Tackling Climate Change with Machine Learning

Parakeet: Emission Factor Recommendation for Carbon Footprinting with Generative AI*

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* The methods discussed are for research purposes only, and are not indicative of Amazon's business use cases for carbon footprinting.

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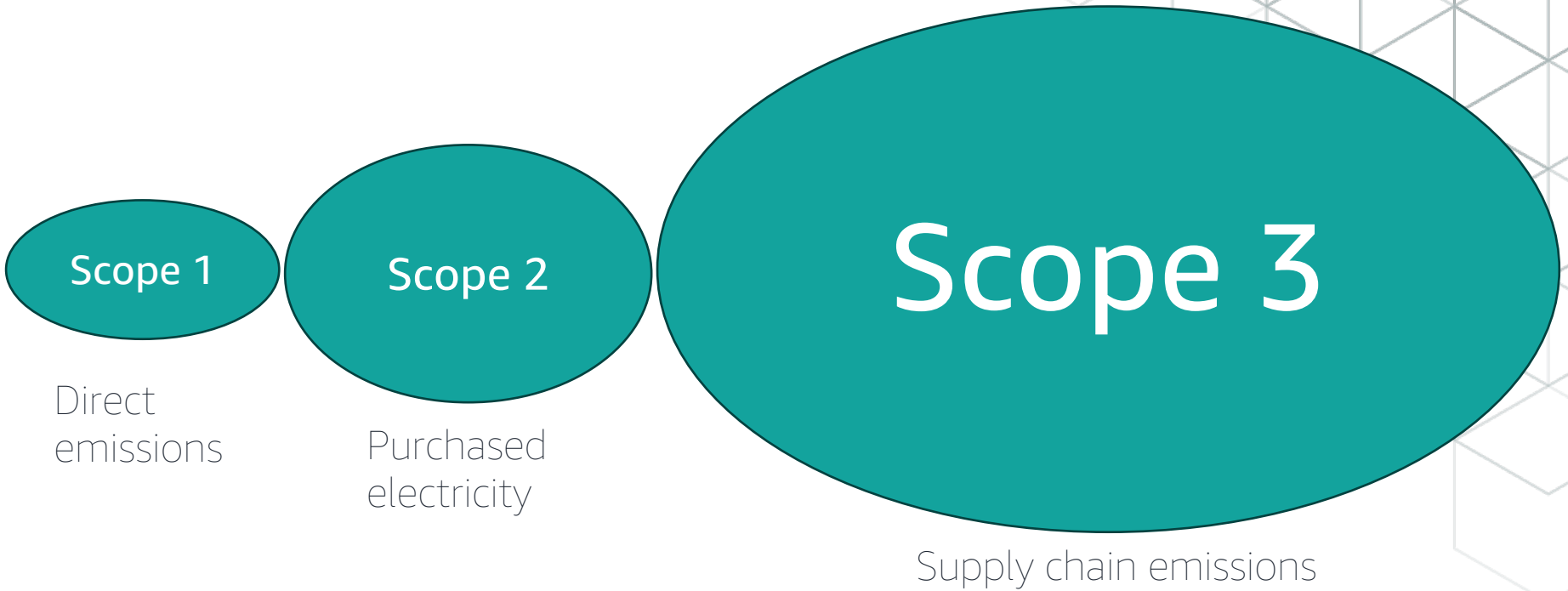
Urgent need to de-carbonize the economy

1.5/2C requires “rapid and deep and, in most cases, immediate GHG emissions reductions in all sectors this decade”

- IPCC AR6 Synthesis Report

Rapid Decarbonization (for corporations)

Scope 3 emissions dominate for most businesses



Life cycle assessment (LCA) – science of estimating impacts across the supply chain

Blanco, C., Caro, F. and Corbett, C.J., 2016. The state of supply chain carbon footprinting: analysis of CDP disclosures by US firms. Journal of Cleaner Production, 135, pp.1189-1197.

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Carbon footprint of household products

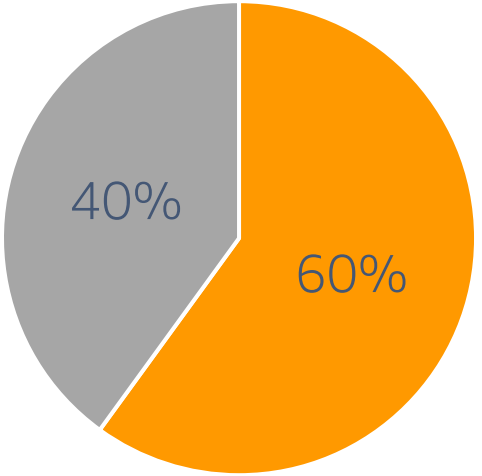
Brussel sprouts
2.1 kgCO2e

Butter
7.5 kgCO2e

Vase
14.1 kgCO2e

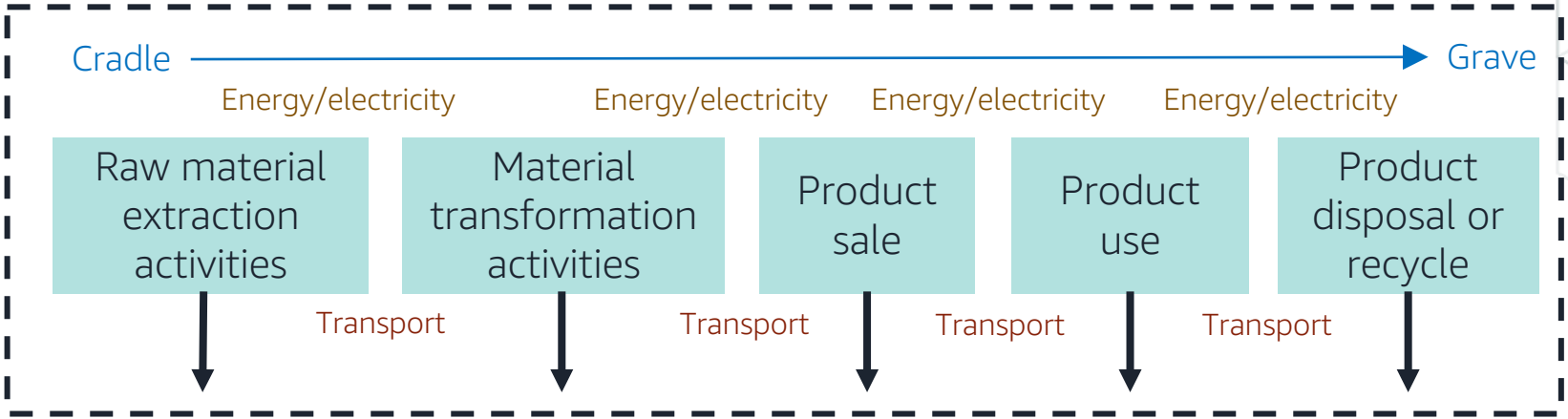
Plastic comb
2.7 kgCO2e

Global carbon footprint[1]



1. Ivanova, Diana, et al. "Environmental impact assessment of household consumption." Journal of Industrial Ecology, 2016.
2. Images licensed under CC BY, CC BY-NC

Life Cycle Assessment (LCA)

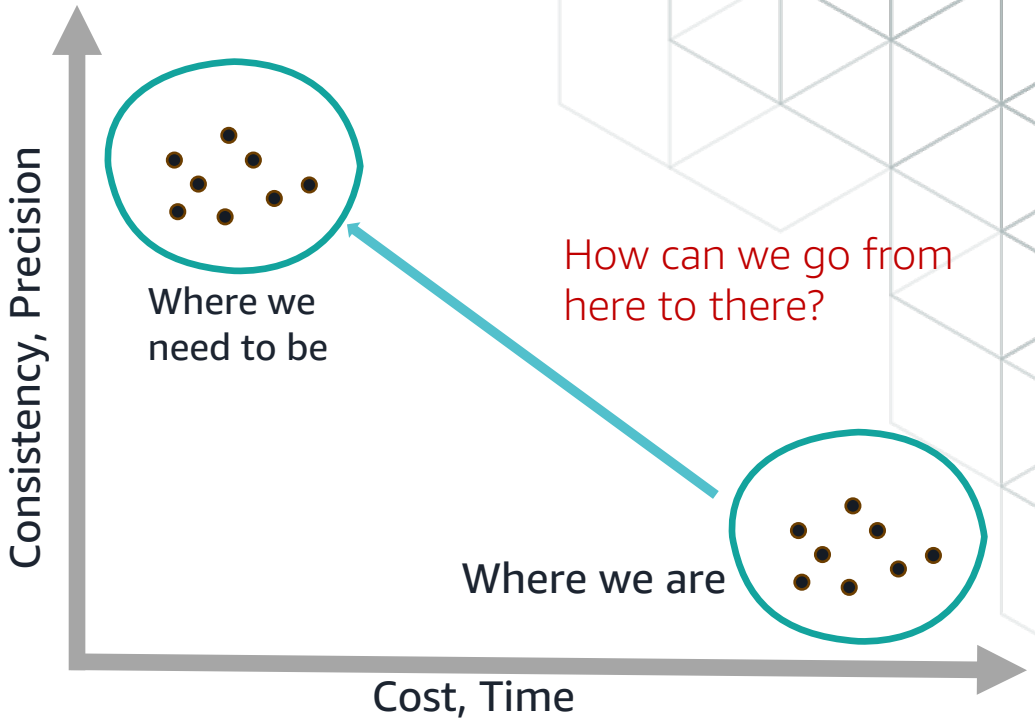


Convert all supporting physical/material flows to kg CO_2 equivalents

Product Carbon Footprint

Challenges in Scaling LCA

- Expensive
- Time consuming
- Expert dependent
- Extensive data collection



Balaji, Bharathan, Geoffrey Guest, Venkata Sai Gargeya Vunnava, Jared Kramer, Aravind Srinivasan, and Michael Taptich. "Scaling carbon footprinting: Challenges and opportunities." In Proceedings of the AAAI Symposium Series, vol. 2, no. 1, pp. 35-39. 2023.

Spend-based Carbon Footprint Estimate

Emission Factor

Manufacturing footprint of Sneaker = **(0.06 kg CO2eq/$)** x **($60)** = 3.60 $kgCO_2e$

USEPA/**USEEIO**

US Environmentally-Extended Input-Output Modeling Framework

$60

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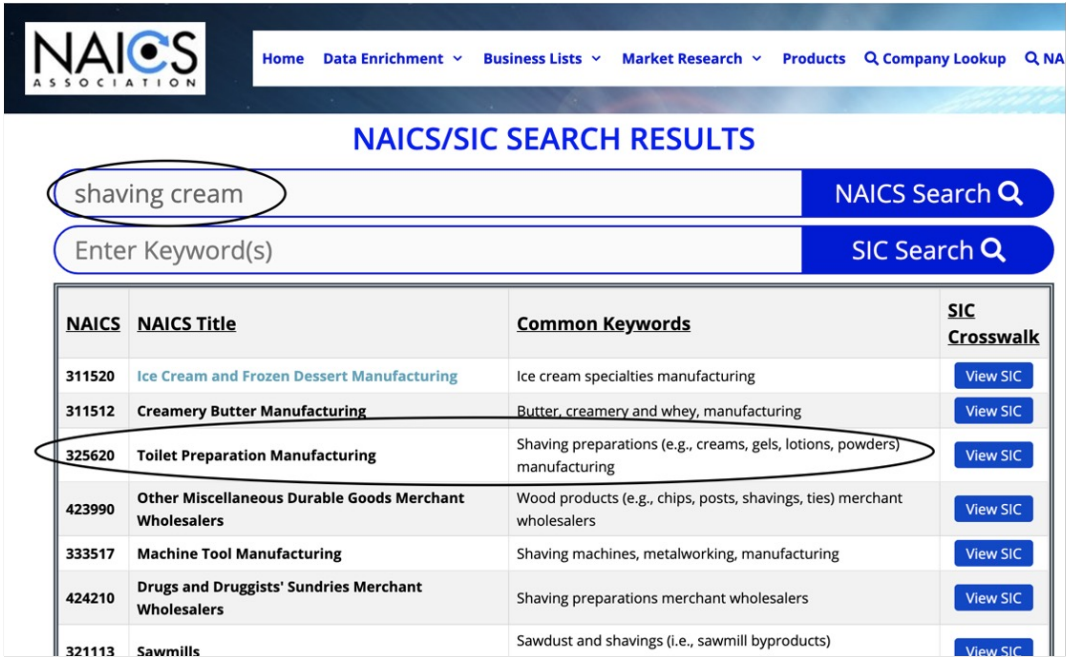
Example of Emission Factor Selection for Spend-based Estimate



NAICS	NAICS Title	Common Keywords	SIC Crosswalk
311520	Ice Cream and Frozen Dessert Manufacturing	Ice cream specialties manufacturing	View SIC
311512	Creamery Butter Manufacturing	Butter, creamery and whey, manufacturing	View SIC
325620	Toilet Preparation Manufacturing	Shaving preparations (e.g., creams, gels, lotions, powders) manufacturing	View SIC
423990	Other Miscellaneous Durable Goods Merchant Wholesalers	Wood products (e.g., chips, posts, shavings, ties) merchant wholesalers	View SIC
333517	Machine Tool Manufacturing	Shaving machines, metalworking, manufacturing	View SIC
424210	Drugs and Druggists' Sundries Merchant Wholesalers	Shaving preparations merchant wholesalers	View SIC
321113	Sawmills	Sawdust and shavings (i.e., sawmill byproducts)	View SIC

After identifying, the NAICS code was then mapped to the BEA sector “Toilet Preparation Manufacturing”

Selection with Retrieval Augmented Generation

Given Activity Input (real example)

FAC.WRC.OAL0508IN9.GRU - Combina o chave, 5/8 pol., 9-1/2 pol. OAL (chave de extremidade aberta)

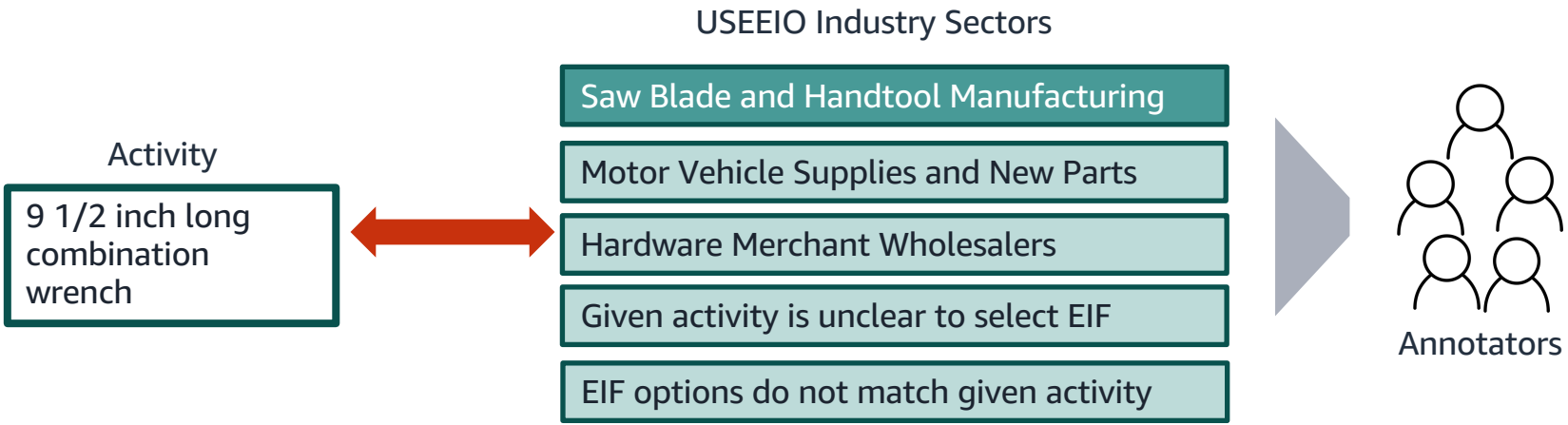
AI Paraphrase

The item is a 9 1/2 inch long combination wrench for use in warehouses and with basic tools.

AI Recommendation

NAICS title is 'Saw Blade and Handtool Manufacturing'. This covers the manufacturing of nonpowered handtools like wrenches, which is what the product is.

Human In The Loop Validation



- Top-1 accuracy of 87% and Top-K accuracy of 98%
- 1000x cheaper than fully manual solutions

Team

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Poster # 52

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Bharathan Balaji, Fahimeh Ebrahimi, Nina Gabrielle G Domingo, Venkata Sai Gargeya Vunnava, Abu-Zaher Faridee, et al.*

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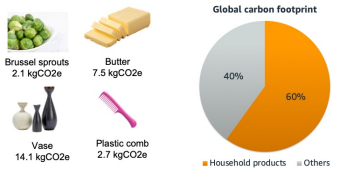
Carbon Footprinting of Products



Household products constitute >60% of global carbon footprint. Measuring the impact of each product is a key step towards reducing their associated carbon emissions.

Life Cycle Assessment

EEIO LCA

Production of Pears = (0.5 $kgCO_2e$/$) x ($2) = 1 $kgCO_2e$

NAICS ASSOCIATION

"Fruit and Tree Nut Farming" Sector

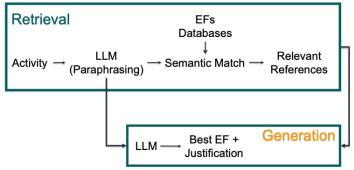
$2

Process-based LCA

Production of Pears = 0.48 $kgCO_2e$ ← *"Market for Pear"*

ecoinvent GaBi

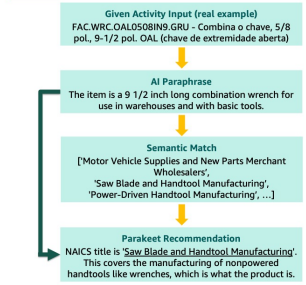
Parakeet



1) A business activity description get converted into a plain English text. **2)** Top K similar reference products or NAICS titles to the business activity get retrieved using an embedding model. **3)** All this information fed into an LLM model and ask for best impact factor that fits this activity. The model also return a human readable justification for its choice.

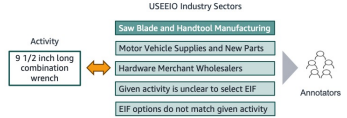
Dataset	Precision@1	Precision@K	Dataset Size
EEIO LCA EF Recommendation			
Govt of Austin Invoices	93.5	98.8	2159
Katana ML Invoices	97.1	100	1121
Procurement Products	90.9	98.1	3980
Heavy Equipment Invoices	82.2	93.5	1803
Process LCA EF Recommendation			
Food.com Ingredients	71.0	72.9	1956
Grocery Packaging	82.2	89.2	195

The results of Parakeet performance on six datasets. We use the General Text Embedding (*gte-large*) model for semantic text matching, and Claude 3 Sonnet as our LLM.



Human in the loop

We provide the query, paraphrased text, the recommended emission factor, and top-ranked list of emission factors to an annotator. The annotator can choose to override the Parakeet recommendation, indicate input data or EFs provided are inappropriate, or that they are uncertain to make a choice.



References

Balaji, Bharathan, et al. (2023). "CaML: Carbon footprinting of household products with zero-shot semantic text similarity." In: Proceedings of the ACM Web Conference 2023, pages 4004–4014

Deng, Zhu, et al. (2023). "Autopcf: Efficient product carbon footprint accounting with large language models.". In: arXiv preprint arXiv:2308.04241.

Balaji, Bharathan, et al. (2023). "Flamingo: Environmental impact factor matching for life cycle assessment with zero-shot machine learning." In:ACM Journal on Computing and Sustainable Societies, 1(2):1–23.

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Climate Change AI Workshop @ NEURIPS 2024

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Thank you!

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