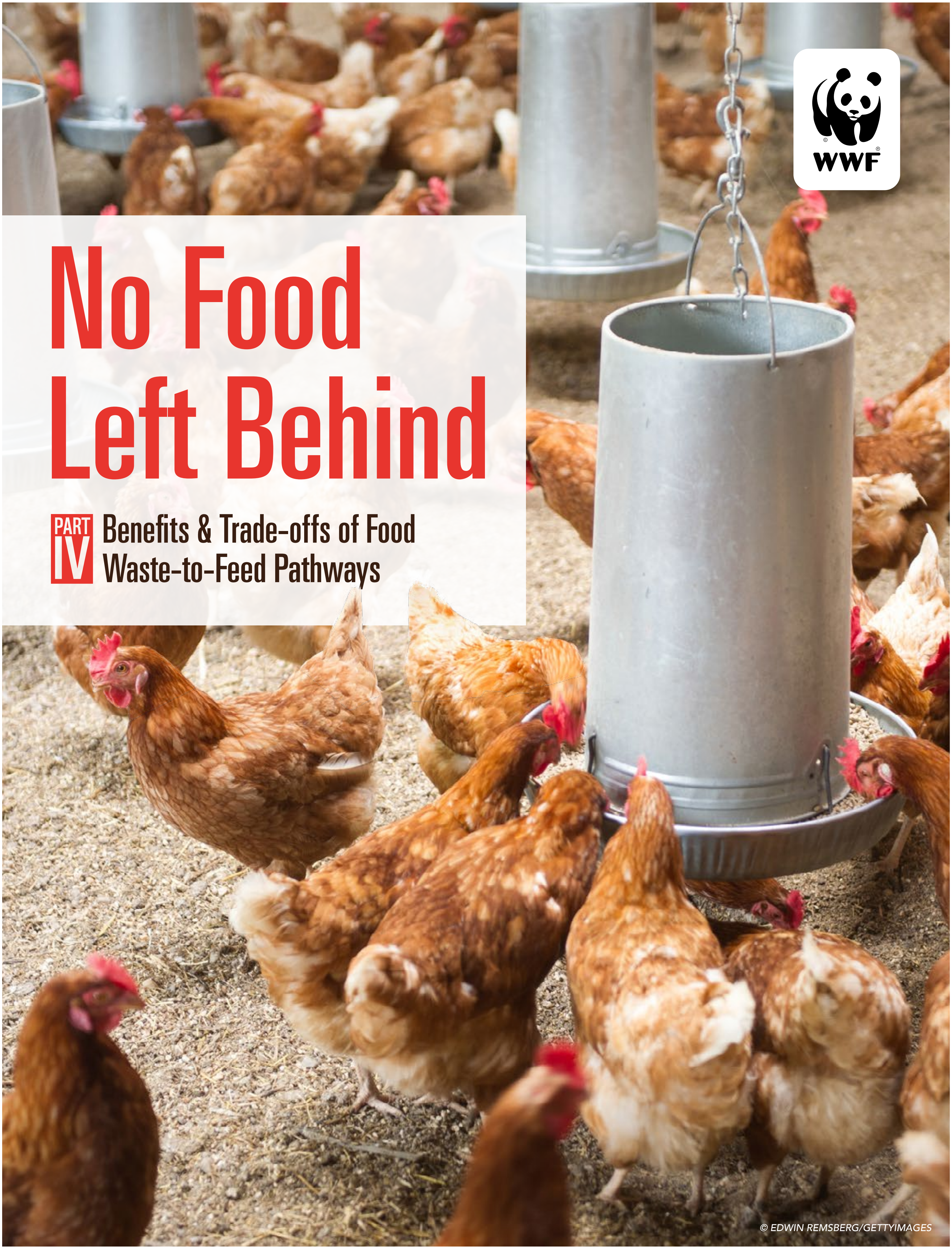
No Food Left Behind

PART IV Benefits & Trade-offs of Food Waste-to-Feed Pathways



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INTRODUCTION

Meat, milk, and eggs play an important role in global food security, but they also have a large environmental footprint. While livestock have a place in maintaining and conserving both natural and agricultural landscapes, the feed production systems supporting them contribute to disrupted biochemical and hydrological cycles, greenhouse gas (GHG) emissions, water pollution, soil erosion, land conversion, and other forms of environmental degradation. To stop further degradation of natural resources and the conversion of existing grasslands and forests, production of livestock and animal feeds must be brought in line with local carrying capacities and the ecological boundaries of our planet. Increasing the use of by-products, co-products, lost and wasted food, as well as novel feed ingredients, provides one potential opportunity to help achieve this balance.

Globally, co-/by-products from crop production and waste from food supply chains constitute nearly 30% of global livestock feed intake (Mottet, et al. 2017). Additionally, in the US, roughly 10% of surplus food (7.66 M tons) is already sent to animal feed (ReFED 2021). Roughly half (3.7 M tons) of this is coming from the manufacturing sector with another large contingent from grocery retail (1.8 M tons). While animal feed is a leading end-of-life option for some of these sectors, there are still roughly 14.7 M tons of food waste going to landfill. This contributes to the 20% of total US methane emissions coming from waste management (US Environmental Protection Agency 2021) that could be going to a higher value use, such as animal feed (ranked third on US EPA's Food Recovery Hierarchy), which is an age-old practice that deserves renewed attention using 21st century technology and practices. It's important to note that total food waste generation estimates in the US are much higher (more than 27.6 M tons annually in the US, ReFED, 2020), but we have estimated that only 14.7 M tons could effectively be used for waste-to-feed pathways due to issues of post-consumer contamination and viability of the feedstock.

The shift away from feeding animals food scraps towards feeding them commodity crops has contributed to improved yield, feed conversion, and production efficiency, so re-incorporating by-products and wastes must be done appropriately to maintain these gains. High-producing livestock require high quality nutrition, and current genetic stocks utilized in the U.S. were developed using corn and soy as base ingredients. Thus, replacing these highly nutritious ingredients with alternatives is not a simple one-to-one substitution, and must be done carefully. Alternative feed ingredients must meet the nutritional requirements of the animal, and nutritionists need to know their quality, nutritional profile, and potential interaction between ingredients. They will also have to be produced with a consistent quality, availability, and scale over time at a reasonable cost to be viable for livestock producers.

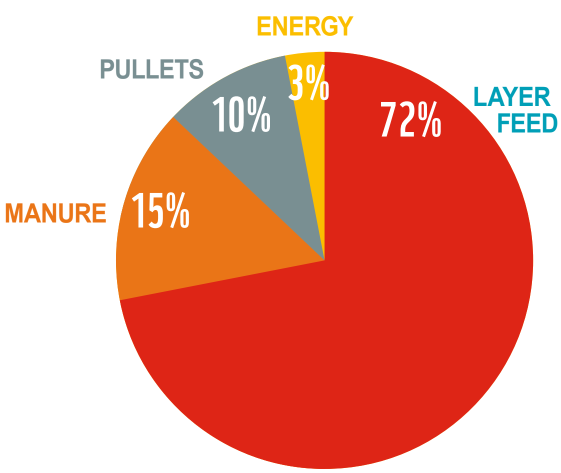
To better understand the environmental impacts associated with transforming food waste into animal feed, World Wildlife Fund (WWF) organized a research project that explores the comparative environmental benefits and impacts of three food-waste-to-feed pathways for egg production. The three waste-to-feed ingredients analyzed were:

1. Food waste from retail outlets fed to black soldier fly larvae (BSFL), which in turn are processed into meal and fed to hens.
2. Food waste from retail outlets that underwent further processing to turn it into a feed ingredient for hens.
3. Bakery by-products from food manufacturing plants processed into ingredients for hens.

FEED FOR HENS

In 2020, 96.9 billion table eggs were produced by 325 million commercial laying hens in the US that consumed about 16.4 million tons of feed (which also includes feed for egg layers, pullets, and breeder layers) (Egg Industry Center 2020). The diets of hens mainly consist of corn, soybeans, distillers' dried grains with solubles (DDGS), animal/vegetable fats, and enzyme and nutrient additives (IFeeder 2017) and make up roughly 70% of the overall GHG footprint of egg production (2.08 ton CO_2 equivalent (CO_2 eq)/ton of eggs) (Pelletier, M. and H. 2014) **FIGURE 1**. It should be noted that layer diets already include some co- or by-products from the food, fuel, and fiber production industries, such as DDGS from the production of ethanol (about 10% of the diet) and bakery meal from manufacturing (another 10% of the diet).

FIGURE 1 U.S. NATIONAL AVERAGE BREAKDOWN FARM GATE CO_2EQ%



METHODOLOGY

For this study, it was important to understand and establish a representative baseline diet for laying hens that utilized standard industry ingredients and nutrient requirements, including energy, protein, minerals, and vitamins, for their corresponding stage of life (i.e., baby chick versus adult hen) to maximize feed efficiency, performance, and health of the animal, as well as factors such as ingredient availability and price. Feed costs for layers can make up 70-80% of total production costs at the farm level, which means least-cost formulation[1] are usually employed to arrive at the optimal ratio of ingredients in the diet. Typically, these formulations do not take environmental impacts into account, and the data bases do not include novel ingredients, such as insect meal or innovative food waste-based ingredients.

COMMON BY-PRODUCT FEEDS

DDGS are a by-product from the ethanol industry (corn is the main ingredient) and are commonly used for their price and high protein content, which is easy to digest by livestock.

Wet distillers grains are a protein-rich by-product from the brewing industry.

Bakery meal is a by-product ingredient coming from the bakery industry and is a source of energy for livestock. By far, most of the bakery meal is used for broilers (7.6 million tons), followed by layers (1.6 million tons) and hogs (0.6 million tons). (American Feed Industry Association 2020)

1 *Ensuring the diet meets the nutritional requirements of the animals while looking for the lowest cost possible.*

The following diets TABLE 1 were formulated to meet the nutritional requirements for US commercial hens at 40 weeks of age. The baseline diet represents US typical ingredients utilized to meet these requirements, while the other nine diets include innovative food-waste-based ingredients at 5%, 10%, and 15% inclusion, while also meeting the same nutritional requirements.

TABLE 1 COMPOSITION OF THE TEN DIETS

		BLACK SOLDIER FLY LARVAE MEAL			FOOD WASTE PELLETS			BAKERY BY-PRODUCT MEAL		
	BASELINE	5%	10%	15%	5%	10%	15%	5%	10%	15%
CORN	54.1	55.8	57.4	61.7	53.3	52.5	50.4	50.1	46.1	45.0
SOYBEAN MEAL	19.9	14.6	9.3	6.6	16.9	13.9	9.9	19.2	18.5	19.7
DDGS	10.0	10.0	10.0	5.0	10.0	10.0	12.0	10.0	10.0	5.1
LARGE PARTICLE CALCIUM	6.2	6.0	6.0	5.6	6.1	6.1	5.8	6.2	6.2	6.2
LIMESTONE	4.0	3.9	3.5	3.5	4.0	4.0	4.2	4.0	4.0	3.9
ANIMAL/VEGETABLE FAT	3.2	2.3	1.4	0.3	2.1	0.9	0	3.0	2.7	2.0
PHOSPHATE SOURCE	1.4	1.3	1.1	1.0	1.4	1.4	1.3	1.4	1.4	1.5
VITAMINS	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
SALT	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3
METHIONINE (AMINO ACID)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.6
LYSINE (AMINO ACID)	0.1	0.2	0.2	0.2	0.2	0.3	0.5	0.2	0.2	0.2
NSP ENZYME	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
PHYTASE (ENZYME)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
FOOD WASTE-BASED INGREDIENT	–	5	10	15	5	10	15	5	10	15
DRY MATTER (%)	85.6	86.8	87.9	89.3	86.6	87.6	88.5	86.0	86.5	87.3
METABOLIZABLE ENERGY (KCAL/KG)	2,833	2,833	2,833	2,833	2,833	2,833	2,833	2,833	2,833	2,833
CRUDE PROTEIN (%)	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5

To quantify the environmental impacts of the baseline and alternative diets, data from life cycle inventory (LCI) databases (e.g., Ecoinvent v3.4, World Food Life Cycle Database) were used, focusing on four environmental impact indicators: global warming potential, land use, water consumption, and marine eutrophication. The assessment relied on the best and more recently available life cycle assessment (LCA)-related information on food production and follows the ISO 14044 standard. The background environmental datasets used for all Table 1 ingredients is based on industry averages, using US averages whenever possible, and therefore might not truly reflect specific location and annual conditions of the dynamic agricultural system in the US (i.e., water use for corn and soy could vary significantly based on the annual rainfall in the production area). Therefore, the results should be taken as directionally correct, but not fully representative of all potential ingredient combinations. Further, it should be noted that no avoided emissions were considered as benefits to production systems; for example, the avoided emissions of not sending food waste to landfill are not considered. For more detail on the method and the results, you can access the full report at: https://c402277.ssl.cf1.rackcdn.com/publications/1520/files/original/WWF_Food_Waste_As_Feed_LCA_Report.pdf?1625243554.

RESULTS

The overall results for the three food waste ingredients do not provide a clear best alternative substitute. Instead, the results are mixed amongst the environmental indicators. Bakery meal had the lowest impact in three of the four impact categories we have focused on, whereas BSFL has the highest value in these same three categories (global warming potential, water consumption, and marine eutrophication impacts). The results for land use are in the opposite order among the three options TABLE 2.

TABLE 2 LIFE CYCLE IMPACT ASSESSMENT (LCIA) FOR 1 KG OF THE THREE FOOD WASTE INGREDIENTS

FOOD WASTE INGREDIENT	GLOBAL WARMING POTENTIAL KG CO2-EQ./KG INGREDIENT	LAND USE POINTS/KG INGREDIENT	WATER CONSUMPTION LITERS/KG INGREDIENT	MARINE EUTROPHICATION G N-EQ./KG INGREDIENT
BSFL MEAL	6.74	11.35	22.04	3.56
FOOD WASTE FEED	1.90	47.58	11.90	2.58
BAKERY MEAL	0.21	58.37	1.87	2.12

White box indicates the highest scores for each one of the four impact categories.

When considering their use in a hen's diet, the results show that no diet leads to clear environmental benefits in all indicators, but rather to environmental trade-offs (positive denoted in blue and negative denoted in red) TABLE 3. Results depend on the environmental profile of the food-waste-based ingredient together with the exact composition of each diet.

TABLE 3 NORMALIZED LCIA RESULTS FOR LAYER HEN DIETS

DIET	INCLUSION LEVEL OF FOOD WASTE INGREDIENT	GLOBAL WARMING POTENTIAL (GWP)	LAND USE	WATER CONSUMPTION	MARINE EUTROPHICATION
BASELINE	100%	100%	100%	100%	100%
BSFL MEAL	5%	179%	86%	108%	98%
	10%	265%	73%	123%	100%
	15%	350%	66%	138%	102%
FOOD WASTE FEED	5%	116%	90%	102%	94%
	10%	131%	79%	104%	88%
	15%	151%	68%	112%	85%
BAKERY MEAL	5%	97%	96%	97%	96%
	10%	95%	92%	96%	93%
	15%	99%	92%	97%	90%

Values show the ratio between each diet and the Baseline diet for each indicator (100%=Baseline value).
Red shaded cells indicate values that are higher than the baseline. Blue shaded cells indicate value lower than the baseline.
Darker shade of each color represents larger differences.

Bakery meal is the only one of the three ingredients that does not lead to an overall increase in potential environmental impacts and has the potential to be a positive alternative to conventional ingredients in a hen's diet. Given inherent uncertainty in LCAs, it should be noted that this diet is roughly equivalent to a baseline diet for GHG emissions and water consumption.

BSFL and food waste feed, the two most novel ingredients, perform poorly compared to the baseline diet for GHG emissions (GWP) and water consumption, but significantly better for land use and moderately better for marine eutrophication. The GWP indicator is driven by energy use during processing. When renewable solar power for food-waste-based ingredients was substituted for traditional sources, this lowered the carbon footprint of the alternative diets between 0.1% (bakery meal at 5%) to 51% (BSFL at 15%); however, even with these improvements, all BSFL diets and all food waste feed diets still have a higher GWP than the baseline diet. For more detailed information on this analysis, please see the longer technical report.

The land use and land use change indicators showed the most interesting comparative results. Greater proportions of the alternative ingredients decreased both indicators due to lower levels of soybean meal and animal/vegetable fat. Between 0.06 and 0.45 m2a (meters squared per year) or 4%-51% of occupied land can be saved annually with the incorporation of food-waste ingredients. Scaling this number based on a 75% increase in diversion to animal feed pathways from landfill/incineration, could result in savings between 206,000 and 269,000 ha annually; equivalent to two-thirds or 86% of the land area of Rhode Island, as well as a reduction in land use change of 48,000 to 64,000 ha; an area that is twice the size of Washington DC.[2]

While the emissions associated with sending food waste to landfill, or other waste management systems, were excluded from the LCA due to the added complexities of looking at three pathways and alignment with carbon accounting standard practices; it is important to note that diverting food to animal feed might have additional climate benefits that could change the overall GHG equation. For example, running the same numbers used in the previous land conversion scenario through ReFED's (2021) Impact Calculator, but changing the end-of-life management from landfill to animal feed, results in 200,000 tons of avoided CO_2eq emissions.

2 These calculations are based on the 5% inclusion diets for the BSFL and the food waste feed alternatives. These inclusion rates match the volume of food waste available when 75% of the food waste currently going to landfill and incineration from grocery retail, food service, and hospitality is diverted to BSFL or food waste feed pathways.

WHAT'S NEXT

Waste-to-animal-feed pathways have been used for centuries. With circularity becoming a priority in food system design, there must be an emphasis on how best to deal with end-of-life decisions for food waste products. Using food-waste-to-feed can provide benefits, but it will depend on how we prioritize cost and benefit trade-offs. In addition, most businesses are starting to prioritize food waste prevention, meaning that food waste volumes will likely be reduced by an unknown percentage over time. Any investments into end-of-pipe infrastructure and waste-to-feed processing must be evaluated to ensure that measurement and food waste prevention are part of the long-term Return-On-Investment analysis. Our findings suggest that emphasis should be kept on preventing food waste wherever possible as the top priority. However, there is a full realization that there will always be some percentage of unavoidable food waste that cannot be prevented, and that unavoidable food waste must be managed via a circular system—never landfilled.

New uses of food waste-to-feed should be assessed on a case-by-case basis to avoid unexpected environmental consequences.
In terms of environmental impact, this study shows that CHG footprints can vary between different waste-to-feed pathways. Energy usage can be a determining factor in terms of a feed processor's emission ranking. Use of renewable energy and other efforts should be employed to minimize carbon impacts within processing operations.

Perhaps the biggest finding of this study was that waste-to-feed pathways have the potential to provide modest benefits from a land footprint perspective when replacing the commodity grains. By fully utilizing and processing larger amounts of food waste, it could be possible to decrease demand of commodity corn, soy, and animal/vegetable fat production. This could have a positive impact on further land use change and native habitat conversion in places like the Northern Great Plains of the US. This is an area where we do not want to see additional loss of grasslands to commodity row crops. This creates an opportunity for feed buyers interested in removing habitat conversion from their supply chains to potentially purchase feed products that use waste-to-feed inputs as an alternative to conventional feed.

It is also critical to note that removing food waste from landfills and sending it to these higher uses must be a major priority in the US. The project herein, did not account for the considerable GHG emissions and environmental benefits from diverting food waste away from landfill, where methane emissions from organic material ranks as one of the top GHG emission sources in the US. Additional studies that incorporate this benefit have the potential to change the final results of this study.

If waste-to-feed pathways can prove to be a more profitable alternative than other diversion measures like composting and anaerobic digestion, our study shows that there can be modest environmental benefits, particularly in offsetting commodity agricultural pressures, that might make waste-to-feed an attractive option. Therefore, waste-to-feed pathways should not be discouraged when deciding what waste diversion infrastructure investments are most strategic and beneficial.

This study has led to more questions than answers, such as, what is the most beneficial use of food waste that cannot be repurposed for human consumption, and how does it differ by production stage and food category? This is a question we hope to continue to probe with future research and partnerships to better understand where animal feed should fit within a more sustainable and more circular food system.

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WWF