**Life Cycle Assessment (LCA) Impact Categories and Characterization Factors**

**1. Global Warming Potential (GWP)**

**Impact:** GWP measures the contribution of various substances to global warming. It quantifies how much a substance contributes to the greenhouse effect compared to carbon dioxide (CO2).

**Characterization Factors:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Substance** | **CML (kg CO2 eq/kg)** | **TRACI (kg CO2 eq/kg)** | **ReCiPe (kg CO2 eq/kg)** |
| CO2 | 1 | 1 | 1 |
| CH4 | 25 | 25 | 28 |
| N2O | 298 | 298 | 265 |
| CFC-11 | 4,750 | 4,750 | 4,750 |
| CFC-12 | 10,900 | 10,900 | 10,900 |

### ****2. Acidification Potential (AP)****

### ****Impact:**** AP quantifies the potential of substances to cause acidification of soil and water bodies, leading to issues such as reduced soil fertility and damage to aquatic life.

**Characterization Factors:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Substance** | **CML (kg SO2 eq/kg)** | **TRACI (kg SO2 eq/kg)** | **ReCiPe (kg SO2 eq/kg)** |
| SO2 | 1 | 1 | 1 |
| NOx | 0.7 | 0.7 | 0.7 |
| NH3 | 1.88 | 1.88 | 1.88 |

### ****3. Eutrophication Potential (EP)****

### ****Impact:**** EP measures the potential for a substance to contribute to nutrient enrichment in water bodies, leading to excessive growth of algae and depletion of oxygen, which harms aquatic life.

**Characterization Factors:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Substance** | **CML (kg PO4^3- eq/kg)** | **TRACI (kg PO4^3- eq/kg)** | **ReCiPe (kg PO4^3- eq/kg)** |
| NO3- | 0.3 | 0.3 | 0.3 |
| PO4^3- | 1 | 1 | 1 |

### ****4. Photochemical Ozone Creation Potential (POCP)****

### ****Impact:**** POCP assesses the potential for substances to create ground-level ozone (smog) through photochemical reactions, which can cause respiratory problems and damage vegetation.

**Characterization Factors:**

|  |  |  |
| --- | --- | --- |
| **Substance** | **CML (kg C2H4 eq/kg)** | **TRACI (kg C2H4 eq/kg)** |
| VOC | 0.5 | 0.5 |
| NOx | 0.2 | 0.2 |

### ****5. Human Toxicity Potential (HTP)****

### ****Impact:**** HTP measures the potential for substances to cause harm to human health through toxicity. It is expressed in terms of 1,4-dichlorobenzene (1,4-DB) equivalents.

**Characterization Factors:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Substance** | **CML (kg 1,4-DB eq/kg)** | **TRACI (kg reference substance/kg)** | **ReCiPe (kg 1,4-DB eq/kg)** |
| Benzene | 0.01 | 0.01 | 0.01 |
| Lead | 0.02 | 0.02 | 0.02 |
| Mercury | 0.03 | 0.03 | 0.03 |

### ****6. Ozone Depletion Potential (ODP)****

### ****Impact:**** ODP measures the potential of substances to deplete the ozone layer, which protects Earth from harmful ultraviolet (UV) radiation.

**Characterization Factors:**

|  |  |  |
| --- | --- | --- |
| **Substance** | **CML (kg CFC-11 eq/kg)** | **ReCiPe (kg CO2 eq/kg)** |
| CFC-11 | 4,750 | 4,750 |
| CFC-12 | 10,900 | 10,900 |
| Halon-1301 | 3,200 | N/A |

### ****7. Resource Depletion****

### ****Impact:**** Resource Depletion assesses the impact of consuming non-renewable resources, including fossil fuels, metals, and minerals.

**Characterization Factors:**

|  |  |  |
| --- | --- | --- |
| **Resource Type** | **CML (kg Sb eq/kg)** | **ReCiPe (kg Antimony eq/kg)** |
| Fossil Fuels | 1 | 1 |
| Metals | 0.5 | 0.5 |
| Minerals | 0.3 | 0.3 |

### ****8. Land Use****

### ****Impact:**** Land Use assesses the impact of changing land use patterns, such as deforestation or agricultural expansion, which affects biodiversity and ecosystem services.

**Characterization Factors:**

|  |  |
| --- | --- |
| **Type** | **ReCiPe (m² year)** |
| Agricultural | 0.1 |
| Forest | 0.2 |

### ****9. Particulate Matter (PM)****

### ****Impact:**** PM measures the impact of particulate emissions on air quality and human health. Fine particulate matter (PM10) can cause respiratory problems and other health issues.

**Characterization Factors:**

|  |  |
| --- | --- |
| **Substance** | **ReCiPe (kg PM10 eq/kg)** |
| Particulate Matter | 1 |

### ****10. Ionizing Radiation****

### ****Impact:**** Ionizing Radiation measures the potential health impacts of exposure to radiation, which can cause cancer and genetic damage.

**Characterization Factors:**

|  |  |
| --- | --- |
| **Type** | **ReCiPe (kg U235 eq/kg)** |
| Ionizing Radiation | 1 |

### ****11. Ecotoxicity****

### ****Impact:**** Ecotoxicity evaluates the potential harmful effects of toxic substances on ecosystems and organisms.

**Characterization Factors:**

|  |  |  |
| --- | --- | --- |
| **Substance** | **CML (kg 1,4-DB eq/kg)** | **ReCiPe (kg 1,4-DB eq/kg)** |
| Specific Toxins | Varies | Varies |

**Orther information (other source):**

**CML**

**1. Global Warming Potential (GWP)**

**Functional Unit**: kg CO₂ equivalents (kg CO₂ eq)

|  |  |
| --- | --- |
| **Substance** | **GWP Factor** |
| CO₂ | 1 |
| CH₄ | 25 |
| N₂O | 298 |
| HFC-134a | 1,430 |
| SF₆ | 23,500 |
| CFC-11 | 4,750 |
| CFC-12 | 10,900 |
| HFC-23 | 14,800 |
| PFCs | varies, up to 12,200 |

**2. Acidification Potential (AP)**

**Functional Unit**: kg SO₂ equivalents (kg SO₂ eq)

|  |  |
| --- | --- |
| **Substance** | **AP Factor** |
| SO₂ | 1 |
| NOₓ | 0.7 |
| NH₃ | 1.88 |
| HCl | 0.88 |
| HF | 1.6 |

**3. Eutrophication Potential (EP)**

**Functional Unit**: kg PO₄³⁻ equivalents (kg PO₄³⁻ eq)

|  |  |
| --- | --- |
| **Substance** | **EP Factor** |
| NO₃⁻ | 0.42 |
| NH₄⁺ | 0.35 |
| PO₄³⁻ | 1 |
| NOₓ | 0.13 |
| COD | 0.022 |

**4. Ozone Depletion Potential (ODP)**

**Functional Unit**: kg CFC-11 equivalents (kg CFC-11 eq)

|  |  |
| --- | --- |
| **Substance** | **ODP Factor** |
| CFC-11 | 1 |
| CFC-12 | 1 |
| CFC-113 | 0.8 |
| Halon-1301 | 10 |
| Halon-1211 | 6 |
| HCFC-22 | 0.05 |
| HCFC-123 | 0.02 |

**5. Photochemical Ozone Creation Potential (POCP)**

**Functional Unit**: kg ethylene equivalents (kg C₂H₄ eq)

|  |  |
| --- | --- |
| **Substance** | **POCP Factor** |
| Ethylene | 1 |
| Propylene | 0.79 |
| Butane | 0.49 |
| Toluene | 0.39 |
| Xylene | 0.44 |
| NOₓ | 0.04 |
| CO | 0.04 |
| Methane | 0.007 |

**6. Human Toxicity Potential (HTP)**

**Functional Unit**: kg 1,4-dichlorobenzene equivalents (kg 1,4-DCB eq)

|  |  |
| --- | --- |
| **Substance** | **HTP Factor** |
| 1,4-Dichlorobenzene | 1 |
| Arsenic | 480 |
| Benzene | 2.7 |
| Cadmium | 230 |
| Chromium VI | 2.1 |
| Lead | 85 |
| Mercury | 1,600 |
| Nickel | 2.5 |
| Zinc | 0.22 |

**7. Freshwater Aquatic Ecotoxicity Potential (FAETP)**

**Functional Unit**: kg 1,4-dichlorobenzene equivalents (kg 1,4-DCB eq)

|  |  |
| --- | --- |
| **Substance** | **FAETP Factor** |
| 1,4-Dichlorobenzene | 1 |
| Cadmium | 2,700 |
| Chromium VI | 4.3 |
| Copper | 6.6 |
| Lead | 3.1 |
| Mercury | 2,000 |
| Nickel | 2.2 |
| Zinc | 0.47 |

**8. Marine Aquatic Ecotoxicity Potential (MAETP)**

**Functional Unit**: kg 1,4-dichlorobenzene equivalents (kg 1,4-DCB eq)

|  |  |
| --- | --- |
| **Substance** | **MAETP Factor** |
| 1,4-Dichlorobenzene | 1 |
| Cadmium | 2,700 |
| Chromium VI | 4.3 |
| Copper | 6.6 |
| Lead | 3.1 |
| Mercury | 2,000 |
| Nickel | 2.2 |
| Zinc | 0.47 |

**9. Terrestrial Ecotoxicity Potential (TETP)**

**Functional Unit**: kg 1,4-dichlorobenzene equivalents (kg 1,4-DCB eq)

|  |  |
| --- | --- |
| **Substance** | **TETP Factor** |
| 1,4-Dichlorobenzene | 1 |
| Cadmium | 230 |
| Chromium VI | 0.07 |
| Copper | 0.21 |
| Lead | 0.1 |
| Mercury | 80 |
| Nickel | 0.089 |
| Zinc | 0.022 |

### TRACI (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts)

**Version: TRACI 2.1 (2012)**

#### Impact Categories and Characterization Factors:

1. **Global Warming Potential (GWP)**
   * **Functional Unit**: kg CO₂ equivalents (kg CO₂ eq)
   * **Calculation**: Sum of the mass of each greenhouse gas multiplied by its GWP factor.

|  |  |
| --- | --- |
| **Substance** | **GWP Factor** |
| CO₂ | 1 |
| CH₄ | 25 |
| N₂O | 298 |

1. **Acidification Potential (AP)**
   * **Functional Unit**: kg SO₂ equivalents (kg SO₂ eq)
   * **Calculation**: Sum of the mass of acidifying substances multiplied by their AP factors.

|  |  |
| --- | --- |
| **Substance** | **AP Factor** |
| SO₂ | 1 |
| NOₓ | 0.7 |
| NH₃ | 1.88 |

1. **Eutrophication Potential (EP)**
   * **Functional Unit**: kg N equivalents (kg N eq)
   * **Calculation**: Sum of the mass of nutrients multiplied by their EP factors.

|  |  |
| --- | --- |
| **Substance** | **EP Factor** |
| NO₃⁻ | 0.42 |
| NH₄⁺ | 0.35 |
| PO₄³⁻ | 1 |

1. **Ozone Depletion Potential (ODP)**
   * **Functional Unit**: kg CFC-11 equivalents (kg CFC-11 eq)
   * **Calculation**: Sum of the mass of ozone-depleting substances multiplied by their ODP factors.

|  |  |
| --- | --- |
| **Substance** | **ODP Factor** |
| CFC-11 | 1 |
| CFC-12 | 1 |
| Halon-1301 | 10 |

1. **Photochemical Ozone Creation Potential (POCP)**
   * **Functional Unit**: kg O₃ equivalents (kg O₃ eq)
   * **Calculation**: Sum of the mass of substances contributing to photochemical ozone formation multiplied by their POCP factors.

|  |  |
| --- | --- |
| **Substance** | **POCP Factor** |
| Ethylene | 1 |
| Propylene | 0.79 |
| NOₓ | 0.04 |

1. **Human Health Particulate (HHP)**
   * **Functional Unit**: kg PM₂.₅ equivalents (kg PM₂.₅ eq)
   * **Calculation**: Sum of the mass of particulate matter and precursors multiplied by their HHP factors.

|  |  |
| --- | --- |
| **Substance** | **HHP Factor** |
| PM₂.₅ | 1 |
| NOₓ | 0.7 |
| SO₂ | 0.8 |

1. **Ecotoxicity**
   * **Functional Unit**: Comparative Toxic Units (CTUe)
   * **Calculation**: Sum of the mass of toxic substances multiplied by their ecotoxicity factors.

|  |  |
| --- | --- |
| **Substance** | **Ecotoxicity Factor** |
| 1,4-Dichlorobenzene | 1 |
| Arsenic | 480 |

### ReCiPe

**Versions: ReCiPe 2008, ReCiPe 2016**

#### Impact Categories and Characterization Factors:

1. **Global Warming Potential (GWP)**
   * **Functional Unit**: kg CO₂ equivalents (kg CO₂ eq)

|  |  |
| --- | --- |
| **Substance** | **GWP Factor** |
| CO₂ | 1 |
| CH₄ | 25 |
| N₂O | 298 |

1. **Acidification Potential (AP)**
   * **Functional Unit**: kg SO₂ equivalents (kg SO₂ eq)

|  |  |
| --- | --- |
| **Substance** | **AP Factor** |
| SO₂ | 1 |
| NOₓ | 0.7 |

1. **Eutrophication Potential (EP)**
   * **Functional Unit**: kg PO₄³⁻ equivalents (kg PO₄³⁻ eq)

|  |  |
| --- | --- |
| **Substance** | **EP Factor** |
| NO₃⁻ | 0.42 |
| NH₄⁺ | 0.35 |

1. **Ozone Depletion Potential (ODP)**
   * **Functional Unit**: kg CFC-11 equivalents (kg CFC-11 eq)

|  |  |
| --- | --- |
| **Substance** | **ODP Factor** |
| CFC-11 | 1 |
| Halon-1301 | 10 |

1. **Photochemical Ozone Creation Potential (POCP)**
   * **Functional Unit**: kg NMVOC equivalents (kg NMVOC eq)

|  |  |
| --- | --- |
| **Substance** | **POCP Factor** |
| Ethylene | 1 |
| Propylene | 0.79 |

1. **Human Toxicity Potential (HTP)**
   * **Functional Unit**: kg 1,4-dichlorobenzene equivalents (kg 1,4-DCB eq)

|  |  |
| --- | --- |
| **Substance** | **HTP Factor** |
| 1,4-Dichlorobenzene | 1 |
| Cadmium | 230 |

1. **Freshwater Aquatic Ecotoxicity Potential (FAETP)**
   * **Functional Unit**: kg 1,4-dichlorobenzene equivalents (kg 1,4-DCB eq)

|  |  |
| --- | --- |
| **Substance** | **FAETP Factor** |
| 1,4-Dichlorobenzene | 1 |
| Cadmium | 2,700 |

1. **Marine Aquatic Ecotoxicity Potential (MAETP)**
   * **Functional Unit**: kg 1,4-dichlorobenzene equivalents (kg 1,4-DCB eq)

|  |  |
| --- | --- |
| **Substance** | **MAETP Factor** |
| 1,4-Dichlorobenzene | 1 |
| Cadmium | 2,700 |

1. **Terrestrial Ecotoxicity Potential (TETP)**
   * **Functional Unit**: kg 1,4-dichlorobenzene equivalents (kg 1,4-DCB eq)

|  |  |
| --- | --- |
| **Substance** | **TETP Factor** |
| 1,4-Dichlorobenzene | 1 |
| Cadmium | 230 |