Supplementary material for

Environmental and Resource Aspects of Substituting Cemented Carbide with Polycrystalline Diamond: The Case of Machining Tools

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1. Data for life cycle inventory calculations and sensitivity analysis

Table S1. Summary of the data applied for the calculations to derive life cycle inventory data for synthetic diamond production (see Section 3.1 in the article) and the sensitivity analysis (see Section 2.5 in the article). Whenever parameter ranges were available, midpoint values were applied for the calculations, unless typical values other than the midpoint value within this range were indicated. Realistic ranges were applied for the sensitivity analysis when available. Otherwise, the low and high value applied for the sensitivity analysis were obtained by changing the parameter with ±50% of its baseline value. Note that for the sensitivity analysis, the values for e.g. yields were never changed so that they exceeded 100%. WC-Co=cemented carbide.

Synthetic diamond production					
Parameter [unit]	**Baseline value**	**Comment**	**Sensitivity analysis**		**References**
			Low value	**High value**	
High-pressure high-temperature synthesis					
Amount metal solvent per amount graphite [-]	1	Mixture-weight of graphite and metal solvents in the conventional cubic high-pressure apparatus assembly is 1:1	0.5	1.5	Han et al. (2015)
Graphite-to-diamond conversion [weight-%]	50	The typical amounts of diamond and non-reacted graphite in the process output are approximately equally large	25	75	Assumption by the authors based on Skury et al. (2004)
Power of large-volume cubic press [kW]	3.6	Large-volume cubic presses with a power of 3.4-3.8 kW are commonly applied for synthetic diamond production in China. The midpoint value of 3.6 kWh/metric ton was applied as the baseline value in this study	3.4	3.8	Li et al. (2018), Zhang et al. (2015)
Reaction time [min]	10	Reaction times to produce diamond crystals with sizes of about 0.1-1 mm, range from a few to tens of minutes	2	30	Assumption by the authors based on Prikhna (2008) and Zhou et al. (2008)
Weight of a conventional cubic apparatus WC-Co anvil [kg]	4.25	Note that there are six WC-Co anvils in one high-pressure apparatus and that the cobalt content in these anvils is 8 weight-%] (Han et al., 2011a)	2.13	6.63	Han et al. (2011b), Han et al. (2011a)

Parameter [unit]	Baseline value	Comment	Sensitivity analysis		References
			Low value	High value	
Output from the reaction (one cycle) [g diamond crystals]	14	Data on the general yield of industrial large volume apparatus of various sample sizes (Prikhna, 2008) were used to obtain the reaction output of an apparatus with the sample size of 27.22 cm^3 (Han et al., 2015), which is the typical sample size for conventional cubic presses, by the application of linear extrapolation.	7	21	Assumption by the authors based on Prikhna (2008) and Han et al. (2015)
Lifetime of WC-Co anvils [# cycles]	100	WC-Co anvils have a lifetime of about 100 cycles	50	150	Prikhna (2008)
Acid treatment					
Metal solvent in diamond crystals after acid treatment [weight-%]	5	Up to 10 weight-% metal solvent can be included in the purified synthetic diamond output	0	10	Marinescu et al. (2016)
Consumption of sulfuric acid in diamond purification [kg]	0.29	About 0.29 kg sulfuric acid and 0.04 kg potassium dichromate are consumed per kg produced synthetic diamond based on global data	0.15	0.44	Skury et al. (2004)
Consumption of potassium dichromate in diamond purification [kg]	0.04		0.02	0.06	
Recovery rate of nickel metal solvent [%]	100	The nickel metal solvent was assumed to be recycled completely since industrial waste nickel catalysts can in general be recovered to a high degree, approaching a 100% recovery rate for many methods. The lowest recovery rate reported by for waste nickel catalysts was 85% and was applied in the sensitivity analysis.	85	100	Assumption by the authors based on Coman et al. (2013)
Yield of purified diamonds [%]	100	Since diamond is chemically inert to most acids, the yield of purified diamond crystals, i.e. diamond grit, in the acid treatment process was assumed to be 100%	50	100	Assumption by the authors based on Abbaschian et al. (2005)

Table S2. Summary of the data applied for the calculations to derive life cycle inventory data for the process of transportation and diamond powder production by crushing, which constitutes a part of the life cycle of a polycrystalline diamond (PCD) tool (see Section 3.2.1 in the article) and the sensitivity analysis (see Section 2.5 in the article). Whenever parameter ranges were available, midpoint values were applied for the calculations, unless typical values other than the midpoint value within this range were indicated. Note that parameter values for the other processes in PCD tool production are not provided here since life cycle inventory data for PCD tip production and WC-Co tip production was provided directly by the collaborators and Furberg et al. (2019) (see Table S4 and Table S5). Also note that the process of assembly and the use phase were assumed to be similar for the PCD and WC-Co tools in this study (see Sections 3.2.4 and 3.2.5 in the article) and that the PCD and WC-Co tips become recycled after use and become cut off. Realistic ranges were applied for the sensitivity analysis when available. Otherwise, the low and high value applied for the sensitivity analysis were obtained by changing the parameter with ±50% of its baseline value. Note that for the sensitivity analysis, the values for e.g. yields were never changed so that they exceeded 100%. WC-Co=cemented carbide.

PCD tool production					
Parameter [unit]	**Baseline value**	**Comment**	**Sensitivity analysis**		**References**
			Low value	**High value**	
Transportation and diamond powder production by crushing					
Freight shipping transportation distance [km]	19 000	The diamond grit was assumed to be transported from the production site, located in China, to Europe via freight shipping. The approximate distance between Shanghai and Rotterdam via the Suez Canal, which is 19 000 km, was applied	9 700	29 000	Sea-distances.org (2019)
Yield in crushing of diamond grit from >100 µm to <2 µm in size [weight-%]	97	The majority (97%) of the milled powder, from a jet mill, converting HPHT diamond grit of 150-190 µm in size into smaller particles, had a size of <2 µm. Thus, a 97% yield of diamond powder with a size of <2 µm was assumed for the crushing process	49	100	Boudou et al. (2009)
Electricity consumed in crushing [kWh/metric ton]	1 650	The specific energy consumption of jet mills varies between 300-3000 kWh/metric ton. This general value for jet mill energy consumption was assumed to also represent the size reduction of HPHT diamond grit into diamond powder <2 µm, specifically, and the midpoint value of 1650 kWh/metric ton was applied in this study	300	3000	Assumption based on Bernotat and Schönert (2000)

2. Life cycle inventory data results

Table S3. Life cycle inventory data for the production of 1 g synthetic diamond grit via high-pressure high-temperature (HPHT) synthesis. Note that the synthetic diamond grit contains some metal impurities. All values are in g/g synthetic diamond grit unless otherwise noted. Values are presented with two significant figures. Note that inventory data in italic are only presented in order to make it easy to obtain process-specific data from this table. WC-8Co=cemented carbide with 8 weight-% cobalt.

Synthetic diamond production			
Input or output	**Parameter**	**Value**	**Comment**
HPHT synthesis			
Input	Chinese WC-8Co	19	
Input	Electricity	0.044	kWh/g synthetic diamond grit
Input	Graphite	2.0	
Input	Metal solvent (nickel)	2.0	
Output	Chinese WC-8Co	19	Recycled, cut off
Output	*HPHT diamond crystals with metal solvent and un-reacted graphite including:*	*4.0*	
	Diamond crystals	*1.0*	
	Metal solvent (nickel)	*2.0*	
	Un-reacted graphite	*1.0*	
Acid treatment after cooling			
Input	*HPHT diamond crystals with metal solvent and un-reacted graphite including:*	*4.0*	
	Diamond crystals	*1.0*	
	Metal solvent (nickel)	*2.0*	
	Un-reacted graphite	*1.0*	

Input or output	Parameter	Value	Comment
Input	Sulfuric acid	0.29	
Input	Potassium dichromate	0.040	
Output	Liquid waste	0.17	cm^3/g synthetic diamond grit. Note that 0.29 g sulfuric acid and 0.040 g potassium dichromate equals 0.17 cm^3
Output	Nickel	2.0	Recycled, cut off
Output	Purified diamond crystals with metal inclusions, including:	1.0	g synthetic diamond grit
	Purified diamond crystals	0.95	
	Metal solvent (nickel) inclusions	0.050	

Table S4. Life cycle inventory data for one polycrystalline diamond (PCD) tool with four tips. All values are in g/one PCD tool unless otherwise noted. The four tips each consist of PCD on a cemented carbide with 13 weight-% cobalt (WC-13Co) substrate. Values are presented with two significant figures. Note that in certain cases, the exact materials cannot be disclosed due to confidentiality. Note that inventory data in italic are only presented in order to make it easy to obtain process-specific data from this table. HPHT=high-pressure high-temperature.

PCD tool production			
Input or output	**Parameter**	**Value**	**Comment**
Transportation and diamond powder production by crushing			
Input	Synthetic diamond grit	0.88	
Input	Transport by freight ship	0.00027	Ton·km/one PCD tool
Input	Electricity	0.0015	kWh/one PCD tool
Output	*Diamond powder, < 2 µm*	*0.86*	
PCD tip production			
Input	Electricity	10	kWh/one PCD tool
HPHT Sintering			
Input	*Diamond powder, < 2 µm*	*0.86*	
Input	Cobalt powder	0.058	
Input	Non-Chinese WC-13Co substrate	9.0	
Input	Non-Chinese WC-Co dies and anvils	7.1	

Input or output	Parameter	Value	Comment
Input	Ceramic insulation materials	9.2	
Input	Capsule components	5.9	
Input	Other apparatus parts	3.2	
Input	Pressure medium	2.2	
Output	Non-Chinese WC-Co dies and anvils	7.1	Recycled, cut off
Output	Ceramic insulation materials	9.2	Solid waste
Output	Capsule components and other apparatus parts	8.0	Recycled, cut off
Output	Capsule components and other apparatus parts	1.1	Solid waste
Output	Pressure medium	2.2	Solid waste
Disc Processing			
Output	PCD consisting of:	0.24	Solid waste
	Diamond powder	0.23	
	Cobalt powder	0.015	
Output	Non-Chinese WC-13Co	4.9	Recycled, cut off
Electrical Discharge Machining			
Output	PCD consisting of:	0.14	Solid waste
	Diamond powder	0.13	
	Cobalt powder	0.0087	
	Non-Chinese WC-13Co	1.2	Recycled, cut off
Output	PCD tool consisting of:	3.5	One PCD tool
	Diamond powder	0.50	
	Cobalt powder	0.034	
	Non-Chinese WC-13Co substrate	3.0	

Table S5. Life cycle inventory data for one cemented carbide (WC-Co) tool with four tips. All values are in g/one WC-Co tool unless otherwise noted. Values are presented with two significant figures. WC-8Co=cemented carbide with 8 weight-% cobalt.

WC-Co tool production			
Input or output	**Parameter**	**Value**	**Comment**
Input	Non-Chinese WC-8Co	4.7	
Output	Non-Chinese WC-8Co	4.7	One WC-Co tool

3. Background system data

Table S6. Sources of the background system data for the production of synthetic diamond grit via high-pressure and high-temperature (HPHT) synthesis. Note that no market processes were available in the Ecoinvent database version 3.5 (2018) for Chinese Henan electricity. Note that potassium dichromate was modelled as sodium dichromate in Ecoinvent since no LCI data was available for potassium dichromate in Ecoinvent, no LCA could be identified in literature and potassium dichromate has largely been replaced by sodium dichromate according to Anger et al. (2012). WC-8Co=cemented carbide with 8 weight-% cobalt, GLO=global, RoW=rest-of-the-world and CN-HE=China, Henan Province.

Data from Ecoinvent database version 3.5 (2018)		
Parameter	**Ecoinvent dataset**	
Input		
Electricity	electricity, high voltage, production mix | electricity, high voltage | Cutoff, U [CN-HE]	
Graphite	market for graphite | graphite | Cutoff, U [GLO]	
Nickel	market for nickel, 99.5% | nickel, 99.5% | Cutoff, U [GLO]	
Potassium dichromate	market for sodium dichromate | sodium dichromate | Cutoff, U [GLO]	
Sulfuric acid	market for sulfuric acid | sulfuric acid | Cutoff, U [RoW]	
Output		
Treatment of liquid aqueous waste	market for wastewater, average | wastewater, average | Cutoff, U [RoW]	
Data from other sources		
Parameter	**Comment**	**Reference**
Input		
WC-8Co	A WC-8Co production mixture of primary and recycled WC-8Co was used in the calculations (with varying recycled content based on the selected WC-Co recycling rate). LCI data for primary Chinese WC-8Co production was obtained by combining LCI data on Chinese WC production and non-Chinese WC-Co production from WC and Co powders as a proxy for Chinese WC-8Co production (applying the zero recycling scenario and baseline case in Furberg et al. (2019)). The main difference between Chinese and non-Chinese WC-Co lie in the processes applied for WC powder production. Recycled non-Chinese WC-8Co via the zinc process was furthermore used as a proxy for recycled Chinese WC-8Co. For this, the baseline case in Furberg et al. (2019) and a WC-Co yield at 95% for the zinc recycling process were applied. See further Table S8 and Table S9.	Ma et al. (2017), Furberg et al. (2019)

Table S7. Sources of the background system data for the direct electricity input applied in the solar and solar-high recycling scenarios. In the current and high recycling scenarios, location-specific background system data was applied for direct electricity inputs to the foreground system. RoW=rest-of-the-world.

Data from Ecoinvent database version 3.5 (2018)	
Parameter	**Ecoinvent dataset**
Input	
Solar electricity	electricity production, photovoltaic, 3kWp flat-roof installation, multi-Si | electricity, low voltage | Cutoff, U [RoW]

Table S8. Sources of the background system data for the production of one polycrystalline diamond (PCD) tool with four tips. GLO=global, RoW=rest-of-the-world, ENTSO-E=European network of transmission systems operators for electricity and WC-13Co=WC-Co with 13 weight-% cobalt.

Data from Ecoinvent database version 3.5 (2018)		
Parameter	**Ecoinvent dataset**	
Input		
Cobalt powder	market for cobalt | cobalt | Cutoff, U [GLO]	
Electricity Western Europe (European Network of Transmission Systems Operators for Electricity)	market group for electricity, medium voltage | electricity, medium voltage | Cutoff, U [ENTSO-E]	
Ceramic insulation materials	Exact materials cannot be disclosed due to confidentiality	
Pressure medium		
Capsule components		
Other apparatus parts		
Transport with freight ship	market for transport, freight, sea, transoceanic ship | transport, freight, sea, transoceanic ship | Cutoff, U [GLO]	
Output		
Treatment of solid waste (landfill)	market for process-specific burdens, inert material landfill | process-specific burdens, inert material landfill | Cutoff, U [RoW]	
Data from other sources		
Parameter	**Comment**	**References**
Input and output		
Non-Chinese WC-13Co and WC-Co	LCI data provided by the reference. A WC-Co production mixture of primary and recycled WC-Co was used in the calculations (with varying recycled content based on the selected WC-Co recycling rate). The zero recycling scenario and the baseline case from the reference were applied for primary non-Chinese WC-Co production while zinc recycling with a 95% WC-Co yield and the baseline case were applied for recycled non-Chinese WC-Co.	Furberg et al. (2019)
Synthetic diamond grit	LCI data based on a literature review.	See Table S4 and Section 3.1 in the article

Table S9. Sources of the background system data for non-Chinese cemented carbide (WC-Co) primary production with various cobalt content. This was also used as the background system data for one cemented carbide (WC-Co) tool with four tips (and in that case the electricity input was changed in the solar and solar-high recycling scenarios according to Table S5). Note that decanol was modelled as fatty alcohol. GLO=global, RoW=rest-of-the-world, CA-NT=Canada Northwest territories and NPCC, US only=Northeast power coordinating council, United States part only. *Only used for the modelling of alamine 336 and/or tannin.

Data from Ecoinvent database version 3.5 (2018)	
Parameter	**Ecoinvent dataset**
Input	
Aluminum sulfate	market for aluminium sulfate, powder | aluminium sulfate, powder | Cutoff, U [RoW]
Ammonia	market for ammonia, liquid | ammonia, liquid | Cutoff, U [RoW]
Bark chips*	market for bark chips, wet, measured as dry mass | bark chips, wet, measured as dry mass | Cutoff, U [GLO]
Carbon black	market for carbon black | carbon black | Cutoff, U [GLO]
Cobalt powder	market for cobalt | cobalt | Cutoff, U [GLO]
Decanol	market for fatty alcohol | fatty alcohol | Cutoff, U [GLO]
Diesel	market for diesel, burned in building machine | diesel, burned in building machine | Cutoff, U [GLO]
Electricity Canada (Northwest territories)	market for electricity, high voltage | electricity, high voltage | Cutoff, U [CA-NT]
Electricity, global market*	market group for electricity, high voltage | electricity, high voltage | Cutoff, U [GLO]
Electricity US (Northeast)	market for electricity, high voltage | electricity, high voltage | Cutoff, U [NPCC, US only]
Fatty alcohol*	market for fatty alcohol | fatty alcohol | Cutoff, U [GLO]
Heptane	market for heptane | heptane | Cutoff, U [GLO]
Hexane	market for hexane | hexane | Cutoff, U [GLO]
Hydrogen	market for hydrogen, liquid | hydrogen, liquid | Cutoff, U [RoW]
Kerosene	market for kerosene | kerosene | Cutoff, U [RoW]
Magnesium sulfate	market for magnesium sulfate | magnesium sulfate | Cutoff, U [GLO]
Nitrogen	market for nitrogen, liquid | nitrogen, liquid | Cutoff, U [RoW]
Oleic acid	market for fatty acid | fatty acid | Cutoff, U [GLO]
Paraffin	market for paraffin | paraffin | Cutoff, U [GLO]
Sodium carbonate	market for sodium bicarbonate | sodium bicarbonate | Cutoff, U [GLO]
Sodium cyanide	market for sodium cyanide | sodium cyanide | Cutoff, U [RoW]
Sodium hydrosulfide	market for sodium hydrosulfide | sodium hydrosulfide | Cutoff, U [GLO]
Sodium hydroxide	market for sodium hydroxide, without water, in 50% solution state | sodium hydroxide, without water, in 50% solution state | Cutoff, U [GLO]
Sodium silicate	market for sodium silicate, solid | sodium silicate, solid | Cutoff, U [RoW]
Sodium sulfide	market for sodium sulfide | sodium sulfide | Cutoff, U [GLO]
Sulfuric acid	market for sulfuric acid | sulfuric acid | Cutoff, U [RoW]
Water	market group for tap water | tap water | Cutoff, U [GLO]
Water (deionized)	market for water, deionised, from tap water, at user | water, deionised, from tap water, at user | Cutoff, U [RoW]

Parameter	Ecoinvent dataset	
Input		
Transport lorry	market for transport, freight, lorry >32 metric ton, EURO3 | transport, freight, lorry >32 metric ton, EURO3 | Cutoff, U [RoW]	
Output		
Treatment of liquid aqueous waste	market for wastewater, average | wastewater, average | Cutoff, U [RoW]	
Treatment of liquid organic waste	market for spent solvent mixture | spent solvent mixture | Cutoff, U [RoW]	
Treatment of solid waste (landfill)	market for process-specific burdens, inert material landfill | process-specific burdens, inert material landfill | Cutoff, U [RoW]	
Treatment of tailings (non-sulfidic)	market for non-sulfidic tailing, off-site | non-sulfidic tailing, off-site | Cutoff, U [GLO]	
Treatment of tailings (sulfidic)	market for sulfidic tailing, off-site | sulfidic tailing, off-site | Cutoff, U [GLO]	
Data from other sources		
Parameter	**Comment**	**Reference**
Input		
Alamine 336	LCI data provided by the reference. Ecoinvent used for LCIA.	Vahidi and Zhao (2017) and Ecoinvent database version 3.5 (2018)
Anyl xanthate	Not included due to negligible amount	-
Frother	Not included due to negligible amount	-
Pine oil	Not included due to negligible amount	-
Tannin	LCI data provided by the reference applying their E1 and P1 scenario. Ecoinvent used for LCIA.	Ding et al. (2017) and Ecoinvent database version 3.5 (2018)

Table S10. Sources of the background system data for recycled non-Chinese cemented carbide (WC-Co) production with various cobalt content. This data was also used as a proxy for recycled Chinese WC-Co. GLO=global, RoW=rest-of-the-world, NPCC, US only=Northeast power coordinating council, United States part only and CN=China. *Only used for recycled Chinese WC-Co (then instead of US (northeast) electricity).

Data from Ecoinvent database version 3.5 (2018)	
Parameter	**Ecoinvent dataset**
Input	
Electricity US (Northeast)	market for electricity, high voltage | electricity, high voltage | Cutoff, U [NPCC, US only]
Electricity China*	market group for electricity, high voltage | electricity, high voltage | Cutoff, U [CN]
Heptane	market for heptane | heptane | Cutoff, U [GLO]
Hexane	market for hexane | hexane | Cutoff, U [GLO]
Nitrogen	market for nitrogen, liquid | nitrogen, liquid | Cutoff, U [RoW]
Paraffin	market for paraffin | paraffin | Cutoff, U [GLO]
Zinc	market for zinc | zinc | Cutoff, U [GLO]
Output	
Treatment of solid waste (landfill)	market for process-specific burdens, inert material landfill | process-specific burdens, inert material landfill | Cutoff, U [RoW]
WC-Co scrap sorting	market for iron scrap, sorted, pressed | iron scrap, sorted, pressed | Cutoff, U [GLO]

Table S11. Sources of the background system data for primary Chinese cemented carbide (WC-Co) production. Note that no market processes were available in the Ecoinvent database version 3.5 (2018) for Chinese electricity in Jiangsu or Jiangxi. The WC-Co production site was assumed to be located in the Jiangxi Province, China, since the tungsten carbide powder is produced there (Ma et al., 2017) and since one of the major WC-Co production plants in the world are located there (Werner et al., 2014). Note that the tungsten content in ore required per kg tungsten carbide powder was included in the calculations and available from Ma et al. (2017). Note also that assumptions had to be made regarding the density and moisture content of the wood in order to estimate its weight and then be able to use the Ecoinvent data. GLO=global, RoW=rest-of-the-world, CN-JS=China, Jiangsu Province and CN-JX=China, Jiangxi Province. *Only used for the modelling of xanthate.

Data from Ecoinvent database version 3.5 (2018)	
Parameter	**Ecoinvent dataset**
Input	
1-Pentanol*	market for 1-pentanol | 1-pentanol | Cutoff, U [GLO]
Ammonium chloride (NH_4Cl)	market for ammonium chloride | ammonium chloride | Cutoff, U [GLO]
Ammonium sulfide ($(NH_4)_2S$)	market for ammonium sulfate, as N | ammonium sulfate, as N | Cutoff, U [GLO]
Calcium carbonate ($CaCO_3$)	market for calcium carbonate, precipitated | calcium carbonate, precipitated | Cutoff, U [RoW]
Carbon black	market for carbon black | carbon black | Cutoff, U [GLO]
Carbon disulfide*	market for carbon disulfide | carbon disulfide | Cutoff, U [GLO]
Coal	market for hard coal | hard coal | Cutoff, U [RoW]
Coal oleic acid	market for fatty acid | fatty acid | Cutoff, U [GLO]
Cobalt powder	market for cobalt | cobalt | Cutoff, U [GLO]
Compressed air	market for compressed air, 600 kPa gauge | compressed air, 600 kPa gauge | Cutoff, U [GLO]
Copper sulfate	market for copper sulfate | copper sulfate | Cutoff, U [GLO]
Electricity, global market*	market group for electricity, high voltage | electricity, high voltage | Cutoff, U [GLO]
Electricity in mining	electricity, high voltage, production mix | electricity, high voltage | Cutoff, U [CN-JS]
Electricity in tungsten carbide and cemented carbide production	electricity, high voltage, production mix | electricity, high voltage | Cutoff, U [CN-JX]
Explosive	market for explosive, tovex | explosive, tovex | Cutoff, U [GLO]
Freshwater	market group for tap water | tap water | Cutoff, U [GLO]
Heptane	market for heptane | heptane | Cutoff, U [GLO]
Hexane	market for hexane | hexane | Cutoff, U [GLO]
Hydrochloric acid (HCl)	market for hydrochloric acid, without water, in 30% solution state | hydrochloric acid, without water, in 30% solution state | Cutoff, U [RoW]
Hydrogen peroxide (H_2O_2)	market for hydrogen peroxide, without water, in 50% solution state | hydrogen peroxide, without water, in 50% solution state | Cutoff, U [RoW]
Iron	market for pig iron | pig iron | Cutoff, U [GLO]
Kerosene	market for kerosene | kerosene | Cutoff, U [RoW]
Liquid ammonia	market for ammonia, liquid | ammonia, liquid | Cutoff, U [RoW]
Nitrogen	market for nitrogen, liquid | nitrogen, liquid | Cutoff, U [RoW]

Parameter	Ecoinvent dataset	
Input		
Paraffin	market for paraffin | paraffin | Cutoff, U [GLO]	
Potassium hydroxide*	market for potassium hydroxide | potassium hydroxide | Cutoff, U [GLO]	
Pure water	market group for tap water | tap water | Cutoff, U [GLO]	
Sodium fluorosilicate	market for sodium silicate, solid | sodium silicate, solid | Cutoff, U [Row]	
Sodium hydroxide (NaOH)	market for sodium hydroxide, without water, in 50% solution state | sodium hydroxide, without water, in 50% solution state | Cutoff, U [GLO]	
Sodium silicate	market for sodium silicate, solid | sodium silicate, solid | Cutoff, U [RoW]	
Steel	market for steel, unalloyed | steel, unalloyed | Cutoff, U [GLO]	
Sulfuric acid (H_2SO_4)	market for sulfuric acid | sulfuric acid | Cutoff, U [RoW]	
Tap water	market group for tap water | tap water | Cutoff, U [GLO]	
Water	market group for tap water | tap water | Cutoff, U [GLO]	
Wood	market for wood chips, wet, measured as dry mass | wood chips, wet, measured as dry mass | Cutoff, U [RoW]	
2# oil	market for heavy fuel oil | heavy fuel oil | Cutoff, U [RoW]	
Output		
Treatment of liquid aqueous waste	market for wastewater, average | wastewater, average | Cutoff, U [RoW]	
Treatment of solid waste (landfill)	market for process-specific burdens, inert material landfill | process-specific burdens, inert material landfill | Cutoff, U [RoW]	
Data from other sources		
Parameter	**Comment**	**Reference**
Input		
Xanthate	LCI data provided by the reference. Ecoinvent database version 3.5 (2018) applied for LCIA.	Kunene (2014)

4. Life cycle impact assessment results

4.1. Synthetic diamond grit production

Table S12. Summary of life cycle impact assessment results for high-pressure high-temperature (HPHT) synthesis of 1 g diamond grit in the current, solar, full recycling and the solar-full recycling scenarios. The main contributors to the impact categories are also presented. Values are presented with two significant figures. WC-8Co=cemented carbide with 8 weight-% cobalt.

Impact category	Value	Main contributors
Current scenario		
Climate change [kg CO_2 eq]	0.92	92% Chinese WC-8Co production
Terrestrial acidification [kg SO_2 eq]	0.0082	61% market for nickel (mainly platinum group metal mine operation and nickel mine operation), 37% Chinese WC-8Co production
Freshwater eutrophication [kg P eq]	0.00028	74% Chinese WC-8Co production, 23% market for nickel (mainly from treatment of sulfidic tailings)
Cumulative energy demand [MJ eq]	10	81% fossil resources in Chinese WC-8Co production
Mineral resource scarcity [kg Cu eq]	0.12	94% Chinese WC-8Co production (mainly tungsten in ground)
Abiotic depletion potential [kg Sb eq]	0.0033	100% Chinese WC-8Co production (mainly tungsten in ground)
Solar scenario		
Climate change [kg CO_2 eq]	0.86	97% Chinese WC-8Co production
Terrestrial acidification [kg SO_2 eq]	0.0081	62% market for nickel (mainly platinum group metal mine operation and nickel mine operation), 38% Chinese WC-8Co production
Freshwater eutrophication [kg P eq]	0.00027	76% Chinese WC-8Co production, 23% market for nickel (mainly from treatment of sulfidic tailings)
Cumulative energy demand [MJ eq]	9.7	83% fossil resources in Chinese WC-8Co production
Mineral resource scarcity [kg Cu eq]	0.12	94% Chinese WC-8Co production (mainly tungsten in ground)
Abiotic depletion potential [kg Sb eq]	0.0033	100% Chinese WC-8Co production (mainly tungsten in ground)
Full recycling scenario		
Climate change [kg CO_2 eq]	0.40	81% Chinese WC-8Co production
Terrestrial acidification [kg SO_2 eq]	0.0063	80% market for nickel (mainly platinum group metal mine operation and nickel mine operation), 18% Chinese WC-8Co production
Freshwater eutrophication [kg P eq]	0.00014	47% Chinese WC-8Co production, 46% market for nickel (mainly from treatment of sulfidic tailings)
Cumulative energy demand [MJ eq]	4.2	71% fossil resources in Chinese WC-8Co production
Mineral resource scarcity [kg Cu eq]	0.016	58% Chinese WC-8Co production (mainly tungsten in ground), 42% market for nickel
Abiotic depletion potential [kg Sb eq]	0.00031	96% Chinese WC-8Co production (mainly tungsten in ground)
Solar-full recycling scenario		
Climate change [kg CO_2 eq]	0.35	93% Chinese WC-8Co production
Terrestrial acidification [kg SO_2 eq]	0.0061	81% market for nickel (mainly platinum group metal mine operation and nickel mine operation), 18% Chinese WC-8Co production
Freshwater eutrophication [kg P eq]	0.00013	49% Chinese WC-8Co production, 48% market for nickel (mainly treatment of sulfidic tailings)
Cumulative energy demand [MJ eq]	3.9	77% fossil resources in Chinese WC-8Co production
Mineral resource scarcity [kg Cu eq]	0.016	57% Chinese WC-8Co production (mainly tungsten in ground), 42% market for nickel
Abiotic depletion potential [kg Sb eq]	0.00032	96% Chinese WC-8Co production (mainly tungsten in ground)

4.2. Comparison between polycrystalline diamond and cemented carbide tools

Table S13. Summary of life cycle impact assessment results for one polycrystalline diamond (PCD) tool with four tips (3.5 g PCD) in the current, solar, full recycling and the solar-full recycling scenarios. The main contributors to the impact categories are also presented. Values are presented with two significant figures. WC-8Co=cemented carbide with 8 weight-% cobalt and WC-13Co=cemented carbide with 13 weight-% cobalt.

Impact category	Value	Main contributors
Current scenario		
Climate change [kg CO_2 eq]	5.4	78% market for electricity in PCD production
Terrestrial acidification [kg SO_2 eq]	0.037	58% market for electricity in PCD production, 12% market for nickel used in HPHT synthesis of synthetic diamond grit
Freshwater eutrophication [kg P eq]	0.013	56% market for molybdenum (mainly from treatment of sulfidic tailings) and 36% market for electricity in PCD production
Cumulative energy demand [MJ eq]	120	39% market for electricity (fossil resources) and 34% market for electricity (nuclear resources) in PCD production
Mineral resource scarcity [kg Cu eq]	0.33	31% market for molybdenum, 29% primary Chinese WC-8Co production (mainly tungsten in ground), 19% primary non-Chinese WC-Co production (mainly tungsten in ground)
Abiotic depletion potential [kg Sb eq]	0.0069	42% primary Chinese WC-8Co production (mainly tungsten in ground), 28% primary non-Chinese WC-Co production (mainly tungsten in ground), 24% primary non-Chinese WC-13Co (mainly tungsten in ground)
Solar scenario		
Climate change [kg CO_2 eq]	1.9	38% photovoltaic electricity production for PCD production, 34% primary Chinese WC-8Co production
Terrestrial acidification [kg SO_2 eq]	0.019	23% market for nickel used in HPHT synthesis of synthetic diamond grit, 20% photovoltaic electricity production for PCD production
Freshwater eutrophication [kg P eq]	0.0088	81% market for molybdenum (mainly from treatment of sulfidic tailings) and 8% photovoltaic electricity production for PCD production
Cumulative energy demand [MJ eq]	67	57% photovoltaic electricity production (wind, solar and geothermal resources) and 13% photovoltaic electricity production (fossil resources) for PCD production
Mineral resource scarcity [kg Cu eq]	0.33	31% market for molybdenum, 29% primary Chinese WC-8Co production (mainly tungsten in ground), 19% primary non-Chinese WC-Co production (mainly tungsten in ground)
Abiotic depletion potential [kg Sb eq]	0.0071	41% primary Chinese WC-8Co production (mainly tungsten in ground), 27% primary non-Chinese WC-Co production (mainly tungsten in ground), 24% primary non-Chinese WC-13Co (mainly tungsten in ground)

Impact category	Value	Main contributors
Full recycling scenario		
Climate change [kg CO_2 eq]	4.8	88% market for electricity in PCD production
Terrestrial acidification [kg SO_2 eq]	0.030	72% market for electricity in PCD production, 15% market for nickel used in HPHT synthesis of synthetic diamond grit
Freshwater eutrophication [kg P eq]	0.012	60% market for molybdenum (mainly from treatment of sulfidic tailings) and 39% market for electricity in PCD production
Cumulative energy demand [MJ eq]	110	43% market for electricity (fossil resources) and 37% market for electricity (nuclear resources) in PCD production
Mineral resource scarcity [kg Cu eq]	0.13	78% market for molybdenum
Abiotic depletion potential [kg Sb eq]	0.00091	28% market for molybdenum, 27% primary Chinese WC-8Co production (mainly tungsten in ground), 18% primary non-Chinese WC-Co production (mainly tungsten in ground)
Solar-full recycling scenario		
Climate change [kg CO_2 eq]	1.3	57% photovoltaic electricity production for PCD production, 18% recycled Chinese WC-8Co production for HPHT synthesis of synthetic diamond grit
Terrestrial acidification [kg SO_2 eq]	0.012	37% market for nickel used in HPHT synthesis of synthetic diamond grit, 32% photovoltaic electricity production for PCD production
Freshwater eutrophication [kg P eq]	0.0080	89% market for molybdenum (mainly from treatment of sulfidic tailings) and 9% photovoltaic electricity production for PCD production
Cumulative energy demand [MJ eq]	58	66% photovoltaic electricity production (wind, solar and geothermal resources) and 14% photovoltaic electricity production (fossil resources) in PCD production
Mineral resource scarcity [kg Cu eq]	0.14	76% market for molybdenum
Abiotic depletion potential [kg Sb eq]	0.0011	23% market for molybdenum, 23% photovoltaic electricity production and 21% primary Chinese WC-8Co production

Table S14. Summary of life cycle impact assessment results for one cemented carbide (WC-Co) tool with four tips (4.7g WC-Co) in the current, solar, full recycling and the solar-full recycling scenarios. The main contributors to the impact categories are also presented. Values are presented with two significant figures. WC-8Co=cemented carbide with 8 weight-% cobalt.

Impact category	Value	Main contributors
Current scenario		
Climate change [kg CO_2 eq]	0.070	24% market for electricity and 20% tannin production in primary non-Chinese WC-8Co production, 11% market for electricity in recycled non-Chinese WC-8Co production
Terrestrial acidification [kg SO_2 eq]	0.0016	98% non-Chinese WC-8Co production (mainly direct emissions to air of ammonia)
Freshwater eutrophication [kg P eq]	0.00020	89% market for sulfidic tailings in primary non-Chinese WC-8Co production
Cumulative energy demand [MJ eq]	1.8	17% market for electricity (nuclear resources), 14% market for electricity and 14% market for kerosene (fossil resources) in primary non-Chinese WC-8Co production
Mineral resource scarcity [kg Cu eq]	0.030	93% tungsten resources and 6.7% market for cobalt in primary non-Chinese WC-8Co production
Abiotic depletion potential [kg Sb eq]	0.00092	98% tungsten resources and 0.85% market for cobalt in primary non-Chinese WC-8Co production
Solar scenario		
Climate change [kg CO_2 eq]	0.049	28% tannin production, 12% market for sodium carbonate and 11% market for diesel burned in building machine in primary non-Chinese WC-8Co production
Terrestrial acidification [kg SO_2 eq]	0.0015	99% non-Chinese WC-8Co production (mainly direct emissions to air of ammonia)
Freshwater eutrophication [kg P eq]	0.00020	89% market for sulfidic tailings in primary non-Chinese WC-8Co production
Cumulative energy demand [MJ eq]	1.3	19% photovoltaic electricity production (wind, solar and geothermal resources), 18% market for kerosene and 12% tannin production (fossil resources) in primary non-Chinese WC-8Co production
Mineral resource scarcity [kg Cu eq]	0.030	93% tungsten resources and 6.7% market for cobalt in primary non-Chinese WC-8Co production
Abiotic depletion potential [kg Sb eq]	0.00092	98% tungsten resources and 0.85% market for cobalt in primary non-Chinese WC-8Co production

Impact category	Value	Main contributors
Full recycling scenario		
Climate change [kg CO_2 eq]	0.024	77% market for electricity in recycled non-Chinese WC-8Co production, 6% market for electricity and 5% tannin production in primary non-Chinese WC-8Co production
Terrestrial acidification [kg SO_2 eq]	0.00020	66% non-Chinese WC-8Co production (mainly direct emissions to air of ammonia), 33% market for electricity in recycled non-Chinese WC-8Co production
Freshwater eutrophication [kg P eq]	2.1E-05	70% market for sulfidic tailings in primary non-Chinese WC-8Co production, 21% market for electricity in recycled non-Chinese WC-8Co production
Cumulative energy demand [MJ eq]	0.81	40% market for electricity (nuclear resources) and 34% market for electricity (fossil resources) in recycled non-Chinese WC-8Co production
Mineral resource scarcity [kg Cu eq]	0.0025	92% tungsten resources and 6.6% market for cobalt in primary non-Chinese WC-8Co production
Abiotic depletion potential [kg Sb eq]	8.3E-05	91% tungsten resources in primary non-Chinese WC-8Co production, 8% market for zinc in recycled non-Chinese WC-8Co production
Solar-full recycling scenario		
Climate change [kg CO_2 eq]	0.0088	50% market for electricity in recycled non-Chinese WC-8Co production, 13% tannin production and 6% market for sodium carbonate in primary non-Chinese WC-8Co production
Terrestrial acidification [kg SO_2 eq]	0.00015	83% non-Chinese WC-8Co production (mainly direct emissions to air of ammonia), 15% photovoltaic electricity production in recycled non-Chinese WC-8Co production
Freshwater eutrophication [kg P eq]	2.1E-05	70% market for sulfidic tailings in primary non-Chinese WC-8Co production, 21% photovoltaic electricity production in recycled non-Chinese WC-8Co production
Cumulative energy demand [MJ eq]	0.43	56% photovoltaic electricity production (wind, solar and geothermal resources) and 12% photovoltaic electricity production (fossil resources) in recycled non-Chinese WC-8Co production
Mineral resource scarcity [kg Cu eq]	0.0025	91% tungsten resources and 6.5% market for cobalt in primary non-Chinese WC-8Co production
Abiotic depletion potential [kg Sb eq]	8.4E-05	89% tungsten resources in primary non-Chinese WC-8Co, 8% market for zinc in recycled non-Chinese WC-8Co production

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