Good Food Institute

BRIGHT GREEN PARTNERS

Plant-based meat manufacturing capacity and pathways for expansion

Photo credit: Beyond Meat

About the authors

Authors

GFI:

Amanda Bess, PhD, Science & Technology Analysis Manager

Simone Costa, PhD, Associate Director of Strategy and Innovation

Daniel Gertner, Business Analyst

Priera Panescu, PhD, Lead Scientist, Plant-based Specialist

BGP:

Floor Buitelaar, Managing Partner

Heinrich von Jagwitz, PhD, Project Manager

Igor Viktorov, Senior Consultant

Matevž Schweiger, Junior Consultant

About GFI: The Good Food Institute is a nonprofit think tank working to make the global food system better for the planet, people, and animals. Alongside scientists, businesses, and policymakers, GFI's teams focus on making plant-based and cultivated meat delicious, affordable, and accessible. Powered by philanthropy, GFI is an international network of organizations advancing alternative proteins as an essential solution needed to meet the world's climate, global health, food security, and biodiversity goals.

About BGP: Bright Green Partners is the leading international strategy consulting boutique that has been exclusively focused on the alternative protein industry ever since its inception. Its in-depth ingredient, product, customer, and market customer knowledge as well as its technical expertise are driven by the symbiosis of its core team of strategy consultants and its unmatched network of alt protein experts. BGP works in all parts of the value chain in the field of plant-, fermentation-, and cell-based alternative meat & dairy and the project scope ranges from strategy definition to design studies and technology reviews for specific production facilities.

Executive summary

The plant-based meat category has experienced strong growth over much of the past decade. As product availability and variety grow, the industry's supply chains must keep pace to avoid shortages and improve accessibility and affordability. These steps, along with continued product innovation, are critical for appealing to meat-eating consumers and ensuring long-term category growth.

This report aims to quantify existing global plant-based meat manufacturing capacity and evaluate the potential for and trade-offs of retrofitting[1] existing facilities to build additional capacity.

Further, this report identifies parallel industries with facilities suitable for retrofitting, provides criteria for facility selection, and compares the associated Capex, lead times, and other trade-offs of greenfield[2] construction versus retrofitting to grow capacity. The analysis focuses on the production of structured plant protein (SPP) via high or low moisture extrusion (referred to in the report as "extrusion") as well as the production of end products from SPP (referred to in the report as "post-processing"). The report does not explore the capacity of the ingredient industry, which is responsible for the production and fractionation of plant proteins and other ingredients.

We estimate that the global plant-based meat production capacity was ~2.2 million metric tons (MMT) in 2022 based on 2022 retail sales data, industry interviews, and a survey of existing facilities. We estimate that the majority of this capacity is in Europe (41%) and North America (34%).

GFI's 2021 report, *Plant-based meat: Anticipating 2030 production requirements*, provides preliminary insight into the need for manufacturing capacity, estimating a potential need for more than 800 extrusion facilities to reach a high-end target production of 25 MMT of plant-based meat in 2030. There remains, however, a limited understanding of the existing manufacturing capacity landscape and pathways to close the anticipated capacity gap.

> *Global plant-based meat production capacity was ~2.2 MMT in 2022.*

[1] Temporary or permanent conversion of existing equipment and operating procedures in a manufacturing facility to produce a closely related product.
[2] Construction of a new facility.

Our analysis demonstrates the significant potential benefits of retrofitting existing suitable[3] facilities, requiring a third of the lead time and a fifth of the capital expenditure (Capex), on average, compared to greenfield.

Facilities suitable for retrofitting for extrusion include those that currently produce pet food, pasta, breakfast cereals, and dry snacks, while animal meat processing facilities are well-suited for retrofitting to plant-based meat post-processing.

We explore the potential benefits of retrofitting further through two hypothetical build-out scenarios that assume incremental production growth from 2.2 MMT in 2022 to 10 MMT in 2030, corresponding to a 2.5% global volume share for plant-based meat.[4]

In Scenario 1

50% greenfield/50% retrofit: half of the new capacity is created by retrofitting existing facilities, while the other half is created through greenfield development.

This results in a modeled total Capex requirement of $10.4 billion.

In Scenario 2

100% greenfield: all of the new capacity is created by constructing greenfield facilities.

This results in a modeled total Capex requirement of $17.5 billion, 60% higher than Scenario 1.

We conclude from Scenario 1 that the retrofit pathway is an efficient and effective solution to quickly scale capacity that affords considerable Capex savings. This is particularly important because industry participants are not likely to perfectly align planned capacity with realized market growth. The greenfield development pathway is riskier since it requires significant up-front Capex investment and approximately three years to build. However, in the long run, greenfield development allows manufacturers to optimize their operating efficiency and potentially lower production costs.

[3] Retrofit suitability means >80% equipment overlap and substantial similarity of supply chain and food safety standards between the facility's prior use and what is required for plant-based meat production.
[4] Based on the 2030 "low" scenario in Bloomberg's 2021 report, *Plant-based food poised for explosive growth*.

> *The retrofit pathway is an efficient and effective solution to quickly scale capacity.*

We provide the following recommendations to both the public and private sectors seeking to proactively and conscientiously expand global production capacity for plant-based meat products.

1. **Focus on retrofitting existing facilities where speed and up-front costs are the priority.** Consider retrofitting existing facilities, particularly in cases where time to market is a higher priority than long-run operating efficiency or lowest marginal production cost, such as when the industry needs to react quickly to the changing market. Retrofitting is also more attractive when access to capital or facility financing is limited.

2. **Source contract manufacturing capacity from parallel industries, especially in Asia.** Strongly incentivizing companies from extrusion industries to open their production lines to function as contract manufacturers would address a potential extrusion capacity deficit. Those companies can add capacity to the plant-based industry when there is high demand and switch to other products when there is low demand.

3. **Retrofit suitable facilities in Europe and North America.** Manufacturers looking to expand in Europe and North America should investigate existing facilities suitable for retrofitting. Consider facilities whose sales and margins in their original industries are under pressure because of either market decline or fierce competition, especially if the owners are willing to sell or lease the facility.

4. **Build a greenfield facility if you have a long-term vision and financing and want to benefit from superior operating and cost structures.** Companies who have the necessary scale and long-term business objectives should investigate a greenfield configuration with a high level of automation, which will allow maximal operational and supply chain efficiency, optimal product quality by targeting production equipment and process to achieve the desirable characteristics, and better cost structures.

5. **Plan in advance.** Finally, it is strongly recommended that all industry stakeholders prepare plans ahead of time and be ready to react on short notice when the market demands it. Current global capacity could be fully exhausted by modest growth in demand. Industry stakeholders should prepare a near-term reaction plan in case the market starts growing rapidly earlier than predicted, such as by using contract manufacturing or retrofitting.

Table of contents

1 Introduction and objectives

As highlighted in GFI's 2021 report, *Plant-based meat: Anticipating 2030 production requirements*, a modest shift in the world's protein supply to alternative proteins will require substantial capital expenditure and significant lead times for infrastructure development, and entire supply chains will need to be reorganized. Manufacturing capacity was identified as a critical bottleneck for this shift. In the 2021 report, GFI estimated a need for as many as 810 structured plant protein (SPP) extrusion facilities and $27 billion in global capital expenditure (Capex) to reach a high-end target production of 25 million metric tons (MMT) of plant-based meat in 2030. There remains, however, a limited understanding of the existing manufacturing capacity landscape and pathways to close the anticipated capacity gap, including the potential contribution of retrofitting existing facilities to create an efficient and effective pathway for capacity growth.

The purpose of this report is to capture the current global landscape of plant-based meat manufacturing capacity and evaluate the potential for retrofitting existing facilities in parallel industries to reduce the lead times and Capex requirements of scaling capacity.

Additionally, this report explores the technical feasibility of retrofitting for different stages of the manufacturing process and provides useful benchmarks for lead time and Capex of both retrofit and greenfield construction gathered from industry interviews and the input of subject matter experts.

This report provides a greater understanding of the pathways for building manufacturing capacity and the need for timely investment to avoid shortages and improve affordability. Increasing the geographic spread and scale of production capacity, along with continued product innovation, is critical for appealing to meat-eating consumers and ensuring long-term category growth.

2 Analysis approach and scope

2.1 Glossary of terms

Term	Explanation
Capacity gap	Difference between current production capacity and estimated capacity needed to meet market demand.
Capex	Capital expenditure; the cost associated with the construction or preparation of a building, purchase and installation of equipment, and other costs such as engineering or design. For retrofitting, we exclude the cost of land and the potential cost of acquiring an existing facility.
CIP	Clean-in-place (CIP) is an automated method of cleaning the interior surfaces of pipes, vessels, equipment, filters, and associated fittings of a piece of equipment without major disassembly. CIP is commonly used for equipment such as piping, tanks, and fillers.
Extrusion	The most common method for producing SPP, which is the base material for the majority of plant-based meat products on the market. Extruders apply shear stress and heat to proteins and other ingredients to align or structure them to produce a fibrous, meat-like texture.
Facility production capacity	Maximum possible production capacity of a facility under realistic conditions, i.e., when running two or three shifts 7 days per week with scheduled maintenance and equipment downtime. Expressed as product mass or count per unit of time.
Facility utilization	Measured as a percentage of facility production capacity. For this report, we assume a facility utilization of 100%. A facility utilization of 100% means that the facility is operating at its facility production capacity, which considers work shifts, switchovers, cleaning, repair, and maintenance. Accordingly, at 100% utilization, the total effective equipment performance is typically around 40-70% due to equipment losses depending on the specific facility and product portfolio.
Greenfield	Construction of a new facility (applicable for both extrusion and post-processing).
HME	High moisture extrusion
LME	Low moisture extrusion
MMT	Million metric tons

PB	Plant-based
Plant-based meat	Products made from plants that are direct alternatives to animal-based products such as whole-cuts, minced meat, and sausages. This includes plant-based fish and seafood and excludes plant-based products that are not attempting to mimic meat, such as tofu and tempeh.
Post-processing	The production steps leading to the final plant-based meat product, starting with SPP as input material. This can include cutting, shredding, mixing, battering, frying, and packaging.
Retrofit	Temporary or permanent conversion of existing equipment and operating procedures in a manufacturing facility to produce a closely related product. For example, an extrusion or animal meat processing facility can be retrofitted to produce structured plant proteins or final plant-based products, respectively.
Retrofitting suitability	An extrusion or post-processing facility is suitable for retrofitting if it fits the following technical requirements: ● 80% of the equipment can be reused; and ● The building can be reused without significant investments in repairs and modifications. This does not necessarily mean that the owners or operators of said facility are willing to retrofit.
SKU	SKU (stock keeping unit) refers to a specific type of product for sale, with distinct properties that distinguish it from other product types such as material, size, packaging, and shape.
SPP	Structured plant protein
TMT	Thousand metric tons

2.2 Approach

The approach we use in this report consists of four steps, summarized below and in Figure 1. For a detailed explanation of the methodology for each step, refer to Section 7.

1. Estimate the current global plant-based meat production capacity.
2. Explore and compare pathways for building capacity.
3. Evaluate the suitability of facilities in parallel industries for retrofitting.
4. Scenario analysis: Explore the potential for the retrofit pathway to reduce lead time and Capex.

Step 1: Estimate 2022 global production capacity

- Calculate 2022 total global PB meat consumption (MMT)
- Estimate production capacity for post-processing based on the 2022 PB meat consumption and expert input (top-down) AND a survey of existing facilities (bottom-up)
- Estimate production capacity for extrusion based on 2022 PB meat production, % SPP in the final product, and expert input (top-down)

Step 2: Explore pathways for increasing capacity

- Gather industry data via expert interviews
- Identify pathways for increasing capacity
- Exclude minor or uneconomic pathways
- Compare viable pathways based on Capex per TMT, lead time, operational efficiency, and environmental footprint

Step 3: Evaluate retrofitting suitability

- Formulate suitability criteria for facility retrofitting
- Identify parallel industries with facilities that meet suitability criteria
- Estimate the size of the retrofit opportunity using 2022 retail sales data for parallel industries

Step 4: Scenario analysis

- Model production growth to 10 MMT in 2030
- Compare scenario-specific growth to 2022 production capacity (step 1) to estimate the resulting capacity gap
- Model two build-out scenarios to fill the gap: retrofit + greenfield or greenfield only
- Evaluate resulting Capex for each build-out scenario

Figure 1. Analysis approach

2.3 Scope

This report focuses on plant-based meat and seafood and does not consider plant-based eggs or dairy products (Figure 2). We divided our global geographic scope of the plant-based meat industry into four regions: Europe, North America, Asia Pacific, and the Rest of the World (RoW). Within the plant-based meat value chain, the focus is on the last two production steps: the production of SPP and the end-product processing, including packaging. Since these two steps are often performed by different companies in separate factories, we split the analysis into these two segments, which we term "extrusion" and "post-processing." Additional simplications and boundaries of this report are detailed in Table 1.

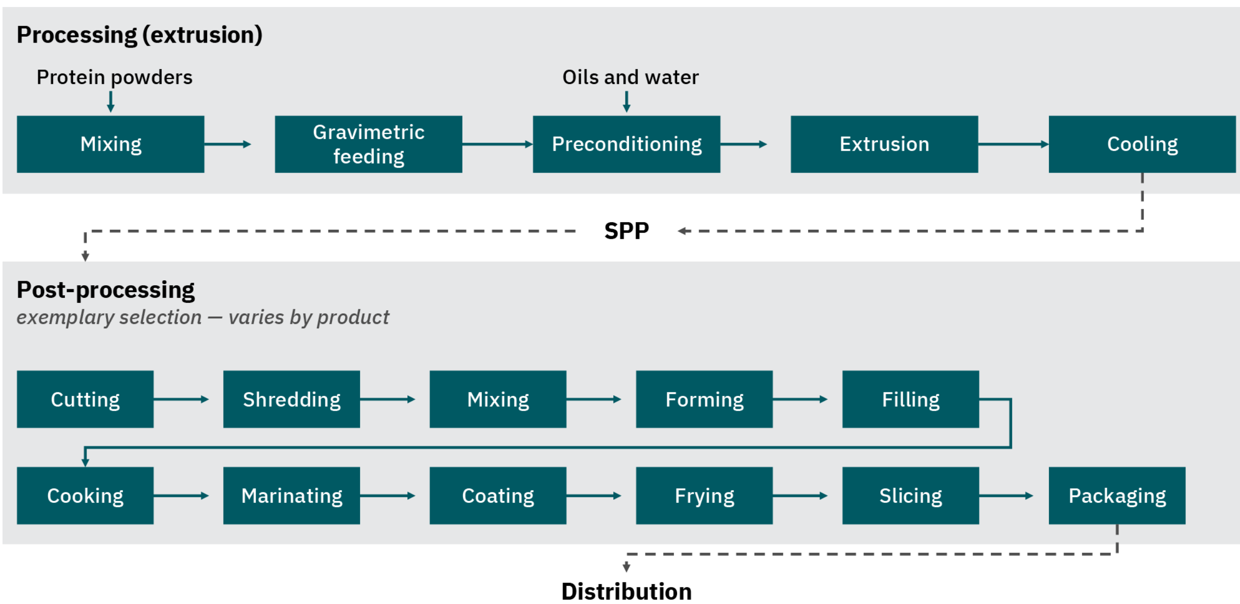
Figure 2. Scope of this report

Table 1. Key simplifications and boundaries of the report

Simplification or analysis boundary	Rationale and implications
Production step focus: processing and post-processing	The report focuses on processing (extrusion) and post-processing (cutting, mixing, marinating, forming, frying, packaging, etc.) and excludes earlier steps of the value chain such as farming and ingredient production. These steps overlap between plant-based meat and other food and animal feed industries, making it difficult to pinpoint those dedicated to plant-based meat alone. Therefore, this analysis may miss an important bottleneck in the earlier stages of plant-based meat production.
Processing technology focus: extrusion	The report considers extrusion technology for producing textured proteins, leaving 3D printing, electrospinning, shear cell, and other emerging technologies out of scope. We assume that extrusion will remain the main technology in use over the next decade. However, throughput optimization innovations would alleviate the infrastructure expansion needed to increase manufacturing capacity.
Focus on greenfield and retrofit pathways	We assume that production space in existing facilities is efficiently utilized, leaving no free space to scale up or scale out production capacity within facilities. We also assume that no ground-breaking optimization technologies will become available in the near term that would significantly increase existing lines' throughput. As a result, we assume that retrofit and greenfield construction are the main pathways for adding capacity.
Maximum possible facility utilization	We assume a maximum possible facility utilization of 100%. However, it would be challenging for the entire industry to run at 100% utilization as demand and supply within the industry may not be ideally matched to utilize every facility to its full potential. For example, some private companies may not be willing to share their in-house capacity with other industry participants. However, maximum utilization can be reached through partnerships among brands and manufacturers—for example, when plant-based meat brands produce private label products for retailers alongside their own products in their facilities. By assuming 100% facility utilization, we may overestimate the current capacity potential.
Exclusion of bottom-up assessment of extrusion capacity	A bottom-up assessment of plant-based meat extrusion capacity would be complicated by partial overlap with other industries and was therefore not included in this report.

2.4 High-level extrusion and post-processing plant-based meat production steps

In this report we consider a typical production process of a plant-based meat product, which starts with the extrusion step where plant proteins and other ingredients are processed into SPP via LME or HME. The subsequent post-processing heavily depends on the product type but generally includes mixing, forming, cooking, packaging, and other product-specific steps (Figure 3).



Extrusion and post-processing are distinct steps that may happen in separate facilities.

Figure 3. High-level extrusion and post-processing steps for plant-based meat production

3 Current manufacturing capacity at industrial scale

3.1 Understanding current capacity: extrusion

We approximated the 2022 global plant-based meat extrusion capacity via a top-down approach, extrapolating from 2022 plant-based meat consumption which is based on 2022 plant-based meat regional market data as described in Section 7.3.

We estimate that 2022 global plant-based meat consumption was ~1.0 MMT. We estimate that 90% (0.9 MMT) was produced using extruded proteins that make up ~43% of end product weight (0.4 MMT), whereas the remainder of end product weight is accounted for by other ingredients, mainly water.[5]

Based on the input of various industry experts, we estimate that global production in 2022 was running at ~70% of global production capacity on average, therefore 0.4 MMT is an underestimate of the actual extrusion production capacity in 2022. Rather, at 100% production capacity utilization, we estimate the global plant-based extrusion capacity was ~0.5 MMT[6] in 2022 (Figure 4).

> *Global plant-based meat extrusion capacity was ~0.5 MMT in 2022.*

[5] When producing plant-based meat from low moisture SPP, a lot of water is added. Our estimate is based on expert opinions regarding the ratio of dry to high moisture SPP, the water added to dry SPP, and the content of other non-SPP ingredients like oils, flavors, seasonings, and non-extruded proteins. We assume a ratio of high moisture SPP versus dry SPP of 15%/85% in 2022 with high moisture extrusion gradually increasing to comprise 70% of production by 2030.
[6] Values include rounding effects.

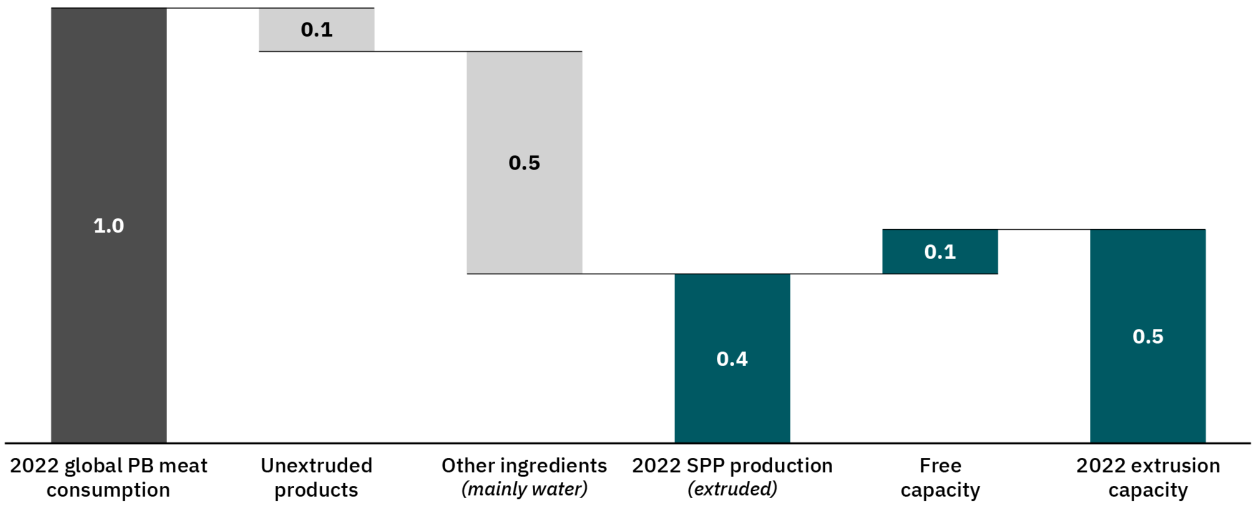


Figure 4: Top-down assessment of global plant-based meat extrusion production (MMT)[7]

3.2 Understanding current capacity: post-processing

For post-processing, we estimate the currently available global capacity both via a top-down and a bottom-up approach. The detailed methodology is described in Sections 7.3 and 7.4.

As stated in Section 3.1, we estimate that the 2022 global plant-based meat consumption was ~1 MMT, and 100% of this volume underwent post-processing. Correspondingly, we estimate that plant-based meat post-processing production in 2022 was ~1 MMT. However, actual post-processing capacity is likely higher than that, due to significant underutilization in 2022.[8] Based on the input of various industry experts, we estimate that global production was running at an average of ~45% utilization of production capacity in 2022. Extrapolating to 100% utilization, we estimate a 2022 global post-processing capacity of ~2.2 MMT (Figure 5).

> *Global post-processing capacity was ~2.2 MMT in 2022.*

[7] Values include rounding effects.
[8] Industry sources shared that many factories were running one shift per day in 2022, and some factories were operating as few as three days per week.

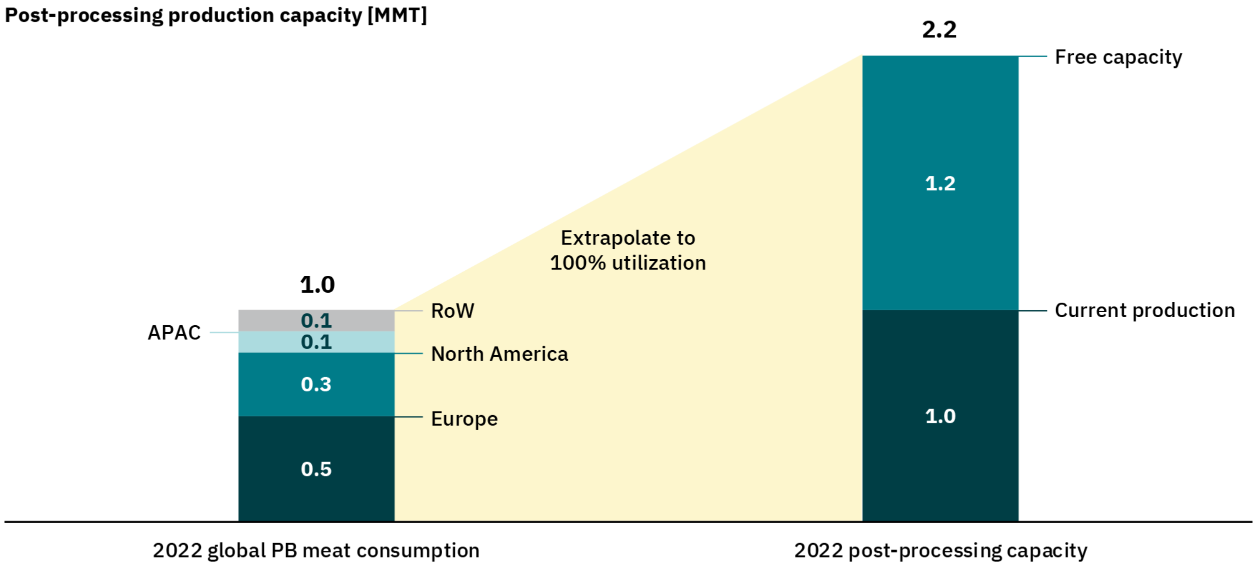


Figure 5. Top-down estimate of 2022 global post-processing capacity

For the bottom-up assessment of post-processing capacity, we first researched, to the best of our knowledge, all known plant-based meat post-processing facilities worldwide, identifying 85 facilities (Figure 6). We estimate, based on the availability and quality of data in different geographies and expert input, that another 58 facilities exist that we were not able to identify.

Next, we estimated the production capacity of each of the 143 facilities by multiplying facility size, capacity density, and share of plant-based meat products (Table 2). These parameters include both primary data from desk research as well as estimates based on industry benchmarks and expert input to fill data gaps. We estimated that Europe has the greatest regional post-processing capacity with 41% of the total capacity (Table 2), followed by North America with 34%, Asia Pacific with 16%, and RoW with 9%. However, this estimate is uncertain given the limited information publicly available on the identity, capacity, and percentage of capacity dedicated to plant-based meat available for existing facilities.

Using this bottom-up approach, we estimate that the total global post-processing capacity in 2022 was 2.1 MMT. This estimate aligns with our estimate of a post-processing capacity of 2.2 MMT in 2022 using the top-down approach, providing greater confidence in these estimates.

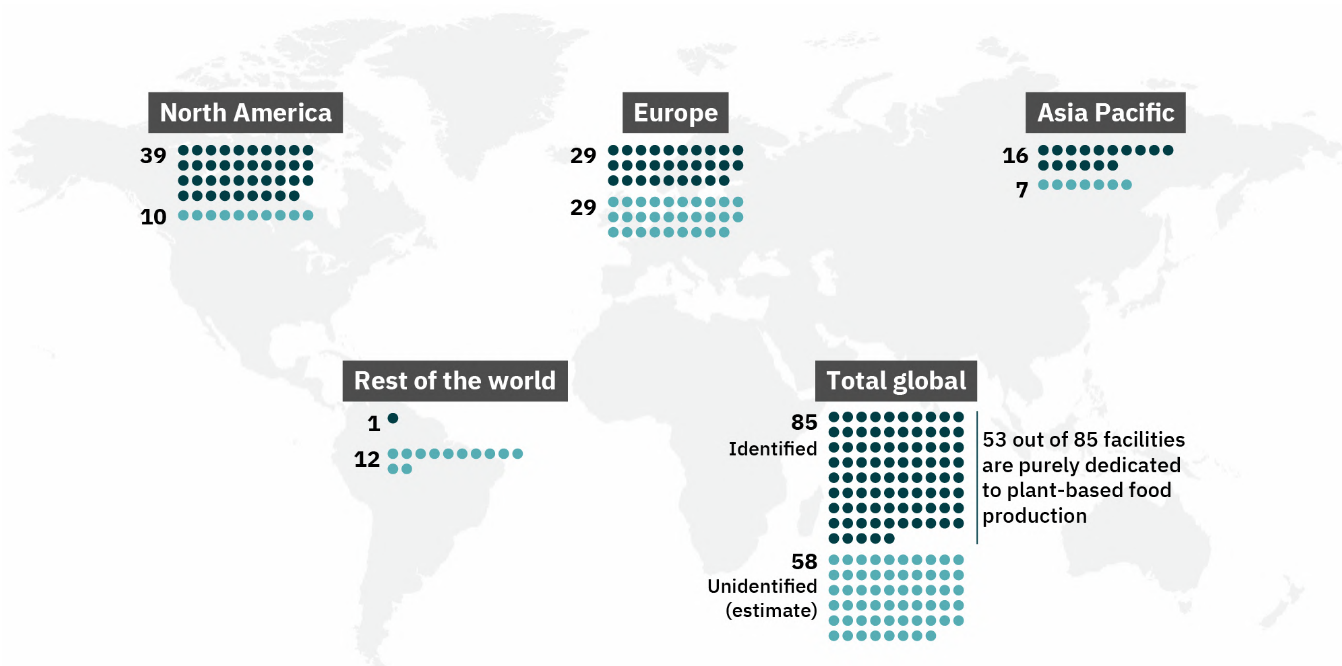


Figure 6. Global distribution of plant-based meat post-processing facilities (bottom-up)

Table 2. Results of global bottom-up plant-based meat processing capacity estimate

Region	Facilities (regional estimate)	Avg. capacity (TMT/facility)	Total capacity (TMT/year)	Regional share (% of total capacity)
North America	49	17	810	34%
Europe	58	15	865	41%
APAC	23	10	241	16%
RoW	13	11	143	9%
Total/Avg.	**143**	**13**	**2,059**	**100%**

4 Pathways for building manufacturing capacity

As global protein demand rapidly increases and plant-based meat emerges as a sustainable protein choice, manufacturers will look for pathways to expand production. There are several potential pathways to increase manufacturing capacity both for extrusion and post-processing, including optimizing the productivity of existing plant-based meat producers or expanding through facility construction (Figure 7).

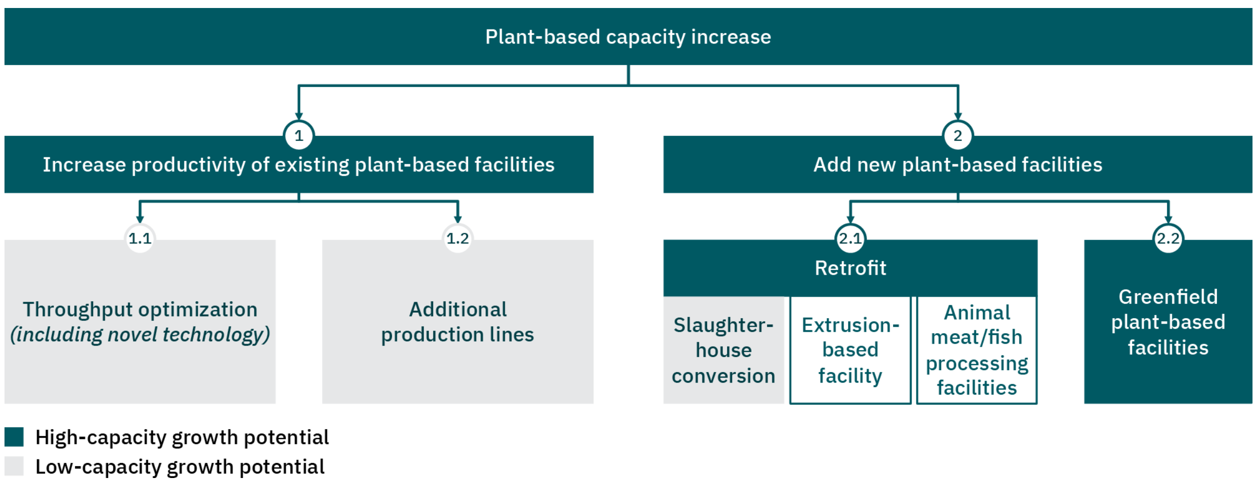


Figure 7. Pathways for increasing manufacturing capacity

Existing plant-based facilities can increase their productivity by optimizing the throughput of their existing lines or adding more production lines, yet feedback from industry experts indicates that most facilities have limited available space to increase capacity by adding production lines. Additionally, industry experts do not anticipate major breakthroughs in production optimization and efficiency in the near future. Thus, this report excludes those pathways to build plant-based meat manufacturing capacity. While throughput optimization innovations would alleviate the need for infrastructure expansion to increase manufacturing capacity, new plant-based facilities can provide manufacturing capacity for plant-based meat without relying on technological breakthroughs. This report focuses on greenfield construction of plant-based facilities and retrofitting existing facilities for building manufacturing capacity.

Within the retrofitting possibilities we considered, we explored the conversion of slaughterhouses to plant-based meat production facilities. We hypothesized that this conversion could be a commercially viable pathway to expand both extrusion and post-processing capacity. However, our research indicates that slaughterhouse equipment cannot be effectively reused for plant-based products. With only the building remaining for reuse and the challenges of building conversion (e.g., adequately cleaning, maximizing energy efficiency, identifying a compatible layout), this is a less economically attractive option to pursue[9] except for specific cases[10] and is therefore not further considered in this report.

Based on the above assessment, two main pathways remain for expanding plant-based meat manufacturing capacity: 1) retrofitting existing extrusion-based and conventional meat processing facilities and 2) greenfield construction. Retrofitting existing facilities for plant protein processing offers other industries the opportunity to expand their climate-forward strategies while utilizing existing infrastructure and equipment. For example, Dutch meat processor Vion plans to repurpose their Leeuwarden facility, originally built in 2017 for beef processing, into a plant-based processing facility. Greenfield construction is an attractive option in the absence of infrastructure or when flexibility is important. For instance, Missouri-based plant-based ingredient company Bunge relied on greenfield construction to efficiently expand their textured soy protein concentrate operations next to their existing soybean processing plant.

There are several considerations when evaluating the effectiveness of retrofitting and greenfield construction in expanding plant-based meat manufacturing capacity. In this section, we explore the trade-offs between retrofitting versus greenfield construction, identify parallel industries with facilities suitable for retrofitting to plant-based production, and discuss key suitability criteria for facilities.

For this study, a facility is considered suitable for a retrofit if both >80% of the equipment and the building can be reused without significant investments. We also assume that most of the retrofits will be performed by the original owners of those facilities and not by other companies. However, this is not always the case—for example, U.S.-based plant-based chicken producer Rebellyous retrofitted a meat processing plant to create their Seattle facility. We also do not consider the willingness to retrofit, as many suitable facilities may not necessarily have owners willing to sell or retrofit the facility.

[9] We estimate that Capex savings for retrofitting a slaughterhouse versus a greenfield facility will only be in the range of 10-20%, so the operational disadvantages are likely to outweigh the savings.

[10] For example, if a slaughterhouse building can be fully reused without significant Capex. That would be the case if the building is food grade, relatively new, and has a layout that does not require many changes.

4.1 Understanding the broader trade-offs of retrofitting versus greenfield for plant-based meat production

First, we assess the advantages and disadvantages of a retrofit versus greenfield development along four dimensions for both extrusion and post-processing (Figure 8):

1. **Capex requirements for providing capacity:**

   For greenfield construction, we consider the costs associated with the construction and preparation of a building, purchase and installation of equipment, and other costs such as engineering and design. For a retrofit, we exclude the cost of land and the potential cost of acquiring an existing facility, as these vary widely by facility, region, and market.

   Retrofitting has a clear advantage. Usually, a few changes to a suitable facility can be sufficient, with Capex requirements ranging between $0.1 and $0.6 M/TMT of capacity. For a greenfield facility, Capex will be in the range of $0.9 to $2.9 M/TMT of capacity.

2. **Lead time:**

   For both greenfield and retrofitting, this includes the amount of time from the binding investment decision to reaching full operations (including internal planning, engineering, permitting, construction, equipment installation, and commissioning).

   Retrofitting has a clear advantage, with the lead time being anywhere between a few days (thoroughly cleaning the entire facility, procuring the right ingredients and materials) and several months (for example, adding and changing equipment, upgrading the warehouse, renovating a building to comply with food safety standards, changing pipes). Lead times for a greenfield facility range from 18 months to three years as permitting and construction speed vary between regions.

3. **Operational efficiency:**

   The evaluated operational expenditure per TMT of product includes the ingredients, packaging materials, utilities, labor costs, and equipment maintenance needed to operate a facility.

   Operational efficiency will likely be higher in greenfield facilities than in retrofit ones. Greenfield facilities can be built specifically for the production process and incorporate the latest, most efficient technologies. This is especially true if large volumes of the same product are produced compared to having many SKU changes.

4. **Environmental footprint:**

This parameter explores the total amount of greenhouse gas emissions, water, soil disturbance, and other adverse environmental effects directly or indirectly caused by facility retrofitting or greenfield construction.

Both short- and long-term environmental impacts should be considered. Constructing a greenfield facility generally has two major adverse environmental effects: it usually leads to soil sealing[11] and has a sizable carbon footprint, both for building materials[12] and for new production equipment. On the other hand, greenfield facilities are usually more environmentally sustainable in their operations. They consume less energy than older facilities by using the latest technologies like heat pumps, solar thermal heating, onsite photovoltaics, and optimized processes. They may create less waste (mainly wastewater) due to improved CIP and other cleaning processes and may include water treatment systems like reverse osmosis. Therefore, it is difficult to generalize the environmental impact of greenfield versus retrofit development as it is highly specific to the location and characteristics of the facilities, so the environmental trade-offs need to be assessed on a case-by-case basis.

In summary, retrofitting is an attractive option due to short lead times and lower Capex. Greenfield facilities are beneficial for the highly efficient production of large-volume SKUs and in the absence of suitable facilities available for retrofitting.

[11] Covering or replacing the topsoil with impervious materials like asphalt, cement, or buildings paired with compaction of the underlying soil layers results in the mostly irreversible loss or degradation of the soil habitat.
[12] This includes steel and concrete as key carbon footprint drivers. Timber-based load bearing structures that replace carbon and steel as a less carbon-intensive alternative are often not viewed as a viable option in the food sector due to hygiene concerns. However, a detailed carbon footprint analysis is out of the scope of this report.

	Retrofit	Greenfield
Capex requirements	✓ $0.1–0.6 MM per TMT capacity	✗ $0.9–2.9 MM per TMT capacity
Lead time	✓ Up to 6 months	✗ 18–36 months
Operational efficiency	✗ Not always an ideal fit for the new process	✓ Fits the production purpose, uses novel technology
Environmental footprint	✗ Usually less resource efficient in operations	✗ Construction leads to soil sealing and has a significant carbon footprint

Figure 8. Trade-offs of retrofitting versus greenfield

4.2 Evaluating the size of the retrofit opportunity

With potential Capex and lead time advantages, retrofitting is positioned as an affordable and speedy option to expand manufacturing capacity if suitable facilities are available. Globally, there is significant production capacity suitable for retrofitting from a technical point of view, both for extrusion and post-processing (Figure 9):

1. **Extrusion:**

   Facilities from the pet food, pasta, breakfast cereals, and dry snacks industries are well-positioned for retrofitting to plant-based products, specifically the production of SPP. The equipment can be reused or upgraded, supply chains are similar, and food safety standards are the same except for pet food (which can be easily upgraded). We estimate global extrusion capacity at ~44 MMT in 2021[13] based on the major extrusion industries described above.[14] As a conservative estimate, we assume that only 80% (~35 MMT) of that capacity is suitable for retrofitting from a technical viewpoint.[15]

[13] We are using 2021 capacity as a base in our calculations because we assume that no newly constructed extrusion facilities would be retrofitted.
[14] For pet food, we estimate 50% of global production is extrusion-based (the rest is based on animal meat or other non-extruded ingredients), for pasta we estimate 90% is extrusion-based, and for the other industries we estimate 100% of global production is extrusion based.
[15] Experts indicate that almost any extruder in the food/pet food industry could be repurposed to SPP production with some alteration (e.g., changing screws and dies). However, there are some cases of very specialized extruders that are not suitable for retrofitting, so we conservatively assume that 80% of extruders are suitable for retrofitting.

2. **Post-processing:**

Animal meat processing facilities can be retrofitted for plant-based meat production. Most of the equipment can be reused, and food safety standards and hygiene measures will be similar. We estimate global meat processing capacity at 65 MMT in 2021,[16] with at least 90%[17] (~58 MMT) being suitable for retrofitting from a technical viewpoint.

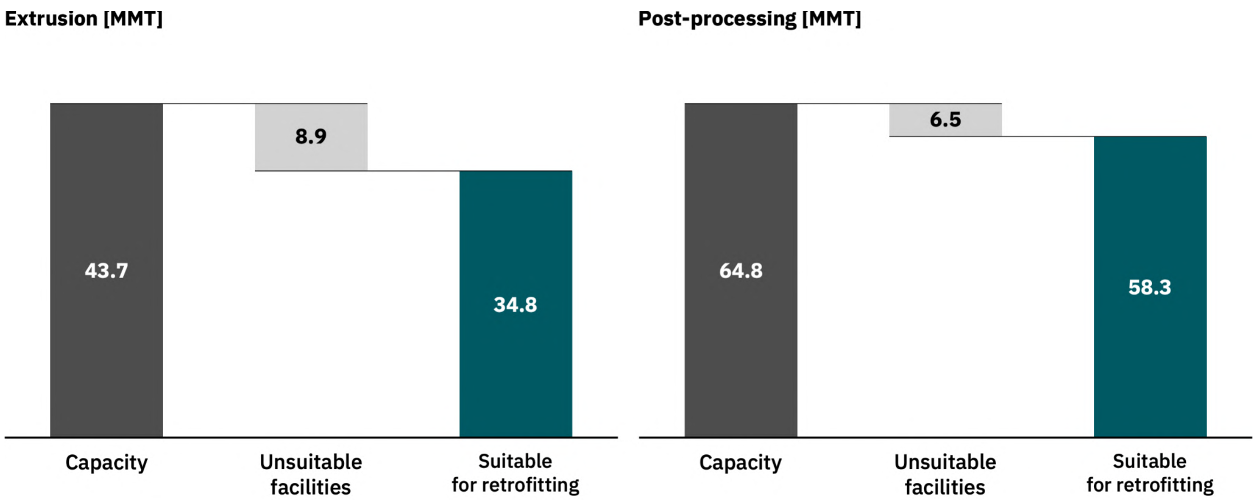


Figure 9. Comparison of the total capacity in relevant industries and the portion that is suitable for retrofitting.

4.3 Evaluating facility criteria for retrofitting suitability

We analyzed existing plant-based facilities using a bottom-up approach for post-processing (Section 7.4) and conducted interviews with numerous industry experts to understand which facilities are most suitable for retrofitting. Four criteria should be considered when retrofitting existing facilities for plant-based meat manufacturing, applying to both extrusion and post-processing unless stated otherwise:

1. **Square footage:**

Suitable facilities should have a size of at least 5,000 square feet (ft^2) to house at least one production line, but ideally >50,000 ft^2 to benefit from economies of scale. Existing plant-based post-processing facilities range from 11,000 to 230,000 ft^2 with an average of ~50,000 ft^2, according to our bottom-up research. Industry stakeholders indicate that both extrusion and post-processing facilities benefit from economies of scale.

[16] This figure relates to processed meats only (excludes all whole-cuts), and therefore only makes up ~20% of the overall slaughtering volume and meat market.
[17] Experts indicate that any animal meat post-processing equipment is normally suitable for plant-based meat, but to be conservative we assume that 10% may not be suitable (such as meat curing facilities).

2. **Facility and equipment:**

   a. **Extrusion:** The facility needs to be food grade or near food grade and have extruders in operation. These criteria would apply to most facilities in the pet food, pasta, breakfast cereals, and dry snacks industries.

   b. **Post-processing:** The facility should be a meat processing facility that has the equipment[18] to produce meat products like nuggets, schnitzels, burgers, mince, meatballs, strips, chunks, cold cuts, or sausages.

3. **Output:**

   We recommend a minimum of 3 TMT per year but ideally >20 TMT per year to reach the relevant commercial scale. Plant-based post-processing facilities currently have output capacities between 1 and 74 TMT per year with an average of 13 TMT per year, according to our bottom-up research.

4. **Utilities/Sustainability:**

   The facility should have all the utilities in place to run extrusion/post-processing. Ideally, the facility would use sustainable energy sources such as solar panels or heat pumps, an effective wastewater treatment system, and high-quality insulation and cooling systems for any refrigerated or freezer areas to reduce the environmental footprint.

Finding the right facility for a retrofit also depends on the product portfolio. For example, a plant-based meat manufacturer mainly producing plant-based chicken nuggets would ideally use an animal-based chicken nugget facility rather than an animal-based burger facility. The burger facility might have the right forming equipment for making the nuggets but would possibly require additional equipment for adding breaded coatings and potentially pre-frying the nuggets, resulting in additional Capex.

[18] Depending on the product portfolio, this may include bag fillers, mixers/bowl choppers, forming equipment, coating equipment, cooking and frying equipment, and freezers.

While some changes in equipment and infrastructure may be required, retrofitting an extrusion or post-processing facility to plant-based is not an overly complex task compared to erecting a greenfield facility. Potential equipment and building adjustments include:

For extrusion facilities:

1. Equipment

a. **Low moisture SPP preparation:**

   i. **Extruders:** Pet food, pasta, breakfast cereals, and dry snack facilities usually have suitable extruders that can produce low moisture SPP. Depending on the specific process, exchanging extrusion screws or adjusting the heating system may be required.

   ii. **Other equipment:** Depending on the process and the equipment already present in the facility, adding a drying system such as a fluidized bed dryer or a convection dryer may be necessary to dry low moisture SPP as it exits the extruder. The packaging system may require changes depending on original and new requirements.

b. **High moisture SPP preparation:**

   i. **Extruders:** If an upgrade to high moisture SPP is intended, this will usually require a twin-screw extruder and the addition of a preconditioner as well as a high-power cooling die. Expert interviews indicated that upgrading an existing twin-screw extruder to high moisture costs approximately 50% of a new high-moisture system.

   ii. **Other equipment:** The switch to producing high moisture SPP may require upgrades to the facility's utilities, such as the electricity system, water reservoir, and heat exchanger. The packaging system may require changes depending on original and new requirements.

2. Building

a. **Layout considerations:**

   In some cases, changes to the production floor layout and the warehouse may be required. High moisture SPP is usually transported in a frozen state and hence requires freezing capabilities that are not usually found in a typical dry snack or pasta facility.

b. **Food safety evaluation:**

The retrofit, especially of pet food facilities, may require a review of food safety considerations and appropriate measures to improve hygiene and reach human food-grade conditions.

For post-processing facilities:

1. Equipment

a. **Production equipment**

Animal meat post-processing facilities usually have suitable production lines for plant-based meat products. However, since the majority of plant-based meat products are composed of low moisture SPP, a common addition to production lines would be a step for adding moisture[19] such as a barrel mixer or a bowl chopper along with a hopper and conveyor belts to feed the SPP into the mixer. An equipment change, such as adding a cutter or shredder, may be required if the plant-based product portfolio differs from the animal-based portfolio.

b. **Other equipment**

As with extrusion, equipment changes or additions can require adapting the utility systems. Changes to the packaging system, such as adding flash freezing capability with a spiral freezer, may be required depending on the type of product and the geographical region, which would also imply changes to the warehouse.

2. Building

a. **Layout considerations:**

Equipment and product changes can result in a need for changes to the production floor layout and the warehouse, such as adding a frozen zone.

b. **Food safety evaluation:**

Although all animal meat processing facilities are food grade, a review of hygiene considerations may be useful in some instances and result in measures to improve hygiene as well as the adaptation of the regular cleaning process.

[19] If the products are based on high moisture SPP, the barrel mixer would not be needed, though the need for a cutter or shredder might remain depending on the specific products.

5 Scenario analysis: Lead time and Capex potential of a retrofit

Given the operational overlaps between plant-based meat production and other parallel industries, retrofitting facilities may allow industry participants to increase plant-based meat production capacity with lower capital expenditures and shorter lead times than greenfield projects. In this section, we explore the potential benefits of retrofitting through two hypothetical build-out scenarios that assume incremental production growth through 2030.

In the two scenarios, plant-based extrusion and post-processing capacity increase from 2.2 MMT in 2022 to 10 MMT in 2030, corresponding to a 2.5% global volume share for plant-based meat.[20] This estimate is below many industry estimates made before the 2021-2022 plant-based meat market slowdown but more optimistic than projections provided by some recent market commentators. This hypothetical scenario is not a statement on GFI's long-term outlook on the market but rather a demonstration of retrofitting's potential lead time and Capex advantages (see call-out box on market conditions). Figures 10 and 11 plot the growth in extrusion and post-processing production capacity for this scenario to achieve a total plant-based meat production of ~10 MMT.

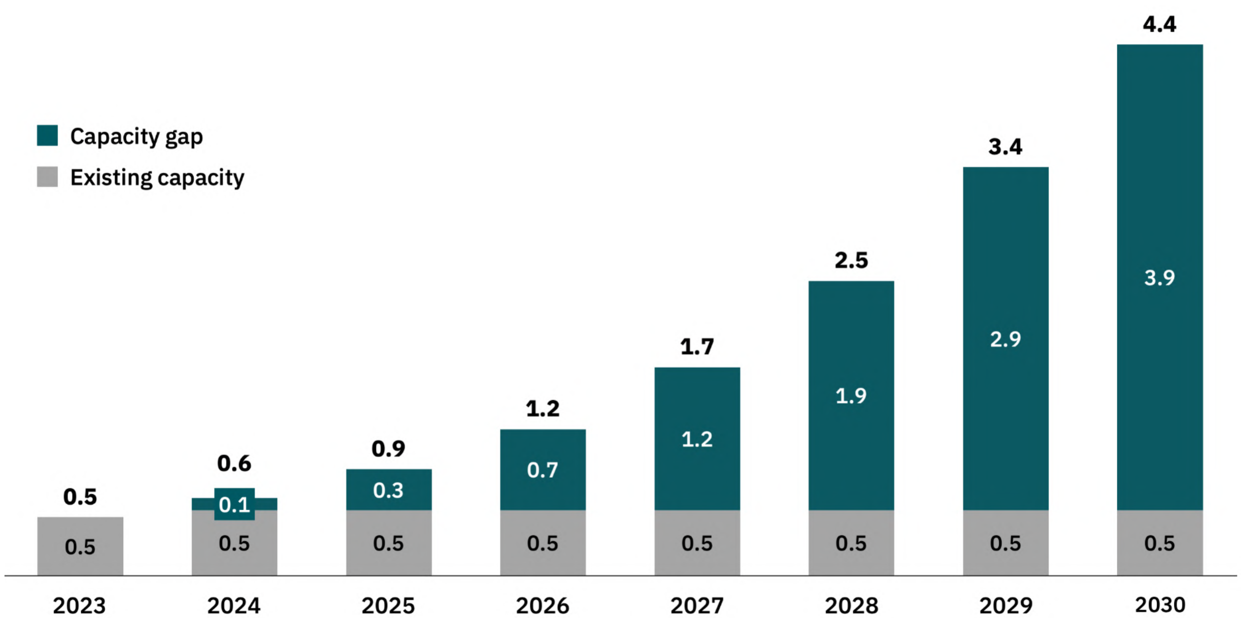


Figure 10. Modeled hypothetical increase in extrusion production capacity to achieve 10 MMT total production in 2030. Gray bars represent the volume of capacity filled by existing extrusion facilities.

[20] Based on the 2030 "low" scenario in Bloomberg's 2021 report, *Plant-based food poised for explosive growth*.

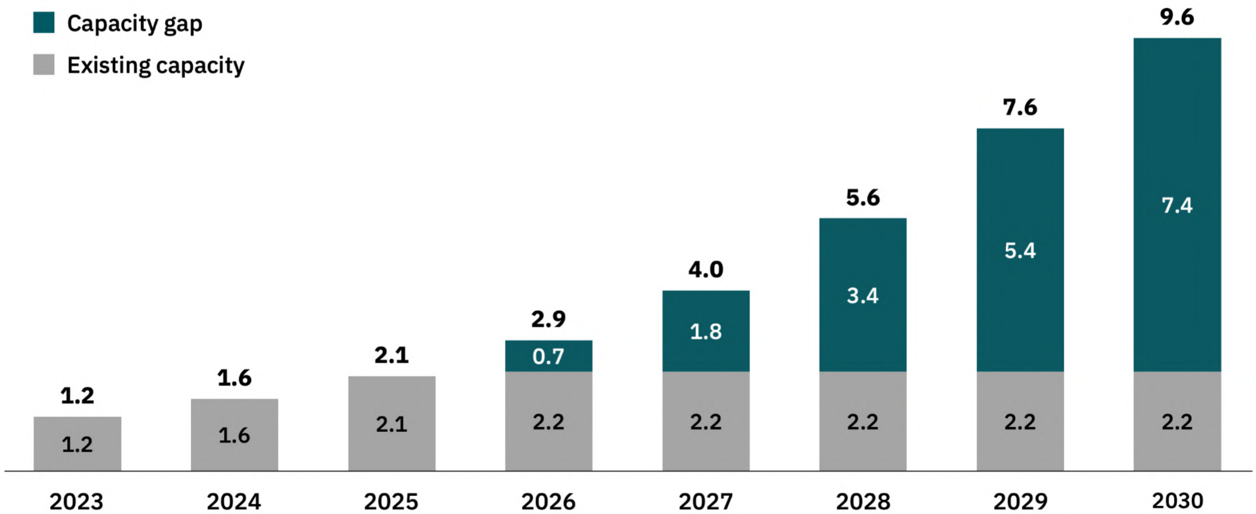


Figure 11. Modeled hypothetical increase in post-processing production capacity to achieve 10 MMT in 2030. Gray bars represent the amount of capacity filled by existing post-processing facilities.

We estimate that fully utilizing existing post-processing and extrusion capacities meet only 12% and 23%, respectively, of the capacity needed for a ~10 MMT plant-based meat market. Current extrusion capacity is well-utilized, while post-processing capacity utilization can increase before needing additional facilities. This means that in this ~10 MMT market growth scenario, there will be a total capacity gap of ~3.9 MMT for extrusion and ~7.4 MMT for post-processing. Based on this scenario, a capacity gap will emerge in 2024 for extrusion and in 2026 for post-processing.

The two build-out scenarios in this study examine the Capex and lead time implications of filling this hypothetical gap by adding capacity through greenfield or a combination of retrofit and greenfield facilities, as described in Table 3.

> *Existing extrusion and post-processing capacities meet only 12% and 23%, respectively, of the capacity needed for a ~10 MMT plant-based meat market.*

Table 3. Build-out scenario parameters

	Retrofit	Greenfield
Scenario 1	50%	50%
Scenario 2	0%	100%
Lead Time	1 year	3 years
Capex per TMT	$0.3MM for extrusion $0.3MM for post-processing	$1.3MM for extrusion $1.7MM for post-processing

Scenario 1 assumes that 50% of the capacity gap will be retrofitted, equivalent to retrofitting ~5% of suitable global extrusion capacity in parallel industries (~4% of total global extrusion capacity) and ~7% of suitable global animal meat processing capacity (~1% of total global meat capacity). The extent to which this scenario is realistic depends on many unknowns, including the growth and profit margins in the original industries compared to plant-based meat.

Figure 12 illustrates the amount of capacity added each year to fill the modeled capacity gaps (shown in Figures 10 and 11) for both scenarios. For these scenarios, we assume a conservative lead time of one year for retrofit facilities and three years for greenfield facilities. This means the soonest retrofit capacity could become operational in these scenarios is 2024. However, in practice, we estimate the lead time for retrofit facilities to be days to several months. Therefore, the results of this analysis likely underestimate the advantages of retrofitting as a relatively rapid means of expanding capacity. Similarly, greenfield facilities in both scenarios emerge starting in 2026 at the earliest, assuming that no major investment decisions for greenfield facilities were made during 2021 and 2022.[21]

While this lead time assumption limits the earliest dates at which new facilities can come online, the model also assumes that new capacity added after those points will exactly fill the estimated capacity gap each year. In other words, it assumes that industry participants will adequately plan to fill future capacity gaps one to three years in advance.

[21] We know of a small pipeline of facilities coming online over the next few years, but these are negligible in relation to the size of the market and the upcoming capacity need.

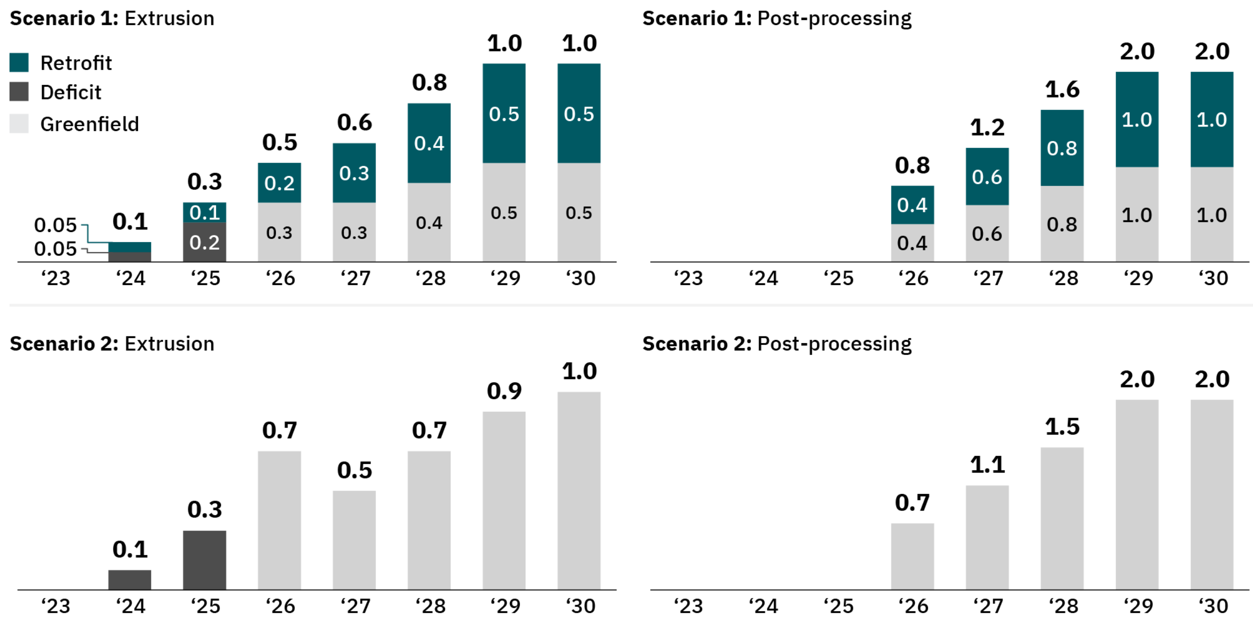


Figure 12. Modeled annual production capacity added each year for Scenarios 1 and 2. The deficit through 2025 for extrusion results from lead time assumptions for retrofit and greenfield facilities.[22]

A precise Capex estimate for each TMT of capacity via retrofitting depends on the facility at hand and the portfolio of plant-based meat products produced. Specific Capex estimates can, therefore, only be made on a case-by-case basis. Having assessed the required changes for retrofitting a facility described in Section 4.3, we assume the average Capex for retrofitting extrusion and post-processing facilities to be $0.3 MM/TMT for this report.[23]

Capex per TMT of greenfield capacity can also be highly variable. For both extrusion and post-processing facilities, the main costs include the production equipment (~50%), the building including utilities (~35%), and indirect costs like planning and project management (~15%).[24]

[22] Values include rounding effects.
[23] This assumption is based on a selection of BGP internal benchmarks as well as conversations with industry experts and engineering firms.
[24] These figures are based on BGP internal benchmarks from real-world construction projects as well as benchmarks provided by industry experts and engineering firms.

The main Capex drivers for greenfield facilities are:

- The geographic location, as planning and construction costs vary by region.
- The quality of the equipment purchased. In some cases, the most expensive supplier's equipment can cost 2-3 times more than an equivalent alternative from the lowest-cost supplier.
- The complexity of the product portfolio to be covered (this applies specifically to post-processing).
- The extent of warehousing required on-site.
- The level of sustainability technologies deployed (such as wastewater pre-treatment or on-site renewable energy).

A detailed Capex estimate depends on the specific facility at hand and can only be made on a case-by-case basis (Figure 13). For this model, we assume the average Capex for greenfield extrusion facilities to be $1.3 MM/TMT and for greenfield post-processing facilities to be $1.7 MM/TMT.[25]

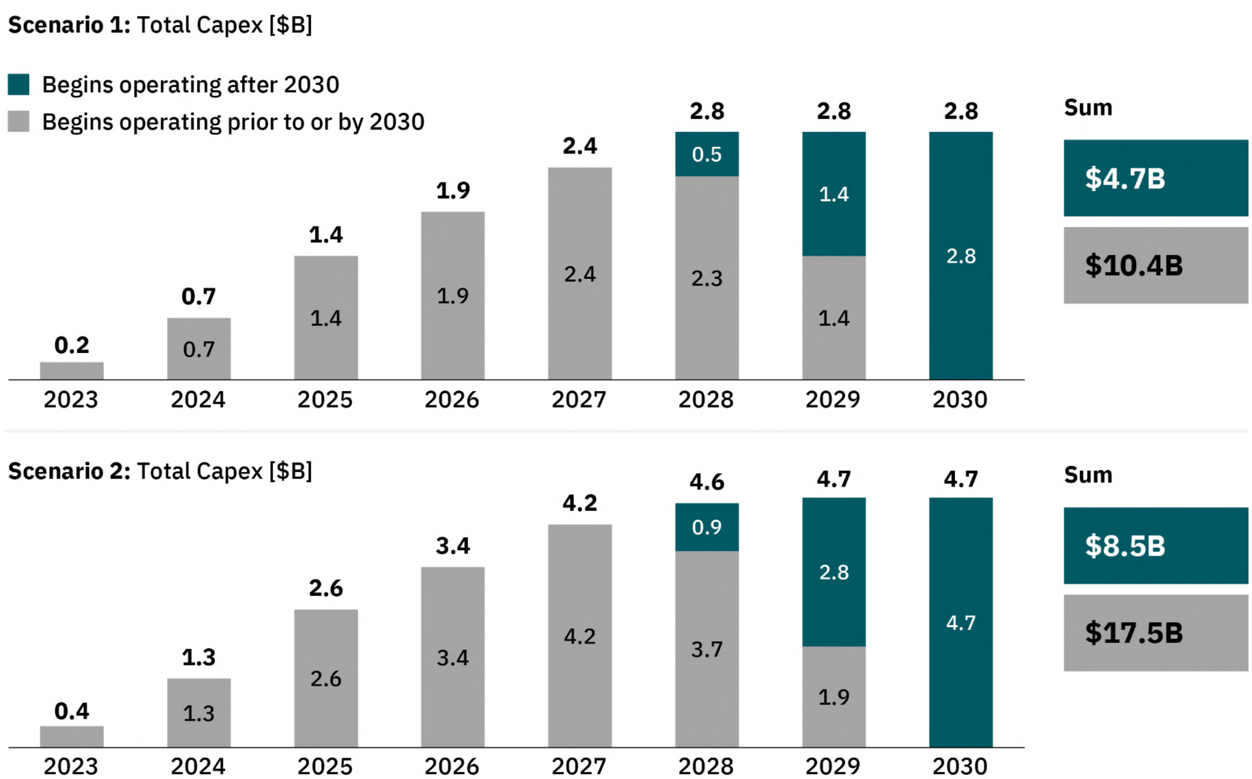


Figure 13. Total annual Capex need through 2030 for Scenarios 1 and 2.[26]

[25] This assumption is based on a selection of BGP internal benchmarks as well as conversations with industry experts and engineering firms.
[26] Values include rounding effects.

For Scenario 1

50% greenfield/50% retrofitting: the modeled total Capex investment needed to increase production to 10 MMT in 2030 is $10.4 billion (gray bars). An additional ~$5 billion (teal bars) is required through 2030 to build out capacity beyond that year given our assumption of flat growth beyond 2030, a one-year lead time for retrofitting, and a three-year lead time for greenfield facilities.

For Scenario 2

100% greenfield: the modeled total Capex required to increase capacity to 10 MMT in 2030 is $17.5 billion. An additional ~$8 billion (teal bars) in Capex investment is required through 2030 to build capacity beyond that year, assuming a flat growth trajectory.

For both scenarios, approximately one-third of the total Capex is required for extrusion and two-thirds for post-processing capacities.

> *Scenario 1 (50% retrofit) allows a considerable total Capex savings of 40%, or $7 billion, compared to Scenario 2.*

The calculations above show that Scenario 1 (50% retrofit) allows a considerable total Capex saving of 40% or $7 billion, compared to Scenario 2.

It is noteworthy in this scenario that retrofitting and greenfield will not be directly competing with each other but will be complementary approaches.

Retrofitting is a flexible pathway that allows a manufacturer to switch to plant-based products within days or months. This makes it especially effective as a short-term solution, which is also Capex effective if there is no facility acquisition.[27] In this model, retrofitting is especially useful in 2024-2025, when greenfield facilities are not yet ready. In practice, a retrofit will remain an effective solution for quickly scaling capacity regardless of the timeframe because industry participants are not likely to perfectly align planned capacity with realized market growth as assumed in this model.

[27] This is the case when a facility owner retrofits and works as a contract manufacturer or enters the plant-based market as opposed to selling the facility to a plant-based company.

Greenfield facilities are riskier since they require significant up-front Capex investment and approximately three years to build. However, in the long run, they allow manufacturers to optimize their operating efficiency and potentially lower production costs, which makes them an effective long-term solution.

Current plant-based meat market conditions

A previous GFI report, *Plant-based meat: Anticipating 2030 production requirements*, assumed 2030 plant-based meat demand volume at 25 MMT, equating to a 6% global volume share of the meat market in 2030. Many projections that we referenced in preparing that report came to similar or more optimistic conclusions based on pre-2020 market growth.

Since that report was published, a unique macroeconomic environment featuring an ongoing pandemic, the war in Ukraine, and rising inflation and interest rates have contributed to tighter consumer spending and moderated plant-based meat market growth. In some cases, observers accordingly lowered their expectations for future plant-based meat expansion. For additional context around plant-based market projections, see the Forecast section of GFI's *2022 Plant-Based State of the Industry Report*.

Despite year-over-year declines in some individual regions, the global plant-based meat and seafood retail industry generated $6.1 billion in global sales in 2022, growing 8% by dollars and 5% by volume from the prior year, according to Euromonitor.

Although challenging macroeconomic and market conditions persist, the personal, public, and planetary health benefits of plant-based meat continue to drive interest in the sector. As plant-based meat products progress toward taste and price parity with conventional meat, the long-term growth prospects of the plant-based meat market remain robust.

6 Conclusions and recommendations

Building on GFI's previous report, this analysis provides a deeper dive into the current global plant-based meat manufacturing capacity landscape and assesses pathways to increase capacity to avoid shortages.

Current global manufacturing capacity is estimated to be ~2.2 MMT per year based on estimates of 2022 plant-based meat production. Extrusion capacity is currently well-utilized, while post-processing capacity utilization can increase before needing additional facilities to meet future demand. We estimate that the majority of this capacity is in North America (34%) and Europe (41%) based on a survey of existing facilities. However, this estimate is uncertain given the limited information publicly available on the identity, capacity, and percentage of capacity dedicated to plant-based meat for existing facilities. Although current capacity is well-utilized, even moderate market growth may outstrip the industry's ability to serve demand within the next few years. We investigated potential paths to avoid a capacity gap via both greenfield and retrofit options.

For extrusion, we identified pet food, pasta, breakfast cereals, and dry snack extrusion facilities as the most technically and operationally suitable facility types for retrofitting. Those facilities have a significant overlap in equipment with the plant-based meat industry, and their operations are consistent with food safety standards. For the post-processing of plant-based meat, conventional animal meat processing facilities likewise overlap in equipment and food safety standards, making them suitable for retrofitting. Willingness to retrofit will be variable, however, and we expect it to be higher in regions where suitable industries (pasta, pet food, dry snacks, breakfast cereals, and animal meat processing) are flat or only growing slowly, as is mostly the case in Europe and North America.

Our analysis demonstrates the significant potential benefits of retrofitting existing suitable facilities compared to greenfield. Reusing equipment and buildings allows manufacturers to retrofit a suitable extrusion or post-processing facility in days or months with up to 80% lower associated Capex than a greenfield facility. In summary, retrofitting is a feasible and capital-efficient solution for quickly scaling capacity.

Greenfield facilities are riskier since they require significant up-front Capex investment and approximately three years to build. However, in the long run, they allow manufacturers to optimize their operating efficiency and lower marginal production costs.

> *There are significant potential benefits of retrofitting existing suitable facilities compared to greenfield.*

As global protein demand rapidly increases and plant-based meat emerges as a sustainable protein choice, we provide the following recommendations for plant-based meat manufacturers and supply chain stakeholders to minimize shortages and productivity loss due to capacity limitations:

1. **Focus on retrofitting existing facilities where speed and up-front costs are the priority**

   Consider retrofitting existing facilities, particularly in cases where time to market is a higher priority than long-run operating efficiency or lowest marginal production cost, such as when the industry needs to react quickly to the changing market. Retrofitting is also more attractive when access to capital or facility financing is limited.

2. **Source contract manufacturing capacity from parallel industries, especially in Asia.**

   Incentivizing companies from extrusion industries to open their production lines to function as contract manufacturers would address a potential extrusion capacity deficit. Those companies can add capacity to the plant-based industry when it is in high demand and switch to other products when there is low demand.

3. **Retrofit suitable facilities in Europe and North America.**

   Manufacturers looking to expand in Europe and North America should investigate existing facilities suitable for retrofitting. Consider facilities whose sales and margins in their original industries are under pressure because of either market decline or fierce competition, especially if the owners are willing to sell or lease the facility.

4. **Build a greenfield facility if you have a long-term vision and financing and want to benefit from superior operating and cost structures.**

   Companies who have the necessary scale and long-term business objectives should investigate a greenfield configuration with a high level of automation, which will allow maximal operational and supply chain efficiency, optimal product quality by targeting production equipment and process to achieve the desirable characteristics, and better cost structures.

5. **Plan in advance.**

   Finally, it is strongly recommended that all industry stakeholders prepare plans ahead of time and be ready to react on short notice when the market demands it. Current global capacity could be fully exhausted by modest growth in demand. Industry stakeholders should prepare a near-term reaction plan in case the market starts growing rapidly earlier than predicted, such as by using contract manufacturing or retrofitting.

7 Methodology

7.1 Estimation of global plant-based meat consumption

For the current plant-based meat consumption estimate, we divided regional retail sales of plant-based meat[28] by the share of retail sales in total sales (includes retail and foodservice) (Figure 14). We assumed the sales value split between retail and foodservice at 50%/50%.[29]

Next, we divided the adjusted regional total sales by pricing estimates for each region, giving the total plant-based meat consumption per region. Finally, we added consumption estimates for each region to calculate total global plant-based meat production in 2022.

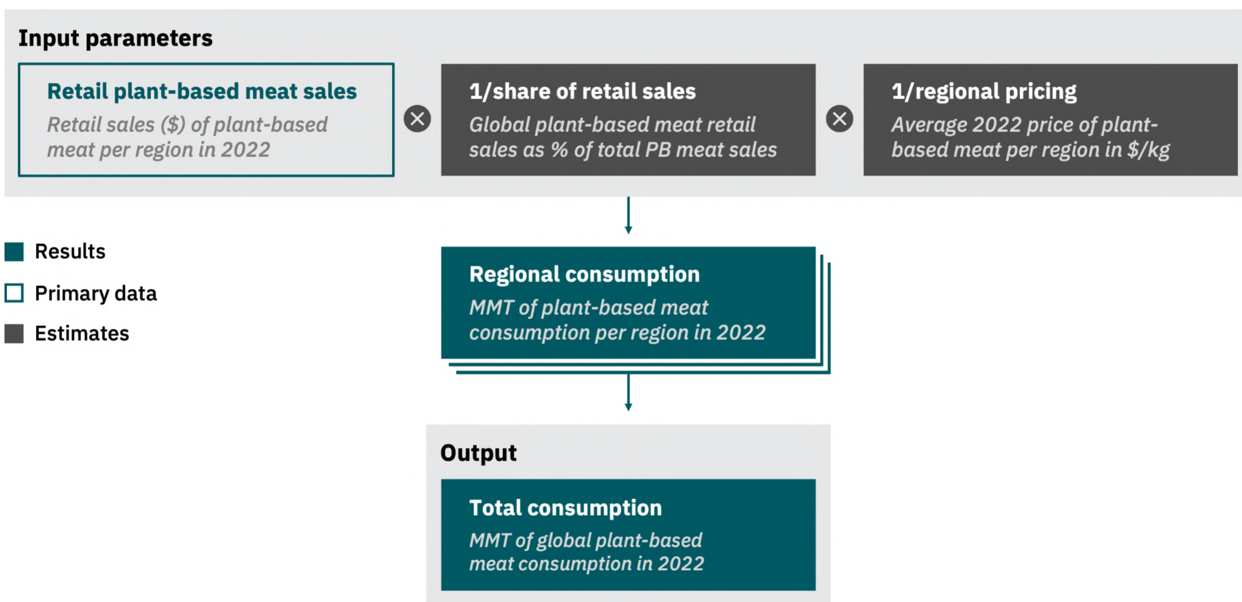


Figure 14. Current global plant-based meat consumption calculation methodology

[28] GFI 2021 State of the Industry report: *Plant-based meat, seafood, eggs, and dairy.*
[29] The split between retail and foodservice is highly variable.

7.2 Estimation of plant-based meat extrusion and post-processing capacity (top-down)

We estimated current plant-based meat capacity in the same way for both extrusion and post-processing, but with an extra step for extrusion (Figure 15). We based our top-down approach on the following market-level data: total plant-based meat consumption (based on total plant-based meat sales as described in 7.1), average facility capacity utilization, and, for extrusion, the share of extruded proteins in final products.

For extrusion, we corrected the total plant-based meat consumption in 2022 for the market share of extruded products (90%) and the share of extruded product in the final product (extruded volume makes up only 43% of the final plant-based meat product).

For both extrusion and post-processing, we divided by the average facility utilization in the industry, which we estimated to be 70% for extrusion and 45% for post-processing, based on expert input.

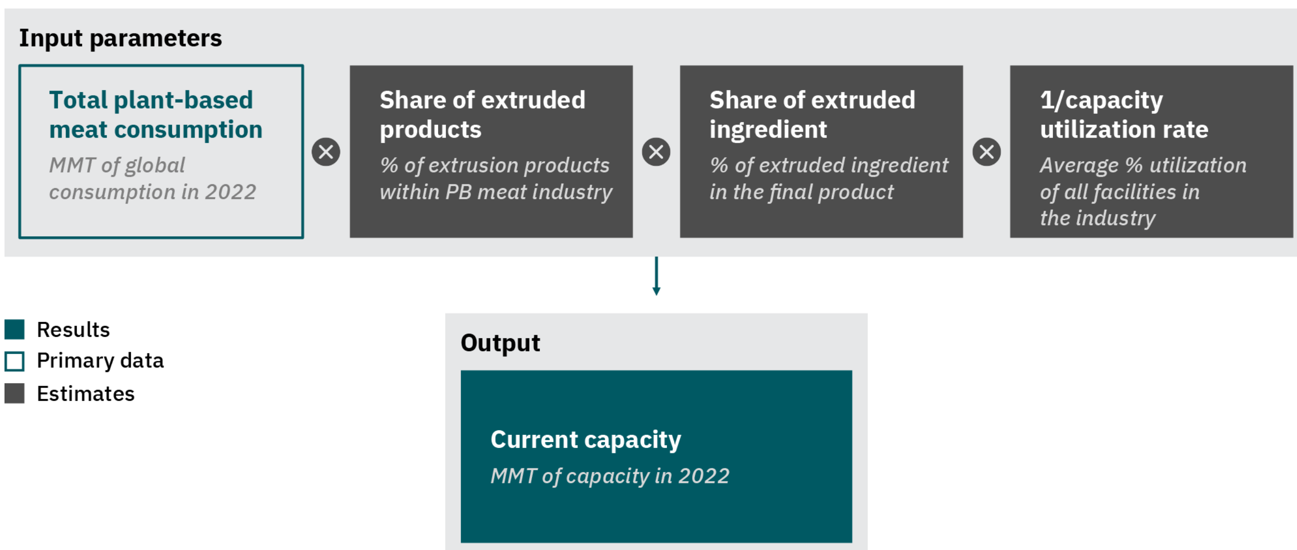


Figure 15. Current plant-based meat extrusion and post-processing capacity calculation methodology

7.3 Current plant-based meat post-processing capacity (bottom-up)

Our bottom-up approach was based on finding existing facilities that produce plant-based meat, assessing their manufacturing capacity, and calculating the total capacity of all facilities (Figure 16).

For the bottom-up assessment we first researched, to the best of our knowledge, all known plant-based meat post-processing facilities worldwide, identifying 85 facilities. Additionally, based on the availability and quality of data in different geographies and expert input, we estimate that another 58 facilities exist that we were not able to identify.

Next, we estimated the production capacity of each of the 143 facilities by multiplying facility size, capacity density, and share of plant-based meat products. These parameters include both primary data from desk research as well as estimates based on industry benchmarks and expert input to fill any data gaps.

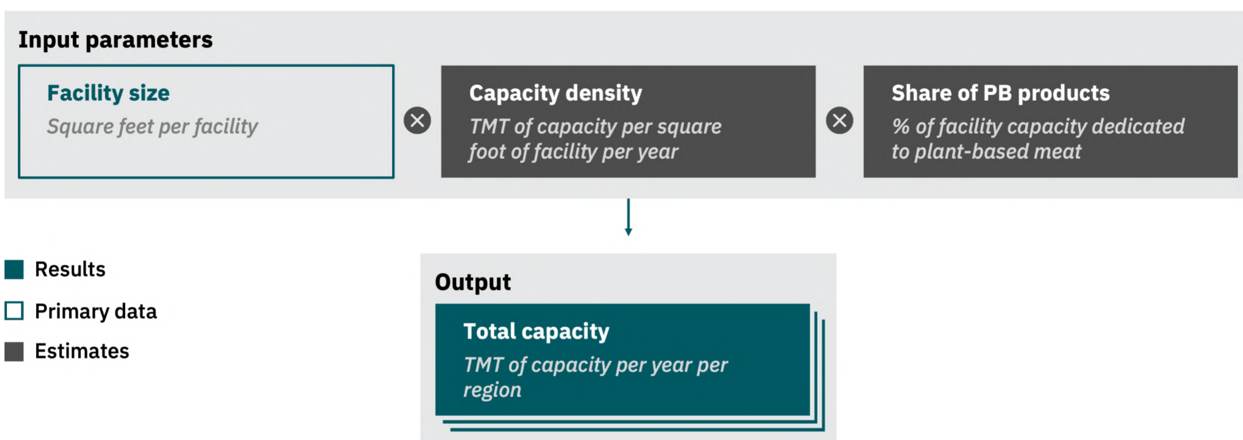


Figure 16. Post-processing bottom-up capacity calculation methodology

7.4 Extrusion capacity suitable for retrofitting

For extrusion retrofitting, we evaluated the pet food, pasta, breakfast cereals, and dry snacks industries as described in Figure 17. First, we assessed the total production for each industry on a regional level based on industry reports and estimates of revenues and average prices. Only the production capacity available in 2021 was considered in the analysis as we assumed that none of the newly built facilities would be retrofitted. Second, we corrected the resulting production for each industry by the share of extruded products within that industry to produce the total extrusion capacity. Based on industry reports and expert interviews, we assumed that the average share of extruded products for all industries is ~70%. Finally, we derived the retrofit potential per industry by multiplying it with the share of suitable facilities, which we assumed is ~80%.

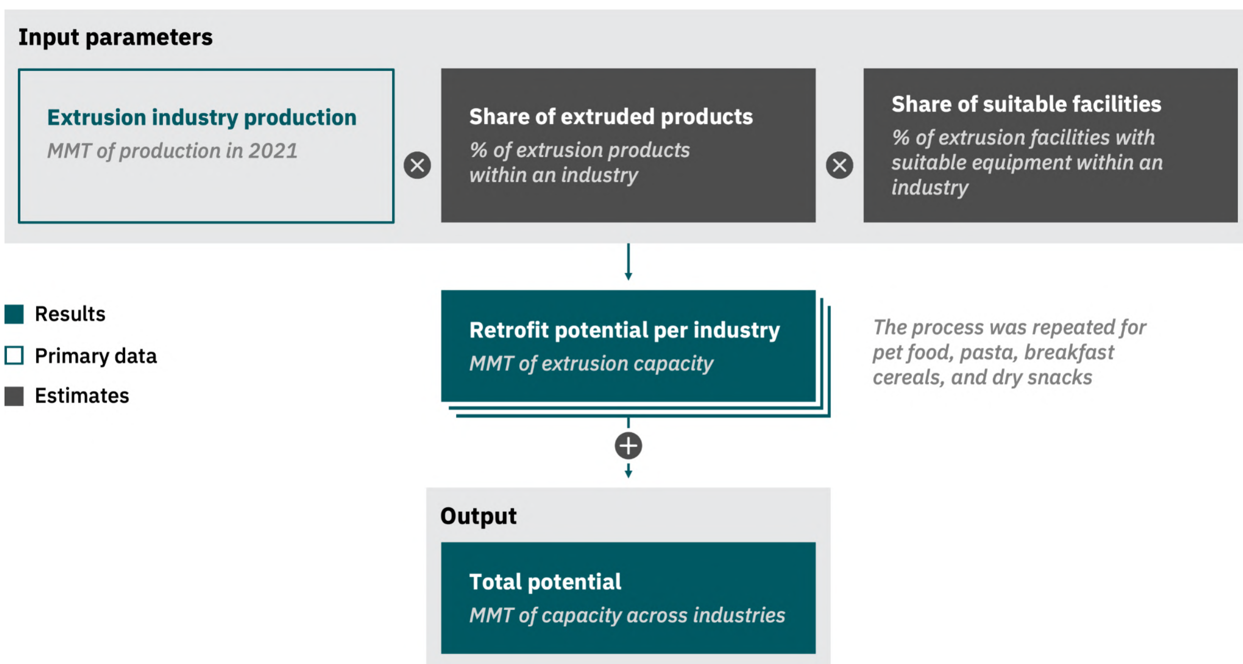


Figure 17. Extrusion retrofitting potential calculation methodology

7.5 Post-processing capacity suitable for retrofitting

We estimated the global capacity suitable for plant-based post-processing using a top-down approach similar to the approach outlined in Section 7.2 but focused on animal meat processing facilities (Figure 18). First, we calculated the total processed meat production by taking a region's total meat production[30] and applying a factor of processed meat share (global average ~20%). We derived the share of processed meat from reports on processed meat consumption from several countries within a given region. We only considered the production capacity available in 2021 in the analysis as we assumed that none of the newly built facilities would be retrofitted.

Second, we adjusted the processed meat capacity to remove unsuitable facilities, such as some curing facilities. We assumed 90% of the facilities would be suitable.

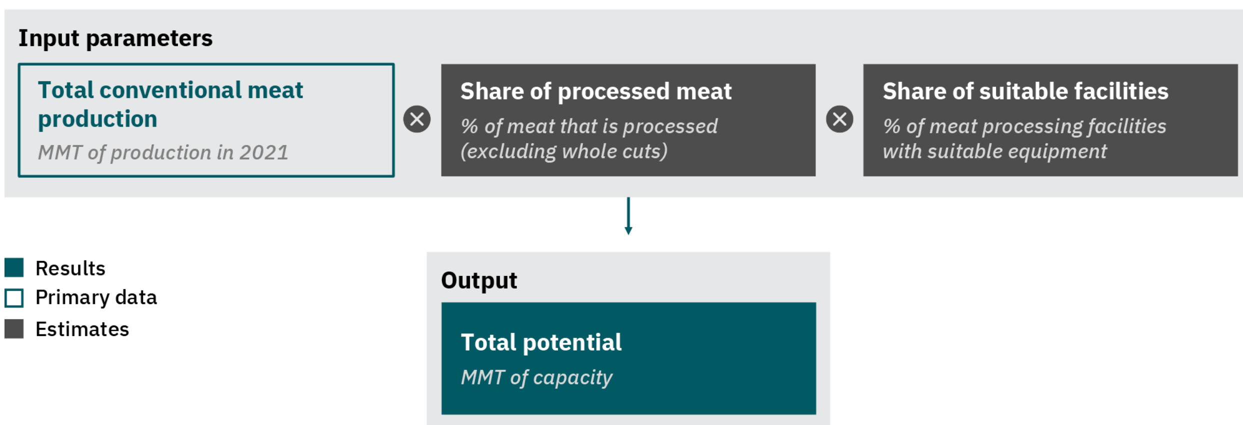


Figure 18. Post-processing retrofitting potential calculation methodology

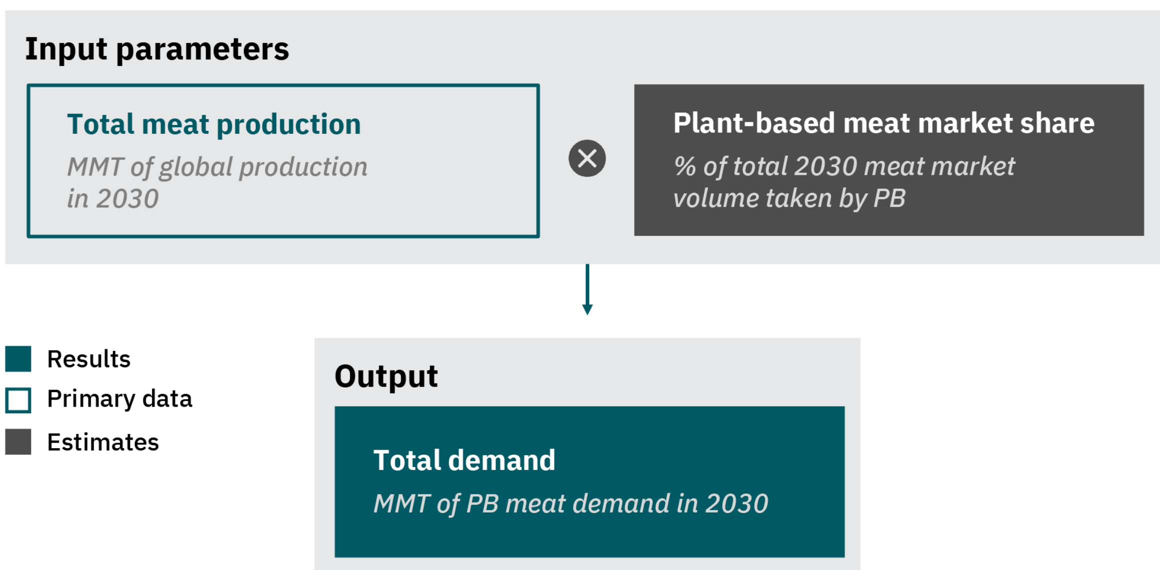
[30] Based on OECD meat production data.

7.6 Scenario analysis

The scenario analysis was carried out in three steps: 1) Model annual production growth from 2.2 MMT in 2022 to 10 MMT in 2030; 2) Estimate the resulting capacity gap; 3) Model the amount of production that can be added each year for the two build-out scenarios to fill the capacity gap (retrofit + greenfield or greenfield only) and estimate the associated Capex for each build-out scenario.

7.6.1 Plant-based meat production growth model

First, we multiplied the total forecasted meat production based on the OECD-FAO Agricultural Outlook 2022-2031 by Bloomberg's plant-based meat market share forecast of 2.5% global volume share in 2030. The 2030 figure matches the "low" scenario in Bloomberg's 2021 report *Plant-based food poised for explosive growth*, which was based on pre-slowdown 2020 market data (Figure 19). The incremental increases in production in the years leading up to 2030 were modeled by BGP based on recent global volume figures.



Source: BGP analysis

Figure 19. Plant-based meat 2030 demand calculation methodology

7.6.2 Estimating the production capacity gap

For each year starting in 2023, we compared the needed capacity estimated in the production growth model to the estimated 2022 plant-based meat production capacity estimate of ~2.2 MMT. The capacity gap is the difference between the needed capacity for this scenario and the 2022 estimate.

7.6.3 Modeling the annual production increase and associated Capex

For both scenarios, for each year from 2023 through 2030, we modeled the amount of capacity gap (estimated in step 2) that could be filled by either a retrofit and/or greenfield development given the lead time and percent contribution as shown in Table 3. For example, in Scenario 1, retrofitting has a lead time of one year and can fill up to 50% of the capacity gap. For extrusion, we increased the share of extruded volume used in the final plant-based meat product to 52% from 43% in 2022, based on an assumed rise in the market share of high moisture SPP. Additionally, we assumed that utilization will be 100% in 2030. For each TMT of production added, we estimated the associated Capex for retrofitting and/or greenfield using the Capex averages listed in Table 3.

Acknowledgments

The authors would like to thank the following GFI team members for their insights.

Liz Specht for helping to develop the intellectual foundations of the analysis and providing a detailed review of the report.

Emma Ignaszewski for providing a detailed review of the report and offering guidance on scenario modeling.

The authors are grateful to industry experts for sharing their perspectives and insights, including Dr. Mehmet Tulbek and Dr. Mahesh Sivakumar, Saskatchewan Food Industry Development Centre Inc.; Willem Cranenbroek, ME-AT (Vion); and Dominique Kull, SGProtein.