12 HAFNIUM

12.1 Overview

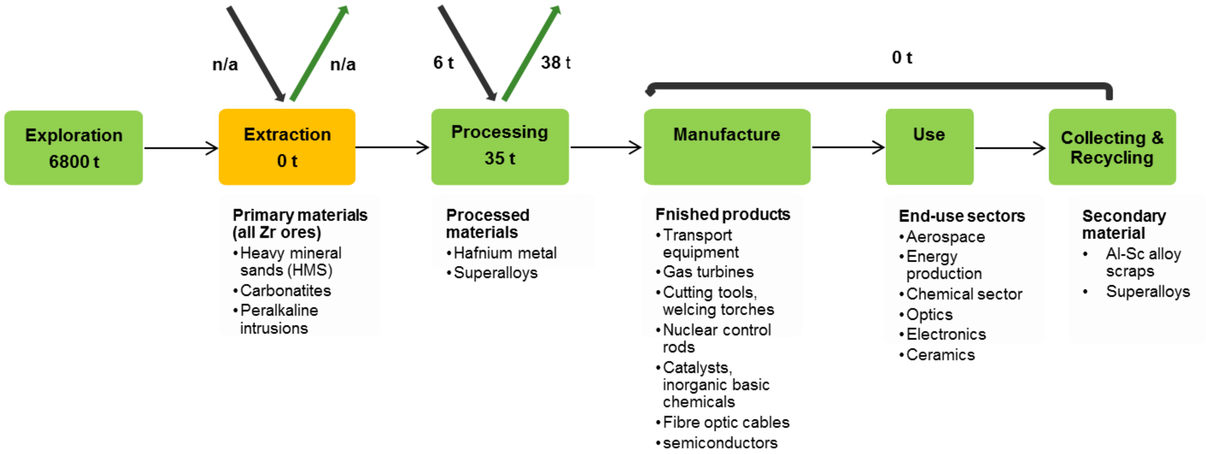

Figure 147: Simplified value chain for hafnium for the EU, averaged over 2012-2016[105], n/a: flow unknown.

Hafnium is a chemical element with chemical symbol Hf and atomic number 72. It was discovered in 1923 and its name is derived from the Latin name for Copenhagen "Hafnia". Hafnium is a hard, ductile metal similar to stainless steel in its appearance and chemically very similar to zirconium. For this reason, zirconium is discussed on several occasions in this factsheet. In nature, hafnium is always bound up with zirconium compounds, from which it needs to be extracted using advance metallurgical processing (ALKANE, 2017). Its main commercial sources are zircon and baddeleyite; these are available as by-products from the extraction of titanium minerals (Nielsen & Wilfing, 2010).

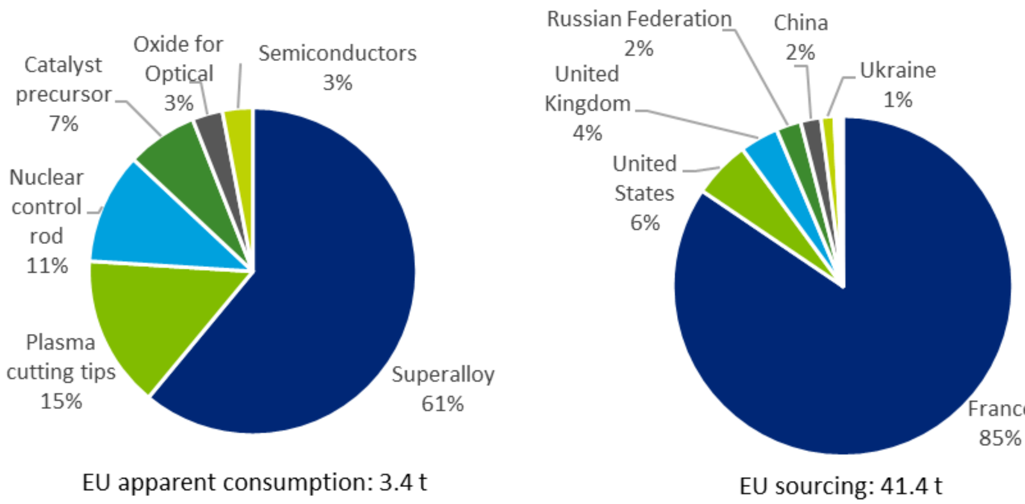

Figure 148: End uses and EU sourcing of hafnium (processing stage) and EU sourcing, average 2012-2016.

Commercial production of hafnium is driven by demand in the nuclear industry for high purity zirconium metal alloys (Moss *et al.*, 2011). Hafnium is used in high-temperature

[105] JRC elaboration on multiple sources (see next sections).

alloys and ceramics, since some of its compounds are very refractory: they will not melt except under the most extreme temperatures (Lenntech, 2016). Major uses of hafnium are located in the aerospace sector (super alloys) and the energy sector (gas turbines), and in the nuclear sector (nuclear reactor control rods).

For the purpose of this assessment, hafnium metal at processing stage is analysed (code CN 8112 92 10). The product group code covering hafnium metal is CN 8112 92 10, and labelled "unwrought hafnium "celtium"; hafnium powders; hafnium waste and scrap (excl. ash and residues containing hafnium)".

The hafnium market is strongly linked to the zirconium market, which shows a volume of US$2,000-3,000 million. No such data is available for the hafnium market. Hafnium metal is not traded publicly, therefore worldwide price trends are not readily available.

The apparent EU consumption of hafnium metal was calculated as 3.4 tonnes per year (average 2012-2016). However, production data are vague and trade data are questionable.
According to the data available, global production is dominated by two countries: France and the United States. France is the world major producer of hafnium, with 35 tonnes per year (49% of global production). The United States follows with 31 tonnes (44%). The remainder is distributed across China, Russia and Ukraine. Due to this high production of France, the EU has no import reliance and at the same time is a major global hafnium exporter (mainly France and Germany, mainly to the US).

Supply of hafnium is heavily dependent on the nuclear industry and its demand for pure zirconium. This is because hafnium is recovered solely as by-product at the zirconium metal purification (high grade separation of zirconium and hafnium). This purified zirconium metal is demanded by the nuclear industry.

Following the Fukushima accident in 2011, several countries such as Germany, Belgium and Switzerland have reconsidered drastically their nuclear energy policies. However, most countries remain committed to their energy programs (Hayashi & Hughes, 2012), thus there are no fundamental concerns about future zirconium demand, and thus no worries about hafnium (co-)production.

The major applications for hafnium are the following:

- Super alloys: the major application for hafnium is as an alloy addition in polycrystalline nickel-based super alloys; for example, MAR-M 247 alloy contains 1.5% hafnium. These alloys are used in the aerospace industry both in turbine blades and vanes but also in industrial gas turbines. The super-alloy industry requires the purest form of hafnium, crystal bars, with low zirconium content. Demand and supply for this form of hafnium approximately equal, making the sector volatile.
- Nuclear control rods: hafnium and zirconium are both used in nuclear reactors and nuclear submarines. Both hafnium and zirconium must be in the pure form in order to work effectively, this leads to the production of hafnium-free zirconium and, as a result, hafnium as a by-product. Hafnium is used in nuclear control rods due to its high thermal neutron absorption cross section (Bedinger, 2016).

Super alloys containing hafnium can contribute to lower vehicle weights and thus contribute to increased energy efficiency in the transport sector. Still, the relevance of this effect depends very much on the number of vehicles where such super alloys can actually be used in spite of the relative high price.

Data on hafnium supply, demand and reserves are not provided by statistics (European Commission, 2014); the figures available are in general individual estimates that are not necessarily aligned with each other. Deposits of heavy metals sands, which are commercially recoverable, are found in China, Malaysia, Thailand, India, Sri Lanka, Australia, South Africa, Madagascar, and the US. World reserves for hafnium are not recorded, but can be estimated from those of zirconium. In the EU, hafnium reserves are reported for the Norra-Kaerr deposit in Sweden (6,800 tonnes).

Global production of hafnium between 2012 and 2016 amounted on average to . 70 tonnes per year. The only reported producers of hafnium are France, United States, Ukraine, Russia and China.

There is no relevant end-of-life (EOL) recycling of hafnium.

The supply of hafnium is basically dependent on a minimum future demand for zirconium by the nuclear industry. Beside a very high concentration of supplier countries, there is also a clear concentration on few hafnium producers (companies and plants); this means that the global supply chain of hafnium is vulnerable to supply shortfall of individual countries and/or companies.

12.2 Market analysis, trade and prices

12.2.1 Global market analysis and outlook

Hafnium is as by-product of a certain part of the zirconium production. At the zirconium metal purification, which is a required process step for zirconium that is used in the nuclear industry, hafnium is accumulated. There are no further viable ways to produce hafnium, therefore the demand for purified zirconium by the nuclear industry implies an upper limit for the hafnium production.

The two largest producers are France and the United States, with comparable average annual output in the period 2012-2016. China, with an average market share of 3% in the same period, plans to increase its nuclear power development. This is likely to result in an increase in demand for nuclear-grade zirconium and hafnium (Bedinger, 2016). Overall it is estimated that hafnium demand for nuclear applications will increase by 4% annually (Moss *et al.*, 2011). It must be noted that, given the interdependency of supply and demand of zirconium and hafnium from the nuclear industry, an expansion of the nuclear energy industry should also result in increased production.

Ukraine showed for the period 2012-2016 an average production of 1 tonne per year (< 1%). The continuation of the Ukrainian hafnium production in the future was considered uncertain. Alternatively, the raw materials related to the hafnium production could be exported to Russia. India and China have some low-volume hafnium production for domestic use but do not export it (Lipmann Walton & Co Ltd., 2012).

The demand and supply are expected to grow in future (

Table 63). Demand in hafnium is expected to increase by 3.6% for alloys in aerospace and by 5% for non-aerospace super alloys (Moss *et al.*, 2011). For nuclear control rods, demand is expected to increase by 4%; a 3% increase is expected for all other applications.

Table 63: Qualitative forecast of supply and demand of hafnium

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
Hafnium	x		+	+	?	+	+	?

12.2.2EU trade

For the purpose of this assessment, hafnium metal at processing stage is analysed. The product group codes covering hafnium metal are CN 8112 92 10, "Unwrought hafnium "celtium"; hafnium powders; hafnium waste and scrap (excl. ash and residues containing hafnium)" and CN 8112 99 20 "Articles of hafnium "celtium" and germanium, n.e.s.".

United States (2.3 tonnes per year, 35%), United Kingdom (1.5 tonnes per year, 24%), the Russian Federation (1 tonne per year, 15%) and China (0.8 t per year; 12%) are the most important suppliers of hafnium metal to the EU (all values relate to the average for the period 2012-2016). Together they make up almost 90% of the 6.4 tonnes per year of the average imports to the EU (see Figure 150). Ukraine follows with 8%.[106] The import structure is very volatile: From the nine import countries, the EU imported only from the four largest importers without interruptions in the period covered. At the same time, the average annual imports grew drastically from 3.3 tonnes in 2013 to 12.4 tonnes in 2016 (Figure 149).

The volumes of internationally traded hafnium are small. They are generally volatile, but from 2013 to 2016 both imports and exports grew steadily (Figure 149).

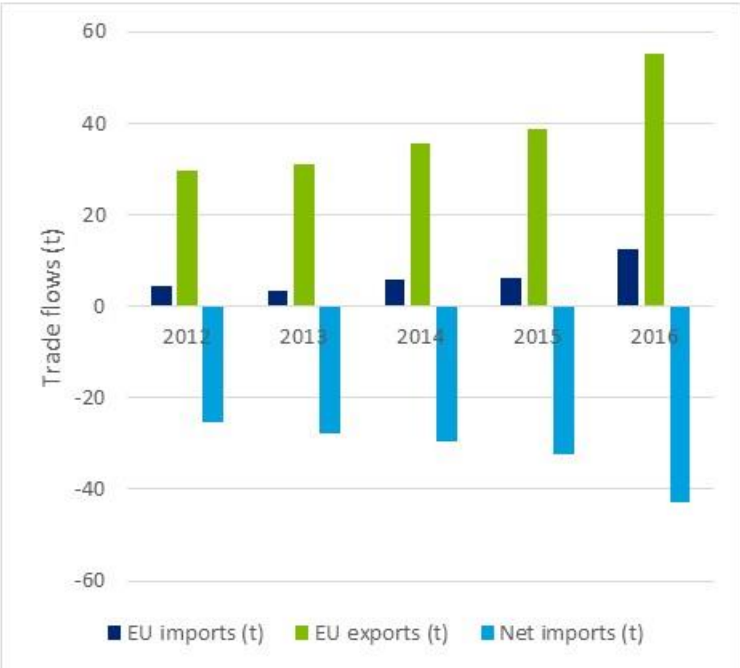

Figure 149: EU trade flows for hafnium, 2012-2016 (Eurostat, 2019)

[106] EU trade is analysed using product group codes. It is possible that materials are part of product groups also containing other materials and/or being subject to re-export, the "Rotterdam-effect". This effect means that materials can originate from a country that is merely trading instead of producing the particular material.

The exports are in average for the period 2012-2016 six times larger than the imports. The dominant destination of the EU exports (22.7 tonnes per year, 60%) are imported by the United States[107], followed by the United Kingdom (8.7 tonnes per year, 23%).

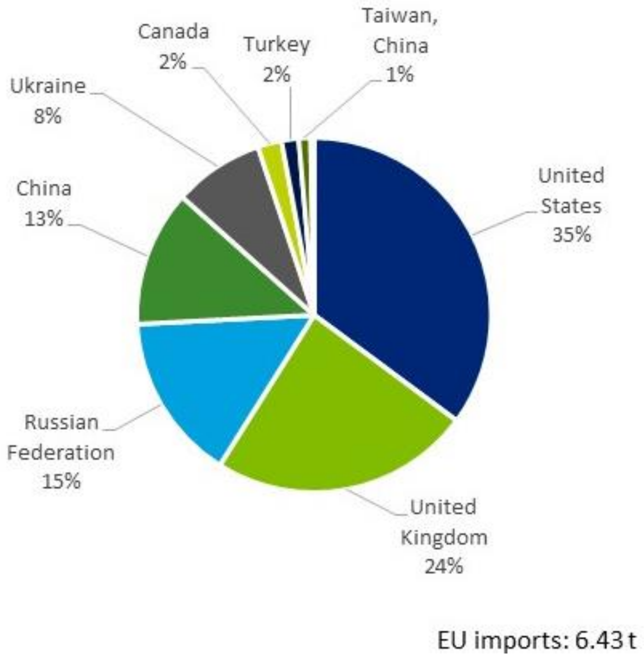

Figure 150: EU imports of hafnium oxides, average 2012-2016 (Eurostat, 2019)

At the moment, there are no export quotas or prohibition in place between the EU and its suppliers with the exception of Russia[108] (OECD, 2016). From the EU's suppliers, only Russia has an export tax (≤ 25 %) (OECD, 2016). There is a general trade agreement in place with Ukraine.

12.2.3Prices and price volatility

Hafnium metal is not traded publicly, therefore worldwide data and price trends are not readily available. Figure 151 shows that there has been a significant increase in price since the early 2000s, following a long decline in prices since 1970 given the maturation of the hafnium market (prices given in constant 98US$ prices).

[107] The imports of unwrought hafnium by the US are in 2015 and 2016 largely dominated by France and Germany.

[108] Although China has put an export quota of 230 tonnes, which is practically irrelevant due to the high threshold.

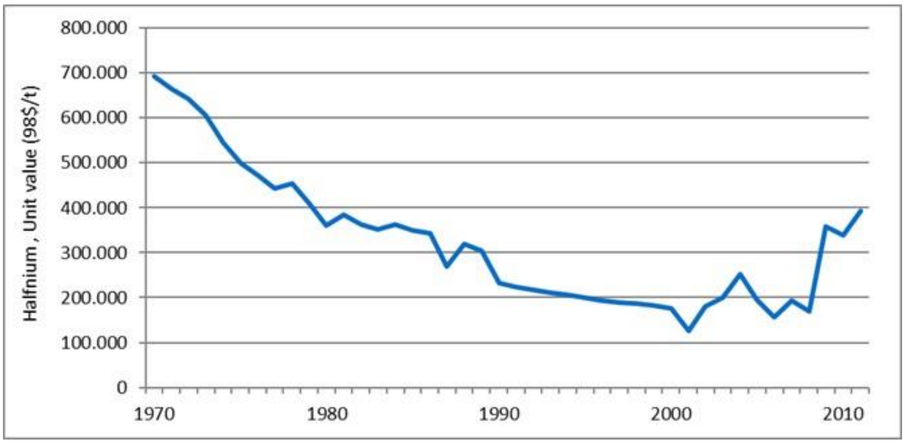

Figure 151: Global developments in price of hafnium, average constant prices (98 US$) for 1970-2013 (USGS, 2016)

The average price between 2011 and 2015 of bulk zirconium shipped from Australia was US$1,511.00 per tonne (DERA, 2016). In the last decade, the price volatility is medium. In the period 2009-2017, the maximum price (ca. €1,900 per kilogram) was about double the minimum price (ca. €850 per kilogram) (Figure 152).

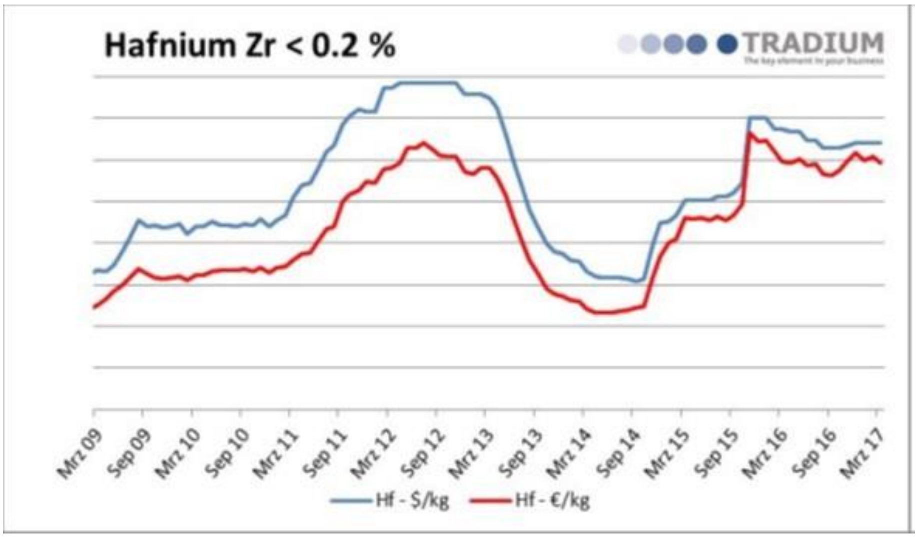

Figure 152: Historical hafnium pricing, nominal prices March 2009-March 2017 (after ALKANE, 2017)

12.3 EU demand

12.3.1 EU demand and consumption

The annual apparent consumption of hafnium in the EU was 3.4 tonnes in 2016. As there is a lack of updated production data, the EU consumption cannot be determined for the earlier years, therefore this value is used as proxy for the period 2012-2016. However, small commodity markets like the hafnium market tend to be very volatile, thus the validity of the consumption figure for the whole period is uncertain. For example, the US imports increased within the above-mentioned period from 24 tonnes per year to 180 tonnes per year (Bedinger, 2016). The figures imply that the hafnium consumption in the US exceeded the EU figure by far in 2016.

12.3.2 Uses and end-uses of Hafnium in the EU

Figure 153 shows that the uses of hafnium metal; super alloys used in the aerospace industry are the major output (Lipmann Walton & Co Ltd., 2012). The nuclear applications are listed as "machinery parts", as they are allocated to NACE 28, manufacturing of machinery.

The major applications for hafnium can be described in more detail as follows:

- Super alloys (61%): the major application for hafnium is as an alloy addition in polycrystalline nickel-based super alloys; for example, MAR-M 247 alloy contains 1.5% hafnium. These alloys are used in the aerospace industry both in turbine blades and vanes but also in industrial gas turbines. The super-alloy industry requires the purest form of hafnium, crystal bars, with low zirconium content. Demand and supply for this form of hafnium approximately equal, making the sector volatile.
- Nuclear control rods (11%): hafnium and zirconium are both used in nuclear reactors and nuclear submarines. Both hafnium and zirconium must be in the pure form in order to work effectively, this leads to the production of hafnium-free zirconium and, as a result, hafnium as a by-product. Hafnium is used in nuclear control rods due to its high thermal neutron absorption cross section (Bedinger, 2016).

Other uses of hafnium are refractory ceramic materials, microchips and nozzles for plasma arc cutting.

The global consumption of hafnium in 2016 is estimated to 67 tonnes (ALKANE, 2017). The EU apparent consumption is calculated as about 3.4 tonnes in 2016 (average 2012-2016).

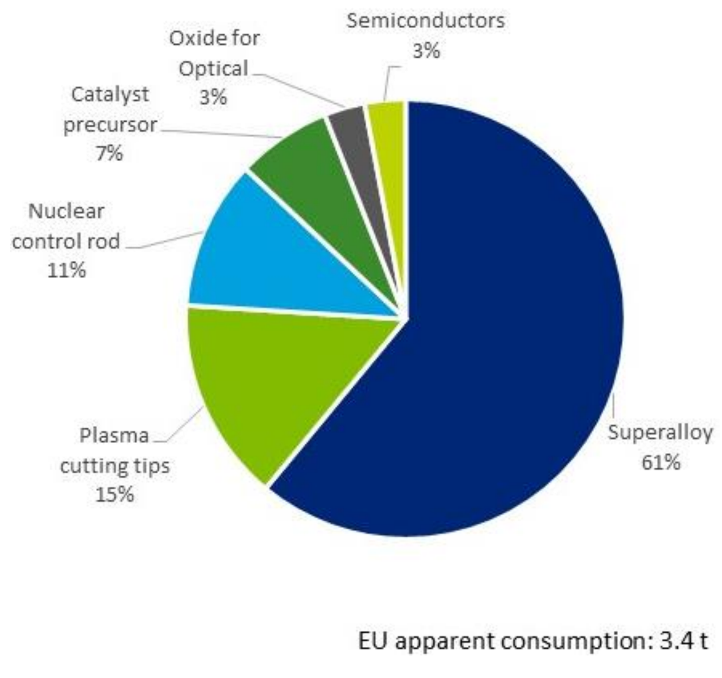

Figure 153: Global end uses of hafnium in 2016 (ALKANE, 2017)

Relevant industry sectors are described using the NACE sector codes (Eurostat, 2016c). The calculation of economic importance is based on the use of the NACE 2-digit codes and the value added at factor cost for the identified sectors (Table 64). The value added data correspond to 2012-2016 average figures.

Table 64: Hafnium applications, 2-digit NACE sectors, associated 4-digit NACE sectors, and value added per sector (Eurostat, 2019)

Applications	2-digit NACE sector	4-digit NACE sector	Value added of sector (M€)
Superalloys	C24 - Manufacture of basic metals	24.45 Other non-ferrous metal production	55,426
Plasma cutting tips	C25 - Manufacture of fabricated metal products, except machinery and equipment	25.73 Manufacture of dyes and pigments	148,351
Nuclear control rod	C25 - Manufacture of fabricated metal products, except machinery and equipment	25.45 Manufacture of other tanks, reservoirs and containers of metal	148,351
Catalyst precursor	C20 - Manufacture of chemicals and chemical products	20.13 Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers	105,514
Oxide for Optical	C26 - Manufacture of computer, electronic and optical products		65,703
Semiconductors	C26 - Manufacture of computer, electronic and optical products	26.6 Manufacture of engines and turbines	65,703

12.3.3Substitution

In superalloys, hafnium can be substituted by other alloy metals, such as magnesium, cobalt, chromium, niobium and tantalum, based on a kind of similarity in performance (corrosion resistance, thermal stress) (Bedinger, 2016). In certain superalloys, zirconium can be used interchangeably with hafnium (USGS, 2018), while showing a lower price. Chromite and olivine can be used instead of zircon for some foundry applications (USGS, 2018).

In nuclear applications, it is a long-standing option to substitute hafnium with silver-cadmium-indium control rods (Graves, 1962; USGS, 2018). This option is well-established in numerous nuclear powerplants. Beyond, niobium (columbium), stainless steel, and tantalum provide limited substitution in nuclear applications (USGS, 2018).

Zirconium can substitute hafnium in catalyst precursor applications. Titanium and synthetic materials may substitute in some chemical processing plant applications (USGS, 2018). Dolomite and spinel refractories can also substitute for zircon in certain high-temperature applications.

12.4 Supply

12.4.1 EU supply chain

France is the world major producer of hafnium, with 35 tonnes of annual production in 2016; correspondingly it is the dominant source of the EU (88%). Given the substantial domestic supply and the limited consumption, there is no import reliance of the EU. Figure 154 presents the EU sourcing[109] data for hafnium. (AlLKANE, 2017; Eurostat, 2019)

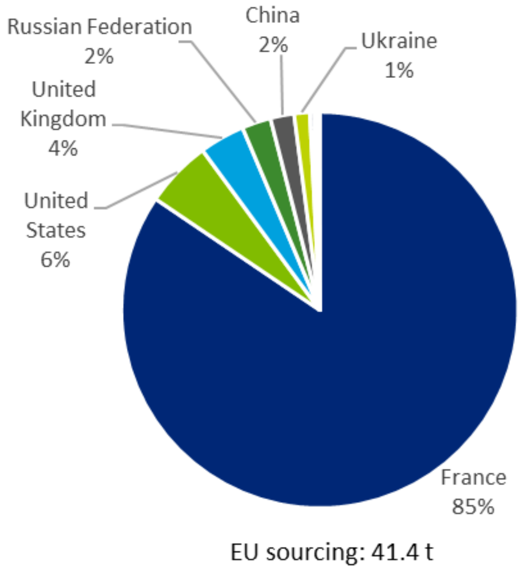

Figure 154: EU sourcing of hafnium, average 2012-2016 (ALKANE, 2017; Eurostat, 2019)

Supply of hafnium is heavily dependent on the nuclear industry and its demand for pure zirconium. This is because production of zirconium requires the separation of the two metals, to allow the extraction of hafnium as by-product. This implies a dependence of hafnium supply on the zirconium market, in particular the zirconium used in nuclear control rods.

Following the Fukushima accident (2011) many countries, such as Germany, Belgium and Switzerland, have reconsidered their nuclear energy policies and decided to step out of the domestic nuclear energy supply. This has possible consequences on also on the (domestic) hafnium supply, however, most countries remain committed to their energy programs with nuclear energy (Hayashi & Hughes, 2012).

Given the geographical concentration of hafnium production, it is remarkable that export restrictions with possible effect on hafnium are widely recorded by OECD (2016). This phenomenon can be explained by the trade code applied for the analysis. The related 6-digit CN product group (code 8112 92), contains also niobium, gallium, indium, vanadium and germanium. Most of the countries applying these exports restrictions[110] are no

[109] EU sourcing = domestic production + imports

[110] According to the trade database of the OECD, Jamaica, Rwanda, Burundi, Indonesia, Kenya issued a prohibition for CN 8112 92. Export taxes are issued by Morocco (7.5%), Russia (6.5%), Argentina (5%), combined with a licensing requirement. Vietnam even has a tax rate around 30% on average of the abovementioned unwrought metal. The restrictions on CN 6-digit level might affect hafnium supply, but also might be a statistical anomaly that is not relevant in international trade in the coming years.

relevant EU sources for hafnium in the period 2012-2016. Russia with almost 0.9 tonnes per year has applied an export tax rate of 6.5%.

12.4.2Supply from primary materials

12.4.2.1 Geology, resources and reserves of hafnium

Geological occurrence: The presence of hafnium in the earth's crust is somewhat rare, with 5.3 ppm[111] upper crustal abundance (Rudnick & Gao, 2003). Hafnium does exist in all silicate rocks and sediments, but in very low concentrations. It is not present in nature in its elemental form. The only mineral known with hafnium as major constituent is hafnon ($(Hf,Zr)SiO_4$).

The occurrence of hafnium is attended by zirconium, which is about 25 times more abundant in earth's crust (132 ppm). Commonly these two elements are combined in solid solution with each other. The two major sources of zirconium and hafnium are zircon ($ZrSiO_4$)[112] and baddeleyite (ZrO_2), in which hafnium is normally present 1.5-3.0 wt%.

Essentially, all hafnium comes from zirconium ores. During the processing of these ores, hafnium is processed as by-product (Zr-Hf ratio is about 50:1). Globally, there exist today three predominant ore types that are relevant zirconium and hafnium sources: heavy mineral sands (HMS), carbonatites and to a minor degree peralkaline intrusions. Zircon sand is obtained from the processing of HMS to recover the titanium minerals rutile and ilmenite.

Global resources and reserves[113]*:* Data on hafnium supply, demand and reserves are not recorded; the figures available are generally estimates (European Commission, 2014). Deposits of heavy metals sands, which are commercially recoverable, are found in China, Malaysia, Thailand, India, Sri Lanka, Australia, South Africa, Madagascar, and the United States. World reserves for hafnium are not recorded, but can be estimated from those of zirconium. Table 65 shows the estimated world reserves of zircon (Bedinger, 2016). USGS estimates world resources of hafnium associated with those of zircon and baddeleyite as exceeding 1,000,000 tonnes.

[111] parts per million

[112] Zircon with unusually high hafnium content is called alvite [$(Hf,Th,Zr)SiO_4 \cdot H_2O$].

[113] There is no single source of comprehensive evaluations for resources and reserves that apply the same criteria to deposits of hafnium 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.[113], 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.

Table 65: Global reserves of zircon reserves in year 2016 (Data from Bedinger, 2016)

Country	Zirconium Reserves (tonnes)	Percentage of total (%)
Australia	51,000,000	65
South Africa	14,000,000	18
Other countries	7,200,000	9
India	3,400,000	4
Mozambique	1,100,000	1
China	500,000	1
United States	500,000	1
Indonesia	N/A	N/A
World total (rounded)	78,000,000	100

EU resources and reserves[114]*:* There are no resources documented in the EU, and the single hafnium reserve in the EU reported is Norra Kärr in Gränna, Sweden[115].Norra Kärr is a rare earths deposit, which contains beside REEs also zirconium, hafnium, uranium and thorium (GBM, 2015). At the Minerals4EU website, no data is available on resources and reserves in Europe (Minerals4EU, 2019).

Table 66: Reserve data for the EU

Country	***Reporting code***	***Quantity***	***Unit***	***Grade***	***Code Resource Type***
Sweden	CIM Guidelines	23,571	ktonnes	0.0286%	Probable

12.4.2.2 World and EU mine production

Hafnium is extracted as by-product from zirconium recovery routes. The world annual hafnium production from zirconium ores is about 71 tonnes in 2016. Due to lack of repeated production data, this value has been used as average for the period 2012-2016 in the calculation for the criticality assessment.

12.4.3Supply from secondary materials/recycling

12.4.3.1 Post-consumer recycling (old scrap)

According to the results of the recent Material System Analysis on Hafnium[116], the EoLRIR (End-of-Life Recycling Input Rate) is calculated to 0% (see Table 67) (European Commission, under publication). Currently, there is little information available on hafnium

[114] For Europe, there is no complete and harmonised dataset that presents total EU resource and reserve estimates for hafnium. The Minerals4EU project is the only EU-level repository of some mineral resource and reserve data for hafnium, 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 hafnium 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.

[115] https://leadingedgematerials.com/norra-karr/

[116] At the time of authoring this factsheet, the Material System Analysis (MSA) on Hafnium was still work in progress. In this sense, the results used for the calculations were preliminary.

recycling. Recycling of superalloys containing hafnium would translate into hafnium recycling, however, experts assessed at the validation workshop that there is no information available on such recycling. It is likely that currently little to no post-use EOL recycling of hafnium is being carried out, given its contamination in the nuclear industry and the low percentage content in superalloys. UNEP reports that the end-of-life recycling rate is lower than 1% (UNEP, 2011). There are no indications that this has changed since then. Hafnium metal recycling is considered insignificant in the United States (Bedinger, 2016).

Table 67: Material flows relevant to the EoL-RIR of Hafnium, average 2012-2016[117] (EC 2019)

MSA Flow	Value (t)
B.1.1 Production of primary material as main product in EU sent to processing in EU	n/a
B.1.2 Production of primary material as by product in EU sent to processing in EU	n/a
C.1.3 Imports to EU of primary material	n/a
C.1.4 Imports to EU of secondary material	n/a
D.1.3 Imports to EU of processed material	4.9
E.1.6 Products at end of life in EU collected for treatment	4.6
F.1.1 Exports from EU of manufactured products at end-of-life	n/a
F.1.2 Imports to EU of manufactured products at end-of-life	n/a
G.1.1 Production of secondary material from post consumer functional recycling in EU sent to processing in EU	n/a
G.1.2 Production of secondary material from post consumer functional recycling in EU sent to manufacture in EU	n/a

12.4.3.2 Industrial recycling (new scrap)

Given the existence of hafnium as a by-product of titanium and zirconium, it is likely that hafnium waste from production processes is reintroduced in the process. At the validation workshop experts assessed that there is no information available on recycling of superalloys.

12.4.4 Processing of Hafnium

Hafnium is extracted from hafnium bearing zirconium ores. As the demand for these ores has been larger for zirconium than for hafnium, and due to the ratio between hafnium and zirconium prices, hafnium is always retrieved as a by-product of the zirconium processing. Hafnium is typically found in zirconium ores with zirconium to hafnium ratios of approximately 50:1.

After crushing, milling and roasting the ore, the material is leached and undergoes a solvent extraction. From this solution, zirconium and hafnium are extracted, and potentially niobium is recovered. The hafnium is then transferred to hafnium oxide (HfO_2).(ALKANE, 2017)

The separation of the pair zirconium and hafnium is difficult due to the similarity of their chemical properties such as atomic radius, ionic radius and electronegativity. Several methods have been applied to separate this ionic pair. Such methods include fractional crystallization, ion exchange, fractional distillation, thermal diffusion, solvent extraction and electrochemical separation (Felipe et al., 2013).

[117] The work carried out in 2019 increased the resolution of the MSA system. Therefore, there are changes in flows in comparison with the previous MSA methodology. B1.1 and B1.2 in the table is the result of the EU extraction after exports (MSA flows B1.1 + B1.2 – B1.3); C1.4 incorporates all secondary raw material imported to the EU both for the processing and manufacturing stages (MSA flows C1.4 and D1.9). D1.3 Incorporates imports to the EU of both semi-processed and processed material stages (MSA flows D1.3 and C1.8).

The global hafnium production is geographically highly concentrated. Most of the global production of hafnium (i.e. refining of zirconium) is done in France and the United States (Figure 155), whereat the production of high purity zirconium for nuclear applications is dominating. For about 2008 and 2012, respectively, AREVA, the only French producer, reported a production of 50 tonnes per year, however, the representativity of this value could not be assessed and the reference year remained unclear, thus it was not considered in the criticality assessment (AREVA, 2008).

The global refined hafnium production is shown in Figure 155.

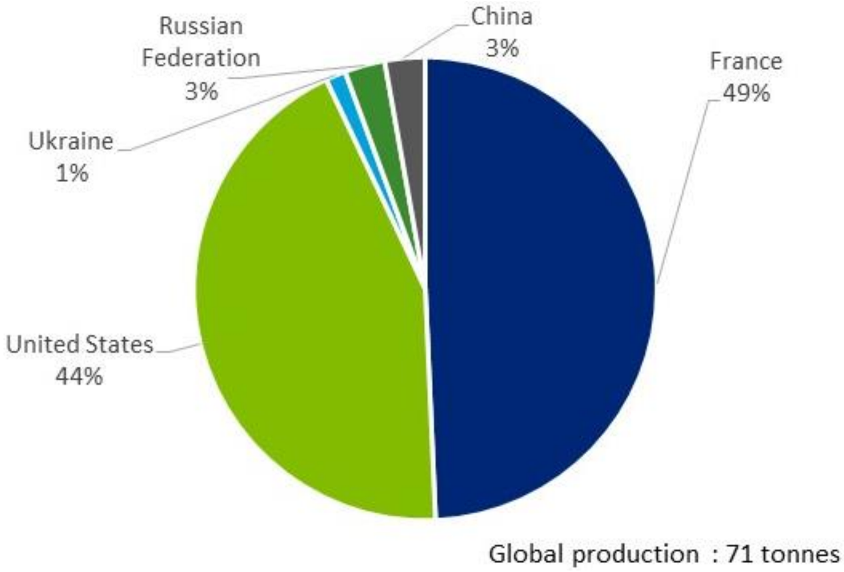

Figure 155: Global refined hafnium production in 2016 (ALKANE, 2017)

Beside a very high concentration of supplier countries, there is also a clear concentration on few hafnium producers (companies and plants), thus the global supply chain is vulnerable accordingly. Relevant producers in 2016 were Areva (France), ATI Wah Chang (U.S.) and Revert-Recycled (U.S.), together making up more than 90% of the global supply.

12.5 Other considerations

12.5.1 Environmental and health and safety issues

There is no comprehensive information available on health and safety issues. At the production process, hydrochloric acid vapours can leak from the processing unit, in exceptional cases of the maintenance procedures (CEZUS, 2008). This issue is commonly considered to be managed well in the extraction plants. At a safety exercise of the AREVA plant in Cezus, France, two risks were considered: firstly, the explosion of Methylchloride, a highly flammable and toxic gas, with possible effects up to a distance of 600 m, secondly the leakage of chlorine with possible effects of up to a distance of 6400 m (AREVA, 2012).

EU occupational safety and health (OSH) requirements exist to protect workers' health and safety. Employers need to identify which hazardous substances they use at the workplace, carry out a risk assessment and introduce appropriate, proportionate and effective risk management measures to eliminate or control exposure, to consult with the workers who should receive training and, as appropriate, health surveillance[118].

[118] https://ec.europa.eu/social/main.jsp?catId=148

12.5.2 Socio-economic issues

Hafnium is not linked to any particular socio-economic issue.

12.6 Comparison with previous EU assessments

The assessment has been performed using the revised methodology introduced in the 2017 assessment. The calculation of the Supply Risk (SR) was carried out at the refining stage of the value chain, using the global HHI calculation only, because the EU is a net exporter.

Overall, the assessment results for hafnium in 2020 are similar to the 2017 results. Compared to the 2017 assessment, both economic importance and supply risk dropped slightly, while it is still assessed as critical (see Table 68).

Hafnium was assessed for the first time at the 2014 criticality assessment. In spite of an Economic Importance of 7.8, it was not considered critical due to a low Supply Risk. In 2017, there was a strong drop of the economic importance compared to 2014, mainly to the revision of the methodology, but also because the use in nuclear reactors has been additionally considered. The economic importance decreased further in 2020, whereat a new data source has been used to describe the sectoral distribution, with a different application terminology.

The supply risk shows a significant rise from 0.4 in 2014 to 1.3 in 2017. This dropped again slightly to 1.1 in 2020, mainly due to the fact that shortcomings in the trade data did not allow to include the EU-28 HHI in the calculation, like in 2017, when the global HHI was higher than the EU-28 HHI. Still, the Supply Risk indicator is above the criticality threshold due to the limited number of reported suppliers of hafnium. It must be noted that the supply risk is dependent on monopoly or quasi-monopoly situations, independent from the fact that the monopoly is in an EU or an extra-EU country.

Table 68: The results of Economic Importance and Supply Risk for hafnium in the assessments of 2011, 2014 (European Commission, 2011; European Commission, 2014) and 2017

Assessment	2011			2014			2017			2020	
Indicator	EI	SR		EI	SR		EI	SR		EI	SR
Hafnium	N/A	N/A		7.8	0.4		4.2	1.3		3.9	1.1

12.7 Data sources

The production data is incomplete and vague as there is only a single estimate available for 2016. For the calculation of the supply risk indicator, the global HHI only has been considered as the EU is a net exporter.

12.7.1 Data sources used in the factsheet

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