Next Rung Technology

TECHNOECONOMIC ANALYSIS WHITE PAPER

Plant-based meat manufacturing

A commercial scale TEA of extrusion and product formulation facilities

Prepared by
Next Rung Technology

In partnership with
The Good Food Institute (GFI)

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About Next Rung Technology

Next Rung Technology is an engineering and consulting company focused on commercializing and scaling sustainable process technologies. Founded by a group of startup veterans, Next Rung is passionate about solving environmental challenges with innovative technology design. Our diverse, experienced team supports growing companies on the complex journey from concept to commercialization, providing plant and product design, unique techno-economic models and analysis, construction support, on-site commissioning and plant engineering troubleshooting. Leveraging our real-world experience, we help our partners scale on time and on budget as they grow towards commercial viability.

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Executive Summary

Plant-based meat products today are priced two to four times higher than conventional meat, and the industry has lacked a detailed, representative cost analysis to guide where investment and R&D should focus to close that gap. Next Rung Technology developed this commercial-scale technoeconomic analysis (TEA) with The Good Food Institute (GFI) to quantify cost of goods sold (COGS) and capital expenditure (CAPEX) of plant-based meat production, providing the ecosystem a basis for prioritizing cost-reduction efforts toward price parity. The TEA finds that increasing scale and improving efficiency puts plant-based meat products on track to achieve price parity but further focus on key ingredient inputs will be required to achieve parity across product formats.

The TEA models two dedicated facility types: an extrusion facility producing low moisture extrudate (LME) and high moisture extrudate (HME), and a product formulation facility producing ground beef, chicken nuggets, and whole cut chicken. This structure reflects the current supply chain, in which product formulators source protein extrudates from larger, centralized extrusion facilities rather than producing them in-house. Each facility is modeled under a current and future scenario reflecting anticipated improvements in process and scale.

Extrusion

Current Scenario

50,000 MTA | 100% LME

Representative of established commercial extrusion facilities, with capacity predominantly dedicated to LME production

Future Scenario

50,000 MTA | 70% LME | 30% HME

Representative of tomorrow's potential, as HME technology matures and is adopted more widely by manufacturers for improved taste and texture

Product Formulation

Current Scenario

5,000 MTA | 50% utilization | 50% ground beef | 30% chicken nugget | 20% whole cut chicken

Representative of today's product formulation facilities where weaker demand limits scale and plant utilization

Future Scenario

15,000 MTA | 100% utilization | 50% ground beef | 30% chicken nugget | 20% whole cut chicken

Representative of tomorrow's potential, as demand grows and allows for large-scale, fully utilized facilities

Major findings

- **Extrudate cost drivers:** Soy protein concentrate is the dominant cost driver for both extrudate products (85% of LME COGS, 54% of HME COGS). While LME is the predominant extrudate product today, the TEA finds that HME is the lower cost extrudate in the future scenario at $1.13/kg, roughly 46% below LME at $2.09/kg. CAPEX requirements increase with the addition of HME capacity in the future extrusion facility, rising from $71M to $91M, with capital intensity increasing from $1.42/kg to $1.82/kg. This increase is largely due to throughput constraints of commercially available HME

extruders (1,000 kg/h max vs. 3,000 kg/h for LME extruders), which therefore require more production lines per kg of output.

- **Formed product cost drivers:** Flavorings are the largest cost driver across formed products, representing 33–39% of COGS today and rising to 43–46% in the future scenario as economies of scale reduce other costs. Plant CAPEX rises from $22M to $39M to support a threefold capacity increase, but capital intensity falls from $4.40/kg to $2.58/kg, demonstrating favorable economies of scale. Based on these expected commercialization trajectories, margin relative to conventional meat price improves across all three products, with ground beef achieving cost parity, while chicken nuggets and whole cut chicken close much of the gap.

- **Path to price parity:** Case studies are presented to quantify the levers available to close the remaining gap to cost parity. Plant capacity is the single largest lever, reducing COGS by 15–19%, while plant utilization and product loss reduction contribute smaller additional gains (8–10% and 6–7%, respectively). International production in Brazil or India reduce COGS by 12–21%, driven primarily by lower labor and depreciation costs. Under a future scenario applying low-end pricing to the highest-leverage ingredient systems, all three formed products clear their cost-parity target, with flavors remaining the dominant residual cost driver in every case.

Recommendations

- Extrudate cost reduction efforts should prioritize soy protein sourcing and formulation, the dominant driver of COGS across both LME and HME.

- Increasing plant capacity achieves the most substantial formed product COGS reduction, reinforcing that economies of scale are one of the largest levers for improving unit economics. Realizing full utilization of commercial scale facilities is the clearest path to cost parity.

- Further formed product cost reduction efforts should center around sourcing of ingredients, focused on high-cost and high-inclusion ingredients such as flavors and extrudates.

- Ingredient price volatility poses a meaningful risk to all products, especially whole cut chicken, and ingredient sourcing strategy should be prioritized accordingly.

1 Introduction

The plant-based meat industry is working to bring products to market at a scale and price that can meaningfully satisfy a growing population's demand for meat. Adoption hinges largely on price: plant-based products still cost two to four times more than their conventional counterparts, yet the industry lacks detailed analysis indicating production cost drivers and pathways to achieve cost parity. To fully realize the environmental, public health, and animal welfare benefits of these products, the industry must close the gap and make plant-based meat an attractive option for both consumers and producers.

1.1 Technoeconomic Analysis

In today's competitive landscape, methods for shortening R&D cycles and minimizing wasted resources are critical. A Technoeconomic Analysis (TEA) is one such method, used to evaluate the technical and economic feasibility of a proposed technology or process. It combines engineering data with economic modeling to assess whether a technology can be developed, scaled, and commercialized in a cost-effective and competitive manner. TEAs serve as a crucial decision-making tool for emerging technology, guiding research and development priorities and informing funding decisions.

Plant-based meat TEAs available today are limited and do not reflect how plant-based meat is produced at scale today. This project aims to close that gap with a commercial-scale TEA of plant-based meat production, capturing both today's manufacturing processes and tomorrow's innovations for improving cost and taste. The analysis presents findings in the form of cost of goods sold (COGS), and capital costs (CAPEX) to provide the ecosystem with critical context to drive plant-based meat toward price parity.

1.2 Partners

Next Rung Technology (Next Rung) has developed the present TEA with The Good Food Institute (GFI) to build off work conducted by GFI to assess environmental impacts of plant-based meat systems. Next Rung led the development of the underlying model based on its extensive experience designing and building food and beverage processing facilities, supported by a proprietary database of equipment pricing and facility costs from similar projects. GFI provided background research, engaged with stakeholders, established the production scenarios, and provided data for the study based on the current state of the plant-based meat industry.

2 Study Design

The TEA models commercial-scale process configurations for the production of plant-based meat products with the goal of identifying key cost components, economic drivers, regional variability, and cost reduction opportunities in the plant-based meat space.

Production scenarios, product recipes, and facility configurations presented in this section are based on interviews with plant-based meat manufacturers and ingredient suppliers and were selected to reflect both the current state of commercial production and the direction the industry is expected to take as it scales.

2.1 Products Modeled

The present study includes analysis of two product types: extruded protein products and formed plant-based meat products. Because extrusion and forming are typically handled by separate entities, each product type is modeled as an independent facility, allowing the economics of each process to be assessed on its own.

Extruded protein products are defined by the unit operation used to texturize the protein: a twin-screw extruder that mixes and shears a starting input protein concentrate under heat and pressure, then forces it through a die.

Formed plant-based meat products are defined by the final formulation steps: a purchased extrudate is mixed with binders, fats, flavorings, and other ingredients, then mechanically shaped, packaged, and frozen for retail sale.

Three formed products— ground beef, chicken nuggets, and whole cut chicken— and two extruded products— low moisture extrudate (LME) and high moisture extrudate (HME)— are considered in the TEA. Each formed and extruded product is modeled with a distinct recipe and process. The results are reported on a cost-per-kg basis for each formed product and extrudate.

2.2 Scenario Definitions

Current and future production scenarios are modeled to assess today's processes against the potential of optimized processes in a future state. A summary of the scenarios modeled in the TEA is provided in Table 1 below.

Table 1. Summary of scenarios included in the TEA.

Product Type	Scenario	Capacity	Plant Utilization[1]	Recipe	Product Split
Extrudate	Current	50,000 MTA	100%	Low Moisture Extrudate	100%
	Future	50,000 MTA	100%	Low Moisture Extrudate	70%
				High Moisture Extrudate	30%
Formed Product	Current	5,000 MTA	50%	Ground Beef	50%
				Chicken Nuggets	30%
				Whole Cut Chicken	20%
	Future	15,000 MTA	100%	Ground Beef	50%
				Chicken Nuggets	30%
				Whole Cut Chicken	20%

The current extrudate scenario is modeled to reflect LME as the dominant, commercially proven pathway in production today, while the future scenario introduces dedicated HME capacity with gas injection to capture broader adoption as the technology matures and innovations being explored for improved organoleptic properties.

The current formed product facility is modeled as a smaller-scale, lower-utilization scenario based on realistic near-term demand and underloaded assets to anticipate future expansion, while the future facility presents a case closer to full commercial operation.

2.3 Product Recipes

Hypothetical product recipes were developed for the extrudates and formed products based on data collected from plant-based meat manufacturers and ingredient suppliers to reflect products sold today.

2.3.1 Extrudate Recipes

The extrudate recipes used in the baseline model are provided in Table 2. Soy-based extrudate recipes were ultimately selected for the purposes of this study to best reflect the current market.

Table 2. Product recipes for LME and HME (wt. %).

Ingredient Type	LME	HME
Soy protein concentrate	97%	33%
Water	3%	67%

[1] Plant utilization is defined as the facility's actual operating time as a percentage of total available operating time. The current formed product plant is sized for the full rated 5,000 MTA capacity, but because it runs only half the available hours, annualized output is only 50% of the nameplate capacity.

2.3.2 Formed Product Recipes

A summary of the formed product recipes used in the baseline model by ingredient type are provided in Table 3. Anticipated recipe developments were gathered from these manufacturers and ingredient providers to inform the future scenario recipes.

Table 3. Product recipes for ground beef, chicken nugget, and whole cut chicken (wt. %).

Ingredient Type	Ground Beef		Chicken Nugget		Whole Cut Chicken	
	Current	Future	Current	Future	Current	Future
Water*	59%	59%	45%	45%	19%	19%
Extrudate	23%	18%	16%	12%	73%	73%
Secondary protein sources		5%	1%	5%		
Binders	1.5%	1.5%	1%	1%		
Liquid fats*	7%	7%	4%	4%	3%	3%
Solid fats	4%	4%				
Flavors	5%	5%	5%	5%	5%	5%
Colors	< 1%	< 1%	< 1%	< 1%	< 1%	
Preservatives & antioxidants	1%	1%	< 1%	< 1%	1%	1%
Vitamins & minerals	< 1%	< 1%	< 1%	< 1%	< 1%	< 1%
Breading & frying ingredients			28%	28%		

** A portion of the water and liquid fat is in the form of an emulsion with the binder ingredients.*
Note: Blank cells for chicken nugget (solid fats) and whole cut chicken (secondary protein sources, binders, solid fats, colors) reflect ingredients not present in those formulations.

2.4 Process Description

Two dedicated facilities are modeled in the TEA—an extrusion facility and a product formulation facility— with packaging, storage, and transportation included for material transfer. Each facility is designed to support production of multiple recipes.

2.4.1 Extrusion Process

Two distinct extrusion processes were modeled for the production of LME and HME. Block flow diagrams (BFDs) of each process are provided in Figure 1.

The extrusion process begins at the receipt of incoming soy protein that is preconditioned with room temperature water and steam injection in the case of LME, and hot water in the case of HME. The preconditioned protein is then extruded through a high or low moisture extruder to produce soy protein extrudate. Gas injection is included on the high moisture extruder.

Following extrusion, the LME is cut, milled, dried, separated, and packaged before being transported to a product formulation facility. The HME is cooled in a cooling die with breaker plates before being cut, frozen, and packaged prior to shipment.

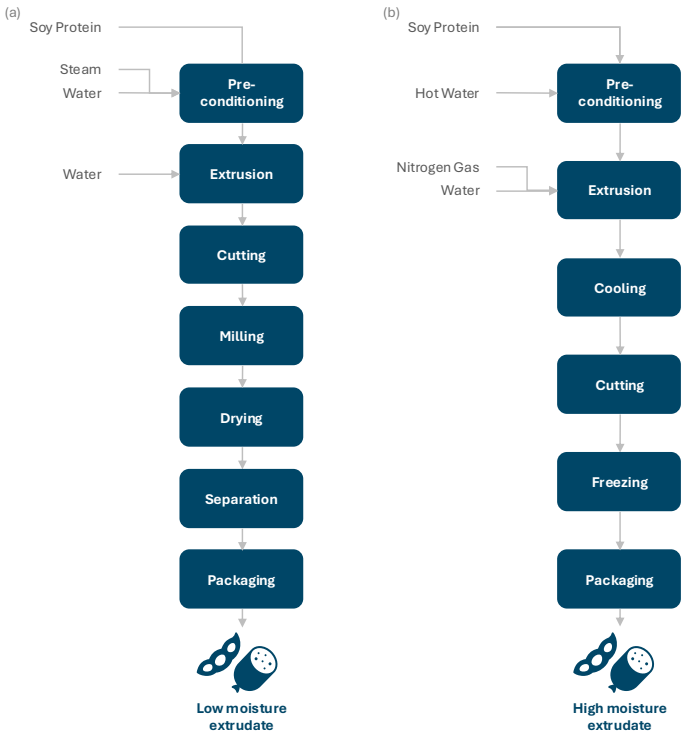


Figure 1. BFDs for (a) low moisture extrudate and (b) high moisture extrudate.

2.4.2 Product Formulation Process

Unique processes were modeled for each of the formed products as shown in Figure 2.

Product formulation begins at the receipt of incoming extrudate from the extrudate provider. Water-soluble ingredients (flavors, colors, preservatives, antioxidants, vitamins, and minerals) are pre-mixed separately to allow full dissolution. A vacuum cutter emulsifies the binder ingredients before transfer to the ribbon blender (also termed ‘paddle mixer’) for final mixing of the water-soluble ingredients, extrudate, liquid fats, and the emulsified ingredients.

The products are then formed, frozen, and packaged for distribution. The chicken nugget production line includes an additional batter, bread, and fry step after forming and prior to freezing.

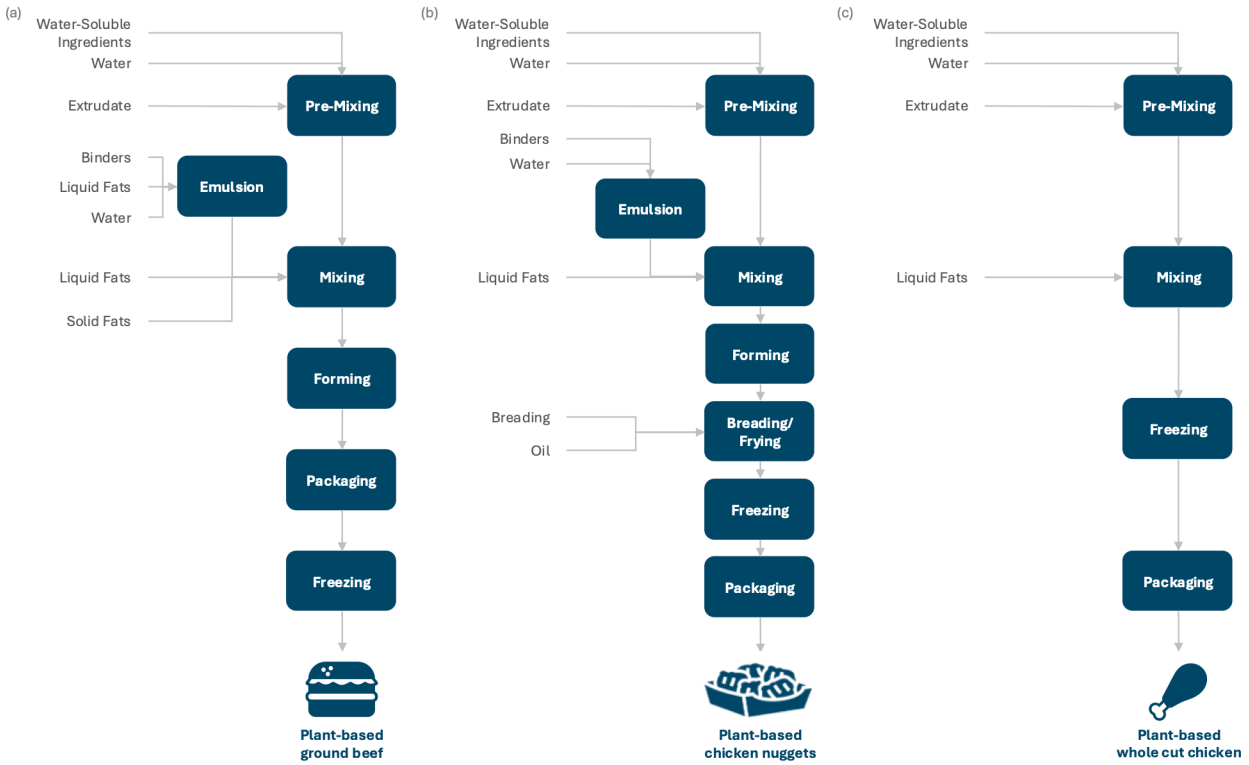


Figure 2. BFDs for (a) ground beef, (b) chicken nuggets, and (c) whole cut chicken.

2.5 Process Equipment

The TEA includes a complete equipment list aligned with the Front-End Loading (FEL) 0/1 design principles for the two facilities. Current and future production scenarios are considered for each facility, with equipment additions and adjustments to sizing made where necessary. Additional engineering and modeling methods employed in this analysis are included in **Appendix C. Additional Engineering & Modeling Methods**.

2.5.1 Extrusion

The extrusion facility is designed to handle continuous production of extrudate. The current scenario models a dedicated facility for production of LME. The future scenario models a multi-product facility to handle the production of both LME and HME in parallel. Equipment is considered for bulk storage, low moisture extrusion, high moisture extrusion, packaging, utilities, and waste management. Major equipment requirements for the baseline facilities are summarized in Table 4.

Soy protein concentrate powder is delivered to the extrusion facility by truck and stored in silos. A vacuum system is included to transport the protein powder to point of use storage receivers near the extruders. Equipment to stabilize extrudate and prepare it for shipping are included in the equipment list. HME is frozen and LME is dried before bulk bagging into food grade FIBC bags, weighing, palletizing, and conditioned storage.

Table 4. Major process equipment for the extrusion facilities.

Process Equipment		Current Scenario	Future Scenario
Low Moisture Extrusion	Preconditioner	4 x 2,500 kg/h	3 x 2,300 kg/h
	Extruder	4 x 2,500 kg/h	3 x 2,300 kg/h
	Cutter	4 x 2,500 kg/h	3 x 2,300 kg/h
	Mill	1 x 9,900 kg/h	1 x 6,900 kg/h
	Dryer & Cooler	1 x 9,900 kg/h	1 x 6,900 kg/h
	Separator	1 x 7,800 kg/h	1 x 5,500 kg/h
High Moisture Extrusion	Preconditioner		3 x 800 kg/h
	Extruder		3 x 800 kg/h
	Cooler		3 x 800 kg/h
	Cutter		3 x 800 kg/h
	Freezer		1 x 2,400 kg/h

2.5.2 Product Formulation

The product formulation facility is designed for production of the three formed products in campaigns with shared equipment for common unit operations. Equipment and facilities are considered for bulk storage, pre-mixing, emulsification, mixing, product forming, freezing & packaging, utilities, and waste management. Major equipment requirements for the baseline facilities are summarized in Table 5.

The facility includes conditioned storage for receipt of bulk extrudate. An emulsifier is included for emulsification of binder ingredients prior to mixing. The ground beef and chicken nugget lines include a shared product former. A batter and fry system is included for the chicken nugget line. The chicken nugget and whole cut chicken lines include a shared product bagger. All products are frozen via a spiral freezer and sent through a check weigher and foreign object detector. Packaged products are loaded into boxes to be refrigerated prior to shipping.

Table 5. Major process equipment for the product formulation facilities.

Process Equipment	Current Scenario	Future Scenario
Water Pre-Mix Tank	1 x 200 L	1 x 500 L
Emulsifier	1 x 30 L	1 x 80 L
Ribbon/Paddle Mixer	1 x 900 kg/h	1 x 2,300 kg/h
Product Former	1 x 700 kg/h	1 x 2,100 kg/h
Fryer System	1 x 500 kg/h	1 x 1,500 kg/h
Freezer System	1 x 700 kg/h	1 x 2,100 kg/h
Bagger	1 x 700 kg/h	1 x 2,100 kg/h

2.5.3 Utilities, Storage, & Waste Management

Utilities, storage, and waste collection are included in the analysis for each facility to provide a complete basis of plant design. Utility equipment considered in both extrusion and product formulation facilities includes boilers, chillers, instrument air compressors, water tanks, water softeners, dust collection systems, and central clean-in-place (CIP) systems.

The included CIP equipment is standard to food grade facilities of this scale and assumes steps for a caustic wash and a no-rinse sanitizer. Waste management equipment includes grease interceptors, wastewater collection (sumps for local collection and central tanks), and pH adjustment skids before discharge to the local publicly owned treatment works (POTW).

3 Key Results

The following section provides the baseline COGS and CAPEX results of the TEA for formed product and extrudate at both current and future production scenarios.

3.1 Extrudate

3.1.1 Extrudate COGS

Figure 3 presents an overview of projected COGS at baseline for extrudates in both current and future scenarios.

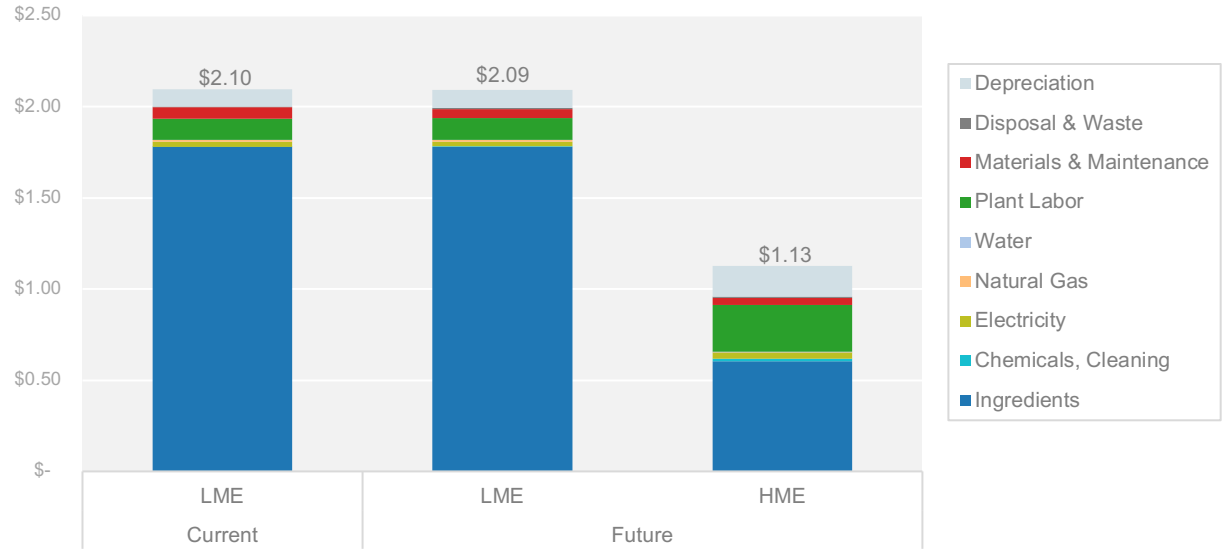


Figure 3. Projected COGS for current and future extrudate recipes ($/kg).

A detailed breakdown of COGS ($/kg) by cost category for each extrudate is provided in Table 6. COGS for LME is nearly flat across current and future scenarios, as both scenarios are modeled at the same 50,000 MTA nameplate capacity and 100% plant utilization (Table 1). Minor COGS improvements in the LME future scenario come primarily from sharing costs of common equipment, utilities, and labor with the added HME production line.

Ingredients remain the largest COGS category for both extrudate types, accounting for 85% of total COGS for LME and 54% for HME. HME is the lower cost extrudate option at $1.13/kg, roughly 46% below the future LME cost, driven primarily by its lower soy protein concentrate content (33% for HME vs. 97% for LME). Plant labor and depreciation are proportionally higher for HME ($0.26/kg and $0.17/kg, respectively) than for LME ($0.12/kg and $0.10/kg), because commercial high moisture extruders are not yet available at the throughputs achievable with low moisture extruders (see **Appendix B. Process Parameters**). More HME production lines are therefore required per kg of output, raising both installed equipment cost (depreciation) and

labor requirements on a per-kg basis. Case studies exploring extrudate production volume and extruder capacity are presented later in **Section 4.1** to further assess these drivers.

Table 6. Projected COGS breakdown for current and future extrudate recipes ($/kg).

COGS Category	LME		HME
	Current	Future	Future
Ingredients	$1.78	$1.78	$0.61
Chemicals, Cleaning	$0.00	$0.00	$0.01
Electricity	$0.03	$0.03	$0.03
Natural Gas	$0.01	$0.01	$0.00
Water	$0.00	$0.00	$0.00
Plant Labor	$0.11	$0.12	$0.26
Materials & Maintenance	$0.06	$0.05	$0.04
Disposal & Waste	$0.01	$0.01	$0.01
Depreciation	$0.09	$0.10	$0.17
Total COGS	**$2.10**	**$2.09**	**$1.13**

3.1.2 Extrudate CAPEX

Both the current and future extrusion facilities are designed for the same 50kMTA extrudate capacity, with the future facility adding dedicated high moisture extrusion and packaging equipment. A project cost summary for the 50kMTA extrusion facilities is provided in Table 7.

Table 7. Project cost summary for current and future extrusion facilities.

PLANT-BASED MEAT EXTRUSION FACILITY PROJECT COST SUMMARY				
PROCESS EQUIPMENT COST				
Facility Area		**Current**		**Future**
Bulk Storage	$	4,886,000	$	4,843,000
Chemical Storage	$	211,000	$	314,000
Low Moisture Extrusion	$	26,977,000	$	19,812,000
High Moisture Extrusion	$	-	$	12,001,000
LME Packaging	$	454,000	$	377,000
HME Packaging	$	-	$	4,956,000
Utilities	$	1,869,000	$	1,914,000
Water & Waste Management	$	302,000	$	462,000
Total Installed Equipment Cost	**$**	**34,699,000**	**$**	**44,679,000**
Unpriced Equipment	$	1,735,000	$	2,234,000
Building & Facility	$	12,144,000	$	15,637,000
Building & Equipment Install Cost	**$**	**48,578,000**	**$**	**62,550,000**
PROJECT INDIRECTS & OWNER'S COSTS				
Project Indirects		**Current**		**Future**
Engineering, Procurement, & Project Management	$	7,835,000	$	10,089,000
Field Indirects & Construction Management	$	3,134,000	$	4,036,000
Owner's Costs				
Commissioning & Startup	$	3,134,000	$	4,036,000
Escalation & Contingency				
Escalation	$	1,881,000	$	2,422,000
Construction Contingency	$	6,268,000	$	8,071,000
TOTAL PROJECT COST	**$**	**70,830,000**	**$**	**91,204,000**

Total project cost is estimated at $71M for the current scenario and $91M for the future scenario, reflecting roughly a 29% cost increase to support the addition of high moisture extrusion production capacity. Process equipment accounts for the largest share at 49% of total project cost at both scales. Low Moisture Extrusion is the single largest equipment area in both scenarios but drops from $27.0M (current) to $19.8M (future) as some throughput shifts to the new High Moisture Extrusion area, which becomes the second-largest equipment area in the future scenario at $12.0M (see Figure 4). With extrudate output capacity held constant at 50,000 MTA across both scenarios, capital intensity rises from roughly $1.42/kg to $1.82/kg, reflecting the added investment in dedicated high moisture extrusion and packaging equipment.

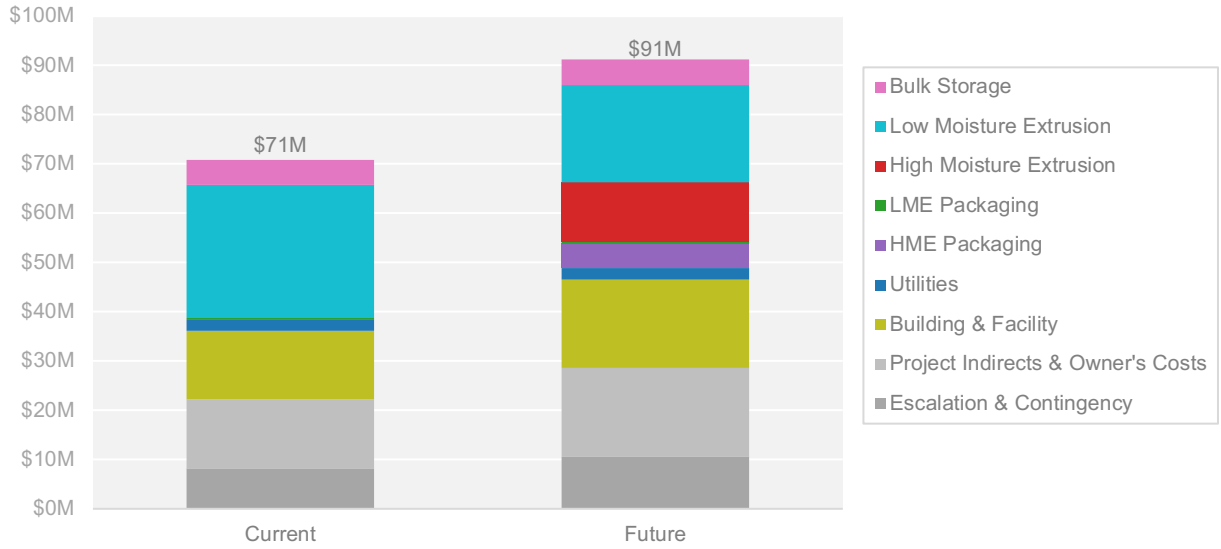


Figure 4. Projected CAPEX for current and future extrusion facilities.

3.1.3 Sensitivity

A sensitivity analysis was performed to identify the primary drivers of extrudate COGS. All extrusion input parameters varied by ±20%, and those with greater than 1% impact on COGS are presented in Figure 5 below.

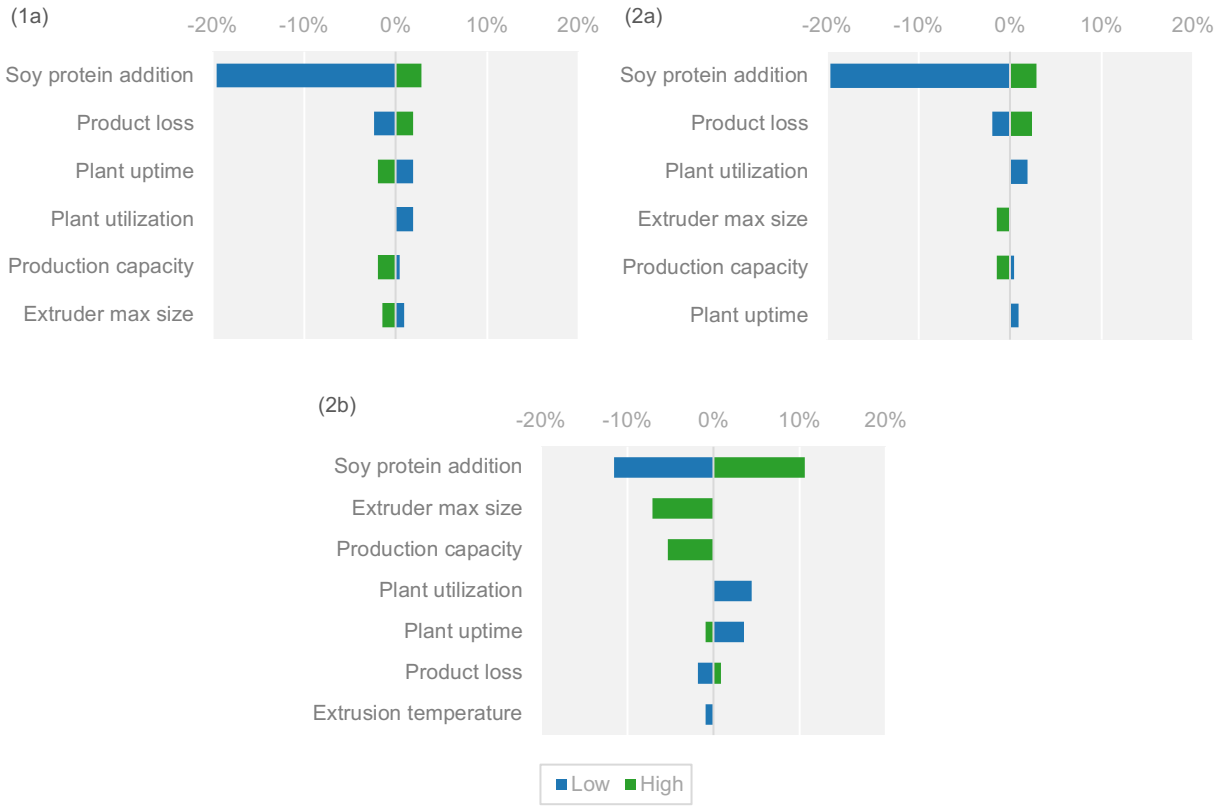


Figure 5. Sensitivity of COGS to ±20% variation in extrusion input parameters for (1a) current LME, (2a) future LME, and (2b) future HME. Only parameters with greater than 1% impact on COGS are shown.

Soy protein addition is the dominant driver of extrudate COGS across all three product scenarios, consistent with ingredients being the largest COGS category identified above. The asymmetric effect demonstrated in the LME cases are due to the practical soy protein loading ceiling being hit at the +20% end (i.e., soy protein cannot exceed 100 wt.%). Plant utilization, uptime, and product loss are consistent secondary drivers across all three scenarios, underscoring the importance of maintaining process efficiency.

Extruder max size and production capacity rank among the top drivers in the HME case. However, the extruder capacity case study later in this report (**Section 4.1.2**) shows doubling HME extruder capacity reduces COGS by only ~7%, suggesting that equipment-level scale-up alone is not a meaningful cost-reduction strategy. Production volume presents a more consequential cost-lever. HME is modeled at a smaller share of total production (30%) than LME, so closing that gap through large-scale production offers a more meaningful path to lowered costs. This highlights an opportunity for direct production of HME by ingredient companies or in-house capacity, rather than smaller contract manufacturing organization (CMO) arrangements. This analysis suggests extrudate cost reduction efforts should prioritize soy protein sourcing/formulation and pursuit of large-scale production volumes for HME.

3.2 Formed Product

3.2.1 Formed Product COGS

Figure 6 presents an overview of projected COGS at baseline for formed products in both current and future scenarios.

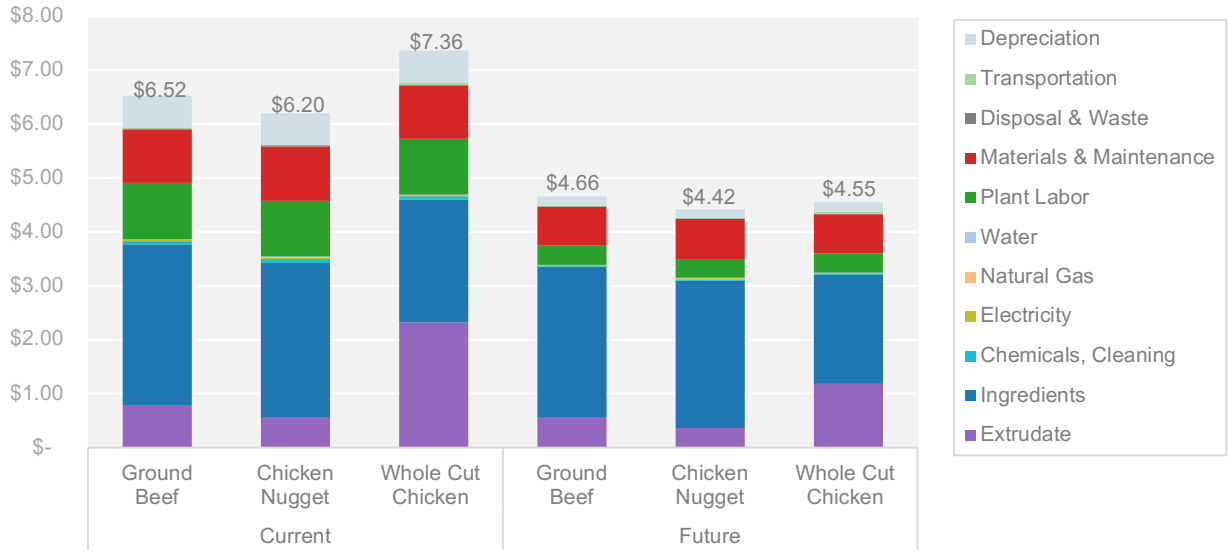


Figure 6. Projected COGS for current and future formed product recipes ($/kg).

A detailed breakdown of COGS by cost category for each formed product is provided in Table 8. Whole cut chicken stands out as the highest-cost product in the current scenario, driven primarily by its 73% inclusion rate of HME, versus the 16–23% LME inclusion in the other two product recipes. The future whole cut chicken scenario uses a future HME ingredient price based on the future HME extrudate COGS ($1.13/kg) with a 30% markup, reducing the cost burden of extrudate and narrowing the cost gap between whole cut chicken and the other two products.

Ingredients are the largest cost category across the other two product cases, with flavorings representing the biggest driver within it. Flavoring ingredients alone account for 33–39% of product COGS in the current case, rising to 43–46% in the future case as economies of scale reduce the relative cost of labor, materials & maintenance, and depreciation. Case studies for ingredient inclusion and pricing are presented in **Section 4.2.3** to further assess this finding.

Table 8. Projected COGS breakdown for current and future formed product recipes ($/kg).

COGS Category	Ground Beef		Chicken Nugget		Whole Cut Chicken	
	Current	Future	Current	Future	Current	Future
Extrudate	$0.79	$0.55	$0.55	$0.37	$2.32	$1.19
Ingredients	$2.98	$2.80	$2.88	$2.73	$2.28	$2.02
Chemicals, Cleaning	$0.06	$0.02	$0.06	$0.02	$0.06	$0.02

COGS Category	Ground Beef		Chicken Nugget		Whole Cut Chicken	
	Current	Future	Current	Future	Current	Future
Electricity	$0.03	$0.02	$0.03	$0.03	$0.03	$0.02
Natural Gas	< $0.01	< $0.01	< $0.01	< $0.01	< $0.01	< $0.01
Water	< $0.01	< $0.01	< $0.01	< $0.01	< $0.01	< $0.01
Plant Labor	$1.04	$0.35	$1.04	$0.35	$1.04	$0.35
Materials & Maintenance	$0.99	$0.72	$1.01	$0.74	$0.98	$0.73
Disposal & Waste	$0.02	$0.01	$0.02	$0.01	$0.02	$0.01
Transportation	$0.01	$0.01	$0.01	$0.01	$0.04	$0.04
Depreciation	$0.59	$0.17	$0.59	$0.17	$0.59	$0.17
Total COGS	**$6.52**	**$4.66**	**$6.20**	**$4.42**	**$7.36**	**$4.55**

3.2.2 Formed Product CAPEX

The current and future product formulation facilities modeled in the baseline scenarios differ in size, comparing today's smaller operations against a larger-scale future state. A detailed project cost summary for the two scenarios is provided in Table 9.

Table 9. Project cost summary for current and future formed product facilities.

PLANT-BASED MEAT
PRODUCT FORMULATION FACILITY
PROJECT COST SUMMARY

PROCESS EQUIPMENT COST		
Facility Area	**Current [5kMTA]**	**Future [15kMTA]**
Bulk Storage	$ 781,000	$ 1,883,000
Pre-Mixing	$ 287,000	$ 396,000
Emulsification	$ 350,000	$ 628,000
Mixing	$ 706,000	$ 1,206,000
Product Forming	$ 541,000	$ 1,046,000
Breading & Frying	$ 2,317,000	$ 4,478,000
Freezing & Packaging	$ 4,685,000	$ 8,098,000
Utilities	$ 739,000	$ 831,000
Water & Waste Management	$ 443,000	$ 420,000
Total Installed Equipment Cost	**$ 10,849,000**	**$ 18,986,000**
Unpriced Equipment	$ 543,000	$ 950,000
Building & Facility	$ 3,796,000	$ 6,645,000
Building & Equipment Install Cost	**$ 15,188,000**	**$ 26,581,000**
PROJECT INDIRECTS & OWNER'S COSTS		
Project Indirects	**Current [5kMTA]**	**Future [15kMTA]**
Engineering, Procurement, & Project Management	$ 2,449,000	$ 4,287,000
Field Indirects & Construction Management	$ 980,000	$ 1,715,000
Owner's Costs		
Commissioning & Startup	$ 980,000	$ 1,715,000
Escalation & Contingency		
Escalation	$ 588,000	$ 1,029,000
Construction Contingency	$ 1,960,000	$ 3,430,000
TOTAL PROJECT COST	**$ 22,145,000**	**$ 38,757,000**

Total project cost is estimated at $22M for the 5kMTA facility modeled in the current scenario and $39M for the 15kMTA facility modeled in the future scenario, reflecting roughly a 75% cost increase to support a threefold increase in capacity. Process equipment accounts for the largest share at 49% of total project cost at both scales, with Freezing & Packaging and Breading & Frying representing the two largest equipment areas (see Figure 7). The capital cost per unit of capacity improves considerably with scale and utilization, dropping from roughly $4.40/kg product at 5kMTA to about $2.58/kg product at 15kMTA, demonstrating favorable economies of scale as the facility grows and operations become more efficient.

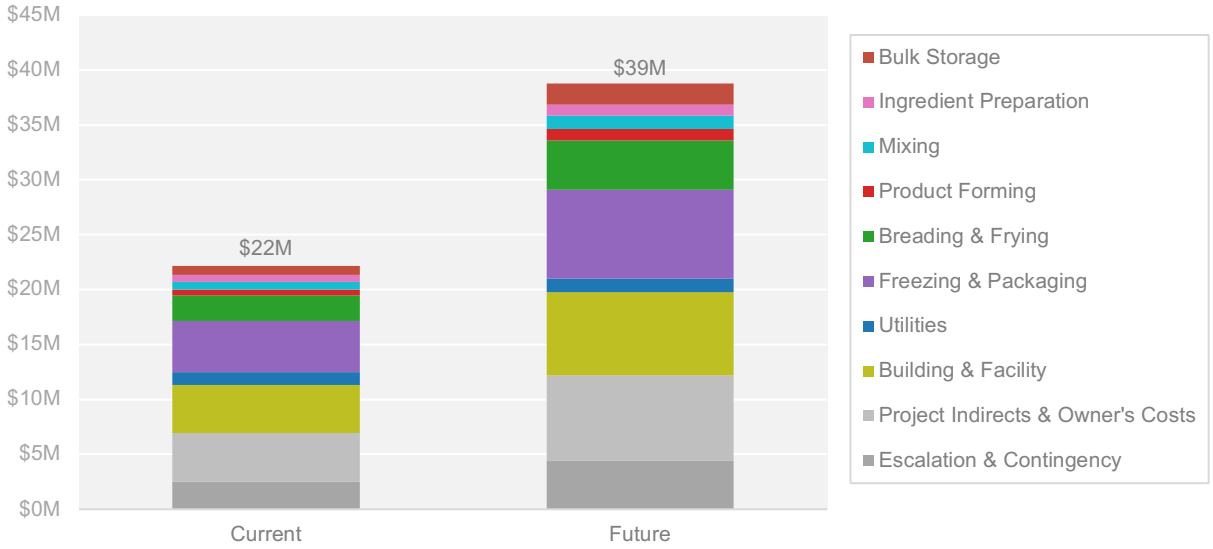


Figure 7. Projected CAPEX for current and future product formulation facilities.

3.2.3 Sensitivity

A sensitivity analysis was performed to identify the primary drivers of formed product COGS. All product formulation input parameters varied by ±20%, and those with greater than 1% impact on COGS are presented in Figure 8 below.



Figure 8. Sensitivity of COGS to ±20% variation in product formulation input parameters. Left-hand column shows current scenario results for (1a) ground beef, (1b) chicken nugget, and (1c) whole cut chicken. Right-hand column shows future scenario results for (2a) ground beef, (2b) chicken nugget, and (2c) whole cut chicken. Only parameters with greater than 1% impact on COGS are shown.

Across all three current scenarios, production capacity and plant utilization consistently emerge as major drivers of COGS. This underscores the importance of achieving target throughput and economies of scale, as underutilized capacity meaningfully erodes unit economics. Liquid flavor or flavor system inclusion also ranks among the top drivers in every product scenario, reflecting the relatively high cost of flavoring inputs relative to other ingredients.

Extrudate inclusion and product loss represent the remaining top drivers across products and scenarios, with extrudate inclusion showing particularly strong sensitivity in both whole cut chicken scenarios where HME makes up a larger share of the recipe. Other ingredient/system inclusions show less than 2% impact on COGS, indicating that cost sensitivity is concentrated in the high-inclusion/high-price ingredients or capacity-related parameters. This finding suggests that future cost reduction efforts should prioritize optimization of plant operations and sourcing of flavors and extrudates over marginal improvements to other ingredients.

4 Case Studies

4.1 Extrudate

This section presents case studies assessing the impacts of two key variables: production volume and extruder capacity. Case studies were structured to isolate the individual effect of each variable on COGS for both LME and HME.

4.1.1 Production Volume

The first case study presented here examines the impact of production capacity on extrudate COGS by comparing the baseline 50kMTA future extrusion facility to a smaller 10kMTA facility, holding recipe and pricing assumptions constant for both LME and HME. The outcomes are presented in Figure 9 below.

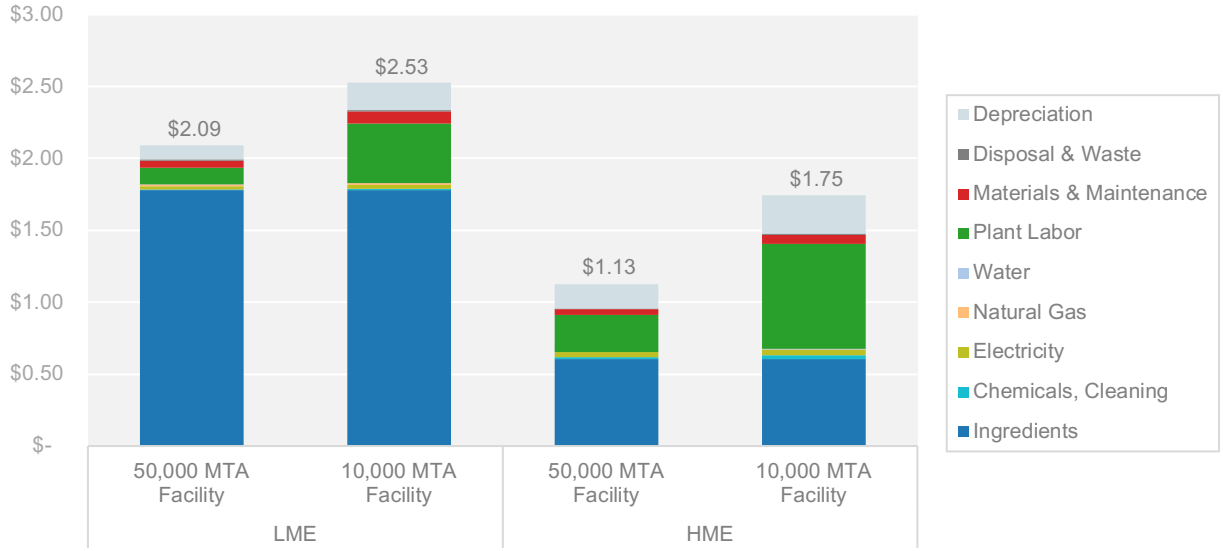


Figure 9. Overview of production volume impacts on COGS ($/kg) for LME and HME in the future scenario (70% LME / 30% HME production split), adjusting overall plant capacity (50,000 → 10,000 MTA).

Reducing overall plant capacity from 50kMTA to 10kMTA increases LME COGS by roughly 21%, driven primarily by higher plant labor and depreciation per kg as the same fixed operating and capital costs are spread across a smaller production volume. The effect is more pronounced for HME, where COGS increases by roughly 55%. This disproportionate sensitivity reflects HME's smaller ingredient cost share: because ingredients make up a smaller fraction of total HME COGS than LME COGS, the labor and depreciation components carry more weight, making HME economics considerably more dependent on achieving scale.

This analysis holds ingredient costs constant across scales as a simplifying assumption. In practice, larger producers can often secure better ingredient pricing through higher purchasing power, which would further widen the COGS gap between scales.

4.1.2 Extruder Capacity

Building on the sensitivity analysis finding that extruder size is a leading driver of HME COGS, this case study explores the potential impacts of technological innovations by comparing the current extruder maximum capacity and a larger unit size for both low and high moisture extruders (see Table 10).

Table 10. Extruder sizing basis (unit count and actual throughput) for baseline and increased max capacity extrusion scenarios.

	Baseline Max Capacity		Increased Max Capacity	
Extrusion Type	**Max Capacity**	**Throughput**	**Max Capacity**	**Throughput**
Low Moisture Extruder	3,000 kg/h	3 x 2,300 kg/h	4,500 kg/h	2 x 3,500 kg/h
High Moisture Extruder	1,000 kg/h	3 x 800 kg/h	2,000 kg/h	2 x 1,200 kg/h

Because real-world cost data for these larger pieces of equipment are not yet available, capital costs for the increased-capacity units are projected using the sixth-tenths rule, a standard practice for estimating equipment cost as a function of capacity. See **Appendix C. Additional Engineering & Modeling Methods** for further details on the capital cost modeling methods applied in this analysis. The outcomes are presented in Figure 10 below.

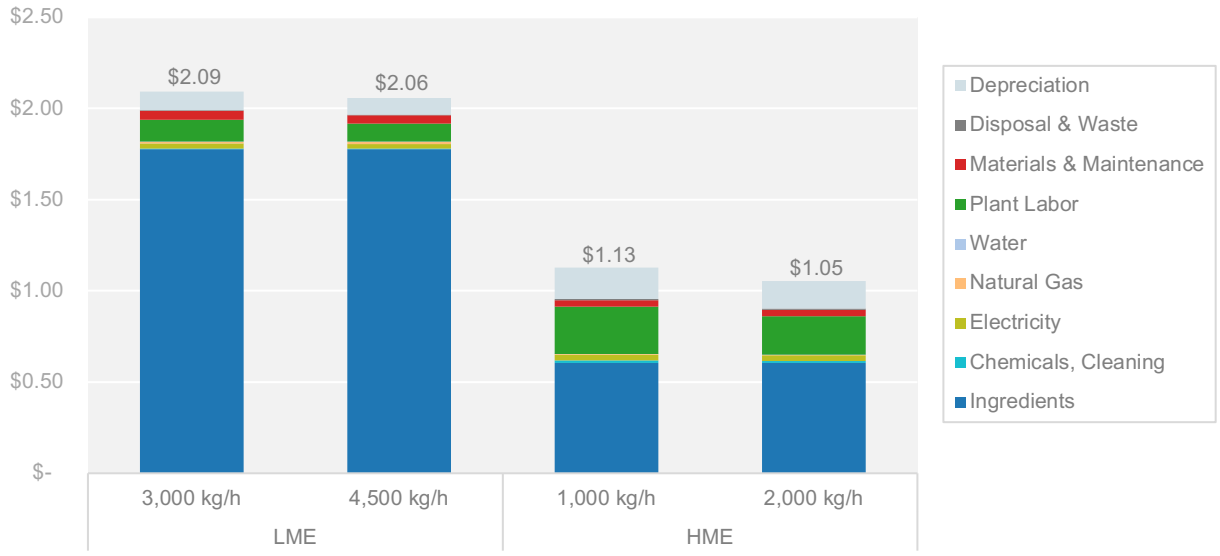


Figure 10. Overview of extruder capacity impacts on COGS ($/kg) for LME and HME in the future scenario, adjusting max extruder size for both low moisture extruders (3,000 → 4,500 kg/h) and high moisture extruders (1,000 → 2,000 kg/h).

Doubling HME extruder maximum capacity from 1,000 to 2,000 kg/h reduces COGS by roughly 7%, driven by lower plant labor and depreciation per kg as fewer, larger units are needed to meet the same output (see Table 10). LME COGS is comparatively insensitive to extruder size, improving only marginally (roughly 2%) since LME cost is largely dominated by ingredient cost.

4.2 Formed Product

This section presents case studies assessing the impacts of key operational, regional, and ingredient pricing variables on the COGS for ground beef, chicken nugget, and whole cut chicken products. Case studies were structured to explore how each of these levers, individually and in combination, could bring baseline COGS down to the target COGS required for cost parity. Figure 11 summarizes this framing, comparing current-scenario and future-scenario COGS against the target COGS for each product.

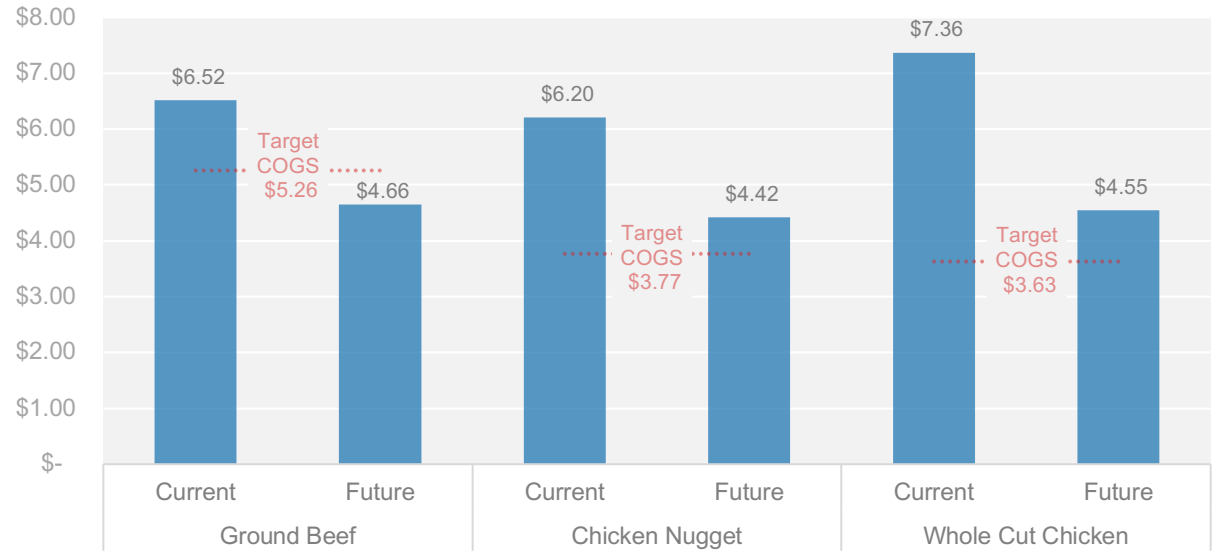


Figure 11. Projected baseline COGS ($/kg) relative to target COGS for ground beef, chicken nugget, and whole cut chicken in the current and future scenarios.

4.2.1 Operational Optimization

This section presents case studies exploring operational optimization pathways by isolating the three parameters identified in the sensitivity analysis as top drivers of COGS: product loss, plant utilization, and plant capacity. Each parameter was varied independently, from its current-scenario value to its future-scenario value, to quantify its individual impact on COGS. Specifically, product loss was reduced from 20% to 10%, plant utilization was increased from 50% to 100%, and plant capacity was scaled from 5,000 MTA to 15,000 MTA (Table 11).

Table 11. Baseline and case study values used in the operational optimization case studies.

Parameter	Baseline Value	Case Study Value
Product Loss	20%	10%
Plant Utilization	50%	100%
Plant Capacity	5,000 MTA	15,000 MTA

The outcomes are presented in Figure 12 below.

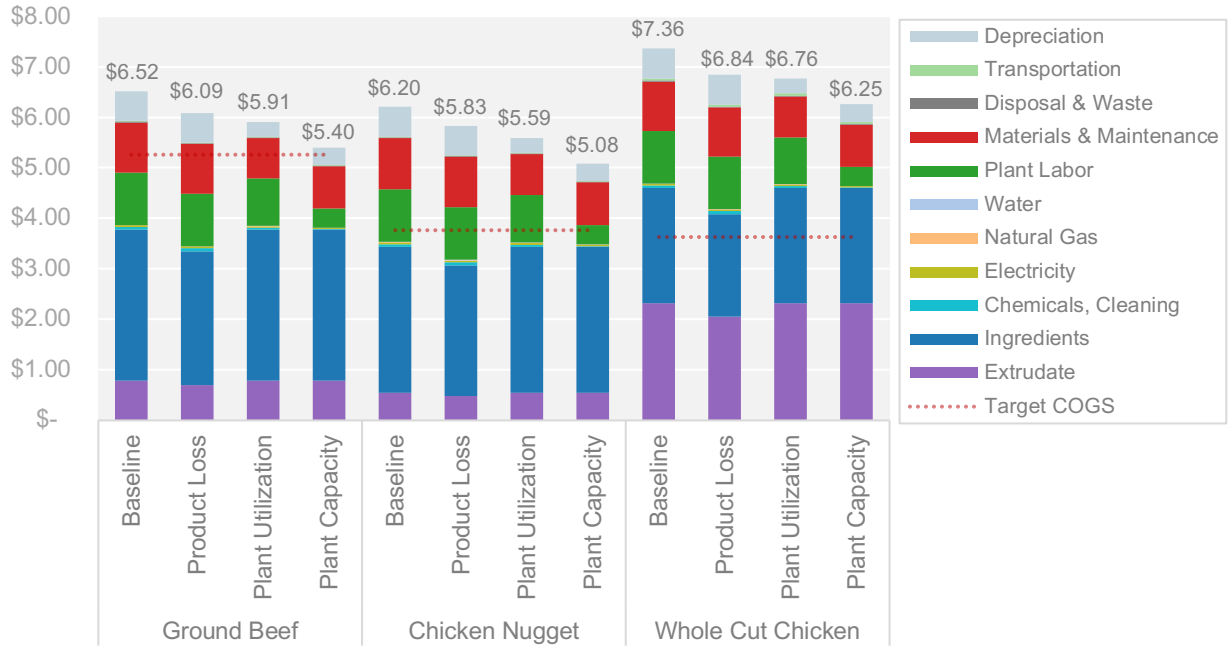


Figure 12. Overview of plant operation optimization impacts on COGS ($/kg) for ground beef, chicken nugget, and whole cut chicken in the current scenario, showing the effect of adjusting product loss (20% → 10%), plant utilization (50% → 100%), and plant capacity (5,000 → 15,000 MTA) independently.

Reducing product loss delivers a modest reduction in COGS across all three products (6–7%) driven primarily by lower ingredient and extrudate consumption. Increasing plant utilization yields a slightly larger benefit (8–10% reduction), with savings distributed across fixed costs (plant labor, materials & maintenance, and depreciation) as production nears the planned capacity and costs are spread more efficiently across a fuller production schedule.

Increasing plant capacity achieves the most substantial COGS reduction (15–19%), reinforcing that economies of scale are one of the single largest levers for improving unit economics across the three products. However, none of these individual impacts are sufficient on their own to bring any of the three products in the current scenario to price parity.

4.2.2 Regional Analysis

To evaluate cost sensitivity to regional variability of inputs, two alternative formed product plant locations, Brazil and India, are presented here as case studies. Regional data for utility pricing, labor costs, and building/construction factors provided in **Appendix A. Operating Cost Assumptions** were used to project costs of production in these regions.

A known limitation of this analysis is that ingredient costs are held constant across all three regions; raw material pricing reflects U.S. Midwest sourcing assumptions (see Table 15) and was not adjusted for Brazil or India. Extrudate prices were validated against local prices and

confirmed to be within the same range as the US base case, however costs of other ingredients may vary. Results of this case study are presented in Figure 13 below.

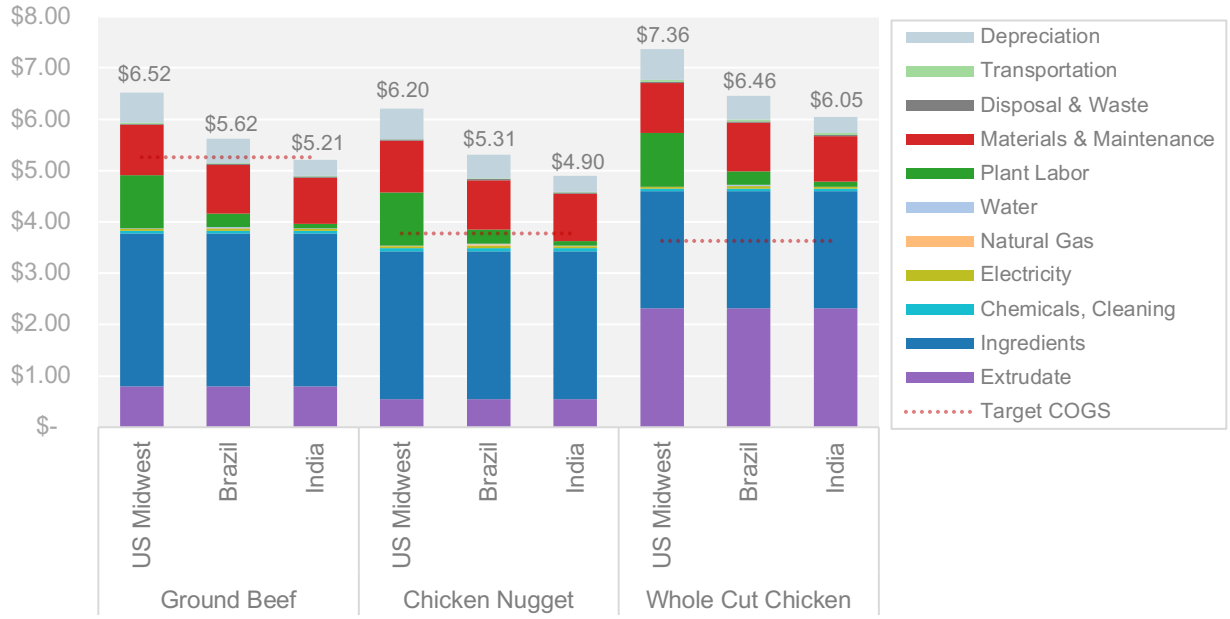


Figure 13. Overview of regional variability impacts on COGS ($/kg) for ground beef, chicken nugget, and whole cut chicken in the current scenario.

Shifting production to Brazil and India is projected to yield meaningful COGS reductions across all three products, driven primarily by lower labor and construction-related costs. Total COGS falls by roughly 12–14% in Brazil and 18–21% in India relative to the US Midwest baseline. Of the three products, only ground beef reaches cost parity in India; chicken nugget and whole cut chicken remain above the parity target in both regional scenarios.

Plant labor is the single largest driver of this gap, dropping from $1.04/kg in the US Midwest to $0.27/kg in Brazil and just $0.09/kg in India, reflecting the substantially lower regional wage rates[2]. Depreciation also declines meaningfully across regions, going from $0.59/kg in the US Midwest to $0.46/kg in Brazil and $0.31/kg in India. While Brazil has notably higher utility and transportation costs compared to the US Midwest, these categories represent a relatively small portion of cost and therefore have little impact on COGS.

4.2.3 Ingredient Pricing Analysis

As the single largest contributor to COGS across all product scenarios, ingredients represent the clearest opportunity for cost reduction. This section presents a series of case studies exploring the sensitivity of COGS to various ingredient pricing scenarios.

[2] Wage rates reflect living-wage levels for each region.

The first case study examines the COGS impact of shifting all ingredient prices simultaneously to their high and low extremes in the current scenario (Figure 14).

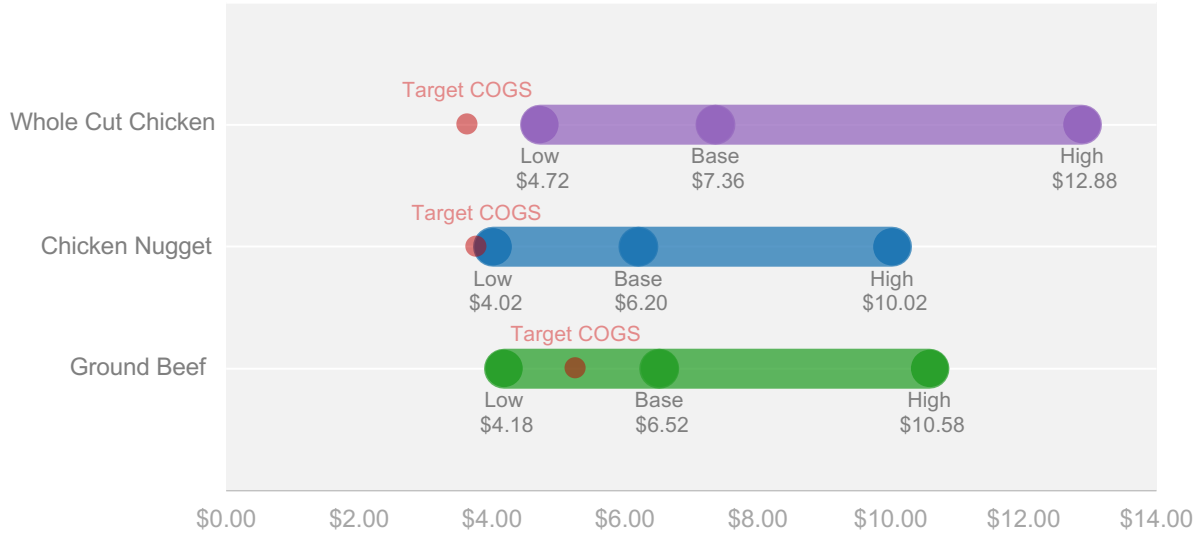


Figure 14. COGS ($/kg) sensitivity to high and low ingredient pricing applied simultaneously for ground beef, chicken nugget, and whole cut chicken in the current scenario.

The wide ranges of COGS outcomes presented above underscore the leverage ingredient pricing holds over overall cost. Under the low ingredient pricing scenario, ground beef once again reaches its cost parity target; chicken nugget and whole cut chicken remain above their targets but come closest to parity of any case study examined for the current scenario.

Whole cut chicken shows the widest cost range, decreasing roughly 36% at the low end and increasing roughly 75% at the high end relative to its $7.36/kg base case. Chicken nugget and ground beef follow a similar pattern, each realizing approximately 35% cost reductions from the base case under low-price and rising 60–62% under high-price assumptions. The upside risk is notably more pronounced for whole cut chicken compared to the other two products, reflecting its greater reliance on higher-cost ingredient inputs such as extrudate. These results suggest that ingredient price volatility poses a meaningful risk to all products, especially whole cut chicken, and that ingredient sourcing strategy should be prioritized accordingly.

The second case study explores ingredient price reductions in the future scenario, where low pricing assumptions were used for systems with the greatest cost leverage (secondary protein sources, liquid fats, solid fats, and flavors) and base prices were assumed for the remainder (Table 12).

Table 12. Ingredient system prices ($/kg) used in the ingredient pricing improvement case study for ground beef, chicken nugget, and whole cut chicken. Low pricing assumptions are indicated in green where used.

Ingredient System	Ground Beef	Chicken Nugget	Whole Cut Chicken
Secondary Protein Sources	↓ $1.50	↓ $1.50	
Binders	$2.11	$1.95	
Liquid Fats	↓ $0.75	↓ $0.75	↓ $0.75
Solid Fats	↓ $1.00		
Flavors	↓ $8.91	↓ $8.61	↓ $8.62
Colors	$40.83	$3.50	
Preservatives & Antioxidants	$5.66	$70.00	$0.75
Vitamins & Minerals	$3.36	$3.28	$3.28

Note: Blank cells for whole cut chicken (secondary protein sources, binders, solid fats, colors) and chicken nugget (solid fats) reflect systems not present in those formulations.

Under this scenario all three products clear their cost target: ground beef by $2.29/kg, chicken nugget by $0.93/kg, and whole cut chicken by $0.62/kg (Figure 15). Flavors remains the dominant cost driver in every product even at its adjusted price, contributing 40% of ingredient system cost for ground beef, 46% for chicken nugget, and 94% for whole cut chicken, since that formulation carries few other ingredient systems.

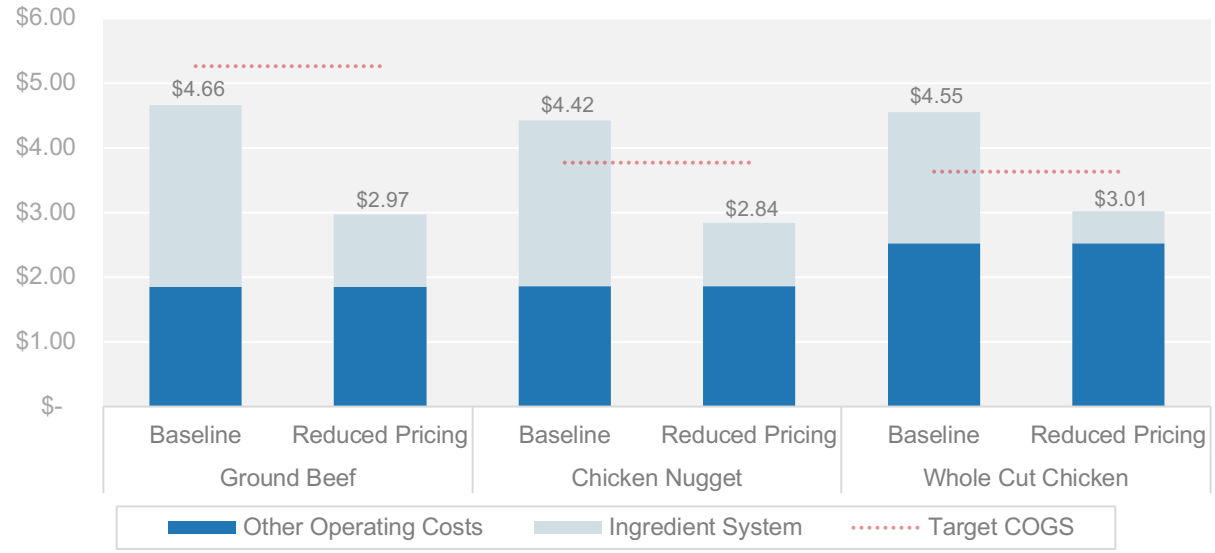


Figure 15. COGS ($/kg) projections for future baseline and reduced ingredient pricing scenarios relative to target COGS for ground beef, chicken nugget, and whole cut chicken.

To further explore how ingredient system pricing might impact each product's ability to reach price parity in the future, an analysis was conducted to derive price ceilings for each ingredient category under which price parity would be achievable. The analysis starts from a target cost for the finished product and subtracts extrudate and other operating costs to yield a residual budget available for the remaining ingredients. Price ceilings were derived for each ingredient system, varying one at a time while holding other ingredient system prices fixed. Table 13 presents the derived price ceilings by ingredient system for each product, and Figure 16 presents these findings graphically for ground beef.

Table 13. Ingredient system price ceilings ($/kg) derived for ground beef, chicken nugget, and whole cut chicken in the future scenario and their percent change over baseline pricing.

Ingredient System	Ground Beef	Chicken Nugget	Whole Cut Chicken
Secondary Protein Sources	$13.63 (+396%)	*N/A*	
Binders	$6.14 (+191%)	*N/A*	
Liquid Fats	$19.63 (+1209%)	*N/A*	*N/A*
Solid Fats	$16.60 (+453%)		
Flavors	$51.06 (+31%)	$24.93 (-33%)	$19.77 (-47%)
Colors	$222 (+444%)	*N/A*	
Preservatives & Antioxidants	$58.99 (+942%)	*N/A*	*N/A*
Vitamins & Minerals	$5,442 (+161,880%)	*N/A*	*N/A*

Note: Blank cells for whole cut chicken (secondary protein sources, binders, solid fats, colors) and chicken nugget (solid fats) reflect systems not present in those formulations.

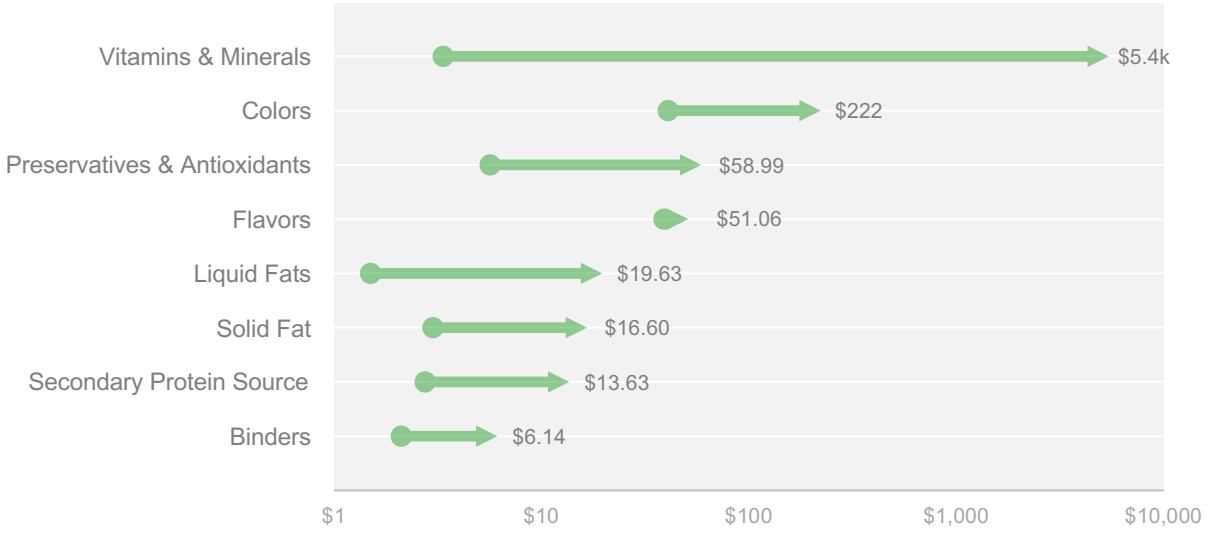


Figure 16. Ingredient system price ceilings ($/kg, log scale) derived for ground beef in the future scenario. Dots mark each system's baseline price; arrows extend to the derived price ceiling.

Ground beef, whose base-case COGS already sit below price parity, shows two distinct patterns in its price ceiling results. First, micronutrient and functional-additive systems including colors, preservatives & antioxidants, and vitamins & minerals carry ceilings far above the baseline prices and plausible market pricing, a direct result of their low inclusion rates. This finding suggests that these systems are not binding constraints on price parity regardless of how their input costs move.

By contrast, bulk systems including secondary protein sources, binders, liquid fats, and solid fats carry ceilings in the roughly $6–$50/kg range, close enough to realistic ingredient pricing that parity can be impacted by how these systems are sourced and priced. The flavors system, previously identified as the primary driver of COGS across the future scenarios (**Section 3.2**), has a comparatively narrow allowance range in the case of ground beef, tolerating only a 31% increase in price from baseline.

Chicken nugget and whole cut chicken present a different picture: because their base-case COGS are projected above price parity, most systems have no price ceiling (indicated in **Table 13** as “N/A), as the residual budget is already exhausted under base pricing for all other systems before that system’s price is varied. In other words, no price for that system, however low, would be sufficient to close the gap to price parity while every other system remains at its base price.

Flavors is the only system with price ceilings for these two products (about $25/kg for chicken nugget, $20/kg for whole cut chicken), making it the sole ingredient with leverage toward reaching price parity. As with ground beef, the findings here highlight flavors as the priority target for sourcing and pricing optimization efforts.

5 Conclusion

This TEA provides the plant-based meat industry a commercial-scale, representative view of cost drivers that has not previously existed at this level of detail, directly addressing the gap identified at the outset of this project: minimizing the price premium for plant-based meat over conventional meat requires an understanding of where cost is concentrated and which levers are most impactful.

Across both extrudate and formed product analyses, scale and ingredient sourcing consistently outweigh all other cost levers. Plant capacity is the single largest driver of COGS identified in every case study, cutting formed product COGS by 15–19% when capacity is increased threefold and raising extrudate COGS by 21–55% when capacity is reduced from 50kMTA to 10kMTA. A case study exploring the cost impact of increasing extruder capacity for HME found that doubling the extruder throughput cuts COGS by approximately 7%. On the ingredient side, cost sensitivity is dominated by flavors and extrudate inclusion for formed products and soy protein content for extrudates, meaning cost reduction efforts concentrated on these high-inclusion, high-price inputs will move the needle far more than marginal improvements elsewhere in the formulation.

Whole cut chicken stands out in this regard, as its high HME inclusion rate (73%) ties its economics to a technology that is less mature and constrained by current extruder throughput limits, and it shows the widest ingredient-price sensitivity of the three formed products (-36% to +75%). Reaching cost parity for this product will likely require the HME supply chain to achieve economies of scale at larger production volumes, in combination with reductions in flavor-system or other ingredient costs.

International production and low ingredient pricing each independently bring the current ground beef COGS projection under its cost-parity target while bringing the other two products close to theirs, suggesting price parity is achievable but likely requires stacking multiple cost reduction efforts rather than relying on any single strategy.

Appendix A. Operating Cost Assumptions

The TEA provides a complete OPEX estimate including cost of raw materials, utilities, labor, materials and maintenance, and waste disposal. Major economic assumptions applied in this analysis are summarized in Table 14. All financial inputs are normalized to a common reference year. The baseline assumption for plant location is the US Midwest, and regional costs are included for utilities and labor costs where applicable. All considered costs are inside battery limits (ISBL) only, and do not include costs associated with connected infrastructure.

Table 14. General economic assumptions for technoeconomic analysis.

Economic parameters	Assumed basis
Basis year for analysis	2026
Plant location	US Midwest
Operating weeks per year	46 weeks
Depreciation life	15 years
Various plant materials	1% of plant CAPEX
Maintenance	3% of plant CAPEX

Raw Materials

Raw material pricing data was provided by GFI. Table 15 summarizes the baseline price assumptions and expected ranges for pricing of all raw materials considered in the TEA.

Table 15. Raw material pricing assumptions ($/kg ingredient).

Ingredient	Base	Low	High
Low moisture extrudate	$2.75	$1.50	$4.50
High moisture extrudate (current)	$2.54	$1.54	$5.04
High moisture extrudate (future)	$1.46	$1.30	$2.25
Liquid flavor	$75.00	$10.00	$200.00
Yeast extract	$12.50	$10.00	$15.00
Salt	$0.75	$0.15	$1.00
Onion powder	$3.50	$2.50	$5.00
Garlic powder	$3.00	$1.50	$7.00
White pepper	$11.50	$11.00	$12.00
Mace	$15.00	$5.00	$40.00
Beet extract	$40.00	$30.00	$50.00
Turmeric extract	$45.00	$20.00	$65.00

Ingredient	Base	Low	High
Paprika	$3.50	$3.00	$4.00
Zinc	$3.00	$2.60	$3.60
B vitamin blend	$3.56	$2.79	$5.44
Vinegar	$0.75	$0.50	$1.25
Cultured dextrose	$8.00	$6.00	$10.00
Canola oil	$1.50	$0.75	$2.25
Methylcellulose	$15.00	$12.00	$20.00
Vitamin E (tocopherols)	$70.00	$60.00	$90.00
Coconut oil	$3.00	$1.00	$6.00
Potato starch	$1.20	$0.70	$1.70
Wheat gluten	$1.50	$1.00	$3.00
Wheat flour	$1.10	$0.70	$1.40
Corn starch	$0.65	$0.50	$0.80
Sodium bicarbonate	$1.50	$1.00	$2.00
Soy protein concentrate	$1.65	$2.15	$3.15

Utilities

Industrial 2026 utility prices for electricity and natural gas are averaged across Midwestern states to reflect the baseline assumption that the plant will be located in this region. Table 16 provides the pricing assumptions for utilities included in the baseline TEA as well as average pricing for Brazil and India used for the regional case study analysis, provided by GFI.

Table 16. Industrial utility pricing assumptions for US Midwest (baseline), Brazil, and India.

Utility	US Midwest	Brazil	India
Electricity, /kWh	$0.08	$0.11	$0.07
Natural gas, /MMBTU	$8.90	$18.83	$8.90
Water, /m^3	$1.02	$4.04	$1.34
Wastewater treatment, /m^3	$1.91	$3.21	$2.89
Solid waste treatment, /kg	$0.05	$0.05	$2.23
Transportation, /truckload/mile	$2.26	$2.35	$0.07

Labor

Labor is estimated for each product formulation and extrusion facility under the assumption that one operator is required for each piece of major process equipment per shift. This assumption is typical of food manufacturing and similar production facilities, where individual pieces of equipment are operated as process lines by teams of four to six people depending on the complexity of the overall manufacturing process.

Plant personnel are categorized into skilled and unskilled operators, mechanics, quality control technicians, foreman, and plant managers. Non-production roles associated with organizations (e.g., sales, administrative personnel) are assumed to be overhead paid for by other parts of the business and are not explicitly included in the labor estimates in the model. Average 2026 Midwest labor rates reported by the US Bureau of Labor Statistics are used to calculate labor costs. Table 17 provides labor rates assumed in the baseline TEA as well as average pricing for Brazil and India used for the regional case study analysis, provided by GFI.

Table 17. Annual salary assumptions for US Midwest (baseline), Brazil, and India by role (USD).

Positional	US Midwest	Brazil	India
Unskilled operator	$47,000	$10,600	$2,600
Skilled operator	$70,000	$14,300	$5,700
Maintenance technician	$52,000	$14,600	$6,500
QA/QC	$77,000	$17,700	$14,000
Shift manager	$75,000	$23,000	$11,300
Plant manager	$115,000	$70,700	$28,000

Capital Cost Estimate Assumptions

The capital cost estimate is prepared using equipment factors, parametric models, and Next Rung's historical database of cost information for similar equipment. Equipment is costed using Next Rung's database of equipment costs of purchased equipment, vendor quotes, and estimates. Extrusion data was provided by Buhler Group and another confidential extrusion equipment vendor. Project costs are heavily dependent on process decisions, facility class decisions, and final equipment selection. Major capital cost basis parameters are summarized in Table 18.

Table 18. Major capital cost basis parameters.

Capital Cost Parameter	Assumed Basis
Installation factor*	1-4x equipment cost
Unpriced equipment	5% of total installed cost
Engineering, procurement, project management	12.5% of total project cost
Field indirects, construction management	5% of total project cost

Capital Cost Parameter	Assumed Basis
Commissioning & startup	5% of total project cost
Escalation	3% of total project cost
Construction contingency	10% of total project cost

* Installation factors vary depending on equipment type.

Regional capital cost adjustments for Brazil and India were derived using a blended capital cost factor that weights four cost components by their actual share of the total baseline installed project cost estimate. Table 19 summarizes the component-level factors and underlying sources by region. The derived factors are applied against the baseline US Midwest capital cost estimate to generate the regional CAPEX results presented in the regional case study (**Section 4.2.2**). Process equipment was assumed to trade near baseline pricing rather than reflecting lower-cost local suppliers, since other factors such as duties, freight, local certifications, and vendor support can potentially offset local sourcing advantage. A factor of 1.0 was therefore applied to both regions for this component.

Table 19. Blended regional capital cost factors for Brazil and India by cost component, with weighting basis and source.

Cost Component	Brazil	India	Weight	Source
Building Costs	0.99	0.30	25%	Arcadis, *International Construction Costs 2024*
Process Equipment	1.00	1.00	39%	No regional factor applied
Bulk Materials	0.44	0.24	18%	Turner & Townsend, *Global Construction Market Intelligence 2025*
Construction Labor	0.40	0.15	18%	*Global Construction Costs Yearbook*, 2020 edition
Blended Factor	**0.79**	**0.53**		

Appendix B. Process Parameters

Table 20. Major process parameters for the low moisture extrusion model.

Parameter		Current	Future
Water to soy protein addition ratio	wt. : wt.	0.27	0.27
Steam to soy protein addition ratio	wt. : wt.	0.04	0.04
Preconditioning water temperature	ºC	20	20
Preconditioning heating temperature	ºC	87.5	87.5
Extruder max size	kg/h	3,000	3,000
Extrusion heating temperature	ºC	100	100

Table 21. Major process parameters for the high moisture extrusion model.

Parameter		Future
Preconditioning water temperature	ºC	85
Preconditioning heating temperature	ºC	87.5
Extruder max size	kg/h	1,000
Extrusion heating temperature	ºC	160
Gas to extrudate addition ratio	wt. : wt.	0.0003
Extrusion cooling temperature	ºC	85

Table 22. Major process parameters for the ground beef product formulation model.

Parameter		Current	Future
Binder emulsion water temperature	ºC	4	4
Forming, patty weight	lb	0.25	0.25
Forming, brick weight	lb	1.00	1.00
Forming, patty to brick ratio		50%	50%
Packaging, tray volume	in^3	55	55
Packaging, brick volume	in^3	384	384
Packaging, box volume	in^3	2,470	2,470
Packaging, patties per tray	ea.	4	4
Product freezing temperature	ºC	-20	-20

Table 23. Major process parameters for the chicken nugget product formulation model.

Parameter		Current	Future
Binder emulsion water temperature	ºC	4	4
Frying water loss	wt. %	10%	10%
Frying oil uptake	wt. %	10%	10%
Frying oil replacement frequency	h	168	168
Frying temperature	ºC	177	177
Fryer heating efficiency factor		85%	85%
Forming, nugget weight	lb	0.04	0.04
Packaging, bag volume	in^3	54	54
Packaging, box volume	in^3	2,470	2,470
Packaging, nuggets per bag	ea.	20	20
Product freezing temperature	ºC	-20	-20

Table 24. Major process parameters for the whole cut chicken product formulation model.

Parameter		Current	Future
Packaging, bag weight	lb	0.88	0.88
Packaging, bag volume	in^3	54	54
Packaging, box volume	in^3	2,470	2,470
Product freezing temperature	ºC	-20	-20

Appendix C. Additional Engineering & Modeling Methods

This appendix provides additional detail on the engineering and modeling methods used to develop the process, equipment, and cost estimates presented in this study. The information provided here supplements the process and equipment descriptions in **Section 2**, covering the mass balance approach, equipment and utility sizing methodology, and the capital cost estimation basis applied across the scenarios modeled in the TEA.

Process Modeling & Mass Balances

Process models are built on mass balances that quantify the flow of raw materials, products, and waste through each stage of production for the scenarios considered in this study. These mass balances form the basis for equipment sizing and cost estimation throughout the analysis.

Equipment Sizing

Equipment is sized based on the average throughput requirements defined by the mass balance for each modeled scenario. Maximum size limits are applied to major equipment to keep scaling realistic across the plant capacities considered in this study. Utility equipment is included in the equipment list and sized from the detailed utility calculations described below.

Utility Sizing

The TEA accounts in detail for utility requirements to support both equipment sizing and OPEX estimates. Heating, cooling, cleaning, water, wastewater, and electricity are all included.

Heating and cooling demands for process equipment are estimated from thermodynamic principles and operating conditions typical of industrial food processing. Heating demand sizes the boiler, which in turn informs the natural gas cost included in OPEX; cooling demand sizes the chiller system.

Clean-in-place (CIP) calculations account for soft water used in pre- and post-rinse cycles and for cleaning chemical dilution. Maximum CIP flow rates size the CIP skid, and average soft water flow rates — which also capture process water demand — size the water softener. Cleaning chemical usage is captured in OPEX.

Annual plant water usage, including soft water and boiler/cooling water makeup, is tracked as part of OPEX. The wastewater treatment system is sized from average flow rates across CIP, boiler blowdown, chiller operation, and process wastewater.

Capital Cost Estimates

Next Rung prepared the TEA using a cost estimating methodology consistent with a blend of AACE (Association for the Advancement of Cost Engineering) International Class 4 and Class 5 practices, targeting an accuracy range of ±25–30%. Capital costs are derived from the outputs of the process model. Capital costs include direct costs for major equipment, installation, and supporting infrastructure, along with indirect costs such as engineering, contingency, and project overhead.

Major equipment costs are developed primarily from Next Rung's internal database of real-world reference equipment costs, built from prior project experience, vendor quotes, and purchased equipment records. Equipment cost is extrapolated based on required capacity using the six-tenths rule, a standard capital cost estimate technique.

Installation factors are applied to all equipment costs to cover instrumentation, electrical, utility, and piping work, with factor selection reflecting the extent of pre-manufacturing or pre-assembly assumed for each item. These factors are drawn from Next Rung's project experience and vendor guidance, and confirmed against published references.

Appendix D. Equipment List

Table 25. Complete sized equipment list for extrusion facility.

Equipment Item	Current Capacity	Current Count	Future Capacity	Future Count
Bulk Storage				
Truck Scale	7,510 kg/h	1	6,023 kg/h	1
Truck Unloading Station	7,510 kg/h	1	6,023 kg/h	1
Check Sieve	7,510 kg/h	2	6,023 kg/h	2
Truck Unloading Supporting Equipment	7,510 kg/h	1	6,023 kg/h	1
Storage Silo	772,500 L	1	619,525 L	1
Chemical Storage				
Sodium Hydroxide Storage Tank	1,500 L	1	3,400 L	1
Sodium Hydroxide Storage Tank Pump	15 LPM	2	15 LPM	2
Subtotal				
Low Moisture Extrusion				
Vacuum Receiver	994 L	1	696 L	1
Loss in Weight Solids Feeder	1,877 kg/h	4	1,752 kg/h	3
Low Moisture Extruder Preconditioner	2,461 kg/h	4	2,297 kg/h	3
Low Moisture Extruder	2,461 kg/h	4	2,297 kg/h	3
Low Moisture Extruder Cutter	2,461 kg/h	4	2,297 kg/h	3
Airlift Conveyor to Mill	9,845 kg/h	1	6,892 kg/h	1
Mincing Mill	9,845 kg/h	1	6,892 kg/h	1
Airlift Conveyor to Dryer	9,845 kg/h	1	6,892 kg/h	1
Dryer & Cooler	9,845 kg/h	1	6,892 kg/h	1
Low Moisture Extruder Separator	7,742 kg/h	1	5,419 kg/h	1
High Moisture Extrusion				
Vacuum Receiver	*Not inlcuded in current scenario*		71 L	1
Loss in Weight Solids Feeder			255 kg/h	3
High Moisture Extruder Preconditioner			774 kg/h	3
High Moisture Extruder			774 kg/h	3
High Moisture Extruder Cooler			774 kg/h	3
High Moisture Extruder Cutter			774 kg/h	3
Gas Injection Add-On			*per extruder*	3
LME Packaging				
Airlift Conveyor to Packaging	3,484 kg/h	2	2,439 kg/h	2
Bag Filler & Weigher	15 bags/h	1	11 bags/h	1
Dry Storage	*Allotted rack storage*		*Allotted rack storage*	
HME Packaging				
Conveyor Cutter to Freezer	*Not included in current scenario*		2,323 kg/h	1
Spiral Freezer			2,323 kg/h	1
Conveyor to Packaging			2,090 kg/h	1
Bag Filler & Weigher			5 bags/h	1
Cold Storage Racking			*Allotted rack storage*	
Cold Storage Refrigeration			*Allotted cold storage*	
Utilities				
Boiler	11,031 lb/h	1	8,322 lb/h	1
Air Compressor	50 scfm	1	50 scfm	1
Dust Collector	*per facility*	4	*per facility*	3
CIP System	*per facility*	1	*per facility*	1
COP Stations	406 LPM	5	406 LPM	13
Water Softener	207 LPM	1	362 LPM	1
Softened Water Tank	46,600 L	1	81,600 L	1
Equipment Foamer	*per facility*	8	*per facility*	14
Hose Stations	*per facility*	8	*per facility*	14
Water & Waste Management				
Wastewater Sump	6,600 L	1	13,700 L	1
Wastewater Sump Pump	190 LPM	2	339 LPM	2
Wastewater Collection Tank	52,100 L	1	109,200 L	1
Wastewater Collection Tank Pump	190 LPM	2	339 LPM	2
pH Adjustment System	29 LPM	1	61 LPM	1

Table 26. Complete sized equipment list for product formulation facility.

Equipment Item	Current [5kMTA] Capacity	Count	Future [15kMTA] Capacity	Count
Bulk Storage				
Extrudate Dry Storage Racking	*Allotted rack storage*		*Allotted rack storage*	
Extrudate Cold Storage Racking	*Allotted rack storage*		*Allotted rack storage*	
Extrudate Cold Storage	*Allotted cold storage*		*Allotted cold storage*	
Forklift	*per facility*	*1*	*per facility*	*4*
Sodium Hydroxide Pump	0.3 LPM	2	0.3 LPM	2
Pre-Mixing				
Food Grade Tote Carts	*Allotted food grade tote carts*		*Allotted food grade tote carts*	
Water Pre-Mix Tank	200 L	1	500 L	1
Water Pre-Mix Tank Agitator	1 HP	1	1 HP	1
Emulsification				
Emulsifier	30 L	1	80 L	1
Chilled Water Pump	1 LPM	1	3 LPM	1
Chilled Water Heat Exchanger	1 LPM	1	3 LPM	1
Mixing				
Food Grade Tote Carts	*Allotted food grade tote carts*		*Allotted food grade tote carts*	
Ribbon/Paddle Mixer	880 kg/h	1	2,330 kg/h	1
Product Forming				
Shared Product Former	697 kg/h	1	2,090 kg/h	1
Breading & Frying				
Fryer System	500 kg/h	1	1,500 kg/h	1
Thermal Fluid Heater	*per fryer*	1	*per fryer*	1
CO_2 Fire Suppression	*per fryer*	1	*per fryer*	1
Freezing & Packaging				
Conveyor to Freezing	697 kg/h	1	2,090 kg/h	1
Spiral Freezer	697 kg/h	1	2,090 kg/h	1
Conveyor to Patty Stacker	697 kg/h	1	2,090 kg/h	1
Patty Stacker	102 /min	1	307 /min	1
Thermoformer	*per facility*	1	*per facility*	1
Bagger	697 kg/h	1	2,090 kg/h	1
Check Weigher	*per facility*	1	*per facility*	1
Foreign Object Detector (X-Ray/Metal Detect)	*per facility*	1	*per facility*	1
Conveyor to Packaging	697 kg/h	1	2,090 kg/h	1
Case Erector	*per facility*	1	*per facility*	1
Semi-Auto Stretch Wrap Machine	*per facility*	1	*per facility*	1
Cold Storage Racking	*Allotted rack storage*		*Allotted rack storage*	
Cold Storage Refrigeration	*Allotted cold storage*		*Allotted cold storage*	
Utilities				
Boiler	684 lb/h	1	953 lb/h	1
Air Compressor	50 scfm	1	50 scfm	1
Chiller	1 ton	1	2 ton	1
Water Softener	259 LPM	1	388 LPM	1
Softened Water Tank	29,200 L	1	43,700 L	1
Dust Collector	*per facility*	3	*per facility*	3
Automated Tote/Cart Washing Station	*per facility*	1	*per facility*	1
COP Stations	406 L	5	406 L	5
Equipment Foamer	*per facility*	10	*per facility*	15
Hose Stations	*per facility*	10	*per facility*	15
Water & Waste Management				
Grease Interceptor	235 LPM	1	348 LPM	1
Wastewater Sump	7,300 L	1	6,000 L	1
Wastewater Sump Pump	235 LPM	2	348 LPM	2
Wastewater Collection Tank	87,200 L	1	71,500 L	1
Wastewater Collection Tank Pump	235 LPM	2	348 LPM	2
pH Adjustment System	48 LPM	1	40 LPM	1

Appendix E. Utility Estimates

Table 27. Extrusion facility annual utility demand.

Utility		Current	Future
Plant Water	LPY	27,105,000	47,533,000
Wastewater	LPY	12,447,000	26,106,000
Natural Gas	MMBTU/yr.	64,000	49,000
Electricity	MWh/yr.	16,000	17,000
CIP Chemicals, Sodium Hydroxide	LPY	115,000	261,000
CIP Chemicals, Phosphoric Acid	LPY	4,000	10,000
CIP Chemicals, PAA	LPY	1,000	2,000
Solid Waste	kg/yr.	5,556,000	5,556,000

Table 28. Product formulation facility annual utility demand.

Utility		Current	Future
Plant Water	LPY	11,985,000	25,439,000
Wastewater	LPY LPM (average)	10,420,000 50 LPM	17,080,000 40 LPM
Natural Gas	MMBTU/yr.	1,600	4,500
Electricity	MWh/yr.	1,000	4,200
CIP Chemicals, Sodium Hydroxide	LPY	90,000	153,000
CIP Chemicals, Phosphoric Acid	LPY	40,000	79,000
CIP Chemicals, PAA	LPY	1,000	2,000
Solid Waste	kg/yr.	573,000	1,525,000