GEO-COAT

DEVELOPMENT OF NOVEL AND COST-EFFECTIVE CORROSION RESISTANT COATINGS
FOR HIGH TEMPERATURE GEOTHERMAL APPLICATIONS

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Executive Summary

The aggressive environment of medium to high temperature geothermal resources makes the geothermal plant components vulnerable to corrosion, erosion and scaling. It is a challenge to maintain the integrity of the various plant components. To counteract aggressive geofluids in future geothermal project development, the Geo-Coat project proposes geothermal components made of Geo-Coat substrate materials coated with cost-effective anticorrosion, anti-scaling coating materials (Geo-Coat technology) selected as an alternative to current state-of-the-art (SOA) materials with the aim of providing improved component performances during the plant lifetime. Determining the environmental impacts of these Geo-Coat substrate materials, coating materials and the deposition processes is an essential step in designing a green, sustainable technology for geothermal components. In this study, the environmental impacts of the Geo-Coat technology adopted for geothermal components have been evaluated, alongside the impacts of SOA materials, by a cradle to gate approach, using the SimaPro 9.0.0.49 LCA tool, and life cycle impact assessment (LCIA) methodology IMPACT 2002+, version 2.14. Three geothermal power plants have been considered: one double flash type (Icelandic case study 1); one combined dry steam & single flash type (Icelandic case study 2); and one binary type (Romanian case study. For each, the environmental impacts have been evaluated, with and without adoption of Geo-Coat technology for pipes, turbine rotors, blades and well casings components. The functional unit of the LCA impact study of geothermal power plant has been taken as 1 MW installed capacity of the plant. In D5.3, the Geo-Coat technologies per application area have been ranked using the laboratory-results of the corrosion, tribological and cost performances and the recommended weightings of these performances. Icelandic case studies 1 (double flash) and 2 (combined single flash & dry steam) and the Romanian case study (binary) geothermal power plants with the adoption of the 2nd ranked Geo-Coat technology instead of SOA materials demonstrated environmental impacts in terms of carbon footprint savings of 75%, 80% and 82%, respectively. The results of this study demonstrate the potential for Geo-Coat technology to enable the design of green and sustainable components for geothermal power plants.

Objective met:

The current deliverable contributes towards the following work package objective:

- Demonstrate the potentialities of Geo-Coat to improve the LCOE and the environmental footprint of geothermal power.

Contents

1. INTRODUCTION

The high temperature and pressure conditions of geothermal resources and corrosive nature of geofluid pose a significant threat to maintaining the integrity of geothermal components such as pipes, turbine components, well casings, and pump impellers. Corrosion, erosion and scale formation, or combinations of these can occur in these components at different locations in geothermal power plants. To obtain higher enthalpy geofluid for increased output of geothermal systems, deeper wells are needed. Geothermal environments become more aggressive at deep wells and hence the increased corrosion, erosion and scaling effects put the efficiency and longevity of the plant components at risk. Several countries such as Iceland, New Zealand, Philippines, Indonesia, Kenya, Uganda, Mexico and US have carried out research activities to counteract aggressive geofluids for future geothermal project development [1]. All these activities recommended different expensive and corrosion resistant materials such as stainless steels 630SS, A470, 304L, titanium alloys, etc as state-of-the-art (SOA) materials for different geothermal components. However, the use of such materials will require huge investment and cause environmental impacts in the context of carbon footprints. It is proposed that the use of Geo-Coat technologies for different geothermal components instead of using SOA materials will enhance the growth of geothermal power with reduced environmental impacts.

The Geo-Coat project has been developing novel coating and MMC component systems (Geo-Coat technologies) for six geothermal application areas: i) pipes and casings (S1); ii) valve stem & turbine blades (S2); iii) turbine rotors (S3); iv) turbine blades (S4); v) pump impellers (S5); and vi) heat exchanger tubes (S6). The overall ranking of Geo-Coat technologies per application area has been evaluated using laboratory-based assessment of the corrosion, tribological and cost performances considering the weightings of different performances as suggested by the advisory board (experts in geothermal energy within Geo-Coat consortium). Two Geo-Coat technologies (1st and 2nd ranked Geo-Coat systems) have been selected for each of the six geothermal application areas listed in Table 1.1. The details of the ranking of the Geo-Coat technologies are described in Geo-Coat deliverable D 5.3.

Table 1.1 - Ranked Geo-Coat technologies for each application area for further analysis in WP6 and WP8 within Geo-Coat project.

Substrates	Application areas	1st ranked Geo-Coat system	2nd ranked Geo-Coat system
S1	Pipes & casings	HVOF_CA2	LC_HEA2
S2	Valve stem & turbine blades	HVOF_CA2	LC_HEA2
S3	Turbine rotors	HVOF_CA2	LC_HEA2
S4	Turbine blades	HVOF_CA2	LC_HEA5
S5	Pump impellers	HIP_IN625+10% SiC	HIP_Ti64+10% TiB_2
S6	Heat exchanger tubes	<u>Undercoat</u>: High P%; <u>Topcoat</u>: High P%, 10 g/l PTFE, no HT (ENP2_DC)	<u>Undercoat:</u> High P%; <u>Topcoat</u>: Low P%, 10 g/l PTFE, no HT (ENP41_DC)

These two best ranked Geo-coat technologies for each substrate/application are being used for further testing in simulated (WP6) and real (WP8) geothermal environments. Under Geo-Coat WP6, WEIR has performed erosion-corrosion tests for the down-selected ranked systems using FEC (free erosion-corrosion) and cathodic

[1] R P Houser, Performance of eleven Ti alloys in high temperature, high pressure brine solution; Proc. World Geothermal Congress 2010.

protection (CP) method with 3.5% NaCl concentration and a pH 4 simulated environment. The results indicated that the 2nd ranked Geo-Coat system LC_HEA2 showed the greatest erosion-corrosion resistant. Flow-through corrosion, static corrosion and stress corrosion cracking exposure tests with simulated geothermal environments are being carried out in WP6 for down-selected coating systems for each substrate/application. In WP8, the well-head in-situ (Test A), aerated pressure vessel (Test A) and erosion-corrosion (Test C) field tests are being carried out. Erosion-wear, scratch testing and three-point bending test (3PBT) are also being carried out after static corrosion (WP6) and Test A exposure field tests (WP8). The selection of the best one Geo-Coat technology per substrate/application is being evaluated based on the results from WP6 and WP8 during the writing of this report.

The Geo-Coat substrate (GCS) materials were selected as a cheaper and environmentally lighter (lower-impact) alternative to the SOA materials with the aim of providing improved component performances when coated. The Geo-Coat project has selected five Geo-Coat substrate materials (S1:S235JR, S2:316SS, S3:1.2746, S4:304L and S6:S235JR) to which the selected best Geo-Coat coatings are to be applied. The pipe and well casing component materials (S1) such as stainless steel 630SS, 316L, carbon steel S235JR or P265GH, K-55, etc, are currently being used at different locations of the pipe network of geothermal power plants worldwide. The SOA materials of either CrMoV steel or 2% Cr Steel or A470 steel for turbine rotors (S3) are being used. Ti alloys are highly resistant to localised corrosion and stress corrosion cracking in the presence of chlorides, halides, halogens and also resistant to hot highly acidic solutions[2], whereas most carbon steels, stainless steels and Ni-based alloys show poor performance. Ti alloys are also recognised for their high resistance to erosion and erosion-corrosion, which is an important characteristic in areas of the geothermal plant where high-flow geothermal fluid is found. For the above reasons, Ti alloys have been recommended for use in turbine blades and well casings as SOA materials[3]. For the LCA impact studies of Icelandic and Romanian plant, the materials 630SS, Ti-6Al-4V, A470, and Ti-6Al-4V have been considered for the pipes, well casings, turbine rotors, and blades respectively – referred to as SOA systems. Table 1.2 lists the SOA materials employed for pipes, turbine rotors, blades and well casing components.

Table 1.2 – SOA materials considerations for geothermal components of pipes, turbines and well casings

SOA ID	Application areas	Geo-Coat proposed SOA materials	SOA materials employed for Icelandic case studies 1 & 2 (ICS1, ICS2) and Romanian case study (RCS)	Recommended SOA materials for LCA studies
S1	Pipes	P265GH	ICS1: S235JR & 316L ICS2: S235JR; RCS: P265GH	630SS
S3	Turbine rotors	A470	ICS1: low alloy steel CrMoV ICS2: 2% Cr steel	A470
S4	Turbine blades	304L	ICS1: stainless steel (17-4PH for last stage) ICS2: stainless steel	Ti-6Al-4V
S1	Well casings	P265GH	ICS1 and ICS2: K-55 RCS: P265GH	Ti-6Al-4V

For maintaining the integrity of the pipe, turbine and well casings components during the lifetime of the plant, it is recommended to use Geo-Coat substrates coated with the best Geo-Coat coatings (HVOF_CA2, LC_HEA2,

[2] J. Niogara and S. J. Zarrouk, "Corrosion in geothermal environment Part 2: Metals and alloys," Renewable and Sustainable Energy Reviews, vol. 82, pp. 1347-1363, 2018.

[3] S. N. Karlsdottir, "Corrosion, scaling and material selection in geothermal power production," in Comprehensive renewable energy, Elsevier, 2012, pp. 241-259

LC_HEA5) – referred to as Geo-Coat technologies/systems alternative to SOA systems in future geothermal power plants.

For comparisons of environmental impacts with and without adoption of Geo-Coat system, i.e. Geo-Coat technology, the pipes (S1), turbine (S3-S4) components and well casings (S1) have been considered for the Icelandic and Romanian plant. The environmental impacts for 1 cm^3 volume of pump impeller component with and without adoption of Geo-Coat technologies has also been evaluated (subsection 2.3.3), even though the pump impeller (application area S5) component has not been used for the Icelandic or Romanian case studies. For these comparative environmental impact studies, we have used the 1st and 2nd ranked Geo-Coat systems for pipes, turbine rotors, blades, well casings and pump impellers, as listed in Table 1.3. The application of Geo-Coat technology for heat exchangers is mainly applied for binary geothermal plant. It was not possible to assess heat exchanger tubes in this work due to lack of available data about the design of the heat exchangers used in the Romanian binary power plant.

Table 1.3 - 1st and 2nd ranked Geo-coat systems for different application areas of the geothermal power plants

Rank	Geo-Coat systems for different geothermal components				
	Pipes (S1)	Turbine rotors (S3)	Turbine blades (S4)	Well casings (S1)	Pump Impellers (S5)
2nd	LC_HEA2_S235JR	LC_HEA2_1.2746	LC_HEA5_304L	LC_HEA2_S235JR	HIP_Ti64+10% TiB2
1st	HVOF_CA2_S235JR	HVOF_CA2_1.2746	HVOF_CA2_304L	HVOF_CA2_S235JR	HIP_IN625+10% SiC

For comparative LCA studies with and without adoption of Geo-Coat technology, double flash type 303 MW Hellisheidi, combined single flash & dry steam type 66 MW Svartsengi and binary type 50 kW Transgex-Oradea geothermal power plants have been considered and these are referred to as Icelandic case study 1 (ICS1), Icelandic case study 2 (ICS2), and Romanian case study (RCS), respectively.

The Life cycle impact assessment (LCIA) for the geothermal components (pipes, turbine rotors, and blades and well casings) employed in ICS1, ICS2 and RCS plants with and without the adoption of 1st and 2nd ranked Geo-Coat systems (Table 1.3) have been carried out using SimaPro 9.0.049 LCA tool. The LCIA impact results with and without the adoption of the 2nd ranked Geo-Coat technology have been evaluated and analysed for 1 MW installed capacity at the ICS1, ICS2 and RCS plants. Also, the LCIA impact results with and without the adoption of the 1st ranked Geo-Coat technology (Table 1.3) have been evaluated and analysed for 1 MW installed capacity for the ICS1 plant only.

The details of the LCA methodology are described in subsection 2.1. The data inventories of SOA and Geo-Coat systems are given in subsection 2.2. The LCA modelling results for 1 kg of SOA (630SS, A470 and Ti-6Al-4V) and Geo-Coat substrate materials (S235JR, 1.2746 and 304L), 1µm thick 1st and 2nd ranked Geo-Coat coatings over 1 m^2 area and 1 cm^3 volume SOA materials (In625 and Ti64) and HIP_IN625+10%SiC and HIP_Ti64+10%TiB_2 MMC components are presented in subsection 2.3. Section 3 presents the comparative LCIA impact results with and without the adoption of Geo-Coat technology for Icelandic and Romanian case studies of geothermal plants based on different power technology options. All the LCIA impact results on environmental footprints due to the adoption of 1st and 2nd ranked Geo-Coat systems are summarised in section 4. This report has been reviewed by an independent LCA reviewer and been updated based on the recommendations.

2. LCA MODELLING OF SOA MATERIALS AND MATERIALS BASED ON GEO-COAT TECHNOLOGY

2.1 LCA Methodology

Life Cycle Assessment (LCA) provides a holistic approach to evaluate environmental performance by considering the potential impacts from all stages of manufacture, product use and end-of-life stages. There are various frameworks for performing LCA but the primary and globally accepted way of doing it follows the ISO LCA Standard, which is comprised primarily of two related standards, 14040:2006[4] and 14044:2006[5]. We refer to both underlying standards as the ISO Standard. The notation "14040:2006" means that the ISO LCA Standard is in the "ISO 14000" family of standards, which are global standards for environmental management and encompass various other processes to track and monitor emissions and releases. The ISO LCA Standard formalises the quantitative modelling and accounting needs to implement life cycle thinking to support decisions.

As per ISO LCA standard 14044: 2006, LCA generally comprises four major phases, summarised in Figure 2.1:

- Goal and scope definition – statements of intent of the study with reference to the study design parameters.
- Inventory analysis - data collection and calculation of an inventory of materials, energy and emissions related to the system being studied.
- Impact assessment - analysis of data to evaluate contributions to various environmental impact categories and
- Interpretation - where the results of impact categories are analysed in the context of the methodology, scope and study goals and where the quality of any study conclusions is assessed.

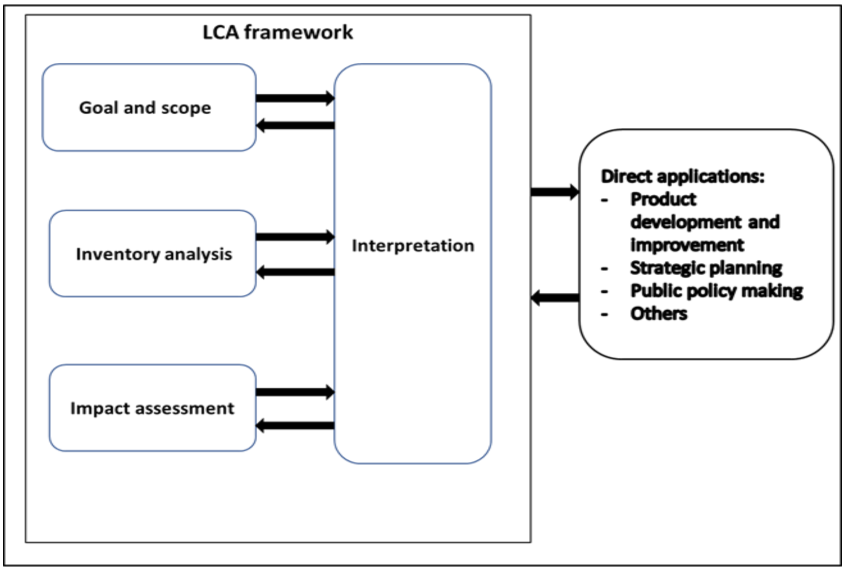


Figure 2.1 – Overview of ISO LCA framework (source: ISO 14040:2006, modified[6])

Life Cycle Impact Assessment (LCIA) is the phase in an LCA where the inputs and outputs of elementary flows that have been collected and reported in the inventory are translated into impact indicator results related to

[4] ISO 14040: 2006 – Environmental management – Life cycle assessment – Principles and framework; Geneva. (2006a).

[5] ISO 14044: 2006 – Environmental management – Life cycle assessment – Requirements and guidelines; Geneva. (2006b).

[6] European Commission-JRC-Institute for Environment and Sustainability: ILCD Handbook: General guide for Life Cycle Assessment - Detailed guidance; 2010; EUR 24708 EN

human health, natural environment (ecosystem quality and climate change), and resource depletion. The purpose of the impact assessment phase is thus to interpret the life cycle emissions and resource consumption inventory in terms of indicators for the Areas of Protection (AoPs), i.e. to evaluate the impact on the entities that we want to protect. The Areas of Protection (endpoint damage categories) considered in the IMPACT 2002+ methodology are Human health, Climate change, Ecosystem quality and Resources. The LCIA methodology involves applying a series of factors to inventory results to generate environmental impact estimates on the ecosystems, human health, climate change or resources. Figure 2.2 shows the cause-effect chain (also referred to as the environmental mechanism) for an emission category.

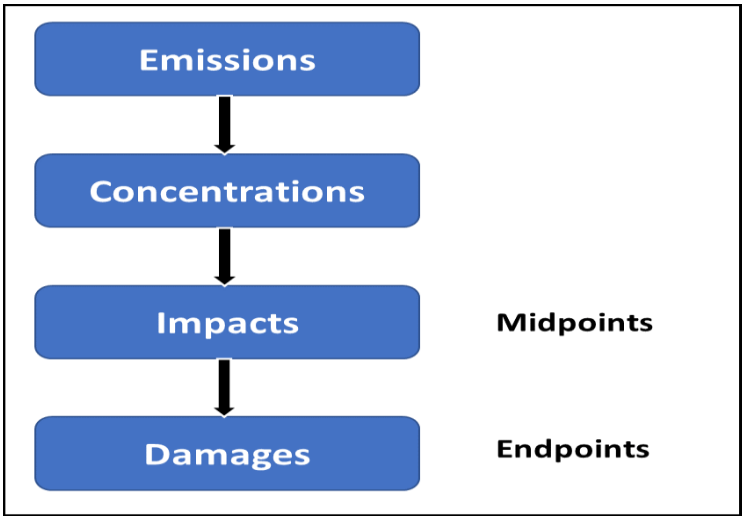


Figure 2.2 - General Cause-Effect chain for Environmental Impacts

In the case of climate change impacts, increased emissions of greenhouse gases (GHGs) lead to increased concentrations of GHGs in the atmosphere. As the concentrations are changed in the environment, we would expect to see intermediate impacts. For the case of climate change, increased concentrations of GHGs are expected to lead to increased warming (radiative forcing). Emissions of conventional pollutant emissions lead to increased concentrations in the local atmosphere. These intermediate points of the chain are also called **midpoints**, which are quantifiable effects that can be linked back to the original emissions but are not fully indicative of the eventual effects in the chain. Finally, damages arise from the impacts. These damages are also referred to as **endpoints** since they are the final part of the chain and represent the inevitable ending point with respect to the original stressors. These damages or endpoints are the 'effects' in the cause-effect chain. Global warming potential (GWP) with a time horizon (TH) of 100 years is the most widely quoted metric in all LCIA methods when quantifying climate change impacts from emissions of GHGs. The impact pathway of climate change is very broad and complex in the sense that it involves multiple impacts of both regional and global nature and extends from the shorter term into the more distant future. Figure 2.3 presents a very simplified version of the impact pathway for climate change category.

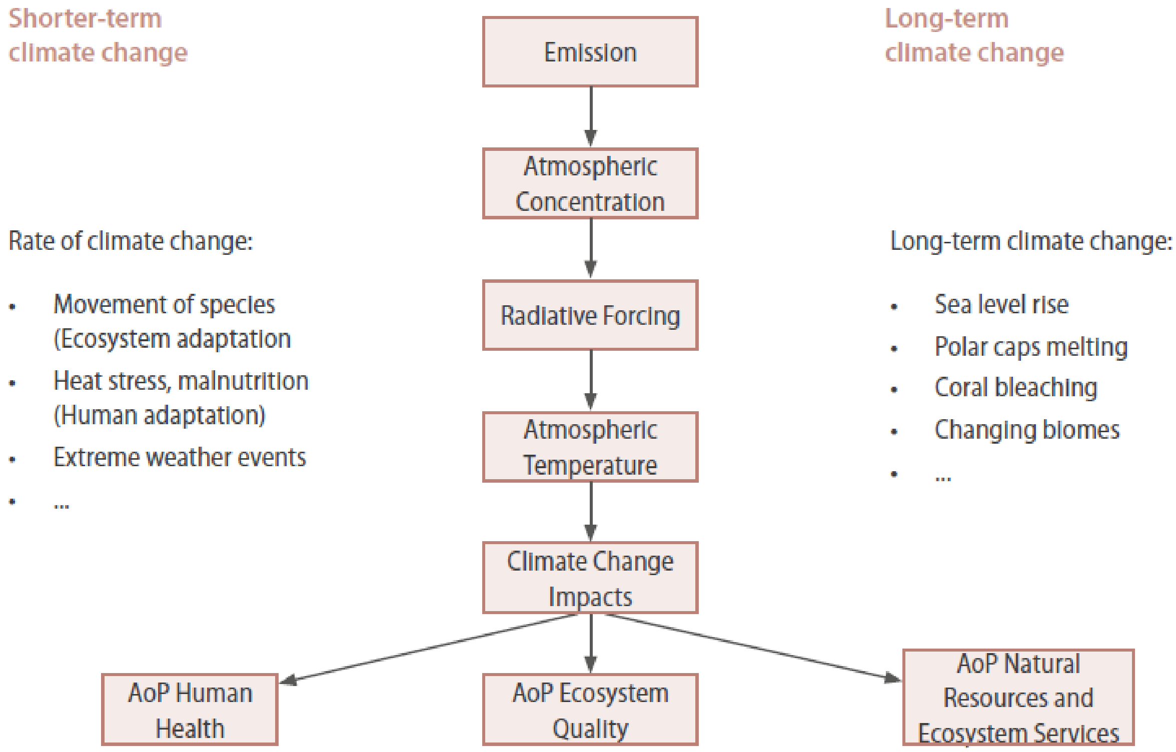


Figure 2.3 - Simplified impact pathway for climate change (AoP: Area of protection)[7]

For global warming (or climate change), the damages/endpoints of concern may be the destruction of coral reefs, rising sea levels, etc. For conventional pollutants, endpoints may be human health effects due to increased exposure to higher concentrations, such as increases in asthma cases or hospital admissions. For ozone depletion, we may be concerned with increases in human cancer rates due to increased UV radiation.

According to ISO 14044, Life Cycle Impact Assessment proceeds through four steps:

1) Selection of impact categories and classification (mandatory): In this step, the environmental impacts relevant to the study are defined. The elementary flows from the life cycle inventory (e.g. resource consumption, emissions into air, etc) are then assigned to impact categories according to the substances‘ ability to contribute to different environmental problems.
2) Characterisation (mandatory): The impact of each emission or resource consumption is modelled quantitatively, according to the environmental mechanism. The result is expressed as an impact score in a unit common to all contributions within the impact category by applying the so-called ‘characterisation factors’. For example, kg of CO_2-equivalents for GHGs contributing to the impact category ‘Climate Change‘. Here, the characterisation factor of CO_2 for climate change is 1, while methane has a characterisation factor of more than 20, reflecting its higher climate change potential.
3) Normalisation (optional): The characterised impact scores are associated with a common reference, such as the impacts caused by one person during one year in a stated geographic context. This facilitates comparisons across impact categories and/or Areas of Protection.

[7] Global Guidance for Life Cycle Impact Assessment Indicators: Volume 1, United Nations Environment Programme (UNEP), 2016.

4) Weighting (optional): The different environmental impact categories and/or Areas of Protection are ranked according to their relative importance. Weighting may be necessary when trade-off situations occur in LCAs which are being used for comparing alternative products.

For impact assessment, IMPACT 2002+ version 2.14 methodology has been considered for this LCA study. IMPACT 2002+, acronym of IMPact Assessment of Chemical Toxics, is an impact assessment methodology originally developed at the Swiss Federal Institute of Technology - Lausanne (EPFL), with current developments carried out by the same team of researchers now under the name of ecointesys-life cycle systems (Lausanne). This methodology proposes a feasible implementation of combined midpoint and damage approaches, linking all types of life cycle inventory results (elementary flows and other interventions) via 14 midpoint categories to four damage (endpoint) categories. The IMPACT 2002+ method (version 2.14) presently provides 15 different midpoint impact categories, as human toxicity is split up in 'Carcinogens' and 'Non-carcinogens'. The respective damage units are DALY (disability-adjusted life year) for Human health, PDF*m^2*yr (potentially disappeared fraction of species) for Ecosystem quality, kg eq CO_2 into air (written "kg CO_2 eq") for Climate change and MJ primary non-renewable (written "MJ primary") for Resources.

2.2 Data Inventories

The Life Cycle Inventory (LCI) building is a fundamental basis necessary to carry out environmentally based assessment LCA. The LCI is a holistic view of the inputs and outputs for a given system such as SOA systems/materials and Geo-Coat systems/technologies for different geothermal components to carry out a cradle to gate LCA analysis. The inventories of all other production processes for making different geothermal components using SOA and Geo-Coat substrate materials are not considered in this LCA study as they both follow similar production processes.

The elemental composition (in wt%) of different SOA and Geo-Coat substrate materials used for pipes, turbine components and well casings are given in Table 2.1.

Table 2.1 - Elemental composition of relevant SOA and Geo-Coat substrate materials in wt%

Elements	Elemental composition of SOA and Geo-Coat substrate materials in wt%					
	SOA materials			Geo-Coat substrate		
	630SS (S1)	A470 (S3)	Ti-6Al-4V (S1 &S4)	S235JR (S1)	304L (S4)	1.2746 (S3)
C	0.07	0.275	0.01	0.22	0.035	0.45
Mn	1	0.1	-	1.6	2	0.7
Si	1	0.12	-	0.05	1	0.25
P	0.04	0.006	-	0.05	0.045	0.025
S	0.03	0.002	-	-	0.03	0.02
Cu	4.0	0.1	-	-	-	-
N	-	-	0.01	-	-	-
Al	-	0.01	6.2	-	-	-
Cr	16.25	1.4	-	-	19	1.5
Ni	4.0	4.0	-	-	10	4.0
Ti	-	-	89.48	-	-	-
Fe	73.31	92.227	0.18	98.08	67.89	91.765
V	-	0.25	4	-	-	0.5
O	-	-	0.12	-	-	-
Nb	0.3	0.035	-	-	-	-
Mo	-	1.45	-	-	-	0.79

The data inventory of the best coating materials (HEA2, HEA5, CA2,) and filler materials (SiC and TiB_2) for Ni- and Ti-MMC components comprising different elements in wt% are listed in Table 2.2.

Table 2.2 - Elemental composition of coating and filler materials in wt%

Elements/Chemical reagents	Composition of different elements/chemical reagents in wt%				
	Coating materials			Filler materials	
	HEA5	HEA2	CA2	SiC	TiB_2
C	-	-	9.5	30	-
Co	18.34	19.19	-	-	-
Al	8.55	-	-	-	-
Cr	16.18	19.19	70.5	-	-
Ni	18.26	19.19	20	-	-
Fe	17.38	19.19	-	-	-
Mo	21.29	23.24	-	-	-
Si	-	-	-	70	-
Ti	-	-	-	-	68.9
B	-	-	-	-	31.1

We have explored inventory data from ecoinvent version 3 database for various elements used in SOA, Geo-Coat substrate and coating materials. The dataset names have been selected from ecoinvent version 3 database for different elements and are listed in Table 2.3.

Table 2.3 – Ecoinvent dataset names of elements

Elements/chemical reagents	Dataset names
C	Carbon black {GLO}| production | APOS, U
Co	Cobalt {GLO}| production | APOS, U
Mn	Manganese {RER}| production | APOS, U
Si	Silicon, metallurgical grade {RoW}| production | APOS, U
P	Phosphorus, white, liquid {RER}| production | APOS, U
S	Sulfur {RoW}| natural gas production | APOS, U
Cu	Copper {RER}| production, primary | APOS, U
Cr	Chromium {RER}| production | APOS, U
Ni	Nickel, 99.5% {GLO}| smelting and refining of nickel ore | APOS, U
Fe	Ferrite {GLO}| production | APOS, U
Nb	Input from nature in ground
Mo	Molybdenum {RER}| production | APOS, U
Ti	Titanium, primary {GLO}| production | APOS, U
N	Input from nature in ground
B	Borax, anhydrous, powder {RER}| production | APOS, U
Al	Aluminium, primary, ingot {IAI Area, EU27 & EFTA}| production | APOS, U
V	Input from nature in ground
O	Input from nature in ground
Nb	Input from nature in ground

The CA2 coating powder has been deposited on Geo-Coat substrates (S235JR, 1.2746 and 304L) through HVOF thermal spraying method. The power levels for HVOF gun working with gases is 100 kW (OERLIKON Metco DJ9W) and other accessories (powder feeder, robotics, diamond jet and others) is 7.5 kW. In HVOF process with CA powders deposition, the main parameters are flow rates of oxygen, propane, air and powder feed rate. The data inventory for HVOF deposition method is given in Table 2.4.

Table 2.4 - HVOF deposition process data for CA2 coating materials

Process parameters and others	Unit	HVOF_CA2
Power of the HVOF thermal spraying system	kW	107.5
Total thickness of coating deposited over 1 m^2 area	µm	23
Time of deposition	min	100
coating powder flow rate	g/min	38
Total mass of the coating material deposited	g	3800
Oxygen flow rate	slpm	240
Propane flow rate	slpm	68
Air flow rate	slpm	375
Total electrical energy consumed (calculated)	kWh	179.2
Total oxygen consumed (calculated)	kg	34.3
Total propane consumed (calculated)	kg	13.7
Total air consumed (calculated)	m^3	37.5
Total propane consumed (calculated)	mol	310.6
Energy released during combustion of 1 mol of propane	kJ	2057
Total energy released due to propane consumed (calculated)	MJ	638.9

The HEA2 and HEA5 coating powders have been deposited onto Geo-Coat substrates (S235JR, 1.2746 and 304L) through Laser Cladding (LC) process. The main parameters for LC process are laser power, argon flow rate, and powder feeding rate. The number of passes 1 and 3 have been carried out for the deposition of HEA2 and HEA5 coating layers of 673 and 1690 µm thickness, respectively. The total deposition time for all corresponding passes for 1 m^2 coating area using laser head speed (10 mm s^{-1}) and the distance between tracks of 0.71 mm has been calculated as 2347 and 7042 minutes, respectively for HEA2 and HEA5 samples. The data inventory of LC deposition process for HEA2 and HEA5 coating materials are given in Table 2.5.

Table 2.5 - LC deposition process data for HEA2 and HEA5 coating materials

Process parameters and others	Unit	LC_HEA2	LC_HEA5
Power of LC machine	kW	0.55	0.55
Total thickness of coating deposited over 1 m^2 area	µm	673	1690
Time of deposition	min	2347	7042
Powder flow rate	g/min	2	2
Total mass of the coating material deposited (calculated)	g	4694	14084
Argon (consumable) flow rate	slpm	9.5	10
Total argon consumed (calculated)	sl	22297	70420
Total mass of argon (calculated)	kg	33.44	105.63

It is assumed that the average transportation distance is 200 km for calculating the transportation flow. Using the inventory data in tables 2.2, 2.3, 2.4, and 2.5, the coating mass, energy and transportation flows have been evaluated for 1 µm thick coating deposition over 1 m^2 area and listed in Table 2.6.

Table 2.6 - Coating mass, consumables, energies, transportation flows for 1 µm thick coating material deposition over 1 m^2 Geo-Coat substrate area.

Coating system	Coating mass	Mass of the consumables	Electrical energy	Transportation	Heat energy due to propane	Compressed air
	(kg)	(kg)	(kWh)	(tkm)	(MJ)	(m^3)
LC_HEA2	0.0697	0.0497	0.0320	0.0099	-	-
LC_HEA5	0.0083	0.0625	0.0382	0.0125	-	-
HVOF_CA2	0.1652	1.4911	7.7899	0.2982	27.78	1.63

In the Geo-Coat project, we are also developing Ti- and Ni-MMCs based components for pump impellers. Geo-Coat consortium partners (TWI & WEIR) have developed a novel Ti MMC with an approximate 100% increase in hardness which can be used as base material for high temperature pumps. The Ti MMC based pump can be used up to 350°C with an extended service life up to 8 to 10 years. For pump impellers, no coating material has been applied. The SOA component systems (S5: IN625 and Ti64) are replaced by the best Geo-Coat technologies/systems (HIP_IN625+10% SiC and HIP_Ti64+10% TiB_2 MMC components). For comparisons of LCIA impacts with and without adoption of Geo-Coat technology, 1 cm^3 volume of the materials of the SOA (S5) and Geo-Coat systems has been considered. SimaPro 9.0.0.49 LCA tool evaluated the LCIA results for 1 cm^3 volume of SOA systems and MMC components using LCIA methodology IMPACT 2002+ version 2.14 and the ecoinvent version 3 database for comparisons of the environmental impacts. The data inventories of these SOA and Geo-Coat systems are given in Tables 2.7-2.8.

Table 2.7 – Basic data of Ni-based and Ti-based alloys of S5 (SOA system)

Substrate	Material type	SOA system	Density	Volume	Mass
			(kg m^{-3})	(cm^3)	(g)
S5	Ni-based alloy	IN625	7794	1	7.794
S5	Ti-based alloy	Ti64	4510	1	4.510

Table 2.8 - Mass, energy and transportation flows for a functional volume of 1 cm^3 of Geo-Coat systems

Geo-Coat systems	Mass of Ni-/Ti-MMCs	Filler mass	Energy consumed for HIP process	Energy consumed for machining	Total electrical energy consumed	Transportation
	(g)	(g)	(kWh)	(kWh)	(kWh)	(tkm)
HIP_IN625+10%SiC	11.6	1.16	1.39	0.02	1.41	0.003
HIP_Ti64+10%TiB2	6.7	0.67	0.92	0.02	0.94	0.002

2.3 LCA Modelling Results

2.3.1 LCIA results for 1 kg of SOA and Geo-Coat substrate materials

Using the inventory data given in Table 2.1 and the respective ecoinvent datasets (Table 2.3), the environmental impacts (LCIA results) for 1 kg of the SOA systems (630SS, Ti-6Al-4V, A470) and Geo-Coat substrates (S235JR, 1.2746 and 304L) have been evaluated and calculated using SimaPro 9.0.0.49 LCA tool considering the impact assessment methodology IMPACT 2002+ version 2.14.

The snapshots of the SimaPro platform for SOA_630SS_1kg and Geo-Coat substrate (GCS) GC_S1&S6_S235JR_1kg are shown in Figures 2.4 and 2.5, respectively.

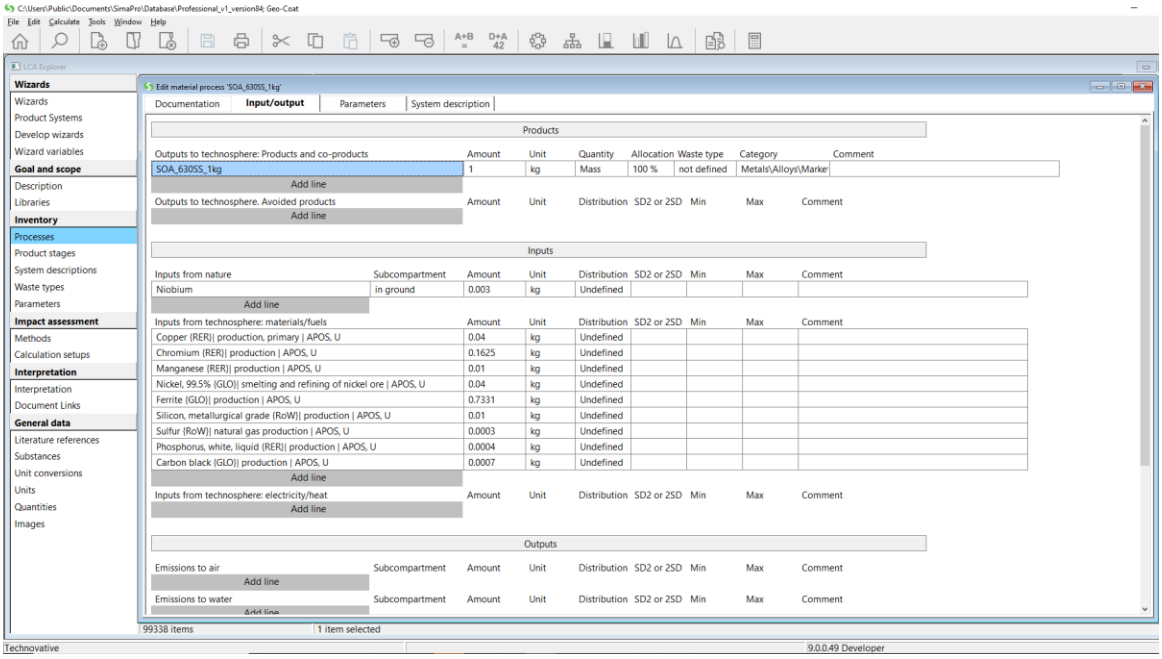


Figure 2.4 - A snapshot from the SimaPro dashboard of data inventory for 1 kg of 630SS material

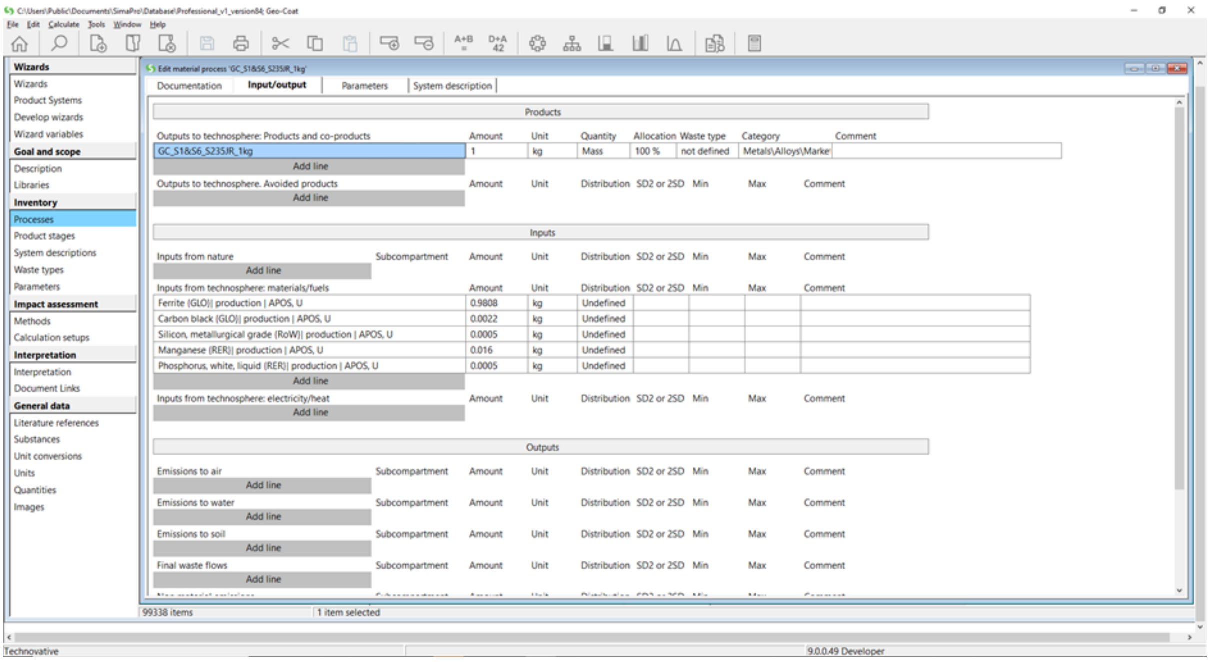
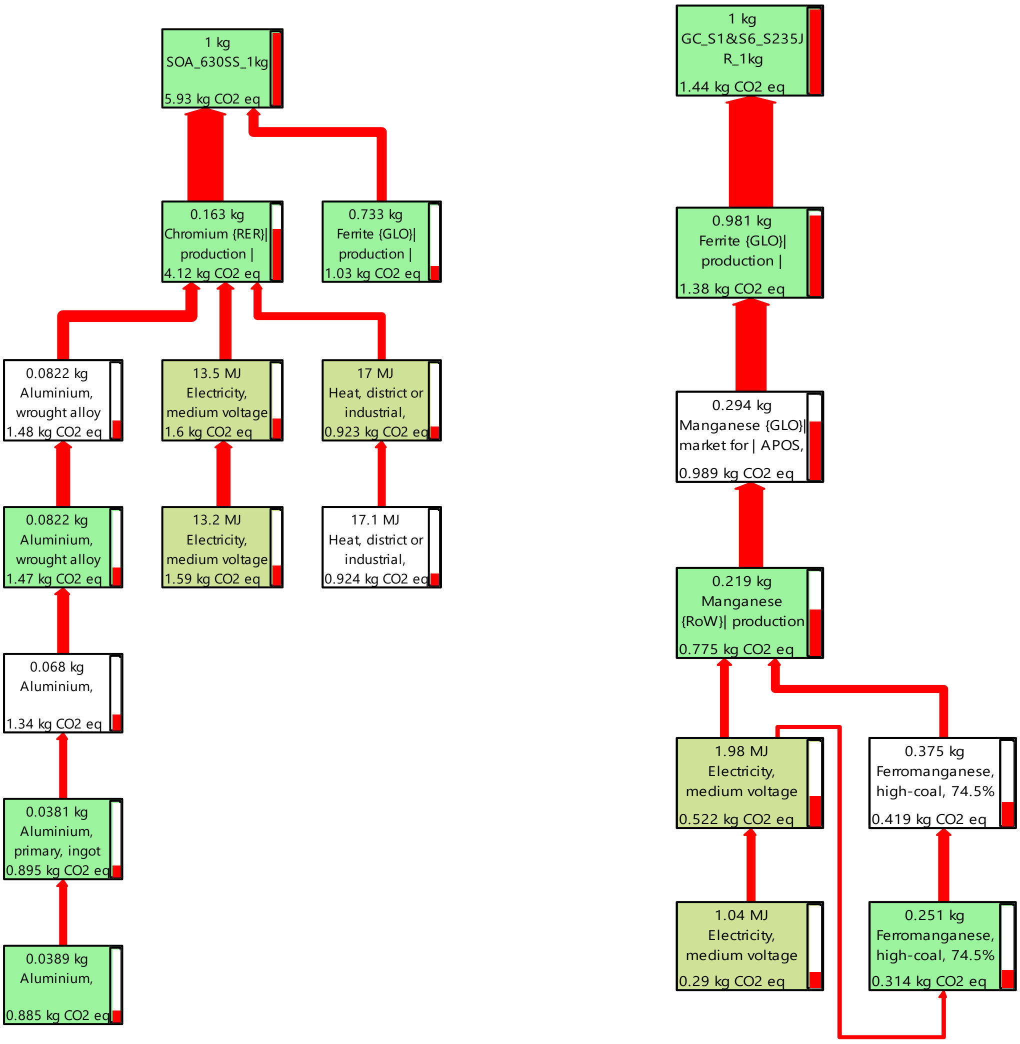


Figure 2.5 - A snapshot from the SimaPro dashboard of data inventory for 1 kg of S235JR material

The network model of climate change damage category for 1 kg of 630SS (SOA) and S235JR (GCS) materials are shown in Figures 2.6 (a) and (b) respectively.



(a) (b)

Figure 2.6 - A part of the climate change network models for 1 kg of (a) 630SS (SOA) and (b) S235JR (Geo-Coat substrate).

The LCA tool calculated 15 mid-point and 4 endpoint damage categories for 1 kg SOA and Geo-Coat substrate materials using IMPACT 2002+ LCIA methodology. The quantification of the LCIA results for mid-point impact and endpoint damage categories of these materials with respective units are given in Tables 2.9 and 2.10, respectively.

Table 2.9 – Quantification of LCIA results of 15 midpoint impact categories of relevant state-of-the-art (SOA) materials and Geo-Coat substrates (GCS) for unit mass of 1 kg

Midpoint Impact categories	Unit	630SS (SOA)	A470 (SOA)	304L (GCS)	Ti-6Al-4V (SOA)	IN625 (SOA)	S235JR (GCS)	1.2746 (GCS)
Carcinogens	kg C2H3Cl eq	0.08	0.05	0.12	0.37	0.43	0.02	0.04
Non-carcinogens	kg C2H3Cl eq	0.15	0.10	0.20	0.49	0.76	0.03	0.08
Respiratory inorganics	kg PM2.5 eq	0.02	0.03	0.04	0.05	0.21	0.01	0.02
Ionising radiation	Bq C-14 eq	107.07	38.00	84.66	340.33	284.41	19.63	34.67
Ozone layer depletion	kg CFC-11 eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Respiratory organics	kg C2H4 eq	0.00	0.00	0.00	0.01	0.02	0.00	0.00
Aquatic ecotoxicity	kg TEG water	1301.67	4553.37	1752.27	1374.71	27495.98	344.89	2649.70
Terrestrial ecotoxicity	kg TEG soil	245.25	1223.36	448.50	284.64	7401.72	97.88	717.62
Terrestrial acid/nutri	kg SO2 eq	0.17	0.28	0.40	0.43	2.40	0.04	0.21
Land occupation	m2org.arable	0.11	0.22	0.12	0.36	2.29	0.05	0.15
Aquatic acidification	kg SO2 eq	0.08	0.09	0.29	0.14	1.06	0.01	0.08
Aquatic eutrophication	kg PO4 P-lim	0.00	0.08	0.00	0.01	0.53	0.00	0.05
Global warming	**kg CO2 eq**	**5.93**	**3.25**	**7.82**	**27.92**	**25.62**	**1.44**	**2.83**
Non-renewable energy	MJ primary	90.15	43.43	105.11	381.54	352.92	19.98	38.50
Mineral extraction	MJ surplus	1.79	24.88	5.95	0.50	154.97	0.29	13.65

Table 2.10 – The quantification of LCIA results of 4 endpoint damage categories of relevant state-of-the-art (SOA) materials and Geo-Coat substrates (GCS) for unit mass of 1 kg

Endpoint Damage categories	Unit	630SS (SOA)	A470 (SOA)	304L (GCS)	Ti-6Al-4V (SOA)	IN625 (SOA)	S235JR (GCS)	1.2746 (GCS)
Human health	DALY	0.000011	0.000020	0.000026	0.000034	0.00	0.000004	0.000015
Ecosystem quality	PDF*m2*yr	2.30	10.44	4.19	3.16	64.93	0.88	6.19
Climate change	**kg CO2 eq**	**5.93**	**3.25**	**7.82**	**27.92**	**25.62**	**1.44**	**2.83**
Resources	MJ primary	91.95	68.31	111.06	382.04	507.89	20.28	52.16

It is seen from Table 2.10 that the SOA material Ti-6Al-4V and GCS material S235JR showed worst and best environmental performances in climate change damage category, respectively. The worst carbon footprint performance of SOA material Ti-6Al-4V is mainly due to a large proportion (89.48%) of Ti material present in this alloy.

2.3.2 LCIA results for 1 µm thick selected coatings over 1 m^2 area

The environmental impacts (LCIA results) for 1 µm thick Geo-Coat selected coatings (LC_HEA2, LC_HEA5, HVOF_CA2) over 1 m^2 surface area, using SimaPro 9.0.0.49 LCA tool with an IMPACT 2002+ version 2.14 LCIA methodology and ecoinvent version 3 database, have been evaluated.

The LCI data of synthesised coatings was mainly collected from primary sources. Some data are estimated and calculated from secondary sources. The secondary data come from literature sources, being specific to either a product, material or process in question. The substrate surface preparation data such as grit blasting time, flow rate, etc before HVOF thermal spraying process have been considered from the secondary source[8]. For those processes, secondary data were lacking, modelled data or assumptions were used as defaults. All the collected data were normalised to the study functional unit of 1 µm thick coating over 1 m² substrate area and then imported into SimaPro9.0.0.49, a commercially available LCA tool. The SimaPro9.0.0.49 tool stores and organises life-cycle inventory and calculates life cycle impacts for a product profile. It is designed to allow flexibility in conducting life-cycle design and cradle to gate LCA functions, and to provide the means to organise inventory data, investigate alternative scenarios, evaluate impacts, and assess data quality.

The snapshots of the SimaPro platform for HEA2_1kg, LC_HEA2_Coating&Deposition and HVOF_CA2_CoatingSystem_1 µm thick over 1 m² area are shown in Figures 2.7, 2.8 and 2.9, respectively.

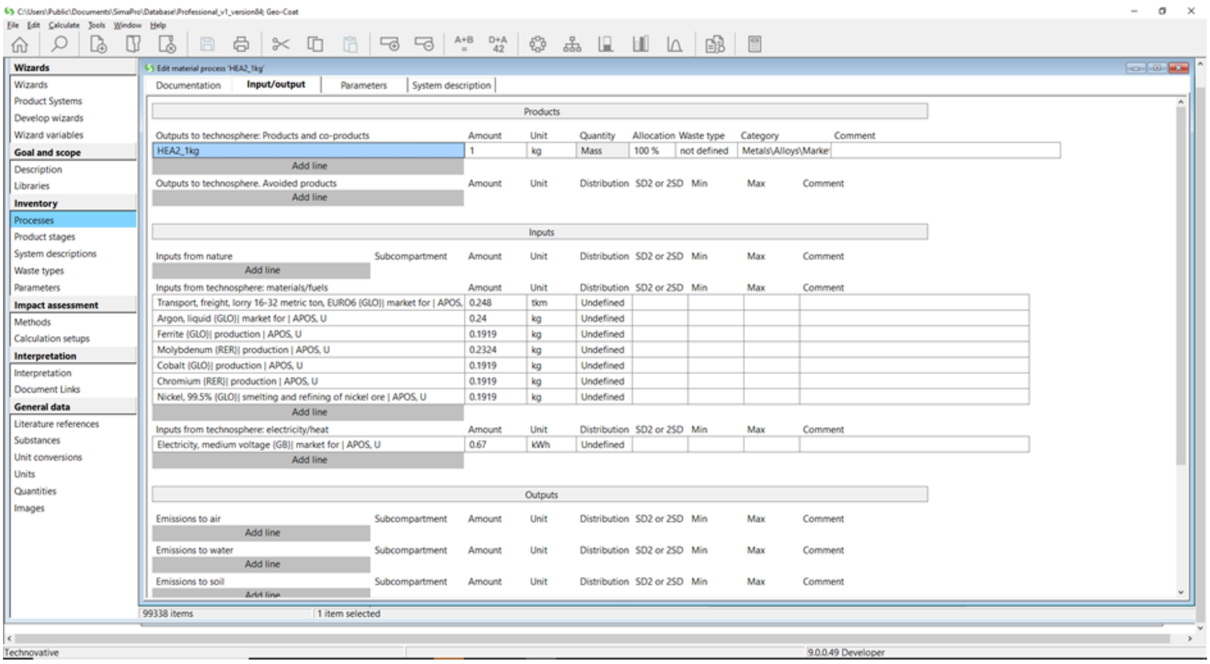


Figure 2.7 - A snapshot from the SimaPro dashboard of data inventory for 1 kg of HEA2 coating material

[8] ASM Handbook, volume 5A, Thermal spray technology 2013 www.asminternational.org; accessed 18 December, 2018.

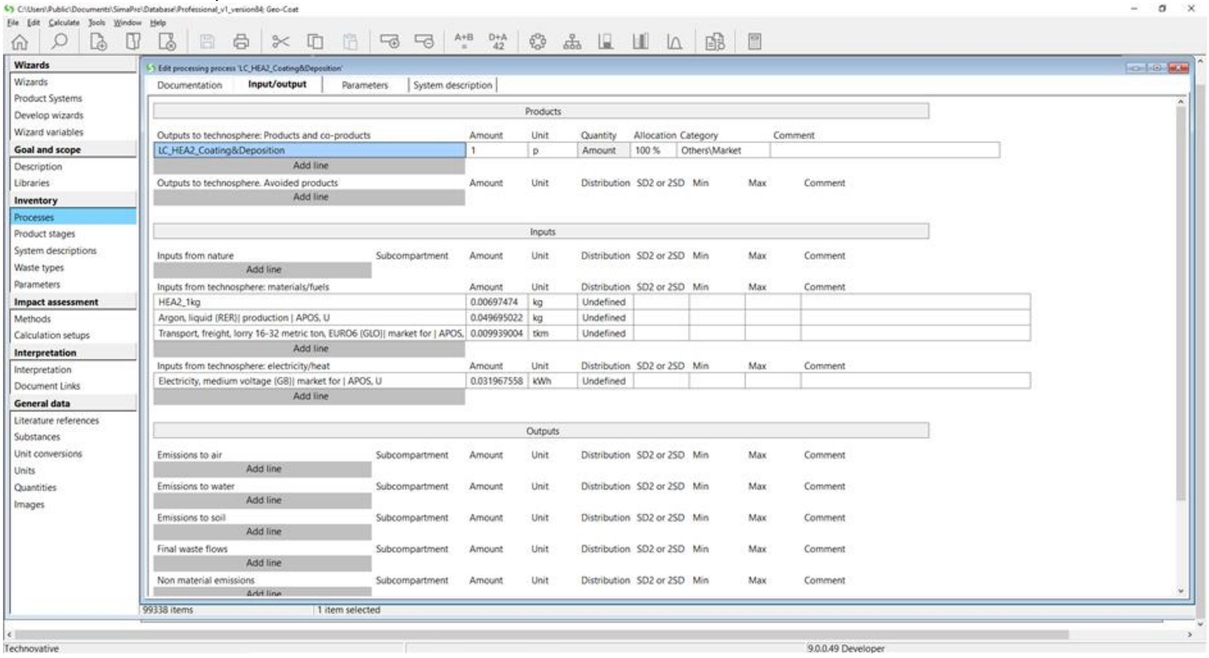


Figure 2.8 - A snapshot from the SimaPro dashboard of data inventory for LC_HEA2 coating deposition

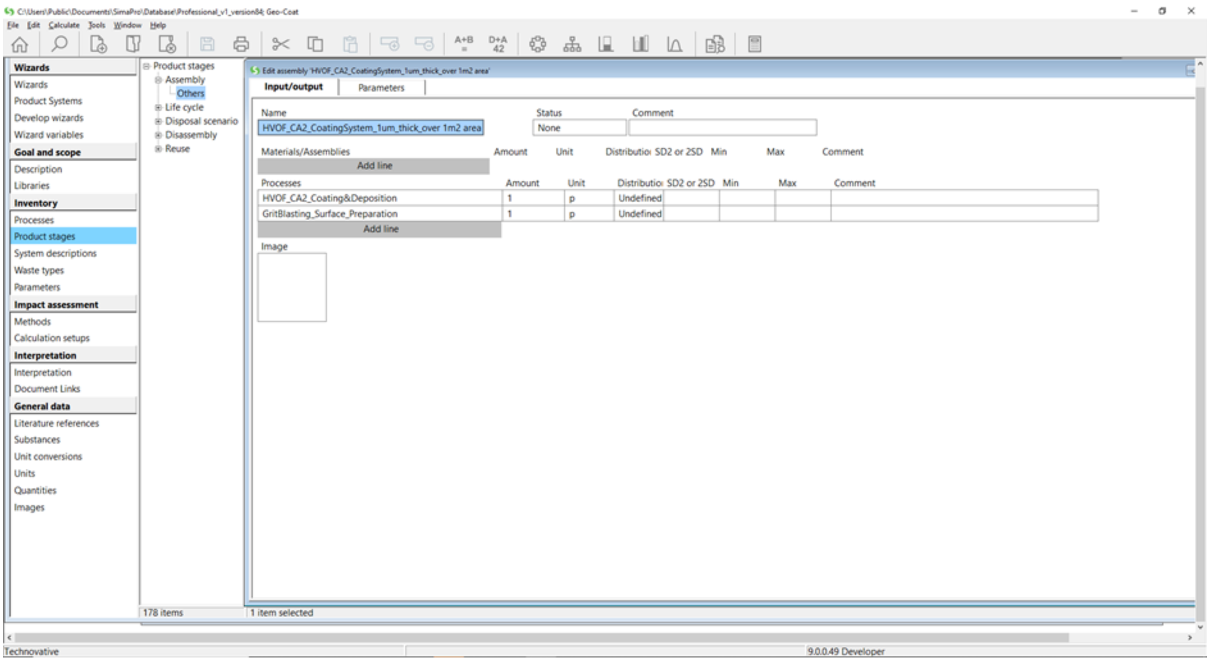


Figure 2.9 - A snapshot from the SimaPro dashboard of data inventory for 1 µm thick HVOF_CA2 coating system over 1 m^2 area

We have modelled substrate surface preparation and coating deposition processes to analyse the LC_HEA2, LC_HEA5, HVOF_CA2 synthesised coatings (each of 1 µm thick) deposited over 1 m^2 area of substrate. The cradle to gate LCA analyses of these coating systems have been performed using SimaPro 9.0.0.49, considering the impact assessment method IMPACT 2002+ version 2.14.

Using the inventory data of coating materials, coating deposition presented in Tables 2.2, 2.3 and 2.6, LCA analyses of three coating systems (LC_HEA2, LC_HEA5, HVOF_CA2) each of 1µm thick over 1 m^2 area have been performed. Figure 2.10a-b show a part of climate change network models of LC_HEA2 and LC_HEA5, synthesised coatings each of 1 µm thick deposited over 1 m^2 area.

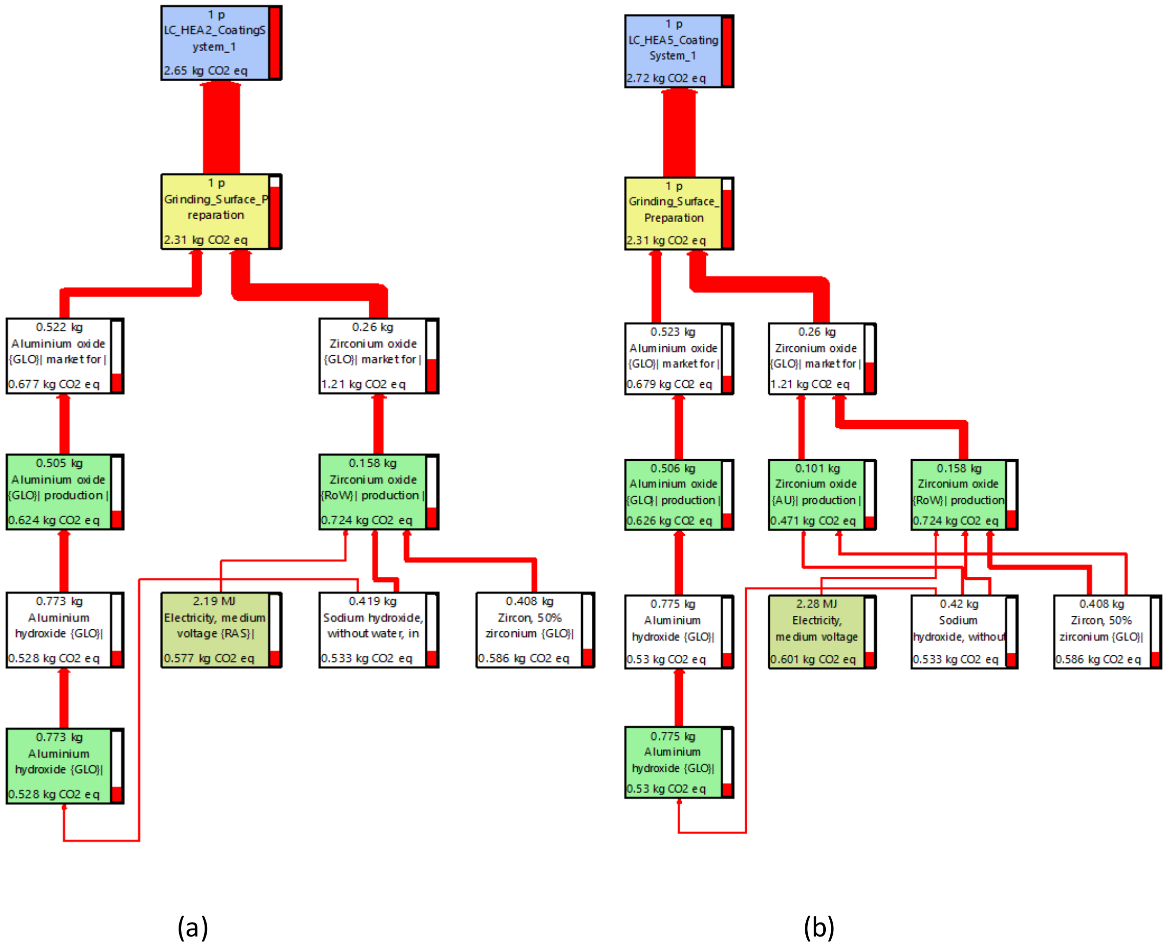


Figure 2.10 – Network models of climate change damage category of (a) LC_HEA2 (18.2% cut-off showing 11 nodes out of 11611 nodes)and (b) LC_HEA5 coating deposition for 1 µm thick over 1 m^2 area (17.3% cut-off showing 12 nodes out of 11611 nodes).

The LCA tool calculated 15 mid-point impact and 4 endpoint damage categories for LC_HEA2, LC_HEA5 and HVOF_CA2 coating systems each of 1 µm thick over 1 m^2 area using IMACT2002+ version 2.14 methodology. The quantification of the LCIA results for mid-point impact categories and endpoint damage categories of these coating systems with respective units are given in Tables 2.11 and 2.12, respectively.

Table 2.11 - Quantification of LCIA results of 15 midpoint impact categories for coating systems (LC_HEA2, LC_HEA5, HVOF_CA2) each of 1 µm thick over 1 m² area.

Midpoint Impact categories	Unit	LC_HEA2	LC_HEA5	HVOF_CA2
Carcinogens	kg C2H3Cl eq	0.036751	0.037574	0.111591
Non-carcinogens	kg C2H3Cl eq	0.170545	0.172319	0.354912
Respiratory inorganics	kg PM2.5 eq	0.005667	0.005951	0.015124
Ionising radiation	Bq C-14 eq	24.15917	25.12143	188.6411
Ozone layer depletion	kg CFC-11 eq	4.68E-07	4.72E-07	1.14E-06
Respiratory organics	kg C2H4 eq	0.000747	0.000777	0.001723
Aquatic ecotoxicity	kg TEG water	854.9278	904.1822	1104.921
Terrestrial ecotoxicity	kg TEG soil	180.2652	193.2466	259.6976
Terrestrial acid/nutri	kg SO2 eq	0.073984	0.076918	0.23667
Land occupation	m2org.arable	0.085915	0.08853	0.262873
Aquatic acidification	kg SO2 eq	0.021648	0.02243	0.107501
Aquatic eutrophication	kg PO4 P-lim	0.009664	0.010539	0.003199
Global warming	**kg CO2 eq**	**2.653318**	**2.719581**	**13.84788**
Non-renewable energy	MJ primary	36.19326	37.12138	207.8143
Mineral extraction	MJ surplus	3.542034	3.803344	1.353972

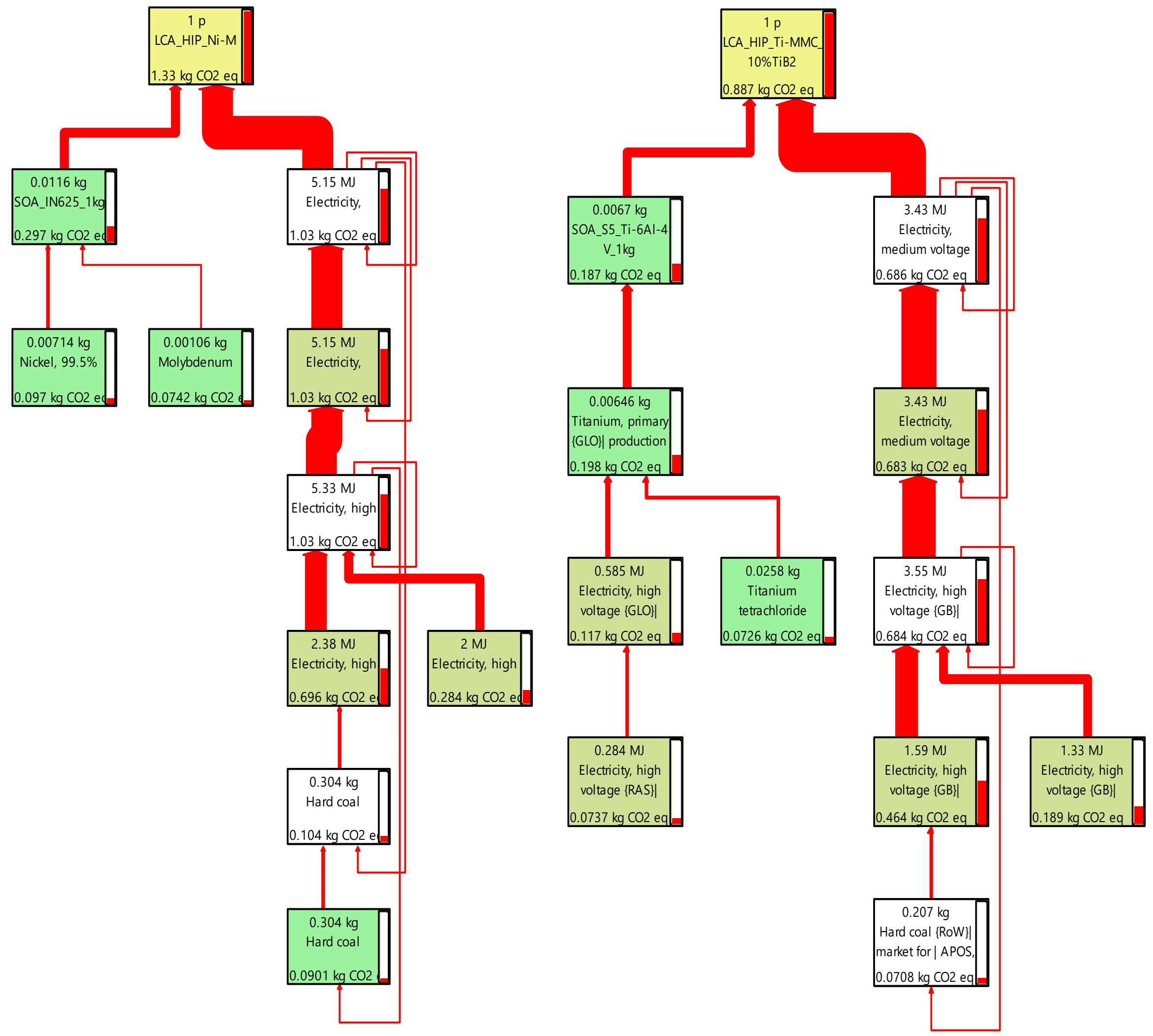
Table 2.12 - Quantification of LCIA results of 4 endpoint damage categories for coating systems (LC_HEA2, LC_HEA5, HVOF_CA2) each of 1 µm thick over 1 m² area.

Endpoint Damage categories	Unit	LC_HEA2	LC_HEA5	HVOF_CA2
Human health	DALY	4.55E-06	4.76E-06	1.19E-05
Ecosystem quality	PDF*m2*yr	1.639406	1.750463	2.642342
Climate change	**kg CO2 eq**	**2.653318**	**2.719581**	**13.84788**
Resources	MJ primary	39.73529	40.92472	209.1683

It is clearly seen from Table 2.12 that the CA2 coating material deposited through HVOF process produced more environmental impacts as compared with HEA materials deposited through LC process except human health damage category. It is mainly due to the consumptions of large electrical (7.79 kWh) and heat (27.78 MJ) energies involved in HVOF process. Hence, HVOF process is more energy-intensive than that of LC process.

2.3.3 LCIA results for 1 cm³ volume of HIP_IN625+10%SiC and HIP_Ti64+10%TiB2 MMC components compared with IN625 and Ti64 SOA systems

Using the inventory data given in Tables 2.1, 2.2, 2.7 and 2.8 and the ecoinvent datasets (Table 2.3), the environmental impacts (LCIA results) for 1 cm³ volume of HIP_IN625+10%SiC and HIP_Ti64+10%TiB2 MMC have been evaluated and calculated using SimaPro 9.0.0.49 LCA tool considering the impact assessment methodology IMPACT 2002+ version 2.14. Figure 2.11a-b show a part of climate change network models of HIP_IN625+10%SiC and HIP_Ti64+10%TiB2 MMC components each of volume 1 cm³.



(a) (b)

Figure 2.11 - A part of climate change network models of (a) HIP_IN625+10%SiC (5.4% cut-off showing 11 nodes out of 11610 nodes) and (b) HIP_Ti64+10%TiB_2 (7.8% cut-off showing 12 nodes out of 11610 nodes) MMC components each of volume 1 cm^3

The quantification of the LCIA results of mid-point impact categories and endpoint damage categories of these MMC components along with IN625 and Ti64 substrate materials each of volume of 1 cm^3 with respective units are given in Tables 2.13 and 2.14, respectively.

Table 2.13 - LCIA results of HIP_IN625+10%SiC, HIP_Ti64+10%TiB2 MMC components, IN625 and Ti64 for the volume of 1 cm^3

Impact category	Unit	IN625	Ti64	HIP_IN625+10%SiC	HIP_Ti64+10%TiB2
Carcinogens	kg C2H3Cl eq	0.0034	0.0017	0.0094	0.0056
Non-carcinogens	kg C2H3Cl eq	0.0059	0.0022	0.0273	0.0158
Respiratory inorganics	kg PM2.5 eq	0.0016	0.0002	0.0031	0.0008
Ionising radiation	Bq C-14 eq	2.2192	1.5361	11.4593	7.7310
Ozone layer depletion	kg CFC-11 eq	0.0000	0.0000	0.0000	0.0000
Respiratory organics	kg C2H4 eq	0.0002	0.0000	0.0003	0.0001
Aquatic ecotoxicity	kg TEG water	214.3351	6.2156	379.9200	50.3757
Terrestrial ecotoxicity	kg TEG soil	57.7142	1.2963	102.4680	13.0827
Terrestrial acid/nutri	kg SO2 eq	0.0187	0.0019	0.0419	0.0124
Land occupation	m2org.arable	0.0179	0.0016	0.0568	0.0227
Aquatic acidification	kg SO2 eq	0.0083	0.0006	0.0174	0.0043
Aquatic eutrophication	kg PO4 P-lim	0.0041	0.0000	0.0063	0.0001
Global warming	**kg CO2 eq**	0.2000	0.1261	1.3323	0.8870
Non-renewable energy	MJ primary	2.7559	1.7234	18.7770	12.4722
Mineral extraction	MJ surplus	1.2079	0.0023	1.8029	0.0070

Table 2.14 - LCIA results of HIP_IN625+10%SiC, HIP_Ti64+10%TiB2 MMC components, IN625 and Ti64 for the volume of 1 cm^3

Damage category	Unit	IN625	Ti64	HIP_IN625+10%SiC	HIP_Ti64+10%TiB2
Human health	DALY	0.0000	0.0000	0.0000	0.0000
Ecosystem quality	PDF*m2*yr	0.5063	0.0144	0.9351	0.1436
Climate change	**kg CO2 eq**	0.2000	0.1261	1.3323	0.8870
Resources	MJ primary	3.9638	1.7256	20.5800	12.4792

From the LCIA results in Table 2.14, it is shown that HIP_Ti64+10%TiB2 and HIP_IN625+10%SiC MMC components have about 7.0 and 6.7 times more environmental footprint in context of climate change damage category than those of Ti64 and IN625 alloys, respectively. These large carbon footprints arise mainly due to the large consumption of electrical energy involved in the HIP consolidation method.

3. LCA IMPACT STUDIES OF GEOTHERMAL PLANTS BASED ON DIFFERENT POWER TECHNOLOGY OPTIONS

3.1 Goal and scope

In the Geo-Coat project, various geothermal components such as pipes & casings (S1), valve stem & turbine blades (S2), turbine rotors (S3), turbine blades (S4), pump impellers (S5) and heat exchanger tubes (S6) of the geothermal power plants have been proposed for the applications of the best Geo-Geo-Coat technologies/Geo-Coat systems. It is recommended to use the best ranked Geo-Coat systems as alternatives to SOA (state-of-the-art) materials for maintaining the integrity of these components during the lifetime of future geothermal power plant. Two Icelandic geothermal power plants, the 303 MW Hellisheidi double flash (Icelandic Case Study1: ICS1) and the 66 MW Svartsengi dry steam & single flash (Icelandic Case Study 2: ICS2), and One Romanian power plant, the 50 kW Transgex-Oradea binary type (Romanian Case Study: RCS), have been considered for the assessment of the environmental impacts with and without adoption of Geo-Coat technology applied for pipes & well casings (S1) and turbine components (S3 and S4).

The amount of electrical energy generated is dependent on the installed capacity of the plant, usually expressed in MW. Therefore, the functional unit of the LCA impact study of geothermal power plant is the 1 MW installed capacity of the geothermal power plant.

First, we have explored the dimensions, length and diameters of different geothermal components such as pipes, well casings, and turbine components employed for ICS1, ICS2 and RCS power plants and calculated the mass and inner surface area per unit length based on the primary data provided by the consortium partners (section 3.2). Then, we have calculated the total mass flows of the SOA and Geo-Coat substrate materials for different geothermal components employed in ICS1, ICS2 and RCS power plants. The coating volume flows for different components have been obtained using the calculated total inner surface areas and the coating thickness, and the respective coating mass flows have been calculated using the volume and density of the coating material. For cradle to gate LCA analysis, the respective SOA and Geo-Coat substrate material mass flows and coating material mass flows in terms of functional unit of 1 MW installed capacity have been evaluated for surface pipes, turbines and well casing components of ICS1, ICS2 and RCS.

The main goal of the LCA impact studies is to provide the environmental performances with and without the adoption of Geo-Coat technology applied for geothermal components considering ICS1, ICS2 and RCS power plants at the installation phase.

The following goals should be achieved:

- Quantify and evaluate the environmental impacts of the SOA materials and Geo-Coat systems (Geo-Coat substrate plus ranked coating) used for geothermal components such as pipes, turbine components and well casings.
- Compare the total environmental impacts with and without the adoption of Geo-Coat systems for Icelandic and Romanian case studies for a functional unit of 1 MW of installed capacity .
- Use this study as a marketing tool for policymakers, stakeholders, and environmental agencies.

The intended audiences for this study are listed below:

- Geothermal pipe manufacturers
- Turbine manufacturers
- Well casing manufacturers
- Stakeholders of the geothermal plants
- Policymakers in the geothermal industry
- Consortium members
- Environmental agencies
- European Commission

We will perform cradle to gate LCA analysis in this study. We are not considering the operating phase and decommissioning phase. In this study, we will be analysing the power plants of different types of power technologies such as combined single flash and dry steam, double flash and binary. The scope of the study is to establish the baseline information to produce SOA and Geo-Coat systems employed for pipes, well casings and turbine rotors and blades and then to compare the environmental impacts of the power plants with and without adoption of the Geo-Coat technology. The scope of the study includes:

- Manufacturing of raw materials for SOA systems and Geo-Coat substrates. The manufacturing processes for making the geothermal components using SOA and Geo-Coat substrate (GCS) materials are not included in this LCA study because they follow similar production processes.
- Coating elements and processes used to manufacture two different types of coating materials: High Entropy Alloys (HEAs) and Cermet Alloys (CAs). Manufacturing of infrastructure equipment, e.g. equipment used for mechanical alloying, gas atomisation etc, is excluded from the LCA study due to the non-availability of data for the manufacturing equipment.
- Different coating deposition processes used for different coating materials. There are two coating deposition processes: HVOF (High Velocity Oxy-Fuel) thermal spraying, and LC (Laser Cladding). We exclude the manufacture of the infrastructure equipment (e.g. spray gun, powder feeder, robotics, electroplating tanks, etc) due to the non-availability data of the ancillary equipment.
- Two substrate surface preparation methods are considered: grit blasting method for HVOF process and grinding surface treatment method for LC process. Manufacturing of the grit blasting and grinding machines are not included in the LCA study due to the non-availability of data for the associated equipment.

Most of the life cycle inventory (LCI) data for SOA and Geo-Coat systems were obtained from primary sources and ecoinvent version 3 database. Environmental institutions have taken the initiative to develop LCI background database to provide standard data to LCA assessors. The databases are continuously updated and maintained to ensure that the LCI data are up-to-date, consistent, and reliable. The ecoinvent version 3 database covers more than 15,000 processes for areas including energy, transportation, waste disposal, construction, chemicals, detergents, paper and board, agriculture and waste management. It is the most widely used LCI database in Europe. Each process is available in two versions, i.e. unit processes and system processes. A unit process contains emission and resources inputs from a single process step, and refers to input from other unit processes. In a system process, the emissions from all the phases are included in a black-box format. In this LCA study, we used ecoinvent version 3 database and unit processes linked to SimaPro9.0.0.49 LCA tool.

For LCI result and LCIA result data sets and for full LCAs, the system boundaries should ideally be set in a way that all flows crossing the boundaries are exclusively elementary flows plus the reference (product) flow(s). Figure 3.1 shows the different boundary systems. In this study, a cradle-to-gate system boundary has been considered for LCA analyses.

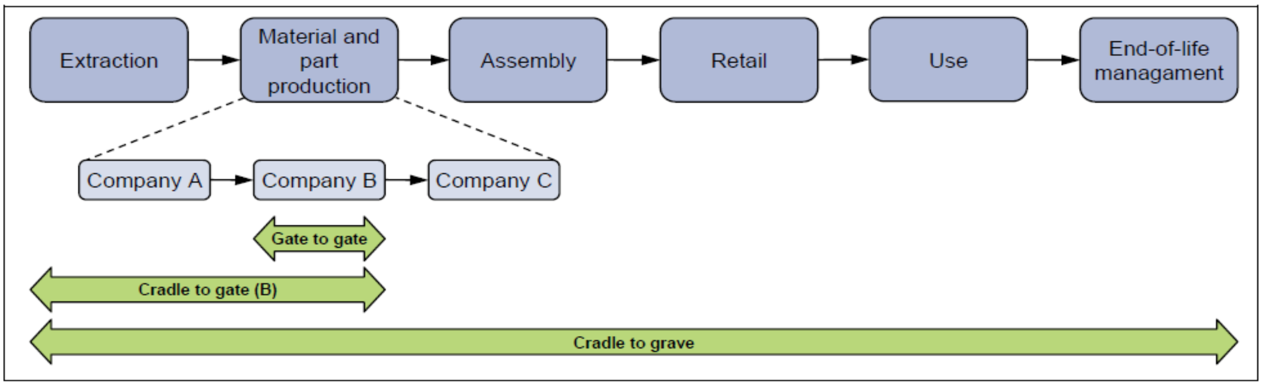


Figure 3.1 - Cradle to grave, cradle to gate and gate to gate data sets as parts of the complete life cycle; schematic. Each type fulfils a specific function as module for use in other LCA studies.

Due to unavailability of some primary processing data and the specifications of ancillary equipment, we have calculated and estimated the data based on secondary sources.

The LCIA modelling results for the unit mass of SOA and Geo-Coat substrate materials have been evaluated and given in subsection 2.3.1. The LCIA modelling results for 1 µm thick 1st and 2nd ranked coatings over 1 m^2 Geo-Coat substrate area have also been evaluated and given in subsection 2.3.2. Using these LCIA modelling results (15 mid-point impact categories and 4 endpoint damage categories), the environmental impacts for ICS1, ICS2 and RCS power plants with and without adoption of Geo-Coat systems have been evaluated and analysed, considering the functional unit of 1 MW installed capacity of these plants.

3.2 Data inventories for geothermal components of Icelandic and Romanian power plants

For LCA impact studies, the 1st and 2nd ranked Geo-Coat systems have been considered for pipes, turbine and well casing components of ICS1[a] case study and the 2nd ranked Geo-Coat systems have been considered for those components of ICS2[b] and RCS[c] case studies. The basic data for these power plants are given in Table 3.1.

Table 3.1 - Basic data of ICS1, ICS2 and RCS geothermal power plants

Plant short name	Power (MW)	Plant type	Geo-Coat systems adopted for		
			Turbines (S3-S4)	Well casings (S1)	Surface Pipes (S1) (km)
ICS1	303	Double flash	7	44	49.5
ICS2	66	Combined Single flash & Dry steam	3	10	11.32
RCS	0.05	Binary	1	2	2.587

a : ICS1 – power plant unit numbers 1-6 & 11; b :ICS2 – power plant unit numbers 3,5 & 6; c :RCS: only one unit

The lengths and dimensions for different geothermal components of ICS1, ICS2 and RCS geothermal power plants were provided by the consortium partners ON power and ICI[9] and METAV R&D[10] (given in Appendix A). To ensure data confidentiality, the pipe length data have been deleted from the Tables 3.2-3.4. The masses per unit length of the pipe components made of 630SS (SOA) and S235JR (GCS) and their inner surface area per unit length have been calculated. Tables 3.2-3.4 list the masses per unit length of different pipe components made of SOA and Geo-Coat substrate materials and inner surface area per unit length of these components employed in ICS1, ICS2 and RCS plants, respectively.

[9] Personal communication with ON and ICI partners, March 2020.

[10] Personal communication with METAV R&D partner, February 2020.

Table 3.2 - Calculated masses and inner surface areas per unit length of different pipe components (S1) employed in ICS1 power plant.

Types of components	Length	Inner diameter	Outer diameter	Inner surface area per unit length	Mass per unit length	
					630SS (SOA)	S235JR (GCS)
	(m)	(mm)	(mm)	($m^2\ m^{-1}$)	($kg\ m^{-1}$)	($kg\ m^{-1}$)
2-phase pipes	deleted	263	273	0.83	33.61	33.18
	deleted	494	508	1.55	87.96	86.83
	deleted	689	711	2.16	193.13	190.64
	deleted	994	1016	3.12	277.29	273.71
Steam pipes	deleted	994	1016	3.12	277.29	273.71
	deleted	1428	1462	4.48	616.15	608.20
Brine pipes-I[a]	deleted	594	610	1.87	120.80	119.24
	deleted	695	711	2.18	141.06	139.24
	deleted	994	1016	3.12	277.29	273.71
Brine pipes-II[b]	deleted	494	508	1.55	87.96	86.83
	deleted	994	1016	3.12	277.29	273.71

a Brine pipes-I are made of carbon steel and b Brine pipes-II are made of stainless steel (Reference:Table A1)

Table 3.3 – Calculated masses and inner surface areas per unit length of different pipe components (S1) employed in ICS2 power plant.

Types of components	Length	Inner diameter	Outer diameter	Inner surface area per unit length	Mass per unit length	
					630SS (SOA)	S235JR (GCS)
	(m)	(mm)	(mm)	($m^2\ m^{-1}$)	($kg\ m^{-1}$)	($kg\ m^{-1}$)
2-phase pipes	deleted	392.2	406.4	1.23	69.84	68.94
Dry steam pipes	deleted	687	711	2.16	206.78	204.11
Steam pipes	deleted	687	711	2.16	206.78	204.11
Brine pipes	deleted	494	508	1.55	86.73	85.62

Table 3.4 - Calculated masses and inner surface areas per unit length of different pipe components (S1) employed in RCS power plant.

Types of components	Length	Inner diameter	Outer diameter	Inner surface area per unit length	Mass per unit length	
					630SS (SOA)	S235JR (GCS)
	(m)	(mm)	(mm)	($m^2\ m^{-1}$)	($kg\ m^{-1}$)	($kg\ m^{-1}$)
uncased pipes	deleted	195	215	0.6123	48.91	48.28
2-phase pipes	deleted	190	200	0.5966	23.83	23.52
Brine pipes	deleted	190	200	0.5966	23.83	23.52

Total masses of SOA and Geo-Coat substrate (GCS) materials consumed by different parts of the turbines employed in ICS1, ICS2 and RCS plants have been calculated using the dimensions and length of rotors and blades provided by consortium partners. The data inventories for these turbine components (S3-S4) of ICS1, ICS2 and RCS plants are listed in Table 3.5.

Table 3.5 - Data inventories for parts of turbine components (rotors: S3 and blades: S4) of ICS1, ICS2 and RCS power plants

Plant type and units	Turbine parts	Number of stages	Annular surface area	Recommended Materials		Mass of the materials (kg)	
			(m^2)	SOA	GCS	SOA	GCS
ICS1 (all units)	Rotor	6	13	A470	1.2746	11870	11755
	Blades	6	25	Ti-6Al-4V	304L	49610	96074
ICS2 (unit 3)	Rotor	2	2	A470	1.2746	1826	1808
	Blades	2	0.27	Ti-6Al-4V	304L	146	283
ICS2 (unit 5)	Rotor	10	10	A470	1.2746	9131	9042
	Blades	10	19	Ti-6Al-4V	304L	42845	82973
ICS2 (unit 6)	Rotor	14	11	A470	1.2746	10044	9947
	Blades	14	22	Ti-6Al-4V	304L	49610	96074
RCS	Rotor	2	1	A470	1.2746	913	904
	Blades	2	2	Ti-6Al-4V	304L	1082	2096

Well casing components have been used in the production wells of ICS1, ICS2 and RCS plants. The total masses of the well casing components have been calculated based on the primary data provided by the consortium partners and listed in Table 3.6.

Table 3.6 - Data inventories for well casing components (S1) of ICS1, ICS2 and RCS power plants.

Plant type and units	Number of production wells	Average length	Thickness	Outer diameter	Recommended material	
		(m)	(mm)	(mm)	SOA	GCS
ICS1	44	960	12	292	Ti-6Al-4V	S235JR
ICS2	10	1420	12	292	Ti-6Al-4V	S235JR
RCS	2	715	10	230	Ti-6Al-4V	S235JR

3.3 Double flash plant with and without adoption of Geo-Coat technology components: Icelandic Case Study 1

The Icelandic Hellisheiði power plant (ICS1) is a cogeneration plant of heat and power and is built up in modular units. The production from the first two 45 MW_e turbines started in 2006 (stage 1: units1 & 2). A low pressure 33 MW_e turbine unit was added in 2007 (stage 2: unit 11) and two additional 45 MW_e turbines built in 2008 (stage 3: units 3 & 4). The last two 45 MW_e turbines were put on line in late 2011 (stage 5: units 5 & 6). The first stage of heating plant of capacity of 133 MW_t was taken into operation (stage 4). The total capacity of the power plant is currently 303 MW_e and that of the thermal plant is 133 MW_t. The Hellisheiði power plant is generally classified as a single-flash plant although they have one low pressure unit, technically making it a double flash plant. In this plant, the different types of the surface pipes such as steam pipes, two-phase pipes and brine pipes-I and II with different dimensions have been used. The total length of the pipe network is 49.5 km. For LCA evaluation, 630SS has been considered as SOA system materials for the pipe network. For comparative LCA impact studies, ICS1 has been considered as the Icelandic example of double flash type geothermal power technology option with adoption of 1st ranked Geo-Coat systems (HVOF_CA2_S235JR, HVOF_CA2_1.2746, HVOF_CA2_304L) and 2nd ranked Geo-Coat systems (LC_HEA2_S235JR, LC_HEA2_1.2746, LC_HEA5_304L) and without adoption of Geo-Coat systems, i.e. with SOA systems (630SS, A470, Ti-6Al-4V and Ti-6Al-4V) for surface pipes, turbine rotors, blades and well casings, respectively.

For data inventories of SOA and Geo-Coat systems, the total material consumption (total mass), the total area of coating, and the coating factors (area of coating multiplied by the required thickness of the coating for 30 years lifetime) for those pipe components have been calculated based on the primary data provided by the plant operators. The total thickness of the coatings, using the 1st and 2nd ranked coatings HVOF_CA2 and LC_HEA2 whose corrosion rates of 0.13 and 0.0022 mm year^{-1} (results from Geo-Coat D5.3), have been calculated for 30 years lifetime of the plant as about 3900 and 66 µm, respectively. Using the data from Table 3.2, the masses of the 630SS and S235JR materials, inner surface areas of all the pipe components used in ICS1 and coating volumes for LC_HEA2 and HVOF_CA2 coatings have been calculated and are presented in Table 3.7.

Table 3.7 - Calculated masses and inner surface areas and coating volumes for 49.5 km pipe network of ICS1.

Types of components	Mass (kg)		Inner surface areas	Coating volumes (m^3)	
	630SS (SOA)	S235JR (GCS)	(m^2)	LC_HEA2	HVOF_CA2
2-phase pipes	3663637	3616396	43784	2.889755	170.76
Steam pipes	4220853	4166428	45059	2.973894	175.73
Brine pipes-I	1886554	1862228	27418	1.809620	106.93
Brine pipes-II	875837	864544	10139	0.669178	39.54
Total	**10646880**	**10509596**	**126400**	**8.342446**	**492.96**

The ICS1 plant consists of seven turbines all condensing, and of the axial exhaust type. The turbines in units 1-4 and 5-6 are high pressure 45 MW turbines from Mitsubishi. They are single-cylinder, single flow, impulse-reaction, axial exhaust, condensing turbines[11]. Unit 11 is a low pressure unit with a 33.6MW turbine from Toshiba[12]. We have developed LC_HEA2 and LC_HEA5 (2nd ranked) and HVOF_CA2 (1st ranked) coating systems for the application areas of S3 (Rotors) and S4 (Blades). The total thickness of the coating required for the LC_HEA5 has been calculated for 30 years lifetime of the plant using the corrosion rate of 0.087 mm year^{-1} (results from Geo-Coat D5.3) as 2610 µm. The total masses of the A470 (SOA), Ti-6Al-4V (SOA), 1.2746 (GCS) and 304L (GCS) materials, outer surface areas of turbine components of all seven turbines used in ICS1 and the respective coating volumes for LC_HEA2, LC_HEA5 and HVOF_CA2 coatings have been calculated using the data from Table 3.5 and are listed in Table 3.8.

Table 3.8 – Calculated total outer surface areas, masses and coating volumes for 7 turbines of ICS1

Turbine components	Total outer surface areas	Total masses (kg)		Coating volumes (m^3)		
	(m^2)	SOA	GCS	LC_HEA2	LC_HEA5	HVOF_CA2
Rotor	91	83092	82286	0.006006	-	0.3549
Blade	175	347270	672518	-	0.45675	0.6825

Wells can have different diameters and lengths depending on the field. Typical high temperature wells reach down to 1200-3000m and are cased down to 600/800-1200m[13]. Regular wells use API 9 5/8" casings and 7" or

[11] R. S. Atlason, R. Unnthorsson and G. V. Oddsson, "Innovation and development in geothermal turbine maintenance based on Icelandic experience," *Geothermics,* vol. 56, pp. 72-78, 2015.

[12] E. Hallgrímsdóttir, C. Ballzus and I. Hrólfsson, "The Geothermal Power Plant at Hellisheiði, Iceland," GRC Transactions, vol. 36, pp. 1067-1072, 2012.

[13] T. M. Ong'au, "Controlled Directional Drilling in Kenya and Iceland (Time analysis)," GRC Transactions, vol. 36, pp. 177-184, 2012.

7 5/8” slotted liners while large diameter wells typically use 13 3/8” production casings with 9 5/8” slotted liners. There are a number of different casing materials that are used and which one is chosen depends on the fluid composition of the reservoir. Using the data from Table 3.6, the inner surface area, total masses of SOA and GCS materials and total coating volumes of LC_HEA2 and HVOF_CA2 coatings for well casings employed in ICS1 have been calculated and listed in Table 3.9.

Table 3.9 - Calculated total inner surface areas, masses and coating volumes for 44 well casings of ICS1

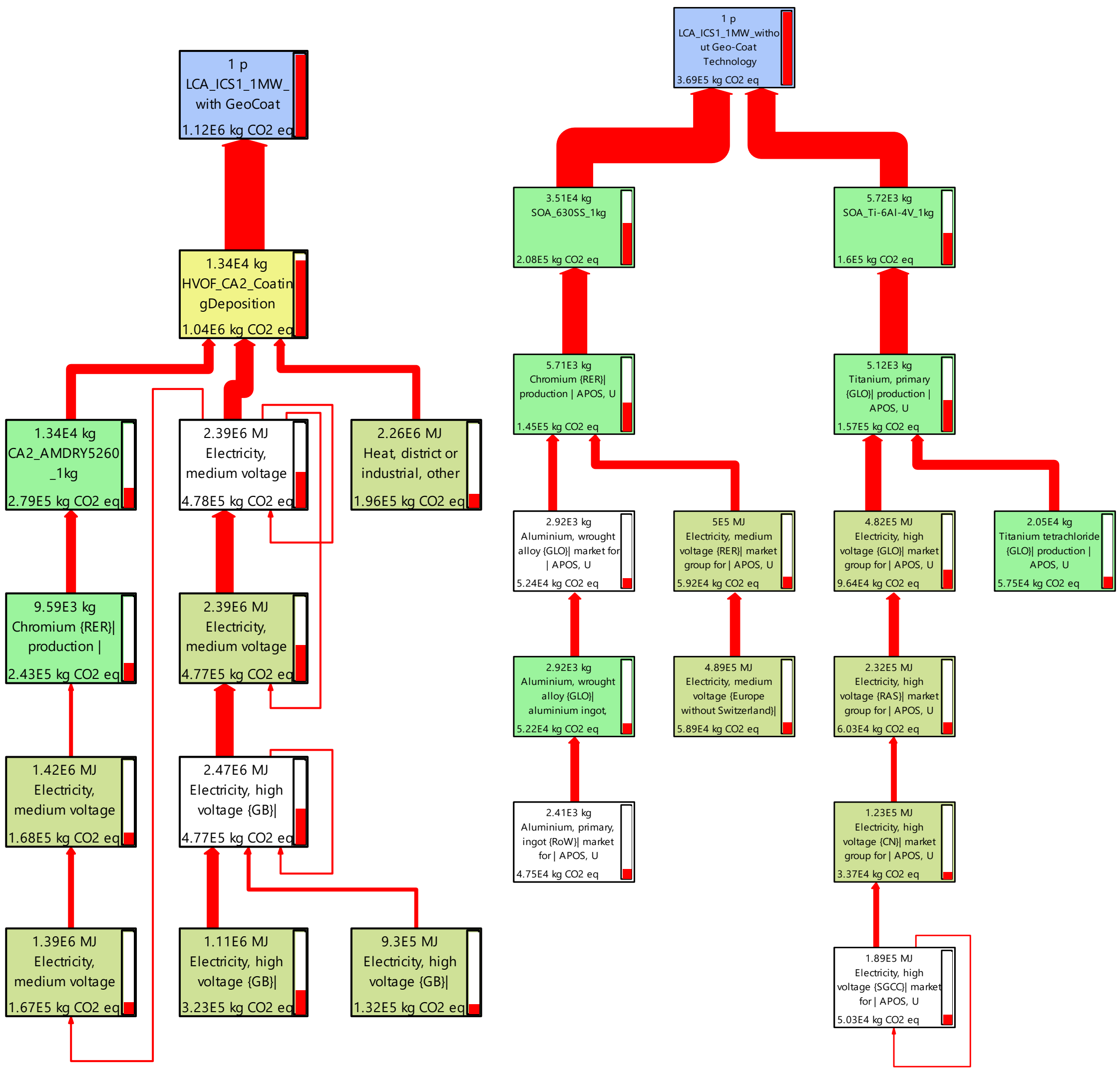
Component	Total inner surface area	Total masses (kg)		Coating volumes (m^3)	
	(m^2)	SOA	GCS	LC_HEA2	HVOF_CA2
Well casings	35546	2009877	3513942	2.35	138.63

For cradle to gate LCA impact analysis, the respective SOA and Geo-Coat substrate material mass flows and coating material mass flows in terms of functional unit of 1 MW installed capacity have been evaluated for surface pipes, turbines and well casing components of ICS1 plant as the Icelandic example of double flash type and listed in Table 3.10.

Table 3.10 – Functional mass flows for surface pipes, turbine rotors, blades and well casing components of ICS1

Components	Quantity	Functional mass flows (kg)			
		SOA	GCS	LC_HEA2 &HEA5	HVOF_CA2
Surface pipes (km)	49.5	35138	34685	239.04	11492.70
Turbine rotos	7	274	272	0.17	8.27
Turbine blades	7	1146	2220	12.35	15.91
Well casings	44	6633	11597	67.22	3231.92

For the application areas of surface pipes & well casings (S1), turbine rotors (S3) and blades (S4), the 1st selected Geo-Coat systems HVOF_CA2_S235JR, HVOF_CA2_S235JR, HVOF_CA2_1.2746 and HVOF_CA2_304L have been used instead of SOA systems 630SS, Ti-6Al-4V, A470 and Ti-6Al-4V, respectively. Using the mass flow data described in Tables 3.7-3.10, material composition and coating deposition data described in section 2.2, the cradle to gate LCA impact analyses for 1 MW installed capacity power plant of ICS1 with and without adoption of 1st ranked Geo-Coat technology have been performed using SimaPro 9.0.0.49 LCA tool, considering the impact assessment methodology IMPACT 2002+ version 2.14. A part of the climate change network models for 1 MW installed capacity power plant of type ICS1 with and without the adoption of 1st ranked Geo-Coat technology are presented in Figures 3.2a and 3.2b, respectively. The cut-off criteria for the Figures 3.2a and 3.2b is 10% which means any process which contributes less than 10% will not be displayed in these figures. For 10% and above, only 12 and 15 nodes are visible out of 11617 and 11616 nodes, respectively, in Figures 3.2a and 3.2b. The small thermometers (as shown in Figure 3.2) attached with the processes give the contribution to the total environmental load. The line thickness also indicates the total environmental load flowing between processes. While a red colour means an environmental load, green means a negative environmental load, or in fact an environmental benefit. The environmental loads have been evaluated using the life cycle impact assessment methodology IMPACT2002+ V2.14 in this study. Climate change models are, in general, developed to assess the future impact on climate resulting from different policy scenarios. Man-made climate change is caused by the emission of greenhouse gases (and by other activities influencing their atmospheric concentration). Greenhouse gases are substances with the ability to absorb infrared radiation from the earth (radiative forcing).



(a) (b)

Figure 3.2 – A part of the climate change network models for 1 MW installed capacity power plant of type ICS1 (a) with and (b) without the adoption of 1st ranked Geo-Coat technology.

It is seen from the network models of Figure 3.2 that 1 MW installed capacity of ICS1 double flash type plant with the adoption of 1st ranked Geo-Coat technology contributes a carbon footprint of 369 t CO_2 eq, whereas without adoption of Geo-Coat technology, i.e. with SOA materials adopted for the same installed capacity of ICS1 contributing the carbon footprint is 1122 t CO_2 eq.

The comparative LCIA results of 15 midpoint impacts (Characterisation indicators), 4 endpoint damage categories (human health, ecosystem quality, climate change and resources) and the environmental impacts in terms of single score for 1 MW installed capacity of ICS1 double flash plant with and without the adoption of 1st ranked Geo-Coat technology are presented in Figures 3.3, 3.4 and 3.5, respectively.

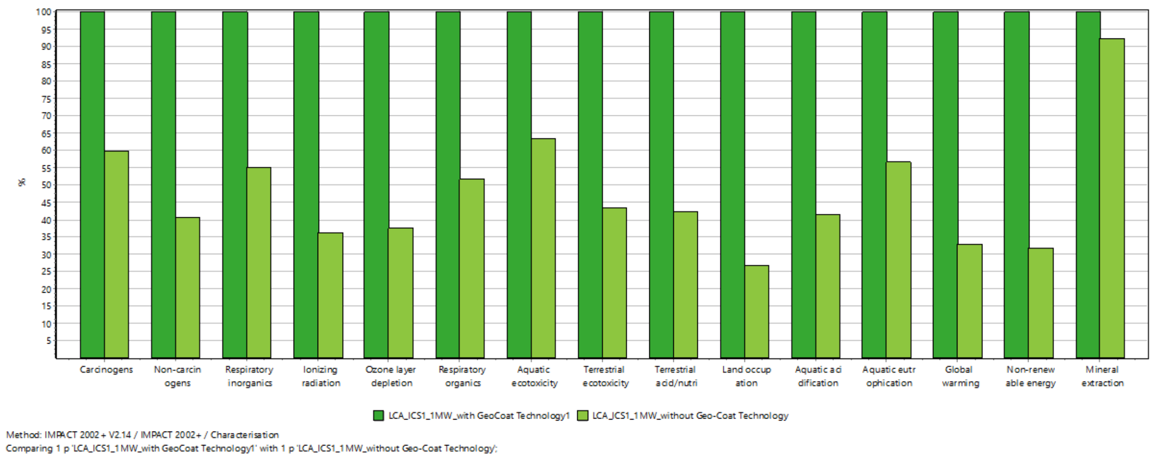


Figure 3.3 - Comparisons of 15 midpoint impact categories for 1 MW installed capacity of ICS1 double flash plant with and without the adoption of 1st ranked Geo-Coat technology.

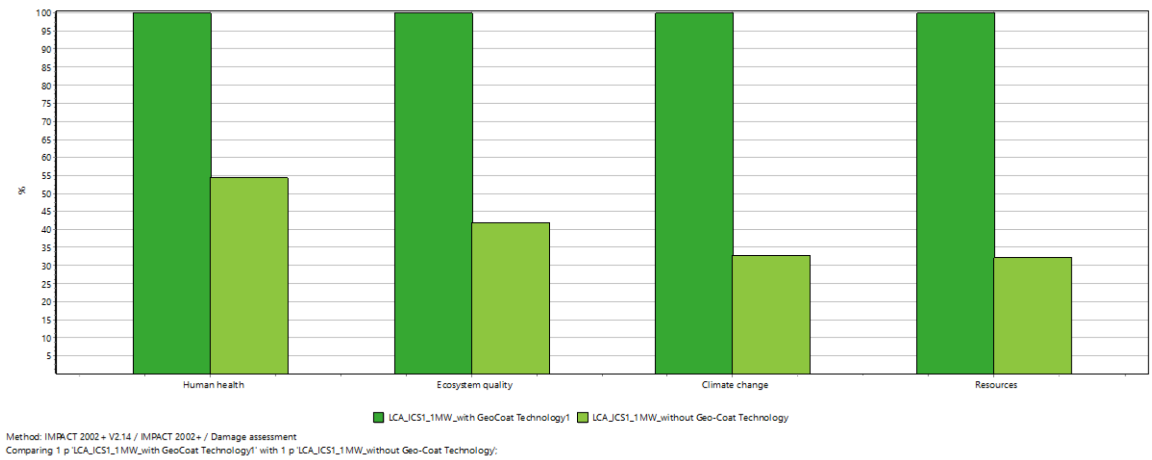


Figure 3.4 - Comparisons of 4 endpoint damage categories for 1 MW installed capacity of ICS1 double flash plant with and without the adoption of 1st ranked Geo-Coat technology.

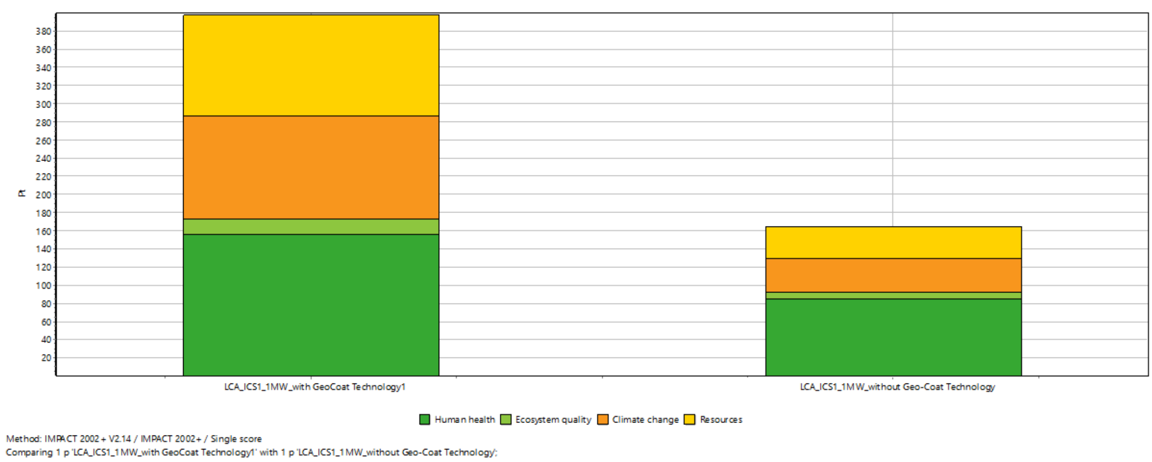


Figure 3.5 - Comparisons of single score results for 1 MW installed capacity of ICS1 double flash plant with and without the adoption of 1st ranked Geo-Coat technology.

The quantification of environmental footprints of over 15 midpoint impact categories for 1 MW installed capacity of ICS1 type plant with and without the adoption of 1st ranked Geo-Coat technology is listed in Table 3.11.

Table 3.11 – Quantification of environmental footprints over 15 midpoint impact categories for ICS1 with and without adoption of 1st ranked Geo-Coat technology.

Midpoint impact category	Unit	With 1st ranked GCT	Without GCT
Carcinogens	kg C2H3Cl eq	8588.37	5127.25
Non-carcinogens	kg C2H3Cl eq	19536.26	7935.42
Respiratory inorganics	kg PM2.5 eq	1457.08	800.48
Ionising radiation	Bq C-14 eq	15774927.31	5719846.26
Ozone layer depletion	kg CFC-11 eq	0.09	0.03
Respiratory organics	kg C2H4 eq	157.57	81.46
Aquatic ecotoxicity	kg TEG water	86438634.47	54852944.65
Terrestrial ecotoxicity	kg TEG soil	24423103.50	10581890.67
Terrestrial acid/nutri	kg SO2 eq	20115.34	8493.60
Land occupation	m2org.arable	22210.72	5956.27
Aquatic acidification	kg SO2 eq	9098.72	3763.63
Aquatic eutrophication	kg PO4 P-lim	283.04	160.20
Global warming	kg CO2 eq	1121574.95	368918.09
Non-renewable energy	MJ primary	16853669.29	5362745.35
Mineral extraction	MJ surplus	78770.44	72734.15

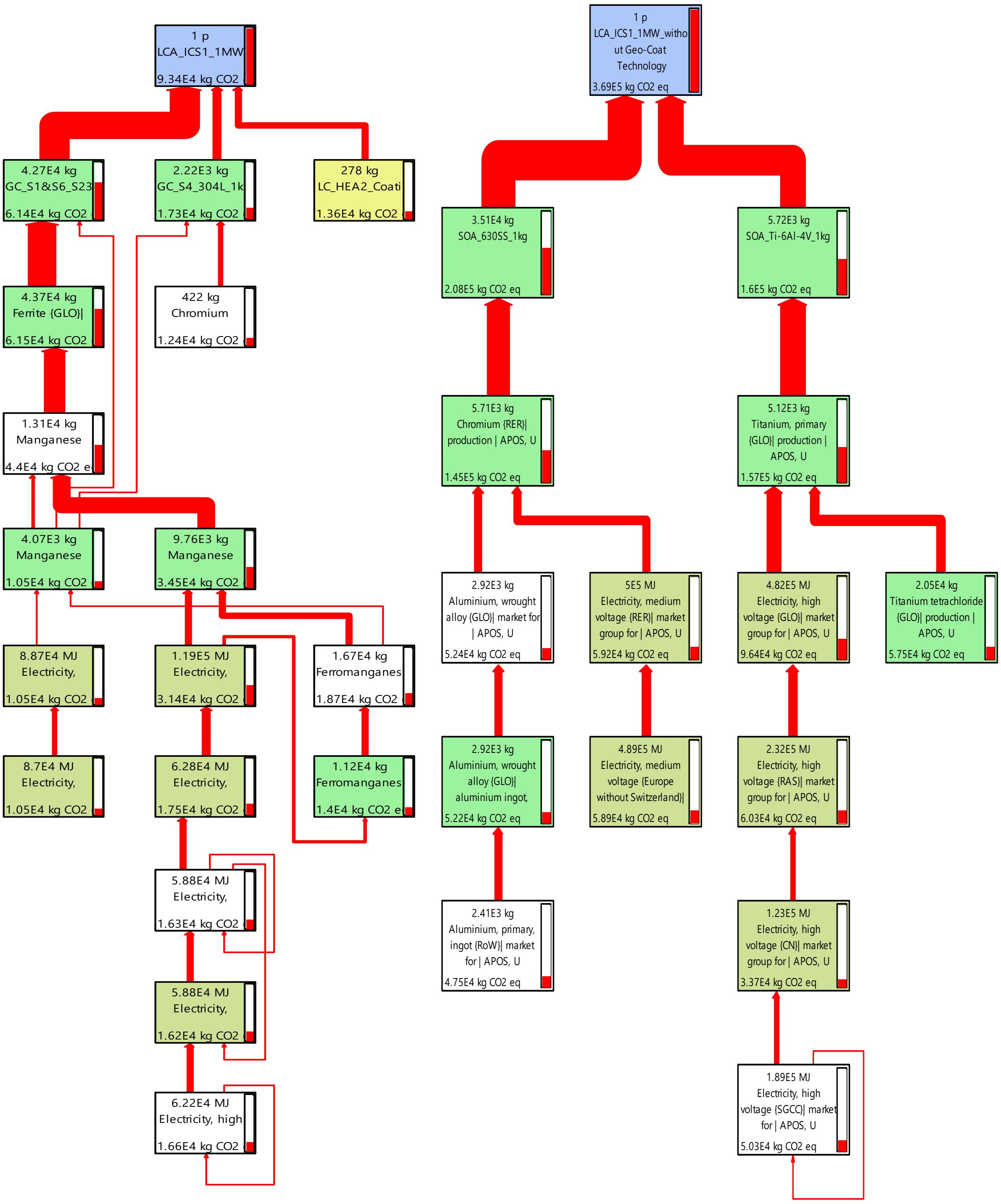
Table 3.12 shows the quantification of environmental burdens over 4 endpoint damage categories for ICS1 plant with and without adoption of 1st ranked Geo-Coat technology and their negative savings of the environmental footprints.

Table 3.12 - Quantification of environmental burdens over 4 endpoint damage categories for ICS1 with and without adoption of 1st ranked Geo-Coat technology and the negative savings of the environmental footprints.

Endpoint Damage category	Unit	With 1st ranked GCT	Without GCT	Negative savings of environmental burdens
Human health	DALY	1.10	0.60	-0.5
Ecosystem quality	PDF*m2*yr	242655.61	101782.05	-140884
Climate change	kg CO2 eq	1121574.95	368918.09	-752657
Resources	MJ primary	16932439.72	5435479.50	-11496960

The adoption of 1st ranked Geo-Coat technology alternative to SOA materials (i.e. without Geo-Coat technology adoption) in ICS1 double flash type plant demonstrated a large amount of negative savings of environmental burdens over endpoint damage categories, especially the climate change, i.e. carbon footprint negative savings of about -753 t CO_2 eq per MW installed capacity of the plant. The information in Tables 3.11 and 3.12 is repeated below in the comparison with the 2nd ranked Geo-Coat technology.

Using the mass flow data described in Tables 3.7-3.10, material composition and coating deposition data described in section 2.2, the cradle to gate LCA impact analyses for 1 MW installed capacity power plant of ICS1 with and without adoption of 2nd ranked Geo-Coat technology have been performed using SimaPro 9.0.0.49 LCA tool, considering the impact assessment methodology IMPACT 2002+ version 2.14. A part of the climate change network models for 1 MW installed capacity power plant of type ICS1 with and without the adoption of 2nd ranked Geo-Coat technology are presented in Figures 3.6a and 3.6b, respectively. The cut-off criteria for the Figures 3.6a and 3.6b is 10% which means any process which contributes less than 10% will not be displayed in these figures. For 10% and above, only 18 and 15 nodes are visible out of 11615 and 11616 nodes, respectively, in Figures 3.6a and 3.6b.



(a) (b)

Figure 3.6 - A part of the climate change network models for 1 MW installed capacity power plant of type ICS1 (a) with and (b) without the adoption of 2nd ranked Geo-Coat technology.

It is seen from the climate change network models of Figure 3.2 that 1 MW installed capacity of ICS1 double flash plant with the adoption of 2nd ranked Geo-Coat technology contributes a carbon footprint of 93.4 t CO_2

eq, whereas without adoption of Geo-Coat technology, i.e. with SOA materials adopted for the same installed capacity of ICS1 contributes a carbon footprint of 369 t CO_2 eq.

The comparative LCIA results of 15 midpoint impacts (Characterisation indicators), 4 endpoint damage categories (human health, ecosystem quality, climate change and resources) and the environmental impacts in terms of single score for 1 MW installed capacity of ICS1 double flash plant with and without the adoption of 2nd ranked Geo-Coat technology are presented in Figures 3.7, 3.8 and 3.9, respectively.

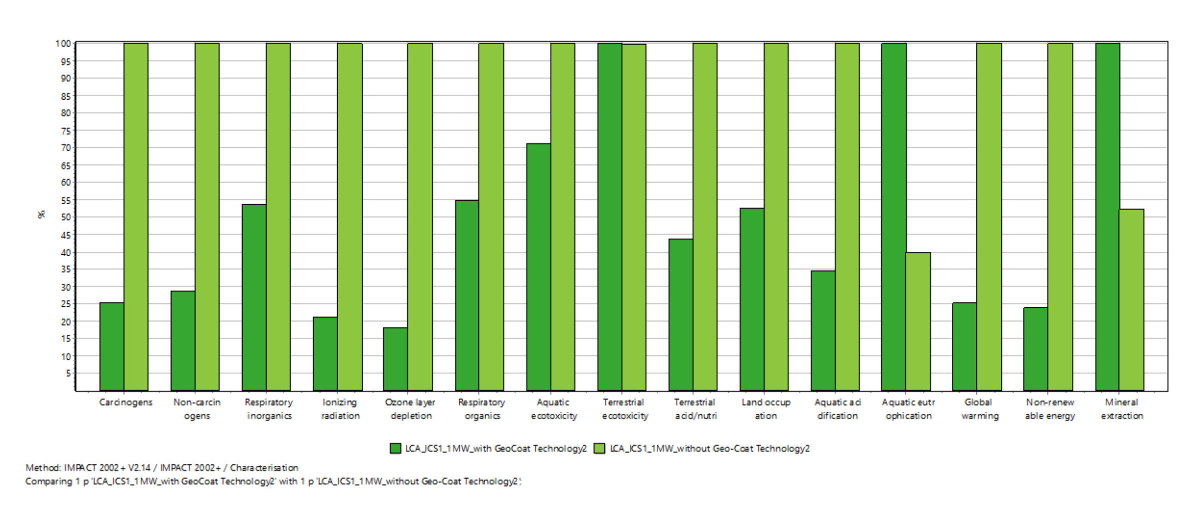


Figure 3.7 - Comparisons of 15 midpoint impact categories for 1 MW installed capacity of ICS1 double flash plant with and without the adoption of 2nd ranked Geo-Coat technology.

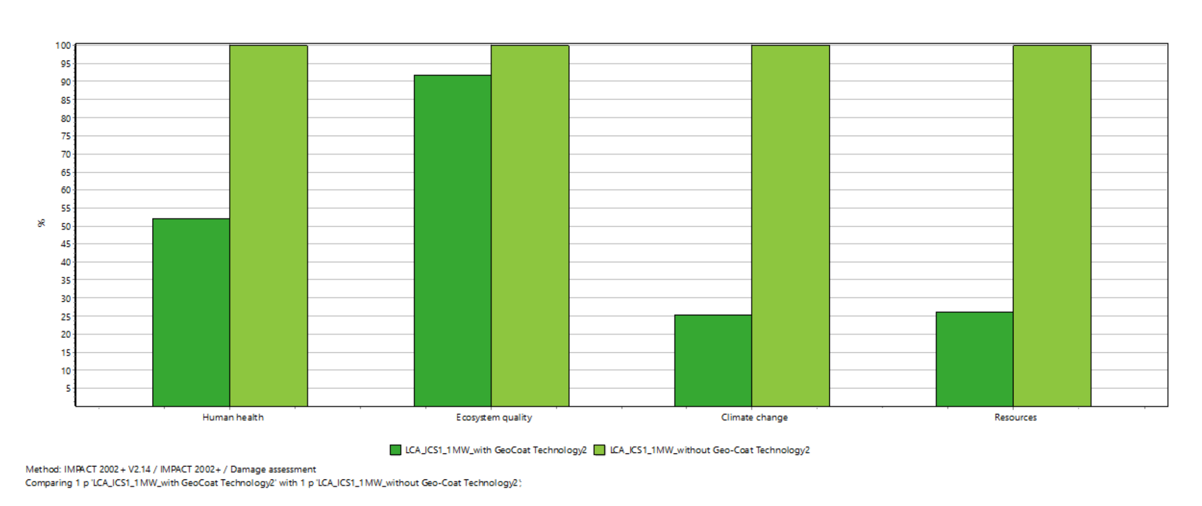


Figure 3.8 - Comparisons of 4 endpoint damage categories for 1 MW installed capacity of ICS1 double flash plant with and without the adoption of 2nd ranked Geo-Coat technology.

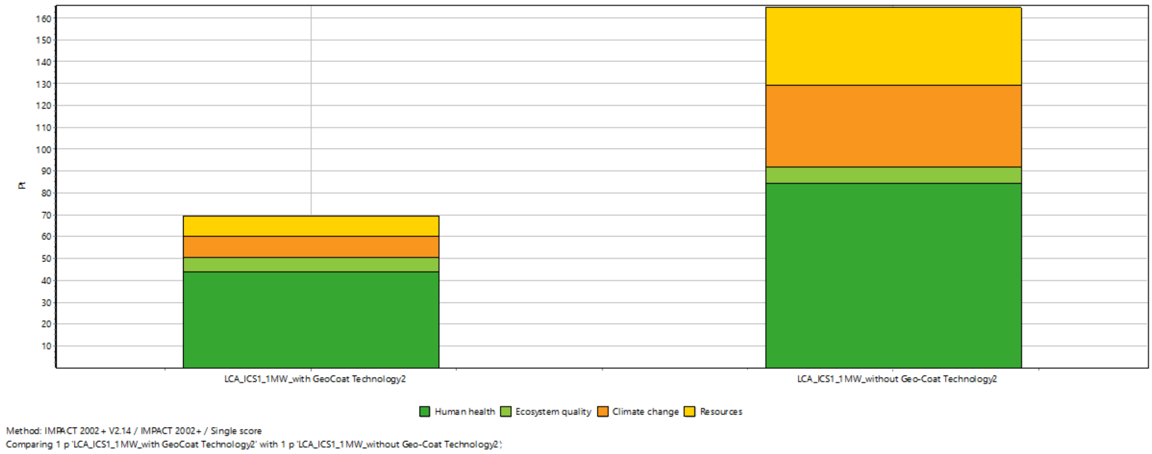


Figure 3.9 - Comparisons of single score results for 1 MW installed capacity of ICS1 double flash plant with and without the adoption of 2nd ranked Geo-Coat technology.

The quantification of environmental footprints of over 15 midpoint impact categories for 1 MW installed capacity of ICS1 double flash plant with and without the adoption of 2nd and 1st ranked Geo-Coat technology is listed in Table 3.13.

Table 3.13 – Quantification of environmental footprints over 15 midpoint impact categories for ICS1 with and without adoption of 1st and 2nd ranked Geo-Coat technology.

Impact category	Unit	2nd ranked Geo-Coat technology	SOA system	1st ranked Geo-Coat technology
Carcinogens	kg C2H3Cl eq	1306	5127	8588
Non-carcinogens	kg C2H3Cl eq	2278	7935	19536
Respiratory inorganics	kg PM2.5 eq	429	800	1457
Ionising radiation	Bq C-14 eq	1217952	5719846	15774927
Ozone layer depletion	kg CFC-11 eq	0	0	0.09
Respiratory organics	kg C2H4 eq	45	81	158
Aquatic ecotoxicity	kg TEG water	39065944	54852945	86438634
Terrestrial ecotoxicity	kg TEG soil	10617366	10581891	24423104
Terrestrial acid/nutri	kg SO2 eq	3695	8494	20115
Land occupation	m2org.arable	3132	5956	22211
Aquatic acidification	kg SO2 eq	1300	3764	9099
Aquatic eutrophication	kg PO4 P-lim	401	160	283
Global warming	kg CO2 eq	93374	368918	1121575
Non-renewable energy	MJ primary	1288110	5362745	16853669
Mineral extraction	MJ surplus	139101	72734	78770

Table 3.14 shows the quantification of environmental burdens over 4 endpoint damage categories ICS1 with and without adoption of 1st and 2nd ranked Geo-Coat technology and their positive/negative savings of the environmental footprints.

Table 3.14 - Quantification of environmental footprints over 4 endpoint damage categories for ICS1 with and without adoption of 1st and 2nd ranked Geo-Coat technology and positive/negative savings of the environmental footprints.

Damage category	Unit	2nd ranked GCT	Without GCT (SOA)	1st ranked GCT	Positive/negative savings of environmental footprints	
					2nd ranked	1st ranked
Human health	DALY	0.31	0.60	1.10	0.29	-0.5
Ecosystem quality	PDF*m2*yr	93200.43	101782.05	242655.61	8582	-140884
Climate change	kg CO2 eq	93373.86	368918.09	1121574.95	275544	-752657
Resources	MJ primary	1427211.51	5435479.50	16932439.72	4008268	-11496960

The adoption of 1st ranked Geo-Coat technology in ICS1 showed an exceptionally large environmental footprints as compared with 2nd ranked Geo-Coat technology. The adoption of 2nd ranked Geo-Coat technology alternative to SOA materials (i.e., without Geo-Coat technology adoption) in ICS1 demonstrated a large amount of savings of environmental footprints over 4 endpoint damage categories, especially the climate change, i.e. carbon footprint savings of about 276 t CO_2 eq per MW installed capacity of the plant.

3.4 Combined Dry steam and single flash plant with and without the adoption of Geo-Coat technology components: Icelandic Case Study 2

The Svartsengi geothermal plant (ICS2) is a combined heat and power (CHP) plant. For LCA impact studies, the single flash 6 MW and 30 MW for power plant units 3 and 5, respectively and dry steam 30 MW for power plant unit 6 of the ICS2 plant have been considered as the Icelandic example of combined dry steam and single flash geothermal power plant application with 2nd ranked Geo-Coat systems LC_HEA2_S235JR, LC_HEA2_1.2746 and LC_HEA5_304L alternative to SOA materials for surface pipes, well casings, turbine rotors and blades.

To maintain the integrity of performances of the future geothermal plant like ICS2 during 30 years lifetime, it is recommended to use the Geo-Coat systems for different geothermal components as an alternative to currently employed SOA systems. Our aim is to calculate the environmental impacts due to Geo-Coat and SOA systems used for different geothermal components such as pipes, turbines, and well casings. The total environmental impacts due to the adoption of 2nd ranked Geo-Coat systems and the SOA systems for 1 MW installed capacity of ICS2 power plant have been evaluated using SimaPro 9.0.0.49 LCA tool, considering IMPACT 2002+ V2.14 LCIA methodology.

Using the data from Table 3.3, the masses of the 630SS and S235JR materials, inner surface areas of all the pipe components used in ICS2 and coating volumes for LC_HEA2 coatings have been calculated and presented in Table 3.15.

Table 3.15 - Calculated masses and inner surface areas and coating volumes for 11.32 km pipe network of ICS2.

Types of components	Mass (kg)		Inner surface areas (m^2)	Coating volumes (m^3)
	630SS (SOA)	S235JR (GCS)		LC_HEA2
2-phase pipes	269601	266124	4754	0.3137
Dry steam pipes	806437	796038	8413	0.5553
Steam pipes	95118	93892	992	0.0655
Brine pipes	268877	265410	4809	0.3174
Total	**1440033**	**1421465**	**18968**	**1.2519**

The ICS2 plant consists of two turbines of 6MW and 30 MW for two single flash units (units 3 and 5) and one turbine of 30MW for dry steam unit (unit 6). The total masses of the A470 (SOA), Ti-6Al-4V (SOA), 1.2746 (GCS) and 304L (GCS) materials, outer surface areas of turbine components of all three turbines employed in ICS2 and the respective coating volumes for LC_HEA2 and LC_HEA5 coatings have been calculated using the data from Table 3.5 and listed in Table 3.16.

Table 3.16 – Calculated total outer surface areas, masses and coating volumes for 3 turbines of ICS2

Turbine components	Total outer surface areas	Total masses (kg)		Coating volumes (m^3)	
	(m^2)	SOA	GCS	LC_HEA2	LC_HEA5
3 Rotors	23	21001	20798	0.0015	-
3 Blades	41	92601	179330	-	0.1077

Using the data from Table 3.6, the inner surface area, total masses of SOA and GCS materials and total coating volumes of LC_HEA2 coatings have been calculated for 10 production well casings and listed in Table 3.17.

Table 3.17 - Calculated total inner surface areas, masses and coating volumes for 10 production well casings of ICS2

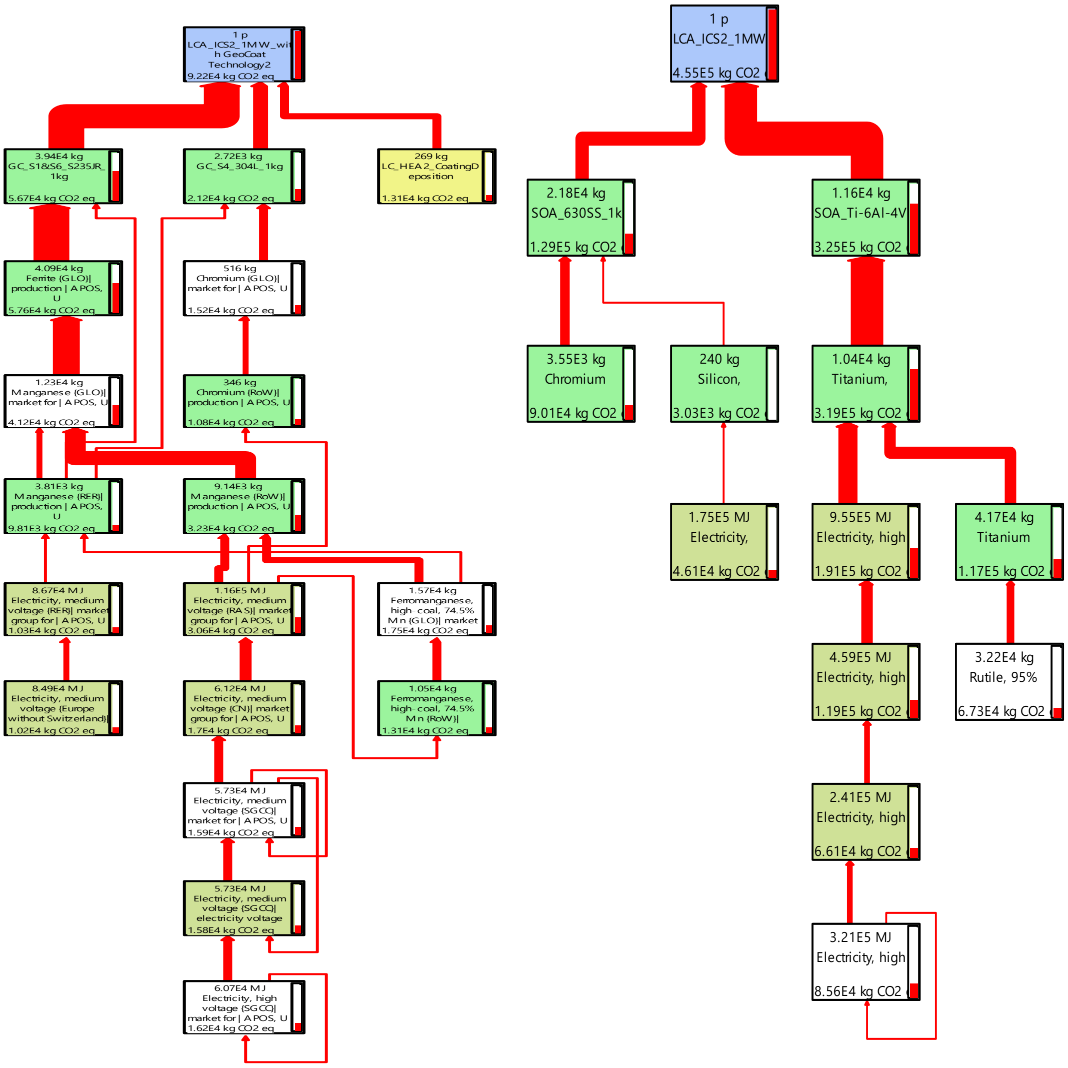
Component	Total inner surface area	Total masses (kg)		Coating volumes (m^3)
	(m^2)	SOA	GCS	LC_HEA2
Well casings	11950	675669	1181297	0.7887

For cradle to gate LCA impact analysis, the respective SOA and Geo-Coat substrate material mass flows and coating material mass flows in terms of functional unit of 1 MW installed capacity have been evaluated for surface pipes, turbines and well casing components of ICS2 plant as one of the Icelandic perspectives of single flash and dry steam type and listed in Table 3.18.

Table 3.18 – Functional mass flows of for surface pipes, turbines and well casing components of ICS2 plant

Components	Quantity	Functional mass flows (kg)		
		SOA	GCS	LC_HEA2 & HEA5
Surface pipes (km)	11.32	21819	21537	164.68
Turbine rotos	3	318	315	0.20
Turbine blades	3	1403	2717	13.38
Well casings	10	10237	17898	103.75

Using the mass flow data described in Tables 3.15-3.18, material composition and coating deposition data described in section 2.2, the cradle to gate LCA impact analyses for 1 MW installed capacity power plant of ICS2 with and without adoption of 2nd ranked Geo-Coat technology have been carried out. A part of the climate change network models for 1 MW installed capacity power plant of type ICS2 with and without the adoption of 2nd ranked Geo-Coat technology are presented in Figures 3.10a and 3.10b, respectively. The cut-off criteria for the Figures 3.10a and 3.10b is 10% and only 19 and 13 nodes are visible out of 11615 and 11616 nodes, respectively, in Figures 3.10a and 3.10b.



(a) (b)

Figure – 3.10 A part of the climate change network models for 1 MW installed capacity power plant of type ICS2 (a) with and (b) without the adoption of 2nd ranked Geo-Coat technology.

It is seen from the network models of Figure 3.10 that 1 MW installed capacity of the ICS2 single flash and dry steam plant with the adoption of 2nd ranked Geo-Coat technology contributes a carbon footprint of 92.2 t CO_2 eq, whereas without adoption of Geo-Coat technology, i.e. with SOA materials adopted for the same installed capacity of ICS2 contributes a carbon footprint of 455 t CO_2 eq.

The comparative LCIA results of 15 midpoint impacts (Characterisation indicators), 4 endpoint damage categories (human health, ecosystem quality, climate change and resources) and the environmental impacts in terms of single score for 1 MW installed capacity of ICS2 single flash and dry steam plant with and without the adoption of 2nd ranked Geo-Coat technology are presented in Figures 3.11, 3.12 and 3.13, respectively.

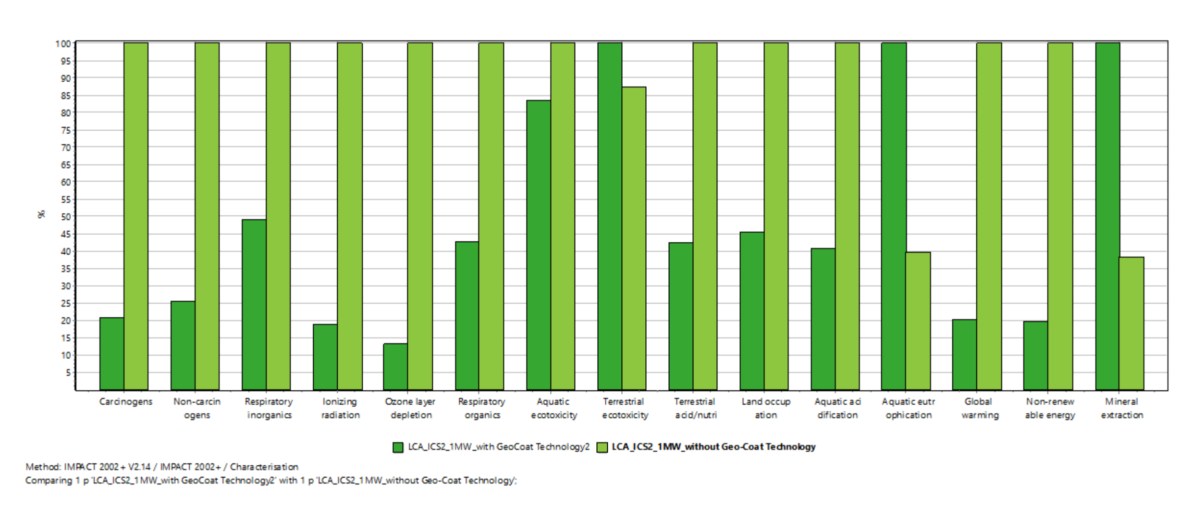


Figure 3.11 - Comparisons of 15 midpoint impact categories for 1 MW installed capacity of ICS2 single flash and dry steam plant with and without the adoption of 2nd ranked Geo-Coat technology.

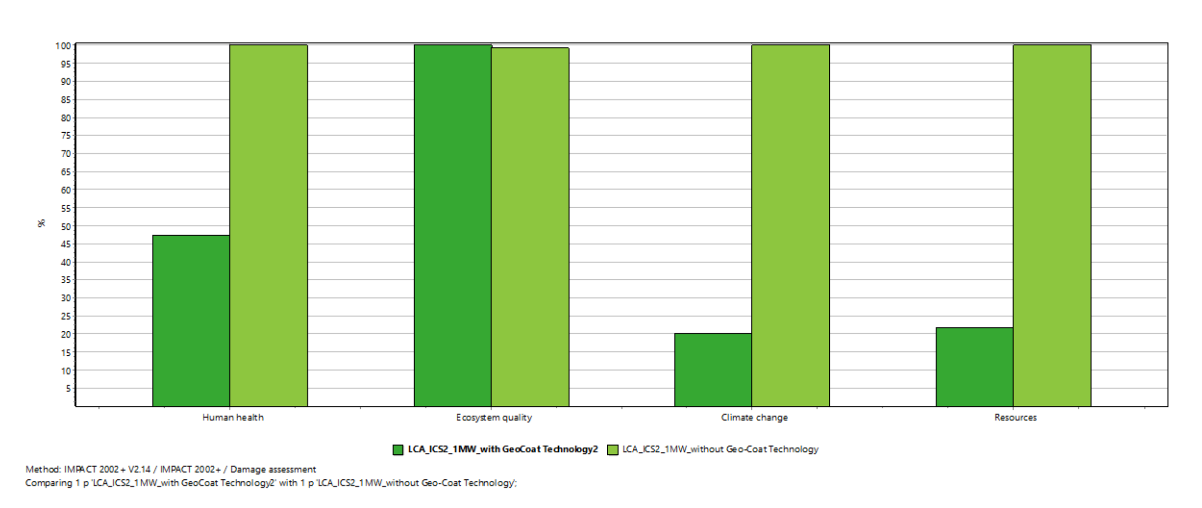


Figure 3.12 - Comparisons of 4 endpoint damage categories for 1 MW installed capacity of ICS2 single flash and dry steam plant with and without the adoption of 2nd ranked Geo-Coat technology.

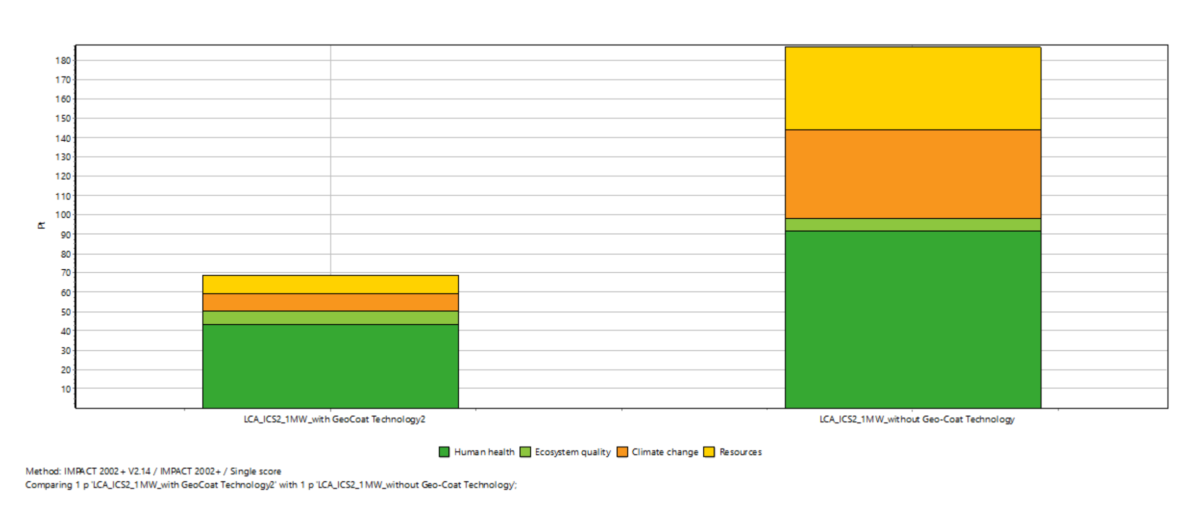


Figure 3.13 - Comparisons of single score results for 1 MW installed capacity of ICS2 single flash and dry steam plant with and without the adoption of 2nd ranked Geo-Coat technology.

The quantification of environmental footprints of over 15 midpoint impact categories for 1 MW installed capacity of ICS2 single flash and dry steam plant with and without the adoption of 2nd ranked Geo-Coat technology is listed in Table 3.19.

Table 3.19 – Quantification of environmental footprints over 15 midpoint impact categories for ICS2 with and without adoption of 2nd ranked Geo-Coat technology.

Midpoint impact category	Unit	With 2nd ranked GCT	Without GCT
Carcinogens	kg C2H3Cl eq	1298.28	6214.09
Non-carcinogens	kg C2H3Cl eq	2260.77	8884.22
Respiratory inorganics	kg PM2.5 eq	425.53	866.67
Ionising radiation	Bq C-14 eq	1191854.73	6309710.86
Ozone layer depletion	kg CFC-11 eq	0.01	0.04
Respiratory organics	kg C2H4 eq	43.02	100.31
Aquatic ecotoxicity	kg TEG water	38234729.78	45851888.63
Terrestrial ecotoxicity	kg TEG soil	10368074.42	9053691.86
Terrestrial acid/nutri	kg SO2 eq	3736.95	8801.69
Land occupation	m2org.arable	3019.73	6617.84
Aquatic acidification	kg SO2 eq	1407.45	3456.22
Aquatic eutrophication	kg PO4 P-lim	391.19	155.81
Global warming	kg CO2 eq	92258.92	455327.20
Non-renewable energy	MJ primary	1270893.26	6422070.97
Mineral extraction	MJ surplus	137834.72	52876.39

Table 3.20 shows the quantification of environmental footprints over 4 endpoint damage categories ICS2 with and without adoption of 2nd ranked Geo-Coat technology and their positive savings of the environmental footprints.

Table 3.20 - Quantification of environmental footprints over 4 endpoint damage categories for ICS2 with and without adoption of 2nd ranked Geo-Coat technology and the positive/negative savings of the environmental footprints.

Endpoint Damage category	Unit	2nd ranked Geo-Coat technology	Without Geo-Coat technology	Positive/negative savings of environmental footprints
Human health	DALY	0.31	0.65	0.34
Ecosystem quality	PDF*m2*yr	91108.79	90283.67	-825.12
Climate change	kg CO2 eq	92258.92	455327.20	363068.28
Resources	MJ primary	1408727.99	6474947.37	5066219.38

The adoption of 2nd ranked Geo-Coat technology alternative to SOA materials (i.e., without Geo-Coat technology adoption) in ICS2 plant demonstrated a large amount of savings of environmental footprints over endpoint damage categories except ecosystem quality, especially the climate change, i.e. carbon footprint savings of about 363 t CO_2 eq per MW installed capacity of the plant.

3.5 Binary plant with and without the adoption of Geo-Coat technology components: Romanian case study

Geothermal based power production also exists in Oradea, Romania, with 0.05 MW_e installed capacity producing 0.4 GWh_e/y. In Oradea, the Transgex company in 2013 installed the first power generation unit of the Transgex-Oradea Binary pilot power plant (RCS) that produces electricity from geothermal water in Romania (on Kalina cycle with pentafloropropan-HFC 245flid). Transgex plans to extend its electricity production up to 1.2 MW_e and also, in the near future, to develop some existing district heating systems.

Using the data from Table 3.3, the masses of the 630SS and S235JR materials, inner surface areas of all the pipe components used in RCS and coating volumes for LC_HEA2 coatings have been calculated and presented in Table 3.21.

Table 3.21 - Calculated masses and inner surface areas and coating volumes for 2.587 km pipe network of RCS.

Types of components	Masses (kg)		Inner surface areas	Coating volumes (m^3)
	630SS (SOA)	S235JR (GCS)	(m^2)	LC_HEA2
uncased pipes	92294	91104	1155	0.0763
2-phase pipes	7148	7056	179	0.0118
Brine pipes	9531	9408	239	0.0158
Total	**108973**	**107568**	**1573**	**0.1039**

Using the data from Table 3.6, the inner surface area, total masses of SOA and GCS materials and total coating volumes of LC_HEA2 coatings have been calculated for 2 production well casings and listed in Table 3.22.

Table 3.22 - Calculated total inner surface areas, masses and coating volumes for 2 production well casings of RCS

Component	Total inner surface area	Total masses (kg)		Coating volumes (m^3)
	(m^2)	SOA	GCS	LC_HEA2
Well casings	943	44552	77891	0.06223

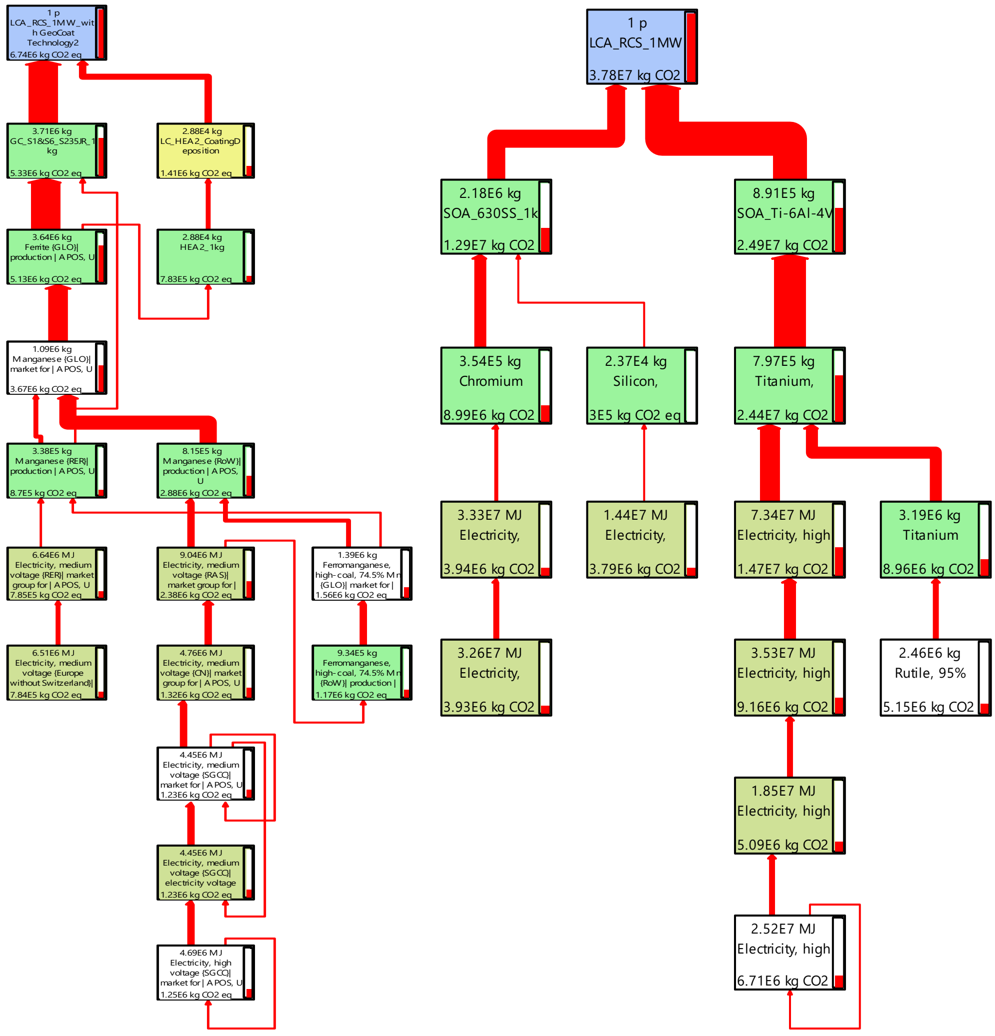
The heat exchanger component used in RCS power plant is not included in this LCA impact study due to the unavailability of the heat exchanger data. For cradle to gate LCA impact analysis, the respective SOA and Geo-Coat substrate material mass flows and coating material mass flows in terms of functional unit of 1 MW installed capacity have been evaluated for surface pipes and well casing components of RCS plant as the Romanian example of binary type and listed in Table 3.23.

Table 3.23 – Functional mass flows of for surface pipes, turbines and well casing components of RCS plant

Components	Quantity	Functional mass flows (kg)		
		SOA	GCS	LC_HEA2
Surface pipes (km)	2.587	2179478	2151375	180
Well casings	2	891035	1557830	108

Using the mass flow data described in Tables 3.21-3.23, material composition and coating deposition data described in section 2.2, the cradle to gate LCA impact analyses for 1 MW installed capacity power plant of RCS with and without adoption of 2nd ranked Geo-Coat technology have been carried out. A part of the climate change network models for 1 MW installed capacity power plant of RCS with and without the adoption of 2nd ranked Geo-Coat technology are presented in Figures 3.14a and 3.14b, respectively. The cut-off criteria for the

Figures 3.14a and 3.14b is 10% and only 17 and 15 nodes are visible out of 11616 and 11610 nodes, respectively, in Figures 3.14a and 3.14b.



(a) (b)

Figure 3.14 - A part of the climate change network models for 1 MW installed capacity power plant of type RCS (a) with and (b) without the adoption of 2nd ranked Geo-Coat technology.

It is seen from the network models of Figure 3.14 that 1 MW installed capacity of RCS binary type plant with the adoption of 2nd ranked Geo-Coat technology contributes a carbon footprint of 6,740 t CO_2 eq, whereas without adoption of Geo-Coat technology, i.e. with SOA materials adopted for the same installed capacity of RCS contributes a carbon footprint of 37,800 t CO_2 eq. A large carbon footprint for SOA materials is mainly due to the use of Ti-alloy.

The comparative LCIA results of 15 midpoint impacts (Characterisation indicators), 4 endpoint damage categories (human health, ecosystem quality, climate change and resources) and the environmental impacts in terms of single score for 1 MW installed capacity of RCS binary type plant with and without the adoption of 2nd ranked Geo-Coat technology are presented in Figures 3.15, 3.16 and 3.17, respectively.

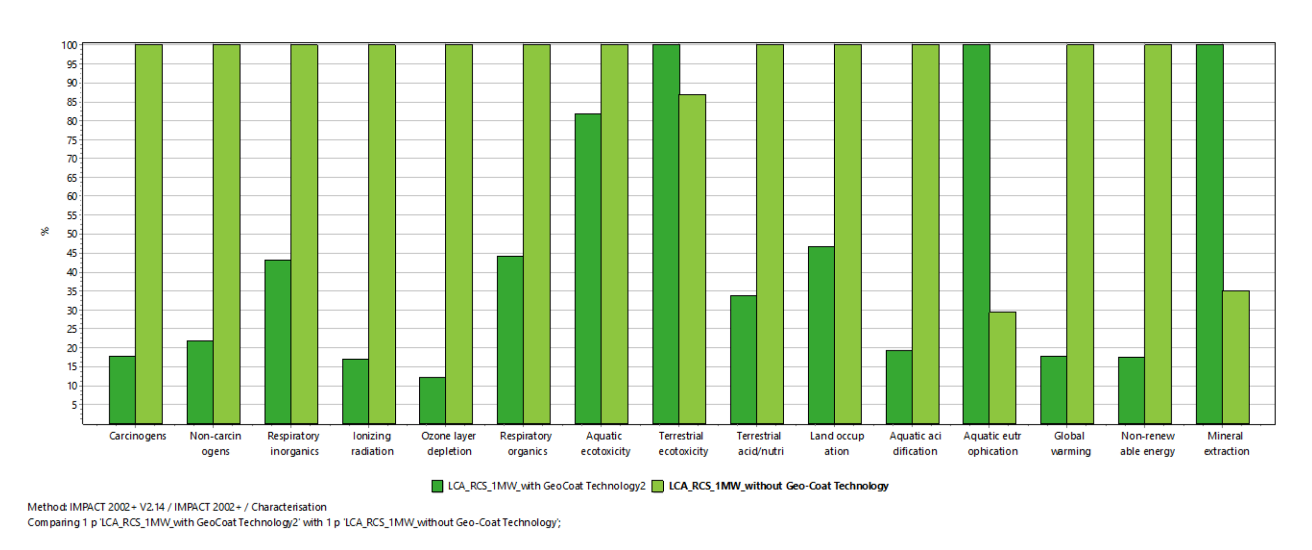


Figure 3.15 - Comparisons of 15 midpoint impact categories for 1 MW installed capacity of RCS binary type plant with and without the adoption of 2nd ranked Geo-Coat technology.

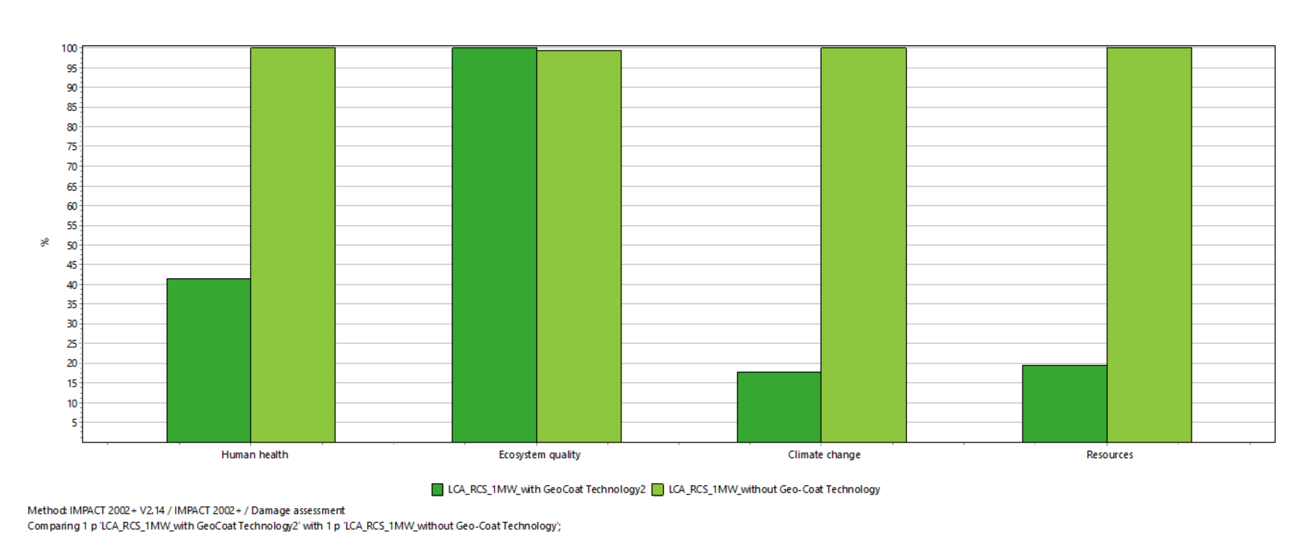


Figure 3.16 - Comparisons of 4 endpoint damage categories for 1 MW installed capacity of RCS binary type plant with and without the adoption of 2nd ranked Geo-Coat technology.

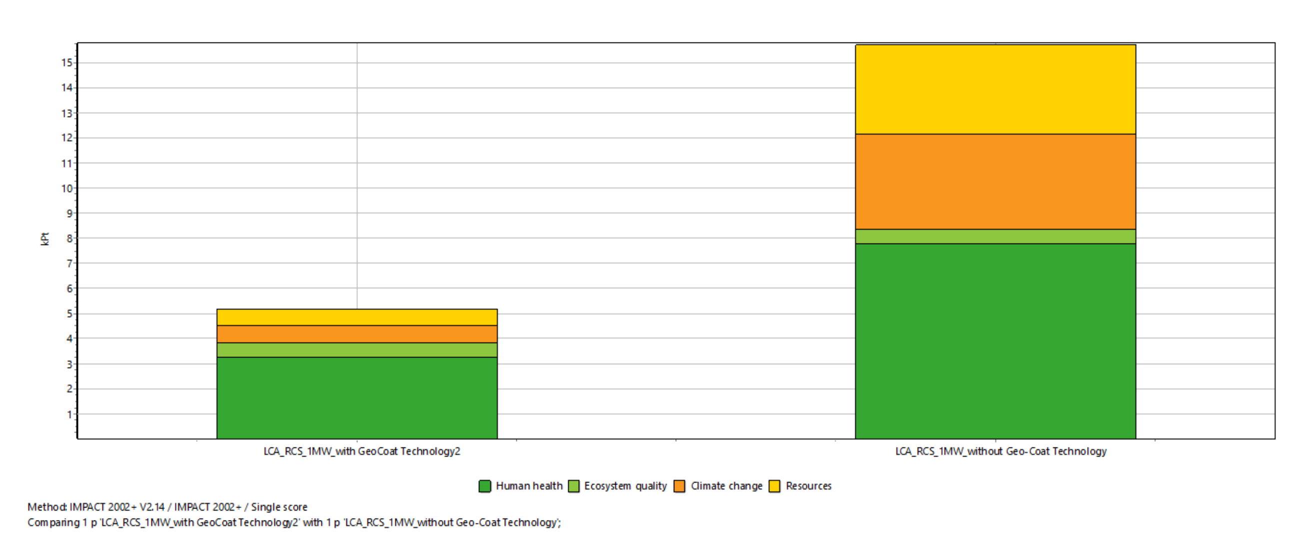


Figure 3.17 - Comparisons of single score results for 1 MW installed capacity of RCS binary type plant with and without the adoption of 2nd ranked Geo-Coat technology.

The quantification of environmental footprints of over 15 midpoint impact categories for 1 MW installed capacity of RCS binary type plant with and without the adoption of 2nd ranked Geo-Coat technology is listed in Table 3.24.

Table 3.24 – Quantification of environmental footprints over 15 midpoint impact categories for RCS with and without adoption of 2nd ranked Geo-Coat technology.

Midpoint impact category	Unit	2nd ranked Geo-Coat technology	Without Geo-Coat technology
Carcinogens	kg C2H3Cl eq	92040.68	517478.14
Non-carcinogens	kg C2H3Cl eq	163416.50	751707.46
Respiratory inorganics	kg PM2.5 eq	31648.88	73396.16
Ionising radiation	Bq C-14 eq	91261017.54	536593570.41
Ozone layer depletion	kg CFC-11 eq	0.44	3.66
Respiratory organics	kg C2H4 eq	3667.27	8267.54
Aquatic ecotoxicity	kg TEG water	3321159882.73	4061880739.62
Terrestrial ecotoxicity	kg TEG soil	906189896.34	788146657.90
Terrestrial acid/nutri	kg SO2 eq	254131.95	753174.82
Land occupation	m2org.arable	259779.89	556941.71
Aquatic acidification	kg SO2 eq	59314.70	305221.50
Aquatic eutrophication	kg PO4 P-lim	38958.46	11452.19
Global warming	kg CO2 eq	6738913.82	37793932.90
Non-renewable energy	MJ primary	93484336.99	536446272.86
Mineral extraction	MJ surplus	12425086.69	4355498.51

Table 3.25 shows the quantification of environmental footprints over 4 endpoint damage categories for RCS plant with and without adoption of 2nd ranked Geo-Coat technology and their positive savings of the environmental footprints.

Table 3.25 - Quantification of environmental footprints over 4 endpoint damage categories for RCS with and without adoption of 2nd ranked Geo-Coat technology and the positive/negative savings of the environmental footprints.

Endpoint Damage category	Unit	With 2nd ranked GCT	Without GCT	Positive savings of environmental footprints
Human health	DALY	22.90	55.07	32.17
Ecosystem quality	PDF*m2*yr	7882141.61	7828514.76	53627
Climate change	kg CO2 eq	6738913.82	37793932.90	31055019
Resources	MJ primary	105909423.68	540801771.37	434892347

The adoption of 2nd ranked Geo-Coat technology alternative to SOA materials (i.e., without Geo-Coat technology adoption) in RCS binary type plant demonstrated a large amount of savings of environmental footprints over endpoint damage categories, especially the climate change, i.e. carbon footprint savings of about 31055 t CO_2 eq per MW installed capacity of the plant.

3.6 Discussions

Two Icelandic (ICS1 and ICS2) and one Romanian (RCS) geothermal power plants have been considered for the evaluation of LCA impacts with and without adoption of Geo-Coat technologies/systems. The two best Geo-Coat systems per application area of geothermal power plant system have been ranked (D5.3) and they are being studied with simulated and real geothermal environments (in the work packages WP6 and WP8 within Geo-Coat project) in order to down-select the best Geo-Coat system per application area. For comparative LCA impact studies, the 2nd ranked Geo-Coat systems for different application areas such as surface pipes (S1), turbine components (S3-S4) and well casings (S1) have been adopted for ICS1, ICS2 and RCS instead of SOA systems for those components usually employed. Also, the comparative LCA impacts have been evaluated using the 1st ranked Geo-Coat systems for ICS1. The cradle-to-gate LCA analyses for these four case studies have been performed with and without adoption of Geo-Coat systems used for different geothermal components such as surface pipe network, turbine components and well casings.

For all 4 endpoint damage categories, the magnitude of the environmental footprints has been converted to a common single score in units of Pt (points). The overall single score values for 4 endpoint damage categories have been evaluated, considering 1 MW installed capacity of ICS1, ICS2 and RCS power plants with adoption of 2nd ranked Geo-Coat technology for pipes, turbine rotors, blades and well casings and listed in Table 3.26.

Table 3.26 – Single score values for different endpoint damage categories considering 1 MW plant capacity of ICS1, ICS2 and RCS plants

Damage category	Single Score values for 1 MW plant capacity with adoption of 2nd ranked Geo-Coat technology		
	ICS1	ICS2	RCS
	Pt	Pt	kPt
Total	69.48	68.69	5.18
Human health	43.85	43.45	3.23
Ecosystem quality	6.80	6.65	0.58
Climate change	9.43	9.32	0.68
Resources	9.39	9.27	0.70

It is seen from Table 3.26 that about 63%, 10%, 14% and 13% of the total single score values are due to human health, ecosystem quality, climate change and resources damage categories, respectively, for all case studies.

The total carbon footprints for SOA and Geo-Coat systems and the positive/negative carbon footprint savings due to the adoptions of the 1st and 2nd ranked Geo-Coat technology for ICS1, ICS2 and RCS case studies are listed in Table 3.27.

Table 3.27 – Positive and negative carbon footprint savings for 1 MW installed capacity of the ICS1, ICS2 and RCS case studies due to the adoption of Geo-Coat technologies.

Case studies	Ranked Geo-Coat technology	Total carbon footprint (t CO_2 eq)		Positive/negative carbon footprint savings
		Without Geo-Coat technology	With Geo-Coat technology	(t CO_2 eq)
ICS1	2nd	369	93	276
ICS2	2nd	455	92	363
RCS	2nd	37794	6739	31055
ICS1	1st	369	1122	-753

It is seen from Table 3.27 that an exceptionally large carbon footprint burden of 1122 t CO_2 eq per MW is incurred for the ICS1 case study with the 1st ranked Geo-Coat technology, compared with the SOA system (without Geo-Coat technology) which is only 369 t CO_2 eq per MW. The possible reasons for this large carbon footprint are due to a high corrosion rate and the high carbon footprint of the HVOF_CA2 coating system (1st ranked Geo-Coat technology adopted for the pipes, well casings and turbine components). With the adoption of the 2nd ranked Geo-Coat technology, the carbon footprint savings are 276, 363 and 31055 t CO_2 eq for 1 MW installed capacity of double flash (ICS1), combined single flash and dry steam (ICS2) and binary (RCS) types power plants, respectively. The inventory results of all compartments for ICS1, ICS2 and RCS power plants of installed capacity of 1 MW with the adoption of 2nd ranked Geo-Coat technology are given in Appendix B.

4. CONCLUSIONS

Geo-Coat technologies are being developed and designed to protect different parts and components in the geothermal power plant, particularly from corrosion, erosion and scaling effects. Geo-Coat technology can be applied on steam turbines, surface pipes, pump impellers, and well casings to extend their lifetime and reliability. Geo-Coat technology will enhance the growth of geothermal energy as it will enable exploitation of corrosive and aggressive geofluid to generate electricity, while significantly reducing the environmental impacts.

It is worth mentioning the following essential points from LCIA results of SOA materials and materials based on Geo-Coat technology

- Among SOA and Geo-Coat substrate materials, Ti-based alloy (Ti-6Al-4V) showed a large carbon footprint (27.92 kg CO_2 eq per kg) due to the large proportion of titanium (89.48%) in the alloy.
- An exceptionally large carbon footprint obtained for the 1st ranked coating system HVOF_CA2 (13.8 kg CO_2 eq per µm-m^2) compared with the 2nd ranked coating system such as LC_HEA2 (2.65 kg CO_2 eq per µm-m^2). This arises mainly due to the large consumption of electrical and heat energy in the HVOF spraying process.
- For the pump impellers, the carbon footprints of Ni- and Ti-MMC components (HIP_IN625+10%SiC and HIP_Ti64+10%TiB2) were about 6.7 and 7.0 times higher than those of the respective SOA systems, IN625 and Ti64 materials, mainly due to the large amount of electrical energy involved in the HIP consolidation method.

For comparative LCA impact studies, the 2nd ranked Geo-Coat systems for different application areas such as surface pipes (S1), turbine components (S3-S4) and well casings (S1) have been adopted for 303 MW double flash (ICS1), 66 MW combined single flash and dry steam (ICS2) and 50 kW binary (RCS) plants instead of SOA systems for those components usually employed. Also, the comparative LCA impacts have been evaluated with the adoption of 1st ranked Geo-Coat systems for ICS1. The cradle-to-gate LCA analyses for 1 MW installed capacity of these four case studies have been performed with and without adoption of Geo-Coat systems for different geothermal components such as surface pipe network, turbine components and well casings. A summary results of the environmental footprints over 4 endpoint damage categories for 1 MW installed capacity of four case studies are given in Table 4.1.

Table 4.1 - A summary results of environmental footprints for 1 MW installed capacity of four case studies

Case studies	Ranked of Geo-Coat technology and SOA system	Environmental footprints			
		Human health	Ecosystem quality	Climate change	Resources
		DALY	PDF*m2*yr	t CO2 eq	MJ primary
ICS1	2nd	0.31	9.32×10^4	93.37	1.43×10^6
	Without (SOA)	0.60	1.02×10^5	368.92	5.44×10^6
ICS2	2nd	0.31	9.11×10^4	92.26	1.41×10^6
	Without (SOA)	0.65	9.03×10^4	455.33	6.47×10^6
RCS	2nd	22.90	7.88×10^6	6738.91	1.06×10^8
	Without (SOA)	55.07	7.83×10^6	37793.93	5.41×10^8
ICS1	1st	1.10	2.43×10^5	1121.57	1.69×10^7
	Without (SOA)	0.60	1.02×10^5	368.92	5.44×10^6

The Geo-Coat impact factors of climate change damage category for these four case studies (ICS1, ICS2 and RCS with 2nd ranked Geo-Coat systems and ICS1 with 1st ranked Geo-Coat systems) with and without adoption of Geo-Coat systems are listed in Table 4.2.

Table 4.2 – Geo-Coat impact factors of climate change damage category (carbon foot print) for four case studies

Case studies	Ranked	Total climate change (t CO_2 eq)		Geo-Coat impact factors
		SOA (without Geo-Coat technology)	With Geo-Coat technology	
ICS1	2nd	368.92	93.37	0.25
ICS2	2nd	455.33	92.26	0.20
RCS	2nd	37793.93	6738.91	0.18
ICS1	1st	368.92	1121.57	3.04

It is seen from Table 4.2 that the Geo-Coat impact factor is exceptionally large for ICS1 with the 1st ranked Geo-Coat systems as compared with the 2nd ranked Geo-Coat systems. This very large impact factor is mainly due to the high corrosion rates of the 1st ranked Geo-Coat systems (HVOF_CA2_S235JR, HVOF_CA2_1.2746 and HVOF_CA2_304L) compared with the 2nd ranked Geo-Coat systems (LC_HEA2_S235JR, LC_HEA2_1.2746 and LC_HEA5_304L) and large environmental burdens for HVOF_CA2 coatings compared with LC_HEA2 and LC_HEA5 coatings. For Icelandic and Romanian case studies with the 2nd ranked Geo-Coat technologies, Geo-Coat impact factors are almost similar. Finally, it is concluded that the Icelandic case studies ICS1 (double flash type) and ICS2 (single flash and dry steam type) and Romanian case study RCS (binary type) with the adoption of 2nd ranked Geo-Coat systems instead of SOA systems demonstrated about 75%, 80% and 82% of total carbon footprint savings respectively, However, ICS1 (double flash type) with adoption of the 1st ranked Geo-Coat technology demonstrated about 3 times more carbon footprint burdens than that of SOA systems. Therefore, this study reveals that the adoption of the 2nd ranked Geo-Coat systems for geothermal components employed in future geothermal power systems of different power technology options would be sustainable with lower environmental impact.

Appendix A – Data sheets regarding Icelandic and Romanian power plants provided by ON Power, ICI and METAV R&D

Table A1 - A data sheet for 303 MW Hellisheidi double flash power plant provided by ON POWER & ICI

For Icelandic power plant case study of GeoCoat application, we need the following information regarding main components involved in that plant for data inventory of GeoCoat deliverables D9.1&D9.2:												
Icelandic double flash power plant												
Name of the plant	Hellisheidi power plant											
Power plant capacity	303.3 MW		(Units 1-6 and a low pressure Unit 11)									
System	**Component**	**Part**	**Quantity/comments**	**ID**	**Surface area - inner**	**Surface area - outer**	**Total length**	**Length**	**Inner Diameter**	**Outer Diameter**	**Thickness**	**Material type**
					(m2)	(m2)	(m)	(m)	(mm)	(mm)	(mm)	
Fluid gathering	Well Pipes	Casings	44 production wells	API 9 5/8"	8668	9612	12513	12-14 (unit length)	221	244.5	12	Carbon steel
				API 13 3/8"	29435	31712	29706	12-14 (unit length)	315	339.8	12.2	Carbon steel
	Downhole pumps	Impeller	not used	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
Fluid transmission	Pipes	2-phase pipes		DN250	deleted	deleted	deleted	deleted	263	273	5	Carbon steel
				DN500	deleted	deleted		deleted	494	508	6-8	Carbon steel
				DN700	deleted	deleted		deleted	689	711	10-12	Carbon steel
				DN1000	deleted	deleted		deleted	994	1016	10-12	Carbon steel
		Steam pipes		DN1000	deleted	deleted	deleted	deleted	994	1016	10-12	Carbon steel
				DN1400	deleted	deleted		deleted	1428	1462	17	Carbon steel
	Turbines	Diaphragm	6 stages (units 1 and 2)			44				700-1300/1900-2900	50-220	
		Rotor	6 stages (units 1 and 2)			13				600-1300	70-160	Low alloy steel
		Rotor blades	general									stainless steel
			unit 1 and 2			*25*		*0,11-0,76*				*stainless steel*
		Turbine casing	1 per unit									Carbon steel (HP pressure units)
Reinjection system	Brine pipelines	Pipes		DN600	deleted	deleted	deleted		594	610	8	Carbon steel
				DN700	deleted	deleted	deleted		695	711	8	Carbon steel
				DN1000	deleted	deleted	deleted		994	1016	10-12	Carbon steel
				DN500	deleted	deleted	deleted		494	508	*6-8*	Stainless steel
				DN1000	deleted	deleted	deleted		994	1016	*10-12*	Stainless steel

Table A2 - A data sheet for 66 MW Svartsengi single flash and dry steam power plant provided by ON POWER & ICI

For Icelandic power plant case study of GeoCoat application, we need the following information regarding main components involved in that plant for data inventory of GeoCoat deliverables								
Icelandic single flash power plant								
Name of the plant	Svartsengi (units 3, 5 and 6)							
Power plant capacity	66 MW							
System	**Component**	**Part**	**Quantity/comments**	**ID**	**Surface area - inner**	**Surface area - outer**	**Total length**	**Length**
					(m2)	(m2)	(m)	(m)
Fluid gathering	Pipes	Casings	One 2-phase	API 9 5/8"	deleted	deleted	deleted	12-14 (unit length)
			One dry steam	API 9 5/8"	deleted	deleted	deleted	12-14 (unit length)
			Four 2-phase	API 13 3/8"	deleted	deleted	deleted	12-14 (unit length)
			Four dry steam	API 13 3/8"	deleted	deleted	deleted	12-14 (unit length)
	Downhole pumps	Impeller	not used	n/a	n/a	n/a		n/a
Fluid transmission	Pipes	2-phase pipes		*DN400*	*deleted*	*deleted*	deleted	3860
		Dry steam pipes	OV-5	*DN700*	*deleted*	*deleted*	deleted	800
		Dry steam pipes	OV-6	*DN700*	*deleted*	*deleted*		3100
		Steam pipes		*DN700*	*deleted*	*deleted*	deleted	460
	Turbine (Unit 3)	Diaphragm	2 stages			*0,1-0,12*		*0,05-0,08*
		Rotor						
		Rotor blades	2 stages			*0,2-0,27*		*0,05-0,12*
	Turbine (Unit 5)	Diaphragm	10 stages			12		*0,1-0,3*
		Rotor						
		Rotor blades	10 stages			19		*0,1-0,5*
	Turbine (Unit 6)	Diaphragm	14 stages			34		*0,07-0,39*
		Rotor						
		Rotor blades	14 stages			22		*0,07-0,487*
Reinjection system	Brine pipelines	Pipes		DN500	*deleted*	*deleted*	deleted	

Table A3 - A data sheet for 50 kW Transgex-Oradea binary power plant provided by METAV R&D

For Romanian power plant case study of GeoCoat application, we need the following information regarding main components involved in that plant for data inventory of Ge

Romanian Binary power plant

Name of the plant	TRANSGEX -Oradea	Binary pilot power plant

System	Component	Part	Quantity	API ID	Total length	Outer Diameter	Thickness	Material type	Material grade
					(m)	(mm)	(mm)		
Brine production	Pipes	Casings	1		deleted	150	10	P265GH	X42
		Casings	2		deleted	311	10		X42
		Uncased	3	API 5L	deleted	215	10	uncased	X42
Brine transmission	Pipes	2-phase pipes			deleted	200			
							5		
				API 5L				P265GH	X42
	Heat exchangers	Tubes					3	316	
Reinjection system	Brine pipelines	Pipes			deleted	200	5		
				API 5L				P265GH	X42

Items	Units	Values
Reservoir depth	km	2280-2370
Reservoir / Geofluid temperature	deg C	95-110
Geofluid outlet temperature	deg C	90
Conversion efficiency	%	38
Installed power capacity	MW	0.05
Full load hours annually	h	7 920
Specific heat capacity of geofluid	kJ /kg K	1,035
Lifetime	years	20
Geofluid flow rate	m3 h-1	75
Specific auxiliary power need for downhole pump relating to fluid rate	kW / m3 h-1	160

Components	Quantities
Number of production wells	2
Number of reinjection wells	1
Evaporators	1
Preheaters	0
Turbines	1
Generators	1
Condensers	1
Downhole pumps	2
Feed pumps	2
Cooling tower	1

Appendix B - Inventory results of all compartments for ICS1, ICS2 and RCS power plants of installed capacity of 1 MW with adoption of 2nd ranked Geo-Coat technology

Table B1 - Inventory results of all compartments for ICS1, ICS2 and RCS power plants of installed capacity of 1 MW with adoption of 2nd ranked Geo-Coat technology

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1	1-Butanol	Air	mg	1.15	1.10	91.74
2	1-Butanol	Water	g	0.51	0.50	47.15
3	1-Pentanol	Air	mg	0.28	0.28	23.74
4	1-Pentanol	Water	mg	0.68	0.67	56.98
5	1-Pentene	Air	mg	0.79	0.77	62.73
6	1-Pentene	Water	mg	0.52	0.51	43.06
7	1-Propanol	Air	g	6.75	7.09	362.78
8	1-Propanol	Water	mg	0.76	0.75	63.76
9	1,3-Dioxolan-2-one	Water	g	0.65	0.64	56.74
10	1,4-Butanediol	Air	mg	7.34	6.92	607.13
11	1,4-Butanediol	Water	g	0.02	0.02	1.38
12	2-Aminopropanol	Air	mg	0.21	0.21	17.33
13	2-Aminopropanol	Water	mg	0.51	0.50	41.92
14	2-Butene, 2-methyl-	Air	µg	0.97	0.96	73.62
15	2-Butene, 2-methyl-	Water	µg	2.32	2.30	176.68
16	2-Chlorobenzaldehyde	Water	mg	0.14	0.14	11.20
17	2-Methyl-1-propanol	Air	mg	0.41	0.40	34.00
18	2-Methyl-1-propanol	Water	mg	0.97	0.96	81.61
19	2-Methyl-4-chlorophenoxyacetic acid	Air	mg	0.03	0.03	2.30
20	2-Methyl-4-chlorophenoxyacetic acid	Water	mg	0.07	0.06	5.38
21	2-Methyl-4-chlorophenoxyacetic acid	Soil	g	0.04	0.04	3.49
22	2-Nitrobenzoic acid	Air	mg	0.08	0.08	6.36
23	2-Propanol	Air	g	10.77	10.54	954.69
24	2-Propanol	Water	g	0.13	0.13	12.18
25	2,4-D	Air	mg	5.69	5.50	468.22
26	2,4-D	Soil	g	0.52	0.50	42.32
27	2,4-D amines	Water	mg	0.09	0.08	7.00
28	2,4-D amines	Soil	mg	2.73	2.67	223.71
29	2,4-D ester	Air	mg	0.16	0.16	13.09
30	2,4-D ester	Water	mg	0.02	0.02	1.54
31	2,4-D ester	Soil	mg	0.73	0.72	60.16
32	2,4-D, dimethylamine salt	Air	mg	0.01	0.01	1.12

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
33	2,4-di-tert-butylphenol	Water	mg	0.64	0.61	50.54
34	4-Methyl-2-pentanol	Water	ng	0.79	0.78	68.05
35	4-Methyl-2-pentanone	Air	µg	5.70	5.58	487.80
36	4-Methyl-2-pentanone	Water	g	0.02	0.02	1.21
37	Abamectin	Soil	mg	0.41	0.40	33.76
38	Acenaphthene	Air	g	0.04	0.04	3.21
39	Acenaphthene	Water	g	0.03	0.03	2.59
40	Acenaphthylene	Air	mg	0.21	0.22	10.87
41	Acenaphthylene	Water	mg	0.18	0.17	13.93
42	Acephate	Air	mg	0.60	0.58	49.77
43	Acephate	Soil	g	0.08	0.08	6.41
44	Acetaldehyde	Air	kg	0.03	0.03	2.66
45	Acetaldehyde	Water	g	2.05	2.02	187.94
46	Acetamide	Air	mg	0.15	0.14	12.25
47	Acetamide	Soil	g	0.01	0.01	1.10
48	Acetamiprid	Soil	g	0.02	0.02	1.68
49	Acetic acid	Air	kg	0.10	0.10	8.12
50	Acetic acid	Water	g	2.95	2.88	260.47
51	Acetochlor	Soil	g	0.25	0.25	22.55
52	Acetone	Air	kg	0.02	0.02	1.83
53	Acetone	Water	g	0.06	0.06	4.70
54	Acetonitrile	Air	g	0.29	0.28	23.33
55	Acetonitrile	Water	mg	0.08	0.08	6.50
56	Acetyl chloride	Water	mg	0.54	0.53	44.76
57	Acidity, unspecified	Water	g	2.30	2.31	166.79
58	Acifluorfen	Air	mg	0.08	0.08	6.83
59	Acifluorfen	Soil	µg	3.56	3.44	292.86
60	Aclonifen	Soil	mg	0.56	0.54	44.49
61	Acrinathrin	Soil	mg	0.03	0.03	2.47
62	Acrolein	Air	g	7.40	7.09	581.79
63	Acrylate	Water	g	0.06	0.06	5.11
64	Acrylic acid	Air	g	0.03	0.03	2.16
65	Acrylonitrile	Air	mg	3.55	3.40	280.74
66	Acrylonitrile	Water	mg	0.09	0.08	6.74
67	Actinides, radioactive, unspecified	Air	kBq	5.95	5.90	424.72
68	Actinides, radioactive, unspecified	Water	kBq	0.26	0.26	19.54
69	Aerosols, radioactive, unspecified	Air	kBq	0.05	0.05	4.03
70	Alachlor	Air	mg	0.59	0.57	48.35
71	Alachlor	Soil	g	0.04	0.04	3.26
72	Aldehydes, unspecified	Air	g	3.79	3.77	273.38

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
73	Aldicarb	Soil	g	0.21	0.21	17.55
74	Aldrin	Soil	g	0.11	0.11	8.32
75	Allyl chloride	Water	mg	4.65	4.55	368.72
76	Alpha-cypermethrin	Soil	mg	0.35	0.35	28.97
77	Aluminium	Raw	tn.lg	0.35	0.41	9.44
78	Aluminium	Air	tn.lg	0.05	0.05	4.52
79	Aluminium	Water	tn.lg	0.96	0.93	85.82
80	Aluminium	Soil	kg	0.25	0.24	19.16
81	Aluminium hydroxide	Water	mg	0.63	0.61	49.89
82	Ametryn	Soil	mg	7.27	7.13	595.07
83	Amidosulfuron	Soil	µg	10.45	10.27	917.04
84	Amine oxide	Air	mg	0.62	0.59	49.07
85	Ammonia	Air	tn.lg	0.02	0.02	1.99
86	Ammonium carbonate	Air	g	0.02	0.02	1.19
87	Ammonium, ion	Water	kg	0.39	0.38	31.00
88	Anhydrite	Raw	g	0.78	0.77	65.76
89	Aniline	Air	mg	1.38	1.35	113.98
90	Aniline	Water	mg	3.58	3.50	294.84
91	Anthracene	Air	ng	4.67	4.58	381.75
92	Anthracene	Water	mg	6.45	6.33	527.33
93	Anthranilic acid	Air	mg	0.06	0.06	4.70
94	Anthraquinone	Soil	mg	3.94	3.87	346.66
95	Antimony	Air	kg	0.07	0.07	5.58
96	Antimony	Water	kg	2.40	2.34	233.21
97	Antimony	Soil	mg	7.89	7.53	630.03
98	Antimony-122	Water	Bq	6.29	6.16	469.99
99	Antimony-124	Air	mBq	7.38	7.24	549.64
100	Antimony-124	Water	kBq	16.43	16.07	1242.68
101	Antimony-125	Air	Bq	0.16	0.16	12.17
102	Antimony-125	Water	kBq	0.33	0.32	24.41
103	AOX, Adsorbable Organic Halogen as Cl	Water	kg	0.04	0.04	3.21
104	Argon	Raw	tn.lg	0.13	0.13	13.00
105	Argon-40	Air	kg	0.52	0.50	43.42
106	Argon-41	Air	kBq	27.59	27.02	2053.23
107	Arsenic	Air	kg	0.02	0.02	1.75
108	Arsenic	Water	kg	7.47	7.29	725.68
109	Arsenic	Soil	g	0.12	0.12	9.08
110	Arsine	Air	µg	0.32	0.30	25.15
111	Asulam	Soil	mg	0.66	0.64	53.56
112	Atrazine	Air	mg	0.64	0.63	53.10
113	Atrazine	Water	mg	1.02	1.00	83.84
114	Atrazine	Soil	g	0.69	0.67	59.13

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
115	Azinphos-methyl	Soil	mg	0.20	0.20	16.65
116	Azoxystrobin	Air	mg	0.27	0.27	22.61
117	Azoxystrobin	Soil	g	0.21	0.20	16.88
118	Barite	Raw	tn.lg	0.02	0.02	1.84
119	Barite	Water	kg	1.64	1.63	117.52
120	Barium	Air	kg	0.06	0.06	4.56
121	Barium	Water	kg	3.78	3.70	320.92
122	Barium	Soil	kg	0.08	0.08	6.13
123	Barium-140	Air	Bq	3.51	3.45	260.81
124	Barium-140	Water	Bq	9.14	8.97	678.25
125	Barium sulfide	Water	mg	0.62	0.59	48.70
126	Basalt	Raw	kg	8.95	8.81	696.04
127	Benfluralin	Soil	g	0.05	0.05	4.03
128	Benomyl	Soil	mg	0.23	0.22	18.22
129	Bensulfuron methyl ester	Soil	µg	5.94	5.97	428.83
130	Bentazone	Air	mg	0.32	0.31	26.02
131	Bentazone	Water	mg	0.44	0.43	36.03
132	Bentazone	Soil	g	0.01	0.01	1.03
133	Benzal chloride	Air	mg	0.08	0.08	6.28
134	Benzal chloride	Water	mg	0.18	0.18	14.52
135	Benzaldehyde	Air	g	5.26	5.02	417.27
136	Benzaldehyde	Water	mg	0.06	0.06	4.76
137	Benzene	Air	kg	0.70	0.68	53.02
138	Benzene	Water	kg	0.11	0.11	9.46
139	Benzene, 1-methyl-2-nitro-	Air	mg	0.07	0.07	5.49
140	Benzene, 1,2-dichloro-	Air	mg	0.94	0.92	77.90
141	Benzene, 1,2-dichloro-	Water	kg	0.04	0.04	3.33
142	Benzene, chloro-	Water	kg	0.06	0.05	4.83
143	Benzene, ethyl-	Air	kg	0.01	0.01	1.06
144	Benzene, ethyl-	Water	g	6.04	5.85	464.94
145	Benzene, hexachloro-	Air	mg	4.93	4.77	407.49
146	Benzene, pentachloro-	Air	mg	0.10	0.09	7.31
147	Benzene, pentachloronitro-	Soil	mg	2.10	2.06	171.60
148	Benzo(a)anthracene	Air	µg	4.03	4.32	209.07
149	Benzo(a)anthracene	Water	mg	0.02	0.02	1.99
150	Benzo(a)pyrene	Air	g	2.75	2.68	206.12
151	Benzo(a)pyrene	Water	µg	2.96	2.90	241.78
152	Benzo(b)fluoranthene	Air	µg	4.76	5.10	246.96
153	Benzo(b)fluoranthene	Water	µg	2.88	2.83	235.81
154	Benzo(g,h,i)perylene	Air	µg	0.29	0.32	15.35
155	Benzo(g,h,i)perylene	Water	µg	0.41	0.40	33.18

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
156	Benzo(k)fluoranthene	Air	µg	3.44	3.69	178.59
157	Benzo(k)fluoranthene	Water	µg	1.36	1.33	110.94
158	Beryllium	Air	g	0.54	0.52	47.91
159	Beryllium	Water	kg	1.01	0.98	97.03
160	Bicarbonate, ion	Water	mg	5.42	5.19	427.49
161	Bifenox	Soil	mg	1.08	1.06	94.65
162	Bifenthrin	Soil	mg	0.93	0.91	82.16
163	Bisphenol A	Water	mg	0.34	0.33	27.08
164	Bitertanol	Soil	mg	0.41	0.40	36.11
165	BOD5, Biological Oxygen Demand	Water	tn.lg	0.14	0.13	10.64
166	Borate	Water	g	0.36	0.36	27.09
167	Borax	Raw	kg	0.02	0.02	1.61
168	Boric acid	Air	µg	0.40	0.47	5.02
169	Boron	Air	kg	0.36	0.35	26.43
170	Boron	Water	tn.lg	0.20	0.19	19.53
171	Boron	Soil	g	3.36	3.29	249.27
172	Boron trifluoride	Air	mg	2.67	3.16	33.97
173	Boscalid	Soil	g	0.01	0.01	1.22
174	Bromacil	Soil	g	0.01	0.01	1.19
175	Bromate	Water	g	13.31	14.15	797.15
176	Bromide	Water	g	3.18	3.12	264.81
177	Bromine	Raw	g	3.90	3.82	324.13
178	Bromine	Air	kg	0.11	0.11	8.21
179	Bromine	Water	kg	1.29	1.27	96.62
180	Bromine	Soil	g	0.08	0.07	6.20
181	Bromopropane	Air	mg	0.82	0.78	64.60
182	Bromopropane	Water	mg	0.03	0.03	2.28
183	Bromoxynil	Air	mg	0.02	0.02	1.31
184	Bromoxynil	Water	mg	0.10	0.09	7.83
185	Bromoxynil	Soil	mg	8.75	8.59	751.63
186	Bromuconazole	Soil	µg	7.90	7.74	643.87
187	Buprofezin	Soil	mg	0.35	0.34	28.30
188	Butadiene	Air	mg	0.35	0.34	28.54
189	Butane	Air	kg	0.55	0.55	39.84
190	Butene	Air	g	6.18	5.98	476.59
191	Butene	Water	g	0.16	0.16	12.23
192	Butyl acetate	Water	g	0.66	0.65	61.02
193	Butyric acid, 4-(2,4-dichlorophenoxy)-	Air	mg	0.14	0.13	11.24
194	Butyric acid, 4-(2,4-dichlorophenoxy)-	Water	mg	0.06	0.06	4.84
195	Butyric acid, 4-(2,4-dichlorophenoxy)-	Soil	mg	2.18	2.14	180.23

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
196	Butyrolactone	Air	mg	6.19	5.81	514.04
197	Butyrolactone	Water	g	0.02	0.01	1.25
198	Cadmium	Raw	kg	0.14	0.14	9.86
199	Cadmium	Air	g	4.95	4.86	391.29
200	Cadmium	Water	kg	4.67	4.56	457.58
201	Cadmium	Soil	g	0.11	0.11	8.77
202	Calcite	Raw	tn.lg	7.03	6.97	503.13
203	Calcium	Air	kg	0.64	0.66	38.07
204	Calcium	Water	tn.lg	9.24	9.00	875.10
205	Calcium	Soil	kg	1.77	1.72	135.67
206	Captan	Soil	g	0.98	0.96	79.83
207	Carbaryl	Air	mg	0.08	0.08	6.40
208	Carbaryl	Water	µg	0.12	0.12	9.83
209	Carbaryl	Soil	mg	0.08	0.08	6.57
210	Carbendazim	Soil	g	0.02	0.02	1.63
211	Carbetamide	Soil	g	0.02	0.02	1.80
212	Carbofuran	Soil	g	0.13	0.12	10.02
213	Carbon	Air	g	0.04	0.04	3.12
214	Carbon	Water	g	0.14	0.14	10.67
215	Carbon	Soil	kg	0.61	0.60	46.37
216	Carbon-14	Air	kBq	443.44	433.30	33360.62
217	Carbon-14	Water	kBq	1.80	1.76	135.93
218	Carbon dioxide, biogenic	Air	tn.lg	2.75	2.69	209.93
219	Carbon dioxide, fossil	Air	kton	0.09	0.09	6.31
220	Carbon dioxide, in air	Raw	tn.lg	2.67	2.62	204.41
221	Carbon dioxide, land transformation	Air	tn.lg	0.14	0.14	9.72
222	Carbon dioxide, to soil or biomass stock	Soil	kg	0.45	0.44	36.73
223	Carbon disulfide	Air	tn.lg	0.03	0.03	2.52
224	Carbon disulfide	Water	mg	9.33	9.15	798.28
225	Carbon monoxide, biogenic	Air	kg	7.10	7.02	502.18
226	Carbon monoxide, fossil	Air	tn.lg	0.68	0.65	55.08
227	Carbon monoxide, land transformation	Air	kg	0.17	0.16	13.48
228	Carbon, organic, in soil or biomass stock	Raw	kg	3.97	3.86	323.68
229	Carbonate	Water	kg	0.06	0.06	4.22
230	Carbonyl sulfide	Air	kg	0.02	0.02	1.70
231	Carboxylic acids, unspecified	Water	kg	1.01	0.98	77.94

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
232	Carfentrazone-ethyl	Air	µg	7.62	7.37	627.16
233	Carfentrazone-ethyl	Soil	mg	0.04	0.04	3.55
234	Carnallite	Raw	kg	0.07	0.07	5.81
235	Cerium	Raw	g	0.48	0.51	24.60
236	Cerium-141	Air	Bq	0.85	0.84	63.20
237	Cerium-141	Water	Bq	4.47	4.39	332.53
238	Cerium-144	Water	Bq	3.35	3.28	250.59
239	Cesium	Water	g	0.24	0.23	18.24
240	Cesium-134	Air	Bq	0.04	0.04	3.03
241	Cesium-134	Water	kBq	0.16	0.16	12.15
242	Cesium-136	Water	Bq	1.95	1.91	146.09
243	Cesium-137	Air	Bq	0.76	0.74	56.19
244	Cesium-137	Water	kBq	31.56	30.89	2365.24
245	Chloramine	Air	mg	2.10	2.05	168.70
246	Chloramine	Water	g	0.02	0.02	1.51
247	Chlorate	Water	kg	0.12	0.13	7.44
248	Chlorfenvinphos	Soil	mg	3.07	3.01	251.00
249	Chloridazon	Soil	mg	0.70	0.69	57.46
250	Chloride	Water	tn.lg	0.67	0.67	48.54
251	Chloride	Soil	kg	0.69	0.67	52.52
252	Chlorides, unspecified	Water	kg	1.54	1.57	116.90
253	Chlorimuron-ethyl	Air	mg	0.14	0.13	11.41
254	Chlorimuron-ethyl	Soil	mg	0.16	0.16	13.23
255	Chlorinated solvents, unspecified	Air	g	0.05	0.05	4.09
256	Chlorinated solvents, unspecified	Water	g	5.12	5.17	361.31
257	Chlorine	Air	kg	0.04	0.04	3.34
258	Chlorine	Water	g	2.21	2.11	175.54
259	Chlorine	Soil	g	2.02	1.93	161.39
260	Chlormequat	Soil	mg	10.54	10.33	897.79
261	Chloroacetic acid	Air	mg	9.07	8.80	735.86
262	Chloroacetic acid	Water	g	0.26	0.25	21.42
263	Chloroacetyl chloride	Water	mg	0.68	0.67	55.91
264	Chloroform	Air	g	0.46	0.46	33.82
265	Chloroform	Water	mg	3.96	3.81	315.90
266	Chloropicrin	Soil	g	0.32	0.32	26.37
267	Chlorosilane, trimethyl-	Air	mg	6.88	6.75	539.31
268	Chlorosulfonic acid	Air	mg	0.13	0.12	10.26
269	Chlorosulfonic acid	Water	mg	0.29	0.28	23.65
270	Chlorothalonil	Soil	g	1.42	1.40	126.47
271	Chlorpyrifos	Air	mg	2.76	2.68	227.64
272	Chlorpyrifos	Soil	g	0.19	0.18	15.48

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
273	Chlorpyrifos methyl	Soil	g	0.31	0.30	25.38
274	Chlorsulfuron	Soil	µg	10.89	10.67	887.62
275	Chlortoluron	Soil	mg	10.18	9.90	862.16
276	Choline chloride	Soil	mg	1.50	1.47	122.37
277	Chromium	Raw	tn.lg	0.73	0.86	13.66
278	Chromium	Air	kg	0.62	0.68	26.75
279	Chromium	Water	g	9.15	9.37	616.15
280	Chromium	Soil	g	1.97	1.92	152.80
281	Chromium-51	Air	Bq	0.05	0.05	4.05
282	Chromium-51	Water	kBq	0.72	0.70	53.16
283	Chromium IV	Air	µg	0.07	0.07	5.48
284	Chromium VI	Air	g	15.69	17.36	676.74
285	Chromium VI	Water	tn.lg	0.07	0.07	5.80
286	Chromium VI	Soil	g	9.76	9.62	714.66
287	Chrysene	Air	µg	0.46	0.49	24.43
288	Chrysene	Water	mg	0.02	0.02	1.28
289	Chrysotile	Raw	g	4.47	4.76	262.92
290	Cinidon-ethyl	Soil	mg	0.01	0.01	1.11
291	Cinnabar	Raw	g	0.07	0.08	4.72
292	Clay, bentonite	Raw	kg	11.18	10.86	883.51
293	Clay, unspecified	Raw	tn.lg	1.10	1.12	78.39
294	Clethodim	Air	mg	0.41	0.40	33.76
295	Clethodim	Soil	mg	0.29	0.28	24.03
296	Clodinafop-propargyl	Soil	mg	0.16	0.16	13.14
297	Clomazone	Soil	mg	0.66	0.65	55.51
298	Clopyralid	Soil	mg	0.20	0.20	17.07
299	Cloquintocet-mexyl	Soil	mg	0.04	0.04	3.17
300	Cloransulam-methyl	Air	mg	0.07	0.07	5.94
301	Cloransulam-methyl	Soil	mg	0.07	0.07	5.72
302	Coal, brown	Raw	tn.lg	9.81	9.64	724.32
303	Coal, hard	Raw	kton	0.02	0.02	1.80
304	Cobalt	Raw	tn.lg	0.07	0.07	7.19
305	Cobalt	Air	g	147.30	177.73	917.77
306	Cobalt	Water	tn.lg	0.02	0.02	1.46
307	Cobalt	Soil	g	0.12	0.12	9.79
308	Cobalt-57	Water	kBq	0.06	0.06	4.64
309	Cobalt-58	Air	Bq	0.15	0.15	11.36
310	Cobalt-58	Water	kBq	8.32	8.15	621.80
311	Cobalt-60	Air	Bq	1.02	1.00	76.21
312	Cobalt-60	Water	kBq	4.70	4.61	350.66
313	Cobalt, Co 5.0E-2%, in mixed ore	Raw	kg	1.39	1.41	108.86

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
314	COD, Chemical Oxygen Demand	Water	tn.lg	0.31	0.30	24.42
315	Colemanite	Raw	kg	0.15	0.15	11.74
316	Copper	Air	kg	0.15	0.16	7.74
317	Copper	Water	tn.lg	0.04	0.04	3.77
318	Copper	Soil	g	10.03	9.84	764.05
319	Copper, 0.52% in sulfide, Cu 0.27% and Mo 8.2E-3% in crude ore	Raw	tn.lg	0.34	0.33	34.06
320	Copper, 0.59% in sulfide, Cu 0.22% and Mo 8.2E-3% in crude ore	Raw	tn.lg	0.48	0.46	47.71
321	Copper, 0.97% in sulfide, Cu 0.36% and Mo 4.1E-2% in crude ore	Raw	tn.lg	0.51	0.49	51.07
322	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore	Raw	kg	5.66	5.56	450.39
323	Copper, 1.13% in sulfide, Cu 0.76% and Ni 0.76% in crude ore	Raw	kg	71.66	87.67	20.26
324	Copper, 1.18% in sulfide, Cu 0.39% and Mo 8.2E-3% in crude ore	Raw	tn.lg	0.56	0.55	56.44
325	Copper, 1.42% in sulfide, Cu 0.81% and Mo 8.2E-3% in crude ore	Raw	kg	0.50	0.50	40.43
326	Copper, 2.19% in sulfide, Cu 1.83% and Mo 8.2E-3% in crude ore	Raw	kg	1.58	1.55	126.50
327	Copper, Cu 0.2%, in mixed ore	Raw	g	4.56	5.22	114.46
328	Copper, Cu 0.38%, Au 9.7E-4%, Ag 9.7E-4%, Zn 0.63%, Pb 0.014%, in ore	Raw	kg	5.30	5.20	424.56
329	Copper, Cu 3.2E+0%, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0% in ore	Raw	kg	44.58	54.51	22.92

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
330	Copper, Cu 5.2E-2%, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Ni 3.7E-2% in ore	Raw	kg	0.57	0.69	3.57
331	Copper, Cu 6.8E-1%, in mixed ore	Raw	tn.lg	0.02	0.02	1.46
332	Cu-HDO	Water	µg	1.03	1.02	75.83
333	Cumene	Air	g	4.55	4.47	412.79
334	Cumene	Water	kg	0.02	0.02	1.47
335	Cyanide	Air	kg	0.04	0.04	2.81
336	Cyanide	Water	kg	1.07	1.06	101.94
337	Cyanoacetic acid	Air	mg	0.09	0.09	7.77
338	Cyclohexane	Air	mg	3.50	3.44	272.93
339	Cyclohexane	Water	mg	3.63	3.48	287.05
340	Cycloxydim	Soil	mg	1.98	1.94	161.98
341	Cyfluthrin	Air	mg	0.01	0.01	1.19
342	Cyfluthrin	Soil	mg	0.88	0.86	73.14
343	Cyhalothrin, gamma-	Air	mg	0.17	0.16	13.67
344	Cyhalothrin, gamma-	Soil	µg	7.12	6.89	586.10
345	Cymoxanil	Soil	mg	7.35	7.21	601.94
346	Cypermethrin	Air	mg	0.04	0.03	2.89
347	Cypermethrin	Soil	g	0.11	0.11	8.97
348	Cyproconazole	Soil	g	0.34	0.33	27.46
349	Cyprodinil	Soil	g	0.05	0.05	4.30
350	Decanoic acid	Water	mg	0.24	0.23	18.84
351	Deltamethrin	Soil	mg	0.12	0.11	10.01
352	Desmedipham	Soil	mg	0.48	0.47	42.78
353	Diatomite	Raw	g	0.32	0.31	24.10
354	Diazinon	Soil	g	0.03	0.03	2.41
355	Dibenz(a,h)anthracene	Air	µg	2.23	2.40	115.86
356	Dibenz(a,h)anthracene	Water	µg	0.28	0.28	23.23
357	Dicamba	Air	mg	0.52	0.50	42.52
358	Dicamba	Water	mg	0.11	0.11	8.89
359	Dicamba	Soil	g	0.01	0.01	1.11
360	Dichlorodimethylsilane	Air	mg	2.76	2.64	218.01
361	Dichlorprop	Air	mg	0.02	0.02	1.61
362	Dichlorprop	Water	mg	0.02	0.02	1.68
363	Dichlorprop	Soil	mg	0.81	0.80	66.71
364	Dichlorprop-P	Soil	g	0.05	0.05	4.30
365	Dichromate	Water	g	0.30	0.29	21.69
366	Diclofop	Soil	mg	6.23	6.12	548.72
367	Diclofop-methyl	Soil	mg	6.30	6.19	554.93
368	Dicrotophos	Soil	mg	11.52	11.30	942.41
369	Diethanolamine	Water	mg	2.14	2.13	174.59

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
370	Diethyl ether	Air	µg	4.82	4.91	309.00
371	Diethylamine	Air	mg	0.78	0.77	64.53
372	Diethylamine	Water	mg	1.88	1.84	154.88
373	Diethylene glycol	Air	µg	28.35	33.51	371.07
374	Diethylene glycol	Water	mg	0.31	0.29	24.28
375	Difenoconazole	Soil	g	0.30	0.29	24.48
376	Diflubenzuron	Air	µg	7.62	7.37	627.16
377	Diflubenzuron	Soil	g	0.24	0.23	19.54
378	Diflufenican	Soil	g	0.03	0.02	2.10
379	Diflufenzopyr-sodium	Soil	mg	0.82	0.81	73.03
380	Dimethachlor	Soil	mg	0.91	0.89	79.35
381	Dimethenamid	Air	mg	0.03	0.03	2.42
382	Dimethenamid	Water	µg	10.50	10.29	865.66
383	Dimethenamid	Soil	g	0.03	0.03	2.65
384	Dimethoate	Soil	g	0.11	0.11	8.87
385	Dimethomorph	Soil	mg	4.64	4.56	380.26
386	Dimethyl carbonate	Air	g	0.06	0.06	5.51
387	Dimethyl hexanediol	Water	mg	0.31	0.29	24.17
388	Dimethyl hexynediol	Water	mg	0.49	0.47	38.97
389	Dimethyl malonate	Air	mg	0.12	0.12	9.74
390	Dimethylamine	Air	mg	4.72	4.52	372.92
391	Dimethylamine	Water	mg	2.58	2.51	209.80
392	Dimethyldichlorosilane	Air	mg	2.11	2.02	166.24
393	Dimethyldichlorosilane	Water	mg	0.08	0.07	6.13
394	Dinitrogen monoxide	Air	kg	5.32	5.26	433.44
395	Dinitrogen tetroxide	Air	mg	4.65	4.72	355.19
396	Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	Air	mg	0.05	0.05	4.13
397	Diphenylether-compound	Water	mg	0.07	0.07	5.66
398	Dipropylamine	Air	mg	0.38	0.37	31.40
399	Dipropylamine	Water	mg	0.91	0.89	75.36
400	Dipropylthiocarbamic acid S-ethyl ester	Soil	mg	8.33	8.18	682.21
401	Diquat	Soil	mg	9.64	9.46	789.04
402	Dithianone	Soil	mg	0.10	0.10	9.17
403	Diuron	Soil	g	0.12	0.11	9.31
404	DOC, Dissolved Organic Carbon	Water	tn.lg	0.12	0.12	9.54
405	Dodecanoic acid	Air	mg	0.26	0.25	20.81
406	Dodecanoic acid	Water	mg	4.44	4.42	362.30
407	Dodecanol	Water	mg	0.60	0.57	47.06
408	Dolomite	Raw	tn.lg	0.27	0.25	22.00
409	Endosulfan	Soil	g	0.07	0.07	5.92

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
410	Endothall	Soil	mg	0.02	0.02	1.34
411	Energy, geothermal, converted	Raw	MWh	0.56	0.55	42.59
412	Energy, gross calorific value, in biomass	Raw	TJ	0.03	0.03	2.19
413	Energy, gross calorific value, in biomass, primary forest	Raw	MWh	0.02	0.02	1.38
414	Energy, kinetic (in wind), converted	Raw	TJ	0.01	0.01	1.05
415	Energy, potential (in hydropower reservoir), converted	Raw	TJ	0.23	0.23	15.28
416	Energy, solar, converted	Raw	GJ	0.02	0.02	1.21
417	Epichlorohydrin	Water	mg	0.15	0.15	12.07
418	Epoxiconazole	Soil	mg	1.38	1.35	121.40
419	Esfenvalerate	Air	mg	0.09	0.08	7.12
420	Esfenvalerate	Soil	mg	0.12	0.12	9.81
421	Ethalfluralin	Soil	mg	0.30	0.30	26.45
422	Ethane	Air	kg	1.79	1.78	124.31
423	Ethane, 1,1-difluoro-, HFC-152a	Air	g	2.13	2.19	160.07
424	Ethane, 1,1,1-trichloro-, HCFC-140	Air	g	0.06	0.06	4.10
425	Ethane, 1,1,1-trichloro-, HCFC-140	Water	ng	6.65	7.87	83.83
426	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a	Air	g	0.36	0.35	28.74
427	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-, CFC-113	Air	g	0.01	0.01	1.07
428	Ethane, 1,2-dichloro-	Air	g	7.99	7.96	594.31
429	Ethane, 1,2-dichloro-	Water	g	3.16	2.99	259.32
430	Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	Air	g	1.42	1.39	106.02
431	Ethane, 2-chloro-1,1,1,2-tetrafluoro-, HCFC-124	Air	mg	8.09	8.06	582.75
432	Ethane, hexafluoro-, HFC-116	Air	g	1.86	2.12	53.23
433	Ethanol	Air	kg	0.03	0.03	2.35
434	Ethanol	Water	g	1.48	1.46	130.77
435	Ethene	Air	kg	0.78	0.74	62.67
436	Ethene	Water	g	9.29	9.13	862.09

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
437	Ethene, chloro-	Air	g	3.37	3.39	242.09
438	Ethene, chloro-	Water	g	0.05	0.05	3.66
439	Ethene, tetrachloro-	Air	g	0.18	0.17	12.75
440	Ethene, trichloro-	Air	g	0.03	0.03	2.12
441	Ethephon	Air	ng	1.02	1.00	83.55
442	Ethephon	Water	ng	0.07	0.07	5.55
443	Ethephon	Soil	g	0.04	0.04	3.40
444	Ethofumesate	Soil	g	0.06	0.06	4.77
445	Ethoprop	Soil	mg	1.93	1.89	158.06
446	Ethyl acetate	Air	kg	0.02	0.02	1.26
447	Ethyl acetate	Water	mg	2.24	2.20	192.49
448	Ethyl cellulose	Air	g	0.03	0.03	2.26
449	Ethylamine	Air	mg	0.98	0.96	80.68
450	Ethylamine	Water	mg	2.36	2.31	193.64
451	Ethylene diamine	Air	mg	2.51	2.46	208.71
452	Ethylene diamine	Water	mg	6.05	5.94	502.77
453	Ethylene oxide	Air	g	0.24	0.24	20.55
454	Ethylene oxide	Water	g	0.19	0.19	14.94
455	Ethyne	Air	kg	0.11	0.11	9.24
456	Europium	Raw	mg	1.20	1.27	61.62
457	Feldspar	Raw	g	0.92	0.89	72.19
458	Fenamiphos	Soil	g	0.04	0.04	3.29
459	Fenbuconazole	Soil	mg	0.11	0.11	8.92
460	Fenoxaprop	Air	mg	0.11	0.11	9.33
461	Fenoxaprop	Soil	mg	0.14	0.14	11.57
462	Fenoxaprop-P ethyl ester	Soil	mg	0.44	0.43	39.04
463	Fenoxaprop ethyl ester	Soil	mg	0.52	0.51	45.73
464	Fenpiclonil	Soil	g	0.05	0.05	4.56
465	Fenpropidin	Soil	g	0.01	0.01	1.25
466	Fenpropimorph	Soil	g	0.02	0.02	1.55
467	Fentin hydroxide	Soil	mg	0.33	0.33	27.35
468	Fipronil	Soil	g	0.07	0.07	5.74
469	Florasulam	Soil	mg	0.10	0.10	9.10
470	Fluazifop	Soil	mg	1.85	1.82	151.80
471	Fluazifop-p-butyl	Air	mg	0.16	0.16	13.38
472	Fluazifop-P-butyl	Soil	mg	9.94	9.75	815.05
473	Flucarbazone sodium salt	Soil	µg	0.68	0.67	55.48
474	Fludioxonil	Soil	mg	4.68	4.59	384.21
475	Flufenacet	Air	mg	0.06	0.06	5.02
476	Flufenacet	Soil	mg	4.16	4.09	367.42
477	Flumetsulam	Air	mg	0.01	0.01	1.17
478	Flumetsulam	Soil	mg	1.44	1.42	127.86

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
479	Flumiclorac-pentyl	Air	mg	0.02	0.02	2.01
480	Flumiclorac-pentyl	Soil	µg	1.05	1.01	86.07
481	Flumioxazin	Air	mg	0.25	0.24	20.32
482	Flumioxazin	Soil	mg	0.09	0.09	7.24
483	Fluoranthene	Air	mg	0.04	0.04	1.91
484	Fluoranthene	Water	g	0.13	0.13	10.45
485	Fluorene	Air	mg	0.03	0.04	1.81
486	Fluorene	Water	g	0.05	0.05	3.85
487	Fluoride	Water	tn.lg	0.37	0.36	35.86
488	Fluoride	Soil	kg	0.01	0.01	1.09
489	Fluorine	Raw	tn.lg	0.02	0.01	1.26
490	Fluorine	Air	kg	0.12	0.12	11.84
491	Fluorine, 4.5% in apatite, 3% in crude ore	Raw	kg	10.74	10.08	887.59
492	Fluorspar	Raw	tn.lg	0.03	0.03	2.20
493	Fluosilicic acid	Air	g	8.52	9.81	222.29
494	Fluosilicic acid	Water	g	16.49	19.01	431.08
495	Flupyrsulfuron-methyl	Soil	µg	1.06	1.04	86.12
496	Fluquinconazole	Soil	mg	0.02	0.02	2.08
497	Fluroxypyr	Soil	mg	0.66	0.65	55.44
498	Flurtamone	Soil	g	0.03	0.02	2.11
499	Flusilazole	Soil	mg	0.56	0.55	49.50
500	Flutolanil	Soil	mg	0.38	0.37	31.10
501	Folpet	Soil	mg	6.40	6.28	523.83
502	Fomesafen	Air	mg	0.92	0.89	75.55
503	Fomesafen	Soil	mg	0.55	0.53	45.07
504	Foramsulfuron	Soil	mg	0.15	0.15	13.69
505	Formaldehyde	Air	kg	0.15	0.14	11.03
506	Formaldehyde	Water	g	1.47	1.44	130.42
507	Formamide	Air	mg	0.52	0.51	43.42
508	Formamide	Water	mg	1.25	1.23	104.21
509	Formate	Water	g	0.09	0.08	6.84
510	Formic acid	Air	g	1.77	1.72	144.09
511	Formic acid	Water	mg	0.36	0.36	30.25
512	Fosetyl	Soil	mg	0.57	0.56	46.45
513	Fosetyl-aluminium	Soil	g	0.14	0.14	11.41
514	Fungicides, unspecified	Soil	g	0.08	0.08	6.79
515	Furan	Air	g	7.63	7.43	622.16
516	Furathiocarb	Soil	mg	6.61	6.49	541.55
517	Gadolinium	Raw	mg	3.00	3.18	153.80
518	Gallium	Raw	mg	0.02	0.02	1.61
519	Gangue, bauxite	Raw	tn.lg	3.75	4.32	100.26

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
520	Gas, mine, off-gas, process, coal mining/m3	Raw	m3	233.31	230.21	16938.02
521	Gas, natural/m3	Raw	m3	7860.05	7919.25	526475.78
522	Glucose	Water	mg	0.74	0.70	58.13
523	Glufosinate	Soil	g	0.04	0.04	3.15
524	Glutaraldehyde	Water	g	0.11	0.11	8.10
525	Glyphosate	Air	g	0.19	0.18	15.27
526	Glyphosate	Water	g	0.01	0.01	1.00
527	Glyphosate	Soil	g	5.77	5.58	464.95
528	Gold	Raw	g	0.13	0.12	10.31
529	Gold, Au 1.0E-7%, in mixed ore	Raw	g	0.29	0.29	22.46
530	Gold, Au 1.1E-4%, Ag 4.2E-3%, in ore	Raw	g	0.03	0.03	2.11
531	Gold, Au 1.3E-4%, Ag 4.6E-5%, in ore	Raw	g	0.04	0.04	3.45
532	Gold, Au 1.8E-4%, in mixed ore	Raw	mg	5.44	6.23	136.62
533	Gold, Au 2.1E-4%, Ag 2.1E-4%, in ore	Raw	mg	9.37	8.99	747.78
534	Gold, Au 4.3E-4%, in ore	Raw	g	0.03	0.02	2.01
535	Gold, Au 4.9E-5%, in ore	Raw	g	0.13	0.12	10.09
536	Gold, Au 5.4E-4%, Ag 1.5E-5%, in ore	Raw	mg	0.81	0.78	65.14
537	Gold, Au 6.7E-4%, in ore	Raw	g	0.13	0.13	10.77
538	Gold, Au 6.8E-4%, Ag 1.5E-4%, in ore	Raw	mg	1.10	1.06	88.52
539	Gold, Au 7.1E-4%, in ore	Raw	g	0.06	0.06	4.98
540	Gold, Au 9.7E-4%, Ag 9.7E-4%, Zn 0.63%, Cu 0.38%, Pb 0.014%, in ore	Raw	g	0.13	0.13	10.34
541	Gold, Au 9.7E-5%, Ag 7.6E-5%, in ore	Raw	mg	3.99	3.82	320.25
542	Granite	Raw	mg	0.97	0.95	72.38
543	Gravel	Raw	kton	0.03	0.03	2.04
544	Gypsum	Raw	tn.lg	0.05	0.05	2.79
545	Halosulfuron-methyl	Soil	µg	1.69	1.70	121.87
546	Heat, waste	Air	MWh	0.75	0.74	58.11
547	Heat, waste	Water	MWh	0.20	0.20	15.74
548	Helium	Air	g	9.43	9.15	719.60

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
549	Heptane	Air	kg	0.06	0.06	4.88
550	Herbicides, unspecified	Soil	g	0.05	0.05	3.84
551	Hexaconazole	Soil	g	0.07	0.07	5.53
552	Hexane	Air	kg	0.31	0.31	22.73
553	Hexazinone	Soil	mg	6.73	6.61	551.26
554	Hydramethylnon	Soil	mg	0.16	0.15	12.70
555	Hydrazine	Water	mg	0.03	0.03	2.33
556	Hydrocarbons, aliphatic, alkanes, cyclic	Air	g	7.88	7.75	681.13
557	Hydrocarbons, aliphatic, alkanes, unspecified	Air	kg	0.40	0.39	31.30
558	Hydrocarbons, aliphatic, alkanes, unspecified	Water	kg	0.03	0.03	2.37
559	Hydrocarbons, aliphatic, unsaturated	Air	kg	0.25	0.24	19.31
560	Hydrocarbons, aliphatic, unsaturated	Water	g	2.83	2.74	218.93
561	Hydrocarbons, aromatic	Air	kg	0.15	0.15	10.96
562	Hydrocarbons, aromatic	Water	kg	0.13	0.12	9.77
563	Hydrocarbons, chlorinated	Air	g	9.60	9.70	670.12
564	Hydrocarbons, unspecified	Air	g	0.24	0.23	19.45
565	Hydrocarbons, unspecified	Water	kg	0.05	0.05	3.34
566	Hydrocarbons, unspecified	Soil	g	0.18	0.17	13.00
567	Hydrogen	Air	kg	0.82	0.85	61.89
568	Hydrogen-3, Tritium	Air	kBq	1471.94	1439.21	110649.24
569	Hydrogen-3, Tritium	Water	kBq	166151.96	162558.60	12508966.80
570	Hydrogen carbonate	Water	kg	0.08	0.08	5.76
571	Hydrogen chloride	Air	kg	11.59	11.49	830.90
572	Hydrogen chloride	Water	kg	0.15	0.15	11.40
573	Hydrogen fluoride	Air	kg	2.43	2.58	125.25
574	Hydrogen peroxide	Air	g	0.02	0.02	1.79
575	Hydrogen peroxide	Water	g	0.46	0.45	35.71
576	Hydrogen sulfide	Air	kg	0.41	0.41	28.07
577	Hydrogen sulfide	Water	kg	1.11	1.09	82.62
578	Hydroxide	Water	g	1.69	1.65	126.40
579	Hypochlorite	Water	kg	0.02	0.02	1.82
580	Imazamox	Air	mg	0.04	0.04	3.00

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
581	Imazamox	Soil	mg	0.07	0.07	5.93
582	Imazapyr	Soil	mg	0.02	0.02	1.83
583	Imazaquin	Air	mg	0.12	0.11	9.58
584	Imazaquin	Soil	µg	4.99	4.82	410.54
585	Imazethapyr	Air	mg	0.24	0.23	19.83
586	Imazethapyr	Soil	mg	0.25	0.24	20.90
587	Imidacloprid	Soil	g	0.11	0.11	8.84
588	Indeno(1,2,3-cd)pyrene	Air	µg	0.88	0.94	45.61
589	Indeno(1,2,3-cd)pyrene	Water	µg	4.46	4.38	364.65
590	Indium	Raw	g	2.27	2.26	164.35
591	Indoxacarb	Soil	g	0.03	0.03	2.78
592	Insecticides, unspecified	Soil	mg	5.03	4.93	411.72
593	Iodide	Water	kg	0.03	0.03	2.46
594	Iodine	Raw	g	0.76	0.75	63.26
595	Iodine	Air	kg	0.06	0.06	4.26
596	Iodine-129	Air	kBq	0.16	0.16	12.03
597	Iodine-131	Air	kBq	6.92	6.77	514.75
598	Iodine-131	Water	kBq	3.21	3.14	242.59
599	Iodine-133	Air	Bq	12.66	12.40	946.21
600	Iodine-133	Water	Bq	7.67	7.52	570.81
601	Iodosulfuron	Soil	µg	1.58	1.56	138.95
602	Iodosulfuron-methyl-sodium	Soil	µg	0.66	0.65	53.74
603	Ioxynil	Soil	mg	11.31	11.09	937.01
604	Iprodione	Soil	g	0.46	0.45	37.59
605	Iron	Raw	kton	0.03	0.03	2.75
606	Iron	Air	kg	1.18	1.13	92.88
607	Iron	Water	tn.lg	1.82	1.77	174.88
608	Iron	Soil	kg	2.04	1.96	160.84
609	Iron-59	Water	kBq	14.66	14.33	1108.78
610	Isocyanic acid	Air	g	3.08	3.08	215.95
611	Isoprene	Air	g	0.03	0.02	2.07
612	Isopropylamine	Air	mg	0.58	0.56	48.56
613	Isopropylamine	Water	mg	1.39	1.36	116.53
614	Isoproturon	Soil	g	0.04	0.04	3.49
615	Isoxaflutole	Soil	mg	4.71	4.63	417.56
616	Kaolin	Soil	mg	3.75	3.68	307.04
617	Kaolinite	Raw	kg	3.08	3.03	272.09
618	Kieserite	Raw	kg	0.01	0.01	1.09
619	Kresoxim-methyl	Soil	mg	0.70	0.69	61.43
620	Krypton	Raw	g	0.17	0.17	12.65

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
621	Krypton-85	Air	kBq	87.55	85.75	6515.10
622	Krypton-85m	Air	kBq	97.43	95.46	7266.36
623	Krypton-87	Air	kBq	11.91	11.68	883.97
624	Krypton-88	Air	kBq	15.47	15.18	1148.36
625	Krypton-89	Air	kBq	6.38	6.26	473.45
626	Lactic acid	Air	mg	0.30	0.29	24.60
627	Lactic acid	Water	mg	0.71	0.70	59.03
628	Lactofen	Air	mg	0.12	0.11	9.65
629	Lactofen	Soil	µg	5.02	4.86	413.44
630	Lambda-cyhalothrin	Air	ng	0.03	0.03	2.64
631	Lambda-cyhalothrin	Water	pg	0.02	0.02	1.34
632	Lambda-cyhalothrin	Soil	mg	2.19	2.15	183.71
633	Lanthanum	Raw	g	0.14	0.15	7.37
634	Lanthanum-140	Air	Bq	0.30	0.29	22.28
635	Lanthanum-140	Water	Bq	12.04	11.80	894.96
636	Lead	Raw	kg	2.27	2.26	164.36
637	Lead	Air	kg	0.09	0.09	6.61
638	Lead	Water	kg	3.69	3.60	358.58
639	Lead	Soil	g	1.09	1.05	86.48
640	Lead-210	Air	kBq	28.07	27.66	2035.02
641	Lead-210	Water	kBq	7.91	7.94	586.13
642	Lead, Pb 0.014%, Au 9.7E-4%, Ag 9.7E-4%, Zn 0.63%, Cu 0.38%, in ore	Raw	kg	0.64	0.63	51.31
643	Lead, Pb 3.6E-1%, in mixed ore	Raw	g	8.21	9.40	206.03
644	Lenacil	Soil	mg	3.73	3.66	307.57
645	Linuron	Soil	g	0.17	0.16	13.42
646	Lithium	Raw	g	0.30	0.29	22.54
647	Lithium	Air	µg	6.85	6.78	532.71
648	Lithium	Water	kg	4.31	4.27	309.34
649	Lithium	Soil	mg	5.06	4.83	404.44
650	m-Xylene	Air	g	6.07	5.83	479.33
651	m-Xylene	Water	g	0.12	0.12	8.78
652	Magnesite	Raw	kg	7.92	7.71	641.61
653	Magnesium	Air	kg	0.72	0.73	46.29
654	Magnesium	Water	tn.lg	5.24	5.11	502.38
655	Magnesium	Soil	kg	0.26	0.25	19.53
656	Malathion	Soil	mg	6.46	6.28	517.03
657	Maleic anhydride	Water	mg	0.31	0.29	24.31
658	Maleic hydrazide	Soil	mg	2.11	2.07	172.88
659	Mancozeb	Soil	g	2.39	2.35	208.78
660	Mandipropamid	Soil	µg	4.56	4.47	373.32

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
661	Maneb	Soil	mg	0.05	0.05	4.02
662	Manganese	Raw	kton	0.03	0.03	2.69
663	Manganese	Air	kg	0.14	0.14	13.16
664	Manganese	Water	tn.lg	0.57	0.56	55.45
665	Manganese	Soil	kg	0.08	0.08	6.54
666	Manganese-54	Air	Bq	0.03	0.03	2.07
667	Manganese-54	Water	kBq	0.24	0.24	18.06
668	MCPB	Air	mg	0.03	0.03	2.21
669	MCPB	Water	mg	0.06	0.06	5.11
670	MCPB	Soil	mg	7.42	7.31	576.29
671	Mecoprop	Soil	mg	0.62	0.61	50.68
672	Mecoprop-P	Soil	mg	1.63	1.57	131.97
673	Mefenpyr	Soil	mg	1.04	1.03	91.87
674	Mefenpyr-diethyl	Soil	mg	0.56	0.55	49.38
675	Mepiquat chloride	Soil	mg	5.51	5.41	476.52
676	Mercury	Air	g	2.97	2.93	222.71
677	Mercury	Water	kg	0.02	0.02	1.78
678	Mercury	Soil	mg	2.07	2.02	168.40
679	Mesosulfuron-methyl (prop)	Soil	µg	3.64	3.56	296.46
680	Mesotrione	Soil	mg	6.69	6.58	593.42
681	Metalaxil	Soil	mg	1.56	1.52	126.05
682	Metalaxyl-M	Soil	g	1.52	1.49	124.65
683	Metaldehyde (tetramer)	Soil	g	0.07	0.06	5.46
684	Metam-sodium dihydrate	Soil	g	0.35	0.34	28.25
685	Metamitron	Soil	g	0.19	0.18	15.41
686	Metamorphous rock, graphite containing	Raw	kg	5.00	5.41	204.56
687	Metazachlor	Soil	g	0.04	0.04	3.22
688	Metconazole	Soil	mg	0.14	0.14	12.32
689	Methane	Air	g	0.14	0.14	11.25
690	Methane, biogenic	Air	kg	4.80	4.78	340.97
691	Methane, bromo-, Halon 1001	Air	mg	0.14	0.13	11.13
692	Methane, bromochlorodifluoro-, Halon 1211	Air	g	0.19	0.20	12.35
693	Methane, bromotrifluoro-, Halon 1301	Air	g	0.26	0.25	20.08
694	Methane, chlorodifluoro-, HCFC-22	Air	g	1.24	1.24	86.19

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
695	Methane, dichloro-, HCC-30	Air	g	0.88	0.88	62.04
696	Methane, dichloro-, HCC-30	Water	g	3.69	3.60	278.59
697	Methane, dichlorodifluoro-, CFC-12	Air	g	0.18	0.19	12.83
698	Methane, dichlorofluoro-, HCFC-21	Air	mg	0.10	0.10	7.54
699	Methane, fossil	Air	tn.lg	0.30	0.30	21.47
700	Methane, land transformation	Air	kg	0.01	0.01	1.20
701	Methane, monochloro-, R-40	Air	g	1.53	1.52	109.23
702	Methane, tetrachloro-, CFC-10	Air	g	0.13	0.13	7.89
703	Methane, tetrafluoro-, CFC-14	Air	g	24.15	27.83	630.40
704	Methane, trichlorofluoro-, CFC-11	Air	mg	0.11	0.11	8.31
705	Methane, trifluoro-, HFC-23	Air	g	0.03	0.03	2.40
706	Methanesulfonic acid	Air	mg	0.10	0.09	7.85
707	Methanol	Air	kg	0.06	0.06	4.64
708	Methanol	Water	g	3.23	3.20	254.84
709	Methiocarb	Soil	mg	0.41	0.40	33.44
710	Methomyl	Air	ng	3.48	3.41	285.83
711	Methomyl	Water	ng	0.05	0.05	4.46
712	Methomyl	Soil	ng	10.98	10.75	900.64
713	Methoxyfenozide	Soil	mg	5.17	5.08	423.43
714	Methyl acetate	Air	mg	0.02	0.02	1.47
715	Methyl acetate	Water	mg	0.04	0.04	3.53
716	Methyl acrylate	Air	g	0.03	0.03	2.45
717	Methyl acrylate	Water	g	0.60	0.58	47.83
718	Methyl borate	Air	mg	0.28	0.27	22.94
719	Methyl ethyl ketone	Air	kg	0.02	0.02	1.26
720	Methyl formate	Air	mg	0.24	0.24	19.84
721	Methyl formate	Water	mg	0.10	0.09	7.92
722	Methyl lactate	Air	mg	0.33	0.32	27.00
723	Methylamine	Air	mg	2.78	2.63	229.40
724	Methylamine	Water	mg	5.68	5.35	471.72
725	Metiram	Soil	mg	1.43	1.41	117.45
726	Metolachlor	Air	mg	2.34	2.27	192.75
727	Metolachlor	Water	mg	0.20	0.20	16.62

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
728	Metolachlor	Soil	g	0.57	0.55	48.02
729	Metosulam	Soil	µg	2.08	2.04	169.81
730	Metribuzin	Air	mg	0.76	0.74	62.57
731	Metribuzin	Soil	g	0.07	0.07	6.19
732	Metsulfuron-methyl	Soil	mg	2.08	2.01	167.79
733	Mineral oil	Soil	g	2.24	2.20	183.17
734	Molinate	Soil	mg	0.51	0.51	36.52
735	Molybdenum	Raw	tn.lg	0.06	0.06	5.82
736	Molybdenum	Air	g	8.45	8.11	665.94
737	Molybdenum	Water	kg	4.77	4.66	462.65
738	Molybdenum	Soil	g	0.03	0.03	2.26
739	Molybdenum-99	Water	Bq	3.38	3.32	251.16
740	Molybdenum, 0.010% in sulfide, Mo 8.2E-3% and Cu 1.83% in crude ore	Raw	kg	0.05	0.05	3.67
741	Molybdenum, 0.014% in sulfide, Mo 8.2E-3% and Cu 0.81% in crude ore	Raw	g	10.35	10.16	829.75
742	Molybdenum, 0.016% in sulfide, Mo 8.2E-3% and Cu 0.27% in crude ore	Raw	kg	8.30	8.06	829.59
743	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.22% in crude ore	Raw	tn.lg	0.01	0.01	1.07
744	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.36% in crude ore	Raw	kg	0.07	0.07	5.97
745	Molybdenum, 0.025% in sulfide, Mo 8.2E-3% and Cu 0.39% in crude ore	Raw	tn.lg	0.01	0.01	1.13
746	Monocrotophos	Soil	g	0.03	0.03	2.37
747	Monoethanolamine	Air	kg	0.03	0.03	2.38
748	Monoethanolamine	Water	mg	3.72	3.66	272.98
749	Monosodium acid methanearsonate	Soil	mg	5.88	5.77	480.81
750	Myclobutanil	Soil	mg	4.77	4.68	390.61
751	Naphthalene	Air	g	0.02	0.02	1.93
752	Naphthalene	Water	mg	9.44	9.27	772.09
753	Napropamide	Soil	g	0.02	0.02	1.27
754	Neodymium	Raw	g	0.08	0.08	4.06
755	Nickel	Raw	kg	2.26	2.44	0.00

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
756	Nickel	Air	kg	0.14	0.15	6.28
757	Nickel	Water	tn.lg	0.04	0.03	2.91
758	Nickel	Soil	g	0.44	0.42	34.27
759	Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore	Raw	kg	139.34	170.46	39.39
760	Nickel, 1.98% in silicates, 1.04% in crude ore	Raw	tn.lg	0.04	0.04	3.48
761	Nickel, Ni 2.3E+0%, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Cu 3.2E+0% in ore	Raw	kg	32.19	39.35	16.54
762	Nickel, Ni 2.5E+0%, in mixed ore	Raw	tn.lg	0.07	0.07	5.25
763	Nickel, Ni 3.7E-2%, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Cu 5.2E-2% in ore	Raw	kg	0.81	0.98	5.08
764	Nicosulfuron	Soil	mg	1.13	1.11	100.42
765	Niobium-95	Air	kBq	17.97	17.57	1359.27
766	Niobium-95	Water	kBq	0.03	0.03	1.97
767	Nitrate	Air	g	4.89	4.71	380.67
768	Nitrate	Water	tn.lg	0.11	0.10	9.46
769	Nitrate	Soil	g	5.83	5.57	466.07
770	Nitrite	Water	g	5.96	5.85	471.72
771	Nitrobenzene	Air	mg	3.54	3.43	286.66
772	Nitrobenzene	Water	g	0.01	0.01	1.15
773	Nitrogen	Raw	tn.lg	7.11	6.90	700.97
774	Nitrogen fluoride	Air	µg	7.78	9.21	98.30
775	Nitrogen monoxide	Air	g	0.05	0.05	3.85
776	Nitrogen oxides	Air	tn.lg	0.43	0.42	34.85
777	Nitrogen, atmospheric	Air	kg	7.10	7.04	623.59
778	Nitrogen, atmospheric	Water	kg	0.66	0.64	57.14
779	Nitrogen, atmospheric	Soil	g	0.14	0.14	10.86
780	Nitrogen, organic bound	Water	kg	6.74	6.70	614.12
781	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	tn.lg	0.07	0.06	5.58
782	Noble gases, radioactive, unspecified	Air	kBq	1544768.53	1512227.61	115819991.30
783	Norflurazon	Soil	mg	6.15	6.04	503.31
784	o-Xylene	Air	g	1.45	1.39	115.56
785	o-Xylene	Water	g	0.09	0.09	6.35

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
786	Occupation, annual crop	Raw	m2a	17.49	17.07	1454.35
787	Occupation, annual crop, greenhouse	Raw	m2a	0.04	0.04	3.55
788	Occupation, annual crop, irrigated	Raw	m2a	0.40	0.39	32.79
789	Occupation, annual crop, irrigated, intensive	Raw	m2a	0.86	0.84	72.45
790	Occupation, annual crop, non-irrigated	Raw	m2a	1.31	1.22	109.10
791	Occupation, annual crop, non-irrigated, extensive	Raw	m2a	4.58	4.49	372.45
792	Occupation, annual crop, non-irrigated, intensive	Raw	m2a	18.54	18.07	1561.61
793	Occupation, arable land, unspecified use	Raw	mm2a	0.37	0.36	30.04
794	Occupation, construction site	Raw	m2a	27.01	26.50	2069.88
795	Occupation, dump site	Raw	ha a	0.24	0.23	20.47
796	Occupation, forest, extensive	Raw	m2a	20.64	20.11	1604.05
797	Occupation, forest, intensive	Raw	ha a	0.41	0.41	31.81
798	Occupation, grassland, natural (non-use)	Raw	m2a	17.19	16.94	1257.39
799	Occupation, industrial area	Raw	ha a	0.03	0.03	2.73
800	Occupation, inland waterbody, unspecified	Raw	m2a	0.01	0.01	1.03
801	Occupation, mineral extraction site	Raw	m2a	95.31	93.46	7373.07
802	Occupation, pasture, man made, extensive	Raw	m2a	0.03	0.03	1.99
803	Occupation, pasture, man made, intensive	Raw	m2a	5.30	5.20	435.50
804	Occupation, permanent crop	Raw	m2a	2.48	2.40	195.93
805	Occupation, permanent crop, irrigated	Raw	m2a	18.15	17.81	1484.37
806	Occupation, permanent crop, irrigated, intensive	Raw	m2a	0.49	0.48	40.01

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
807	Occupation, permanent crop, non-irrigated, intensive	Raw	m2a	0.06	0.06	5.28
808	Occupation, seabed, drilling and mining	Raw	m2a	1.48	1.48	105.24
809	Occupation, seabed, infrastructure	Raw	m2a	0.02	0.02	1.22
810	Occupation, shrub land, sclerophyllous	Raw	m2a	17.29	16.56	1354.80
811	Occupation, traffic area, rail network	Raw	m2a	47.42	45.24	3762.32
812	Occupation, traffic area, rail/road embankment	Raw	ha a	0.01	0.01	1.02
813	Occupation, traffic area, road network	Raw	ha a	0.04	0.04	3.04
814	Occupation, urban, discontinuously built	Raw	m2a	0.22	0.21	17.79
815	Occupation, urban/industrial fallow (non-use)	Raw	m2a	0.01	0.01	0.88
816	Occupation, water bodies, artificial	Raw	ha a	0.06	0.06	4.47
817	Octaethylene glycol monododecyl ether	Air	mg	0.69	0.66	54.17
818	Oil, crude	Raw	tn.lg	4.71	4.56	365.26
819	Oils, biogenic	Water	g	0.33	0.32	27.15
820	Oils, biogenic	Soil	kg	0.07	0.06	5.12
821	Oils, unspecified	Water	tn.lg	0.02	0.01	1.14
822	Oils, unspecified	Soil	tn.lg	0.02	0.02	1.25
823	Olivine	Raw	g	0.35	0.35	28.49
824	Orbencarb	Soil	g	0.32	0.31	28.57
825	Organic carbon	Air	g	0.10	0.10	7.76
826	Organic carbon	Water	g	0.32	0.32	25.24
827	Organic carbon	Soil	g	0.32	0.32	25.24
828	Oryzalin	Soil	mg	8.95	8.78	732.57
829	Oxamyl	Soil	mg	1.72	1.69	140.60
830	Oxydemeton methyl	Soil	mg	0.11	0.11	9.72
831	Oxyfluorfen	Soil	g	0.08	0.08	6.38
832	Oxygen	Raw	tn.lg	2.50	2.43	239.70
833	Oxygen	Water	mg	0.07	0.06	5.16
834	Ozone	Air	kg	0.43	0.43	31.78
835	PAH, polycyclic aromatic hydrocarbons	Air	kg	0.05	0.05	3.32

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
836	PAH, polycyclic aromatic hydrocarbons	Water	kg	1.09	1.02	90.76
837	PAH, polycyclic aromatic hydrocarbons	Soil	g	0.02	0.01	1.21
838	Palladium, Pd 1.6E-6%, in mixed ore	Raw	g	4.55	4.63	356.37
839	Palladium, Pd 2.0E-4%, Pt 4.8E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore	Raw	g	1.58	1.91	9.92
840	Palladium, Pd 7.3E-4%, Pt 2.5E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore	Raw	g	10.16	12.42	5.22
841	Paraffins	Air	g	0.08	0.08	6.11
842	Paraffins	Water	g	0.36	0.36	27.16
843	Paraquat	Air	mg	0.49	0.47	40.25
844	Paraquat	Soil	g	0.24	0.24	19.57
845	Parathion	Soil	g	0.11	0.10	8.81
846	Parathion, methyl	Air	mg	0.09	0.09	7.72
847	Parathion, methyl	Soil	µg	4.02	3.89	331.12
848	Particulates, < 2.5 um	Air	tn.lg	0.29	0.28	24.20
849	Particulates, > 10 um	Air	tn.lg	0.18	0.17	13.67
850	Particulates, > 2.5 um, and < 10um	Air	tn.lg	0.17	0.16	14.55
851	Peat	Raw	tn.lg	0.06	0.06	4.29
852	Pendimethalin	Air	mg	5.31	5.14	437.45
853	Pendimethalin	Water	mg	0.01	0.01	1.18
854	Pendimethalin	Soil	g	0.06	0.06	4.86
855	Pentane	Air	kg	0.71	0.70	51.43
856	Pentane	Water	mg	0.04	0.04	2.96
857	Pentane, 2-methyl-	Air	g	0.04	0.04	3.39
858	Pentane, 2,2,4-trimethyl-	Air	µg	11.56	11.34	945.75
859	Perlite	Raw	kg	0.03	0.03	2.43
860	Permethrin	Air	mg	0.08	0.07	6.30
861	Permethrin	Soil	mg	0.53	0.52	46.84
862	Pesticides, unspecified	Soil	g	0.68	0.67	55.99
863	Phenanthrene	Air	mg	0.52	0.55	26.79
864	Phenanthrene	Water	g	0.11	0.10	8.67
865	Phenmedipham	Soil	g	0.04	0.03	2.92
866	Phenol	Air	g	6.85	6.50	560.18
867	Phenol	Water	kg	0.03	0.02	1.97
868	Phenol, 2,4-dichloro-	Air	mg	0.32	0.31	25.82
869	Phenol, pentachloro-	Air	g	0.61	0.60	46.07

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
870	Phenol, pentachloro-	Soil	mg	0.19	0.19	13.93
871	Phorate	Soil	mg	3.49	3.42	285.76
872	Phosgene	Air	mg	0.05	0.05	4.08
873	Phosmet	Soil	mg	1.77	1.73	144.54
874	Phosphate	Water	tn.lg	1.11	1.08	105.22
875	Phosphine	Air	mg	18.19	21.53	231.39
876	Phosphoric acid	Air	µg	14.08	16.66	177.82
877	Phosphoric acid	Water	mg	0.36	0.34	28.17
878	Phosphorus	Raw	tn.lg	0.04	0.04	3.50
879	Phosphorus	Air	kg	0.02	0.02	1.28
880	Phosphorus	Water	kg	0.03	0.03	1.93
881	Phosphorus	Soil	kg	0.05	0.04	3.56
882	Phosphorus oxychloride	Water	mg	0.14	0.13	10.69
883	Phosphorus pentachloride	Water	mg	0.65	0.63	51.57
884	Phosphorus trichloride	Air	g	0.04	0.04	3.07
885	Phosphorus trichloride	Water	mg	0.02	0.02	1.91
886	Phosphorus, 18% in apatite, 4% in crude ore	Raw	tn.lg	0.06	0.06	5.04
887	Picloram	Soil	µg	1.36	1.33	110.95
888	Picoxystrobin	Soil	mg	1.36	1.34	120.32
889	Piperonyl butoxide	Soil	mg	1.06	1.04	86.39
890	Pirimicarb	Soil	g	0.05	0.05	4.13
891	Pirimiphos methyl	Soil	g	0.02	0.02	1.37
892	Platinum	Air	g	0.33	0.33	29.35
893	Platinum, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore	Raw	g	3.48	4.26	1.79
894	Platinum, Pt 4.7E-7%, in mixed ore	Raw	g	1.32	1.34	103.08
895	Platinum, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore	Raw	g	3.72	4.49	23.35
896	Plutonium-238	Air	mBq	0.02	0.02	1.64
897	Plutonium-alpha	Air	mBq	0.05	0.05	3.76
898	Polonium-210	Air	kBq	49.47	48.76	3583.36
899	Polonium-210	Water	kBq	8.45	8.55	632.10
900	Polychlorinated biphenyls	Air	mg	9.27	8.97	759.24
901	Polychlorinated biphenyls	Water	µg	3.84	3.89	303.73
902	Potassium	Air	kg	0.66	0.64	51.67

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
903	Potassium	Water	tn.lg	2.91	2.84	279.34
904	Potassium	Soil	kg	0.27	0.26	20.76
905	Potassium-40	Air	kBq	9.12	8.99	658.61
906	Potassium-40	Water	kBq	4.79	4.74	352.52
907	Potassium chloride	Raw	kg	2.20	2.16	182.70
908	Praseodymium	Raw	mg	8.39	8.90	430.32
909	Primisulfuron	Soil	mg	0.51	0.51	45.65
910	Prochloraz	Soil	mg	0.31	0.31	27.05
911	Procymidone	Soil	mg	0.15	0.14	12.68
912	Profenofos	Soil	mg	9.14	8.97	748.22
913	Prohexadione-calcium	Soil	µg	0.82	0.80	66.85
914	Prometryn	Soil	mg	4.91	4.82	401.58
915	Pronamide	Soil	µg	3.67	3.50	290.70
916	Propachlor	Soil	g	0.25	0.24	20.10
917	Propamocarb HCl	Soil	mg	0.02	0.02	1.37
918	Propanal	Air	g	0.12	0.11	9.28
919	Propanal	Water	mg	0.69	0.68	58.32
920	Propane	Air	kg	0.91	0.89	66.57
921	Propanil	Soil	mg	1.31	1.32	94.59
922	Propargite	Soil	mg	1.12	1.10	91.66
923	Propene	Air	kg	0.14	0.13	11.03
924	Propene	Water	kg	0.06	0.06	5.56
925	Propiconazole	Air	mg	0.09	0.09	7.41
926	Propiconazole	Water	µg	0.14	0.14	12.53
927	Propiconazole	Soil	mg	5.06	4.98	444.89
928	Propionic acid	Air	g	4.11	4.14	275.01
929	Propionic acid	Water	mg	1.73	1.69	141.77
930	Propoxycarbazone-sodium (prop)	Soil	µg	4.55	4.46	370.64
931	Propylamine	Air	mg	0.12	0.12	9.88
932	Propylamine	Water	mg	0.28	0.28	23.72
933	Propylene oxide	Air	g	0.44	0.43	35.33
934	Propylene oxide	Water	g	1.03	0.99	82.30
935	Prosulfuron	Soil	mg	0.19	0.18	16.47
936	Protactinium-234	Air	kBq	0.43	0.43	31.27
937	Protactinium-234	Water	kBq	1.40	1.37	104.78
938	Prothioconazol	Air	ng	0.09	0.09	7.30
939	Prothioconazol	Water	pg	9.28	9.08	761.24
940	Prothioconazol	Soil	mg	0.43	0.42	37.82
941	Pumice	Raw	kg	1.87	1.85	141.16
942	Pymetrozine	Soil	mg	0.11	0.11	8.78
943	Pyraclostrobin (prop)	Air	mg	0.21	0.21	17.47
944	Pyraclostrobin (prop)	Water	µg	0.12	0.12	9.98

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
945	Pyraclostrobin (prop)	Soil	g	0.16	0.15	12.80
946	Pyrene	Air	mg	0.03	0.03	1.39
947	Pyrene	Water	g	0.10	0.09	7.87
948	Pyrethrin	Soil	mg	1.16	1.14	94.94
949	Pyrimethanil	Soil	mg	9.20	9.03	753.21
950	Pyrithiobac sodium salt	Soil	mg	0.33	0.32	26.87
951	Quinclorac	Soil	mg	0.02	0.02	1.58
952	Quinoxyfen	Soil	mg	0.04	0.04	3.24
953	Quizalofop-P	Soil	mg	0.02	0.02	1.82
954	Quizalofop-p-ethyl	Soil	mg	7.78	7.63	636.76
955	Quizalofop ethyl ester	Air	mg	0.03	0.03	2.34
956	Quizalofop ethyl ester	Soil	mg	0.02	0.02	1.72
957	Radioactive species, alpha emitters	Water	kBq	0.59	0.55	48.13
958	Radioactive species, Nuclides, unspecified	Water	kBq	161.43	158.07	12106.67
959	Radioactive species, other beta emitters	Air	kBq	513.10	507.16	38829.10
960	Radium-224	Water	kBq	11.79	11.40	912.02
961	Radium-226	Air	kBq	10.26	10.06	756.66
962	Radium-226	Water	kBq	492.75	482.63	36865.56
963	Radium-228	Air	kBq	9.22	8.90	707.44
964	Radium-228	Water	kBq	31.06	30.20	2360.16
965	Radon-220	Air	kBq	182.53	180.93	13058.06
966	Radon-222	Air	kBq	6509028.06	6375127.78	486528564.26
967	Rhenium	Raw	mg	0.50	0.49	38.43
968	Rhodium, Rh 1.6E-7%, in mixed ore	Raw	g	0.45	0.45	34.97
969	Rhodium, Rh 2.0E-5%, Pt 2.5E-4%, Pd 7.3E-4%, Ni 2.3E+0%, Cu 3.2E+0% in ore	Raw	mg	278.03	339.94	142.90
970	Rhodium, Rh 2.4E-5%, Pt 4.8E-4%, Pd 2.0E-4%, Ni 3.7E-2%, Cu 5.2E-2% in ore	Raw	g	0.19	0.22	1.17
971	Rimsulfuron	Soil	mg	0.57	0.56	49.95
972	Rotenone	Soil	mg	0.65	0.64	53.17
973	Rubidium	Water	g	2.36	2.28	182.40
974	Ruthenium-103	Air	mBq	0.73	0.71	54.07
975	Ruthenium-103	Water	Bq	2.03	1.99	151.91
976	Samarium	Raw	mg	5.99	6.35	307.07
977	Sand	Raw	kg	0.42	0.42	29.69
978	Scandium	Air	g	0.74	0.72	55.49

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
979	Scandium	Water	kg	1.79	1.75	171.72
980	Selenium	Air	g	9.76	9.62	719.51
981	Selenium	Water	kg	3.60	3.51	349.40
982	Selenium	Soil	g	0.08	0.07	6.20
983	Sethoxydim	Air	mg	0.06	0.06	5.03
984	Sethoxydim	Soil	mg	0.14	0.14	12.10
985	Shale	Raw	kg	6.84	6.92	464.04
986	Silicon	Air	kg	2.47	2.41	181.36
987	Silicon	Water	tn.lg	5.87	5.67	461.81
988	Silicon	Soil	kg	0.35	0.34	27.28
989	Silicon dioxide	Water	g	0.40	0.43	21.76
990	Silicon tetrachloride	Air	g	0.05	0.05	2.56
991	Silicon tetrafluoride	Air	g	0.05	0.05	3.92
992	Silthiofam	Soil	mg	0.06	0.06	4.98
993	Silver	Air	g	0.05	0.05	1.98
994	Silver	Water	kg	0.27	0.26	26.11
995	Silver	Soil	mg	0.39	0.37	31.16
996	Silver-110	Air	Bq	0.02	0.02	1.63
997	Silver-110	Water	kBq	2.64	2.59	195.90
998	Silver, 0.007% in sulfide, Ag 0.004%, Pb, Zn, Cd, In	Raw	g	3.31	3.29	239.71
999	Silver, 3.2ppm in sulfide, Ag 1.2ppm, Cu and Te, in crude ore	Raw	mg	0.25	0.24	19.48
1000	Silver, Ag 1.5E-4%, Au 6.8E-4%, in ore	Raw	mg	0.25	0.24	19.87
1001	Silver, Ag 1.5E-5%, Au 5.4E-4%, in ore	Raw	mg	0.02	0.02	1.82
1002	Silver, Ag 1.8E-6%, in mixed ore	Raw	g	5.08	5.17	397.60
1003	Silver, Ag 2.1E-4%, Au 2.1E-4%, in ore	Raw	mg	9.54	9.15	761.43
1004	Silver, Ag 4.2E-3%, Au 1.1E-4%, in ore	Raw	g	1.00	0.96	79.05
1005	Silver, Ag 4.6E-5%, Au 1.3E-4%, in ore	Raw	g	0.02	0.01	1.23
1006	Silver, Ag 5.4E-3%, in mixed ore	Raw	g	0.12	0.14	3.11
1007	Silver, Ag 7.6E-5%, Au 9.7E-5%, in ore	Raw	mg	3.13	3.00	250.92
1008	Silver, Ag 9.7E-4%, Au 9.7E-4%, Zn 0.63%, Cu 0.38%, Pb 0.014%, in ore	Raw	g	6.53	6.41	523.16

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1009	Simazine	Soil	g	0.04	0.04	3.64
1010	Sodium	Air	kg	0.14	0.13	10.68
1011	Sodium	Water	tn.lg	1.54	1.51	133.74
1012	Sodium	Soil	kg	0.40	0.39	30.49
1013	Sodium-24	Water	kBq	0.07	0.07	5.36
1014	Sodium chlorate	Air	g	0.35	0.36	26.16
1015	Sodium chlorate	Water	mg	1.35	1.32	110.43
1016	Sodium chloride	Raw	tn.lg	0.25	0.28	11.26
1017	Sodium dichromate	Air	g	0.06	0.06	4.92
1018	Sodium formate	Air	g	0.04	0.04	3.43
1019	Sodium formate	Water	g	0.10	0.10	8.24
1020	Sodium hydroxide	Air	g	0.09	0.08	6.75
1021	Sodium nitrate	Raw	mg	0.09	0.09	6.82
1022	Sodium sulfate	Raw	kg	1.39	1.44	105.47
1023	Sodium tetrahydroborate	Air	mg	5.17	6.12	65.26
1024	Solids, inorganic	Water	tn.lg	0.04	0.04	2.83
1025	Spinosad	Soil	mg	0.47	0.46	38.68
1026	Spiroxamine	Soil	mg	1.21	1.19	104.44
1027	Spodumene	Raw	g	0.84	0.86	63.51
1028	Stibnite	Raw	g	0.03	0.03	2.50
1029	Strontium	Raw	g	2.51	2.51	179.09
1030	Strontium	Air	kg	0.04	0.04	2.89
1031	Strontium	Water	tn.lg	0.08	0.08	8.00
1032	Strontium	Soil	g	1.68	1.64	127.20
1033	Strontium-89	Water	kBq	0.07	0.07	5.48
1034	Strontium-90	Water	kBq	187.86	183.96	13985.63
1035	Styrene	Air	g	2.27	2.18	178.93
1036	Sulfate	Air	kg	0.90	0.95	52.90
1037	Sulfate	Water	kton	0.03	0.03	3.08
1038	Sulfate	Soil	g	9.74	9.29	778.07
1039	Sulfentrazone	Air	mg	0.58	0.57	48.15
1040	Sulfentrazone	Soil	mg	0.82	0.80	67.70
1041	Sulfide	Water	g	2.65	2.59	202.45
1042	Sulfite	Water	kg	0.07	0.07	5.16
1043	Sulfosate	Soil	mg	3.29	3.19	270.28
1044	Sulfosulfuron	Soil	mg	0.02	0.02	1.33
1045	Sulfur	Raw	kg	0.39	0.40	27.62
1046	Sulfur	Water	kg	0.08	0.07	5.87
1047	Sulfur	Soil	kg	0.14	0.14	10.77
1048	Sulfur dioxide	Air	tn.lg	0.92	1.03	29.11
1049	Sulfur hexafluoride	Air	g	12.21	12.10	872.08
1050	Sulfur oxides	Air	g	2.11	2.05	162.63
1051	Sulfur trioxide	Air	g	0.03	0.03	2.47

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1052	Sulfuric acid	Air	g	0.78	0.78	55.73
1053	Sulfuric acid	Soil	g	0.39	0.39	32.25
1054	Suspended solids, unspecified	Water	tn.lg	6.37	5.97	528.29
1055	t-Butyl methyl ether	Air	g	0.27	0.27	19.18
1056	t-Butyl methyl ether	Water	mg	8.47	8.50	589.53
1057	t-Butylamine	Air	mg	0.28	0.27	22.18
1058	t-Butylamine	Water	mg	0.67	0.65	53.24
1059	Talc	Raw	kg	0.36	0.35	31.09
1060	Tantalum	Raw	g	6.58	6.28	524.91
1061	Tebuconazole	Air	ng	0.24	0.23	19.44
1062	Tebuconazole	Water	ng	0.07	0.07	6.02
1063	Tebuconazole	Soil	mg	2.81	2.75	241.97
1064	Tebupirimphos	Soil	mg	4.32	4.25	383.45
1065	Tebutam	Soil	g	0.06	0.06	5.00
1066	Technetium-99m	Water	kBq	0.09	0.09	6.70
1067	Teflubenzuron	Soil	mg	3.93	3.87	352.75
1068	Tefluthrin	Air	µg	7.52	7.38	620.64
1069	Tefluthrin	Water	ng	0.04	0.04	3.04
1070	Tefluthrin	Soil	mg	3.42	3.36	303.33
1071	Tellurium	Raw	mg	0.04	0.04	2.92
1072	Tellurium-123m	Water	kBq	0.02	0.02	1.19
1073	Tellurium-132	Water	Bq	0.59	0.57	43.78
1074	Terbacil	Soil	g	0.09	0.09	7.37
1075	Terbufos	Soil	g	0.31	0.31	25.59
1076	Terpenes	Air	g	0.24	0.23	19.44
1077	Tetramethyl ammonium hydroxide	Air	g	0.19	0.22	2.36
1078	Thallium	Air	g	0.19	0.18	14.53
1079	Thallium	Water	kg	0.44	0.43	42.93
1080	Thiamethoxam	Soil	g	0.27	0.27	22.12
1081	Thiazole, 2-(thiocyanatemethylthio)benzo-	Soil	g	0.03	0.03	2.66
1082	Thidiazuron	Soil	mg	0.58	0.56	47.08
1083	Thifensulfuron	Air	µg	8.33	8.06	686.20
1084	Thifensulfuron-methyl	Soil	mg	0.01	0.01	1.14
1085	Thiobencarb	Soil	mg	0.28	0.28	20.24
1086	Thiodicarb	Air	mg	0.03	0.03	2.45
1087	Thiodicarb	Soil	µg	1.27	1.23	104.83
1088	Thiram	Soil	mg	2.68	2.59	211.36
1089	Thorium	Air	g	0.18	0.17	13.85
1090	Thorium-228	Air	kBq	1.73	1.70	127.63

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1091	Thorium-228	Water	kBq	47.21	45.63	3651.09
1092	Thorium-230	Air	kBq	1.56	1.49	122.90
1093	Thorium-230	Water	kBq	118.68	116.24	8871.27
1094	Thorium-232	Air	kBq	2.03	2.00	146.96
1095	Thorium-232	Water	kBq	0.82	0.81	60.19
1096	Thorium-234	Air	kBq	0.43	0.43	31.27
1097	Thorium-234	Water	kBq	1.40	1.37	104.82
1098	Tin	Raw	kg	0.06	0.05	4.39
1099	Tin	Air	g	9.47	9.44	681.78
1100	Tin	Water	kg	4.20	4.10	411.69
1101	Tin	Soil	mg	5.36	5.34	436.88
1102	TiO2, 54% in ilmenite, 18% in crude ore	Raw	kg	0.79	0.81	60.19
1103	TiO2, 54% in ilmenite, 2.6% in crude ore	Raw	kg	10.80	11.03	820.98
1104	TiO2, 95% in rutile, 0.40% in crude ore	Raw	kg	1.66	1.70	126.33
1105	Titanium	Air	kg	0.06	0.05	4.40
1106	Titanium	Water	tn.lg	0.04	0.04	2.85
1107	Titanium	Soil	g	6.82	6.62	532.97
1108	TOC, Total Organic Carbon	Water	tn.lg	0.12	0.12	9.55
1109	Toluene	Air	kg	0.40	0.39	29.21
1110	Toluene	Water	kg	0.04	0.04	2.79
1111	Toluene, 2-chloro-	Air	mg	1.00	0.98	82.39
1112	Toluene, 2-chloro-	Water	mg	1.90	1.86	156.75
1113	Tralkoxydim	Soil	mg	9.55	9.39	843.66
1114	Transformation, from annual crop	Raw	m2	24.13	23.54	2004.14
1115	Transformation, from annual crop, greenhouse	Raw	m2	0.10	0.10	8.18
1116	Transformation, from annual crop, irrigated, intensive	Raw	m2	1.69	1.66	138.44
1117	Transformation, from annual crop, non-irrigated	Raw	m2	3.97	3.75	326.37
1118	Transformation, from annual crop, non-irrigated, extensive	Raw	m2	8.10	7.94	658.72
1119	Transformation, from annual crop, non-irrigated, intensive	Raw	m2	22.93	22.34	1954.17

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1120	Transformation, from cropland fallow (non-use)	Raw	m2	0.07	0.08	1.92
1121	Transformation, from dump site, inert material landfill	Raw	m2	0.52	0.50	40.51
1122	Transformation, from dump site, residual material landfill	Raw	m2	2.91	2.79	228.25
1123	Transformation, from dump site, sanitary landfill	Raw	m2	0.02	0.02	1.52
1124	Transformation, from dump site, slag compartment	Raw	sq.in	6.53	6.39	490.40
1125	Transformation, from forest, extensive	Raw	m2	3.24	3.16	256.06
1126	Transformation, from forest, intensive	Raw	m2	46.20	45.25	3544.35
1127	Transformation, from forest, primary (non-use)	Raw	m2	0.34	0.34	26.17
1128	Transformation, from forest, secondary (non-use)	Raw	m2	0.21	0.20	17.15
1129	Transformation, from forest, unspecified	Raw	m2	8.10	7.94	597.30
1130	Transformation, from grassland, natural (non-use)	Raw	m2	0.08	0.08	6.49
1131	Transformation, from heterogeneous, agricultural	Raw	cm2	4.16	4.07	313.22
1132	Transformation, from industrial area	Raw	m2	0.07	0.07	5.43
1133	Transformation, from mineral extraction site	Raw	m2	1.61	1.64	103.90
1134	Transformation, from pasture, man made	Raw	m2	7.48	7.24	566.90
1135	Transformation, from pasture, man made, extensive	Raw	cm2	5.24	5.18	397.32
1136	Transformation, from pasture, man made, intensive	Raw	m2	4.17	4.09	343.29
1137	Transformation, from permanent crop	Raw	m2	0.15	0.15	12.19

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1138	Transformation, from permanent crop, irrigated	Raw	m2	0.78	0.77	63.93
1139	Transformation, from permanent crop, irrigated, intensive	Raw	m2	0.44	0.43	35.68
1140	Transformation, from permanent crop, non-irrigated, intensive	Raw	m2	0.06	0.06	5.28
1141	Transformation, from seabed, infrastructure	Raw	cm2	1.31	1.33	86.20
1142	Transformation, from seabed, unspecified	Raw	m2	1.49	1.48	105.51
1143	Transformation, from shrub land, sclerophyllous	Raw	m2	4.98	4.84	370.56
1144	Transformation, from traffic area, rail/road embankment	Raw	m2	0.35	0.34	26.23
1145	Transformation, from traffic area, road network	Raw	cm2	0.47	0.45	37.50
1146	Transformation, from unknown	Raw	m2	31.73	30.75	2608.49
1147	Transformation, from unspecified, natural (non-use)	Raw	sq.in	6.93	6.77	523.15
1148	Transformation, from wetland, inland (non-use)	Raw	cm2	9.87	9.47	782.58
1149	Transformation, to annual crop	Raw	m2	19.97	19.55	1634.76
1150	Transformation, to annual crop, fallow	Raw	m2	0.10	0.11	3.44
1151	Transformation, to annual crop, greenhouse	Raw	m2	0.10	0.10	8.18
1152	Transformation, to annual crop, irrigated, extensive	Raw	m2	0.09	0.09	7.30
1153	Transformation, to annual crop, irrigated, intensive	Raw	m2	2.30	2.26	192.34
1154	Transformation, to annual crop, non-irrigated	Raw	m2	3.49	3.27	291.18

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1155	Transformation, to annual crop, non-irrigated, extensive	Raw	m2	8.21	8.06	667.96
1156	Transformation, to annual crop, non-irrigated, intensive	Raw	m2	28.94	28.18	2443.51
1157	Transformation, to dump site	Raw	m2	17.76	17.05	1531.23
1158	Transformation, to dump site, inert material landfill	Raw	m2	0.52	0.50	40.51
1159	Transformation, to dump site, residual material landfill	Raw	m2	2.91	2.79	228.26
1160	Transformation, to dump site, sanitary landfill	Raw	m2	0.02	0.02	1.52
1161	Transformation, to dump site, slag compartment	Raw	sq.in	6.53	6.39	490.40
1162	Transformation, to forest, extensive	Raw	m2	0.18	0.18	14.10
1163	Transformation, to forest, intensive	Raw	m2	49.05	48.03	3772.93
1164	Transformation, to forest, secondary (non-use)	Raw	cm2	0.56	0.53	44.18
1165	Transformation, to forest, unspecified	Raw	m2	3.84	3.71	293.76
1166	Transformation, to grassland, natural (non-use)	Raw	m2	0.23	0.23	16.82
1167	Transformation, to heterogeneous, agricultural	Raw	m2	0.21	0.21	15.75
1168	Transformation, to industrial area	Raw	m2	7.63	7.47	606.06
1169	Transformation, to inland waterbody, unspecified	Raw	cm2	1.44	1.44	102.56
1170	Transformation, to mineral extraction site	Raw	m2	9.10	8.95	675.05
1171	Transformation, to pasture, man made	Raw	m2	0.28	0.27	22.68
1172	Transformation, to pasture, man made, extensive	Raw	cm2	5.24	5.18	397.32

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1173	Transformation, to pasture, man made, intensive	Raw	m2	3.90	3.82	321.17
1174	Transformation, to permanent crop	Raw	m2	0.42	0.41	33.58
1175	Transformation, to permanent crop, irrigated	Raw	m2	0.78	0.77	63.93
1176	Transformation, to permanent crop, irrigated, intensive	Raw	m2	0.44	0.43	35.68
1177	Transformation, to permanent crop, non-irrigated	Raw	cm2	0.56	0.53	44.18
1178	Transformation, to permanent crop, non-irrigated, intensive	Raw	m2	0.06	0.06	5.28
1179	Transformation, to seabed, drilling and mining	Raw	m2	1.48	1.48	105.24
1180	Transformation, to seabed, infrastructure	Raw	sq.in	5.50	5.36	426.22
1181	Transformation, to seabed, unspecified	Raw	cm2	1.31	1.33	86.20
1182	Transformation, to shrub land, sclerophyllous	Raw	m2	3.45	3.31	270.60
1183	Transformation, to traffic area, rail network	Raw	m2	0.11	0.10	8.70
1184	Transformation, to traffic area, rail/road embankment	Raw	m2	0.69	0.67	53.72
1185	Transformation, to traffic area, road network	Raw	m2	2.90	2.77	228.69
1186	Transformation, to unknown	Raw	m2	0.26	0.25	20.90
1187	Transformation, to urban, discontinuously built	Raw	sq.in	7.76	7.59	623.64
1188	Transformation, to urban/industrial fallow	Raw	cm2	1.59	1.57	117.56
1189	Transformation, to water bodies, artificial	Raw	m2	6.49	6.48	442.55
1190	Transformation, to wetland, inland (non-use)	Raw	cm2	1.76	1.69	139.91

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1191	Triadimenol	Soil	mg	0.07	0.07	5.79
1192	Triallate	Soil	mg	0.04	0.04	3.00
1193	Triasulfuron	Soil	µg	10.89	10.67	887.62
1194	Tribenuron	Soil	µg	5.97	5.87	523.82
1195	Tribenuron-methyl	Soil	mg	0.23	0.23	20.50
1196	Tribufos	Soil	mg	5.38	5.28	440.28
1197	Tributyltin compounds	Water	g	2.89	2.76	229.00
1198	Trichlorfon	Soil	µg	1.68	1.64	137.21
1199	Triclopyr	Soil	g	0.03	0.03	2.46
1200	Triethylene glycol	Water	g	1.30	1.32	84.09
1201	Trifloxystrobin	Air	µg	5.33	5.16	439.06
1202	Trifloxystrobin	Water	pg	2.75	2.69	225.35
1203	Trifloxystrobin	Soil	mg	0.74	0.73	65.58
1204	Trifluralin	Air	mg	8.42	8.15	693.44
1205	Trifluralin	Soil	g	0.06	0.05	4.55
1206	Triforine	Soil	mg	1.93	1.90	158.27
1207	Trimethylamine	Air	mg	0.03	0.03	2.70
1208	Trimethylamine	Water	mg	0.08	0.08	6.48
1209	Trinexapac-ethyl	Soil	mg	8.26	8.12	729.14
1210	Trisodium phosphate	Air	mg	1.13	1.09	89.55
1211	Tungsten	Air	g	0.07	0.07	5.01
1212	Tungsten	Water	kg	6.37	6.21	623.60
1213	Ulexite	Raw	kg	0.03	0.03	2.06
1214	Uranium	Raw	kg	0.33	0.33	24.87
1215	Uranium	Air	g	0.23	0.22	17.73
1216	Uranium-234	Air	kBq	2.32	2.24	178.38
1217	Uranium-234	Water	kBq	1.62	1.59	121.27
1218	Uranium-235	Air	kBq	0.03	0.03	2.16
1219	Uranium-235	Water	kBq	1.81	1.77	135.31
1220	Uranium-238	Air	kBq	7.81	7.66	576.10
1221	Uranium-238	Water	kBq	6.65	6.60	496.18
1222	Uranium alpha	Air	kBq	3.33	3.26	248.91
1223	Uranium alpha	Water	kBq	54.73	53.61	4091.07
1224	Urea	Water	mg	0.87	0.85	72.17
1225	Vanadium	Raw	kg	1.36	1.58	0.00
1226	Vanadium	Air	kg	0.06	0.06	4.59
1227	Vanadium	Water	tn.lg	0.02	0.02	1.94
1228	Vanadium	Soil	g	0.16	0.15	12.20
1229	Vermiculite	Raw	kg	0.63	0.62	47.52
1230	Vinclozolin	Soil	mg	0.05	0.05	4.23
1231	VOC, volatile organic compounds	Air	mg	3.34	3.30	252.68

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1232	VOC, volatile organic compounds, unspecified origin	Water	kg	0.09	0.08	6.68
1233	Volume occupied, final repository for low-active radioactive waste	Raw	dm3	1.44	1.40	109.29
1234	Volume occupied, final repository for radioactive waste	Raw	cu.in	8.18	8.01	613.64
1235	Volume occupied, reservoir	Raw	m3y	1057.31	1056.42	73275.23
1236	Volume occupied, underground deposit	Raw	dm3	0.96	0.95	69.31
1237	Water, AR	Water	m3	0.01	0.01	1.13
1238	Water, AT	Water	m3	14949.04	14613.89	1118734.53
1239	Water, AU	Water	m3	3712.33	3769.49	238541.79
1240	Water, BA	Water	m3	2453.65	2527.46	147780.85
1241	Water, BE	Water	m3	223.33	218.45	16691.94
1242	Water, BG	Water	m3	1981.23	1937.28	148191.78
1243	Water, BR	Water	m3	11920.00	11852.91	854911.59
1244	Water, CA	Water	m3	13297.45	13340.72	905821.83
1245	Water, CH	Water	m3	10504.94	10210.51	798921.08
1246	Water, CI	Water	m3	0.05	0.05	3.99
1247	Water, CL	Water	m3	3787.66	3696.45	291807.60
1248	Water, CN	Water	m3	175675.00	173223.60	12767472.62
1249	Water, CO	Water	dm3	1.77	1.73	143.80
1250	Water, cooling, unspecified natural origin, AT	Raw	m3	4.61	4.58	324.32
1251	Water, cooling, unspecified natural origin, AU	Raw	m3	48.05	48.54	3152.37
1252	Water, cooling, unspecified natural origin, BA	Raw	m3	5.40	5.30	397.15
1253	Water, cooling, unspecified natural origin, BE	Raw	m3	28.95	28.40	2142.23
1254	Water, cooling, unspecified natural origin, BG	Raw	m3	28.60	27.97	2137.99
1255	Water, cooling, unspecified natural origin, BR	Raw	m3	26.78	26.38	1986.74
1256	Water, cooling, unspecified natural origin, CA	Raw	m3	91.28	89.15	6962.61

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1257	Water, cooling, unspecified natural origin, CH	Raw	m3	21.11	20.60	1588.95
1258	Water, cooling, unspecified natural origin, CL	Raw	m3	7.53	7.35	580.43
1259	Water, cooling, unspecified natural origin, CN	Raw	m3	845.25	842.28	58962.93
1260	Water, cooling, unspecified natural origin, CY	Raw	m3	0.90	0.88	67.95
1261	Water, cooling, unspecified natural origin, CZ	Raw	m3	211.16	206.48	15791.65
1262	Water, cooling, unspecified natural origin, DE	Raw	m3	252.34	247.46	18685.68
1263	Water, cooling, unspecified natural origin, DK	Raw	m3	6.07	6.01	434.48
1264	Water, cooling, unspecified natural origin, EE	Raw	m3	9.54	9.34	708.15
1265	Water, cooling, unspecified natural origin, ES	Raw	m3	72.65	71.56	5288.39
1266	Water, cooling, unspecified natural origin, Europe without Switzerland	Raw	m3	3.33	3.21	260.29
1267	Water, cooling, unspecified natural origin, FI	Raw	m3	20.70	20.32	1526.96
1268	Water, cooling, unspecified natural origin, FR	Raw	m3	303.95	297.70	22751.19
1269	Water, cooling, unspecified natural origin, GB	Raw	m3	144.71	141.16	12457.44
1270	Water, cooling, unspecified natural origin, GLO	Raw	m3	7.00	7.08	480.82
1271	Water, cooling, unspecified natural origin, GR	Raw	m3	61.72	60.45	4588.77
1272	Water, cooling, unspecified natural origin, HR	Raw	m3	2.29	2.27	160.90

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1273	Water, cooling, unspecified natural origin, HU	Raw	m3	16.68	16.38	1230.67
1274	Water, cooling, unspecified natural origin, ID	Raw	m3	35.22	34.64	2585.00
1275	Water, cooling, unspecified natural origin, IE	Raw	m3	7.17	7.04	531.94
1276	Water, cooling, unspecified natural origin, IN	Raw	m3	254.57	250.99	18517.31
1277	Water, cooling, unspecified natural origin, IR	Raw	m3	64.85	63.46	4843.88
1278	Water, cooling, unspecified natural origin, IS	Raw	dm3	2.63	2.68	167.17
1279	Water, cooling, unspecified natural origin, IT	Raw	m3	63.58	62.66	4618.98
1280	Water, cooling, unspecified natural origin, JP	Raw	m3	120.87	118.04	9106.48
1281	Water, cooling, unspecified natural origin, KR	Raw	m3	99.16	97.07	7396.55
1282	Water, cooling, unspecified natural origin, LT	Raw	m3	1.55	1.58	101.26
1283	Water, cooling, unspecified natural origin, LU	Raw	m3	0.82	0.81	58.50
1284	Water, cooling, unspecified natural origin, LV	Raw	m3	2.31	2.31	156.39
1285	Water, cooling, unspecified natural origin, MA	Raw	m3	0.06	0.06	4.73
1286	Water, cooling, unspecified natural origin, MK	Raw	m3	2.70	2.64	200.78
1287	Water, cooling, unspecified natural origin, MT	Raw	m3	1.42	1.39	106.26
1288	Water, cooling, unspecified natural origin, MX	Raw	m3	37.26	36.36	2870.45
1289	Water, cooling, unspecified natural origin, MY	Raw	m3	23.50	22.94	1772.59

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1290	Water, cooling, unspecified natural origin, NL	Raw	m3	37.85	37.34	2784.54
1291	Water, cooling, unspecified natural origin, NO	Raw	m3	1.36	1.36	92.53
1292	Water, cooling, unspecified natural origin, NP	Raw	dm3	0.22	0.21	16.41
1293	Water, cooling, unspecified natural origin, PE	Raw	m3	5.00	4.88	382.85
1294	Water, cooling, unspecified natural origin, PH	Raw	dm3	0.75	0.75	57.92
1295	Water, cooling, unspecified natural origin, PL	Raw	m3	286.14	279.80	21393.18
1296	Water, cooling, unspecified natural origin, PT	Raw	m3	7.46	7.38	536.68
1297	Water, cooling, unspecified natural origin, RER	Raw	m3	132.49	128.12	11816.25
1298	Water, cooling, unspecified natural origin, RNA	Raw	cm3	2.66	2.63	202.88
1299	Water, cooling, unspecified natural origin, RO	Raw	m3	52.90	52.11	3852.21
1300	Water, cooling, unspecified natural origin, RoW	Raw	m3	803.81	793.02	63477.81
1301	Water, cooling, unspecified natural origin, RS	Raw	m3	60.94	59.61	4552.11
1302	Water, cooling, unspecified natural origin, RU	Raw	m3	581.68	590.27	36802.66
1303	Water, cooling, unspecified natural origin, SA	Raw	m3	58.97	58.08	4285.41
1304	Water, cooling, unspecified natural origin, SE	Raw	m3	44.83	43.97	3316.30
1305	Water, cooling, unspecified natural origin, SI	Raw	m3	38.80	38.01	2883.41
1306	Water, cooling, unspecified natural origin, SK	Raw	m3	36.85	36.36	2665.72

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1307	Water, cooling, unspecified natural origin, TH	Raw	m3	21.77	21.25	1641.98
1308	Water, cooling, unspecified natural origin, TR	Raw	m3	37.93	37.28	2780.72
1309	Water, cooling, unspecified natural origin, TW	Raw	m3	35.13	34.31	2648.25
1310	Water, cooling, unspecified natural origin, TZ	Raw	m3	0.83	0.81	62.06
1311	Water, cooling, unspecified natural origin, UA	Raw	m3	98.00	96.17	7234.53
1312	Water, cooling, unspecified natural origin, US	Raw	m3	577.07	565.09	43415.97
1313	Water, cooling, unspecified natural origin, WEU	Raw	cu.in	10.34	10.28	754.12
1314	Water, cooling, unspecified natural origin, ZA	Raw	m3	52.85	53.66	3363.86
1315	Water, CR	Water	dm3	0.58	0.57	47.30
1316	Water, CY	Water	m3	0.90	0.87	67.53
1317	Water, CZ	Water	m3	855.03	836.10	63939.66
1318	Water, DE	Water	m3	8027.20	7863.57	596636.54
1319	Water, DK	Water	m3	8.89	8.76	644.28
1320	Water, EC	Water	dm3	6.55	6.42	536.08
1321	Water, EE	Water	m3	9.34	9.15	693.83
1322	Water, ES	Water	m3	10661.69	10449.26	790721.96
1323	Water, Europe without Switzerland	Water	m3	1.40	1.40	111.71
1324	Water, FI	Water	m3	3666.84	3586.23	274028.66
1325	Water, FR	Water	m3	25501.61	24954.23	1913684.67
1326	Water, GB	Water	m3	151.98	149.27	12738.97
1327	Water, GH	Water	m3	0.05	0.05	3.88
1328	Water, GLO	Water	m3	161.52	162.18	11907.87
1329	Water, GR	Water	m3	1672.01	1647.93	121421.96
1330	Water, HN	Water	cu.in	3.67	3.60	300.31
1331	Water, HR	Water	m3	175.28	171.44	13093.64
1332	Water, HU	Water	m3	138.16	135.17	10313.63
1333	Water, IAI Area, Africa	Water	m3	0.08	0.09	2.05
1334	Water, IAI Area, Asia, without China and GCC	Water	m3	0.15	0.17	3.79

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1335	Water, IAI Area, EU27 & EFTA	Water	m3	1.84	2.12	48.12
1336	Water, IAI Area, Gulf Cooperation Council	Water	m3	0.18	0.20	4.57
1337	Water, IAI Area, North America, without Quebec	Water	m3	0.11	0.12	2.81
1338	Water, IAI Area, Russia & RER w/o EU27 & EFTA	Water	m3	0.27	0.31	7.11
1339	Water, IAI Area, South America	Water	m3	0.10	0.11	2.56
1340	Water, ID	Water	m3	357.10	350.17	26502.23
1341	Water, IE	Water	m3	277.18	271.04	20822.25
1342	Water, IL	Water	dm3	0.21	0.21	17.25
1343	Water, IN	Water	m3	12040.73	11757.97	907540.68
1344	Water, IR	Water	m3	2412.33	2367.58	178487.90
1345	Water, IS	Water	m3	729.01	839.89	19128.07
1346	Water, IT	Water	m3	7733.35	7568.33	576483.64
1347	Water, JP	Water	m3	9045.43	8890.21	665614.96
1348	Water, KR	Water	m3	479.08	467.99	36048.10
1349	Water, lake, AT	Raw	cm3	0.09	0.09	7.03
1350	Water, lake, BE	Raw	cm3	0.18	0.17	13.91
1351	Water, lake, BG	Raw	cm3	4.01	3.89	310.21
1352	Water, lake, CA	Raw	m3	11.45	11.31	871.20
1353	Water, lake, CH	Raw	m3	0.11	0.10	8.12
1354	Water, lake, CN	Raw	cm3	1.15	1.14	85.82
1355	Water, lake, CZ	Raw	mm3	2.64	2.57	204.19
1356	Water, lake, DE	Raw	cu.in	11.97	11.68	921.15
1357	Water, lake, DK	Raw	cm3	0.25	0.24	18.96
1358	Water, lake, ES	Raw	cm3	0.20	0.20	15.61
1359	Water, lake, Europe without Switzerland	Raw	m3	0.12	0.12	9.66
1360	Water, lake, FI	Raw	cm3	0.06	0.06	4.78
1361	Water, lake, FR	Raw	cm3	0.47	0.46	36.46
1362	Water, lake, GB	Raw	cm3	0.37	0.36	28.44
1363	Water, lake, GLO	Raw	dm3	0.58	0.57	46.40
1364	Water, lake, HU	Raw	cm3	0.40	0.39	31.01
1365	Water, lake, IT	Raw	cm3	0.43	0.42	33.21
1366	Water, lake, JP	Raw	cm3	0.13	0.13	8.39
1367	Water, lake, KR	Raw	mm3	3.15	3.23	201.45
1368	Water, lake, LU	Raw	mm3	6.24	6.06	482.21
1369	Water, lake, NL	Raw	cm3	0.39	0.38	29.86
1370	Water, lake, NO	Raw	cm3	0.02	0.02	1.31

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1371	Water, lake, PL	Raw	cm3	0.03	0.03	2.70
1372	Water, lake, PT	Raw	cm3	0.08	0.08	6.00
1373	Water, lake, RER	Raw	dm3	0.94	0.92	80.11
1374	Water, lake, RNA	Raw	cm3	0.28	0.28	21.23
1375	Water, lake, RoW	Raw	m3	1.12	1.10	83.87
1376	Water, lake, RU	Raw	cm3	0.04	0.04	2.52
1377	Water, lake, SE	Raw	cm3	12.36	14.82	98.91
1378	Water, lake, SK	Raw	mm3	5.07	4.92	391.91
1379	Water, lake, TR	Raw	mm3	1.40	1.43	89.15
1380	Water, lake, TW	Raw	cm3	0.05	0.05	3.35
1381	Water, lake, US	Raw	cm3	2.38	2.25	194.71
1382	Water, LT	Water	m3	6.59	6.50	476.96
1383	Water, LU	Water	m3	126.96	124.15	9493.07
1384	Water, LV	Water	m3	2.34	2.35	158.97
1385	Water, MA	Water	m3	0.06	0.06	4.82
1386	Water, MK	Water	m3	109.55	107.14	8190.35
1387	Water, MT	Water	m3	1.42	1.38	105.90
1388	Water, MX	Water	m3	6350.96	6197.99	489301.67
1389	Water, MY	Water	m3	403.99	395.57	30152.46
1390	Water, NL	Water	m3	83.92	82.47	6262.84
1391	Water, NO	Water	m3	1162.05	1169.20	77490.20
1392	Water, NORDEL	Water	dm3	3.21	3.15	236.79
1393	Water, NP	Water	m3	568.32	554.85	42869.43
1394	Water, NZ	Water	cm3	4.52	4.44	370.44
1395	Water, PE	Water	m3	66.96	65.35	5156.31
1396	Water, PG	Water	dm3	5.46	5.24	435.90
1397	Water, PH	Water	m3	0.04	0.04	3.20
1398	Water, PL	Water	m3	1146.73	1121.21	85771.15
1399	Water, PT	Water	m3	4494.54	4395.24	336027.29
1400	Water, RAF	Water	m3	0.48	0.47	37.47
1401	Water, RAS	Water	m3	44.46	43.17	4444.25
1402	Water, RER	Water	m3	96.96	94.42	8385.32
1403	Water, river, AT	Raw	dm3	0.28	0.28	21.99
1404	Water, river, AU	Raw	m3	0.06	0.06	4.85
1405	Water, river, BE	Raw	dm3	0.56	0.55	43.53
1406	Water, river, BG	Raw	dm3	12.55	12.18	970.44
1407	Water, river, BR	Raw	m3	0.33	0.32	26.20
1408	Water, river, CH	Raw	m3	0.65	0.63	51.18
1409	Water, river, CN	Raw	m3	1.15	1.13	95.61
1410	Water, river, CZ	Raw	cm3	8.27	8.03	638.79
1411	Water, river, DE	Raw	m3	0.89	0.87	66.03
1412	Water, river, DK	Raw	dm3	0.77	0.75	59.31
1413	Water, river, ES	Raw	m3	0.07	0.07	6.03

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1414	Water, river, Europe without Switzerland	Raw	m3	2.39	2.33	193.71
1415	Water, river, FI	Raw	cu.in	11.82	11.48	913.22
1416	Water, river, FR	Raw	m3	0.01	0.01	1.07
1417	Water, river, GB	Raw	dm3	1.15	1.12	88.97
1418	Water, river, GLO	Raw	m3	139.50	135.28	11771.27
1419	Water, river, HU	Raw	dm3	1.25	1.22	97.01
1420	Water, river, IN	Raw	m3	0.57	0.56	47.62
1421	Water, river, IT	Raw	dm3	1.35	1.31	103.91
1422	Water, river, JP	Raw	dm3	0.41	0.42	26.25
1423	Water, river, KR	Raw	m3	1.25	1.22	94.57
1424	Water, river, LU	Raw	cu.in	1.19	1.16	92.06
1425	Water, river, MY	Raw	m3	0.07	0.06	5.21
1426	Water, river, NL	Raw	dm3	1.54	1.51	115.35
1427	Water, river, NO	Raw	cu.in	3.24	3.15	250.59
1428	Water, river, PE	Raw	cu.in	3.35	3.22	267.77
1429	Water, river, PH	Raw	m3	0.20	0.19	16.13
1430	Water, river, PL	Raw	cu.in	6.66	6.46	514.51
1431	Water, river, PT	Raw	dm3	0.24	0.24	18.78
1432	Water, river, RAS	Raw	m3	88.93	86.35	8890.19
1433	Water, river, RER	Raw	m3	53.90	53.28	3954.29
1434	Water, river, RLA	Raw	m3	40.40	39.22	4043.07
1435	Water, river, RNA	Raw	m3	83.90	81.46	8398.14
1436	Water, river, RO	Raw	m3	1.94	1.91	141.06
1437	Water, river, RoW	Raw	m3	141.07	139.48	10208.65
1438	Water, river, RU	Raw	m3	11.73	14.35	6.04
1439	Water, river, SE	Raw	dm3	2.23	2.20	168.01
1440	Water, river, SK	Raw	cu.in	0.97	0.94	74.82
1441	Water, river, TN	Raw	dm3	2.78	2.73	231.77
1442	Water, river, TR	Raw	cm3	4.37	4.47	278.83
1443	Water, river, TW	Raw	cu.in	10.00	10.24	638.76
1444	Water, river, TZ	Raw	dm3	0.84	0.81	67.23
1445	Water, river, US	Raw	m3	0.56	0.55	47.10
1446	Water, river, WEU	Raw	cm3	0.01	0.01	1.07
1447	Water, river, ZA	Raw	m3	0.68	0.82	4.28
1448	Water, RLA	Water	m3	20.34	19.75	2032.34
1449	Water, RME	Water	m3	4.76	4.60	368.45
1450	Water, RNA	Water	m3	43.59	42.32	4324.23
1451	Water, RO	Water	m3	7861.93	7731.10	575841.63
1452	Water, RoW	Water	m3	2008840.35	2034064.64	129589284.74
1453	Water, RS	Water	m3	3801.94	3717.85	284266.03
1454	Water, RU	Water	m3	38351.40	40436.73	2031574.86
1455	Water, SA	Water	m3	59.22	58.34	4302.04

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1456	Water, salt, ocean	Raw	m3	6.91	7.40	342.09
1457	Water, salt, sole	Raw	m3	3.21	3.16	230.81
1458	Water, SE	Water	m3	23163.65	22713.98	1714273.37
1459	Water, SI	Water	m3	151.98	168.01	5960.99
1460	Water, SK	Water	m3	1725.86	1706.28	123860.10
1461	Water, TH	Water	m3	176.57	172.39	13318.76
1462	Water, TR	Water	m3	3920.23	3832.29	294305.11
1463	Water, turbine use, unspecified natural origin, AT	Raw	m3	14947.76	14612.56	1118659.69
1464	Water, turbine use, unspecified natural origin, AU	Raw	m3	3662.94	3719.62	235296.04
1465	Water, turbine use, unspecified natural origin, BA	Raw	m3	2449.07	2522.99	147432.51
1466	Water, turbine use, unspecified natural origin, BE	Raw	m3	194.29	189.96	14543.63
1467	Water, turbine use, unspecified natural origin, BG	Raw	m3	1953.39	1910.05	146110.46
1468	Water, turbine use, unspecified natural origin, BR	Raw	m3	11936.02	11869.09	855994.24
1469	Water, turbine use, unspecified natural origin, CA	Raw	m3	13251.06	13296.33	901968.91
1470	Water, turbine use, unspecified natural origin, CH	Raw	m3	10485.18	10191.43	797390.31
1471	Water, turbine use, unspecified natural origin, CL	Raw	m3	3780.04	3689.01	291220.32
1472	Water, turbine use, unspecified natural origin, CN	Raw	m3	174792.84	172344.44	12705965.44
1473	Water, turbine use, unspecified natural origin, CZ	Raw	m3	650.23	635.82	48624.09
1474	Water, turbine use, unspecified natural origin, DE	Raw	m3	7781.08	7622.18	578419.32

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1475	Water, turbine use, unspecified natural origin, DK	Raw	m3	6.64	6.50	495.68
1476	Water, turbine use, unspecified natural origin, ES	Raw	m3	10591.97	10380.56	785651.61
1477	Water, turbine use, unspecified natural origin, FI	Raw	m3	3648.27	3567.99	272662.17
1478	Water, turbine use, unspecified natural origin, FR	Raw	m3	25200.94	24659.74	1891181.57
1479	Water, turbine use, unspecified natural origin, GB	Raw	m3	5.75	6.63	150.95
1480	Water, turbine use, unspecified natural origin, GLO	Raw	dm3	6.88	7.07	433.95
1481	Water, turbine use, unspecified natural origin, GR	Raw	m3	1611.42	1588.59	116918.08
1482	Water, turbine use, unspecified natural origin, HR	Raw	m3	175.81	171.93	13144.12
1483	Water, turbine use, unspecified natural origin, HU	Raw	m3	121.45	118.77	9081.65
1484	Water, turbine use, unspecified natural origin, ID	Raw	m3	321.60	315.26	23896.37
1485	Water, turbine use, unspecified natural origin, IE	Raw	m3	269.92	263.92	20283.55
1486	Water, turbine use, unspecified natural origin, IN	Raw	m3	11788.15	11508.89	889181.97
1487	Water, turbine use, unspecified natural origin, IR	Raw	m3	2346.76	2303.42	173590.56
1488	Water, turbine use, unspecified natural origin, IS	Raw	m3	731.65	842.93	19197.16
1489	Water, turbine use, unspecified natural origin, IT	Raw	m3	7682.40	7518.01	572810.04

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1490	Water, turbine use, unspecified natural origin, JP	Raw	m3	8924.94	8772.53	656537.95
1491	Water, turbine use, unspecified natural origin, KR	Raw	m3	380.79	371.77	28719.16
1492	Water, turbine use, unspecified natural origin, LT	Raw	m3	5.08	4.97	379.62
1493	Water, turbine use, unspecified natural origin, LU	Raw	m3	126.13	123.33	9433.76
1494	Water, turbine use, unspecified natural origin, MK	Raw	m3	107.11	104.74	8008.93
1495	Water, turbine use, unspecified natural origin, MX	Raw	m3	6313.21	6161.15	486393.22
1496	Water, turbine use, unspecified natural origin, MY	Raw	m3	381.46	373.58	28451.64
1497	Water, turbine use, unspecified natural origin, NL	Raw	m3	49.31	48.30	3727.07
1498	Water, turbine use, unspecified natural origin, NO	Raw	m3	1200.61	1208.00	80063.73
1499	Water, turbine use, unspecified natural origin, NP	Raw	m3	568.32	554.85	42869.41
1500	Water, turbine use, unspecified natural origin, PE	Raw	m3	64.18	62.64	4944.91
1501	Water, turbine use, unspecified natural origin, PL	Raw	m3	894.94	874.99	66947.43
1502	Water, turbine use, unspecified natural origin, PT	Raw	m3	4488.47	4389.22	335595.07
1503	Water, turbine use, unspecified natural origin, RER	Raw	m3	5.27	5.34	413.47
1504	Water, turbine use, unspecified natural origin, RNA	Raw	dm3	0.22	0.22	16.73

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1505	Water, turbine use, unspecified natural origin, RO	Raw	m3	7811.73	7681.64	572188.42
1506	Water, turbine use, unspecified natural origin, RoW	Raw	m3	2008040.29	2033278.78	129527336.76
1507	Water, turbine use, unspecified natural origin, RS	Raw	m3	3742.93	3660.13	279858.18
1508	Water, turbine use, unspecified natural origin, RU	Raw	m3	37794.09	39869.07	1996978.13
1509	Water, turbine use, unspecified natural origin, SE	Raw	m3	23122.68	22673.80	1711243.29
1510	Water, turbine use, unspecified natural origin, SI	Raw	m3	113.93	130.74	3134.28
1511	Water, turbine use, unspecified natural origin, SK	Raw	m3	1690.57	1671.47	121308.14
1512	Water, turbine use, unspecified natural origin, TH	Raw	m3	155.00	151.33	11691.47
1513	Water, turbine use, unspecified natural origin, TR	Raw	m3	3883.98	3796.63	291651.55
1514	Water, turbine use, unspecified natural origin, TZ	Raw	m3	72.95	71.22	5473.48
1515	Water, turbine use, unspecified natural origin, UA	Raw	m3	3101.81	3033.18	231924.20
1516	Water, turbine use, unspecified natural origin, US	Raw	m3	35061.10	34587.33	2567431.76
1517	Water, turbine use, unspecified natural origin, ZA	Raw	m3	51.24	53.13	2962.27
1518	Water, TW	Water	m3	35.02	34.20	2639.58
1519	Water, TZ	Water	m3	73.52	71.78	5516.44
1520	Water, UA	Water	m3	3199.99	3129.54	239170.92
1521	Water, UCTE	Water	cu.in	2.03	1.99	151.89
1522	Water, UCTE without Germany	Water	cu.in	1.26	1.24	93.96

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1523	Water, UN-OCEANIA	Water	m3	0.10	0.12	2.73
1524	Water, unspecified natural origin, AT	Raw	dm3	0.71	0.69	54.54
1525	Water, unspecified natural origin, AU	Raw	cm3	0.71	0.72	47.08
1526	Water, unspecified natural origin, BE	Raw	dm3	1.38	1.34	106.75
1527	Water, unspecified natural origin, BG	Raw	m3	0.03	0.03	2.34
1528	Water, unspecified natural origin, BR	Raw	dm3	0.62	0.61	50.48
1529	Water, unspecified natural origin, CA	Raw	m3	0.09	0.10	3.91
1530	Water, unspecified natural origin, CH	Raw	m3	11.21	10.71	885.23
1531	Water, unspecified natural origin, CL	Raw	cm3	5.93	5.70	469.70
1532	Water, unspecified natural origin, CN	Raw	m3	0.80	0.92	20.82
1533	Water, unspecified natural origin, CO	Raw	cu.in	5.41	5.31	443.04
1534	Water, unspecified natural origin, CZ	Raw	cu.in	3.30	3.21	255.43
1535	Water, unspecified natural origin, DE	Raw	dm3	9.03	8.76	697.24
1536	Water, unspecified natural origin, DK	Raw	dm3	1.85	1.79	142.75
1537	Water, unspecified natural origin, EE	Raw	cm3	6.47	6.28	500.64
1538	Water, unspecified natural origin, ES	Raw	dm3	1.53	1.49	118.32
1539	Water, unspecified natural origin, Europe without Switzerland	Raw	m3	0.17	0.18	9.06
1540	Water, unspecified natural origin, FI	Raw	dm3	0.47	0.46	36.59
1541	Water, unspecified natural origin, FR	Raw	dm3	3.59	3.48	277.00
1542	Water, unspecified natural origin, GB	Raw	dm3	2.78	2.70	214.99
1543	Water, unspecified natural origin, GLO	Raw	m3	4.87	5.15	267.03
1544	Water, unspecified natural origin, HN	Raw	cu.in	3.67	3.60	300.31

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1545	Water, unspecified natural origin, HU	Raw	dm3	3.02	2.93	233.55
1546	Water, unspecified natural origin, IAI Area, Africa	Raw	m3	0.06	0.07	1.54
1547	Water, unspecified natural origin, IAI Area, Asia, without China and GCC	Raw	m3	0.11	0.13	2.86
1548	Water, unspecified natural origin, IAI Area, EU27 & EFTA	Raw	m3	0.64	0.74	16.72
1549	Water, unspecified natural origin, IAI Area, Gulf Cooperation Council	Raw	m3	0.13	0.15	3.44
1550	Water, unspecified natural origin, IAI Area, North America, without Quebec	Raw	m3	0.08	0.10	2.18
1551	Water, unspecified natural origin, IAI Area, Russia & RER w/o EU27 & EFTA	Raw	m3	0.19	0.22	5.08
1552	Water, unspecified natural origin, IAI Area, South America	Raw	m3	0.08	0.09	2.05
1553	Water, unspecified natural origin, ID	Raw	cu.in	8.82	8.66	722.42
1554	Water, unspecified natural origin, IN	Raw	dm3	0.27	0.26	21.60
1555	Water, unspecified natural origin, IT	Raw	dm3	3.28	3.19	253.70
1556	Water, unspecified natural origin, JP	Raw	dm3	1.03	1.06	65.92
1557	Water, unspecified natural origin, KR	Raw	cu.in	2.84	2.91	180.01
1558	Water, unspecified natural origin, LU	Raw	cu.in	2.87	2.78	221.56
1559	Water, unspecified natural origin, MX	Raw	cm3	0.58	0.60	36.59
1560	Water, unspecified natural origin, NL	Raw	dm3	2.95	2.86	227.70
1561	Water, unspecified natural origin, NO	Raw	cu.in	7.93	7.70	612.67
1562	Water, unspecified natural origin, PG	Raw	dm3	0.67	0.64	53.22

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1563	Water, unspecified natural origin, PH	Raw	cu.in	11.48	11.40	883.65
1564	Water, unspecified natural origin, PL	Raw	dm3	0.28	0.28	22.01
1565	Water, unspecified natural origin, PT	Raw	dm3	0.59	0.57	45.19
1566	Water, unspecified natural origin, RAF	Raw	m3	0.57	0.55	44.08
1567	Water, unspecified natural origin, RER	Raw	m3	3.27	3.21	251.94
1568	Water, unspecified natural origin, RME	Raw	m3	5.60	5.42	433.48
1569	Water, unspecified natural origin, RNA	Raw	m3	0.18	0.17	13.25
1570	Water, unspecified natural origin, RoW	Raw	m3	72.05	72.22	4985.74
1571	Water, unspecified natural origin, RU	Raw	m3	0.80	0.77	61.70
1572	Water, unspecified natural origin, SE	Raw	dm3	3.16	3.29	176.55
1573	Water, unspecified natural origin, SK	Raw	cu.in	2.49	2.42	192.69
1574	Water, unspecified natural origin, TH	Raw	cu.in	4.61	4.54	388.18
1575	Water, unspecified natural origin, TR	Raw	cm3	13.78	14.13	877.75
1576	Water, unspecified natural origin, TW	Raw	dm3	0.40	0.41	25.43
1577	Water, unspecified natural origin, UA	Raw	cm3	3.41	3.31	263.97
1578	Water, unspecified natural origin, UN-OCEANIA	Raw	m3	0.08	0.09	2.05
1579	Water, unspecified natural origin, US	Raw	m3	0.14	0.14	8.90
1580	Water, unspecified natural origin, VN	Raw	dm3	0.28	0.27	22.64
1581	Water, unspecified natural origin, WEU	Raw	cu.in	1.14	1.14	84.26
1582	Water, US	Water	m3	35634.68	35148.96	2610591.71
1583	Water, VN	Water	dm3	4.63	4.54	378.90
1584	Water, well, in ground, AT	Raw	cm3	3.72	3.62	287.72
1585	Water, well, in ground, AU	Raw	m3	0.83	0.82	61.74

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1586	Water, well, inground, BE	Raw	cm3	7.37	7.15	569.37
1587	Water, well, inground, BG	Raw	cu.in	10.02	9.72	774.63
1588	Water, well, inground, BR	Raw	m3	0.08	0.07	6.05
1589	Water, well, inground, CA	Raw	m3	0.16	0.15	11.03
1590	Water, well, inground, CH	Raw	m3	0.55	0.53	44.15
1591	Water, well, inground, CN	Raw	m3	24.72	24.55	1745.86
1592	Water, well, inground, CZ	Raw	cm3	0.11	0.10	8.36
1593	Water, well, inground, DE	Raw	m3	0.03	0.03	2.60
1594	Water, well, inground, DK	Raw	cm3	10.04	9.75	775.85
1595	Water, well, inground, ES	Raw	m3	0.04	0.04	3.53
1596	Water, well, inground, Europe without Switzerland	Raw	m3	0.43	0.42	34.87
1597	Water, well, inground, FI	Raw	cm3	2.53	2.46	195.76
1598	Water, well, inground, FR	Raw	dm3	9.03	8.86	774.26
1599	Water, well, inground, GB	Raw	cu.in	0.92	0.89	71.02
1600	Water, well, inground, GLO	Raw	m3	36.48	41.49	1254.59
1601	Water, well, inground, HU	Raw	cu.in	1.00	0.97	77.43
1602	Water, well, inground, ID	Raw	m3	1.03	1.00	77.20
1603	Water, well, inground, IN	Raw	m3	0.99	0.96	82.45
1604	Water, well, inground, IS	Raw	cm3	3.13	3.06	236.53
1605	Water, well, inground, IT	Raw	cu.in	1.28	1.24	98.43
1606	Water, well, inground, JP	Raw	cm3	6.95	7.04	461.89
1607	Water, well, inground, KR	Raw	cm3	0.13	0.13	8.24
1608	Water, well, inground, LU	Raw	cm3	0.26	0.25	19.73
1609	Water, well, inground, MA	Raw	m3	0.04	0.03	2.92

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1610	Water, well, inground, MX	Raw	cm3	3.50	3.42	264.08
1611	Water, well, inground, MY	Raw	dm3	5.67	5.49	453.01
1612	Water, well, inground, NL	Raw	cu.in	0.97	0.94	74.58
1613	Water, well, inground, NO	Raw	cm3	0.70	0.67	53.72
1614	Water, well, inground, NORDEL	Raw	dm3	3.78	3.71	278.57
1615	Water, well, inground, PE	Raw	cu.in	5.44	5.22	434.20
1616	Water, well, inground, PG	Raw	dm3	5.76	5.53	459.61
1617	Water, well, inground, PH	Raw	m3	0.03	0.03	2.52
1618	Water, well, inground, PL	Raw	m3	0.87	0.84	66.39
1619	Water, well, inground, PT	Raw	cm3	3.27	3.17	252.25
1620	Water, well, inground, RER	Raw	m3	55.61	52.66	4507.94
1621	Water, well, inground, RLA	Raw	m3	0.15	0.15	11.59
1622	Water, well, inground, RNA	Raw	m3	1.06	1.03	81.15
1623	Water, well, inground, RoW	Raw	m3	122.27	116.25	9846.10
1624	Water, well, inground, RU	Raw	m3	0.70	0.73	38.22
1625	Water, well, inground, SE	Raw	dm3	0.23	0.23	17.57
1626	Water, well, inground, SK	Raw	cm3	0.21	0.20	16.04
1627	Water, well, inground, TH	Raw	mm3	0.60	0.59	45.40
1628	Water, well, inground, TN	Raw	dm3	4.28	4.19	356.48
1629	Water, well, inground, TR	Raw	cm3	2.49	2.41	193.67
1630	Water, well, inground, TW	Raw	cm3	2.14	2.20	136.96
1631	Water, well, inground, US	Raw	m3	0.97	0.95	80.97
1632	Water, well, inground, WEU	Raw	m3	1.01	0.99	75.92
1633	Water, well, inground, ZA	Raw	m3	0.44	0.48	18.45

No	Substance	Compartment	Unit	ICS1	ICS2	RCS
1634	Water, WEU	Water	m3	1.12	1.10	84.39
1635	Water, ZA	Water	m3	105.68	108.54	6387.16
1636	Water/m3	Air	m3	786.18	773.40	62992.51
1637	Wood, hard, standing	Raw	m3	1.26	1.24	94.44
1638	Wood, soft, standing	Raw	m3	1.36	1.33	106.27
1639	Wood, unspecified, standing/m3	Raw	cu.in	1.57	1.56	113.91
1640	Xenon	Raw	g	0.02	0.02	1.48
1641	Xenon-131m	Air	kBq	62.94	61.74	4671.63
1642	Xenon-133	Air	kBq	5082.16	4978.15	379353.23
1643	Xenon-133m	Air	kBq	2.82	2.77	209.57
1644	Xenon-135	Air	kBq	1671.84	1638.07	124675.59
1645	Xenon-135m	Air	kBq	563.72	553.09	41840.53
1646	Xenon-137	Air	kBq	17.43	17.11	1293.87
1647	Xenon-138	Air	kBq	130.82	128.36	9709.08
1648	Xylene	Air	kg	0.51	0.50	37.23
1649	Xylene	Water	kg	0.03	0.03	2.09
1650	Zeta-cypermethrin	Soil	µg	1.50	1.46	123.87
1651	Zinc	Raw	kg	4.09	4.06	296.08
1652	Zinc	Air	kg	3.06	2.88	256.20
1653	Zinc	Water	tn.lg	0.24	0.24	23.92
1654	Zinc	Soil	kg	0.04	0.04	3.08
1655	Zinc-65	Air	Bq	0.14	0.14	10.36
1656	Zinc-65	Water	kBq	1.50	1.46	112.73
1657	Zinc, Zn 0.63%, Au 9.7E-4%, Ag 9.7E-4%, Cu 0.38%, Pb 0.014%, in ore	Raw	kg	0.83	0.81	66.52
1658	Zinc, Zn 3.1%, in mixed ore	Raw	kg	0.07	0.08	1.77
1659	Zirconium	Raw	kg	1.61	1.65	122.70
1660	Zirconium	Air	mg	0.83	0.80	65.45
1661	Zirconium-95	Air	Bq	0.41	0.40	30.27
1662	Zirconium-95	Water	kBq	7.34	7.17	555.01