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Report on balance between demand and supply of refractory metals in the EU

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Summary

Report on balance between demand and supply of refractory metals in the EU

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MATCH BETWEEN SUPPLY AND DEMAND OF REFRACTORY METALS IN THE EU

MSP-REFRAM D 1.3

November 2016

Contributors

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CONTENT

INTRODUCTION

Task 1.3 final goal is to assess the potential for Europe to fulfil its needs of refractory metals, both from internal and external sources, based on the previous analysis of the value chains **(Task 1.2),** and of the mapping of secondary resources potentially available in EU **(Tasks 3.1, 3.2 and 4.1, 4.2 respectively)**.

In order to achieve this goal, both current and future consumptions trends have to be taken into account. A methodology was developed to analyse how European demand and supply for refractory metals currently match. This methodology is presented below. Then data for each one of the metals are analysed separately.

METHODOLOGY

The present methodology to estimate EU 28 current consumption of refractory metals is based on trade statistics from EUROSTAT COMEXT database (http://epp.eurostat.ec.europa.eu/newxtweb).

Various aspects are important to understand the approach:

1 The study focuses on imports/exports figures of products containing the different metals at stake. **Not all products containing the metals were considered but only a selection of the ones judged important for EU consumption, on the basis of customs codes available in the database (NC8 - CN8).**

2 The assessment is based on the following theoretical formula [1]:

EU production + EU Imports – EU Exports = EU apparent consumption

3 For both EU Imports and EU Exports, data considered was the one reported as **EXTRA EU,** to avoid double counting of flows occurring between EU 28 countries. However, some discrepancies may exist. (It is important to be aware that some flows are exchanges between subsidiaries of the same company in different countries and are thus only intermediary, or that some countries choose not to report all exchanges for reasons of confidentiality, etc.)

4 It is important to note that the quantities expressed in the tables **do not always represent 100% metal content but only GROSS WEIGHT of the products containing the metal.** Information on metal grades within these products is sometimes missing or contradictory. The following quantities are given as an indication only and should be interpreted as such.

[1] Figures for EU production are given separately (depending on the products) and not always included in the tables

TUNGSTEN: HOW TO MATCH EUROPEAN SUPPLY AND DEMAND

Contributors: Quentin Monge (E-Mines), Nigel Maund (E-Mines), Gaétan Lefebvre (BRGM)

PRIMARY PRODUCTION

Annual global mined tungsten production amounts to some 87 000 tons of tungsten content (USGS, 2016) and is largely dominated by China producing 82-85% of the total, Russia producing around 5% and Canada 3.5%. Total global supply of tungsten varies between 100 000 and 120 000 tons with the balance being provided from scrap recovery and reprocessing.

There are 4 mines currently operating in Europe, but the production of each one of them represents less than 1% of the world total production[2]. Characteristics of these mines are found in Tables 1 and 2.

- **Panasqueira (PORTUGAL)** with annual production of about 700 tons (W content)
- **Los Santos (SPAIN)** with annual production of about 500 tons (W content)
- **Mittersill (AUSTRIA)** with annual production of about 650-700 tons (W content)
- **Drakelands (UK, WOLF Minerals Ltd)** with annual production of about 900 tons of W content (to be increased to up to 3 000 tons at full capacity)

Table 1 : Significant Primary Tungsten Mines in Europe

Project Specifics	Panasqueira (PORTUGAL)	Los Santos (SPAIN)	Drakelands - Hemerdon (UNITED KINGDOM)
Company / Operator & Stock Exchange	Almonty Industries Inc (TSX-V) 100%	Almonty Industries Inc (TSX-V) 100%	Wolf Minerals Ltd (ASX) 100%
Ore Resources M&I	9.54 Mt	2.21 Mt	56.60 Mt
WO_3 Grade %	0.22	0.29	0.17
Operating Cost / MTU US$	160 - 170	88	155
CAPEX US$	Long Established Mine	80 million	150 million
Annual Production MTU'S WO_3	85,000 to 95,000	65,000 – 75,000	110,000 – 120,000 to be increased to 500,000
Mine Life	➢ 10 years	➢ 4 years	➢ 20 years
Mine Type	Underground	Open pit & underground	Open Pit
Deposit Type	Major horizontal sheeted quartz wolframite vein stockwork	Contact scheelite skarn	Major sheeted & stockwork quartz - wolframite veining system

[2] Conversion factor from Table1: MTU = 10kg, therefore 100 MTU = 1 metric ton. WO3 contains 0,792966819 W.

Table 2: Significant Primary Tungsten Mines in Europe

Project Specifics	Mittersill (AUSTRIA)	La Parilla (SPAIN)
Company / Operator & Stock Exchange	SANDVIK AB (100%) (WOLFRAM BERGBAU und HUTTEN AG)	W – Resources plc London AIM: WRES (100%)
Ore Resources M&I	6.10 Mt	51 Mt
WO_3 Grade %	0.7 (1967) now 0.2 (2015)	0.096
Operating Cost / MTU US$	No Published data available	95
CAPEX US$	Long Established Mine (1975)	52 million to 2020
Annual Production MTU'S WO_3	85,000	250,000 (2017) to 500,000 (2020)
Mine Life	➢ 10 years	➢ 15 years
Mine Type	Underground	Open Pit Mining just commenced June 2016
Deposit Type	Structurally controlled veins and replacement bodies adjacent to felsic & granitic gneisses intercalated with boninite mafic amphibolites	Quartz vein system in metamorphosed slates flanking late Variscan granite

Note: M&I = Measured and Indicated Resources.

The APT (Ammonium Para-Tungstate) and Ferrotungsten prices have recently showed high variations. Tungsten trioxide (WO_3) prices have now returned to prices of US$ 180-200 / MTU but their levels in 2012 were 450 US$ / MTU. These market downturns have impacted heavily mine closures and development of new projects outside of China. From Tables 1 and 2 it is apparent that at today's tungsten trioxide prices, European mines are currently operating at or close to the economic cut-off grade and are making losses (Drakelands), or are just breakeven or making modest profits.

SECONDARY PRODUCTION: POTENTIAL INPUT FROM RECYCLING

In Europe, potential of re-treating mining tailings could be an interesting secondary source of Tungsten, as well as new projects detailed in the last paragraph. Secondary production is also known to take place in Germany by existing Tungsten products manufacturers (H.C. Starck, Buss & Buss Spezialmetalle) but it is hard to evaluate the amount.

For more information on these aspects, please refer to Deliverables 4.1 and 4.2 as well as 3.1 and 3.2.

EUROPEAN DEMAND

APPARENT EU CONSUMPTION

The International Tungsten Industry Association (ITIA) is an entity which represents W market industrials and gathers global statistics on this metal. Figure 1 presents estimates of the main uses for different regions in 2010.

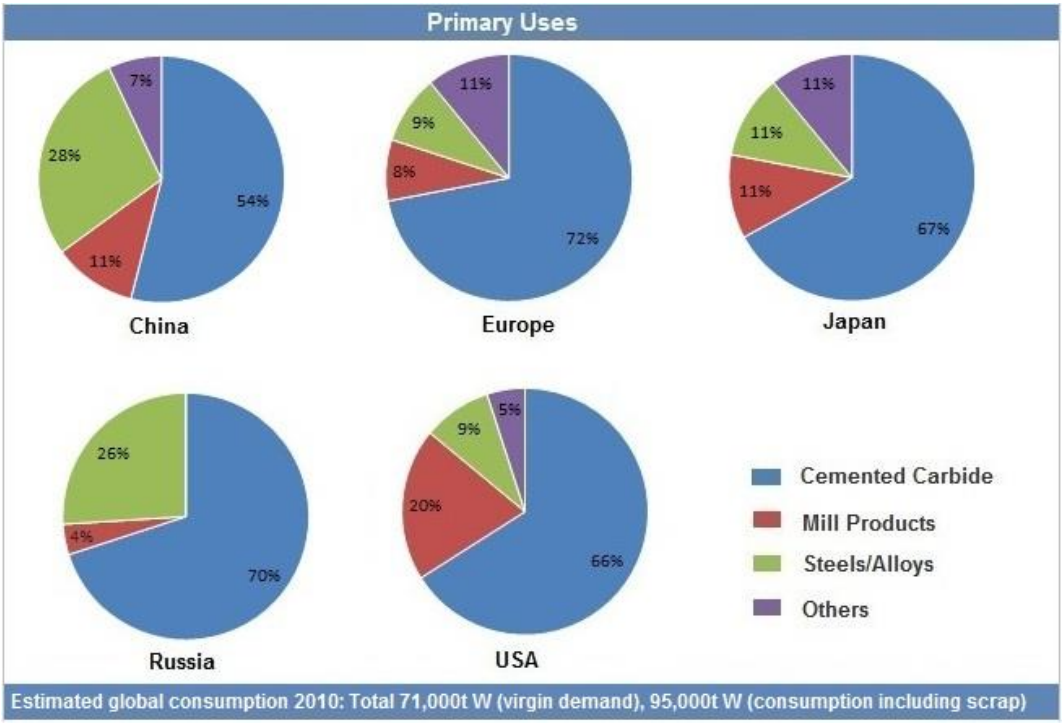

Figure 1 : Estimated consumption of tungsten by regions and applications in 2010 (quantities expressed in W content). Source: ITIA

At a global level, tungsten demand is driven by four types of product groups: cemented carbides; steel alloys; tungsten mill products and chemicals[3]. Cemented carbides dominate the market by far, with major applications being cutting tools, mining and oil&gas drilling and other machine tools.

Another estimation of global demand is given in Figure 2.

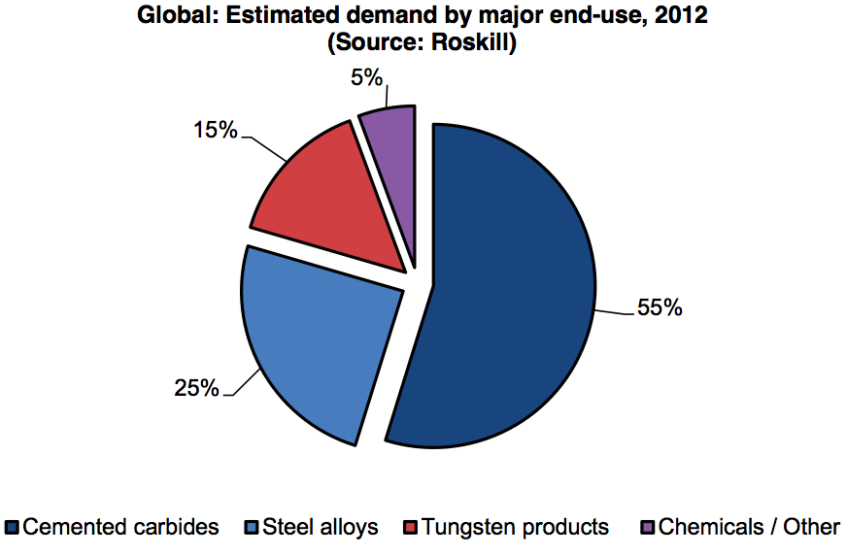

Figure 2 : World estimated demand of tungsten by major end-uses. Source: Roskill, 2013

[3] For the detailed description of W applications, see Deliverable 1.2

As regards EU apparent consumption, the following balances by product categories are obtained for 2014 and 2015. For description of the methodology used to obtain the following table, please refer to the Introduction (p. 4).

Table 3 : Balance between imports and exports of tungsten products in EU 28

	2014		2015	
	Quantity	Value	Quantity	Value
Tungsten ores and concentrates (NC8 : 26110000)				
TOTAL EXTRA EU IMPORTS	458 t	63 M€	878 t	57 M€
TOTAL EXTRA EU EXPORTS	3 862 t	42 M€	3 602 t	32 M€
BALANCE	***3 404 t***	***-21 M€***	***2 724 t***	***-25 M€***
Tungsten oxides and hydroxides (NC8 : 28259040)				
TOTAL EXTRA EU IMPORTS	4 501 t	117 M€	3 541 t	81 M€
TOTAL EXTRA EU EXPORTS	71 t	1 M€	382 t	1 M€
BALANCE	***-4 430 t***	***-116 M€***	***-3 159 t***	***-80 M€***
Tungstates (NC8 : 28410000)				
TOTAL EXTRA EU IMPORTS	3 613 t	76 M€	4 370 t	77 M€
TOTAL EXTRA EU EXPORTS	14 t	0,2 M€	24 t	0,5 M€
BALANCE	***-3 599 t***	***-75,8 M€***	***-4 346 t***	***-76,5 M€***
Tungsten carbides (NC8 : 28499030)				
TOTAL EXTRA EU IMPORTS	1 275 t	44 M€	1 120 t	38 M€
TOTAL EXTRA EU EXPORTS	418 t	18 M€	318 t	14 M€
BALANCE	***-857 t***	***-26 M€***	***-802 t***	***-24 M€***
Ferro-tungsten and Ferro-silicon-tungsten (NC8 : 72028000)				
TOTAL EXTRA EU IMPORTS	2 566 t	61 M€	3 037 t	61 M€
TOTAL EXTRA EU EXPORTS	302 t	7 M€	132 t	2 M€
BALANCE	***-2 264 t***	***-54 M€***	***-2 905 t***	***-59 M€***
Tungsten powders (NC8 : 81011000)				
TOTAL EXTRA EU IMPORTS	517 t	14 M€	332 t	13 M€
TOTAL EXTRA EU EXPORTS	362 t	11 M€	350 t	10 M€
BALANCE	***-155 t***	***-3 M€***	***18 t***	***-3 M€***
Tungsten waste and scrap (NC8 : 81019700)				
TOTAL EXTRA EU IMPORTS	3 404 t	66 M€	2 402 t	38 M€
TOTAL EXTRA EU EXPORTS	1 913 t	30 M€	1 316 t	19 M€
BALANCE	***-1 491 t***	***-36 M€***	***-1 086 t***	***-19 M€***

Warning : These figures represent gross weight quantities and NOT metal content.
They are only an approach to global consumption estimation and should be interpreted with caution

EUROPEAN USERS

The following tables present a mapping of European companies susceptible to use tungsten in their activities, whether as intermediate product manufacturers, or as end-users.

Table 4 : List of EU companies using tungsten alloys or chemicals

Company	Country	Activity
ABSCO Materials	UK	Chemical industry
Acerinox	SPAIN	Stainless steel
Althammer	GERMANY	Stainless steel/ Steel Alloys
Ampere Alloys	FRANCE	Steel Alloys
Aperam Sourcing SCA	LUXEMBOURG	Stainless steel
Arcelor Mittal	Luxembourg	Steelmaker
Boehler Edelstahl GmbH & Co KG	AUSTRIA	Steel Alloys
Bollinghaus GmbH & Co KG	GERMANY	Stainless steel/ Steel Alloys
CM Chemiemetall GmbH	GERMANY	Steel alloys
Core Alloys UK ltd	UK	Stainless steel/ Steel Alloys
Cogne Acciai Speciali Spa	ITALY	Steel alloys/Stainless steel
Cronimet Suisse	SWITZERLAND	Stainless steel scrap/ Steel Alloys
Delachaux	FRANCE	Steel alloys
Deutsche Edelstahlwerke GmbH	GERMANY	Stainless steel/steel alloys
ELG Haniel Trading GmbH	GERMANY	Stainless steel/steel alloys
Elektrowerk Weisweiler GmbH	GERMANY	Steel alloys
Eurecat France	FRANCE	Chemical
Europa Tool Co. LTd	UK	Tool steels
GFE Metalle Und Materialien	GERMANY	Steel alloys/Chemicals
Haldor Topsoe	DENMARK	Chemicals
HC Starck GmbH	GERMANY	Steel alloys
Ireland Alloys	IRELAND	Stainless steel/steel alloys
JSC Dneprospetsstal	UKRAINIAN	Steelmaker
Outokumpu Stainless AB	SWEDEN	Stainless steel
Plansee	AUSTRIA	Steel alloys
Sandvik	SWEDEN	engineering group, mining, construction
Savinox	ITALY	Steel alloys
SIJ - Slovenska Industrija Jekla	SLOVENIA	Stainless steel/Steel alloys/tool steels
SSAB Oxelosund	SWEDEN	Steelmaker
Thyssenkrupp Acciai Speciali Terni Spa	ITALY	Stainless steel
Torrecid Group	SPAIN	Chemicals
Treibacher Industrie	AUSTRIA	Stainless steel/ Steel Alloys

Ugitech SA	FRANCE	Stainless steel/ Steel Alloys

Table 5 : List of End users companies of tungsten-based products

Company	Country	Activity
Royal Dutch Shell	NETHERLANDS & UK	Oil &gas
Total	FRANCE	Oil &gas
Volkswagen	GERMANY	Automotive
Eni	ITALY	Oil &gas
Daimler	GERMANY	Automotive
Statoil	NORWAY	Oil and gas
Fiat	ITALY	Automotive
BMW	GERMANY	Automotive
ArcelorMittal	LUXEMBOURD	Steel
EADS	NETHERLANDS	Aeronautics and defence
Airbus	FRANCE	Aeronautics and defence
Vallourec & Mannesmann Tubes	FRANCE	End user oil&gas, power generation, construction, automotive
Akzonobel	NETHERLANDS	Chemical/Petrochemical
BASF	GERMANY	Chemical/Petrochemical
British Gas	UK	Oil &gas
Sandvik	SWEDEN	Mechanical engineering
Outokumpu	SWEDEN	Mechanical engineering
Vacuumschmelze	GERMANY	Materials manufacture
Ceratizit Group	LUXEMBOURG	Mechanical engineering
BIC	FRANCE	Pen's manufacturer
3M - *WINTERTHUR*	EUROPE	Abrasive tools – cutting tools
PHILIPS	EUROPE	lamps

BALANCE BETWEEN SUPPLY AND DEMAND

Demand for tungsten products is still estimated with a moderate but permanent growth, as next figure from HC Starck shows. Tungsten will remain an important partner for tool steels, high speed steels and creep-resistant steels and alloys in the medium and long term.

However, this demand is dependent on many industrial activities. Recently, the tungsten market has suffered of the drop of mining, and oil&gas industries, heavily hit by the collapse of commodity prices to down to 30 – 40% since 2012 highs. This resulted in severe cut backs in the mining and oil industries, mine closures, reduced oil&gas drilling and reduced investment in major infrastructure projects. Tungsten two most important markets: cemented carbides and specialty steels have suffered accordingly.

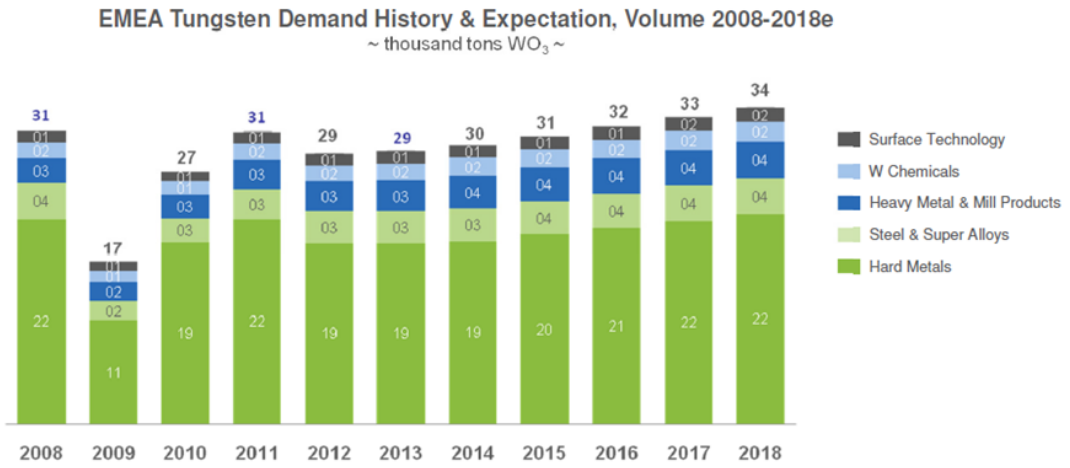

Figure 3 : Tungsten Demand Perspectives. Source: H.C.Starck

In 2010, USGS estimated global tungsten ore reserves stood at 2.8 million tons of contained tungsten metal with more than 60% of these located in China. A substantial portion (500 000 tons) of these reserves occur in higher grade and more easily worked (lower cost) wolframite porphyry stockwork and sheeted vein array system. However, China has apparently been mining high grade deposits for over 15 years, damaging the resource and reducing the long term mine economics. The remaining resources occur as skarn hosted scheelite which, in most cases, is of lower grade than the present wolframite resources. It is hard to say how long this exploitation can be sustainable.

Nevertheless, in 2016, China still rules the tungsten market and prices, and has imposed export restrictions on tungsten to prevent a faster depletion of its resources.

New sources of supply have been studied. During the period 2008 to 2013, new tungsten exploration and mining projects started. The two largest new developments were the Drakelands (Hemerdon Ball) open pit deposit in the UK and Nui Phao in Vietnam, where major resources were drilled and both projects have come on stream in 2015-2016.

In Europe, a major tungsten metallotect is the Variscan age belts of Portugal and Western Spain where some 290 000 tons of extractable WO_3 has been defined in five projects. Three of them are currently in production (Table 6) and the remaining two shall be reaching production by 2018. Other important areas of tungsten potential are Czech Republic and perhaps the most important may be France, which exhibits superb geology and is one of the most seriously underexplored major country in the world outside Africa. However, these projects in France will not be fully explored and evaluated to Definitive Feasibility Study until 2022 to 2025 and mines will not get into production until the 2024 – 2028 period. Also, old major producing districts such as the Dolphin Mine at King Island, Tasmania, Australia are being re – evaluated to be re – opened during the 2017 period.

Table 6 : A Summary of the most significant European Tungsten Projects and Resources

Project Specifics	Valtreixal (SPAIN)	Barruecopardo (SPAIN)	Regua (PORTUGAL)
Company / Operator & Stock Exchange	Almonty Industries Corp. TSX-V: ATT (25%) and SIEMCALSA (75%)	Ormonde Mining plc LON: ORM (30%)	W – Resources plc London AIM: WRES (100%)
Ore Resources M&I	2.83 Mt	17.8 Mt	5.46 Mt
WO_3 Grade %	0.34 (equiv. with Sn)	0.30	0.28 – 0.30
Operating Cost / MTU US$	Projected 80 to 90	117	Not yet estimated
CAPEX US$	45 million	57.2 million	Not Estimated
Annual Production MTU'S WO_3	90,000 +/- (2018)	Projected 2017 at 260,000	130,000 (under development 2017)
Mine Life	➢ 10 years	➢ 7 to 10 years	➢ 5 years
Mine Type	Planned Open Pit	Open pit then underground	Underground
Deposit Type	Complex Vein Array and replacement in favorable sediments associated with Late Variscan granites	Shear controlled vein array system proximal to Variscan granitoids	Scheelite calcic skarns developed on the flanks of a Late Variscan granitoid

Table 7 : List of the principal mining companies in Europe for Tungsten

Company	Country	Activity
Almonty Industries Inc	Canada	Mining
Wolf Minerals Ltd	UK	Exploration, Mining
Wolfram Bergbau Und Hutten Ag	Austria	Mining
W – Resources plc	UK	Exploration, Mining
Ormonde Mining plc	UK	Exploration, Mining
Variscan Mines SAS	France	Exploration

DISCUSSION ABOUT TUNGSTEN INVESTMENT IN EUROPE

An interesting thing to do would be to study the arrangements and agreements between the different companies. One would notice that Asian funds sometimes take large shareholdings in mining companies whose resources are essentially outside China. One example is the Drakeland project, which hosts the RCF Capital fund. When the participations are not capital-intensive, they constitute purchasing the raw materials in the form of off-take contracts, as is the case with the project in Spain Barruecopardo, where Noble group, which is Singaporean, buys production in advance.

In the longer term, the tungsten industry looks especially bright in Europe, especially as its own substantial tungsten mineral endowment will finally be explored and brought into production. Given the geology of Europe, there is every chance that Europe should be wholly self-sustaining with respect to internal primary (mine) tungsten supplies by 2040 – 2050, assuming Governments are supportive of mine development. This should then permit expansion of downstream manufacturing facilities in Europe providing a secure tungsten resource base well into the future and underpinning a key element of Europe's high technology manufacturing base.

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NIOBIUM: HOW TO MATCH EUROPEAN SUPPLY AND DEMAND

Contributors: Marta Macías Aragonés (IDENER), María González Moya (IDENER), Gaétan Lefebvre (BRGM)

PRIMARY PRODUCTION

Primary production of Niobium is concentrated in 2 countries: Brazil which accounts for about 88-90% of global output, and Canada with around 9%. The remaining has various sources (Central Africa, Malaysia, etc.). Mine production of niobium has increased rapidly over the last 15 years, from 18 323 tons of contained niobium in concentrates in 1994 to 59 000 tons in 2014 (USGS, 2016). **There is no primary production on Nb in Europe**, like its sister-element Tantalum, but some exploration projects are presented in Deliverable 1.2.

The main product from niobium metallurgy is Ferro-niobium (about 90% of the uses), which is traded all over the world for steel alloys. Annual production of Ferro-niobium is about 80 000-85 000 tons (65% Nb grade).

SECONDARY PRODUCTION: POTENTIAL INPUT FROM RECYCLING

The potential sources for Niobium recovery are mostly steels. However, either steel products are entirely recycled but not specifically for niobium because of the low amount (< 0.5% in weight) or if they are, it is in a closed loop (from scraps or from high value Nb-alloyed steels returning directly to the initial producer). For the time being, it is in most cases not economically viable to develop the infrastructure for Nb recovery.

Despite this fact, USGS states the following in 2016 (Mineral Commodity Summary):

- Nb was recycled when niobium-bearing steels and superalloys were recycled
- Scrap recovery specifically for niobium content was negligible
- The amount of niobium recycled is not available, but it may be as much as 20% of apparent consumption.

Furthermore, some companies in Europe are identified as Nb recyclers, as presented in Table 7.

For more information on these aspects, please refer to Deliverables 4.1 and 4.2 as well as 3.1 and 3.2.

EUROPEAN DEMAND

Globally, 89% of the global Niobium production is used to produce Ferro-niobium, which is used in high strength low alloy (HSLA) steels. 11% is used in the manufacture of Niobium alloys, chemicals, carbides, high-purity Ferro-niobium (Vacuum Grade) and other Niobium metal products which correspond to different market segments as shown in Figure 4.

Niobium is mainly used as an alloying element to strengthen and lighten high-strength-low-alloy steels used to build automobiles and high pressure gas transmission pipelines. A secondary role for this metal is to provide creep strength in superalloys operating in the hot section of aircraft gas turbine engines. It is also used in stainless steel automobile exhaust systems and in the production of superconducting niobium-titanium alloys used for building MRI magnets. It is used in minor quantity in electronics ceramics and camera lenses [1].

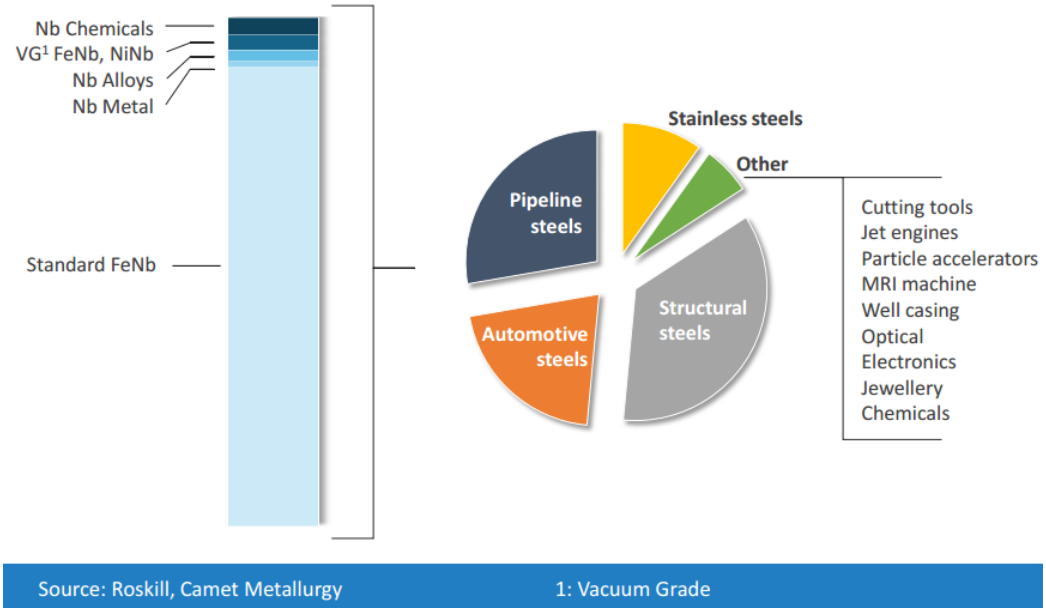

Figure 4 : Niobium products repartition by applications. Source: Roskill, Camet Metallurgy

APPARENT EU CONSUMPTION

As regards EU apparent consumption, the following balances by product categories are obtained for 2014 and 2015. For description of the methodology used to obtain the following table, please refer to the Introduction (p. 4). Ferro-niobium represents more than 95% of total imports in quantities and 90% in value. Main partners are by far Brazil and Canada.

Table 8: Balance between imports and exports of niobium products in EU 28.

	2014		2015	
	Quantity	Value	Quantity	Value
Ferroniobium (NC8 : 72029300)				
TOTAL EXTRA EU IMPORTS	21 652 t	406 M€	22 675 t	422 M€
TOTAL EXTRA EU EXPORTS	1 553 t	30 M€	2 552 t	41 M€
BALANCE	***-20 099 t***	***-376 M€***	***-20 123 t***	***-381 M€***
Unwrought niobium (or rhenium) and powders (NC8 : 81129231)				
TOTAL EXTRA EU IMPORTS	783 t	35 M€	737 t	33 M€
TOTAL EXTRA EU EXPORTS	3 t	1 M€	11 t	1 M€
BALANCE	***-780 t***	***-34 M€***	***-726 t***	***-32 M€***
Articles of niobium (or rhenium) (NC8 : 81129930)				
TOTAL EXTRA EU IMPORTS	163 t	25 M€	221 t	42 M€
TOTAL EXTRA EU EXPORTS	86 t	8 M€	632 t	19 M€
BALANCE	***-77 t***	***-17 M€***	***411 t***	***-23 M€***

Warning : These figures represent gross weight quantities and NOT metal content.
They are only an approach to global consumption estimation and should be interpreted with caution

EUROPEAN USERS

The following tables present a mapping of European companies susceptible to use Niobium in their activities, whether as products manufacturers (steelmakers or alloy producers) or as end-users. Trading companies are also mentioned, as they can play an important role in the value chain. Most of them are members of either Nb-Ta International Study Center association (T.I.C) or Minor Metals Trade Association (MMTA).

Table 9 : List of European companies manufacturing Nb products

Company	Country	Sector/Activity	Reference
ArcelorMittal	Luxembourg	Steelmaker	[2]
Thyssen Krupp	Germany	Steelmaker	[3]
Aperam	Luxembourg	Steelmaker	[4]
Outokumpu	Finland	Steelmaker	[5]
SSAB	Sweden	Steelmaker	[6]
Vallourec	France	Steelmaker	[7]
Voestalpine	Austria	Steelmaker	[8]
Tata Steel	UK	Steelmaker	[9]
Acerinox	Spain	Steelmaker	[10]
Rautaruukki	Finland	Steelmaker	[11]
Salzgitter AG	Germany	Steelmaker	[12]
Commexim Group A.S	Czech Republic	FeNb alloy producer (also recycler and trader)	MMTA
Fondel Metals BV	UK	FeNb alloy producer (also trader)	MMTA
Treibacher Industrie AG	Austria	Carbides	TANB
Villares Metal	Netherlands,Finland	Carbides	[1]
Böhler	Spain	Carbides	[1]
Sygma Aldrich	International	Nb chemicals	[13]
Cabot	Latvia	Nb chemicals	[14]
American Elements	UK,France,Germany	Nb chemicals	[15]
NEC	International	Producer of Niobium containing ceramic condensers and actuators	[1]
Corning	France	Optical. Producer of optical lenses containing Niobium	[1]
Shott	Germany	Optical. Producer of optical lenses containing Niobium	[1]
Bayer	Germany	Catalyst systems	[1]

Table 10 : List of Nb traders and recyclers in EU

Company	Country	Activity/Description	Reference
A&M Minerals and Metals Ltd	UK	Trading	TANB
Cronimet Central Africa AG	Switzerland	Trading	TANB
DM Chemi-met Ltd	UK	Trading	TANB
Krome Commodities Limited	UK	Trading	TANB
Scandmetal International S.A	Belgium	Trading	TANB
Stapleford Trading Limited	UK	Trading	TANB
Traxys	Luxembourg	Trading	TANB
CellMark Metals/Sonaco	Sweden	Trading	MMTA
Delta Products UK ltd	UK	Trading	MMTA
FerroMet AB	Sweden	Trading	MMTA
Grondment gmbh &Co Kg	Germany	Trading	MMTA
Lipmann Walton&Co Ltd	UK	Trading	MMTA
London Chemical&Resources	UK	Trading	MMTA
RJH Trading Ltd	UK	Trading	MMTA
Stapleford Minerals&Metals	UK	Trading	MMTA
William Rowland Ltd	UK	Trading	MMTA
Wogen Resources Ltd	UK	Trading	MMTA
Euroinvest commodities	Romania	Trading	MMTA
Womet Gmbh	UK	Trading	MMTA
F.W. Hempel Metallurgical Gmbh	Germany	Trading	MMTA
Firth Rixson Metals	UK	Trading	MMTA
Maritime House	UK	Trading	MMTA
ATI Specialty Alloys &Components	UK, Poland	Secondary Processing	TANB
Elite Material Solutions	UK	Secondary Processing	TANB
Heraeus Deuschland GmbH&Co	Germany	Secondary Processing	TANB
Plansee SE	Austria	Secondary Processing	TANB
H.C. Starck GmbH	Germany	Processing	TANB
Buss&Buss Spezialmetalle GmbH	Germany	Recycling	TANB
Innova Recycling GmbH	Germany	Recycler, trading	MMTA
Jean Goldschmidt International SA	Belgium	Recycler, trading	MMTA
Metherma KG	Germany	Trading and recycling	MMTA, TANB
ELG Utica Alloys Ltd	UK	Processing, recycling, alloys	TANB
Metallum Metal Trading AG	Switzerland	Recycler, Trading	MMTA

As said before, niobium is mainly used in alloy steel in automotive, aeronautic, and gas industries, so mainly the end-users are related to these fields.

Table 11 : Non exhaustive list of companies using Nb as end-users

Company	Country	Activity	Reference
Mercedes Benz	International	Incorporate Nb steels in the design of automotive pieces	[1]
Toyota	International	Incorporate Nb steels in the design of automotive pieces	[16]
Ford	International	Incorporate Nb steels in the design of automotive pieces	[16]
Jaguar	International	Incorporate Nb steels in the design of automotive pieces	[16]
Europipe	Germany	Linepipe producers	[1]
Norwegian Statoil	Norway	Linepipe consumer	[1]
Exxon	International	Linepipe consumer	[1]
British Gas	UK	Linepipe consumer	[1]
Alstom	International	Cable manufacturer. Buy Niobium alloy products in such finished forms as billets, rods and sheets	[1]
Outokumpu	Finland	Cable manufacturer. Buy Niobium alloy products in such finished forms as billets, rods and sheets	[1]
Vacuumschmelze	Germany	Cable manufacturer. Buy Niobium alloy products in such finished forms as	[1]

		billets, rods and sheets	

BALANCE BETWEEN SUPPLY AND DEMAND

The Ferro-Niobium market is an oligopoly controlled by few producing firms. The Brazilian leader CBMM has about 85% of the market shares. However, important foreign players have a 15 % stake in the company, by the intermediary of investors groups. One is Chinese, another one is Japanese and Korean composed of: JFE Steel Corporation (JFE), Nippon Steel Corporation (NSC), Sojitz Corporation (Sojitz) and Japan Oil, Gas and Metals National Corporation (JOGMEC), together with major Korean steel producer POSCO and National Pension Service (NPS). This mechanism allows them to secure their niobium supply [3] which doesn't exist at the EU level.

Globally, the Niobium market is well structured and not much change are expected on the short to medium term. The Brazilian leader CBMM (http://www.cbmm.com.br/en) has good trade relationships with most of its partners and has invested in the building of new capacities to be able to remain operational and competitive with potential forecasted growth of demand. New players are unlikely to enter the market at the current level of prices and no new mines shall be able to come into production shortly. However, it is important to note that the company China Molybdenum is the new owner of Boa Vista and Catalao mines in the states Goiás and São Paulo (Brazil), sold by Anglo American in June 2016, which represents 7-8% of total world mine production.

On the demand side, it is likely that steel production will continue to drive demand for niobium, which will continue to rise until Chinese, Indian, and Russian steels reach the same levels of niobium content/quality as in the EU and United States, Japan, South Korea.

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MOLYBDENUM: HOW TO MATCH EUROPEAN SUPPLY AND DEMAND

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PRIMARY PRODUCTION

Molybdenum is obtained mainly from the mineral molybdenite (MoS_2). It can be extracted both as primary ore (China) and as a by-product of copper extraction, which are the two main commercial sources of molybdenum [1].

Molybdenum reserves and production capacity are concentrated in a few countries of the world. Almost 80% of the production is concentrated in China (38%), United States (21%) and Chile (18%) [2], [3]. Worldwide production percentages are presented in the following figure.

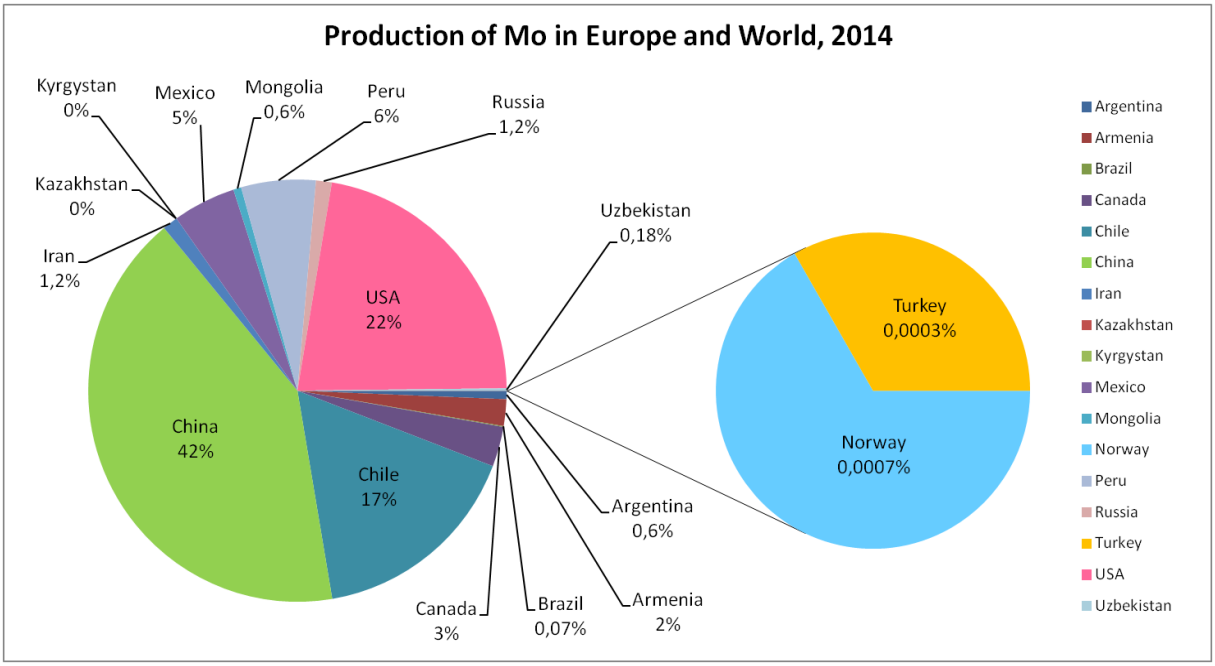

Figure 5: Production of molybdenum concentrates in 2014

The only producer of primary Molybdenum in EU is Norway, with a very small and declining production over the years (as referenced in D1.2) and Figure 6 (World Mining Data, 2016).

Molybdenum

Country	2010 metr. t	2011 metr. t	2012 metr. t	2013 metr. t	2014 metr. t	Rem
Argentina	468	854	1 617	1 915	954	1n
Armenia	4 373	4 636	5 253	5 723	5 796	1e
Australia					28	1e
Canada	8 648	8 326	8 936	7 956	9 514	1e
Chile	37 186	40 889	35 090	38 715	48 770	1e
China	96 615	103 320	120 576	122 260	123 000	2s
Iran	3 676	3 365	3 516	3 471	3 494	1n
Kazakhstan	360	360	360	0	0	2n
Korea, South	238	439	421	453	490	1e
Mexico	10 849	10 787	11 366	12 562	14 370	1e
Mongolia	2 198	1 957	1 904	1 819	1 999	1e
Norway			4	8	2	1a
Peru	16 963	19 141	16 790	18 140	17 018	1e
Russia, Asia	4 590	4 650	4 640	4 200	4 200	2n
Russia, Europe	190	190	190	180	180	2n
Turkey	0	1 424	0	620	0	1e
United States	59 400	63 700	61 500	61 000	68 200	1e
Uzbekistan	477	544	560	490	450	1e
Total	246 231	264 582	272 723	279 512	298 465	

Figure 6: Production of primary Molybdenum by country. Source: World Mining Data, 2016

Table 12 presents the largest mining companies producing primary Mo in the world. These producers account for over 60% percent of Mo total primary production [4]. It is worth noting that all of these companies are multinational groups with extracting and transforming activities all over the world (not only the countries of origin or where they have headquarters).

Table 12 : Main producers of Molybdenum in the world

Company	Country	Production	Activity/Description	Reference
Freeport-McMoran	USA	47 000 tonnes (2013)	Cu by-product	[4]
Codelco	Chile	23 000 tonnes (2013)	Cu-by product	[4]
Southern Copper (Grupo Mexico)	Mexico	19 896 tonnes (2013)	Cu-by product	[4]
China Molybdenum	China	15 270 tonnes (2013)	Primary	[4]
Thomson Creek Metals	Canada	13 590 tonnes (2013)	Primary	[4]
Jinduicheng Molybdenum	China	13 300 tonnes (2013)	Primary	[4]
Antofagasta	Chile	9 000 tonnes (2013)	Cu by-product	[4]
Rio Tinto	USA	5 700 tonnes (2013)	Primary	[4]
Anglo American	USA	4 700 tonnes (2013)	Cu by-product	[4]
Teck	Canada	3 780 tonnes (2013)	Cu by-product	[4]

Golden Phoenix Minerals	USA	230 tonnes (2005)	Primary	[2]
Roxmark Mines	Canada	450 tonnes (2005)	Primary	[2]
Amerigo (Minera Valle Central	Chile	450 tonnes (2005)	Cu by-product	[2]
Anglo-American/Falconbrige	Chile	3 000 tonnes (2005)	Cu by-product	[2]
Taseko Mines	Canada	450 tonnes (2005)	Cu by-product	[2]
Quadra Mining Ltd.	USA	450 tonnes (2005)	Cu by-product	[2]

From the molybdenite concentrates, the main route[4] is roasting to obtain a Technical Mo oxide (TMO) as presented in Figure 7 from the IMOA website (IMOA is an entity which represents Mo market industrials and gathers global statistics) [2]. TMO is a key element for almost all other following products (and one the main commercial products of Molybdenum).

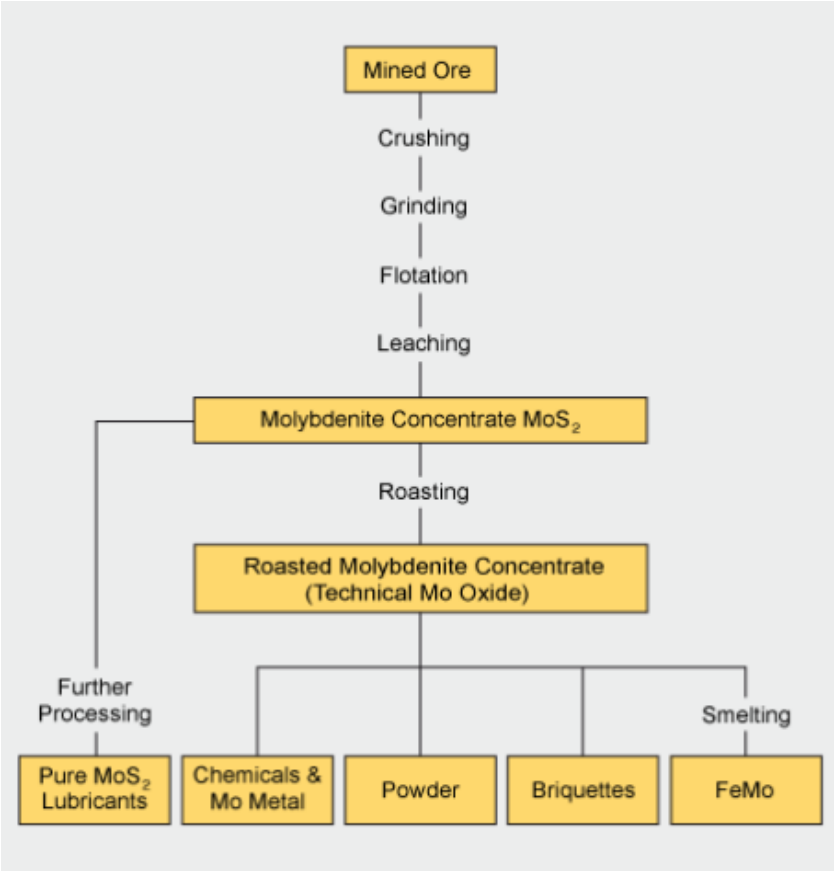

Figure 7: Molybdenum processing flowsheet. Source: IMOA

Meltstock Mo products	Supper-Alloys	Stainless Steel	Alloy Steel	Tool Steel & High Speed Steel	Cast Iron
Mo Oxide		X	X	X	
Ferromolybdenum		X	X	X	X
Mo metal pellets	X				

Figure 8: Molybdenum products uses for specific applications

[4] For the detailed description of Mo processing and metallurgy, see Deliverables 1.2 and 2.3

About 30-40% of the Technical Mo oxide (TMO) production is processed into ferromolybdenum (FeMo). **In EU, Austria is the only country that produces Ferro-Molybdenum (4 000 tons in 2014) [5].**

SECONDARY PRODUCTION: POTENTIAL INPUT FROM RECYCLING

Sources for Mo recovery are mainly: tailings, copper slags, or recycling of mill products.

Regarding steel products containing molybdenum, most of the time, either they are entirely recycled, but not specifically for Mo because of the low amount (< 0.5% in weight) or if they are, it is in a closed loop (from scraps or from High value Mo-alloyed steels returning directly to the initial producer), either because it is not economically viable to develop the infrastructure for Mo recovery in Cu slag due to its low value and high abundance. However scrap can be re-used directly to produce new steel products.

For more information on these aspects, please refer to Deliverables 4.1 and 4.2 as well as 3.1 and 3.2.

EUROPEAN DEMAND

The most important end-use applications of molybdenum include machinery, electrical, transportation, automotive, chemical industry, and the oil and gas industries. According to IMOA [2], Molybdenum produced from “new molybdenum” (Molybdenum produced from mined ore) is mainly used for metallurgic applications (approximately 87%) and around 13% is using in chemicals (Figure 9-left). Metallurgic applications includes, 45% for engineering steels, 22% in stainless steel, 8% for tools and high speed steels, 8% or cast iron, 5% Mo metals and 3% for alloys and super alloys. However, Mo is a fully recyclable metal. About 60% of Molybdenum scrap is used to produce stainless steel and constructional engineering steels. The rest is used to produce alloy tool steel, super alloys, high-speed steel, cast irons and chemicals Figure 9- right [2].

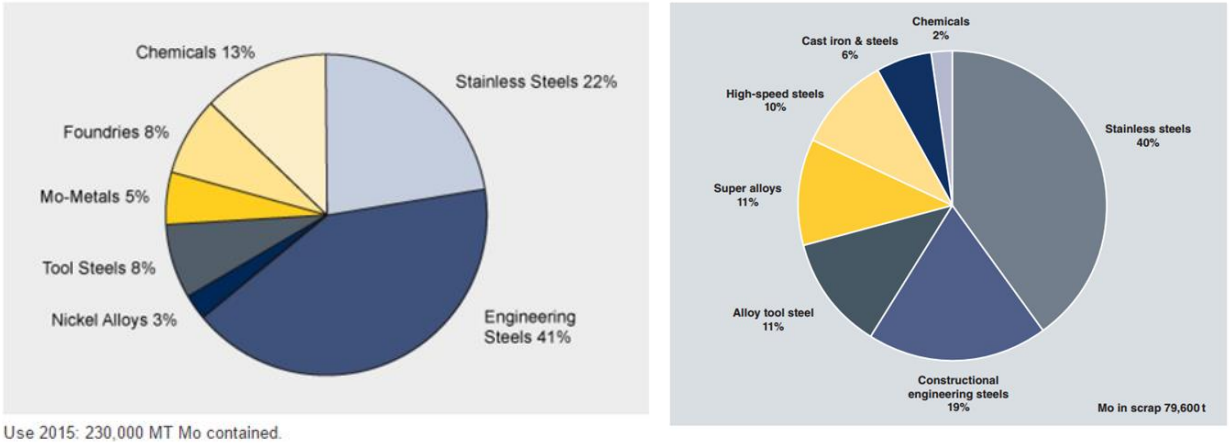

Figure 9: The use of Molybdenum from recycling scrap (left). The use of Molybdenum from mine ores (right). Source: IMOA

APPARENT EU CONSUMPTION

As already indicated in D1.2, IMOA [2] estimates that in 2015, Europe’s consumption of Molybdenum amounted to about 130 million lb (contained Mo), **which equals to 59 000 tons of Contained Mo used in Europe in 2015** (Figure 10). This data illustrates that EU is the second region in the world where Mo is most used, after China.

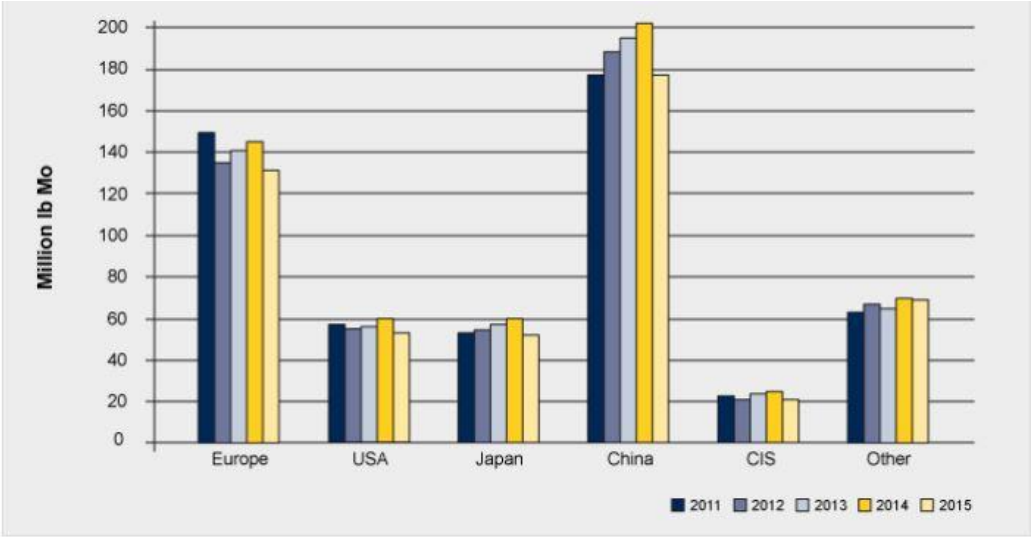

Figure 10: Estimated demand for contained Mo by region. Source: IMOA, 2015

As regards EU apparent consumption, the following balances by product categories are obtained for 2014 and 2015. For description of the methodology used to obtain the following table, please refer to the Introduction (p. 4). **Austria is the only country in EU that produces Ferro-Molybdenum (4 000 tons in 2014) [5].**

Table 13. Balance between imports and exports of molybdenum products in EU 28.

	2014		2015	
	Quantity	Value	Quantity	Value
Non-roasted Mo concentrates (NC8 : 26139000)				
TOTAL EXTRA EU IMPORTS	57 505 t	495 M€	50 283 t	377 M€
TOTAL EXTRA EU EXPORTS	596 t	1 M€	826 t	3 M€
BALANCE	***-56 909 t***	***-494 M€***	***-49 457 t***	***-374 M€***
Roasted Mo concentrates (NC8 : 26131000)				
TOTAL EXTRA EU IMPORTS	48 928 t	573 M€	41 241 t	369 M€
TOTAL EXTRA EU EXPORTS	17 130 t	59 M€	15 811 t	52 M€
BALANCE	***-31 798 t***	***-514 M€***	***-25 430 t***	***-317 M€***
Mo oxides and hydroxides (NC8 : 28257000)				
TOTAL EXTRA EU IMPORTS	2 986 t	43 M€	3 543 t	42 M€
TOTAL EXTRA EU EXPORTS	817 t	8 M€	1 776 t	18 M€
BALANCE	***-2 169 t***	***-35 M€***	***-1 767 t***	***-24 M€***
Ferromolybdenum (NC8 : 72027000)				
TOTAL EXTRA EU IMPORTS	16 665 t	223 M€	19 711 t	214 M€
TOTAL EXTRA EU EXPORTS	4 587 t	63 M€	3 753 t	36 M€
BALANCE	***-12 078 t***	***-160 M€***	***-15 958 t***	***-178 M€***
Mo waste and scrap (NC8 : 81029700)				
TOTAL EXTRA EU IMPORTS	2 542 t	37 M€	2 130 t	24 M€
TOTAL EXTRA EU EXPORTS	337 t	5 M€	78 t	1 M€
BALANCE	***-2 205 t***	***-32 M€***	***-2 052 t***	***-23 M€***

Warning : These figures represent gross weight quantities and NOT metal content.
They are only an approach to global consumption estimation and should be interpreted with caution

EUROPEAN USERS

The following tables present a mapping of European companies susceptible to use Molybdenum in their activities, whether as products manufacturers (steelmakers or alloy producers) or as end-users. Trading companies are also mentioned, as they can play an important role in the value chain (most of them are members of IMOA).

Table 14 : European companies manufacturing Mo products and alloys

Company	Country	Activity/Description	Ref.
Treibacher Industrie AG	AUSTRIA	Produces FeMo	[2]
Plansee SE	AUSTRIA	Development and manufacture of Mo mill products and finished products for applications in lighting and electronics industries, high-temperature furnace construction as well as medical and coating technologie	[2]
Jean Goldschmidt International SA	BELGIUM	Processing and Recycling	[6]
Sadaci NV	BELGIUM	Produces roasted Mo concentrates, FeMo and sodium molybdate	[2]
Haldor Topsoe A/S	DENMARK	Conversion based suppliers of Mo products	
Ampere Alloys	FRANCE	Part of a distribution network in Europe for ferroalloys and non-ferrous metals for foundries. Traders of Mo products	[2]
CM Chemiemetall GmbH Bitterfeld	GERMANY	Producer of Mo metal powders	[2]
AB Ferrolegeringar	SWEDEN	Producer's agent, and supplier of ferroalloys. Trading	[2]
Alfred H Knight International Ltd	UK	Samplers and Assayers of Mo products (Mo concentrates, Mo oxides, FeMo, Mo metal and Mo products)	[2]
ALS Inspection UK Ltd	UK	Samplers and Assayers of Mo products (Mo concentrates, Mo oxides, FeMo, Mo metal and Mo products)	[2]
S.J.M Alloys and Metals	UK	Suppliers of Pure Mo/ Mo airmelt/Super alloys containing Mo	[7]
Climax Molybdenum	Netherlands	Molybdenum chemicals producer	[8]
Luma Metal	SWEDEN	Wire Mo products	[9]
ABSCO Materials	UK	Chemical industry	[13]
Acerinox	SPAIN	Stainless steel	[6]
Althammer	GERMANY	Stainless steel/ Steel Alloys	[14]
Ampere Alloys	FRANCE	Steel Alloys	[6]

Aperam Sourcing SCA	LUXEMBOURG	Stainless steel	[2]
Arcelor Mittal	Luxembourg	Steelmaker	[6]
Boehler Edelstahl GmbH & Co KG	AUSTRIA	Steel Alloys	[6]
Bollinghaus GmbH & Co KG	GERMANY	Stainless steel/ Steel Alloys	[6]
CM Chemiemetall GmbH	GERMANY	Steel alloys	[6]
Core Alloys UK ltd	UK	Stainless steel/ Steel Alloys	[14]
Cogne Acciai Speciali Spa	ITALY	Steel alloys/Stainless steel	[6]
Cronimet Suisse	SWITZERLAND	Stainless steel scrap/ Steel Alloys	[6]
Delachaux	FRANCE	Steel alloys	[6]
Deutsche Edelstahlwerke GmbH	GERMANY	Stainless steel/steel alloys	[6]
ELG Haniel Trading GmbH	GERMANY	Stainless steel/steel alloys	[6]
Elektrowerk Weisweiler GmbH	GERMANY	Steel alloys	[6]
Eurecat France	FRANCE	Chemical	[6]
Europa Tool Co. LTd	UK	Tool steels	[15]
GFE Metalle Und Materialien	GERMANY	Steel alloys/Chemicals	[6]
Haldor Topsoe	DENMARK	Chemicals	[6]
HC Starck GmbH	GERMANY	Steel alloys	[6]
Ireland Alloys	IRELAND	Stainless steel/steel alloys	[6]
JSC Dneprospetsstal	UKRAINIAN	Steelmaker	[6]
Outokumpu Stainless AB	SWEDEN	Stainless steel	[2]
Plansee	AUSTRIA	Steel alloys	[6]
Sandvik	SWEDEN	engineering group in tooling, materials technology, mining and construction	[6]
Savinox	ITALY	Steel alloys	[14]
SIJ - Slovenska Industrija Jekla	Slovenia	Stainless steel/Steel alloys/tool steels	[6]
SSAB Oxelosund	SWEDEN	Steelmaker	[6]
Thyssenkrupp Acciai Speciali Terni Spa	ITALY	Stainless steel	[6]
Torrecid Group	SPAIN	Chemicals	[6]
Treibacher Industrie	AUSTRIA	Stainless steel/ Steel Alloys	[6]
Ugitech SA	FRANCE	Stainless steel/ Steel Alloys	[6]

Table 15 : Traders of Mo products in EU

Company	Country	Activity/Description	Ref.
Metherma KG	GERMANY	Trading (MoO3, FeMo, ADM, pure MoO3, metal powder, scraps and residues)	[2]
Groundmet Metall-und	GERMANY	Trading and converting FeMo	[2]

Rohstoffvertriebs GmbH			
Traxys Europe S.A.	LUXEMBOURG	Trading (Suppliers of Mo oxide and FeMo)	[2]
Scandinavian Steel AB	SWEDEN	Trading (Mo concentrates, oxide, FeMo metal)	[2]
FW Hempel Intermetaux Sa	SWITZERLAND	Trades of Mo concentrates, Mo oxide/ ammonium molybdate/ Mo semis such as bars Trading	[2]
Cronimet Metal Trading AG	SWITZERLAND	Purchase and sale of Mo concentrates and ferro molybdenum. Trading	[2]
Derek Raphael& Co Ltd	UK	Trading (Mo concentrates, oxides, FeMo and metal)	[2]
Moxba BV	NETHERLANDS	Trading Mo oxide, Mo concentrate	[6]
SADACI	NETHERLANDS	Trading Mo products (FeMo, Roasted Mo concentrate)	[9]
Lipmann Walton & Co Ltd	UK	Trading of Mo products	[9]
London Metal Exchange	UK	Trading of Mo products	[9]

Table 16: Main end-user European companies

Company	Country	Activity
Royal Dutch Shell	NETHERLANDS & UK	Oil &gas
Total	FRANCE	Oil &gas
Volkswagen	GERMANY	Automotive
Eni	ITALY	Oil &gas
Daimler	GERMANY	Automotive
Statoil	NORWAY	Oil and gas
Fiat	ITALY	Automotive
BMW	GERMANY	Automotive
ArcelorMittal	LUXEMBOURD	Steel
EADS	NETHERLANDS	Aeronautics and defence
Airbus	FRANCE	Aeronautics and defence
Vallourec & Mannesmann Tubes	FRANCE	End user oil&gas, power generation, construction, automotive
Akzonobel	NETHERLANDS	Chemical/Petrochemical
BASF	GERMANY	Chemical/Petrochemical
British Gas	UK	Oil &gas
Sandvik	SWEDEN	Mechanical engineering
Outokumpu	SWEDEN	Mechanical engineering
Vacuumschmelze	GERMANY	Materials manufacture
Ceratizit Group	LUXEMBOURG	Mechanical engineering

BALANCE BETWEEN SUPPLY AND DEMAND

The iron and steel industries are very likely to continue driving molybdenum consumption in Europe and over the world. Molybdenum is primarily used as an alloying element in steel, cast iron and nonferrous metals. EU is the second largest consumer and producer of steel in the world after China. Its output is over 177 million tons of steel a year, accounting for 11% of global output [11]. The ISSF reported that the average production (2008-2014) of stainless steel in Europe was 7.2 million tonnes [12].

EU has good trade relationships with Mo producers overall. Moreover, due to the relative low value and high abundance of Molybdenum, the balance between supply and demand shouldn't be at high risk for the European industry in the short to medium terms.

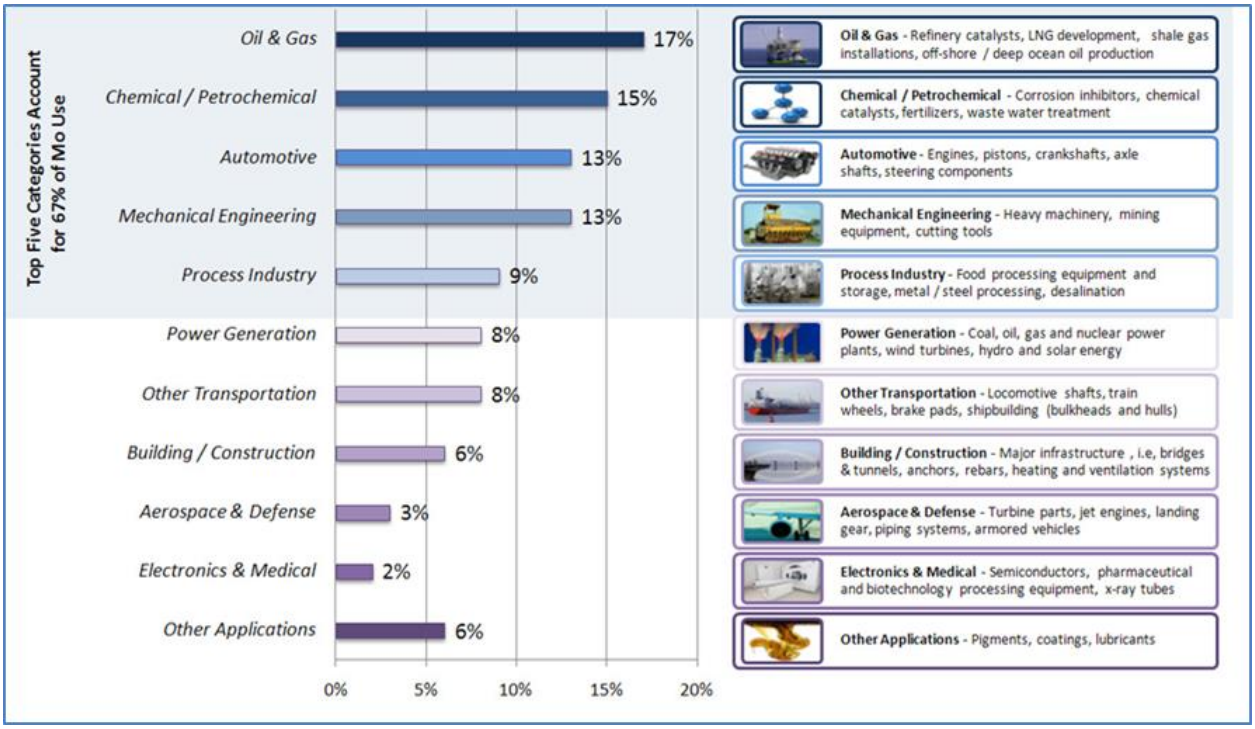

Figure 11 : End uses of Molybdenum. Source: SMR

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RHENIUM: HOW TO MATCH SUPPLY AND DEMAND IN EUROPE

This question was already well covered in Deliverable 1.2, from which much of the following content is taken.

PRIMARY PRODUCTION

For most bibliographical sources, Rhenium production amounts to approximately 50 tons 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, followed by United States with 6.3 tonnes, Peru with 5 tonnes and Poland with 4.7 tonnes (2011 figures, but not much change since).

KGHM Ecoren is the only EU company recovering rhenium from molybdenite (around 6 tons per year) which it receives from its copper-producing parent, KGHM Polish Coppera (BRGM, 2010) [1].

The main companies producing rhenium are presented in Figure 12.

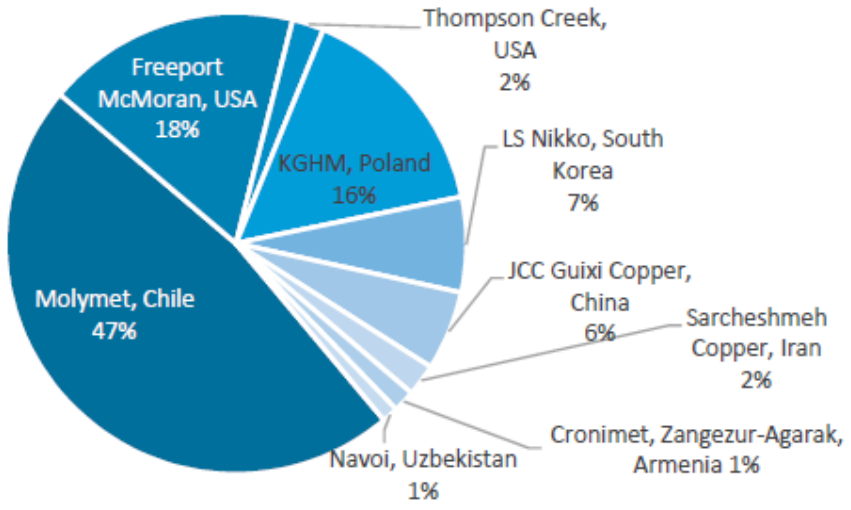

Figure 12: Primary refined Re supply by company in 2013. Source: Lippman Walton Co Ltd

The value chain of Rhenium is quite complex: specific applications require specific intermediary products. The basic form, ammonium perrhenate (APR) is the starting material for the production of perrhenic acid and rhenium metal in the form of powder, pellets or briquettes. A high proportion of the APR is used in the manufacture of reforming catalysts and then ultimately re-used within the petroleum catalysts industry.

Table 17: Rhenium products uses by applications

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

SECONDARY PRODUCTION: POTENTIAL INPUT FROM RECYCLING

Recycling of rhenium is an important source of supply in the market and has become even more important over time. Approximately 15 tons of rhenium is in use as catalysts in the economy. This industry has an 80 % recovery efficiency, reducing the virgin rhenium needs to replace spent catalysts. It is a closed-loop recycling in between Pt-Re reforming catalysts producers.

There is also a small 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, or grindings [4].

In Europe, 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].

EUROPEAN DEMAND

Rhenium world demand was estimated about 60-65 tons in 2013 [4] of which 78% for aerospace super-alloys, 6% for industrial gas turbines super-alloys, 9% for catalysts and the remaining 7% for minor uses (anodes for medical equipment, thin filaments for spectrographs and lighting, alloy spray powders...)

APPARENT EU CONSUMPTION

The previous methodology could not be applied to rhenium. The reason is that in customs statistics, rhenium is reported in a single category along with gallium, hafnium, indium or niobium. Thus, figures obtained based on this category are neither reliable nor representative of EU Re consumption which is known to be much smaller than other products (Niobium), either for trade values or net weights.

EUROPEAN USERS

The European Chemicals Agency (ECHA) provides information on registered substances in compliance with REACH. Thus, some data is publicly available on ranges of quantities of Re and Re compounds manufactured and/or imported in the European Economic Area, for companies that have registered. They are presented in Table 18.

Table 18: Rhenium products registered users in Europe. Source: 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 Metraco S.A. Sw. Poland	Heraeus Deutschland GmbH & Co. KG Climax Molybdenum Netherlands Lipmann Walton & Co, UK	Heraeus Deutschland GmbH & Co. KG	Heraeus Deutschland GmbH & Co. KG	Climax Molybdenum Netherlands

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

Big end-users of Rhenium in the EU are found mostly in the aerospace and defence industry. Aircraft manufacturers such as AIRBUS are directly concerned.

The manufacture of aircraft engines is dominated by only 4 players in the world: Cannon-Muskegon (USA), General Electric (USA), Pratt & Whitney (USA) and Rolls Royce (UK). They are important users of nickel superalloys containing rhenium, and represent up to 55% of the total consumption.

BALANCE BETWEEN SUPPLY AND DEMAND

Demand for rhenium is showing growth at the present because of demand for engines in both commercial and military jets. This is forecasted to continue to rise strongly over the next 20 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 is 0.6 tons/year by 2020-2030, which could represent an important material requirement [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].

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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TANTALUM: HOW TO MATCH SUPPLY AND DEMAND IN EUROPE

The following is a compilation from the report "**EU TANTALUM SECTOR OVERVIEW"**, Roskill, 25th November 2016, consultancy for the REFRAM project.

Foreword: Tantalum is not a simple industry and it is certainly not transparent. The supply chain is complicated and often involves transfers within corporate groups; most processors are either government- or privately owned; and the primary supply sector is shrouded in secrecy. There is no terminal market for tantalum (e.g., no LME).

PRIMARY PRODUCTION

The tantalum market is supplied with material from a variety of sources:

- **Primary production of tantalum minerals by conventional mining companies**
    - With the possible exception of very small quantities of by-product from kaolin mining in France, there is currently no primary mine production of tantalum in the EU**.** Globally, relatively little of the tantalum being mined is from mines that have tantalum as their main focus; it is usually a by-product or co-product. Future increases in primary supply will largely come from similar sources, particularly lithium mines.
- **Artisanal production of tantalum minerals**
    - This form of mining is largely non-mechanised and takes place mainly in Africa, particularly Central Africa, and in South America, mostly in Brazil. It accounted for about half of total primary production in 2015, according to Roskill estimates. Material from Central Africa has caused concern for some years because it is linked to the issue of Conflict Minerals.
- **Synthetic concentrates produced from tin slags**
    - Slags produced by the smelting of tin contain tantalum that can be recovered. In the EU context, the only company of any real significance is H.C. Starck, which processes Malaysian and Brazilian slags at a plant in Germany (it may move processing to its plant in Thailand). A tin-mining and smelting operation in Spain is due to come into production in Q1 2017. That will create a new EU source of tantalum feedstock (in slags) but there is no guarantee that it will be supplied to processors in the EU.
- **Material from producer, processor, customer and government inventories**
    - Inventories of tantalum are held at all stages of the supply chain. Government inventories are no longer of any real importance because the US sold off a very large stockpile during the 2000s. Downstream inventories can be substantial, however. The capacitor manufacturer AVX, which has a manufacturing operation in the Czech Republic, is believed to hold inventory sufficient to last two years.
- **Intermediate materials, such as tantalum oxide, K-salt and metal/alloys**
    - Such materials probably form most of the supply of tantalum units to companies in the EU but the amount is hard to evaluate.

SECONDARY PRODUCTION: POTENTIAL INPUT FROM RECYCLING

Recycled use, processor scraps and other secondary materials are an important part of tantalum supply. About 25% of new demand for tantalum in any year is met from such material (Roskill estimates). Capacitor manufacturing is one of the largest sources of recycled material, where scrap generated during manufacturing is returned to processors. Used items containing tantalum, such as sputtering targets, are also reprocessed. There are other examples. There is also supply from used turbine blades. In this case, the tantalum is not recovered from the superalloys involved but the alloy composition is known, or can be tested, and the alloys are added to the melt when producing new alloys.

For more information on these aspects, please refer to Deliverables 4.1 and 4.2 as well as 3.1 and 3.2.

EUROPEAN DEMAND

The global market for tantalum is not large in tonnage terms. **Roskill estimates consumption in 2015 at about 1 800t contained Ta**, which is a little below the 2008 peak. The consumption figure relates to total demand for tantalum units. That demand would have been met by "new" tantalum, inventory drawdown and recycling.

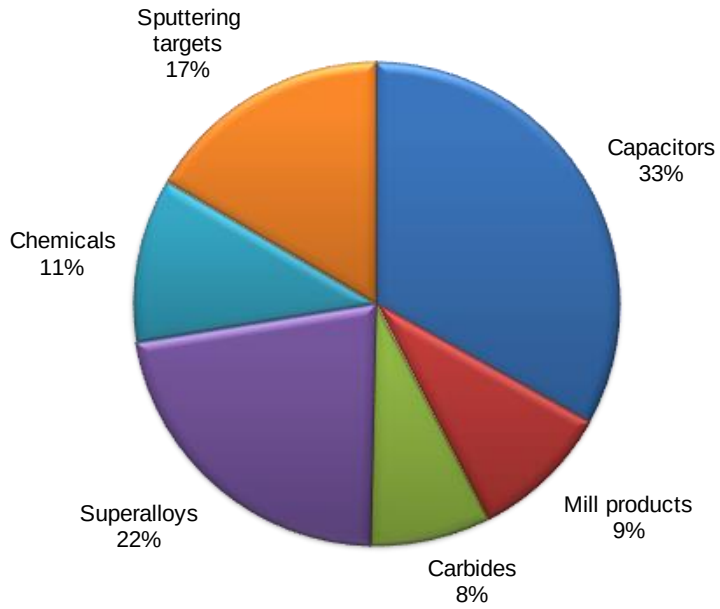

Figure 13: World estimated consumption of tantalum by application in 2015. Source: Roskill

The main application for tantalum is in electronics. The largest single use is in **capacitors**. All electronic devices contain capacitors but the vast majority of those capacitors do not contain tantalum. Because of the high price and supply volatility associated with tantalum, manufacturers have been seeking for some years to engineer-out the use of the metal. They have had some success, for example through niobium capacitors. The use of tantalum is now limited to applications where its superior performance currently makes it critical and irreplaceable. Capacitor manufacturing is a large source of recycled material. An EU-related risk in this market segment is that cost factors may prompt the only capacitor manufacturer in Czech Republic to move its production to a lower-cost country.

Sputtering targets are another major application for tantalum. Sputtering is a method of applying thin films of metal to a substrate and is used in the manufacture of storage media, inkjet printer heads, electronic circuitry

and flat-panel displays, among others. The target is the source of the metal that is deposited. Targets are generally recycled after use. The processor H.C. Starck is a major supplier of tantalum to this market, although probably not from its EU plants.

Tantalum **chemicals** have a very wide range of applications and are intermediates in the manufacture of other products that are often destined for the electronics industry.

Superalloys are a variety of high-performance alloys that are used in, for example, aerospace (jet engines) and land-based gas turbines. As aircraft design and performance expectations improve, the alloys involved become more sophisticated and the loading of tantalum in alloys is increasing. A lot depends on the outlook for the commercial aerospace industry, particularly Airbus in the EU context.

Tantalum **carbides** are used in cutting tools. This is probably a declining market for tantalum.

Tantalum **mill products** have a very wide range of uses, including chemical processing equipment, ballistics and surgical implants.

APPARENT EU CONSUMPTION

It is almost impossible to estimate how much tantalum is consumed in the EU. Tantalum units imported into the EU for processing are often finally consumed elsewhere and intra-company material transfers are common. A useful way of looking at how much tantalum is processed in the EU is to analyse the international trade statistics. Feedstock for processing might not ultimately be consumed within the EU but the processing adds value within the EU.

In the case of ores and concentrates, the picture is blurred somewhat by the fact that the customs code 261590 includes tantalum, niobium, vanadium and often materials that have been wrongly classified. It is necessary to analyse unit values and countries of origin to determine what is actually tantalum feedstock. Roskill's analysis includes the niobium mineral columbite, which also contains tantalum that is recovered during processing, although the material is sold and priced as niobium.

The EU is not a large importer of tantalum-containing minerals. **Imports in 2015 were about 800t (gross weight)** (Roskill estimates) which is lower than US imports and very much lower (by multiples) than imports into China. The largest EU importer was Latvia (275t). That material was probably destined for onward shipment to Russia. The next-largest was Estonia (247t). That feedstock was almost certainly for use by the predominantly niobium-focussed processor Silmet (also a rare earths producer). In essence, mined material is not a critical part of EU tantalum supply.

The EU processing sector is fed to a large extent by processed/secondary materials. These include unwrought tantalum and powders (810320), tantalum scrap and waste (810330) and tantalum articles (810390). There is very probably some crossover in classification and trade volumes are thus combined for the analysis. **Roskill estimates for 2015 are that total EU imports were 648t (gross weight),** compared with 1 042t for the USA (China is mainly an exporter of tantalum in finished forms, not an importer). Approximately 40% of that was imported by the UK and the Netherlands but much was probably re-exported to other EU countries. The main importers for use were most likely the Czech Republic (172t reported imports), where AVX has a capacitor-manufacturing operation, and Germany (144t).

Despite the lack of hard data for EU consumption of tantalum units, some rough estimates can be made as to the usage of tantalum in the EU, even if it does not originate there.

Because of the importance of the aerospace sector in the EU, it is probably the largest user of **superalloys** worldwide. It may have "consumed" about half of the estimated 400t of tantalum used globally in superalloys in 2015.

In the case of **capacitors**, Roskill estimates that global consumption of tantalum (powder and wire) in 2015 was 600t. Czech tantalum imports of 172t in 2015 appear to have been mostly of capacitor feedstock. **Sputtering targets** are an important use for tantalum (an estimated 300 t in 2015) but it is not clear how much tantalum is used in that application in the EU. Although there are EU producers of **tantalum carbides**, such as Treibacher, most of the estimated 143t of tantalum consumed in 2015 was probably used by companies in China and elsewhere in Asia. The markets for tantalum **chemicals** and **mill products** are too diverse to allow meaningful analysis.

EUROPEAN USERS

As is the case with most minor metals, the EU is host to many companies active in the tantalum market. The list shown in the table below is probably not complete but should contain the main players. Swiss companies have been included as they are part of the EU supply chain. The list is split into traders, processors/recyclers and companies involved in mining. There is often an overlap, however; some companies are active throughout the supply chain. (Note: Primary processors can use tantalum concentrates, synthetic concentrates or scrap. Secondary processors rely on intermediate products, such as K-salt and tantalum ingot.)

Table 19: Key supply-side players in the EU tantalum sector

Company	Country	Activity	Notes
Trading			
A&M Metals and Minerals	UK	Trading	Ta minerals.
Cronimet Central Africa	Switzerland	Trading	Ta minerals. Major trader of Central African tantalum minerals.
Delta Products	UK	Trading	
DM Chemi-Met	UK	Trading	Minerals, compounds, metallurgical products.
E & C Trading	Switzerland	Trading	
Engelhart Commodities	UK	Trading	
Krome Commodities	UK	Trading	
Lipmann Walton	UK	Trading	Various minor metals.
Maritime House	UK	Trading	Authorised distributor for a Chinese processor.
Metallum Metal Trading	Switzerland	Trading	
RJH Trading	UK	Trading	Covers most metals.
Scandmetal International	Belgium	Trading	
Specialty Metals Resources	Belgium	Trading	
Stapleford Trading	UK	Trading	Mostly Ta minerals.
Tradium	Germany	Trader	Various minor metals.
Traxys	Luxembourg	Trading	Mostly minerals, compounds and scrap.

Table continued….

….Table continues

Company	Country	Activity	Notes
Processing and recycling			
Avon Specialty Metals	UK	Recycling	Mainly in aluminium but involved in other metals.
Buss & Buss	Germany	Recycling	Production approximately 40tpy Ta.
ELG Utica Alloys	UK	Processing, recycling	Various Ta products, mostly from recycling.
Elite Material Solutions	UK	Secondary processing	Mainly Ta metal products.
Freiberger NE-Metall	Germany	Processing (probably secondary).	Various alloys.
GfE (AMG)	Germany	Processing (probably secondary).	Various alloys. AMG is also a major tantalum miner (in Brazil – output goes to the USA).
GMH Stachow-Metall	Germany	Recycling, trading	
H.C. Starck	Germany	Processing	Various refractory metals.
Heraeus Deutschland	Germany	Secondary processing	Alloy additives and finished products.
Honeywell Specialty Chemicals	Germany	Processing Chemicals	
Innova Recycling	Germany	Recycling, trading	Various metals from scrap and residues.
Metalysis	UK	Secondary processing	New process, not yet fully commercialised.
Metherma	Germany	Recycling, trading	
Nordmet	Estonia	Recycling, trading	Appears to be mainly focussed on rhenium.
NPM Silmet	Estonia	Processing	Mainly a Nb producer. Raw materials imported mainly from Brazil and Nigeria.
Plansee	Austria	Secondary processing	Approximately 50% of sales are in Europe.
Treibacher Industrie	Austria	Carbides	Ta, Nb and mixed.
Mining			
Imerys Ceramics	France	Mining (France)	Produces a small amount of tantalum as a by-product of kaolin mining. All output believed to be exported from the EU.
Minerals Resources International	Switzerland	Mining (DRC)	
Strategic Minerals	Spain	Mining (Spain)	Mainly a tin project but will supply tantalum in slags. Expected to come into production in Q1 2017.

Sources: T.I.C.; MMTA; Roskill

BALANCE BETWEEN SUPPLY AND DEMAND

The price/value of tantalum escalates rapidly as it moves through the chain. Companies in the EU are at the higher end of the value chain.

The prices shown in the table below are market prices in China (the most complete price series available) for various products but are considered to be representative of the market in general. The tantalum concentrate price has been converted from US$/lb Ta_2O_5 (the normal unit used for Ta concentrate) to US$/kg, for purposes of comparison.

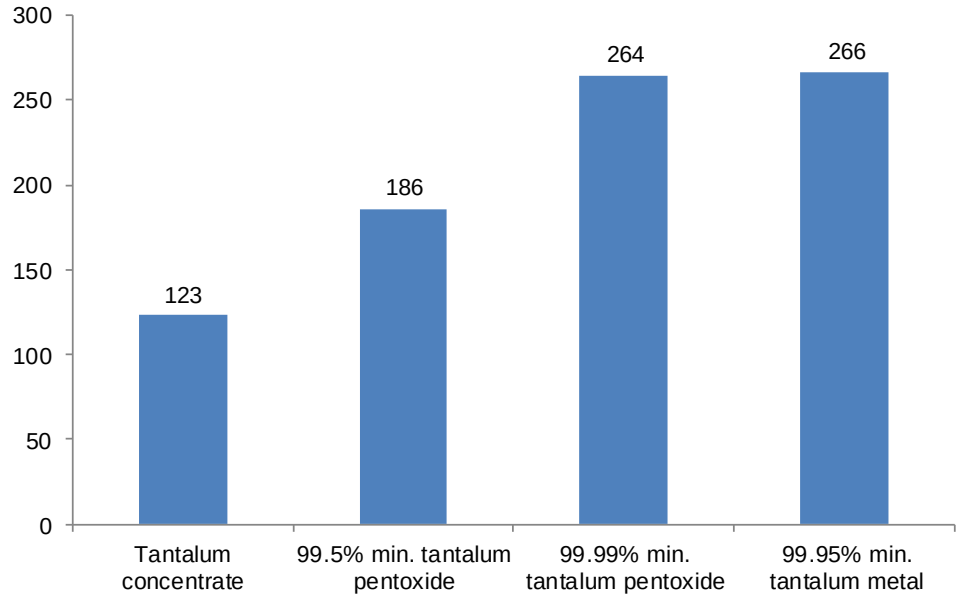

Figure 14: Market prices for selected tantalum products, August 2016 (US$/kg)[1]. Source: Asian Metal

Note: 1. Prices are for the Chinese market but are considered to be representative of the market in general.

Even at a very crude level, the differential between raw material cost and finished product value is at least 100%. Digging deeper, the unit value of tantalum imports into the Czech Republic in 2015 (mostly destined for capacitor manufacture) averaged US$458/kg (varying between US$338 and US$610, probably owing to different grades of powder).

In conclusion, from the EU perspective tantalum unit inputs from non-primary sources are probably of most importance. Furthermore the value of tantalum to the EU lies not in raw materials but in processing and manufacturing, despite the risk of European manufacturers moving their production to lower-cost countries if economic conditions grow unfavourable. Strategic Minerals' tin-mining and smelting projects in Spain are a potential source of tantalum supply (in slags), although modest and could come into production in Q1 2017.