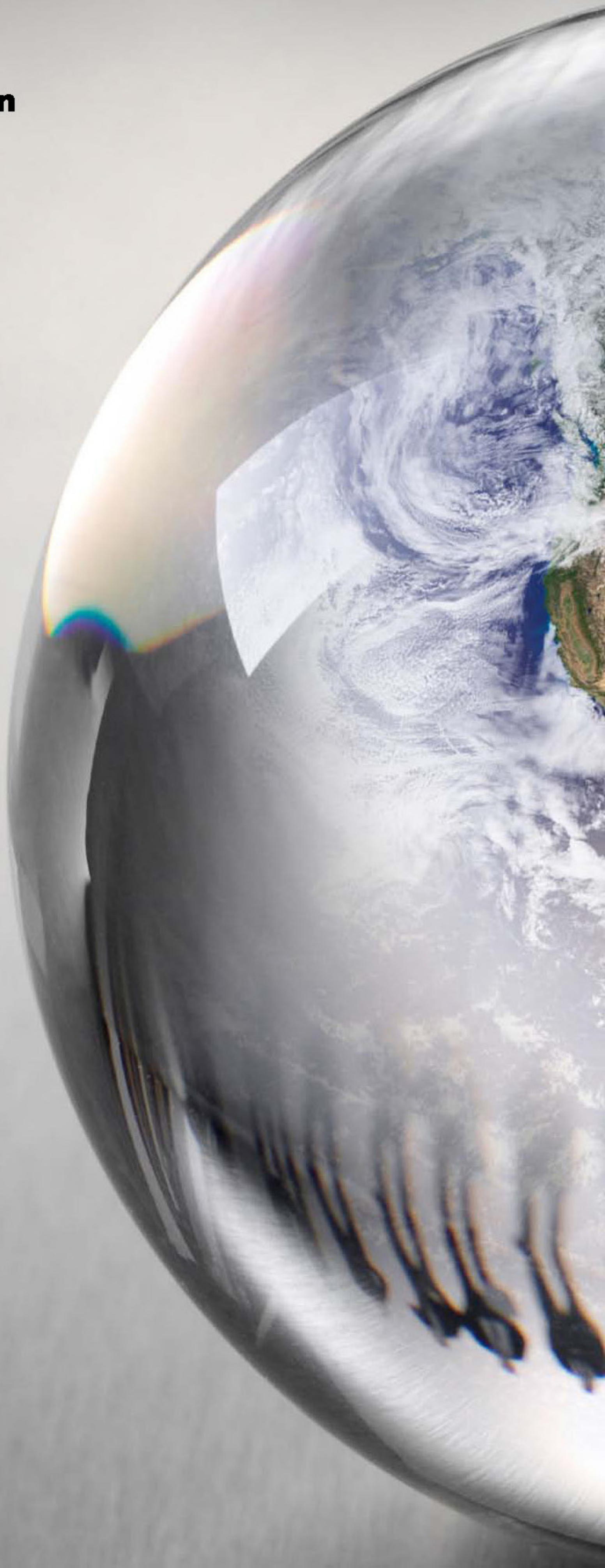
Asia-Pacific
Economic Cooperation

# Socio-Economic Study of Impact of EU Nickel Compounds Classification on APEC Economies



Mining Task Force

June 2012

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APEC Project: MTF 01/2010S

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# Abstract

This report sets out a quantification of socio-economic impacts on selected APEC economies of a 2009 European Commission decision to classify as hazardous 138 nickel-containing chemicals (1st ATP of EU Classification, Labelling and Packaging regulation).

Concerns were raised by industry stakeholders, members of the WTO, the Russian Federation and others at the time as to the scientific methodology employed, and the proportionality of the classifications, given that only 23 of the nickel-containing chemicals were subsequently found to be in use in Europe. In spite of the widespread use of nickel and nickel chemicals in many critical applications, the European Commission carried out no impact assessment on this decision.

This report contains the results of a socio-economic assessment undertaken by the Russian Federation with the assistance of the Nickel Institute, which quantified the likely impact of this classification decision on nickel production and demand in a number of nickel producing and consuming APEC economies. The assessment involved extensive data gathering, analysis and modelling based on identified impact scenarios.

The study revealed that nickel is highly important for APEC economies. Some 71% of the world's mined nickel is produced by APEC economies, led by the Russian Federation, Indonesia, Australia, the Philippines and Canada, with China also notable as the eighth largest producer. The proportions of global primary nickel production (69%) and first usage (71%) attributed to APEC members are similar to APEC member's mining share, and highlight the significant impact and socio-economic contribution that the nickel industry has within the APEC region.

Econometric modelling using defined scenarios identified a spectrum of likely and possible impacts for the selected APEC economies. A limited negative impact was identified if the classification decision is purely confined to the EU. If the classification decision of the European Union is followed elsewhere, more severe impacts appeared, threatening a number of applications, and, by extension, the sustainability of nickel producing and consuming operations in the target APEC economies. The negative impact on aggregate GDP for the target APEC economies was quantified as a possible US $71 billion over the period to 2025 if the European hazard classifications of the 138 nickel chemicals were to be generally adopted.

# Executive Summary

Nickel is critical to many economic and societal functions. It can be found in critical applications that bring widespread benefits to society, from clean air, clean water, safe food preparation, and health care, to everyday items in the home as diverse as kitchen utensils and computers. Nickel catalysts and alloys are at the heart of an efficient and modern chemical industry, including oil refining, allowing the production of low sulphur fuels. Nickel enables clean power generation, and is found in all renewable energy solutions. It is also found in advanced, green technology that increases energy efficiency and reduces carbon emissions. In architecture, nickel alloys combine functionality and high recyclability with aesthetics.

In 2009 the European Commission introduced chemical hazard classifications for 138 nickel-containing chemicals. The hazard classifications have applied in the EU from 1 December 2010.

At the time, the nickel industry and other industry stakeholders expressed concern as to the science employed in deriving these classifications. Twenty-one nickel producing and consuming economies expressed similar concerns via the Technical Barriers to Trade Committee of the World Trade Organization and bilaterally. Other economies, including the Russian Federation, also echoed these concerns. The fact that only 23 of the 138 nickel-containing chemicals were found to be on the market in the EU from the subsequent European REACH registrations, gives rise to additional concerns as to the proportionality of this classification decision and whether its impact might be felt well beyond the borders of the European Union.

During the regulatory setting process, the European Commission did not conduct any socio-economic impact assessment of the consequences of these classifications. However, because of the widespread use of nickel in applications critical to society, there is the potential for significant impact on these applications, and the many different production chains and industrial processes that produce them.

As a response to these developments, in 2010 the APEC Mining Task Force adopted a proposal by the Russian Federation, supported by Canada, to undertake a socio-economic assessment of the impact of the EU nickel chemicals classification on APEC economies. The APEC Secretariat invited the Russian Federation in association with the Nickel Institute, representing the nickel industry, to undertake an independent study to analyse the likely direct and indirect impacts of the EU classification on APEC economies. This report is the requested study.

Ten APEC economies – designated as Target Economies - were selected to be examined in detail: Australia, Canada, People's Republic of China, Indonesia, Japan, Republic of Korea, the Republic of the Philippines, the Russian Federation, Chinese Taipei and the United States. The project is to describe the nickel value chain in the selected APEC economies, identify and quantify the direct and indirect impacts on their nickel value chains and evaluate economic impacts beyond those chains.

## *Importance of nickel to APEC economies*

The study revealed that nickel is highly important for APEC economies. Some 71% of the world's mined nickel is produced by APEC economies, led by the Russian Federation, Indonesia, Australia, the Philippines and Canada, with China also notable. The APEC economies also account for 69% of global refined nickel production and 71% of first usage of nickel.

As the world's major primary nickel user, China also headed the list of producers of finished primary nickel in 2010, supplementing its domestically-sourced production with material derived from imported ores and concentrates. Japan, second placed in terms of nickel first use, is also among the top five finished nickel producers, for which it relies entirely on imported nickel feedstocks.

The Russian Federation, Canada and Australia occupy their high positions in the list of finished nickel producers by virtue of their natural resource reserve strength and long history in mining. They are large exporters – of finished nickel in the case of Russia, and of both finished nickel and intermediate feedstocks from Canada and Australia.

Both Indonesia and the Philippines are major miners and exporters of lateritic nickel ore, while their current downstream development into finished metal production is less established.

Despite being the largest global economy and the third largest user of primary nickel, the United States has at present no nickel mining or extraction capacity, relying on imports of finished metal, largely from other APEC members. However, nickel plays an essential role in the economy's aerospace industry, and other high tech industries.

The Republic of Korea and Chinese Taipei are respectively fifth and sixth in the world in primary nickel usage. Although they have no mined production of nickel, both economies have refineries that re-refine imported finished nickel.

### *Socio-economic assessment methodology*

The socio-economic assessment included an analysis of the impact of the classification decision on nickel-chain industries and then considered how changes in the prospects of the nickel-chain industries affect the overall prospects of the Target Economies

The methodology focused on nickel value chain impacts of two sorts: impacts on the demand for nickel-containing products, taking into consideration various types of producer and consumer responses, and impacts on the costs of the producers and users of these products, including transport costs.

### *Three scenarios*

For the purposes of the evaluation of the consequences on the nickel value chain of the EU's classification decision, three regulatory scenarios have been developed. They are:

- **Scenario A1** – EU implements the classifications for 138 nickel-containing chemicals set out in the 1st ATP of the CLP while the APEC economies maintain their current classifications for the nickel-containing chemicals in use.
- **Scenario A2** – EU implements the classifications for nickel-containing chemicals set out in the 1st ATP of the CLP and the APEC economies and the rest of the world adopt the same classifications so as to include all 138 nickel-containing chemicals in the 1st ATP.
- **Scenario B** – EU implements the classifications for nickel-containing chemicals set out in the 1st ATP of the CLP; APEC economies and the rest of the world adopt the same classifications so as to include all 138 nickel-containing chemicals in the 1st ATP and there are additional spill-over effects on the global nickel value chain due to stigmatization.

For each of the three scenarios, the analysis looked at what regulatory consequences for the nickel value chain are triggered by the classifications assigned to nickel-containing chemicals. The main regulatory consequences identified are:

- effects on the operating costs of industries producing or using the relevant nickel chemicals
- effects on bilateral transport costs for international trade flows of the relevant nickel chemicals
- effects on the demand for first- and end-use nickel products.

The study looked at how the classification of nickel-containing chemicals can trigger market demand responses, following official regulatory responses and non-regulatory responses (producer, user and gatekeeper activities and consumer stigmatization) on the demand for nickel-containing products and on the costs of their producers and users, including transport costs.

Both gatekeeper activities and consumer stigmatization illustrate how regulatory hazard classifications can lead to market and reputational impacts, beyond the direct regulatory sphere of influence.

### *Modelling*

To calculate the overall economic impacts, a Computable General Equilibrium (CGE) model – known as GTAP_Ni – was developed and, adapted to the specific technical and economic constraints of the nickel value chain. It studied the effects of the classification of nickel-containing chemicals in two particular years:

- 2015 to represent the medium term when the EU and OECD economies are assumed to have completed transition to the classification changes, phasing them in from 2012
- 2020 by when it is assumed that non-OECD economies would have completed their transitions.

For this purpose, historical data and forecasts were used for mining, finished production and first uses of primary nickel for the years 2007, 2010, 2015 and 2020.

The approach chosen in the model considers costs of implementation (e.g. occupational protection) and costs resulting from forced or chosen substitution. The model identifies a net effect in the medium and longer term where immediate effects (e.g. on employment) are offset by re-allocation of resources.

The study has not attempted formal quantitative modelling of stock effects, nor has it addressed the criticality of nickel for the advancement of innovation and technology in areas such as green technologies, energy efficiency, carbon control, environmental protection and human health.

### *Nickel demand impact assessment - results*

### *Scenario A1*

Under this scenario, market impacts are largely confined to the EU, slightly depressing global demand for nickel chemicals, and potentially increasing Target Economies' export costs to the EU for nickel ores and concentrates, intermediates and nickel-containing chemicals.

Global usage of primary nickel is depressed below the baseline forecasts by 2.6% (48kt) in 2015 and 6.2% (136kt) in 2020. The immediate impact is likely to fall largely on European producers supplying European markets. Any reduction in demand will, however, also depress nickel prices below their levels under baseline forecast conditions, and this will flow through to affect the output levels of producers in the high cost bracket, many of which are in APEC. Through the price effect, reductions will not be confined to existing producers of nickel-containing chemicals.

In 2015, the Target Economy nickel-producing activities likely to be much affected under Scenario A1 are nickel pig iron smelting and other laterite processing in China, which would suffer a combined production fall of about 9kt or 2.7%.

About 19% of the 2015 production decrease falls on Target Economies. This proportion increases to 47% by 2020, and the load is spread more widely. Because of its relatively high cost, Chinese production will be the most severely affected, but effects will also be felt by producers of finished nickel in Australia, Canada, Japan and Russia, with consequent effects on nickel mining rates in Australia, Canada and Russia.

In both 2015 and 2020, reductions in Chinese nickel pig iron smelting will flow through to depressed demand for laterite ore exports from Indonesia and the Philippines.

### *Scenario A2*

Under this scenario, classification effects spread to depress nickel demand world-wide and the global market reductions are much more severe than under Scenario A1, particularly so in 2020, when the tonnage reduction is about twice as severe.

Global usage of primary nickel is 4.4% (82kt) below the baseline forecast in 2015 and 12.4% (270kt) below in 2020.

In 2015 the impact on production is also felt in the Target Economies as the market reductions are no longer concentrated in the EU, and also because their greater magnitude means that prices will be more severely depressed (focussing pressure on high-cost producers). Consequently, by comparison with Scenario A1, in 2015 there will be a greater impact on production from China, and some impacts in Australia and Japan.

By 2020, producers in the Target Economies are forecast to absorb 55% of the global market reduction. At this stage the impact on nickel production will be felt more deeply than under Scenario A1 particularly in China, but also in Australia, Canada, and Japan. However, because a large proportion of production in the Target Economies is relatively low-cost, the 12.4% fall in global usage will cause production in the Target Economies to fall by 10.7% while in the Rest of the World it falls by 43%.

### *Scenario B*

Under this risk analysis scenario, global usage of primary nickel is depressed below the baseline forecasts by 8.2% (152kt) in 2015 and 21.6% (471kt) in 2020. The impact in 2020 is particularly severe, and would strip more than half the baseline growth out of the industry.

As in Scenario A2, the market reductions gather pace between 2015 and 2020; but they are already sufficiently great in 2015 to cause market nickel prices to be quite substantially less than they would be under the baseline forecast, and consequently the impact on production will be heavy on high-cost production such as nickel pig iron in China, matte refining and laterite processing in Australia, and Japanese producers in general. Nevertheless, their impact will be much greater on producers in Europe and other non-APEC economies.

By 2020 under Scenario B, the magnitudes of nickel production decreases are such as to threaten the viability of several plants operating in the Target Economies, and many more in the rest of the world. China’s nickel pig iron industry will be producing less than in 2010, and the same applies to ferronickel and other laterite processing in Japan, and to laterite mining in the Philippines. While production from matte refining would be curtailed significantly across the board, some growth from 2010 levels would be maintained.

### *Broader economic effects*

### *GDP impacts*

Model results indicate that the impacts on Target Economies' GDP growth rates are proportionate to the nickel-chain activities' share in the Target Economies' GDPs.

The aggregate GDP costs to the Target Economies under the three scenarios can also be estimated, as present values, at 2010 prices, using a 2% real social time preference rate, over the 15-year period 2010-2025.

Under Scenario A1, the present value of the aggregate GDP cost is US$3.2 billion.

Under Scenario A2, where the classifications are more widely adopted, the present value of the aggregate 15-year cost to the ten Target Economies' GDP is US$23.4 billion.

Under Scenario B, where stigmatization is included, the discounted aggregate cost expands to US$71 billion through to 2025.

### *Conclusions*

Nickel and the nickel industry are major socio-economic contributors to APEC member economies. Employment, investment, and use in critical applications, all highlight the importance of this metal and its chemicals to society.

This report concludes that the EU chemical hazard classification decision will have adverse consequences for the nickel-chain industries within the target APEC economies. The economy-wide impacts vary between nickel-producing and nickel-using economies and according to relative positions on the industry cost curve. Assumptions in the report indicate that stigmatization related to a perception of risk that could be associated with any nickel product, could lead to 21% of the total nickel usage being adversely affected.

The macro-economic model used for this study indicates that the EU classification or its widespread application will not entail large direct GDP losses to the APEC economies if compared to their overall GDP levels. However, the present value of the aggregate GDP loss for the target APEC economies is estimated at up to US$71 billion in the period to 2025. Likewise, the study reveals that the impact can be very significant on particular groups – industries or regions within the economies of interest. This is particularly true for nickel mining communities.

Finally, the report findings suggest that APEC economies, as the main producers and users of nickel, should advocate for scientific as well as proportionate chemical management policy and regulation. This position has recently been supported in the OECD Recommendation of the Council for Regulatory Policy and Governance, published on the 22$^{nd}$ of March, 2012. Approaches to chemical regulation that are not based on sound science and lack appropriate impact assessment can impact the sustainability of resources development as well as material innovation.

# 1 Introduction – The value of nickel to society

It is hard to imagine a world without nickel. In use, nickel is of high value as it can be found in many critical applications that bring widespread benefits to society, from the fundamental human rights of clean air, clean water, safe food preparation, and health care, to everyday items in the home as diverse as kitchen utensils and computers. In industry, nickel catalysts and alloys are at the heart of an efficient and modern chemical industry, including oil refining, allowing the production of low sulphur fuels. Nickel enables clean power generation, and is found in all renewable energy solutions. It can be found in advanced, green technology that increases energy efficiency and reduces carbon emissions. In architecture, nickel alloys combine functionality and high recyclability with aesthetics.

Nickel is not directly visible to the general public due to the way in which it is normally used – namely, in alloys and complex materials. It is therefore said to be an 'enabling technology' making equipment solid and lasting whether used in its metallic, alloying or chemical forms. Whatever the form in which it is used, it contributes significantly to a sustainable human and economic development.

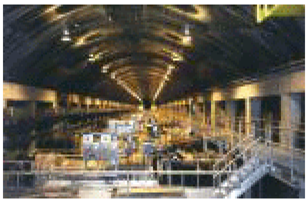
Stainless steels and other alloys in total account for about 85% of the use of all new nickel sold each year. About 9% goes into plating and the balance of 6% into batteries, catalysts, fuel cells and other chemicals. As a result of the benefits that it provides, nickel use is growing at about 4% each year.

**Nickel is unique as no other metallic element has the same combination of critical characteristics:**

- **High melting point**
- **Corrosion and oxidation resistance**
- **Ductility, resists to cracking or breaking under stress**
- **Ability to form alloys with other metals**
- **Magnetic at room temperature**
- **Can be deposited by electroplating to provide a protective layer**
- **Catalytic properties**

### *Safety of food and water*

Nickel enables solutions for the provision of the safe food to eat and safe water to drink that are

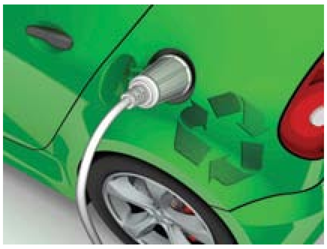


fundamental to life. All the equipment used for processing, storage and distribution of food and water must maintain hygienic conditions, and must not introduce contamination. Nickel-containing stainless steel alloys are the most common materials of choice in those industries, a choice based on their unique combination of economic affordability and physical and chemical properties. It carries over into the domestic situation, where nickel-containing stainless steels are popular for cookware and cutlery. Nickel-containing stainless steel alloys are also increasingly used for plumbing systems.

### *Healthcare*

The medical and healthcare industry requires even higher safety and quality standards from medical devices and surgical equipment as well as equipment to produce pharmaceuticals. Nickel-containing stainless steels are again extensively used because of their properties and affordability.

### *Utilities and green power*



Large parts of power generation rely critically on nickel-containing stainless steel and other nickel alloys, which have already proved to be vital for the successful transition to a low carbon green economy (carbon capture and storage, for example). Nickel also plays critical roles in clean and efficient energy conversion – whether from fossil fuels, nuclear power, renewable energy technologies or fuel cells. Both nickel metal and nickel-containing chemicals make electric and hybrid cars possible.

### *Building*

Energy efficient and durable buildings contribute greatly to lowering the environmental impact of the production of the materials used. Nickel-containing stainless steels are used for cladding, roofing, fixtures and fittings – both for prestigious and more ordinary buildings. This happens not just for aesthetic reasons but because of rational choices that consider durability, performance and cost. These materials are fully recyclable which further contributes to the reduction of the environmental impacts over the whole life cycle of a building.

### *Industry and its processes*

The efficiency of production processes in oil refining, the petrochemical industry, detergent production, and oil and fat processing for the food industry all depend on catalysts. In many cases, those catalysts are nickel-based, requiring nickel-containing chemicals for their manufacture. Catalysts are always very specific to a particular chemical reaction. Currently, there are no substitutes for the nickel-based catalysts used in these reactions, which could maintain the same high level of performance even at a greater cost.

To remain efficient, these processes also require safe and reliable equipment able to operate under very demanding conditions. Nickel-containing stainless steel and nickel-alloys are materials of choice for pipes, reactors, storage tanks and in machines.

### *Information and communication technologies*

Generally, global communication technologies rely heavily on metals. Computers, mobile phones and other communication equipment, control equipment as well as consumer entertainment systems all depend on nickel-containing materials to operate. CDs and DVDs are pressed in pure nickel metal moulds, which can only be made by using nickel-containing chemicals in the production processes. The same technology is used in the manufacture of security holograms on credit cards, and in printing fabrics for clothing and furnishings.

### *Unique properties to support innovation*

A common thread running through the above applications is nickel-containing stainless steels. Whilst chromium is the element that confers the necessary corrosion resistance, nickel (commonly 8-12% of stainless steel) improves formability, weldability, and corrosion resistance. So important is nickel that over 70% of the stainless steel produced each year contains nickel and about 67% of the nickel processed each year, is used in stainless steels. The current annual growth rate for the use of nickel-containing stainless steels is around 6%.

Nickel-based alloys, which are closely related to stainless steels but enjoy a much higher percentage of nickel, are used in critical applications that demand exceptional resistance to very high and very low temperatures or corrosion resistance. Gas turbines – whether for power generation or as aircraft engines – would not have developed to the high level of green efficiency and fuel performance they have today without nickel-based alloys in their hottest parts.

Liquid natural gas transport, radio valves, colour television tubes, electronic integrated circuit packaging and screening against electromagnetic interference may not seem to have much in common but they have all exploited the unusual magnetic properties and thermal expansion characteristics of the family of iron-nickel alloys.

Many other nickel-containing alloys have important applications: copper-nickel alloys in coinage and for seawater systems on ships; nickel-titanium alloys for medical devices and earthquake protection of structures; nickel plating for wear resistance and computer hard discs.

Nickel chemicals are found as intermediates in the nickel metal production process, but, as products in their own right, also have some unique properties as catalysts, and in electronic applications. Through electrolytic processes, pure nickel metal can be deposited on other metal and plastic surfaces to produce a hard wearing and corrosion resistant surface. It can also reproduce fine detail that can be used in moulds for plastics and high quality printing screens.

Nickel-containing materials, through innovation, have often enabled other technologies to develop and flourish. Moreover, they clearly demonstrate the criticality of nickel for the advancement of innovation and technology in the fields that have established themselves over the last decades as fundamental for the sustainable development of modern society: green technologies, energy efficiency, carbon control, environmental protection and human health.

### *A material for a sustainable society*

Of all the unique properties of nickel, two stand out and become crucial: durability and recyclability. Society aims for a new harmony between its aspirations for high quality of life and the need to ensure greater sustainability. Most nickel-containing products have long useful lives. Average life is between 15-20 years, with many applications lasting much longer. Nickel-containing products frequently can provide optimum solutions to practical challenges at a lower total cost, with more efficient use of resources, including energy, and with lower environmental impact.

At the end of their useful life, nickel-containing products can be collected and recycled for future use and re-use. Nickel is one of the most recycled metals globally. It is collected and recycled, mostly in the form of alloys such as stainless steel or special alloys such as those used for off-shore operations or in planes. About 40% of the nickel content of a stainless steel product made today will have come from recycled sources. This percentage grows steadily though at a slow pace as the availability of recycled material is limited by long useful life and growth in use.

# 2 Background to the study

On 10 August 2009, the European Commission adopted a decision classifying 138 nickel-containing chemicals as amongst other hazard properties, category 1A (Cat 1A) human carcinogens[1] by inhalation. This decision was published as the First Adaptation to Technical and Scientific Progress (1st ATP)[2] to its Regulation concerning the Classification, Labelling and Packaging (CLP) of substances and mixtures. The classifications have applied in the EU from 1 December 2010.

## 2.1 Basis for the EU classification

The extensive list of 138 nickel-containing chemicals (listed in Appendix A of this report) results from the application of a non-test method for determining hazard properties called "read-across" methodology, by which an established hazard endpoint associated with one nickel-containing chemical for which detailed test data is available is extrapolated to other similar nickel-containing chemicals on the basis of water solubility alone.

"Read-across" is a well-documented and accepted approach that involves taking existing hazard information from (data-rich) source substances and extrapolating them to a data-poor substance. When applied scientifically following international standards such as those of the OECD, read-across is a useful tool as, among other things, it minimises the testing of chemicals on animals. In the case of the extensive classification of 138 nickel-containing chemicals, however, an important validation step was not followed. Such an important deviation from the published protocol leads to questions as to whether the classifications are justified on both scientific and procedural grounds.

This concern has recently been clearly demonstrated as a result of testing for classification of some hazard properties for the nickel-containing chemicals registered by the Nickel Consortia to comply with the EU REACH Regulation. This testing, undertaken by the Nickel Producers Environmental Research Association (NiPERA) an independently incorporated division of the Nickel Institute, highlighted inconsistencies for a number of hazard properties. Two papers describing the correct scientific application of read-across methodology based on bioaccessibility in relevant fluids were accepted in early 2012 for publication in the journal *Regulatory Toxicology and Pharmacology*. Importantly, one of these papers describes how the more robust read-across methodology can result in classifications that are either less or more stringent than those simply assigned on the basis of water solubility.

## 2.2 Proportionality of the EU classification

A small number of nickel-containing chemicals (including some that are encountered in metallurgical refining) have long been identified as carcinogenic to humans, the principal hazardous exposure route being via inhalation. The industrial processes where they occur or are used are heavily regulated and controlled in the jurisdictions where these facilities are located to minimise worker exposure and environmental release.

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[1] Global Harmonised System for Classification and Labelling Category 1A is attributed to chemicals that are known to have carcinogenic potential for humans. Classification in this category is largely based on human evidence.

[2] Commission Regulation (EC) No. 790/2009 amending, for the purposes of its adaptation to technical and scientific progress, Regulation (EC) No1272/2008 of the European Parliament and of the Council on the classification, labelling and packaging of substances and mixtures. (This is commonly referred to as the 1st ATP to the CLP Regulation).

Prior to the 1st ATP, only five nickel-containing chemicals (three oxides and two sulfides) were considered to be cat 1A carcinogens under the CLP regulations in the EU.

The 138 classified nickel-containing chemicals include:

- Some naturally-occurring minerals;
- Chemicals used as intermediates in various nickel production chains;
- Nickel-containing chemicals currently required for a variety of industrial processes (e.g. catalysts) and in the manufacture of plated products, rechargeable batteries and other end applications.

Under the EU REACH[3] Regulation, all 138 of the nickel chemicals were required to be registered by the 30th of November 2010. In fact only 23 of the classified nickel-containing chemicals have been registered - 14 of them by the Nickel Consortia. These registered chemicals are imported, manufactured and used in the EU commercially to support a wide range of industrial activities producing nickel-based products or other products.

With respect to market and use reality the following should be noted:

- Only 23 of the nickel-containing chemicals are registered as on the market or used in the European Union;
- Their use is in industrial settings;
- There is no direct consumer use or exposure[4].

The sweeping nature of the classification immediately appeared disproportionate to either the use in Europe, or public concern, as there is no direct public exposure. It also raised concerns that the classification could impact the nickel industry and its downstream users. One is the impact of reputational damage to the entire industry with unintended consequences for non-related nickel substances. Another likely impact is that the EU classification decision exposes any new chemical formulation containing nickel to automatically be classified in line with the EU nickel chemical classifications. This will clearly affect consideration of nickel in chemicals as early as the R&D and patenting stage. No economic model can compute such a constraint on research and innovation but it is a consequence of the classification decision and will deter the use of nickel in R&D in seeking solutions to industrial or societal problems.

## 2.3 Socio-economic impact assessment

The European Commission did not conduct any socio-economic impact assessment of the consequences of the extensive nickel-containing chemicals classifications in the 1st ATP to the CLP. However it would have been impossible for it to do so, as one cannot assess the direct costs and benefits to industry and society of a classification of chemicals that do not exist on the market. Existing EU guidelines for developing socio-economic impacts analysis do not address such an eventuality.

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[3] Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) is a European Commission Regulation concerning the production and use of chemical substances and their potential impacts on human health and the environment. The regulation came into force on 1 June 2007 with a phased implementation of its procedures planned over the following decade.

[4] The EU has recently adopted a restriction under REACH on the sale or use by consumers on their own or in mixtures of all 138 nickel-containing chemicals (Commission Regulation 109/2012 of 9 February 2012). The practical effect of this is limited as none of the nickel-containing chemicals is used directly by consumers.

With respect to the CLP regulation itself, which implemented the UN Global Harmonised System for Classification, Labelling & Packaging of Chemicals, the European Commission published an impact assessment in June 2007 that mainly focused on the direct economic costs and benefits for companies as well as on recurring costs of operating the GHS. Its major conclusion was that *"the implementation costs need to be kept in check so as to arrive at net benefits in the foreseeable future"*.[5]

The nickel industry along with 21 nickel producing and consuming economies expressed their concerns to the European Commission over the classification decision in various fora including the Technical Barriers to Trade Committee of the WTO between March 2007 and March 2008. In spite of the concerns from such a large number of WTO members that the classifications may have disproportionate trade impacts, the European Commission moved ahead[6] without recourse to any assessment of the likely socio-economic or trade impact of the decision.

In July 2011, the European Court of Justice rejected a challenge to the European Commission's classification of nickel-containing chemicals. While concluding that the European Commission did not exceed the limits of its broad discretion, the Court also recognized that the classifications exist in a complex and continuously changing technical and legal context.

## 2.4 Involvement of APEC

APEC economies are predominant in terms of production, refining and use of nickel. They account for 70% of global nickel mined output, 70% of refined nickel production and 70% of global nickel use (see Chapter 6).

Australia, Canada, China, Indonesia, Japan, the Philippines and the Russian Federation are the world's largest producers of mined and refined nickel. China, Chinese Taipei, Japan, the United States and the Republic of Korea are among the world's largest users of primary nickel, particularly in stainless steel. Nickel-containing goods manufactured in these economies are exported and consumed throughout the developing and industrialized world.

In August 2009, APEC ministers adopted a statement encouraging the establishment of a productive dialogue with the EC regarding the issue of classifications of chemicals, and nickel-containing chemicals in particular.

In May 2010 at the MTF meeting in Sapporo, APEC member economies considered the need for a socio-economic analysis that would inform a high-level dialogue between APEC and the European Union, particularly about the consequences of its expansive classification decision relating to nickel-containing chemicals for nickel use and demand globally.

In the summer of 2010 the APEC MTF adopted a proposal by the Russian Federation, supported by Canada, to undertake a socio-economic assessment of the impact of the EU nickel chemicals classification for APEC economies. The APEC Secretariat invited the Russian Federation in association with the nickel industry to plan an independent study to analyse the likely direct and

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[5] Commission Staff Working Document – Impact Assessment – Brussels, 27.6.2007 SEC(2007) 854, page 13.

[6] On 21 August 2008, the Commission adopted the 30th ATP Directive and, in particular, the proposed revised classification of the nickel carbonates. On 15 January 2009, it adopted the 31st ATP Directive, in particular the proposed classification of nickel hydroxide, nickel dihydroxide and the group of nickel substances. Those two directives were adopted in accordance with the regulatory procedure set out by Directive 67/548. Finally, on 10 August 2009, the Commission adopted the 1st ATP Regulation on the basis of Article 53 of Regulation No 1272/2008. The contested classifications were therefore inserted into Annex VI to that regulation with effect from 25 September 2009.

indirect impacts of the EU classification on APEC economies and demand for nickel metal. This study would be undertaken at the industry's cost, and managed by the Nickel Institute.

In December 2010, the Nickel Institute proceeded with the first steps of this socio-economic analysis. Following an international selection and assessment process, an Australia-based consortium of experts was invited to assist in the execution of the project. Frontier Economics helped develop the framework (including scenarios) for evaluating the regulatory impacts; Metalytics has contributed its mining and commodity expertise, whilst the Centre of Policy Studies at Monash University undertook macro-economic modelling.

# 3 Design and scope

This study looks at the impact of the EU classification of 138 nickel-containing chemicals on APEC economies.

The study comprises an analysis of the micro-economic impacts on the nickel value chain (implementation costs), an estimate of the likely structural consequences on the nickel value chain (demand impacts) as well as a quantification of macro-economic consequences for APEC economies (broader impacts).

An econometric model has been developed to help in the analysis using scenarios about the uptake of the EU classifications beyond the European borders (spread through GHS mechanisms). The methodology specifically developed for this study is described in **Section 4**.

Central to this study are three regulatory scenarios about the uptake of the EU classification in APEC and the rest of the world, which have been defined in Section 4.2. They are accompanied by an analysis of the elements that could lead to substitution or encourage moving away from products containing nickel. The analysis took into consideration the factors that make market loss unlikely such as the criticality of a specific use. This has allowed quantifying likely demand effects to be used by the economic model.

The report presents three phases of data collection and analysis:

1. **Mapping and quantifying the nickel value chain.** The analysis starts in **Section 5** with a view of the global nickel value chain. It requires a detailed view of the nickel mining, production and supply chains and how their products feed into the first use industries. The role and importance of APEC in this value chain is considered in **Section 6**, which presents key points to remember arising from a detailed analysis of ten Target Economies, i.e. Australia, Canada, People's Republic of China, Indonesia, Japan, Republic of Korea, the Republic of the Philippines, the Russian Federation, Chinese Taipei and the United States. This provides the study with the data needed for the broader impact analysis, including a clear view of the vulnerability of nickel production units in APEC to cost and demand impacts;
2. **Establishing how the Target Economies' classifications compare to the EU classification.** In **Section 7,** a comparative analysis between EU and APEC regulations provides an indication of where there might be additional costs for occupational health protection and transport in particular;
3. **Identifying and quantifying the direct and indirect impacts on both the nickel value chain and the overall economies.** **Section 8** identifies and quantifies the consequences on industry costs and demand. It also provides the outcomes of the econometric model that provides a quantification of the net economic impact of the regulatory consequences on the selected APEC economies, accounting for direct impacts, indirect impacts, induced impacts and broad economy impacts.

# 4 Assessment of impact methodology

## 4.1 Economic effects

This study's approach to formal quantitative modelling of the general economic effects of the classification of nickel-containing chemicals focuses mainly on flow effects. It starts with the impact on nickel-chain industries and then considers how changes in the prospects of the nickel-chain industries affect the overall prospects of the Target Economies. The study does not attempt formal quantitative modelling of the possibility that the classification decisions could lead to the premature retirement of existing nickel-containing stocks. The main stocks at risk in the APEC economies are:

- deposits of nickel ores
- mine-specific capital and supporting infrastructure that have been sunk into nickel-mining projects and have no alternative economic uses – because of their location in remote regions with few other mining activities, for example
- stocks of nickel first-use products, including recyclable scrap; and
- stocks of nickel-containing end-use products (medical equipment, household appliances, coins etc). These have use value and recycle value as well. Their forced or accelerated replacement, possibly by potentially inferior materials, would also constitute a cost to society.

The principal drivers of this study's quantitative modelling of the general economic effects of the classification of nickel-containing chemicals are estimates of the impact of official regulatory responses and non-regulatory responses (producer, user and specifier/gatekeeper activities, and consumer stigmatization) on the demand for nickel-containing products and on the costs of their producers and users, including transport costs. The size of these impacts on demand and costs for the nickel-chain industries depend on how widely the EU's current classification spreads geographically, and on the extent to which classification spills over to affect the demand for non-classified nickel-containing products or the costs of producers and users of those products.

To cover the range of likely outcomes for these determinants of the size of the impacts, three scenarios are analysed in the modelling. These scenarios are described in Section 4.2.

### 4.1.1 Effects on Target Economies

The implications of the nickel-chain impacts of the classification of nickel-containing chemicals for a particular economy depend principally on two factors:

- the importance of the nickel-chain industries in its aggregate economic activity
- whether the impacts are resource-using (or saving) or just reallocate resources within the economy.

The first of these factors is explored thoroughly in Section 5. The overall conclusion is that for each Target Economy, the nickel-chain industries (defined as the mining, refining and first use sectors, *not* including the end use industries) account for small shares of GDP. Although those data are *inputs* to a properly specified economic-impact evaluation, not its outputs, they do suggest that the economy-wide impacts of shocks to the nickel value chain are likely to be modest.

However, the impacts can be significant in value terms and will often have a regional significance affecting mining or industrial assets.

The study focuses on nickel-chain impacts of two sorts:

- impacts on the demand for nickel-containing products; and
- impacts on the costs of the producers and users of these products, including transport costs.

The cost impacts are definitely resource-using, i.e., they recognise that economies' regulations generally require producers and users of classified chemicals to use more resources (incur higher costs) in the handling of the chemicals than would have been the case in the absence of classification.

The demand impacts reflect users' decisions to replace nickel with alternative inputs. The analysis assumes that nickel is replaced by nickel-free alternatives (metals or alloys). A key decision is whether to assume that the replacement is cost-neutral, costly or cost-reducing. If cost neutrality is assumed, then the demand shocks affect the way in which the economy's resources are allocated among different possible uses, but not the amount of resources required to undertake any given aggregate level of activity. If the demand for nickel-containing products falls, this releases resources previously used in the nickel chain for alternative uses. If the replacements are assumed to be cost-increasing (decreasing), then the amount of resources required to undertake a given aggregate level of activity would be greater (smaller).

Because of the role of resource-reallocation possibilities, the economic significance of adverse regulatory shocks on an economy's nickel-chain industries will depend on the stage of the chain at which the main nickel-chain industries lie. The reason is that the likelihood that resources released from nickel-chain uses can be absorbed into other economically valuable uses varies along the chain.

Resources used in industries early in the chain – mining and basic processing – tend to be nickel-chain specific. This is largely the case for ore deposits – nickel ore is economically valuable only to the extent that nickel itself has economic value. It would also be the case for items of human-made infrastructure and other capital equipment that have been sunk into nickel mining or processing but have no feasible alternative uses.

On the other hand, the prospect of reallocating to other uses resources used in many nickel-end-use industries is likely to be much greater. A factory manufacturing cutlery from austenitic i.e. nickel-containing stainless steel, for example, could switch to an alternative metal feedstock. Though re-tooling and other training costs may be significant to the individual factories, the impacts may not be felt at the broader economy level (employment, GDP etc.).

The key point is that regulatory shocks that reduce the nickel-chain value of resources that have no alternative uses (or for which the economic value of the alternative uses is sharply lower than their nickel-chain value) reduce the economic wealth of the relevant economy. On the other hand, if the resources used in the nickel chain can readily be reallocated to uses with similar economic value, then the regulations will trigger just a change in economic structure, not a reduction in wealth.

## 4.2 The scenarios

For the purposes of the evaluation of the nickel-chain consequences of EU's classification decision, three regulatory scenarios have been developed. They are:

- **Scenario A1** – EU implements the classifications for 138 nickel-containing chemicals set out in the 1st ATP of the CLP while the APEC economies maintain their current classifications for chemicals in use.
- **Scenario A2** – EU implements the classifications for nickel-containing chemicals set out in the 1st ATP of the CLP and the APEC economies and the rest of the world adopt the same classifications for all 138 nickel-containing chemicals in the 1st ATP.
- **Scenario B** – EU implements the classifications for nickel-containing chemicals set out in the 1st ATP of the CLP; APEC economies and the rest of the world adopt the same classifications for all 138 nickel-containing chemicals in the 1st ATP and there are substantial additional stigmatization effects on the global nickel value chain.

Scenarios A1 and A2 are regarded as the *central cases* that reflect the likely nickel-chain consequences of a regulatory environment that remains focussed on the classified chemicals themselves and does not have severe spill-over effects on other nickel substances.

Scenario B should be interpreted as a *risk analysis* to illustrate the economic dangers of the possibility that the regulatory environment might precipitate gatekeeper and consumer reactions that are disproportionate to the public-health risks that the environment is designed to control. An example of how this might eventuate is that the EU classifications notionally cover 138 nickel-containing chemicals although only about 23 are in common commercial use. The greater the number of nickel chemicals listed in the classifications, the greater the risk that the wider reputation of nickel substances can be inappropriately harmed. This is stigmatization.

The consequences of the classification decisions for nickel-chain industries arise from supply-side and demand-side factors – referred to as cost effects and demand effects, respectively.

Occupational Health & Safety (OH&S), transport and consumer-protection regulations can give rise to nickel-chain cost effects in economies that upgrade their classifications of nickel-containing chemicals to EU standards from less stringent pre-existing classifications.

Demand-side effects arise from formal regulatory requirements restricting the use of classified nickel chemicals but also from the reactions to classification upgrades from two groups: consumers, who may reduce their demand for nickel-containing products out of precautionary behaviour, and producers, who may opt to shift away from nickel use altogether to reduce their regulatory burdens.

The basis of the approach is to consider, for each of the three scenarios, what regulatory consequences for the nickel value chain are triggered by the classifications assigned to nickel-containing chemicals. The main regulatory consequences identified are:

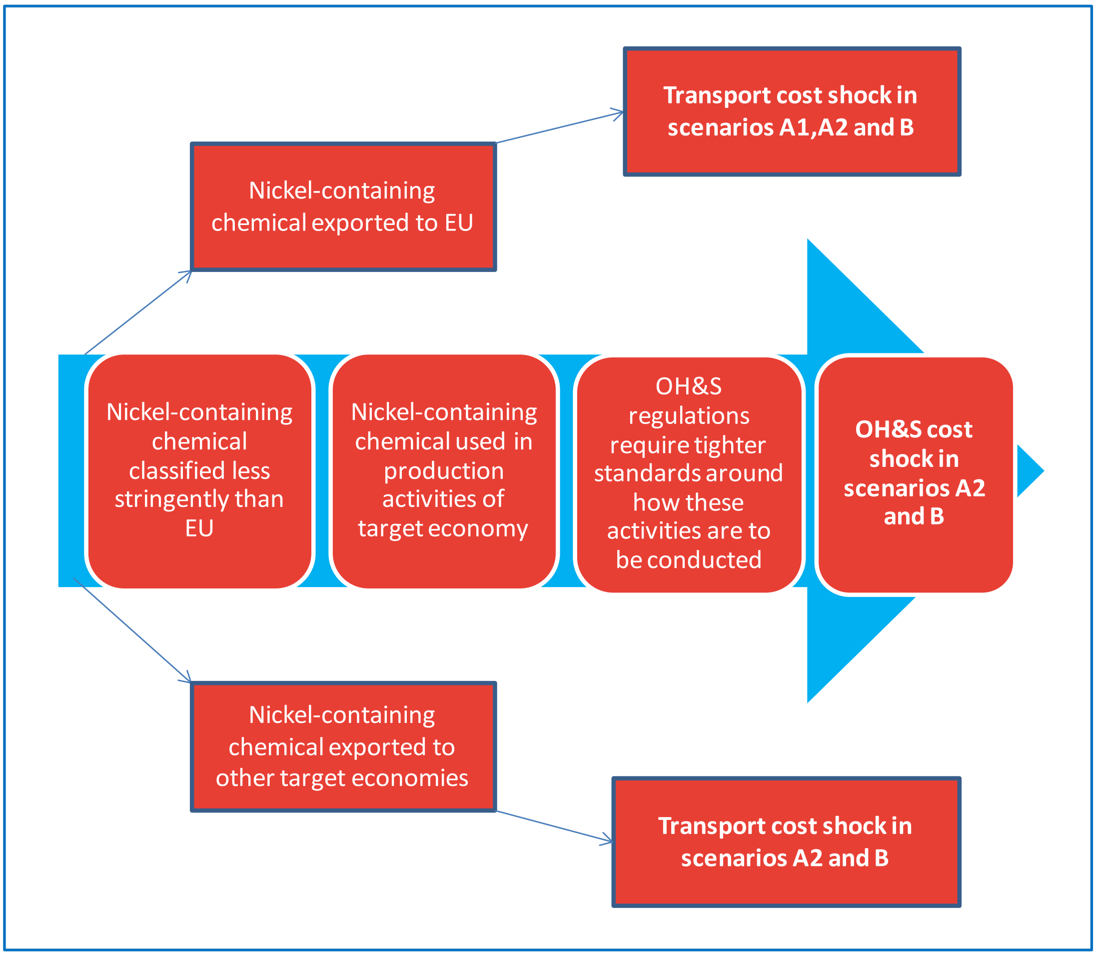
- effects on the demand for first- and end-use nickel products
- effects on the operating costs of industries producing or using the relevant nickel-containing chemicals
- effects on bilateral transport costs for international trade flows of the relevant nickel-containing chemicals.

### 4.2.1 Cost effects

This subsection identifies the cost shocks that are relevant to each of the three regulatory scenarios and specifies assumptions about their magnitudes.

Figure 4.1 summarises the circumstances under which the classification decisions can affect nickel-chain costs. It also indicates which cost effects are relevant to the Target Economies under the three regulatory scenarios.

**Figure 4.1: Cost-effect pathways**




*Source: Frontier Economics' analysis*

Occupational Health & Safety costs will be affected in a Target Economy in Scenarios A2 and B (but not in Scenario A1) if three conditions are met:

- classification of the nickel-containing chemical of interest in that economy is less stringent than in the EU
- activities involving the use of the nickel-containing chemical of interest are conducted in the economy
- the economy's existing regulatory environments apply tighter standards regarding how these activities are conducted following reclassification of the nickel-containing chemical.

Table 4.1 also illustrates the effects on transport cost that arise for Target Economies' exports to the EU and to other Target Economies.

It is assumed that the costs of meeting additional OH&S requirements consequent on re-classification of nickel-containing chemicals would be equivalent to about 12.3% of labour costs. This covers additional costs of protective-equipment, input and product labelling, training, health monitoring and other safety and environmental requirements.

Protective equipment to comply with worker health and safety requirements for employees exposed to Cat 1A carcinogens accounts for the largest component of OH&S cost effects. This includes local exhaust ventilation and de-dusting systems, and respiratory protective equipment.

Cat 1A carcinogens used in the workplace must be accompanied by labelling and safety data sheets to make workers aware of how the chemicals are to be handled, stored and transported. When nickel-containing chemicals are upgraded in classification to Cat 1A carcinogens, businesses would have to revise the labelling and safety data sheets associated with those chemicals. The extent of such costs will depend of the current level of classifications and worker protection in the Target Economies. This is examined in Section 4. Because these chemicals are already well regulated and exposures are already being managed by producing and consuming companies, these additional costs are expected to be small. The estimates that are made do not make a judgement as to whether the additional procedures are necessary, as this will depend on the scientific validity of the EU classifications.

The EU classification decision is not expected to generate material consumer-protection costs. The classified nickel-containing chemicals are not commonly contained in consumer goods with the notable exception of rechargeable batteries.

Arising from alignment of the IMO bulk and hazard shipments codes with the UN GHS in the coming years, transport cost are expected to increase for any nickel-containing chemicals that are currently transported in bulk This is mainly due to the environmental hazard classifications assigned to the nickel-containing chemicals.

**Table 4.1: Cost effects expected in each Scenario**

| Scenario | Cost effects for Target Economies and brief description |
|---|---|
| A1 | • Transport: exports of nickel-containing chemicals to EU |
| A2 | • Transport: exports of nickel-containing chemicals to EU and other Target Economies<br>• OH & S: Handling and storage of nickel-containing chemicals |
| B | • Transport: exports of nickel-containing chemicals to EU and other Target Economies<br>• OH & S: Handling and storage of nickel-containing chemicals |

*Source: Frontier Economics' analysis*

### 4.2.2 Demand effects

#### *Direct regulatory requirements*

In some cases, regulatory provisions triggered by the classifications would directly enforce reductions in the usage of the chemicals concerned, or of products that contain them. Such reductions can come through several channels, including:

- bans and restrictions imposed either on a classified substance or on products which contain it
- the provision of incentives to replace the classified substance with alternatives.

There is an important difference between exposure to classified chemicals and contact with products that contain them. There are very few nickel end-use products that pose realistic prospects of direct consumer exposure to classified nickel-containing chemicals. Do-it-yourself (DIY) plating kits, which could pose a danger to consumers, are a rare example, but they are not in common use.

#### *Indirect regulatory effects*

Indirect regulatory effects arise when demand for re-classified chemicals or products that contain them is affected not as a consequence of *formal* regulatory *requirements*, but by the *autonomous* and *voluntary* responses of producers and users to the reclassification within a particular set of regulatory arrangements.

Indirect regulatory effects can arise from producers' responses to initiatives by civil society groups (e.g., consumer advocacy groups) to encourage substitution, based, at least in part, on information on substance hazard classification.

A significant example of such initiatives is the "substitute it now" (SIN) list developed by a coalition of NGOs, supported by the Swedish government and published by ChemSec[7]. This list uses the EU classifications and the REACH criteria developed for classifying a substance as a SVHC to establish a list of products that SIN-list proponents believe should be phased out. Investors, producers, and consumers are then approached with a view to persuading them to seek alternatives. While the SIN list was initiated within Europe, the NGOs involved are active globally and information in the list can be disseminated widely – the list has been translated into Chinese, Japanese and Korean, and there is considerable interest in the initiative in some jurisdictions in the United States. A related list[8] identifying companies operating in Europe that are major users of chemicals on the SIN List has also been published in a bid to raise awareness among consumers and investors.

Producers might also develop their own internal "black lists" which identify substances to be phased out. The selection of substances to be placed on such lists can reflect perceptions of regulatory risk but also an assessment by the producer of the vulnerability of substances to adverse consumer reaction as a consequence of advocacy efforts.

#### *Stigmatization*

A stigma has been defined as "a negative feature that typically pervades and dominates an otherwise acceptable entity". In the context of nickel-containing chemicals, stigmatization could occur if:

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[7].The International Chemical Secretariat (ChemSec) is a non-profit non-government organisation seeking the elimination from the environment of what it identifies as hazardous substances.

[8] See www.chemsec.org/images/stories/publications/ChemSec_publications/SIN_Producers_List_111017.pdf

- the classification of nickel-containing chemicals as Cat1A carcinogens creates a general perception that nickel and products containing nickel are unsafe
- the presence of classified nickel-containing chemicals in a product triggers an adverse response by users and consumers, even though actual risks to health through exposure do not warrant such a reaction.

As a summary, Table 4.2 sets out the cost and demand effects expected for each scenario. The first column lists the regulatory effects that could occur in the Target Economies. The first row, which discusses intermediate and final demand effects for nickel-containing products, demonstrates that demand effects would be smallest in Scenario A1 and greatest in Scenario B. Cost effects are identical in scenarios A2 and B because these two scenarios differ only by the extent of reputational effects.

**Table 4.2: Effects of EU classifications on nickel value chain in Target Economies**

| Effect on | Central cases: modest stigmatization of nickel products | | Risk analysis |
|---|---|---|---|
| | A1<br>EU classifications not adopted by Target Economies | A2<br>EU classifications adopted by Target Economies | B<br>EU classifications adopted by Target Economies and significant stigmatization of nickel products |
| Intermediate and final demand for nickel products | Minor demand effects via reputational effects induced by classification of nickel-containing chemicals | Demand effects via official regulatory requirements covering nickel-containing chemicals, and modest reputational effects covering nickel-containing chemicals and other nickel-containing products | Demand effects via official regulatory requirements covering nickel-containing chemicals, and strong reputational effects covering nickel-containing chemicals and other nickel-containing products |
| Operating costs of producers and users of nickel-containing products | Operating costs likely to increase for industries producing or using nickel-containing chemicals in the EU | Operating costs likely to increase for industries producing or using nickel-containing chemicals in the EU and in the Target Economies | Operating costs likely to increase for industries producing or using nickel-containing chemicals operating in the EU and the Target Economies |
| Bilateral transport costs for nickel trade flows | Increases in Target Economies' export costs to the EU for nickel ores and concentrates, intermediates and nickel-containing chemicals | Increases in Target Economies' export costs to each other and to the EU for nickel ores and concentrates, intermediates and nickel-containing chemicals | Increases in Target Economies' export costs to each other and to the EU for nickel ores and concentrates, Intermediates and nickel-containing chemicals |

*Source: Frontier Economics' analysis*

## 4.3 The modelling process

The study specifications require that the assessment of economy-wide impacts of the nickel-chain implications of the classification of nickel-containing chemicals should account for *direct* impacts, *indirect* impacts, *induced* impacts and *broad economy* impacts. This requires models of the relevant economies, not just snapshot economic data such as GDP shares for particular years.

The Computable General Equilibrium (CGE) model used in this study – known as GTAP_Ni – was developed with a view to studying the effects of the classification of nickel-containing chemicals in two particular years:

- 2015 to represent the medium term when the EU and OECD economies are assumed to have completed transition to the classification changes, phasing them in from 2012
- 2020 by when it is assumed that non-OECD economies would have completed their transitions.

The model is a study-specific offshoot of the standard Global Trade Analysis Project (GTAP) model[9], which is a static multi-economy, multi-commodity CGE model of the world economy and is further described in Appendix B. It must be noted that the model does not address the criticality of nickel for the advancement of innovation and technology in areas such as green technologies, energy efficiency, carbon control, environmental protection and human health.

### 4.3.1 The GTAP_Ni model

The database used for the modelling work is built using the Global Trade Analysis Project (GTAP) version 7 database as a starting point (Narayanan and Walmsley, 2008).

The GTAP database contains values (in US dollars) of production, consumption and trade for 57 commodities across 113 regions (economy or economy aggregates) for the year 2004. The GTAP version 7 database (with additional data on income payments and convergence parameters) supports the detailed structure of the dynamic GTAP model (Ianchovichina and McDougall, 2012). The GTAP database contains:

- input-output tables for each region, containing the values of 57 commodities (distinguished as domestically-produced and imported) and 4 primary factors (labour, capital, land and natural resources) used by each of 57 industries or in the 3 final demand categories (investment, private consumption and government consumption)
- bilateral trade flows in each of the 57 commodities between each pair of regions
- international income flows and savings for each region
- parameters governing the modelled responsiveness of activities to price and output changes.

The first two items were the primary focus of constructing an amended GTAP database to support the extension – GTAP_Ni – of the dynamic GTAP model that was used to generate the results reported in Section 8.

[9] Hertel, Thomas W. (Editor). 1997. *Global Trade Analysis: Modeling and Applications*. New York: Cambridge University Press.

As is typically the case when applying an off-the-shelf economy-wide model and associated database to a sector-specific policy issue, the standard GTAP database required extensive modification to allow this detailed industry analysis.

Three main adjustments were made to the dynamic GTAP database:

- Aggregation/ disaggregation to commodity sectors and “regions of interest” – the Target Economies plus the EU, India, New Caledonia and the Rest of the World (ROW). The aggregated commodity groups and selected regions after these processes are shown in Table 4.3.
- Updating to the year 2007 in line with indicators of growth in economy GDP, world trade etc., paying particular attention to GTAP’s broadly-defined mining and metal processing sectors to ensure that they were able to accommodate the nickel-specific data supplied by Metalytics. Although data were available for the more recent years 2008 and 2009, those years were judged to be too heavily influenced by the global financial crisis to be suitable as base data. The principal growth rates shown in Table 4.4 were used for this updating process.
- Disaggregation of some commodity sectors to include the new sectors for nickel mining, processing and first-use activities shown in Table 4.5.

Subject to considerable limitations on the availability and reliability of data, Metalytics prepared such datasets for all of the Target Economies. The underlying information on nickel-chain activities in each is reported and discussed in detail in Section 6 and Appendix D.

### Table 4.3: Commodities and regions in aggregated database

| Commodities | Regions |
|---|---|
| • Agriculture, forestry & fishing | • **Australia** |
| • Coal, oil & gas mining and extraction | • **Canada** |
| • Other mining (OMN) | • **China** |
| • Manufacturing (not elsewhere classified) | • **Indonesia** |
| • Chemicals, rubber & plastics | • **Japan** |
| • Iron & steel production (I_S) | • **The Philippines** |
| • Non-ferrous metals (NFM) | • **Russia** |
| • Fabricated metal products (FMP) | • **Republic of Korea** |
| • Motor vehicles & parts | • **Chinese Taipei** |
| • Other transport equipment | • **The United States** |
| • Other machinery & equipment | • European Union |
| • Electricity generation and distribution | • India |
| • Services (not elsewhere classified) | • New Caledonia |
| • Construction | • Rest of world (ROW) |

### Table 4.4: Percentage growth (current $US) between 2004 and 2007

| Target Economy | GDP* | Aggregate Exports** | Aggregate Imports** | Other Mining (OMN) and Non-Ferrous Metals (NFM)** | |
|---|---|---|---|---|---|
| | | | | Exports | Imports |
| Australia | 45 | 58 | 49 | 161 | 127 |
| Canada | 44 | 31 | 39 | 126 | 62 |
| China | 81 | 105 | 71 | 99 | 176 |
| Indonesia | 68 | 58 | 55 | 178 | 75 |
| Japan | -5 | 27 | 33 | 98 | 111 |
| Korea | 45 | 48 | 60 | 118 | 99 |
| The Philippines | 66 | 38 | 28 | 193 | 35 |
| Russia | 120 | 93 | 114 | 110 | 44 |
| Chinese Taipei | 16 | 35 | 30 | 35 | 30 |
| United States | 18 | 42 | 32 | 125 | 85 |

**Derived using IMF data*

**Derived using World Bank Data except for the case of Chinese Taipei

### Table 4.5: Nickel sectors

| Mining (including initial processing and smelting) | Processing | First Use | End Use |
|---|---|---|---|
| • Laterite mining and initial processing<br>• Sulfide mining, concentrating, and smelting | • Matte refining<br>• Laterite smelting for ferronickel<br>• Laterite smelting for nickel pig iron<br>• Laterite processing for Class 1 & 2 nickel metal and oxide | • Stainless steel<br>• Other steel alloys<br>• Non-ferrous alloys<br>• Plating<br>• Foundry and other | • Metal products for engineering, building & construction<br>• Batteries<br>• Motor vehicles<br>• Aerospace<br>• Other transport equipment<br>• Domestic appliances and homeware<br>• Electronic equipment<br>• Machinery |

### 4.3.3 Imposing production chain realities

In addition to the specific changes made to the GTAP data base, it was necessary to assess GTAP_Ni model outputs against real-world criteria, and check their feasibility against cost rankings and mine/plant interdependencies. This ensured the model outputs with respect to the nickel production chain would conform to real-world considerations:

- The discrete nature of mines and plants (rather than a production continuum), means that any severe cutback in a particular economy must be considered against the likelihood of the required closure of a production unit or units

- Reductions in nickel demand will fall more heavily on production units with higher break-even costs, while those with very low costs will be protected

- Even modest production cuts may increase unit costs, possibly pushing middle-cost plants towards closure

- Vertical integration in the primary nickel industry has led to complex interdependencies between finished nickel plants in one economy and mines or plants in another.

Therefore, an iterative procedure was developed to feed constraints back into the model and reassess the results until outputs for the base case and each scenario were feasible and sensible.

## 4.4 Data

### 4.4.1 Baseline nickel industry forecasts

Metalytics has supplied historical data and forecasts for the mining, finished nickel production and first uses of primary nickel for the years 2007, 2010, 2015 and 2020.

The 2010 historic data (shown in Table 4.6) were presented as the most recently available picture of the current nickel industry and the basis for making forecasts of production and first use demand for the years to be modelled.

Baseline business-as-usual forecasts for the two reference years under study (Table 4.7 for 2015 and Table 4.8 for 2020) were developed by Metalytics. Supply-side forecasts reflected current production performance and reported company plans for expansions, greenfields projects and plant and mine closures, tempered by a cautious view of the speed of new developments. These forecasts are based on careful examination of individual nickel production chains from mine via intermediate (if applicable) and final processing to finished Class 1 or Class 2 metal.

Table 4.7 and Table 4.8 show forecast global first uses of primary nickel of 1,862kt and 2,180kt respectively. The end-uses associated with these forecasts are shown by industry sector in Table 4.9.

**Table 4.6: 2010 Primary nickel production and first use**
(thousands of tonnes of contained nickel)

| | Australia | Canada | China | Indonesia | Japan | Korea |
|---|---|---|---|---|---|---|
| ***Mined production of nickel*** | | | | | | |
| in laterite ores | 33.5 | | | 283.5 | | |
| in sulfide concentrates | 150.5 | 153.5 | 84.8 | | | |
| ***Production of primary nickel by process*** | | | | | | |
| matte refining | 43.6 | 71.4 | 138.0 | | 42.7 | |
| ferronickel smelting | | | | 18.7 | 67.5 | 20.5 |
| nickel pig iron smelting | | | 165.0 | | | |
| other laterite processing | 58.0 | 34.0 | 29.3 | | 55.8 | |
| **Total production** | 101.6 | 105.4 | 332.3 | 18.7 | 166.1 | 20.5 |
| further refining | | | | | | 26.0 |
| ***First usage of primary nickel*** | | | | | | |
| in stainless steel | | | 423.0 | | 99.6 | 71.0 |
| in other steel alloys | 0.1 | 1.3 | 19.3 | | 26.4 | 4.1 |
| in non-ferrous alloys | 2.0 | 0.7 | 12.0 | | 22.8 | 1.5 |
| in plating | 0.1 | 1.6 | 54.4 | 0.1 | 2.6 | 6.3 |
| in foundry and other uses | 0.3 | 1.3 | 48.8 | 0.4 | 20.6 | 2.1 |
| **Total First Use** | 2.5 | 4.9 | 557.5 | 0.5 | 172.0 | 85.0 |

| Philippines | Russia | Chinese Taipei | United States | ROW | World | |
|---|---|---|---|---|---|---|
| | | | | | | ***Mined production of nickel*** |
| 173.5 | 39.8 | | | 366.9 | **897.2** | in laterite ores |
| | 245.1 | | | 112.3 | **746.2** | in sulfide concentrates |
| | | | | | | ***Production of primary nickel by process*** |
| | 235.5 | | | 240.9 | **772.2** | matte refining |
| | 17.0 | | | 146.3 | **270.0** | ferronickel smelting |
| | | | | 0.0 | **165.0** | nickel pig iron smelting |
| | 9.8 | | | 56.4 | **243.3** | other laterite processing |
| | 262.3 | | | 443.6 | **1,450.5** | **Total production** |
| | | 11.0 | | | | **further refining** |
| | | | | | | ***First usage of primary nickel*** |
| | 8.4 | 55.2 | 49.2 | 273.2 | **979.6** | in stainless steel |
| 0.2 | 7.6 | 1.3 | 6.6 | 38.4 | **105.3** | in other steel alloys |
| | 2.5 | 0.6 | 43.5 | 48.2 | **133.8** | in non-ferrous alloys |
| | 2.7 | 7.5 | 10.2 | 44.5 | **130.0** | in plating |
| | 1.8 | 5.2 | 10.5 | 44.0 | **135.0** | in foundry and other uses |
| 0.2 | 23.0 | 69.8 | 120.0 | 448.3 | **1,483.8** | **Total First Use** |

**Table 4.7: 2015 baseline forecasts of primary nickel production and first use**
(thousands of tonnes of contained nickel)

| | Australia | Canada | China | Indonesia | Japan | Korea |
|---|---|---|---|---|---|---|
| ***Mined production of nickel*** | | | | | | |
| in laterite ores | 75.0 | | | 443.5 | | |
| in sulfide concentrates | 152.0 | 220.0 | 115.0 | | | |
| ***Production of primary nickel by process*** | | | | | | |
| matte refining | 65.0 | 125.0 | 162.0 | | 70.0 | |
| ferronickel smelting | | | | 22.0 | 72.0 | 28.0 |
| nickel pig iron smelting | | | 300.0 | | | |
| other laterite processing | 85.0 | 35.0 | 35.0 | | 60.0 | |
| **Total production** | 150.0 | 160.0 | 497.0 | 22.0 | 202.0 | 28.0 |
| **further refining** | | | | | | 26.0 |
| ***First usage of primary nickel*** | | | | | | |
| in stainless steel | | | 622.5 | | 104.0 | 79.3 |
| in other steel alloys | 0.2 | 1.8 | 23.0 | 0.1 | 28.5 | 4.5 |
| in non-ferrous alloys | 2.2 | 1.0 | 15.0 | | 26.5 | 2.0 |
| in plating | 0.2 | 1.8 | 69.5 | 0.3 | 3.5 | 6.5 |
| in foundry and other uses | 0.4 | 1.9 | 60.0 | 0.7 | 22.5 | 2.9 |
| **Total First Use** | 3.0 | 6.5 | 790.0 | 1.0 | 185.0 | 95.2 |

| Philippines | Russia | Chinese Taipei | United States | ROW | World | |
|---|---|---|---|---|---|---|
| | | | | | | ***Mined production of nickel*** |
| 284.4 | 38.0 | | | 672.1 | **1,513.0** | in laterite ores |
| | 245.0 | | 17.0 | 155.0 | **904.0** | in sulfide concentrates |
| | | | | | | ***Production of primary nickel by process*** |
| | 240.0 | | | 264.0 | **926.0** | matte refining |
| | 17.0 | | | 297.0 | **436.0** | ferronickel smelting |
| | | | | | **300.0** | nickel pig iron smelting |
| | 13.0 | | | 116.0 | **344.0** | other laterite processing |
| | 270.0 | | | 677.0 | **2,006.0** | **Total production** |
| | | 11.0 | | | | **further refining** |
| | | | | | | ***First usage of primary nickel*** |
| | 9.5 | 50.0 | 56.5 | 308.6 | **1,230.4** | in stainless steel |
| 0.2 | 9.2 | 1.8 | 7.5 | 51.5 | **128.3** | in other steel alloys |
| | 4.5 | 0.8 | 50.6 | 62.8 | **165.4** | in non-ferrous alloys |
| 0.1 | 3.3 | 6.5 | 9.2 | 59.1 | **159.9** | in plating |
| | 3.5 | 5.9 | 16.2 | 64.0 | **178.0** | in foundry and other uses |
| 0.3 | 30.0 | 65.0 | 140.0 | 546.0 | **1,862.0** | **Total First Use** |

**Table 4.8: 2020 baseline forecasts of primary nickel production and first use**
(thousands of tonnes of contained nickel)

| | Australia | Canada | China | Indonesia | Japan | Korea |
|---|---|---|---|---|---|---|
| ***Mined production of nickel*** | | | | | | |
| in laterite ores | 84.9 | | | 455.0 | | |
| in sulfide concentrates | 150.0 | 200.0 | 115.0 | | | |
| ***Production of primary nickel by process*** | | | | | | |
| matte refining | 65.0 | 125.0 | 190.0 | | 75.0 | |
| ferronickel smelting | | | | 23.0 | 77.0 | 28.0 |
| nickel pig iron smelting | | | 300.0 | | | |
| other laterite processing | 90.0 | 36.0 | 50.0 | | 65.0 | |
| **Total production** | 155.0 | 161.0 | 540.0 | 23.0 | 217.0 | 28.0 |
| **further refining** | | | | | | 26.0 |
| ***First usage of primary nickel*** | | | | | | |
| in stainless steel | | | 847.0 | | 100.0 | 86.7 |
| in other steel alloys | 0.3 | 2.0 | 29.0 | 0.1 | 27.0 | 5.0 |
| in non-ferrous alloys | 3.0 | 1.0 | 24.0 | | 29.0 | 3.0 |
| in plating | 0.2 | 2.0 | 83.0 | 0.5 | 3.5 | 7.0 |
| in foundry and other uses | 0.5 | 2.5 | 67.0 | 0.9 | 22.5 | 3.3 |
| **Total First Use** | 4.0 | 7.5 | 1,050.0 | 1.5 | 182.0 | 105.0 |

| Philippines | Russia | Chinese Taipei | United States | ROW | World | |
|---|---|---|---|---|---|---|
| | | | | | | ***Mined production of nickel*** |
| 313.4 | 38.0 | | | 759.7 | **1,651.0** | in laterite ores |
| | 260.0 | | 15.0 | 143.0 | **883.0** | in sulfide concentrates |
| | | | | | | ***Production of primary nickel by process*** |
| | 255.0 | | | 298.0 | **1,008.0** | matte refining |
| | 17.0 | | | 357.0 | **502.0** | ferronickel smelting |
| | | | | | **300.0** | nickel pig iron smelting |
| | 13.0 | | | 134.0 | **388.0** | other laterite processing |
| | 285.0 | | | 789.0 | **2,198.0** | **Total production** |
| | | 11.0 | | | | **further refining** |
| | | | | | | ***First usage of primary nickel*** |
| | 11.5 | 53.7 | 54.0 | 329.5 | **1,482.4** | in stainless steel |
| 0.4 | 9.5 | 2.1 | 7.5 | 53.4 | **136.3** | in other steel alloys |
| | 5.0 | 1.2 | 58.0 | 67.6 | **191.8** | in non-ferrous alloys |
| 0.1 | 3.5 | 6.5 | 7.5 | 64.9 | **178.8** | in plating |
| 0.1 | 4.5 | 6.5 | 13.0 | 70.0 | **190.8** | in foundry and other uses |
| 0.5 | 34.0 | 70.0 | 140.0 | 585.5 | **2,180.0** | **Total First Use** |

**Table 4.9: Primary end use by industry sector - 2010 and baseline forecasts (thousands of tonnes)**

| Industry sector | 2010 | 2015 | 2020 |
|---|---|---|---|
| **Transport** | 221.6 | 274.8 | 316.2 |
| **Electro and Electronic** | 170.5 | 221.0 | 253.3 |
| **Engineering** | 343.1 | 431.0 | 503.9 |
| **Building and construction** | 200.5 | 256.1 | 305.5 |
| **Tubular Products** | 147.0 | 189.4 | 226.6 |
| **Metal goods** | 300.1 | 383.6 | 456.2 |
| **Non-allocated** | 79.4 | 106.1 | 118.2 |
| **Total** | **1,462.2** | **1,862.0** | **2,180.0** |

*Source: Metalytics*

### 4.4.2 Macro-economic forecasts

The extension of the GTAP_Ni model to represent the two forecast years is based on forecasts of GDP growth derived from historical data and current projections published by the International Monetary Fund and illustrated in the following two figures:

**Figure 4.2: Target Economies and World GDP growth rates forecast to 2020**

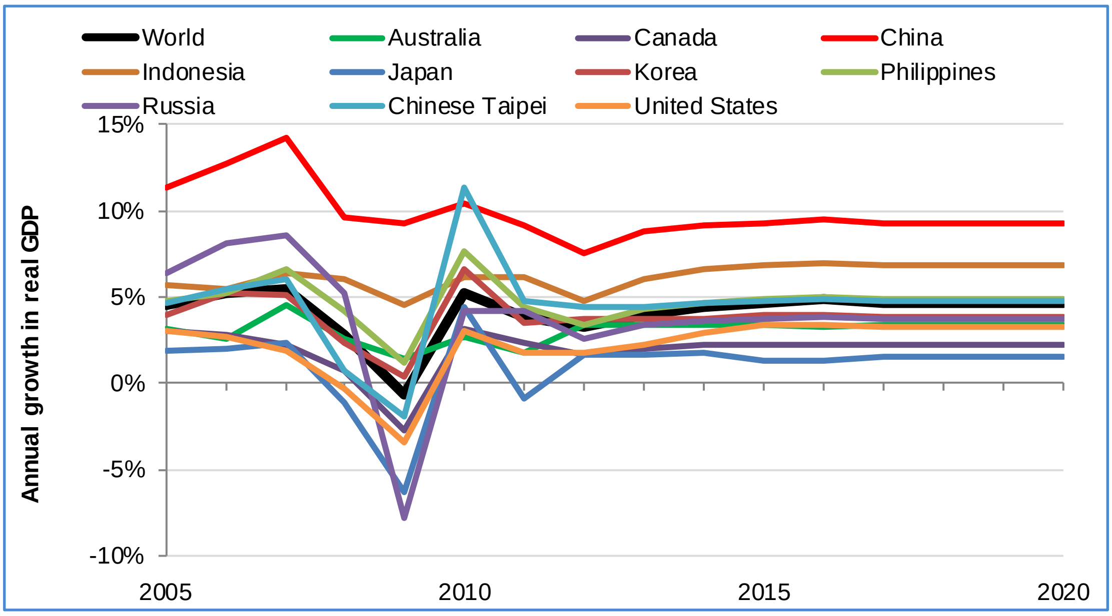
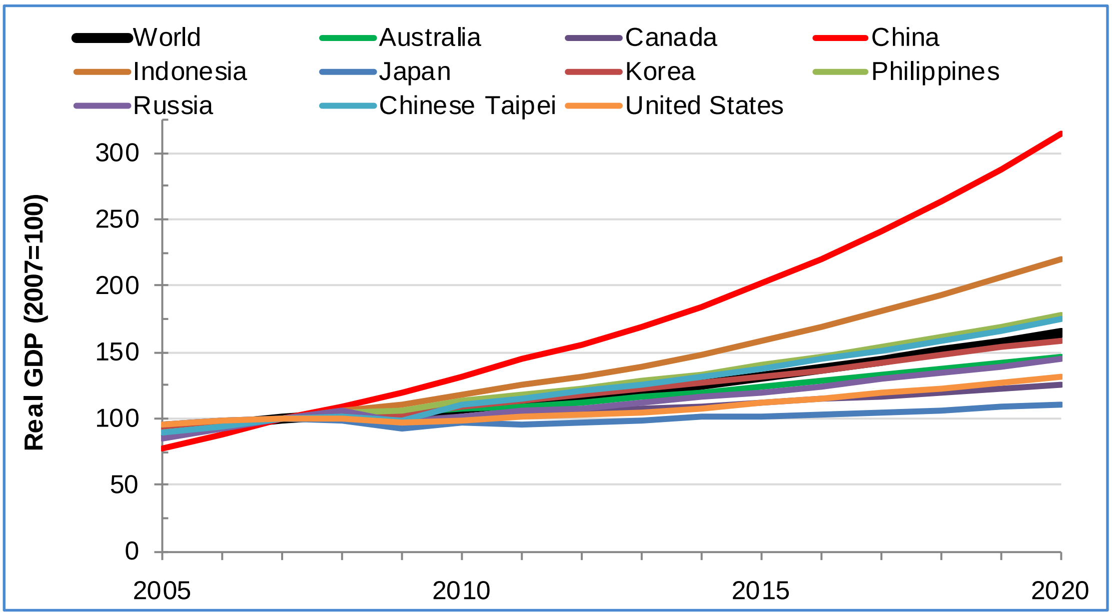



**Figure 4.3: Target Economies and World indexed real GDP forecasts to 2020**



# 5 The global nickel industry

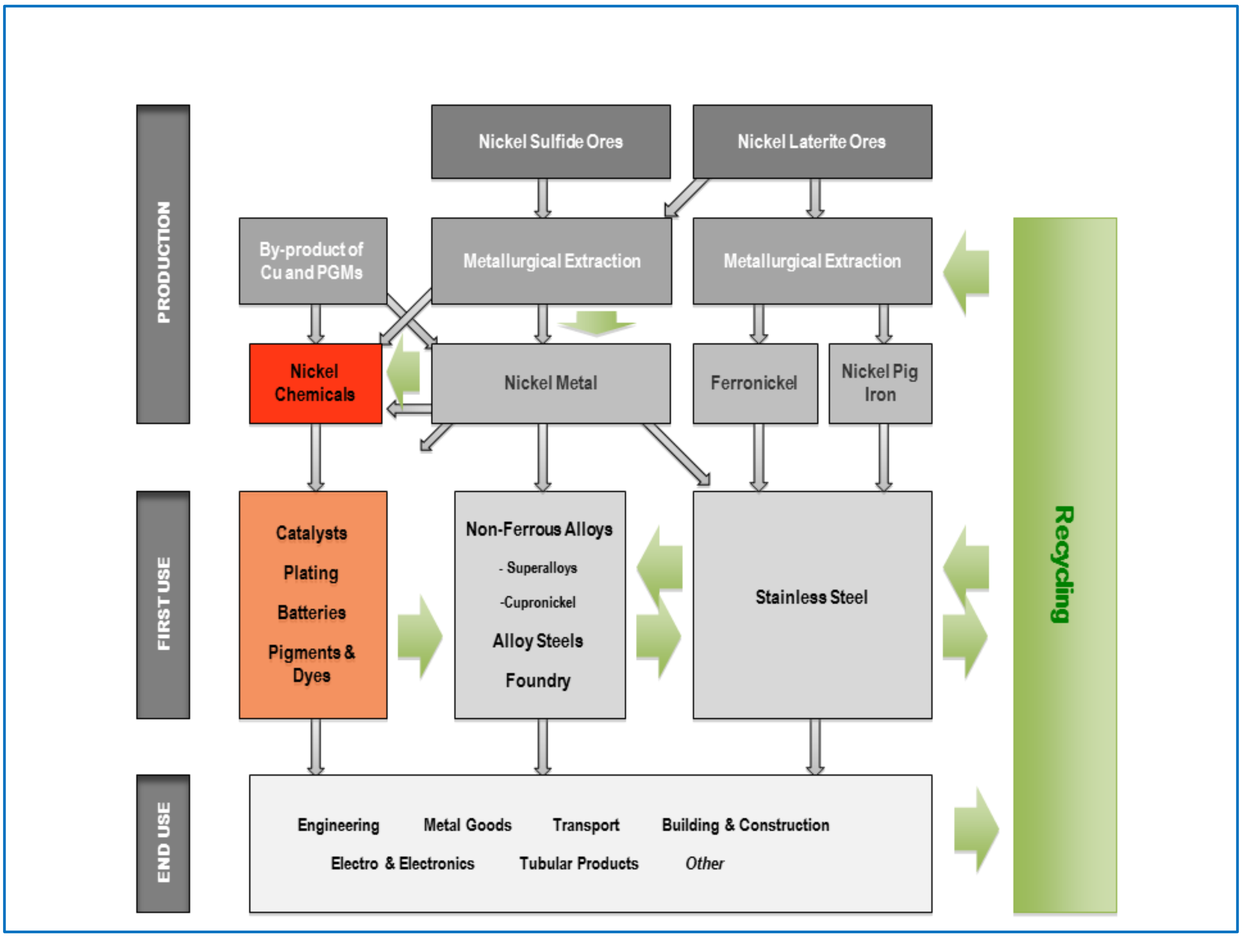
## 5.1 The nickel value chain

A commodity or product's "value chain" describes the sequential range of activities and linked processes that characterise its production and use. For nickel, as with many other minerals and metals, the value chain has several identifiable stages:

- identification and mining of in-ground geological resources,
- the concentration and processing of mined ores,
- metallurgical extraction by smelting or other technologies,
- refining and "first usage" of primary metal products
- fabrication or manufacture of "end-use" goods for industrial applications or for retail consumption
- disposal or recycling.

This section describes the global nickel industry and various components of its value chain, which can be depicted schematically as shown in Figure 5.1 below.

**Figure 5.1 Schematic representation of the nickel value chain**




*Source: Nickel Institute*

## 5.2 Nickel mining and primary production

Nickel occurs in economic concentrations in the Earth's crust in two distinct ore types: sulfide and laterite. Although around 70% of the world's nickel resources are in laterite ores, historically most of the world's mined supply has come from sulfide deposits in which nickel commonly occurs in association with other valuable metals such as copper, cobalt, and members of the platinum group of elements. These can be extracted as by-products. Major sulfide mines are currently operating in Russia, Canada, Australia, southern Africa, China and Brazil, with deposits exploited by both open pit and underground mining methods.

Laterite ores are formed by weathering at or close to the earth's surface in tropical regions and are almost always mined in open pits. There are a variety of laterite ore sub-types, depending on the occurrence of the nickel, which may be in silicate, oxide or clay minerals. The world's principal laterite mines are located in New Caledonia, Indonesia, the Philippines and Australia, as well as in Caribbean and South American economies.

There are enormous variations in the chemistry and physical characteristics of both types of nickel ores, which means that each has a unique optimal processing route. In general, sulfides tend to have higher mining and concentrating costs with lower metallurgical processing costs through a traditional smelting and refining route to produce pure nickel metal, while laterite ores typically have very low mining costs but require higher-cost and more energy-intensive metallurgical extraction methods.

### 5.2.1 Finished primary nickel products

The nickel extraction processes discussed above generate a wide range of nickel-bearing products all referred to as "finished nickel" and ready to feed appropriate first uses in the nickel value chain.

These products are broadly divided into three classes. Products with a nickel content of 99% or more are grouped as "Class 1" or "refined nickel". Less pure forms generally suitable for producing stainless steel and other alloys are called "Class 2" or "charge nickel". Finally, some nickel is passed on to consumers combined in a chemical compound, and is classed as "Chemical".

Refined metal is produced in various forms such as cathodes, pellets, briquettes and rondelles designed for ease of handling and use in various applications.

**Class 1**

- Electrolytic nickel: generally in cathode (sheet) form
- Pellets
- Briquettes
- Granules
- Rondelles
- Powder/Flakes

**Class 2**

- Nickel oxide sinter: anhydrous nickel oxide containing 75-92% nickel
- Utility nickel and Tonimet
- Ferronickel: an iron-nickel alloy well suited to the production of stainless steel
- Nickel pig iron: a similar but less pure product produced in China via a low-technology process.

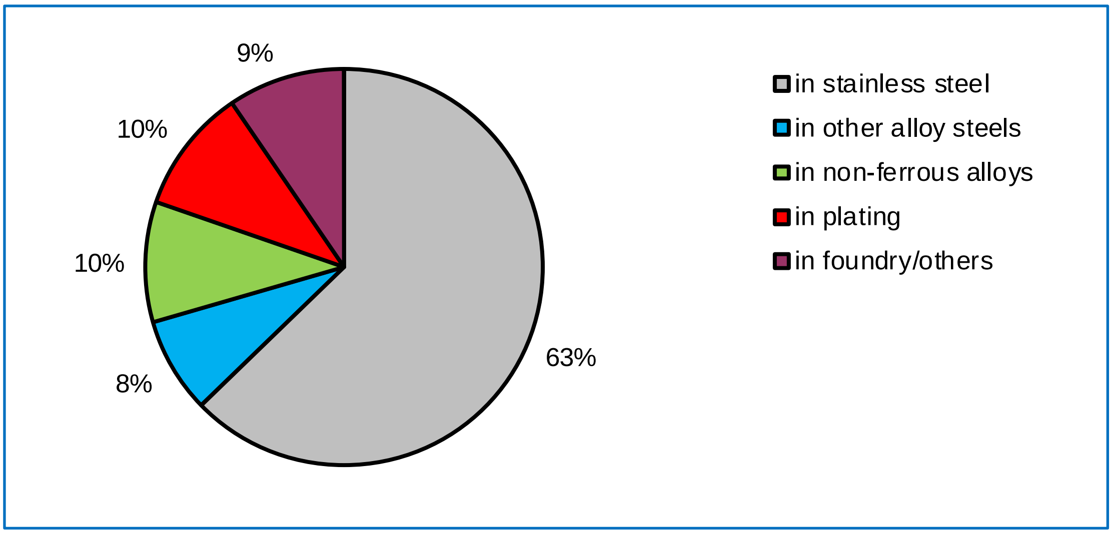
**Chemical, e.g.**

- Chemical nickel oxide
- Nickel sulfate
- Nickel chloride
- Nickel carbonate
- Nickel acetate
- Nickel hydroxide

# 5.3 World demand for nickel: First uses

As noted above, nickel is rarely used in end-use applications in its pure form: over 80% of global demand is for alloying, the rest being divided between metal for foundries and chemicals for plating, catalysts, batteries, pigments, dyes etc. The first users of primary nickel, therefore, are mostly other metal industries, which purchase Class 1 and 2 nickel products as raw materials for their own production lines.

**Figure 5.2: World primary nickel first use sectors (2006-10 average)**




*Source: Metalytics*

## 5.3.1 Stainless steel

The group of alloys now known as stainless steels was first commercially manufactured early in the 20th century and nickel was found to have a very beneficial role in many of the common grades, a situation which continues to this day.

By definition, stainless steel contains at least 10% chromium, which imparts basic corrosion resistance. The addition of nickel enhances the strength and corrosion resistance of simple chromium-bearing stainless steel, as well as changing the metallic structure from ferrite to austenite; for this reason, the term *austenitic* is used interchangeably with *nickel-bearing* when referring to different types of stainless steel. The addition of manganese similarly produces an austenitic alloy, but without appreciable increase in corrosion resistance.

Around 75% of the stainless steel produced today is austenitic, most of this in one of the nickel-chrome grades of the 300 series (e.g. grade 304 that typically contains around 8.5% nickel and 18% chromium)[10]. The remainder of current austenitic output is produced in one of the chrome-manganese grades of the 200 series (these contain up to around 7.5% manganese and up to 5.5% nickel, as well as the essential metals iron and chromium). However, the 'family' of stainless steels also includes grades, which contain no nickel through to those which contain in excess of 30% nickel.

The success of stainless steel in the industrialized world is built on this family and the wide range of properties and material costs that it offers. While all grades of stainless steel are corrosion resistant, different grades offer different protection against specific environments. Similarly, stainless steels exhibit a range of tensile strength and ductility over a range of temperatures from cryogenic cold to extreme heat depending on the grade of stainless steel selected. The greatest range of properties is found in the nickel-containing stainless steels, where formability and weldability also enable complex shapes to be fabricated and joined. From the humble stainless steel sink to high pressure reactor vessels used in chemical engineering, nickel-containing stainless steels are the material of choice for a vast array of applications.

### 5.3.2 Alloy steels

Nickel provides additional strength, hardness and shock resistance in a wide range of non-stainless alloy steels where it is used in contents ranging from 0.3% to 4.5%, commonly in association with chromium and molybdenum. These steels have vital uses in automotive, general engineering, and military applications.

### 5.3.3 Non-ferrous alloys

Where the properties of stainless steel eventually reach their limits, nickel based "superalloys" take over. Development of these high performance alloys has been driven primarily by the aerospace industry, and has relied heavily on chemical and metallurgical process innovation. These are unique high-temperature materials with extreme resistance to mechanical and chemical degradation. Their use in the turbine blades, vanes and rotor discs in gas turbine aircraft engines has made modern jet flight possible. The unique properties of high temperature strength and ductility allow them to operate at the very limits of metals. Gas temperatures striking the first stage turbine blades of a modern gas turbine engine are higher than the melting point of the alloys.

Superalloys used for these purposes can contain over 60% nickel, alloyed with typically ten additional metals such as chromium, aluminium, titanium, cobalt, molybdenum, tungsten, niobium and tantalum as well as iron. Because of the extreme operating conditions inside modern jet engines, there are no real alternatives in this end use currently available. While around 80% of nickel-based superalloys are used in aerospace applications, similar alloys are now also used in nuclear reactors, land-based gas turbine engines and in equipment in the oil and chemical industry where extreme corrosion resistance is required. However, these remarkable alloys are today also used in turbine wheels in cars and trucks. Again, no real alternatives are available.

The blades of gas turbines and jet engines may also be coated by chemical vapour deposition with materials based on nickel alumide ($Ni_3Al$), an intermetallic compound with properties similar to both a metal and a ceramic. These substances have high hardness and thermal conductivity with an extremely high strength-to-weight ratio.

[10] The remainder of current austenitic output is produced in one of the chrome-manganese grades of the 200 series (these contain up to around 7.5% manganese and up to 5.5% nickel, as well as the essential metals iron and chromium).

Cupro-nickel alloys have been widely used to produce ‘silver’ coinage; other coins have been minted from pure nickel, stainless steel and nickel-plated carbon steel to inhibit corrosion and enhance resistance to extended wear. Alloys of nickel and copper have high resistance to corrosion in marine environments and by strong acids and alkalis, Sea water pipes in desalination plants, heat exchangers and chemical reaction vessels and pipes are typical applications.

### 5.3.4 Foundry castings

Nickel in iron and steel castings imparts machinability and toughness as well as corrosion and wear resistance. Major uses are in engine blocks (a market where aluminium is also a strong contender) and other automotive components.

### 5.3.5 Other first uses: Nickel-containing chemicals

Nickel-containing chemicals play an important role in underpinning the competitiveness of major industrial and service sectors (such as aerospace, automotive, oil refining, and optical media), in supporting economic efficiency and innovation across large parts of the APEC economies, and in helping APEC economies achieve their environmental goals.

#### *Plating*

Of the nickel-containing chemicals that are the object of this study, nickel sulfate, nickel sulfamate, nickel hydroxycabonate, nickel dichloride and nickel acetate represent the bulk of the chemicals used for plating.

Plating is one of the wide range of technologies known as surface engineering that are used to modify the surface properties of metallic and non-metallic components for specific engineering purposes. These surface modifications can be broadly classified into processes that:

- Extend useful component life
- Improve the appearance
- Impart special properties such as enhanced lubricity
- Improve electrical conductivity
- Metallize plastic component surfaces
- Provide shielding against electromagnetic interference.

The industry distinguishes between the decorative uses of plating and the industrial applications.

Two principal methods are employed in nickel plating: electro and electroless plating.

The traditional electroplating method requires a supply of direct current to release nickel ions from the anode (a piece of metallic nickel) to the cathode (the article to be plated) across a bath in which both anode and cathode are suspended. The bath contains a nickel salt (generally nickel sulfamate, nickel sulfate, or nickel chloride).

In many applications electroplating has been displaced by an auto-catalytic chemical technique which requires no electric current. The electroless process relies on a reducing agent such as hydrated sodium hypophosphite ($NaPO_2H_2 \cdot H_2O$) to react with the metal ions to deposit metal. It has the added advantage of giving an even coating regardless of the shape of the article being plated, but cannot achieve coatings as thick as the electrolytic method.

The addition of a layer of nickel imparts significantly higher resistance to corrosion than use of chromium alone. Electroless deposition of nickel on polymer is used to make the surface electric conducting and useful for further electroplating.

Nickel and chromium plated steel components have a variety of end uses in household appliances and automobiles. The addition of nickel to zinc in galvanised steel can also significantly increase corrosion resistance and product life. Nickel plating is widely used for decorative purposes especially in combination with bright chromium or with a top layer of tin, gold or silver.

Nickel electroforming is an electrodeposition technology that differs from electroplating – nickel is deposited onto a mandrel or mold non-adherently so that it can later be separated. Electroforming applications include the fabrication of molds and dies, mesh and other products such as CDs and DVDs that are indispensable to operations in the textile, aerospace, communication, electronics, automotive, photocopying and entertainment industries.

### *Catalysts*

The modern chemical industry is very dependent on the use of catalysts to facilitate and speed up reactions, and to enable these reactions to take place more efficiently and at lower temperatures and pressures than would otherwise be the case.  This improves competitiveness and reduces energy consumption. Nickel is a good catalyst for many reactions because it adsorbs strongly enough to hold and activate the reactants, but not so strongly that the desired product remains in the reactor. The choice of a catalyst depends on its catalytic activity (speed) and selectivity (only produces the desired reaction), its active life (before deactivation of the catalyst) and cost.

Of the nickel-containing chemicals that are the object of this study, seven constitute the bulk of the chemicals used in surface treatment processes: nickel oxide, nickel sulfate, nickel nitrate, nickel hydroxycarbonate, nickel dichloride, nickel sulfide and nickel subsulfide.

Nickel catalysts are used in the following processes:

- Oil refining (in many production stages among which hydrogenation, sulphur trapping in order to produce low-sulphur, high quality fuels)
- Production of hydrogen
- Production of fertilisers
- Production of petrochemicals (hydrogenation, amination, sulfur trapping)
- Fine chemicals
- Oleochemicals (chemicals derived from plant and animal fats)

### *Pigments and Dyes*

Nickel oxide is the main nickel-containing chemical used in pigments. Other chemicals such as nickel hydroxycarbonate are also used for ceramic pigments whilst nickel hydroxide is used in plastic pigments.

Due to their high electrical conductivity, nickel pigments are used in the manufacture of electrically-conductive coatings that shield against electromagnetic and radio frequency interference. As they are corrosion-resistant and inert to water, they will not generate hydrogen gas in waterborne coatings.

Nickel-containing chemicals can be used as wool dyes, direct dyes used on cellulose fibres (for example cotton), dyes for synthetic fibres, and colours for leather and plastics.

Nickel oxide is used in the ceramic industry to make frits (i.e. constituents of industrial ceramic glazes), ferrites (ferromagnetic materials used in magnetic applications), and porcelain glazes.

### *Rechargeable Batteries*

Three main rechargeable battery types use nickel-containing chemicals:

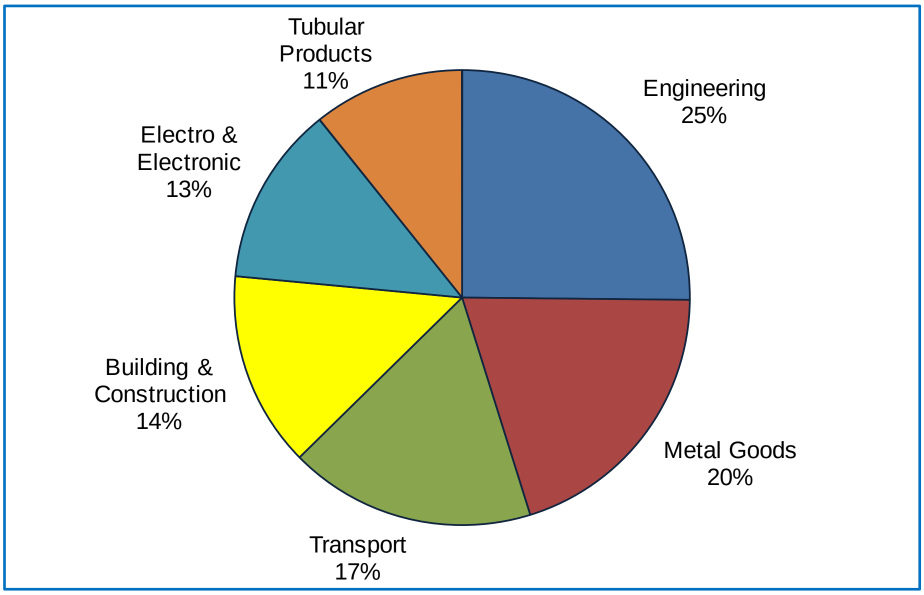
- **Nickel-cadmium (Ni-Cd) batteries** are used in industrial applications, such as a guaranteed electricity supply in the event of an electricity grid failure, typically in highly specialised industrial processes and in some mission-critical networks (e.g. telecom, information processing, oil and gas, power distribution) as well as in the transportation sector.
- **Nickel–metal hydride (NiMH) batteries** are a type similar to the nickel–cadmium batteries but can have two to three times the capacity of one of equivalent size. NiMH cells and chargers are readily available in retail stores in the common AAA and AA sizes.
- **Lithium Ion (Li-ion) batteries** utilize nickel-containing cathode materials such as doped nickel oxide, which offers the best cycling capability and service life, as called for in professional applications. The casing is often made of stainless steel or nickel-plated steels.

## 5.4 End uses of nickel

Nickel is widely used in numerous products for consumer, industrial, military, transport, aerospace, marine and architectural applications. The huge diversity of its applications makes it a commodity of considerable importance in many economies.

This versatility and diversity of end uses also makes it difficult to group nickel end uses such that they can be related back to trade statistics. However, this is an important step in the modelling process.

**Figure 5.3: World primary nickel end uses by industrial sector (2006-10 average)**




*Source: Metalytics*

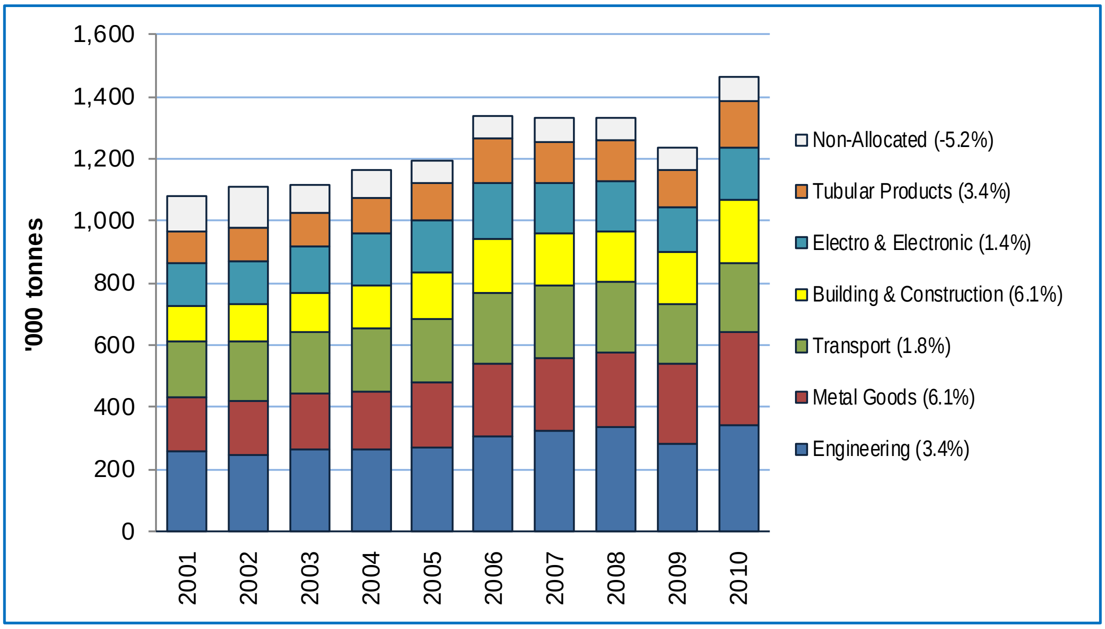
Comprehensive statistics on the end uses of primary nickel are compiled annually by Heinz H. Pariser Alloy Metals & Steel Market Research (e.g. Pariser, 2011). These classify nickel end uses under six main industry sectors, whose relative importance on a global basis can be seen in Figure 5.3.

The Pariser end-use data for the world also give an insight into how end use in these industrial categories has changed over the past decade.

Figure 5.4 shows the changing pattern of world end uses over the period 2001-10, with trend annual growth rates[11] shown in the legend. This chart shows the small "non-allocated" sector which is omitted from Figure 5.3 and from calculations of market share.

Total primary world end use grew from 1,082kt to 1,462kt in 2010, according to the Pariser data. This growth can be measured as a Compound Annual Growth Rate (CAGR) of 3.4%, or alternatively as a trend growth rate (which takes account of all of the intervening years) of 3.0% p.a..

**Figure 5.4: World primary nickel end uses by Industrial sector (2006-10 average)**




*Source: Metalytics*

### 5.4.1 Engineering

Engineering is the largest end-use sector, accounting for 343,000 tonnes of nickel end use in 2010 and an average 25.2% share of global end use over the entire period 2001-10. Its trend growth rate of 3.4% p.a. is marginally ahead of the 3.0% p.a. of total end-uses.

The most important applications of nickel in the engineering sector are in the form of stainless steel. Pariser reports that in 2010 63% of nickel used in engineering was contained in stainless steel, and its most important uses were in the Chemical, Petrochemical and Offshore industry sub-sector. These industries prize stainless steel for its ability to withstand attack from corrosive chemicals and seawater. They make up about one third of engineering sector demand for nickel in stainless steel and also for total nickel end use, finding widespread applications for the metal also in non-ferrous alloys and foundry products.

Food Processing is the fastest-growing engineering sub-sector with a 2001-10 trend annual growth rate of 6.0%. It covers about 20% of engineering sector demand for nickel. The appropriate austenitic

[11] Annual growth rate of the best-fit exponential trend line

stainless steels are not only heat-resistant but afford a hygienic environment for the processing of dairy products, beer and wine making, and the manufacture of confectionery, cooked meats and many other products – its durability and corrosion resistance making it easy to keep clean and non-reactive with the products.

Other important applications for nickel in the engineering sector are found in Energy, Vessels, Tanks and Heat Exchangers and in the Packaging and Pulp and Paper industries.

### 5.4.2 Metal Goods

The fast-growing Metal Goods sector accounts for about 20% of world nickel end use. Almost half of this category represents Cutlery, Tableware and Hollowware, reflecting the appeal of stainless steel and nickel-plated cutlery, and stainless steel jugs, trays, bowls etc.

While the Cutlery sub-sector is stagnant, Tableware and Hollowware exhibited a 9.1% trend annual growth rate over the last decade. This has been driven largely by growth in medical uses of stainless steel items such as bowls, trays and bed-pans. More than 80% of these products are manufactured in Asia, and much the same applies to the other fast-growing Metal Goods sub-sector, Catering Equipment. In these categories austenitic stainless grades have for some time been under challenge from ferritic and low nickel grades.

The Metal Goods sector also includes stainless steel Kegs; stainless steel or other Alloy Fasteners (screw, bolts, nuts), Stranded Wire, Cable and Ropes; Wire and Woven Products; Coinage and a host of miscellaneous applications.

#### *Medical equipment*

A variety of different nickel alloys are used in medical implants such as vascular stents. To shield a medical device from electromagnetic interference, a special ink containing a metallic powder is sprayed upon the inside surface of its plastic enclosure. Nickel is by far the most frequently used metal for coated shielding systems because it is highly magnetic and absorbs more electromagnetic interference than alternative materials.

### 5.4.3 Transport

In the early half of the past decade, the Transport industry sector was the second-largest end-use category, but slow growth has seen it overhauled by metal goods. The Automotive and Accessories sub-sector is a heavy user of nickel plating and remains the most important user of nickel in the Transport sector. Material use efficiency slowed down growth over the decade 2.0% p.a. Uses in Aircraft & Aerospace are growing more rapidly, but this is offset by negative growth in the use of nickel in Shipbuilding and the manufacture of Bicycles and transport Containers.

The car industry relies heavily on coatings. The main plating techniques used are electrolytic zinc-nickel and electroless nickel coating. Zinc-nickel plating has in many cases replaced zinc plating with hexavalent chromium passivation and would be very difficult to replace in the automotive industry due to its unique combination of corrosion resistance, durability and adhesion. Zinc-nickel coatings are very corrosion resistant in salt spray and do not form heavy corrosion products. The technique is therefore very useful for fasteners (screws and bolts) in cars. Electroless nickel plating is the best known technique for protecting against wear and is used on elements in hydraulic systems, shafts of different parts (e.g. electrical mirrors, door locks), parts in parking brakes, elements in automatic gear boxes, and on so-called “slip yokes”, which transfer the power from the engine to the wheels.

Nickel plating has grown rapidly within the aerospace industry after many years of development and testing. Nickel coatings are recognized to provide a unique combination of functional properties such as corrosion protection, hardness, wear and erosion resistance as well as uniform thickness on complex components. Electroless nickel plated parts are used within the aerospace industry where wear and corrosion resistance are important, for example in landing gear, engine shafts, engine mounts and hydraulic systems. This type of plating allows the refurbishment of used aircraft parts.

### 5.4.4 Building & Construction

The fourth-largest sector, Building & Construction, is also one of the fastest-growing. Over 95% of its nickel usage is in stainless and other alloy steels. Their uses in this sector are many and varied, but the fastest-growing, Sinks and Bath Tubs, by 2010 had almost overtaken Window Frames, Sashes and Roofs as the largest sub-sector. Other important sub-sectors include Lifts and Escalators, Stone Anchors, Space Heating and Air Conditioning and Panels. The first two of these sub-categories grew very rapidly over the last decade, both achieving trend annual growth rates of 14.7%, the highest of any in the entire range of sub-categories reported by Pariser.

This sector is clearly driven by the rapid rates of urban and industrial construction being achieved in China and elsewhere in Asia.

### 5.4.5 Electro & Electronic

The use of nickel in the Electro & Electronic industry sector grew slowly (1.4%p.a) over the past decade, and in 2010 was slightly short of its peak in 2006. Stainless steel applications are responsible for about 60% of nickel usage in this sector, particularly in Washing Machines, Domestic Cookers, Dishwashers and Other Appliances. Another quarter of the use in the sector is in nickel plating, chiefly as a sub-coat on polymers for bright chromium electroplating in various domestic appliances and in Data Processing Equipment and Consumer Electronics.

### 5.4.6 Mobile phones, laptop computers, digital cameras

Layers of ultrafine nickel powder are used in the new generation of capacitors in mobile phones.

Hard disc drives are devices that store or reproduce data by moving a magnetic head to the desired storage location. Evolution in computer technology can be attributed in part to advancements in the magnetic heads that are used to read and write data. Today’s most advanced read-and-write heads use thin-film technology. Nickel is a critical component of this technology – two parts of the film heads are magnetic alloy layers consisting of 81% nickel.

Nickel is a key part of several rechargeable battery systems used in electronics, power tools, transport and emergency power supply. Most common today are nickel-containing Lithium-ion and nickel-metal hydride (NiMH) batteries.

### 5.4.7 Tubular products

Tubular Products mostly only reach the end use stage when they are employed in applications such as Automotive, Engineering or Building and Construction. They are nevertheless treated by Pariser as an end use category because they account for more than 10% of total nickel end use. The 3.4% trend annual growth rate of this sector is similar to that of the Engineering sector. The most important tubular product from a nickel perspective is Welded Tubes, which in 2010 had a 56% share, growing at around 2.7% per year, half the rate of growth being achieved by nickel in Flanges and Fittings. Over 90% of the nickel used in the Tubular Products category is in stainless steel.

## 5.5 Recycling of nickel

Nickel is among the most valuable of the common non-ferrous metals (e.g. aluminium, copper, zinc, lead). The economic motivation for using nickel effectively in the first place is therefore very strong. Similarly, the incentive for recovering and recycling nickel at all stages of production and use is also very strong. Products made of stainless steel, for example, rarely remain waste at the end of their useful life. They are systematically separated and recovered to go back into the production process through recycling.

The vast majority of nickel in end uses is recycled by the stainless steel, steel, copper and brass industries and by companies that supply those industries with material. Exceptions are the recycling of rechargeable batteries and catalysts, which happens in highly specialized and dedicated operations. But the nickel smelters also take in some "secondary" nickel. Primary nickel indeed contains an average of 2% of recycled nickel, in the case of Nickel Institute members.

Recycled content in stainless steel (60% on average) could theoretically reach 100%. However, availability of materials for recycling depends on the often-long service life of products and on production levels from decades ago, which were significantly lower than current levels.

# 6 Nickel and APEC Economies

## 6.1 Introduction

This section describes the primary nickel value chain in the ten Target APEC Economies. For this analysis, statistical data were compiled for a base year of 2007 to avoid distortions resulting from the global financial and economic crises of 2008 and 2009. Together with available industry information for 2010, these formed the primary data input for the economic modelling. A baseline set of nickel industry forecasts was compiled by Metalytics.

## 6.2 Data sources

The principal sources used in this study for statistics on mined and primary nickel production and on international trade in ores, concentrates, intermediate products and finished nickel were the monthly and annual compilations produced by the International Nickel Study Group (INSG)[12]. These were supplemented where necessary by data from company reports, government publications and industry journals.

Data on first and end usage of nickel were primarily obtained from annual reports prepared by Heinz H. Pariser Alloy Metals & Steel Market Research (e.g. Pariser, 2010, 2011)[13]. In general, however, reported information on nickel usage is far less reliable than that on production, and no single source is definitive. In order to compile the best quality data for modelling, information from the above sources was validated and in some instances revised by Metalytics to take account of additional information obtained from a variety of additional sources including the US Geological Survey, industry and trade publications and independent estimates. The resulting data set on nickel usage is referred to in this report as the *Modified Pariser data*.

Statistics on stainless steel production and trade were taken from annual compilations by Vale (e.g. Vale, 2010, 2011), supplemented with data from the International Stainless Steel Forum[14].

Metalytics maintains an extensive information base on the world nickel industry containing historical statistics, forecasts and production cost estimates, together with detailed information on nickel reserves and resources, mining, ore processing and metallurgical extraction, the refining and use of primary nickel and the utilisation of secondary (scrap) material.

Using the above sources, Metalytics compiled sets of nickel industry statistics for 2007 and for 2010, as well as generating base-case forecasts of nickel mined output, finished metal production and first use for each of the ten Target Economies and globally.

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[12] The International Nickel Study Group is an autonomous intergovernmental organization with headquarters in Lisbon. Its publications include World Nickel Statistics Monthly Bulletin and World Directory of Nickel Production Facilities

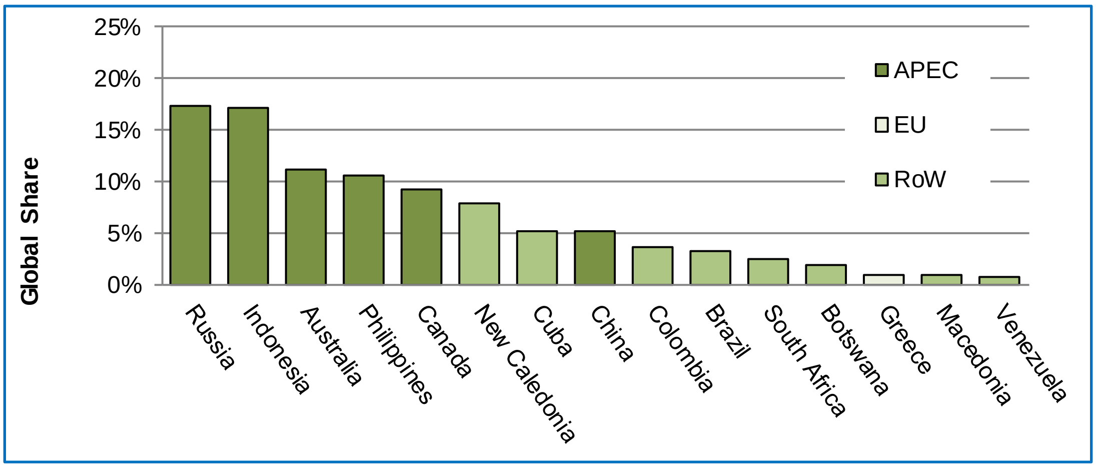
[13] Heinz H. Pariser Alloy Metals & Steel Market Research is a leading supplier of global and regional statistics on nickel usage and the world stainless steel industry.

[14] See www.worldstainless.org

## 6.3 Nickel production and usage in the APEC economies

APEC members occupy the top five places in a world list of nickel mining economies (Figure 6.1), measured by nickel contained in laterite ores and sulfide concentrates. Overall, 71% of the world's mined nickel in 2010 was produced by APEC economies, led by the Russian Federation, Indonesia, Australia, the Philippines and Canada, with China the eighth largest producer. This level of dominance is broadly consistent with APEC members' aggregate 59% share of world nickel reserves and resources, discussed in Section 6.4 of this report.

**Figure 6.1: World Top 15 Economies by Mined Nickel Production in 2010**

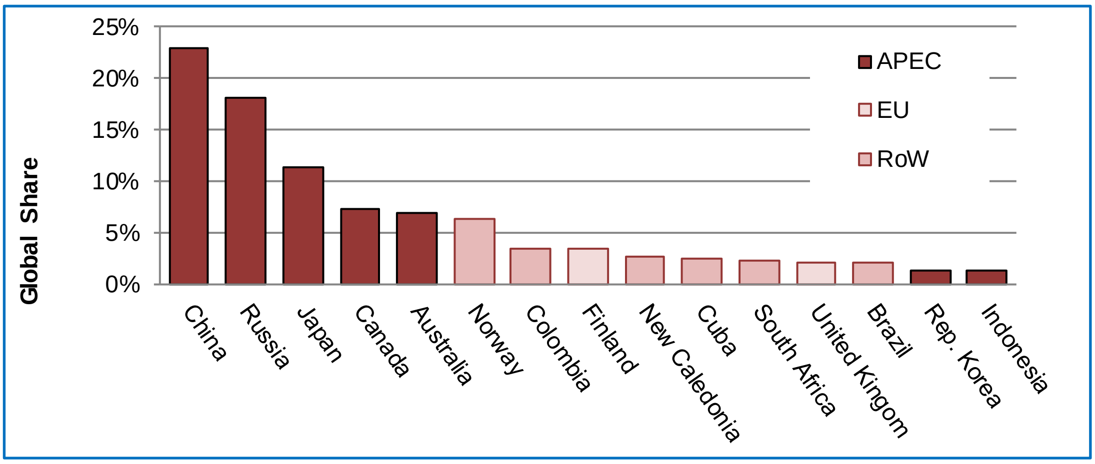



*Source: Metalytics*

The proportions of global primary nickel production (69%) and first usage (71%,) attributed to APEC members are remarkably similar to APEC's mining share, even though the shares held by individual economies and their rankings are very different in each of the three categories.

As the world's major primary nickel user (Figure 6.3), China also heads the list of 2010 producers of finished primary nickel (Figure 6.2), supplementing its domestically-sourced production with material derived from imported ores and concentrates. Japan, second placed in terms of nickel first use, is also among the top five finished nickel producers, for which it relies entirely on imported nickel feedstocks.

**Figure 6.2: World Top 15 Economies by Production of Primary Nickel in 2010**




*Source: Metalytics*

The Russian Federation, Canada and Australia occupy their high positions in the list of finished nickel producers by virtue of their strengths in mining, and are large exporters – of finished nickel in the case of Russia, and of both finished nickel and intermediate feedstocks in the case of Canada and Australia.

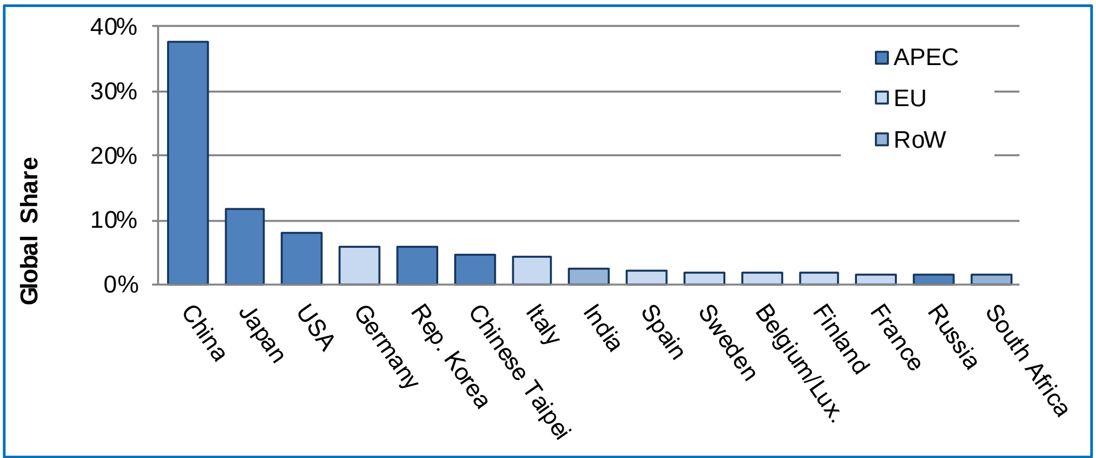
Indonesia and the Philippines are both major miners and exporters of lateritic nickel ore, and their downstream development into finished metal production is relatively slight, impeded by their small domestic markets and reflecting their degrees of industrialisation.

Despite being the third largest economy in the world in terms of primary nickel usage, the United States has at present no nickel mining or extraction capacity, relying on imports of finished metal, largely from other APEC members.

The Republic of Korea and Chinese Taipei are respectively fifth and sixth in the world in primary nickel usage, yet neither figures strongly as a producer. In finished nickel terms, Korea's ferronickel production affords it 14th ranking, and Chinese Taipei has no production. Both economies, however, have refineries that re-refine imported finished nickel and whose outputs are not included in the statistics on which Figure 6.2 is based, in order to avoid double counting.

Detailed Target Economy reports can be found in Appendix D.

**Figure 6.3 World Top 15 Economies by First Use of Primary Nickel in 2010**




*Source: Modified Pariser data*

## 6.4 APEC economies share of nickel production and usage

The world's currently reported in-ground nickel Resources contain 220 million tonnes of the metal[15], including 57.2 million tonnes (26%) classed as Reserves. Fifty-nine percent of the Resources are in APEC member economies, with Indonesia, Australia and Russia alone accounting for 40% of the total.

Table 6.1 and Figure 6.4 summarise the distribution between APEC and non-APEC economies of the global "Measured and Indicated" and "Inferred" categories of nickel Resources in both major ore types. Note that Reserves are a sub-set of Resources. APEC economies account for 53% of the world's known lateritic nickel on a contained-metal basis and 68% of the world's sulfides. Although 63% of global nickel Resources are in laterite ores, the proportion within APEC is a slightly lower 57%.

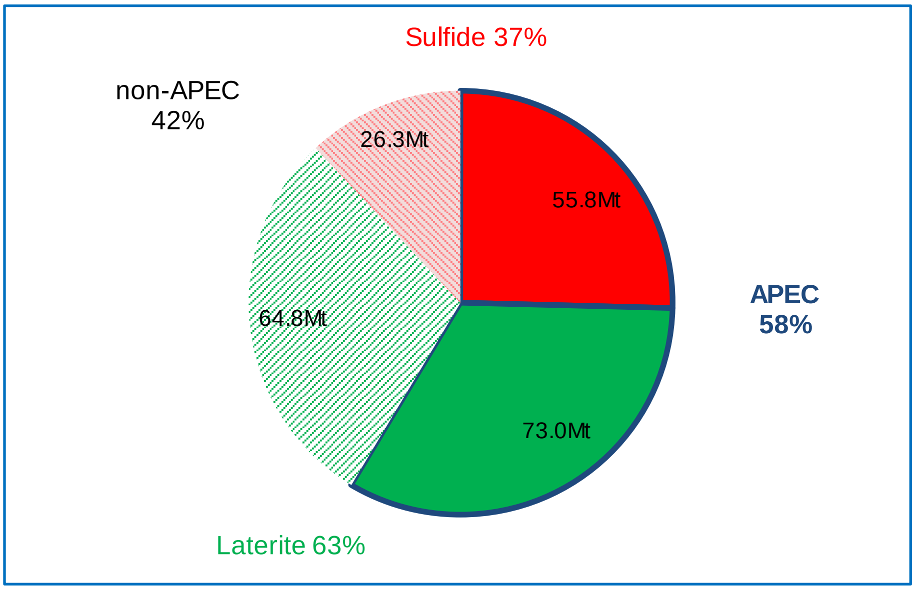
**Table 6.1: World Nickel Resources by Ore Type**

| Million tonnes of contained nickel in: | Laterites | | Sulfides | | Total | | World Totals |
|---|---|---|---|---|---|---|---|
| | APEC | Non-APEC | APEC | Non-APEC | APEC | Non-APEC | |
| Measured & Indicated† | 37.5 | 36.8 | 38.6 | 17.3 | 76.1 | 54.1 | 130.1 |
| Inferred | 35.5 | 28.0 | 17.3 | 9.0 | 52.8 | 37.0 | 89.8 |
| **Total** | **73.0** | **64.8** | **55.8** | **26.3** | **128.8** | **91.1** | **219.9** |

† includes Reserves

[15] This estimate, and other reserve and resource data quoted in this report, derive from a comprehensive survey by Metalytics that analysed information reported by 126 exploration and mining companies covering nickel deposits in 37 economies

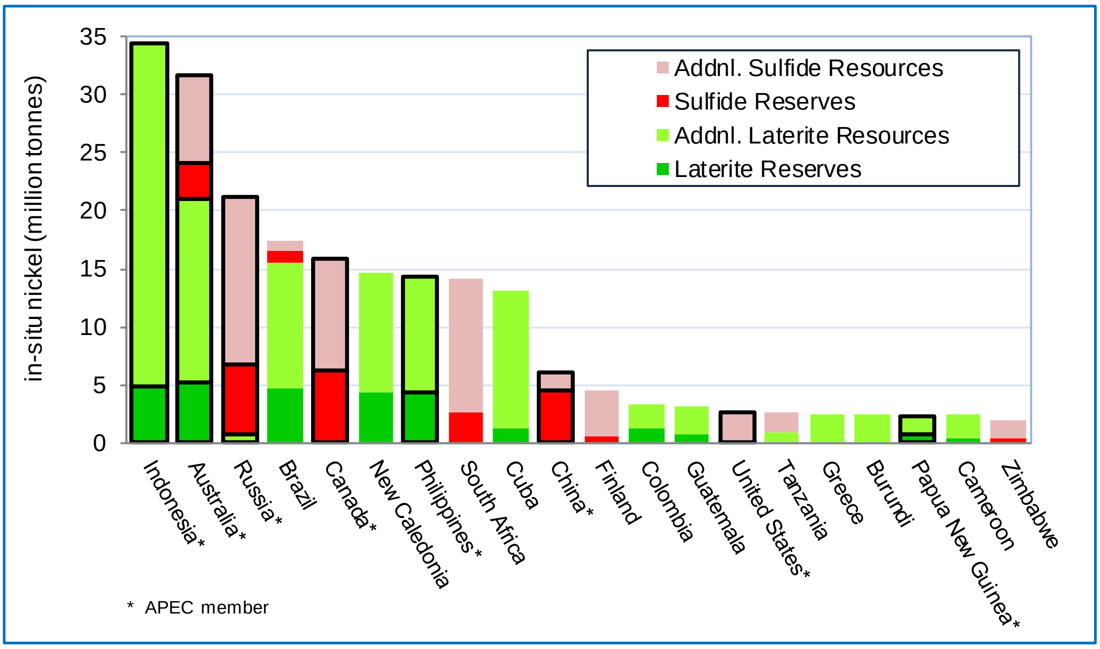
### Figure 6.4: Shares of World Nickel Resources (contained nickel basis)




*Source: Metalytics*

Figure 6.5 shows the world's top twenty economies in terms of contained nickel in reported resources, broken down into Reserves and Additional Resources. In this chart APEC member economies are indicated by an asterisk (*) and the columns representing their resources are outlined in black.

### Figure 6.5: World Top 20 Economies' Nickel Reserves and Resources




*Source: Metalytics*

Nine APEC economies have reported nickel resources, and eight of these appear in the chart above; the additional economy is Viet Nam, ranked 32nd in the world. Among the APEC members with no reported nickel resources are the Target Economies Japan, Korea and Chinese Taipei.

# 6.5 The APEC economies in the world primary nickel industry

## 6.5.1 Economic importance

Table 6.2 shows the aggregate shares of the nickel mining, primary nickel processing and nickel first use industries in the GDP of each Target Economies. These represent the ratios of nickel industry value added to total value added in the economy. The table also summarises the shares of each of the Target Economies in the nickel mining, primary production and first use steps of the Nickel Value Chain.

**Table 6.2: Primary nickel's economic contributions to the Target Economies**

| Economy | 2010 shares in global nickel* | | | nickel mining, processing and first use | |
|---|---|---|---|---|---|
| | Mine output | primary production | first use | Share in economy's GDP† | Contribution to GDP (US$ billion) |
| Australia | 11.2% | 7.0% | 0.2% | 0.52% | 6.4 |
| Canada | 9.3% | 7.3% | 0.3% | 0.27% | 4.3 |
| China | 5.2% | 22.9% | 37.6% | 0.19% | 11.2 |
| Indonesia | 17.2% | 1.3% | 0.03% | 0.72% | 5.1 |
| Japan | | 11.5% | 11.6% | 0.17% | 9.3 |
| Korea | | 1.4% | 5.7% | 0.20% | 2.0 |
| The Philippines | 10.6% | | 0.01% | 0.56% | 1.1 |
| Russia | 17.3% | 18.1% | 1.6% | 0.53% | 7.8 |
| Chinese Taipei | | | 4.7% | 0.44% | 1.9 |
| USA | | | 8.1% | 0.02% | 2.9 |
| **10 Target Economies** | **70.8%** | **69.4%** | **69.8%‡** | **0.16%** | **52.0** |

* *Source: Metalytics*

† *Source: Frontier Economics' analysis (Note that employment shares will be lower because nickel sectors are relatively capital intensive)*

‡ *APEC's total first-use share including members not among the ten Target Economies is estimated as 70.9%*

## 6.5.2 Cash cost comparisons

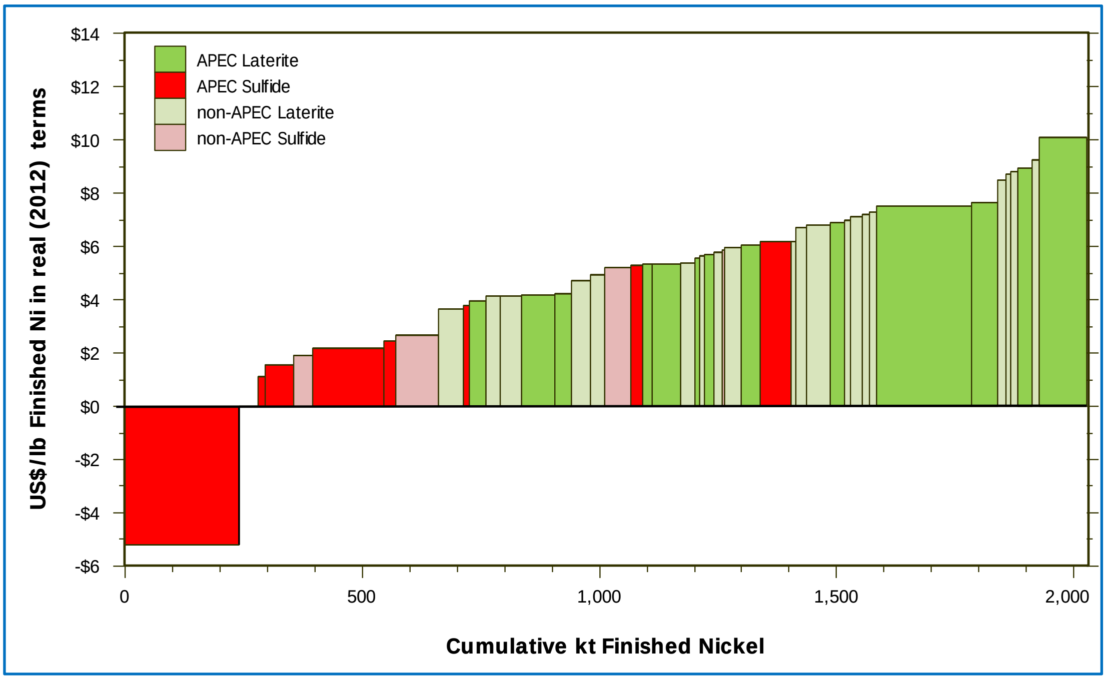
The sector-level analysis produced by the GTAP_Ni model required supplementation with input on the spread of production costs between the different primary nickel operations within the Target Economies to pinpoint the relative exposures of those operations to the impact of the EU classification.

The cash "cost curve" shown in Figure 6.6 illustrates a forecast of world primary nickel production by plant ranked in ascending order of estimated cash operating cost per unit of finished nickel output. Non-cash and non-operating costs such as depreciation and amortisation, debt servicing charges, taxation and corporate overheads are excluded. The operating cash costs cover all of the activities from mining through to final processing, including transport of ores, concentrates and intermediate products.

For plants treating feeds derived from polymetallic mines, the market values of products other than nickel (such as copper and cobalt and Platinum Group Metals) are deducted from the cost of producing metal. This method of dealing with by-product revenue streams, commonly known as "normal costing", results in negative nickel costs for some producers.

**Figure 6.6: Primary nickel cash cost of production by plant in 2015**

(Normal costing – all other metals treated as by-products)




*Source: Metalytics analysis*

By using different colours for the primary ore types feeding production from each plant, the dominance of lateritic nickel in forecast global output in 2015 is readily apparent. The competitive advantage held by plants recovering nickel together with by-products from sulfide ores is also clear from the cost curve. Sulfide-based producers in the upper half of the cost curve have few or no such by-product benefits.

Producers of Class 1 nickel from laterites benefit from cobalt revenues (cobalt is commonly present in laterite ores at about one tenth of the concentration of nickel) but do not rely on them for their economic survival because of the nature of the cobalt market. Producers of ferronickel and other class 2 nickel products from laterite ores do not benefit from other non-ferrous metal revenues. Other things being equal, the greatest pressure to cut supply in response to any reduction in demand for nickel will be felt by high cost producers with low profit margins as the supply demand balance adjusts to meet the new demand reality.

# 7 Classification of nickel-containing chemicals in APEC economies

Although the EU classification decision covered some 138 nickel-containing chemicals, only a small number of these are in actual commercial use. By way of illustration, only 23 are registered for import and use in the EU under its REACH Regulation.

This section provides the results of an analysis of how ten of those nickel-containing chemicals registered by the Nickel Consortia[16] as well as slimes and sludges are currently classified in the ten Target Economies.

Direct substance-for-substance interpolation by hazard-end point was not undertaken simply because no APEC economy has attempted such a large-scale classification of nickel-containing chemicals in the manner undertaken by the EU. Hence, it was not possible to compare APEC and EU classifications of the chemicals relative to all the EU hazard endpoints. The approach adopted was to take one hazard endpoint – carcinogenicity – and look at how each of the Target Economies classified the 11 nickel-containing-chemicals in relation to this endpoint.

The results of this analysis are shown in Table E4.1 (Appendix E), in which. a simplified comparative index is used to show whether the Target Economy's classification is less (L), more (M) or equally stringent (E) to the EU classification. Box E.1 contains notes on data sources and the assumptions that have been made for this compilation.

This analysis reveals that by and large, there is equivalence between the EU and APEC economy classifications for carcinogenicity. Only the Republic of Korea, Indonesia and Chinese Taipei show current classifications which are generally lower than the EU classification for this hazard endpoint. There are also a number of economies which have not classified some chemicals at all. Nickel matte – a key intermediate produced from smelting of nickel ores is the most prominent example here.

In summary, this assessment confirms that, in general, nickel-containing chemicals on the market in the EU are also acknowledged to be present on the market in the Target Economies and are classified at an equivalent level for the carcinogenicity hazard property. Box E.1 highlights the extensive variability in approaches to classification of nickel-containing chemicals within the Target Economies with scientific data from actual testing of the chemicals being a key determinant for hazard properties and classification.

Notwithstanding current hazard classifications, it should be noted that chemicals management regulations and other environmental and occupational health & safety regulations in the Target Economies currently regulate these nickel-containing chemicals as well as nickel metal. The regulatory instruments in place are designed to limit release to the environment or exposure to workers in industrial settings where these nickel-containing chemicals are used. Appendix E also provides an overview of the existing chemicals management, occupational health & safety (OH&S) and environmental regulations in the Target Economies.

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[16] The **Nickel Consortia** have been created by the Nickel Institute to help companies comply with REACH obligations. For more information: http://www.nickelconsortia.org/

# 8 Assessment of impact: Results

## 8.1 Demand Effects

Demand effects estimates have taken into consideration the rationale as described in Section 4.2. Four main factors were taken into account:

- the extent to which different end uses involve human contact with nickel-containing components. The analysis has considered that adverse demand responses, including stigmatization, were likely to be stronger when consumers can be directly exposed to the end use of interest. In these cases, consumers are more likely to respond to awareness campaigns by advocacy groups. Regulators are also more likely to monitor substances to which consumers are exposed, increasing regulatory risks;
- how directly humans are exposed to classified chemicals when human contact with end-use products occurs such as with Do-It-Yourself nickel plating kits;
- the extent to which it is possible to substitute away from (or reduce) the nickel content of end-use/first-use applications. The more valuable or essential are the foregone attributes, the higher is the cost of switching to alternative applications. The more essential nickel is in a particular application, the less exposed a producer is likely to be to regulatory risk (i.e. the risk that nickel may be restricted in that application in the future), and the less likely is anticipatory substitution;
- any history of concern with nickel substances used in particular products.

Table 8.1 summarises the main conclusions that were drawn from an extensive analysis involving company and independent expert opinions in quantifying the most likely demand effects for nickel end-use/first-use combinations on the basis of the four considerations listed above.

Column 2 of Table 8.1 lists Pariser end-use categories, arranged in seven blocks reflecting Frontier's judgements about the extent to which different end uses involve direct human contact with nickel-containing components.

- The first block includes only the *Medical Appliances* end use. This is a heterogeneous category, however, including stainless-steel medical implants as well as general medical equipment such as stainless-steel trolleys, receptacles and tables. Nevertheless, of all the end-use categories, medical implants are regarded as involving the most intrusive human contact with nickel-bearing alloys.
- The second block comprises end uses related to the preparation and consumption of food for humans. These end uses might involve the possibility of contact with nickel via ingestion.
- End uses in the third block involve a high level of human contact in domestic situations.
- End uses in the fourth block are assumed likely to be associated with some human contact, but at a lower level than for the preceding blocks.
- Human contact associated with end uses in the fifth block is assessed to be low.
- The sixth block contains end uses that are assumed to be protected from the impact of regulations on nickel-containing chemicals. Nickel-alloy and nickel-plated items used in the aerospace industry are a prime example. Human contact is likely to be minimal – limited to workers engaged in the manufacture and maintenance of aircraft – and prospects for substituting away from nickel-based inputs are very low.
- The final block comprises industrial end uses for which the risk of human contact is judged to be minimal, with demand effects limited to possible stigmatization.

Column 3 of Table 8.1 subdivides the end-use blocks by their nickel first uses. As for the end uses, the first uses are blocked in line with the extent to which Frontier's judgements about demand effects distinguish between individual first-use categories. The main distinctions recognised between first uses are those between the Pariser first-use category *Others* (which includes batteries, chemicals and catalysts) and all other first uses, and the distinction between *Plating* and the four alloys categories (including stainless steel).

- *Others* is treated separately because it includes the nickel-containing chemicals that are classified in the EU as Cat 1A carcinogens in all scenarios. Hence, it is assumed that there is an 80% reduction in use of the first-use category *Others* in the EU by 2020, for all scenarios.
- In scenarios A2 and B where the Target Economies adopt the EU's classifications, all OECD members are assumed to reduce usage of this first-use category by 80% by 2020 and all non-OECD economies are assumed to reduce usage by 40%.
- In Scenario A1 where Target Economies retain their pre-existing classifications, only stigmatization can lead to a reduction in the use of nickel-containing chemicals in these economies. Hence in Scenario A1, OECD members are assumed to decrease their usage of the first-use category *Others* by 25% by 2020 while non-OECD economies decrease their usage by 5%.
- Under these assumptions, the percentage reduction in global demand for primary nickel due to reductions in the usage of the *Others* category in a particular end use is a weighted average of the percentage reduction in each economy, with the weights reflecting shares in global aggregate usage.
- The *Plated* category is treated separately from alloys on the grounds that exposure to nickel from plated items is more direct than is exposure from items made of nickel-bearing alloys. Hence, for all end uses that involve significant human contact (i.e. blocks 2-4), demand effects assumed for plated items are larger than effects assumed for alloy items.

Table 8.2 provides the percentage reductions in primary nickel demand in 2020 that Frontier has subsequently estimated for the three scenarios on the basis of the rationale set out in Table 8.1.

The aggregate demand and cost shock effects on global primary nickel usage under all three scenarios for 2015 and 2020 are shown in Table 8.3.

These demand effects have been integrated into the model to compute the nickel chain effects with full consideration of the economic and technical constraints that are specific to this value chain.

## Table 8.1: Rationale for specifying demand effects

| Block | End-uses | First uses | Rationale |
|---|---|---|---|
| 1 | • Medical appliances | All* | Some products included in this category (e.g., medical implants) involve highly intrusive exposure. Others (e.g., medical trolleys and tables) are less likely to be affected. |
| 2 | • Domestic cooking<br>• Food processing<br>• Cutlery<br>• Kegs<br>• Catering | Plated | Ingestion risk with direct nickel contact |
| | | Others† | Ingestion risk, regulatory exposure risk/effects of consumer advocacy e.g. through SIN Lists |
| | | All other first uses | Ingestion risk with partial nickel contact |
| 3 | • Automotive & Accessories<br>• Bicycles<br>• Washing Machines, Dishwashers, etc<br>• Freezers, Refrigerators<br>• Data Processing, Consumer Electronics<br>• Other Electro and Electronics and Other Appliances<br>• Sinks, inc. bath tubs<br>• DIY markets<br>• Tableware, Hollowware<br>• Fasteners, Screws and Bolts;<br>• Coinage | Plated | High contact risk with direct nickel contact. Regulatory risk and effects of consumer advocacy, e.g. through SIN lists. |
| | | Others† | High contact risk with direct nickel contact. Regulatory risk and effects of consumer advocacy, e.g. through SIN lists. |
| | | All other first uses | Partial nickel contact Regulatory risk and effects of consumer advocacy, e.g. through SIN lists |
| 4 | • Railway<br>• Containers<br>• Packaging<br>• Lifts and escalators<br>• Window frames, Sashes, Roofs<br>• Panels<br>• Tubular products (all types) | All except Others† | Mid-range contact risk |
| | | Others† | Mid-range contact risk with regulatory risk and effects of consumer advocacy, e.g. through SIN lists |
| 5 | • Vessels, tanks and heat exchangers<br>• Chemical, Petrochemical and Offshore | All | Low contact risk but stigmatization possible |
| 6 | • Aircraft & Aerospace, 'Others' (Transport, Engineering, Building & Construction and Metal Goods) and 'Unallocated ' | All | Assumed to include protected uses in which nickel is an essential input and there is minimal contact risk |
| 7 | • All other categories | All | Stigmatization risk by association with nickel (low risk) |

† "Others" includes batteries, chemicals and catalysts

### Table 8.2 Demand effects in 2020

<table>
<tr><th rowspan="2">End-uses</th><th rowspan="2">First uses</th><th colspan="3">2020 percentage reduction in primary nickel demand in Scenario</th></tr>
<tr><th>A1</th><th>A2</th><th>B</th></tr>
<tr><td>• Medical appliances</td><td>All</td><td>15</td><td>22.5</td><td>52.5</td></tr>
<tr><td rowspan="3">• Domestic cooking<br>• Food processing<br>• Cutlery<br>• Kegs<br>• Catering</td><td>Plated</td><td>20</td><td>30</td><td>65</td></tr>
<tr><td>Others (batteries, chemicals, catalysts)</td><td>18.8</td><td>47.6</td><td>47.6</td></tr>
<tr><td>All other first uses</td><td>10</td><td>15</td><td>35</td></tr>
<tr><td rowspan="3">• Automotive & Accessories<br>• Bicycles<br>• Washing Machines, Dishwashers, etc<br>• Freezers, Refrigerators<br>• Data Processing, Consumer Electronics<br>• Other Electro and Electronics and Other Appliances<br>• Sinks, inc. bath tubs<br>• DIY markets<br>• Tableware, Hollowware<br>• Fasteners, Screws Bolts<br>• Coinage</td><td>Plated</td><td>10</td><td>20</td><td>40</td></tr>
<tr><td>Others (batteries, chemicals, catalysts)</td><td>20.0</td><td>58.5</td><td>58.5</td></tr>
<tr><td>All other first uses</td><td>5</td><td>10</td><td>20</td></tr>
<tr><td rowspan="2">• Railway<br>• Containers<br>• Packaging<br>• Lifts and escalators<br>• Window frames, Sashes, Roofs<br>• Panels<br>• Tubular products</td><td>All except “Others (batteries, chemicals, catalysts)”</td><td>3.75</td><td>7.5</td><td>10</td></tr>
<tr><td>Others (batteries, chemicals, catalysts)</td><td>10</td><td>40</td><td>40</td></tr>
<tr><td>• Vessels, tanks and heat exchangers<br>• Chemical, Petrochemicals and Offshore</td><td>All</td><td>2.5</td><td>5</td><td>7.5</td></tr>
<tr><td>• Aircraft & Aerospace, ‘Others’ (Transport, Engineering, Building & Construction and Metal Goods) and ‘Unallocated ‘</td><td>All</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>• All other categories</td><td>All</td><td>0</td><td>0</td><td>0</td></tr>
</table>

*Source: Frontier Economics’ analysis*

**Table 8.3: Percentage changes in nickel market tonnages**

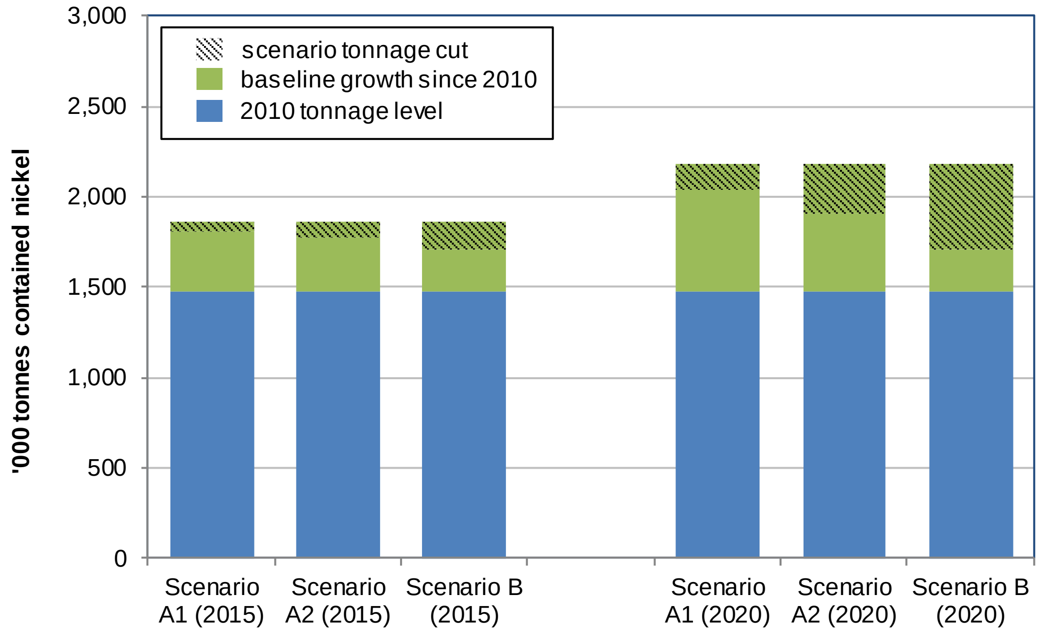
| Due to | Year | 2015 | | | 2020 | | |
|---|---|---|---|---|---|---|---|
| | Scenario | A1 | A2 | B | A1 | A2 | B |
| demand shocks only | | 2.5% | 4.2% | 8.0% | 6.2% | 12.0% | 21.3% |
| combined demand, transport and cost shocks | | 2.6% | 4.4% | 8.2% | 6.2% | 12.4% | 21.6% |

## 8.2 Nickel-chain effects

The modelling procedure described in Section 6.3 has shown the effects of the demand, transport and cost shocks for each scenario in each of the modelled years. The global reductions in first use flowed through to primary nickel production decreases.

The total first-use impact of each scenario is compared with baseline forecasts in Figure 8.1.

**Figure 8.1: Scenario impacts on global first use of primary nickel.**




In this chart:

- the blue-coloured sections of the bars represent the base-year (2010) tonnages
- the green-coloured sections above the blue coloured ones represent the base-case growth projections – the increases over the 2010 level – for 2015 or 2020. The top boundary of a green-coloured section shows the base case tonnage in the relevant forecast year.
- hatching overlays on the coloured bars represent the tonnage reductions that apply under each scenario. The bottom of the hatched area (if present) represents the tonnage under the relevant scenario. Hatching that overlays only part of a green section indicates that growth prospects are reduced but not eliminated. When hatching overlays all of the green and part of the blue section, this indicates that under this scenario, negative growth is in prospect.

Table 8.4 shows the allocations of the market losses between first uses, and again by end use sector, and the distribution of the associated production decreases among the ten Target Economies and the Rest of the World.

**Table 8.4: Summary of cost, demand and transport shock effects on the nickel market**

(thousands of tonnes)

| | Year | 2015 | | | 2020 | | |
|---|---|---|---|---|---|---|---|
| | Scenario | A1 | A2 | B | A1 | A2 | B |
| ***Global market reductions by first use*** | | | | | | | |
| in stainless steel | | 34 | 58 | 108 | 100 | 186 | 344 |
| in other steel alloys | | 1 | 2 | 3 | 2 | 5 | 8 |
| in non-ferrous alloys | | 2 | 3 | 5 | 5 | 9 | 16 |
| in plating | | 6 | 11 | 22 | 17 | 32 | 64 |
| in foundry and other uses | | 5 | 9 | 15 | 13 | 39 | 39 |
| **Total market reductions** | | **48** | **82** | **152** | **136** | **270** | **471** |
| ***Global market reductions by end-use sector*** | | | | | | | |
| Transport | | 5 | 11 | 20 | 16 | 35 | 62 |
| Electro and electronic | | 9 | 18 | 33 | 26 | 59 | 89 |
| Engineering | | 12 | 15 | 28 | 27 | 51 | 91 |
| Building and construction | | 4 | 7 | 11 | 11 | 23 | 36 |
| Tubular products | | 5 | 9 | 12 | 14 | 30 | 38 |
| Metal goods | | 13 | 22 | 48 | 42 | 73 | 155 |
| **Total market reductions** | | **48** | **82** | **152** | **136** | **270** | **471** |
| ***Primary nickel production decreases in Target Economies, by process*** | | | | | | | |
| Australia | matte refining | - | 4 | 5 | 2 | 7 | 10 |
| | other laterite processing | - | 4 | 10 | 2 | 10 | 25 |
| Canada | matte refining | - | - | - | 3 | 3 | 5 |
| | other laterite processing | - | - | - | 3 | 3 | 4 |
| China | matte refining | - | 5 | 15 | 7 | 20 | 35 |
| | nickel pig iron smelting | 5 | 10 | 22 | 25 | 60 | 150 |
| | other laterite processing | 4 | 5 | 10 | 7 | 10 | 15 |
| Indonesia | | - | - | - | - | - | - |
| Japan | matte refining | - | 3 | 5 | 5 | 10 | 15 |
| | ferronickel smelting | - | - | 10 | - | 10 | 20 |
| | other laterite processing | - | 3 | 5 | 5 | 10 | 15 |
| Korea | | - | - | - | - | - | - |
| Philippines | | - | - | - | - | - | - |
| Russia | matte refining | - | - | - | 5 | 5 | 5 |
| Chinese Taipei | | - | - | - | - | - | - |
| United States | | - | - | - | - | - | - |
| **Total decreases in Target Economies** | | 9 | 34 | 82 | 64 | 148 | 299 |
| *Target Economies' % of global decreases* | | *19%* | *41%* | *54%* | *47%* | *55%* | *63%* |
| Rest of World | matte refining | 15 | 18 | 20 | 25 | 42 | 54 |
| | ferronickel smelting | 20 | 25 | 45 | 40 | 60 | 95 |
| | other laterite processing | 4 | 5 | 5 | 7 | 20 | 23 |
| ***Primary nickel production decreases by process*** | | | | | | | |
| World | matte refining | 15 | 30 | 45 | 47 | 87 | 124 |
| | ferronickel smelting | 20 | 25 | 55 | 40 | 70 | 115 |
| | nickel pig iron smelting | 5 | 10 | 22 | 25 | 60 | 150 |
| | other laterite processing | 8 | 17 | 30 | 24 | 53 | 82 |
| **Global production decreases** | | **48** | **82** | **152** | **136** | **270** | **471** |

## *Scenario A1*

*EU implements the classifications for 138 nickel-containing chemicals set out in the 1st ATP of the CLP while the APEC economies maintain their current classifications for chemicals in use.*

Under Scenario A1 the market impact is largely confined to the EU, slightly depressing global demand for nickel chemicals, and potentially increasing Target Economies' export costs to the EU for nickel ores and concentrates, intermediates and nickel-containing chemicals.

Under this scenario, global usage of primary nickel is depressed below the baseline forecasts by 2.6% (48kt) in 2015 and 6.2% (136kt) in 2020. The immediate impact is likely to fall largely on European producers supplying European markets. Any reduction in demand will, however, also depress nickel prices below their levels under baseline forecast conditions, and this will flow through to affect the output levels of higher cost producers. Through the price effect, reductions will not be confined to existing producers of nickel chemicals.

In 2015, the Target Economy nickel-producing activities likely to be much affected under Scenario A1 are nickel pig iron smelting and other laterite processing in China, which would suffer a combined production fall of about 9kt or 2.7%.

About 19% of the 2015 production decrease falls on Target Economies. This proportion increases to 47% by 2020, and the load is spread more widely. This comes about through the combined effects of a more severely depressed price and the prominent share (83%) of baseline forecast world nickel production commanded by the Target Economies. Because of its relatively high cost, Chinese production will be the most severely affected, but effects will also be felt by producers of finished nickel Australia, Canada, Japan and Russia, with consequent effects on nickel mining rates in Australia, Canada and Russia.

In both 2015 and 2020, reductions in Chinese nickel pig iron smelting will flow through to depressed demand for laterite ore exports from Indonesia and the Philippines.

## *Scenario A2*

*EU implements the classifications for nickel-containing chemicals set out in the 1st ATP of the CLP and the APEC economies and the rest of the world adopt the same classifications so as to include all 138 nickel-containing chemicals in the 1st ATP.*

With classification effects spreading to depress nickel demand world-wide, the global market reductions under Scenario A2 are much more severe than under the relatively mild Scenario A1, and particularly so in 2020, when (assuming delayed introduction outside the EU) the tonnage reduction is about twice as severe.

Under this scenario, global usage of primary nickel is 4.4% (82kt) below the baseline forecast in 2015 and 12.4% (270kt) below in 2020.

In 2015 the impact on production is skewed towards Europe and away from the Target Economies, but this bias is much less pronounced than under Scenario A1. This is partly because the market reductions are no longer concentrated in the EU, and also because their greater magnitude means that prices will be more severely depressed (focussing pressure on high-cost producers). Consequently, by comparison with Scenario A1, in 2015 there will be a greater impact on production from China, and some impacts in Australia and Japan.

By 2020, when it is hypothesised that the global consequences of reclassification have been quite fully realized, producers in the Target Economies are forecast to absorb 55% of the global market reduction. At this stage the impact on nickel production will be felt more deeply than under Scenario A1 particularly in China, but also in Australia, Canada, and Japan. However, because a large proportion of production in the Target Economies is relatively low-cost (see Figure 6.6), this 55% share of the market reduction still falls well short of the Target Economies' 83% share of baseline output. This bias can be expressed another way: a 12.4% fall in global usage will cause production in the Target Economies to fall by 10.7% while in the Rest of the World it falls by 43%. However, some economies with high cost production with be impacted.

### Scenario B

*EU implements the classifications for nickel-containing chemicals set out in the 1st ATP of the CLP; APEC economies and the rest of the world adopt the same classifications so as to include all 138 nickel-containing chemicals in the 1st ATP and there are substantial additional stigmatization effects on the global nickel value chain.*

Under this risk analysis scenario, global usage of primary nickel is depressed below the baseline forecasts by 8.2% (152kt) in 2015 and 21.6% (471kt) in 2020. The impact in 2020 is particularly severe, and as Figure 8.1 illustrates, would strip more than half the baseline growth out of the industry.

As in Scenario A2, the market reductions gather pace between 2015 and 2020; but they are already sufficiently great in 2015 to cause market nickel prices to be quite substantially less than they would be under the baseline forecast, and consequently the impact on production will be heavy on high-cost output such as nickel pig iron in China, matte refining and laterite processing in Australia, and Japanese producers in general. Nevertheless, their impact will be much greater on producers in Europe and other non-APEC economies.

By 2020 under Scenario B, the magnitudes of nickel production decreases are such as to threaten the viability of several plants operating in the Target Economies, and many more in the rest of the world. China's nickel pig iron industry will be producing less than in 2010, and the same applies to ferronickel and other laterite processing in Japan, and to laterite mining in the Philippines. While production from matte refining would be curtailed significantly across the board, some growth from 2010 levels would be maintained.

### Reductions in nickel first uses

Figure 8.1 showed the overall reductions in primary nickel usage under the three scenario for 2015 and 2020. Figure 8.2 and Figure 8.3 illustrate how these reductions (detailed in the following figures) are distributed across the five first usage categories, showing them in the context of the baseline forecasts.

Figure 8.2 and Figure 8.3 show how, as the dominant first use of nickel, stainless steel bears the largest proportion of the usage reductions. The next biggest proportion falls on nickel in plating, because of its association with the affected chemicals.

Figure 8.2: Nickel first use and scenario impacts by sector – 2015

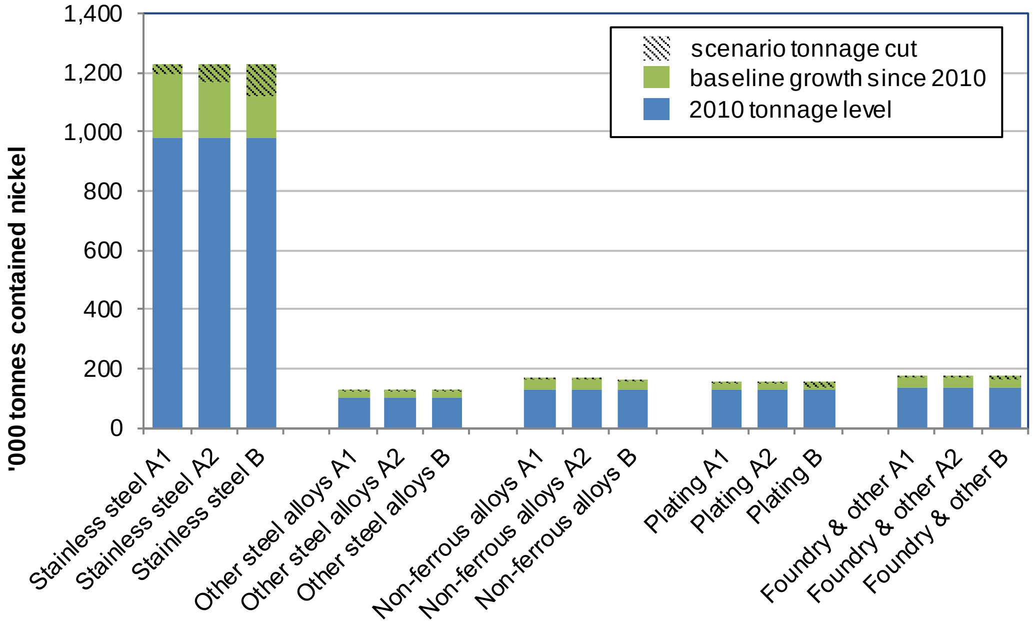
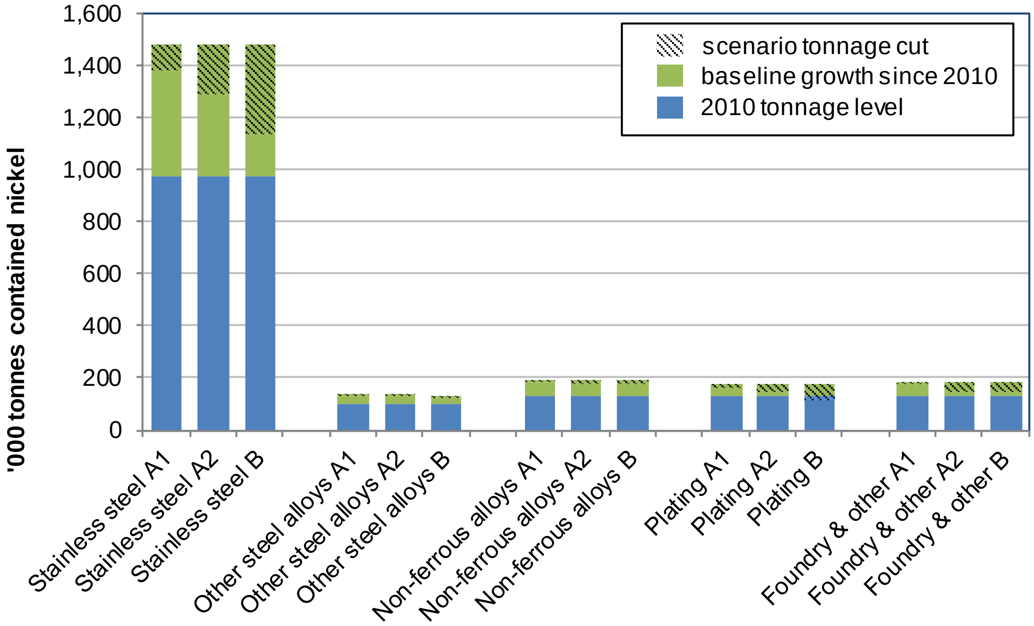



Figure 8.3: Nickel first use and scenario impacts by sector – 2020



In 2015, nickel use in stainless steel (Figure 8.4) is not greatly affected, but by 2020 growth prospects are severely reduced under scenarios A2 and B, and particularly under Scenario B, in which stigmatization depresses the use of austenitic grades of stainless steel across all industry sectors.

Figure 8.5 shows how the use of nickel in plating is strongly affected, and under Scenario B there will be very little growth in up to 2015. By 2020 the market will be smaller than in 2010.

**Figure 8.4: Nickel in stainless steel - first use forecasts and scenario impacts**

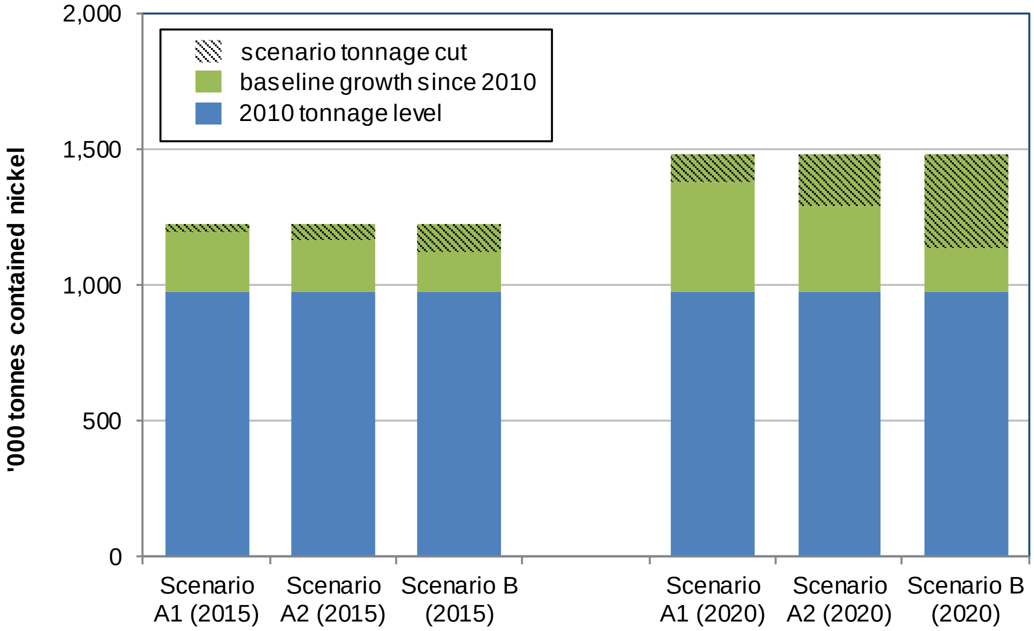
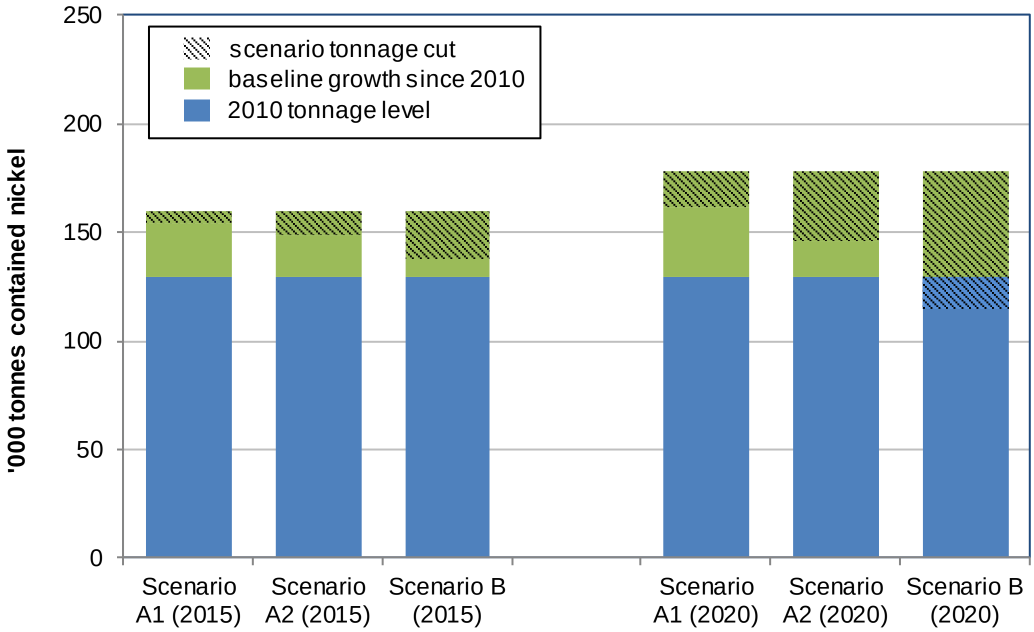


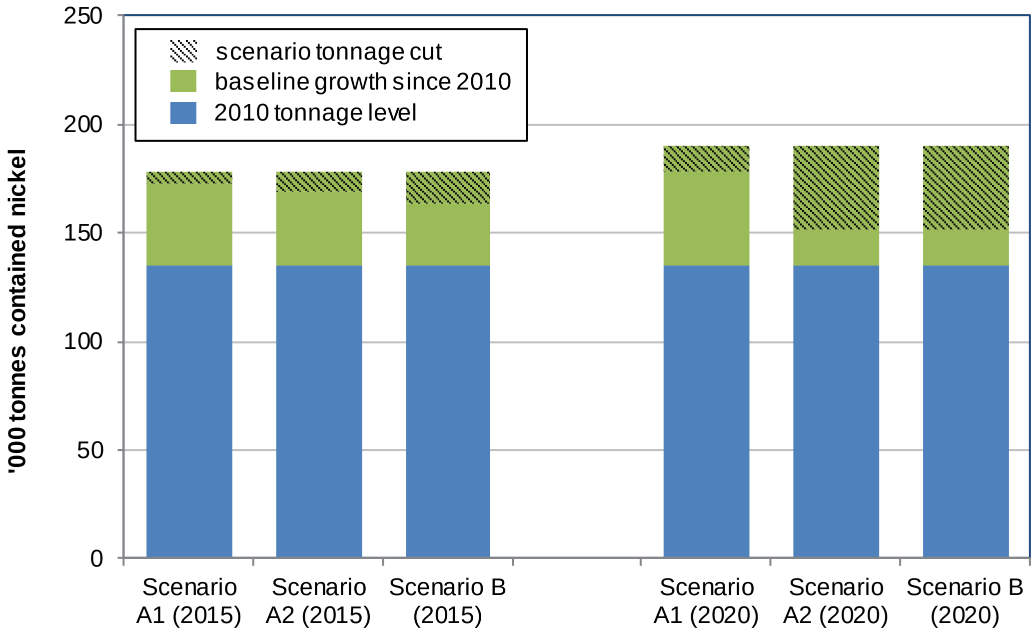

**Figure 8.5: Nickel in plating - first use forecasts and scenario impacts**



The “Other steel alloys” and “Non-ferrous alloys” first uses sectors are relatively minor, and so are the tonnage cuts to these sectors under each scenario, as Figures 8.2 and 8.3 indicate.

While the final first use category, “foundry and other” is also relatively minor, Figure 8.6 shows that the reductions under scenarios A2 and B are sufficient to almost wipe out growth out to 2020.

**Figure 8.6: Nickel in foundry and other - first use forecasts and scenario impacts**



## 8.2.1 Reductions in nickel production

As shown in Table 4.6, the refining of nickel matte accounts for around half of world production of primary nickel. Most of this is produced by the smelting of nickel sulfide concentrates. Among the Target Economies, matte refining takes place in Australia, Canada, China, Japan and Russia. Figure 8.7 shows their baseline forecasts and the tonnage reductions associated with the three scenarios for 2015, and Figure 8.8 shows parallel data for 2020. All four producing economies' matte refining activities are impinged under all scenarios in 2020.

**Figure 8.7: Matte refining forecasts and scenario impacts - 2015**

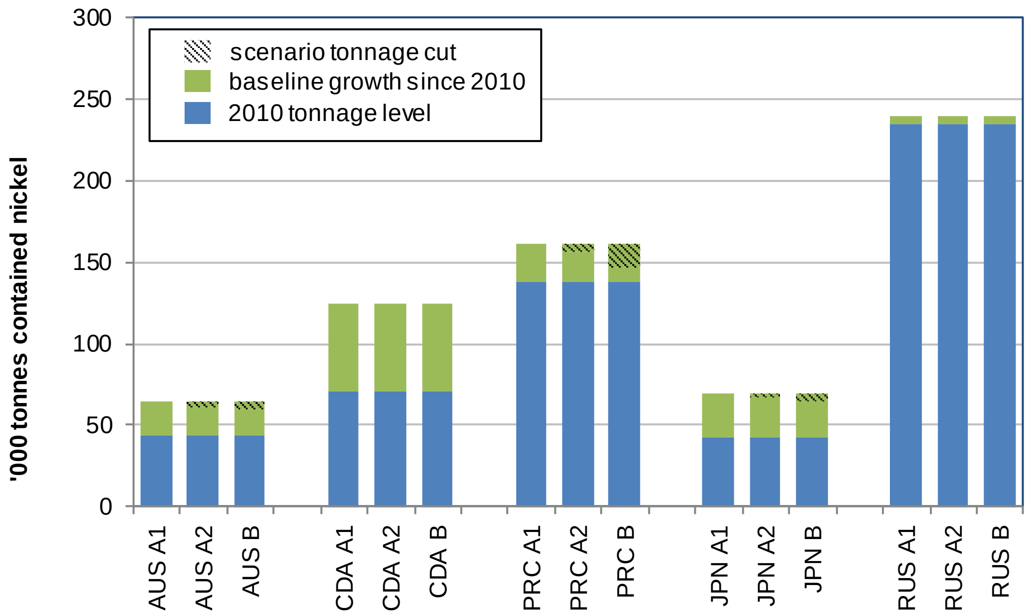
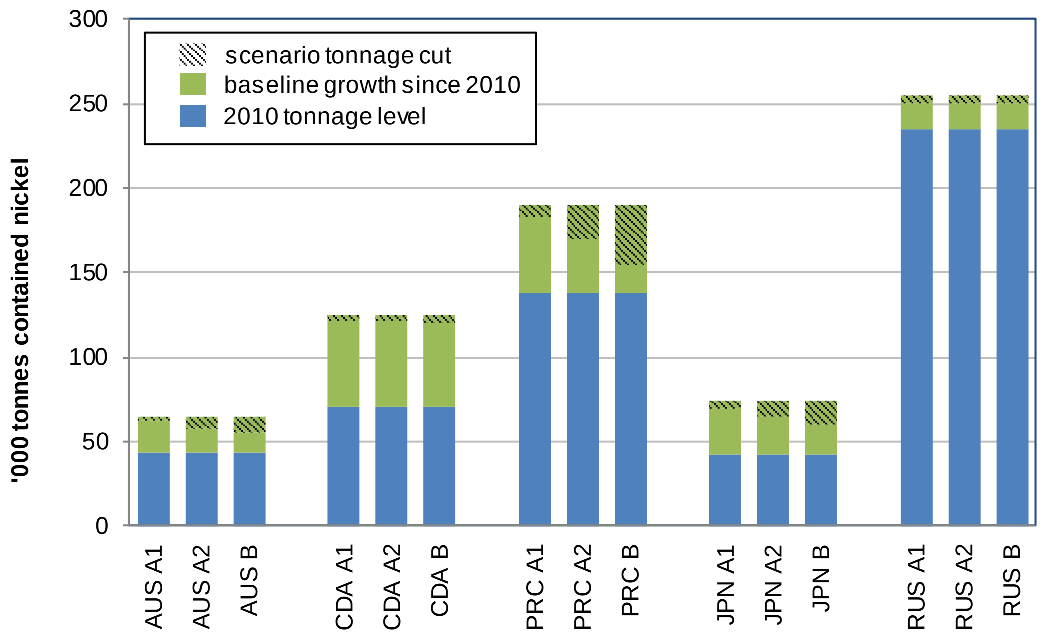



**Figure 8.8: Matte refining forecasts and scenario impacts – 2020**



## 8.3 Economic effects

### 8.3.1 GDP impacts

As shown in Table 8.5, model results indicate that the impacts of the EU's classification of nickel-containing chemicals on Target Economies' base-case GDP levels are generally adverse but relatively limited – with none of the ten Economies experiencing a reduction of more than 0.15% under any of the analysed scenarios. This is to be expected because nickel-chain activities account for modest shares of the Target Economies' GDPs (less than 0.8%). The principal determinant of the size of the macroeconomic impact of the classifications on a particular economy is the nickel chain industries' share of that economy's aggregate economic activity.

**Table 8.5: Scenario effects: percentage derivations from Target Economies' base-case GDP levels**

| Year | 2015 | | | 2020 | | |
|---|---|---|---|---|---|---|
| Scenario | A1 | A2 | B | A1 | A2 | B |
| Australia | -0.003% | -0.007% | -0.017% | -0.014% | -0.025% | -0.080% |
| Canada | -0.002% | - | -0.005% | -0.004% | +0.002% | -0.011% |
| China | +0.002% | - | +0.005% | +0.001% | -0.005% | -0.021% |
| Indonesia | -0.004% | -0.040% | -0.055% | -0.014% | -0.100% | -0.148% |
| Japan | +0.001% | -0.002% | -0.003% | -0.001% | -0.014% | -0.026% |
| Korea | +0.001% | - | +0.005% | -0.001% | -0.005% | -0.017% |
| Philippines | -0.001% | -0.027% | -0.033% | -0.004% | -0.058% | -0.076% |
| Russia | -0.001% | +0.002% | -0.001% | -0.005% | +0.011% | +0.005% |
| Chinese Taipei | +0.002% | +0.001% | +0.011% | -0.001% | -0.006% | -0.035% |
| USA | - | - | +0.001% | - | - | +0.001% |

Despite the small relative GDP effects, however, it is instructive to examine the differential impacts of the three scenarios, and their aggregate costs to ten Target Economies.

#### *Scenario A1*

In Scenario A1, the demand shocks are small, and production and cost shocks do not affect any Target Economy's nickel sector.

In 2015, Indonesia is affected the most, followed by Australia. Impacts are in the order of -0.004% and -0.003% respectively. Economies that enjoy a very minute positive deviation are China and Chinese Taipei. In implementing the demand shocks, it was assumed that nickel-containing items would be replaced by nickel-free metals produced in the model's *Residual Iron & Steel*, *Residual non-ferrous metals* or *Residual Fabricated Metal Products* sectors. The large sizes of these replacement sectors in the economies of China and Chinese Taipei relative to the sizes of their nickel-chain sectors account for the net positive impact that the demand shocks have on their GDPs.

In 2020, the negative effects exacerbate the impact on Indonesia and Australia. Russia, the Philippines and Canada also experience negative impacts.

### *Scenario A2*

Most of the deviations in 2015 are very close to zero. The primary exceptions are Indonesia and the Philippines – they are the most negatively affected; impacts are in the order of -0.04% and -0.03%, respectively. No Target Economy enjoys a noticeable positive impact on base-case real-GDP.

In 2020, the negative impacts are exacerbated in Indonesia and the Philippines (about -0.1% and -0.06%, respectively). However, Russia benefits from a positive GDP impact in the order of +0.01%. This translates to a benefit of about US$220 million. Canada also enjoys a small positive deviation.

A factor contributing to the positive outcomes for Russia and Canada is the cost advantage that the Russian and Canadian nickel-mining and nickel-processing industries gain in the modelling period over those in other Target Economies. This cost advantage stems from the modelling assumption that no production- or transport-cost shocks apply to Russian and Canadian nickel-chain industries in this regulatory scenario. These impacts are not as observable in Scenario B because the demand shocks are far greater than those applied in Scenario A2, and significantly offset the cost advantages gleaned by Russia and Canada.

### *Scenario B*

Most Target Economies bear negative GDP deviations across the modelling period. In 2015, Indonesia faces the steepest deviation among the Target Economies (albeit a relatively low value of -0.055%), followed by the Philippines. The adverse GDP impact in Indonesia translates to almost US$375 million (in real terms). Indonesia and the Philippines are significant lateritic-ore exporters and the results clearly show that the combined impact of the demand and cost shocks affect nickel-mining economies (with less stringent classifications than the EU of relevant nickel-containing chemicals) more adversely than other Target Economies.

However, there are some economies that are made better off. This is explained by the proposition that the reduced demand for nickel-containing products triggers an increased demand for output from 'replacement' sectors, i.e. sectors in which outputs can serve as substitutes for the nickel-containing products. This can have positive effects on Target Economies in which production of these replacement items is significant. In 2015, Chinese Taipei and Korea experience noticeable positive deviations in the order of +0.01% and +0.005% respectively.

By 2020, the negative impacts in Indonesia are exacerbated to -0.15% (worth $1.4 billion US dollars). An interesting observation is that Chinese Taipei and Korea, which are anticipated to experience positive deviations to their GDPs in 2015, face negatives deviations in 2020. An explanation for this outcome lies in the extent of the demand shocks in 2015 relative to 2020; the negative impacts of the demand shocks more than offset the positive economic effects in 2020 garnered by the replacement sectors. As depicted in Table 8.5, only the Russian economy benefits from a noticeable positive deviation of +0.005% among the Target Economies in 2020.

## 8.3.2 Cumulative costs to Target Economies

Calculations of the Present Value (PV) of the aggregate costs to the ten Target Economies' GDPs over a period of several years provide another measure of the relative socio-economic impacts under each analysed scenario.

Under Scenario A1, because the classifications apply in the EU only, the short-term effect if for a very slight rise in the total GDP of the Target Economies above the base case (e.g. by about US$75 million in 2015). Over a longer term, however, the impact on aggregate GDP turns negative as a result of reduced nickel demand growth and other factors. Using a 2% real social time preference rate, the modelled costs of Scenario A1 to the Target Economies' GDP over the 15-year period 2010-2025 have a PV of US$3.2 billion at 2010 prices. Of course, this is a small proportion of the PV of aggregate GDP.

Under Scenario A2, where the classifications are more widely adopted, the PV of the aggregate 15-year cost to the ten Target Economies' GDP is US$23.4 billion.

Under the risk analysis scenario, official and unofficial responses to the classification of nickel-containing chemicals include levels of stigmatization that trigger significant consequences for the use of nickel metal and nickel-bearing alloys. Clearly under these assumptions there is a much greater potential to produce adverse socio-economic consequences for economies participating in the nickel value chain than the central-case assumptions for Scenarios A1 and A2.

Under Scenario B, where substantial stigmatization is included, the discounted aggregate cost expands to US$71 billion.

# 9 Conclusions

This study has identified and quantified the range of impacts triggered by the classification of 138 nickel containing-chemicals in the 1st ATP to the CLP.

In making the assessment of the socio-economic consequences of the EU classification decision for the 10 APEC-member Target Economies, the report focuses on the effects of the classifications on the costs to the industries that produce or use the classified chemicals, on the demand for the classified chemicals and products that contain them as well as demand for nickel itself. These effects have been examined for three regulatory scenarios in an econometric model Computational General Equilibrium model which computed estimates of impacts to the Target Economies examined.

These effects arise in two ways. The first is official: economies' regulatory environments generally mandate restrictions on the use of classified chemicals and impose requirements on firms that produce them, transport them, sell them to intermediate or final users, or use them as inputs to their production processes. The second way in which demand and cost effects arise is unofficial. In some cases, non-government pressure groups focussed on health and environmental issues or industry groups averse to regulatory risk may act deliberately to restrict the use of classified chemicals or may pressure households or other users to do so. In other cases, adverse consumer reactions to the classifications may lead to the stigmatization of products that are related to the classified chemicals, in this case nickel metal used in alloys such as stainless steel.

APEC economies are key stakeholders on anything that has the potential of affecting the nickel value chain. Together, they indeed dominate the world mined (71%) and primary production (69%) as well as the first uses of nickel (71%). APEC also holds 58% of the world's nickel resources. These economies are likely to bear most of the consequences of any regulatory burden or reputational damage affecting nickel and its uses in alloys and chemicals.

This report establishes that overall the classification decision will have adverse consequences for nickel-chain industries, although not necessarily for the prospects of those industries in all economies.

The key findings below are based on three scenarios used to assess the impacts:

- Scenario A1: The effect of the classification is confined to the EU's nickel-containing chemical producers, first users and end-users as well as to its import of nickel-containing chemicals. The impact on the Target Economies' nickel industries will be limited and represent no more than a few points off growth rates.

  Because the classifications apply in the EU only, the short-term effect is a very slight rise in the total GDP of the Target Economies above the base case (e.g. by about US$75 million in 2015). Over a longer term, however, the impact on aggregate GDP turns negative as a result of reduced nickel demand growth and other factors. Using a 2% real social time preference rate, the modelled cost of Scenario A1 to the Target Economies' GDP over the 15-year period 2010-2025 is US$3.2 billion in 2010 prices.

- Scenario A2: In the case that the classification would be taken up by the Target Economies and OECD economies more generally, growth in primary nickel usage over the current decade would slow to a CAGR of 2.6%. This could cause some real impact to the nickel industry globally, with a few producing units facing the threat of closure and workers needing to find other employment.

  The discounted aggregate 15-year net cost to the Target Economies' GDP under this scenario is estimated at US$23.4 billion.

- Scenario B: The *risk analysis* scenario illustrates the economic dangers of the risk that the expansive nature of the EU nickel chemical classifications (138 chemicals) will precipitate specifier, gatekeeper and consumer reactions to nickel that are disproportionate to any public-health risk. Effectively, the greater the number of nickel-containing chemicals listed in the classifications, the easier it is for specifiers/gatekeepers to make a case that other chemicals and even nickel metal itself should be avoided resulting in demand stigmatization of nickel products. The modelling analysis for this scenario leads to an estimate that this could cut nickel demand in 2020 by almost half a million tonnes, which could easily be accommodated by the industry at its present size, but would represent trimming its growth rate to a CAGR of only 1.4%. On this basis, some of the more nickel-dependent economies such as those of Indonesia and the Philippines may see a measurable socio-economic effect, in the range of 0.1 to 0.15 per cent of the GDP.

  At the economy-level, for about 13 out of 46 nickel-chain industries, the negative impacts of the demand shocks in this scenario are big enough to eliminate all or a substantial part of the base-case growth prospects.

  The discounted net costs to the Target Economies under this scenario are estimated at US$71.0 billion.

The approach chosen for this report and in particular in the model, considers that costs of implementation (occupational protection, for example) and costs resulting from forced or chosen substitution are often offset by gains enjoyed by other groups, or that they have a modest weight in an economy's overall prospects. However, the overall conclusions from this study are that policies that do not entail large net socio-economic costs when compared to the overall GDP can still impose significant costs on particular groups – industries or regions within the economies of interest, for example.

It must also be stressed that the criticality of nickel for the advancement of innovation and technology in areas such as green technologies, energy efficiency, carbon control, environmental protection, human health could not be modelled but constitutes an additional factor one should consider, especially when facing the risk of stigmatization of nickel (or indeed any other metal) as an unintended consequence of classifications dealing with chemicals.

The report findings suggest that APEC economies, as the main producers and users of nickel and other metals, should promote a scientific as well as proportionate global chemical management policy framework. This position has recently been supported in the OECD Recommendations for Regulatory Decisions and Governance, published on 22 March 2012.

# **Appendix A –** EU 1st ATP nickel-containing chemicals classifications

| | Index No.† | Substance | CAS Reg No.§ |
|---|---|---|---|
| 1 | 028-003-00-2 | nickel monoxide | 1313-99-1 |
| 2 | 028-003-00-2 | nickel oxide | 11099-02-8 |
| 3 | 028-003-00-2 | bunsenite | 34492-97-2 |
| 4 | 028-004-00-8 | nickel dioxide | 12035-36-8 |
| 5 | 028-005-00-3 | dinickel trioxide | 1314-06-3 |
| 6 | 028-006-00-9 | nickel sulfide [NiS] | 16812-54-7 |
| 7 | 028-006-00-9 | nickel subsulfide [$Ni_3S_2$] | 11113-75-0 |
| 8 | 028-006-00-9 | millerite [mineral] | 1314-04-1 |
| 9 | 028-007-00-4 | nickel subsulfide [$Ni_3S_2$, 99.7%, -150 mesh] | 12035-72-2 |
| 10 | 028-007-00-4 | heazlewoodite [mineral] | 12035-71-1 |
| 11 | 028-008-00-X | nickel dihydroxide | 12054-48-7 |
| 12 | 028-008-00-X | nickel hydroxide | 11113-74-9 |
| 13 | 028-009-00-5 | nickel sulfate | 7786-81-4 |
| 14 | 028-010-00-0 | nickel carbonate | 3333-67-3 |
| 15 | 028-010-00-0 | carbonic acid, nickel salt | 16337-84-1 |
| 16 | 028-010-00-0 | [μ-[carbonato(2-)-O:O']] dihydroxy trinickel | 65405-96-1 |
| 17 | 028-010-00-0 | [carbonato(2-)] tetrahydroxytrinickel | 12607-70-4 |
| 18 | 028-011-00-6 | nickel dichloride | 7718-54-9 |
| 19 | 028-012-00-1 | nickel dinitrate | 13138-45-9 |
| 20 | 028-012-00-1 | nitric acid, nickel salt | 14216-75-2 |
| 21 | 028-013-00-7 | nickel matte | 69012-50-6 |
| 22 | 028-017-00-9 | nickel dipotassium bis(sulfate) | 13842-46-1 |
| 23 | 028-014-00-2 | slimes & sludges, copper electrolytic refining, decopperised, nickel sulfate | 92129-57-2 |
| 24 | 028-015-00-8 | slimes & sludges, copper electrolytic refining, decopperised | 94551-87-8 |
| 25 | 028-016-00-3 | nickel perchlorate | 13637-71-3 |
| 26 | 028-017-00-9 | diammonium nickel bis(sulfate) | 15699-18-0 |
| 27 | 028-018-00-4 | nickel bis(sulfamidate); nickel sulfamate | 13770-89-3 |
| 28 | 028-019-00-X | nickel bis(tetrafluoroborate) | 14708-14-6 |
| 29 | 028-021-00-0 | nickel diformate | 3349-06-2 |
| 30 | 028-021-00-0 | formic acid, nickel salt | 15843-02-4 |
| 31 | 028-021-00-0 | formic acid, copper nickel salt | 68134-59-8 |
| 32 | 028-022-00-6 | nickel di(acetate) | 373-02-4 |
| 33 | 028-022-00-6 | nickel acetate | 14998-37-9 |
| 34 | 028-024-00-7 | nickel dibenzoate | 553-71-9 |
| 35 | 028-025-00-2 | nickel bis(4-cyclohexylbutyrate) | 3906-55-6 |
| 36 | 028-024-00-7 | nickel(II) stearate; nickel(II) octadecanoate | 2223-95-2 |
| 37 | 028-027-00-3 | nickel dilactate | 16039-61-5 |
| 38 | 028-028-00-9 | nickel(II) octanoate | 4995-91-9 |
| 39 | 028-029-00-4 | nickel difluoride | 10028-18-9 |
| 40 | 028-029-00-4 | nickel dibromide | 13462-88-9 |

| | Index No.† | Substance | CAS Reg No.§ |
|---|---|---|---|
| 41 | 028-029-00-4 | nickel diiodide | 13462-90-3 |
| 42 | 028-029-00-4 | nickel potassium fluoride | 11132-10-8 |
| 43 | 028-030-00-X | nickel hexafluorosilicate | 26043-11-8 |
| 44 | 028-031-00-5 | nickel selenate | 15060-62-5 |
| 45 | 028-032-00-0 | nickel hydrogen phosphate | 14332-34-4 |
| 46 | 028-032-00-0 | nickel bis(dihydrogen phosphate) | 18718-11-1 |
| 47 | 028-032-00-0 | trinickel bis(orthophosphate) | 10381-36-9 |
| 48 | 028-032-00-0 | dinickel diphosphate | 14448-18-1 |
| 49 | 028-032-00-0 | nickel bis(phosphinate) | 14507-36-9 |
| 50 | 028-032-00-0 | nickel phosphinate | 36026-88-7 |
| 51 | 028-032-00-0 | phosphoric acid, calcium nickel salt | 17169-61-8 |
| 52 | 028-032-00-0 | diphosphoric acid, nickel(II) salt | 19372-20-4 |
| 53 | 028-033-00-6 | diammonium nickel hexacyanoferrate | 74195-78-1 |
| 54 | 028-034-00-1 | nickel dicyanide | 557-19-7 |
| 55 | 028-035-00-7 | nickel chromate | 14721-18-7 |
| 56 | 028-036-00-2 | nickel(II) silicate | 21784-78-1 |
| 57 | 028-036-00-2 | dinickel orthosilicate | 13775-54-7 |
| 58 | 028-036-00-2 | nickel silicate (3:4) | 31748-25-1 |
| 59 | 028-036-00-2 | silicic acid, nickel salt | 37321-15-6 |
| 60 | 028-036-00-2 | trihydrogen hydroxybis[orthosilicato(4-)] trinickelate(3-) | 12519-85-6 |
| 61 | 028-037-00-8 | dinickel hexacyanoferrate | 14874-78-3 |
| 62 | 028-038-00-3 | trinickel bis(arsenate); nickel(II) arsenate | 13477-70-8 |
| 63 | 028-039-00-9 | nickel oxalate | 547-67-1 |
| 64 | 028-039-00-9 | oxalic acid, nickel salt | 20543-06-0 |
| 65 | 028-040-00-4 | nickel telluride | 12142-88-0 |
| 66 | 028-041-00-X | trinickel tetrasulfide | 12137-12-1 |
| 67 | 028-042-00-5 | trinickel bis(arsenite) | 74646-29-0 |
| 68 | 028-043-00-0 | cobalt nickel gray periclase [C.I. Pigment Black 25] | 68186-89-0 |
| 69 | 028-043-00-0 | cobalt nickel dioxide | 58591-45-0 |
| 70 | 028-043-00-0 | cobalt nickel oxide | 12737-30-3 |
| 71 | 028-044-00-6 | nickel tin trioxide [nickel stannate] | 12035-38-0 |
| 72 | 028-045-00-1 | nickel triuranium decaoxide | 15780-33-3 |
| 73 | 028-046-00-7 | nickel dithiocyanate | 13689-92-4 |
| 74 | 028-047-00-2 | nickel dichromate | 15586-38-6 |
| 75 | 028-048-00-8 | nickel(II) selenite | 10101-96-9 |
| 76 | 028-049-00-3 | nickel selenide | 1314-05-2 |
| 77 | 028-050-00-9 | silicic acid, lead nickel salt | 68130-19-8 |
| 78 | 028-051-00-4 | nickel diarsenide | 12068-61-0 |
| 79 | 028-051-00-4 | nickel arsenide | 27016-75-7 |
| 80 | 028-052-00-X | nickel barium titanium primrose priderite [C.I. Pigment Yellow 157] | 68610-24-2 |

| | Index No.† | Substance | CAS Reg No.§ |
|---|---|---|---|
| 81 | 028-053-00-5 | nickel dichlorate | 67952-43-6 |
| 82 | 028-053-00-5 | nickel dibromate | 14550-87-9 |
| 83 | 028-053-00-5 | ethyl hydrogen sulfate, nickel(II) salt | 71720-48-4 |
| 84 | 028-054-00-0 | nickel(II) trifluoroacetate | 16083-14-0 |
| 85 | 028-054-00-0 | nickel(II) propionate | 3349-08-4 |
| 86 | 028-054-00-0 | nickel bis(benzenesulfonate) | 39819-65-3 |
| 87 | 028-054-00-0 | nickel(II) hydrogen citrate | 18721-51-2 |
| 88 | 028-054-00-0 | citric acid, ammonium nickel salt | 18283-82-4 |
| 89 | 028-054-00-0 | citric acid, nickel salt | 22605-92-1 |
| 90 | 028-054-00-0 | nickel bis(2-ethylhexanoate) | 4454-16-4 |
| 91 | 028-054-00-0 | 2-ethylhexanoic acid, nickel salt | 7580-31-6 |
| 92 | 028-054-00-0 | dimethylhexanoic acid nickel salt | 93983-68-7 |
| 93 | 028-054-00-0 | nickel(II) isooctanoate | 29317-63-3 |
| 94 | 028-054-00-0 | nickel isooctanoate | 27637-46-3 |
| 95 | 028-054-00-0 | nickel bis(isononanoate) | 84852-37-9 |
| 96 | 028-054-00-0 | nickel(II) neononanoate | 93920-10-6 |
| 97 | 028-054-00-0 | nickel(II) isodecanoate | 85508-43-6 |
| 98 | 028-054-00-0 | nickel(II) neodecanoate | 85508-44-7 |
| 99 | 028-054-00-0 | neodecanoic acid, nickel salt | 51818-56-5 |
| 100 | 028-054-00-0 | nickel(II) neoundecanoate | 93920-09-3 |
| 101 | 028-054-00-0 | bis(d-gluconato-O1,O2)nickel | 71957-07-8 |
| 102 | 028-054-00-0 | nickel 3,5-bis(tert-butyl)-4-hydroxybenzoate (1:2) | 52625-25-9 |
| 103 | 028-054-00-0 | nickel(II) palmitate | 13654-40-5 |
| 104 | 028-054-00-0 | (2-ethylhexanoato-O)(isononanoato-O)nickel | 85508-45-8 |
| 105 | 028-054-00-0 | (isononanoato-O)(isooctanoato-O)nickel | 85508-46-9 |
| 106 | 028-054-00-0 | (isooctanoato-O)(neodecanoato-O)nickel | 84852-35-7 |
| 107 | 028-054-00-0 | (2-ethylhexanoato-O)(isodecanoato-O)nickel | 84852-39-1 |
| 108 | 028-054-00-0 | (2-ethylhexanoato-O)(neodecanoato-O)nickel | 85135-77-9 |
| 109 | 028-054-00-0 | (isodecanoato-O)(isooctanoato-O)nickel | 85166-19-4 |
| 110 | 028-054-00-0 | (isodecanoato-O)(isononanoato-O)nickel | 84852-36-8 |
| 111 | 028-054-00-0 | (isononanoato-O)(neodecanoato-O)nickel | 85551-28-6 |
| 112 | 028-054-00-0 | fatty acids, C6-19-branched, nickel salts | 91697-41-5 |
| 113 | 028-054-00-0 | fatty acids, C8-18 and C18-unsaturated, nickel salts | 84776-45-4 |
| 114 | 028-054-00-0 | 2,7-naphthalenedisulfonic acid, nickel(II) salt | 72319-19-8 |
| 115 | 028-055-00-6 | nickel(II) sulfite [$NiO_3S$] | 7757-95-1 |
| 116 | 028-055-00-6 | nickel tellurium trioxide | 15851-52-2 |
| 117 | 028-055-00-6 | nickel tellurium tetraoxide | 15852-21-8 |
| 118 | 028-055-00-6 | molybdenum nickel hydroxide oxide phosphate | 68130-36-9 |
| 119 | 028-056-00-1 | nickel boride [NiB] | 12007-00-0 |
| 120 | 028-056-00-1 | dinickel boride [$Ni_2B$] | 12007-01-1 |

| | Index No.† | Substance | CAS Reg No.§ |
|---|---|---|---|
| 121 | 028-056-00-1 | trinickel boride | 12007-02-2 |
| 122 | 028-056-00-1 | nickel boride | 12619-90-8 |
| 123 | 028-056-00-1 | dinickel silicide | 12059-14-2 |
| 124 | 028-056-00-1 | nickel disilicide | 12201-89-7 |
| 125 | 028-056-00-1 | dinickel phosphide | 12035-64-2 |
| 126 | 028-056-00-1 | nickel boron phosphide | 65229-23-4 |
| 127 | 028-057-00-7 | dialuminium nickel tetraoxide | 12004-35-2 |
| 128 | 028-057-00-7 | nickel titanium trioxide | 12035-39-1 |
| 129 | 028-057-00-7 | nickel titanium oxide | 12653-76-8 |
| 130 | 028-057-00-7 | nickel divanadium hexaoxide | 52502-12-2 |
| 131 | 028-057-00-7 | cobalt dimolybdenum nickel octaoxide | 68016-03-5 |
| 132 | 028-057-00-7 | nickel zirconium trioxide | 70692-93-2 |
| 133 | 028-057-00-7 | molybdenum nickel tetraoxide | 14177-55-0 |
| 134 | 028-057-00-7 | nickel tungsten tetraoxide | 14177-51-6 |
| 135 | 028-057-00-7 | olivine, nickel green | 68515-84-4 |
| 136 | 028-057-00-7 | lithium nickel dioxide | 12031-65-1 |
| 137 | 028-057-00-7 | molybdenum nickel oxide | 12673-58-4 |
| 138 | 028-058-00-2 | cobalt lithium nickel oxide | 193214-24-3 |

These chemicals were listed in the First Adaptation to Technical and Scientific Progress (1st ATP) to the European Commission's Regulation No. 790/2009 relating to the classification, labelling and packaging (CLP) of substances and mixtures (10 August 2009)

† Index Number in First ATP

§ Chemical Abstracts Service Registration Number (These numbers are unique identifiers of chemicals)

# **Appendix B -** The Models on which the GTAP-Ni is based

## *Computable general equilibrium (CGE) modelling*

The *direct*, *indirect*, *induced* classification of economic impacts has its origins in input-output (IO) economics. IO computations recognise that the consequences of changes in the scale of a particular industry's operations are not limited to the *direct* changes. Rather, the direct changes lead *indirectly* to changes in the scale of operations in industries that supply inputs to the directly affected industry (backward linkages) and in industries requiring the directly-affected industry's outputs as inputs (forward linkages). But the IO method is naïve in its implicit assumptions about the macroeconomic system in which the industries all operate. Essentially, it assumes that if an industry contracts, then the resources no longer required all become unemployed. This includes not only the resources previously used by the industry itself but also those used previously by the industries to which it has backward and forward linkages. Similarly, if the direct shock is an expansion of an industry, the method implicitly assumes that the directly-affected industry (and the industries to which it has backward and forward linkages) can obtain all the additional resources required from previously unemployed resources. In summary, the IO method fails to recognise that some of the resources released from contracting industries will be absorbed into other uses, or that additional demands for resources by expanding industries will be met partly by diverting resources from existing uses.

IO calculations are superficially attractive to industries facing adverse shocks or seeking support for expansion, because they suggest that the adverse macroeconomic consequences of their decline (or the stimulatory macroeconomic consequences of their expansion) will be large – through so-called multiplier effects. But such multiplier-based estimates of economic impacts are no longer credible with policy makers who rely on advice from specialists with training in modern methods of economic analysis.

The current study uses a computable general equilibrium (CGE) model as a key impact-evaluation tool. Like IO computations, CGE models also recognise the importance of indirect, induced and broad-economy impacts, as well as direct impacts. But the CGE approach recognises a range of additional features of the macroeconomic system that allow the models to account for the role of resource reallocation in evaluating economic impacts. For example, a CGE model of an economy will recognise:

- that an increase (decrease) in an industry's demand for labour will amplify (ease) pressure on the labour market, with the consequential upward (downward) pressure on wage rates affecting the demand for labour in other industries;
- that the supply of capital is limited and that an increase (decrease) in investment in a particular industry will tend to divert capital from (to) other industries by putting upward (downward) pressure on the cost of capital;
- that an increase (decrease) in a particular industry's export earnings will put upward (downward) pressure on the exchange rate, inhibiting (improving) the ability of other traded-goods industries to export or replace imports.

Methods that recognise such resource-reallocation possibilities tend to give more modest estimates of the economic impact of shocks affecting particular industries than do IO methods.

### *The standard GTAP model*

The standard GTAP model represents each economy as a set of industries and final demands. The final demands include: private consumption; government consumption; and investment. Each industry produces a single commodity as output and uses domestically-produced and imported varieties of each commodity as inputs, as well as primary factors of production – labour, capital, agricultural land and natural resources. Industries in the model choose inputs to minimise the cost of producing a given level of output. Primary factors can be reallocated between industries, with varying degrees of flexibility, so as to maximise revenue accruing to the factors. Industries' outputs are sold to other domestic industries, final demands or into the international market.

Industry output and the price of the commodity produced by each industry are determined by the model's zero-pure-profits and market-clearing constraints. The zero-pure-profits constraints equate total revenue and total costs (including payments to primary factors, part of which is profit in the conventional sense) for each industry.

Different individual economies are linked by bilateral trade flows of each commodity. Domestic production or imports of a commodity from different exporters are treated as being imperfectly substitutable for one another. The degree of switching between sources of a commodity is determined by relative prices.

Each economy's transport sectors also sell some of their services for conveying internationally traded commodities between sources and destinations. Therefore, the model represents free-on-board (FOB) export prices and cost, insurance and freight (CIF) import prices for each commodity between each source and destination.

### *The dynamic GTAP model*

The standard GTAP model is "comparative static". That is, for a particular policy it provides a snapshot of how the economy would differ at a hypothetical future point in time because of the policy. The dynamic GTAP model (GDyn)[17] allows the generation of hypothetical *time paths* of the development of the global economy by incorporating extra features:

- a theory of how investment evolves over time in response to changes in rates of return;
- capital accumulation driven by investment and depreciation;
- wealth accumulation, as regional savings add to the stock of assets owned by each region; and
- net foreign income flows as regions receive income from assets owned abroad and make payments to the foreign owners of domestically-located capital.

The first step in applying the dynamic GTAP model to analyse the effects of a policy issue is to generate a baseline (also called a base or reference case) that is a projected "business-as-usual" time path of the economy in the absence of the policies to be analysed (regulation of nickel-containing chemicals, in the current study). The baseline incorporates projections of general economic growth (e.g. real GDP growth) and of aspects of the economy that are important for the policy to be analysed. For the current study, projections of production and usage of nickel-related commodities have been built into the baseline.

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[17] Ianchovichina, Elena and Terrie L. Walmsley, Eds. 2012 (In progress). *GDyn Book: Global Economic Analysis: Dynamic Modeling and Applications*, available online at https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=3169

The second step is to generate an alternative time path of the economy (called a policy simulation) that incorporates the policy changes while preserving those features of the baseline that would be unaffected by the policy. The latter include any changes in technical efficiency that are introduced into the baseline as instruments for accommodating the projections of real GDP growth and nickel production and usage.

The third step is to calculate deviations between the baseline and policy simulations. These deviations (called "policy deviations") provide a time series of policy-induced economic impacts.

Although the dynamic features are essential in generating the profile of the economic impacts over time, the dynamic GTAP model shares the bulk of its equations – those governing supply and demand of commodities and inter–national trade – with the standard GTAP model.

# **Appendix C** – Mining and processing of nickel ores

## *Mining and processing of sulfide ores*

The extraction of metallic nickel from sulfide ores historically relied exclusively on a smelting process, and this still dominates. Smelting requires that the ore first be concentrated (using flotation methods), which has the added advantage of making it more economical to transport and so is generally carried out at, or close to, the mine.

Flash smelting is the most commonly employed variant, but more complex raw materials may require the added flexibility of electric smelting. In the furnace of the flash smelter, most of the iron and sulfur is oxidised in exothermic reactions, and the product is usually a liquid matte containing up to 45% nickel. This furnace matte still contains iron and sulfur which are oxidised by injecting air or oxygen into a molten bath, a process known as converting. As a readily transportable intermediate product, nickel matte is often traded internationally.

Smelting must be followed up by a process to refine the nickel matte. Various processes are in use. The most common is electrowinning using inert cathodes. Alternatively, high-grade nickel oxides (containing more than 95% nickel) can be produced by fluid bed roasting followed by chlorine-hydrogen reduction. The Carbonyl process is another alternative, in which high-purity nickel pellets are produced by dissolving the matte in carbonyl vapour. The Sherritt process employing pressure leaching with ammonia is particularly suitable for treating matte containing valuable nickel and cobalt.

## *Mining and processing of laterite ores*

Nickel laterite mining employs surface mining methods almost universally, generally involving removal of light overburden cover. Open pits are generally shallow and large-scale. There are instances of underground mining, but not in the APEC member economies.

The principal laterite ore minerals are nickeliferous limonite: $(Fe, Ni)O(OH)$ and garnierite (a hydrous nickel silicate): $(Ni, Mg)_3Si_2O_5(OH)_4$.

Various leaching processes based on acids or ammonia, and often carried out under high pressure in autoclaves, can be employed to extract the nickel into a solution from which it is then recoverable in metallic form as Class 1 nickel by solvent extraction-electrowinning (SX-EW), or alternatively precipitated as a chemical, e.g. nickel carbonate produced by the ammonia-based Caron process.

A popular pyrometallurgical route for exploiting laterite nickel ores (often called RKEF) utilises roasting in a rotary kiln, followed by melting in an electric furnace to produce ferronickel, an iron-nickel alloy typically containing 20-35% nickel.

In recent years, Chinese companies re-developed methods of processing imported lateritic nickel ores in low-technology furnaces, including blast furnaces to produce an impure and low-grade iron-nickel product known as nickel pig iron (NPI). There is now a trend towards higher grade NPI produced in electric furnaces.

# **Appendix D** – Detailed overview of nickel value chain in target economies

## 1. Australia

### *Overview*

Australia is a major global supplier of both mined and finished primary nickel. It is the world's fourth-largest producer of mined nickel, with output in 2007 reaching 189.6kt contained in sulfide concentrates and laterite ores. Australia ranked fifth in global primary-nickel production in 2007, with its three refineries producing 114.3kt of finished metal. Over 95% of this annual production is exported.

Figure D.1.1 is a flow chart giving a schematic illustration of primary-nickel flows in the Australian economy. Table D.1.1 gives supporting tonnage data for 2007, the base year for modelling, and for 2010. Table D.1.2 gives the estimated value for Australian primary nickel production in 2007.

### *Reserves and resources*

Australia is one of the few economies in the world with significant in-ground resources of both sulfide and laterite nickel ores. Its currently reported mineable endowment contains 31.6 million tonnes of nickel (14% of the global total), second only to Indonesia. One third of these resources (10.5 million tonnes of contained metal) are in sulfide form, but this is the source of more than 80% of current production. Australia has the world's second largest resource of nickel in laterite ores, again behind Indonesia. Of the total resources, 8.3 million tonnes are classed as reserves.

### *Sulfide mining and smelting*

In 2007, Australia's sulfide mines produced 146.1kt of nickel in concentrates grading up to around 20% Ni. All sulfide mining was in Western Australia, with the principal production chain including major mines and mills at Mt Keith and Leinster, a concentrator at Kambalda, and an Outokumpu flash-furnace smelter at Kalgoorlie. Most of the concentrate was smelted to nickel matte at Kalgoorlie, with the remainder being exported for processing overseas.

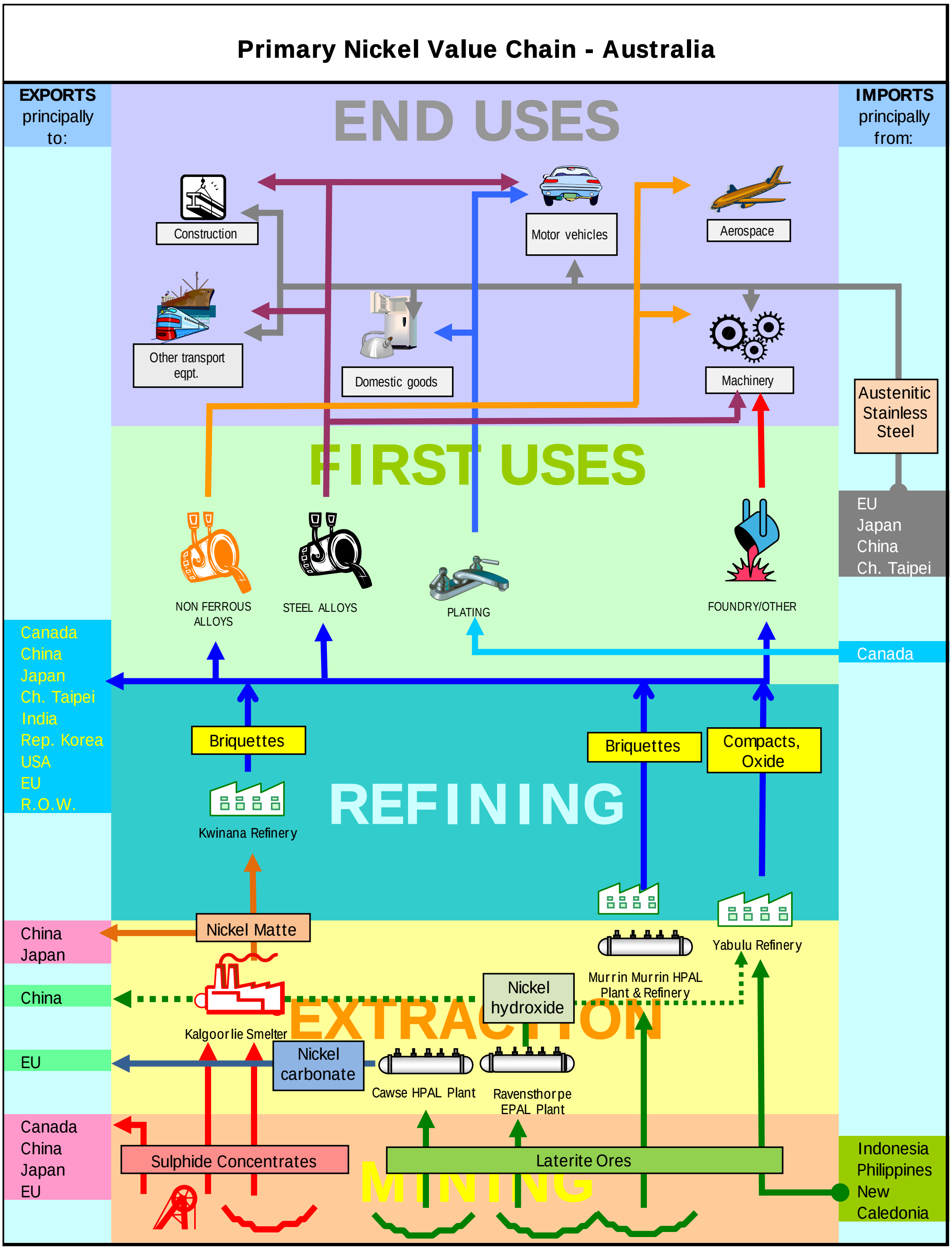
The Kambalda mill processed sulfide ores supplied by several junior mining companies, while other sites in Western Australia produced sulfide concentrates for export to Canada, China and Finland.

### *Laterite mining and processing*

In 2007, dry limonitic laterite ores were mined and processed at two integrated facilities (Murrin Murrin and Cawse) in Western Australia. High pressure acid leaching (HPAL) was used at both sites, with an carbonate intermediate being shipped from Cawse for further refining in Finland. Production at Cawse ceased in 2008 when the plant was placed on indefinite care and maintenance.

Australia's laterite output in 2007 also included trial mine production at the Ravensthorpe site, also in Western Australia, where an enhanced-pressure-acid-leach (EPAL) hydrometallurgical plant was commissioned in 2008. Operations at Ravensthorpe were suspended in January 2009, but the plant reopened under new ownership in late 2011.

**Figure D.1.1: Primary nickel flows in Australia's nickel value chain**



## Table D.1.1: Primary nickel production and use in Australia

| AUSTRALIA | '000 tonnes contained Ni 2007 | 2010 | Notes |
|---|---|---|---|
| **Mine Production** | | | |
| Sulfide concentrate | 146.1 | 150.5 | Chiefly from mines in Western Australia |
| Laterite ore | 43.5 | 33.5 | Murrin Murrin and Cawse mines, WA |
| **Total** | **189.6** | **184.0** | |
| **Ores and Concentrates Trade** | | | |
| Laterite ore imports | 31.6 | 44.2 | *Chief origins:* New Caledonia, Indonesia, Philippines |
| Sulfide concs exports | 41.6 | 41.9 | *Chief destination:* China |
| **Metallurgical Extraction** | | | |
| ***from Sulfides*** | | | |
| Nickel matte | 105.6 | 105.7 | Kalgoorlie smelter, WA |
| ***from laterites*** | | | |
| Nickel carbonate intermediate | 9.6 | nil | Cawse HPAL plant, WA (idled from Oct 2008) |
| **Trade in Intermediates** | | | |
| Nickel matte exports | 46.6 | 60.5 | *Chief destinations:* China, Finland, Japan |
| Carbonate intermediate exports | 9.6 | nil | *Destination:* Finland |
| **Finished Nickel Production**† | | | |
| ***from Sulfides*** | | | |
| Cl. 1 Nickel briquettes | 57.9 | 43.6 | Kwinana refinery, WA (Sherritt process) |
| ***from laterites*** | | | |
| Class 1 Nickel briquettes | 27.6 | 28.4 | Murrin Murrin, WA (HPAL; Sherritt process refinery) |
| Cl. 1 Nickel compacts, Cl. 2 oxide sinter | 28.8 | 29.6 | Yabulu refinery, QLD (Caron process; ammoniacal SX) |
| **Total** | **114.3** | **101.6** | |
| **Finished Nickel Trade** | | | |
| Exports, Class 1 nickel | 99.1 | 104.1 | *Chief destinations:* China, EU, USA, Japan, Korea |
| Exports, Class 2 nickel | 11.0 | 10.9 | *Chief destinations:* Korea, Chinese Taipei, Japan |
| Imports, Class 1 nickel | 1.2 | 0.7 | *Chief origin:* Canada |
| **Primary Nickel Usage** | | | |
| ***First Usage*** | | | |
| Stainless Steel | nil | nil | |
| Other Alloy Steels | 0.2 | 0.1 | |
| Non-ferrous Alloys | 1.5 | 2.0 | |
| Plating | 0.4 | 0.1 | |
| Foundry/Other | 0.4 | 0.3 | |
| **Total** | **2.5** | **2.5** | |
| ***End Usage*** | | | |
| Engineering, Bldg, Constrn | 1.3 | 1.1 | |
| Motor Vehicles | 0.3 | 0.1 | |
| Aerospace | 0.1 | 0.1 | |
| Other Transport | 0.4 | 0.3 | |
| Domestic and Homeware | 0.4 | 0.3 | |
| Electronics | 0.1 | 0.0 | |
| Machinery & Other | 1.9 | 1.6 | |
| **Total** | **4.5** | **3.6** | |
| **Nickel in Stainless Steel end usage**‡ | | | |
| Primary | 3.9 | 4.0 | |
| Scrap | 3.3 | 3.2 | |
| **Total** | **7.2** | **7.2** | |

† Major product forms
‡ Metalytics estimates

### *Primary nickel production*

A Sherritt-process refinery at Kwinana in Western Australia produces finished Class 1 nickel in the form of briquettes and steelmaking powder from matte smelted from sulfide concentrates at Kalgoorlie while at Murrin Murrin, the Sherritt process is also used to produce Class 1 briquettes by refining the mixed sulfide intermediate output from the HPAL circuit (see above).

Limonitic laterite ore imported from New Caledonia, Indonesia and the Philippines was also refined to finished nickel (mainly in compacts and oxide sinter) in 2007 at the Yabulu refinery in Queensland. This plant uses the Caron process augmented by ammoniacal solvent extraction and hydrogen reduction.

**Table D.1.2: Output value of Australia's primary nickel production in 2007**

| Sector | Products | Value, 2007$USm |
|---|---|---|
| Sulfide mining, concentrating and smelting | Nickel concentrates for export; matte for domestic smelting and export | $3,876.3 |
| Laterite mining and processing to intermediate products | Dry limonitic ore for HPAL processing; hydroxide intermediate for export | $484.0 |
| Finished primary nickel production | Nickel briquettes, compacts, oxide sinter and associated products | $4,215.0 |

### *First and end usage*

Table D.1.1 shows that in 2007 Australia's first use of primary nickel was 2.5kt, with over 96% of its production being exported.

All of Australia's stainless steel requirements are also imported, with net imports totalling 119kt in 2007, of which an estimated 90kt were austenitic, containing 7.4kt of nickel. The chief sources of these imports are Japan, Chinese Taipei, the EU and China.

Australia's total end use of primary nickel in 2010 totalled about 3,600 tonnes, with engineering, building, construction and machinery the dominant sectors.

### *Nickel chain's share of GDP*

Nickel mining, primary processing and first usage are estimated to contribute 0.52% to Australia's Gross Domestic Product, or 2.0% of industry's GDP share. In 2010, this was equivalent to US$6.4 billion. Nickel mining has risen to be an important part of Australia's natural resource economy. It has brought considerable regional employment, particularly in Western Australia, through direct employment but also indirect employment through the use of ports, rail and other infrastructure, and other industries that support mining, exploration and mineral processing.

### *Baseline forecast*

Over the ten years ending 2020, Australia's primary nickel production is forecast to expand at a Compound Annual Growth Rate (CAGR) of 4.3%. Growth rates will be similar in the sulfide and laterite sectors. The forecast envisages expansion of the Kwinana matte refinery. Laterite-based production growth will be largely driven by the ramping up of production from the recently restarted Ravensthorpe mine/HPAL complex, and a possible expansion of the Yabulu refinery.

Rapid growth (CAGR 12.6%) in end use of primary nickel is forecast for the period to 2020, although in global terms Australia will remain a relatively small first user.

# 2. Canada

## *Overview*

Canada's mined nickel production is the second-largest in the world, and Canada ranks fourth in global primary nickel output. It has six sulfide ore concentrators and three smelters, whose products feed two domestic refineries as well as overseas processing plants. A third refinery treats imported feed from Cuba.

Primary nickel flows in the Canadian value chain are depicted schematically in Figure D.2.1, with tonnage data for 2007 (the base year for modelling) and 2010 listed in Table D.2.1.

## *Reserves and resources*

Canada's nickel resources are exclusively in sulfide ores. With 15.8 million reported tonnes of contained nickel, they rank fifth in the world overall, and second (behind Russia) in terms of nickel in sulfides.

Traditionally, Canada's nickel production has been focussed on the Sudbury deposits of Ontario, which still contain about 25% of the economy's nickel endowment. Manitoba and Quebec are also important nickel-mining provinces, and Newfoundland & Labrador has risen to prominence since mining began at the Voisey's Bay deposit in 2005.

## *Sulfide mining and smelting*

Two concentrators in the Sudbury district process sulfide ores from nearby mines operated by two major producers and a number of junior miners. A Ni-Cu concentrate from the Clarabelle mill is smelted using oxygen flash furnace technology in a plant at Copper Cliff. The resulting converter matte is slow-cooled for processing and separation, with the nickel subsulfide fraction being roasted to oxide. Some of this is processed to metal at the neighbouring carbonyl-process refinery; the remainder is exported for refining in the EU, (in another carbonyl-process refinery) or exported to Asia for processing into utility nickel).

At another plant in the Sudbury area, an electric furnace smelts concentrates from the local Strathcona mill and nickel sulfide concentrate shipped from the Raglan mine on the Ungava Peninsula in northern Quebec. In 2007 this smelter also processed feed from the Montcalm mine in eastern Ontario (which closed in 2009), and other operations in Ontario. The plant's entire production of nickel-copper matte is exported to Norway for refining to cathode.

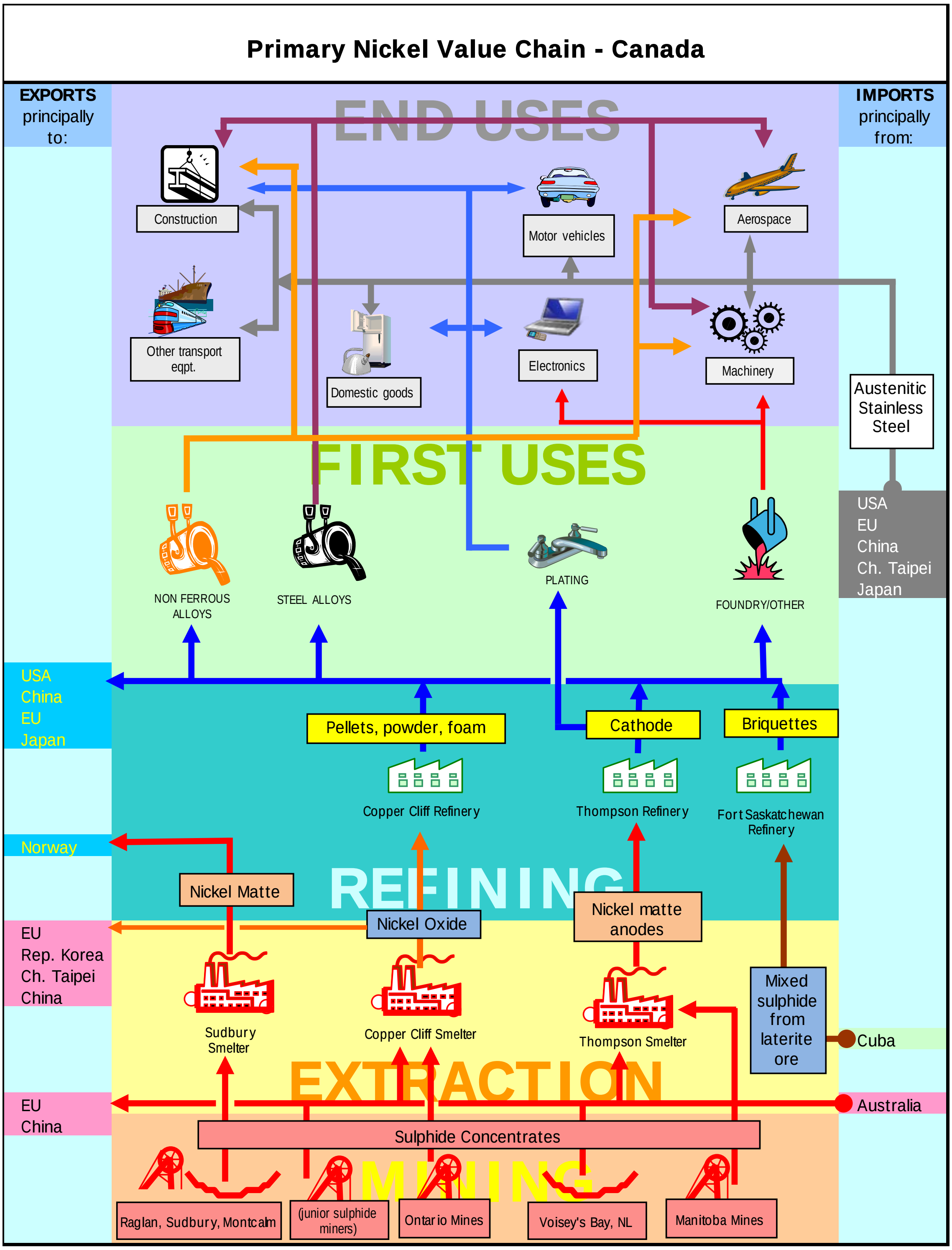
In Manitoba, sulfide concentrates from the Thompson and Birchtree mines feed an electric furnace smelter whose low-iron matte product is cast into anodes for electrolytic refining.

Pending start-up of a planned hydrometallurgical processing plant at Long Harbour, Newfoundland, nickel concentrate from Voisey's Bay is being smelted at Copper Cliff and Thompson.

## *Primary nickel production*

Canada produces finished primary nickel from three plants. A pressure-carbonyl (modified Mond process) refinery at Copper Cliff, Ontario, refines nickel oxide feed to high-purity pellets and powders.

**Figure D.2.1: Primary nickel flows in Canada's nickel value chain**



## Table D.2.1: Primary nickel production and use in Canada

| CANADA | '000 tonnes contained Ni 2007 | 2010 | Notes |
|---|---|---|---|
| **Mine Production** | | | |
| Sulfide concentrate | 254.0 | 153.5 | Mines in Ontario, Manitoba, Labrador and Quebec |
| **Total** | **254.0** | **153.5** | |
| **Ores and Concentrates Trade** | | | |
| Sulfide concs imports | 7.8 | 20.3 | *Chief origins:* South Africa, Australia |
| Sulfide concs exports | 11.5 | nil | *Chief destinations:* EU, China |
| **Metallurgical Extraction** | | | |
| ***from Sulfides*** | | | |
| Nickel matte | 67.6 | 73.7 | Sudbury smelter, Ontario |
| Nickel oxide/sinter | 113.3 | 51.3 | Copper Cliff smelter & matte processing plant, Ontario |
| Nickel anodes | 51.2 | 46.3 | Thompson smelter, Manitoba |
| **Trade in Intermediates** | | | |
| Mixed Sulfide imports | 30.4 | 34.3 | *Origin:* Cuba |
| Matte and oxide sinter imports | 15.3 | 5.9 | *Chief origin:* Botswana |
| Nickel matte and oxide exports | 115.6 | 106.4 | *Destinations:* Norway & EU (UK) |
| **Finished Nickel Production**† | | | |
| ***from Sulfides*** | | | |
| Pellets, powder (Cl. 1 Ni) | 63.4 | 21.0 | Copper Cliff refinery, Ontario (Mond process) |
| Nickel oxide sinter | 7.9 | 4.5 | Copper Cliff matte processing plant, Ontario |
| Cathode (Cl.1 Ni) | 50.9 | 46.0 | Thompson refinery, Manitoba (electrolytic) |
| ***from imported feed sourced from laterites*** | | | |
| Cl. 1 Nickel briquettes | 31.4 | 34.0 | Fort Saskatchewan refinery, Alberta (Sherritt process) |
| **Total** | **153.6** | **105.4** | |
| **Finished Nickel Trade** | | | |
| Imports, Class 1 nickel | 2.4 | 3.8 | *Chief origins:* Australia, EU |
| Exports, Class 1 nickel | 142.5 | 95.2 | *Chief destinations:* USA, EU, China, Japan |
| Exports, Class 2 oxide sinter | 12.4 | 9.0 | *Chief destinations:* Korea, China, Chinese Taipei, US |
| **Primary Nickel Usage** | | | |
| ***First Usage*** | | | |
| Stainless Steel | nil | nil | |
| Other Alloy Steels | 1.5 | 1.3 | |
| Non-ferrous Alloys | 1.3 | 0.7 | |
| Plating | 2.2 | 1.6 | |
| Foundry/Other | 2.6 | 1.3 | |
| **Total** | **7.6** | **4.9** | |
| ***End Usage*** | | | |
| Engineering, Bldg, Constrn | 4.2 | 3.3 | |
| Motor Vehicles | 2.1 | 1.6 | |
| Aerospace | 2.1 | 0.8 | |
| Other Transport | 0.7 | 0.5 | |
| Domestic and Homeware | 1.6 | 1.2 | |
| Electronics | 0.9 | 0.4 | |
| Machinery & Other | 6.9 | 5.0 | |
| **Total** | **18.5** | **12.8** | |
| **Nickel in Stainless Steel end usage** | | | |
| Primary | 7.4 | 6.5 | |
| Scrap | 9.0 | 8.8 | |
| **Total** | **16.4** | **15.3** | |

† Major product forms

At Thompson, Manitoba, cathode and rounds are produced by electrolysis of matte anodes from the neighbouring smelter.

A Sherritt-process refinery at Fort Saskatchewan, Alberta, processes mixed sulfide intermediate imported from laterite mining and high-pressure acid leach operations at Moa Bay, Cuba to produce Class 1 nickel briquettes.

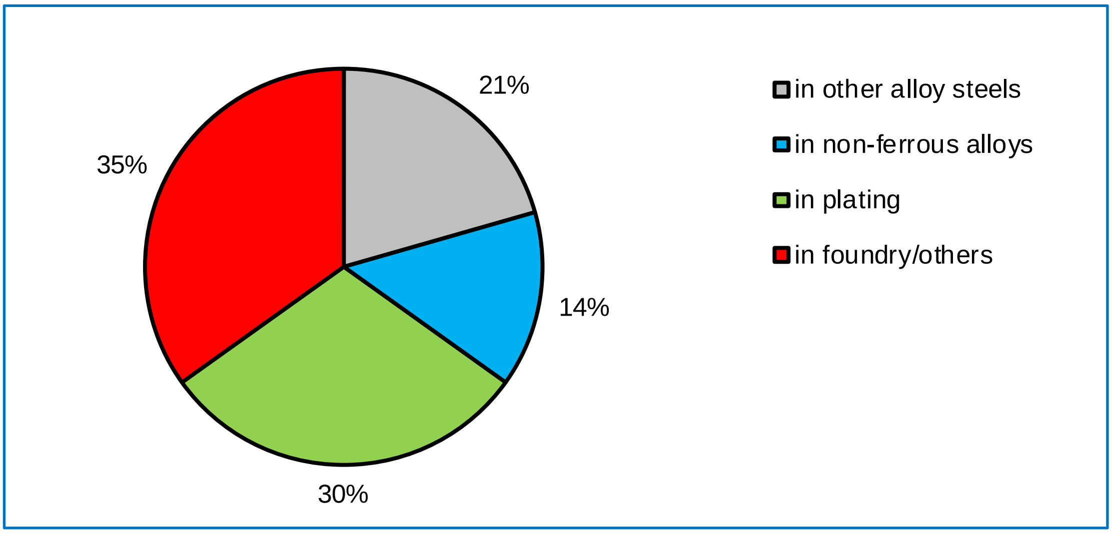
**Table D.2.2: Output value of Canada's Primary Nickel Production in 2007**

| Sector | Products | Value, 2007$USm |
|---|---|---|
| Sulfide mining, concentrating and smelting | Nickel matte (and minor amounts of concentrate) for export; nickel oxide and processed matte for domestic refining and export; nickel matte anodes for refining | $7,576 |
| Finished primary nickel production | Nickel as cathode, pellets, powders, and other minor forms refined from intermediates produced by the smelting of sulfide ores | $4,316 |
| Finished primary nickel production | Nickel briquettes refined from imported mixed sulfide feed | $1,177 |

### *First and end usage*

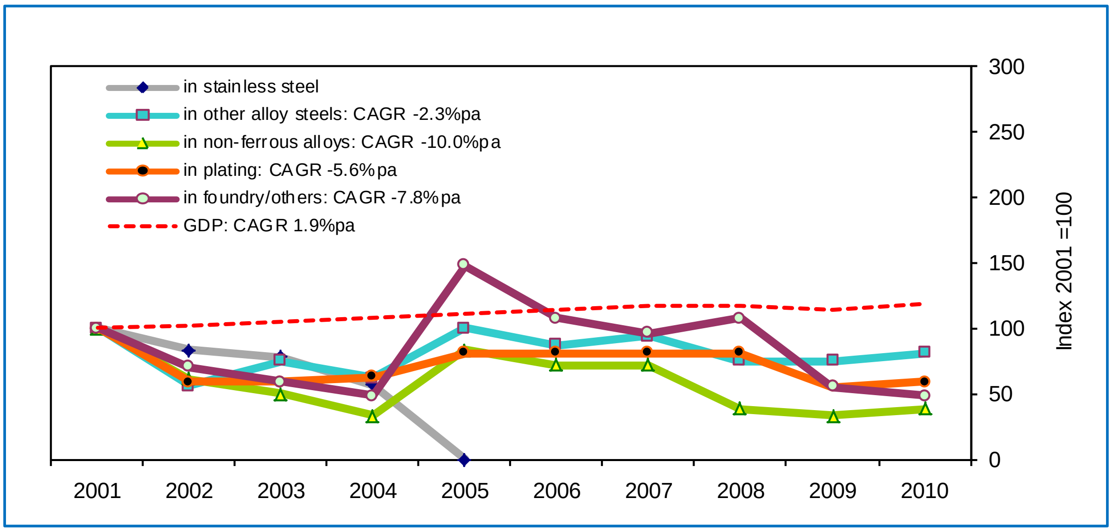
Canada's estimated first use of primary nickel totalled 7.6kt ranked in 2007, with plating the largest single demand category. However, first usage was less than half the end-usage total because of stainless steel imports of over 300kt – around 70% of this was austenitic. More than half of the stainless imports came from the USA, and another 30% from Western Europe.

**Figure D.2.2: Nickel First Use sectors (2006-10 average): Canada**




*Source: modified Pariser data*

**Figure D.2.3: First use of primary nickel – growth in Canada, 2001-2010**




*Source: Metalytics; modified Pariser data*

## *Nickel chain's share of GDP*

The aggregate value-added contribution of nickel mining, primary processing and first use to Canada's Gross Domestic Product is estimated at 0.27% or around 1.0% of the industry sector's GDP share. In 2010, this amounted to US$4.3 billion.

Nickel mining and refining has long been an important pillar of Canada's natural resource economy. Many critical applications of nickel were first developed in Canada. From its historical roots in the Sudbury basin, the industry has built on its knowledge, and nickel mining and processing is now important to a number of provinces across Canada. It has brought regional employment and wealth, including to native communities where some pioneering agreements have become the benchmark for fair treatment of native land rights and local collaboration.

## *Baseline forecast*

Canada's 105.4kt of finished nickel production in 2010 was depressed by extended industrial action at some major operations. Production in 2015 is forecast at 160kt, including 35kt from the processing of Cuban laterite intermediates.

Like Australia, Canada does not have any stainless steel production capacity, and so will remain a relatively small first user of nickel. Nevertheless, its first and end use tonnages are both forecast to grow at CAGRs of around 5.7% through the current decade. Forecasts for 2020 are for first use applications to supply about one third of 22.3kt of primary end use.

# 3. China

## *Overview*

Since 2005, China has been the world's largest user of primary nickel. Although Chinese domestic finished nickel production has risen rapidly (from 73kt in 2004 to an estimated 332kt in 2010), it is also a major importer of the metal. A feature of China's primary nickel production over the last five years has been the advent and rapid expansion of the production of nickel pig iron (NPI) in small plants smelting imported laterite ores. NPI output in 2010 contained an estimated 165kt of nickel, providing a vital source of primary metal units for China's stainless steel industry which, since 2006, has also been the largest in the world and accounts for 75% of the economy's nickel first usage.

Simplified material flows in China's primary nickel value chain are shown schematically in Figure D.3.1, with tonnage data for 2007 and 2010 presented in Table D.3.1. Table D.3.2 lists output values for China's primary nickel production in 2007.

## *Reserves and resources*

China is host to around 4% of the current global nickel resources, and 90% of its reported endowment is in sulfide ores. Although the two north-western provinces of Gansu and Xinjiang contain around two-thirds of the total, nickel deposits are also known in Sichuan, Yunnan, Hubei and Jilin. Chinese mined and finished nickel production is dominated by operations near Jinchang in Gansu, where sulfide resources are reported to contain over six million tonnes of nickel.

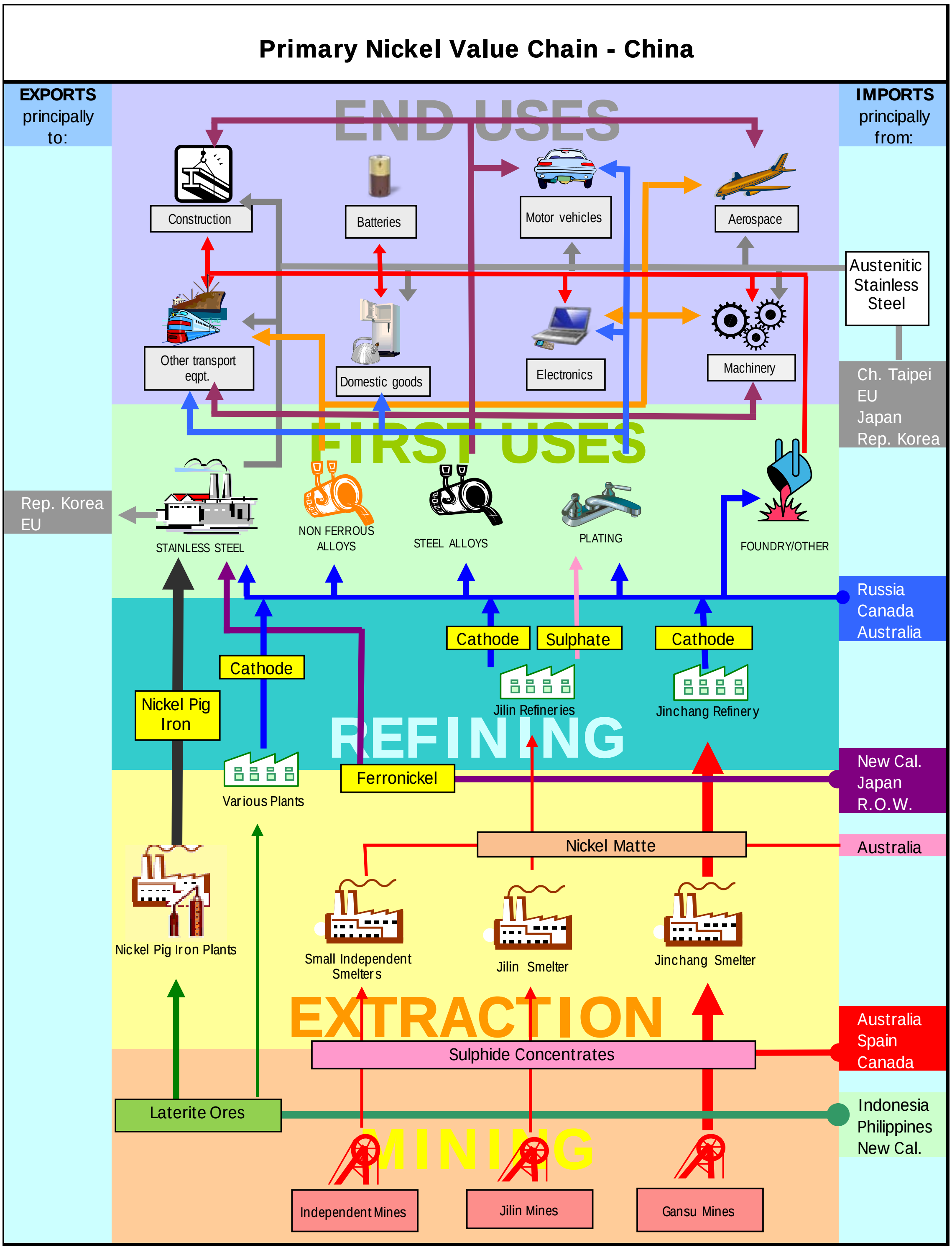
## *Sulfide mining and smelting*

China's production of an estimated 67.5kt of nickel in sulfide concentrate ranked it ninth in global mined nickel output in 2007. The Yongchang underground mining complex at Jinchang in Gansu Province provides concentrate feed for nearby electric and flash-furnace smelting operations, supplemented by sulfide concentrate imports from Australia, Spain and Canada. Other sulfide mines in Xinjiang, Jilin and Yunnan feed a number of much smaller smelters, including plants at Honquiling, Jilin Province (which also treated some imported concentrate in 2007), and a complex in the Xinjiang Uygur Autonomous Region.

## *Laterite mining and smelting*

The production of nickel pig iron (NPI) in China from smelting relatively low-grade imported laterite ores began in 2005, providing additional primary nickel units required by the Chinese stainless steel mills. In 2007, an estimated 15.3Mwt of laterite were imported from the Philippines, Indonesia and New Caledonia for this purpose. Product grades had improved as well, with 1,5%-8%Ni being achieved in small blast furnaces and 8%-15% in electric arc furnaces. As the technology developed, impurities were lowered and NPI began to displace other nickel sources in the production of 300-series stainless steel grades. There were over 100 small plants producing NPI in 2007, widely distributed across China but more common in areas with transportation availability and access to coke supplies (e.g., in Shandong, Shanxi, Fujian, Henan, Hainan Hebei, Jiangsu and Zhejiang provinces). Their contained nickel output is estimated at 84.5kt in 2007, but the total nickel content of China's NPI producers had risen to 165kt in 2010.

Figure D.3.1: Primary nickel flows in the Chinese nickel value chain



## Table D.3.1: Primary nickel production and use in China

| CHINA | '000 tonnes contained Ni 2007 | 2010 | Notes |
|---|---|---|---|
| **Mine Production** | | | |
| Sulfide concentrate | 67.5 | 84.8 | Chiefly from mines in Gansu province |
| Laterite ore | nil | nil | |
| **Total** | **67.5** | **84.8** | |
| **Ores and Concentrates Trade** | | | |
| Laterite ore imports | 142.4 | 224.0 | *Chief origins:* Indonesia, the Philippines |
| Sulfide concs imports | 33.0 | 40.0 | *Chief origins:* Australia, EU (Spain), Canada |
| **Metallurgical Extraction** | | | |
| ***from Sulfides*** | | | |
| Nickel matte | 94.5 | 118.5 | Smelters in Gansu & Jilin; other small plants |
| ***from laterites*** | | | Many small plants smelt imported laterite ores to nickel pig iron or low-grade ferronickel |
| NPI & Ferronickel | see below | | |
| **Trade in Intermediates** | | | |
| Nickel matte imports | 27.7 | 43.3 | *Chief origin:* Australia |
| **Finished Nickel Production**† | | | |
| ***from Sulfides*** | | | |
| Chiefly Cl. 1 cathode, Ni salts | 114.9 | 167.3 | Electrolytic refinery, Gansu (106kt in 2007 & 130kt in 2010); smaller plants in Jilin, Xinjiang, Sichuan |
| ***from laterites*** | | | |
| Cl. 2 Nickel pig iron/ | 40.0 | 71.5 | Smelted from imported laterite ores in small blast furnaces and electric furnaces |
| low-grade ferronickel | 44.5 | 93.5 | |
| **Total** | **199.4** | **332.3** | |
| **Finished Nickel Trade** | | | |
| Imports, Class 1 nickel | 104.2 | 184.2 | *Chief origins:* Canada, Australia, Russia, EU |
| Imports, Class 2 nickel oxide | 22.7 | 38.8 | *Chief origins:* ROW (Cuba), Australia |
| Imports, Class 2 ferronickel | 25.5 | 36.5 | *Chief origins:* New Caledonia, Japan, Colombia |
| **Total** | **152.4** | **259.5** | |
| **Primary Nickel Usage** | | | |
| ***First Usage*** | | | |
| Stainless Steel | 234.5 | 423.0 | |
| Other Alloy Steels | 11.0 | 19.3 | |
| Non-ferrous Alloys | 8.0 | 12.0 | |
| Plating | 50.0 | 54.4 | |
| Foundry/Other | 31.3 | 48.8 | |
| **Total** | **334.8** | **557.5** | |
| ***End Usage*** | | | |
| Engineering, Bldg, Constrn | 104.0 | 190.3 | |
| Motor Vehicles | 12.5 | 19.9 | |
| Aerospace | 3.4 | 5.9 | |
| Other Transport | 21.7 | 27.5 | |
| Domestic and Homeware | 80.3 | 134.7 | |
| Electronics | 19.6 | 28.7 | |
| Machinery & Other | 83.6 | 155.2 | |
| **Total** | **325.1** | **562.1** | |
| **Nickel in Stainless Steel end usage** | | | |
| Primary | 244.8 | 401.9 | |
| Scrap | 138.2 | 97.7 | |
| **Total** | **383.0** | **499.6** | |

† Major product forms

### *Primary nickel production*

China is the largest primary nickel producer in the world, with aggregate 2010 production of 332kt, including nickel in NPI. The largest single producing plant, an electrolytic refinery in Jinchang, produced 130kt of nickel cathode from cast matte anodes, while a number of smaller producers added to China's output of primary nickel in cathode and sulfate.

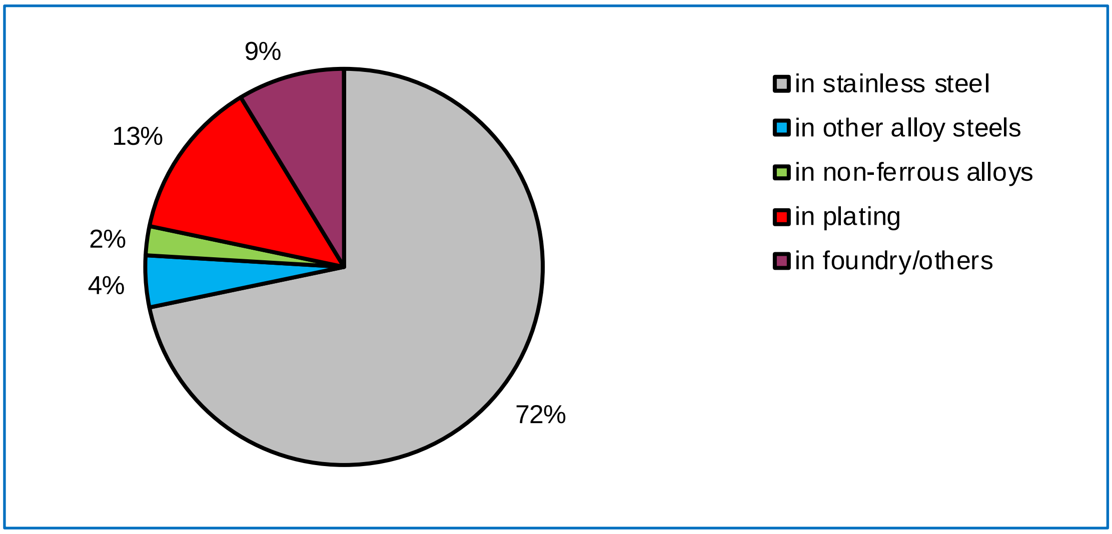
**Table D.3.2: Output values for primary nickel production in China in 2007**

| Sector | Products | Value, 2007$USm |
|---|---|---|
| Sulfide mining, concentrating and smelting | Nickel matte smelted from domestic and imported concentrates at Jinchuan, Jilin and other smelters | $2,649 |
| Matte refining producing nickel | Class 1 nickel cathode (and minor nickel salts) refined from local and imported matte | $4,342 |
| Nickel pig iron smelted from imported laterite ores | NPI grading 1.5% to 8%Ni from small blast furnaces and 8% to 15% from electric arc furnaces | $2,965 |

### *First and end usage*

China has been the world's largest user of primary nickel since 2005. As Figure D.3.2 illustrates, stainless steel dominates first use. Chinese production grew at a compound annual rate of 36% between 2001 and 2010 (see Figure D.3.3), and in the latter year stainless steel accounted for 76% of nickel first use. In 2007, the four largest producers accounted for about 60% of output on a liquid steel basis.

**Figure D.3.2: Nickel First Use sectors (2006-10 average): China**

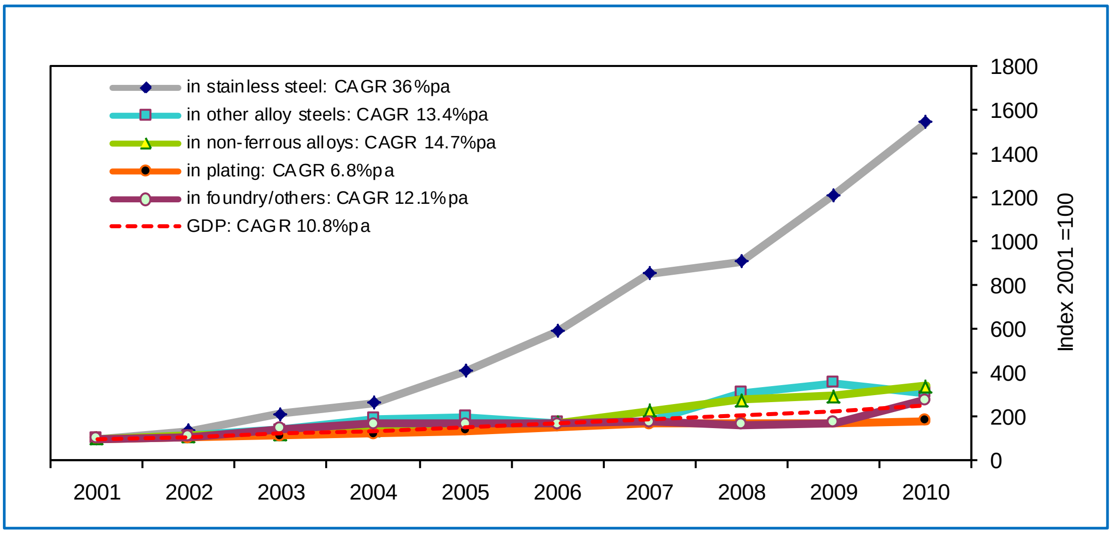



*Source: Modified Pariser data*

China's entire output of nickel pig iron and its total ferronickel imports provided less than half the primary nickel units required for its austenitic stainless steel production in 2007. Domestic supplies of Class 1 nickel are supplemented with imported nickel metal and oxide sinter – these totalled 126.9kt of contained nickel in 2007, principally sourced from Canada, Australia, Russia, Cuba and the EU. China's electroplating industry is the economy's second largest first use, accounting for over 50ktpy of primary nickel.

Over the period 2001-10 China's end usage of primary nickel expanded at a CAGR of 13.7%. This rapid growth has seen its share of global demand expand from 16.5% to 38% over the same interval. Offtake into the Building and Construction and Engineering sectors has risen at around 20% per year in an economy whose infrastructure is developing rapidly.

**Figure D.3.3: First use of primary nickel – growth in China, 2001-2010**




*Source: Metalytics; modified Pariser data*

## *Nickel chain's share of GDP*

Nickel mining, primary processing and first use industries' contribution to China's Gross Domestic Product is estimated at 0.19%, equivalent to US$11.2 billion in 2010, or 0.41% of the industrial sector's GDP share. Given China's industrial growth in recent years, these shares are significant. China's economic growth is founded on adding value all along the value chain. As described earlier, nickel plays a vital role in many aspects of modern life, and stainless steel in particular is essential in any industrialized economy, through infrastructural investment and industrial plant and equipment. There is a well-established correlation between economic growth and stainless steel use. As one of the main ingredients of high quality stainless steel, nickel is one of the building blocks of this value chain. A number of Chinese companies are engaged in developing nickel mines and plants around the world (e.g. at the Ramu project in Papua New Guinea) to keep fuelling China's integrated industrial development.

## *Baseline forecast*

Chinese primary finished nickel production is forecast to grow at a CAGR of 5% between 2010 and 2020. The production of nickel pig iron (NPI) from imported laterite ores is already the largest and fastest-growing segment, almost doubling between 2007 and 2010, when 165kt of nickel in NPI represented 50% of the China's total primary finished nickel output.

NPI production is assumed to almost double again by 2015 (to 300kt) but to stabilise thereafter, so that the forecast CAGR for 2010-20 is 6.2%. Meanwhile the domestic sulfide mining and metallurgical sector will continue growing at a more modest CAGR of 3.2%. Growth will be slightly faster in other technologies, including hydrometallurgical processing of laterites, but even so this segment will contribute less than 10% to Chinese nickel production by 2020.

China's primary first use and end use tonnages will remain closely aligned. In 2010 these commanded, respectively, 38% and 36% of global totals. With rapid growth (forecast CAGRs of 6.5% and 6.1% respectively), these proportions are expected to be approaching 50% by 2020, when China's finished nickel production of 540kt is forecast to satisfy just over 51% of first use demand.

# 4. Indonesia

### *Overview*

Indonesia is a major producer and exporter of mined and intermediate nickel as well as primary ferronickel (Table D.4.1). The economy hosts two laterite smelters, both on the island of Sulawesi, that are fed by domestic ores. All production is exported. Mine output rose from around 75ktpy of contained nickel in the late 1990s to 229kt in 2007 and 283kt in 2010 as a result of increases in ore exports, particularly since shipments to China for nickel pig iron production began in 2006.

Indonesia has small nickel first- and end-use sectors that are based entirely on imports of primary nickel and stainless steel, mostly from other APEC economies.

Figure D.4.1 is a schematic depiction of primary nickel flows, with tonnage data for 2007 and 2010 presented in Table D.4.1.

### *Reserves and resources*

Indonesia's known nickel resources are all lateritic and contain 34 million tonnes of nickel – the largest reported endowment in the world.

### *Laterite mining and processing*

Indonesia is the world's second largest producer of mined nickel, all of it in laterites. There are major mines in Southeast Sulawesi and at several sites in the Moluccas. In the period since 2005, there has been an eightfold increase in laterite ore exports. China is now the largest market, but Japan and Australia are long-term customers, and recent destinations have diversified to include the EU and Ukraine.

A mining complex in South Sulawesi feeds the Soroako plant, which employs rotary kiln and electric furnace (RKEF) technology to produce a 78%Ni matte. This is exported for further processing to primary nickel products in Japan.

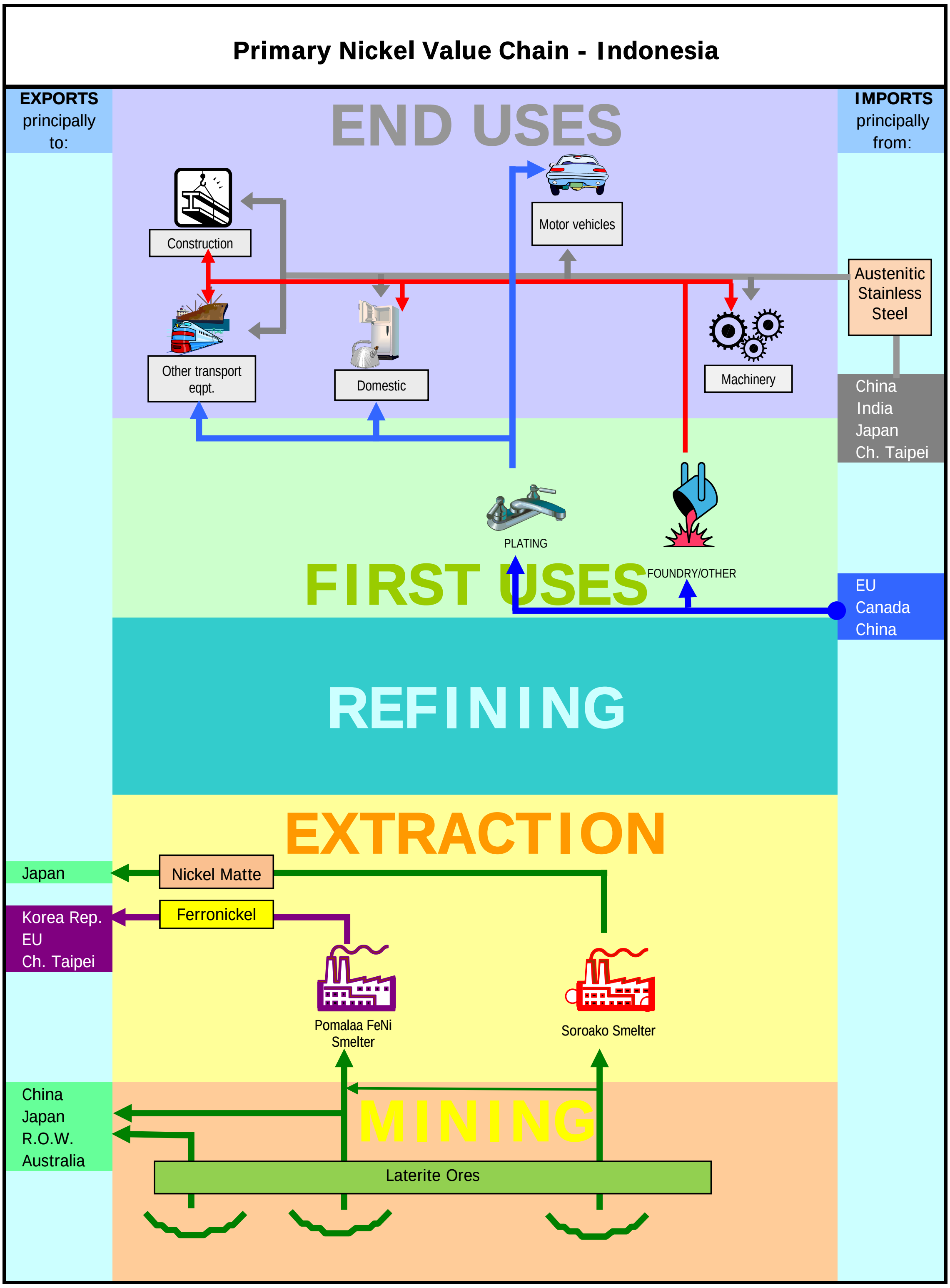
### *Primary nickel production*

The Pomalaa smelter in Southeast Sulawesi also utilises RKEF technology, with the output refined to a ferronickel product grading around 20%Ni that is sold to stainless steel-making customers mainly in the EU, Republic of Korea and Chinese Taipei.

**Table D.4.1: Output values for Indonesian nickel production in 2007**

| Sector | Products | Value, 2007$USm |
|---|---|---|
| Laterite mining and processing to intermediates | Laterite ores for export and domestic smelting to ferronickel; nickel matte for export | $3,081 |
| Laterite smelting to ferronickel | Ferronickel ingot and shot for export | $633 |

**Figure D.4.1: Primary nickel flows in Indonesia's nickel value chain**



## Table D.4.2: Primary nickel production and use in Indonesia

| INDONESIA | '000 tonnes contained Ni 2007 | 2010 | Notes |
|---|---|---|---|
| **Mine Production** | | | |
| Sulfide concentrate | nil | nil | |
| Laterite ore | 229.0 | 283.5 | Saprolites for smelting and export, limonites for export |
| **Total** | **229.0** | **283.5** | |
| **Ores and Concentrates Trade** | | | |
| Laterite ore exports | 114.5 | 172.6 | *Chief destinations:* China, Japan, Australia, Ukraine |
| **Metallurgical Extraction** | | | |
| ***from laterites*** | | | |
| Nickel matte | 76.7 | 76.0 | Soroako smelter, South Sulawesi (RKEF) |
| Ferronickel | see below | | |
| **Trade in Intermediates** | | | |
| Nickel matte exports | 76.6 | 69.7 | *Destination:* Japan |
| **Finished Nickel Production** | | | |
| ***from Sulfides*** | nil | nil | |
| ***from laterites*** | | | |
| Ferronickel | 18.5 | 18.7 | Pomalaa FeNi smelter, SE Sulawesi (RKEF) |
| **Total** | **18.5** | **18.7** | |
| **Finished Nickel Trade** | | | |
| Exports, Class 2 ferronickel | 17.7 | 18.4 | *Chief destinations:* Korea, EU (Germany), |
| **Primary Nickel Usage** | | | |
| ***First Usage*** | | | |
| Stainless Steel | nil | nil | |
| Other Alloy Steels | nil | 0.0 | |
| Non-ferrous Alloys | nil | nil | |
| Plating | 0.2 | 0.1 | |
| Foundry/Other | 0.3 | 0.4 | |
| **Total** | **0.5** | **0.5** | |
| ***End Usage*** | | | |
| Engineering, Bldg, Constrn | | | |
| Motor Vehicles | | | |
| Aerospace | | | |
| Other Transport | | | |
| Domestic and Homeware | | | |
| Electronics | | | |
| Machinery & Other | | | |
| **Total** | ***3.1*** | ***8.2*** | |
| **Nickel in Stainless Steel end usage‡** | | | |
| Primary | 2.6 | 7.7 | |
| Scrap | 2.1 | 4.6 | |
| **Total** | **4.7** | **12.3** | |

‡ *Metalytics estimates*

### *First and end usage*

With all of Indonesia's primary nickel production exported, all first use, currently estimated at around 500tpy, employs imported nickel or nickel-containing products. End uses also currently include about 8ktpy of primary nickel contained in imported stainless steel; Figure D.4.1 presents a conceptual view of material flows.

### *Nickel chain's share of GDP*

Indonesia is rich in natural resources, and the mining industry, including nickel laterite mining, has become an increasingly important part of the Indonesian economy. It is expected that this natural resource wealth will become the foundation of an integrated industrialised economy as Indonesia develops. Currently, nickel mining, primary processing and first use are estimated to contribute 0.72% to its Gross Domestic Product (around US$5.1 billion in 2010) or about 1.6% of industry's GDP share.

### *Baseline forecast*

Indonesia's laterite mining industry is expected to expand at a CAGR of over 5% between 2010 and 2020, driven by expanding demand for primary nickel in China. The Indonesian government is currently developing and implementing policies to promote value-adding operations such as smelting and metallurgical processing within Indonesia. It is therefore likely that, over the forecast period, an increasing proportion of the economy's nickel exports will be in intermediate or finished products rather than unprocessed ores. The existing Pomalaa plant is also expected to increase its production of ferronickel.

# 5. Japan

### *Overview*

Japan has the third-largest production of primary nickel metal in the world, but with no domestic nickel mines, its producers are dependent on the importation of ores and intermediate products to feed the economy's five long-established finished nickel plants. The aggregate output of these facilities exceeds 160ktpy. This production is augmented by imported metal to satisfy Japan's current first-use demand, which is the second largest in the world, and dominated by stainless steel.

Figure D.5.1 is a flow chart giving a schematic illustration of the way in which primary-nickel flows are represented in the Japanese economy. Table D.5.2 provides supporting quantitative tonnage details for 2007, the base year for modelling and industry forecasts, and for 2010.

### *Reserves and resources*

Japan has no current or planned nickel mining operations and no reported nickel reserves. The economy's entire primary nickel production uses imported feedstock, around 95% of which are laterite ores mined in other APEC economies or intermediates products derived from them.

### *Primary nickel production*

Japan is the world's largest producer of ferronickel; the economy's three smelters have a combined annual output capacity of 375,000 gross tonnes containing 75kt of nickel. They are fed by high-grade (nominally 2.3-2.5% Ni) saprolite ores imported from Indonesia, the Philippines and New Caledonia. In 2007, these imports totalled 4.3 million wet tonnes.

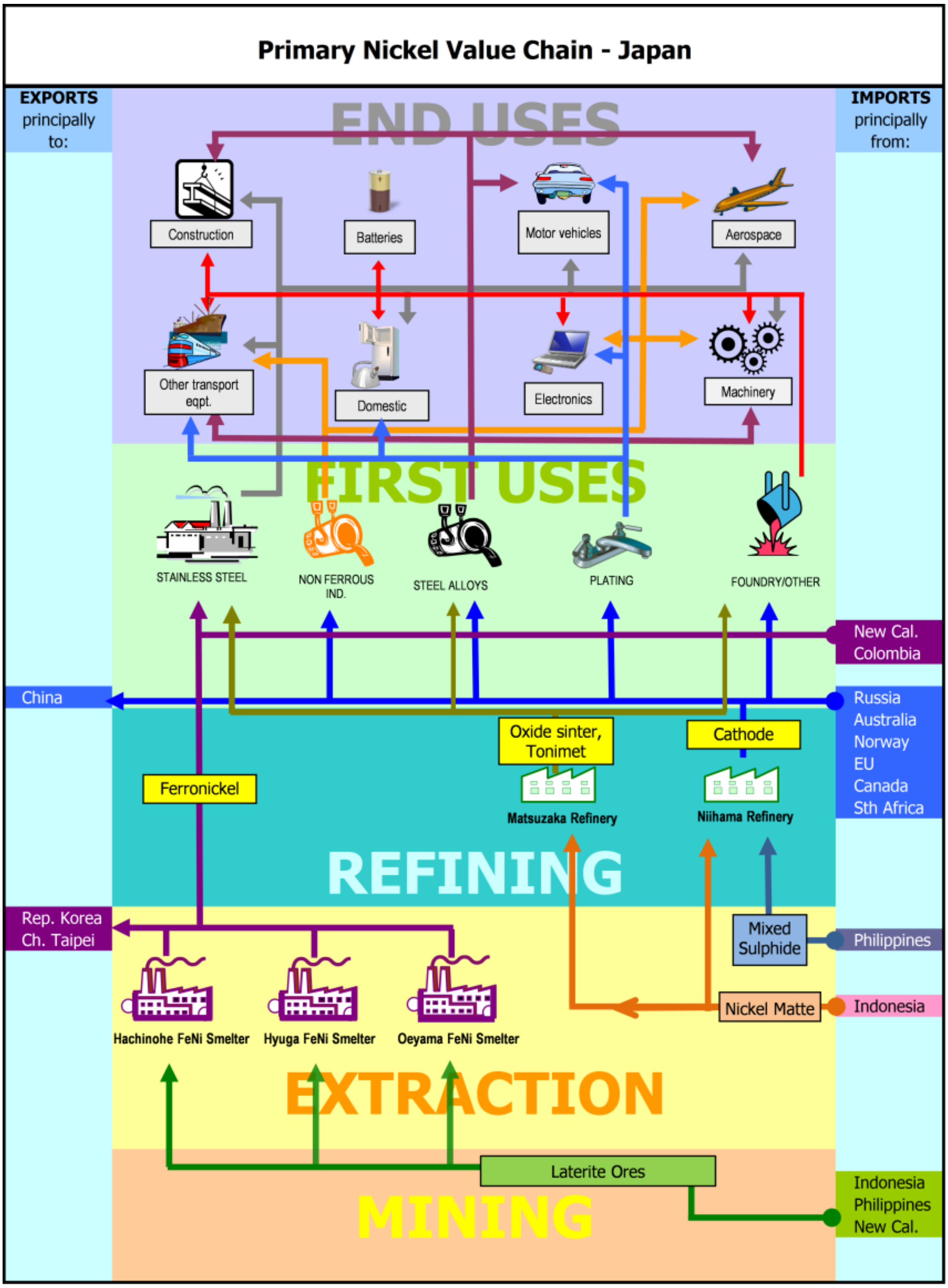
Although Japan's ferronickel is produced primarily to supply the economy's stainless-steel manufacturers with primary nickel units for their austenitic grades, exports to the Republic of Korea, Chinese Taipei and, more recently, China have been growing and now account for between one third and one half of total output.

**Table D.5.1: Japan's three ferronickel smelters**

| Plant | Process Technology | Capacity (cont'd Ni) | Production (cont'd Ni) |
|---|---|---|---|
| Hachinohe (Pamco), Aomori | Rotary kiln, electric furnace | 41,000t | 2007: 33,216t<br>2010: 40,422t |
| Hyuga, Miyazaki | Rotary kiln, electric furnace | 21,000t | 2007: 23,649t<br>2010: 17,663t |
| Oeyama, Miyazu | Krupp-Renn process (sub-solidus rotary kiln reduction) | 13,000t | 2007: 11,481t<br>2010: 9,461t |

Japan's two nickel refineries are also supplied by imported feedstock. A plant at Niihama utilises matte-chlorine-leach and electrowinning technology to produce high-purity cathode and nickel salts by refining matte imported from Indonesia and elsewhere as well as the mixed sulfide output from the Coral Bay HPAL facility in the Philippines. The Matsuzaka refinery in Mie Prefecture produces oxide sinter and Tonimet, also from imported matte. Some volumes of nickel oxide sinter are exported to other economies in APEC for processing into utility nickel. Table D.5.3 gives the estimated sales value of Japan's primary nickel production in 2007.

## Figure D.5.1: Primary nickel flows in Japan's nickel value chain



## Table D.5.2: Primary nickel production and use in Japan

| JAPAN | '000 tonnes contained Ni 2007 | 2010 | Notes |
|---|---|---|---|
| **Mine Production** | | | |
| Sulfide concentrate | nil | nil | |
| Laterite ore | nil | nil | |
| **Ores and Concentrates Trade** | | | |
| Laterite ore imports | 71.6 | 77.4 | *Chief Origins:* Indonesia., New Caledonia, Philippines |
| **Metallurgical Extraction** | | | |
| ***from Sulfides*** | nil | nil | |
| ***from laterites*** | see below | | Three plants smelt imported laterite ores to produce ferronickel |
| **Trade in Intermediates** | | | |
| Nickel matte imports | 81.9 | 83.1 | *Chief origins:* Indonesia, Australia |
| Mixed Sulfide imports | 10.8 | 18.6 | *Chief origin:* Philippines |
| **Finished Nickel Production†** | | | |
| ***from imported intermediates*** | | | |
| Cl. 1 Ni cathode & salts | 32.9 | 42.7 | Niihama ref., Ehime (MCLE) |
| Cl. 2 Tonimet | 60.3 | 55.8 | Matsuzaka ref. (fluid bed roasting) |
| ***from imported laterite ores*** | | | |
| Cl. 2 Ferronickel | 68.3 | 67.5 | Hachinohe smelter, Aomori (RKEF), Hyuga smelter, Miyazaki (RKEF), Oeyama smelter, Miyazu (Krupp-Renn process) |
| **Total** | **161.5** | **166.1** | |
| **Finished Nickel Trade ‡** | | | |
| Imports, Class 1 nickel | 58.5 | 48.7 | *Chief origins:* Russia, Australia, Norway, EU, |
| Imports, ferronickel | 15.4 | 13.9 | *Chief origins:* New Caledonia, Colombia |
| Exports, Class 1 nickel | 2.4 | 11.4 | *Chief destination:* China |
| Exports, ferronickel | 20.4 | 33.0 | *Chief destinations:* Korea, Taiwan |
| **Primary Nickel Usage ‡** | | | |
| ***First Usage*** | | | |
| Stainless Steel | 110.3 | 99.6 | |
| Other Alloy Steels | 31.3 | 26.4 | |
| Non-ferrous Alloys | 18.7 | 22.8 | |
| Plating | 3.5 | 2.6 | |
| Foundry/Other | 25.9 | 20.6 | |
| **Total** | **189.7** | **172.0** | |
| ***End Usage*** | | | |
| Engineering, Bldg, Constrn | 47.4 | 36.6 | |
| Motor Vehicles | 18.8 | 16.1 | |
| Aerospace | 5.5 | 4.8 | |
| Other Transport | 15.1 | 12.3 | |
| Domestic and Homeware | 10.4 | 10.6 | |
| Electronics | 12.5 | 15.2 | |
| Machinery & Other | 52.7 | 48.3 | |
| **Total** | **162.5** | **143.8** | |
| **Nickel in Stainless Steel end usage** | | | |
| Primary | 74.9 | 65.5 | |
| Scrap | 38.5 | 33.9 | |
| **Total** | **113.4** | **99.4** | |

† Major product forms

**Table D.5.3: Output value of primary nickel production in Japan in 2007**

| Sector | Products | Value, 2007$USm |
|---|---|---|
| Laterite smelting for ferronickel | Ferronickel in shot, ingots and luppen | $2,694 |
| Matte refining to nickel metal | Tonimet (grading 95-97% Ni), oxide sinter, Class 1 nickel cathode, salts | $3,685 |

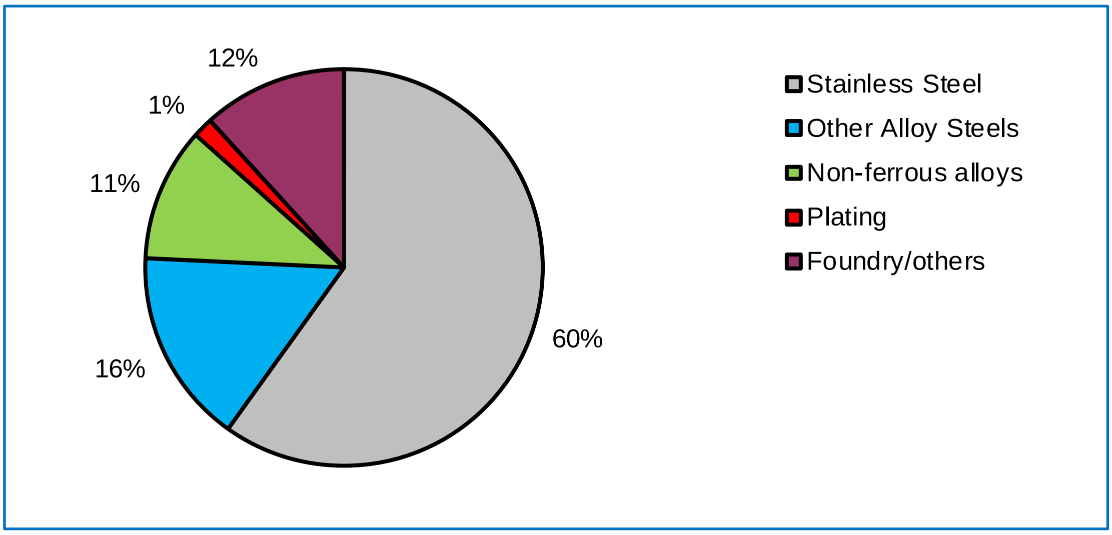
### *First usage*

Japan exports small amounts of cathode to China and Korea, and a larger amount to the Rest of the World (ROW). But most of its production is absorbed by domestic first-use industries – in order of importance Stainless Steel, Other Steel Alloys, Foundry, Non-Ferrous Alloys and Plating. Similarly, most of Japan's production of ferronickel is used by the domestic stainless steel industry, with smaller amounts exported as noted above.

As Table D.5.2 shows, Japan's primary nickel production is insufficient to meet its first-use requirements. The primary-nickel imports that are needed to fill the gap are sourced from a wide variety of nickel-producing economies: primary metal is imported from Russia, Norway, South Africa, Zimbabwe, Brazil, Australia and Canada; and ferronickel comes from New Caledonia and Colombia.

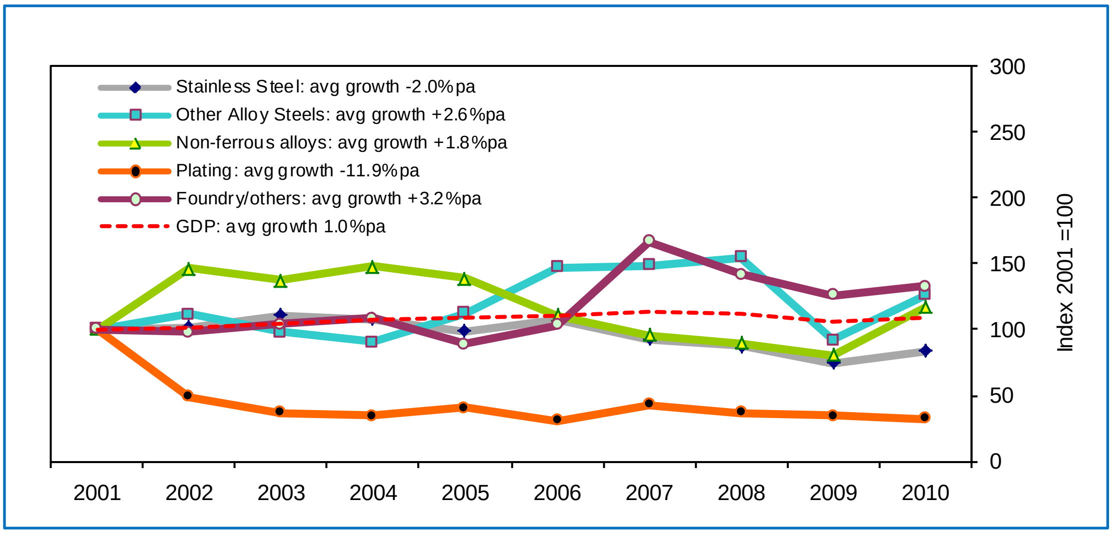
Imports account for about one third of the primary nickel inputs used for Japan's Non-Ferrous Alloys and Plating industries, about 16% in the Stainless Steel and Other Steel Alloys industries, and about 10% in Foundry. In 2010, Japan's total estimated first usage of primary nickel was 172kt.

**Figure D.5.2: Nickel First Use sectors (2006-10 average): Japan**




*Source: Modified Pariser Data*

**Figure D.5.3: First Usage of primary nickel – growth in Japan, 2001-2010**

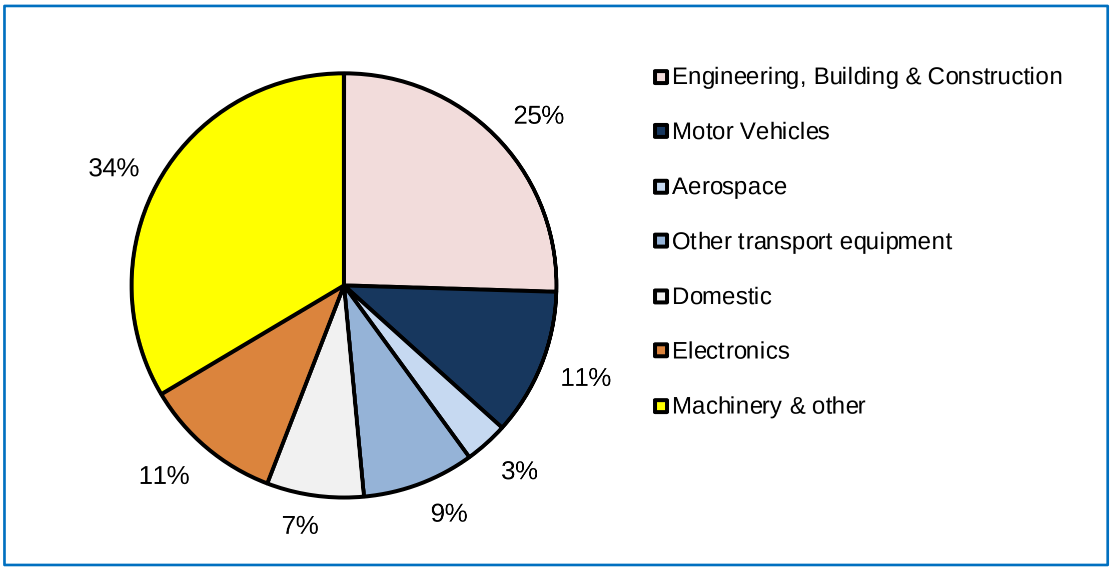



*Source: Metalytics; modified Pariser data*

## *End usage*

Japanese end users were responsible for one tenth of world primary nickel use in 2010, making it the third-largest nickel using economy, after China and the European Union. The current end use breakdown is shown in Figure D.5.4.

**Figure D.5.4: Japan's primary nickel end-use pattern in 2010**




*Source: Modified Pariser data*

### *Nickel chain's share of GDP*

The total contribution to Japan's Gross Domestic Product of primary nickel processing and first use is estimated at 0.17% (US$9.3bn in 2010; 0.71% of industry's share of GDP). While these proportions are explicable given the size and maturity of the Japanese economy, any visitor to Japan can immediately see the importance of nickel-containing stainless steel in everyday life from street furniture to the commuter trains. While lacking natural deposits of nickel, Japanese companies have long been back-integrated into nickel mining with investments in nickel projects, and this continues today across the globe in many joint ventures.

### *Baseline forecast*

The baseline forecasts for 2015 and 2020 predicate Japan's primary finished nickel production expanding at a CAGR of 2.7% with first and end uses growing at CAGRs of around 0.5% over the forecast period.

# 6. Republic of Korea

## *Overview*

A highly developed industrial base makes the Republic of Korea a major end-user of nickel and ranks it sixth in the world in terms of first use. In 2007, the base year for modelling and industry forecasts, the economy's only nickel production facility was a plant producing upgraded Class 2 finished nickel from imported primary feedstock. All requirements for Class 1 nickel metal and ferronickel were imported. A ferronickel smelter that treats imported saprolitic laterite ores began production in 2008.

The flowchart in Figure D.6.1 schematically illustrates the primary nickel flows in the Korean Republic's economy. Table D.6.2 provides supporting tonnage data for 2007 and 2010.

## *Reserves and resources*

The Republic of Korea has no reported resources or reserves of nickel and no current or planned nickel mining activity.

## *Primary nickel production*

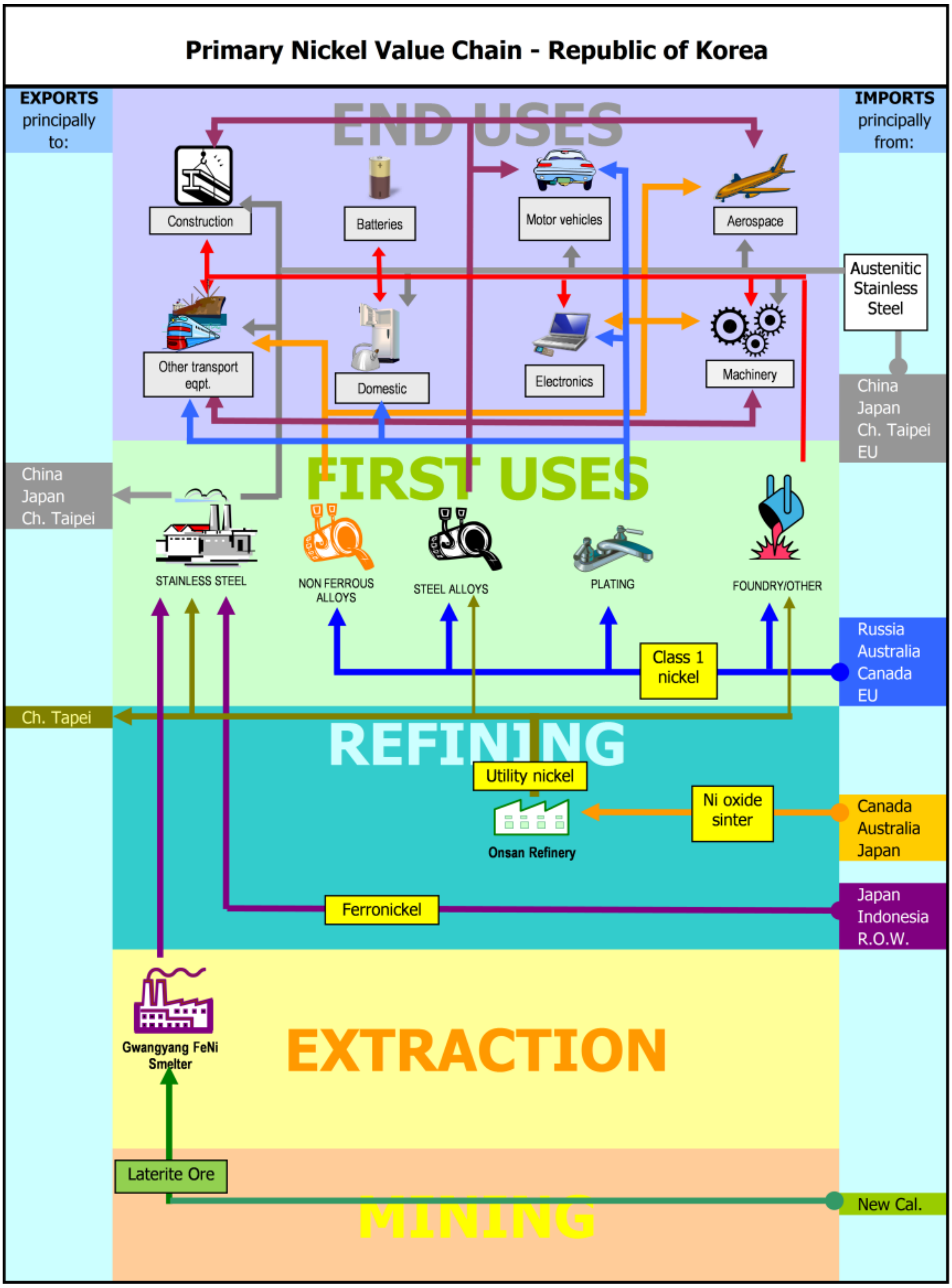
A nickel refinery at the port of Onsan with a rated capacity of 32ktpy of nickel treats nickel oxide sinter feed imported chiefly from Canada, Australia and Japan. Its product is in shot (3-80mm) form sold as "utility nickel" containing around 97% nickel. Its 2007 output had a value of US$1,098 million. Because this facility essentially re-refines (upgrades) nickel products from other plants, its output is, by convention, not included in global primary-nickel production totals to avoid double counting. (A similar convention applies in respect of output from the Kaohsiung refinery in Chinese Taipei.)

In late 2008, a new ferronickel smelter, Gwangyang, came into production, treating saprolite ore imported from New Caledonia. In 2009, its first full year of operation, this plant produced 21.6kt of nickel contained in ferronickel cones.

## *First usage*

The Republic of Korea is the world's fourth-largest producer of raw stainless steel, and the stainless steel sector dominates first use of primary nickel (Figure D.6.2). Over the five years to 2009, an average 78% of nickel first use was by stainless steel producers consuming Onsan utility nickel and ferronickel imported principally from Japan and Indonesia. This has been augmented since 2008 by domestic production from Gwangyang. About half of the Republic's stainless steel production is exported, mainly to China, Japan and Chinese Taipei. Nevertheless, Korea is also a substantial importer of stainless steel and, as Table D.6.1 shows, of primary nickel products in addition to ferronickel. Since 2001 there has also been steady expansion in the plating market segment (Figure D.6.3).

### Figure D.6.1: Primary nickel flows in Korea's nickel value chain

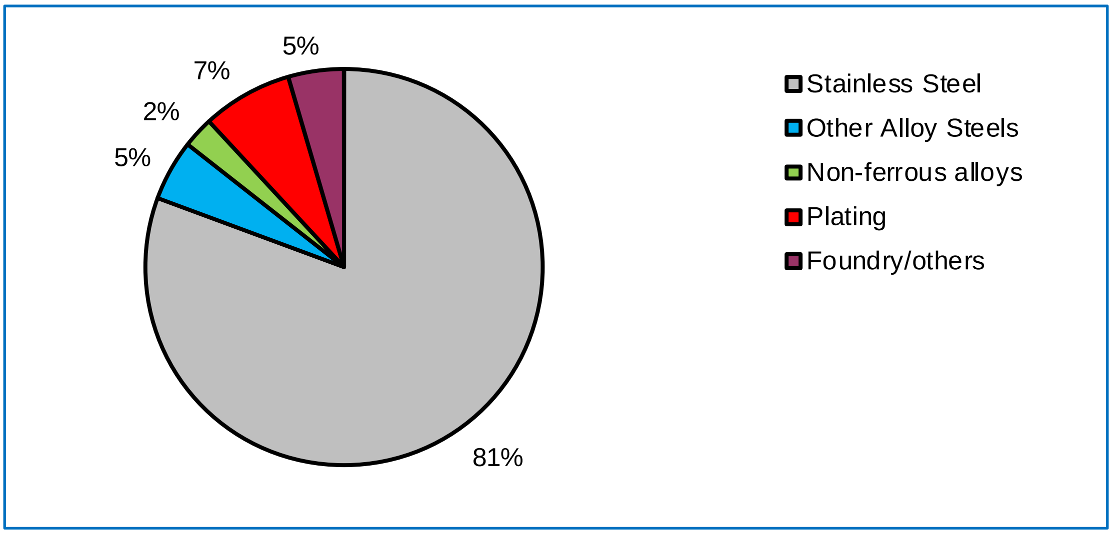


## Table D.6.1: Primary nickel production and use in the Republic of Korea

| REPUBLIC OF KOREA | '000 tonnes contained Ni 2007 | 2010 | Notes |
|---|---|---|---|
| **Mine Production** | | | |
| Sulfide concentrate | nil | nil | |
| Laterite ore | nil | nil | |
| **Ores and Concentrates Trade** | | | |
| Laterite ore imports | nil | 23.3 | *Chief origin:* New Caledonia |
| **Metallurgical Extraction** | | | |
| ***from Sulfides*** | nil | nil | |
| ***from laterites*** | nil | see below | |
| **Trade in Intermediates** | nil | nil | |
| **Finished Nickel Production**† | | | |
| ***from further refining of imported oxide sinter*** | | | |
| Cl. 2 Utility nickel ‡ | 28.7 | 20.9 | KNC refinery, Onsan (reduction furnace) |
| ***from laterites*** | | | |
| Cl. 2 ferronickel | nil | 20.5 | Gwangyang FeNi smelter (since 2008) |
| **Total** | **28.7** | **41.4** | |
| **Finished Nickel Trade** | | | |
| Imports, oxide sinter | 28.7 | 21.0 | *Chief origins:* Canada, Australia, Japan |
| Imports, ferronickel | 19.5 | 23.4 | *Chief origins:* Japan, Indonesia, Colombia, Dom. Rep. |
| Imports, Class 1 nickel | 19.5 | 25.9 | *Chief origins:* Russia, Australia, Canada |
| **Primary Nickel Usage** | | | |
| ***First Usage*** | | | |
| Stainless Steel | 62.5 | 71.0 | |
| Other Alloy Steels | 3.0 | 4.1 | |
| Non-ferrous Alloys | 2.0 | 1.5 | |
| Plating | 5.0 | 6.3 | |
| Foundry/Other | 4.0 | 2.1 | |
| **Total** | **76.5** | **85.0** | |
| ***End Usage*** | | | |
| Engineering, Bldg, Constrn | 21.7 | 26.0 | |
| Motor Vehicles | 8.1 | 9.6 | |
| Aerospace | 0.4 | 0.3 | |
| Other Transport | 4.8 | 4.4 | |
| Domestic and Homeware | 10.7 | 12.2 | |
| Electronics | 7.9 | 6.8 | |
| Machinery & Other | 16.5 | 17.6 | |
| **Total** | **70.2** | **76.9** | |
| **Nickel in Stainless Steel end usage** | | | |
| Primary | 45.3 | 52.4 | |
| Scrap | 35.0 | 31.5 | |
| **Total** | **80.3** | **83.9** | |

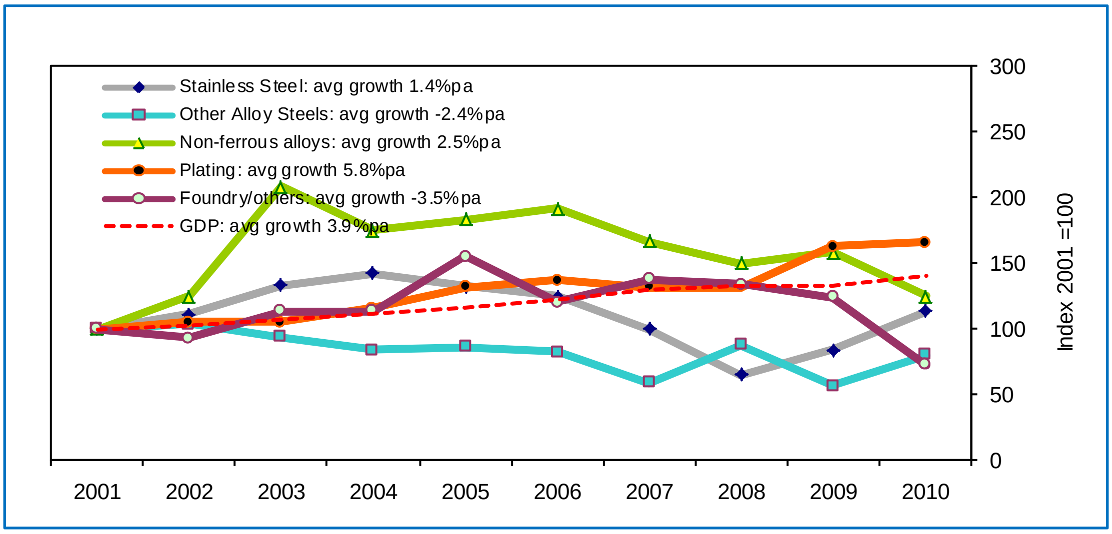
† Major product forms
‡ Production not included in global totals to avoid double counting

**Figure D.6.2: Nickel First Use sectors (2006-10 average): Republic of Korea**




*Source: modified Pariser data*

**Figure D.6.3: First use of primary nickel – growth in Republic of Korea, 2001-2010**



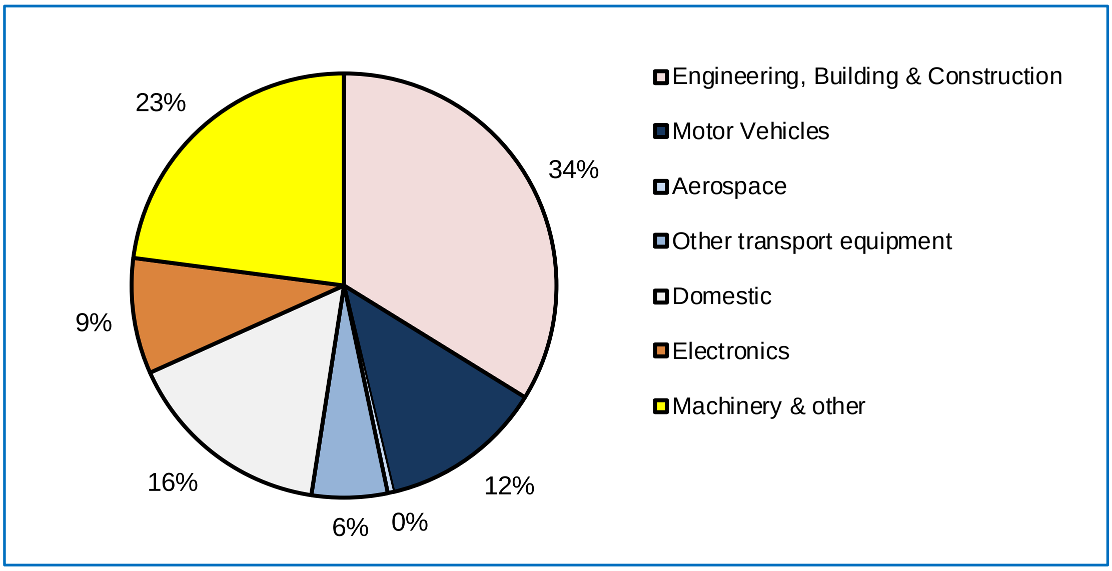

*Source: Metalytics; modified Pariser data*

## *End usage*

Primary nickel end use in the Republic of Korea equated to about 5% of the global total, ranking the economy fourth among the APEC economies. Between 2001 and 2010 end use expanded at a CAGR of 3.1%, the strongest performance after China and Chinese Taipei.

End use growth is led by the Automotive industry, which averaged 10.6% growth over the 2001-2010 period. Other stand-out growth rates were achieved in export-oriented goods such as washing machines, dish washers, refrigerators and air conditioners. On the other hand, nickel use in the Building and Construction industry has shown hardly any growth over the period.

**Figure D.6.4: Republic of Korea's primary nickel end-use pattern in 2010**




*Source: Metalytics; modified Pariser data*

## *Nickel chain's share of GDP*

The estimated contribution made by primary nickel processing and first use to the Gross Domestic Product of the Republic of Korea is 0.17%. This was US$2.0 billion in 2010, about 0.43% of industry's share of GDP. Korea's large stainless steel manufacturing industry supports the extensive use of stainless steel in the many engineering applications just described, as well as exports. Korean companies can be found in a number of joint ventures in nickel projects across the globe, thereby securing supply for future growth in this sector.

## *Baseline forecast*

From 2010 to 2020 the forecast CAGRs are 3.2% for Korea's ferronickel production (as expansion plans for the Gwangyang plant take effect) and 3.1% for primary nickel end use.

# 7. The Philippines

### *Overview*

Massive increases in laterite ore exports to China have led to mined nickel output in the Philippines more than doubling over the last three years, so that the economy's ranking in global mined production has moved from seventh-largest to fourth (in 2010). Laterite ores are also exported to Japan and Australia for processing and, since 2005, an HPAL facility has produced a mixed sulfide intermediate for export to Japan. The flowchart in Figure D.7.1 illustrates the primary nickel tonnage flow data presented in Table D.7.1.

### *Reserves and resources*

The Philippines ranks seventh in the world in contained-nickel resources, all of which are lateritic. Several companies have future production plans utilising a variety of metallurgical extraction technologies, and often requiring the building of new infrastructure. Most of the economy's nickel resources are found on the southern islands of Mindanao and Palawan.

### *Laterite mining and processing*

Mined nickel production in the Philippines in 2007 totalled 93.2kt of nickel contained in 10.9Mwt of saprolite and limonite ores. Except as noted below for Coral Bay, all mined production is exported, most of it now destined for nickel pig iron production in China. Smaller tonnages of high-grade saprolite are smelted to ferronickel in Japan, and limonitic laterite is sold to the Yabulu refinery in Australia.

### *Primary nickel production*

The Philippines has not produced finished primary nickel since the closure of the Caron-process refinery at Nonoc in 1986. However, as noted above, there are several major projects at the planning stage that could result in production of nickel, principally via hydrometallurgical treatment of limonitic laterite ores.

### *First and end usage*

Total first use of primary nickel in 2010 is estimated at around 240 tonnes, of which about 90% is used to produce non-stainless steel alloys. End uses also include about 1,500t of primary nickel contained in imported stainless steel.

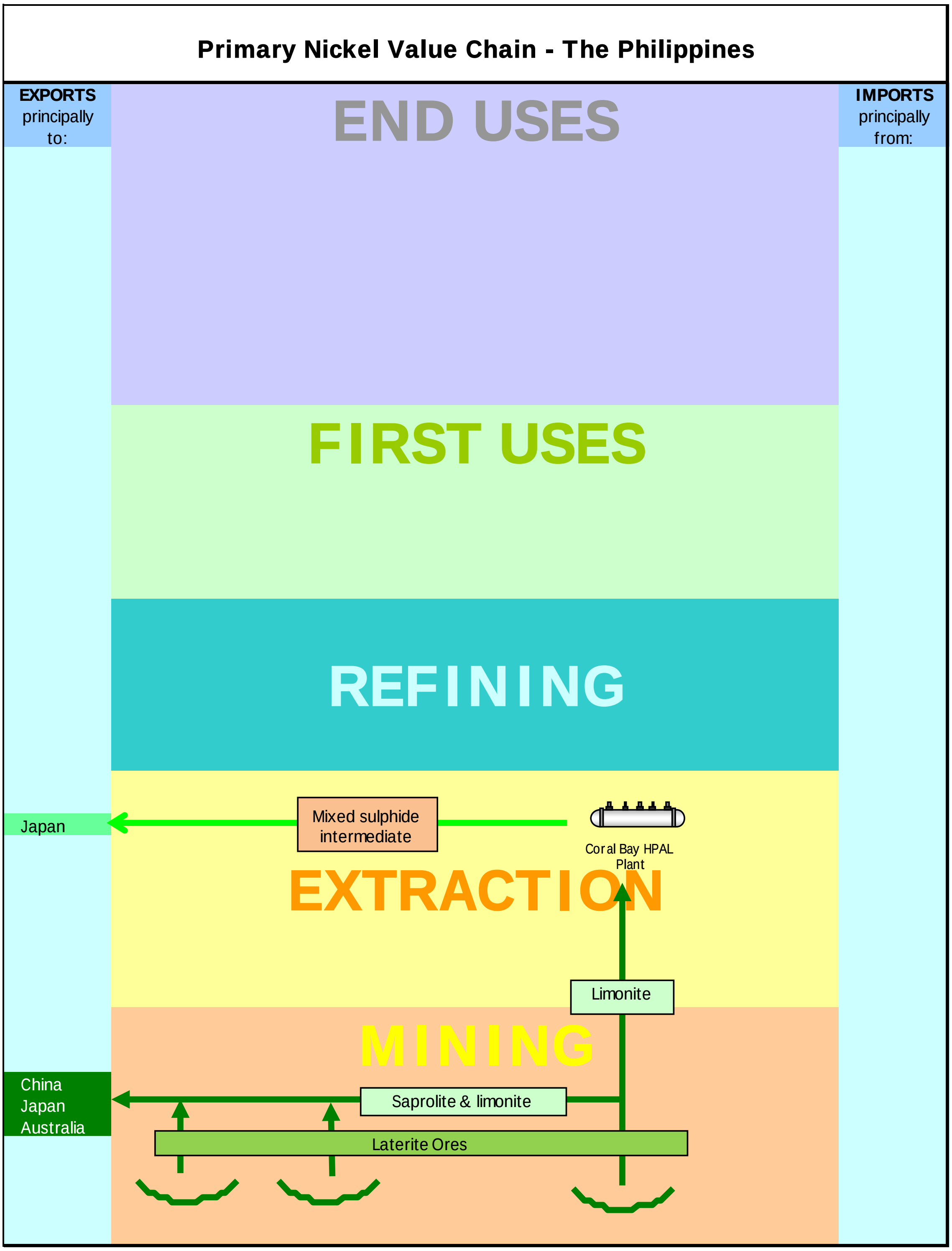
### *Nickel chain's share of GDP*

Nickel mining, initial processing and first use are estimated to contribute 0.56% of Philippines' Gross Domestic Product. This was about US$1.1 billion in 2010, representing around 1.7% industry's share of GDP. The Philippines' extensive resource base of nickel has seen considerable growth in mining in recent years to feed the Nickel Pig Iron (NPI) demand of China, and may one day become the basis of further industrialisation of the economy.

### *Baseline forecast*

First use of primary nickel in the Philippines is forecast to grow as the economy develops. The laterite mining, initial processing and export sector is forecast to grow with expansion of the Coral Bay HPAL plant as well as through laterite ore exports to other APEC economies, particularly China.

Figure D.7.1: Primary nickel flows in the Philippines’ nickel value chain



## Table D.7.1: Primary nickel production and use in the Philippines

| THE PHILIPPINES | '000 tonnes contained Ni 2007 | 2010 | Notes |
|---|---|---|---|
| **Mine Production** | | | |
| Sulfide concentrate | nil | nil | |
| Laterite ore | 93.2 | 173.5 | Limonite ores for acid leaching, saprolites and limonites for export |
| **Total** | **93.2** | **173.5** | |
| **Ores and Concentrates Trade** | | | |
| Laterite ore exports | 82.1 | 152.0 | *Chief destinations:* China, Japan, Australia |
| **Metallurgical Extraction** | | | |
| ***from laterites*** | | | |
| Mixed Sulfide intermediate | 10.1 | 20.5 | Coral Bay HPAL plant, Palawan |
| Trade in Intermediates | | | |
| Mixed Sulfide inter. exports | 9.8 | 18.6 | *Destination:* Japan (Niihama refinery) |
| **Finished Nickel Production** | | | |
| from Sulfides | nil | nil | |
| from laterites | nil | nil | |
| **Primary Nickel Usage** | | | |
| ***First Usage*** | | | |
| Stainless Steel | nil | nil | |
| Other Alloy Steels | 0.0 | 0.2 | |
| Non-ferrous Alloys | nil | nil | |
| Plating | 0.0 | 0.0 | |
| Foundry/Other | 0.1 | 0.1 | |
| **Total** | **0.1** | **0.3** | |
| ***End Usage*** | | | |
| Engineering, Bldg, Constrn | | | |
| Motor Vehicles | | | |
| Aerospace | | | |
| Other Transport | | | |
| Domestic and Homeware | | | |
| Electronics | | | |
| Machinery & Other | | | |
| **Total** | **1.7** | **1.8** | |
| **Nickel in Stainless Steel end usage** | | | |
| Primary | 1.5 | 1.5 | |
| Scrap | 1.3 | 1.0 | |
| **Total** | **2.8** | **2.5** | |

# 8. The Russian Federation

### *Overview*

The Russian Federation ranks at the top of the list of the world's nickel-mining economies. It is also by far the largest producer of Class 1 nickel metal, extracted overwhelmingly from sulfide ores. With annual finished nickel output the world's largest exporter of primary nickel metal.

### *Reserves and resources*

Russia has the world's third largest reported nickel resource, containing around 21 million tonnes of nickel. Over 96% of the Federation's nickel endowment is in sulfide ores, and about 75% of this is on the Taimyr Peninsula in remote northern Siberia. There are some small laterite ore deposits in the southern Urals that support mining to feed ferronickel production and small integrated smelter/refinery operations producing various forms of finished nickel.

### *Sulfide mining and smelting*

The Russian nickel industry is dominated by two main vertically integrated production units.  located on the Taimyr and Kola Peninsulas. Both units are based around large mining complexes exploiting nickel/copper sulfide ores with significant co-product endowments of copper, cobalt and platinum group metals.

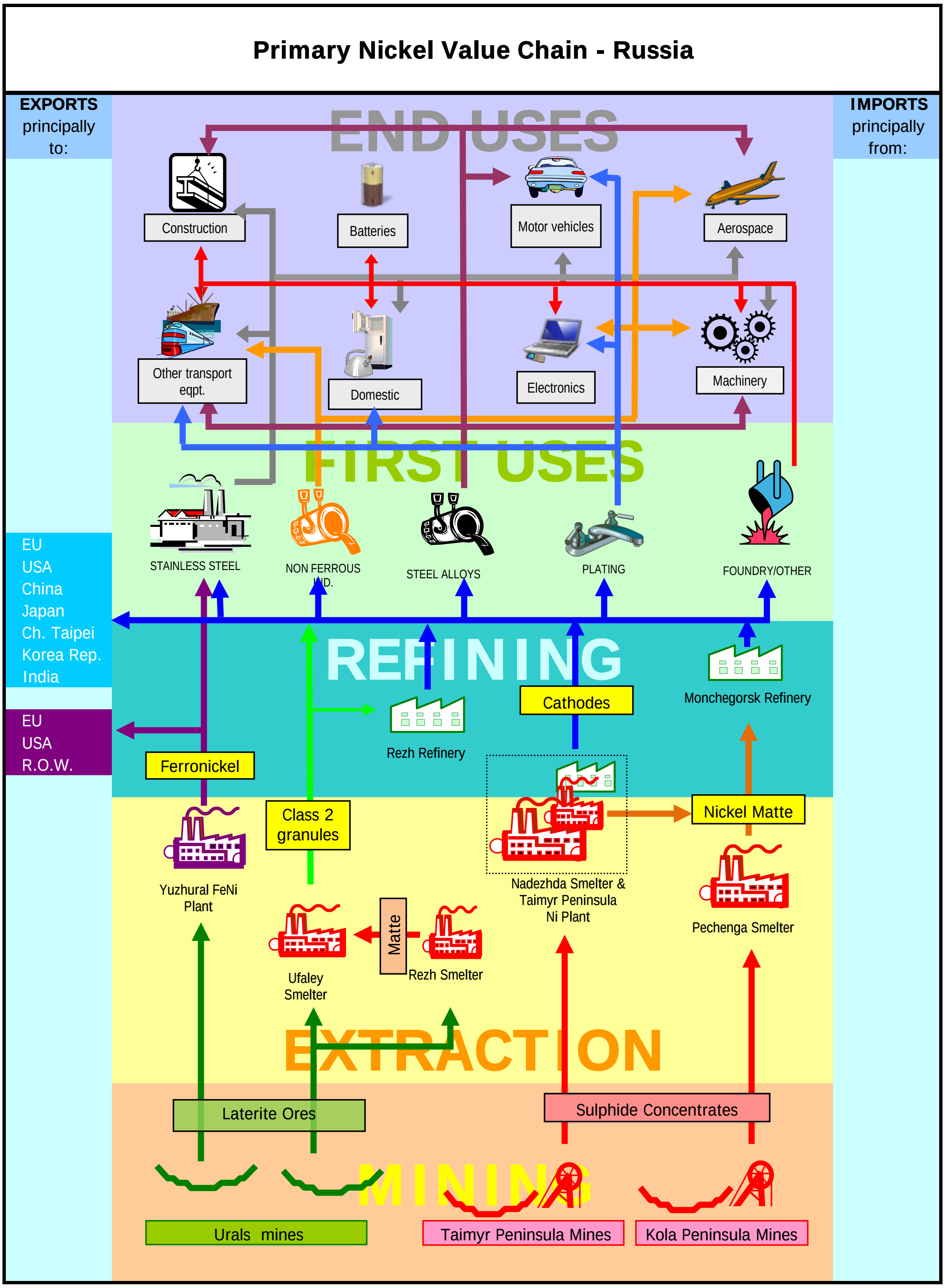
Operations on the Taimyr Peninsula are situated above the Arctic Circle. Six underground mines and one open pit work three distinct deposits, and the ore is enriched at two mills. The Nadezhda Metallurgical Plant near the city of Norilsk nickel produces high-grade matte and copper anodes. A separate Nickel Plant treats nickel concentrate and other feed including some of the matte from Nadezhda, producing finished nickel cathodes and cobalt. The rest of the matte is shipped to the Kola Peninsula via the Yenisei River and the Northern Sea Route.

Nickel sulfide mining and metallurgical operations on the Kola Peninsula, close to the Finnish border, are fully integrated into Russia's transport infrastructure. A complex of mines exploit the deposits of the Pechenga ore field and feed a common concentrator. Copper and nickel concentrates are transferred to the Pechenga smelter for roasting and further processing.

### *Laterite mining and processing*

Russia has several nickel laterite mines in the southern Ural Mountains. The Serovsky mine supplies both the Ufaley and Rezh nickel plants. The Southern Urals Nickel Plant is fed from its own Buruktal and Sakhara mines.

**Figure D.8.1: Primary nickel flows in Russia's nickel value chain**



## Table D.8.1: Primary nickel production and use in Russia

| RUSSIAN FEDERATION | '000 tonnes contained Ni 2007 | 2010 | Notes |
|---|---|---|---|
| **Mine Production** | | | |
| Sulfide concentrate | | | Taimyr and Kola Peninsulas: OP and UG mines |
| Laterite ore | | | Open-pit mines in the southern Ural Mountains |
| **Total** | **288.0** | **270.0** | |
| **Ores and Concentrates Trade** | nil | nil | |
| **Metallurgical Extraction** | | | |
| ***from Sulfides*** | | | |
| Nickel matte | | | Nadezhda and Pechenga smelters |
| ***from laterites*** | | | |
| Granules and Ni oxide | | | Ufaley and Rezh plants |
| Ferronickel | | | Orsk FeNi Plant |
| **Trade in Intermediates** | nil | nil | |
| **Finished Nickel Production**[T] | | | |
| ***from Sulfides*** | | | |
| Cl. 1 Ni cathode | | | Nickel Plant, Taimyr Peninsula |
| Cl. 1 cathode and other forms | | | Monchegorsk Refinery |
| ***from laterites*** | | | |
| Nickel metal, in various forms | | | Ufaley (granules and Ni oxide) & Rezh (refined metal) |
| Cl. 2 ferronickel | | | Orsk FeNi Plant (Mechel Steel) |
| **Total** | **272.0** | **262.3** | |
| **Finished Nickel Trade** | | | |
| Exports, Class 1 nickel | 208.0 | 227.0 | *Chief destinations:* EU, China, USA, Japan, India |
| Exports, Class 2 ferronickel | 11.0 | 9.4 | *Chief destinations:* EU, China, USA, ROW |
| **Primary Nickel Usage** | | | |
| ***First Usage*** | | | |
| Stainless Steel | | | |
| Other Alloy Steels | | | |
| Non-ferrous Alloys | | | |
| Plating | | | |
| Foundry/Other | | | |
| **Total** | **26.0** | **23.0** | |
| ***End Usage*** | | | |
| Engineering, Bldg, Constrn | | | |
| Motor Vehicles | | | |
| Aerospace | | | |
| Other Transport | | | |
| Domestic and Homeware | | | |
| Electronics | | | |
| Machinery & Other | | | |
| **Total** | **33.3** | **30.6** | |
| **Nickel in Stainless Steel end usage** | | | |
| Primary | 12.9 | 12.8 | |
| Scrap | 4.7 | 4.7 | |
| **Total** | **17.6** | **17.5** | |

[T] Major product forms

## *Primary nickel production*

The Nickel Plant on the Taimyr Peninsula in the city of Norilsk produces refined nickel cathode directly from matte. The matte shipped from Nadezhda and additional feed smelted at Pechenga is refined at a plant near the city of Monchegorsk The main nickel product of the Monchegorsk refinery is nickel cathodes.

The rest of Russian finished nickel production comes from the processing of laterite ore in the Urals, into ferronickel and nickel metal.

The Southern Urals Nickel Plant located in the city of Orsk (Orenburg region), can produce up to 17.5kt per year of nickel in low-iron ferronickel.

Another plant at Verkhniy Ufaley in the Chelyabinsk region has a rated capacity of 15kt per year. The plant smelts ore in shaft furnaces to produce a matte which after conversion in a Bessemer furnace is processed to obtain nickel oxide. This is finally reduced to metal granules in electric furnaces and some is delivered to the Rezh plant for refining to ingot metal. Output is exported to Europe, the USA, China, India and Japan.

The 9ktpy Rezh smelter in the Sverdlov region smelts ore in shaft furnaces to matte which is then transferred to the Ufaley plant for processing to metal granules. The plant also refines some granules from Ufaley to metal.

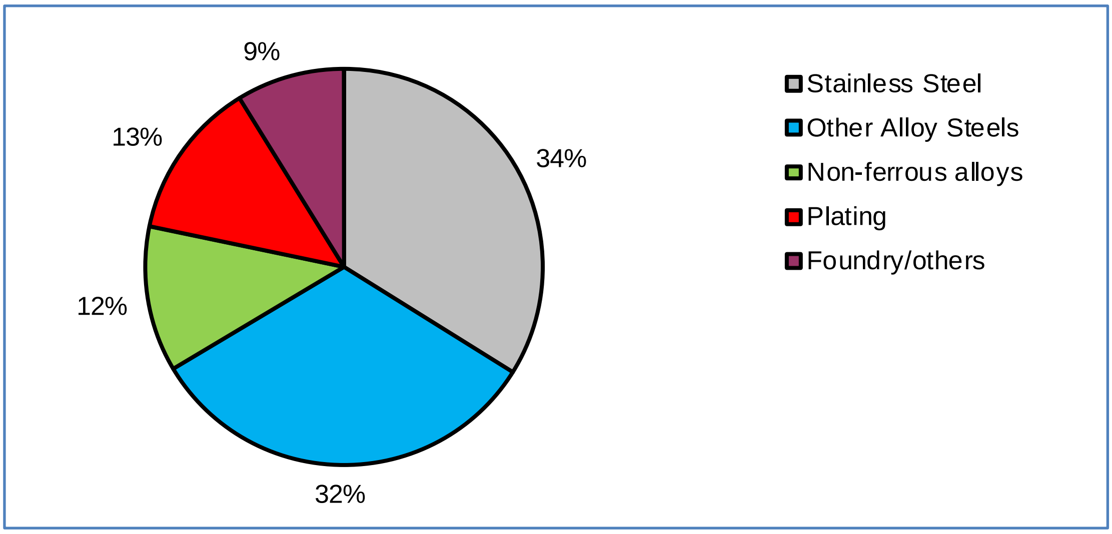
**Table D.8.2: Output values for primary nickel production in Russia in 2007**

| Sector | Products | Value, 2007$USm |
|---|---|---|
| Sulfide mining, concentrating and smelting | Nickel matte for further processing | $6,639 |
| Laterite mining | Laterite smelter feed | $308 |
| Finished primary nickel production from sulfide matte refining | Nickel as cathode and other forms for domestic sale and export | $8,148 |
| Laterite smelting to produce ferronickel | Ferronickel for domestic sale and export | $602 |
| Laterite processing for Class 1 and 2 nickel | Nickel in granules, ingots and oxide | $595 |

## *First and end usage*

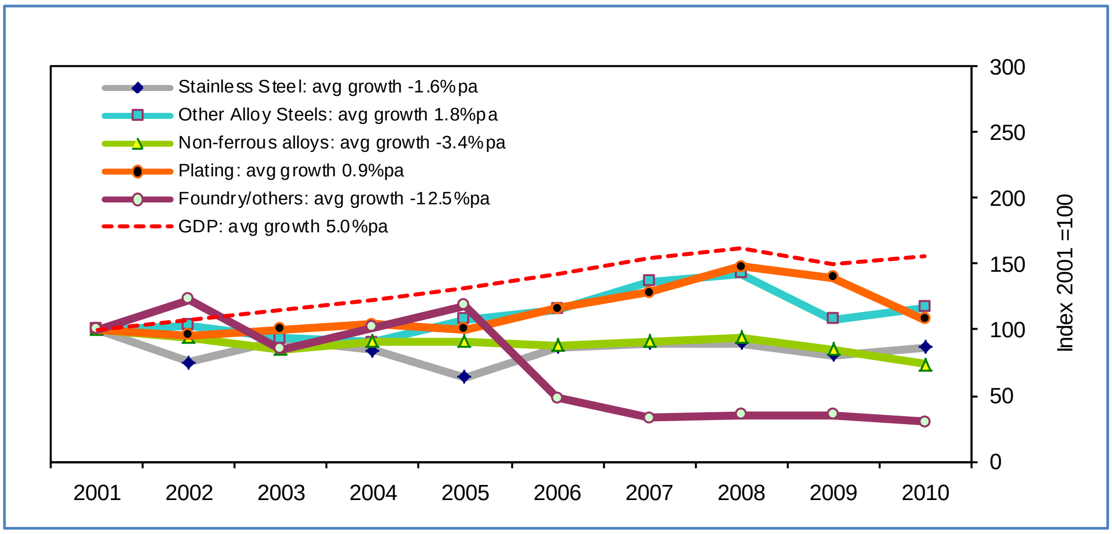
On average over the period 2006-10, around 34% of Russia's first usage of primary nickel was by stainless steel producers (Figure D.8.2). Figure D.8.3 shows growth in Russia's first uses over the last decade. In sectors other than stainless steel, usage is spread over a myriad of small and a few medium-scale shops generally operating in local markets.

#### Figure D.8.2: Nickel First Use sectors (2006-10 average): Russia




*Source: Modified Pariser data*

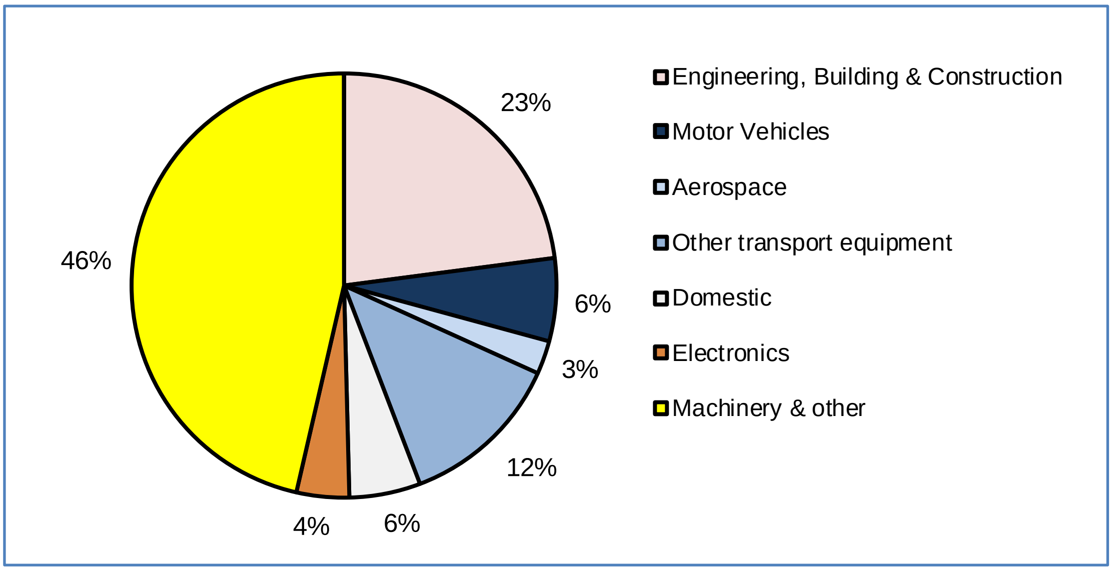
#### Figure D.8.3: First use of primary nickel – growth in Russia, 2001-2010




*Source: Metalytics; modified Pariser data*

The Federation's primary nickel end use is estimated to have totalled 30.6kt in 2010. The 46% share devoted to the 'Machinery & Other' category is the largest share for this category of any of the Target Economies or of the European Union, reflecting the importance of the Engineering industry sector in the Russian economy.

Figure D.8.4: Russia's primary nickel end-use pattern in 2010




*Source: Modified Pariser data*

## *Nickel chain's share of GDP*

In aggregate, nickel mining, primary processing and first use are estimated to contribute 0.53% to the Gross Domestic Product of the Russian Federation. This is around 1.45% of the estimated industry share of GDP, valued at US$7.8 billion in 2010. The nickel producing industry is a significant exporter for the Russian economy, and the role of the industry in the remote communities where mining takes place goes far beyond that of providing employment and local wealth. It indirectly supports the enormous Russian oil and gas industry through nickel-containing pipelines, plant and equipment. Nickel also plays a strategic role in the Russian defence and aerospace industries.

## *Baseline forecast*

Russia's primary nickel production is dominated by sulfide mining, smelting and refining, and these operations are expected to grow slowly in the period to 2020. First and end uses are forecast to expand more in line with industrial growth, at CAGRs of 4.0% and 3.5% respectively.

# 9. Chinese Taipei

## *Overview*

Chinese Taipei is a major end-user of primary nickel, and ranks fifth in the world in first usage of the metal. It has no nickel mining industry, and a single plant produces finished nickel from imported feedstocks. The flow chart in Figure D.9.2 schematically illustrates the primary nickel flows in Chinese Taipei's economy. Table D.9.1 lists tonnage data for 2007, the base year for modelling and industry forecasts, and for 2010.

## *Resources and mining*

Chinese Taipei has no reported nickel reserves or resources, and no current or planned nickel mining activity.

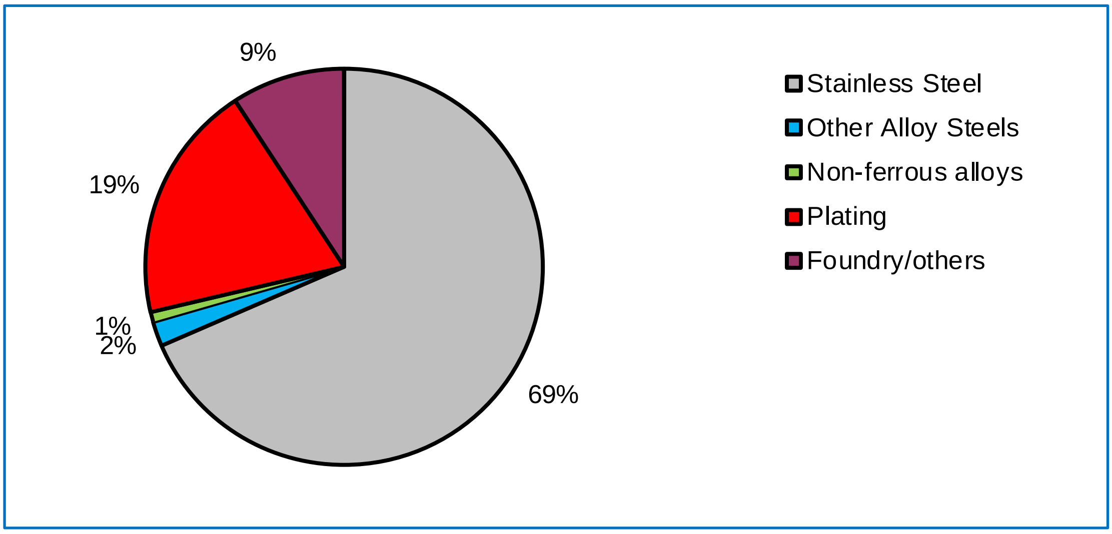
## *Primary nickel production*

A refinery at Kaohsiung refines nickel oxide sinter feed imported chiefly from Canada, Australia and Japan to produce "utility nickel" containing a minimum 97% nickel in shot form. Because this plant essentially upgrades nickel products from other facilities, its output is, by convention, not included in global primary nickel production totals to avoid double counting. (A similar convention applies in respect of output from the Onsan refinery in the Republic of Korea.)

## *First usage*

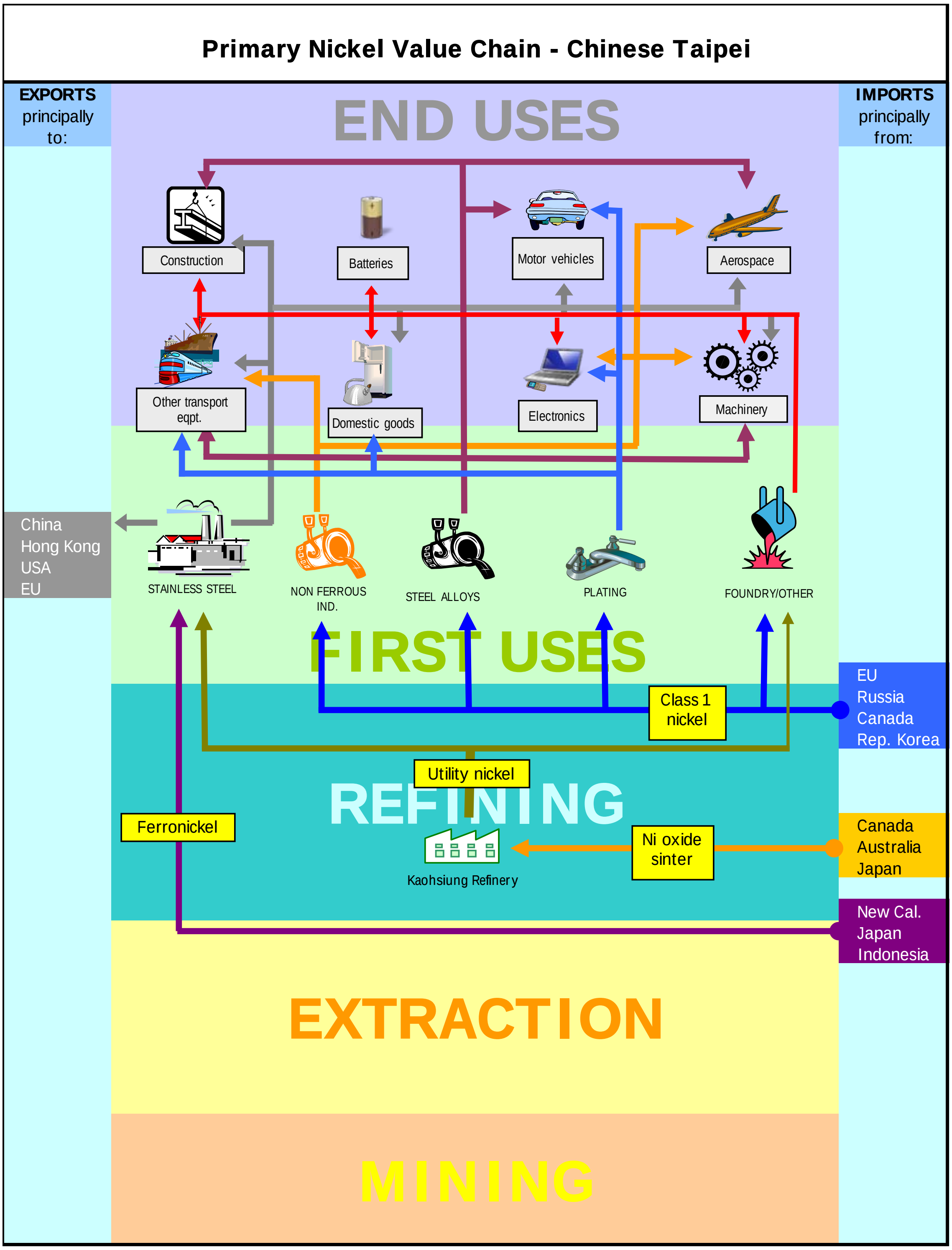
On average over the period 2005-09, 64% of nickel first usage in Chinese Taipei was by stainless steel producers, consuming domestically-produced utility nickel as well as ferronickel imported principally from New Caledonia, Japan and Indonesia. Most of the stainless steel production is exported, mainly to China, Hong Kong and other Asia/Pacific destinations. Figure 8.1 illustrates the average shares of the principal first-use sectors in 2006-10, and volume growth rates for the period 2001 to 2010.

**Figure D.9.1: Nickel First Use sectors (2006-10 average): Chinese Taipei**




*Source: Modified Pariser data*

## Figure D.9.2: Primary nickel flows in Chinese Taipei's nickel value chain

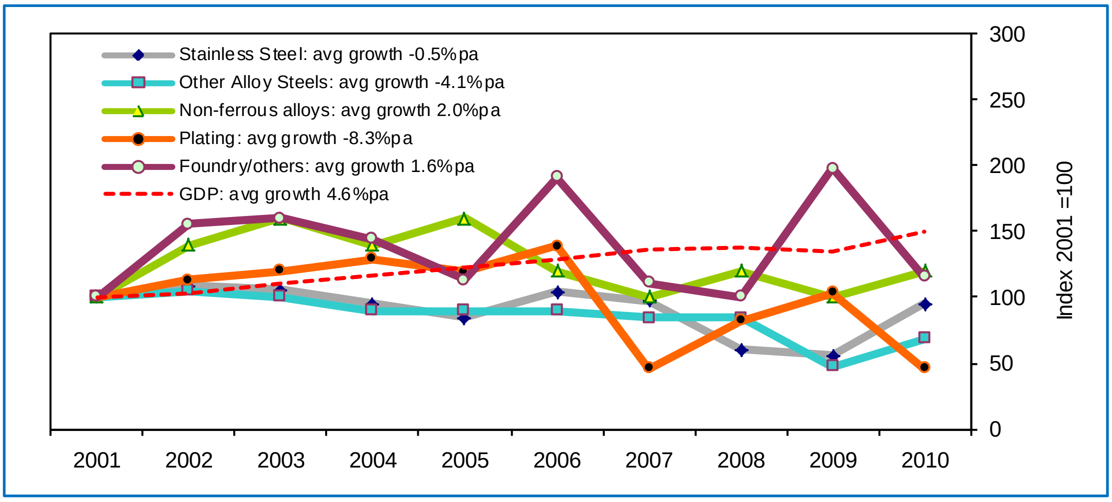


### Table D.9.1: Primary nickel production and use in Chinese Taipei

| CHINESE TAIPEI | '000 tonnes contained Ni 2007 | 2010 | Notes |
|---|---|---|---|
| **Mine Production** | | | |
| Sulfide concentrate | nil | nil | |
| Laterite ore | nil | nil | |
| **Ores and Concentrates Trade** | | | |
| Laterite ore imports | nil | nil | |
| **Metallurgical Extraction** | | | |
| ***from Sulfides*** | nil | nil | |
| ***from laterites*** | nil | nil | |
| **Trade in Intermediates** | | | |
| | nil | nil | |
| **Finished Nickel Production**[†] | | | |
| ***from further refining of imported oxide sinter*** | | | |
| Cl. 2 Utility nickel [‡] | 11.0 | 11.0 | (reduction furnace) |
| ***from laterites*** | nil | nil | |
| **Total** | **11.0** | **11.0** | |
| **Finished Nickel Trade** | | | |
| Imports, oxide sinter | 18.2 | 15.4 | *Chief origins:* Canada, Australia, Japan |
| Imports, ferronickel | 21.4 | 24.2 | *Chief origins:* New Caledonia, Japan |
| Imports, Class 1 nickel | 29.0 | 23.7 | *Chief origins:* EU, Russia, Canada, Korea, Australia |
| **Primary Nickel Usage** | | | |
| ***First Usage*** | | | |
| Stainless Steel | 56.5 | 55.2 | |
| Other Alloy Steels | 1.6 | 1.3 | |
| Non-ferrous Alloys | 0.5 | 0.6 | |
| Plating | 7.5 | 7.5 | |
| Foundry/Other | 5.0 | 5.2 | |
| **Total** | **71.1** | **69.8** | |
| ***End Usage*** | | | |
| Engineering, Bldg, Constrn | 12.6 | 15.2 | |
| Motor Vehicles | 6.6 | 8.2 | |
| Aerospace | 0.3 | 0.2 | |
| Other Transport | 1.9 | 2.2 | |
| Domestic and Homeware | 10.6 | 13.0 | |
| Electronics | 3.6 | 4.2 | |
| Machinery & Other | 9.6 | 10.9 | |
| **Total** | **45.2** | **54.0** | |
| **Nickel in Stainless Steel end usage** | | | |
| Primary | 19.9 | 25.1 | |
| Scrap | 12.5 | 15.4 | |
| **Total** | **32.4** | **40.5** | |

[†] Major product forms
[‡] Production not included in global totals to avoid double counting

**Figure D.9.3: First use of primary nickel – growth in Chinese Taipei, 2001-2010**

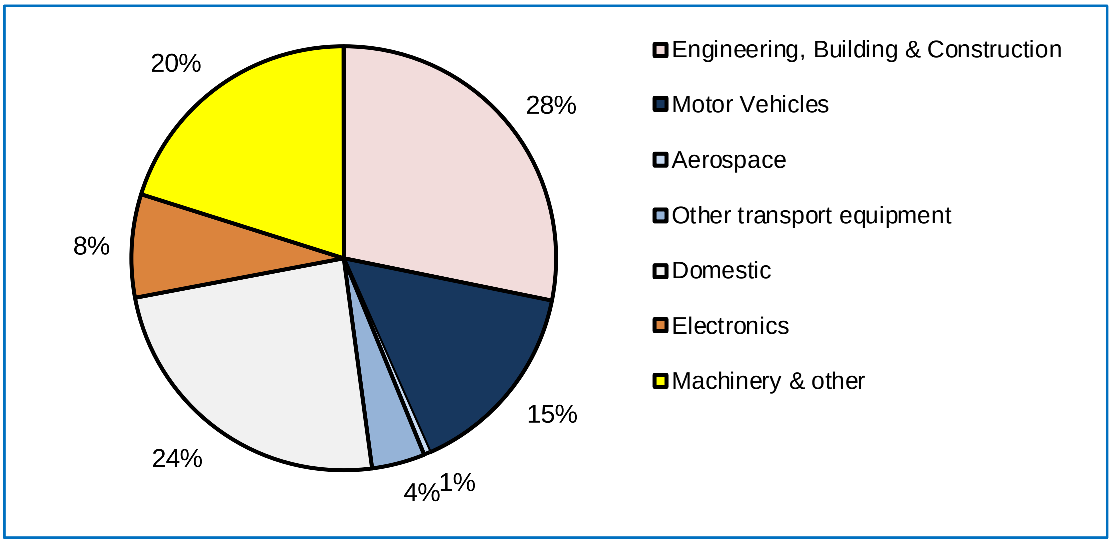



*Source: Metalytics; modified Pariser data*

## *End usage*

With a total of 54kt in 2010, Chinese Taipei ranks as the fifth largest of the Target Economies in terms of primary nickel end use. The usage pattern is similar to that of most industrialised economies in that 'Engineering, Building & Construction' is the largest sector.

**Figure D.9.4: Chinese Taipei's primary nickel end-use pattern in 2010**




*Source: Modified Pariser data*

### *Nickel chain's share of GDP*

Nickel processing and first use is estimated to contribute 0.44% of the Gross Domestic Product of Chinese Taipei. This was equivalent to about US$1.9 billion in 2010, representing 1.4% of industry's share of GDP.

### *Baseline forecast*

Chinese Taipei is forecast to maintain finished nickel production at around its current level in the period to 2020. First usage varies strongly with the austenitic ratio of stainless steel production.

# 10. The United States

### *Overview*

The United States is one of APEC's largest users of primary nickel, behind China and Japan. Currently there is no significant primary nickel production, although limited amounts of by-product nickel are recovered from the processing of ores from platinum-palladium and copper mines.

Primary nickel flows in the US value chain are depicted schematically in Figure D.10.1, with tonnage data for 2007 and 2010 listed in Table D.10.1.

### *Resources and mining*

Although the US possesses the seventh largest in-ground sulfide nickel resource in the world, it has hosted no nickel mining activity since laterite open pit operations ceased at Nickel Mountain, Oregon, in 1995 after known resources there were exhausted. However, a new underground mine is currently under construction at the Eagle nickel and copper sulfide deposit in Michigan, where production is scheduled to begin in 2014. Annual output at the site will be approximately 16kt of nickel and 10kt of copper in separate concentrates, which will most likely be exported across the Great Lakes to Canada for processing.

### *Primary nickel production*

There has been no production of finished primary nickel in the USA since 1998, when a ferronickel plant at Riddle, Oregon (which had been processing saprolite ore imported from New Caledonia) was finally shut down, though small annual tonnages (531kg in 2007) of nickel in nickel sulfate are recovered as a by-product from platinum-group metal operations in Montana.

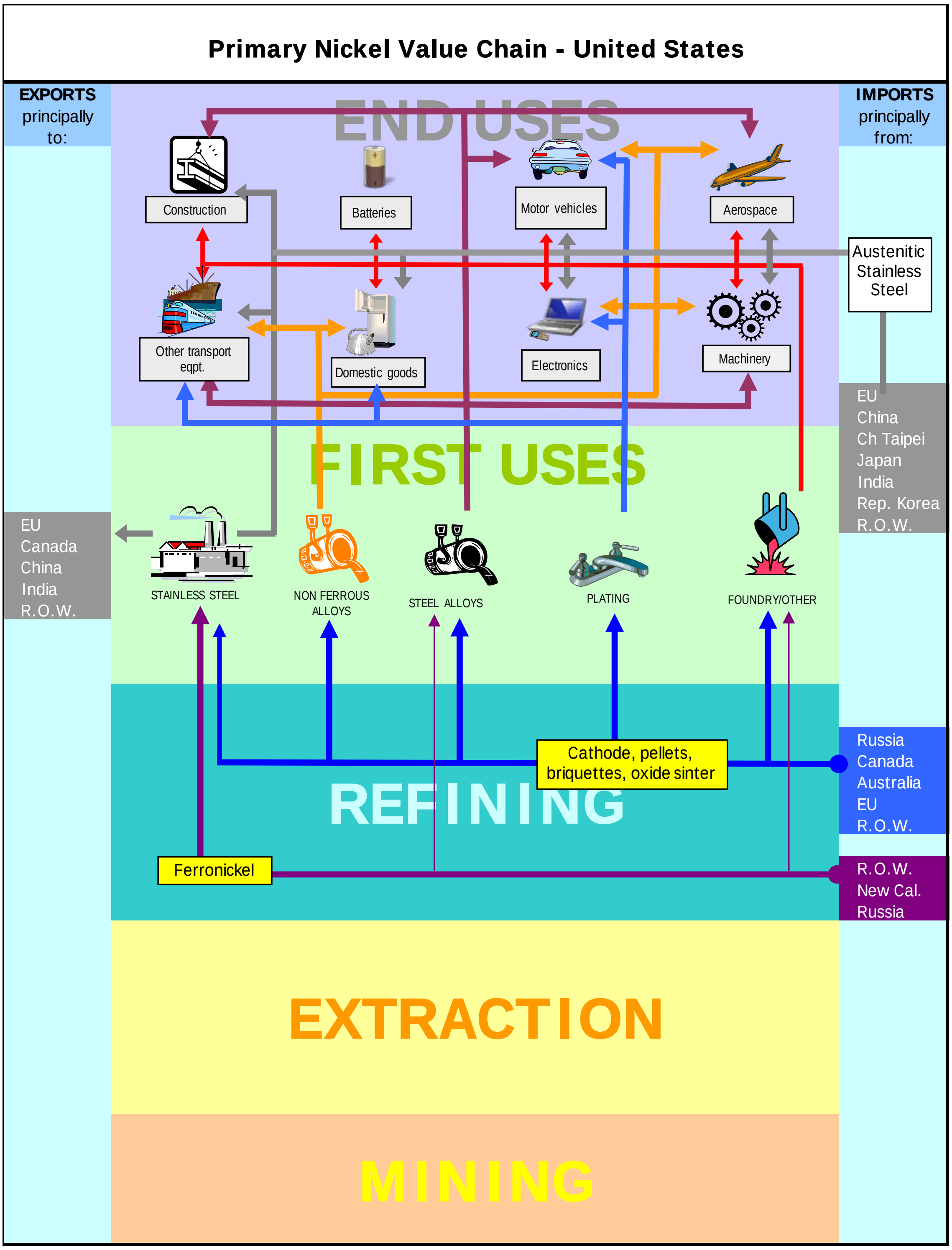
### *First and end usage*

In 2010, the USA imported 147kt of nickel to feed its first-use industries. The vast bulk of this was in the form of Class 1 products from Canada, Russia, Australia, Norway and the EU. About 20% of imports were as ferronickel, mainly from Colombia, the Dominican Republic, New Caledonia and Russia.

The USA's primary nickel usage profile is unusual in that offtake into non-ferrous alloys and stainless steel are virtually equal (Table D.10.2). Over the five years to 2010, only 40% of the economy's first usage was by stainless-steel producers, compared with a world average of 63%.

As shown in Table D.10.1, end use of primary nickel in 2010 is estimated at 119kt. The end-use pattern in the USA is also unusual in comparison with other economies because of the relatively low share (21% in 2010) commanded by 'Engineering, Building & Construction' and the unique importance of the 'Aerospace' sector (16%) with its implications for non-ferrous alloy first-use demand.

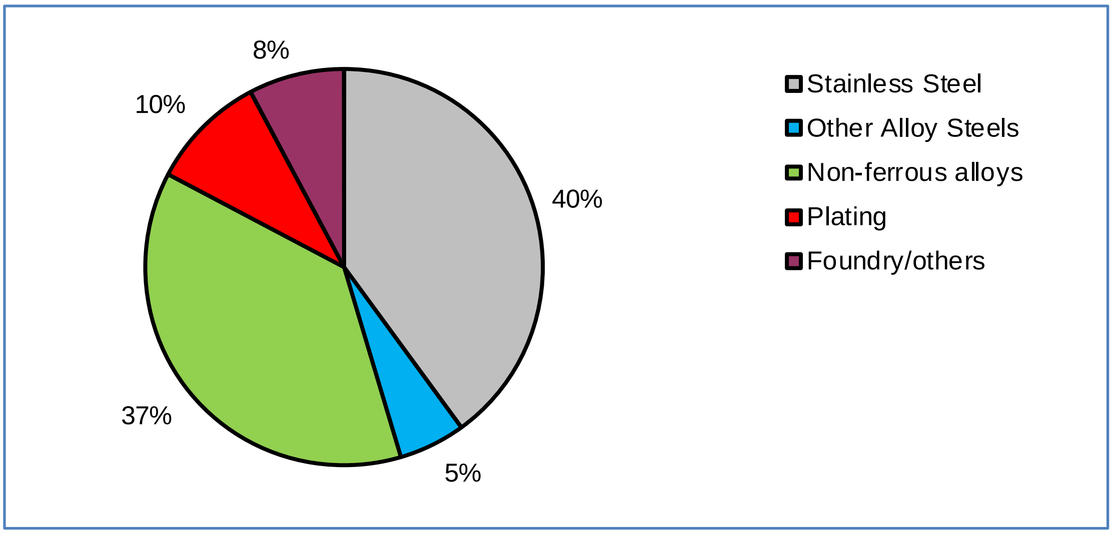
**Figure D.10.1: Primary nickel flows in the United States' nickel value chain**



## Table D.10.1: Primary nickel production and use in the USA

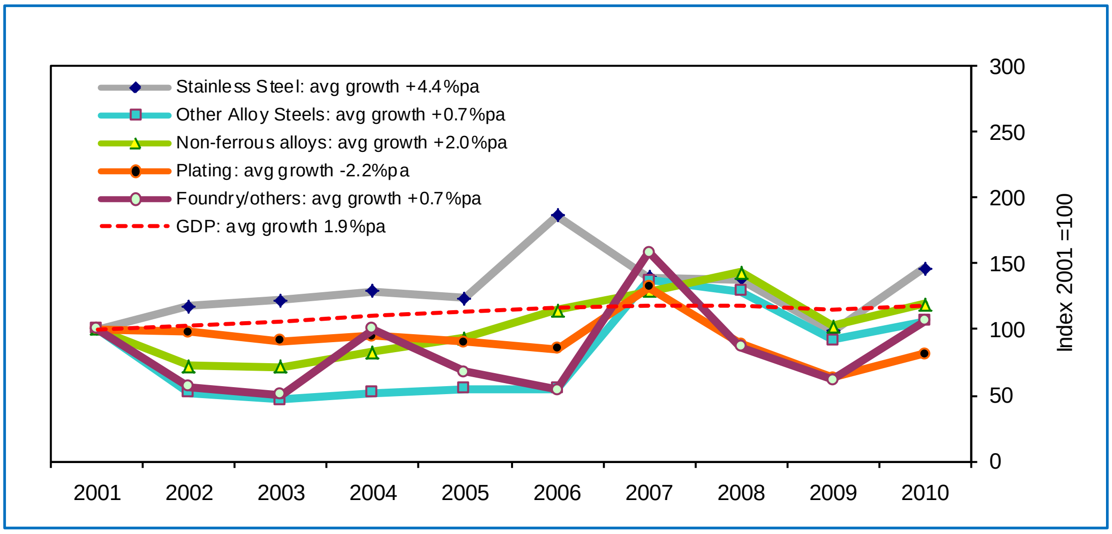
| UNITED STATES | '000 tonnes contained Ni 2007 | 2010 | Notes |
|---|---|---|---|
| **Mine Production** | | | |
| Sulfide concentrate | nil | nil | Eagle Mine to start up in 2013 |
| Laterite ore | nil | nil | |
| **Ores and Concentrates Trade** | nil | nil | |
| **Metallurgical Extraction** | | | |
| ***from Sulfides*** | nil | nil | |
| ***from laterites*** | nil | nil | |
| **Trade in Intermediates** | nil | nil | |
| **Finished Nickel Production** | nil | nil | |
| **Finished Nickel Trade** | | | |
| Imports, Class 1 nickel | 111.4 | 116.5 | *Chief origins:* Canada, Russia, Australia, Europe |
| Imports, Class 2 ferronickel | 22.6 | 30.2 | *Chief origins:* Colombia, Dom. Rep., New Caledonia |
| **Primary Nickel Usage** | | | |
| ***First Usage*** | | | |
| Stainless Steel | 46.8 | 49.2 | |
| Other Alloy Steels | 8.5 | 6.6 | |
| Non-ferrous Alloys | 47.1 | 43.5 | |
| Plating | 16.5 | 10.2 | |
| Foundry/Other | 15.7 | 10.5 | |
| **Total** | **134.6** | **120.0** | |
| ***End Usage*** | | | |
| Engineering, Bldg, Constrn | 27.0 | 24.6 | |
| Motor Vehicles | 15.9 | 9.3 | |
| Aerospace | 23.7 | 19.8 | |
| Other Transport | 9.0 | 9.8 | |
| Domestic and Homeware | 6.9 | 5.5 | |
| Electronics | 11.2 | 6.6 | |
| Machinery & Other | 48.6 | 43.7 | |
| **Total** | **142.3** | **119.3** | |
| **Nickel in Stainless Steel end usage** | | | |
| Primary | 65.3 | 60.6 | |
| Scrap | 73.1 | 81.2 | |
| **Total** | **138.4** | **141.8** | |

**Figure D.10.2: Nickel First Use sectors (2006-10 average): United States**




*Source: Modified Pariser data*

**Figure D.10.3: First Usage of primary nickel – growth in the USA, 2001-2010**

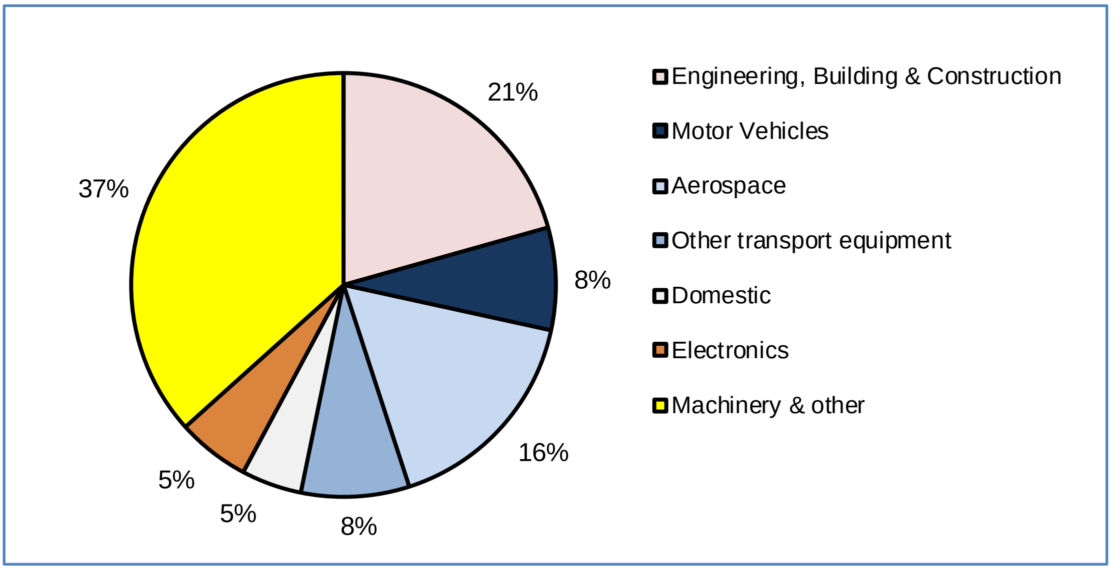



*Source: Metalytics; modified Pariser data*

## *Nickel chain's share of GDP*

Nickel first use is estimated to contribute 0.02% to the Gross Domestic Product of the United States. This is 0.09% of industry's share of GSP, valued at US$2.9 billion in 2010. As implied by the ranking of the United States in first use nickel consumption, these figures must be understood in terms of the size of the US economy, and the strategic applications for which much of the nickel is used. The United States is the world's leader in the production of high performance nickel-based superalloys. Its economy's large aerospace and defence industries are highly dependent on nickel, and in the past the US government carried a strategic stockpile of nickel metal, such was its importance.

**Figure D.10.3: US primary nickel end-use pattern in 2010**




*Source: Modified Pariser data*

## *Baseline forecast*

The USA will remain a significant importer of primary nickel throughout the period to 2020, with its first usage expected to expand with a CAGR of around 1.5%. Following recovery from the global economic slowdown of recent years, the baseline forecast has US stainless steel output regaining 2006 levels in 2013 and then rising slowly at around 1.5% per year until 2020. Long-term growth in US primary nickel usage will chiefly be driven by the non-stainless applications, particularly demand for high performance alloys.

# **Appendix E –** Nickel-containing chemicals classifications and Management Regulations in Target Economies

**Table E.1 Classification of nickel-containing chemicals in target economies relative to EU**

| Nickel-containing chemical | Target Economy | | AUS | CDA | PRC | INA | JPN | ROK | RP | RUS | CT | USA | Substance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Use of substance | EU Carc Cat.* | Classification relative to EU classification (**L**ess, **M**ore, **E**qually stringent)** | | | | | | | | | | |
| Nickel dichloride | Catalysts; industrial masks; electroplating | 1A | E | E | E | L / OH&S | E | L / OH&S | E | E | L / OH&S | E | Nickel dichloride |
| Nickel sulfamate | Nickel plating | 1A | L / OH&S | E | E | L / OH&S | E | L / OH&S | E | E | L / OH&S | E | Nickel sulfamate |
| Nickel sulfate | Nickel plating | 1A | E | E | E | L / OH&S | E | E | E | E | L / OH&S | E | Nickel sulfate |
| Slimes & sludges | By-product of copper electrolytic refining | 1A | L / OH&S | E | L / Trans OH&S | L / Trans OH&S | L / OH&S | L / OH&S | L / Trans OH&S | E | L / OH&S | E | Slimes & sludges |
| Nickel matte§ | [Intermediate product] Nickel refining | 1A | L (unlisted) / OH&S | E | L (unlisted) / Trans OH&S | L (unlisted) / Trans OH&S | L (unlisted) / OH&S | L | L (unlisted) / Trans OH&S | E | L (unlisted) | E | Nickel matte§ |
| Nickel sulfide† | Catalysts and catalyst production | 1A | E | E | L Trans / OH&S | E | E | E | L / Trans OH&S | E | L | E | Nickel sulfide† |
| Trinickel disulfide / nickel subsulfide‡ | Catalysts and catalyst production | 1A | E | E | E | E | E | E | E | E | M | E | Trinickel disulfide / nickel subsulfide‡ |
| Oxides of nickel | Alloys, catalysts; powders; ceramics; pigments | 1A | E | E | E | E | E | E | E | E | L / OH&S | E | Oxides of nickel |

| Nickel-containing chemical | Target Economy | | AUS | CDA | PRC | INA | JPN | ROK | RP | RUS | CT | USA | Substance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Use of substance | EU Carc Cat.* | Classification relative to EU classification (Less, More, Equally stringent)** | | | | | | | | | | |
| Nickel hydroxide | Rechargeable batteries; catalysts | 1A | L | E | E | E | E | L / OH&S | E | E | L / OH&S | E | Nickel hydroxide |
| Nickel carbonate | Powders, chemicals; catalysts; plating; pigments | 1A | L / OH&S | E | E | E | E | L / OH&S | E | E | L / OH&S | E | Nickel carbonate |
| Nickel hydroxy-carbonate | Nickel powder; salts, chemicals, catalysts; plating | 1A | L (unlisted) / OH&S | E | E | E | E | L (unlisted) / Trans OH&S | E | E | L / OH&S | E | Nickel hydroxyl-carbonate |

*Source: Frontier Economics analysis*

* Commission Regulation (EC) N° 790/2009 amending Regulation (EC) N°1272/2008 of the European Parliament and of the Council on classification, labelling and packaging of substances and mixtures. (First ATP to the CLP Regulation)

** In the Target Economy columns: L, M and E indicate whether the economy's classification of the relevant substance is less stringent (L), more stringent (M) or equivalent (E) to the EU classification. Yellow-shaded cells for a particular Target Economy identify cases in which a substance is classified less stringently than in the EU and where the main nickel-chain uses of the substance in that particular Target Economy are significant activities. The "L" indicates that the relevant substance is classified less stringently in the Target Economy than in the EU, and the cell also flags the nature of the cost impacts (OH&S-related, transport-related, or consumer-related) expected to be triggered by the Target Economy's adoption of the EU classifications.

§ Nickel matte is a mixture of non-stoichiometric nickel-bearing sulfide and metal-alloy phases that is formed when nickel sulfide concentrates are smelted.

† Nickel sulfide (NiS) occurs in nature as the mineral *millerite*.

‡ Nickel subsulfide ($Ni_3S_2$) occurs in nature as the mineral *heazlewoodite*.

### Box E.1: Notes to Table E.1

| | |
|---|---|
| AUS | Nickel-bearing chemicals are currently classified in Australia under the Safe Work Australia Hazardous Substances Information System (HSIS), though stricter, GHS-aligned Model Work Health and Safety (WHS) Regulations are under consideration by Commonwealth, State and Territory OHS authorities. If adopted, this would align the Australian classification closely with that of the EU. |
| CDA | Under Section 54 of the Controlled Product Regulations of Canada, a substance is considered poisonous if deemed to be a Group 1 or Group 2 carcinogen under IARC or if listed as a carcinogen in Appendix A, section A1a, A1b or A2 o1f the ACGIH rules. As a result, all the listed nickel chemicals are classified as Cat1A carcinogens. |
| PRC | Analysis is based on the web version of the Inventory of Existing Chemical Substances China. For nickel chemicals listed in that database, an equivalent classification to the EU is assigned, though this may not always be correct (for example if the substance is included in the Inventory for reasons other than carcinogenicity). If a nickel substance is not found in the database, it has been assessed as classified less stringently than in the EU. |
| INA | Nickel oxides, carbonates and sulfides in powdered form are all considered highly toxic under the Ministry of Manpower Decree N°187/MEN/1999 in Indonesia; these are assigned as currently having equally stringent classification in Indonesia and the EU. Other nickel chemicals are assessed as less stringently classified. Adoption of GHS-based classifications under Regulation of the Minister of Industry N°87/M-IND/PER/9/2009 is pending but not yet implemented. |
| JPN | Nickel chemicals that are declared as 'Specified Class I' substances in the Chemical Risk Information Platform of Japan's National Institute of Technology and Evaluation are considered here to have an equivalent classification to Cat1A carcinogens in the EU. Nickel chemicals without this rating are assessed as having a lower rating. This is corroborated by the Japanese Pollution Release and Transfer Register's citation of nickel and nickel –containing chemicals in carcinogenicity Class 2 and Class 1, respectively. |
| ROK | The data source for Korea is the Toxic Chemicals database produced by the National Institute of Environmental Research, but it is not clear whether individual nickel chemicals have been classified as toxic because of carcinogenicity or other factors. Nickel-containing chemicals listed in the database are deemed here to be considered Cat1A carcinogens, and those not listed to be classified less stringently than in the EU. Data from the Korean Center for Chemical Safety Management corroborate this assessment. |
| RP | Nickel chemicals listed on the Philippines Inventory of Chemicals and Chemical Substances (PICCS, updated in 2007) are assessed as having equal classification to the EU. Nickel chemicals not on the list are assumed to be classified less stringently. The Philippines has yet to adopt a GHS-aligned classification. [There is a Table 8d: Human carcinogens: Recognized to have carcinogenic potentials referred to in Rule 1073 of the Occupational Health and Safety Standards as amended, but the table has not been found. This table would be more useful than the PICCS database.] |
| RUS | Data were sourced from the Russian System of Chemicals Management and the draft Russian Federal Law on Technical Regulations concerning Chemical Safety. GOST R 53856-2010 Hazard Classification of Chemicals, the Russian regulation for classification of chemicals, has the same classification rules for carcinogenicity as the UN GHS, but although its labelling and hazard communications regulations are mandatory, compliance with the carcinogenicity classification system appears still to be voluntary. However, Russia's current occupational exposure limits (0.05 $mg/m^3$) are tighter than in most EU economies. On the basis of this information, the carcinogenic classifications of most nickel-containing chemicals are assessed as the same as (or stricter than) in the EU. |
| CT | In Chinese Taipei, only nickel tetracarbonyl and trinickel disulfide (nickel subsulfide) are classified as toxic under the Handling Management Including Restricted Uses for Toxic Chemical Substances Such as Polychlorinated Biphenyls regulation as announced in the List of 161 Regulatory Control Numbers, and trinickel disulfide is commercially prohibited. A new GHS-aligned set of regulations and classifications relating to the "labelling and hazard communication of dangerous and harmful substances" is currently being prepared in Chinese Taipei, but because these are not yet publicly available, all other nickel chemicals are assessed here as classified less stringently than in the EU. |
| USA | Under the existing Hazard Communication Standard in the United States, a chemical is considered to be a carcinogen if it is found to be so by the International Agency for Research on Cancer (IARC), the National Toxicology Program (NTP) or if it is listed in 29 CFR 1910, Subpart Z, Toxic and Hazardous Substances, by OSHA. The NTP's Report on Carcinogens (12th ed., 2011) lists nickel chemicals as known to be human carcinogens (although not in a substance-specific manner or with substance-specific hazard categories) and nickel metal as reasonably anticipated to be a human carcinogen. This classification of nickel metal equates with the EU's 1B carcinogenic rating (i.e. stricter than Cat2). |

## Table E.2. Overview of chemicals management regulations

| Economy | OH&S regulations | chemicals management regulations | Transport regulations | Environmental regulations | Consumer protection regulations | GHS Adoption Status |
|---|---|---|---|---|---|---|
| AUS | National Exposure Standards for Atmospheric Contaminants [NOHSC:1003(1995)]<br>National Standard for Storage & Handling of Dangerous Goods (NOHSC: 1015(2001)<br>Code of Practice: Preparation of Safety Data Sheets for Hazardous Chemicals<br>** Final Model Work Health and Safety Regulations (Nov 2011) | Criteria for Classifying Hazardous Substances [NOHSC:1008(2004)] to be replaced by WHS Regulations from 1 Jan 2012 | Code for Transport of Dangerous Goods by Road and Rail (ADG Code 7th edition) | Drinking Water Guidelines 6 (2011)<br>National Environment Protection Council Act (1994) | Competition and Consumer Act 2010 | To commence 1 Jan 1st 2012<br>Deadline for substances (as of 31 Mar 2011) is 2 years after commencement, or by 1 Jan 2013 |
| CDA | Labour Code<br>OH&S Regulations (separate regulations for Maritime, Oil and Gas, On Board Trains, and Aviation) | Hazardous Products Act (II) (1985)<br>Controlled Products Regulations SOR/88-66<br>Hazardous Materials Information Review Act<br>Workplace Hazardous Material Information System (WHMIS)<br>Domestic Substances List | Transportation of Dangerous Goods Act (1992)<br>Shipping Act 2001 and associated Regulations for Prevention of Pollution from Ships and for Dangerous Chemicals | Environmental Protection Act (1999) | Consumer Product Safety Act<br>Consumer Chemicals and Containers Regulations (2001) | Unclear when final recommendations for GHS implementation under WHMIS will be released<br>Implemented for transport |

| Economy | OH&S regulations | chemicals management regulations | Transport regulations | Environmental regulations | Consumer protection regulations | GHS Adoption Status |
|---|---|---|---|---|---|---|
| PRC | Labour Law (1994)<br>Prevention and Control of Occupational Diseases (President Order No. 60) (2001)<br>Labour Protection Where Toxic Substances are Used (2002) | Safe Management of Hazardous Chemicals in China (Decree 591,1 Dec 2011)<br>Safety Rules for Classification, Precautionary Labelling and Statements of Chemicals [GB 20576 ~ GB 20602 (2006)]<br>Classification and Hazard Communication of Chemicals [GB 13690 (2009)]<br>Preparation of Precautionary Labelling for Chemicals [GB 15258 (2009)]<br>Preparation of MSDS [GB 16483:2002] | General Specifications for Transport of Dangerous Goods (Packages) (GB12463-90)<br>Regulations on Safe Management of Hazardous Chemicals (Decree No. 591, 2011)<br>Measures for Administration of Licenses for Purchase and Road Transportation of Highly Toxic Chemicals (2005) | Measures on Environmental Administration of New Chemical Substances (2010)<br>Prevention and Control of Water Pollution (amended 2008) | Protection of Consumer Rights and Interests (1993) | GHS implementation in progress, classification criteria in place (standards may be updated to align with UN GHS Rev. 3), regulations in place. |

| Economy | OH&S regulations | Toxic chemicals regulations | Transport regulations | Environmental regulations | Consumer protection regulations | GHS Adoption Status |
|---|---|---|---|---|---|---|
| INA | Control of Hazardous Chemicals (Decree 187/MEN/1999)<br>Safety Management of Toxic and Hazardous Substances (Decree 148/M/SK/1985)<br>Import and Distribution of Specific Hazardous Substances (Decree 254/MPP/KEP/7/2000)<br>Data on Dangerous Substances (Decree KEP-612/MEN/1989) | GHS Classification and Labelling of Chemicals (Decree 87/M-IND/PER/9/2009)<br>ACGIH carc. classifications (Letter SE-01/MEN/1997)<br>Management of Hazardous and Toxic substances (Regulation 74/2001)<br>Safety of Hazardous Substances for Human Health (Decree 472/1996) | Hazardous Substances Handling in Maritime Operations (Decree 17/2000)<br>Land Transport Classifications (Decree 41/1993)<br>Land Transport of Substance (Decree 69/1993)<br>Transport of Hazardous and Toxic Substances on Road (Decree. SK.725.AJ.302/DRJD/2004) | Management of Hazardous and Toxic Substances (Regulation 74/2001)<br>Safety of Hazardous Substances for Human Health (Decree 472/1996) | Law No. 8 on Consumer Protection (1999) | Regulation of the Minister of Industry 87/M-IND/PER/9/2009 regarding GHS Classification and Labelling of Chemicals entered into force in March 2010. |

| Economy | OH&S regulations | chemicals management regulations | Transport regulations | Environmental regulations | Consumer protection regulations | GHS Adoption Status |
|---|---|---|---|---|---|---|
| JPN | Industrial Safety and Health Law<br>Society for Occupational Health Recommendation of Occupational Health Exposure Limits<br>Ordinance on Prevention of Hazards Due to Specified Chemical Substances | Chemical Substances Control Law<br>Poisonous and Deleterious Substances Control Law<br>MSDS for Chemical Products: Industrial Standards JIS Z7250:200 and Z7251:2006 | Regulations for Carriage and Storage of Dangerous Goods by Ships | Pollutant Release and Transfer Register and Promotion of Chemical Management Law (1999) | Consumer Product Safety Act<br>Household Goods Quality Labelling Act (and Handbook)<br>Handbook for Consumer Products Import Regulations 2010<br>Act on Control of Household Products Containing Harmful Substances | GHS implemented; government classification of substances still underway |
| ROK | Industrial Safety and Health Act (30 Dec 2002)<br>Occupational Safety and Health Act (30 Nov 2010)<br>Enforcement Decree of the Occupational Safety and Health Act (24 Feb 2010) | Toxic Chemicals Control Act (1991)<br>"Korea REACH" expected to replace Toxic Chemicals Control Act in 2013<br>Standard for Classification and Labelling of Chemical Substance and MSDS (29th Oct 2009)<br>GHS Hazards Classification of Chemicals (Nov 2008) | Dangerous Goods Safety Management Act | Environmental Health Act (2008) | Fair Labelling and Advertising Act<br>Product Liability Act<br>Quality Management And Safety Control Of Industrial Products Act | Fully implemented for substances (mixtures by June 2013 or possibly 2014) |

| Economy | OH&S regulations | chemicals mangement regulations | Transport regulations | Environmental regulations | Consumer protection regulations | GHS Adoption Status |
|---|---|---|---|---|---|---|
| RP | Occupational Safety and Health Standards | Inventory of Chemicals and Chemical Substances (including Priority Chemical List)<br>Table 8d in Occupational Safety and Health Standards | Toxic Substances and Hazardous and Nuclear Wastes Control Act (6969, 1990) | Toxic Substances and Hazardous and Nuclear Wastes Control Act (6969, 1990)<br>Clean Air Act (8749) | Consumer Act (7394) | Review and amendment of regulations underway. Member of UNITAR and ILO Global GHS Capacity Building Programme |

| Economy | OH&S regulations | chemicals management regulations | Transport regulations | Environmental regulations | Consumer protection regulations | GHS Adoption Status |
|---|---|---|---|---|---|---|
| RUS | Labour Code (30 December 2001)<br><br>Industrial Safety of Hazardous Production Facilities Law (1997) | Technical Regulation "On Safety of Chemical Products"<br><br>Labelling of Chemicals GOST 31340-2007<br><br>Hazard Classification of Chemicals and Mixtures GOST R 53856-2010 GOST R 53854-2010<br><br>MSDS (GOST 30333-2007) | Dangerous Goods. Classification and Marking GOST 19433-1988<br><br>Marking of Cargoes GOST 14192-1996 | Hazard Classification of Chemicals - General Requirements GOST 53857-2010<br><br>Hazard Classification of Chemical Mixtures GOST 53858-2010 | Consumer Protection Act 1982<br><br>Federal Service on Customers' Rights Protection and Human Well- Being Surveillance | The National Standards (GOST R) implement the GHS.<br><br>A newer Technical Regulation "On Safety of Chemical Products" is aligned with UN GHS Rev. 3<br><br>Final Technical Regulation expected to be finalised in 2012 and will supersede the national standards. |
| CT | Labour Safety and Health Act<br><br>Toxic Chemical Substances Labelling and MSDS Regulations | Toxic Substances Control Act (and Enforcement Rules)<br><br>Regulation of Labelling and Hazard Communication of Dangerous and Harmful Substances<br><br>National Standard CNS 15030 Classification and Labelling of Chemicals<br><br>Chemical Substance Nomination and Notification National Existing Chemical Inventory | Toxic Chemical Substances Transportation Management Regulations<br><br>Toxic Chemical Substances Hazard Prevention and Response Plan Regulations | Environmental Agents Control Act<br><br>Standards for Defining Hazardous Industrial Waste<br><br>Marine Pollution Control Act (and Enforcement Rules) | Consumer Protection Law | GHS-aligned regulations entered into force 12 Dec 2008; classifications inventory not yet publicly available<br><br>Full implementation by 2015 |
| USA | Occupational Safety and Health Standards<br><br>OSHA Rulemaking Actions such as Hazard Communication; Proposed Rule OSHA-H022K-2006-0062 | Toxic Substances Control Act<br><br>Federal Hazardous Substances Act | Federal Hazardous Materials Transportation Law<br><br>Hazardous Materials and Oil Transportation 49 CFR 100 to 199 | Comprehensive, Environmental Response, Compensation and Liability Act<br><br>Resource Conservation and Recovery Act<br><br>Clean Water and Air Acts | Consumer Product Safety Act (1972) | Final workplace implementation expected in 2012 (Rule 74 FR 50279-50549)<br><br>Updating implementation outside the workplace (transport (done), consumers, etc.). |

## Table E.3. OH&S regulations

| Condition | AUS | CDA | PRC | INA | JPN | ROK | RP | RUS | CT | USA |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Recording and Labelling*** | | | | | | | | | | |
| Labelling | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MSDS | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Keeping registers | ✓ | × | × | × | × | × | × | × | × | ✓ |
| ***Assessing, training and protecting*** | | | | | | | | | | |
| Risk assessment | ✓ | ✓ | Unclear | Unclear | ✓ | ✓ | ✓ | ✓ | ✓ | Unclear |
| Induction and training | ✓ | ✓ | ✓ | ✓ | Unclear | ✓ | ✓ | ✓ | ✓ | ✓ |
| Protective equipment etc | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| ***Monitoring effectiveness*** | | | | | | | | | | |
| Monitoring of exposure | ✓ | ✓ | ✓ | ✓ | Unclear | ✓ | ✓ | ✓ | ✓ | ✓ |
| Health examinations | × | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | × |
| ***Special protection*** | | | | | | | | | | |
| Stand-by assistance | × | × | × | × | × | × | ✓ | × | × | × |
| Juveniles and women | × | × | ✓ | ✓ | × | × | × | × | ✓ | × |
| ***Substitution policies*** | ✓ | ✓ | × | × | × | × | ✓ | × | × | ✓ |

## Table E.4. Transport regulations

| Condition | AUS | CDA | PRC | INA | JPN | ROK | RP | RUS | CT | USA |
|---|---|---|---|---|---|---|---|---|---|---|
| Appropriately marked, labelled and placarded cargo transport units | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Cargo units must be closed | ✗[18] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Restrictions on plastic, textile and paper bags for closed cargo units | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Environmental hazardous-substance markings on at least 2 opposing sides of the unit (for packages > 5kg) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Use of sift-proof, water-resistant IBCs[19] and other restrictions | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Pressure requirements for portable containers | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Restrictions on non-IBC use (sealed drums, jerricans and boxes etc.) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Large packaging with volume cap of $3m^3$ are to be sift proof | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Limit on net quantity of substance per inner and outer packaging | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Double language requirements | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ |

[18] Exemption granted for nickel matte

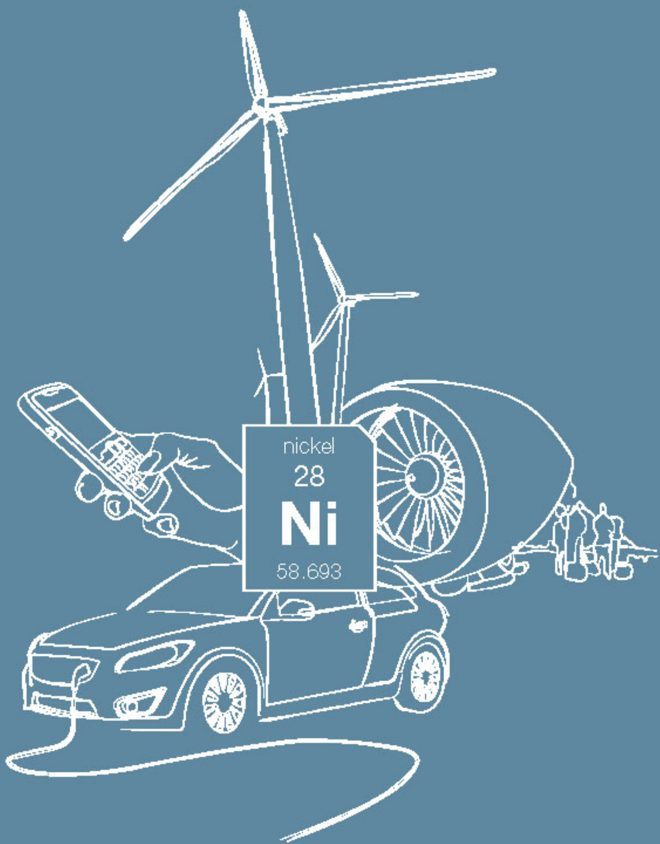
[19] Intermediate Bulk Containers

### Table E.5. Consumer protection regulations for hazardous substances

| Condition | AUS | CDA | PRC | INA | JPN | ROK | RP | RUS | CT | USA |
|---|---|---|---|---|---|---|---|---|---|---|
| Assessment of exposure | ✓ | ✓ | Unclear | Unclear | ✓ | ✓ | Unclear | Unclear | ✓ | ✓ |
| Information and labelling standards | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Unclear | ✓ | ✓ | ✓ |
| Product recalls | ✓ | ✓ | Unclear | Unclear | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Interim/permanent bans | ✓ | ✓ | Unclear | Unclear | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

### Table E.6. Occupational exposure limits (mg/m$^3$)

| Nickel substance | AUS | CDA | PRC | INA | JPN | ROK | RUS | RP | CT | USA |
|---|---|---|---|---|---|---|---|---|---|---|
| Chemicals (soluble) | 0.1 | 0.1 | 0.5 | 0.1 | 0.01 | 0.1 | 0.05 | 0.1 | 0.1 | 1 |
| Chemicals (insoluble) | - | 0.2 | 1 | 1 | 0.1 | 0.5 | 0.05 | 1 | 0.2 | 1 |
| Carbonyl | 0.12 | 0.12 | - | 0.12 | 0.07 | - | 0.0005 | 0.007 | 0.12 | 0.007 |
| Nickel metal | 1 | 1 | 1 | 1 | 1 | 1 | 0.05 | 1 | 1.5 | 1 |

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