Supporting Materials

Table S1 Life cycle inventories for the synthesis processes of EEG and HG10.

Processes	**Inputs and emissions**	**Input / Output**	**Consumption**	**Unit**	**Unit Process**
Synthesis of 1 kg EEG by the electrochemical exfoliation method	***Inputs***				
		graphite	1.25	kg	Graphite {RoW}| production | APOS, U
		sulfuric acid	4.97	kg	Sulfuric acid {RoW}| market for sulfuric acid | APOS, U
		deionised water	227.30	kg	Water, deionised {RoW}| market for water, deionised | APOS, U
		Electricity	19.75	kWh	Electricity, medium voltage {IR}| market for | APOS, U
	Emissions to air				
		CO_2 (g)	1.88	kg	Carbon dioxide
		SO_2 (g)	2.74	kg	Sulphur dioxide
		O_2 (g)	2.05	kg	Oxygen
	Emission to water				
		SO_4^{2-}	0.69	kg	Waste water, to water
		H^+	0.34	kg	Waste water, to water
Synthesis of 1 kg HG10 by the chemical activation method	***Inputs***				

	graphene	2.19	kg	Compiled inventory for graphene
	Potassium hydroxide	21.90	kg	Potassium hydroxide {GLO}| market for | APOS, U
	deionised water	1587.30	kg	Water, deionised {RoW}| market for water, deionised | APOS, U
	Electricity	7.04	kWh	Electricity, medium voltage {IR}| market for | APOS, U
Emissions to air				
	CO_2 (g)	1.14	kg	Carbon dioxide
	CO (g)	4.20	kg	Carbon monoxide
	H_2 (g)	0.41	kg	Hydrogen
Emission to water				
	KOH	15.04	kg	Waste water, to water

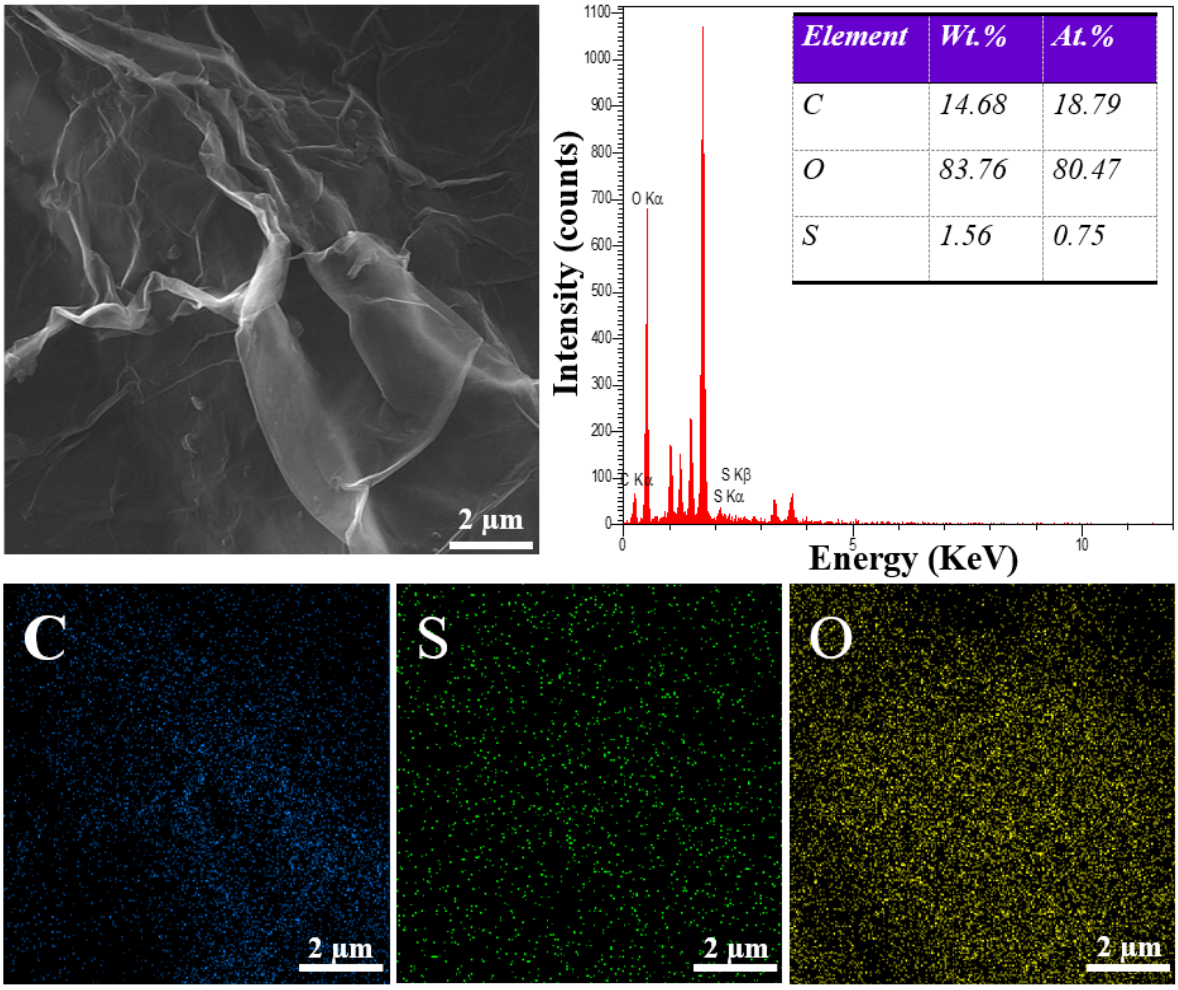

Fig. S1 The EDS-mapping analysis along with the FESEM image of the EEG sample.

Table S2 Details of LCA results for EEG synthesis procedure.

TRACI	Unit	Graphite	Sulfuric acid	Dionised water	Electricity	Direct Emissions	Total
Ozone depletion	kg CFC-11 eq	1.89E–09	9.64E–08	4.77E–08	1.42E–06	0	1.57E–06
Global warming	kg CO_2 eq	4.61E–02	7.90E–01	8.46E–02	1.27E + 01	1.88E + 00	1.55E + 01
Smog	kg O_3 eq	3.95E–03	1.21E–01	5.36E–03	3.99E–01	0	5.30E–01
Acidification	kg SO_2 eq	2.80E–04	3.85E–02	6.16E–04	2.88E–02	3.19E + 00	3.26E + 00
Eutrophication	kg N eq	1.43E–04	1.10E–02	2.98E–04	4.13E–03	0.00E + 00	1.56E–02
Carcinogenics	CTUh	3.75E–09	2.99E–07	1.00E–08	2.05E–07	0	5.18E–07
Non carcinogenics	CTUh	9.94E–09	5.46E–06	4.21E–08	4.76E–07	0	5.99E–06
Respiratory effects	kg $PM_{2.5}$ eq	8.79E–05	3.24E–03	1.08E–04	3.00E–03	1.67E–01	1.74E–01
Ecotoxicity	CTUe	3.60E–01	3.45E + 02	2.59E + 00	4.96E + 01	2.07E + 02	6.05E + 02
Fossil fuel depletion	MJ surplus	2.98E–02	1.71E + 00	1.04E–01	3.08E + 01	0	3.27E + 01

Table S3 Numerical values to create the 100% columns histogram in Fig. 4(a).

TRACI	Unit	Graphite	Sulfuric acid	Dionised water	Electricity	Direct Emissions
Ozone depletion	kg CFC-11 eq	1.20E–01	6.15E + 00	3.04E + 00	9.07E + 01	0.00E + 00
Global warming	kg CO_2 eq	2.97E–01	5.08E + 00	5.44E–01	8.20E + 01	1.21E + 01
Smog	kg O_3 eq	7.46E–01	2.29E + 01	1.01E + 00	7.54E + 01	0.00E + 00
Acidification	kg SO_2 eq	8.60E–03	1.18E + 00	1.89E–02	8.86E–01	9.79E + 01
Eutrophication	kg N eq	9.14E–01	7.07E + 01	1.91E + 00	2.65E + 01	0.00E + 00
Carcinogenics	CTUh	7.24E–01	5.77E + 01	1.93E + 00	3.96E + 01	0.00E + 00
Non carcinogenics	CTUh	1.66E–01	9.12E + 01	7.02E–01	7.94E + 00	0.00E + 00
Respiratory effects	kg $PM_{2.5}$ eq	5.05E–02	1.87E + 00	6.22E–02	1.73E + 00	9.63E + 01
Ecotoxicity	CTUe	5.95E–02	5.71E + 01	4.28E–01	8.20E + 00	3.42E + 01
Fossil fuel depletion	MJ surplus	9.11E–02	5.25E + 00	3.17E–01	9.43E + 01	0.00E + 00

Table S4 Details of LCA results for HG10 synthesis procedure.

TRACI	Unit	Graphene	Potassium hydroxide	Dionised water	Electricity	Direct Emissions	Total
Ozone depletion	kg CFC-11 eq	3.43E−06	4.47E−06	3.33E−07	5.07E−07	0.00E + 00	8.74E−06
Global warming	kg CO_2 eq	3.40E + 01	5.65E + 01	5.90E−01	4.54E + 00	1.14E + 00	9.68E + 01
Smog	kg O_3 eq	1.16E + 00	3.81E + 00	3.75E−02	1.42E−01	2.34E−01	5.38E + 00
Acidification	kg SO_2 eq	7.13E + 00	2.87E−01	4.30E−03	1.03E−02	0.00E + 00	7.43E + 00
Eutrophication	kg N eq	3.42E−02	1.85E−01	2.08E−03	1.47E−03	0.00E + 00	2.23E−01
Carcinogenics	CTUh	1.14E−06	5.74E−06	7.00E−08	7.32E−08	0.00E + 00	7.02E−06
Non carcinogenics	CTUh	1.31E−05	1.80E−05	2.94E−07	1.70E−07	0.00E + 00	3.16E−05
Respiratory effects	kg $PM_{2.5}$ eq	3.81E−01	6.66E−02	7.56E−04	1.07E−03	1.50E−03	4.51E−01
Ecotoxicity	CTUe	1.32E + 03	1.08E + 03	1.81E + 01	1.77E + 01	0.00E + 00	2.44E + 03
Fossil fuel depletion	MJ surplus	7.15E + 01	6.37E + 01	7.24E−01	1.10E + 01	0.00E + 00	1.47E + 02

Table S5 Numerical values to create the 100% columns histogram in Fig. 4(b).

TRACI	Unit	Graphene	Potassium hydroxide	Dionised water	Electricity	Direct Emissions
Ozone depletion	kg CFC-11 eq	3.93E + 01	5.11E + 01	3.81E + 00	5.80E + 00	0.00E + 00
Global warming	kg CO_2 eq	3.52E + 01	5.84E + 01	6.10E–01	4.69E + 00	1.18E + 00
Smog	kg O_3 eq	2.15E + 01	7.08E + 01	6.96E–01	2.64E + 00	4.34E + 00
Acidification	kg SO_2 eq	9.59E + 01	3.86E + 00	5.79E–02	1.38E–01	0.00E + 00
Eutrophication	kg N eq	1.53E + 01	8.31E + 01	9.32E–01	6.59E–01	0.00E + 00
Carcinogenics	CTUh	1.62E + 01	8.18E + 01	9.98E–01	1.04E + 00	0.00E + 00
Non carcinogenics	CTUh	4.15E + 01	5.70E + 01	9.30E–01	5.37E–01	0.00E + 00
Respiratory effects	kg $PM_{2.5}$ eq	8.45E + 01	1.48E + 01	1.68E–01	2.37E–01	3.32E–01
Ecotoxicity	CTUe	5.44E + 01	4.41E + 01	7.43E–01	7.26E–01	0.00E + 00
Fossil fuel depletion	MJ surplus	4.87E + 01	4.34E + 01	4.92E–01	7.47E + 00	0.00E + 00

Table S6 TRACI results for per kg EEG: electricity generation by natural gas, diesel, and natioanal power grid.

Impact category	Unit	Natural gas per kg EEG	Diesel per kg EEG	Grid per kg EEG
Ozone depletion	kg CFC-11 eq	1.76E–06	4.35E–06	**1.57E–06**
Global warming	kg CO_2 eq	1.71E + 01	2.11E + 01	**1.55E + 01**
Smog	kg O_3 eq	1.26E + 00	4.58E–01	**5.30E–01**
Acidification	kg SO_2 eq	3.27E + 00	3.25E + 00	**3.26E + 00**
Eutrophication	kg N eq	1.47E–02	1.87E–02	**1.56E–02**
Carcinogenics	CTUh	4.95E–07	4.18E–07	**5.18E–07**
Non carcinogenics	CTUh	5.79E–06	5.76E–06	**5.99E–06**
Respiratory effects	kg $PM_{2.5}$ eq	1.72E–01	1.73E–01	**1.74E–01**
Ecotoxicity	CTUe	5.67E + 02	5.64E + 02	**6.05E + 02**
Fossil fuel depletion	MJ surplus	3.90E + 01	3.86E + 01	**3.27E + 01**

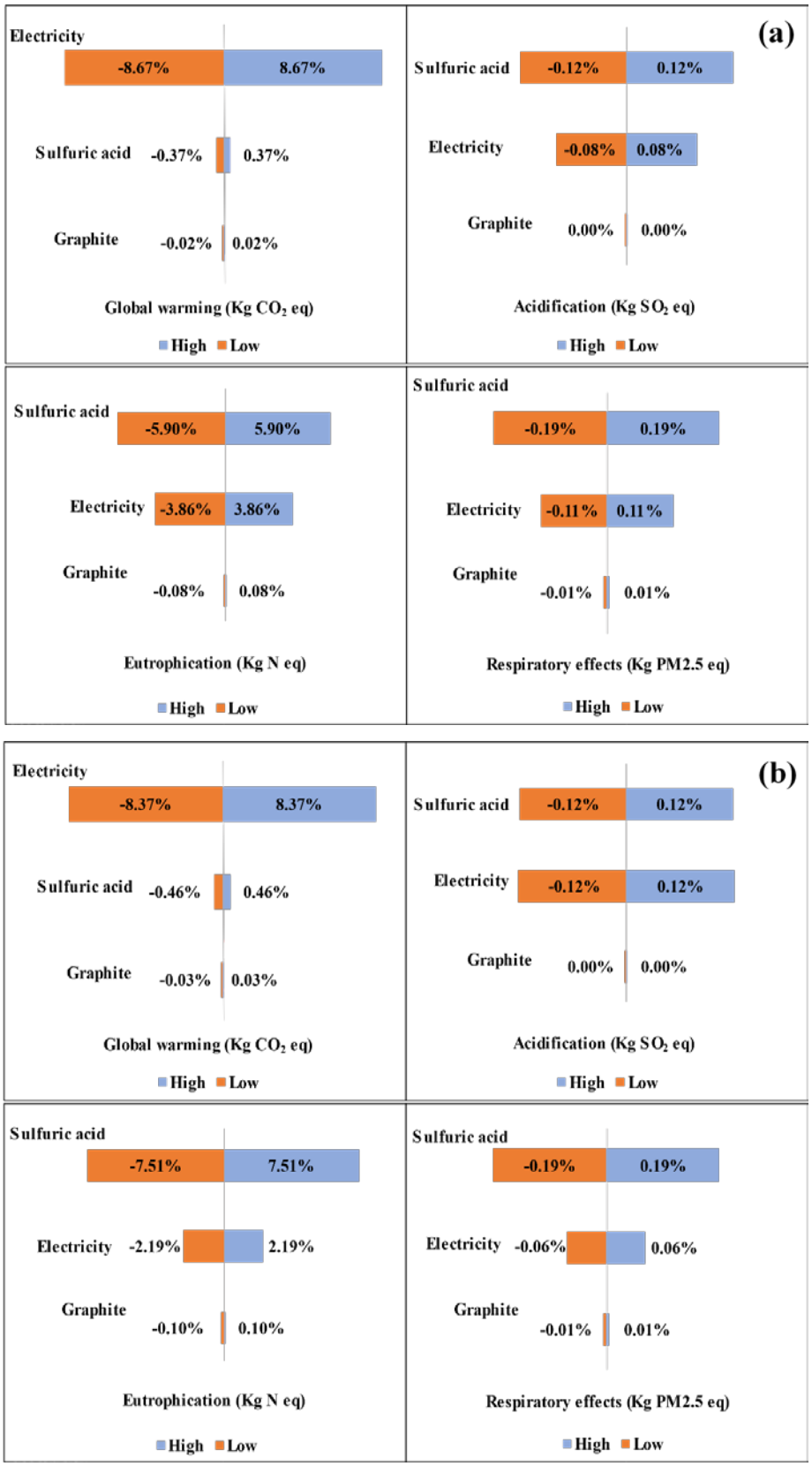

Fig. S2 Sensitivity analysis on main contributors for cradle-to-gate LCA to produce 1 kg of EEG: (a) with diesel generator, and (b) natural gas as electricity sources.