Impact Case Study: Sustainable Food Waste Management Strategies in Tortilla Production through Life Cycle Assessment and Life Cycle Costing

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11/08/2026

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Engineering and Physical Sciences Research Council

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Summary

This case study demonstrates the environmental and economic impact of applying Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) to food waste management in tortilla production at Cool Chile Co., a London-based Mexican food manufacturing company. The project evaluated food waste generation across the tortilla production process and compared five food waste management strategies: anaerobic digestion (AD), animal feed, beer production, reworking waste within production, and upgrading the tortilla machine.

The study identified that the cooling and forming stages generated the highest levels of food waste, accounting for nearly 90% of the total waste. Environmental analysis showed that reworking waste within the production process was the most sustainable solution, with significant reductions across 17 of 18 environmental impact categories. Economic analysis further confirmed that reworking waste was the most financially viable strategy, reducing net production costs to GBP 4.96/ kg of tortilla compared to GBP 5.09/ kg in the reference scenario.

As a direct result of this work, the company gained a clear operational strategy to reduce waste at source, improve production efficiency, reduce disposal costs, and improve profitability. The findings supported process optimisation in the cooling and forming stages, improved machine performance, reduced environmental burden, and strengthened the company's progress toward circular economy practices and net-zero food production goals.

Background and challenge

Cool Chile Co. is a London-based, family-run food manufacturing company specialising in Mexican food products, including tortillas, totopos, sauces, and dried chillies. Established in 1993, the company has grown steadily over the past three decades, building a strong reputation in the UK market for authentic, high-quality products. Alongside its commercial growth, the company has shown a commitment to sustainability through initiatives such as redistributing surplus food via Too Good To Go and reusing unsold tortillas in the production of totopos.

However, like many food manufacturing operations, tortilla production at Cool Chile Co. involves complex, high-throughput processes that naturally generate food waste. Waste arises at multiple stages in the production process that include forming (due to dough inconsistency and machine clogging), cooling (due to conveyor inefficiencies and product defects), and distribution (due to returns and overproduction). While some waste streams

are valorised internally, a significant proportion is currently sent for anaerobic digestion (AD) through external waste contractors.

At the same time, the company operates within an increasingly demanding regulatory and market environment. UK policies such as the Resources and Waste Strategy and the Courtauld Commitment (2030) are placing strong pressure on food businesses to reduce waste and lower greenhouse gas emissions. In parallel, rising energy prices, raw material costs, and sustainability expectations from consumers and retailers are intensifying the need for more efficient and environmentally responsible production systems.

Despite existing waste reduction practices, Cool Chile Co. faced several critical challenges:

1. High Levels of Production Waste

A substantial proportion of food waste was generated during the forming and cooling stages, accounting for nearly 90% of total waste. This indicated inefficiencies in process design, equipment performance, and operational control.

2. Limited Visibility of Environmental Impacts

The company lacked a comprehensive understanding of the environmental consequences of its current waste management practices. While AD was assumed to be sustainable, its comparative performance against alternative options had not been quantified.

3. Uncertainty in Economic Trade-offs

There was no clear evidence on the cost-effectiveness of different waste management strategies. Decisions regarding waste handling, equipment upgrades, or process improvements were not supported by systematic economic analysis.

Approach and methodology

The project systematically quantified food waste across the production stages including mixing, forming, baking, cooling, packaging, and distribution. On-site measurements conducted over one month revealed that the cooling stage alone contributed 55.63% of total food waste, followed by the forming stage at 34.00%, while distribution contributed 10.36%. Packaging waste was negligible, and no waste was recorded. The findings identified clear operational inefficiencies, particularly related to conveyor belt design, short cooling conveyors, poorly shaped tortillas, and dough consistency management. To evaluate alternative waste management options, the study employed Life Cycle Assessment (LCA) following ISO 14044 standards using SimaPro 9.2 software (Pre-Sustainability, Netherlands) with the ReCiPe Midpoint (E) method and Eco-invent 3.6

database (Figure 1). Eighteen environmental impact categories were assessed, including climate change, human toxicity, marine ecotoxicity, eutrophication, fossil fuel depletion, and water depletion. The functional unit was defined as 1 kg of tortilla, and the system boundary covered the full gate-to-gate production process from mixing to packaging and food waste management.

Five alternative food waste management scenarios were evaluated against a baseline scenario in which food waste is assumed to be released into the environment. These scenarios include AD, use as animal feed, conversion into beer production, reworking the waste back into the production process, and upgrading the tortilla machine with a more advanced model.

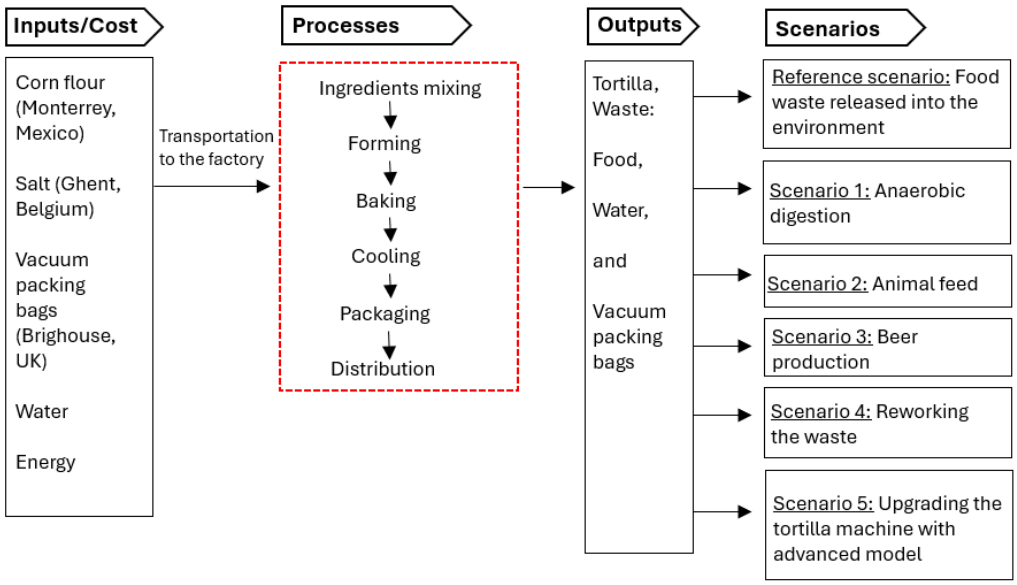

Figure 1: System boundary tortilla production and food waste management options

Results and Impact

The environmental assessment showed that the reference scenario (waste released into the environment) had the highest environmental burden, particularly in human toxicity (21.53 kg 1,4-DB eq), marine ecotoxicity (16.96 kg 1,4-DB eq), and climate change impact (5.00 kg CO_2 eq). Among all scenarios, reworking food waste directly within the production process delivered the strongest sustainability performance, making it the most environmentally preferable solution. The most significant improvements were observed in marine ecotoxicity, freshwater ecotoxicity, and marine eutrophication. This confirms that waste prevention and reuse are more sustainable than downstream disposal options, fully supporting the food waste hierarchy. Upgrading the tortilla

machine provided the second-best environmental performance, highlighting the importance of equipment modernisation in reducing waste generation and improving process efficiency. Anaerobic digestion remained a positive option compared to disposal but was less beneficial than prevention-based solutions (Table 1).

Table 1: Environmental Impacts of Tortilla Production and Food Waste Management Options

Impact category	Unit	Ref Scenario	AD	Animal Feed	Beer Production	Reworking	Upgrading Tortilla Machine
CC	kg CO2 eq	5.0042	4.9966	5.0632	5.1781	4.9903	4.9899
OD	kg CFC-11 eq	7.013E-08	7.020E-08	7.163E-08	7.386E-08	7.012E-08	7.017E-08
TA	kg SO2 eq	0.0255	0.0255	0.0265	0.0273	0.0254	0.0254
FE	kg P eq	2.71E-04	2.67E-04	2.93E-04	3.25E-04	2.67E-04	2.66E-04
ME	kg N eq	0.0039	0.0037	0.0042	0.0044	0.0038	0.0037
HT	kg 1,4-DB eq	21.5326	20.4817	20.8676	21.4851	20.5977	20.4971
POF	kg NMVOC	0.0310	0.0310	0.0314	0.0318	0.0310	0.0310
PMF	kg PM10 eq	0.0077	0.0077	0.0080	0.0082	0.0077	0.0077
TET	kg 1,4-DB eq	0.0088	0.0088	0.0100	0.0108	0.0088	0.0088
FET	kg 1,4-DB eq	0.0370	0.0248	0.0269	0.0293	0.0264	0.0253
MET	kg 1,4-DB eq	16.9572	13.1503	13.8028	14.8163	13.6535	13.2905
IR	kBq U235 eq	0.0608	0.0608	0.0623	0.0662	0.0608	0.0619
ALO	m2a	0.3120	0.3121	0.3604	0.3926	0.3120	0.3124
ULO	m2a	0.0327	0.0326	0.0354	0.0377	0.0326	0.0326
NLT	m2	0.0032	0.0032	0.0034	0.0036	0.0032	0.0032
WD	m3	0.0391	0.0402	0.0495	0.0450	0.0391	0.0387
MD	kg Fe eq	0.0834	0.0836	0.0884	0.0945	0.0834	0.0834
FD	kg oil eq	1.6256	1.6274	1.6412	1.6744	1.6253	1.6257

The economic assessment further strengthened these findings. LCC showed that reworking waste into the production process resulted in the lowest net production cost of GBP 4.96 per kg of tortilla, compared to GBP 5.09 per kg under the reference scenario. AD followed at GBP 5.08, while upgrading the tortilla machine resulted in GBP 5.10 per kg. Beer production and animal feed were less economically attractive, with net costs of GBP 6.01 and GBP 6.45 per kg respectively (Figure 2).

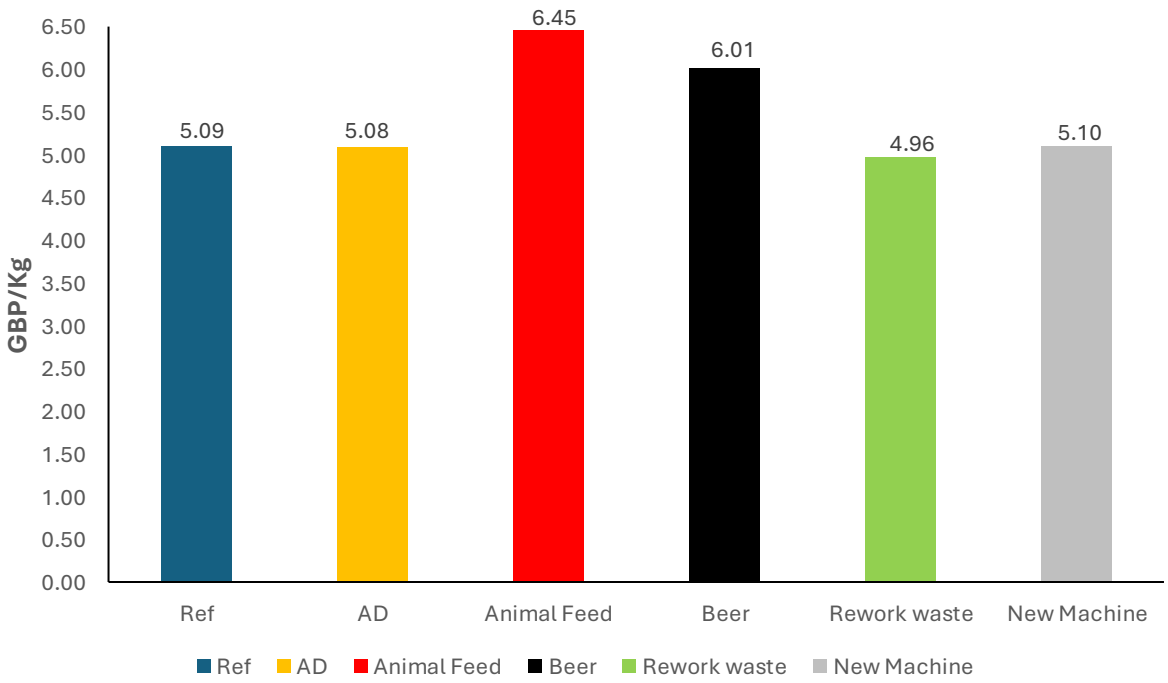

Figure 2: Life cycle costs of the different food waste management scenarios

Implementation of these findings is expected to deliver significant operational and financial benefits for the company. These include reduced raw material losses through improved reuse of tortilla waste, lower disposal costs, and decreased reliance on external waste contractors. In addition, internal reprocessing will improve profitability by generating additional saleable products from materials that would otherwise be discarded. These improvements contribute to enhanced environmental performance, reduced carbon footprint, and stronger alignment with UK sustainability regulations and net-zero targets. Beyond the company-level impact, the project contributes to wider industrial sustainability by offering a transferable model for food manufacturers seeking practical and measurable solutions for food waste prevention, circular economy implementation, and carbon reduction.

Future work

Future work should include optimising the forming and cooling stages, where most waste occurs, through better process control, and potential use of automation technologies. The proposed upgrade of the tortilla machine should be further assessed through detailed techno-economic analysis and pilot testing.

Expanding the environmental assessment beyond the current system boundary would provide a more complete view of impacts across the value chain. In parallel, alternative valorisation routes for unavoidable waste, such as higher-value products or bio-based applications, should be explored.

Digital tools, including process modelling or digital twins, could further improve optimisation and decision-making. Finally, the methodology developed in this study can be applied across the food sector, supporting wider adoption of sustainable, circular production practices.