**Sustainability Assessment of Additive Manufacturing End-of-Life Material Management**

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**Data**

Figure 2. GREENSCOPE score indicator results for (a) efficiency, (b) environment, (c) energy, and (d) economic indicators. Calculated indicators with maximized radius value correspond to a 100% sustainability score (best) in their respective categories

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| --- | --- |
| 1. Efficiency Indicators
 | 1. Environmental Indicators
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| 1. Energy Indicators
 | 1. Economic Indicators
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| --- | --- | --- | --- | --- | --- | --- |
| **Indicators** | **Symbol** | **Value** | **Unit** | **Best Value** | **Worst Value** | **Score** |
|  | **Efficiency** |
| Total Material Consumption | mmat,tot | 3,984 | kg/hr | 344 | 13,760 | 72.9 |
| Mass Intensity | MI | 11.6 | kg input/kg product | 1 | 40 | 72.9 |
| Mass Productivity | MP | 0.086 | kg product/kg material input | 1 | 0 | 8.6 |
| Environmental Factor | *E* | 10.6 | kg waste/kg product | 0 | 39 | 72.9 |
| Mass Loss Index | MLI | 10.6 | kg unconverted/kg valuable products | 0 | 100 | 89.4 |
| Renewability-material index | RIM | 0.00053 | kg renewable/kg material input | 1 | 0 | 0.1 |
| Breeding-material factor | BFM | 1.00053 | kg input/kg nonrenewable material | 10 | 0 | 10.0 |
| Recycled material fraction | wrecycl,mat | 0.21 | kg recyclable material/kg material input | 1 | 0 | 21.3 |
| Mass fraction of products designed for recycling | wrecov,prod | 1 | kg recyclable material/kg product | 1 | 0 | 100.0 |
|  | **Environment** |
| Mass of hazardous materials input | mhaz,mat | 3,113 | kg/hr | 0 | 3,984 | 21.9 |
| Specific hazardous raw materials input | mhaz,mat,spec | 9.05 | kg hazardous material/kg product | 0 | 11.5 | 21.9 |
| Safety hazard, acute toxicity | SHacute tox | 592 | m3 polluted air/kg product | 0 | 10,000 | 94.1 |
| Environmental Quotient | EQ | 221 | m3/kg | 0 | 340 | 34.9 |
| Environmental hazard, air hazard | EHair | 417,890 | m3 polluted air/kg product | 0 | 10,000,000 | 95.8 |
| Environmental hazard, water hazard | EHwater | 12,163 | m3 polluted water/kg product | 0 | 100,000 | 87.8 |
| Environmental hazard, solid waste (inorganic pollutants) | EHsolid | 0.00030 | kg inorganic solid/kg product | 0 | 1 | 100.0 |
| Environmental hazard, bioaccumulation (in food chain/soil) | EHbioacc | 31 | kg/kg product | 0 | 100 | 68.8 |
| Total solid waste mass | ms,tot | 1,257 | kg solid waste/hr | 0 | 1,282 | 1.9 |
| Specific solid waste mass | ms,spec | 3.66 | kg solid waste/kg product | 0 | 3.7 | 1.9 |
| Solid waste mass for recovery | ms,recov | 347.5 | kg solid recoverable waste/hr | 1,257 | 0 | 27.6 |
| Solid waste mass for disposal | ms,disp | 910 | kg nonrecoverable solid/hr | 0 | 1,257 | 27.6 |
| Recycling mass fraction | ws,recycl | 0.28 | kg solid recovered/kg solid waste | 1 | 0 | 27.6 |
| Disposal mass fraction | ws,non-recycl | 0.72 | kg nonrecoverable solid/kg solid waste | 0 | 1 | 27.6 |
| Hazardous solid waste mass fraction | ws,haz | 0 | kg nonrecoverable hazardous solid/kg nonrecoverable solid waste | 0 | 1 | 100.0 |
| Total hazardous solid waste disposal | ms,haz | 0 | kg nonrecoverable hazardous waste/hr | 0 | 1,257 | 100.0 |
| Specific hazardous solid waste | ms,haz,spec | 0 | kg nonrecoverable hazardous waste/kg product | 0 | 1 | 100.0 |
| Total non-hazardous solid waste disposal | ms,n-haz | 913 | kg non-hazardous waste/hr | 910 | 0 | 100.0 |
| **Indicators** | **Symbol** | **Value** | **Unit** | **Best Value** | **Worst Value** | **Score** |
|  | **Energy** |
| Total energy consumption | Etotal | 63254 | MJ/h | 44,769 | 447694 | 95.4 |
| Specific energy intensity | RSEI | 0.0230 | MJ/kg | 0.016 | 0.16 | 95.4 |
| Energy intensity | REI | 0.0000427 | MJ/$ | 0.000030 | 0.00030 | 95.4 |
| Waste treatment energy | WTE | -0.0185 | MJ/kg | 0 | 0.0023 | 100.0 |
| Solvent recovery energy | SRE | 0 | MJ/kg | 0 | 0.0023 | 100.0 |
| Resource-energy efficiency | ηE | 0.057 | MJ product/MJ feedstock | 1 | 0  | 5.7 |
| Renewability-energy index | RIE | 0.00250 | MJ renewable/MJ total supplied | 1 | 0  | 0.2 |
| Breeding-energy factor | BFE | 0.057 | MJ total output/MJ nonrenewable input | 10  | 0 | 0.6 |
| Energy for recycling | Erecycl | 0.02 | MJ/kg | 0.0 | 0.002298 | 0.0 |
|  | **Economic** |
| Total process cost (end-of-life) | TPC | 25,793,470 | $/yr | 22,631,358 | 35,203,909 | 74.8 |
| Annual operation of EoL Processes (COM) | COM | 20,634,776 | $/yr | 9,801,518 | 43,848,898 | 68.2 |
| Specific raw material cost | CSRM | 2.16 | $/kg | 1 | 11 | 85.6 |
| Total material cost | Cmat. tot. | 5,945,864 | $/yr | 2,020,657 | 29,336,591 | 85.6 |
| Total energy cost | CE, tot. | 1,774,922 | $/yr | 821,013 | 8,019,199 | 86.7 |
| Average cost of energy source | CE, source | 0.000004 | $/kJ | 0.00000172 | 0.0000168 | 86.7 |
| Specific energy cost | CE, spec. | 0.07 | $ energy cost/$ total | 0.041 | 0.22 | 84.2 |
| Total solid waste cost | Cs tot. | 1,635,394 | $/yr | 0 | 20,463,520 | 92.0 |
| Solid waste cost fraction | Cs, spec. | 0.06 | $ solid waste cost/$ total | 0 | 0.79 | 92.0 |
| Total liquid waste cost | Cl tot. | 3,391,849 | $/yr | 0 | 42,441,849 | 92.0 |
| Liquid waste cost fraction | Cl, spec. | 0.13 | $ liquid waste cost/$ total | 0 | 1.65 | 92.0 |
| Revenues from eco-products | REV | 762,741 | $/yr | 762,741 | 0 | 100.0 |
| Revenues fraction of eco-products |  REVeco-prod | 1 | $/$ | 1 | 0 | 100.0 |