MSP REFRAM

Multi-Stakeholder Platform for a Secure Supply of Refractory Metals in Europe

FACTSHEET

FUTURE REFRACTORY METALS SCENARIOS IN THE EU

WHAT ARE THE MAIN FACTORS DRIVING THE METALS MARKET?

The major factors influencing the future of the world's minerals and metals sector are human population growth, economic development and environmental change. As the economy of a country grows, mineral consumption also grows. In the early stages of economic development, the demand for minerals grows in line with the economy as manufacturing, infrastructure, building and communications activities begin to burgeon. However, as an economy matures and more emphasis is placed on the services sector (education, health, retail, etc.), which is not so dependent on minerals, economic growth is no longer correlated with overall mineral consumption. Nowadays, significant quantities of energy and construction minerals are still required for the maintenance and development of infrastructure. In the future as well, minerals and metals will inevitably continue to underpin the global economy. Transport, energy, manufacturing, health, agriculture and housing are likely to remain heavily dependent on raw materials derived from terrestrial resources. Thus, the demand for refractory metals is expected to grow in the developing BRIC countries (Brazil, Russia, India and China), which is not to say that developed countries, such as those of the EU, will no longer need large quantities of refractory metals to meet the needs of their major steel producers, aeronautic manufacturers, gas and oil pipeline manufacturers and automotive industries, where the demand of refractory metals is high and increasing.

The task of establishing the relationship between reserves and consumption (i.e., number of years supply remaining equals reserves divided by annual consumption) is extremely complicated. Consumption and reserves change continually in response to scientific advances and market forces, making it difficult to obtain exact figures. Market forces influence reserve size, as most metals occur in graded deposits: if prices rise, reserves will extend into lower-grade ore; if prices fall, reserves will contract to include only higher-grade material.

Another factor to be considered when analysing the metals market is that, due to the climate change phenomenon, the introduction of low-carbon technologies is becoming ever more widespread in modern society. These technologies require “critical metals” for their manufacturing processes just as low-emission vehicles and energy storage activities do. For example, Niobium has been declared “critical” for “clean” energy technologies. Thus, an assessment of the future refractory metals is essential for EU countries in order to guarantee the supply of these refractory metals in the best possible way and thereby ensure high-quality technological development.

FUTURE DEMAND FOR REFRACTORY METALS IN THE EU

The future demand for refractory metals in the EU has been analysed in the MSP-Refram project. In general, an increase in the demand for refractory metals in the EU is expected due to their unique characteristics and main applications, the lack of cost effective substitutes with the same properties, and electronic and infrastructure development.

TUNGSTEN

China is predicted to continue dominating the world Tungsten market both in terms of production and exports. Global Tungsten production is forecasted to grow at an average rate of 3.8% in the years ahead and reach 100,100 tonnes by 2017. According to this forecast for the EU, Tungsten mine production would reach 3,049 tons in 2017, taking into account the fact that EU Tungsten production was approximately 2,830 tons in 2015. Total Tungsten production, if end-of-life scrap recycling is included, would reach over 8,000 tons.

In 2015 Wolf Minerals opened its Hemerdon Tungsten mine in the UK and produced 600 tons of Tungsten. According to Investing News, mine production in the UK is estimated to be 5,000 tonnes of Tungsten concentrate per year in the future. In Spain, the company W Resources conducted a mine development study at La Parrilla mine and predicted a 150-percent increase in its production target there. The full mine will be developed by 2017 or 2018, and target production will increase to 5,000 tons of Tungsten concentrate, which means an increase in production of 1,000 tons of Tungsten from mining in three years, which will bring overall Tungsten production to over 9,000 tonnes, a mere 1,000 tonnes short of the 10,000-tonne overall target.

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RHENIUM

Data on the current EU demand for Rhenium is scarce, so as the aerospace industry is the main application of Rhenium, global aerospace industry forecasts will be considered here. Demand for Rhenium is currently showing growth because of demand for engines in both commercial and military jets. Roskill stated that Rhenium demand will experience a period of sharp growth between 2015 and 2018 followed by a period of stability through to 2020 (6%/year). Airbus has estimated a demand for 6,508 new aircraft in Europe for the period 2016-2035, which means a 20% share of total world demand for new aircrafts. Boeing has estimated that 7,450 new airplanes will be needed in Europe between 2014 and 2033. Considering an average demand of 50 kg of Rhenium per aircraft, a demand of up to 1,450 tons of Rhenium may be expected by 2033. In addition, DERA (2016) estimates an anticipated demand for Rhenium in emerging technologies using superalloys of 120 t per year by 2035, or 250% of Rhenium production in 2013 (46 tons).

The use of Rhenium catalysts in reforming is also growing, if at a lower rate. The annual demand for Rhenium in the EU for advanced fossil fuel power generation forecasted for the period 2020-2030 is 0.6 tonnes/year, which represents one of the greatest material requirements.

MOLYBDENUM

The International Molybdenum Association (IMOA) estimates that end-user demand for Molybdenum could increase by an average of 3.6% in the period to 2024 due to a number of sectors expected to generate future demand for Mo through use in applications influenced by global trends. According to The Roskill Report, Mo demand in Europe is expected to increase by some 105 kt per year in the years to 2025, and current capacity is insufficient to meet this increase in demand. The applications that will increase the Molybdenum demand are:

- The steel industry: In 2015, demand from the steel industry represented 70% of global Molybdenum demand, which is expected to increase to 73% by 2025.
- Automotive light weighting using Molybdenum for high-strength steels and reduction in total vehicle weight for greater efficiency.
- Hydrodesulphurization of fuels, using Molybdenum-based catalysts. This technology has already achieved a 100-fold reduction in sulphur dioxide emissions in the European vehicle sector since 1993. This will play an important role in the future as emissions standards are tightened across the world.
- Industries such as the manufacture of catalysts, lubricants and pigments are also forecast to increase Molybdenum use by 2025, though at a lower growth-rate.
- Uses in power generation: boosting the efficiency of coal-fired, solar, wind and hydroelectric power stations. Molybdenum offers resistance to corrosion, strength and performance at high temperatures as an alloy. Non-fossil energy generation has grown considerably in recent years and is predicted to more than double in the period to 2020.

For the main applications (automotive, oil and gas, chemical/petrochemical, processing, transportation, aerospace, defence, electronic and medical industries, mechanical engineering and power generation) there are no potential substitutes for Mo. However, there are potential viable substitutes for Mo in construction applications, where it is easily and fully substitutable at no additional cost.

Lastly, Molybdenum has been defined as a potential substitute for Tungsten and Niobium, both of which are considered to be critical raw materials.

NIOBIUM

Sharp growth in demand (over 8% per year) in the years up to 2020 due to two main factors. Firstly, there is generally a high demand worldwide for steel in construction, infrastructure and automotive applications. Secondly, there is also a trend towards greater use of high strength low-alloy (HSLA) steels. Increasing demand for natural gas is expected to result from a rising demand for pipeline steel. Combining the two trends means that worldwide growth in demand for Ferro-Niobium is likely to exceed that for steel, due to the higher intensification of predicted Niobium use. ArcelorMittal, whose headquarters are in Luxembourg is the world's top steel maker (96.1 million tonnes of crude steel production in 2013). ThyssenKrupp from Germany is also among the leading steel makers (15.9 million tonnes crude steel production in 2013). The projected 8% annual increase in demand coupled with 2015 FeNb import figures means that the expected demand for FeNb in 2025 will be 55,000.

TANTALUM

With all of the uncertainty concerning current Tantalum needs among EU industries, it is much harder to assess future needs. Future demand for Tantalum has been analysed in D1.1 of MSP-Refram, making several assumptions (see D1.1 MSP-Refram for an overview of the full procedure). The study states that the demand for Tantalum in 2035, driven the manufacture of micro-capacitors and medical

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technology applications, will be four times the amount that was produced in 2013. As for micro-capacitors, world demand for Tantalum was 128 tons in 2013 and is estimated to be between 360 and 1,070 tons in 2035, which corresponds to annual growth rates of 4% and 7%, respectively and is based on and other assumptions concerning prices and efficiency.

The core use of tantalum in capacitors has several possible substitutes (aluminium, ceramic capacitors) that are likely to satisfy most common needs, albeit with a loss in performance. Only niche capacitor applications with strong size and robustness/tolerance requirements may be more difficult to replace, but with lower demand volumes and possibly higher value.

WHAT IS THE CURRENT GEOGRAPHIC DISTRIBUTION AND STATUS OF TUNGSTEN RESERVES?

TUNGSTEN

China is the main producer of Tungsten with 71,000 tons in 2015, followed by Vietnam (5,000 tons) and the EU (2,830 tons). Estimated reserves are 1,900,000 tons in China and 670,000 tons all other countries combined (290,000 tons in Canada, 250,000 tons in Russia and 100,000 tons in Vietnam (USGS, 2016). In the EU, the estimated reserves are 10,000 tons in Austria, 4,200 tons in Portugal, 32,000 in Spain and 51,000 in the UK (USGS, 2016). Thus, total reserves in EU stand at 97,200 tons of Tungsten. France is also a potential Tungsten-producing country in the EU, owing to its extraordinary geological qualities, but because of government policy is one of the most seriously under-explored countries in the world outside of Africa.

China has apparently been mining high grade deposits for over 15 years, damaging the resource to the detriment of long-term mine economics. The remaining resources occur as skarn hosted scheelite which, in most cases, is of a lower grade than that of currently available wolframite resources. It is hard to say how long this exploitation can be sustainable.

RHENIUM

Geographic distribution figures for mine-produced Rhenium in 2015 were as follows: 26 tons in Chile, 8.5 tons in United States, 7.8 tons in Poland, 1 ton in Uzbekistan and minor quantities from Armenia and Kazakhstan. Global reserves are estimated to be 1,300 tons in Chile, 390 tons in United States, 310 tons in Russia, 190 tons in Kazakhstan, 95 tons in Armenia, 45 tons in Peru, 32 tons in Canada, and 91 tons in all other countries Combined. Information on reserves in Poland is not available (USGS, 2016).

MOLYBDENUM

Molybdenum production in 2015 was dominated by China, the leading producer with 101,000 tons, followed by the United States (56,300 tons) and Chile (49,000 tons). Peru (18,100 tons) and Mexico (13,000 tons) also played significant roles. Approximate total world Molybdenum production was 267,000 tons in 2015. The main estimated reserves (in thousands of metric tons) are 4,300 in China, 2,700 in the United States and 1,800 in Chile, bringing (with minor contributions from other countries) the total to 11,000 thousand metric tons of Molybdenum reserves (USGS, 2016). No Molybdenum reserves have been identified in the EU.

NIOBIUM

Niobium production is dominated by Brazil, which accounts for about 90% of total world production, followed by Canada, which produces about 10% of the world total. Niobium is also produced in Africa via traditional archaic mining methods, but there is no data available due to ongoing conflicts in these countries, where extractive mining techniques is are practiced. Estimated reserves and resources of Niobium are large and more than sufficient to meet global demand for the foreseeable future, possibly for the next 500 years. Brazil continues to lead production, with reserves estimated at 4,100,000 tons. Canada's reserves are estimated to be 200,000 tons, bringing total worldwide reserves to over 4,300,000 tons (USGS, 2016).

TANTALUM

Rwanda provided almost 50% of the 2014 worldwide production of concentrate. Other countries, such as Congo and Brazil, played a smaller but still significant role (16.56% and 12.58%, respectively). Australia and China also contributed with low percentages to total production. Available figures for worldwide Tantalum reserves indicate that there are 67,000 tons in Australia and 36,000 in Brazil (for a combined total of over 100,000 tons). There is no information available for China, Congo and Rwanda.

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IS THERE ANY PRODUCTION OF PRIMARY OR SECONDARY REFRACTORY METALS IN THE EU? IS THERE A DEMAND FOR REFRACTORY METALS IN EUROPEAN INDUSTRY?

Currently, the extraction of refractory metals from primary resources is quite limited when considering total worldwide production of refractory metals. Some recycling of refractory metals is conducted in Europe, but a lot of new infrastructure and investment will be needed if demand for refractory metals in the EU is to be satisfied.

The EU produces Tungsten from concentrates in Spain, Portugal, Austria and the UK, although the production is low compared to total worldwide production and when considering demand for Tungsten in EU. Worldwide Tungsten production in 2015 was 87,000 tons. In the same year, Austria produced 870 tons, Spain, 730 tons, Portugal, 630 tons and the UK, 600 tons, which means total EU production in 2015 was 2,830 (3.25% of total production). Reportedly, Tungsten consumption in Europe has been about 10,000 tons since 2008. Using this value as reference, the EU would need about 7,000 more tons of W production to meet its consumption needs. According to 2013 data from the International Tungsten Industry Association, the recycling rate in Europe is 50%, which means that 5,000 tons of Tungsten are produced by recycling end-of-life scraps. Thus, if this quantity and production values are combined, total EU production of W from primary and secondary resources would be 7,830, meaning that approximately 2170 tons would be needed for the EU to meet its demand (estimated at 10,000 tons). It is important to note here that there are secondary producers in Germany (H.C.Starck, Buss & Buss Spezialmetalle). Cemented carbides dominate the Tungsten market, with major applications being cutting tools, mining, oil and gas drilling and other machine tools. 3M is an important tool manufacturer in the EU. W is also added to steels, the primary use of Tungsten in the EU. The companies that are end-user consumers of Tungsten-based products work mainly in the oil and gas, automotive, aeronautics and defence industries.

Rhenium occurs in amounts in the range of 0.001% to 0.2% in the mineral Molybdenite, the main commercial source. Most of the Rhenium that is extracted is a by-product of copper mining, with about 80% recovered from flue dust during the processing of molybdenite concentrates from porphyry copper deposits. As for the EU, only in Poland is Rhenium recovered as a by-product from copper concentrates, and the supply of it is estimated to be 4.7 tons. Worldwide production of Rhenium is estimated to be about 50 tons per year. In 2012, the Minor Metals Trade Association estimated global demand to be about 54 tons and set world production at 44.8 tons. This insufficiency in meeting the demand is attributed to the recycling of Rhenium from spent reforming catalysts, which is estimated to be 15 tons of Rhenium. Rhenium from secondary resources is produced in Germany, along with other refractory metals, by H.C.Starck and Heraus Precious Metals and in Estonia, by Toma Group. Rhenium use is linked to high-value applications, mainly in superalloys used in the following industries: aerospace, gas turbines, automotive, tools and oil and gas. It is also used in producing catalysts. The EU is a net exporter of aerospace and gas turbines, which means that Rhenium is highly strategic for the EU. Axens, in France, is one of the main producers of catalysts used in oil refineries, accounting for 3% of the worldwide catalytic reforming capacity.

The extraction of Molybdenum from primary resources in the EU is practically nil. Mine production of Molybdenum has taken place only in Norway, which produced 4 tons in 2012, 8 tons in 2013 and 2 tons in 2014 (worldwide production of Molybdenum in 2015 was 267,000 tons). The EU is the second biggest consumer of Molybdenum, after China, with an average consumption of 63,500 in 2011 and 2012. This high consumption is mainly due to iron and steel industry activities, where Molybdenum is used as alloying element in steel, cast iron and non-ferrous metals. The EU is the second largest producer of steel (China is the leader). The overall output of steels is over 177 million tons of steel a year, with stainless steel accounting for 7.2 million tons of the total figure. Ferro-Molybdenum, used in steels, has 60-75% Mo content. Austria is the only country in the EU that produces ferro-Molybdenum (4,000 tons in 2014). Molybdenum scrap is an important source of Molybdenum, as in 2011, almost 80,000 tons, or about 26% of all Mo used, came from recycled Mo resources. Europe is the region with the highest first use of Molybdenum scrap, at a rate of about 30,000 tons per year.

The EU extracts neither Niobium nor Tantalum from primary resources. Only one French company, Imerys, located in Echassières, produces 55 t/year of a Niobium-Tantalum concentrate from cassiterite. However, EU consumption of these metals is high. The main application of Niobium is in the form of Ferro-Niobium for high-strength low-alloy steels (HSLA), used in the automotive, gas and oil pipeline and structural metals (bridges and buildings, for example) industries. Ferro-Niobium imports to the EU were 25,219 tons in 2015 (32.7 % of total production). The main application of Tantalum is in capacitors for the electronics industry, although it is also widely used in superalloys, carbides, mill products, sputtering targets and chemicals. It is also used in high-temperature applications,

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e.g. aircraft engines (the Airbus headquarters in France is the world's second biggest producer of aeronautic infrastructures). EU Tantalum consumption is estimated to lie somewhere between a quarter and a third of total worldwide production, so assuming a global production of 1000 t Ta for 2015, the corresponding figure for the EU is between 250 and 330 tons of Ta. Although there are companies in EU registered as Nb and Ta recyclers (H.C. Starck, Innova Recycling, Hean Goldschmidt International, Metallum Metal Trading, Buss&Buss, ELG Utica Alloys) with the Tantalum-Niobium International Study Center and Minor Metals Trade Association, there is no information available concerning the current status of Niobium and Tantalum recycling from secondary resources and urban mining in the EU.

WILL EU COUNTRIES BE ABLE TO SATISFY PART OF THE DEMAND USING THEIR OWN RESOURCES?

The EU has an estimated 97,200 tons of Tungsten reserves. Reportedly, Tungsten consumption in Europe has about 10,000 tons since 2008, which means that the EU could satisfy part of its overall demand for about 10 years. As stated above, Tungsten recycling in the EU is estimated to be about 5000 tons. Therefore, if EU production rates and recycling sources are both taken into account, the EU could satisfy its own Tungsten demand in the coming years if more recycling and production efforts were to be undertaken, including the recovery of tailings. Thus, the estimated increases in primary mine supply are predicted to be outpaced by 2018. Tungsten recycling is expected to continue growing at a rate of 8% per year over the next five years, which will increase global production of recycled tungsten materials from 23% of total supply in 2012 to 28% of global supply in 2018.

Although there are no Niobium nor Tantalum mines currently in operation in the EU, reserves have been identified at the following sites:

- the Penouta Mine in Spain, with alkaline granite deposits of 95.6 Mt (0.0094% Tantalum oxide and 0.0009% Niobium oxide), is currently under exploration by Strategic Minerals Spain.
- the Alberta II Mine in Spain, with pegmatites deposits of 12.3 Mt (0.0121% Tantalum oxide) is currently under exploration by Strategic Minerals Spain.
- the Motzfeldt Mine in Greenland (Denmark) with Syenite deposits of 340 Mt (0.19% Niobium oxide and 0.012% Tantalum oxide) is currently under exploration by Regency Mines.
- the Treguennec Mine in Brittany (France) has the potential to produce 1,600 tons of Tantalum.

No information on Niobium and Tantalum production from secondary resources or urban mining in the EU has been made available. It is known that H.C.Starck recycle these metals, but no information as to exact quantities has been published. Moreover, the Treibacher and Plansee mines in Austria as well as the Silmet mine in Estonia refine Tantalum. The EU imports about 20,000 tons of FeNb per year, which, assuming 60% Nb content, would mean 12,000 tons of Niobium. Niobium exports are quite low in comparison to this figure, so considering that 12,000 tons of Niobium are consumed by EU countries, it would not be possible for the EU to meet its demand using its own resources in the next several years. The case of Tantalum is even more complicated as there is little information available on it. However, there are potential end-of-life products and secondary resources from which Niobium and Ta could be extracted in the EU, including end-of-life vehicles (there were an estimated 6.28 million EOL vehicles in the EU in 2012) and electrical and electronic equipment waste (about 9000 electrical and electronic devices go onto the market every per year). The Niobium and Tantalum content in these end-of-life products is not reported, except in the cases of computers, which are estimated to have a Niobium content of 0.0002 %. The amount of Niobium recovered from the collected IT and telecommunications equipment could potentially be as high as 1.2 tons (the grade of Niobium in PCB is about 36 g/t). Tantalum recycling accounts for about 20% of the world's total supply, although figures for the EU are not available. It is recovered from a number of different items including cemented carbides and alloys, sputtering targets, and edge trimmings from metallurgical processes. However, recycling from capacitors (the main application) is difficult and current technology is ill-equipped to do so. If the technology were to be developed, significant amounts of Tantalum could be recycled and used in the EU.

The situation for the remaining metals is quite different, as there are no identified reserves in EU (except for Re reserves in Poland, about which there is no information available). Therefore, production in EU would entail exploiting secondary resources and undertaking urban mining activity. There is high potential in recycling refractory metals from steels. One of the most important Rhenium applications is in aeroturbines, but the market is quite closed and it is difficult to obtain spent aeronautic components.

HOW CAN THE DEPENDENCE ON REFRACTORY METALS FROM NON-EU COUNTRIES BE REDUCED?

The extraordinary properties of refractory metals, the possible difficulties encountered in finding substitutes for them, the improving EU economy and the development of electronic devices and the need for refractory metals in that industry all contribute to the prospect of a continued demand for refractory metals in the EU. Different pathways have been identified in the MSP-Refram Project to improve the prospects for the supply of refractory metals to the EU, and mostly concern technical performance and policy recommendations. In general, more investing in new extracting technologies and subventions for recycling will be needed as well as more transparency in actions undertaken in Europe, such as recycling rates.

TUNGSTEN

- Recycling of Tungsten Carbide is essential, as most scrap materials are richer in Tungsten than ore concentrates. Demand for Tungsten products is increasing, and companies can lower their raw material costs and make greater profits by recycling Tungsten scrap. Also of importance, although not so related to dependence issues, is the environmental aspect of recycling. Recycling of Tungsten carbide may be better performed by direct methods than indirect methods, i.e. transforming Tungsten scrap into powder of the same composition through chemical or physical treatment, or a combination of both. Recycling will be made more effective with the implementation of better product-collection programs and new Tungsten-recycling facilities, which underscores the need for more investment in new recycling technologies.

- Investment in the development of new mines.

MOLYBDENUM

- Potential innovations in the recovery from secondary resources (mill scale, dust, slag, etc.) are needed. For example, smelting reduction Mo-containing mill scale in EAF. ~ 5 wt.% mill scale can be charged into EAF without any operational problems.
- Establishing more efficient sorting and recovery systems (could improve Mo recovery by > 50 %)
- Using the generated residual materials as by-products rather than wastes.

RHENIUM

- Establishment of a database for Re containing product inventories, sales, product information on components, predicted waste.
- Promotion of sorting logistics and collection as well as improvements in the efficiency of Rhenium-containing end-of-life products, and the establishment of a stable supply source.
- Promotion of pre-processing efficiency using innovative and scale-up technologies.
- Scaling-up of market access and the involvement of large companies, suppliers and specialized groups in Re recycling efforts.
- Encouragement of manufacturers to improve product design by taking ease of disassembly, re-use and recycling into account.
- Development of a Rhenium recovery method for materials with diameters of over 30 mm, which currently cannot be processed.
- Innovative technologies for the conversion of commercially prepared Rhenium compounds (mainly ammonium perrhenate) to more technologically advanced and processed functional compounds, materials or components.
- Promotion of superalloy recycling programs (83.3% of the Re production).

NIOBIUM

- In 2020, 12 million tons of waste of electrical and electronic equipment are expected and the number end-of-life vehicles are expected to reach 9 million in 2019. The recycling of Niobium from these applications could partially satisfy EU Niobium demands for the foreseeable future, but more investment in extraction facilities and methodology is needed.
- The extraction of Niobium from High Strength Low Alloys Steels (HSLA) alloys could be a promising source of Niobium, as this is the main application of Niobium. Research is needed in this field.
- Investment in research for the recovery of Nb and Ta from Tungsten carbide sludge ([Nb] = 5.6% and [Ta] = 7.2%).

TANTALUM

Consideration of capacitors and electronic parts as possible new resources, which could lead to a 40% Ta recycling rate in the EU.

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- Old tin tailings containing Tantalum (or Niobium) could be exploited for Tantalum extraction by using improved technologies (they represented only 10% of worldwide Tantalum production in 2012).
- Investment in new innovative processing and innovative extractive metallurgy for secondary resources and recycling, which means that, if a 20% of recycling rate is assumed, about 60 tons Ta recycled/year could be obtained.
- Improved recycling programs, which means that central waste collection centres and channelling waste streams will be needed.
- Penalties for companies that import from conflict-affected regions or countries with poor working conditions.

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