Low-Carbon Pathways for Cement Recovery from Waste Concrete

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Highlights

- The cement industry is a key driver of climate change (8% of total anthropogenic emissions in 2023[1]).
- The United States generate a large quantity of concrete waste.
- Recovering cement from waste concrete provides a sustainable and cost-effective pathway, mitigating both carbon emissions and waste generation.
- This study evaluates three potential waste concrete-to-cement pathways via techno-economic & life cycle analyses (TEA/LCA).
- These concrete recycling pathways can significantly lower the carbon footprint of cement production, while being market competitive with traditional Portland cement.

Problem

The cement industry is a key driver of climate change.

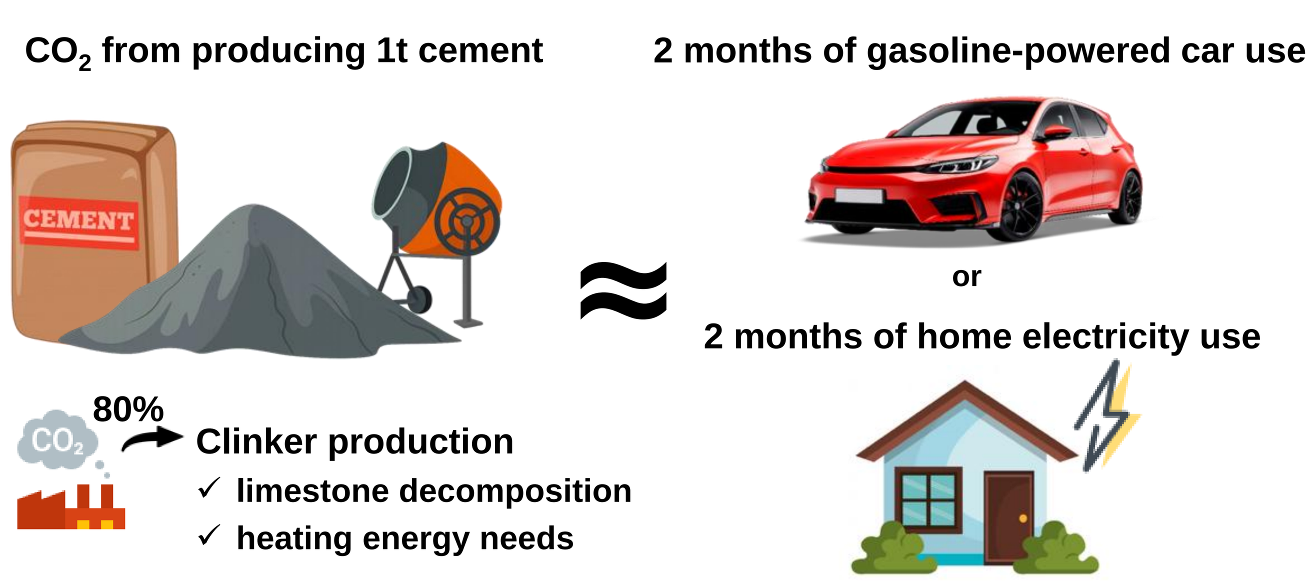


Fig 1. Equivalent CO_2 emissions from producing 1t of cement[2]

US/NJ generate a large quantity of concrete waste.

CABB: Concrete, Asphalt, Brick & Block

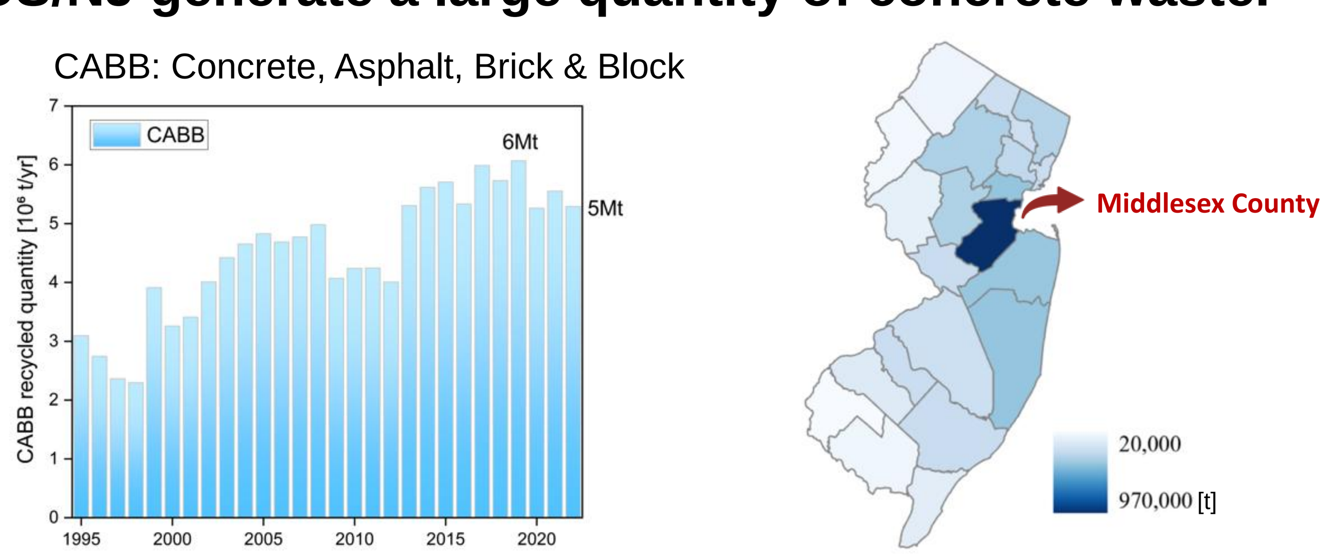
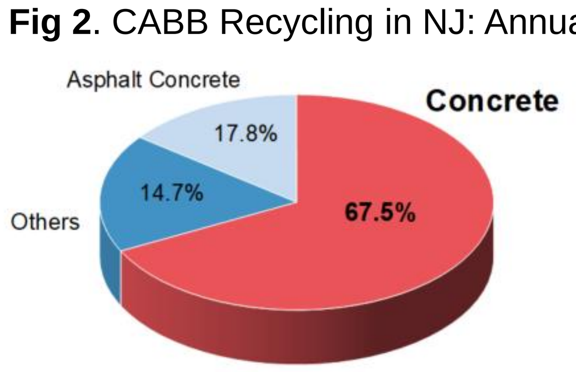


Fig 2. CABB Recycling in NJ: Annual Volume and 2022 Spatial Distribution



Over 4 Mt of waste concrete recycled in NJ in 2022

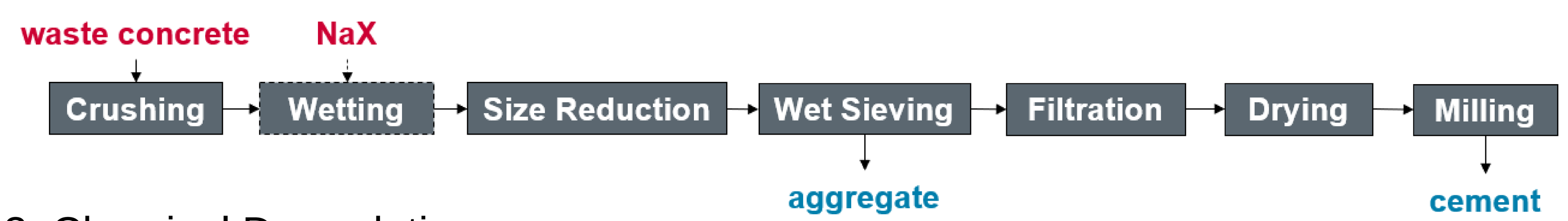
Fig 3. Composition of U.S. Recycled C&D Debris (2018) [3]

Solution

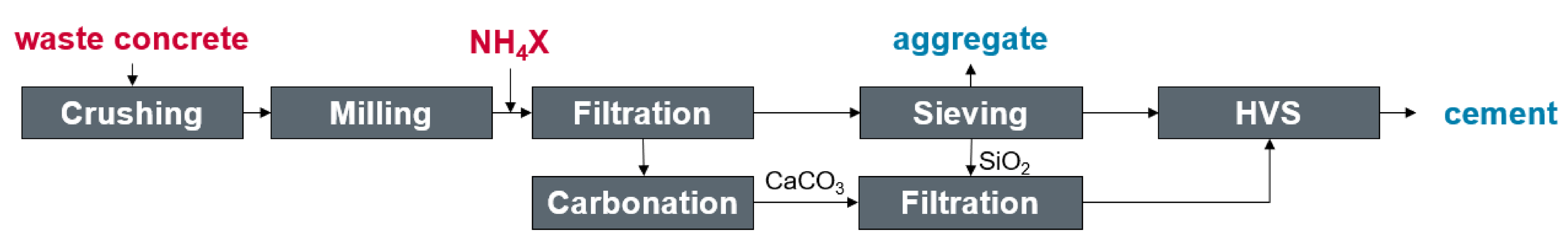
Concrete Recycling Methods:

1. Primary Separation

2. Secondary Separation



3. Chemical Degradation



HVS: Hydrothermal Vapor Synthesis

Process Modeling: TEA & LCA

$$Avg.\,emission/cost = \frac{Total\ emission/Cost}{Cement\ output}$$

Estimated under current experimental recovery rates:

Method	Air Classification	Forth Flotation	Sieving	Sec. Separation	Chemical
Recovery Rate	40%	30%	20%	60%	40%

Results

Emissions

- Mechanical routes: 70–85% CO_2 compared to conventional cement.
- Chemical route: 37–60% CO_2 compared to conventional cement.
- The chemical route shows higher emissions due to energy used for heating.
- Recycling-based routes demonstrate clear carbon reduction potential in cement production.

For recycled cement routes, emissions are estimated only from energy consumption, including indirect emissions from electricity use.

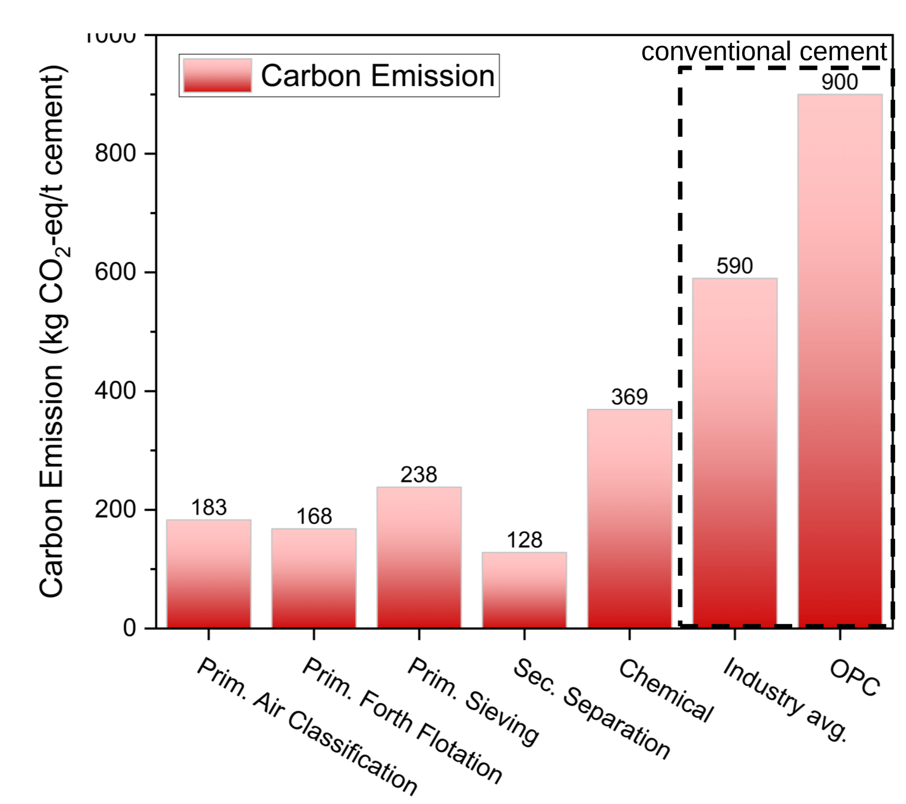


Fig 4. Carbon emissions of recycled cement compared with conventionally produced cement

OPC: Ordinary Portland Cement

Results

Costs

- Unit cost **> $150/t** cement vs $70–80/t OPC
- Mechanical < Chemical
- Major cost: energy + labor
- Chemical route also driven by heat use

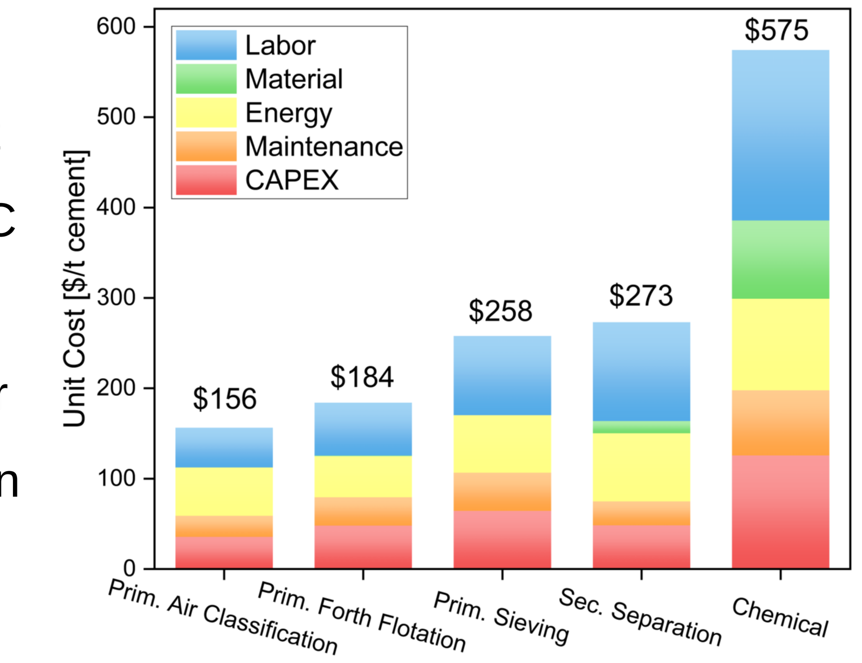


Fig 5. Cost breakdown for recycled cement

Cost Reduction

Three main strategies were evaluated to reduce the cost:

➤ **Automation**

Reduces labor demand.

➤ **Aggregates**

Sell as coproducts.

➤ **Tipping fee**

Credits from waste concrete.

Each measure cuts cost **20-40%**

All combined cuts cost **>80%** even leading **net gain**

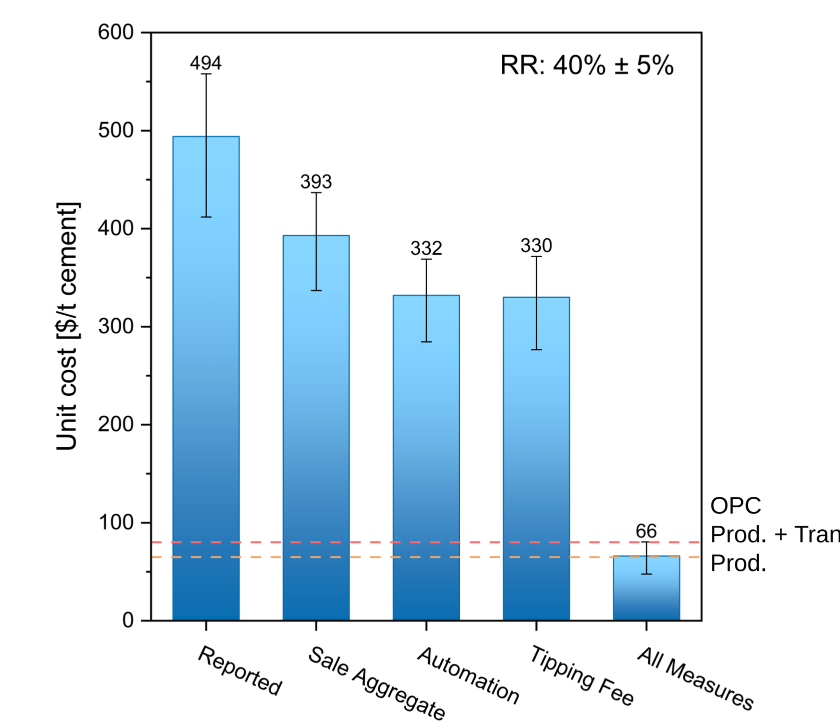


Fig 6. Cost reduction after process optimization (Chemical method example)

Future Direction

- Enhance recovery rates across all processing routes.
- Minimize energy use and CO_2 emissions through process optimization.
- Complete LCA with upstream material inputs & end-of-life emissions.

References

[1] Cheng, D., Reiner, D. M., Yang, F., Cui, C., Meng, J., Shan, Y., Liu, Y., Tao, S. & Guan, D. Projecting future carbon emissions from cement production in developing countries. Nat. Commun. 14, 8213 (2023).
[2] U.S. Environmental Protection Agency (EPA). (2024). Greenhouse gas equivalencies calculator. Washington, DC: U.S. Environmental Protection Agency.
[3] U.S. Environmental Protection Agency (EPA). (2020). Advancing sustainable materials management: 2018 fact sheet. Washington, DC: U.S. Environmental Protection Agency.

Acknowledgement

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