27 TUNGSTEN

27.1 Overview

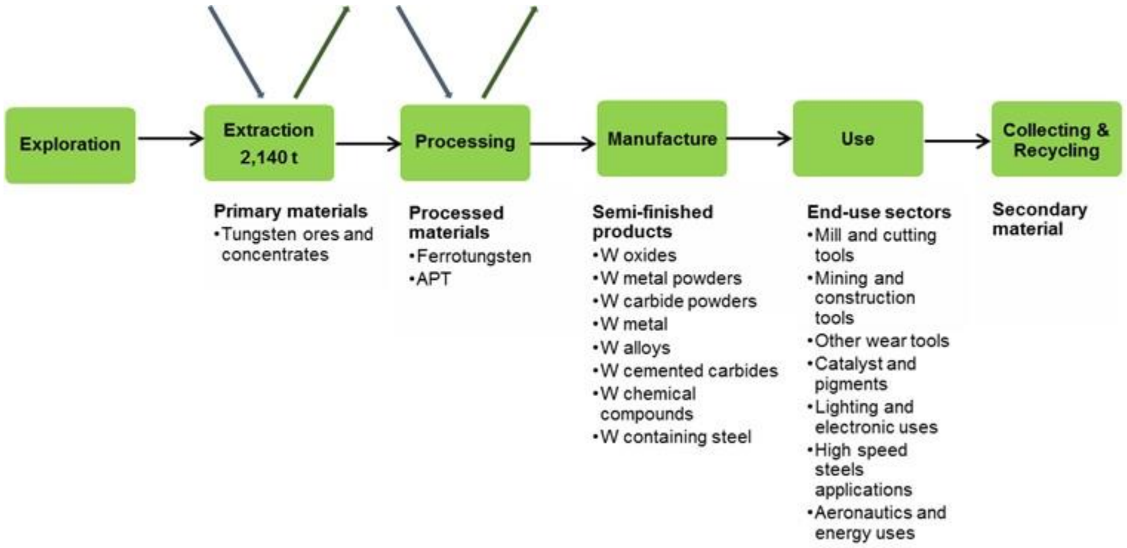
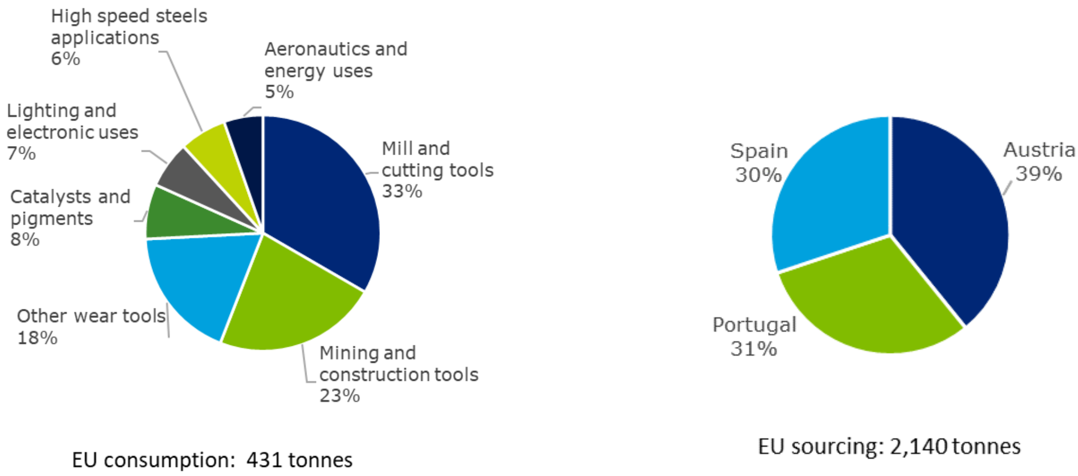


Figure 487: Simplified value chain for tungsten for the EU, average 2012-2016[281]

Tungsten (chemical symbol W), also known as wolfram, is a hard, rare metal. Tungsten is found naturally on Earth almost exclusively in chemical compounds. Its important ores include wolframite and scheelite. The free element is remarkable for its robustness and has the highest melting point of all the elements. Its high density is 19.3 g/cm³, comparable to uranium and gold. Tungsten was on the EU's list of CRMs in 2011, 2014 and 2017.



[281] JRC elaboration on multiple sources (see next sections). Import figure (represented by black arrow) and export figure (represented by green arrow) at mine stage and processing stage are not reported due to the lack of data reliability (see EU trade section).

Figure 488: End uses of tungsten (SCRREEN, 2019) and EU sourcing of ores and concentrates[282], 2012-2016 (WMD, 2019)

For the purpose of this assessment tungsten is analysed at both extraction and processing stage. At mine stage, tungsten is assessed as tungsten ores and concentrates (Trade code CN8 26110000). At processing stage, the assessment focused on ferrotungsten (CN code 72028000 Ferro-tungsten and ferro-silico-tungsten, containing 22% of W), Amonium Paratungstate (APT) (CN code 284180 Tungstates 'wolframates', containing 70.2% of W), tungsten carbides (28499030 Carbides of tungsten, whether or not chemically defined), and tungsten powders (81011000) (Eurostat Comext, 2019).

The majority of tungsten is traded on annual contracts and only small amounts are sold on the open market (BGS, 2011; SCRREEN workshops, 2019). The prices of tungsten concentrates at the US spot market have reached their lowest in 2016 since 2012, from USD 358 per tonne of WO_3 in 2012 to USD 148 per tonne of WO_3 in 2016 as reported by the USGS. The same trend was observed also for the prices of APT and ferrotungsten. After 2016, the prices of tungsten concentrates, APT, and ferrotungsten showed an increasing trend. Experts argue that the state-influenced decision in China, as the largest producer of tungsten products, may influence the price mechanism and as a consequence, affecting the viability of tungsten mine and processing sector in the EU (Eurometaux, 2020).

Over the years 2012 to 2016, the average EU apparent consumption of tungsten ores and concentrates was estimated at 431 tonnes per year. The EU production of tungsten ores and concentrates, accounting for a total of 2,140 tonnes took place in Austria (39%), Portugal (31%), and Spain (30%). The figure on the EU import and export of tungsten ores and concentrates suggested that the EU was a net exporter of tungsten ores and concentrates during 2012-2016. At processing stage, the EU was a net importer of several tungsten products. However, the reliability of Eurostat-Comext data was challenged by experts both for tungsten ores and concentrates and tungsten-based products, since several companies have withheld from giving information for confidentiality issue (Eurometaux, 2019). Therefore, the import and export figures of tungsten ores and concentrates and tungsten-based products presented in this factsheet may not represent the full picture for the EU. As a result, in this criticality assessment, a reliable EU supply risk value for tungsten in ores and concentrates form could not be calculated.

Tungsten is an important metal with no substitutes, and a key component in steel manufacturing, construction, oil drilling, and mining industries. It is also used in the fabrication of wires and filaments used in electrical, heating, and lighting applications. The hardness and high density of this metal give it military applications in penetrating projectiles. Tungsten compounds are also often used as industrial catalysts. Tungsten has very special performance and is most of the time the best choice of material, so very low substitution exists for this material in the industrial reality.

World tungsten known resources have been estimated at 7 million tonnes of contained W metal (USGS, 2019a). World tungsten resources are geographically widespread. The largest tungsten resources and reserves are known to be in China. Other countries like Canada, Kazakhstan, Russia, and the United States also have significant tungsten resources (USGS, 2019a).

According to the USGS (2019a), world known reserves of tungsten stand at 3.3 million tonnes of contained tungsten metal, with more than 57% of these located in China. In Europe, according to Minerals4EU (2019), tungsten reserves are known to exist in Spain, the UK, Portugal, Poland,

[282] The EU import of tungsten ores and concentrates was not included in the estimation of EU sourcing due to the lack of completeness of the information reported in Eurostat-Comext.

Slovakia, and Czechia. However, the number cannot be summed as they are partial and they do not use the same reporting code.

During the years 2012-2016, the world annual production of tungsten ores and concentrates was estimated at 85,000 tonnes with 82% of production in China. (WMD, 2019). The European production of tungsten ores and concentrates took place in Austria, Portugal, and Spain, accounting for 3% of global tungsten ores and concentrates production (WMD, 2019). At processing stage, however, there is no official public source of information on the global production of processed tungsten.

Tungsten scrap continued to be an important source of raw material for the tungsten industry worldwide (USGS, 2019). Based on the material flow analysis performed in the MSA study, a 42% End-of-Life Recycling Input Rate (EOL-RIR) has been estimated (Bio Intelligence Service, 2015). A recent estimate reported 30% of EOL-RIR value (ITIA, 2018b).

China, the biggest tungsten producer worldwide, imposed an export quota 100,000 tonnes of tungsten concentrates in 2018. The quotas was split into 76,150 tonnes from primary tungsten mines and 23,850 tonnes of tungsten concentrate produced as a by-product from mining of other metals (ITIA, 2019). China also applied an export tax for its export of tungsten ores, together with Bolivia, Russia, Rwanda, and Vietnam. China applied export tax on ferrotungsten, APT, carbides of tungsten, and tungsten powders. On tungsten powders, Vietnam applied 5% export tax, that ended in 2017 (OECD, 2019).

With regards to safety issue, chronic inhalation or severe exposure to airborne tungsten dust particles and ingestion of large amounts of soluble tungsten compounds is known to be hazardous to human health (BGS, 2011; SCRREEN workshops, 2019).

Tungsten is one of the four minerals falling under the scope of by an EU regulatory initiative (European Parliament, 2016).

27.2 Market analysis, trade and prices

27.2.1 Global market analysis and outlook

The global demand for tungsten in 2018 was estimated to be 104,500 tonnes of tungsten content. The demand for tungsten has increased from the demand in 2012 at 76,150 tonnes of W content (ITIA, 2019).

China is the biggest producer, exporter, and consumer of tungsten concentrates. Since more than 10 years, China does not allow export of tungsten concentrates (Eurometaux, 2019). Tungsten has been defined in the "National Mineral Resources Planning" (2016-2020) as a strategic mineral resource. Therefore, China planned to control tungsten exploitation at 120,000 tonnes of tungsten concentrates, equal to 62,000 tonnes of tungsten content by 2020. China has also imposed an environmental protection tax on pollution release generated by tungsten exploitation activities. To guarantee its domestic supply and demand of tungsten, China imposed an export quota 100,000 tonnes of tungsten concentrates in 2018, split into 76,150 tonnes from primary tungsten mines and 23,850 tonnes of tungsten concentrate produced as a by-product from mining of other metals (ITIA, 2019).

In 2012-2016, the big producers of tungsten concentrates outside China are Bolivia, Canada, Russia, Rwanda and Vietnam. The production of tungsten ores and concentrates from Canada ended in 2015 (World Mining data, 2019; Eurometaux, 2019). Bolivia, Russia, Rwanda, and Vietnam imposed a tax on its export of tungsten ores.

China is also a major exporter of tungsten intermediates such as tungsten oxides, tungstates (APT), tungsten powder, tungsten carbide, and ferrotungsten. China's export of these intermediates was estimated at 25,969 tonnes in 2018, much higher than in 2014 at 17,270 tonnes (of W content, tungsten carbides excluded) (ITIA, 2019). These figures suggested that China increased the export of downstream products.

China applied an export tax on ferrotungsten, APT, carbides of tungsten, and tungsten powders. Vietnam applied an export tax on tungsten powders (OECD, 2019).

Tungsten materials, such as APT were traded on two Chinese exchanges—the Tianjin International Mining Exchange and the Fanya Metal Exchange (FYME) until the latter collapsed in 2015. Although the Fanya Metal Exchange ceased operations in 2015 following an investment scandal, the exchange reportedly held 29,651 tonnes of gross weight, of APT (containing nearly 20,900 tonnes of tungsten) by 2016 (USGS, 2016).

Experts (Eurometaux, 2020) argue that the economic viability of western mines depends on opaque pricing mechanisms dominated by state-influenced decisions in China (e.g., "environmental inspections" to reduce inflow or release of stockpiles) and severe over-capacity of APT production in Asia (notably China). The refinery-level industry in the EU faces the risk to be cut off from concentrate supplies, if APT prices are (possibly artificially) depressed.

There is no solid qualitative forecast of supply and demand of tungsten. Some experts view the overall supply risk of the EU midstream tungsten industry rather increased than reduced compared to 2017. Experts also believe that as a consequence, the downstream tungsten consuming industry in the EU would face an increased reliance on Asian (largely Chinese) tungsten supplies, with their competitivity possibly wiped out by an artificially low margin between Chinese mid-and downstream products released into the western market (Eurometaux, 2019).

Table 208: Qualitative forecast of supply and demand of tungsten

Materials	Criticality of the material in 2020		Demand forecast			Supply forecast		
	Yes	No	5 years	10 years	20 years	5 years	10 years	20 years
Tungsten	x		?	?	?	?	?	?

27.2.2EU trade

According to the data reported by Eurostat-Comext database, on average between 2013 and 2017[283], the EU imported 208 tonnes tungsten content per year of tungsten ores and concentrates. However, the reliability of import figure for tungsten reported in Eurostat-Comext (2019) has been questioned by experts. For commercial confidentiality reason, the real figures related to import statistics of the customs authorities were not reported, as for the case of Austria, one of the most important tungsten producing and importing countries in the EU (Eurometaux, 2019). The import of Austria was estimated to be much higher than indicated in these figures which consequently would have resulted in a positive net import. Due to such limitation, the EU import reliance, apparent consumption, and supply risk of tungsten could not be estimated.

Portugal produces wolframite concentrate from the Panasqueira Mine and beneficiation plant in central Portugal. The wolframite concentrate produced from Panasqueira is sent to the United

[283] 2012 excluded, as not representative

States, Japan and elsewhere to be processed (USGS, 2016b). According to the data from USGS (2019b), Spain is one of the major suppliers of tungsten ores and concentrates to the United States. The mass balance between the production of Spain and trade with the United States suggests that most of tungsten ores and concentrates production from Spain was exported to the United States.

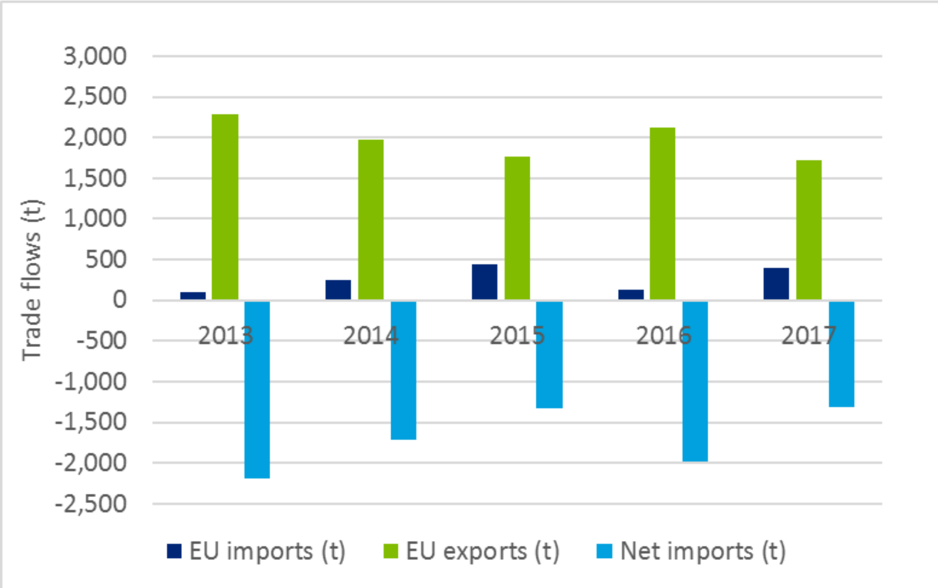


Figure 489: EU trade flows for tungsten ores and concentrates in t of tungsten content (Eurostat, 2019) – incomplete figure for Austria due to confidentiality reason (Eurometaux, 2020)

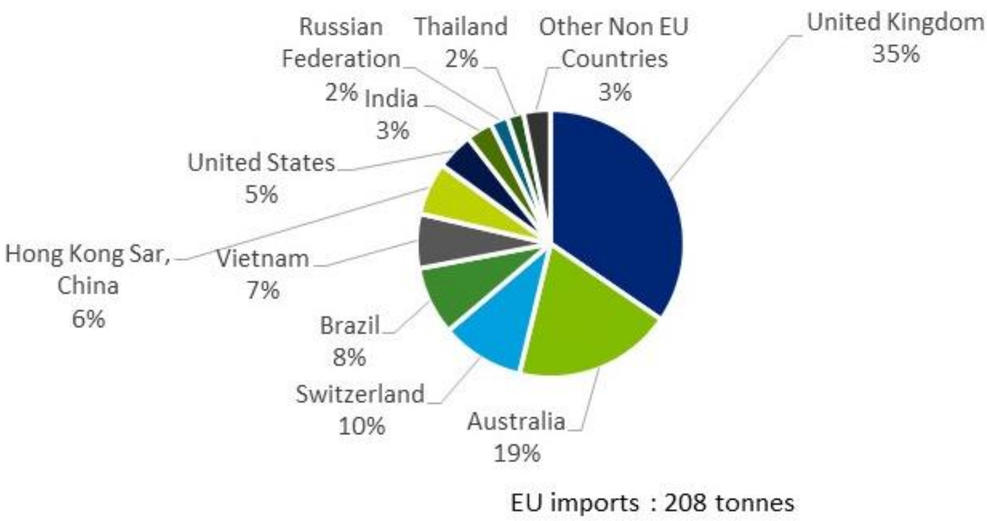


Figure 490: EU imports[284] of tungsten ores and concentrates, 2013-2017 (data source: Eurostat, 2019a) – incomplete figure for Austria due to confidentiality reason (Eurometaux, 2020)

Figure 491 presents the trade flow of various processed tungsten products from 2012-2016. At processing stage, the EU is a net importer of tungsten powders, ammonium paratungstate (APT), tungsten carbides, and ferrotungsten. The average 2012-2016 annual EU import was 340 tonnes

[284] Except for 2012, EU is a net exporter of tungsten ores and concentrates, therefore the picture of importer countries is of limited relevance.

per year for tungsten powder, 3,619 tonnes per year for APT, 1124 tonnes per year for carbides of tungsten, and 2,969 tonnes per year for ferrotungsten.

The main EU suppliers for these products are shown in Figure 491, among which China, Vietnam, and the United States.

According to experts (SCRREEN workshops, 2019), some companies have officially withheld from reporting trade figures for tungsten intermediates due to confidentiality reason. Hence, trade figures have to be interpreted carefuly since they may not give a complete picture of the trade situation, nor the apparent consumption in the EU.

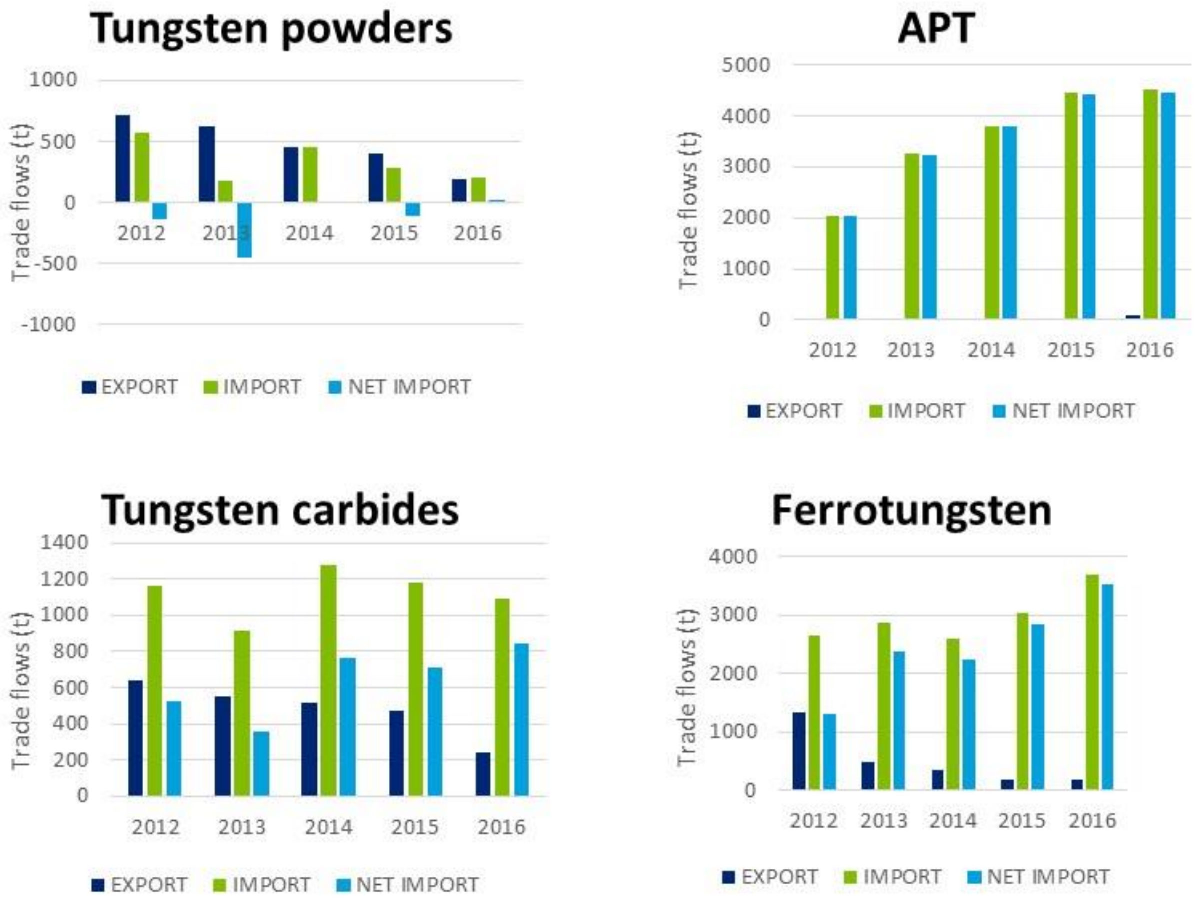


Figure 491: EU trade flows for processed tungsten 2012-2016 (Data source: Eurostat, 2019a)

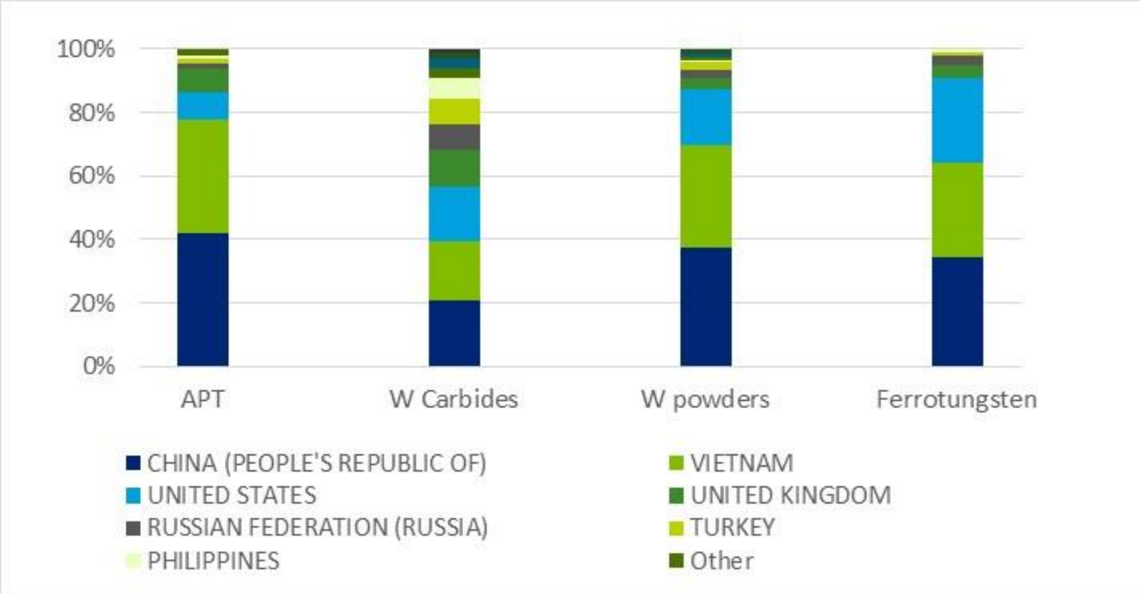


Figure 492: The share of EU suppliers of: APT, tungsten carbides, tungsten powders, and ferrotungsten (average 2012-2016)

27.2.3Prices and price volatility

Figure 493 and Figure 494 display the price trend of tungsten and tungsten products from two different sources, covering the prices of tungsten concentrates at the US spot market, tungsten concentrates in China, the prices of ammonium paratungstate (APT) and ferrotungsten in the EU. Both figures show the increasing prices of tungsten post-economic crisis in 2009 until 2011, followed by a gradual decrease until their lowest in 2016.

Prices for concentrates, APT, and ferrotungsten seemed to recover in 2017 and 2018.

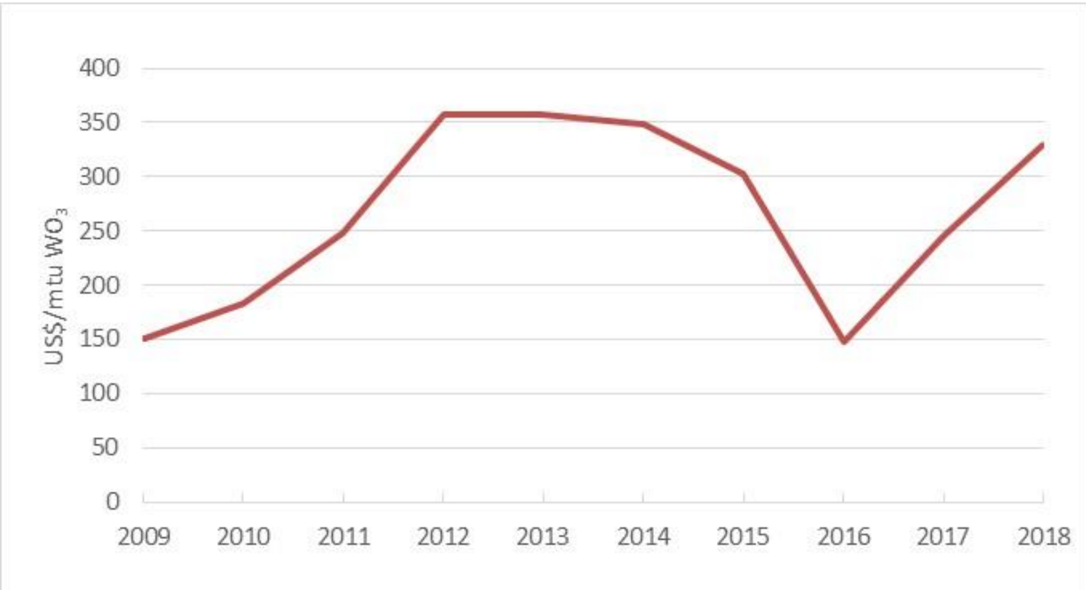


Figure 493: Tungsten prices, US spot market (USD/mtu) between 2009 and 2018. (USGS, 2019)

Figure 494: APT prices in $ as mtu (=10kg) of WO_3 contained in APT. (ITIA, 2019)

27.3 EU demand

27.3.1 EU demand and consumption

The EU's average annual demand for tungsten (concentrates and tungsten products) over the period 2012-2016 was estimated at 10,010 tonnes per year (of W content). The EU's demand was higher, at 14,250 tonnes in 2018, by far the highest since the global economic crisis in 2009 (ITIA, 2019). In the period of 2012-2016, the EU's demand represents about 12% of the world consumption, and is the second market after China (that consumes half of the tungsten available worldwide).

Criticality assessment 2017 mentioned the discrepancy between the estimation of EU sourcing for primary tungsten compared to the figure of primary tungsten demand announced by the International Tungsten Industry Association (ITIA). This difference can be explained by the fact that industrial experts have raised the issue of the absence of some important EU suppliers, such as Canada and Rwanda, in the Comext figures used in the assessment (European Commission, 2017).

27.3.2 Uses and end-uses of tungsten in the EU

Due to its exceptional physical properties, tungsten is used for a wide range of applications. The largest share is used for the production of cemented carbides. The rest is used for fabricated products, alloy steels, super alloys and tungsten alloys. The majority of tungsten is used for hard metals, whose main component is tungsten carbide (WC). They are characterized by high wear resistance even at high temperatures. Therefore hard metals are used for cutting and drilling tools. Similar properties arise from the addition of tungsten to steel. The widest range of applications is represented by tungsten alloys. They are used in lighting technology, electrical and electronic technology, high-temperature technology (e.g. furnaces, power stations), welding, spark erosion, space travel and aircraft devices, armaments and laser technology.

The end-use of tungsten has not changed greatly from the previous assessment . The tungsten consumed in the EU for the manufacture of the following products (Bio Intelligence Service, 2015; SCRREEN, 2019):

- 67% of tungsten consumed in the EU is used for the manufacturing of tungsten carbides. Tungsten cemented carbides, or hardmetals, are materials made by "cementing" very hard tungsten monocarbide grains in a binder matrix of a tough cobalt or nickel alloy by liquid phase sintering. Cemented carbides combine high hardness and strength with toughness and plasticity. Tungsten carbide is the most metallic of the carbides, and by far the most important hard phase. Due to those characteristics, tungsten carbides are used in mill and cutting tools, as well as in mining and construction tools. Other tools (wear resistance, mirrors, forming tools) are made of tungsten carbides.
- 11% of tungsten consumed in the EU is used for the manufacturing of tungsten metal Tungsten metal is used for the manufacture of fabricated products in the lighting and electronic industry. The lamp industry covers incandescent bulb filament containing W, compact fluorescent lamp, and high intensity discharge lamp HID. In the electronic & electrical industry, tungsten metal is used as an electron emitter in integrated circuits, and also in X-ray tubes.
- 3% of tungsten consumed in the EU is used for the manufacturing of tungsten alloys
- 8% of tungsten consumed in the EU is used for the manufacturing of tungsten containing steels
- 11% of tungsten consumed in the EU is used for the manufacturing of chemical applications.

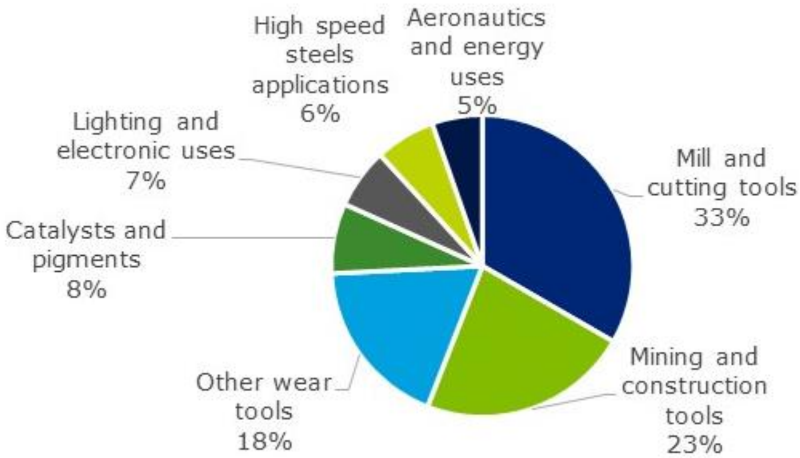


Figure 495: End uses of tungsten, 2012-2016 (SCRREEN, 2019).

Relevant industry sectors are described using the NACE sector codes (Eurostat, 2019b), presented in Table 209.

Table 209: Tungsten applications, 2-digit and associated 6-digit NACE sectors, and value added per sector (Eurostat, 2019b)

Applications	2-digit NACE sector	4-digit NACE sectors	Value added of NACE 2 sector (millions €)
Mill and cutting tools	C28 - Manufacture of machinery and equipment n.e.c.	C2841- Manufacture of metal forming machinery	182,589
Mining and construction tools	C28 - Manufacture of machinery and equipment n.e.c.	C2892- Manufacture of machinery for mining, quarrying and construction	182,589
Other wear tools	C28 - Manufacture of machinery and equipment n.e.c.	C2849- Manufacture of other machine tools	182,589
Catalysts and pigments	C20 - Manufacture of chemicals and chemical products	C2012- Manufacture of dyes and pigments; C2059- Manufacture of other chemical products n.e.c.	105,514
Lighting and electronic uses	C26 - Manufacture of computer, electronic and optical products	C2611- Manufacture of electronic components	65,703
High speed steels applications	C25 - Manufacture of fabricated metal products, except machinery and equipment	C2562- Machining	148,351
Aeronautics and energy uses	C28 - Manufacture of machinery and equipment n.e.c.	C2811- Manufacture of engines and turbines, except aircraft, vehicle and cycle engines; C2812- Manufacture of fluid power equipment; C3030- Manufacture of air and spacecraft and related machinery	182,589

27.3.3Substitution

Tungsten has very special performance and is most of the time the best choice of material. Therefore, very low-performing substitution exists for this material in the industrial reality.

The consumption of tungsten continues to increase as the amount of carbide tool production increases with the expansion of markets in developing countries. Potential substitutes for cemented tungsten carbides include cemented carbides based on molybdenum carbide, niobium carbide, or titanium carbide; ceramics; ceramic-metallic composites (cermets); and tool steels (USGS 2019). For tungsten carbide-based cemented carbides, substitution appears to be technically possible but implies higher costs and a decrease in performance in some cases. Titanium carbides (TiC) and titanium nitride (TiN) are potential substitute but the technology is not competitive at the moment. Tungsten can be replaced by other refractory metals such as niobium (critical in 2020) or molybdenum in steel products. In other application areas, possible substitution of tungsten is affordable, for example super-alloys substituted by Ceramic Matrix Composites (CMCs) made from a silicon carbide/nitride matrix for gas turbine engines. Substitution with nanostructured n-alloys such as FeTa, could be possible in 10 years since current TRLs are very low (TRL 3-4). Substitution in the lighting sector is well underway (Bilewska et al. 2016; Pavel et al. 2016c; Tercero Espinoza et al. 2015).

27.4 Supply

27.4.1 EU supply chain

- In Europe, during the period 2012-2016 the extraction of primary tungsten ores and concentrates took place in Austria, Spain, and Portugal.
- At processing stage, the EU also has the capacity to process tungsten ores and concentrates into tungsten-based products. ITIA identified at least two tungsten ores and concentrates processing facilities in the EU, one located in Austria and one located in Germany. While the EU demand for ammonium paratungstate (APT) and tungsten carbides is supplemented by imports, ferrotungsten is entirely supplied from imports.
- Regarding secondary source of tungsten, recycling in the EU is generally strong. Tungsten scrap was estimated to be re-used in Europe, at a rate between 45-50% (Baylist, 2014 and ITIA, 2018). Recent figures from ITIA mentioned 8,800 tonnes of recycled tungsten generated in the EU in 2018 (ITIA, 2019).

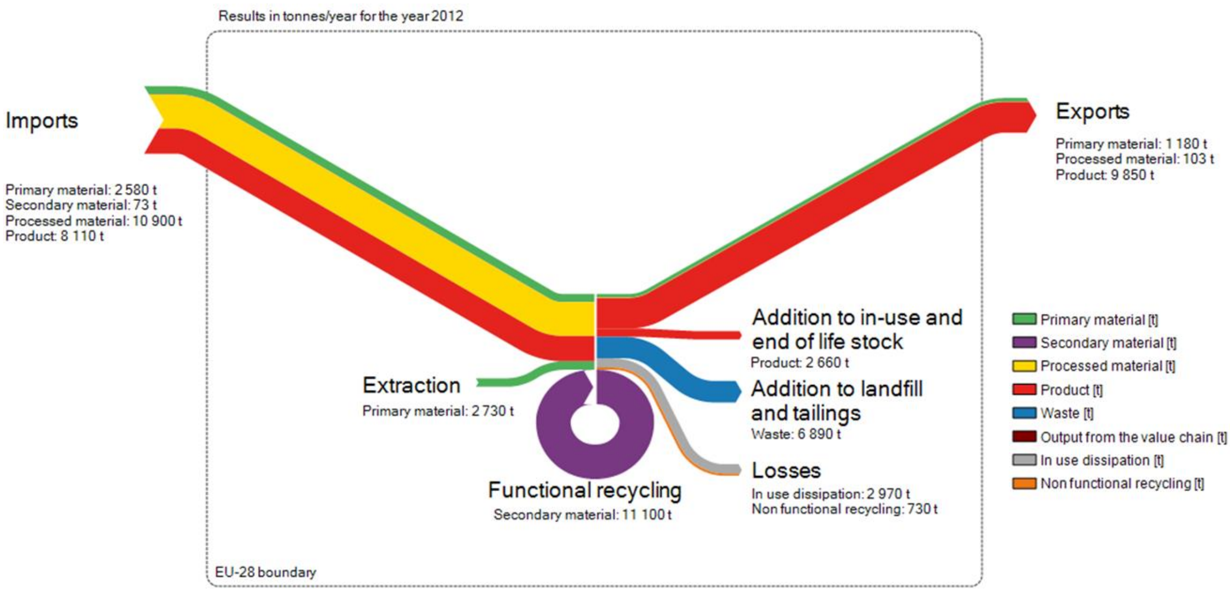


Figure 496: Simplified diagram of material system analysis of tungsten in the EU27+the UK, for the year 2012 (Bio Intelligence Service, 2015)

27.4.2 Supply from primary materials

27.4.2.1 Geology, resources and reserves of tungsten

Geological occurrence:

The average abundance of tungsten in the Earth's crust is estimated to be 1.25-1.50 ppm (BGS, 2011), and its concentration in the upper crust is 3.3±1.1 ppm (Rudnick, 2003). In nature, tungsten does not occur as free metal but in 45 different minerals, of which only two, wolframite and scheelite, have any economic importance. Tungsten minerals often occur as monotungstates, such as scheelite (calcium tungstate, $CaWO_4$), stolzite (lead tungstate, $PbWO_4$), and wolframite. Wolframite is a solid solution of ferberite (ferrous tungstate, $FeWO_4$) and hübnerite (manganous tungstate, $MnWO_4$) (BGS, 2011). Scheelite is the most abundant tungsten mineral and is present in approximately two-thirds of known tungsten deposits (BGS, 2011).

Global resources and reserves[285]*:*

World tungsten known resources are estimated at 7 million tonnes of contained tungsten metal (BGS, 2011; USGS, 2019). World tungsten resources are geographically widespread. Major tungsten deposits are located in China, Canada and Russia. Canada, Kazakhstan, Russia, and the United States also have significant resources (USGS, 2019).

According to USGS (2019), world known reserves of tungsten is estimated at 3.3 million tonnes of contained tungsten metal, with more than 57% of these located in China.

Table 210: Global reserves of tungsten (Data source: USGS, 2019)

Country	Tungsten Reserves (tonnes of tungsten content)
United States	NA
Austria	10,000
Bolivia	NA
Canada	290,000
China	1,900,000
Portugal	2,700
Russia	83,000
Rwanda	NA
Spain	32,000
United Kingdom	51,000
Vietnam	95,000
Other countries	680,000

EU resources and reserves[286]*:* Resource information for Spain, Portugal, Poland, Slovakia, Czechia are available at Minerals4EU (2019) (see Table 211) but cannot be summed as they are partial and they do not use the same reporting code. About 500,000 tonnes of tungsten are contained in EU known resources according to the MSA study, estimated by contacting several geological survey in EU member states (Bio Intelligence Service, 2015). According to industry experts, there are more deposits known or ready to be developed in Europe, such as Hemerdon

[285] There is no single source of comprehensive evaluations for resources and reserves that apply the same criteria to deposits of tungsten in different geographic areas of the EU or globally. The USGS collects information about the quantity and quality of mineral resources but does not directly measure reserves, and companies or governments do not directly report reserves to the USGS. Individual companies may publish regular mineral resource and reserve reports, but reporting is done using a variety of systems of reporting depending on the location of their operation, their corporate identity and stock market requirements. Translations between national reporting codes are possible by application of the CRIRSCO template.[285], which is also consistent with the United Nations Framework Classification (UNFC) system. However, reserve and resource data are changing continuously as exploration and mining proceed and are thus influenced by market conditions and should be followed continuously.

[286] For Europe, there is no complete and harmonised dataset that presents total EU resource and reserve estimates for tungsten. The Minerals4EU project is the only EU-level repository of some mineral resource and reserve data for tungsten, but this information does not provide a complete picture for Europe. It includes estimates based on a variety of reporting codes used by different countries, and different types of non-comparable datasets (e.g. historic estimates, inferred reserves figures only, etc.). In addition, translations of Minerals4EU data by application of the CRIRSCO template is not always possible, meaning that not all resource and reserve data for tungsten the national/regional level is consistent with the United Nations Framework Classification (UNFC) system (Minerals4EU 2019).Many documented resources in Europe are based on historic estimates and are of little current economic interest. Data for these may not always be presentable in accordance with the UNFC system. However a very solid estimation can be done by experts.

deposit (UK) that led to a mine opening in 2016, Barruecopardo (Spain) which has already financing in place, and some work is done at La Parilla (Spain) (Wolfram, 2016).

Table 211: Resource data for the EU compiled in the European Minerals Yearbook of Minerals4EU (Minerals4EU, 2019)

Country	Reporting code	Quantity	Unit	Grade	Code Resource Type
Spain	NI 43-101	615	kt	0.0032% WO_3	Measured
Portugal	NI 43-101	1495	Mt	0.55% WO_3	Indicated
Poland	Nat. rep. code	0.24	Mt	0.04% W	C2+D
Slovakia	none	2846	Mt	0.23% W	-
Czech Republic	Nat. rep. code	70.2	kt	0.8% W	Potentially economic

In the EU, an estimated of 80,000 tonnes of tungsten reserve were identified by several EU geological surveys (Bio Intelligence Service, 2015). Similarly to resource, quantitative information on tungsten reserve for some countries in Europe are available in the Minerals4EU website but cannot be summed as they are partial and they do not use the same reporting code.

To date, there has not been any new information referring to EU resources and reserves of tungsten at Minerals4EU (2019).

In 2018, Lauri et al. (2018) reported tungsten occurrences in the following EU member states:

- Austria: an estimated quantity of 24,000 tonnes of tungsten resources was reported at the Mittersill mine
- Finland: 17 occurrences with tungsten as main commodity and 6 occurrences with tungsten as minor commodity were listed in the FODD database. Four deposits have a non-compliant resource estimate of 2,333 tonnes of tungsten metal
- France: 15 tungsten deposits with an estimated resource quantity of 66,000 tonnes and 100 occurrences without resources data.
- Greece: One medium-sized tungsten deposit with a non-compliant resource of 6,000 tonnes of tungsten.
- Portugal: The resources (including reserves) at Panasqueira mine were estimated to be 27,240 tonnes of tungsten at the end of 2016. At S. Pedro da Águias (Tabuaço), there is an indicated resource of 0.76 Mt with 0.58 % WO_3 and inferred 1.33 Mt at 0.57% WO_3, accounting for a total estimate of 9,500 tonnes of tungsten content. The ProMine database lists eight closed tungsten mines for Portugal; jointly these are reported to contain resources of nearly 40,000 t W. In addition, there are six tungsten occurrences without resource data in the ProMine database.
- Spain: A total resource of 15,334 tonnes of tungsten metal was estimated at Los Santos and 15,400 tonnes fo Valtreixal in 2015. In addition, an estimated of 21,800 tonnes of tungsten resources, 15 closed mines and other occurrences without resource information were listed for Spain in ProMine database.
- Sweden: Non-compliant resource estimates are available for three W occurrences that have not been exploited. Two of these give information on the tungsten content of the ore, with a total of 2.1 Mt of tungsten-bearing ore at 0.2 % of W.
- Bulgaria, Czechia, Germany, Ireland, Italy: occurrences of tungsten were reported with no available information on the resource quantity.

27.4.2.2 World and EU mine production

Mining of tungsten is performed through both open-pit mining and underground mining. The ore from mine is crushed and milled, and then upgraded by means of gravity enrichment or flotation. For commercial trading 65-75% WO_3 content is required for further refining (European Commission, 2014). The ore beneficiation allows to increase the tungsten content of the concentrate up to 65-75% WO_3, which can be (BGS, 2011):

- directly used for production of ferrotungsten or steel manufacture, or
- converted by hydrometallurgy into intermediate tungsten compounds (APT or tungsten oxides), or
- further refined by pyrometallurgy into pure tungsten (metal, carbide, alloys, etc.).

The global production of tungsten concentrates amounts about 85,300 t (in W content) annually over the years 2012-2016 (WMD, 2019). In average between 2012 and 2016, about 82% of the world's tungsten production came from China (WMD, 2019). To provide the domestic industry with a target and to manage the country's natural resources in a way to balance supply and demand, China imposed a tungsten mining quota in 2002. Since the introduction, the amount of the quota has increased from 43,700 t concentrate of 65% WO_3 in 2002 to 100,000 t in 2018 (ITIA, 2019). However, despite the quota, Chinese production has been stable from 2012 to 2016.

From 2014, Vietnam went from a medium-scale to the world's second largest producer of tungsten concentrates outside China by the opening of the Nui Phao mine in 2013 (about 4000 tonnes in 2014 and more in 2016). In contrast, Canada will be "zero" from 2016 onwards, due to the closure of the Cantung mine in late 2015 (Wolfram, 2016).

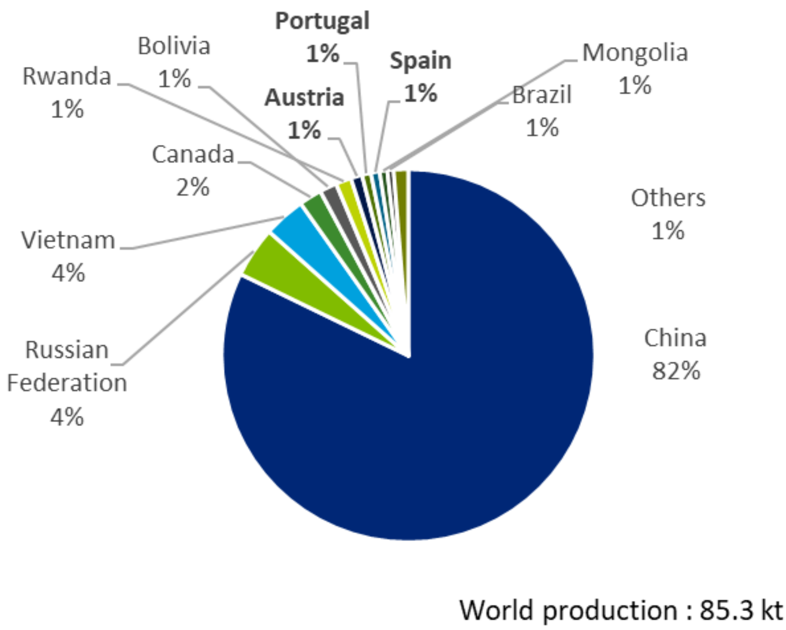


Figure 497: Global mine production of tungsten ores and concentrates in tonnes and percentage. Average for the years 2012-2016. (WMD, 2019)

Tungsten extraction in the EU is exclusively located in Austria, Portugal and Spain and represents around 2,140 t of tungsten content, i.e 3% of the global extraction.

In 2016, a tungsten mine in England was opened. Due to a combination of technical problems and depressed prices, this mine stopped in late 2018 and will likely not be producing in the foreseeable future. The Los Santos mine in Spain ceased mining in 2019, but minor production is maintained by retreating old tailings. In total, this accounts for a loss of over 4000 t of (planned) production in Europe (Eurometaux, 2019).

The concentrate facility of Barruecopardo mine (Salamanca), Spain, formerly active until 1991, obtained a licence to operate in September 2019. The first WO_3 production is expected to be put on the market in 2019. A new project in Spain, owned by Valtreixal Resources Spain, SL (Almonty Group), has recently obtained a research permit, and currently conducting a Environmental Impact Assesement (Marchan, 2019).

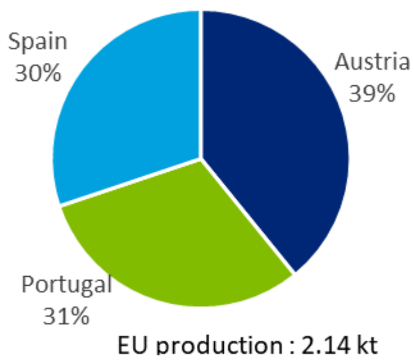


Figure 498: EU mine production of tungsten ores and concentrates in tonnes and percentage. Average for the years 2012-2016. (WMD, 2019)

27.4.3Supply from secondary materials/recycling

Secondary tungsten can be found in two main types of sources: in waste from processing the material containing niobium as well as in end of life products from urban mines and manufacturing residues (Sundqvist Oeqvist, Pr. Lena et al. ,2018). Tungsten scrap, due to its high tungsten content in comparison to ore, is a very valuable source.

Several research projects to recover tungsten have been developed in the EU, for example:

- Recovery of tungsten from spent selective catalytic reduction (SCR) catalysts used in chemical industry. A method used to recover tungsten includes pressure leaching reaction with soda digestion process, using NaOH as leaching agent. The obtained solution contained tungsten and vanadium. The method proved to successfully recover both metals (Witold Kurylak, 2016).
- Recovery of tungsten from wastewater of PCB. Althouth used in minor quantities, tungsten can be traced in printed circuit boards (PCB), used in wiring, contacts, electrode emitters and heat sinks. The process used to recover tungsten is called emulsion liquid membrane (ELM) and is commonly used to separate metal ions and also hydrocarbons or biological compounds. The technology is still at early stage of development, but the tests results has shown, that the separation of W from wastewater is possible (Sundqvist Oeqvist, Pr. Lena et al. ,2018).

The recycling activities inside Europe have considerably increased since the global economic crisis in 2009. Experts reported a recycling rate for tungsten in the EU as high as 45-50%. The recycling input rate from new and old scrap for tungsten was estimated at 35%. Experts estimated end-of-life recycling rate as high as 30% (ITIA, 2018).

Based on the material flow analysis performed in the MSA study, a 42% End of Life Input-Recycling-Rate (EoL-RIR) has been estimated (Bio Intelligence Service, 2015). This is consistent with Roskill's estimate of secondary tungsten (scrap re-use) that reached 50% in 2013 in Europe (Baylis, 2014), but a little higher than ITIA's estimate of 30% (ITIA, 2018). These values are higher than the old estimates made by UNEP in 2011 of 10-25% of end-of-life recycling; with secondary tungsten representing 34% of supply (10% from new scrap and 24% from old scrap) (UNEP, 2011). In this criticality assessment, the value resulted from MSA study (42% of EOL-RIR) was used.

27.4.4Processing of Tungsten

There is no official data on the production of processed tungsten. Figure 499 shows the number of companies that are known to be the global consumer of tungsten ores and concentrates identified by the International Trade Administration (ITA, 2018). Most of smelters of tungsten are located in China.

In the EU, tungsten smelters are located in Austria and Germany, both process tungsten ores and concentrates into mainly ammonium paratungstate. Despite the lack of quantitative data on the production capacity of each country, Figure 499 indicates the domination of China in the mid-downstream of tungsten supply chain (ITA, 2018).

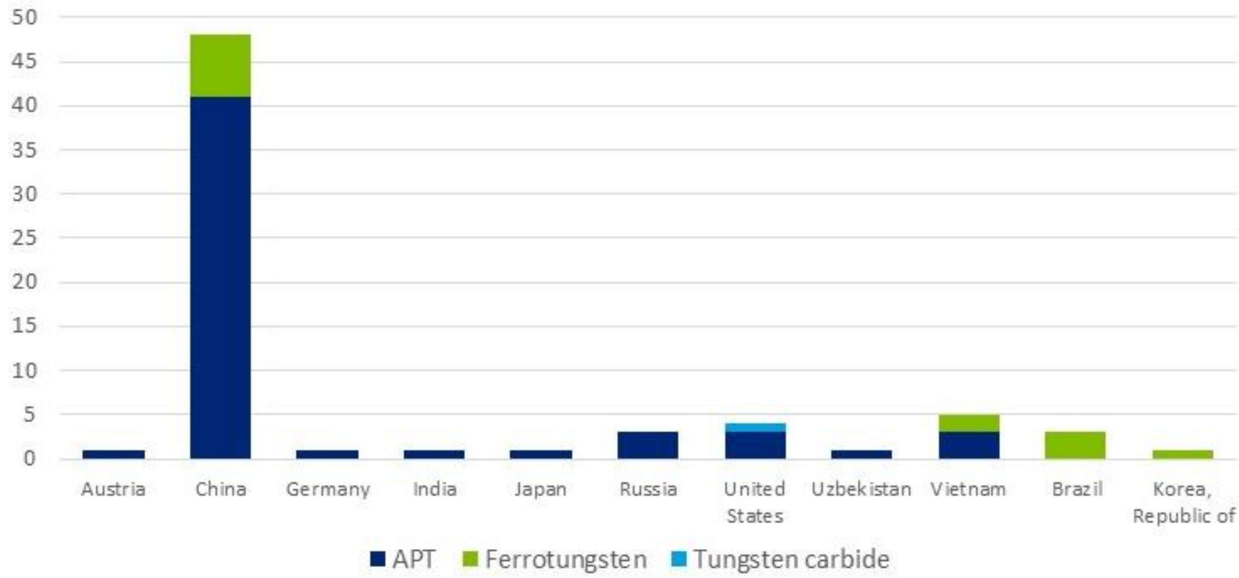


Figure 499: Number of identified global consumers of tungsten concentrates in 2017 (ITA, 2018)

27.5 Other considerations

27.5.1 Environmental and health and safety issues

Chronic inhalation or severe exposure to airborne tungsten dust particles and ingestion of large amounts of soluble tungsten compounds is known to be hazardous to human health (BGS, 2011).

However, tungsten and its compounds are not actually concerned by REACH, except nickel tungstate ($NiWO_4$) cited as carcinogen in the Appendix 1 of Annex XVII as nickel compound. In addition, the cemented tungsten carbide sector will be seriously impacted by upcoming reclassification of tungsten carbide-Cobalt compounds (presence of cobalt as binder) in REACH (WKO, 2016). The substitution products will be less performing, more expensive and not necessarily more health and/or environment friendly (WKO, 2016).

27.5.2 Socio-economic issues

The Regulation of the European Parliament and of the Council sets up a Union system for supply chain due diligence self-certification in order to curtail opportunities for armed groups and unlawful security forces to trade in tin, tantalum and tungsten, their ores, and gold. It will take effect on 1st January 2021. It is designed to provide transparency and certainty as regards the supply practices of importers, (notably smelters and refiners) sourcing from conflict-affected and high-risk areas. The EU regulation covers tin, tantalum, tungsten, and gold because these are the four metals that are most mined in areas affected by conflict or in mines that rely on forced labour.

The regulation also draws on well-established rules drawn up by the Organisation for Economic Co-operation and Development (OECD) in a document called 'Due Diligence Guidance for Responsible Supply Chains from Conflict-Affected and High-Risk Areas.' The regulation only applies directly to EU-based importers of tin, tantalum, tungsten and gold, whether these are in the form of mineral ores, concentrates or processed metals.

27.6 Comparison with previous EU assessments

The results of this and earlier assessments are shown in Table 212. Supply risk has been analysed at both mine and processing stages.

Table 212: Economic importance and supply risk for tungsten in the assessments of 2011, 2014, 2017, 2020 (European Commission, 2011-2014-2017)

Assessment	2011			2014			2017			2020	
Indicator	EI	SR		EI	SR		EI	SR		EI	SR
Tungsten	8.75	1.81		9.05	1.99		7.3	1.8		8.12	1.61

The economic importance of tungsten has changed between 2012-2016 due to the change in the added value of the sector for which tungsten is relevant.

The assessment of supply risk of tungsten was challenged by the lack of reliable data in both mine and processing stage. In assessing the EU supply risk of tungsten ores and concentrates, export and import figure from Eurostat-Comext were reported. The reported import figures, for example, were considered underestimated by experts, due to confidentiality issue. Therefore, a reliable value of supply risk at mining stage could not be obtained.

At processing stage, apart from the complex nature of supply chain of tungsten, no data on the global supply of processed tungsten was available. The figure of the EU import and export of processed tungsten for EU supply risk calculation was available in Eurostat Comext. Similar to the figure of tungsten ores and concentrates, due to confidentiality reason, the figures reported in Eurostat-Comext may not reflect the reality in the EU.

The United States International Trade Administration (ITA) identified a list of companies known to be consumers of tungsten ores and concentrates. The list was not accompanied by production capacity information, thefore it can not be used as a proxy of the concentration of processed tungsten production globally. Nevertheless, the figure clearly suggests the domination of China, which was confirmed by experts. Therefore, the final score for supply risk in Table 212, is a result of the global supply risk based on the distribution of tungsten smelters worldwide.

27.7 Data sources

The credibility of the EU import figure for tungsten in Eurostat-Comext database has been questioned by experts. Import has been said to be underestimated; this is however due to the confidentiality issue. For this reason, a reliable figure of EU apparent consumption and EU import reliance of tungsten ores and concentrates could not be calculated. EU import and export of processed tungsten was available in Eurostat Comext. On the other hand, the data on global supply of processed tungsten was not available. The distribution of tungsten smelters and refiners have been used as a proxy of the supply concentration.

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