Environmental Product Declaration

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EPD Program and Program Operator Name, Address, Logo, and Website	NSF Certification, LLC 789 North Dixboro Road. Ann Arbor, MI, 48105, United States https://www.nsf.org/
General Program Instructions and Version Number	Part A: Life Cycle Assessment Calculations and Report Requirements Version 4.0
Manufacturer Name and Address	Carrier Corporation 13995 Pasteur Boulevard Palm Beach Gardens, Florida 33418
Declaration Number	EPD11017
Product and Functional Unit	AquaEdge® 19DV Water-Cooled Centrifugal Chiller, 1 ton chilling capacity
Reference PCR and Version Number	Part A: Life Cycle Assessment Calculation Rules and Report Requirements (UL Environment, V4.0, 2022) Part B: Water Cooled Chiller EPD Requirements (UL Environment V2.0, 2018)
Product's Intended Application and Use	The AquaEdge® 19DV is a water-cooled centrifugal chiller that utilizes a two-stage back-to-back compressor and refrigerant lubricated ceramic bearings to deliver a high operating range and consistent efficiency. The function of the chillers included in this study is to provide chilled water for use in cooling the interior of a building.
Product RSL	25 years
Markets of Applicability	North America, Global
Date of Issue	12/17/2024 - 12/17/2029
Period of Validity	5 Years from the date of issue
EPD Type	Product Specific
Range of Dataset Variability	N/A
EPD Scope	Cradle-to-Grave
Year of reported manufacturer primary data	2023
LCA Software and Version Number	One Click LCA v0.33.1
LCI Database and Version Number	Ecoinvent v3.10
LCIA Methodology and Version Number	TRACI 2.1 + CML-IA v4.1 + PEF
The sub-category PCR review was conducted by:	Lise Laurin, EarthShift Global Sean Beilman, BCER Engineering, Inc. François Charron-Doucet, Group AGÉCO
This declaration was independently verified in accordance with ISO 14025: 2006. The PCR chosen conforms to ISO 21930:2017. ☐ INTERNAL ☒ EXTERNAL	Jack Geibig - EcoForm jgeibig@ecoform.com 
This life cycle assessment was conducted in accordance with ISO 14044 and the reference PCR by:	Shashikumar M S, HCLTech
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by:	Jack Geibig - EcoForm jgeibig@ecoform.com 

Limitations:
Environmental declarations from different programs (ISO 14025) may not be comparable.
Comparison of the environmental performance of products using EPD information shall be based on the product's use and impacts at the building level, and therefore EPDs may not be used for comparability purposes when not considering the building use phase as instructed under this PCR. Previous versions of the PCR vary in the prescribed default refrigerant leakage rate and do not necessitate the reporting of B4 impacts. These variations make it imperative to ensure that EPDs are aligned with all the following conformance requirements for comparisons.

Full conformance with the PCR for Water Chillers allows EPD comparability only when all stages of a life cycle have been considered, when they comply with all referenced standards, use the same sub-category PCR, and use equivalent scenarios with respect to construction works. However, variations and deviations are possible. Example of variations: Different LCA software and background LCI datasets may lead to differences results for upstream or downstream of the life cycle stages declared.

No use phase grid mix is explicitly defined by the PCR. As such, Carrier has elected to report multiple use phase electricity demand scenarios for increased reader utility. This reporting is described in the text of the EPD.

1 – GENERAL INFORMATION

Description of Company

Carrier is the leading global provider of healthy, safe, and sustainable building and cold chain solutions with a world-class, diverse workforce. Through performance-driven culture, shareholder value is driven by growing earnings and investing strategically to strengthen its position in the market. Carrier's industry leading solutions and services are designed to reduce energy consumption and facility operating costs in HVAC & Refrigeration.

Product Description

This environmental product declaration covers the following products from CSI division 23 64 16.16: AquaEdge® 19DV Water-Cooled Centrifugal Chiller. Further explanatory material may be obtained through the company website: https://www.carrier.com/commercial/en/us/products/chillers-components/water-cooled-chillers/.

The AquaEdge® 19DV is a water-cooled centrifugal chiller that utilizes a two-stage back-to-back compressor and an oil-free ceramic bearing system to deliver more operating range and consistent efficiency. Product shown in Figure 1.

Figure 1: AquaEdge® 19DV Water-Cooled Centrifugal Chiller Product Image

AquaEdge® 19DV chiller has cooling capacities ranging from 350 - 1,150 tons. Further 650 ton which is the most common configuration by sales volume is assessed for the purpose of this EPD. The chiller models allow for a nearly endless amount of variability in configuration based on the specifications and needs of the ultimate consumer.

This configuration uses refrigerant, R-1233zd(E).

No substances required to be reported as hazardous according to the US Resources Conservation and Recovery Act, Subtitle 3 are associated with the production of this product.

Technical Data

The AquaEdge® 19DV chiller series is certified to the following standards:

- High tier variable speed starter equipped with harmonic filter (optional), total harmonic distortion. (THD) ≤5% and fully complies with IEEE519 standard.
- AquaEdge® 19DV chillers can achieve up to 7.3 (0.4818 kW/Ton) full load COPR and 12.3 (0.2859 kW/Ton) IPLV.IP at AHRI conditions.
- AquaEdge® 19DV chillers can meet 18001 standards recommended by Occupational Health and Safety Advisory Services (OHSAS).
- ASME Section VIII Div. 1 "U" stamped certified.
- Certified in accordance with the AHRI Water-Cooled Water-Chilling and Heat Pump Water-Heating Packages.
- Certification Program, which is based on AHRI Standard 550/590 (I-P) and AHRI Standard 551/591 (SI).
- Certified units may be found in the AHRI Directory at http://www.ahridirectory.org.

Table 1 shows the technical specifications of the products, including any testing data as appropriate.

Table 1: Technical Data

Name	Value	Unit
Chilling Capacity	650	tons of refrigeration (RT)
Energy Efficiency*	100% Load at 85°F	kW/ton at different combinations of load % and Entering Condenser Water Temperature
	75% Load at 75°F	
	50% Load at 65°F	
	25% Load at 65°F	

*Values from AHRI 550/590 Standard

The dimensions of each configuration as delivered to the customer are reported in Table 2.

Table 2: Product Dimensions

	650 ton	Unit
Length	5.2	m
Width	2.6	m
Height	3.1	m

Application

The function of the chiller included within this study is to provide chilled water for use in cooling the interior of a building, for a functional unit of 1 ton chilling capacity. In this study, the reference service life (RSL) of the products is 25 years. Therefore, after initial installation in a building with an estimated service life (ESL) of 75 years there will be two replacements needed.

Material Composition

The raw materials for the product were obtained from local suppliers in the United States and China. The general compositions of the products are represented in Table 3.

Table 3: Material Composition per Functional Unit

Materials	650 ton
R-1233zd(E) Charged Chiller: Material Composition per Functional Unit	
Steel [kg]	13.34
Iron [kg]	6.32
Copper [kg]	3.00
Aluminum [kg]	0.01
Refrigerant [kg]	0.92
Other [kg]	1.38
R-1233zd(E) Charged Chiller: Contribution to Total Material Composition	
Steel	55.32%
Iron	27.32%
Copper	7.63%
Aluminum	0.96%
Refrigerant	3.86%
Other	4.92%

Manufacturing

All major components are manufactured within the US and the final assembly occurs at the main manufacturing facility in Charlotte, NC, US. The same components are manufactured in Shanghai, China and the final assembly also occurs in Shanghai. The final product is then shipped to US catering its customers . Components include the tube sheets, the evaporator, the condenser, and the control box.

Manufacture impacts of capital goods and infrastructure flows are excluded as they are estimated to impact, at most, 0.12 kg CO_2e per ton of chilling capacity over the life cycle of the manufacturing infrastructure, which is considered negligible. This assumption is in alignment with typical building product LCA practice.

The functional unit according to the PCR is one (1) ton of chilling capacity. The products under study have a reference service life (RSL) of 25 years. Table 4 shows additional details related to the functional unit, reporting the values for the chiller with R-1233zd(E).

Table 4: Functional Unit Details

	650 ton	Unit
Functional Unit	1 ton chilling capacity	
Mass of one delivered product	15456	kg
Conversion factor (kg per Functional Unit)	23.7	kg/ton of chilling capacity

Transportation

The product is delivered to the customer via truck in US whereas the products from China is transported via ocean freight to customers in US. Transportation distances are set by the PCR and are shown in Table 5, along with additional transportation data. It is assumed that each chiller is shipped individually using a flatbed truck. Additionally, it is assumed that the return route for the truck is empty. These factors contribute to a low-capacity utilization factor, as seen in the Table 5.

Table 5: Transport to Building Site (A4) per Functional Unit

	650 ton
Vehicle Type	>32000 Kg payload Flatbed Truck
Product Weight (Kg)	15455.7
Fuel Efficiency [L/100km]	36.3
Fuel Type	Diesel
Distance [km]	500
Additional Ocean Freight Distance [km]	13681
Capacity Utilization [%]	24%
Gross density of products transported [kg/m3]	369
Capacity utilization volume factor	<1

Chillers are removed from the truck and positioned in HVAC rooms where all required connections to the HVAC system of the building are made.

Installation

A crane is necessary to unload the chiller from the truck based on the installation procedures described by Carrier. It is assumed that the crane is operational for 3 hours and consumes 12.6 gallons of diesel fuel per hour (47.8 liters per hour) based on information provided by the crane manufacturer. Other than unloading, installation procedures are assumed to be manual and require no operational energy use as described by the default assumptions in the PCR. It is assumed that no product loss occurs to the chiller during installation. The packaging wastes are carton and TPE film, of which TPE film has only one useful life and is assumed to be disposed of via landfilling whereas carton are entirely sent for recycling. No single use accessories are required for the installation of the chillers. Installation details are summarized in Table 6.

Table 6: Installation Scenario Details per Functional Unit

	650 ton	Unit
Other energy carriers by type – Diesel Fuel	8.38	MJ
Packaging Waste to Landfill	0.050	kg
Packaging Waste to Recycling	0.040	kg

Other parameters indicated by PCR, such as net freshwater consumption, electricity consumption, product loss, waste materials at the construction site, and direct emissions to air, water, and soil, are zero and thus not included in the table.

RSL and ESL Scenarios

Standard interior building operating conditions are assumed throughout the use phase of the chiller. The Reference Service Life (RSL) of the chiller is 25 years as described by the PCR. Details regarding the RSL and replacement of each configuration are provided in Table 7.

Table 7: Reference Service Life and Estimated Service Life of Chillers

	650 ton	Unit
Product RSL (years)	25	years
Building ESL (years)	75	years
Replacement Cycle(s)	2	number
Use Conditions (based on R-1233zd(E) refrigerant)	688,967	Annual energy demand (kWh)

Modules B2-B5 Scenarios

Tables describing use phase scenarios developed for modules B2-B5 are provided below in Table 8 & Table 9.

No impacts associated with repair, refurbishment, or operational water use (B3, B5, or B7) are included within this study. 90% of water-cooled chillers use water from cooling towers however, no water is consumed in processing. While this is relevant to the study, this life cycle module is believed to have negligible impacts. Auxiliary materials such as water treatment chemicals were excluded from the study because their impacts are not directly related to a chiller

Impacts from refrigerant loss are assigned to the maintenance impacts module (B2). A 2% refrigeration loss and replacement rate is assumed based on guidance from the PCR.

Table 8: Maintenance (Module B2)

	650 ton	Unit
Maintenance process information	Replacement of leaked refrigerant assuming a 2% annual loss rate	n/a
Maintenance cycle (per RSL)	25	cycles
Maintenance cycle (per ESL)	75	cycles
Refrigerant replacement, R-1233zd(E)	11.92	kg
Direct emissions to ambient air, soil and water (refrigerant to air)	11.92	kg

No inputs or outputs are associated with Module B3 (repair).
Since net freshwater consumption, ancillary materials, other resources, electricity, and other energy sources are zero, they are not included in the table. No additional assumptions for scenario development are made.
The impacts reported in module B4 will be approximately twice the total score of modules A1-A5, assuming two replacements are made.

Table 9: Replacement (Module B4)

	650 ton	Unit
Replacement cycles (ESL/RSL-1)	2	cycles
Direct emissions to ambient air, soil and water (refrigerant to air) (R-1233zd(E))	59.6	kg
Further assumptions for scenario development	90% of refrigerant is recovered at EOL but 10% is emitted to ambient air	As appropriate

No inputs or outputs are associated with Module B5 (refurbishment).
Since net freshwater consumption, ancillary materials, and replacement of worn parts are not applicable, they are excluded from the table.

Operational Energy Use (Module B6)

Water cooled chillers transfer heat away from spaces that require climate control by cooling water and allowing it to absorb heat from an environment. The process involves a significant expenditure of electricity and requires a large charge of refrigerant. The operational energy requirements of chillers are highly dependent on the climate and demands of the location of installation. As such, the PCR has developed a calculation tool for generating a life cycle energy demand estimation.

Operational efficiencies of each chiller configuration are reported in Table 10. These values are imported into a standardized formula for determining the annual hours of operation and ultimate annual energy demand. This formula has been tested in compliance with ANSI/ASHARE Standard 140-2007, 2007 and was approved for use by UL. After determining the configuration efficiency, the calculator is used to determine the energy usage for each of 55 global city locations, independent of actual production markets. To determine the annual hours of operation and efficiency, calculations in the Centrifugal Chiller Average Efficiency Calculator excel file are based on actual weather data from the following global cities:

> Atlanta, Bangkok, Beijing, Berlin, Boston, Buenos Aires, Cairo, Cancun, Cape Town, Caracas, Chicago, Dallas, Denver, Dubai, Hanoi, Ho Chi Minh, Hong Kong, Houston, Jerusalem, Kansas City, London, Los Angeles, Madrid, Manila, Melbourne, Mexico City, Miami, Moscow, Mumbai, New Delhi, Ottawa, Paris, Perth, Phoenix, Raleigh, Riyadh, Rome, San Diego, San Francisco, San Juan, Sao Paulo, Seattle, Seoul, Shanghai, Singapore, Sydney, Taipei, Tokyo, Toronto, Vancouver, Venice, Warsaw, and Washington D.C.

Annual hours of operation and chiller capacity are defined as per the appended document for each respective chiller configuration. Chiller capacity is defined as the chilling capacity declared on the product. Operational efficiencies & Annual energy demand of each chiller configuration are reported in below Table 10.

Table 10: Operational Energy Efficiencies and Use (B6)

Name	Value	Unit
Chilling Capacity	650	tons of refrigeration (RT)
Electricity Consumption/Year (1 year)	688,967	kWh
Electricity Consumption/Year for ESL (75 Years)	51,672,525	kWh
Electricity Consumption/Year (per functional unit)	1059.949	kWh/ton

Other parameters indicated by PCR, such as net fresh water consumption, other energy carriers, and equipment power output, are zero and not included in the table.Sales data from 2023 were used to choose the region for which impacts associated with the operational energy use. The quantity and city of sales of AquaEdge® 19DV chiller units are considered. Depending on the quantity of sales the use phase electricity is selected as US as shown in Table 11.

Table 11: Operational Energy Use Phase

Country	Percent Contribution [%]	Emission Factor $KgCo_2e/kWh$
US	100	0.45

Additionally, results are presented according to the ESL of 75 years, as required by the PCR, and the RSL of the product (25 years).

Disposal (Module C1-C4)

The chiller, in its entirety, is assumed to be delivered via truck to a recycling facility for dismantling and further product disposal. After separation at the facility, all metal components are assumed to be recycled and all plastic components are assumed to be landfilled. The refrigerant charge in the chiller at the time of disposal is assumed to be recycled at 90% with the remaining 10% lost to the atmosphere during disassembly. Table 12 shows the parameters for the end-of-life scenario utilized in the model for each model charged with R-1233zd(E). Currently, products are not reused from chillers at the end-of-life.

Table 12: End-of-Life Scenario Details (C1-C4)

	650 ton
Collected separately	0
Collected as mixed construction waste [kg]	14100.52
Waste to Reuse [kg]	0
Distance to Reuse [km]	0
Waste to Landfill [kg]	756.9
Distance to Landfill [km]	100
Waste to Incineration [kg]	0
Distance to Incineration [km]	0
Waste to Recycling [kg]	13939.76
Distance to Recycling [km]	100

2 – LIFE CYCLE ASSESSMENT METHODOLOGY

This LCA is a Cradle-to-Grave study. An overview of the system boundary is shown in *Figure 2* and a summary of the life cycle stages included in this LCA is presented in *Table 13*.

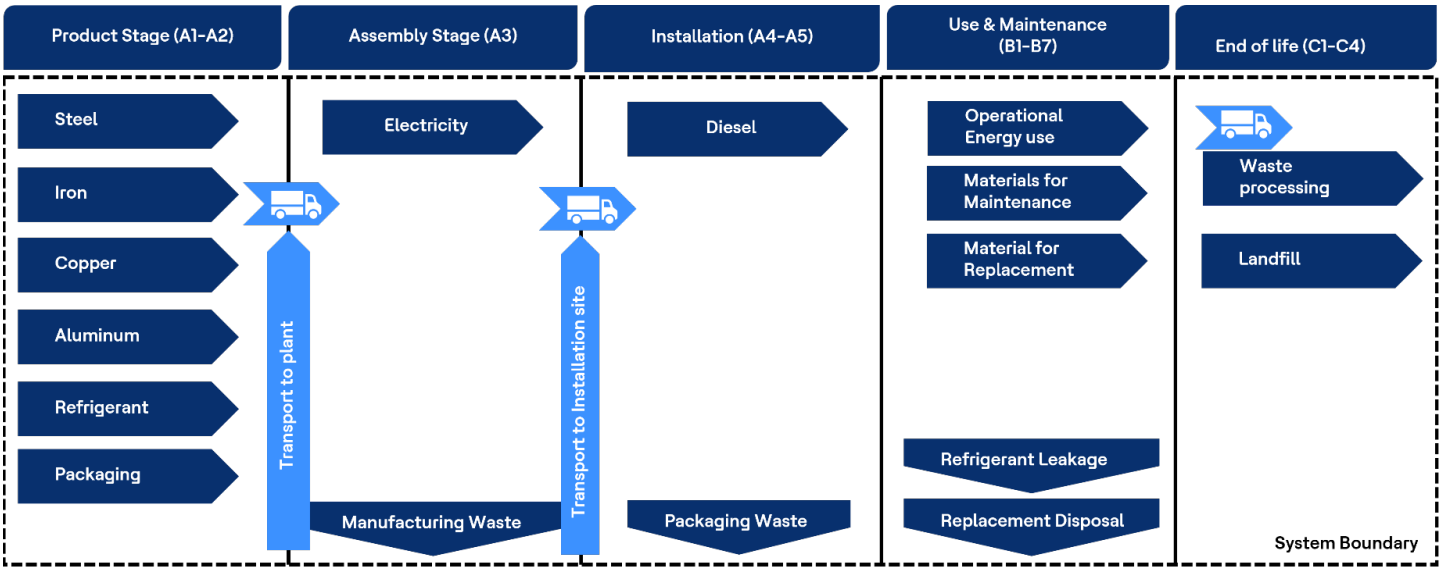

Figure 2: System Boundary Diagram

Table 13: Life Cycle Stages Included in the Study

Product stage			Assembly stage		Use stage							End of life stage				Beyond the system boundaries		
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D	D	D
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	MND	MND	MND
Raw materials	Transport	Manufacturing	Transport	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Demolition.	Transport	Waste processing	Disposal	Reuse	Recovery	Recycling
US & Global	Global	US / China	Global	Global	Global	Global	-	Global	-	US & Global	-	-	Global	Global	Global	-	-	-

X = Module Included in LCA, MND = Module not Declared

Cut-off Criteria

The study does not exclude any modules or processes which are stated mandatory in the reference standard and the applied Product Category Rule. The study does not exclude any hazardous materials or substances. The study includes all major raw material and energy consumption. All inputs and outputs of the unit processes, for which data is available for, are included in the calculation. There is no neglected unit process more than 1% of total mass or energy flows. The module specific total neglected input and output flows also do not exceed 5% of energy usage or mass. The list of excluded materials and energy inputs include:

- As the tools used during the installation of the product are multi-use tools and can be reused after each installation, the per-declared unit impacts are considered negligible and therefore are not included.
- While required by the PCR, inclusion of capital goods and infrastructure flows is a typical within LCA practice following construction product PCRs. Infrastructure flows for Carrier production facilities are assumed to be negligible to the life cycle of an individual product based on the volume of product output and the lifetime of the infrastructure. Additionally, the use phase of the product is by far the largest impact and overshadows any additional burden of infrastructure flows.
    - Furthermore, the infrastructure flow has been estimated to impact, at most, 0.12 kg CO2e per ton of chilling capacity. This estimation was based on the embodied carbon of buildings per unit area[1], the facility square footage, and the number of units produced within the last 20 years at the facility.
- Some material inputs may have been excluded within the datasets used for this project. All datasets have been critically reviewed and conform to the exclusion requirement of the PCR, Part A: "Calculation Rules for the Life Cycle Assessment and Requirements on the Background Report".

No known flows are deliberately excluded from this EPD.

Allocation

General principles of allocation were based on ISO 14040/44. There are no products other than the product under study that are produced as part of the manufacturing processes. Since there are no co-products, no allocation based on co-products is required.

To derive a per-unit value for manufacturing electricity, the manufacturer product is analyzed using aPriori to provide manufacturing energy consumption. The proportion of thermal energy and water use are assumed to be minimal.

Throughout the study recycled materials were accounted for via the cut-off method. Under this method, impacts and benefits associated with the previous life of a raw material from recycled stock are excluded from the system boundary. Additionally, impacts and benefits associated with secondary functions of materials at end of life are also excluded (i.e., production into a third life or energy generation from the incineration plant). The study does include the impacts associated with reprocessing and preparation of recycled materials that are part of the bill of materials of the products under study.

Data Quality

Primary data was collected from the manufacturer specific to the temporal and technological aspects of the chiller life cycle. All primary data is from calendar year 2023. Secondary data was sourced from Ecoinvent Datasets, taking into consideration the most accurate and representative options. The data included is considered complete. The precision of the data is considered high and represents detailed Bills of Materials provided by facility engineers. The data is considered complete and does not exclude any known energy or material flows except those clearly stated in the cut-off criteria section.

The consistency of the LCA is considered high with the Bills of Materials generated from regularly maintained internal documentation. Modeling assumptions are consistent across the model and preference of datasets is given towards Ecoinvent data, where available.

This study is considered reproducible. Descriptions of the data and assumptions through this report would allow a practitioner to utilize the LCA tool to generate results for the products.

[1] https://www.istructe.org/IStructE/media/Public/TSE-Archive/2020/A-brief-guide-to-calculating-embodied-carbon.pdf

3 – LIFE CYCLE ASSESSMENT RESULTS

All results are given per functional unit, which is one ton of Chilling Capacity.
Each product under study is reported separately by life cycle stage. The study does not consider long-term emissions (i.e., over one hundred years). Characterization factors CML-IA version 4.1, PEF, TRACI 2.1 have been used throughout the study. Parameters used in the study are presented in the table Table 14, Table 15, Table 16, Table 17.

Table 14: Parameters describing environmental impacts (NS-EN15804 2012)

Impact Category	Parameter	Unit (expressed per functional unit or per declared unit)
Global Warming	Global warming potential GWP	kg CO_2- equiv 100 yr
Ozone Depletion	Depletion potential of the stratospheric ozone layer ODP	kg CFC-11- equiv 20 yr
Acidification for soil and water	Acidification potential of soil and water AP	kg SO_2 - equiv
Eutrophication	Eutrophication potential EP	kg PO_4 - equiv
Photochemical ozone creation	Formation potential of tropospheric ozone POCP	kg C_4H_4- equiv
The abiotic depletion potential is calculated and declared in two different indicators: ADP-elements (kg Sb equiv): include all non-renewable abiotic material resources (i.e. excepting fossil resources) ADP-fossil fuels (MJ net calorific value): include all fossil resources		

Table 15: Parameters describing core environmental impacts – EN 15804+A2

Impact category	Indicator	Unit (expressed per functional unit or per declared unit)
Climate change – total [a]	Global Warming Potential total (GWP-total)	kg CO_2 eq.
Climate change - fossil	Global Warming Potential fossil fuels (GWP-fossil)	kg CO_2 eq.
Climate change - biogenic	Global Warming Potential biogenic (GWP-biogenic)	kg CO_2 eq.
Climate change - land use and land use change [b]	Global Warming Potential land use and land use change (GWP-luluc)	kg CO_2 eq.
Ozone Depletion	Depletion potential of the stratospheric ozone layer (ODP)	kg CFC_{-11} eq.
Acidification	Acidification potential Accumulated Exceedance (AP)	mol H^+ eq.
Eutrophication aquatic freshwater*	Eutrophication potential fraction of nutrients reaching freshwater end compartment (EP-freshwater)	kg P eq.
Eutrophication aquatic marine	Eutrophication potential fraction of nutrients reaching marine end compartment (EP-marine)	kg N eq.
Eutrophication terrestrial	Eutrophication potential Accumulated Exceedance (EP-terrestrial)	mol N eq.
Photochemical ozone formation	Formation potential of tropospheric ozone (POFP)	kg NMVOC eq.
Depletion of abiotic resources - minerals and metals [c d]	Abiotic depletion potential for non-fossil resources (ADP minerals & metals)	kg Sb eq.
Depletion of abiotic resources - fossil fuels [c]	Abiotic depletion for fossil resources potential (ADP-fossil)	MJ net calorific value
Water use	Water (user) deprivation potential deprivation-weighted water consumption (WDP)	m^3 world eq. deprived

a. The total global warming potential (GWP-total) is the sum of
— GWP-fossil
— GWP-biogenic
— GWP-luluc
b. It is permitted to omit GWP-luluc as separate information if its contribution is < 5 % of GWP-total over the declared modules excluding module D.
c. The abiotic depletion potential is calculated and declared in two different indicators:
— ADP-minerals & metals include all non-renewable abiotic material resources (i.e. excepting fossil resources);
— ADP-fossil include all fossil resources and includes uranium.
d. ultimate reserve model of the ADP-minerals & metals model

Additional Environmental Impact Indicators		
Particulate Matter	Potential incidence of disease due to PM emissions (PM)	Disease incidence
Ionizing radiation human health	Potential Human exposure efficiency relative to U235 (IRP)	kBq U235 eq.
Eco-toxicity (freshwater)	Potential Comparative Toxic Unit for ecosystems (ETP-fw)	CTUe
Human toxicity cancer effects	Potential Comparative Toxic Unit for humans (HTP-c)	CTUh
Human toxicity non-cancer effects	Potential Comparative Toxic Unit for humans (HTP-nc)	CTUh
Land use related impacts/ Soil quality	Potential soil quality index (SQP)	dimensionless

**EN 15804:2012+A2:2019 specifies that the unit for the indicator for Eutrophication aquatic freshwater shall be kg PO4 eq, although the reference given ("EUTREND model, Struijs et al., 2009b, as implemented in ReCiPe") uses the unit kg P eq. This is a typographical error in EN 15804, which is expected to be corrected in a future revision. The results in kg PO4 eq. can be obtained by multiplying the results in kg P eq. with a factor of 3.07.*

Table 16: Parameters describing use of natural resource, waste and output flows

Parmeter	Unit (expressed per functional unit or per declared unit)
Use of renewable primary energy excluding renewable primary energy resources used as raw materials	MJ net calorific value
Use of renewable primary energy resources used as raw materials	MJ net calorific value
Total use of renewable primary energy resources (primary energy and primary energy resources used as materials)	MJ net calorific value
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	MJ net calorific value
Use of non-renewable primary energy resources used as raw materials	MJ net calorific value
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as materials)	MJ net calorific value
Use of secondary material	kg
Use of renewable secondary fuels	MJ net calorific value
Use of non-renewable secondary fuels	MJ net calorific value
Net use of fresh water	m^3
Waste and Output Flows	
Hazardous waste disposed*	kg
Non-hazardous waste disposed	kg
Radioactive waste disposed	kg
Components for re-use	kg
Materials for recycling	kg
Materials for energy recovery	kg
Exported energy	MJ per energy carrier

**The characteristics that render waste hazardous are described in existing applicable legislation, e.g., in the European Waste Framework Directive. The estimated impact results are only relative statements which do not indicate the end points of the impact categories, exceeding threshold values, safety margins or risks.*

Table 17: Parameters describing environmental impacts (TRACI 2.1)

Impact Category	Indicator	Unit (expressed per functional unit or per declared unit)
Global warming potential	GWP 100: Global Warming Potential	kg CO2e
Ozone depletion	ODP: Ozone Depletion Potential	kg CFC-11e
Photochemical Smog Formation	SFP: Smog Formation Potential	kg O3e
Acidification	AP: Acidification Potential	kg SO2e
Eutrophication	EP: Eutrophication Potential	kg Ne
Depletion of non-renewable energy	ADP fossil: Abiotic Resource Depletion Potential of Non-renewable (fossil) energy resources	MJ

These six impact categories are globally deemed mature enough to be included in Type III environmental declarations. Other categories are being developed and defined and LCA should continue making advances in their development, however the EPD users shall not use additional measures for comparative purposes.

Third party verified ISO 14040/44 secondary LCI data sets contribute not more than 67% of total impact to the required impact categories identified by the applicable PCR.

Biogenic Carbon Removal and Emissions are required to be reported according to ISO 21930. However, no biogenic carbon is relevant to the product or its packaging. As such, no impacts are reported.

AquaEdge® 19DV Water-cooled chiller (US)

The LCIA results presented below are for 1 ton of chilling capacity of AquaEdge® 19DV (R-1233zd(E)).

Table 18: LCIA results for AquaEdge® 19DV (R-1233zd(E)), per 1 ton of chilling capacity (Mfg: US), PEF

CORE ENVIRONMENTAL IMPACT INDICATORS – EN 15804+A2, PEF

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
GWP – total[1]	kg CO_2e	1.65E+02	1.24E+00	8.41E-01	1.38E+00	3.52E+00	0.00E+00	3.33E+02	0.00E+00	3.59E+04	0.00E+00	2.59E+00	0.00E+00	4.21E-01	2.07E+00	9.90E-02	0.00E+00
GWP – fossil	kg CO_2e	1.64E+02	1.24E+00	8.43E-01	1.38E+00	3.52E+00	0.00E+00	3.33E+02	0.00E+00	3.59E+04	0.00E+00	2.59E+00	0.00E+00	4.21E-01	2.07E+00	9.90E-02	0.00E+00
GWP – biogenic	kg CO_2e	1.52E-03	0.00E+00	-1.52E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-1.69E-16	0.00E+00	-1.69E-22	0.00E+00	-1.69E-22	0.00E+00	0.00E+00	0.00E+00
GWP – LULUC	kg CO_2e	1.27E-01	5.23E-04	7.69E-05	0.00E+00	1.11E-03	0.00E+00	2.54E-01	0.00E+00	1.75E+00	0.00E+00	7.74E-04	0.00E+00	1.69E-04	6.00E-04	4.31E-06	0.00E+00
Ozone depletion pot.	kg CFC_{-11}e	2.46E-05	2.00E-08	1.29E-08	0.00E+00	3.38E-05	0.00E+00	4.93E-05	0.00E+00	3.54E-04	0.00E+00	1.51E-08	0.00E+00	6.15E-09	8.77E-09	2.00E-10	0.00E+00
Acidification potential	mol H^+e	1.31E+00	3.15E-03	7.60E-03	0.00E+00	4.37E-02	0.00E+00	2.64E+00	0.00E+00	2.29E+01	0.00E+00	7.20E-03	0.00E+00	9.85E-04	6.17E-03	5.08E-05	0.00E+00
EP-freshwater	kg Pe	8.38E-03	1.17E-05	3.08E-06	0.00E+00	5.85E-05	0.00E+00	1.68E-02	0.00E+00	6.59E-02	0.00E+00	3.32E-05	0.00E+00	3.85E-06	2.92E-05	8.00E-08	0.00E+00
EP-marine	kg Ne	1.66E-01	7.85E-04	3.52E-03	0.00E+00	5.37E-03	0.00E+00	3.40E-01	0.00E+00	8.96E+00	0.00E+00	1.57E-03	0.00E+00	2.31E-04	1.32E-03	2.00E-05	0.00E+00
EP-terrestrial	mol Ne	1.91E+00	8.65E-03	3.85E-02	0.00E+00	6.01E-02	0.00E+00	3.92E+00	0.00E+00	9.81E+01	0.00E+00	1.79E-02	0.00E+00	2.51E-03	1.52E-02	2.15E-04	0.00E+00
POCP ("smog")[2]	kg NMVOCe	6.28E-01	4.77E-03	1.15E-02	0.00E+00	1.80E-02	0.00E+00	1.29E+00	0.00E+00	7.83E+01	0.00E+00	5.98E-03	0.00E+00	1.37E-03	4.54E-03	7.38E-05	0.00E+00
ADP-minerals & metals[3]	kg Sbe	9.35E-03	3.54E-06	3.23E-07	0.00E+00	1.42E-04	0.00E+00	1.87E-02	0.00E+00	1.23E-02	0.00E+00	3.37E-05	0.00E+00	1.40E-06	3.23E-05	1.48E-08	0.00E+00
ADP-fossil resources	MJ	1.97E+03	1.86E+01	1.10E+01	0.00E+00	4.03E+01	0.00E+00	4.00E+03	0.00E+00	5.94E+05	0.00E+00	1.39E+01	0.00E+00	5.92E+00	7.82E+00	1.66E-01	0.00E+00
Water use[4]	m^3e depr.	5.09E+01	8.91E-02	2.75E-02	0.00E+00	1.38E+00	0.00E+00	1.02E+02	0.00E+00	3.31E+03	0.00E+00	1.48E-01	0.00E+00	2.70E-02	1.20E-01	6.77E-04	0.00E+00

ADDITIONAL (OPTIONAL) ENVIRONMENTAL IMPACT INDICATORS – EN 15804+A2, PEF

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Particulate matter	Incidence	1.31E-05	1.22E-07	2.15E-07	0.00E+00	5.38E-07	0.00E+00	2.68E-05	0.00E+00	1.15E-04	0.00E+00	1.17E-07	0.00E+00	3.23E-08	8.31E-08	1.14E-09	0.00E+00
Ionizing radiation[5]	kBq U235e	4.21E+00	6.38E-03	1.98E-03	0.00E+00	2.44E-02	0.00E+00	8.43E+00	0.00E+00	6.19E+01	0.00E+00	1.41E-02	0.00E+00	1.94E-03	1.21E-02	5.08E-05	0.00E+00
Ecotoxicity (freshwater)	CTUe	2.24E+03	4.47E+00	1.64E+00	0.00E+00	5.81E+01	0.00E+00	4.48E+03	0.00E+00	3.65E+04	0.00E+00	1.17E+01	0.00E+00	1.58E+00	7.95E+00	2.13E+00	0.00E+00
Human toxicity, cancer	CTUh	4.00E-06	6.31E-09	3.38E-09	0.00E+00	9.69E-09	0.00E+00	8.02E-06	0.00E+00	5.54E-05	0.00E+00	6.98E-09	0.00E+00	2.15E-09	4.62E-09	2.15E-10	0.00E+00
Human tox. non-cancer	CTUh	1.06E-05	1.22E-08	1.54E-09	0.00E+00	1.38E-07	0.00E+00	2.13E-05	0.00E+00	4.92E-05	0.00E+00	4.05E-08	0.00E+00	3.85E-09	2.92E-08	7.38E-09	0.00E+00
SQP[6]	-	9.36E+02	1.87E+01	8.33E-01	0.00E+00	8.18E+00	0.00E+00	1.91E+03	0.00E+00	1.18E+04	0.00E+00	1.63E+01	0.00E+00	3.66E+00	1.21E+01	4.89E-01	0.00E+00

Table 19: Use of natural resources, waste, and output flows for 1 ton of chilling capacity of AquaEdge® 19DV (R-1233zd(E)) (Mfg: US)

USE OF NATURAL RESOURCES

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Renew. PER as energy[7)]	MJ	3.09E+02	2.44E-01	-5.75E-01	0.00E+00	1.70E+00	0.00E+00	6.17E+02	0.00E+00	1.35E+03	0.00E+00	1.14E+00	0.00E+00	7.87E-02	1.06E+00	2.02E-03	0.00E+00
Renew. PER as material	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total use of renew. PER	MJ	3.09E+02	2.44E-01	-5.75E-01	0.00E+00	1.70E+00	0.00E+00	6.17E+02	0.00E+00	1.35E+03	0.00E+00	1.14E+00	0.00E+00	7.87E-02	1.06E+00	2.02E-03	0.00E+00
Non-re. PER as energy	MJ	1.91E+03	1.86E+01	9.02E+00	0.00E+00	3.54E+01	0.00E+00	3.87E+03	0.00E+00	5.94E+05	0.00E+00	2.79E+00	0.00E+00	5.92E+00	-3.30E+00	1.66E-01	0.00E+00
Non-re. PER as material	MJ	2.16E+00	0.00E+00	-2.15E+00	0.00E+00	0.00E+00	0.00E+00	2.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total use of non-re. PER	MJ	1.91E+03	1.86E+01	6.88E+00	0.00E+00	3.54E+01	0.00E+00	3.87E+03	0.00E+00	5.94E+05	0.00E+00	2.79E+00	0.00E+00	5.92E+00	-3.30E+00	1.66E-01	0.00E+00
Secondary materials	kg	1.34E+01	7.89E-03	4.68E-03	0.00E+00	1.13E-02	0.00E+00	2.68E+01	0.00E+00	7.41E+01	0.00E+00	1.04E-02	0.00E+00	2.69E-03	7.69E-03	5.38E-05	0.00E+00
Renew. secondary fuels	MJ	7.35E-02	1.00E-04	1.32E-05	0.00E+00	1.54E-04	0.00E+00	1.47E-01	0.00E+00	1.24E-01	0.00E+00	3.73E-04	0.00E+00	3.38E-05	3.38E-04	1.08E-06	0.00E+00
Non-ren. secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of net fresh water	m^3	1.43E+00	2.74E-03	7.38E-04	0.00E+00	3.33E-02	0.00E+00	2.87E+00	0.00E+00	8.11E+01	0.00E+00	4.28E-03	0.00E+00	8.00E-04	3.32E-03	1.52E-04	0.00E+00

END OF LIFE – WASTE

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Hazardous waste	kg	9.52E+01	3.15E-02	1.26E-02	0.00E+00	1.46E-01	0.00E+00	1.91E+02	0.00E+00	4.08E+02	0.00E+00	1.39E+00	0.00E+00	1.04E-02	9.05E-01	4.72E-01	0.00E+00
Non-hazardous waste	kg	6.57E+02	5.84E-01	1.76E-01	0.00E+00	3.62E+00	0.00E+00	1.31E+03	0.00E+00	4.46E+03	0.00E+00	1.88E+00	0.00E+00	1.96E-01	1.61E+00	6.76E-02	0.00E+00
Radioactive waste	kg	2.72E-03	4.00E-06	1.25E-06	0.00E+00	1.54E-05	0.00E+00	5.46E-03	0.00E+00	3.52E-02	0.00E+00	8.92E-06	0.00E+00	1.20E-06	7.69E-06	3.23E-08	0.00E+00

END OF LIFE – OUTPUT FLOWS

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for recycling	kg	0.00E+00	0.00E+00	4.05E-02	0.00E+00	0.00E+00	0.00E+00	8.09E-02	0.00E+00	0.00E+00	0.00E+00	2.14E+01	0.00E+00	0.00E+00	2.14E+01	0.00E+00	0.00E+00
Materials for energy rec	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Exported energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 20: Results 1 ton of chilling capacity of AquaEdge® 19DV (R-1233zd(E)) (Mfg: US), CML

Environmental impacts – EN 15804+A1, CML / ISO 21930

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Global Warming Pot.	kg CO_2e	1.66E+02	1.23E+00	8.42E-01	1.38E+00	3.39E+00	0.00E+00	3.36E+02	0.00E+00	3.57E+04	0.00E+00	2.40E+00	0.00E+00	4.18E-01	1.88E+00	9.90E-02	0.00E+00
Ozone depletion Pot.	kg CFC-$_{11}$e	3.23E-05	1.54E-08	1.02E-08	0.00E+00	4.62E-05	0.00E+00	6.47E-05	0.00E+00	2.77E-04	0.00E+00	1.26E-08	0.00E+00	4.92E-09	7.54E-09	1.54E-10	0.00E+00
Acidification	kg SO_2e	1.11E+00	2.51E-03	5.34E-03	0.00E+00	3.75E-02	0.00E+00	2.24E+00	0.00E+00	1.68E+01	0.00E+00	5.79E-03	0.00E+00	7.85E-04	4.97E-03	3.85E-05	0.00E+00
Eutrophication	kg PO_4^3e	1.92E-01	6.00E-04	1.25E-03	0.00E+00	2.29E-03	0.00E+00	3.88E-01	0.00E+00	5.76E+00	0.00E+00	9.08E-04	0.00E+00	1.85E-04	7.08E-04	1.52E-05	0.00E+00
POCP ("smog")	kg C_2H_4e	6.58E-02	2.31E-04	4.00E-04	0.00E+00	1.77E-03	0.00E+00	1.33E-01	0.00E+00	3.02E+00	0.00E+00	3.71E-04	0.00E+00	7.54E-05	2.92E-04	3.38E-06	0.00E+00
ADP-elements	kg Sbe	9.32E-03	3.54E-06	3.23E-07	0.00E+00	1.28E-04	0.00E+00	1.87E-02	0.00E+00	1.18E-02	0.00E+00	3.37E-05	0.00E+00	1.37E-06	3.23E-05	1.45E-08	0.00E+00
ADP-fossil	MJ	1.97E+03	1.86E+01	1.10E+01	0.00E+00	4.03E+01	0.00E+00	4.00E+03	0.00E+00	5.94E+05	0.00E+00	1.39E+01	0.00E+00	5.92E+00	7.82E+00	1.66E-01	0.00E+00

Table 21: Results 1 ton of chilling capacity of AquaEdge® 19DV (R-1233zd(E)) (Mfg: US), TRACI 2.1

Environmental impacts – TRACI 2.1. / ISO 21930

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Global Warming Pot.	kg CO_2e	1.64E+02	1.22E+00	8.35E-01	1.38E+00	3.39E+00	0.00E+00	3.32E+02	0.00E+00	3.53E+04	0.00E+00	2.49E+00	0.00E+00	4.15E-01	1.98E+00	9.89E-02	0.00E+00
Ozone Depletion	kg CFC-$_{11}$e	3.23E-05	2.15E-08	1.35E-08	0.00E+00	4.62E-05	0.00E+00	6.47E-05	0.00E+00	3.69E-04	0.00E+00	1.60E-08	0.00E+00	6.62E-09	9.23E-09	2.00E-10	0.00E+00
Acidification	kg SO_2e	1.08E+00	2.72E-03	7.03E-03	0.00E+00	3.56E-02	0.00E+00	2.18E+00	0.00E+00	2.06E+01	0.00E+00	6.11E-03	0.00E+00	8.46E-04	5.22E-03	4.62E-05	0.00E+00
Eutrophication	kg Ne	1.39E-01	3.38E-04	4.77E-04	0.00E+00	1.20E-03	0.00E+00	2.81E-01	0.00E+00	2.64E+00	0.00E+00	5.76E-04	0.00E+00	1.08E-04	4.62E-04	6.62E-06	0.00E+00
POCP ("smog")	kg O_3e	1.06E+01	5.82E-02	2.32E-01	0.00E+00	3.47E-01	0.00E+00	2.17E+01	0.00E+00	7.56E+02	0.00E+00	1.04E-01	0.00E+00	1.68E-02	8.62E-02	1.29E-03	0.00E+00
ADP-fossil	MJ	1.91E+03	1.86E+01	9.02E+00	0.00E+00	3.54E+01	0.00E+00	3.87E+03	0.00E+00	5.94E+05	0.00E+00	2.79E+00	0.00E+00	5.92E+00	-3.30E+00	1.66E-01	0.00E+00

1. GWP = Global Warming Potential.
2. EP = Eutrophication potential. Required characterization method and data are in kg P-eq. Multiply by 3.07 to get PO4e.
3. POCP = Photochemical ozone formation.
4. ADP = Abiotic depletion potential.
5. EN 15804+A2 disclaimer for Abiotic depletion, Water use, and optional indicators except Particulate matter, Ionizing radiation, and human health. The results of these environmental impact indicators shall be used with care as the uncertainties on these results are high or as there is limited experience with the indicator.
6. EN 15804+A2 disclaimer for Ionizing radiation, and human health. This impact category deals mainly with the eventual impact of low dose ionizing radiation on human health of the nuclear fuel cycle. It does not consider effects due to possible nuclear accidents, occupational exposure nor due to radioactive waste disposal in underground facilities. Potential ionizing radiation from the soil, from radon and from some construction materials is also not measured by this indicator.
7. SQP = Land use related impacts/soil quality.
8. PER = Primary energy resources.

9. Biog. C in product = Biogenic carbon content in product.

Table 22: Results 1 ton of chilling capacity of AquaEdge® 19DV (R-1233zd(E)) (Mfg: US), Additional

Additional Impact categories ISO 21930

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
RW-high level	kg	8.26E-04	1.18E-06	3.57E-07	0.00E+00	5.28E-06	0.00E+00	1.66E-03	0.00E+00	1.03E-02	0.00E+00	2.74E-06	0.00E+00	3.58E-07	2.37E-06	9.40E-09	0.00E+00
RW-int. and low	kg	1.91E-03	2.83E-06	8.92E-07	0.00E+00	1.03E-05	0.00E+00	3.82E-03	0.00E+00	2.48E-02	0.00E+00	6.13E-06	0.00E+00	8.48E-07	5.26E-06	2.34E-08	0.00E+00
Recovered energy	MJ	3.11E+00	3.38E-03	7.78E-04	0.00E+00	1.83E-02	0.00E+00	6.22E+00	0.00E+00	1.72E+01	0.00E+00	1.39E-02	0.00E+00	1.31E-03	1.25E-02	5.12E-05	0.00E+00

RW= Radioactive Waste

AquaEdge® 19DV Water-cooled chiller (China)

The LCIA results presented below are for 1 ton of chilling capacity of AquaEdge® 19DV (R-1233zd(E)).

Table 23: LCIA results for AquaEdge® 19DV (R-1233zd(E)), per 1 ton of chilling capacity (Mfg: China), PEF

CORE ENVIRONMENTAL IMPACT INDICATORS – EN 15804+A2, PEF

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
GWP – total [1]	kg CO_2e	1.65E+02	4.57E+00	8.41E-01	1.38E+00	3.52E+00	0.00E+00	3.41E+02	0.00E+00	3.59E+04	0.00E+00	2.59E+00	0.00E+00	4.21E-01	2.07E+00	9.90E-02	0.00E+00
GWP – fossil	kg CO_2e	1.65E+02	4.57E+00	8.43E-01	1.38E+00	3.52E+00	0.00E+00	3.41E+02	0.00E+00	3.59E+04	0.00E+00	2.59E+00	0.00E+00	4.21E-01	2.07E+00	9.90E-02	0.00E+00
GWP – biogenic	kg CO_2e	1.52E-03	-8.62E-20	-1.52E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-1.69E-16	0.00E+00	-1.69E-22	0.00E+00	-1.69E-22	0.00E+00	0.00E+00	0.00E+00
GWP – LULUC	kg CO_2e	1.26E-01	2.26E-03	7.69E-05	0.00E+00	1.11E-03	0.00E+00	2.57E-01	0.00E+00	1.75E+00	0.00E+00	7.74E-04	0.00E+00	1.69E-04	6.00E-04	4.31E-06	0.00E+00
Ozone depletion pot.	kg CFC_{-11}e	2.46E-05	6.77E-08	1.29E-08	0.00E+00	3.38E-05	0.00E+00	4.94E-05	0.00E+00	3.54E-04	0.00E+00	1.51E-08	0.00E+00	6.15E-09	8.77E-09	2.00E-10	0.00E+00
Acidification potential	mol H^+e	1.30E+00	1.01E-01	7.60E-03	0.00E+00	4.37E-02	0.00E+00	2.82E+00	0.00E+00	2.29E+01	0.00E+00	7.20E-03	0.00E+00	9.85E-04	6.17E-03	5.08E-05	0.00E+00
EP-freshwater	kg Pe	8.22E-03	2.46E-05	3.08E-06	0.00E+00	5.85E-05	0.00E+00	1.65E-02	0.00E+00	6.59E-02	0.00E+00	3.32E-05	0.00E+00	3.85E-06	2.92E-05	8.00E-08	0.00E+00
EP-marine	kg Ne	1.66E-01	2.51E-02	3.52E-03	0.00E+00	5.37E-03	0.00E+00	3.90E-01	0.00E+00	8.96E+00	0.00E+00	1.57E-03	0.00E+00	2.31E-04	1.32E-03	2.00E-05	0.00E+00
EP-terrestrial	mol Ne	1.92E+00	2.79E-01	3.85E-02	0.00E+00	6.01E-02	0.00E+00	4.47E+00	0.00E+00	9.81E+01	0.00E+00	1.79E-02	0.00E+00	2.51E-03	1.52E-02	2.15E-04	0.00E+00
POCP ("smog") [2]	kg NMVOCe	6.29E-01	7.81E-02	1.15E-02	0.00E+00	1.80E-02	0.00E+00	1.44E+00	0.00E+00	7.83E+01	0.00E+00	5.98E-03	0.00E+00	1.37E-03	4.54E-03	7.38E-05	0.00E+00
ADP-minerals & metals [3]	kg Sbe	9.35E-03	6.77E-06	3.23E-07	0.00E+00	1.42E-04	0.00E+00	1.87E-02	0.00E+00	1.23E-02	0.00E+00	3.37E-05	0.00E+00	1.40E-06	3.23E-05	1.48E-08	0.00E+00
ADP-fossil resources	MJ	1.97E+03	5.94E+01	1.10E+01	0.00E+00	4.03E+01	0.00E+00	4.07E+03	0.00E+00	5.94E+05	0.00E+00	1.39E+01	0.00E+00	5.92E+00	7.82E+00	1.66E-01	0.00E+00
Water use [4]	m^3e depr.	5.09E+01	2.00E-01	2.75E-02	0.00E+00	1.38E+00	0.00E+00	1.02E+02	0.00E+00	3.31E+03	0.00E+00	1.48E-01	0.00E+00	2.70E-02	1.20E-01	6.77E-04	0.00E+00

ADDITIONAL (OPTIONAL) ENVIRONMENTAL IMPACT INDICATORS – EN 15804+A2, PEF

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Particulate matter	Incidence	1.34E-05	2.15E-07	2.15E-07	0.00E+00	5.38E-07	0.00E+00	2.76E-05	0.00E+00	1.15E-04	0.00E+00	1.17E-07	0.00E+00	3.23E-08	8.31E-08	1.14E-09	0.00E+00
Ionizing radiation [5]	kBq U235e	3.99E+00	1.36E-02	1.98E-03	0.00E+00	2.44E-02	0.00E+00	8.00E+00	0.00E+00	6.19E+01	0.00E+00	1.41E-02	0.00E+00	1.94E-03	1.21E-02	5.08E-05	0.00E+00
Ecotoxicity (freshwater)	CTUe	2.24E+03	1.14E+01	1.64E+00	0.00E+00	5.81E+01	0.00E+00	4.50E+03	0.00E+00	3.65E+04	0.00E+00	1.17E+01	0.00E+00	1.58E+00	7.95E+00	2.13E+00	0.00E+00
Human toxicity, cancer	CTUh	4.00E-06	2.00E-08	3.38E-09	0.00E+00	9.69E-09	0.00E+00	8.05E-06	0.00E+00	5.54E-05	0.00E+00	6.98E-09	0.00E+00	2.15E-09	4.62E-09	2.15E-10	0.00E+00
Human tox. non-cancer	CTUh	1.06E-05	2.31E-08	1.54E-09	0.00E+00	1.38E-07	0.00E+00	2.13E-05	0.00E+00	4.92E-05	0.00E+00	4.05E-08	0.00E+00	3.85E-09	2.92E-08	7.38E-09	0.00E+00
SQP [6]	-	9.39E+02	2.18E+01	8.33E-01	0.00E+00	8.18E+00	0.00E+00	1.92E+03	0.00E+00	1.18E+04	0.00E+00	1.63E+01	0.00E+00	3.66E+00	1.21E+01	4.89E-01	0.00E+00

Table 24: Use of natural resources, waste, and output flows for 1 ton of chilling capacity of AquaEdge® 19DV (R-1233zd(E)) (Mfg: China)

USE OF NATURAL RESOURCES

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Renew. PER as energy[7]	MJ	3.10E+02	5.45E-01	-5.75E-01	0.00E+00	1.70E+00	0.00E+00	6.20E+02	0.00E+00	1.35E+03	0.00E+00	1.14E+00	0.00E+00	7.87E-02	1.06E+00	2.02E-03	0.00E+00
Renew. PER as material	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total use of renew. PER	MJ	3.10E+02	5.45E-01	-5.75E-01	0.00E+00	1.70E+00	0.00E+00	6.20E+02	0.00E+00	1.35E+03	0.00E+00	1.14E+00	0.00E+00	7.87E-02	1.06E+00	2.02E-03	0.00E+00
Non-re. PER as energy	MJ	1.90E+03	5.94E+01	9.02E+00	0.00E+00	3.54E+01	0.00E+00	3.95E+03	0.00E+00	5.94E+05	0.00E+00	2.79E+00	0.00E+00	5.92E+00	-3.30E+00	1.66E-01	0.00E+00
Non-re. PER as material	MJ	2.16E+00	0.00E+00	-2.15E+00	0.00E+00	0.00E+00	0.00E+00	2.19E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total use of non-re. PER	MJ	1.91E+03	5.94E+01	6.88E+00	0.00E+00	3.54E+01	0.00E+00	3.95E+03	0.00E+00	5.94E+05	0.00E+00	2.79E+00	0.00E+00	5.92E+00	-3.30E+00	1.66E-01	0.00E+00
Secondary materials	kg	1.34E+01	2.73E-02	4.68E-03	0.00E+00	1.13E-02	0.00E+00	2.69E+01	0.00E+00	7.41E+01	0.00E+00	1.04E-02	0.00E+00	2.69E-03	7.69E-03	5.38E-05	0.00E+00
Renew. secondary fuels	MJ	7.35E-02	1.43E-04	1.32E-05	0.00E+00	1.54E-04	0.00E+00	1.47E-01	0.00E+00	1.24E-01	0.00E+00	3.73E-04	0.00E+00	3.38E-05	3.38E-04	1.08E-06	0.00E+00
Non-ren. secondary fuels	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Use of net fresh water	m^3	1.43E+00	5.45E-03	7.38E-04	0.00E+00	3.33E-02	0.00E+00	2.88E+00	0.00E+00	8.11E+01	0.00E+00	4.28E-03	0.00E+00	8.00E-04	3.32E-03	1.52E-04	0.00E+00

END OF LIFE – WASTE

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Hazardous waste	kg	9.53E+01	8.56E-02	1.26E-02	0.00E+00	1.46E-01	0.00E+00	1.91E+02	0.00E+00	4.08E+02	0.00E+00	1.39E+00	0.00E+00	1.04E-02	9.05E-01	4.72E-01	0.00E+00
Non-hazardous waste	kg	6.50E+02	1.32E+00	1.76E-01	0.00E+00	3.62E+00	0.00E+00	1.30E+03	0.00E+00	4.46E+03	0.00E+00	1.88E+00	0.00E+00	1.96E-01	1.61E+00	6.76E-02	0.00E+00
Radioactive waste	kg	2.62E-03	8.46E-06	1.25E-06	0.00E+00	1.54E-05	0.00E+00	5.25E-03	0.00E+00	3.52E-02	0.00E+00	8.92E-06	0.00E+00	1.20E-06	7.69E-06	3.23E-08	0.00E+00

END OF LIFE – OUTPUT FLOWS

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Components for re-use	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Materials for recycling	kg	0.00E+00	0.00E+00	4.05E-02	0.00E+00	0.00E+00	0.00E+00	8.09E-02	0.00E+00	0.00E+00	0.00E+00	2.14E+01	0.00E+00	0.00E+00	2.14E+01	0.00E+00	0.00E+00
Materials for energy rec	kg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Exported energy	MJ	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 25: Results 1 ton of chilling capacity of AquaEdge® 19DV (R-1233zd(E)) (Mfg: China), CML

Environmental impacts – EN 15804+A1, CML / ISO 21930

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Global Warming Pot.	kg CO_2e	1.66E+02	4.54E+00	8.42E-01	1.38E+00	3.39E+00	0.00E+00	3.44E+02	0.00E+00	3.57E+04	0.00E+00	2.40E+00	0.00E+00	4.18E-01	1.88E+00	9.90E-02	0.00E+00
Ozone depletion Pot.	kg CFC-$_{11}$e	3.23E-05	5.38E-08	1.02E-08	0.00E+00	4.62E-05	0.00E+00	6.47E-05	0.00E+00	2.77E-04	0.00E+00	1.26E-08	0.00E+00	4.92E-09	7.54E-09	1.54E-10	0.00E+00
Acidification	kg SO_2e	1.10E+00	8.07E-02	5.34E-03	0.00E+00	3.75E-02	0.00E+00	2.38E+00	0.00E+00	1.68E+01	0.00E+00	5.79E-03	0.00E+00	7.85E-04	4.97E-03	3.85E-05	0.00E+00
Eutrophication	kg PO_4^3e	1.92E-01	9.18E-03	1.25E-03	0.00E+00	2.29E-03	0.00E+00	4.05E-01	0.00E+00	5.76E+00	0.00E+00	9.08E-04	0.00E+00	1.85E-04	7.08E-04	1.52E-05	0.00E+00
POCP ("smog")	kg C_2H_4e	6.56E-02	4.11E-03	4.00E-04	0.00E+00	1.77E-03	0.00E+00	1.40E-01	0.00E+00	3.02E+00	0.00E+00	3.71E-04	0.00E+00	7.54E-05	2.92E-04	3.38E-06	0.00E+00
ADP-elements	kg Sbe	9.32E-03	6.62E-06	3.23E-07	0.00E+00	1.28E-04	0.00E+00	1.87E-02	0.00E+00	1.18E-02	0.00E+00	3.37E-05	0.00E+00	1.37E-06	3.23E-05	1.45E-08	0.00E+00
ADP-fossil	MJ	1.97E+03	5.94E+01	1.10E+01	0.00E+00	4.03E+01	0.00E+00	4.07E+03	0.00E+00	5.94E+05	0.00E+00	1.39E+01	0.00E+00	5.92E+00	7.82E+00	1.66E-01	0.00E+00

Table 26: Results 1 ton of chilling capacity of AquaEdge® 19DV (R-1233zd(E)) (Mfg: China), TRACI 2.1

Environmental impacts – TRACI 2.1. / ISO 21930

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
Global Warming Pot.	kg CO_2e	1.65E+02	4.51E+00	8.35E-01	1.38E+00	3.39E+00	0.00E+00	3.40E+02	0.00E+00	3.53E+04	0.00E+00	2.49E+00	0.00E+00	4.15E-01	1.98E+00	9.89E-02	0.00E+00
Ozone Depletion	kg CFC-$_{11}$e	3.23E-05	7.08E-08	1.35E-08	0.00E+00	4.62E-05	0.00E+00	6.48E-05	0.00E+00	3.69E-04	0.00E+00	1.60E-08	0.00E+00	6.62E-09	9.23E-09	2.00E-10	0.00E+00
Acidification	kg SO_2e	1.07E+00	8.59E-02	7.03E-03	0.00E+00	3.56E-02	0.00E+00	2.33E+00	0.00E+00	2.06E+01	0.00E+00	6.11E-03	0.00E+00	8.46E-04	5.22E-03	4.62E-05	0.00E+00
Eutrophication	kg Ne	1.38E-01	3.48E-03	4.77E-04	0.00E+00	1.20E-03	0.00E+00	2.85E-01	0.00E+00	2.64E+00	0.00E+00	5.76E-04	0.00E+00	1.08E-04	4.62E-04	6.62E-06	0.00E+00
POCP ("smog")	kg O_3e	1.06E+01	1.63E+00	2.32E-01	0.00E+00	3.47E-01	0.00E+00	2.49E+01	0.00E+00	7.56E+02	0.00E+00	1.04E-01	0.00E+00	1.68E-02	8.62E-02	1.29E-03	0.00E+00
ADP-fossil	MJ	1.90E+03	5.94E+01	9.02E+00	0.00E+00	3.54E+01	0.00E+00	3.95E+03	0.00E+00	5.94E+05	0.00E+00	2.79E+00	0.00E+00	5.92E+00	-3.30E+00	1.66E-01	0.00E+00

1. GWP = Global Warming Potential.
2. EP = Eutrophication potential. Required characterization method and data are in kg P-eq. Multiply by 3.07 to get PO4e.
3. POCP = Photochemical ozone formation.
4. ADP = Abiotic depletion potential.
5. EN 15804+A2 disclaimer for Abiotic depletion, Water use, and optional indicators except Particulate matter, Ionizing radiation, and human health. The results of these environmental impact indicators shall be used with care as the uncertainties on these results are high or as there is limited experience with the indicator.

6. EN 15804+A2 disclaimer for Ionizing radiation, and human health. This impact category deals mainly with the eventual impact of low dose ionizing radiation on human health of the nuclear fuel cycle. It does not consider effects due to possible nuclear accidents, occupational exposure nor due to radioactive waste disposal in underground facilities. Potential ionizing radiation from the soil, from radon and from some construction materials is also not measured by this indicator.
7. SQP = Land use related impacts/soil quality.
8. PER = Primary energy resources.
9. Biog. C in product = Biogenic carbon content in product.

Table 27: Results 1 ton of chilling capacity of AquaEdge® 19DV (R-1233zd(E)) (Mfg: China), Additional

Additional Impact categories ISO 21930

Impact category	Unit	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1-C4	C1	C2	C3	C4	D
RW-high level	kg	8.03E-04	2.51E-06	3.57E-07	0.00E+00	5.28E-06	0.00E+00	1.61E-03	0.00E+00	1.03E-02	0.00E+00	2.74E-06	0.00E+00	3.58E-07	2.37E-06	9.40E-09	0.00E+00
RW-int. and low	kg	1.82E-03	6.02E-06	8.92E-07	0.00E+00	1.03E-05	0.00E+00	3.64E-03	0.00E+00	2.48E-02	0.00E+00	6.13E-06	0.00E+00	8.48E-07	5.26E-06	2.34E-08	0.00E+00
Recovered energy	MJ	3.11E+00	6.55E-03	7.78E-04	0.00E+00	1.83E-02	0.00E+00	6.23E+00	0.00E+00	1.72E+01	0.00E+00	1.39E-02	0.00E+00	1.31E-03	1.25E-02	5.12E-05	0.00E+00

RW= Radioactive Waste.

4 – LIFE CYCLE ASSESSMENT INTERPRETATION

In this section, the results of the life cycle assessment are interpreted according to the goal and scope of the study. This interpretation includes analysis of Impact indicators conclusions based on the LCA. An Impact Analysis carried out on the AquaEdge® 19DV LCA using the refrigerant R-1233zd(E) to show which of the life cycle modules contributes to most of the impacts.

Global Warming Potential (GWP)

Global warming potential (GWP) is a measure of how much heat a greenhouse gas traps in the atmosphere up to a specified time horizon and measured relative to carbon dioxide. Figure 3 presents GWP per ton of chilling capacity for 650 ton configuration using R-1233zd(E) refrigerant for TRACI.

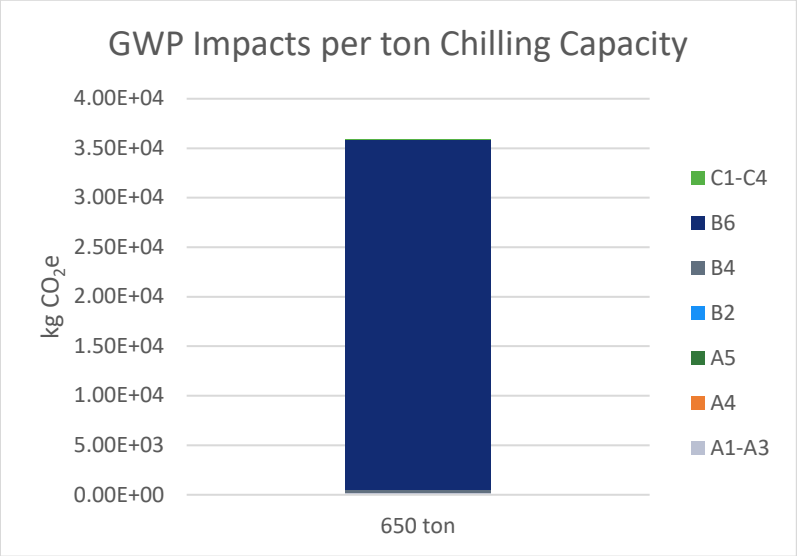

Figure 3: GWP impacts per ton Chilling Capacity, TRACI

Acidification Potential (AP)

Acidification Potential (AP) refers to the acidification of soils and water due to the release of gasses such as nitrogen oxides and sulfur oxides which increase the concentration of hydrogen ions (H+) within the local environment. Figure 4 presents AP per ton of chilling capacity for 650 ton configuration using R-1233zd(E) refrigerant for TRACI.

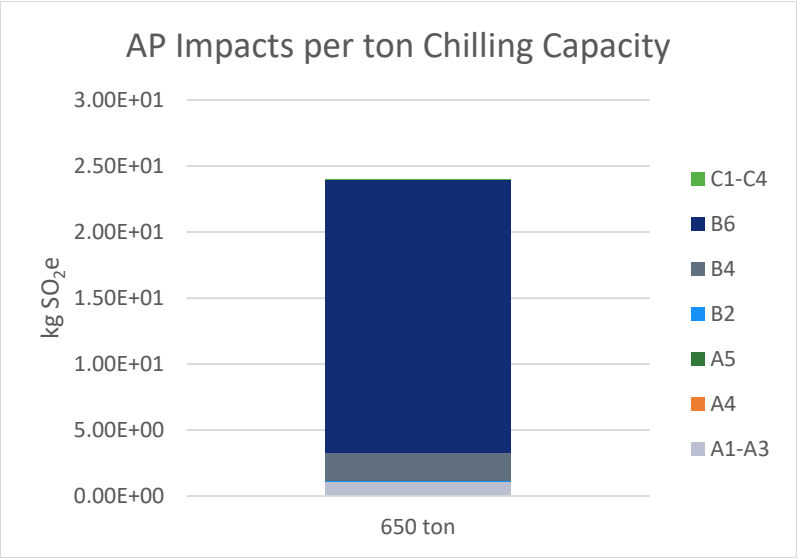

Figure 4: AP Impacts per Ton Chilling Capacity, TRACI

The release of refrigerants into the atmosphere do not meaningfully contribute to AP. The burning of coal or other fossil-based sources of energy for the generation of power contributes to AP. The energy associated with the operational energy use of the product contributes most of the emissions in the product, along with replacement of chiller, installation energy and raw material procurement and processing accounts to smaller proportions. As a result, the only module which is visible in the figure is the use phase.

This is the case for all other impact categories considered including EP, ODP, POCP, and resources.

Further Analysis

Impacts from operational energy use were removed from the life cycle impacts to determine the driving impacts across all other modules. Impacts presented in Figure 5 reflects 650 ton configuration of the AquaEdge® 19DV Chiller when charged using R-1233zd(E) refrigerant for TRACI.

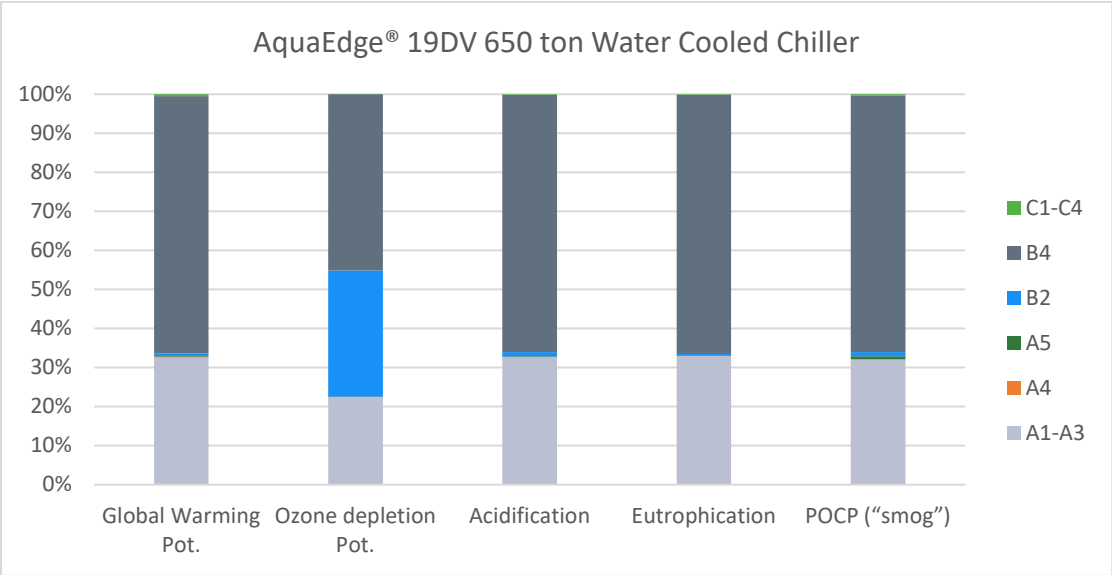

Figure 5: Contribution of modules excluding B6 to overall impacts, TRACI

Two replacements are required for the chiller to satisfy the ESL of the building. The impacts associated with these replacements dominate the categories of AP, EP, ODP, and POCP. The emissions associated with raw material during the maintenance phase (A1-A3) dominate the GWP impacts.

Impacts associated with each material for one 650 ton chiller are presented in secondary data set in Figure *6*.

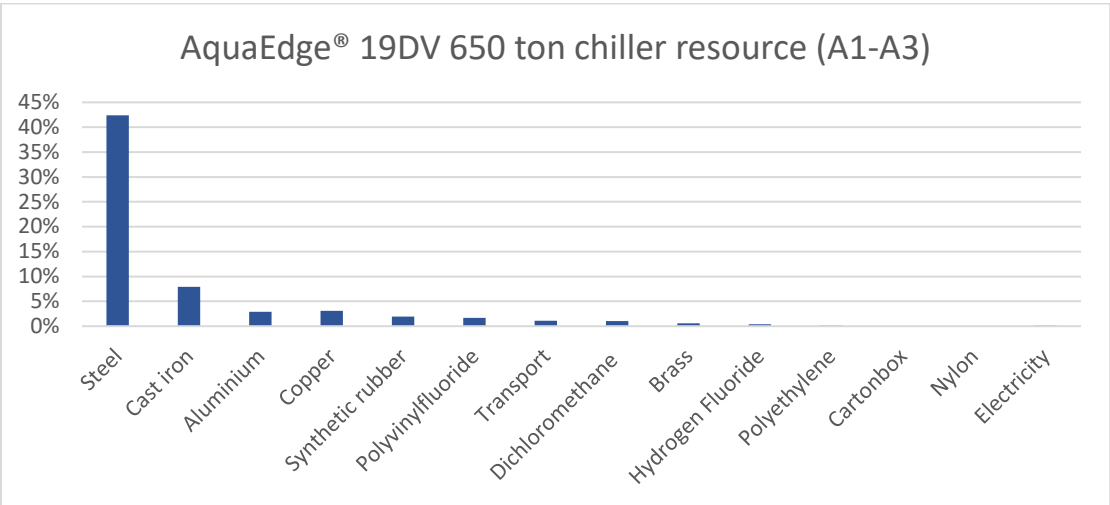

Figure 6: Material impact contribution of AquaEdge® 19DV 650 ton chiller for (A1-A3)

Steel and iron make up most of the impacts of the chiller of the primary materials used in the chiller. Aluminum has the lowest impacts.

The Figure 7 shows the impacts for A1-A5 stages due to multiple manufacturing facilities, in US and China for AquaEdge® 19DV 650 ton chiller catering customers in US.

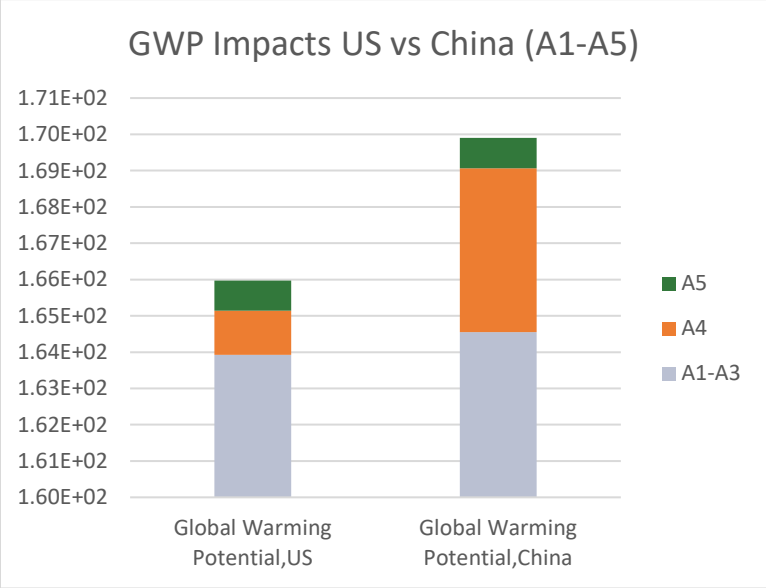

Figure 7: GWP Impacts: US vs China (A1-A5)

Supplemental B6 results:

The results provided in the section above are representative of the North America scope of the EPD. However, since the B6 module has a large impact on the total results, some extra results are provided for this module for all mandatory environmental impact categories in the table below. The extra results represent switching the electricity used in module B6 to Global, Europe & China. The rest of the modules have identical results and are excluded from the Table 26.

Table 28 Results Switching Electricity in B6 using TRACI 2.1 for AquaEdge® 19DV 650 ton chiller per Functional Unit

Impact category	Unit	B6- 650 ton		
		Global	Europe	China
Global Warming Pot.	kg CO_2e	5.67E+04	2.56E+04	7.37E+04
Ozone depletion Pot.	kg CFC_{-11}e	3.89E-04	4.66E-04	1.82E-04
Acidification	kg SO_2e	2.40E+02	1.07E+02	3.52E+02
Eutrophication	kg Ne	2.75E+01	2.09E+01	2.26E+01
POCP ("smog")	kg O_3e	3.29E+03	1.13E+03	5.25E+03
ADP-fossil	MJ	7.42E+05	6.08E+05	7.32E+05

Assumptions and Limitations

The use and selection of secondary datasets from Eco-Invent database. The selection of which generic dataset to use to represent an aspect of a supply chain is a significant value choice. However, no generic data can be a perfect fit. Improved supply chain specific data would improve the accuracy of results.

Use phase calculations are based on default scenarios provided by an excel calculator sheet as described by the PCR and do not reflect actual consumption in a specific location.

Availability of geographically more accurate datasets would have improved the accuracy of the study.

REFERENCES

AHRI. (2023). Retrieved from https://www.ahrinet.org/standards

ASHRAE. (2023). Retrieved from https://www.ashrae.org/technical-resources/standards-and-guidelines

ASME. (2023). Retrieved from https://www.asme.org/codes-standards/find-codes-standards

CEN. (2013). *EN 15804+A1: Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.* European Committee for Standardization.

CEN. (2019). *EN 15804+A2: Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products.* European Committee for Standardization.

CML.(2016) Department of Industrial Ecology. (2016, September 05). *CML-IA Characterisation Factors*. Retrieved from https://www.universiteitleiden.nl/en/research/research-output/science/cml-ia-characterisation-factors

ISO. (2006). *ISO 14025: Environmental labels and declarations - Type III environmental declarations - Principles and procedures.* Geneva: International Organization for Standardization.

ISO. (2006). *ISO 14040/Amd 1:2020: Environmental management - Life cycle assessment - Principles and framework.* Geneva: International Organization for Standardization.

ISO. (2006). *ISO 14044/Amd 1:2017/Amd 2:2020: Environmental Management - Life cycle assessment - Requirements and Guidelines.* Geneva: International Organization for Standardization.

ISO. (2017). *ISO 21930: Sustainability in buildings and civil engineering works - Core rules for environmental product declarations of construction products and services.* Geneva: International Organization for Standardization.

UL Environment. (2022). *Part A: Life Cycle Assessment Calculation Rules and Report Requirements, UL 10010, V4.0.*

UL Environment Part B. (2018). *Product Category Rule (PCR) Guidance for Building-Related Products and Services; Part B: Water Cooled Chiller EPD Requirements.*

US EPA. (2012). *TRACI: The Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts. Version 2.1 - User Guide*. Retrieved from https://nepis.epa.gov/Adobe/PDF/P100HN53.pdf