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Report on current state of value chains of refractory metals in the EU

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Summary

Report on current state of value chains of refractory metals in the EU

Approval

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CONTENT

APPLICATIONS OF TUNGSTEN

Approximately half of the tungsten is consumed for the production of hard materials – namely tungsten carbide – with the remaining major use being in alloys and steels. Less than 10% is used in other chemical compounds [5].

HARD MATERIALS

Tungsten is mainly used in the production of hard materials based on tungsten carbide, one of the hardest carbides, with a melting point of 2770 °C. WC is an efficient electrical conductor, but W_2C is less so. WC is used to make wear-resistant abrasives, and "carbide" cutting tools such as knives, drills, circular saws, milling and turning tools used by the metalworking, woodworking, mining, petroleum and construction industries[6]. Carbide tooling is actually a ceramic/metal composite, where metallic cobalt acts as a binding (matrix) material to hold the WC particles in place. This type of industrial use accounts for about 60% of current tungsten consumption [7].

ALLOYS

The hardness and density of tungsten are applied in obtaining heavy metal alloys. A good example is high speed steel, which can contain as much as 18% tungsten [8]. Tungsten´s high melting point makes tungsten a good material for applications like rocket nozzles, for example in the UGM-27 Polaris submarine-launched ballistic missile1. Tungsten alloys are used in a wide range of different applications, including the aerospace and automotive industries and radiation shielding [10]. Superalloys containing tungsten, such as Hastelloy and Stellite, are used in turbine blades and wear-resistant parts and coatings.

CHEMICAL APPLICATIONS

Tungsten(IV) sulfide is a high temperature lubricant and is a component of catalysts for hydrodesulfurization [11]. MoS_2 is more commonly used for such applications[12]. Tungsten oxides are used in ceramic glazes and calcium/magnesium tungstates are used widely in fluorescent lighting. Crystal tungstates are used as scintillation detectors in nuclear physics and nuclear medicine. Other salts that contain tungsten are used in the chemical and tanning industries . Tungsten oxide (WO_3) is incorporated into selective catalytic reduction (SCR) catalysts found in coal-fired power plants. These catalysts convert nitrogen oxides (NO_x) to nitrogen (N_2) and water (H_2O) using ammonia (NH_3). The tungsten oxide helps with the physical strength of the catalyst and extends catalyst life [14].

HISTORICAL INTRODUCTION.

During all these early years, the amount of tungsten used for chemical applications was always small in comparison to steel, mill products and hard metals. However, tungsten chemicals are used today in the form of tungsten oxides, tungstates, tungstic acid, silicotungstic acid, phosphotungstic acid or tungsten sulfides across a broad range of applications in the oil, lubricants, electronics, medical, dental and mining industries [15].

TUNGSTEN IN CATALYSTS

The major modern day use of tungsten chemicals is in the area of catalysts. Catalysis is the change in rate of a chemical reaction due to the participation of a substance called a catalyst. Unlike other reagents that participate in the chemical reaction, a catalyst is not consumed by the reaction itself. A catalyst may participate in multiple chemical transformations. Catalysts that speed the reaction are called positive catalysts. Since the 1930´s, the oil industry has been using tungsten in the catalysts for treating of crude oils. The four major catalytic reactions in the treatment of crude oil are: Dehydrogenation, isomerization, aromatization and hydrocracking.

HYDROCRACKING CATALYSTS

Various tungsten species are used to prepare catalysts for hydrocracking, hydrodesulfurization, hydrodenitrogenation, and hydrodearomatisation. These catalysts use tungsten and various other metal compounds supported on a ceramic carrier. The goal of these catalysts is to improve the yields of highly desirable organic components in gasoline, and reduce environmentally harmful byproducts, such as sulfur and nitrogen compounds.

DE-NO_X CATALYSTS

More recently, tungsten compounds have found increasing use as catalysts for the treatment of exhaust gases for the reduction of nitrogen oxide emissions. The term NOX is used to describe a mixture of nitrogen oxides NO and NO_2, both gases, which are produced by fuel combustion. NO_X gas is a major air pollution problem, causing acid rain and contributing to depletion of the ozone layer. "De-NOX" treatment aims to convert NOX gas to inert nitrogen gas. This conversion is a difficult process and catalysts are required to allow this to happen. Typical De-NOX catalysts are honeycomb-shaped $TiO_2WO_3V_2O_5$ ceramics. De-NOX catalysts are used on the stack gases of power plants, chemical plants, cement plants and diesel engines. These catalysts use ammonia or urea to yield harmless products of nitrogen and water (waste heat recovery boiler).

REFORMING CATALYSTS

Many of the above catalysts typically start with Ammonium Metatungstate (AMT), (NH4)6[H2W12O40]·xH2O, as the tungsten precursor. AMT is a wonderful molecule that allows tungsten to become highly soluble in water as metatungstate ion. At 25°C, 1.6 Kg of AMT is soluble per liter of water, with a density of about 2.5 g/mL. Once the AMT is impregnated into the ceramic substrate, it can be decomposed or converted to the appropriate tungsten species required for the catalytic reaction.

This highly soluble form is also used for the preparation of other heteropoly acids and polyoxometallates (POM). Such compounds are attractive catalysts for many kinds of organic reactions.

HETEROPOLY ACID COMPOUNDS OF TUNGSTEN

Tungsten heteropoly compounds, or polyoxometalates, start from single WO6 building blocks that form tungsten trimers (W3O13) that further combine to form a variety of polymerized metal forms. Four trimers combine around a central hetero atom (for example P) tetrahedron into the famous “structure of J. F. Keggin”. Keggin was one of the pioneers of deducing chemical structures.

Today, the various polyoxometalate compounds are the subject of extensive research for energy, industrial and health applications. They hold promise for catalysis, nanoscale magnets, drugs and drug delivery, insulin and metabolic control, separation science and technology, lignin separation for paper, and more recently in the decontamination of chemicals used in chemical warfare.

TUNGSTEN IN PIGMENTS[12]

Tungsten compounds are used for the manufacture of inorganic pigments for ceramic glazes and enamels.

- Tungsten trioxide WO3 is used for bright yellow glazes.
- Tungsten bronzes, i.e. partly reduced alkali and alkaline earth tungstates, are available in many bright colors.
- Barium and zinc tungstate are examples of bright white pigments.
- Colored organic dyes and pigments based on phosphotungstic acid and phosphotungsto molybdic acid are made for paints, printing inks, plastic, rubber and other materials.

TUNGSTEN IN LUBRICANTS[12]

Tungsten disulfide, WS2, is one of the most lubricous materials known to science with a dynamic coefficient of friction of ~ 0.03. It offers excellent dry lubricity that can be superior to that of molybdenum disulfide and graphite. It can operate in air up to 583°C and up to 1316°C under vacuum. Recent studies have shown that nano-sized Tungsten disulfide (WS2)–zinc oxide (ZnO) composite is a candidate material that exhibits adaptive lubricant behavior. Adaptive lubricants undergo chemical changes with changing environment to provide lubrication in extreme environments. Tungsten Diselenide is also being studied as a solid lubricant. Lubrication by tungsten dislenide coatings is intended for reducing friction and wear. Dichalcogenides of refractory metals are of great importance in providing the reliability and increased life of different friction units. Tungsten diselenides have higher corrosive resistance in water and are capable of operating stably in water vapor as variations in the environment humidity and pressure have insignificant effect on their friction coefficients. Shortcomings of these solid lubricants from their oxidation and fatigue failure can be overcome by inserting gallium and indium in the diselenide coatings.

TUNGSTEN IN MEDICAL AND DENTAL APPLICATIONS[12]

There are a number of tungsten chemicals that have been used in the medical and dental fields for X-ray shielding and conversely, X-ray opacity.

DENTAL FILLING MATERIALS.

Known tungsten compounds in dental composites are sodium tungstate, potassium tungstate, manganese tungstate, calcium tungstate, strontium tungstate, and barium tungstate. These various tungstates are added to give good definition in the dental X-rays. Interestingly, dental x-rays also use calcium tungstate as the X-ray intensifying phosphor to allow patients to receive smaller doses of radiation.

X-RAY SHIELDING

Tungsten compounds have been in use for the manufacturing of non-Lead radiation apparel. The advantage of non-Lead radiation apparel is that they are approximately 20% lighter than a corresponding lead version.

METALLURGY APPLICATIONS

MINING AND MINERAL SEPARATIONS[12]

Heavy liquids are dense fluids or solutions used to separate materials of different density through their buoyancy. Materials with a density greater than the heavy liquid will sink, while materials with a density less than the heavy liquid will float on the liquid surface. There are several tungstate compounds (sodium polytungstate (SPT), lithium metatungstate (LMT)) that are used as safe and effective alternatives to traditional organic heavy liquids. Solutions of Lithium Metatungstate with a specific gravity of 3.7; (H2O = 1) are widely used as heavy liquids. LMT was originally developed and patented by BHP-Utah International Corp in the early 1990´s. A recent addition to these compounds has been the introduction of LST, a solution consisting of greater than 80% sodium heteropolytungstate.

In the mineral industry, heavy liquids are commonly used in the laboratory to separate the “light” minerals such as quartz and clay from the “heavy” minerals. The density used for this type of separation is about 2.85 g/mL, nearly three times the density of water. The introduction of heteropolytungstates has found great acceptance. Rio Tinto Exploration Pty Ltd and lluka Resources Ltd were highly commended at the Year 2000 Australian National Safety and Health Innovation Award for using LST in place of the traditional organic heavy liquids.

Heavy liquid separations are carried out for varied reasons, depending on the industry. The mineral sands industry uses heavy liquid separations to check the grade of samples in their process, and to determine the efficiency of their industrial separations. The diamond exploration industry uses heavy liquids to separate the dense “indicator” minerals from sand and clay.

Another use of heavy liquids is in paleontology. Typically, these heavy liquid separations are conducted at a lower density (e.g. 2.2 g/mL) since the separation is not between minerals of different types, but between fossil bones and minerals.

OTHERS APPLICATIONS OF TUNGSTEN

GOLD SUBSTITUTION

Its density, similar to that of gold, allows tungsten to be used in jewelry as an alternative to gold or platinum [16],[17]. Metallic tungsten is hypoallergenic, and is harder than gold alloys (though not as hard as tungsten carbide), making it useful for rings that will resist scratching, especially in designs with a brushed finish. Because the density is so similar to that of gold (tungsten is only 0.36% less dense), tungsten can also be used in counterfeiting of gold bars, such as by plating a tungsten bar with gold [18],[19],[20], which has been observed since the 1980´s [21], or taking an existing gold bar, drilling holes, and replacing the removed gold with tungsten rods [22]. The densities are not exactly the same, and other properties of gold and tungsten differ, but gold-plated tungsten will pass superficial tests [14].

Gold-plated tungsten is available commercially from China (the main source of tungsten), both in jewelry and as bars [23].

ELECTRONICS

Because it retains its strength at high temperatures and has a high melting point, elemental tungsten is used in many high-temperature applications [24], such as light bulb, cathode-ray tube, and vacuum tube filaments, heating elements, and rocket engine nozzles [13]. Its high melting point also makes tungsten suitable for aerospace and high-temperature uses such as electrical, heating, and welding applications, notably in the gas tungsten arc welding process (also called tungsten inert gas (TIG) welding).

Because of its conductive properties and relative chemical inertness, tungsten is also used in electrodes, and in the emitter tips in electron-beam instruments that use field emission guns, such as electron microscopes. In electronics, tungsten is used as an interconnect material in integrated circuits, between the silicon dioxide dielectric material and the transistors. It is used in metallic films, which replace the wiring used in conventional electronics with a coat of tungsten (or molybdenum) on silicon [25].

The electronic structure of tungsten makes it one of the main sources for X – ray targets [26], [27] and also for shielding from high-energy radiations (such as in the radiopharmaceutical industry for shielding radioactive samples of FDG). It is also used in gamma imaging as a material from which coded apertures are made, due to its excellent shielding properties. Tungsten powder is used as a filler material in plastic composites, which are used as a nontoxic substitute for lead in bullets, shot, and radiation shields. Since this element´s thermal expansion is similar to borosilicate glass, it is used for making glass-to-metal seals [10].

CURRENT USAGE OF TUNGSTEN (W) IN INDUSTRIAL VALUE CHAINS OF EU

According to the USGS reports [1] the mine productions of tungsten in the years of 2010 and 2011 67700 and 73100 metric tons of WO3. ITIA's 2011 Market Report showed that primary mine production of tungsten in 2010 totalled 97,000t WO3 [2]. It can be calculated in the total production 97,000 t in 2010 67700t or 69.8% from mining and 29300t or 30.2% from sources. So the estimated total production of tungsten in 2011 should be about 104728t WO3 (73100t from mining and 31628t from other sources).
It was reported [3] that EU consumption of Tungsten is about 18% of the world's consumption in 2011. However, according to the report [4] the World and EU consumption estimates of tungsten from 2002 to 2013 are shown in the following table 1. The EU consumption of tungsten is only about 13.6% of the world's consumption in 2011.

	World consumption (t W)	EU consumption (t W)	Consumption rate in EU %
2002	42000	9090	21.6
2003	52000	16363	31.5
2004	52500	11818	22.5
2005	62000	16364	26.4
2006	71500	17273	24.2
2007	69000	14545	21.1
2008	67000	12727	19.0
2009	53000	6364	12.0
2010	71000	9091	12.8
2011	80000	10909	13.6
2012	78000	7273	9.3

2013	77000	7636	9.9

Table 1 World and EU consumption of tungsten from 2002 to 2013

It was reported [3] 61.0% of global consumption in 2011 was used in cemented carbides; 20.3% used in high speed steels and super alloys; 11.4% used in mill products; 7.3% used in the chemical industries. The consumption distributions of tungsten in 2011 would be 6,654 t in cemented carbides, 2,214 t in speed steels and super alloys, 1,244 t in mill products and 796 t in chemical industries.

The tungsten imports ($) for European countries according to the statistics [4] are shown in Table 2.

Ranking	Country	Import ($)	Date
1	Austria	76, 508, 569	2014
		88,251,638	2012
2	Russia	17,368,334	2014
3	Germany	6,946,644	2014
		15,136,212	2011
4	France	8,626,815	2013
5	Estonia	7,625,369	1997
6	Spain	175,124	2014
7	UK	725,535	2014
8	Sweden	50,100	2014
9	Slovakia	31,868	2014
10	Finland	28,743	2008
11	Czech Republic	25,718	2014
10	Ukraine	25065	2011

Table 2 Tungsten imports ($) for European countries

EU TUNGSTEN SUPPLY CHAIN

EU TUNGSTEN SUPPLY CHAIN

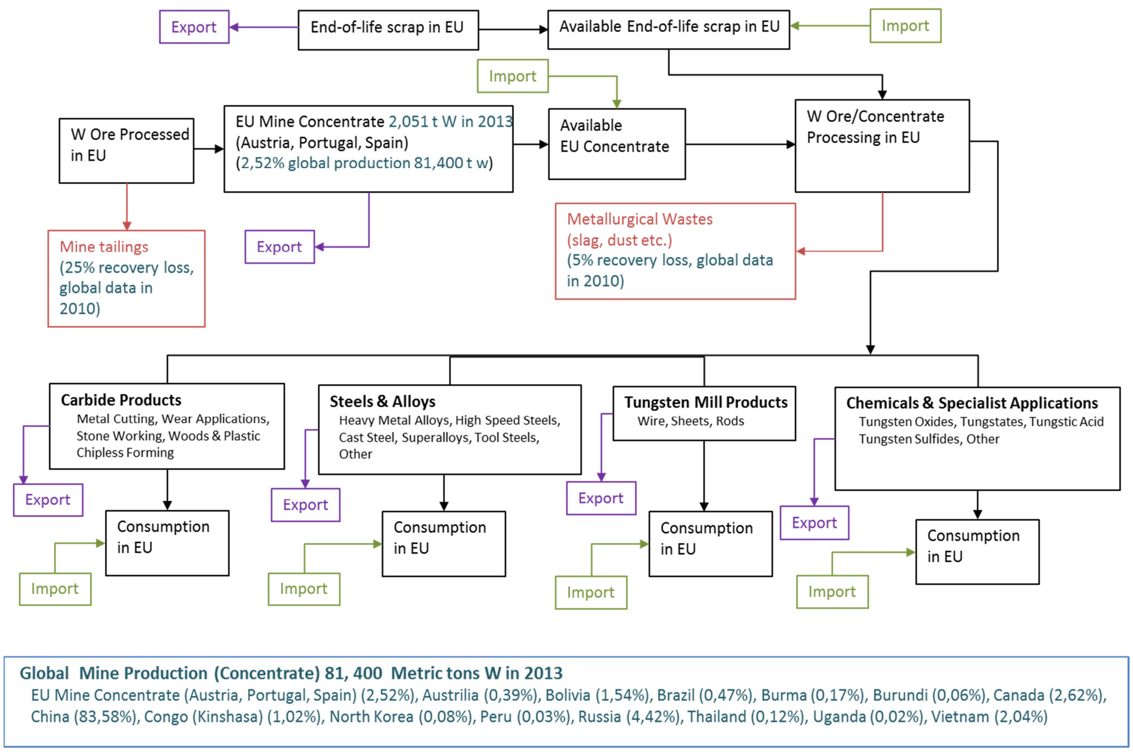

Figure 1 EU Tungsten supply chain

FUTURE APPLICATIONS OF TUNGSTEN [28]

NEW TECHNOLOGIES

The need for a more energy-conscious society in relation to the efficient production and consumption of energy has intensified in past years and will become increasingly important for that society in the future. Currently, worldwide energy use is growing much faster than supply can match. The efficiency of conventional technologies must be improved in order to reduce losses in transmission and distribution of energy, and new strategies and technologies must be developed for "doing more, using less".

Whatever form such solutions may take in the future, it may be expected that tungsten-based materials and components will play their positive part in meeting these challenges. Tungsten products have contributed in the past in this way, both as functional materials and advanced tools with outstanding properties, and this contribution will not diminish in the near future.

Current discussions on global warming, and the conclusion that anthropogenic greenhouse gases are responsible for most of the observed temperature increase since the middle of the twentieth century, have brought calls for reductions in emissions which will demand a more conscientious handling of fossil energy worldwide. The search for alternatives will be intensified, as coal, oil and natural gas reserves become depleted and the need to use existing natural and renewable resources steadily increases.

There is a great opportunity for tungsten-containing products which have strategic importance in the field of fossil energy production, fossil energy or renewable power generation, power transmission and power distribution, because of their outstanding properties.

OTHER INFORMATION [29]

TUNGSTEN VALUE CHAIN. Worldwide loss of know how if EU Tungsten value chain is destroyed as it is the leader in the development of many tungsten products development for automotive, aerospace, medical, lighting applications disappearance of EU tungsten industry would result in full dependence of several key industries on imports from abroad.

MARKET DEVELOPMENT. Slow market growth projected in the next five years.

In the figure 1 is could be seen:

- In 2013, external demand was the main driver for the European economy.
- In 2014, domestic demand was taking over as main demand driver.
- Strong influence of the Tungsten market Europe on the global Automotive, Machine Tools and Mining Industry.
- As a result, Europe Tungsten market outperforms the European GDP (Gross domestic product) growth.

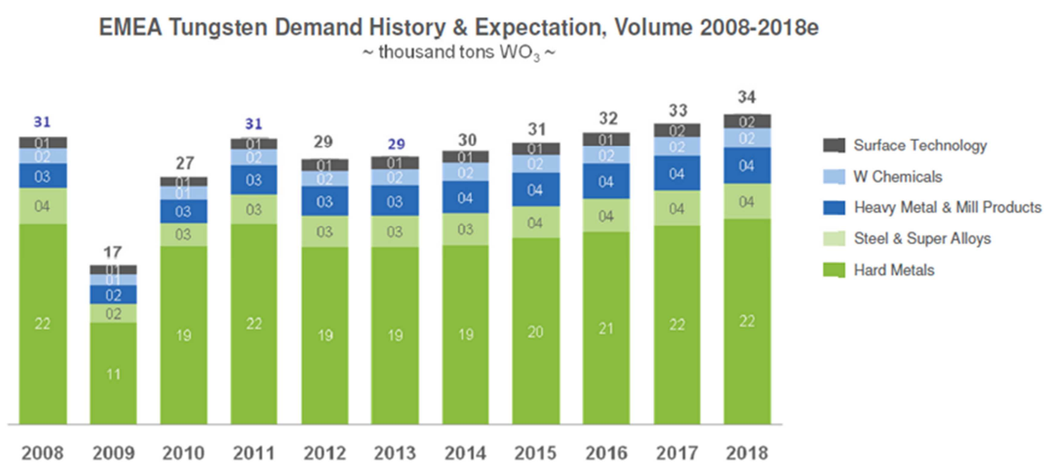

Figure 2. EMEA (Europe, the Middle East and Africa) Tungsten Demand. Source: H.C.Starck.

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RHENIUM PRODUCTION/DEMAND AND ITS APPLICATIONS

The consulted information sources regarding rhenium production and main applications agree on a world mine production of approximately 50 tonnes per year, the majority of which is produced as a by-product of copper-molybdenum deposits. Molymet in Chile dominates world rhenium supply supplying 26 tonnes in 2011, followed by United States with 6.3 tonnes, Peru with 5 tonnes and Poland with 4.7 tonnes [1].

Table 3 shows collected figures on world production by applications.

Table 3. World Re production figures based on consulted sources.

<table>
<tr><th>Application</th><th>World production 2011 [1]</th><th>World production 2010 [3]</th><th>World production 2011 [2]</th><th>World production 2012 [4]</th></tr>
<tr><td>Aerospace superalloys</td><td>59 %</td><td rowspan="2">78</td><td rowspan="7"></td><td rowspan="7"></td></tr>
<tr><td>Gas turbine</td><td>12 %</td></tr>
<tr><td>Catalysts</td><td>14 %</td><td>14</td></tr>
<tr><td>Other</td><td>12 %</td><td>8</td></tr>
<tr><td>Automotive</td><td>5 %</td><td></td></tr>
<tr><td>Oil/gas</td><td>1 %</td><td></td></tr>
<tr><td>Tools</td><td>1 %</td><td></td></tr>
<tr><td>TOTAL (in mt)</td><td>50 mt</td><td>53.5 mt</td><td>46 mt</td><td>44.8 mt</td></tr>
</table>

Rhenium is consumed in several forms (Table 4). The basic form, ammonium perrhenate (APR), is used in the manufacture of reforming catalysts. APR is also the starting material for the production of perrhenic acid (also used in catalysts), rhenium powder, pellets and briquettes, which have applications in superalloys and other metallurgical uses. A high proportion of the ammonium perrhenate consumed is ultimately re-used, mainly because of petroleum catalyst recycling industry.

Table 4. Rhenium products and their typical applications.

Product	Typical application
Ammonium perrhenate	Production of rhenium metal and perrhenic acid, manufacture of Pt-Re reforming catalysts, addition to superalloys
Perrhenic acid	Manufacture of Pt-Re reforming catalysts
Rhenium metal powder	Addition to superalloys, production of sheet, foil, strip and wire Rhenium metal briquettes
Rhenium metal briquettes	Addition to superalloys

Typical Re content and/or consumption in main applications is shown in Table 5.

Table 5. Rhenium content/consumption in typical applications.

Application	Re content
Nickel-base super alloys	3% [1] [4]
Platinum in bi-metallic reforming catalysts	0.3% [4]
Turbine blades (assuming CMSX-4 alloy)	0.030 kg/MW [1]
Technology GTL (natural gas)	12.5 tonnes/100,000 barrels [1]

As for rhenium world demand, Lipmann Walton & Co Ltd [4]estimated rhenium world demand at about 54 mt in 2012, of these, 45 mt were used in super-alloy for the aerospace and industrial gas turbine industry. The same source estimated Re world production in 44.8 mt (2012) as observed in Table 6.

Table 6. World Re demand vs. production figures.

Application	World demand 2012 [4]	World production 2012 [4]
Superalloys	45 mt 83.3%	
Catalysts	5 mt 9.2%	
Other	4 mt 7.5%	
TOTAL	**54 mt**	**44.8 mt**

Difference between supply and demand values is due to the recycling of 15mt of rhenium each year from spent reforming catalysts. The figure of 5mt catalyst demand represents top-up quantities for the manufacture of new catalyst and demand for other rhenium-bearing catalysts. The remaining 4mt approx. is consumed variously in anodes for medical equipment, thin filaments for spectrographs and lighting and the Re content in alloy spray powders [4].

Missing from these figures is the amount of rhenium that finds its way back into the super-alloy production loop from nickel-base alloy scrap such as end-of-life turbine blades, casting scrap, grindings. It is these units that presently make up the deficit of this market [4].

CURRENT RHENIUM CONSUMPTION IN THE EU

No data on consumption, imports or exports of Re, Re compounds or Re containing materials could be obtained from statistics data sources such as UN COMTRADE or Eurostat. The reason is that rhenium is reported in a single category along with gallium, hafnium, indium and niobium, so figures obtained based on this category are not representative of EU consumption for either trade value or netweight.

However, the European Chemicals Agency (ECHA) provides with information on registered substances in compliance with REACH. Thus, ranges of quantities of Re and Re compounds manufactured and/or imported in the European Economic Area, their registered applications/uses and the companies that have registered them are publicly available.

Table 7. Re substances registered at ECHA.

Substance	Rhenium	Ammonium perrhenate	Perrhenic acid	Potassium perrhenate	Sodium rhenate
Quantities manufactured and/or imported	0 - 10 tonnes per annum	10 - 100 tonnes per annum	0 - 10 tonnes per annum	0 - 10 tonnes per annum	-
Companies	Heraeus Deutschland GmbH & Co. KG Heraeusstr. 12-14 63450 Hanau Germany Metraco S.A. Sw. M. Kolbe 9 59-220 Legnica Dolny Slask Poland	Climax Molybdenum B.V. Theemsweg 20 3197 KM BOTLEK-Rt Netherlands Heraeus Deutschland GmbH & Co. KG Heraeusstr. 12-14 63450 Hanau Germany Lipmann Walton & Co Ltd Palace Gate House, Palace Gate, Hampton Court Road, KT8 9BN East Molesey Surrey United Kingdom	Heraeus Deutschland GmbH & Co. KG Heraeusstr. 12-14 63450 Hanau Germany	Heraeus Deutschland GmbH & Co. KG Heraeusstr. 12-14 63450 Hanau Germany	Climax Molybdenum B.V. Theemsweg 20 3197 KM BOTLEK-Rt Netherlands
Uses	Manufacture of susbtances Manufacture of alloys Manufacture of computer, electronic and optical products, electronic equipment	Manufacture of susbtances Use as an intermediate	Use as a catalyst Use as an intermediate	Manufacture of susbtances Use as an intermediate	Intermediate Use Only

Other relevant information on current consumption trends has been collected from different sources and summarized as follows:

- The development of the European aerospace industry has reduced the American market domination. Main consumers of superalloys containing rhenium are engine manufacturers, which contribute with a 55% of the total consumption. The main final users of superalloys of nickel containing rhenium are Cannon-Muskegon, General Electric, Pratt & Whitney and Rolls Royce [3].
- KGHM Ecoren is the only EU company recovering rhenium from molybdenite (6 tonnes in 2009) which receives from its copper-producing parent, KGHM Polish Coppera, BRGM report, 2010 [3].
- Axens (France) is one of the main producers of catalysts used in oil refinery, contributing with a 3% of the worldwide catalytic reforming capacity [3].

• **Uses**	Manufacture of susbtances Manufacture of alloys Manufacture of computer, electronic and optical products, electronic equipment	Manufacture of susbtances Use as an intermediate	Use as a catalyst Use as an intermediate	Manufacture of susbtances Use as an intermediate	Intermediate Use Only

RHENIUM EU CHAIN VALUE

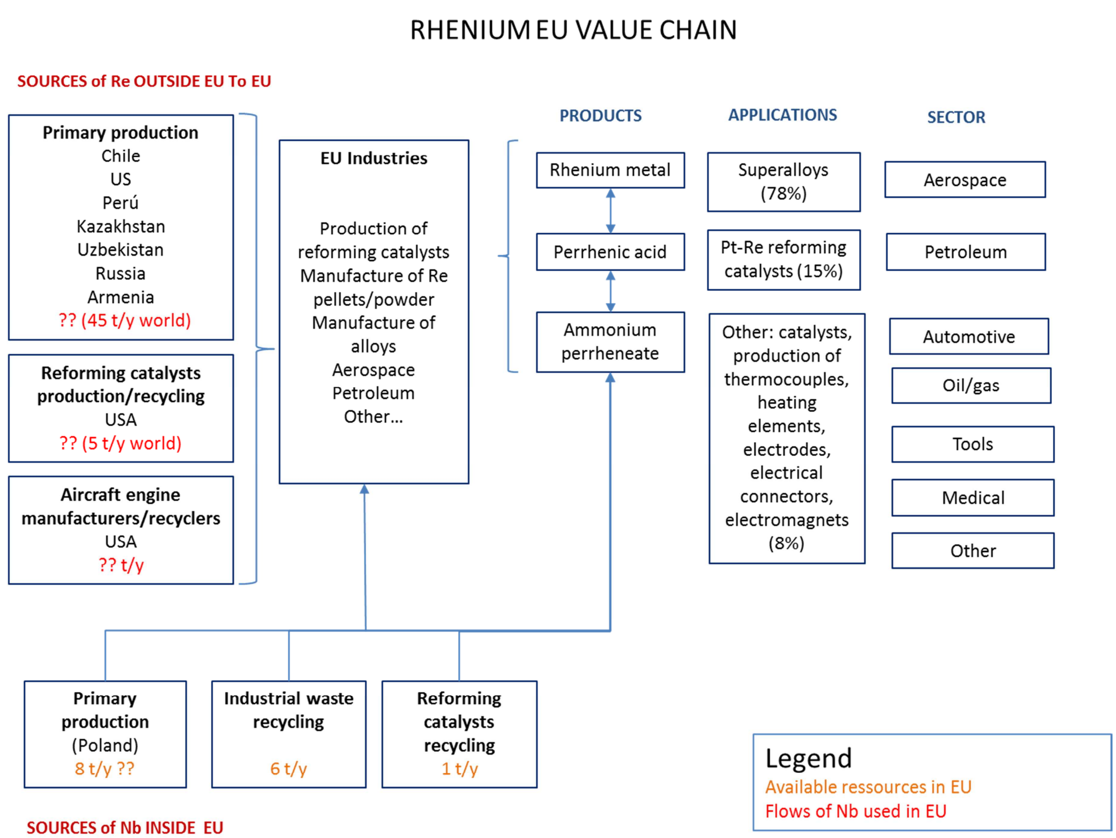

Figure 3 Rhenium EU value chain

EU MARKET FORECAST

In 2013, projected demand for the metal was forecast to amount to some 55-60 tons, of which the vast majority would go into super-alloys, with 5 tons going into catalysts, 2 tons into medical anodes and 2 tons into filaments [5].

Demand for rhenium is showing growth at the present because of demand for engines in both commercial and military jets. This is forecast to continue to rise strongly over the next twenty-five years. The use of rhenium catalysts in reforming is also growing but at a lower rate. The rhenium annual EU demand for advanced fossil fuel power generation forecasted by 2020 and 2030 is 0.6 tonnes/year, which represents one of the greatest material requirements [1].

However, for the last few years, the gap between supply and demand has been made up by tributaries and streams of saved units, rescued from rhenium to be wasted in the past. Thus, recycling of the metal has grown considerably over the past several years, particularly among the leading consumers, e.g., General Electric Aviation with its "Rhenium Reduction Program" [4] [5].

Rhenium secondary production takes place in Germany (Buss & Buss Spezialmetalle, H.C. Starck and Heraeus Precious Metals). And according to the USGS, secondary rhenium is also recovered in Estonia (Toma Group) [5].

In general, it is considered that, despite some worries within the industry as to future supply, "primary and secondary resources are sufficient to allow producers and potential producers to keep pace with demand" [4].

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MOLYBDENUM IN INDUSTRIAL VALUE CHAINS OF EU

According to the collected information of molybdenum presented in the 1st workshop and Deliverables 2.2-4.2, the molybdenum industrial value chains of EU are drawn and shown in Figure 1 and Figure 2.

INPUTS OF MOLYBDENUM IN INDUSTRIAL VALUE CHAINS

Molybdenum ores. In Europe there are primary molybdenum mines in Sweden (Munka Mine, with the reserve of 1.7 Mt of molybdenum ore at 0.156% Mo, which equals to 2652 metric tons of molybdenum) and Norway (Knaben Molybdenum Mines, with reserve of 8.6 Mt of ore with an average of 0.2% MoS_2 at Knaben II[1]). There are also Cu-Mo mines in Turkey. Though it is reported that Mo can be also produced from Co-product ores[2] and scheelite/wulfenite ores[3], there is little information regarding Mo production from these materials in Europe. Due to limited mining and a limited amount of proved reserves of molybdenum ores in EU, the imported molybdenum ores from countries outside EU is an important chain in the whole molybdenum industrial value chains.

Waste rock and tailings. During mining and mineral processing of molybdenum ores waste rock and tailing are generated as a consequence. In EU neither how much of these materials are generated and were historically generated/deposited nor the grades of these materials are known as open information.

Technical grade MoO_3. The mined or imported molybdenum ore concentrates in EU are domestically processed by the metallurgical routines described in D2.2 to produce various end-use products and intermediate products. Moreover, a large quantity of molybdenum (for example, technical grade MoO_3) is imported and input in the value chains. It should be noted that technical grade MoO_3 is an important starting compound for producing various Mo products and/or Mo-containing intermediate products.

Other inputs. The other inputs include imported Mo-containing products, ferroalloys, scraps and external industrial wastes/residuals (such as fly ash described in D3.2). So far there is no statistical information on the amount of molybdenum that is extracted from the external industrial wastes/residuals.

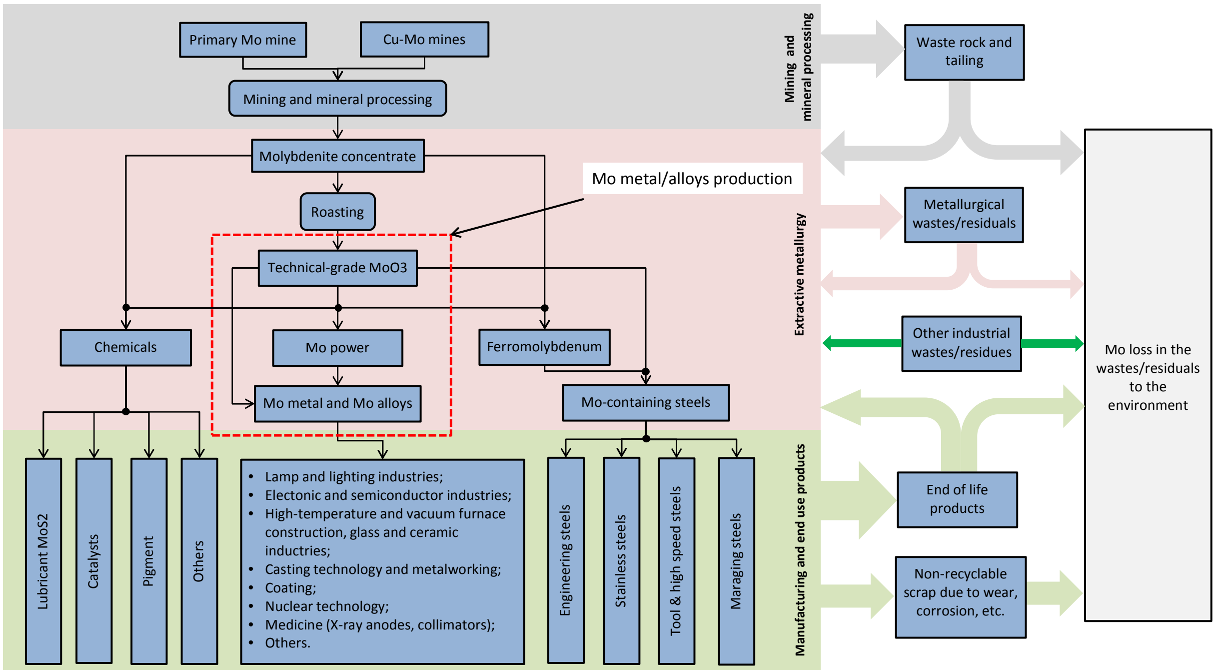

Figure 4 Molybdenium industrial value chains of EU. (The applications Mo metal and Mo alloys are derived from [5])

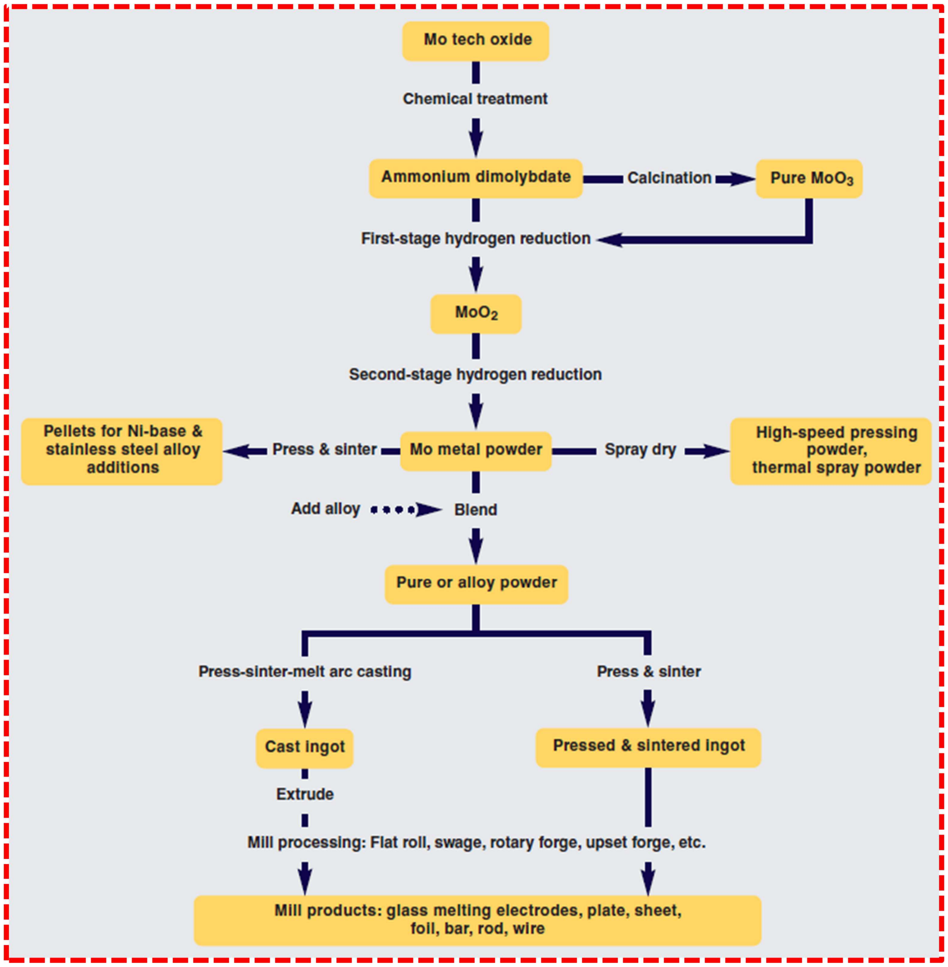

Figure 5 Molybdenium metal and alloy production in the value chains (shown in Figure 1).

OUTPUTS OF MOLYBDENUM IN INDUSTRIAL VALUE CHAINS

The outputs of molybdenum in the industrial value chains of EU are believed to be mainly various Mo-containing products or intermediate products. Figure 3 shows the global use of molybdenum produced from mined molybdenum ores. It is seen that Mo is largely used to produce steels, molybdenum metal/alloys. A small amount of molybdenum is also used to produce chemicals. The end use of molybdenum is however split across several industries, as shown in Figure 4.[4] The molybdenum grades in various products are shown in Table 1.

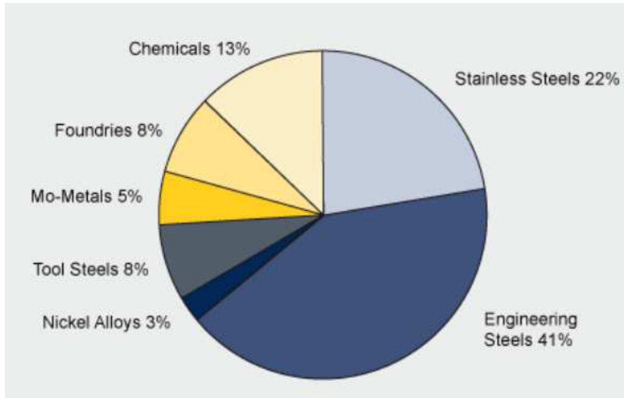

Figure 6 The use of molybdenum produced from mined ore [6]

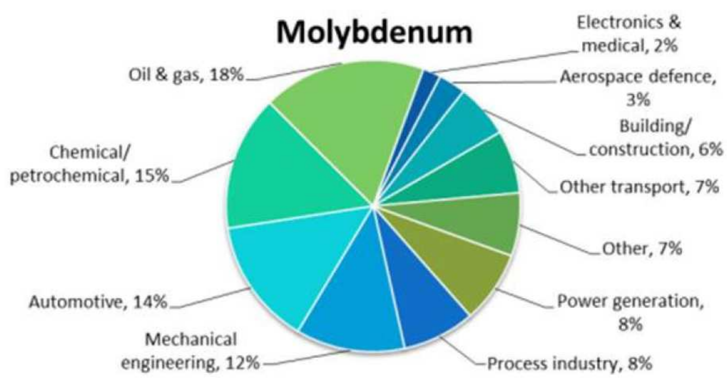

Figure 7. Worldwide use of molybdenum in different industries.[4]

CIRCULATION OF MO IN INDUSTRIAL VALUE CHAINS

The Mo-containing materials that are circulating in the industrial value chains of EU can be classified as: (a) metallurgical wastes/residuels; (b) waste/residual materials generated during the manufacturing; (c) recycled end-of-life products (such as spent catalysts). The Mo grades in these materials vary with the source of the materials. The recycled molybdenum amounts to 1/4 to 1/3 of the total molybdenum need, as described in D3.2.

MOLYBDENUM LOSS FROM INDUSTRIAL VALUE CHAINS TO THE ENVIRONMENT

The loss of Mo to the environment is unavoidable. This happens: (a) during the mining and mineral processing process, when molybdenum gets lost in the waste rock and tailings even a further treatment of waste rock and tailings is implemented; (b) during the metallurgical process (for example, in the slag and dust); (c) during the end-use application due to the corrosion, wear of the products, discard of the products, etc.

Material type		Mo grades	Reference
Steel products	Stainless steels	1-6.1%	[7]
	Tool & high speed steels	0.5-9%	[8]

	Maraging steels	4-5%	
	Other steels	0.2-0.5%	
Mo super alloys		2-28.5%	[9]
Mo metal and alloys	Mo metal	99.5-99.97%	[5]
	Mo-W alloys	10-50%	
	Mo-Re alloys	52.5-97%	
	Mo-Ta alloys	89.3%	
	Mo-Nb alloys	90.3-97%	
	Carbide-stabilized alloys	~99%	
	Dispersion-strengthen alloys	~99%	
	Cu-Mo-Cu laminate	75-87%	
	Mo-Ni laminate	95%	
	Mo-Cu powder	70/85%	
	Mo-Ti	50 atomic%	
	Mo-Na powder	97-99%	
	Pure Mo metal powder	99.0%	
	Mo-C powder	>94%	
	17.8Ni-4.3Cr-1.0Si-0.8B powder	76.1%	
Mo chemicals	Lubricant grade MoS_2 (> 98%)	MoS_2 > 98%	[10]
	Desulphurization catalysts	~ 8%	[11]

Table 8 Molybdenum grades in various products

RECENT DATA ON PRODUCTION, CONSUMPTION, IMPORT AND EXPORT OF MOLYBDENUM IN EU

MOLYBDENUM PRODUCTION AND CONSUMPTION IN EU AND/OR EUROPE.

The available data on Mo production from mined ore within Europe shows that 4 metric tons (metal content) of molybdenum was produced in 2012 and 8 metric tons in 2013. The available information indicates that all of these productions were from Norway.[12] No information on mining molybdenum ore/concentrates in EU is found. The consumption of molybdenum in Europe is shown in Figure 5. It indicates that the molybdenum consumption of molybdenum in 2013 amounted to 140 million lb, which equals to 63.5 kt. Unfortunately, no data for consumption of molybdenum in EU can be derived.

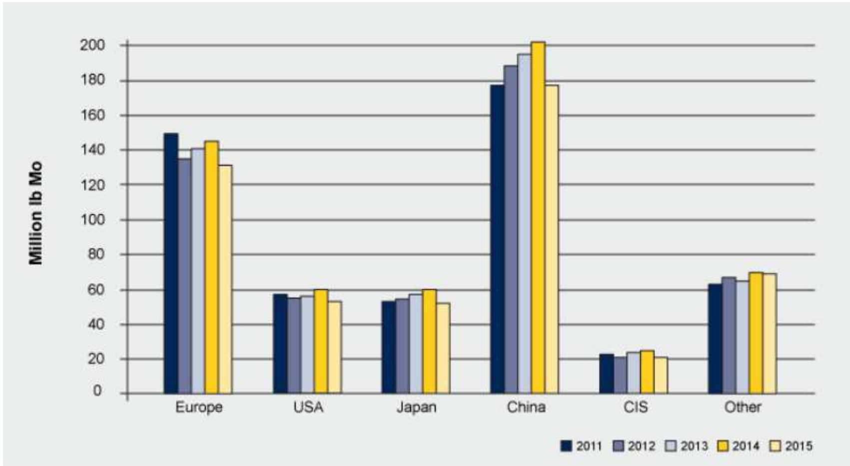

Figure 8 Molybdenum consumption in Europe and the other regions of the world.[13]

MOLYBDENUM IMPORTS IN EUROPE

Europe imports a lot of molybdenum in the form of roasted molybdenum concentrate (technical grade MoO_3), molybdenum metal and molybdenum ores/concentrates. The statistical data on molybdenum import is shown in Figure 6.

MOLYBDENUM EXPORTS FROM EUROPE.

Some molybdenum-containing materials are also exported in Europe; the statistical data on molybdenum export is shown in Figure 7.

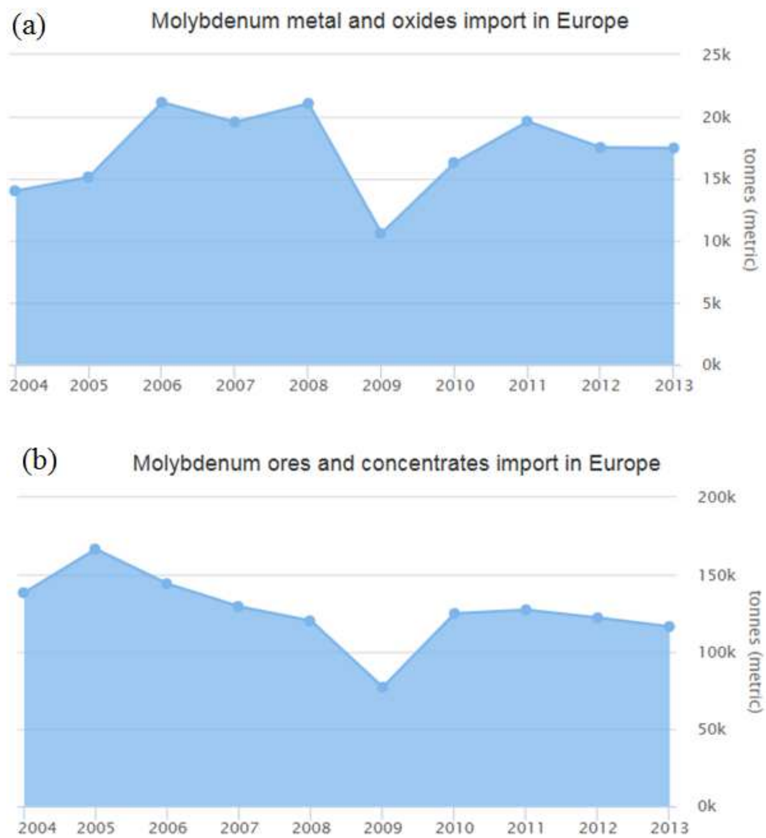

Figure 9. Europe import in the form of: (a) molybdenum metal and oxides; (b) molybdenum ores and concentrates. [12]

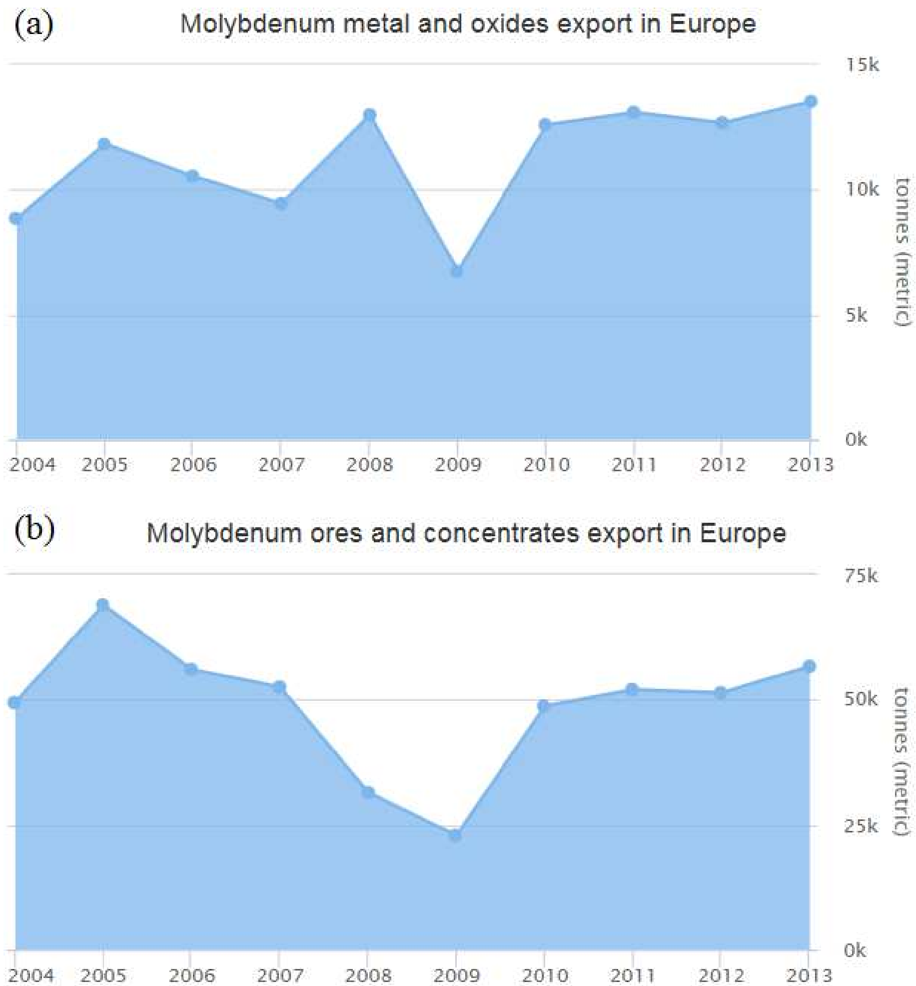

Figure 10. Europe molybdenum export in the form of: (a) molybdenum metal and oxides; (b) molybdenum ores and concentrates. [12]

MOLYBDENIUM EU CHAIN VALUE

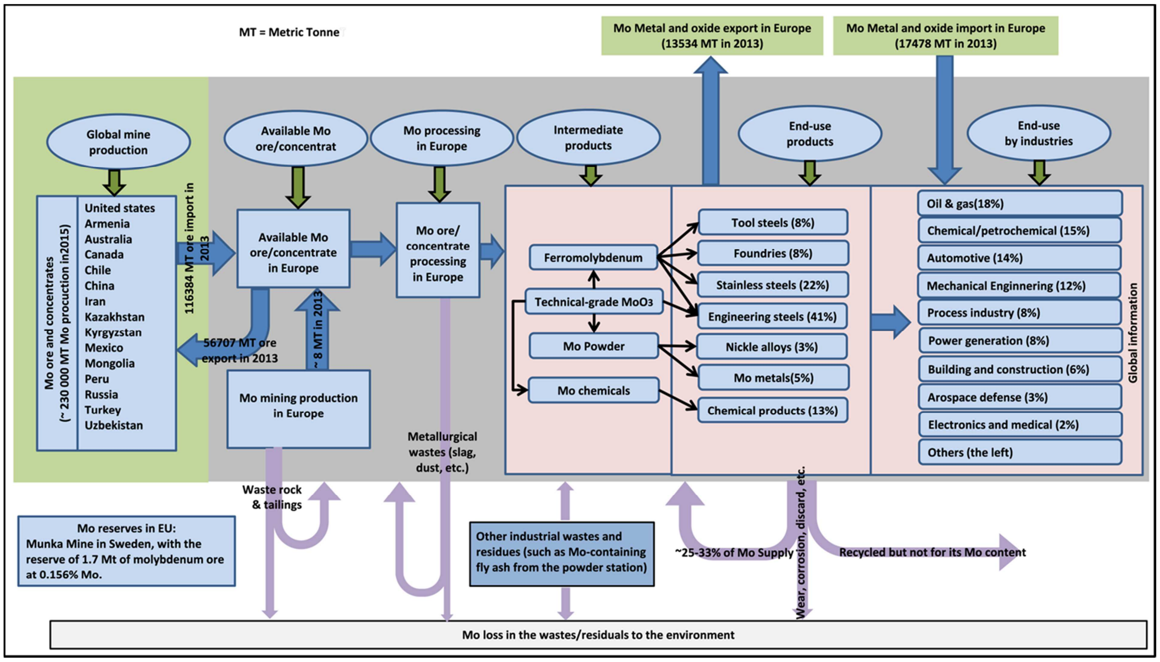

Figure 11 Molybdenium Chain value in EU

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COMPILATION OF DATA ON CURRENT USAGE OF NIOBIUM (NB) IN INDUSTRIAL VALUE CHAINS OF EU

Niobium is used in a variety of forms has shown in the following table, but by far the most important in tonnage terms is HSLA (High Strength Low Alloy) ferroniobium that has applications in the production of certain types of steel. This market now accounts for about 90% of niobium usage and has been responsible for most of the increase in overall consumption.

Form of Nb	Applications	Principal markets	Nb grade
HSLA FeNb	HSLA steels	Automobiles, gas linepipe, construction, heavy engineering	~0.1%
	Stainsless and heat resistant steels	Automobiles, petrochemical and power plants	0.04-0.08%
Vacuum grade FeNb and NiNb	Superalloys	Aircraft engines, electricity generation, petrochemicals	3-5%
Nb metal and alloys	Superconductors	Particle accelerators, magnetic resonance imaging, various small tonnage uses	45-89%
Nb chemicals	Functionnal ceramics and catalysts	Optical, electronics	21-66%

Table 9 Summary of applications of Niobium. [1] [3]

Vacum grade ferro-niobium and nickel-niobium find widespread application in superalloys used in the aerospace industry, particularly in commercial aircraft engines, as well as in land-based gas turbines for electricity generation, and in corrosion-resistant alloys. Strong demand in end-use markets saw shipments of superalloys rise during the late 1990s and into the early part of this century, until an economic slowdown, coupled with terrorists acts, resulted in a sharp downturn in aircraft sales and the land-based power generation market, and thus in demand for superalloys. Both end-use markets bottomed out in 2003 and then entered a strong growth phase.

Other niobium alloys, typically containing titanium or zirconium, find use in such industries as aerospace, superconductors and nuclear energy.

Niobium chemicals have a wide variety of applications, for example in catalysts and functional ceramics. Very little information is available regarding the amount of niobium chemicals used in individual applications.

FIGURES OF SHIPMENTS OF MATERIALS CONTAINING NIOBIUM IN EU:

In order to have an overview of Niobium primary sources and products exports and imports in EU, a list of materials was established, their CN8 code identified and flows extracted from website Eurostat [2], that is to note that to make this estimation, the database chosen for all research was "EU Trade Since 1999 by HS2,4,6 and CN8 (daily updated) ".

The list of materials considered is given in the following table:

Type of material	Material CN8 designation	CN8 code
Source	Niobium, Tantalum, Vanadium ores and concentrates	26159000
	Slag, ashes and residues containing Niobium and Tantalum	26209920
	Wastes containing Niobium(Columbium)	81129139
Product	Ferro-Niobium	72029300
	Crude and powders of Niobium and Rhenium	81129231

Table 10. List of materials considered to have an overview of Niobium flows in EU [2]

SOURCES OF NIOBIUM

MINES IN EU

The following table shows niobium and tantalum mines in European Union, their grades and resources available. That is to note that none of them are operational and so that Niobium sources are imported.

Deposit Name	Company	Country	Type of ore	Status	Reserves
Penouta mine	Strategic Minerals Spain	Spain	Alkaline granite	Exploration	95.6 Mt @ 0.0094% Ta_2O_5, 0.0090% Nb_2O_5, 0.044% Sn
Alberta II	Strategic Minerals Spain	Spain	Pegmatites	Exploration	12.3 Mt @ 0.0121% Ta_2O_5, 0.044% Sn, 0.204% Li
Motzfeldt	Regency Mines	Greenland (Denmark)	Syenite	Exploration	340 Mt @ 0.19% Nb_2O_5, 0.012% Ta_2O_5, 0.46 ZrO_2
Sokli	Yara Internation al ASA	Finland	Carbonatite	Exploration stopped	110 Mt @ 0.1% Nb_2O_5, 16.5% P_2O_5

Table 11 . Review of Nb-Ta mines in Europe [3]

NIOBIUM, TANTALUM AND VANADIUM ORE CONCENTRATES

From 2011 to April 2016, no significant flows of imports and exports of Niobium, Tantalum, Vanadium ores and concentrates were recognized outside and inside EU, because no Niobium, and Tanatalum mines are on operations and because main Niobium and Tantalum mines outside EU (Canada, Brazil) do the extraction step on site.

END OF LIFE PRODUCTS (EOL)[4]

Two kinds of End of Life products containing Niobium has been identified:

WASTE ELECTRIC AND ELECTRONIC EQUIPMENTS (WEEE)

The following figure shows tonnage between 2007 to 2012 of WEEE tons put on the market, collected, treated, recovered, reused and recycled. As a figure, it was estimated that a computer can contain 0.0002% of Nb. It was said also that Niobium among other critical metals is not recovered from WEEE at present in the EU. Moreover, Nb recovered from the collected IT and telecommunications equipment would be up to 1.2 tonnes and that the grade of Niobium in PCB is about 36 g/t.

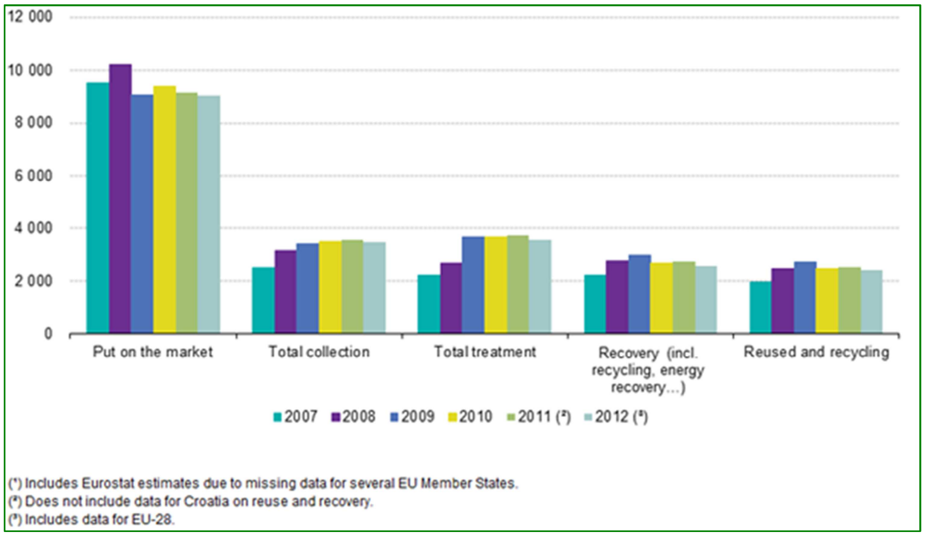

Figure 12. Electric and electronic Equipment (EEE) put on the market and waste EEE collected and treated in the EU for 2007-12 (Eurostat)

END OF LIFE VEHICLES (ELV)

	Total number of end-of life vehicles						
	2006	2007	2008	2009	2010	2011	2012
EU-27	6 120 000 s	6 500 000 s	6 270 000 s	9 000 000 s	7 350 000 s	6 760 000 s	6 280 000 s
Belgium	131 043	127 949	141 521	140 993	170 562	165 016	160 615
Bulgaria	45 127	23 433	38 600	55 330	69 287	62 937	57 532
Czech Republic	56 582	72 941	147 259	155 425	145 447	132 452	125 587
Denmark	102 202	99 391	101 042	96 830	100 480	93 487	106 504 p
Germany	499 756	456 436	417 534	1 778 593	500 193	466 160	476 601
Estonia	11 035	12 664	13 843	7 528	7 268	11 413	12 835
Ireland	:	112 243	127 612	152 455	158 237	:	102 073
Greece	29 689	47 414	55 201	115 670	95 162	112 454	:
Spain	954 715	881 164	748 071	952 367	839 637	671 927	687 824
France	930 000	946 497	1 109 876	1 570 593	1 583 283	1 515 432	1 209 477
Croatia	:	:	:	:	:	:	35 213 p
Italy	1 379 000	1 692 136	1 203 184	1 610 137	1 246 546	952 461	902 611
Cyprus	1 032	2 136	14 273	17 303	13 219	17 145	17 547
Latvia	6 288	11 882	10 968	10 590	10 640	9 387	10 228 p
Lithuania	13 877	15 906	19 534	19 656	23 351	26 619	22 885 p
Luxembourg	4 864	3 536	2 865	6 908	6 303	2 341	2 834
Hungary	20 976	43 433	37 196	26 020	15 907	13 043	15 357 p
Malta	:	:	:	:	330	2 526	2 530 p
Netherlands	192 224	166 004	152 175	191 980	232 448	195 052	187 143
Austria	87 277	62 042	63 975	87 364	82 144	80 004	64 809
Poland	150 987	171 258	189 871	210 218	259 576	295 152	344 809
Portugal	25 641	90 509	107 746	107 946	107 419	77 929	92 008
Romania	21 234	36 363	51 577	55 875	190 790	128 839	57 950 p
Slovenia	9 418	8 409	6 780	7 043	6 807	6 598	5 447
Slovakia	15 069	28 487	39 769	67 795	35 174	39 717	33 469
Finland	14 945	15 792	103 000	96 270	119 000	136 000	119 000 p
Sweden	283 450	228 646	150 197	133 589	170 658	184 105	185 616
United Kingdom	995 569	1 138 496	1 210 294	1 327 517	1 157 438	1 220 873	1 163 123
Iceland	:	:	9 386	5 109	4 195	4 075	5 824 p
Liechtenstein	:	82	91	72	107	94	114
Norway	105 324	95 128	130 018	95 000	112 537	124 563	119 905

: not available
s Eurostat estimate
p provisional

Figure 13. Eurostat data on end of life vehicles from 2009 to 2012

Number of ELV reported in 2009 was 9.0 milllon, far from the expected total number forecasted, up to 14 millions (64%). No references on content or recyclability rates of niobium in end of live vehicles were found.

The grade of Niobium in ELV can be estimated thanks grades of Niobium used in stainless steels that would be under 0.04-0.08%.

IMPORTS OF NIOBIUM MATERIALS IN EU

SLAG, ASHES AND RESIDUES CONTAINING NIOBIUM AND TANTALUM

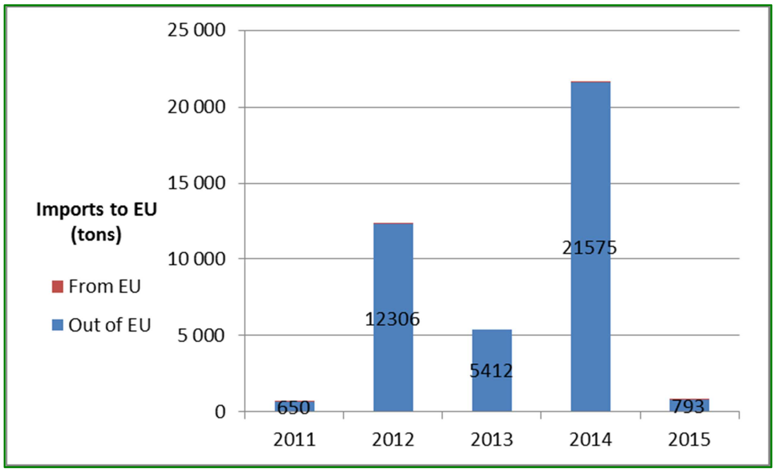

Figure 14. Imports of slags, ashes and residues containing Niobium and Tantalum to EU from 2011 to 2015 ".[2]

From 2011 to 2015, slags, ashes and residues containing niobium and tantalum varied from 650 to 21 575 tons per year. With a very strong decrease in 2015. Only very small quantities of importations from inside of EU were identified. During this period, the only country identified importing these products was Germany, 83% from Malaysia, 13% from Brazil, about 1% from Japan and low quantities from Thailand, India, South Korea and Taiwan.

Exporting flows from EU were checked on this period but were almost zero.

WASTES CONTAINING NIOBIUM

From 2011 to 2015, no imports or exports of wastes containing niobium were found in Eurostat databasis. These figures could be explained that flows of products containing Niobium even very low quantities as mentioned before are not referenced.

FERRO-NIOBIUM

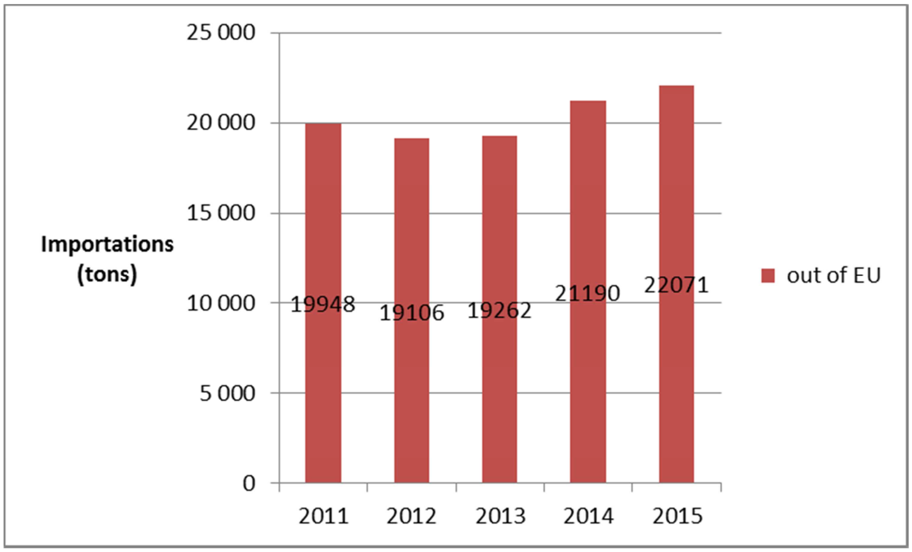

Figure 15. Imports FeNb to EU from 2011 to 2015 from out of EU [2]

From 2011 to 2015, Fe-Nb importations to EU from out of EU remained around 20 000t per year. Most of the production came from Brazil (71%) and Canada (13.3%).

The main source of Niobium in Europe is Ferro-niobium.

CRUDE AND POWDERS OF POWDERS OF NIOBIUM AND TANTALUM

According to Eurostat databasis, from 2011 to 2015, no imports of crude and powders of Niobium and Tantalum were found. However, during this period, a few hundreds of tons of products were found in the EU, The assumption to explain these figures are that most of these products are made in the EU.

EU NIOBIUM CHAIN VALUE

The following drawing tends to summary figures of Niobium in the EU:

Main sources of Niobium coming in EU are FeNb with 20 000 t/year of importation followed by slags and ashes residues with tonnages between 1000 and 20 000 t/year. No ore and concentrate and wastes containing Niobium are imported in EU. Inside the EU no Niobium mine is on operation at this time. Moreover, there are other sources of niobium such as ELV, WEE and PCB, but Niobium is not recovered at this time from these sources.

NIOBIUM EU CHAIN VALUE

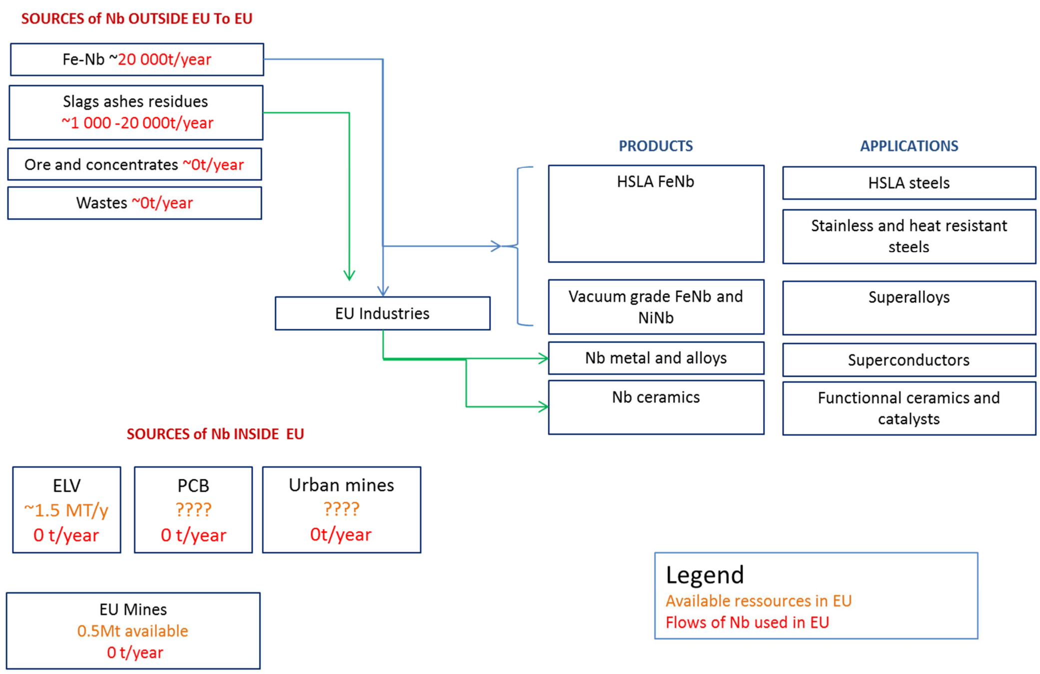

Figure 16. NIOBIUM EU CHAIN VALUE

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CURRENT USAGE OF TANTALUM (Ta) IN INDUSTRIAL VALUE CHAINS OF EU

SOURCES OF TANTALUM

PRIMARY SOURCES

Tantalum occurs almost always with niobium, an element with some end-uses in common, in a wide range of minerals that have greatly varying proportions of both metals. Some of these minerals are mined exclusively for the niobium values, and the tantalum is probably rarely recovered during processing (for instance the Araxá pyrochlore deposit in Brazil). Some others, such as the Wodgina mine in Australia, are exploited for the tantalum and the niobium is disregarded. Yet others contain commercially viable proportions of both elements and the two can be considered as co-products, even if the tantalum commands a much higher price, perhaps in a ratio of 10:1 [1].

For most of the 2000s it was often reported that the majority of the world's tantalum resources were located in Central Africa and in the Democratic Republic of Congo (DRC) in particular. Towards the end of the decade, however, the Tantalum-Niobium International Study Center, the industry's principal forum, estimated that some 40% of the most likely global resource base is in Brazil and elsewhere in South America, followed by Australia, with 21%. Central Africa was estimated to account for less than 10%. At about 700 Mlb Ta_2O_5 (317.5 kt), the estimated global tantalum resource is sufficient to last for more than 150 years at historical peak production levels [1].

That's why many experts share the opinion that tantalum is not a critical material, despite its strategic importance for different industries. This viewpoint has been validated by the European Commission in 2014, which has withdrawn tantalum from the updated list of 20 critical materials [2].

The supply of tantalum to the market derives from several sources: hard rock or artisanal mining, tin slags and synthetic concentrates, scrap and stockpiles.

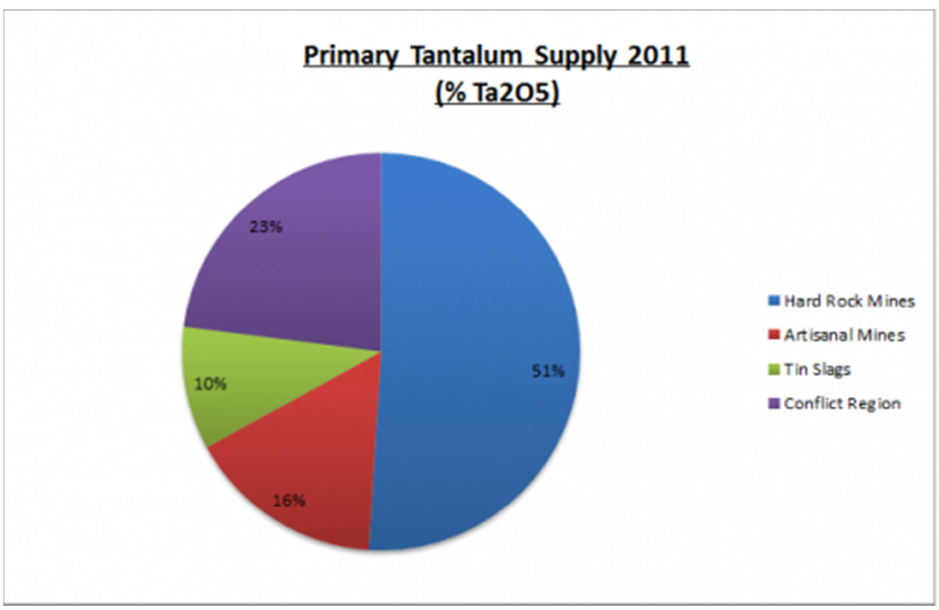


Figure 17 : World primary tantalum supply in 2011 [1]

In Europe, the only primary production of Ta comes from the Echassières kaolin quarry (France), which produced in 2011 55 tonnes of a Sn-Ta-Nb concentrate at 10 % Ta_2O_5, i.e. around 4.5 tonnes Ta [3].

SECONDARY SOURCES

According to the Tantalum-Niobium International Study Center (TIC) [4], the production from secondary resources (tin slags, manufacturing and end-of-life scraps) has grown considerably between 2008 and 2012.

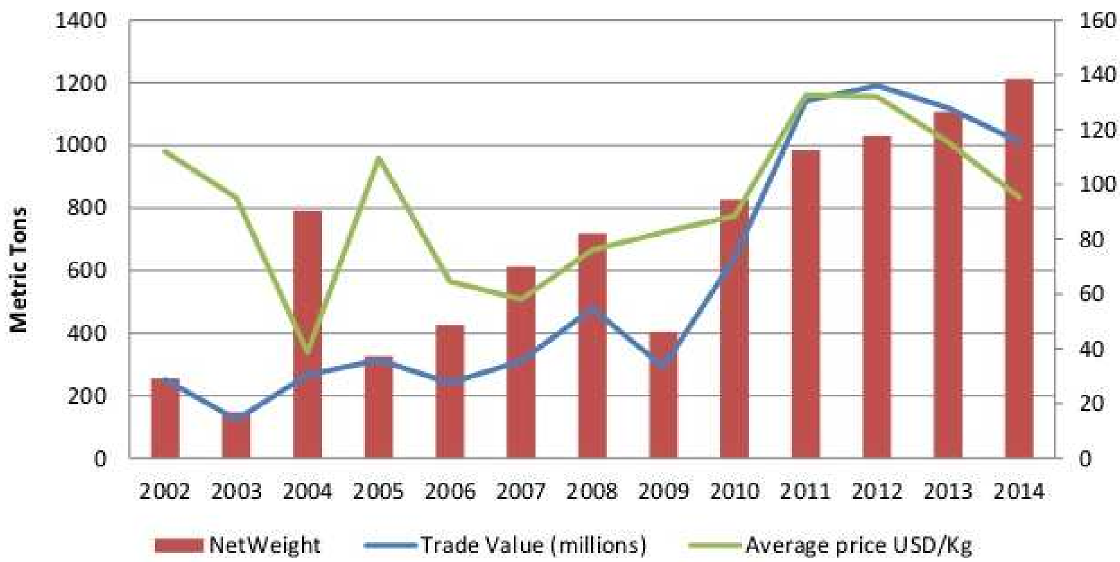


Figure 18 : Trade in Ta waste and scrap [5]

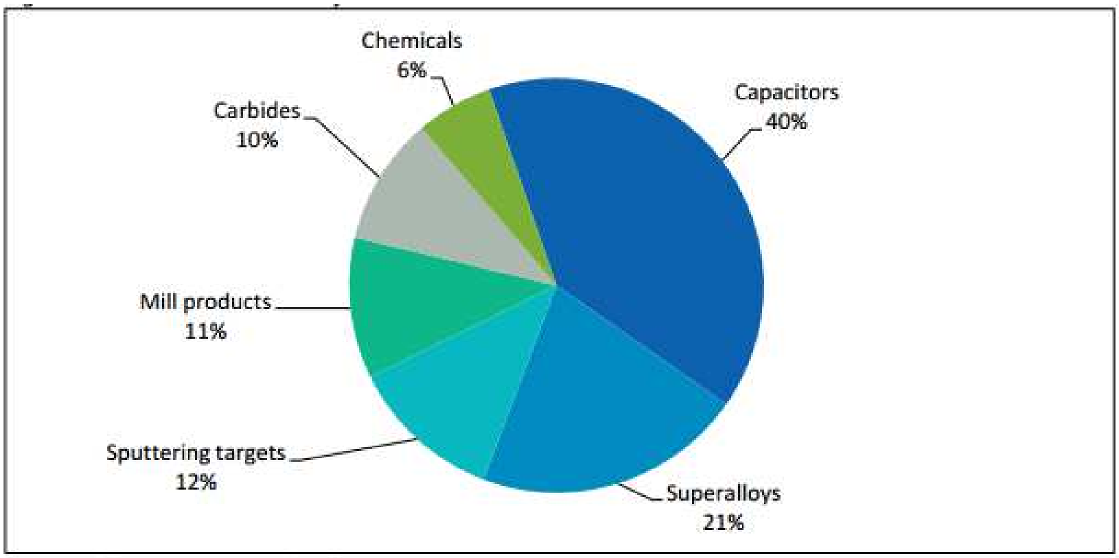
Ta recycling accounts for about 20 % of world total supply. It is recovered from a number of different items including cemented carbides and alloys, sputtering targets, edge trimmings from metallurgical processes. However, recycling from capacitors is difficult and current technology is poorly developed [6]. Figures are not openly known for Europe.

Around Europe, there many municipal landfills containing WEEE and disposal areas of incineration slags that could be future sources of Ta, but their content are usually very low or unknown.

APPLICATIONS OF TANTALUM

Tantalum is used in different sectors of the industry. Two characteristics have led to its economic importance: its corrosion-resistance and its applicability as capacitor, the latter being the most important application, with billions of units produced every year.

The other applications in electric and electronic equipments (EEE) are the sputtering targets (Ta metal, Ta_2O_5, TaN) and surface acoustic wave filters, of which the applications are cellular and wireless telephones, TV sets, video recorders, tire pressure control and keyless entry systems [3].



Source: Roskill 2013 in Minor Metals Conference

Figure 19: Worldwide end-use of tantalum in 2011

Details about the chemical forms of Ta in the different applications are given hereafter [7].

- Capacitors: The main application of tantalum is in electronic devices. Tantalum, in the form of metal powder, is chiefly used to manufacture capacitors which are key components of mobile phones and other communication systems, and of instruments to control ships or aircrafts.

- Corrosion-resistant equipment: Due to the thin oxide film which coats tantalum in air, the metal has outstanding corrosion-resistance. This passive layer enables the use of tantalum in the chemical industry. It is used for manufacturing corrosion- and heat-resistant equipment. Tantalum has similar properties to platinum with several corrosive agents.

- Medicine: Tantalum is used in several medical applications because of its non-toxicity in human tissue. Due to its passive oxide layer, the metal is completely bio-inert in the body.

- Optical industry: Tantalum compounds, mainly tantalum pentoxide, are used for special glasses (heat-reflecting, high refractive index, low optical scattering).

CURRENT VALUE CHAIN DEFINITION

The world supply chain of tantalum is known. Figure 20 shows the mine producers, processing plants, chemical forms and the end applications.

Focusing on Europe, the production of tantalum has been estimated from the differences between exports and imports, and compared to the apparent consumption (Figure 21). Some figures need to be further discussed by experts. For instance, the apparent consumption of Ta from concentrates (600 tons) is doubtful because the EU imports cannot represent 89 % of the world production. In 2014, the USGS gives for Ta a world production of 1083 t of mineral concentrates (expressed in Ta_2O_5) [3]. The estimated percentage of EU consumption is roughly evaluated between 1/4th and 1/3rd , i.e. between 222 and 296 tons [8].

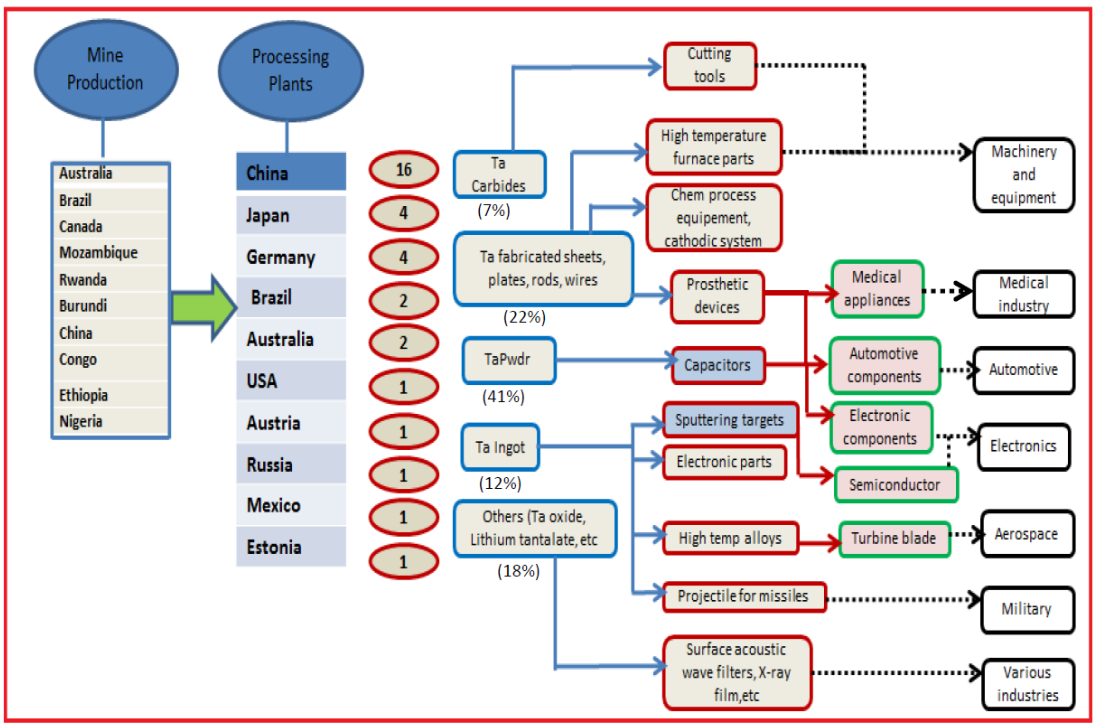


Figure 20 : World Tantalum supply chain [9]

	Product stage	Export	Import	Production	Apparent Consumption
Concentrates	Raw material	7	597	10	600
Carbides	Raw material	3	10	31	38
Articles	Raw material	345	493	254	401
wave filters	Sub-component	2	3	2	3
Semiconductors	Sub-component	46	39	32	25
other lenses	Sub-component	3	6	5	8
camera lenses	Sub-component	21	151	16	147
HDD	Sub-component	103	635	5	537
Capacitors	Sub-component	183	100	398	315
Cameras	Final product	16	196	5	185 (331 including lenses)
TVs	Final product	25	57	195	226
DVD players	Final product	0.1	2.2	0.3	2
Artificial joints	Final product	53	61	184	192
hearing aid	Final product	15	28	30	42
pacemakers	Final product	4	6	9.5	12
GPS	Final product	0.5	0.6	2.6	3
vision correction lenses	Final product	3	18	12	27
Mobile phones	Final product	122	213	216	307
passenger cars	Final product	7	16	90	98
public transport vehicles	Final product	0.5	0.1	0.3	0
freight vehicles	Final product	4	3	26	24
carbide tools	Final product	3	2	38	37
furnaces	Final product	6	1	15	9
Laptop PCs	Final product	21	149	61	189
Desktop PCs	Final product	138	123	209	195

Figure 21 : Tantalum containing products & their trade and production flows for Europe in 2007 (in tons Ta) [9]

At this time of the project, one can consider that the tantalum value chain is uncompletely known. Therefore, a further investigation on the EU tantalum market is in progress with a ROSKILL commercial expertise especially devoted to our needs.

CURRENT PRODUCERS OF TANTALUM

The most important producers in the world are:

- Advanced Metallurgical Group (Netherlands),through its subsidiary CIF, exploiting the largest mine of Volta Grande in Brazil
- Global Advanced Minerals in Australia, ensuring 25 % of the world production
- Cabot Corp. through Tantalum Mining Corporation (Tanco) in Canada
- Noventa Resources in Mozambique (Marropino mine)
- Ningxia Non-ferrous Metals in China.

As said before, the only primary production of tantalum in Europe in made by Imerys in Echassières (France), but with a very low production.

There are many refiners around the world. Focusing on Europe, the main actors are [3]:

- H.C. Starck (5 production sites in Europe) and Heraeus in Germany
- Treibacher and Plansee in Austria
- Silmet in Estonia
- Affilips in Belgium, with 2 metallurgical plants in the Netherlands and one in Belgium.

The downstream sector for transforming tantalum metal to end products is very limited. The major companies in Europe are [3]:

- Mersen (Germany), producing anticorrosion coatings (56 production sites in 40 countries)
- EPCOS (Germany) producing surface acoustic wave filters, but mostly in California through its subsidiary Crystal Technology
- Thyssen Krupp VDM (Germany) producing superalloys
- Rolls-Royce (UK) producing civilian and military turbines
- Firadec and Tantalum Capacitors (subsidiary of Vishay) in France
- Sofradir (France), producing sputtering targets.

CURRENT END USERS OF TANTALUM

There are numerous end users, according to the different applications of tantalum.

The tantalum capacitors represent around 33 % of the world capacitor market and there are many end users in electronics, but few of them are located in Europe.

The European companies working for National Defence and aeronautics are wide users of tantalum alloys: Airbus, Safran, Thalès, EADS Astrium, Dassault, Sagem, MBDA (missile systems)…

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