DATA QUALITY ASSESSMENT FRAMEWORK FOR CRITICAL RAW MATERIALS
THE CASE OF COBALT

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SUPPLEMENTARY INFORMATION
1. Applications

The description given in this section is specific for the applications studied in the research.

Portable batteries

Portable batteries are defined as sealed batteries that can be carried by hand, excluding industrial and vehicle batteries (European Commission, 2006). Cobalt is found in lithium-ion (Li-ion), nickel-cadmium (NiCd) and nickel-metal hydride (NiMH) batteries, being Li-ion batteries the most commonly used (Cobalt Institute, 2018). Li-ion batteries based on lithium cobalt oxide (LiCoO₂, LCO) present the higher amount of cobalt (approximately 14%), while in NiCd, NiMH and in Li-ion batteries based on lithium nickel manganese cobalt oxide (NMC) and lithium nickel cobalt aluminum oxide (NCA), the metal is present only in minor amounts (Sommer et al., 2015). The three type of batteries are rechargeable, and can be found in mobile phones, laptops, tablets, cameras, cutting tools, and other household products.

In 2017, around 23% of the global consumption of Co was in portable batteries (Darton Commodities Limited, 2018).

Mobility batteries

Mobility batteries are found in electric vehicles and hybrid electric vehicles (xEV), electric trains, electric buses, and electric bikes (Cobalt Institute, 2018). The battery stores electrical energy that the electric motor uses to power the vehicle (European Environment Agency, 2016). Batteries containing cobalt used in these devices are NMC, NCA, and NiHM batteries (Al-Thyabat et al., 2013; Darton Commodities Limited, 2018).

In 2017, 29% of the global consumption of Co was in mobility batteries. Around 1% was used in ESS (energy storage systems) (Darton Commodities Limited, 2018).

Hydroprocessing catalyst

Hydroprocessing catalysts are used to produce clean fuels and other usable oil feedstocks and products, upgrading oil fraction through the removal of impurities such as sulphur and nitrogen. By adding hydrogen, they also improve the properties and performance of the products (Darton Commodities Limited, 2018). The activity of the catalyst decreases in time, and when it drops below an economically determined level, the catalyst is removed from the reactor. The three main reasons for the loss of activity are coke deposition, poisoning, and sintering of the active phase. Depending on the type of deactivation, the catalyst can be regenerated, recycled, or sent out for disposal (Dufresne, 2007).

In 2017, 3% of the global consumption of Co was in hydroprocessing catalysts (Darton Commodities Limited, 2018).

Hydroformylation and GTL process catalysts

Cobalt catalysts are used in the production of different hydrocarbons, through the hydroformylation reaction and the gas to liquid (GTL) process. In hydroformylation, an alkene reacts with CO and H₂ to produce aldehydes, which are then used in the production of alcohols (used in detergents and plasticizers), and carboxylic acids (used in pharmaceuticals) (De et al., 2013). The GTL process is commonly performed using Fischer–Tropsch synthesis (FTS), where syngas (CO and H₂) react to produce liquid hydrocarbons, which are further processed into liquid fuels (e.g. gasoline, jet fuel, and diesel) (Dry, 1999).

Hydroformylation uses homogeneous catalysts (same phase as the reactants), while FTS involves heterogeneous catalysts (different phase from the reactants) (De et al., 2013; Jahangiri et al., 2014). In hydroformylation, the catalyst is recycled to the process. However, it tends to build-up on the walls of the reactor and on the tower packing, which makes it necessary to periodically remove it and send it to recycling (National Research Council, 1983; Hebrard and Kalck 2009). In FTS, the catalyst can be regenerated to be used in the same process or recycled for metal recovery (Brumby et al., 2005; Jahangiri et al., 2014).
In 2017, 0.5% of the global consumption of Co was in hydroformylation and GTL process catalysts (Darton Commodities Limited, 2018).

**PET precursor catalyst**

Cobalt-manganese-bromide (CMB) and cobalt-manganese-acetate (CMA) are liquid catalysts used for the oxidation of para-xylene (PX), in the synthesis of terephthalic acid (TPA) and di-methyl terephthalate (DMT). These compounds are raw materials in the production of polyester fibres articles, such as polyethylene terephthalate (PET) bottles, films, and paints (Joo et al., 2016; Darton Commodities Limited, 2018). CMB and CMA are homogeneous catalysts, which are recycled to the process. (National Research Council, 1983; Joo et al., 2016).

In 2017, 2.6% of the global consumption of Co was in PET precursors catalysts (Darton Commodities Limited, 2018).

**Dissipative uses**

Dissipative uses include applications of cobalt chemicals, from which the metal is not recovered. This category comprises pigments and drying agents; and agricultural, nutritional, and medical uses. Pigments and drying agents are applied in glasses, ceramics, refractories, driers, paints, and varnishes. In agriculture and nutrition, chemicals are used to correct cobalt deficiencies in soils and in animals. Medical uses includes the treatment of certain types of anemia, and as an antidote in cyanide poisoning (Donaldson and Beyersmann, 2012).

In 2017, around 8% of the global consumption of Co was in dissipative uses (Darton Commodities Limited, 2018).

**Hard metals**

Hard metals or cemented carbides are composite materials consisting of hard tungsten carbide (WC) particles bonded together by a metallic binder. This metallic binder is usually Co, although it can also be Fe, Ni, and other metallic phases (Freemantle et al., 2014; Cobalt Institute, 2018). Its uses comprises cutting tools and wear-resistant components in metalworking, mining, oil drilling, and construction industries. Cobalt is also used in diamond tools, applied as a binding agent to hold together wear-resistant particles (in this case diamonds) (Shedd, 2004).

The two main methods for the recycling of hard metals are chemical processes and the zinc process (Shedd, 2004). The former considers the use of acids, electrochemistry or chemical modification techniques (Freemantle et al., 2014); the latter consists of the addition of Zn, which dissolves the binder phase of the cemented carbide without changing the composition of the material. Chemical processes produce material equivalent to virgin material, contrary to the Zn process that produces material to be used in the production of new hard metals (Kurylak et al., 2016).

In 2017, 7% of the global consumption of Co was in hard metals (Darton Commodities Limited, 2018).

**Magnets**

Cobalt is mainly found in permanent magnets, which are magnets with high coercivity that can be permanently magnetised by applying a magnetic field (Cobalt Institute, 2018). There are three type of permanent magnets composed by cobalt: AlNiCo (aluminium- nickel-cobalt), SmCo (samarium-cobalt), and NdFeB (neodymium-iron-boron) magnets. Cobalt is mainly found in SmCo magnets (50-60%), followed by AlNiCo magnets (3-36%) and NdFeB magnets (1-5%) (Donaldson and Beyersmann, 2012; Sinha et al., 2017; Cobalt Institute, 2018). Permanent magnets are applied in automotive (traditional, hybrid, and electric), computer and consumer electronics, wind turbines, HVAC (heating, ventilating and air conditioning), and industrial motors (Benecki, 2017).

In 2017, 3% of the global consumption of Co was in magnets (Darton Commodities Limited, 2018).
Other metallic uses

This category includes semi-conductors and integrated circuits, tool steels, and hardfacing and coatings. Semi-conductors and integrated circuits are contained in all modern electronic devices or systems (e.g. televisions, laptops, cameras, cell phones) (Cobalt Institute, 2018). Tools steel are used to work, cut and form metal components, for which they require high hardness and strength (International Molybdenum Association, 2018). Hardfacing and coating is the process where harder material is put onto to a base metal. It is used to increase the wear resistance of metallic components, or to refurbish a surface that is worn-down on used parts (A&A Coatings, 2018).

In 2017, around 7% of the global consumption of Co was in other metallic uses (Darton Commodities Limited, 2018).

Superalloys

Superalloys are Ni, Fe-Ni, or Co based alloys, usually used at temperatures above 540 ºC (Donachie and Donachie 2002). High melting temperatures, and excellent creep, corrosion, and oxidation resistance characterize this type of material (Srivastava et al., 2014). Due to these properties, superalloys are used in a number of applications such as aircraft, rocket, and gas turbine engines; heat exchanger tubing; and nuclear reactors. Superalloys scrap is partly recycled for Co recovery; the rest is downcycled for steel production (Reck and Graedel, 2012).

In 2017, 16% of the global consumption of Co was in superalloys (Darton Commodities Limited, 2018).

2. Parameters definition

Processing/manufacturing yield

Ratio of usable output from the processing/manufacturing process to the input quantity, expressed as a percentage.

Processing/manufacturing scrap recovery

Ratio of the processing/manufacturing scrap that is recycled to the process to the total scrap produced, express as a percentage.

Processing/manufacturing downcycled scrap

Ratio of the processing/manufacturing scrap that is downcycled (for the production of low-end applications, such as steel) to the total scrap produced, express as a percentage.

Lifetime

Different definitions can be given to lifetime (or lifespan) of a product (National Institute for Environmental Studies, 2018):

Total lifetime: period where the product exists in the society in its original form (regardless of whether the product still functions or not).

Service lifetime: period where the product functions and can be put to use, including the duration of distribution for the next use. Service lifetime differs from total lifetime in that it excludes collection span of discarded products (for recycling or disposal).

Other lifetime-related periods are:

Possession span: denotes how long one owner possesses the product in question.

Duration in use: denotes how long one owner uses the product in question. Duration in use differs from possession span in that it excludes hoarding periods.

Product age: denotes the period from the beginning of life of product to the time of interest.
Shape parameter (Weibull distribution)

The Weibull distribution is a continuous probability distribution, commonly used to assess product reliability and survival analysis, analyse life data, and model failure times. The function is characterised by three parameters: the scale parameter (normally denoted as α), the shape parameter (normally denoted as β), and the location parameter (normally denoted as τ). When τ is zero the function becomes the two-parameter distribution. The shape parameter determines the appearance or shape of the distribution (Lai et al., 2006).

Hoarding rate

Hoarding or hibernation refers to the dead storage of a product that is no longer in use anymore (Wilson et al., 2017). Here is understood as the hoarding of end-of-service (EoS) products.

This parameter is understood as the ratio of hoarded EoS products to the total EoS products produced in a year, expressed as a percentage.

Hoarding time

Hoarding time refers to the period in which the EoS product is hoarded. It is understood as the time between the EoS of the product until its collection (for recycling or disposal).

Non-selective collection rate

Non-selective collection rate is related to the misplacement of EoL products in waste bins.

This parameter is understood as the ratio of not-selectively collected EoL products to the total EoL products produced in a year, expressed as a percentage.

Collection rate

Waste collection is defined as “collection of solid waste from point of production (residential, industrial commercial, institutional) to the point of treatment or disposal” (Hoornweg and Bhada-Tata, 2012). However, the UNEP defined collection rate as the ratio of EoL products collected for recycling to the total EoL products produced in a defined period (UNEP, 2011). In the case of WEEE, the EU defined it as “the volumes collected divided by the average sum of EEE (electrical and electronic equipment) put on the market in the previous three years” (European Parliament, 2006).

In the research, collection rate is understood as the ratio of EoL products collected for recycling to the total EoL products produced in a year, expressed as a percentage.

It is noteworthy to distinguish between collection rate and recycling rate. The EU and the UNEP define the latter as the collection rate multiplied by the rate of recycling at the treatment facilities, assuming that the total amount of collected WEEE is indeed sent to treatment/recycling facilities (European Parliament, 2006; UNEP, 2011).

Pre-treatment efficiency

Pre-treatment covers several operations such as separation, sorting, physical processes, and chemical processes.

In the research this parameters is understood as the ratio of usable output from any pre-treatment operation (or a set of them) to the input quantity, expressed as a percentage.

Distribution to recycling processes

Waste and scrap can be recycled through different processes. This parameter refers to the distribution of waste or scrap to the different processes (how much of the total waste is recycled by one or another process), expressed as a percentage.

Recycling efficiency

Ratio of usable output from the recycling processes to the input quantity, expressed as a percentage.
3. DQA methods description

In 1996, Weidema and Wesnæs proposed a DQA method called Pedigree-matrix, which consisted of five independent DQIs: Reliability, Completeness, Temporal correlation, Geographical correlation, and Further technological correlation (hereafter referred to as Technological correlation). The indicator Reliability was related to the assessment of the sampling methods and verification procedures. The indicator Completeness defined how complete the available datum was in function of its statistical representativeness, the number of measurements in the sample, and the time periods for data collection. The indicators Temporal and Geographical correlation described the representativeness of the datum regarding its year of generation and the intended geographical area, respectively. The indicator Technological correlation evaluated the congruence of the available data and the targeted data with respect to technology, product, etc. In the matrix, each indicator was described by a score from 1 to 5, with 1 for the highest quality and 5 for the lowest quality. This matrix was established to be used in data quality management for life cycle inventories (LCI).

Manfredi et al. (2012), and Edelen and Ingwersen (2016) established their own modified Pedigree-matrix, to be applied likewise on LCI. Manfredi and colleagues established six DQIs: Completeness, Methodological appropriateness and consistency, Time representativeness, Technological representativeness, Geographical representativeness, and Parameter uncertainty. Edelen and Ingwersen defined DQIs at flow level (making a distinction between reliability and representativeness) and at process level. At flow level five DQIs were given: Reliability, Temporal correlation, Geographical correlation, Technological correlation, and Data collection methods. The latter four were linked to representativeness. For processes, two DQIs were defined: process review and process completeness.

Laner et al. (2015) based their work on the Pedigree-matrix, applying the same five indicators, although modifying their definition to be applicable to MFA studies. Furthermore, an additional DQI was added, termed Expert estimate. This indicator was used alone, as a replacement of the other five. In this work, the DQIs were described by a score from 1 to 4, with 1 for the highest quality and 4 for the lowest quality.

Table A1 present a summary of the comparison between the four described methods.

| Method | Application | Scoring | Reliability | Representativeness | Other |
|--------|-------------|---------|--------------|-------------------|-------|
| Weidema and Wesnæs (1996) | LCA | 1 to 5 | Reliability | Temporal correlation | Completeness |
| | | | | Geographical correlation | |
| | | | | Further technological correlation | |
| Manfredi et al. (2012) | LCA | 1 to 5 | - | Time-related representativeness | |
| | | | | Geographical representativeness | |
| | | | | Technological representativeness | |
| | | | | Completeness | Methodological appropriateness and consistency |
| | | | | Precision/uncertainty | |
| Laner et al. (2015) | LCA | 1 to 4 | Reliability Expert estimate | Temporal correlation | Completeness |
| | | | | Geographical correlation | |
| | | | | Other correlation | |
| Edelen and Ingwersen (2016) | MFA | 1 to 5 | Flow reliability Process review | Temporal correlation | Process completeness |
| | | | | Geographical correlation | |
| | | | | Technological correlation | |
| | | | | Data collection methods | |

a: Flow indicators. b: Process indicators.
## 4. Full dataset

Table A2. Full dataset of the application portable batteries. It includes the DQA results in terms of $R_l$ (reliability), $R_e$ (representativeness) and DQR (data quality rating).

| Parameter                        | Data country/region | Data year | Value | Unit | $R_l$ | $R_e$ | DQR | Reference                                                                 |
|----------------------------------|--------------------|-----------|-------|------|-------|-------|-----|---------------------------------------------------------------------------|
| Life time                        | Global             | 2001      | 1-3   | years | 4.0   | 2.7   | 3.2 | Contestabile et al. (2001)                                               |
| Life time                        | EU 25              | 2006      | 5     | years | 2.5   | 2.0   | 2.2 | EuroP 2007                                                                |
| Life time                        | EU                 | 2015      | 6.2   | years | 2.5   | 1.0   | 1.6 | Desmet and Colin (2017)                                                  |
| Life time                        | South Africa       | 2015      | 3-5   | years | 4.0   | 1.7   | 2.6 | Knights and Saloojee (2015)                                               |
| Life time                        | Germany            | 2012      | 6.6   | years | 4.0   | 2.0   | 2.8 | Buchert et al. (2012)                                                     |
| Life time                        | Not available      | 2017      | 2-4   | years | 4.0   | 2.0   | 2.8 | Kumar and Suman (2017)                                                    |
| Life time                        | EU                 | 2006      | 2.7   | years | 4.0   | 2.3   | 3.0 | Müller and Friedrich (2006)                                               |
| Life time                        | Not available      | 2002      | 2.7   | years | 4.0   | 3.0   | 3.2 | Heegn et al. (2003)                                                       |
| Life time                        | EU                 | 2015      | 7.1   | years | 2.5   | 1.7   | 2.0 | Desmet and Colin (2017)                                                  |
| Life time                        | Japan              | 2003      | 4.3   | years | 3.0   | 2.7   | 2.8 | Oguchi et al. (2006)                                                      |
| Life time                        | EU5                | 2015      | 1.7   | years | 4.0   | 1.3   | 2.4 | Kantar WorldPanel (2016)                                                  |
| Life time                        | USA and others     | 2005      | 2.5   | years | 4.0   | 2.3   | 3.0 | Harper et al. (2011)                                                      |
| Life time                        | Japan              | 2012      | 7.4   | years | 3.0   | 2.0   | 2.4 | Nomura and Suga (2013)                                                    |
| Life time                        | Japan              | 2012      | 10.2  | years | 3.0   | 2.0   | 2.4 | Nomura and Suga (2013)                                                    |
| Life time                        | EU                 | 2018      | >10   | years | 4.0   | 1.0   | 1.8 | EBRA (2018)                                                               |
| Shape parameter                  | Japan              | 2003      | 3.1   | -    | 3.0   | 2.7   | 2.8 | Oguchi et al. (2006)                                                      |
| Shape parameter                  | Japan              | 2012      | 2.57  | -    | 3.0   | 2.0   | 2.4 | Nomura and Suga (2013)                                                    |
| Hoarding rate                    | Japan              | 2010      | 54.5  | % (w) | 3.0   | 1.7   | 2.2 | Asari and Sakai (2013)                                                    |
| Hoarding rate                    | EU                 | 2006      | 65    | %     | 4.0   | 2.3   | 3.0 | Müller and Friedrich (2006)                                               |
| Hoarding rate                    | EU                 | 2012      | 50    | % (w) | 4.0   | 1.3   | 2.0 | BIO by Deloitte (2015)                                                    |
| Hoarding time                    | EU                 | 2012      | 3.5   | years | 3.0   | 1.3   | 1.8 | BIO by Deloitte (2015)                                                    |
| Hoarding time                    | EU                 | 2006      | 2.4   | years | 4.0   | 2.7   | 3.2 | Müller and Friedrich (2006)                                               |
| Non-selective collection rate    | EU 28 + Switzerland and Norway | 2015 | 18.5 | % (w) | 2.5   | 2.0   | 2.2 | Huisman et al. (2017)                                                     |
| Non-selective collection rate    | EU 28 + Switzerland and Norway | 2015 | 2.3 | % (w) | 2.5   | 2.0   | 2.2 | Huisman et al. (2017)                                                     |
| Non-selective collection rate    | Global             | 2017      | 19-29 | % (w) | 2.5   | 2.0   | 2.2 | thinkstep AG (2017)                                                       |
| Collection rate                  | EU                 | 2007      | 2.7   | %     | 4.0   | 1.7   | 2.6 | Weyhe (2008)                                                              |
| Collection rate                  | EU                 | 2007      | 9     | %     | 4.0   | 2.0   | 2.8 | Weyhe (2008)                                                              |
| Collection rate                  | EU 28 + Switzerland and Norway | 2015 | 13 | % (w) | 2.5   | 1.3   | 1.8 | Huisman et al. (2017)                                                     |
| Collection rate                  | EU 28 + Switzerland and Norway | 2015 | 6.5 | % (w) | 2.5   | 1.3   | 1.8 | Huisman et al. (2017)                                                     |
| Collection rate                  | EU                 | 2016      | 5     | %     | 3.5   | 1.0   | 2.0 | Darton Commodities Limited (2018)                                         |
| Collection rate                  | EU                 | 2014      | 10    | %     | 4.0   | 1.0   | 2.2 | Circular Energy Storage (2018)                                            |
| Collection rate                  | Japan              | 2010      | 9     | % (w) | 3.0   | 1.7   | 2.2 | Asari and Sakai (2013)                                                    |
| Collection rate                  | Germany            | 2011      | 17    | % (w) | 3.0   | 2.0   | 2.4 | Sommer et al. (2015)                                                     |
| Collection rate                  | Germany            | 2012      | 50    | % (w) | 4.0   | 2.0   | 2.8 | Buchert et al. (2012)                                                     |
| Collection rate                  | Germany            | 2012      | 5     | % (w) | 4.0   | 2.0   | 2.8 | Buchert et al. (2012)                                                     |
| Collection rate                  | USA                | 2005      | 10    | %     | 3.5   | 2.0   | 2.6 | Willburn (2008)                                                           |
| Collection rate                  | Japan              | 2005      | 30    | % (w) | 4.0   | 2.0   | 2.5 | Harper et al. (2011)                                                      |
| Collection rate                  | Europe             | 2017      | 45    | % (w) | 2.5   | 1.3   | 1.8 | thinkstep AG (2017)                                                       |
| Collection rate                  | EU                 | 2012      | 64    | % (w) | 2.5   | 1.7   | 2.0 | BIO by Deloitte (2015)                                                    |
| Pre-treatment efficiency         | Belgium            | 2013      | 98    | %     | 3.5   | 2.7   | 3.0 | Tran et al. (2017)                                                        |
| Pre-treatment efficiency         | Germany            | 2011      | 95    | % (w) | 3.0   | 2.0   | 2.4 | Sommer et al. (2015)                                                     |
| Pre-treatment efficiency         | Germany            | 2012      | 80    | % (w) | 4.0   | 2.0   | 2.5 | Buchert et al. (2012)                                                     |
| Pre-treatment efficiency         | EU                 | 2018      | 97-98 | % (w) | 3.0   | 2.0   | 2.3 | Saubermacher AG (2018)                                                    |
| Recycling efficiency             | Germany            | 2011      | 90    | % (w) | 3.0   | 2.0   | 2.4 | Sommer et al. (2015)                                                     |
| Recycling efficiency             | Germany            | 2012      | 96    | % (w) | 4.0   | 2.0   | 2.5 | Buchert et al. (2012)                                                     |
| Recycling efficiency             | India              | 2017      | 95    | % (w) | 4.0   | 1.7   | 2.6 | Kumar and Suman (2017)                                                    |
Table A3. Full dataset of the application mobility batteries. It includes the DQA results in terms of $R_c$ (reliability), $R_p$ (representativeness) and DQR (data quality rating).

| Parameter                  | Data country/region | Data year | Value | Unit | $R_c$ | $R_p$ | DQR | Reference                                |
|----------------------------|---------------------|-----------|-------|------|-------|-------|-----|------------------------------------------|
| Processing yield           | USA                 | 2017      | 85    | %    | 4.0   | 1.3   | 2.4 | Dai et al. (2017)                        |
| Life time                  | USA                 | 2011      | 10    | years | 4.0   | 2.0   | 2.8 | Environmental Protection Agency (2013)   |
| Life time                  | USA and others      | 2005      | 8     | years | 4.0   | 2.3   | 3.0 | Harper et al. (2011)                     |
| Life time                  | EU                  | 2014      | 10    | years | 3.0   | 1.0   | 1.8 | EUROBAT (2014)                          |
| Life time                  | Global              | 2015      | 8     | years | 3.0   | 1.7   | 2.0 | Ahmadi et al. (2017)                     |
| Life time                  | Global              | 2010      | 10    | years | 4.0   | 2.0   | 2.5 | Ziemann et al. (2018)                    |
| Life time                  | Global              | 2014      | 10    | years | 4.0   | 2.0   | 2.5 | Habib and Wenzel (2014)                  |
| Life time                  | Global              | 2016      | 8-10  | years | 4.0   | 1.7   | 2.6 | Jiao and Evans (2018)                    |
| Hoarding rate              | EU                  | 2012      | 0     | % (w) | 4.0   | 1.3   | 2.0 | BIO by Deloitte (2015)                   |
| Collection rate            | EU                  | 2012      | 100   | % (w) | 4.0   | 1.3   | 2.0 | BIO by Deloitte (2015)                   |
| Collection rate            | Global              | 2005      | 90    | % (w) | 4.0   | 2.7   | 3.0 | Harper et al. (2011)                     |
| Collection rate            | Europe              | 2017      | 95    | % (w) | 2.5   | 1.0   | 1.6 | thinkstep AG (2017)                      |

Table A4. Full dataset of the application unspecified Co batteries. It includes the DQA results in terms of $R_c$ (reliability), $R_p$ (representativeness) and DQR (data quality rating).

| Parameter                  | Data country/region | Data year | Value | Unit | $R_c$ | $R_p$ | DQR | Reference                                |
|----------------------------|---------------------|-----------|-------|------|-------|-------|-----|------------------------------------------|
| Manufacturing yield        | Belgium and others  | 2008      | 100   | % (w) | 3.0   | 2.0   | 2.4 | Dewulf et al. (2010)                     |
| Manufacturing yield        | USA                 | 1980      | 92    | % (w) | 2.5   | 2.7   | 2.6 | National Research Council (1983)         |
| Production scrap recovery  | USA and others      | 2005      | 100   | % (w) | 4.0   | 1.7   | 2.3 | Harper et al. (2011)                     |
| Life time                  | Japan               | 2002      | 10.9  | years | 3.0   | 2.7   | 2.8 | Nomura (2005)                            |
| Shape parameter (Weibull distribution) | Japan  | 2002     | 2.2   | -     | 3.0   | 2.7   | 2.8 | Nomura (2005)                            |
| Collection rate            | Europe              | 2018      | 10.0  | %     | 4.0   | 1.0   | 2.2 | Tytgat and Van Damme (2018)              |
| Pre-treatment efficiency   | EU                  | 2018      | 80-90 | % (w) | 3.0   | 1.0   | 1.5 | Undisclosed company                      |
| Recycling efficiency       | EU                  | 2010      | >98   | % (w) | 3.5   | 1.3   | 2.2 | Swart et al. (2014)                      |
| Recycling efficiency       | EU                  | 2004      | 70    | % (w) | 4.0   | 1.7   | 2.6 | Georgi-Maschler et al. (2012)            |
| Recycling efficiency       | EU                  | 2009      | 65-80 | % (w) | 4.0   | 1.7   | 2.6 | Meskers et al. (2009)                    |
| Recycling efficiency       | EU                  | 2004      | 80    | % (w) | 4.0   | 2.3   | 3.0 | Saeki et al. (2004)                      |
| Recycling efficiency       | EU                  | 2017      | 90    | %     | 4.0   | 1.3   | 2.4 | Mathieux et al. (2017)                   |
| Recycling efficiency       | EU                  | 2012      | 95    | % (w) | 4.0   | 2.0   | 2.5 | BIO by Deloitte (2015)                   |
| Recycling efficiency       | EU                  | 2017      | For different type of cells | kg/kg of cell | 2.5 | 1.0 | 1.6 | thinkstep AG (2017)                      |
| Recycling efficiency       | Global              | Not available     | 94    | % (w) | 4.0   | 2.7   | 3.2 | Lebedeva et al. (2016)                   |
| Recycling efficiency       | Global              | Not available     | >90   | %     | 3.5   | 1.7   | 2.4 | Kushnir (2015)                           |
| Recycling efficiency       | Global              | Not available     | >95   | %     | 3.5   | 1.7   | 2.4 | Kushnir (2015)                           |

Table A5. Full dataset of the application hydrometallurgical catalysts. It includes the DQA results in terms of $R_c$ (reliability), $R_p$ (representativeness) and DQR (data quality rating).

| Parameter                  | Data country/region | Data year | Value | Unit | $R_c$ | $R_p$ | DQR | Reference                                |
|----------------------------|---------------------|-----------|-------|------|-------|-------|-----|------------------------------------------|
| Processing yield           | USA                 | 1980      | 97    | % (w) | 3.5   | 2.7   | 3.0 | Shedd (1993)                             |
| Manufacturing yield        | USA                 | 1980      | 96    | % (w) | 3.5   | 2.7   | 3.0 | Shedd (1993)                             |
| Life time                  | USA                 | 1980      | 0.5-several years | - | 3.5   | 2.3   | 2.8 | National Research Council (1983)         |
| Life time                  | USA                 | 2005      | 2     | years | 4.0   | 2.0   | 2.5 | Harper et al. (2011)                     |
| Regeneration times          | Europe              | 1994      | 2-3   | times | 4.0   | 2.3   | 3.0 | Berrebi et al. (1994)                    |
| Regeneration period         | Europe              | 1994      | 2-6   | years | 4.0   | 2.3   | 3.0 | Berrebi et al. (1994)                    |
| Regeneration efficiency     | Global              | 2009      | 70-80/>95 | %     | 4.0   | 2.0   | 2.8 | Rosso (2009)                             |
Table A6. Full dataset of the application hydroformylation and GTL process catalysts. It includes the DQA results in terms of $R_L$ (reliability), $R_P$ (representativeness) and DQR (data quality rating).

| Parameter                  | Data country/region | Data year | Value | Unit | $R_L$ | $R_P$ | DQR | Reference                           |
|----------------------------|---------------------|-----------|-------|------|-------|-------|-----|-------------------------------------|
| Processing yield           | USA                 | 1980      | 97    | % (w) | 3.5   | 2.7   | 3.0 | Shedd (1993)                        |
| Use loss                   | Global              | 2015      | 9     | %     | 3.0   | 2.0   | 2.3 | Ciacci et al. (2015)                |
| Collection rate            | USA                 | 1980      | 90    | % (w) | 2.5   | 2.3   | 2.4 | National Research Council (1983)    |

Table A7. Full dataset of the application PET precursors catalysts. It includes the DQA results in terms of $R_L$ (reliability), $R_P$ (representativeness) and DQR (data quality rating).

| Parameter                  | Data country/region | Data year | Value | Unit | $R_L$ | $R_P$ | DQR | Reference                           |
|----------------------------|---------------------|-----------|-------|------|-------|-------|-----|-------------------------------------|
| Processing yield           | USA                 | 1980      | 97    | % (w) | 3.5   | 2.7   | 3.0 | Shedd (1993)                        |
| Life time                  | USA                 | 2005      | 8     | years| 4.0   | 2.3   | 3.0 | Harper et al. (2011)               |
| Life time                  | EU                  | 2018      | 0.5   | years| 3.0   | 1.0   | 1.5 | PET Manufacturers in Europe (2018) |
| Use loss                   | Global              | 2015      | 9     | %     | 3.0   | 2.0   | 2.3 | Ciacci et al. (2015)               |
| Collection rate            | EU                  | 2018      | 50    | % (w) | 3.0   | 1.0   | 1.5 | Committee of PET Manufacturers in Europe (2018) |
| Collection rate            | USA                 | 1980      | 50    | % (w) | 2.5   | 2.3   | 2.4 | National Research Council (1983)    |
| Recycling efficiency       | USA                 | 1998      | 80    | %     | 3.0   | 2.7   | 2.8 | Misseri (2000)                     |

Table A8. Full dataset of the application unspecified Co catalysts. It includes the DQA results in terms of $R_L$ (reliability), $R_P$ (representativeness) and DQR (data quality rating).

| Parameter                  | Data country/region | Data year | Value | Unit | $R_L$ | $R_P$ | DQR | Reference                           |
|----------------------------|---------------------|-----------|-------|------|-------|-------|-----|-------------------------------------|
| Processing yield           | USA                 | 1980      | 95.9  | % (w) | 2.5   | 2.7   | 2.6 | National Research Council (1983)    |
| Processing yield           | USA                 | 1980      | 97.1  | % (w) | 2.5   | 2.7   | 2.6 | National Research Council (1983)    |
| Manufacturing yield        | USA                 | 1980      | 95.7  | % (w) | 2.5   | 2.7   | 2.6 | National Research Council (1983)    |
| Manufacturing yield        | USA                 | 1980      | 97.0  | % (w) | 2.5   | 2.7   | 2.6 | National Research Council (1983)    |
| Production scrap recovery  | USA                 | 1980      | 0     | % (w) | 2.5   | 2.7   | 2.6 | National Research Council (1983)    |
| Production scrap recovery  | EU                  | 2012      | 100   | % (w) | 4.0   | 1.7   | 2.3 | BIO by Deloitte (2015)             |
| Life time                  | USA                 | 1980      | 2     | years| 2.5   | 2.7   | 2.6 | National Research Council (1983)    |
| Hoarding rate              | EU                  | 2012      | 0     | % (w) | 4.0   | 1.7   | 2.3 | BIO by Deloitte (2015)             |
| Hoarding rate              | EU                  | 2012      | 0     | years| 4.0   | 1.7   | 2.3 | BIO by Deloitte (2015)             |
| Collection rate            | USA                 | 2005      | 100   | % (w) | 4.0   | 2.0   | 2.5 | BIO by Deloitte (2015)             |
| Recycling efficiency       | USA                 | 1998      | 97    | % (w) | 3.5   | 3.3   | 3.4 | Shedd (2004)                       |
| Recycling efficiency       | EU                  | 2012      | 85    | % (w) | 4.0   | 2.0   | 2.5 | BIO by Deloitte (2015)             |

Table A9. Full dataset of the application dissipative uses. It includes the DQA results in terms of $R_L$ (reliability), $R_P$ (representativeness) and DQR (data quality rating).

| Parameter                  | Data country/region | Data year | Value | Unit | $R_L$ | $R_P$ | DQR | Reference                           |
|----------------------------|---------------------|-----------|-------|------|-------|-------|-----|-------------------------------------|
| Processing yield           | USA                 | 1980      | 97    | % (w) | 2.5   | 2.7   | 2.6 | National Research Council (1983)    |
| Parameter                          | Data country/region | Data year | Value | Unit | $R_L$ | $R_p$ | $DQR$ | Reference                                      |
|-----------------------------------|---------------------|-----------|-------|------|-------|-------|-------|-----------------------------------------------|
| Processing yield                  | USA                 | 1980      | 98.3  | % (w) | 2.5   | 2.3   | 2.4   | National Research Council (1983)              |
| Manufacturing yield               | USA                 | 1980      | 100   | % (w) | 2.5   | 2.3   | 2.4   | National Research Council (1983)              |
| Manufacturing yield               | USA                 | 1980      | 95    | % (w) | 3.5   | 2.3   | 2.8   | Shedd (1993)                                 |
| Manufacturing scrap recovery      | USA                 | 1980      | 100   | % (w) | 2.5   | 2.3   | 2.4   | National Research Council (1983)              |
| Life time                         | USA                 | 1980      | 2     | years | 2.5   | 2.3   | 2.4   | National Research Council (1983)              |
| Life time                         | USA                 | 2005      | 1     | year  | 4.0   | 2.0   | 2.8   | Harper et al. (2011)                         |
| Life time                         | Japan               | 2012      | 10.7  | years | 2.5   | 1.7   | 2.0   | Nomura and Suga (2013)                       |
| Shape parameter                   | Japan               | 2012      | 1.16  | -     | 2.5   | 1.7   | 2.0   | Nomura and Suga (2013)                       |
| Hoarding rate                     | Global              | Not available | 67    | % (w) | 4.0   | 2.0   | 2.8   | BIO by Deloitte (2015)                       |
| Hoarding time                     | EU                  | 2012      | 1.0   | years | 4.0   | 1.3   | 2.0   | BIO by Deloitte (2015)                       |
| Non-selective collection rate     | USA                 | 2007      | 53    | % (w) | 3.5   | 2.0   | 2.6   | BIO by Deloitte (2015)                       |
| Collection rate                   | USA                 | 2007      | 47    | % (w) | 3.5   | 2.0   | 2.6   | BIO by Deloitte (2015)                       |
| Collection rate                   | USA                 | 1998      | 60    | %     | 4.0   | 2.3   | 3.0   | American Metal Market (2001)                 |
| Collection rate                   | Not available       | Not available | 50    | %     | 4.0   | 1.7   | 2.6   | Karhumaa and Kulkela (2013)                  |
| Collection rate                   | USA                 | 2007      | 50    | % (w) | 3.5   | 2.0   | 2.6   | Harper et al. (2011)                         |
| Collection rate                   | USA                 | 2007      | 75    | % (w) | 3.5   | 2.0   | 2.6   | Harper et al. (2011)                         |
| Collection rate                   | USA                 | 1980      | 36    | % (w) | 3.5   | 2.3   | 2.8   | Shedd (1993)                                 |
| Pre-treatment efficiency          | Korea               | 2017      | 77.3  | % (w) | 2.5   | 1.3   | 1.8   | Lee et al. (2017)                            |
| Pre-treatment efficiency          | EU                  | 2018      | Almost 100 | % (w) | 3.0   | 1.0   | 1.5   | Wolfram (2018)                               |
| Distribution to recycling processes | USA                 | 1996      | 80    | %     | 4.0   | 2.3   | 3.0   | Jana et al. (1996)                           |
| Distribution to recycling processes | Not available    | Not available | 58    | %     | 3.5   | 2.3   | 2.8   | Sjørenberg and Johnson (1998)                |
| Distribution to recycling processes | Not available    | Not available | 42    | %     | 3.5   | 2.3   | 2.8   | Sjørenberg and Johnson (1998)                |
| Distribution to recycling processes | Not available    | Not available | 67    | %     | 4.0   | 2.3   | 3.0   | Šandorová (2017)                             |
| Distribution to recycling processes | Not available    | Not available | 33    | %     | 4.0   | 2.3   | 3.0   | Šandorová (2017)                             |
| Recycling efficiency              | EU                  | 2012      | 85    | % (w) | 4.0   | 2.0   | 2.5   | BIO by Deloitte (2015)                       |
| Recycling efficiency              | EU                  | 1996      | 95    | %     | 4.0   | 2.7   | 3.2   | Kurylak et al. (2016)                        |

Table A10. Full dataset of the application hard metals. It includes the DQA results in terms of $R_L$ (reliability), $R_p$ (representativeness) and $DQR$ (data quality rating).
Table A11. Full dataset of the application magnets. It includes the DQA results in terms of $R_L$ (reliability), $R_P$ (representativeness) and DQR (data quality rating).

| Parameter                        | Data country/region | Data year | Value | Unit | $R_L$ | $R_P$ | DQR | Reference                                      |
|----------------------------------|---------------------|-----------|-------|------|-------|-------|-----|-----------------------------------------------|
| Processing yield                 | USA                 | 1980      | 95.7  | % (w) | 2.5   | 2.3   | 2.4 | National Research Council (1983)              |
| Processing yield                 | USA                 | 1980      | 89.9  | % (w) | 2.5   | 2.3   | 2.4 | National Research Council (1983)              |
| Processing yield                 | USA                 | 1980      | 92.2  | % (w) | 2.5   | 2.3   | 2.4 | National Research Council (1983)              |
| Processing downcycled scrap yield| USA                 | 1980      | 50    | % (w) | 2.5   | 2.3   | 2.4 | National Research Council (1983)              |
| Manufacturing yield              | USA                 | 1980      | 70.85 | % (w) | 4.0   | 1.7   | 2.6 | Liu and Chinnasamy (2012)                    |
| Manufacturing yield              | USA                 | 2012      | 50    | % (w) | 4.0   | 1.7   | 2.6 | Liu and Chinnasamy (2012)                    |
| Manufacturing yield              | USA                 | 2013      | 70    | % (w) | 4.0   | 2.0   | 2.8 | Binnemans et al. (2013)                      |
| Manufacturing scrap recovery     | USA                 | 1980      | 0     | % (w) | 2.5   | 2.3   | 2.4 | National Research Council (1983)              |
| Manufacturing scrap recovery     | USA                 | 1980      | 0     | % (w) | 2.5   | 2.3   | 2.4 | National Research Council (1983)              |
| Manufacturing scrap recovery     | USA                 | 1980      | 0     | % (w) | 2.5   | 2.3   | 2.4 | National Research Council (1983)              |
| Manufacturing scrap recovery     | USA                 | 1980      | 0     | % (w) | 2.5   | 2.3   | 2.4 | National Research Council (1983)              |
| Manufacturing scrap recovery     | USA                 | 1980      | 0     | % (w) | 2.5   | 2.3   | 2.4 | National Research Council (1983)              |
| Life time                        | USA                 | 1980      | 10 years | 2.5   | 2.3   | 2.4 | National Research Council (1983)              |
| Life time                        | USA                 | 2005      | 5 years | 4.0   | 2.0   | 2.5 | Harper et al. (2011)                         |
| Life time                        | Japan               | 2012      | 6.9 years | 3.0   | 2.0   | 2.4 | Nomura and Suga (2013)                       |
| Life time                        | Japan               | 2012      | 8.3 years | 3.0   | 2.0   | 2.4 | Nomura and Suga (2013)                       |
| Life time                        | Global              | 2016      | 6 years | 4.0   | 2.0   | 2.5 | Schulze and Buchert (2016)                   |
| Life time                        | Japan               | 2012      | 8 years | 3.0   | 2.0   | 2.4 | Nomura and Suga (2013)                       |
| Life time                        | Global              | 2016      | 15 years | 4.0   | 2.0   | 2.5 | Schulze and Buchert (2016)                   |
| Life time                        | Global              | 2016      | 13 years | 4.0   | 2.7   | 3.0 | Schulze and Buchert (2016)                   |
| Life time                        | Global              | 2014      | 10 years | 4.0   | 2.0   | 2.5 | Habib and Wenzel (2014)                      |
| Shape parameter (Weibull distribution) | Japan     | 2012      | 1.83 | - | 3.0 | 2.0 | 2.4 | Nomura and Suga (2013)                       |
| Shape parameter (Weibull distribution) | Japan     | 2012      | 2.25 | - | 3.0 | 2.0 | 2.4 | Nomura and Suga (2013)                       |
| Shape parameter (Weibull distribution) | Japan     | 2012      | 1.98 | - | 3.0 | 2.0 | 2.4 | Nomura and Suga (2013)                       |
| Shape parameter (Weibull distribution) | Japan     | 2012      | 1.6  | - | 3.0 | 2.0 | 2.4 | Nomura and Suga (2013)                       |
| Shape parameter (Weibull distribution) | Japan     | 2012      | 1.65 | - | 3.0 | 2.0 | 2.4 | Nomura and Suga (2013)                       |
| Parameter                      | Data country/region | Data year | Value | Unit | RL  | Rₚ  | DQA | DQR | Reference                              |
|-------------------------------|--------------------|-----------|-------|------|-----|-----|-----|-----|----------------------------------------|
| Processing yield             | USA                | 1980      | 90    | % (w)| 2.5 | 2.7 | 2.6 | National Research Council (1983)       |
| Processing yield             | USA                | 1973      | 78    | % (w)| 2.5 | 2.7 | 2.6 | Curwick et al. (1980b)                 |
| Processing yield             | USA                | 1976      | 78.7  | % (w)| 3.0 | 2.7 | 2.8 | Curwick et al. (1980a)                 |
| Processing yield             | USA                | 1980      | 97-99 | % (w)| 2.5 | 2.7 | 2.6 | National Research Council (1983)       |
| Processing yield             | USA                | 1980      | 84    | % (w)| 2.5 | 2.7 | 2.6 | National Research Council (1983)       |
| Processing yield             | USA                | 1976      | 50.1  | % (w)| 3.0 | 2.7 | 2.8 | National Research Council (1983)       |
| Processing scrap recovery    | USA                | 1980      | 100   | % (w)| 2.5 | 2.7 | 2.6 | National Research Council (1983)       |
| Processing scrap recovery    | USA                | 1973      | 36.4  | % (w)| 3.0 | 2.7 | 2.8 | Curwick et al. (1980b)                 |
| Processing downcycled scrap  | USA                | 1980      | 50    | % (w)| 2.5 | 2.7 | 2.6 | National Research Council (1983)       |
| Processing downcycled scrap  | USA                | 1973      | 36.4  | % (w)| 3.0 | 2.7 | 2.8 | Curwick et al. (1980b)                 |
| Manufacturing yield          | USA                | 1980      | 63.6  | % (w)| 3.5 | 2.7 | 3.0 | National Research Council (1983)       |
| Manufacturing yield          | USA                | 1973      | 68    | % (w)| 3.0 | 2.7 | 2.8 | Curwick et al. (1980b)                 |
| Manufacturing yield          | USA                | 1976      | 59.5  | % (w)| 3.0 | 2.7 | 2.8 | Curwick et al. (1980a)                 |
| Manufacturing yield          | USA                | 1980      | 97.6  | % (w)| 2.5 | 2.7 | 2.6 | National Research Council (1983)       |
| Manufacturing scrap recovery | USA                | 1980      | 47.6  | % (w)| 2.5 | 2.7 | 2.6 | National Research Council (1983)       |
| Manufacturing scrap recovery | USA                | 1973      | 90.6  | % (w)| 3.0 | 2.7 | 2.8 | Curwick et al. (1980b)                 |
| Manufacturing downcycled scrap| USA              | 1980      | 47.6  | % (w)| 2.5 | 2.7 | 2.6 | National Research Council (1983)       |
| Manufacturing downcycled scrap| USA              | 1973      | 0     | % (w)| 3.0 | 2.7 | 2.8 | Curwick et al. (1980b)                 |
| Life time                    | USA                | 1980      | 5     | years| 2.5 | 2.7 | 2.6 | National Research Council (1983)       |
| Life time                    | USA                | Not avali  | 4.6 - | years| 4.0 | 3.3 | 3.6 | Ely (2014)                             |
| Life time                    | EU 28 + Switzerland and Norway | 2015     | 0     | % (w)| 2.5 | 2.0 | 2.2 | Huisman et al. (2017)                 |
| Life time                    | EU 28 + Switzerland and Norway | 2015     | 0.9   | % (w)| 2.5 | 2.0 | 2.2 | Huisman et al. (2017)                 |
| Collection rate              | USA                | 2005      | 10    | % (w)| 4.0 | 2.0 | 2.5 | Harper et al. (2011)                  |
| Collection rate              | Europe             | 2016      | 35    | % (w)| 2.5 | 2.0 | 2.2 | Balde et al. (2017)                   |
| Collection rate              | EU 28 + Switzerland and Norway | 2015     | 44.6  | % (w)| 2.5 | 2.0 | 2.2 | Huisman et al. (2017)                 |
| Collection rate              | EU 28 + Switzerland and Norway | 2015     | 44.8  | % (w)| 2.5 | 2.0 | 2.2 | Huisman et al. (2017)                 |
| Collection rate              | Global             | 2016      | 90    | % (w)| 4.0 | 2.0 | 2.5 | Schulze and Buchert (2016)            |
| Collection rate              | Global             | 2016      | 90    | % (w)| 4.0 | 2.0 | 2.5 | Schulze and Buchert (2016)            |
| Collection rate              | Global             | 2016      | 60    | % (w)| 4.0 | 2.0 | 2.5 | Schulze and Buchert (2016)            |
| Collection rate              | Global             | 2016      | 80    | % (w)| 4.0 | 2.0 | 2.5 | Schulze and Buchert (2016)            |
| Collection rate              | Global             | 2016      | 80    | % (w)| 4.0 | 2.7 | 3.0 | Schulze and Buchert (2016)            |
| Pre-treatment efficiency     | Global             | 2016      | 90    | % (w)| 4.0 | 2.0 | 2.5 | Schulze and Buchert (2016)            |
| Pre-treatment efficiency     | Global             | 2016      | 90    | % (w)| 4.0 | 2.0 | 2.5 | Schulze and Buchert (2016)            |
| Pre-treatment efficiency     | Global             | 2016      | 60    | % (w)| 4.0 | 2.0 | 2.5 | Schulze and Buchert (2016)            |
| Pre-treatment efficiency     | Global             | 2016      | 90    | % (w)| 4.0 | 2.0 | 2.5 | Schulze and Buchert (2016)            |
| Pre-treatment efficiency     | Global             | 2016      | 40    | % (w)| 4.0 | 2.7 | 3.0 | Schulze and Buchert (2016)            |

Table A12. Full dataset of the application other metallic uses. It includes the DQA results in terms of RL (reliability), Rp (representativeness) and DQR (data quality rating).
| Parameter                          | Data country/region | Data year | Value | Unit   | \( R_L \) | DQA | DQR | Reference                                |
|-----------------------------------|---------------------|-----------|-------|--------|-----------|-----|-----|------------------------------------------|
| Processing yield                  | USA                 | 1976      | 80    | % (w)  | 3.0       | 2.3 | 2.6 | Curwick et al. (1980a)                    |
| Processing yield                  | USA                 | 1976      | 50    | % (w)  | 3.0       | 2.3 | 2.6 | Curwick et al. (1980a)                    |
| Processing yield                  | USA                 | 1976      | 54    | % (w)  | 3.0       | 2.3 | 2.6 | Curwick et al. (1980a)                    |
| Processing yield                  | USA                 | 1976      | 79    | % (w)  | 2.5       | 2.3 | 2.4 | National Research Council (1983)          |
| Processing yield                  | USA                 | 1980      | 94    | % (w)  | 2.5       | 2.3 | 2.4 | National Research Council (1983)          |
| Processing yield                  | USA                 | 1980      | 87    | % (w)  | 2.5       | 2.3 | 2.4 | National Research Council (1983)          |
| Processing yield                  | USA                 | 1980      | 91    | % (w)  | 2.5       | 2.3 | 2.4 | National Research Council (1983)          |
| Processing yield                  | USA                 | 1980      | 61    | % (w)  | 3.0       | 2.3 | 2.6 | Shedd (1993)                              |
| Processing yield                  | Global              | 2001      | 50-75 | %      | 4.0       | 2.7 | 3.2 | Donachie and Donachie (2002)              |
| Processing scrap recovery         | USA                 | 1980      | 93    | % (w)  | 3.0       | 2.3 | 2.6 | Shedd (1993)                              |
| Processing scrap recovery         | USA                 | 1976      | 91    | % (w)  | 3.0       | 2.3 | 2.6 | Curwick et al. (1980a)                    |
| Processing scrap recovery         | Global              | 2005      | 100   | % (w)  | 4.0       | 2.0 | 2.5 | Harper et al. (2011)                      |
| Processing downcycled scrap       | USA                 | 1980      | 69    | % (w)  | 2.5       | 2.3 | 2.4 | National Research Council (1983)          |
| Processing downcycled scrap       | USA                 | 1980      | 50    | % (w)  | 2.5       | 2.3 | 2.4 | National Research Council (1983)          |
| Processing downcycled scrap       | USA                 | 1980      | 57    | % (w)  | 2.5       | 2.3 | 2.4 | National Research Council (1983)          |
| Processing downcycled scrap       | USA                 | 1976      | 5     | % (w)  | 3.0       | 2.3 | 2.6 | Curwick et al. (1980a)                    |
| Manufacturing yield               | USA                 | 1976      | 40    | % (w)  | 3.0       | 2.3 | 2.6 | Curwick et al. (1980a)                    |
| Manufacturing yield               | USA                 | 1976      | 54    | % (w)  | 3.0       | 2.3 | 2.6 | Curwick et al. (1980a)                    |
| Manufacturing yield               | USA                 | 1976      | 51    | % (w)  | 3.0       | 2.3 | 2.6 | Curwick et al. (1980a)                    |

Table A13. Full dataset of the application superalloys. It includes the DQA results in terms of \( R_L \) (reliability), \( R_P \) (representativeness) and DQR (data quality rating).
| Manufacturing yield | USA | 1980 | 40 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
|--------------------|-----|------|----|--------|-----|-----|-----|---------------------------------|
| Manufacturing yield | USA | 1980 | 53 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Manufacturing yield | USA | 1980 | 48 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Manufacturing yield | USA | 1980 | 65 | % (w) | 3.0 | 2.3 | 2.6 | National Research Council (1983) |
| Manufacturing scrap recovery | USA | 1980 | 13 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Manufacturing scrap recovery | USA | 1980 | 81 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Manufacturing scrap recovery | USA | 1980 | 46 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Manufacturing scrap recovery | USA | 1980 | 91 | % (w) | 3.0 | 2.3 | 2.6 | National Research Council (1983) |
| Manufacturing scrap recovery | USA | 1976 | 30 | % (w) | 3.0 | 2.3 | 2.6 | National Research Council (1983) |
| Manufacturing downcycled scrap | USA | 1980 | 81 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Manufacturing downcycled scrap | USA | 1980 | 17 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Manufacturing downcycled scrap | USA | 1980 | 50 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Manufacturing downcycled scrap | USA | 1980 | 0 | % (w) | 3.0 | 2.3 | 2.6 | National Research Council (1983) |
| Manufacturing downcycled scrap | USA | 1976 | 63 | % (w) | 3.0 | 2.3 | 2.6 | National Research Council (1983) |
| Life time | USA | 1980 | 5 | years | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Life time | USA | 2005 | 5 | years | 4.0 | 2.3 | 3.0 | National Research Council (1983) |
| Life time | Japan | 2006 | 6 | years | 3.0 | 2.3 | 2.6 | National Research Council (1983) |
| Life time | Japan | 2006 | 20 | years | 3.0 | 2.3 | 2.6 | National Research Council (1983) |
| Life time | Japan | 2012 | 23 | years | 3.0 | 2.0 | 2.4 | National Research Council (1983) |
| Life time | Japan | 2012 | 19 | years | 3.0 | 2.0 | 2.4 | National Research Council (1983) |
| Shape parameter (Weibull distribution) | Japan | 2006 | 2.0 | - | 3.0 | 2.3 | 2.6 | National Research Council (1983) |
| Shape parameter (Weibull distribution) | Japan | 2006 | 1.8 | - | 3.0 | 2.3 | 2.6 | National Research Council (1983) |
| Hoarding rate | USA | 2010 | 100 | % (w) | 3.5 | 2.0 | 2.6 | National Research Council (1983) |
| Hoarding rate | USA | 2010 | 5 | years | 3.5 | 2.0 | 2.6 | National Research Council (1983) |
| Non-selective collection rate | USA | 1980 | 21 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Non-selective collection rate | USA | 1980 | 17 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Non-selective collection rate | USA | 1980 | 15 | % (w) | 3.0 | 2.3 | 2.6 | National Research Council (1983) |
| Collection rates | EU | 2012 | 100 | % (w) | 4.0 | 1.7 | 2.3 | National Research Council (1983) |
| Collection rate | USA | 2012 | 90 | % (w) | 4.0 | 1.7 | 2.5 | National Research Council (1983) |
| Collection rate | USA | 1973 | 50-60 | % (w) | 3.0 | 2.3 | 2.6 | National Research Council (1983) |
| Collection rate | USA | 1980 | 50 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Collection rate | USA | 1980 | 50 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Collection rate | USA | 2010 | 90 | % (w) | 4.0 | 2.3 | 3.0 | National Research Council (1983) |
| Distribution to recycling processes | USA | 2012 | 80/20 | % | 4.0 | 1.7 | 2.6 | National Research Council (1983) |
| Distribution to recycling processes | USA | 1980 | 63/37 | % (w) | 2.5 | 2.3 | 2.4 | National Research Council (1983) |
| Distribution to recycling processes | USA | 1980 | 60/40 | % (w) | 3.5 | 2.3 | 2.8 | National Research Council (1983) |
| Distribution to recycling processes | USA | 1980 | 59/41 | % (w) | 1.5 | 2.3 | 2.0 | National Research Council (1983) |
| Recycling efficiency | USA | 2012 | 76 | % (w) | 4.0 | 2.0 | 2.8 | National Research Council (1983) |
5. List of consulted experts

Fifteen experts from academia; 18 associations, groups or societies; and more than 110 companies (producers, users, and recyclers) were contacted for collection and/or validation of data. Of these, 51 gave a general answer. Table A14 lists the institutions that provided an expert insight about Co flows, and/or information used in data collection or validation. Some of these institutions and/or experts asked not to reveal their identity.

Table A14. List of companies, associations, and experts consulted for data collection and/or validation.

| Material or application | Affiliation | Expert | Position | Information about Co flows | Information used in data collection or validation |
|-------------------------|-------------|--------|----------|-----------------------------|-----------------------------------------------|
| Batteries               | Accurec     | Anonymous | -        | No                          | No                                             |
|                         | Undisclosed company | Anonymous | -        | Yes                         | Yes                                             |
|                         | EBRA (European Battery Recycling Association) | Alain Vassart | Secretary General of EBRA ivzw/aisbl | Yes | Yes |
|                         | EPBA (European Portable Battery Association) | Anonymous | -        | Yes                         | No                                             |
|                         | EUROBAT (Association of European Automotive and Industrial Battery Manufacturers) | Anonymous | -        | No                          | No                                             |
|                         | FFE (Forschungsstelle für Energiewirtschaft) | Anonymous | -        | No                          | No                                             |
|                         | JRC (Joint Research Centre) | Silvia Bobba | PhD researcher | Yes | No |
|                         | Saubermacher AG | Anonymous | -        | Yes                         | Yes                                             |
| Catalysts               | Clariant | Thomas Cotter | BU Catalysts, Emission Control and Zeolites R&D Department Manager | Yes | No |
|                         | CPME (Committee of PET Manufacturers in Europe) | Anonymous | -        | Yes                         | Yes                                             |
|                         | European Catalyst Manufacturers Association | Anonymous | -        | No                          | No                                             |
| Cobalt and other materials | BRGM (Bureau de Recherches Géologiques et Minières) | Raphael Danino-Ferraud | PhD researcher | Yes | Yes |
|                         | CI (Cobalt Institute) | Carol-lyne Pettit | REACH & Sustainability Manager | Yes | Yes |
|                         | CMI (Critical Material Institute) | Roderick Eggert | Deputy Director | Yes | Yes |
|                         | DERAM (German Mineral Resources Agency) | Siyamend Ingo Al Barazi | Scientist | Yes | Yes |
|                         | Empa | Anonymous | -        | No                          | No                                             |
|                         | Ghent University | Stijn Dewaele | Professor | Yes | No |
|                         | Glencore – Nikkelverk | Oluf Backman | Senior Specialist, R&D | Yes | Yes |
|                         | IMA-Europe (Industrial Minerals) | Anonymous | -        | No                          | No                                             |
|                         | JRC (Joint Research Centre) | Anonymous | -        | No                          | No                                             |
| Materials Type                  | Company Name                                      | Contact Person             | Role                        | Disclosure | Publication Status |
|-------------------------------|--------------------------------------------------|----------------------------|-----------------------------|------------|--------------------|
| Cobalt and other materials   | KIT (Karlsruhe Institute of Technology)           | Anonymous                  | -                           | No         | No                 |
|                               | KU Leuven                                        | Anonymous                  | -                           | No         | Yes                |
|                               | Leiden University                                | Sebastiaan Deetman         | PhD researcher              | Yes        | No                 |
|                               | Kanva EU Ltd                                     | Andrejs Kopils             | Development Director        | Yes        | Yes                |
|                               |                                                  | Sergejs Kopils             | Managing Director           | Yes        | Yes                |
|                               | Undisclosed company                              | Anonymous                  | -                           | No         | No                 |
|                               | NTNU (Norwegian University of Science and Technology) | Anonymous                  | -                           | Yes        | No                 |
|                               | PNO Consultants                                  | Anonymous                  | -                           | No         | No                 |
|                               | Umicore                                          | Anonymous                  | -                           | Yes        | No                 |
|                               | Yale University                                  | Anonymous                  | -                           | No         | No                 |
| Dissipative uses             | Inorganic Pigments Consortium                    | Anonymous                  | -                           | No         | No                 |
|                               | Undisclosed company                              | Anonymous                  | -                           | Yes        | Yes                |
|                               | EuroHM (European Hard Materials Group)            | Steven Moseley             | Chief Scientist – Hard Materials | No        | No                 |
|                               | Oerlikon                                         | Anonymous                  | -                           | No         | No                 |
|                               | Sumitomo                                         | Anonymous                  | -                           | No         | No                 |
|                               | Wolfram                                          | Michael Dornhofer          | Director Sales & Purchasing | Yes        | Yes                |
| Magnets                      | Goudsmit Magnetics                               | Anonymous                  | -                           | No         | No                 |
|                               | UK Magnetics Society                             | Anonymous                  | -                           | Yes        | Yes                |
| Other metallic uses          | ACB                                              | Eddy Geerinckx             | -                           | Yes        | No                 |
|                               | Dutch Surface Treatment Association              | Anonymous                  | -                           | No         | No                 |
|                               | Undisclosed association                           | Anonymous                  | -                           | No         | No                 |
|                               | Euro circuits                                    | Anonymous                  | -                           | Yes        | No                 |
|                               | German Surface Treatment Association             | Anonymous                  | -                           | No         | No                 |
|                               | Multi-CB                                         | Anonymous                  | -                           | No         | No                 |
|                               | Schmolz + Bickenbach Group                       | Anonymous                  | -                           | No         | No                 |
|                               | Surface Engineering Association                  | Anonymous                  | -                           | No         | No                 |
| Superalloys                  | Doncasters                                       | Anonymous                  | -                           | No         | No                 |
|                               | Undisclosed company                              | Anonymous                  | -                           | No         | No                 |
|                               | Composite Recycling                              | Frank Riedewald            | CEO                         | No         | No                 |
| Other                        | RELIGHT                                          | Anonymous                  | -                           | Yes        | No                 |
|                               | Renewi                                           | Anonymous                  | -                           | No         | No                 |
|                               | Stena                                            | Anonymous                  | -                           | Yes        | No                 |
|                               | The Shift                                        | Anonymous                  | -                           | No         | No                 |
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