Ocean Conservancy

Plastics & Life Cycle Assessments (LCAs)

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What are LCAs?

Life Cycle Assessments (LCAs) are analytical modeling tools intended to evaluate the total environmental impacts of a product–from material extraction to end-of-life. They aim to trace the energy and materials flowing into and out of the life cycle of a product and translate those inputs into measurable impacts like greenhouse gas (GHG) emissions, water use and pollution. Like any model, the results of LCAs are dependent on the quality of the data used and assumptions made, meaning small changes to these inputs can significantly alter the conclusions.

Limits of LCAs: Garbage In, Garbage Out

In the context of plastics, LCAs have been used for identifying energy and emissions-intensive stages of production and guiding design toward lower-impact materials. However, they have also been misused: ignoring key impacts, relying on outdated data, or making assumptions that make plastics appear more sustainable.

The reliability of any LCA hinges on the quality of its data and the assumptions made in the analysis. Several common challenges can lead to poor or unreliable outcomes.[1]

Limitations	How these limitations can impact results
Data availability and quality Many packaging producers, especially small and medium-sized businesses, lack access to high quality data necessary for an LCA.[2] Even large producers often rely on outdated, generic or regionally mismatched data sets.	Lack of high quality or locally relevant data can result in biased or misleading LCA outcomes. For example, a product could look more favorable, assuming a higher rate of renewable energy use (e.g., a national or regional average) instead of the energy mix used locally at production facilities.[3] Using a national average recycling rate, for instance, can badly misrepresent outcomes in regions where local infrastructure and end markets don't exist.
Assumptions Many LCAs depend on idealized or narrow assumptions about product use, recycling rates or disposal pathways, skewing the results to favor plastic products.[4]	Improved reuse assumptions or the addition of data on other impacts like pollution can entirely change outcomes, for example, a study on glass versus plastic milk bottles found that recycled plastic bottles had the lowest GHG emissions even compared to a glass bottle reused eight times, largely because of the light weight of the plastic and low reuse assumptions in the model used.[5] However, when the model was adjusted to account for the likelihood that a material would contribute to marine pollution, the conclusions reversed.
Cost burden Detailed LCAs are expensive and time-intensive, meaning conducting detailed and updated LCAs for every product or packaging decision is an unmanageable burden for many producers.	Policies that require or incentivize LCAs could disadvantage small businesses or lead businesses to rely on outdated information or simplified analyses due to costs, resulting in analyses that are inaccurate or miss important local nuances.
Omission of key harms Even the most rigorous LCAs fail to capture many of the unique harms from plastics, such as ecosystem degradation, social costs and human health impacts of plastic pollution, microplastics and toxic additives, often because they are hard to accurately quantify, even when studies try to incorporate them.[6]	There is no standardized accounting for microplastics or other environmental impacts of plastics in LCAs, so LCAs systematically undervalue the environmental and human health cost of microplastics and plastic pollution.[7] It is a challenge for LCAs to incorporate new and emerging science on impacts and harms. For example, recent research has found that methane leakage across the fossil fuel supply chain significantly increases the climate impacts of plastic production. LCAs that omit these new emissions can underestimate plastics' true climate impacts by as much as 25-40%.[8]
Stuck in the present LCAs are a snapshot of current systems. They rely on assumptions about existing waste management systems, energy sources, supply chains and other factors. As a result, an LCA may favor plastics today, but this advantage could vanish with increased decarbonization.	A lightweight plastic product could be portrayed as lower-impact than a reusable glass alternative based on today's fossil-fuel heavy energy mix. Yet, reuse and non-plastic materials become more favorable when electrification and scaled investments in the recycling and reuse system (such as those that are required under new extended producer responsibility laws or deposit return systems) are taken into consideration.[9]

Case Study: How LCAs Can Miss the True Impacts of Chemical Recycling

Chemical recycling[10] technologies often appear promising in LCAs. However, many of these analyses are flawed due to limited transparency and narrowly defined boundaries:

- **Data transparency:** Most published LCAs analyzing chemical recycling rely on incomplete or confidential industry data.[11] As there are very few full-scale operational facilities, many LCAs rely on pilot data or proprietary modeled estimates. Moreover, each technology and facility performs differently based on operational conditions and feedstocks used, making it all but impossible to draw generalizations or make comparisons across technologies.
- **Defining boundaries:** Many LCAs credit chemical recycling processes with avoided emissions by assuming the process displaces incineration (a higher-emission outcome) rather than landfilling, skewing results.[12] Moreover, very few analyses model scenarios comparing chemical recycling to upstream redesigning of materials for mechanical recycling or reuse.
- **Comparing outputs:** Many chemical recycling facilities operating today result in converting plastics into oil and gas (conversion technologies).[13] As a result, they perpetuate the need for more virgin plastics and do not achieve a circular economy, yet these outcomes are often overlooked in the analysis, along with other environmental or societal harms.[14]

How to Use LCAs Appropriately

To ensure LCAs support progress rather than hinder it, their use should follow these guidelines:

- **Used in a suite of assessments:** LCAs should be combined with other analyses (e.g., material flow analysis, environmental justice assessments, true cost accounting) to offer a more holistic picture, especially when it comes to plastics.
- **Ensure transparency:** LCA outcomes are only as credible as their inputs. To improve trust and accountability, LCAs should disclose boundaries and assumptions, draw on publicly available data and include peer-review by independent experts.
- **Keep data current and locally relevant:** LCAs should reflect regional conditions, such as waste management infrastructure, energy availability, and consumer behavior, and be updated as science on impacts evolves.
- **Acknowledge what's missing**: LCAs should recognize that they fail to capture many critical impacts of plastics and therefore alone cannot provide a comprehensive answer. LCAs used to inform policy should include explicit discussion of their limitations and the harms unable to quantified.

Technical contributions by Eunomia.

Conclusion

LCAs are not neutral tools. They reflect the systems, values and assumptions embedded in them–-an LCA designed to justify a decision will almost always find a way to do so. Used carelessly, they risk defending the status quo rather than helping achieve a more sustainable future.

At their best, LCAs can help guide design by highlighting the stages of production with the greatest environmental impact (e.g., excessive energy use or high GHG emissions) or by comparing design variations within the same material type. Used incorrectly as the final word on measuring impacts, LCAs risk obscuring more than they reveal.

Ultimately, LCAs should inform, not dictate, decisions or policies. They can be valuable instruments for understanding pathways toward sustainability when paired with transparency, updated science and other assessments to provide a more complete picture of impacts.

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[1] Miller, S.A. (2022). *Front. Sustain.*
[2] *Id.* Miller
[3] Eunomia. (2023). "*Plastics: Can Life Cycle Assessment Rise to the Challenge?*
[4] Jiao, H., et al. (2024). *Ecotoxicol. Environ. Saf.*
[5] Steganini, R., et al. (2021). *Int. J. Life Cycle Assess.*
[6] Xayachuk, T., et al. (2024). *Sci. Total Environ.*; Sabate, K. and A. Kendall. (2024). *Cleaner Environ. Systems.*
[7] *Id.* Xayachuk, Sabate, Jiao; Marhoon, A., et al. (2026). *Mar. Pollut. Bull.*
[8] Hmiel, B., et al. (2020). *Nature*.
[9] *Id.* Eunomia.
[10] Ocean Conservancy considers chemical recycling technologies harmful if they do not recover plastic and create environmental and societal harm. Learn more about chemical recycling.
[11] Zero Waste Europe. (2020). "Understanding the Environmental Impacts of Chemical Recycling – Ten Concerns with Existing Life Cycle Assessments;" Singla, V. (2026). "Major gaps in life cycle assessments (LCAs) for chemical recycling technologies."
[12] *Id.* Eunomia, Zero Waste Europe.
[13] Ocean Conservancy. (2025). "Defining Plastics Recycling and other End of Life Options."
[14] *Id.* Zero Waste Europe, Singla.