

Supplementary Materials

Life cycle carbon footprint of battery electric bus: coupling effects of mileage, energy mix and recycling processes

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Table S1. Material components and proportion of bus body

Vehicle body materials	Proportion (%)
steel	66.85
plastic	19.7
rubber	0.45
Cu	1.89
glass	6.49
paint	1.91
organic compound	1.91
forged aluminum	0.74
Mg	0.04
Zn	0.02
total mass (kg)	4950

Table S2. Material components and weight of bus chassis

Component name	Material	Weight (kg)
drive system	100% steel	813.73
Suspension system	100% steel	449.37
braking system	60%Fe, 35% steel, 5% friction material	419.22
frame	100% steel	329.60
wheel(4.5 , spare =0.5)	100% steel	454.40
tyre(4.5 , spare =0.5)	67% rubber, 33% steel	449.37
steering system	80% steel, 15% forged aluminum, 5% rubber	244.58
chassis electrical appliances	59% plastic, 41%Cu	109.73
Controllor/inverter	5.0% steel, 47% forged aluminum, 8.2%Cu, 3.7% rubber, 23.8% plastic, 12.3% organic compound	533.97
welding blanks and fasteners	100% steel	109.73
total mass(kg)	——	3913.69

Table S3. Liquid composition and weight of passenger cars

Component	Weight (kg)
propylene glycol	0.34
epoxypropane	0.91
ethylene glycol	35.24
benzoic acid	0.13
lubricating oil base oil	24.11
additive	1.27
water	32.70
alcohol	6.62
epoxy resin	73.50
total	175

Table S4. Composition and proportion of balancing device

Component	proportion(%)	Weight (kg)
steel	60.00	578.40
forged aluminum	18.00	173.52
Cu	10.40	100.26
plastic	9.40	90.62
rubber	1.60	15.42
others	0.60	5.78
total	100	964

Table S5. Inventory analysis of battery system N5

Large module form - battery system N5	part Name	Material quality	Brand	Weight (kg)
others	box frame	Al	6061-T6	166.78
	liquid cooling plate	Al	3003-4045	82.69
	box bottom protection plate	carbon steel	HC340/590DP	112.29
	box cover	Al	5754	45.81
	thermal conductive adhesive	silica gel	silica gel	21.14
	copper busbar assembly	Cu	T2	19.92
	low voltage wiring harness	Cu	copper wire+fabric tape	8.46
	high voltage connectors	Cu	plastic +T2	2.49
	explosion proof valve	Al	Main material 5 series Al	1.88
	fasteners	carbon steel	carbon steel	5.64
	control board	Cu+ Resin +SiO2	chip integration	5.17
module 1P22S	end plate	Al	6063 T6	56.94
	end insulation cover	PC+MPP	PC+ MPP	2.04
	output pole base	PBT+ Fiberglass	PBT-GF30	2.26
	middle side panel	Al	5083	24.07
	outer side panel	Al	AL5083	25.82
	output pole	PP+ Fiberglass	PP-GF20	0.34

	protection cover			
	Lithium iron phosphate battery cell A			1395.35
	mouth frame rubber pad	rubber	SR60-A	7.05
	rivet	nylon	PA66	0.02
	blister cover	PC	PC	4.68
	bottom insulation film	PC	PC	1.63
	wire harness	PC	PC	13.62
	isolation board			
	connecting aluminum bars	Al	1060 O	16.35
	output pole aluminum bar	Al	1060 H	1.47
	output pole copper bar	Cu	T2 Y2	2.71
	FPC	plastic	plastic	1.30
BDU	housing	PBT	PBT	9.40
	copper bar	Cu	T2	8.79
	fasteners	carbon steel	carbon steel	0.94
	relay components	Plastic+chip+metal	Plastic+chip+metal	18.70
total	N5 shell	——	——	2065.71

Table S6. Inventory analysis of battery system N6

Large module	Part name	Material	Brand	Weight (kg)
form - battery system N6				
Others	box frame	Al	6061-T6	108.84
	liquid cooling plate	Al	3003-4045	55.56
	box bottom	carbon steel	HC340/590DP	62.03
	protection plate			
	box cover	carbon steel	HC340/590DP	57.84
	thermal	silica gel	silica gel	15.22
	conductive			
	adhesive			
	copper busbar	Cu	T2	11.42
	assembly			
	low voltage	Cu	Copper	5.71
	wiring harness		wire+fabric tape	
	high voltage	Cu	plastic+T2	1.01
	connectors			
	explosion proof	Al	main material 5	0.65
	valve		series AL	
	fastener	carbon steel	carbon steel	5.71
	control board	Cu+resin+SiO2	chip integration	6.09
	mica board	mica	——	26.64
	end plate	Al	6063 T6	28.92
	end insulation	PC+MPP	PC+MPP	0.57
	cover			
	output pole base	PBT+fiberglass	PBT-GF30	0.76
	Steel straps	stainless steel		14.77
	output pole	PP+fiberglass	PP-GF20	0.23
	protection cover			
	cell D	NCM	——	1048.03

	rubber frame	EPDM	——	3.81
	insulation pad	SiO2	——	12.18
		aerogel+glass		
		fiber		
	rivet	nylon	PA66	0.11
	upper cover	PC	PC+MPP	2.39
	wire harness	PC	PC	2.44
	isolation board			
	connecting	Al	1060 O	9.89
	aluminum bars			
	output pole	Al	1060 H	1.14
	aluminum bar			
	output pole	Cu	T2 Y2	1.90
	copper bar			
	FPC	plastic	plastic	0.95
BDU	housing	PBT	PBT	4.57
	copper bar	Cu	T2	5.71
	fasteners	carbon steel	carbon steel	0.76
	relay components	plastic+chip+metal	plastic+chip+metal	9.89
total	——	——	——	1505.73

Table S7. Energy Consumption for manufacturing and assembly of driving motor^[82]

Component name	Electric energy (kWh/kg)	Heat energy (kWh/kg)
stator winding	1.67	0.57
core	0.18	—
stator manufacturing	0.48	—
motor shaft	1.36	—
permanent magnet rotor	2.05	1.43
motor housing and base	1.16	0.59
motor assembly	0.17	—

Table S8. Energy consumption of body parts during manufacturing and assembly

Component name	Electric energy (kWh/kg)
car door	0.55
vehicle exterior decoration	1.85
decorative and barrier components	0.84
automotive internal electrical appliances	1.26
air conditioning system	0.18
car light	1.23
white body	1.64
vehicle body assembly	0.21

Table S9. Energy consumption data of vehicle assembly stage

	Applicati on	air conditioning system and lighting	heating material handling	welding workshop compressed air
Electric energy	2.72	2.18	— 0.45	0.61 0.9
MJ/kg				
Heat				
energy			2.03	
MJ/kg				

Table S10. Production list of carbon fiber composites^[84]

Input materials	Unit	Weight
acrylonitrile	kg	1.225
vinyl acetate	kg	0.112
steam	kg	21.98
electric energy	kWh	41.83
water	kg	1.94
sulphuric acid	kg	0.014
natural gas	MJ	177.8
original carbon fiber	kg	0.7
epoxy resin	kg	0.3
output materials		
CFRP	kg	1

Table S11. Metal recovery efficiency and energy consumption per kg

Energy	Cu^[92]	Fe^[93]	Al	Steel^[94]
Coal (kg)	—	0.31	—	—
Gasoline (kg)	—	—	4.85E-05	—
diesel oil (kg)	—	—	3.08E-05	—
electric power (kWh)	2.65	0.62	0.22	1.18
natural gas (m3)	—	—	0.05	6.60E-03
recycling efficiency	90%	80%	85%	85%

Table S12. Recovery list of 1kg CFRP

Input materials	Unit	Weight
waste CFRP	kg	1.0E+00
stainless steel	kg	3.4E-02
Al	kg	3.1E-03
Cu	kg	1.6E-03
tap water	kg	4.0E-01
electric energy	kWh	1.4E+01
n-butanol	kg	8.1E+00
KOH	kg	2.8E-02
aluminum silicate cotton	kg	3.6E-04
output materials		
original carbon fiber	kg	7.0E-01

Table S13. Recycling list of LFP battery

Category	Material name	Unit	Weight
Raw material	Used LFP power batteries	kg	1.00
	liquid nitrogen	kg	3.72
	DMC solvent	kg	0.18
	Lithium carbonate glucose	kg	0.02
	NaClO	kg	0.05
	water	kg	0.19
		kg	2.45
Energy	electric energy	kWh	3.75
Recycled substances	aluminum foil	kg	0.25
	Copper foil	kg	0.08
	FePO ₄	kg	0.20
	Li ₂ CO ₃	kg	0.033
	NaCl	kg	0.14

Table S14. Recycling list of NMC battery

Category	name	Unit	Weight
raw material	Waste NMC power batteries	kg	1.00
	H ₂ SO ₄	kg	x
	HCl	kg	0.04
	NaOH	kg	1.87
	Na ₂ CO ₃	kg	0.02
	ammonia	kg	0.11
	P507	kg	0.00
	kerosene	kg	0.01
	H ₂ O ₂	kg	0.37
	Industrial water use	ton	0.01
	Lithium carbonate	kg	0.12
	tea polyphenols	kg	0.12
energy	electric energy	kWh	2.33
	natural gas	m ³	0.28
Recycled substances	Cu foil	kg	0.10
	Al foil	kg	0.06
	Ni ion	%	93.63
	Mn ion	%	98.54
	Co ion	%	94.97
	Li ion	%	67.74