

Supplementary Information

Energy, greenhouse gas, and water life cycle analysis of synthetic graphite anode production in the United States

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S1. Life cycle inventory data of calcined petroleum coke

The life cycle inventory data for calcined petroleum coke (CPC) was obtained from Edwards et al.¹ This study provides detailed material and energy requirements, as well as output streams, for an industrial coke calciner operated by Rain Carbon. The data, based on the production of one kg of CPC, is presented in Table S1. It is important to note that the reported thermal energy was converted to natural gas consumption, assuming an energy efficiency of 85%.

Table S1. Material and energy requirements and output streams of CPC production¹.

Category	Item	Flow
Material inputs	Green Petroleum Coke	1.346 kg
	Hydrated Lime	0.040 kg
	Dedusting oil	0.002 kg
	Process water	0.988 L
Energy inputs	Natural gas	0.014 kWh
	Electricity	0.101 kWh
Output streams	CPC	1.000 kg
	Electricity	0.613 kWh
	Sulfated lime	0.063 kg
Non-combustion emissions	CO ₂	0.723 kg
	SO _x	0.289 g

The data in Table S1 were further processed to account for allocation factors associated with the coproducts generated from the calcination process. First, the process water used is assumed to be discarded rather than recovered, and it is included in the water consumption estimates of the process. Also, according to Edwards et al.¹, sulfated lime is supplied to a local brick factory to avoid landfilling. As such, sulfated lime was treated as a waste residue and excluded from the allocation. However, the electricity generated from the process was exported to the local grid and was therefore included in the allocation estimations. Market-value allocation was selected as the method for distributing impacts between CPC and electricity. The price of CPC was set at 413.3 USD/tonne, based on the average value from the range reported by Jinsun Carbon for CPC in the United States². For electricity, a price of 112.7 USD/MWh was used, base on the average cost of commercial electricity in the United States between 2015 and 2024, as reported by the U.S. Energy Information administration³. Using these prices and the quantities of CPC and electricity produced, a market-value allocation factor for CPC of 0.857 was estimated. This allocation factor was applied to the material and energy inputs, as well as non-combustion emissions, to determine the life cycle inventory (LCI) data after allocation. These adjusted data was then implemented in R&D GREET 2023 to estimate

the corresponding environmental impacts. Degusting oil, which comprises less than 1% of the material inputs, was considered negligible and excluded from the LCI data. The final LCI data for CPC is presented in Table S2.

Table S2. Life cycle inventory data, after allocation, for one kg of CPC.

Category	Item	Flow
Material inputs	Green petroleum coke	1.153 kg
	Hydrated lime	0.034 kg
	Water consumption	0.847 L
Energy inputs	Natural gas	0.012 kWh
	Electricity	0.086 kWh
Product	CPC	1.000 kg
Non-combustion emissions	CO ₂	0.620 kg
	SO _x	0.248 g

S2. Life cycle inventory data of Synthetic graphite (SG) battery anode material (BAM)

Table S3 provides a summary of the material and energy inputs, along with the output streams, of the various stages of The SG BAM process.

Table S3. Material and energy requirements and outputs streams of the SG BAM production process

Stage	Category	Item	Flow		Source
Milling	Material input	Calcined coke	2.029	kg	Carrere et al. ⁴
	Energy inputs	Natural gas	0.334	kWh	Carrere et al. ⁴
		Electricity	3.043	kWh	Carrere et al. ⁴
	Output streams	Coke fines	0.406	kg	Carrere et al. ⁴
		Ground coke	1.623	kg	Carrere et al. ⁴
Crucible manufacturing	Material input	Graphite block	1.490	kg	Carrere et al. ⁴
	Output streams	Crucible chips	1.057	kg	Data estimated from crucible yield from graphite block
		Crucible	0.433	kg	Data estimated from crucible yield from graphite block
Graphitization	Material inputs	Ground coke	1.623	kg	Carrere et al. ⁴
		Metallurgical coke	0.791	kg	Carrere et al. ⁴
		Crucible	0.433	kg	Carrere et al. ⁴
	Energy input	Electricity	25.916	kWh	Carrere et al. ⁴
	Output streams	Packing media losses to air	0.372	kg	Updated calculations based on discussions with Tokai COBEX ⁵
		Used packing media	0.419	kg	Carrere et al. ⁴
		Used crucible	0.432	kg	Carrere et al. ⁴
		Graphite powder	1.620	kg	Carrere et al. ⁴
Micronizing/Spheroidizing	Material input	Graphite powder	1.620	kg	Carrere et al. ⁴
	Energy inputs	Natural gas	0.267	kWh	Carrere et al. ⁴
		Electricity	3.240	kWh	Carrere et al. ⁴
	Output streams	Graphite fines	0.667	kg	Carrere et al. ⁴
		Micronized graphite powder	0.972	kg	Carrere et al. ⁴
Coating (Kneading)	Material inputs	Micronized graphite powder	0.972	kg	Carrere et al. ⁴
		Coal tar pitch (CTP)	0.051	kg	Carrere et al. ⁴
	Energy input	Electricity	0.170	kWh	Carrere et al. ⁴
	Output stream	CTP-coated BAM	1.023	kg	Carrere et al. ⁴
Coating (Thermal treatment)	Material input	CTP-coated BAM	1.023	kg	Carrere et al. ⁴
	Energy inputs	Natural gas	2.149	kWh	Carrere et al. ⁴
		Electricity	0.212	kWh	Carrere et al. ⁴
	Output streams	Coating losses to air	0.023	kg	Updated calculations based on discussions with Tokai COBEX ⁵
		Coated BAM	1.000	kg	Carrere et al. ⁴
Packaging	Material inputs	Coated BAM	1.000	kg	Carrere et al. ⁴
		Cardboard	0.020	kg	Carrere et al. ⁴

		Pallet	0.020	kg	Carrere et al. ⁴
		Big bag	0.001	kg	Carrere et al. ⁴
	Energy inputs	Natural gas	0.031	kWh	Carrere et al. ⁴
		Electricity	0.047	kWh	Carrere et al. ⁴
	Output stream	Packed coated BAM	1.000	kg	Carrere et al. ⁴

References

- 1 L. Edwards, M. Hunt, P. Verma, P. Weyell and J. Koop, CB05-Sustainable CPC Production at the Vizag Calciner, *raincarbon.com*, 2020, 16–18.
- 2 Jinsun Carbon, Petroleum Coke Price Overview, https://jinsuncarbon.com/petroleum-coke-price/#Latest_Price_Updates_for_Calcined_Petroleum_Coke, (accessed 27 August 2025).
- 3 US Energy Information Administration, Electric Power Monthly. Table 5.3. Average Price of Electricity to Ultimate Customers, https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_3, (accessed 27 August 2025).
- 4 T. Carrère, U. Khalid, M. Baumann, M. Bouzidi and B. Allard, Carbon footprint assessment of manufacturing of synthetic graphite battery anode material for electric mobility applications, *J Energy Storage*, 2024, **94**, 112356.
- 5 T. Carrère, *Personal communication with TOKAI COBEX*, 2024.