

Supplementary Materials

Environmental impact of China's semi-solid-state batteries: a cradle-to-gate life cycle assessment

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Supplementary Tables

Table S1 List of Abbreviations

abbreviation	full name	abbreviation	full name
SSSB	Semi-solid-state Batteries	LIB	Lithium-ion Batteries
ASSB	All-solid-state Batteries	SSB	Solid-state Batteries
LCA	Life Cycle Assessment	CTG	Cradle-to-Gate
CLCD	China Local Life Cycle Database	GWP	Global Warming Potential
PED	Primary Energy Demand	ADP	Abiotic Depletion Potential
WU	Water Use	AP	Acidification Potential
EP	Eutrophication Potential	RI	Respirable Particulate Formation Potential

ODP	Ozone Depletion Potential	POFP	Photochemical Ozone Formation Potential
LCI	Life Cycle Inventory	LCIA	Life Cycle Impact Assessment
NCM811	Lithium Nickel Cobalt Manganese Oxide (811 type)	LATP	Lithium Aluminum Titanium Phosphate
LLTO	Lithium Lanthanum Titanium Oxide	LiPF ₆	Lithium Hexafluorophosphate
LiPOF ₂	Lithium Difluorophosphate	PC	Propylene Carbonate
EC	Ethylene Carbonate	DMC	Dimethyl Carbonate
EMC	Ethyl Methyl Carbonate	NMP	N-Methyl-2- Pyrrolidone
CNT	Carbon Nanotube	CMC	Carboxymethyl Cellulose
SBR	Styrene Butadiene Rubber	PVDF	Polyvinylidene Fluoride
NMHC	Non-Methane Hydrocarbon	EOL	End-of-Line
MBR	Membrane Bioreactor	COD	Chemical Oxygen Demand
TN	Total Nitrogen	TP	Total Phosphorus
NH-N	Ammonia Nitrogen	PAC	Poly Aluminum Chloride
PAM	Polyacrylamide	NaOH	Sodium Hydroxide
NaClO	Sodium Hypochlorite	CTGr	Cradle-to-Grave
C	Cathode	A	Anode
CC	Current Collector	S	Separator
ES	Electrolyte Solvent	T	Tab
SH	Shell	BM-A	Batch Mixing- Anode
CD-A	Coating & Drying-Anode	CAL-A	Calendering-Anode
KS-A	Knife Slitting-Anode	VD-A	Vacuum Drying- Anode
BM-C	Batch Mixing-Cathode	CD-C	Coating & Drying- Cathode
CAL-C	Calendering-Cathode	KS-C	Knife Slitting- Cathode
VD-C	Vacuum Drying-Cathode	CT-A	Cutting-Anode
CT-C	Cutting-Cathode	STK	Stacking
WPFC	Welding-Packaging-Filling-Closing	WSH	Washing
FOR	Formation	AG	Aging
EOL-T	End-of-Line -Testing	MH	Material Handling
DR	Dry Rooms	TWV	Total Wastewater Volume

HW	Hazardous Waste	HW-HDTT	Hazardous Waste- Heavy-duty Diesel Truck Transportation
LFP	Lithium Iron Phosphate	i	Stage Serial Number
j	Sub-Stage / Raw Material Serial Number	SC	Sensitivity Coefficient Parameter
C	Carbon Footprint Value	Δ	Fluctuation Amplitude Sensitivity Coefficient
total	Total Cumulative Carbon Footprint of Corresponding Stage	$SC_{i,j}$	Associated With the j-th Sub-Stage or Raw Material Within the i-th Stage
$C_{i,j}$	Carbon Footprint of the j-th Sub- Stage or Raw Material Within the i-th Stage	$C_{i,total}$	Aggregated Carbon Footprint of the i-th Stage

Table S2 Life cycle impact assessment (LCIA) characterization models and characterization factor sources.

Abbreviation	Adopted LCIA Characterization Model	Source of Characterization Factors (CFs)	Equivalent Unit	Core Calculation Description
GWP	IPCC 2021 100- year horizon model	CLCD database embedded IPCC localized CF dataset	kg CO ₂ eq	Characterize greenhouse gas emissions via standardized IPCC 2021 conversion factors
ADP	CML 2002 midpoint model	eFootprint built- in CML 2002 module	kg antimony eq	Quantify mineral & metal resource depletion based on CML depletion factors

PED	No pollutant characterization model	Direct inventory aggregation without CF conversion	MJ	Directly sum all primary fossil/renewable energy input flows across processes Sum total freshwater consumption of all manufacturing and raw material extraction procedures Convert acid-forming gaseous pollutants (NO _x , SO ₂) to sulfur dioxide equivalents
WU	No pollutant characterization model	Direct inventory aggregation without CF conversion	kg	Characterize nitrogen & phosphorus nutrient emissions triggering water eutrophication Convert PM _{2.5} precursor gaseous pollutants to fine particulate equivalent mass
AP	CML 2002 atmospheric acidification model	CLCD air pollution sub-database	kg SO ₂ eq	Quantify ozone-depleting substance emissions with CML 2001 ozone attenuation factors
EP	CML 2002 aquatic eutrophication model	eFootprint built-in CML 2002 module	kg PO ₄ ³⁻ eq	
RI	IMPACT 2002+ midpoint model	eFootprint IMPACT 2002+ embedded CF library	kg PM _{2.5} eq	
ODP	CML 2001 Montreal Protocol model	CLCD global atmospheric impact sub-library	kg CFC-11 eq	

POFP	ReCiPe Midpoint tropospheric ozone model	eFootprint built- in ReCiPe Midpoint module	kg NMVOC eq	Calculate ozone generation risk induced by industrial VOC and NO _x emissions
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Table S3 Background data of raw materials.

Upstream raw materials	Background data	Year
Lubricating Oil	Diesel (diesel hydroprocessing) (t, unclassified); China	2023
Oxygen	Oxygen m3, unclassified; China	2020
Electricity	China Power Grid (kWh); China	2024
Coating Additive	Aluminum oxide (t, Bayer process); China	2023
Manganese Precursor	Manganese sulfate (t, unclassified); China	2023
Lithium Carbonate	Lithium carbonate (t; unclassified); China	2023
Water	Tap water (t, unclassified); China	2020
Steam	1.6MPa steam (t, unclassified); China	2020

	unclassified); China	
Ammonia Water	Synthetic ammonia (t, 2013 unclassified); China	
Manganese Sulfate	Manganese sulfate (t, 2023 unclassified); China	
Sodium Hydroxide Solution	sodium hydroxide-Sodium 2012 hydroxide(RER); ELCD	
Phosphorus Remover	Polyacrylamide (PAM) (t, 2023 unclassified); China	
Soda Ash	Soda ash (market average) t, 2020 unclassified; China	
Extractant	Mass is negligible and / excluded per LCA accounting rules	
Sodium Dimethyldithiocarbamate	Sodium fluoride ; China	2013
Cobalt Hydroxide	Cobalt Cobalt - Electrolytic Refining Method ; China	2013
Solvent Oil	Light Oil - Light Oil (Coal Tar Distillation) ; China	2013
Hydrogen Peroxide	Hydrogen peroxide (t, 2024 unclassified); China	
Sodium Thiosulfate	Sodium sulfate (t, 2020	

Pentahydrate	unclassified); China	
Hydrochloric Acid	31% hydrochloric acid (t, 2020 mass fraction 31%); China	
Liquid Caustic Soda	Liquid caustic soda - caustic soda (30%) - diaphragm method ; China	2013
Catalyst($\text{Fe}_2\text{O}_3 \cdot 1.3\text{Al}_2\text{O}_3 \cdot 0.1\text{MoO}_3$)	Iron oxide (kg, unclassified); China	2021
Propylene	Propylene (t; Ethylene Plant - Mixed Treatment); China	2023
Liquid Nitrogen	Nitrogen (m3, unclassified); China	2020
Silane Coupling Agent	Silane cross-linked polyethylene (kg, unclassified); China	2020
Sodium Dodecylbenzenesulfonate (SDBS)	Sodium dodecylbenzenesulfonate, unclassified; China	2023
Modifier	Mass is negligible and / excluded per LCA accounting rules	
Lignin	Wood sawdust activated carbon (t, unclassified); China	2020
Graphene	Artificial graphite ; China	2013

Carbon Black	Coke (t; Sichuan); China	2024
Vinylidene Fluoride	Butadiene (t; Butadiene Unit Acetonitrile (ACN) Method); China	2023
Hexafluoropropylene	Propylene (t; ethylene plant chemical plant recovery and treatment); China	2023
LATP power	Phosphate brick (dense refractory brick) (t, natural mineral (calcined material); Tunnel kiln sintering); China	2024
PVP	Silane cross-linked polyethylene (kg, unclassified); China	2020
Catalyst	Mass is negligible and / excluded per LCA accounting rules	
Methylamine	Monomethylamine (t; China)	2025
1,4-Butanediol	Ethylene glycol (t, petroleum route - ethylene glycol mass fraction 99.9%); China	2022
Nitrogen	Nitrogen (m3, unclassified); China	2020
Asphalt	Coal tar pitch (market	2020

	average) (t, unclassified); China	
Needle Coke	Coal tar - market average (kg, unclassified); China	2020
Graphite (Raw)	Artificial graphite ; China	2013
Silicon Dioxide Particles	Industrial silicon t, silicon content $\geq 99\%$; China	2020
Silicon Particles	Industrial silicon t, silicon content $\geq 99\%$; China	2020
Acetylene	Acetylene Acetylene - Market Average ; China	2020
Styrene	Styrene ; China	2013
1,3-Butadiene	Butadiene (petroleum tube cracking) (t, unclassified); China	2020
48% (Hydroxymethyl)acrylamide Solution	N- Polyacrylamide (PAM) (t, unclassified); China	2023
CS-8 Starch	Modified starch (moisture content $\leq 11\%$, 30-80 mesh), enterprise LCA - represents specific enterprise and supply chain level (used for enterprise product reporting/process equipment selection analysis);	2016

	China	
Emulsifier (DB-45)	Mass is negligible and / excluded per LCA accounting rules	
Sodium Thiosulfate	Sodium sulfate (t, 2020 unclassified); China	
Butyl Acrylate	Butyl acrylate ; China	2013
Acrylamide	Polyacrylamide (PAM) (t, 2023 unclassified); China	
tert-Dodecyl Mercaptan	Hydrogen sulfide (t, 2023 atmospheric and vacuum); China	
Sodium Persulfate	Sodium sulfate (t, 2020 unclassified); China	
Fatty Alcohol Surfactant	Mass is negligible and / excluded per LCA accounting rules	
Emulsifier (AEO)	Mass is negligible and / excluded per LCA accounting rules	
37% Formaldehyde	Formaldehyde aqueous solution; China	2013
Ammonium Persulfate	Ammonium sulfate (kg, 2020 unclassified); China	

Sodium Bicarbonate	Sodium bicarbonate (kg, 2023 ammonium bicarbonate metathesis method); Ammonium bicarbonate+steam; China
Acetic Acid	Acrylic acid ; China 2013
Ferrous Sulfate	Ferrous sulfate (t, 2018 unclassified); China
Sodium Bisulfite	Amino resin tanning agent (t, 2024 100% melamine resin, retanning agent); Melamine+formaldehyde+sod ium bisulfite, etc., condensation+sulfonation+ne utralization; China
Emulsifier (AMK)	Mass is negligible and / excluded per LCA accounting rules
Defoamer	Mass is negligible and / excluded per LCA accounting rules
Gemini Emulsifier	Mass is negligible and / excluded per LCA accounting rules
Molecular Weight Regulator	Mass is negligible and /

	excluded per LCA accounting rules	
Emulsifier (No.203)	Mass is negligible and / excluded per LCA accounting rules	
Methyl Red	Methyl monomer (t, organic silicon monomer); China	2024
Refined Cotton Linter	cotton seed, at farm; China	2007
Potassium Chloride	Potassium chloride - Potassium chloride (cold decomposition flotation method) ; China	2013
Chloroacetic Acid	Vinyl acetate ; China	2013
Bromothymol Blue	Mass is negligible and / excluded per LCA accounting rules	
Liquid Caustic Soda	Liquid caustic soda - caustic soda (30%) - market average ; China	2013
LLTO power	Phosphate brick (dense refractory brick) (t, natural mineral (calcined material); Tunnel kiln sintering); China	2024
Chromic anhydride	Chromium Anhydride Chromium Anhydride	2013

	(Double Tank Method) ; China	
Activated carbon	Coal based activated carbon (t, 2020 unclassified); China	
Collagen	Mass is negligible and / excluded per LCA accounting rules	
Sulfuric acid	Sulfuric acid (sulfuric acid 2020 production) (t, 98% sulfuric acid); China	
Charcoal	Coke (t; Sichuan); China	2024
Emulsion	Mass is negligible and / excluded per LCA accounting rules	
Graphite flakes	Artificial graphite ; China	2013
Copper	Cathodic copper 2020 pyrometallurgical copper smelting (t, in accordance with the A-level copper standard in GB/T467-2010 Cathodic Copper, with a copper content of not less than 99.95%); China	
PAC	Basic aluminum chloride \ 2013 polyaluminum chloride \ PAC ; China	

Nickel sulfate	Mass is negligible and / excluded per LCA accounting rules
Sodium hydroxide	sodium hydroxide-Sodium 2012 hydroxide(RER)
Potassium pyrophosphate	Mass is negligible and / excluded per LCA accounting rules
Glucose	Glucose t, monohydrate 2022 glucose, from cradle to gate, corn starch, dual enzyme method, from data survey - representative of typical levels; China
Gelatin	Mass is negligible and / excluded per LCA accounting rules
Diatomaceous Earth	Mass is negligible and / excluded per LCA accounting rules
Aluminum Substrate	Primary aluminum 2023 (electrolytic aluminum)/aluminum alloy ingot (t, unclassified); China
Cleaning Agent	Sodium silicate sodium 2020

	carbonate method (t, modulus 3.4); China
Rolling Oil	Thin oil (Daqing Oilfield) t, 2020 thin oil, from cradle to gate (from resource exploitation to product delivery), from data investigation - representing typical level; China
Stock Solution	Thin oil (Daqing Oilfield) t, 2020 thin oil, from cradle to gate (from resource exploitation to product delivery), from data investigation - representing typical level; China
Lubricating Oil	Light Oil - Light Oil (Coal Tar 2013 Distillation) ; China
Hydraulic Oil	Gasoline (refinery) (t, 2020 unclassified); China
PP Resin	Polypropylene - 2013 Polypropylene (Market Average) ; China
Packaging Material	PET plastic packaging bag 2024 (kg); China
Natural Gas	Natural gas (m3, unclassified); 2020 China

30% LiPF ₆ + 70% EMC	Methanol (market average)	2020
Electrolyte Base	(kg, unclassified); China	
Propyl Propionate	Acrylic resin tanning agent (t, 2024 main component: acrylic acid methyl acrylic acid acrylonitrile copolymer; Light yellow viscous liquid; Content 35%; pH (10%): 5~7; Type: Retanning agent); China	
PS	Polyacrylamide (PAM) (t, 2023 unclassified); China	
Purification Column Material	Mass is negligible and / excluded per LCA accounting rules	
LiDFOB	Boric acid - Boric acid (market 2013 average) ; China	
LiPO ₂ F ₂	Hydrofluoric acid (40%) ; 2013 China	
FEC	Vinyl acetate ; China	2013
Ethanol	Ethanol Ethanol (Petroleum 2013 Source) ; China	
TPP	Phenol phenol 2013 (isopropylbenzene method) ; China	

LiPF ₆	Lithium hexafluorophosphate	2023
	t, unclassified, from cradle to gate (from resource extraction to product delivery) clinker limestone raw material powder, new dry rotary kiln, coal-fired, from and representing specific enterprises - does not include the main supply chain; China	
PC	Ethylene oxide production	2013
	(oxygen oxidation method) ; China	
DMC	Dimethyl carbonate (1kg, unclassified); Methanol; China	2024
Dimethyl Carbonate (LiPF ₆ -containing)	Dimethyl carbonate (1kg, unclassified); Methanol; China	2024
Dimethyl Carbonate (LiFSI-containing)	Dimethyl carbonate (1kg, unclassified); Methanol; China	2024
DEC	Diethyl carbonate (kg; ≥ 99.99); China	2025
EMC	Diethyl carbonate (kg; ≥ 99.99); China	2025

VC	Ethylene oxide production 2013 (oxygen oxidation method) ; China
EC	Ethylene oxide production 2013 (oxygen oxidation method) ; China
EA	Ethylene oxide production 2013 (oxygen oxidation method) ; China
Ethyl Acetate (LiPF ₆ - containing)	Ethylene oxide production 2013 (oxygen oxidation method) ; China
Tab Adhesive	Polypropylene Polypropylene 2013 (Intermittent Liquid Phase Bulk Method) ; China
Aluminum Tab Strip	Aluminum Strip - Aluminum 2013 Strip (Casting and Rolling) ; China
Nickel Tab Strip	Metallic Nickel - Metallic 2013 Nickel - Market Average ; China
CPP Tape	Polypropylene - 2013 Polypropylene (Market Average) ; China

Table S4 Life cycle inventory(LCI) of 1 kWh semi solid state battery(SSSB).

Component	Materials	Unit	Quantity
Cathode	Nickel Cobalt Manganese Lithium Oxide (NCM)	kg	1.8
	Carbon Nanotubes (CNT)	kg	0.2
	Acetylene Black (AB)	kg	0.012
	Polyvinylidene Fluoride (PVDF)	kg	0.036
	Lithium Aluminum Titanium Phosphate (LATP)	kg	0.15
Anode	1-Methyl-2-Pyrrolidone (NMP)	kg	0.5
	Graphite	kg	0.72
	Silicon Oxide (SiO)	kg	0.12
	Acetylene Black (AB)	kg	0.008
	Carbon Nanotubes (CNT)	kg	0.086
	Styrene-Butadiene Rubber (SBR)	kg	0.2
	Sodium Carboxymethyl Cellulose (CMC)	kg	0.2
	Lithium Lanthanum Titanate (LLTO)	kg	0.07
	Pure Water	kg	1
	Copper Foil	kg	0.18
Current collector	Aluminum Foil	kg	0.09
Separator	Separator	m ²	1
Electrolyte	Electrolyte	kg	0.35
Tab	Tab	pairs	3.6
Shell	Aluminum	kg	0.298

Table S5 LCI of 1 kg NCM.

Materials	Unit	Quantity
Lubricating Oil	kg	0.000278
Oxygen	kg	0.16463
Electricity	kWh	26.1
Coating Additive	kg	0.07

Manganese Precursor	kg	0.83
NCM Precursor(NCM hydroxide)	kg	0.91
Lithium Carbonate	kg	0.57

Table S6 LCI of 1 kg NCM hydroxide.

Materials	Unit	Quantity
Electricity	kWh	6
Water	kg	10
Steam	kg	6.2
Ammonia Water	kg	0.0049
Sulfuric Acid	kg	0.19
Cobalt Sulfate	kg	0.31
Manganese Sulfate	kg	0.26
Nickel Sulfate	kg	3.1
Sodium Hydroxide Solution	kg	3.15

Table S7 LCI of 1 kg Cobalt Sulfate.

Materials	Unit	Quantity
Electricity	kWh	6.74
Water	kg	58.29
Natural Gas	kg	233
Steam	kg	8.99
Phosphorus Remover	kg	0.01
Soda Ash (Sodium Carbonate)	kg	0.18
Extractant	kg	0.00141
Sodium Dimethyldithiocarbamate	kg	0.00605
Sulfuric Acid	kg	3.58
Cobalt Hydroxide	kg	3.15
Solvent Oil	kg	0.09
Hydrogen Peroxide	kg	0.05
Sodium Thiosulfate Pentahydrate	kg	0.000209
Hydrochloric Acid	kg	9.48
Liquid Caustic Soda (Sodium Hydroxide)	kg	9.27

Table S8 LCI of 1 kg CNT.

Materials	Unit	Quantity
Catalyst($\text{Fe}_2\text{O}_3 \cdot 1.3\text{Al}_2\text{O}_3 \cdot 0.1\text{MoO}_3$)	kg	0.02
Propylene	kg	1.6
Liquid Nitrogen	kg	3.2

Table S9 LCI of 1 kg AB.

Materials	Unit	Quantity
Electricity	kWh	1.8
Natural Gas	kg	0.07174
Fresh Water	kg	3.9
Silane Coupling Agent	kg	0.004
Sodium Dodecylbenzenesulfonate (SDBS)	kg	0.01
Modifier	kg	0.001
Lignin	kg	0.005
Graphene	kg	1
Carbon Black	kg	1

Table S10 LCI of 1 kg PVDF.

Materials	Unit	Quantity
Vinylidene Fluoride	kg	1.0541
Hexafluoropropylene	kg	0.01345

Table S11 LCI of 1 kg LATP.

Materials	Unit	Quantity
LATP power	kg	0.2
Polyvinylpyrrolidone (PVP)	kg	0.001
N-Methylpyrrolidone (NMP)	kg	0.8

Table S12 LCI of 1 kg NMP.

Materials	Unit	Quantity
Electricity	kWh	0.2652
Natural Gas	kg	0.1359
Steam	kg	2.3
Catalyst	kg	0.0006
Methylamine	kg	0.79
1,4-Butanediol	kg	0.636

Table S13 LCI of 1 kg Graphite.

Materials	Unit	Quantity
Electricity	kWh	0.53
Water	kg	0.67
Natural Gas	m ³	0.07219
Nitrogen	m ³	0.00000266
Asphalt	kg	0.05
Needle Coke	kg	1.24
Graphite (Raw)	kg	1.05

Table S14 LCI of 1 kg SiO.

Materials	Unit	Quantity
Water	kg	0.15
Natural Gas	m ³	0.000933
Nitrogen	m ³	0.00833
Silicon Dioxide Particles	kg	0.05
Silicon Particles	kg	0.05
Lubricating Oil	kg	0.000226
Graphite	kg	0.897
Acetylene	kg	0.00433

Table S15 LCI of 1 kg SBR.

Materials	Unit	Quantity
Water	kg	0.4686
Styrene	kg	0.2792
1,3-Butadiene	kg	0.1639
32% Liquid Caustic Soda	kg	0.0166
Acrylic Acid	kg	0.0162
48% N-(Hydroxymethyl)acrylamide Solution	kg	0.0099
CS-8 Starch	kg	0.0057
Emulsifier (DB-45)	kg	0.0051
Sodium Thiosulfate	kg	0.006
Butyl Acrylate	kg	0.004
Acrylamide	kg	0.0038
tert-Dodecyl Mercaptan	kg	0.0035
Sodium Persulfate	kg	0.003
Fatty Alcohol Surfactant	kg	0.0023
Emulsifier (AEO)	kg	0.0022
37% Formaldehyde	kg	0.0024
27.5% Hydrogen Peroxide	kg	0.0018
Ammonium Persulfate	kg	0.0015
Sodium Bicarbonate	kg	0.0012
Acetic Acid	kg	0.0007
Ferrous Sulfate	kg	0.0006
Sodium Bisulfite	kg	0.0006
Emulsifier (AMK)	kg	0.0008
Defoamer	kg	0.0008
Gemini Emulsifier	kg	0.0003
Molecular Weight Regulator	kg	0.0003
Emulsifier (No.203)	kg	0.0001

Table S16 LCI of 1 kg CMC.

Materials	Unit	Quantity
Electricity	kWh	2.5342
Steam	kg	14.27
Methyl Red	kg	0.00000000371
Refined Cotton Linter	kg	0.78
Sulfuric Acid	kg	0.00000351
Potassium Chloride	kg	0.00000742
Chloroacetic Acid	kg	0.62
Sodium Hydroxide	kg	0.00000295
Sodium Bicarbonate	kg	0.00000037
Bromothymol Blue	kg	0.00000019
Hydrochloric Acid	kg	0.01
Liquid Caustic Soda	kg	1.05
Ethanol	kg	0.04
Water	kg	14.7

Table S17 LCI of 1 kg LLTO.

Materials	Unit	Quantity
LLTO power	kg	0.2
Polyvinylpyrrolidone (PVP)	kg	0.001
N-Methylpyrrolidone (NMP)	kg	0.8

Table S18 LCI of 1 kg Copper Foil.

Materials	Unit	Quantity
Electricity	kWh	8.74
Water	t	10.07
Natural gas	m ³	0.11
Steam	kg	2.98
Chromic anhydride	kg	0.000332
Diatomaceous earth	kg	0.000666
Activated carbon	kg	0.00166
Collagen	kg	0.000373
Sulfuric acid	kg	0.0307
Charcoal	kg	0.00145
Emulsion	kg	0.00004
Lubricating oil	kg	0.0001
Graphite flakes	kg	0.00025
Copper	kg	1.1
PAC (Poly Aluminum Chloride)	kg	0.004
Nickel sulfate	kg	0.0006
Sodium hydroxide	kg	0.00396
Potassium pyrophosphate	kg	0.00645

Glucose	kg	0.00046
Gelatin	kg	0.00025

Table S19 LCI of 1 kg Aluminum Foil.

Materials	Unit	Quantity
Electricity	kWh	5.345
Water	kg	0.96
Diatomaceous Earth	kg	0.00632
Aluminum Substrate	kg	1.16
Cleaning Agent	kg	0.26
Lubricating Oil	kg	0.00108
Rolling Oil	kg	0.01
Stock Solution	kg	0.000064

Table S20 LCI of 1 m² Separator.

Materials	Unit	Quantity
Electricity	kWh	0.06
Water	kg	0.6996
Lubricating Oil	kg	0.0000006
Hydraulic Oil	kg	0.0000002
PP Resin	kg	0.0144
Packaging Material	kg	0.01

Table S21 LCI of 1 kg Electrolyte.

Materials	Unit	Quantity
Electricity (National Average)	kWh	1.19
Water	kg	0.205
Natural Gas	m ³	0.000325
Steam	kg	1.85
30% LiPF ₆ + 70% EMC Electrolyte Base	kg	0.06
Propyl Propionate	kg	0.00167
1,3-Propane Sultone (PS)	kg	0.0087
Purification Column Material	kg	0.00028
Lithium Difluorooxalatoborate (LiDFOB)	kg	0.000104
Lithium Difluorophosphate (LiPO ₂ F ₂)	kg	0.00418
Fluoroethylene Carbonate (FEC)	kg	0.0112
Ethanol	kg	0.000018
Triphenyl Phosphate (TPP)	kg	0.000208
Lithium Hexafluorophosphate (LiPF ₆)	kg	0.0502
Propylene Carbonate (PC)	kg	0.00125
Dimethyl Carbonate (DMC)	kg	0.147
Dimethyl Carbonate (LiPF ₆ -containing)	kg	0.219

Dimethyl Carbonate (LiFSI-containing)	kg	0.0734
Diethyl Carbonate (DEC)	kg	0.1
Ethyl Methyl Carbonate (EMC)	kg	0.118
Vinyl Carbonate (VC)	kg	0.0192
Ethylene Carbonate (EC)	kg	0.239
Ethyl Acetate (EA)	kg	0.0313
Ethyl Acetate (LiPF ₆ -containing)	kg	0.0417

Table S22 LCI of 1 pair Tabs.

Materials	Unit	Quantity
Electricity	kWh	0.21
Tab Adhesive	g	0.888
Aluminum Tab Strip	g	0.124
Nickel Tab Strip	g	0.124
CPP Tape	g	1.85

Table S23 LCI of 1 kWh Lithium Nickel Cobalt Manganese Oxide (NCM) battery.

Component	Material	Quantity	Unit
Anode	Artificial graphite	0.903	kg
	SBR	0.019	kg
	CMC	0.009	kg
	NMP	0.009	kg
	Deionized water	0.950	kg
	Copper foil	0.302	kg
Cathode	NCM material	1.403	kg
	CNT	0.014	kg
	PVDF	0.014	kg
	NMP	0.509	kg
	Aluminium foil	0.136	kg
Separator	PE	0.070	kg
	Al ₂ O ₃	0.032	kg
	PVDF	0.015	kg
Electrolyte solvent	EMC	0.452	kg
	EC	0.194	kg
	LiPF ₆	0.133	kg
Shell	Aluminium	0.298	kg

Supplementary Figures

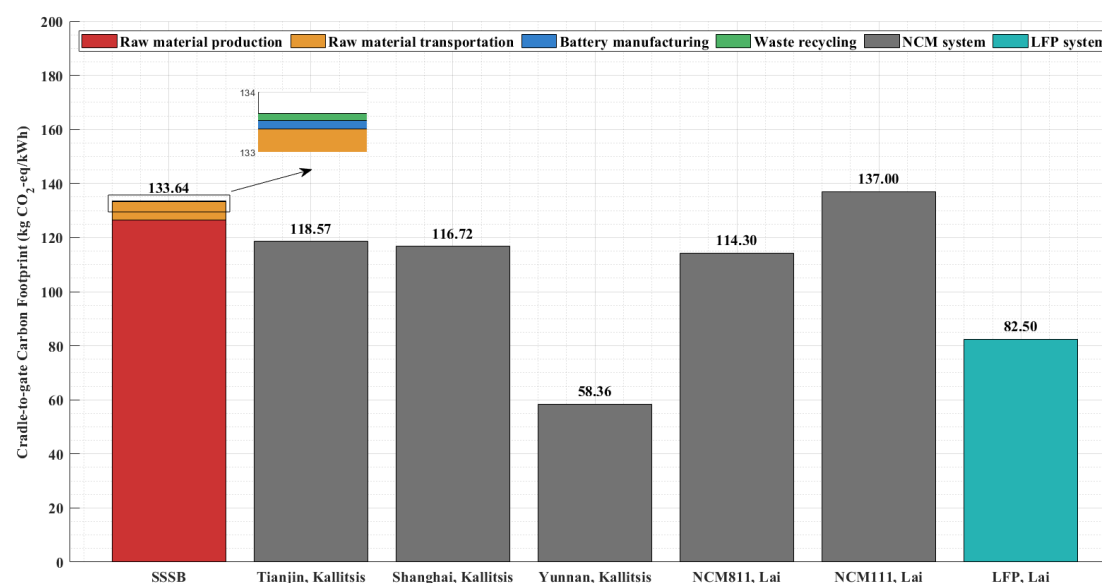


Fig. S1. Comparative analysis of cradle-to-gate total GWP between this semi-solid-state battery and representative domestic lithium-ion battery literature. Resource 1: Average CTG carbon footprints of NCM lithium batteries across multiple Chinese provinces ^[1]; Resource 2: Average CTG carbon footprints of commercial NCM811, NCM111 and LFP liquid lithium-ion batteries^[2].

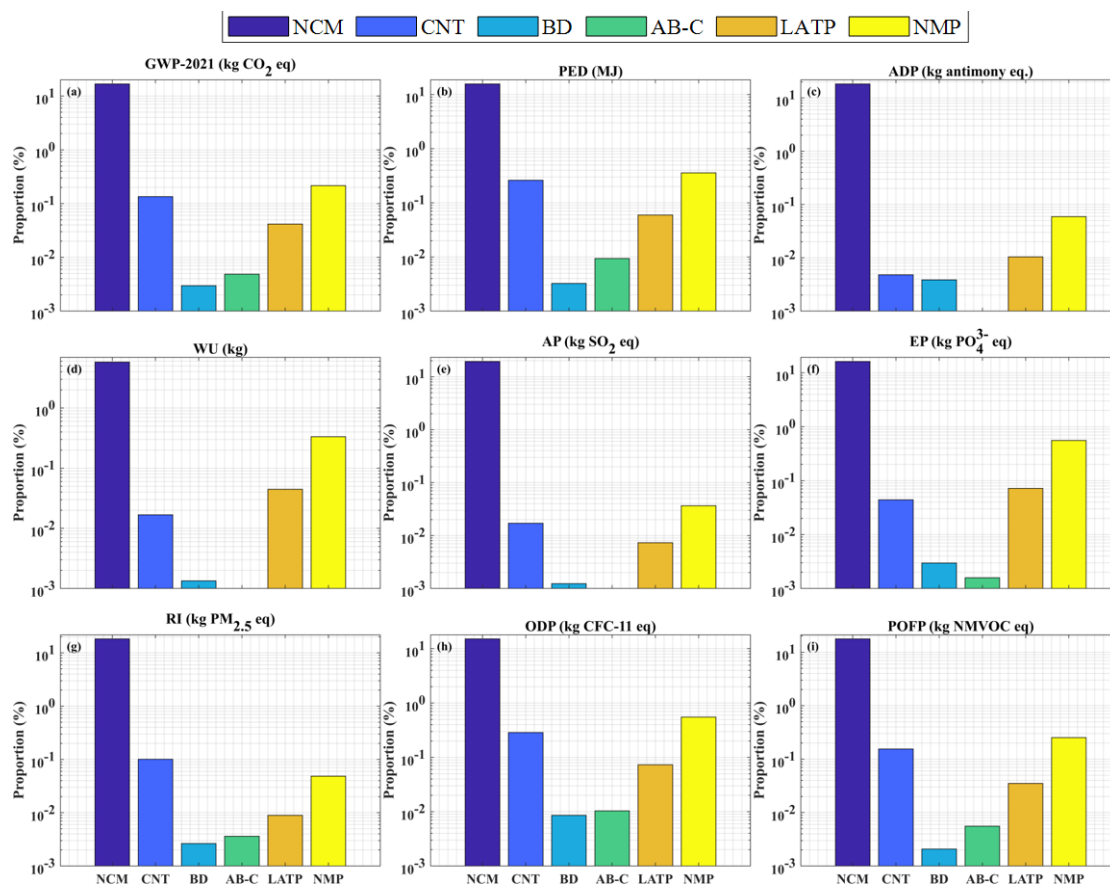


Fig. S2. Environmental impact sensitivity during the acquisition stage of SSSB cathode raw materials in 2024: (a) Global warming potential (GWP); (b) Primary energy demand (PED); (c) Abiotic depletion potential (ADP); (d) Water use (WU); (e) Acidification potential (AP); (f) Eutrophication potential (EP); (g) Respiratory impact (RI); (h) Ozone depletion potential (ODP); (i) Photochemical ozone formation potential (POFP). Abbreviations: Nickel Cobalt Manganese Ternary Oxide (NCM); Carbon Nanotubes (CNT); Binder (BD); Cathode Acetylene Black (AB-C); Lithium Aluminum Titanium Phosphate Slurry (LATP); Cathode Solvent (N-Methyl-2-pyrrolidone) (NMP).

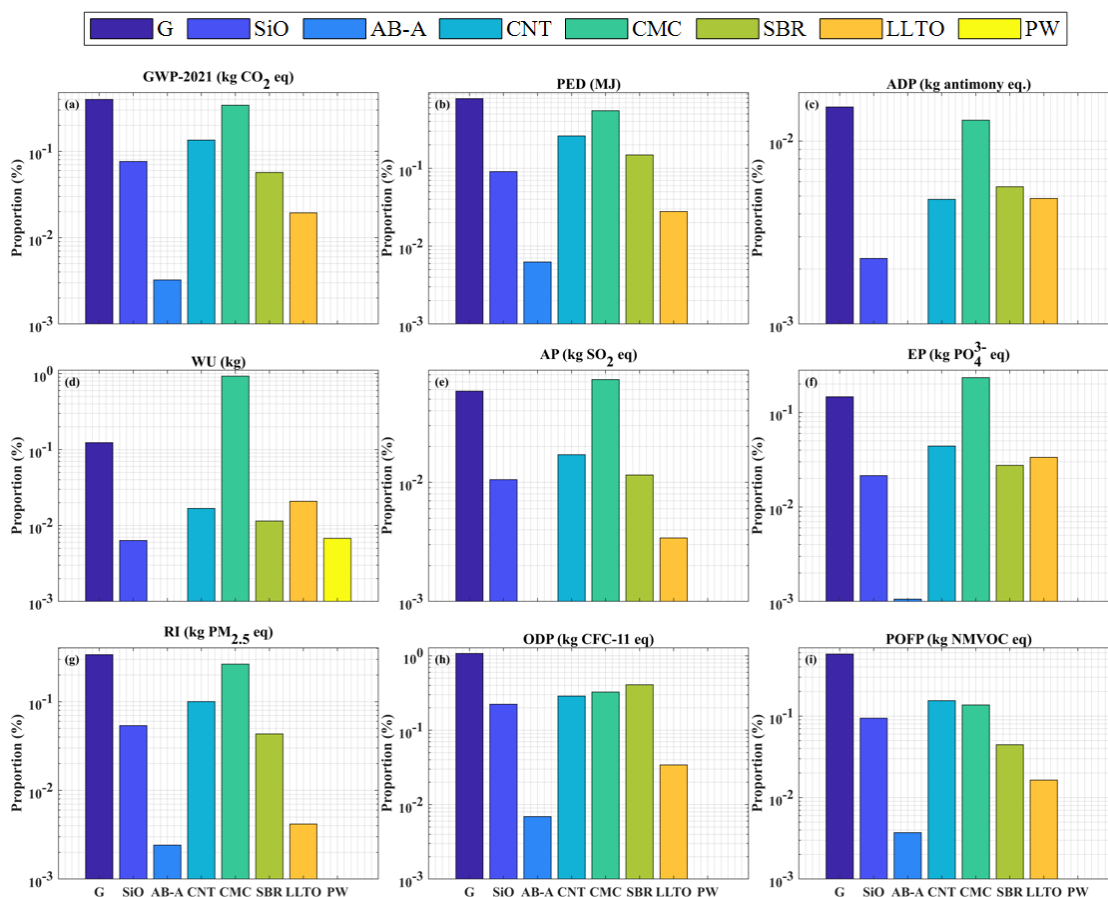


Fig. S3. Environmental impact sensitivity during the acquisition stage of SSSB anode raw materials in 2024. Abbreviations: Graphite (G); Silicon Oxide (SiO); Anode Acetylene Black (AB-A); Anode Binder (Carboxymethyl Cellulose) (CMC); Anode Binder (Styrene Butadiene Rubber) (SBR); Lithium Lanthanum Titanium Oxide Slurry (LLTO); Pure Water (PW).

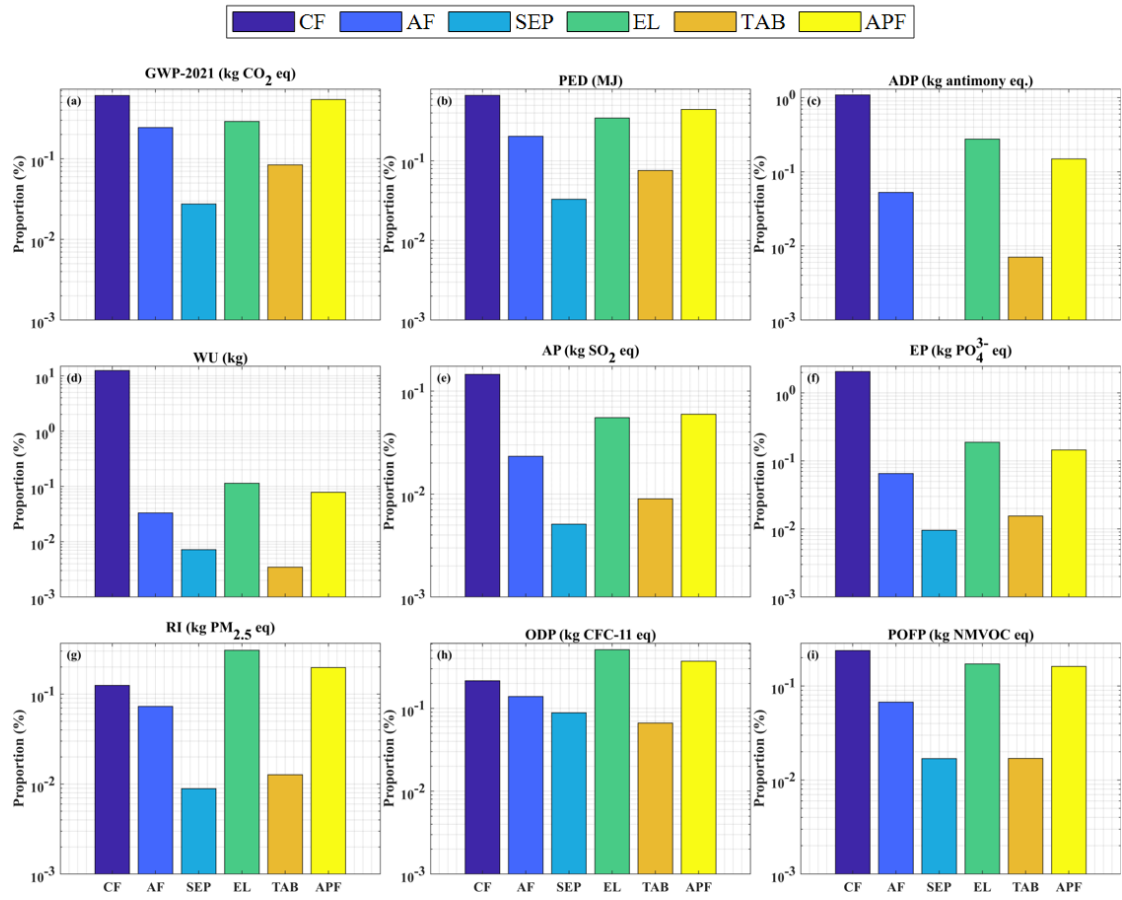


Fig. S4. Environmental impact sensitivity during the acquisition stage of SSSB other raw materials in 2024. Abbreviations: Copper Foil (CF); Aluminum Foil (AF); Separator (SEP); Electrolyte (EL); Battery Tab (TAB); Aluminum Plastic Laminated Film (APF).

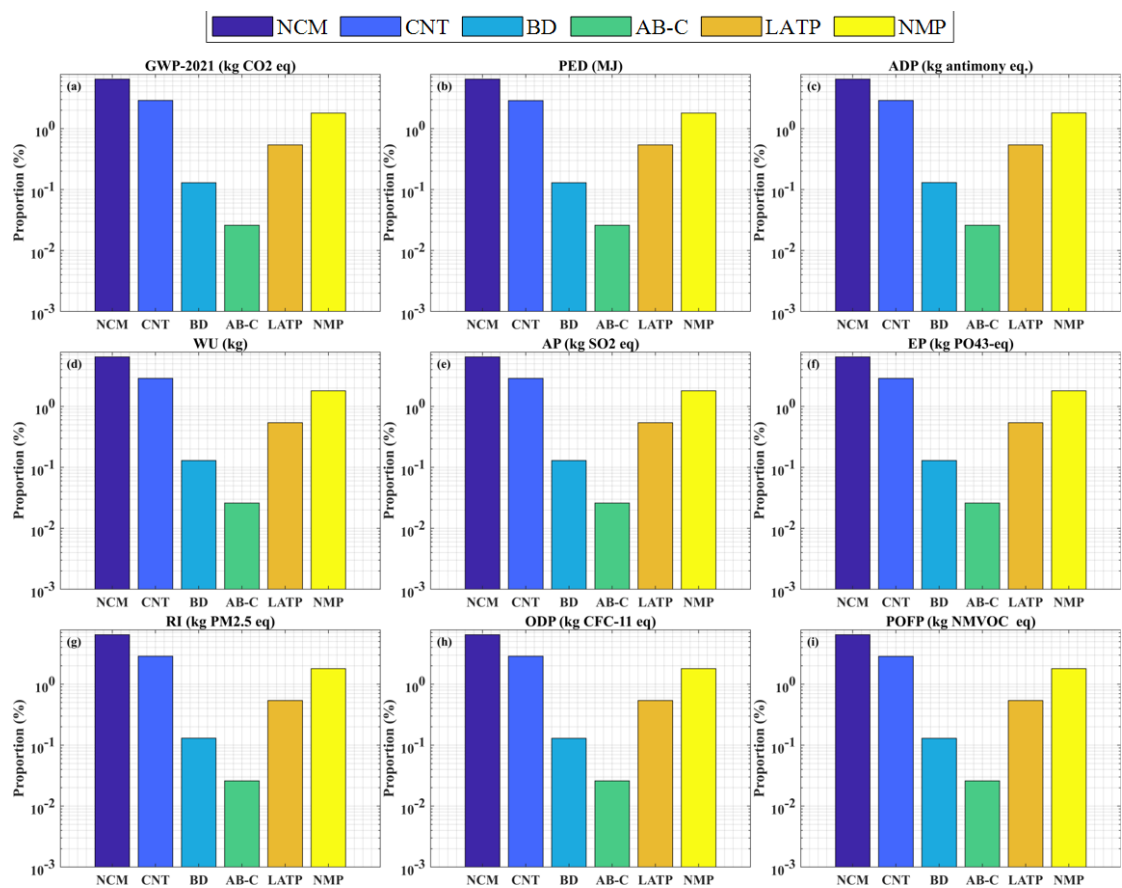


Fig. S5. Environmental impact sensitivity during the transportation stage of SSSB cathode materials in 2024.

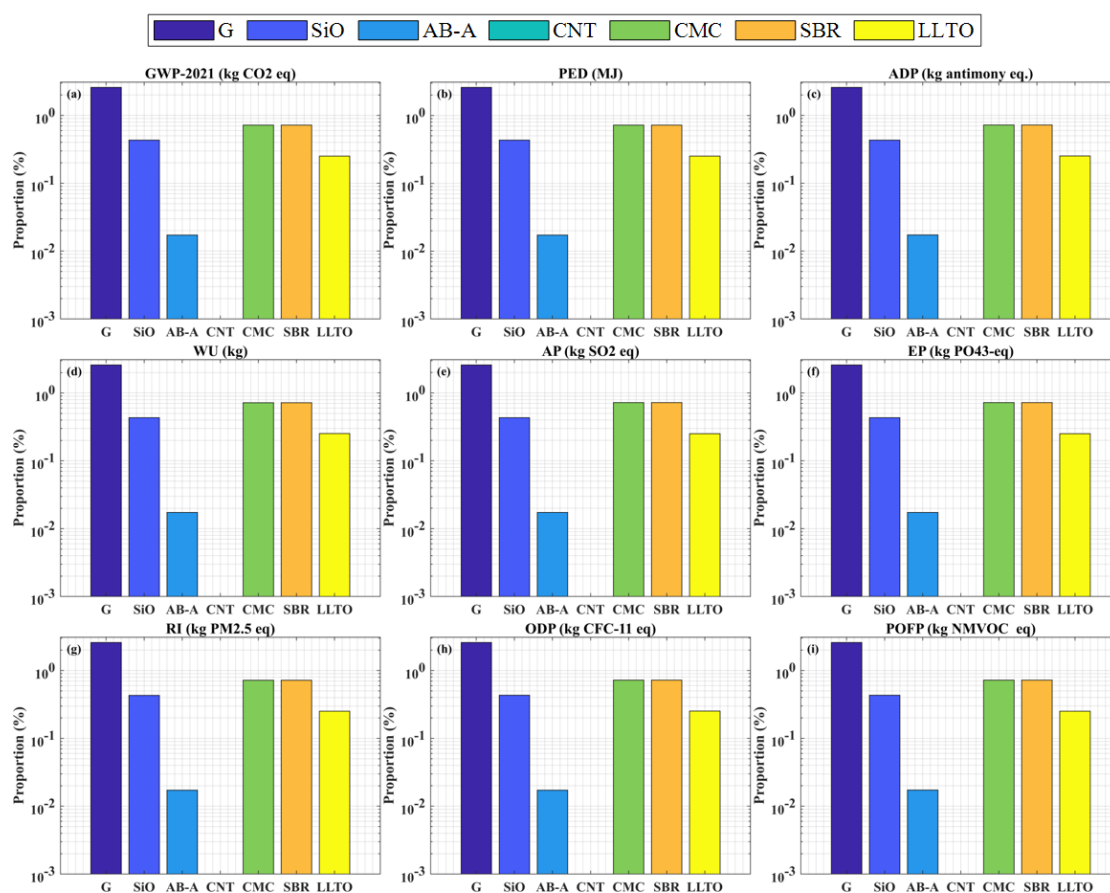


Fig. S6. Environmental impact sensitivity during the transportation stage of SSSB anode materials in 2024.

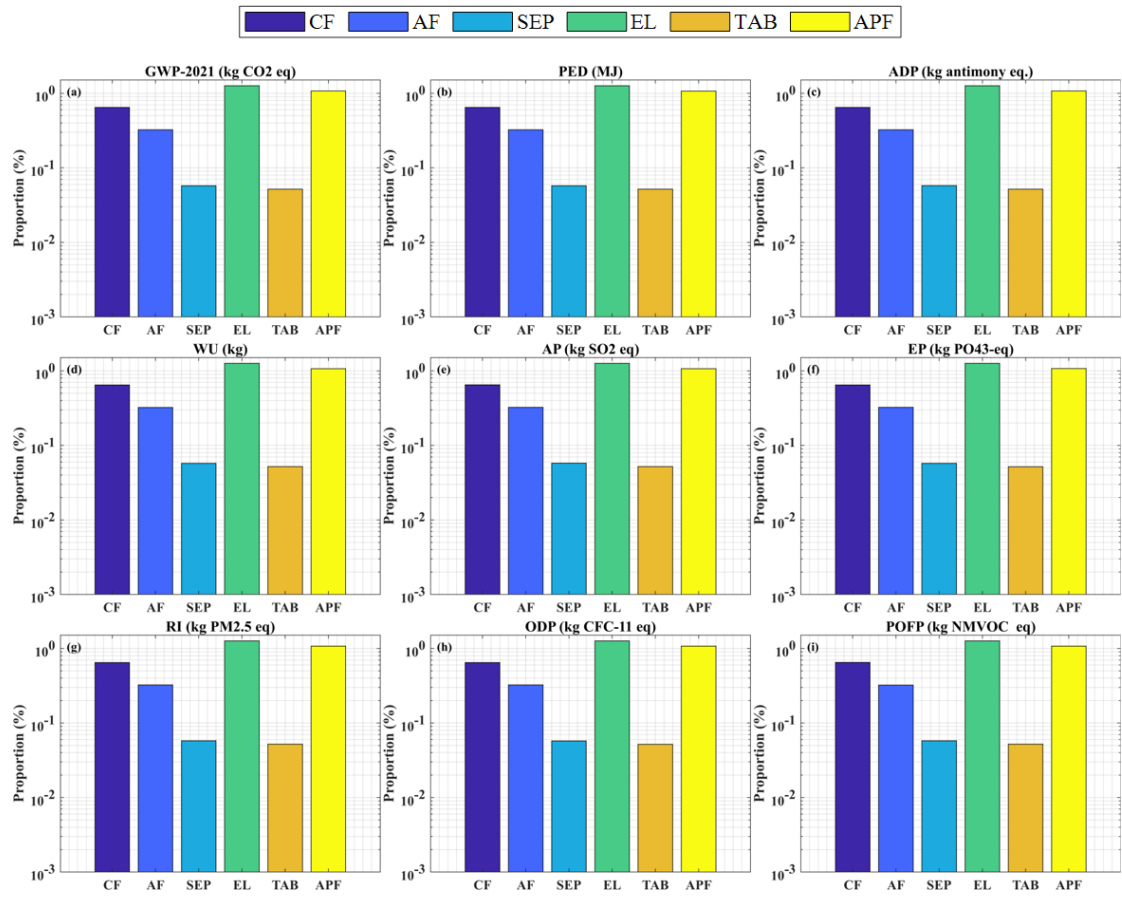


Fig. S7. Environmental impact sensitivity during the transportation stage of SSSB other materials in 2024.

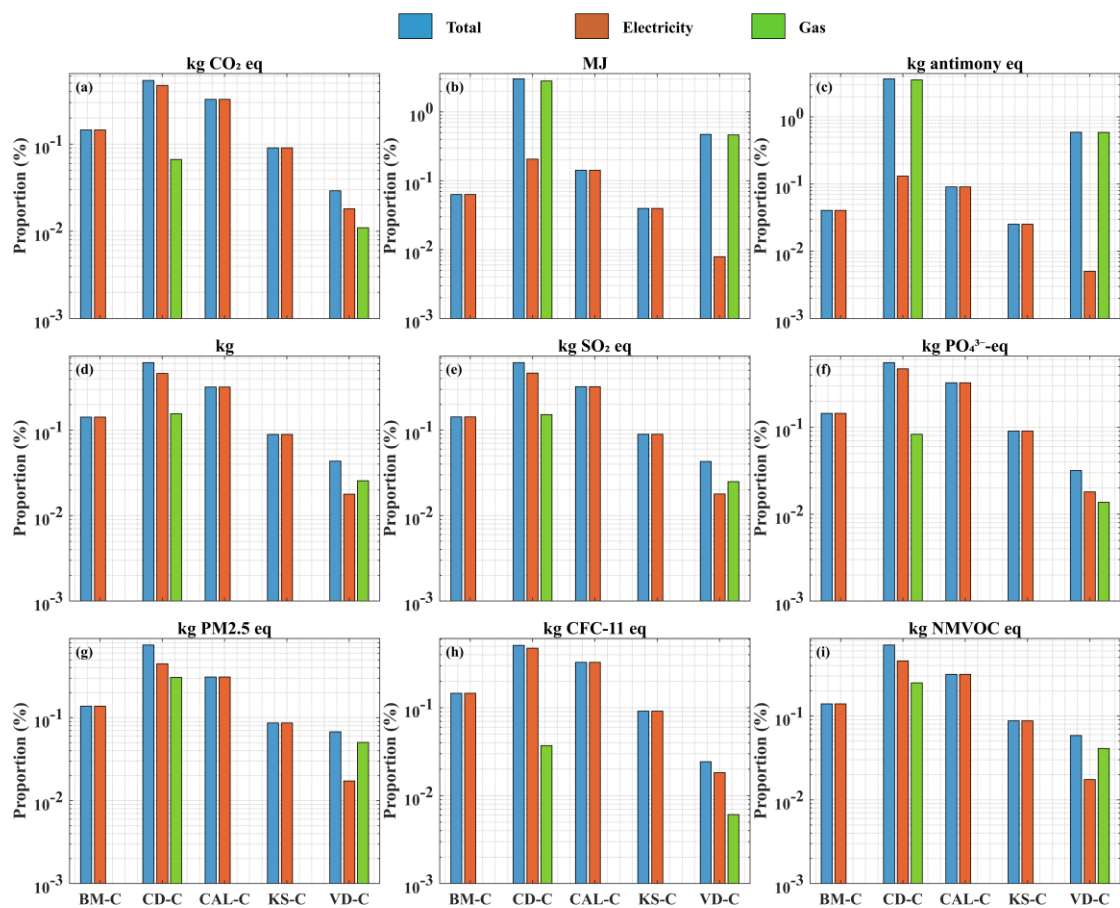


Fig. S8. Environmental impact sensitivity during the manufacturing stage of SSSB cathode electrode in 2024. Abbreviations: BM-C (Batch mixing, Cathode); CD-C (Coating & drying, Cathode); CAL-C (Calendering, Cathode); KS-C (Knife slitting, Cathode); VD-C (Vacuum drying, Cathode).

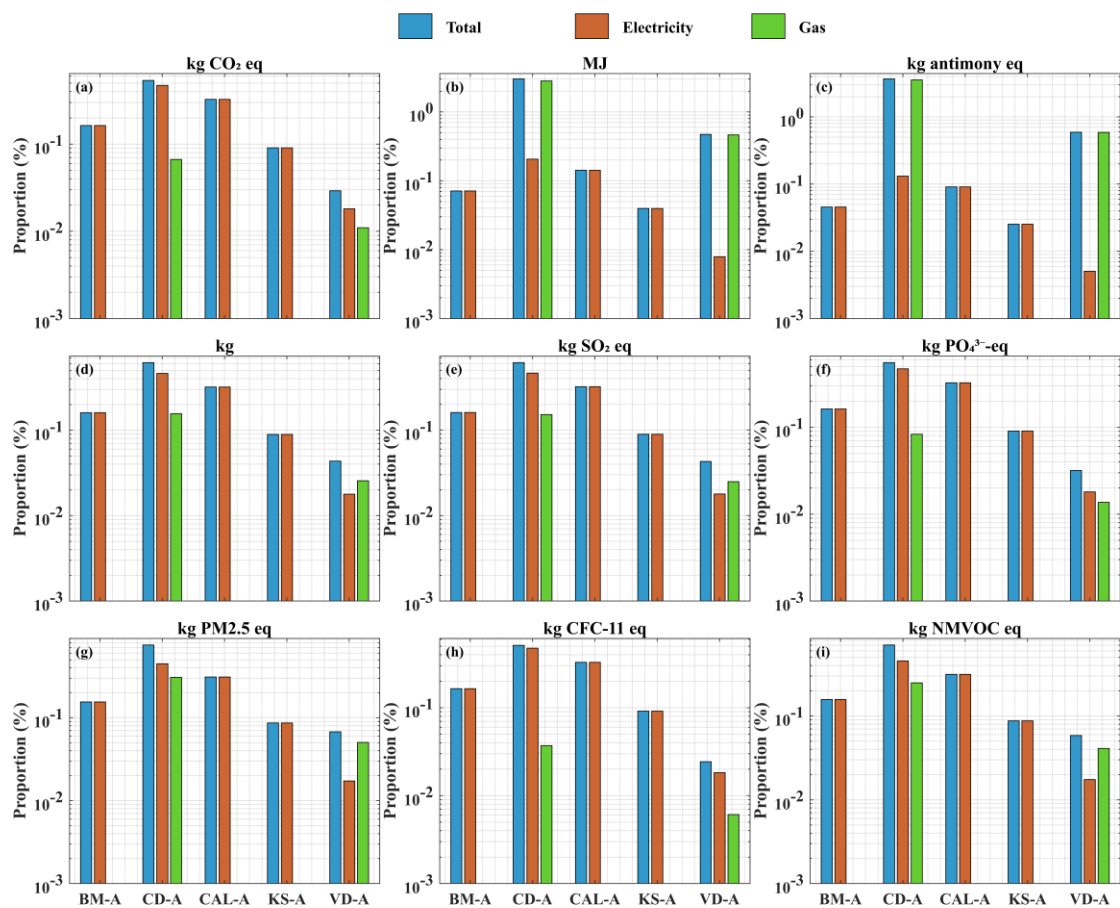


Fig. S9. Environmental impact sensitivity during the manufacturing stage of SSSB anode electrode in 2024. Abbreviations: BM-A (Batch mixing, Anode); CD-A (Coating & drying, Anode); CAL-A (Calendering, Anode); KS-A (Knife slitting, Anode); VD-A (Vacuum drying, Anode).

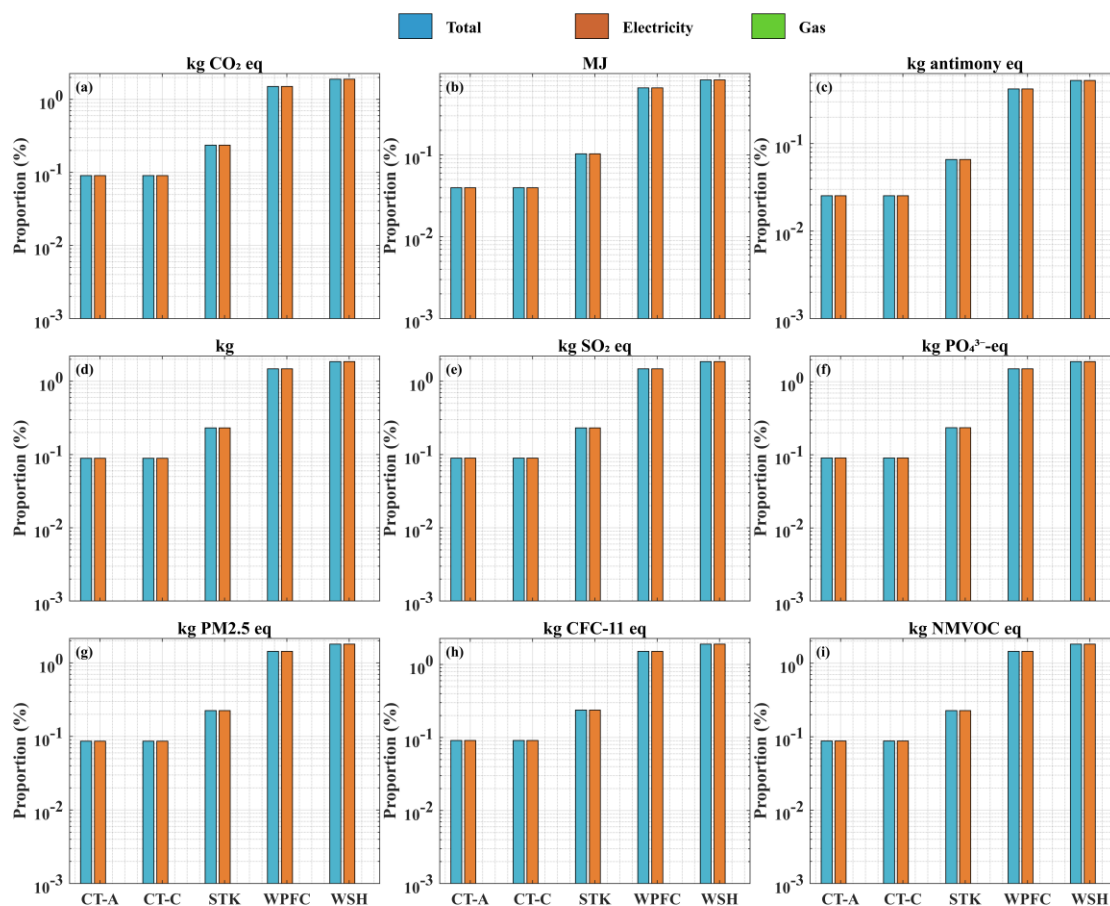


Fig. S10. Environmental impact sensitivity during the manufacturing stage of SSSB assembly in 2024. Abbreviations: CT-A (Cutting, Anode); CT-C (Cutting, Cathode); STK (Stacking); WPFC (Welding, Packaging, Filling, Closing); WSH (Washing).

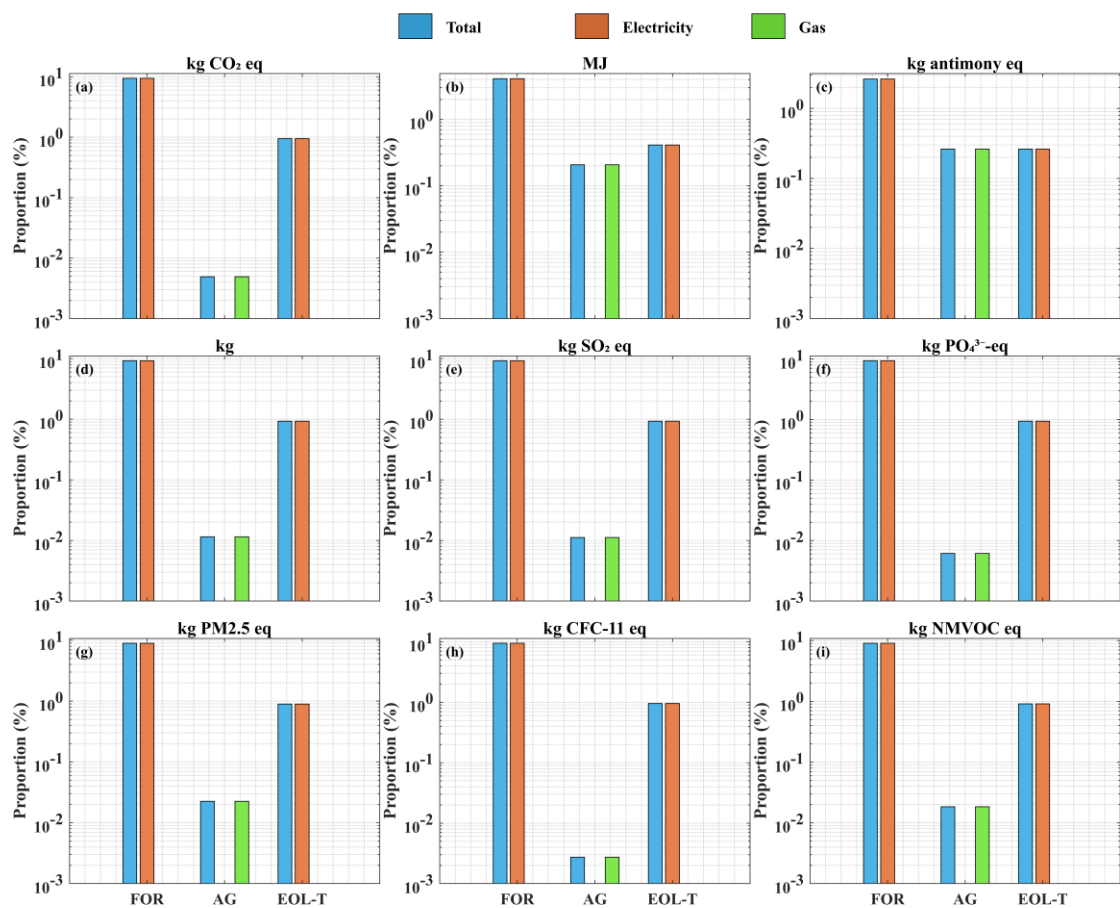


Fig. S11. Environmental impact sensitivity during the formation & aging stage of SSSB assembly in 2024. Abbreviations: FOR (Formation); AG (Aging); EOL-T (EOL testing).

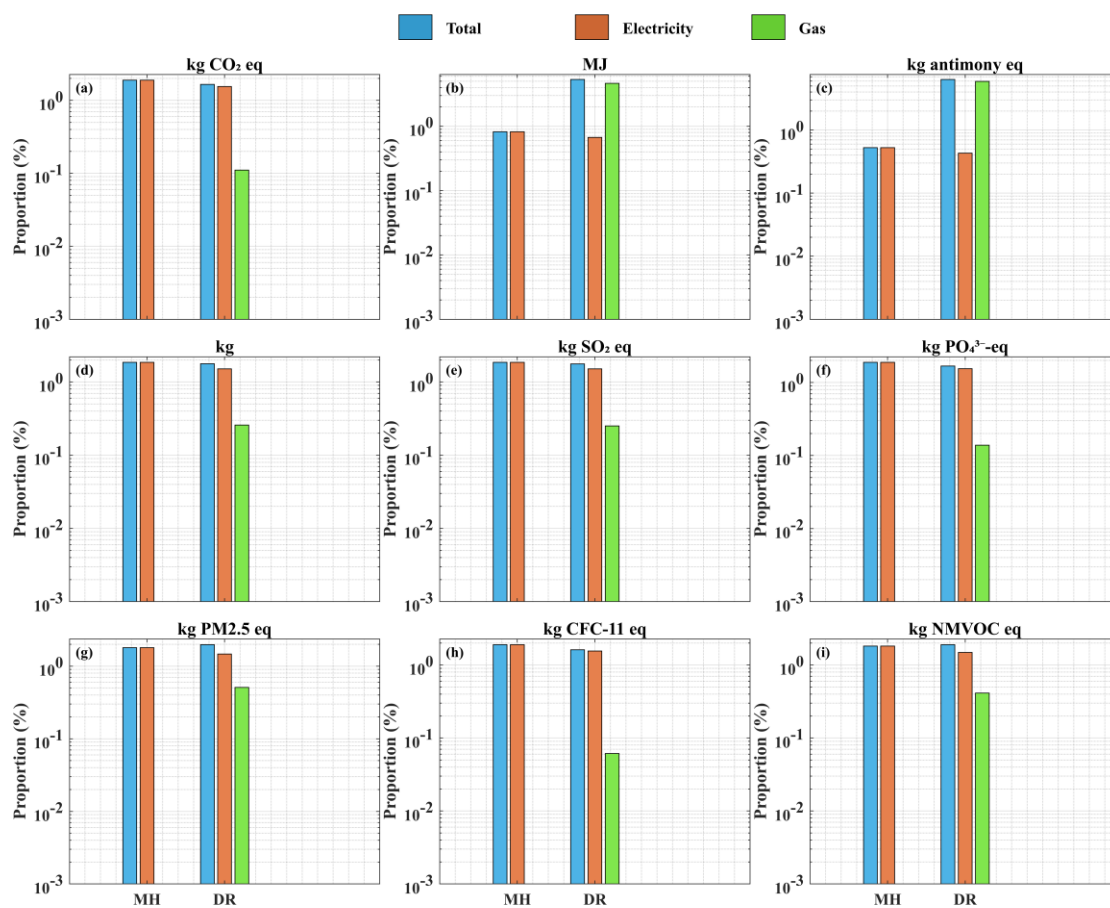


Fig. S12. Environmental impact sensitivity during the manufacturing stage of SSSB miscellaneous assembly in 2024. Abbreviations: MH (Material handling); DR (Dry Rooms).

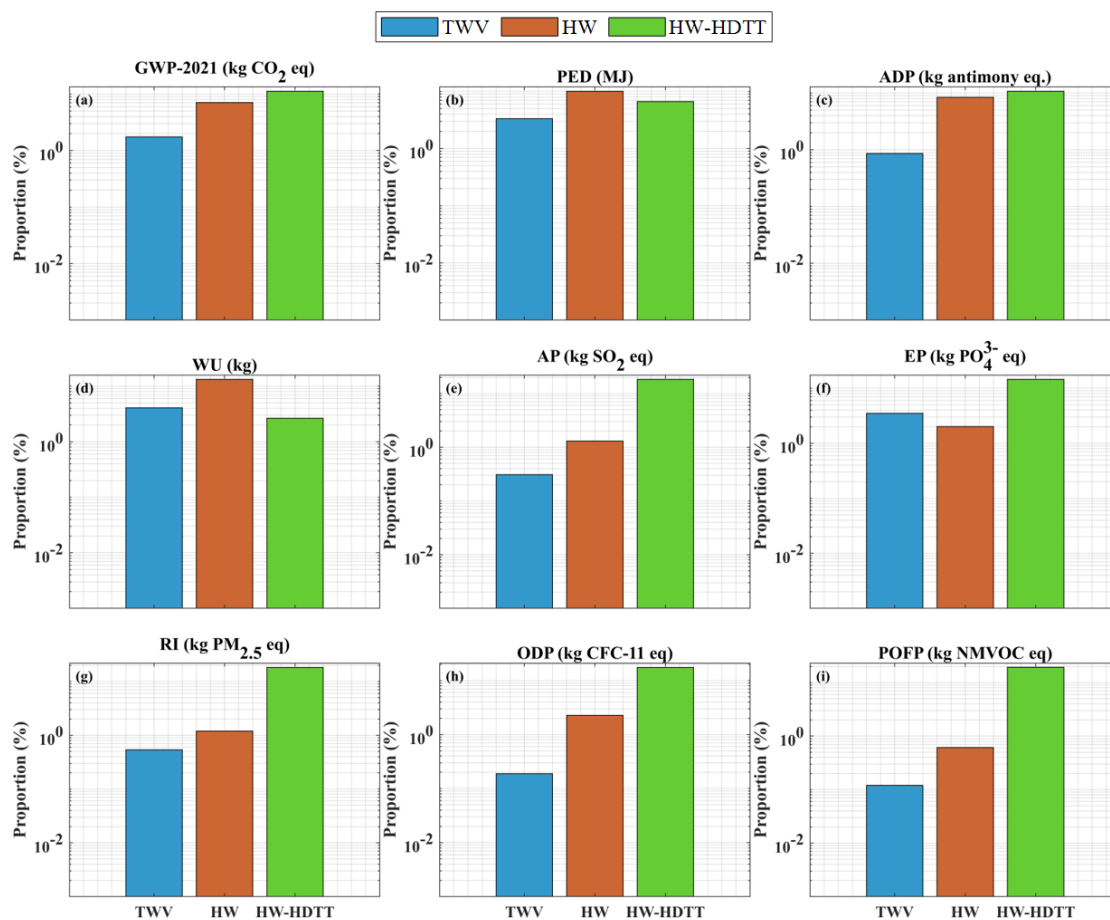


Fig. S13. Environmental impact sensitivity during the disposal stage of SSSB in 2024.

Abbreviations: Total Wastewater Volume (TWV); Hazardous Waste (HW); Hazardous Waste - 18t Heavy-duty Diesel Truck Transportation - China (HW-HD TT).

1. Kallitsis E, Korre A, Kelsall GH. Life cycle assessment of recycling options for automotive Li-ion battery packs. *Journal of Cleaner Production*. 2022;371. <http://dx.doi.org/10.1016/j.jclepro.2022.133636>
2. Lai X, Gu HH, Chen QW, Tang XP, Zhou YQ, Gao FR, et al. Investigating greenhouse gas emissions and environmental impacts from the production of lithium-ion batteries in China. *JOURNAL OF CLEANER PRODUCTION*. 2022;372. <http://dx.doi.org/10.1016/j.jclepro.2022.133756>