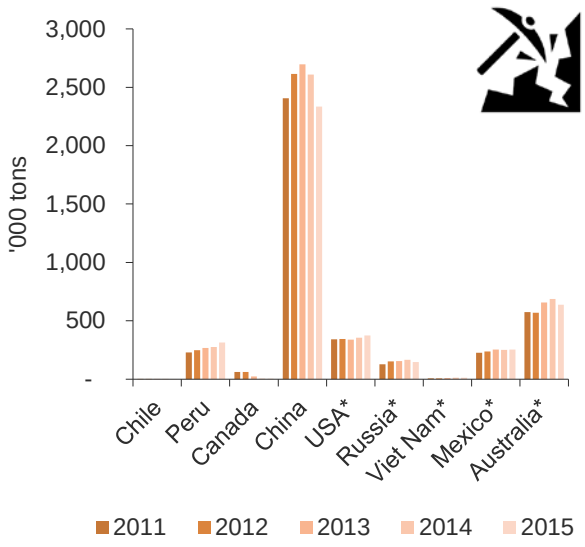
**Figure 17 Productivity: Produced metal/ Processed ore, Zinc ('000 t/Mt)**



## Lead

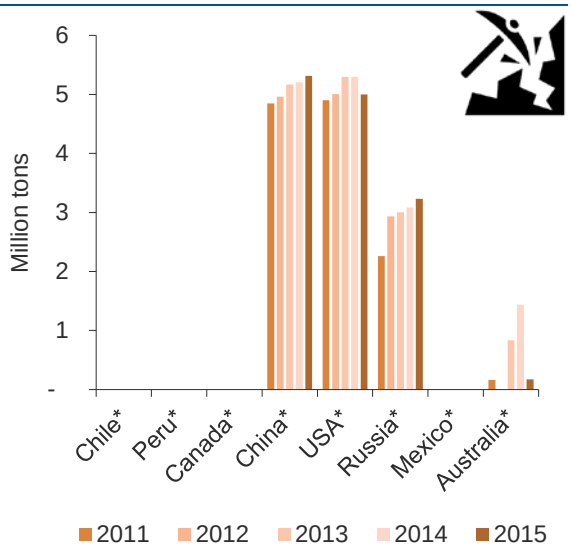
In the case of lead, Chile, Peru, Canada and Mexico have production only as a by-product.

**Figure 18 Produced metal, Lead ('000 t)**




(*) Estimated data

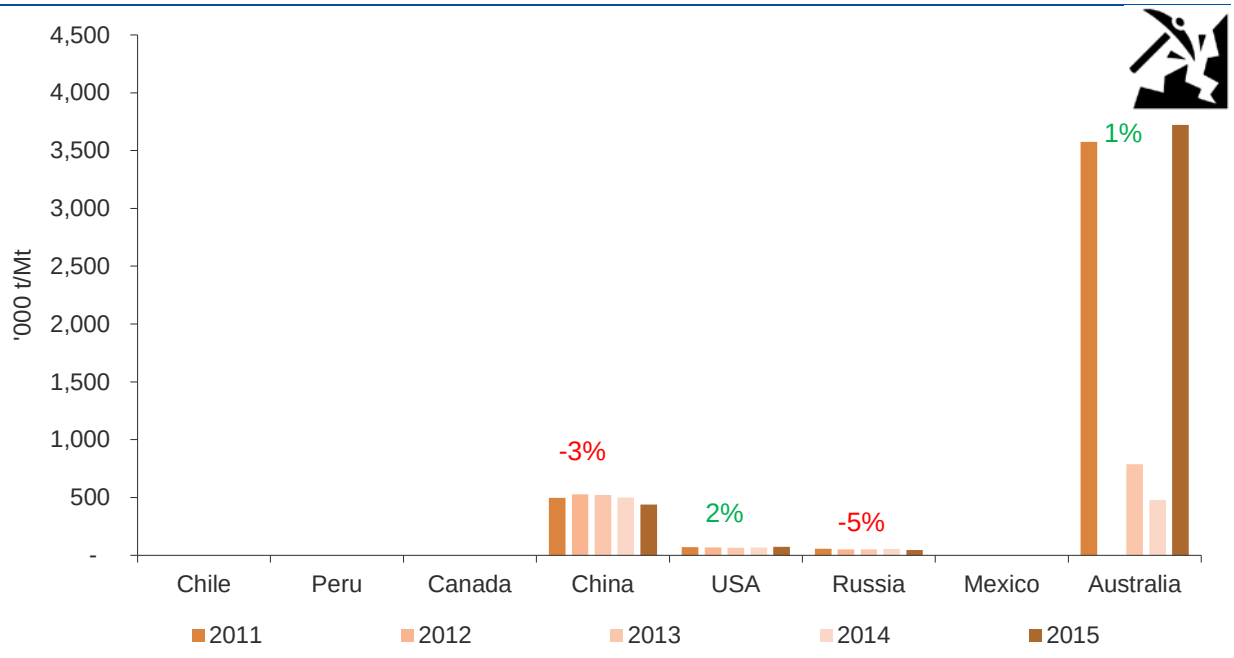
**Figure 19 Processed ore, Lead (Mt)**




(*) Estimated data

Therefore, there is no ore processed specifically for lead production in these economies.

**Figure 20 Productivity: Produced metal/ Processed ore, Lead ('000 t/Mt)**



# Tin

In terms of processed ore, there is only information for Peru.

**Figure 21 Produced metal, Tin (’000 t)**

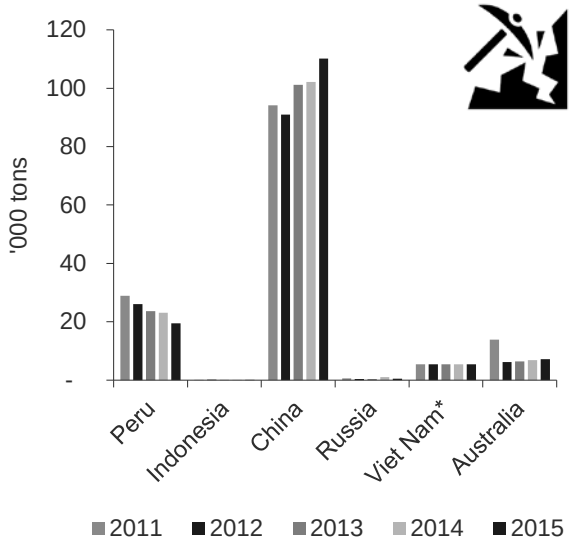
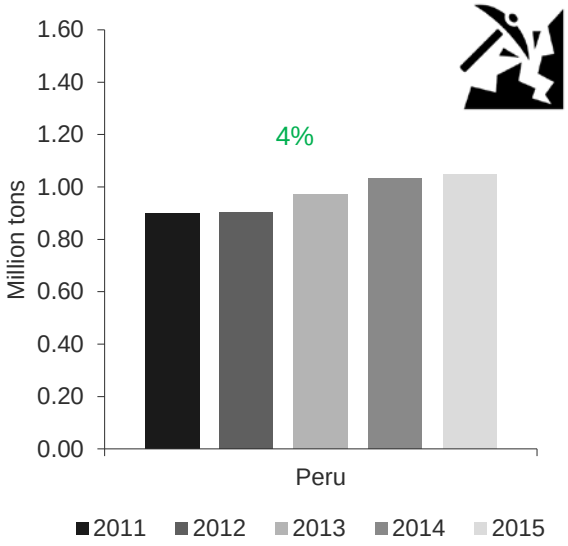



**Figure 22 Processed ore, Tin (Mt)**

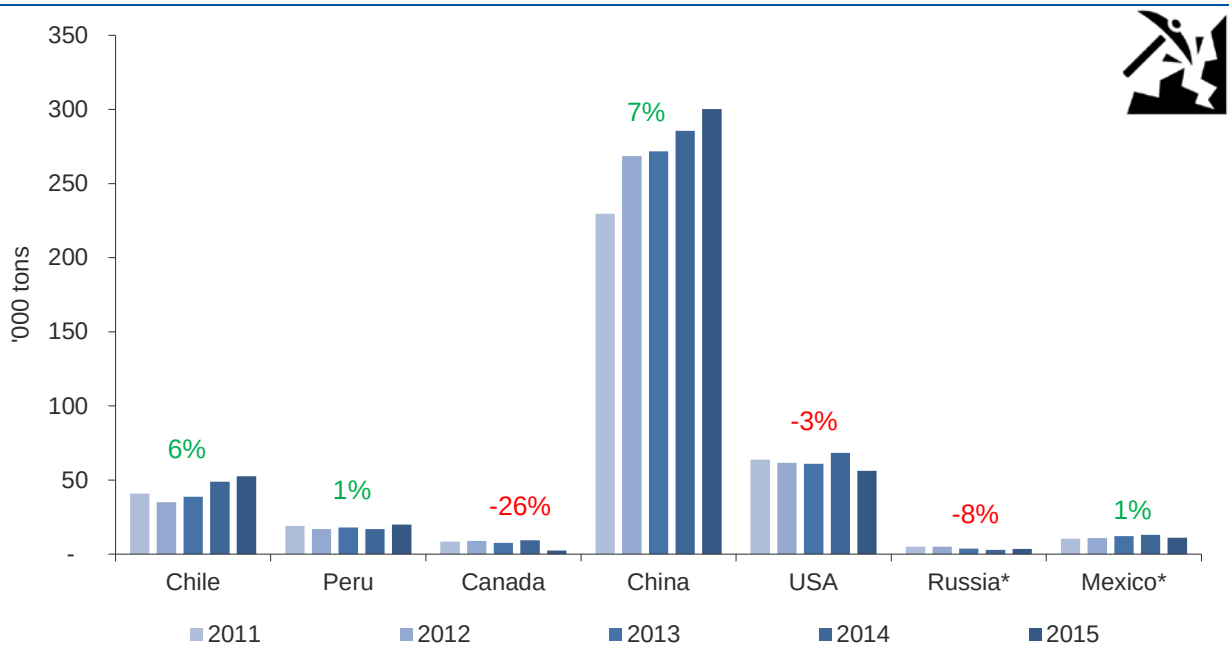



(*) Estimated data

## Molybdenum

All of the molybdenum production coming from Chile and Peru is in the form of by-product, and there is no information available for the rest of the economies.

**Figure 23 Produced metal, Molybdenum ('000 t)**

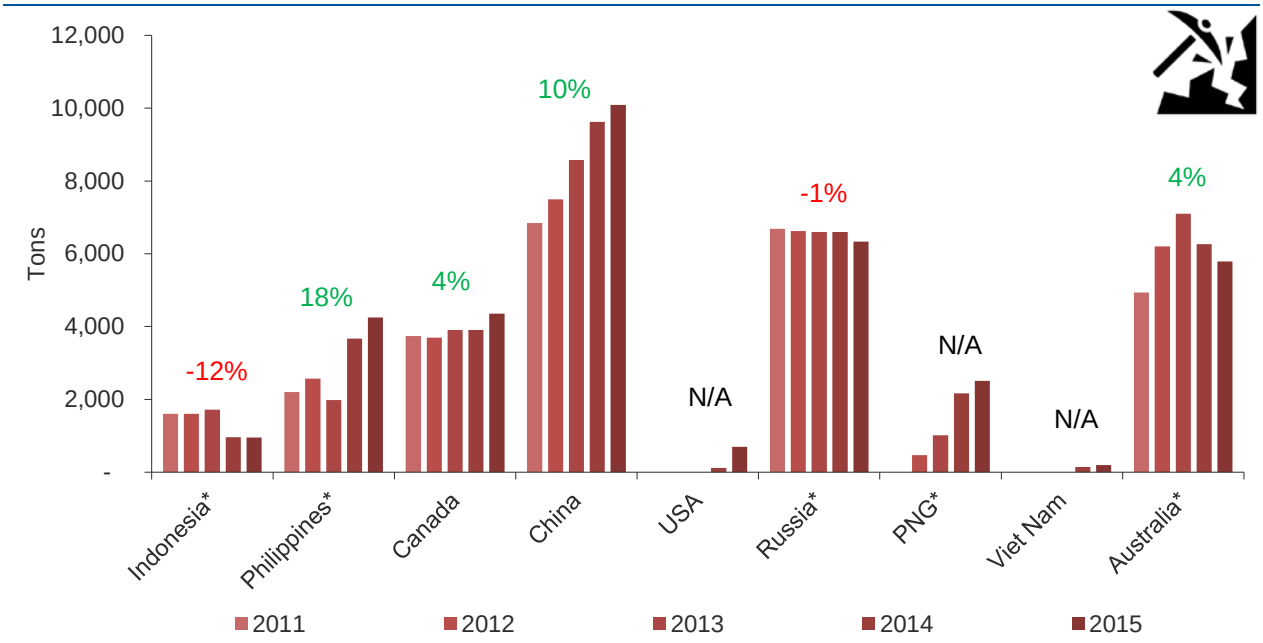



(*) Estimated data

## Cobalt

There is no information available on ore processed to obtain cobalt in any of the cobalt producing economies.

**Figure 24 Produced metal, Cobalt (tons)**

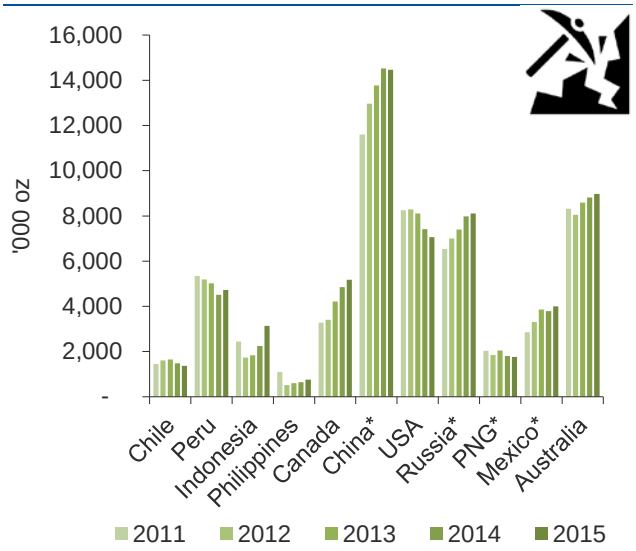



(*) Estimated data

## Gold

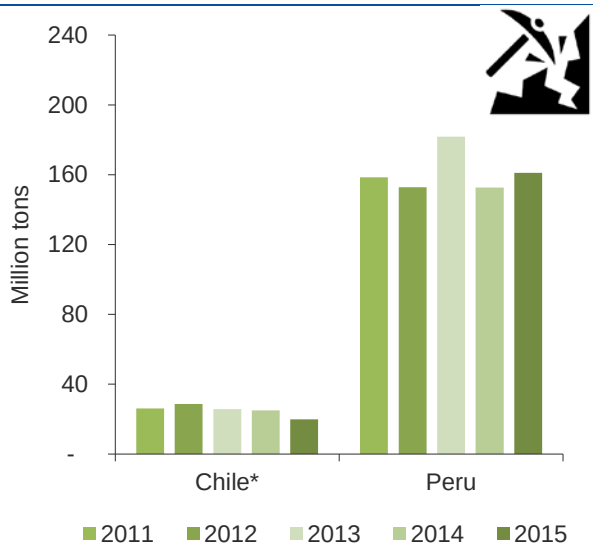
In terms of processed ore, there is only information for Peru and Chile.

**Figure 25 Produced metal, Gold ('000 oz)**



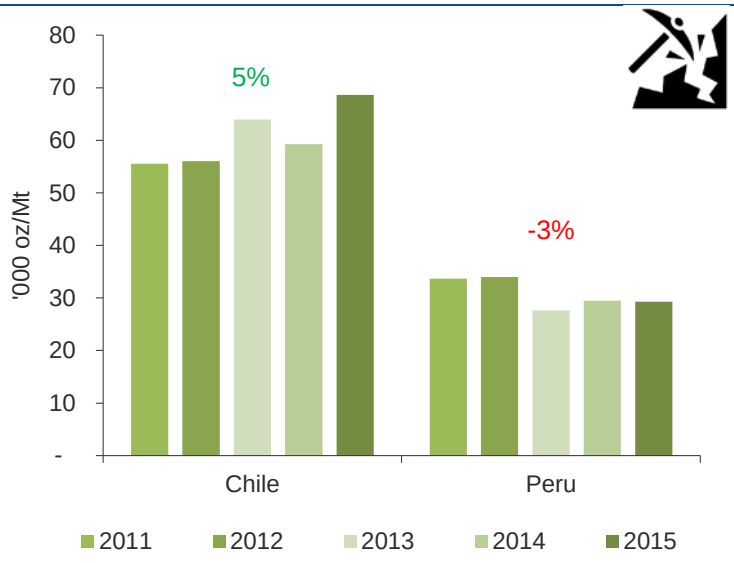

(*) Estimated data

**Figure 26 Processed ore, Gold (Mt)**




(*) Estimated data

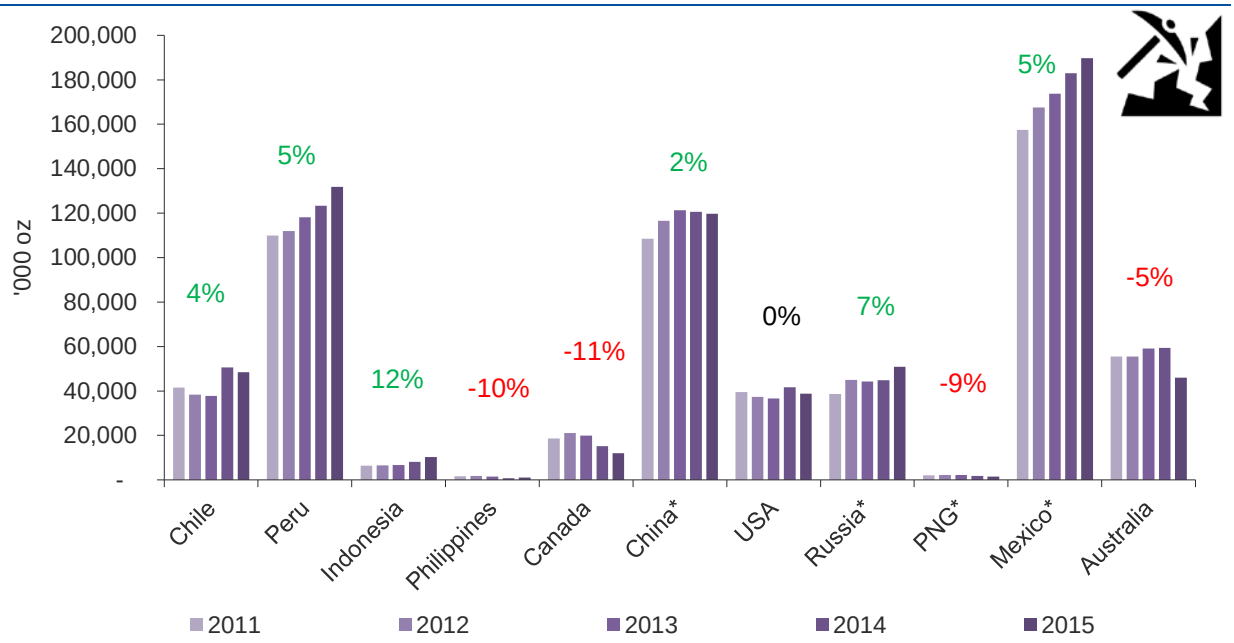
**Figure 27 Productivity: Produced metal/ Processed ore, Gold ('000 oz/Mt)**



## Silver

There is no information about processed ore for silver. In the majority of the cases, silver is obtained as a by-product.

**Figure 28 Produced metal, Silver ('000 oz)**

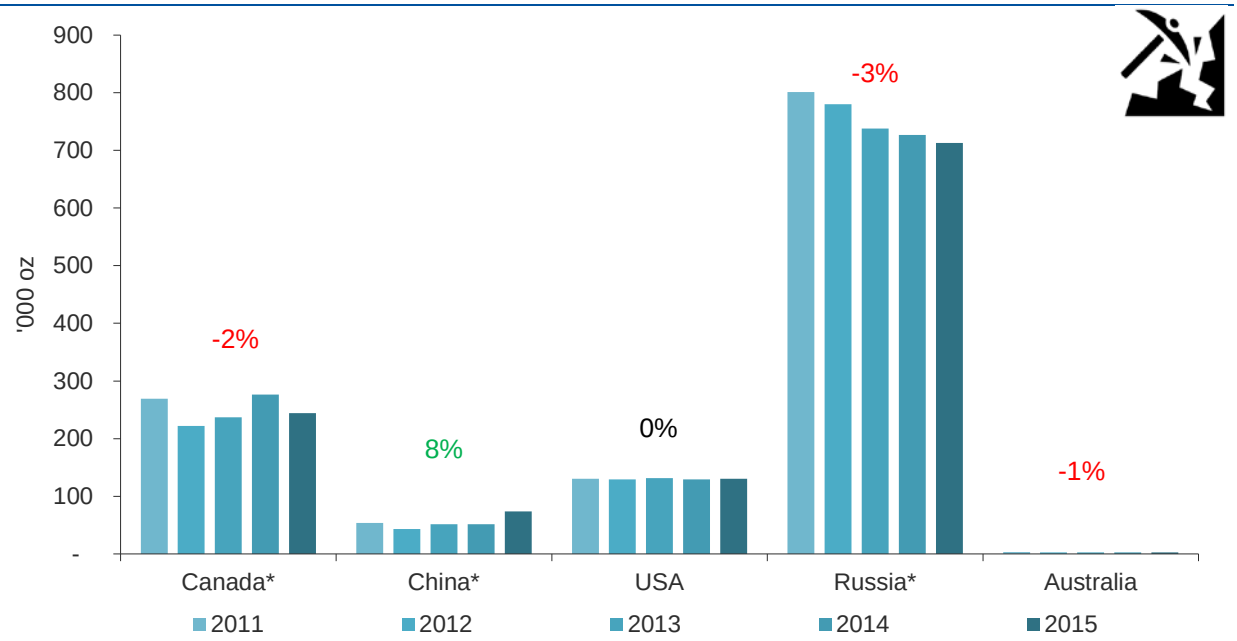



(*) Estimated data

## Platinum

There is no information about processed ore for platinum

**Figure 29 Produced metal, Platinum ('000 oz)**

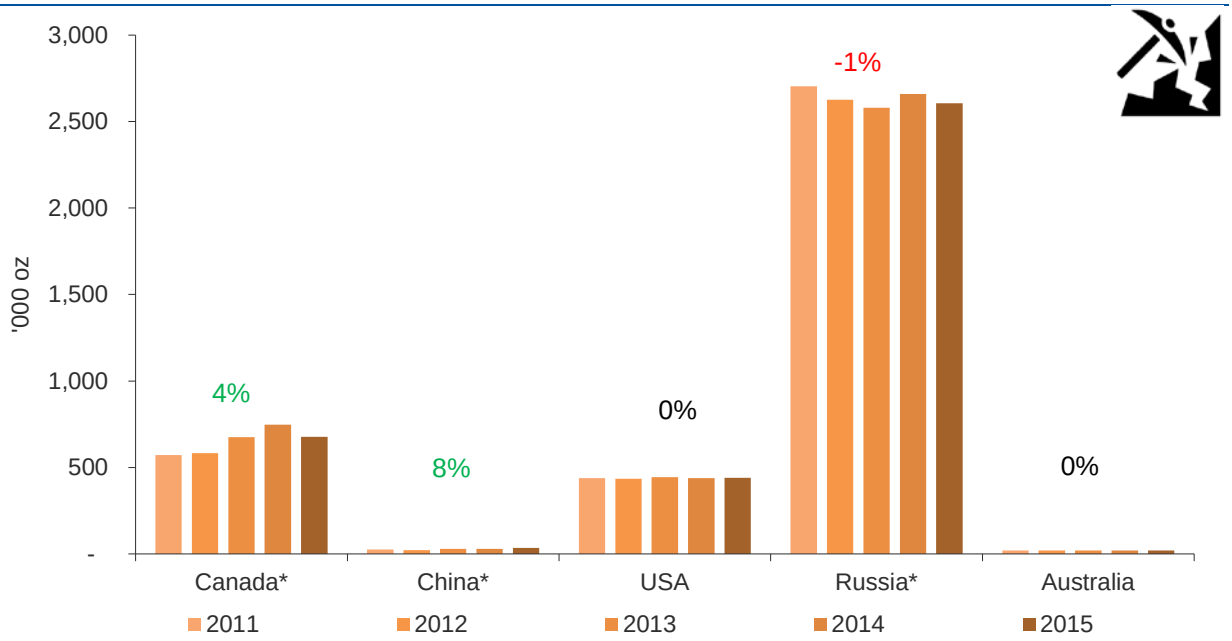



(*) Estimated data

## Palladium

There is no information about processed ore for palladium.

**Figure 30 Produced metal, Palladium ('000 oz)**




(*) Estimated data

### 4.2.2. Productivity for electricity consumption (productivity of Indicator 3)

This measure corresponds to the yield of electricity in terms of metal produced. This metric is useful to incorporate several factors, such as mineralogy, and processes used. At the same time, it has to be noted that it can be distorted by production as by-product.

## Copper

**Figure 31 Electricity consumption / produced metal, Copper (GWh/'000 t)**

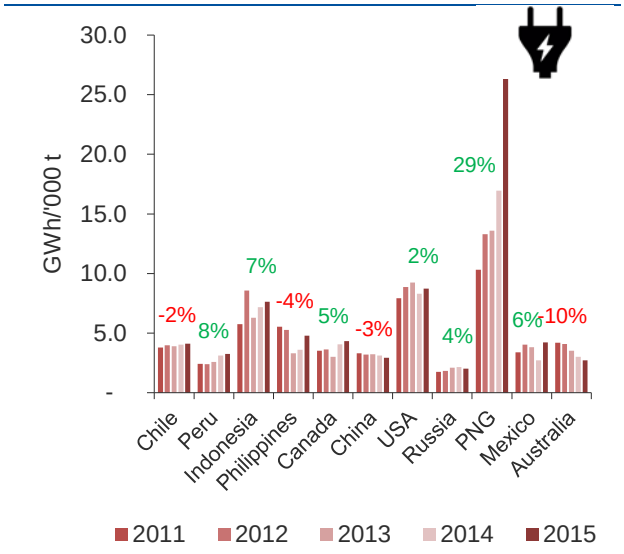
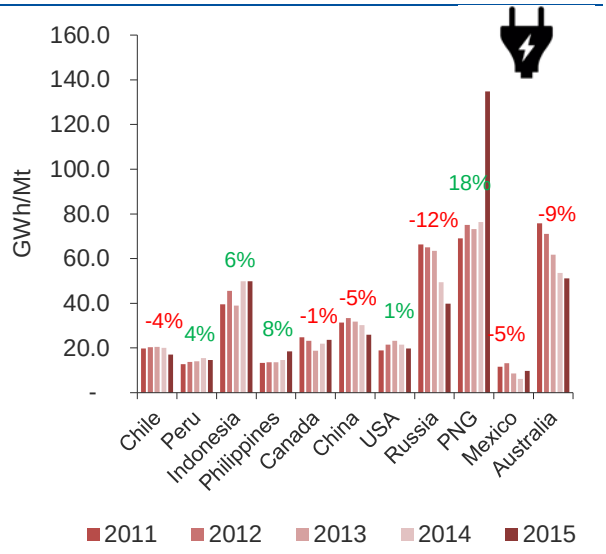



**Figure 32 Electricity consumption / processed ore, Copper (GWh/Mt)**



## Nickel

**Figure 33 Electricity consumption / produced metal, Nickel (GWh/'000 t)**

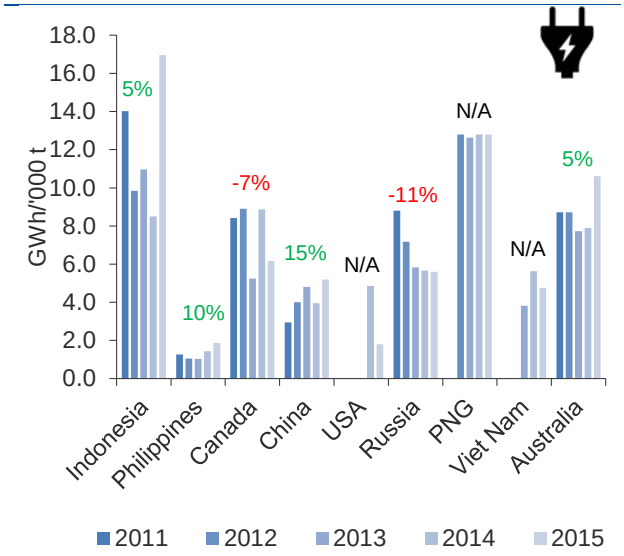
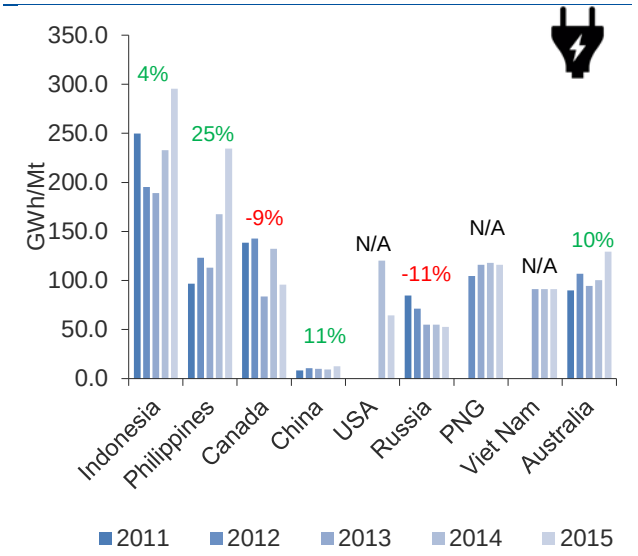



**Figure 34 Electricity consumption / processed ore, Nickel (GWh/Mt)**




## Iron ore

**Figure 35 Electricity consumption / produced metal, Iron ore (GWh/Mt)**

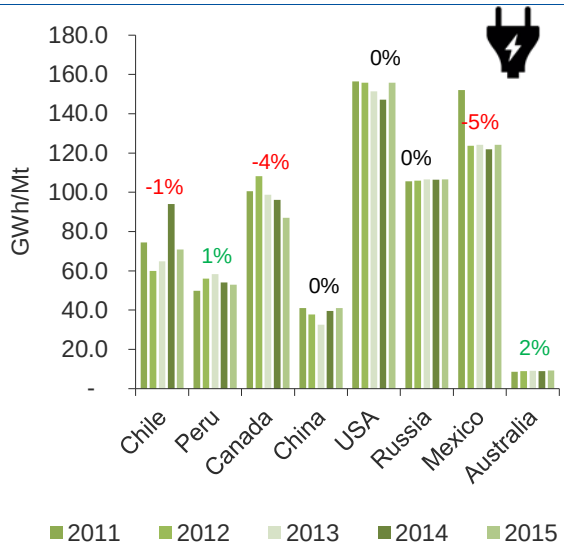
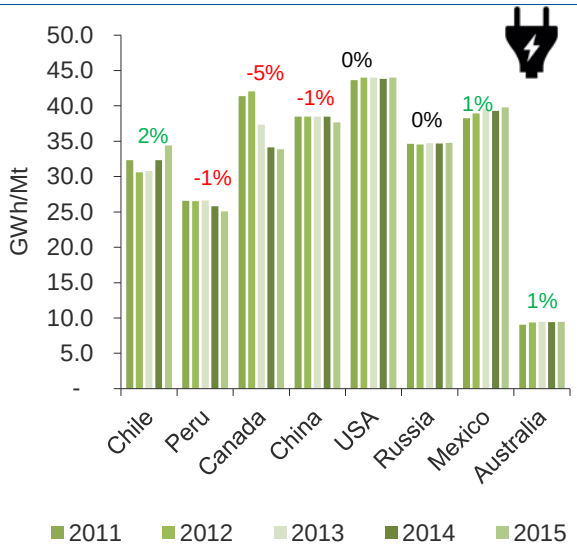


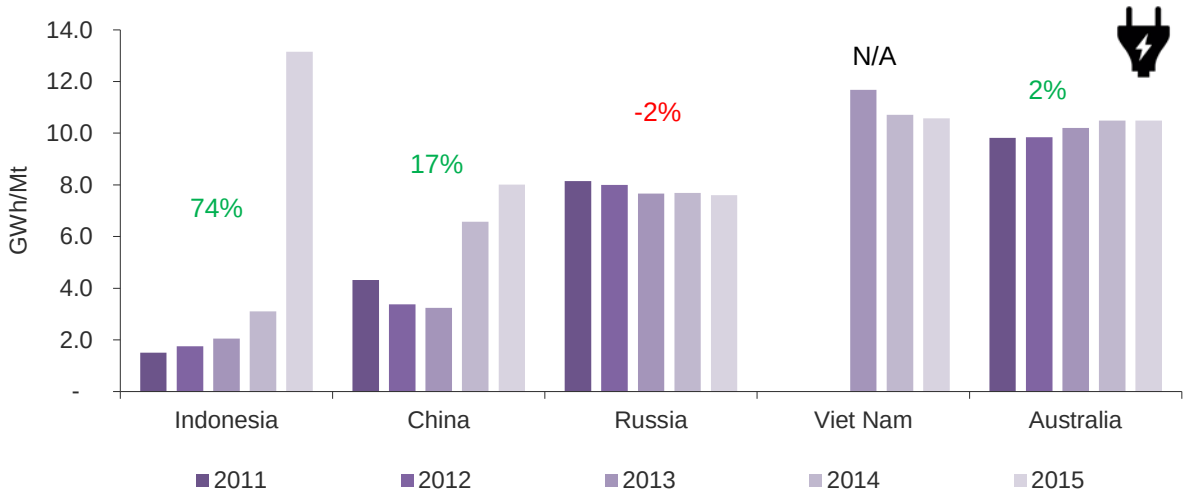

**Figure 36 Electricity consumption / processed ore, Iron ore (GWh/Mt)**



## Bauxite

As mentioned in the previous section, produced metal is not applicable in the case of bauxite so there´s only one productivity indicator: electricity consumption over processed ore.

**Figure 37 Electricity consumption / processed ore, Bauxite (GWh/Mt)**




## Zinc

**Figure 38 Electricity consumption / produced metal, Zinc (GWh/'000 t)**

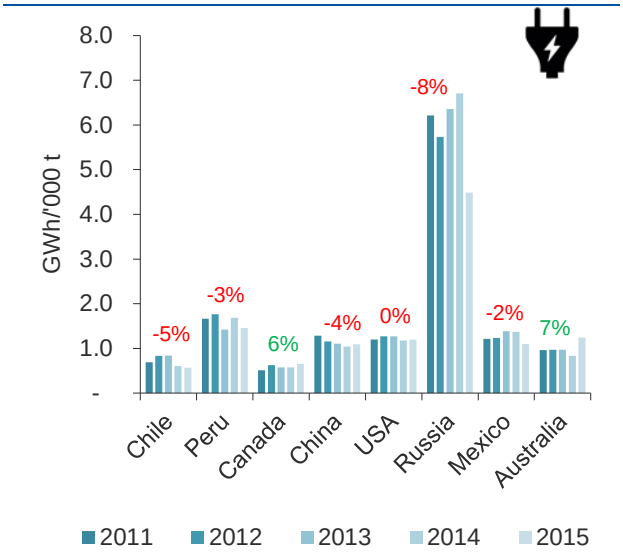
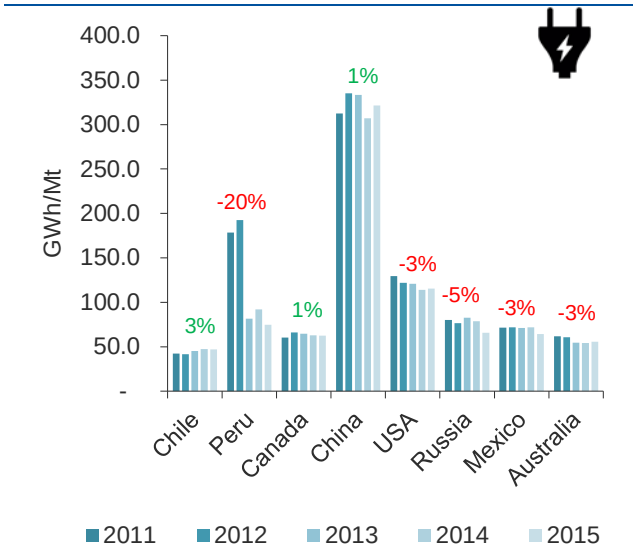



**Figure 39 Electricity consumption / processed ore, Zinc (GWh/Mt)**



# Lead

**Figure 40 Electricity consumption / produced metal, Lead (GWh/'000 t)**

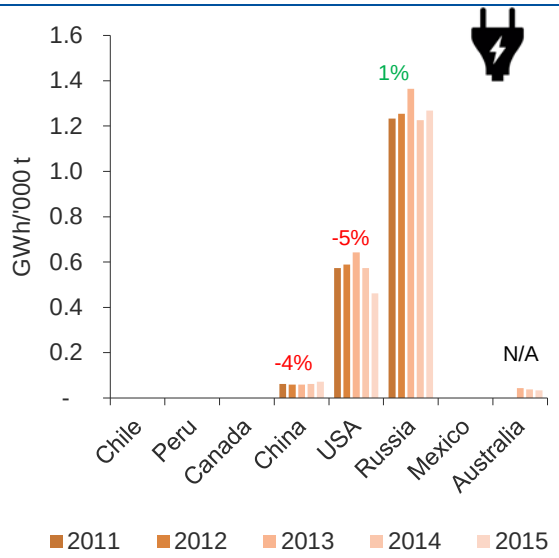
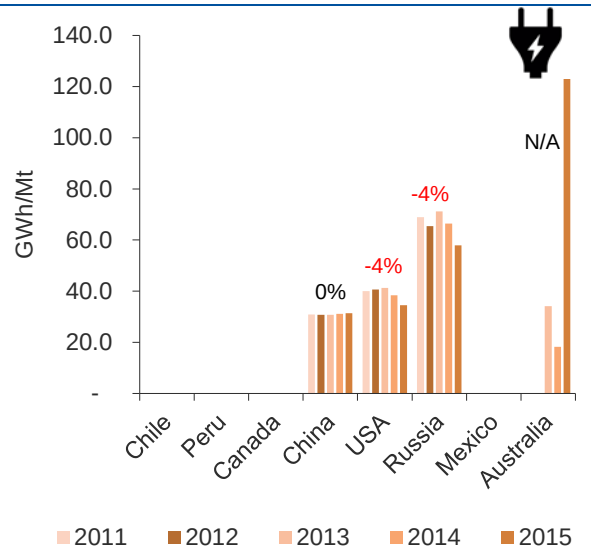



**Figure 41 Electricity consumption / processed ore, Lead (GWh/Mt)**




# Tin

**Figure 42 Electricity consumption / produced metal, Tin (GWh/'000 t)**

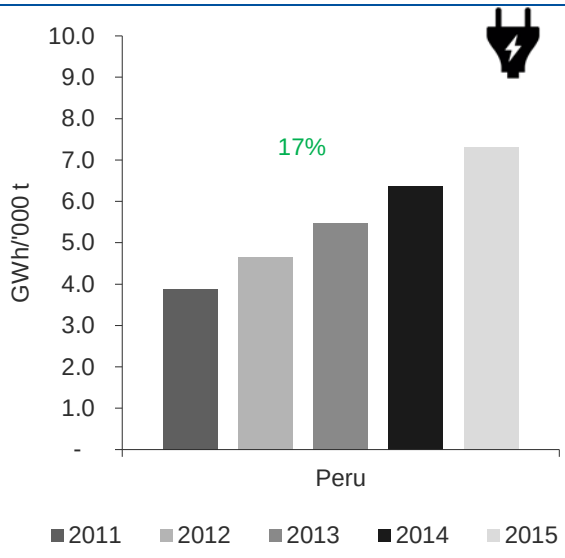
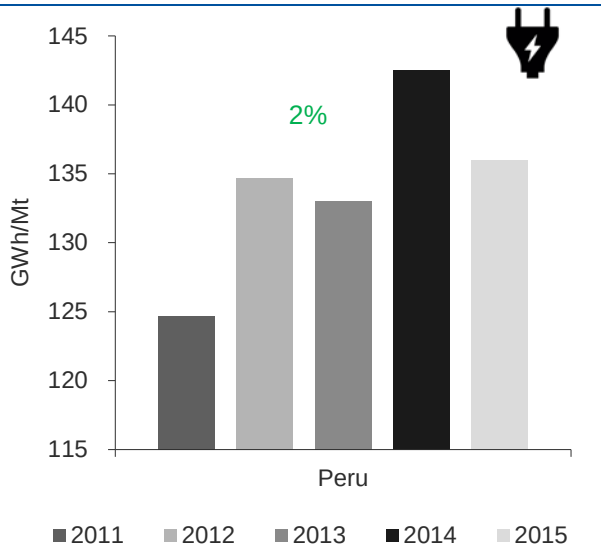


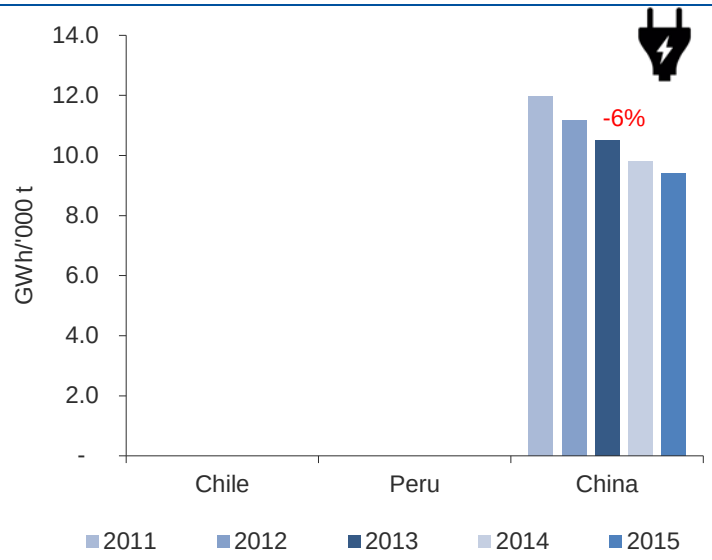

**Figure 43 Electricity consumption / processed ore, Tin (GWh/Mt)**



## Molybdenum

There is no data for molybdenum ore processed in China; therefore, the corresponding chart is obviated.

**Figure 44 Electricity consumption / produced metal, Molybdenum (GWh/'000t)**




Note: Chile and Peru have molybdenum production but as by-product.

## Gold

**Figure 45 Electricity consumption / produced metal, Gold (GWh/'000 oz)**

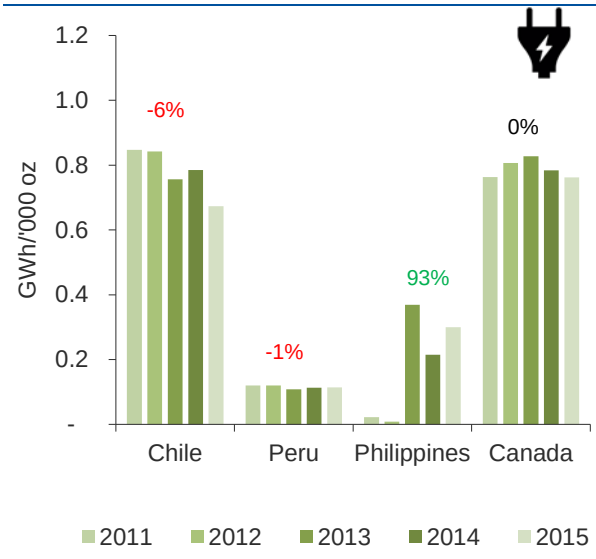
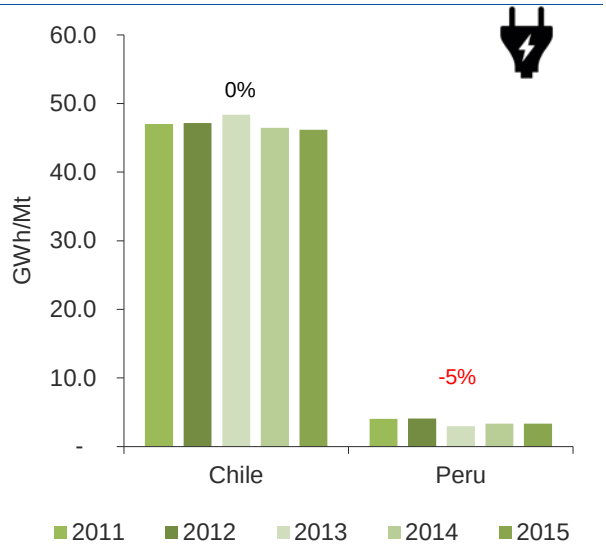


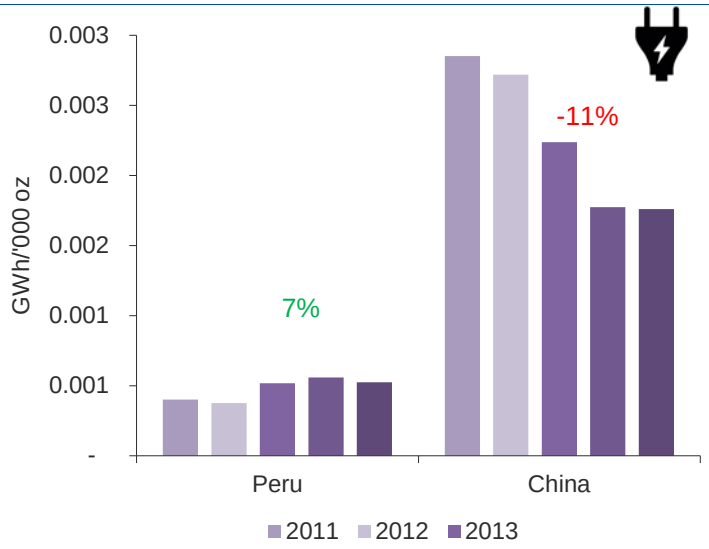

**Figure 46 Electricity consumption / processed ore, Gold (GWh/Mt)**



## Silver

There is no data for silver ore processed; therefore, the corresponding chart is obviated.

**Figure 47 Electricity consumption / Produced metal, Silver (GWh/'000 oz)**



### 4.2.3. Productivity for fuel consumption (productivity of Indicator 4)

There is no information available for lead, tin, cobalt, silver, platinum and palladium. Same as in the previous sections, the numbers on top of the series correspond to CAGR (Compound Annual Growth Rate) for 2011-2015.

## Copper

**Figure 48 Fuel consumption / produced metal, Copper (TJ /'000 t)**

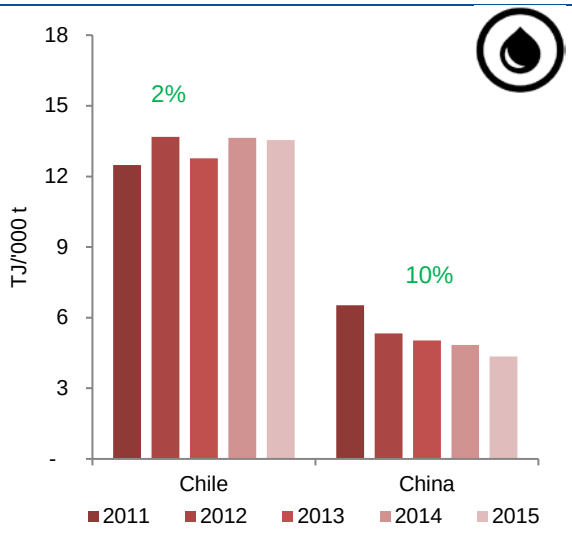
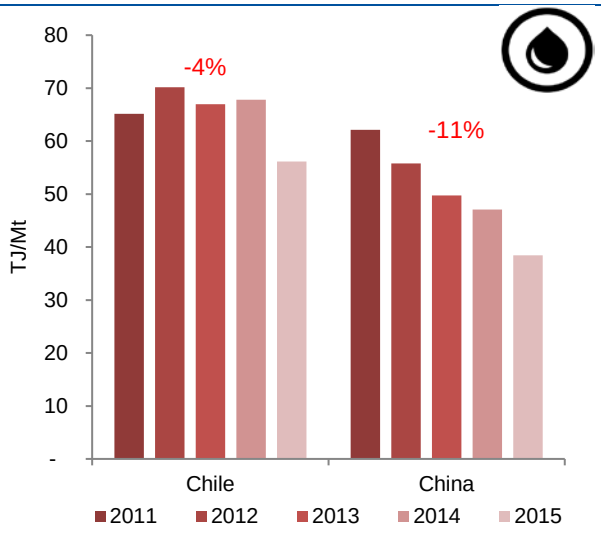



**Figure 49 Fuel consumption / processed ore, Copper (TJ /Mt)**



## Nickel

**Figure 50 Fuel consumption / produced metal, Nickel (TJ /'000 t)**

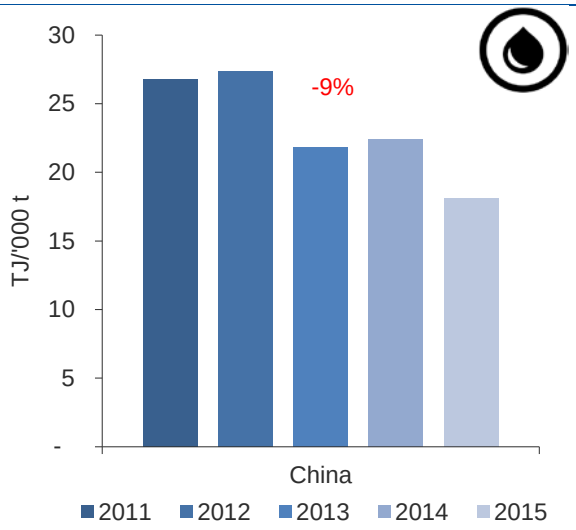
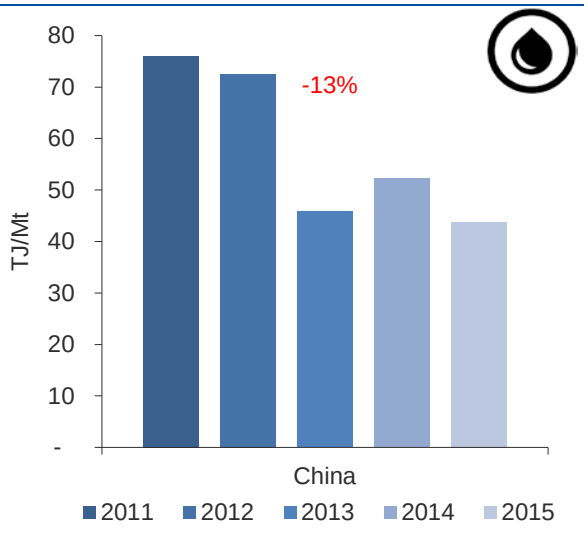



**Figure 51 Fuel consumption / processed ore, Nickel (TJ /Mt)**




## Iron ore

**Figure 52 Fuel consumption / produced metal, Iron ore (TJ / Mt)**

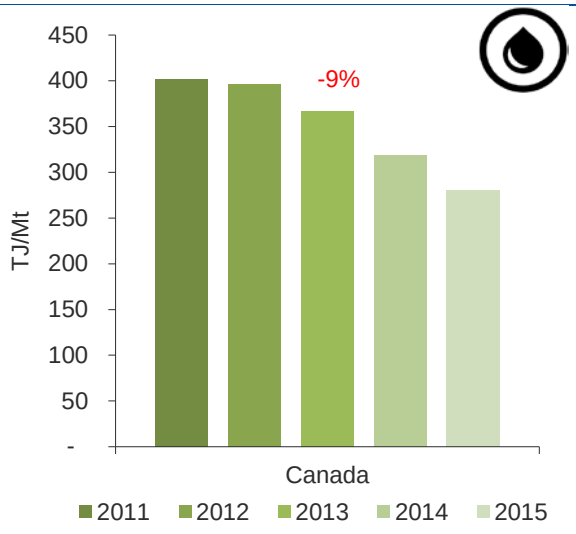
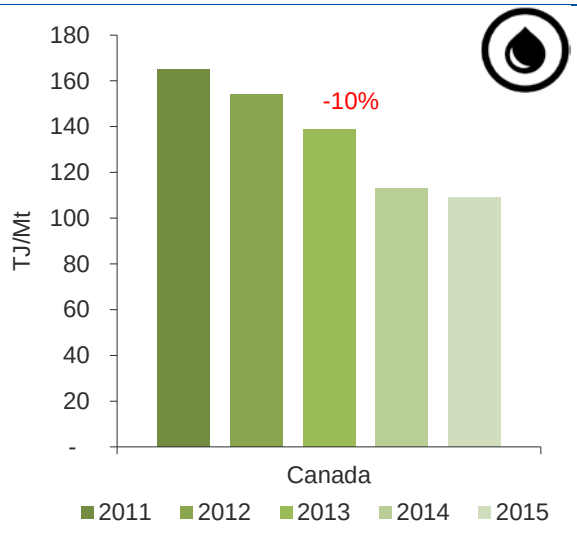
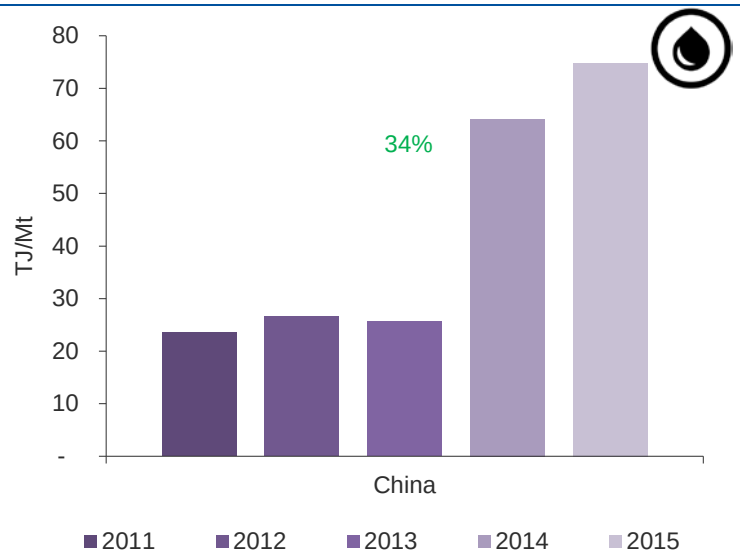



**Figure 53 Fuel consumption / processed ore, Iron ore (TJ / Mt)**



## Bauxite

**Figure 54 Fuel consumption / processed ore, Bauxite (TJ/Mt)**




## Zinc

**Figure 55 Fuel consumption / produced metal, Zinc (TJ/'000 t)**

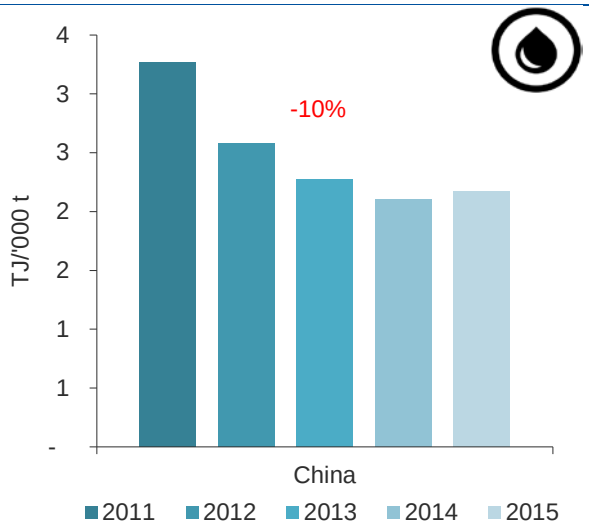
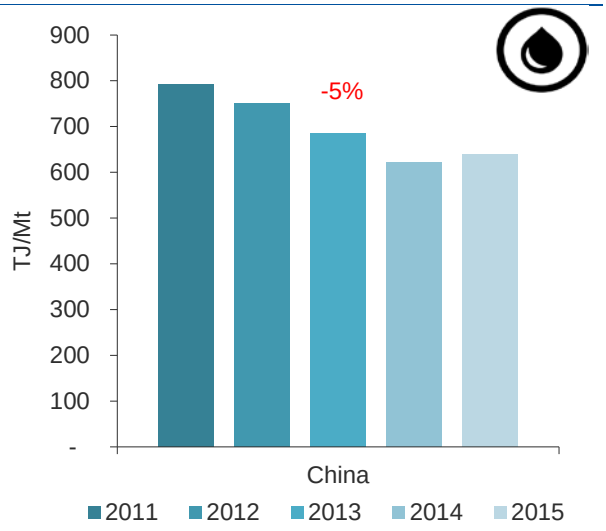


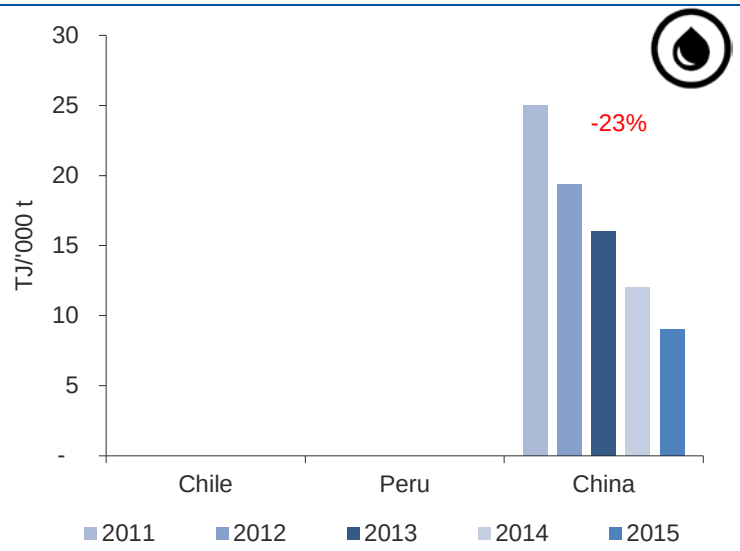

**Figure 56 Fuel consumption / processed ore, Zinc (TJ/Mt)**



## Molybdenum

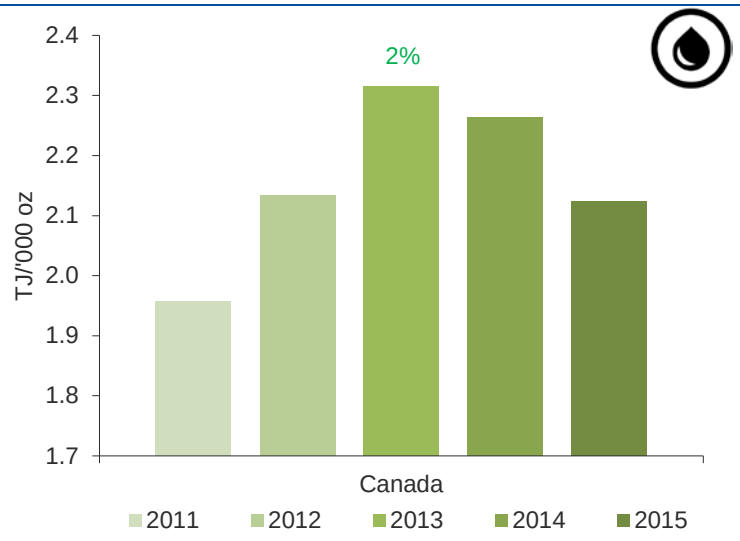
Since there is no primary production of molybdenum in Chile and Peru, there is no fuel consumption assigned to this production.

**Figure 57 Fuel consumption / produced metal, Molybdenum (TJ/'000 t)**



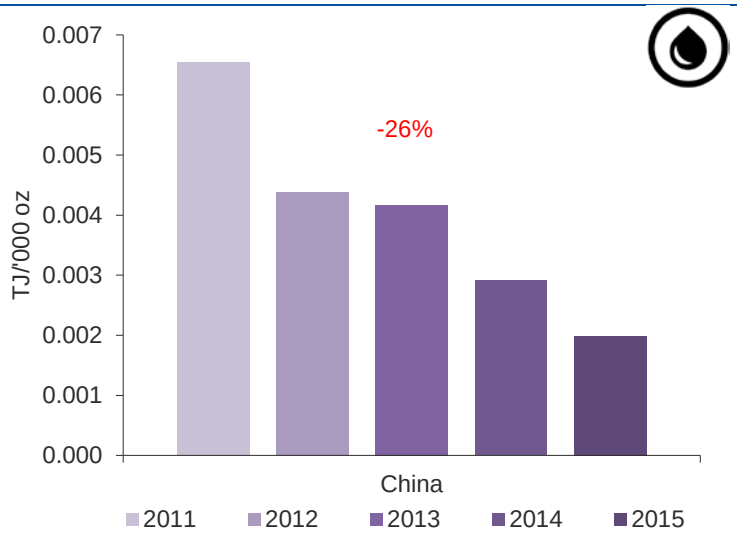

## Gold

**Figure 58 Fuel consumption / produced metal, Gold (TJ/'000 oz)**



## Silver

**Figure 59 Fuel consumption / produced metal, Silver (TJ/'000 oz)**



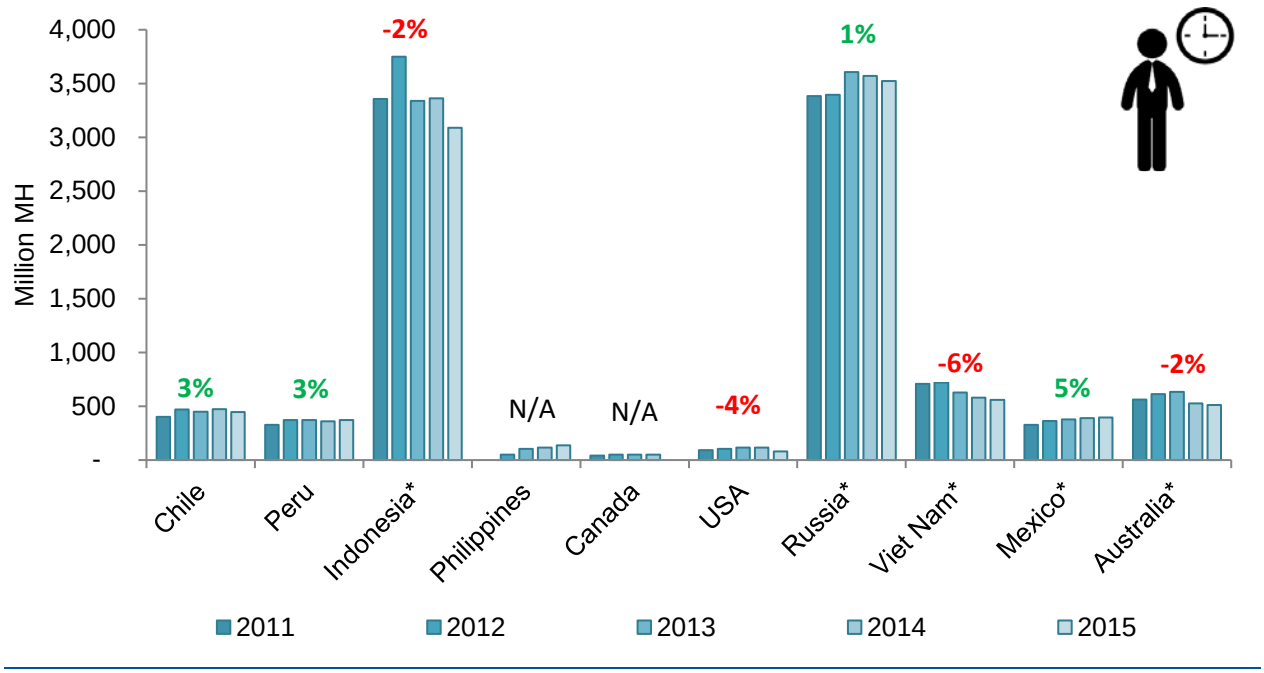

### 4.2.4. Total hours worked

Based on the dataset constructed for this study, Russia and Indonesia are by far the largest economies in terms of workforce (measured in man hours). As mentioned before, workforce data has been obtained from different sources and may not be fully consistent across economies. As such, the findings have to be considered as a general representation of the mining industry in each economy rather than an exact picture of the workforce of the selected commodities.

Indonesia and Russia are the two economies with the highest number of worked hours. Both figures have been obtained from the respective domestic statistics bureaus and correspond to the "Mining & Quarrying" sector. Indonesia's large workforce may be partially explained by the important size of the independent (also known as artisanal) mining sites, particularly in the gold sector.

As indicated above, all data estimated is marked with an asterisk next to the economy name.

**Figure 60 Indicator 5: Total hours worked by economy (Mill MH)**




(*) Estimated data

### 4.2.5. Labour productivity

This measure of productivity corresponds to the yield of labour in terms of metal processed. It is useful but presents the same potential problem as the one discussed for productivity for electricity consumption.

There is no information available for lead, molybdenum, cobalt and palladium. The data presented in this subsection has been obtained from three main sources: the primary survey, local bureaus of statistics and company reports. Typically, aggregated figures at economy level correspond to the mining and quarrying industry – hence, it includes a larger pool of commodities than the one under analysis in this report. However, it was finally decided to incorporate such data in the understanding that it serves the purposes of the study.

## Copper

**Figure 61 Total hours worked/ produced metal, Copper (Mill MH/'000 t)**

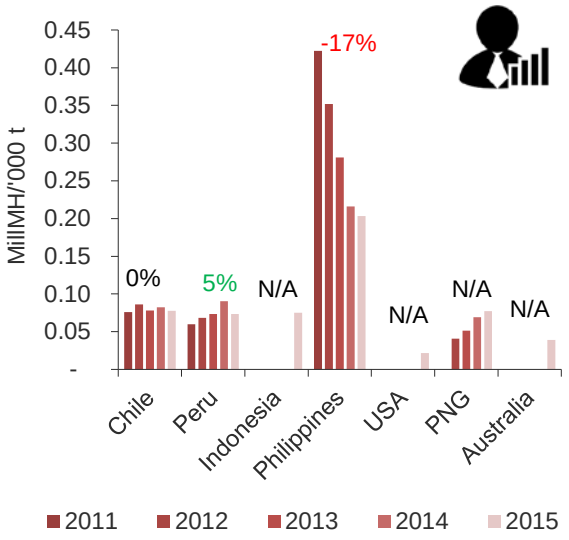
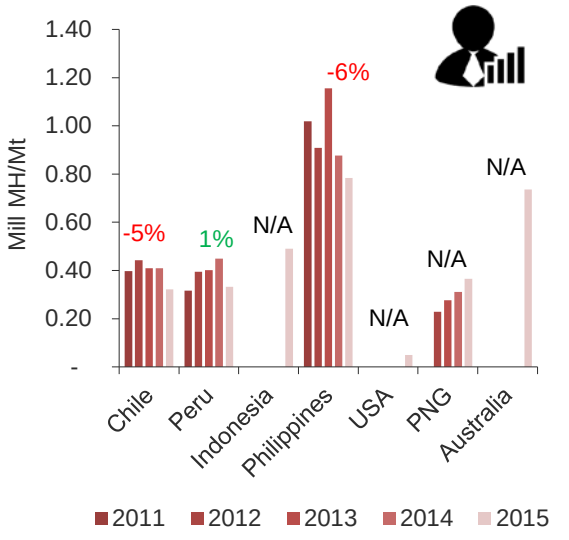



**Figure 62 Total hours worked/ processed ore, Copper (Mill MH/Mt)**




## Nickel

**Figure 63 Total hours worked/ produced metal, Nickel (Mill MH/'000 t)**

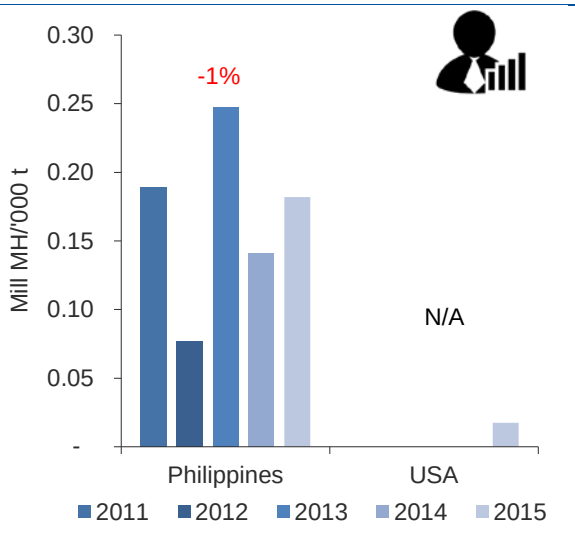
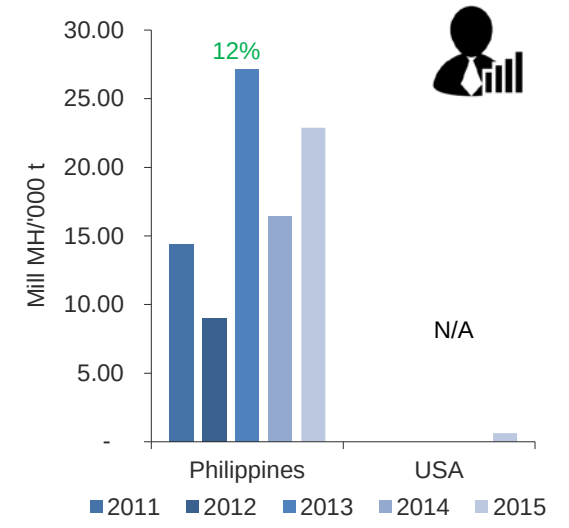



**Figure 64 Total hours worked/ processed ore, Nickel (Mill MH/Mt)**



## Iron ore

**Figure 67 Total hours worked/ produced metal, Iron ore (Mill MH/Mt)**

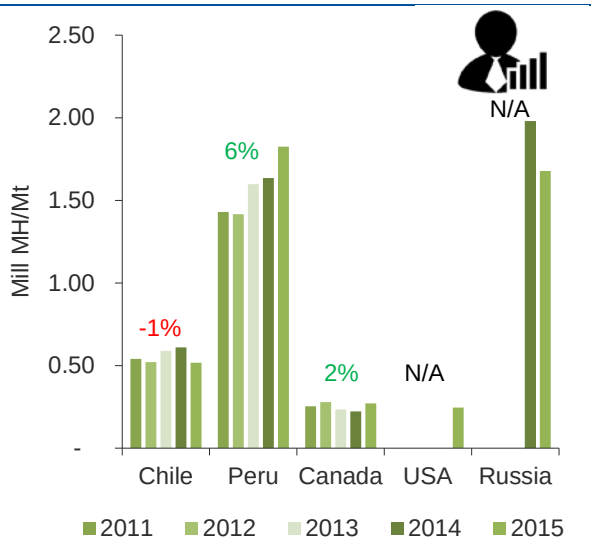
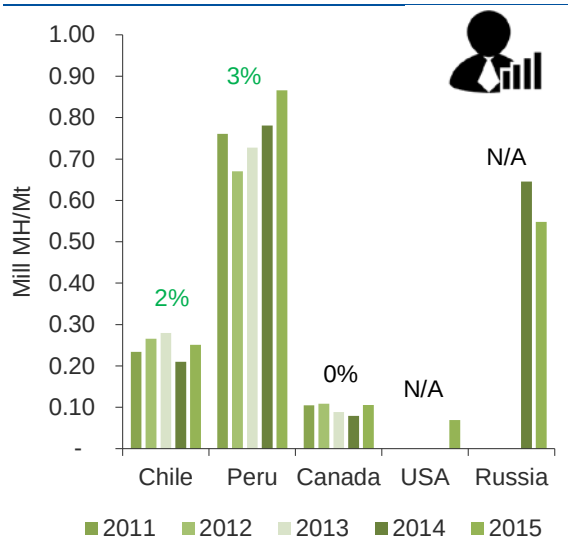



**Figure 68 Total hours worked/ processed ore, Iron ore (Mill MH/Mt)**




## Zinc

**Figure 65 Total hours worked/ produced metal, Zinc (Mill MH/'000 t)**

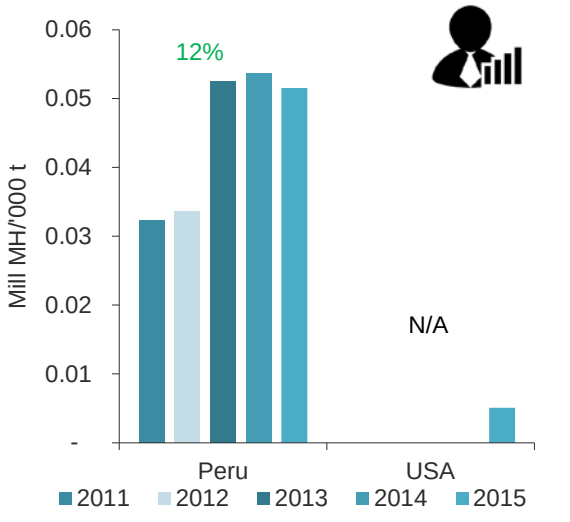
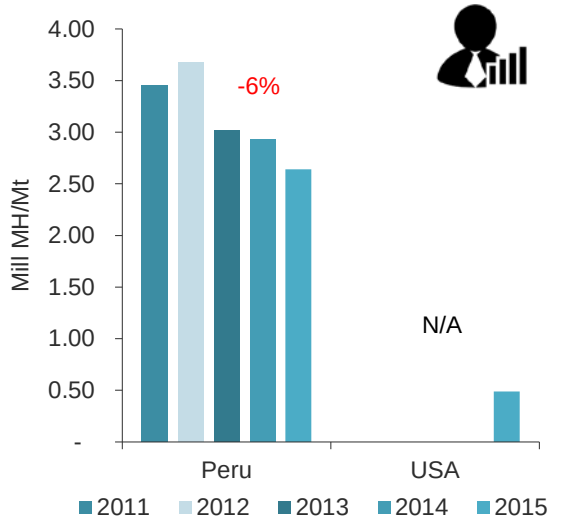



**Figure 66 Total hours worked/ processed ore, Zinc (Mill MH/Mt)**



## Tin

**Figure 70 Total hours worked/ produced metal, Tin (Mill MH/'000 t)**

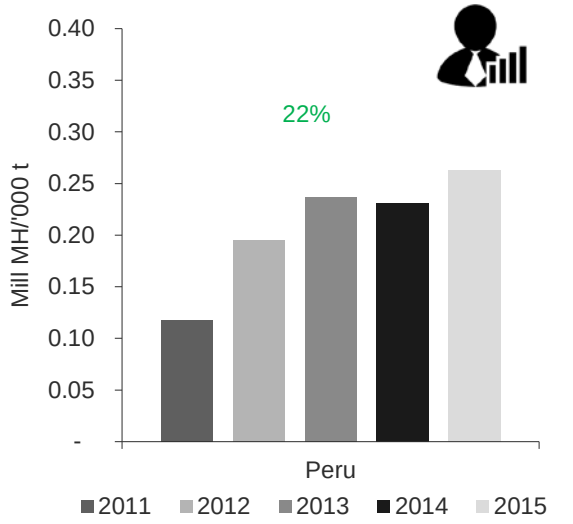
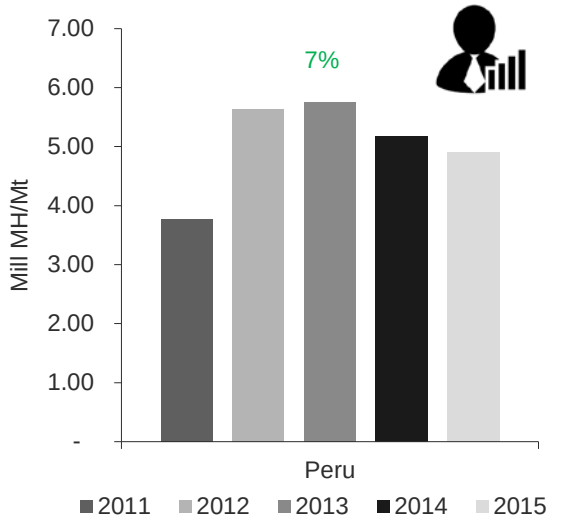



**Figure 69 Total hours worked/ processed ore, Tin (Mill MH/Mt)**




## Gold

There is no information available on how much ore is processed for gold extraction in the Philippines and the United States.

**Figure 71 Total hours worked/ produced metal, Gold (Mill MH/'000 oz)**

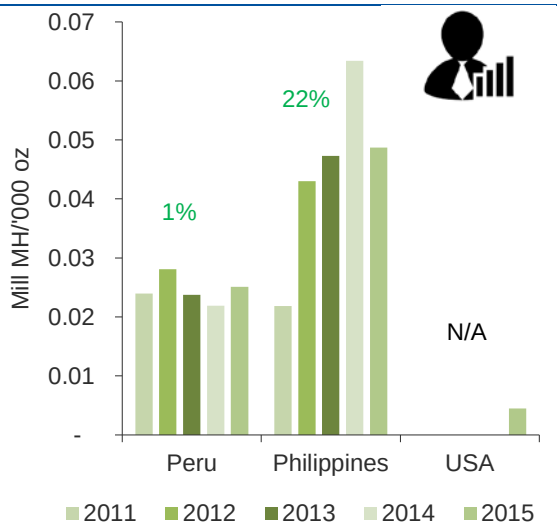
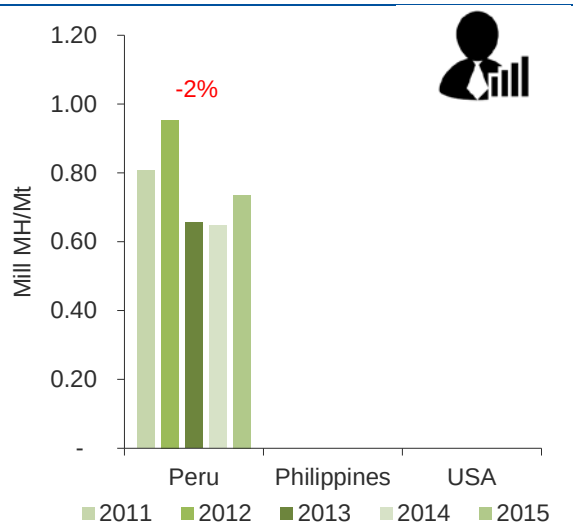
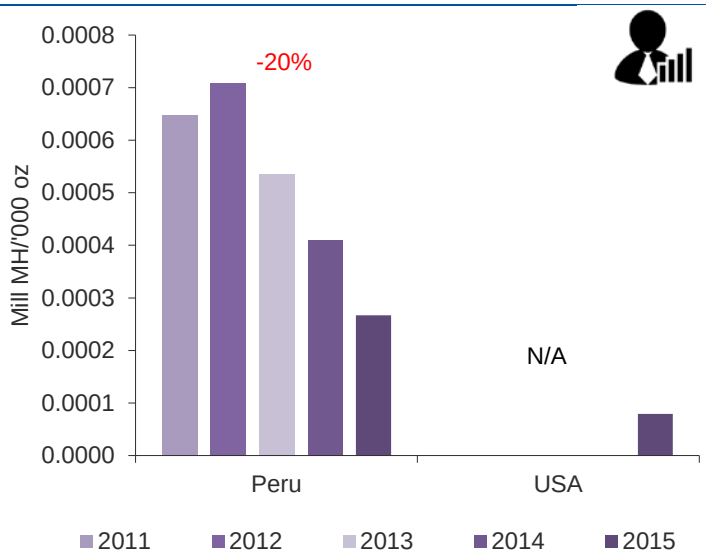



**Figure 72 Total hours worked/ processed ore, Gold (Mill MH/Mt)**



## Silver

**Figure 73 Total hours worked/ produced metal, Silver (Mill MH/'000 oz)**




### 4.2.6. Gender diversity

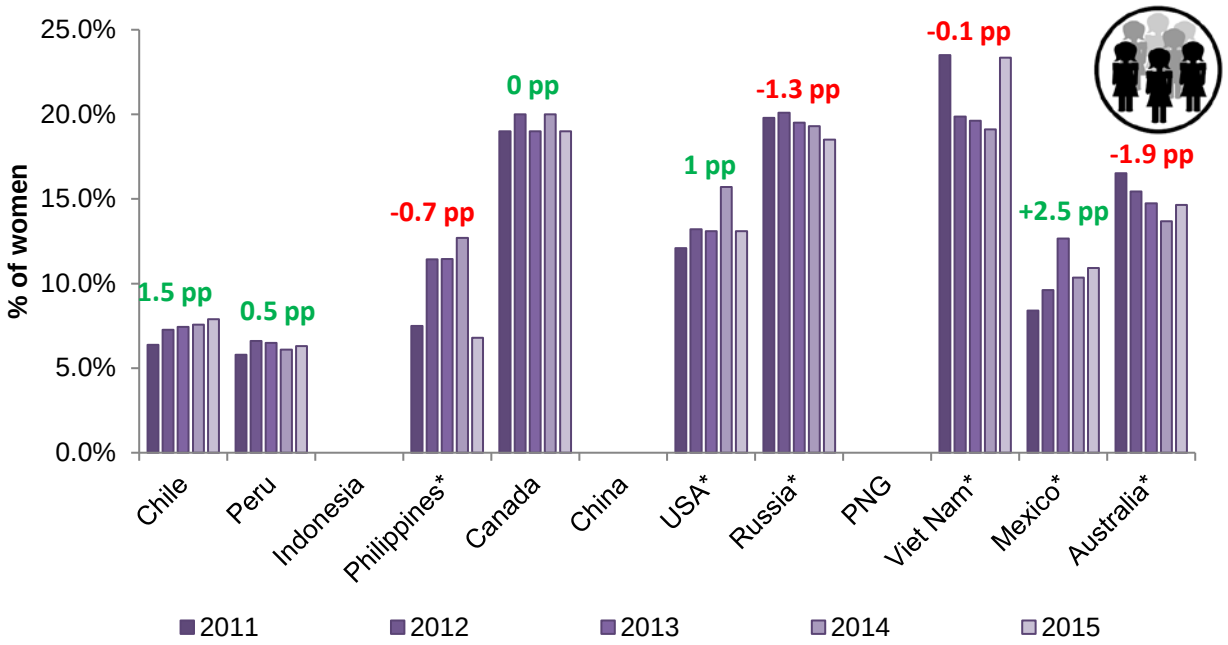
This information is usually available for the mining industry at aggregated level by economy (i.e. no detail by commodity). Only Canada, Chile and Peru provided information about this indicator. In the case of Canada values correspond to mining, quarrying and oil & gas extraction because more detailed data is not available.

The dataset has been complemented via secondary research for the following economies: the Philippines, USA, Russia, Viet Nam, Mexico and Australia. In most of the cases the percentage corresponds to the mining and quarrying sector as a whole.

Viet Nam, Russia and Canada are the three economies with the highest penetration of female employees which stands at ~20%. Chile and Peru are located on the opposite side of the spectrum with the lowest participation of women in the industry: 8% and 6% respectively. These percentages have not changed significantly in the last five years.

The chart below shows in numbers the percentage point variation from 2011 to 2015.

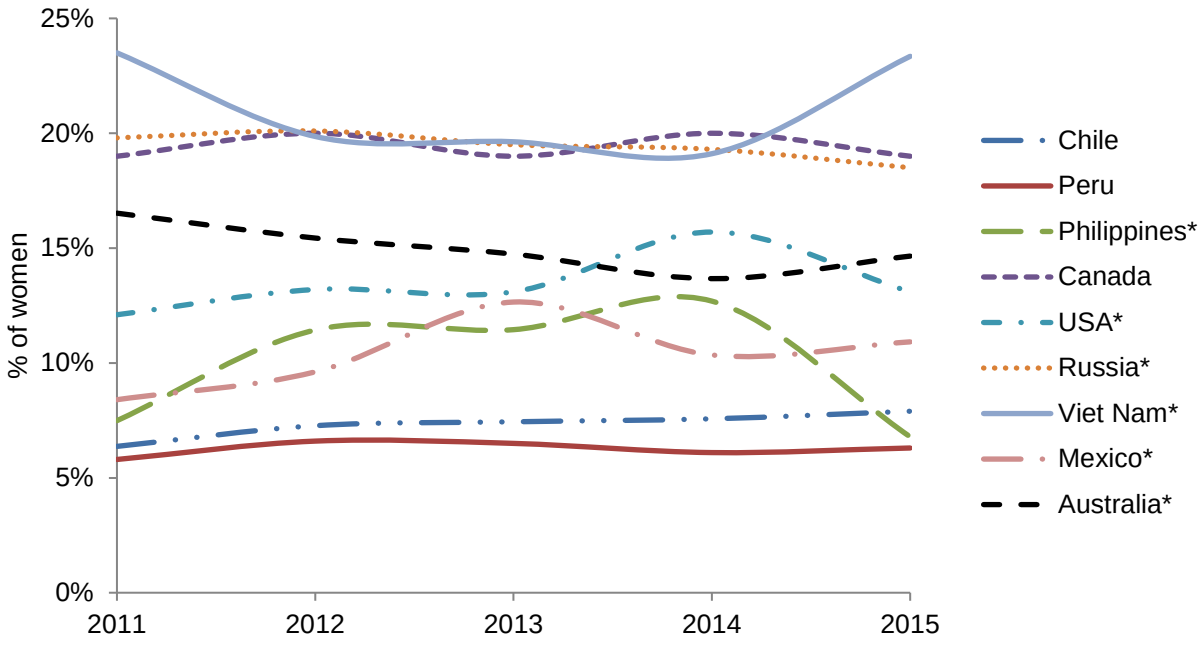
**Figure 74 Indicator 6: Gender distribution, aggregated information (% of women)**




(*) Estimated data

More broadly, gender distribution has remained relatively stable among the economies under analysis. The chart below presents the same information in a different manner, showing that no clear growth pattern can be observed during the forecast period: every year the maximum and minimum values have remained practically the same.

**Figure 75 Indicator 6: Gender distribution, evolution by year (% of women)**




(*) Estimated data

### 4.2.7. Fixed assets

This information is only available for Chile and Canada, as shown in the table below:

**Table 18 Value of non-current assets (PPE) ($ million)**

| | Chile | | | Canada |
|---|---|---|---|---|
| | Copper | Iron Ore | Gold | Copper |
| **2011** | 43,165 | 866 | 1,433 | 56,323 |
| **2012** | 49,958 | 1,461 | 2,101 | 69,637 |
| **2013** | 61,022 | 2,354 | 1,686 | 79,135 |
| **2014** | 71,513 | 2,515 | 1,646 | 85,730 |
| **2015** | 73,111 | 2,546 | 1,378 | 89,556 |

**Table 19 Non-current assets / produced metal ($ million/produced metal)**

| | Chile | | | Canada |
|---|---|---|---|---|
| | Copper | Iron Ore | Gold | Copper |
| | ($ mn / '000 t) | ($ mn / Mt) | ($ mn / '000 oz) | ($ mn / '000 t) |
| **2011** | 8 | 112 | 1.0 | 102 |
| **2012** | 9 | 155 | 1.3 | 124 |
| **2013** | 11 | 259 | 1.0 | 127 |
| **2014** | 12 | 267 | 1.1 | 131 |
| **2015** | 13 | 278 | 1.0 | 128 |

**Table 20 Non-current assets / processed ore ($ million/processed ore)**

| | Chile | | | Canada |
|---|---|---|---|---|
| | Copper | Iron Ore | Gold | Copper |
| | ($ mn / Mt) | ($ mn / Mt) | ($ mn / Mt) | ($ mn / Mt) |
| **2011** | 43 | 49 | 55 | 719 |
| **2012** | 47 | 79 | 73 | 794 |
| **2013** | 55 | 123 | 65 | 793 |
| **2014** | 62 | 92 | 66 | 707 |
| **2015** | 53 | 135 | 69 | 704 |

# 5. Final Analysis

## 5.1. General conclusions on productivity

This section presents further analysis on the productivity indicators presented in the previous chapter. The tables below present a ranking for each indicator and commodity where the least productive economy is assigned a score of 1 and is coloured in red. Colour coding shifts to a green palette as the score improves – the most productive economy gets the highest number. The ranking has been constructed considering the average indices for 2011-2015 and is based on the combination of surveyed and estimated data.

Electricity and fuel consumption are presented in terms of produced metal which is deemed as the most relevant metric for productivity analysis purposes. Production data is certainly more accurate and has been obtained, in the majority of the cases, first hand from APEC partner organisations. Processed ore, on the other hand, has been estimated in many cases which could result in a less accurate outcome if used for productivity calculations.

Cobalt and palladium has been excluded from the analysis as there is no available data in any economy. Fuel consumption productivity cannot be analysed because only China, Chile (for copper) and Canada (for iron ore) provided information.

Russia presents the highest ratio of produced metal over processed ore for copper. This is likely because a significant proportion of copper production comes as a by-product of nickel. Australia is the most productive economy in iron ore whereas the Philippines in nickel. Chile and Peru are among the least productive in the copper industry. This may be explained by the fact that a very large proportion of their production comes from large open pit mines whereas other economies (e.g. Australia) present significant volumes from underground operations.

**Figure 76 Produced metal / Processed ore, ranking**

| Country | Chile | Peru | INA | PH | Canada | China | USA | Russia | PNG | VN | Mexico | AUS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Copper | 4 | 5 | 8 | 3 | 7 | 9 | 1 | 11 | 6 | n.a. | 2 | 10 |
| Nickel | n.a. | n.a. | 5 | 6 | 4 | 1 | n.a. | 2 | n.a. | n.a. | n.a. | 3 |
| Iron Ore | 5 | 6 | n.a. | n.a. | 4 | 7 | 1 | 3 | n.a. | n.a. | 2 | 8 |
| Bauxite | n.a. | n.a. | 1 | n.a. | n.a. | 1 | n.a. | 1 | n.a. | n.a. | n.a. | 1 |
| Zinc | 4 | 5 | n.a. | n.a. | 7 | 8 | 6 | 1 | n.a. | n.a. | 2 | 3 |
| Lead | n.a. | n.a. | n.a. | n.a. | n.a. | 3 | 2 | 1 | n.a. | n.a. | n.a. | n.a. |
| Gold | 2 | 1 | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Tin | n.a. | 1 | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Moly | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Silver | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Platinum | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |

As presented in the figure below, Peru seems to be highly productive in terms of electricity consumption across most of the commodities under analysis. China also ranks high in relevant industries such as iron ore, copper, nickel and bauxite. The reasons for such results could be further explored by a detailed analysis at mining operation level that exceeds the scope of work of this study. No clear differences can be observed between developed and emerging economies in this field.

**Figure 77 Electricity consumption / Produced metal, ranking**

| Country | Chile | Peru | INA | PH | Canada | China | USA | Russia | PNG | VN | Mexico | AUS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Copper | 5 | 10 | 3 | 4 | 6 | 9 | 2 | 11 | 1 | n.a. | 7 | 8 |
| Nickel | n.a. | n.a. | 2 | 9 | 4 | 7 | 8 | 5 | 1 | 6 | n.a. | 3 |
| Iron Ore | 5 | 6 | n.a. | n.a. | 4 | 7 | 1 | 3 | n.a. | n.a. | 2 | 8 |
| Bauxite | n.a. | n.a. | 5 | n.a. | n.a. | 4 | n.a. | 3 | n.a. | 1 | n.a. | 2 |
| Zinc | 7 | 2 | n.a. | n.a. | 8 | 5 | 4 | 1 | n.a. | n.a. | 3 | 6 |
| Lead | n.a. | n.a. | n.a. | n.a. | n.a. | 3 | 2 | 1 | n.a. | n.a. | n.a. | 4 |
| Gold | 2 | 4 | n.a. | 3 | 1 | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Tin | n.a. | 1 | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Moly | n.a. | n.a. | n.a. | n.a. | n.a. | 1 | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Silver | n.a. | 2 | n.a. | n.a. | n.a. | 1 | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Platinum | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |

The analysis of labour productivity shows that the United States is the most productive in all the commodities where data has been obtained (source: the U.S. Bureau of Labor Statistics). In general terms, one of the key findings of the study is that developed economies (Australia; Canada; USA) seem to present the highest indices of labour productivity among APEC economies. This insight certainly requires further research to be fully understood. Labour regulation, work practices and education may be some areas of interest for future studies.

**Figure 78 Total hours worked / Produced metal, ranking**

| Country | Chile | Peru | INA | PH | Canada | China | USA | Russia | PNG | VN | Mexico | AUS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Copper | 2 | 3 | 5 | 1 | n.a. | n.a. | 7 | n.a. | 4 | n.a. | n.a. | 6 |
| Nickel | n.a. | n.a. | n.a. | 1 | n.a. | n.a. | 2 | n.a. | n.a. | n.a. | n.a. | n.a. |
| Iron Ore | 3 | 1 | n.a. | n.a. | 4 | n.a. | 5 | 2 | n.a. | n.a. | n.a. | n.a. |
| Bauxite | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Zinc | n.a. | 1 | n.a. | n.a. | n.a. | n.a. | 2 | n.a. | n.a. | n.a. | n.a. | n.a. |
| Lead | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Gold | n.a. | 2 | n.a. | 1 | n.a. | n.a. | 3 | n.a. | n.a. | n.a. | n.a. | n.a. |
| Tin | n.a. | 1 | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Moly | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| Silver | n.a. | 1 | n.a. | n.a. | n.a. | n.a. | 2 | n.a. | n.a. | n.a. | n.a. | n.a. |
| Platinum | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | 1 | n.a. | n.a. | n.a. | n.a. | n.a. |

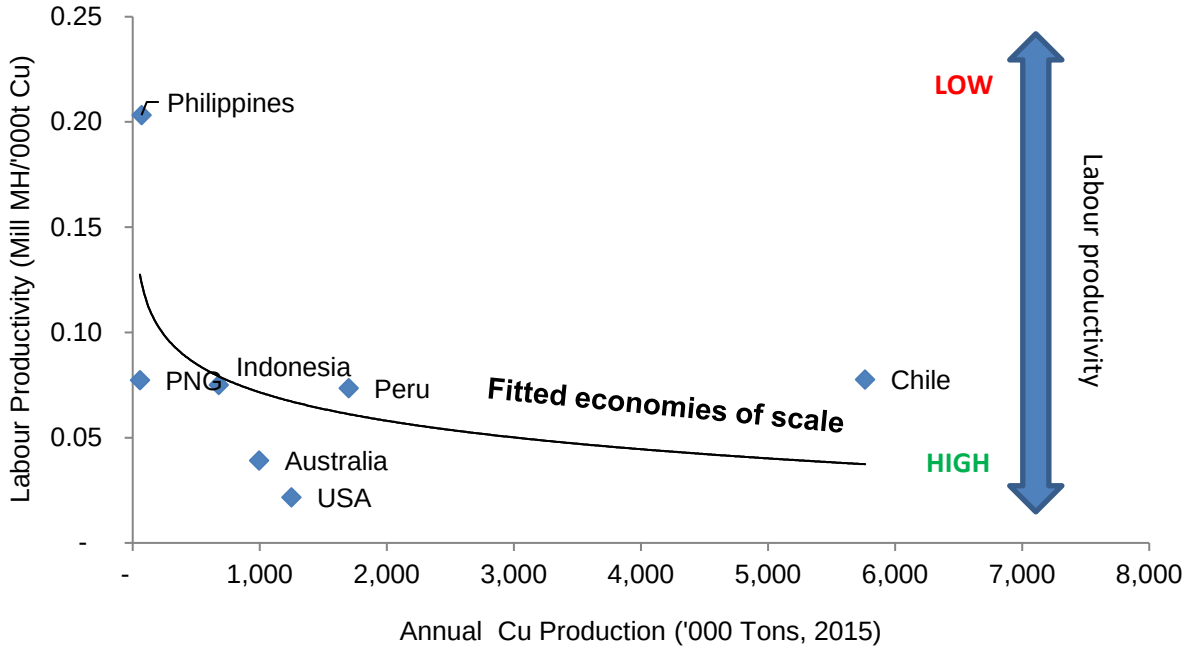
Labour productivity in the copper and iron ore industries (the two largest commodity markets by value) have been compared to production volumes with the objective of identifying potential gains that may occur as result of economies of scale.

The chart below plots this relationship for the copper industry. The ‘x’ axis shows annual production and the ‘y’ axis refers to labour productivity which improves as values decrease (less man hours are used to produce a ton of copper).

The limited dataset restricts the ability to draw definitive conclusions. However it can be noted economies of scale do not seem to yield benefits in terms of labour productivity. It is interesting to observe that Chile, Peru, Indonesia and PNG present similar labour productivity indices (all of them demanding 74,000 to 77,000 man-hours to produce a tonne of copper) but with totally different production levels – Chile’s annual output is 100 times larger than that of PNG. Intuitively, it may be expected that such difference in production volumes results in important gains in labour productivity but this dataset indicates that this may not apply.

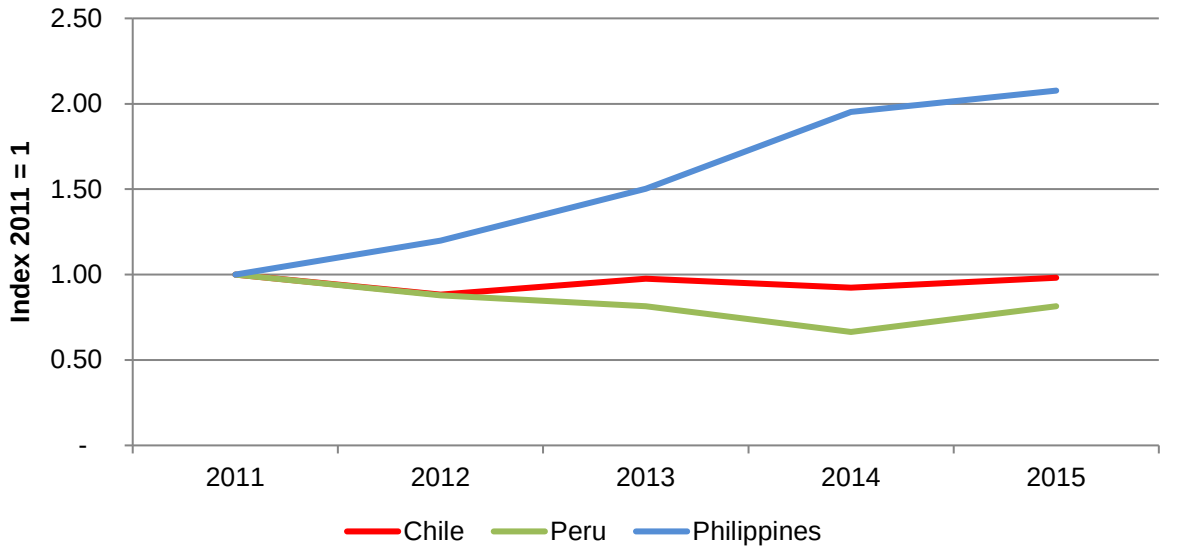
Further analysis would be required to better support these findings.

**Figure 79 Relationship labour productivity / annual production, Copper**




Only three economies present a full dataset to analyse the evolution of labour productivity in the copper industry since 2011: Chile, Peru and the Philippines. The picture diverges in each case: Peru has experienced a decline of ~20% in its productivity during the period under analysis; Chile has remained stable whereas the Philippines more than doubled the labour productivity though from a very low base, corresponding to a reduced production level (less than 100,000 tons/year).

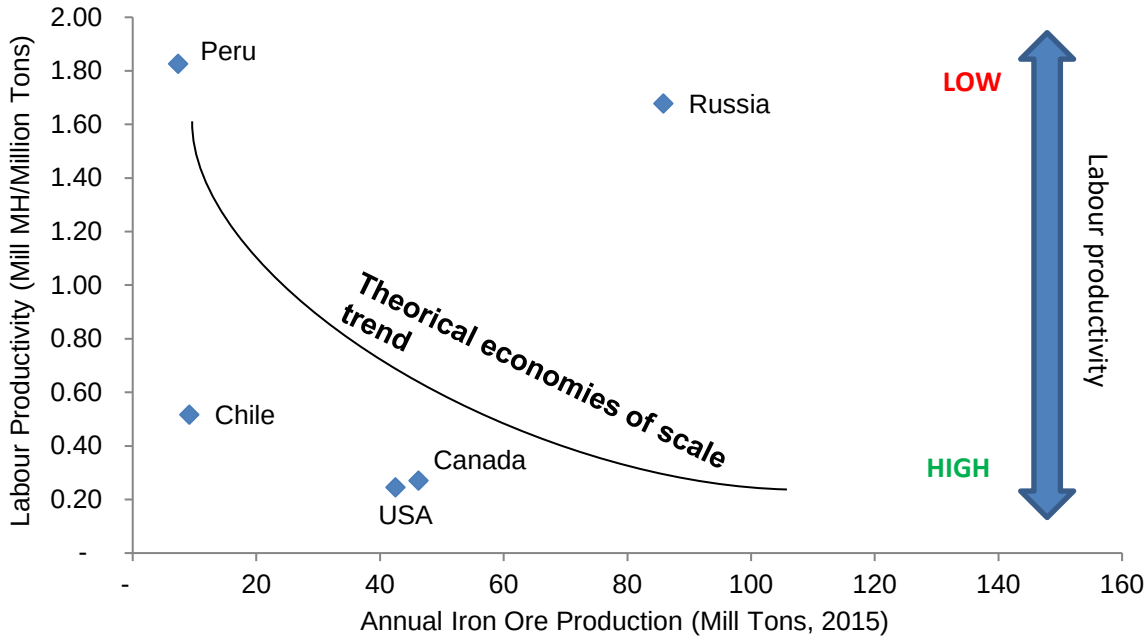
**Figure 80 Evolution of labour productivity, Copper, Index 2011=1**



Following a similar approach as with copper, labour productivity in the iron industry has been estimated for Chile, Peru, Canada, USA and Russia. Interestingly, Canada and USA are the two leading economies within this sample with very similar productivity and production levels. The North American economies are followed by Chile in a distant third place and Peru and Russia close the ranking with remarkably low levels.

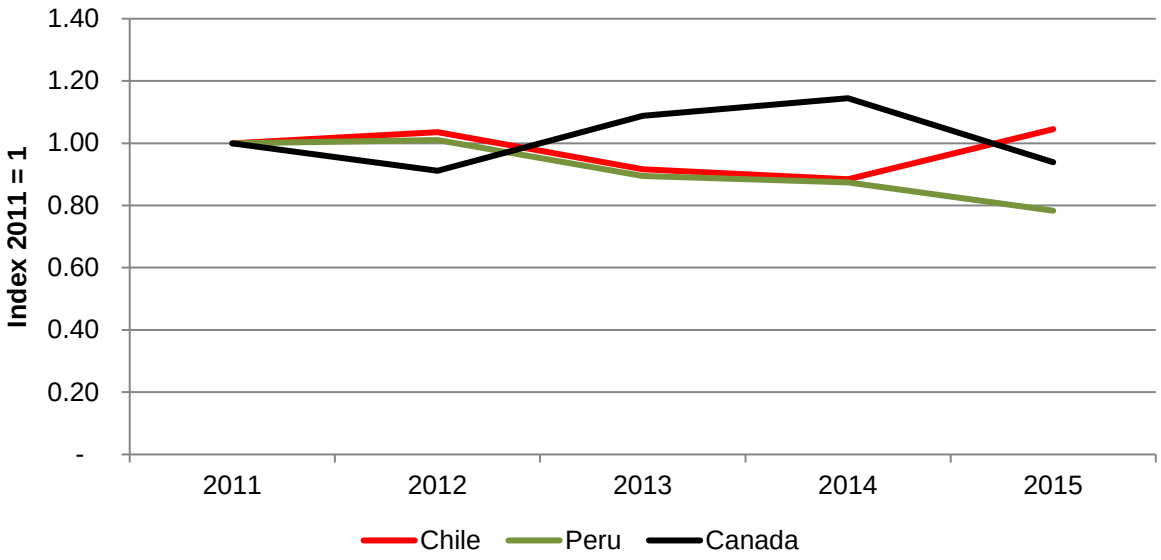
Same as with copper, data suggests that labour productivity does not correlate with production levels. In other words, economies of scale would not result in productivity gains. These conclusions need to be further analysed in subsequent studies, incorporating additional datapoints.

**Figure 81 Relationship labour productivity / annual production, Iron ore**




The chart below shows the evolution of labour productivity in the iron ore industry for Chile, Peru and Canada – the only three economies where the data is available. Both Canada and Chile show similar levels in 2015 than in 2011 whereas Peru's productivity decreased by ~20% in the same period.

**Figure 82 Evolution of labour productivity, Iron ore, Index 2011=1**




## 5.2. Continuity of the project

The main objective of this project is the dissemination of key industry information in an economy level to increase the competitiveness of APEC economies, increasing their productive efficiency. The longer term impact is to strengthen economic growth, investment, trade and business capacity, delivering development benefits for communities and resources for expanding industries. As such, it is intended to become a long term product to serve the needs of APEC economies.

The methodological framework and network of contacts developed for this project should serve as basis for the replication of the analysis in coming years – presumably on an annual basis. APEC's Mining Task Force, is expected to lead these efforts, levering on the experience already gained. The goal is to enlarge and improve the dataset by building capacity in the APEC member economies.

Knowledge sharing will be of outmost importance for the success of this going forward: 'partner organisations' should be engaged and made aware of the results of the present study.

# Sources of information

## Primary survey

- National Mining Association, USA
    - Contact person: Leslie Coleman
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- Department of Industry, Innovation and Science, Australia
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- Natural Resources Canada, Canada
    - Contact person: Eleni Deroukakis
    - Email: eleni.deroukakis@canada.ca
- China Nonferrous Metals Industry Association, China
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    - Email: Liyusheng@chinania.org.cn
- Cochilco, Chile
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- Directorate General of Mineral and Coal, Indonesia
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- Chamber of Mines, the Philippines
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    - Email: nch@chamberofmines.com.ph
- Mines and Geosciences Bureau, the Philippines
    - Contact person: Glenn Marcelo C. Noble
    - Email: glnnoble@yahoo.com
- Ministry of Energy and Mines, Peru
    - Contact person: Alfredo Rodríguez Muñoz
    - Email: arodriguez@minem.gob.pe

## Second layer survey

- Russia
  - Evraz, Annual Report & Accounts (2015, 2014, 2013)
  - Metalloinvest, Annual Report (2016)
  - Severstal, Annual Report (2015, 2014, 2013, 2012, 2011)
  - NLMK, Corporate website (https://sgok.nlmk.com/en/about/)
- Papua New Guinea
  - OK Tedi Mining, Annual Review (2016, 2014)
- Indonesia
  - Newmont Mining, Annual Report to the Voluntary Principles on Security and Human Rights (2015)
  - PT Freeport Indonesia, Form 10-K (2015, 2014, 2013, 2012, 2011)
- USA
  - Cliff Natural Resources, Annual Report (2016, 2012)
- Australia
  - BHP, Annual Report (2015)
  - Fortescue Metals Group, Annual Report (2015)
  - Glencore, Corporate Profile Australia
  - Newcrest, Bank of Montreal Global Metals & Mining Conference (2017), Annual Report (2015, 2014, 2013, 2012, 2011)
  - OZ Minerals, Annual Report (2015, 2014)
  - Sandfire Resources, Annual Report (2015, 2014, 2013)
- Canada
  - ArcelorMittal, Sustainability Report (2015)
  - Glencore, Annual Report (2016)
  - Iron Ore Company (IOC), Sustainable Development Report (2016)

## Estimates

Estimates have been prepared based on the following proprietary models and databases:

- CRU Copper Cost Model
- CRU Nickel Cost Model
- CRU Iron ore Cost Model
- CRU Bauxite Cost Model
- CRU Lead Cost Model
- CRU Zinc Cost Model
- CRU Tin Monitor 2017 June Data
- CRU Molybdenum Market Outlook 2017 Edition Data
- CRU Cobalt Market Outlook 2016 Edition Data
- CRU Precious Metals Market Outlook