

Environmental Impact Assessment of a 1 kW Proton-Exchange Membrane Fuel Cell: A Mid-point and End-point Analysis

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Table S1: Ecoinvent 3.7.1 dataset documentation f fuel cell production, stack polymer electrolyte membrane, 1kW.

Reference products	Amount
Fuel cell, stack polymer electrolyte membrane, 2kW electrical, future	1 unit
By-products	Amount
Waste plastic, industrial electronics	6.6 kg
Waste polyvinylfluoride	0.052 kg
Inputs from technosphere	Amount
Activated carbon, granular	0.0008 kg
Aluminium, wrought alloy	0.3 kg
Building, hall, steel construction	0.00022 m ²
Building, multi-storey	0.0013 m ³
Electricity, medium voltage	16.9 kWh
Glass fibre	0.1 kg
Graphite	4.5 kg
Heat, district or industrial, natural gas	22.3 MJ
Isopropanol	0.0095 kg
Phenolic resin	1.1 kg
Platinum	0.00075 kg
Steel, chromium steel 18/8, hot rolled	0.1 kg
Tetrafluoroethylene	0.052 kg
Water, deionised	0.006 kg
Inputs from environment	Amount
Occupation, industrial area	0.0395 m ² /year
Transformation, from unspecified	0.0008 m ²
Transformation, to industrial area	0.0008 m ²
Emissions to air	Amount
Propanol	0.0095 kg
Water	9×10^{-7} m ³
Emissions to water	Amount
Water	5.1×10^{-6} m ³

Table S2: Uncertainty results for mid-point analysis of 1kW fuel cell stack

Impact category	Unit	Mean	Median	SD	CV (%)	2.50%	97.50%	SEM
Fine particulate matter formation	kg PM2.5 eq	1.545637	1.523025	0.249825	16.16324	1.113291	2.080725	0.0079
Fossil resource scarcity	kg oil eq	45.755	45.34617	6.217977	13.58972	35.02779	59.33366	0.19663
Freshwater ecotoxicity	kg 1,4-DCB	70.46081	67.1621	19.71698	27.9829	39.37635	118.3482	0.623506
Freshwater eutrophication	kg P eq	0.14016	0.126833	0.05889	42.01628	0.063995	0.270474	0.001862
Global warming	kg CO2 eq	193.4671	192.268	22.07744	11.41147	154.8792	241.5544	0.69815
Human carcinogenic toxicity	kg 1,4-DCB	21.10689	18.87397	9.463032	44.83385	11.45735	44.72427	0.299247
Human non-carcinogenic toxicity	kg 1,4-DCB	2170.034	2041.736	866.8337	39.94563	984.531	4182.628	27.41169
Ionizing radiation	kBq Co-60 eq	7.796904	4.593087	9.697046	124.3705	1.024844	36.04705	0.306648
Land use	m2a crop eq	7.77326	7.428748	1.763206	22.68296	5.442225	12.1864	0.055757
Marine ecotoxicity	kg 1,4-DCB	89.87938	85.85128	24.67589	27.45445	50.70243	149.9709	0.78032
Marine eutrophication	kg N eq	0.006402	0.006227	0.001249	19.50855	0.004517	0.009347	3.95×10^{-5}
Mineral resource scarcity	kg Cu eq	12.52376	12.33332	1.883338	15.03812	9.306844	16.67465	0.059556
Ozone formation, Human health	kg NOx eq	1.508793	1.480051	0.273288	18.11301	1.04773	2.084004	0.008642
Ozone formation, Terrestrial ecosystems	kg NOx eq	1.544384	1.520168	0.277387	17.96099	1.070523	2.11916	0.008772
Stratospheric ozone depletion	kg CFC11 eq	0.000615	0.000602	0.000113	18.43116	0.000425	0.000871	3.58×10^{-6}
Terrestrial acidification	kg SO2 eq	5.211917	5.131594	0.865048	16.5975	3.731698	7.064497	0.027355

Terrestrial ecotoxicity	kg 1,4-DCB	256.9126	245.639	55.55967	21.6259	183.664	385.0839	1.756951
Water consumption	m3	1.961452	2.669477	20.85124	1063.051	-43.2772	39.05895	0.659374

Table S3: Uncertainty results for end-point analysis of 1kW fuel cell stack

Impact category	Unit	Mean	Median	SD	CV %	2.50%	97.50%	SEM
Fine particulate matter formation	DALY	0.000968	0.000958	0.000159	16.47292	0.000695	0.001327	5.04E-06
Fossil resource scarcity	USD2013	9.442593	9.307683	1.106613	11.71937	7.63168	11.69944	0.034994
Freshwater ecotoxicity	species.yr	4.86×10^{-8}	4.62×10^{-8}	1.36×10^{-8}	27.87818	2.80×10^{-8}	8.17×10^{-8}	4.29×10^{-10}
Freshwater eutrophication	species.yr	9.47×10^{-8}	8.57×10^{-8}	4.25×10^{-8}	44.90077	4.06×10^{-8}	1.97×10^{-7}	1.34×10^{-9}
Global warming, Freshwater ecosystems	species.yr	1.47×10^{-11}	1.46×10^{-11}	1.66×10^{-12}	11.27988	1.18×10^{-11}	1.83×10^{-11}	5.26×10^{-14}
Global warming, Human health	DALY	0.000179	0.000178	2.02×10^{-5}	11.27895	0.000144	0.000223	6.38×10^{-7}
Global warming, Terrestrial ecosystems	species.yr	5.40×10^{-7}	5.36×10^{-7}	6.09×10^{-8}	11.27894	4.34×10^{-7}	6.72×10^{-7}	1.92×10^{-9}
Human carcinogenic toxicity	DALY	7.04×10^{-5}	6.30×10^{-5}	3.81×10^{-5}	54.14627	3.65×10^{-5}	0.000136	1.21×10^{-6}
Human non-carcinogenic toxicity	DALY	0.000506	0.000458	0.000199	39.37839	0.000233	0.001013	6.30×10^{-6}
Ionizing radiation	DALY	6.55×10^{-8}	3.84×10^{-8}	8.67×10^{-8}	132.4376	9.34×10^{-9}	2.85×10^{-7}	2.74×10^{-9}
Land use	species.yr	7.00×10^{-8}	6.67×10^{-8}	1.71×10^{-8}	24.38061	4.80×10^{-8}	1.15×10^{-7}	5.40×10^{-10}
Marine ecotoxicity	species.yr	9.42×10^{-9}	8.96×10^{-9}	2.59×10^{-9}	27.44572	5.50×10^{-9}	1.57×10^{-8}	8.18×10^{-11}
Marine eutrophication	species.yr	1.11×10^{-11}	1.06×10^{-11}	3.23×10^{-12}	29.22409	7.61×10^{-12}	1.67×10^{-11}	1.02×10^{-13}
Mineral resource scarcity	USD2013	2.876437	2.846825	0.45116	15.68468	2.087613	3.901329	0.014267
Ozone formation, Human health	DALY	1.38×10^{-6}	1.35×10^{-6}	2.64×10^{-7}	19.18995	9.16×10^{-7}	1.97×10^{-6}	8.36×10^{-9}

Ozone formation, Terrestrial ecosystems	species.yr	2.00×10^{-7}	1.95×10^{-7}	3.80×10^{-8}	19.02185	1.33×10^{-7}	2.85×10^{-7}	1.20×10^{-9}
Stratospheric ozone depletion	DALY	3.23×10^{-7}	3.15×10^{-7}	5.72×10^{-8}	17.73435	2.34×10^{-7}	4.55×10^{-7}	1.81×10^{-9}
Terrestrial acidification	species.yr	1.10×10^{-6}	1.09×10^{-6}	1.87×10^{-7}	16.94984	7.79×10^{-7}	1.53×10^{-6}	5.91×10^{-9}
Terrestrial ecotoxicity	species.yr	2.95×10^{-9}	2.82×10^{-9}	6.59×10^{-10}	22.32437	2.05×10^{-9}	4.59×10^{-9}	2.08×10^{-11}
Water consumption, Aquatic ecosystems	species.yr	1.43×10^{-12}	2.41×10^{-12}	3.42×10^{-11}	2386.809	-7.05×10^{-11}	6.84×10^{-11}	1.08×10^{-12}
Water consumption, Human health	DALY	2.77×10^{-6}	6.86×10^{-6}	3.66×10^{-5}	1320.103	-7.84×10^{-5}	6.32×10^{-5}	1.16×10^{-6}
Water consumption, Terrestrial ecosystem	species.yr	2.09×10^{-8}	4.49×10^{-8}	2.25×10^{-7}	1076.625	-5.08×10^{-7}	3.96×10^{-7}	7.11×10^{-9}

Table S4: Uncertainty results for Damage assessment of 1kW fuel cell stack

Damage category	Unit	Mean	Median	SD	CV%	2.50%	97.50%	SEM
Ecosystems	species.yr	2.09×10^{-6}	2.08×10^{-6}	3.69×10^{-7}	17.6546	1.39×10^{-6}	2.84×10^{-6}	1.17×10^{-8}
Human health	DALY	0.001728	0.001693	0.000318	18.39704	0.001198	0.002448	1.01×10^{-5}
Resources	USD2013	12.31903	12.16569	1.490457	12.09881	9.775526	15.58111	0.047132