Enhancing the Ecosystem for Alternative Protein Innovation:
Strategies for Scaling Success

INVEST-NL

Foodvalley®

Contents

Executive Summary

Introduction

The Netherlands, a global leader in agriculture and biotechnology, is poised to play a pivotal role in the burgeoning alternative protein sector. This report, a result of collaboration between Foodvalley NL and Invest-NL, provides an in-depth analysis of the challenges and opportunities in scaling this industry within the Dutch landscape. The transition from animal-based to alternative proteins is not merely a trend but a necessity, driven by environmental concerns, health considerations and the need to feed a growing global population. The Netherlands, with its expertise in food production and innovation, is uniquely positioned to lead this transition.

Market Potential

The Dutch alternative protein market is on the cusp of exponential growth, projected to surpass €10 billion by 2030. This growth is fueled by declining production costs, technological advancements and changing consumer preferences towards healthier and more sustainable food options. The Netherlands, with its strong agricultural base and innovative spirit, is well-positioned to capitalize on this growing market. However, to fully realize this potential, it is crucial to address the challenges that hinder the scaling of alternative protein production in The Netherlands.

Scaling Challenges

Startups and scale-ups in the alternative protein sector face a myriad of challenges as they strive to move from lab-scale to commercial production. These challenges include:

- Limited Access to Pilot and Demonstration Facilities: The current infrastructure for pilot-scale and demonstration-scale production is insufficient to meet the growing demand. This lack of access hinders companies' ability to test and optimize their processes, delaying their time-to-market.

- High Operational Costs: The high costs associated with operating pilot facilities, including equipment, personnel and raw materials, pose a significant financial burden on startups and scale-ups.

- Regulatory Complexities: Navigating the regulatory landscape for novel food products can be a time-consuming and expensive process, further hindering the scaling of alternative protein production.

- Valley of Death: The 'Valley of Death' refers to the critical funding gap that many startups face between the research and development phase and commercialization. This lack of funding can stifle innovation and prevent promising technologies from reaching the market.

Shared Facilities Landscape

Shared facilities play a crucial role in supporting the growth of the alternative protein sector by providing startups and scale-ups with access to essential infrastructure and expertise. However, the current landscape of shared facilities in the Netherlands is fragmented and faces several challenges, including:

- Limited Capacity: The existing capacity of shared facilities is insufficient to meet the growing demand from companies across different protein categories, such as plant-based, fermentation-derived and cell-cultured proteins.

- Lack of Specialization: Many shared facilities lack the specialized equipment and expertise required for specific protein production processes, limiting their effectiveness in supporting diverse companies.

- Operational Inefficiencies: High operational costs, scheduling conflicts and limited flexibility can hinder the efficient use of shared facilities.

International Best Practices

Examining successful models from countries like the United States, Israel, Belgium, Germany and Singapore reveals valuable insights for the Dutch ecosystem. These models emphasize flexibility, cost-consciousness, strong leadership, robust networks and government support as key drivers of success. By learning from these international best practices, The Netherlands can develop a more effective and supportive ecosystem for scaling alternative protein production.

Recommendations:

To overcome the challenges and unlock the full potential of the alternative protein sector in The Netherlands, several key recommendations are proposed:

1. Develop a National Strategy with Ecosystem Collaboration: Create innovation clusters to facilitate interaction among startups, research institutions and corporate partners. Additionally, there is a call to streamline regulations and introduce policy incentives like tax breaks to spur growth in the alternative protein sector. Government policies should support these collaborations with structural funding and infrastructure.

2. Strategic Investment in Shared Facilities: Establish regional hubs with state-of-the-art shared facilities across The Netherlands, backed by public-private partnerships. It is necessary to invest in specialized equipment and expert personnel to cater to various protein production processes and additionally implement flexible access models to make these facilities more affordable for startups and scale-ups.

3. Financial Support Mechanisms: Expand financial support through voucher systems, operational subsidies and innovative funding models like co-investment funds to alleviate financial burdens. Additionally, it will be necessary to introduce bridge-funding programs to support startups from R&D to commercialization, ensuring that policies provide adequate financial assessment and incentives for the alternative protein sector.

Conclusion

The Netherlands has a unique opportunity to become a global frontrunner in the alternative protein revolution. By addressing the scaling challenges, investing in infrastructure and fostering a collaborative ecosystem, the Dutch market can unlock its full potential, contributing to a more sustainable, healthy and ethical food system. This report serves as a call to action for stakeholders across the value chain to collaborate and drive the growth of this promising sector.


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1. Introduction

In a world increasingly focused on sustainability and health, the Netherlands stands at a pivotal point in the transition from animal-based to alternative proteins[1]. This shift is not just a local preference but aligns with global efforts to reduce environmental impacts, increase biodiversity, minimize land use and promote healthier lifestyles while ensuring that there is sufficient food for a world population which is expected to grow to 10 billion[2]. The food systems are responsible for about 30% of the current anthropogenic GHG emissions, and animal products account for almost 60% of those emissions. Simultaneously, the global demand for animal proteins is expected to rise significantly, presenting a challenge to current agricultural practices.

The negative effects of the current system are especially visible in The Netherlands, with the livestock industry, which covers a large part of the country with extensive grasslands and fields full of silage maize, producing far too much manure. And in the Netherlands, we slaughter 1.5 million chickens, 45,000 pigs, and 5,000 cows per day[3].

This results in a host of problems, including the emission of a significant amount of nitrogen. Other issues include water pollution, soil degradation, high emissions of nitrous oxide and methane (potent greenhouse gases), and further intensification of scale, leading in turn to an increasingly dull countryside and a continuous cycle of new farmers forced to close their doors so that others can expand. Not only has this resulted in increasingly less nature, a barren landscape, and rising costs to meet basic needs such as clean water, it also becoming a threat to agriculture itself, as dry summers pose an ever-growing problem for farmers. Moreover, as nature disappears from pastures and fields, soil fertility deteriorates.

The livestock population in The Netherlands will need to shrink significantly to fit within European regulations, especially to prevent further deterioration of the ecosystem on which we depend. There is a need to change the way we produce and consume the food we eat, because of its growing impact

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1 https://doi.org/10.1016/bs.afnr.2022.02.003

2 https://www.unep.org/resources/whats-cooking-assessment-potential-impacts-selected-novel-alternatives-conventional

3 https://opendata.cbs.nl/#/CBS/nl/dataset/7123slac/table?dl=4D994

1.1 Alternative Proteins

A shift to alternative protein sources, particularly through innovative technologies like precision fermentation and cellular agriculture, offers a sustainable and efficient solution[4]. These methods, relying on fermentation and cell cultivation, can produce meat, dairy products and alternatives in a more animal-friendly, healthy and environmentally sustainable way. The alternative protein market is diverse and rapidly evolving, with significant potential for growth. Success in this sector depends on technological innovation, consumer acceptance, regulatory support and market-specific strategies. Scaling up alternative proteins can significantly reduce the environmental impacts associated with traditional animal protein production. However, ongoing innovation and careful management are crucial to fully realize these environmental benefits. The industry's future will see more collaborations between traditional food companies and alternative protein startups, further driving innovation and market expansion.

1.2 Methodology and Outline of the Report

The primary objective of this study is to thoroughly investigate and understand the specific challenges faced by alternative protein companies in the Netherlands during their scaling-up phase. The following research questions were formulated:

- How can The Netherlands improve the scale-up process for alternative protein companies?
- Specifically by improving access to faster and more effective testing capacity and optimizing the availability and use of testing and production facilities, technological capabilities, and financing?
- By drawing lessons from countries where this process is perceived as more efficient?

This study aims to give recommendations to transform the operations of alternative protein companies in The Netherlands, to develop a national strategy, fostering a sustainable and innovative future. By addressing scaling challenges and proposing solutions, there is the potential to influence policymaking, industry practices and investment decisions. The findings will contribute to advancing the protein transition and solidifying The Netherlands' reputation as a leading business hub.

This study uses both quantitative and qualitative methods, thereby allowing us to quantify the alternative protein industry and gain an in-depth understanding of stakeholders' attitudes, experiences and proposals.

The main steps of the research were:

- Stakeholder interviews: The goal was to understand their perspectives, demands and expectations, and to identify potential challenges. This also includes the analysis of the interview results.
- Literature review and synthesis: We reviewed the current literature relevant to our project.
- Analysis of international case studies: We analyzed globally relevant case studies to apply insights from similar projects.
- Strategy formulation and intervention: Based on the findings, a comprehensive strategy was formulated, including contingency plans for potential risks.

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4 https://doi.org/10.1111/1541-4337.13094

2.
Dutch Market Growth Potential in Alternative Proteins

The Netherlands, renowned for its agricultural innovation and biotechnological expertise, is uniquely positioned to lead this emergent market. The Dutch approach is characterized by a blend of traditional agricultural strengths and innovative biotechnological research, creating an ideal environment for alternative protein ventures. This potential is further bolstered by the presence of numerous startups in this field, which are successfully attracting private investments. Recognizing this opportunity, Invest-NL and Foodvalley NL are focused on investigating and supporting the growth of this sector to achieve world-class status. This study delves into the specific obstacles small and medium-sized enterprises (SMEs) encounter as they aim to upscale alternative protein production to foster an innovative ecosystem that is both supportive and conducive to growth. Through this exploration, we seek to illuminate the path forward for The Netherlands to solidify its position as a leader in the burgeoning market of alternative proteins, paving the way for a sustainable future in global food production.

The EY 2022 global market value for alternative proteins was reported at €13.6 billion, with an expected compound annual growth rate (CAGR) of 36% from 2020 to 2030, signalling a sector poised for rapid expansion. Key factors fueling this growth include decreasing production costs and improving the quality of alternative proteins. In 2022, the economic value of the Dutch market in the protein transition sector was estimated at €346 million, constituting a 2.5% share of the global market from the EY 2022 forecast. This highlights the Dutch market's significant role in the global alternative proteins landscape.

Our analyses underscore the Dutch market's significant potential within the growing alternative proteins sector, compared to global market forecasts projected by EY. This comparison illustrates not only the sector's promising growth, transitioning from a 2022 baseline of €346 million, but also its anticipated expansion, potentially exceeding €10 billion by 2030. This considerable growth provides a compelling business case for strategic investment, signifying opportunities for stakeholders across the value chain—from emergent startups to established corporates (Appendix 3)

Technological innovations in plant-based production and cellular cultivation are pivotal in this transition. Milestones such as the opening of 'The Chicken', a lab-grown meat restaurant in Israel, and Singapore's regulatory approval of cultivated chicken meat highlight the rapid progress and adoption potential of these technologies. Advancements in fermentation technology also promise significant cost reductions and expanded applications, further propelling the alternative protein sector's growth[5].

Additionally, this highlights the imperative for stakeholders to capitalize on the unique positioning of the Dutch market. Amidst a global increase in demand for alternative proteins—driven by declining production costs, technological advancements and shifting consumer diets—the Dutch market is uniquely positioned to contribute to the sector's evolution.

By strategically leveraging identified growth opportunities and navigating anticipated challenges, the Dutch market will be positioned as a key player in the rapidly growing global alternative protein landscape.

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5 Economic-Data-The-Protein-Transition-Map-NL-and-BUCK-Report2.pdf (foodvalley.nl)

3. Development of Alternative Proteins

Alternative protein process development is divided into several stages, each with the goal of minimizing risks and maximizing commercial feasibility. At the outset of the Idea Generation phase, insights from many domains like R&D, manufacturing and marketing are incorporated to evaluate the possible risks and rewards of new goods or processes. This brings us to the Feasibility Phase when potential and market demands are assessed, and the fundamental concepts are validated in the lab to establish proof of concept.

Taking concepts from the lab and turning them into bench- and pilot-scale processes, the Development Phase identifies the best operational strategies for protein concentration, extraction and purification. Based on production costs and logistics, this phase is critical for defining the product and its market potential.

The Process Scale-Up Phase extends these approaches to larger scales, equivalent to commercial operations, focusing on the durability and scalability of the processes. Here, too, market testing is done to make sure that production and consumer demand match. The development process results in the Demo Phase, where extended operations are conducted with the goal of optimizing yield and process capacity to get ready for commercial launch.

Finally, the Plant Startup phase represents the transition to full-scale operations, addressing any emergent challenges and verifying the process's robustness and market readiness.

This complex process, which spans preparation of ingredients to creation of the finished product, highlights how challenging and costly it is to create alternative protein solutions. To promote innovation and satisfy the changing dietary tastes of consumers worldwide, it is essential that scale-up difficulties be addressed and this process streamlined.

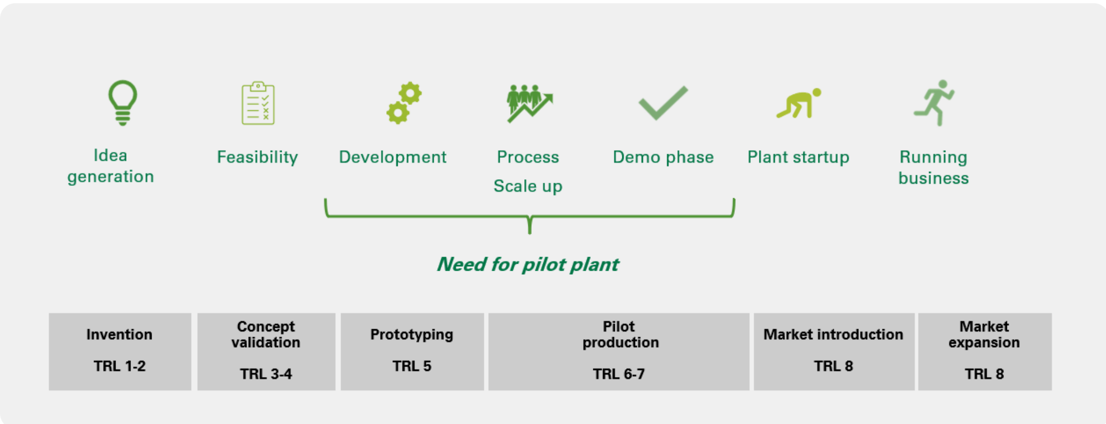

Fig 3.1. Phases in the development of alternative proteins (Cooper, 1990).

To develop a process for a new alternative protein, pilot testing and the availability of a pilot facility are essential in the development, scale-up and demo phase. Figure 3.2 illustrates the objectives that must be met during the pilot testing phases:

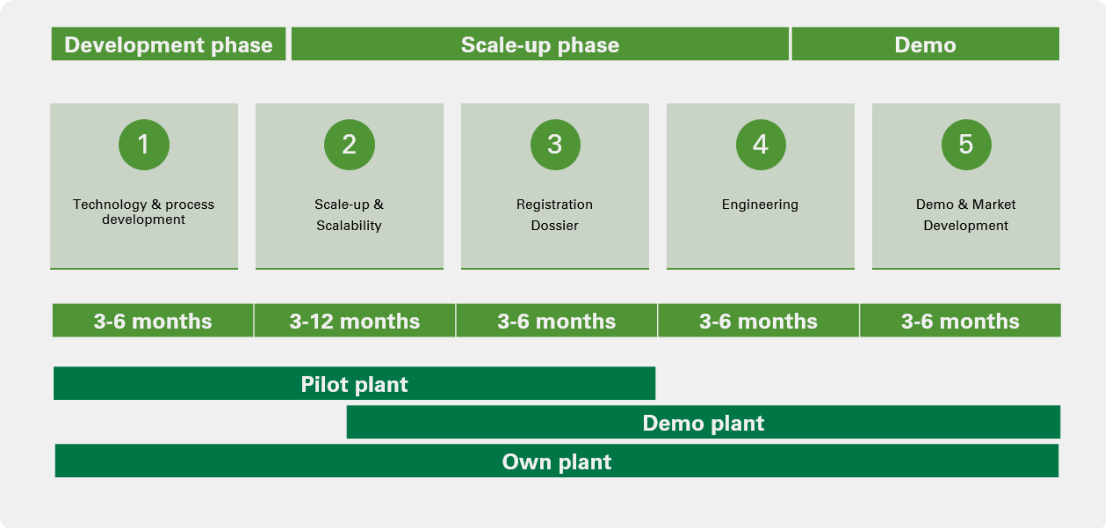

Fig 3.2 Objectives during the development, scale-up and demo phase of an alternative protein, average time it might take and options for test facilities.

Technology & Process Development

The first reason to use a pilot plant is to develop and test processes that will deliver a product according to specifications. This is done during the development phase and many different unit operations are evaluated to find the best-performing configuration. Best performing means in this respect: consistent and high yields as well as capacity with predictable and low costs.

Pilot testing allows product developers to refine the formulation, texture, taste and nutritional profile of alternative protein products. It's a crucial step in developing a product that meets consumer expectations and industry standards.

Scalability Assessment

Once the process configuration has been determined, further tests on a larger pilot scale will be needed to assess whether the production technology works on a larger scale. Larger-scale pilot testing can reveal technical hurdles in the production process that might not be apparent on a smaller scale. The scalability of the process is tested to determine what the scale-up parameters for the design of a large-scale manufacturing plant are.

The approach towards a scale-up of process technology is unfortunately not straightforward. The larger volume can cause many parameters that are essential for the extraction or purification to change. For example, precision fermentation requires different pressure, oxygen transfer and shear in a fermenter on a large scale which influences the production kinetics of the micro-organisms. Lower production yields, slower kinetics and the production of impurities on a larger scale are all factors that may result in the desired specifications not being met.

Equipment used on the pilot scale is in general quite different from the laboratory scale for reasons that they run continuously and do not have the same separation yield as the lab equipment. This, of course, influences the product quality and capacity of the process.

Regulatory Dossier

If an alternative protein is regarded as a novel food, a regulatory dossier needs to be filed. A regulatory dossier must demonstrate consumer safety and show that the product can be representative and safely produced. As proof of that, five batches need to be produced according to the specifications and fully analyzed. These batches are generally produced on a scale that is representative of the full scale, many times a pilot or demo scale.

Engineering

All information needed for the engineering process must be generated during the development and scale-up phase. These are phases where the technology is still not fixed but is under development. These phases are clearly complex, and a lot of data must be generated at the same time.

Demo Scale and Market Development

During a later stage of the scale-up, the product needs to be produced in larger quantities to enable potential customers to formulate the product in their end-products. This phase has two purposes:

- Derisking. If the product is new on the market, it is uncertain if there is sufficient market acceptance and market demand. Before the investment is made, it must be shown that the product is accepted in the market and consumers are willing to buy it.
- Faster market introduction. The business development will enable a much faster introduction of the product once the commercial plant is up and running. B2C companies also need considerable introduction time (sometimes up to 1 year) before they can launch a new product or application.

The demo phase involves understanding consumer acceptance and market demand for the product. Feedback from these tests can guide marketing strategies and product positioning. It shows whether the new product is within the market price and whether customers are willing to purchase, and so enables faster market introduction.

3.1 The Role of Contract Manufacturing in Scaling Alternative Proteins: A Strategic Approach in a Dynamic Landscape

The integration of Contract Manufacturing Organizations (CMOs) and Contract Research and Manufacturing Organizations (CRMOs) into the business models of alternative protein companies is a strategic imperative for scaling production. By leveraging the specialized knowledge, infrastructure and scalability offered by these organizations, companies can accelerate product development, mitigate financial risk and achieve growth objectives. This strategic approach streamlines the path to market, reduces financial burdens, and fosters a more agile and competitive industry.

However, the increasing reliance on CMOs and CRMOs, while advantageous for scaling, presents challenges for Contract Research Organizations (CROs) specializing in pilot-scale testing and optimization. As more companies opt for the integrated solutions offered by CMOs and CRMOs, the demand for independent CRO services may decline. To remain viable, CROs must strategically adapt by focusing on specialized expertise, developing unique service offerings that complement CMO/CRMO capabilities, and fostering collaborations that ensure a seamless transition from research to commercialization. By doing so, CROs can continue to play a vital role in the alternative protein ecosystem, supporting innovation and contributing to the industry's long-term growth.

This evolving landscape underscores the importance of collaboration and strategic partnerships within the alternative protein sector. By working together, CROs, CMOs and CRMOs can create a more efficient and resilient ecosystem that supports the development and commercialization of innovative and sustainable food solutions.


NUTRICIA RESEARCH

4.
Supply and Demand in Shared Facility Landscape

This chapter explores the supply and demand dynamics within The Netherlands' shared facility landscape for alternative proteins, focusing on the essential capabilities that ventures require for scaling. It assesses the current and anticipated needs against available and developing facilities, with a particular emphasis on ingredient processing. By examining what facilities are currently available or in development, and what is required by ventures now and in the foreseeable future, this section offers a comprehensive overview of the supply and demand dynamics in the shared facility landscape for alternative proteins.

CAPABILITY LANDSCAPE

Needed capacity on different technologies for ventures to develop, process scale-up and demonstration

Capabilities	Pilot Volumes			Pre-Commercial Volumes	
Extraction	0-50kg/h	0-150kg/h	1000-2000 kg/h	>2000kg/h	
Spray Drying	0-25L/h Evaporation	80L/h Evaporation	250L/h Evaporation	>250L/h Evaporation	
Precision Fermentation	100L	1000L	1000-10000L	>10000L/h	
Biomass fermentation	Up to 100L	600-1000L	4000L	10000L	>10000L/h
Air Proteins	100L	1000L	1000-10000L		>10000L/h
Cellular Agriculture	Up to 10L	1000L	10000-20000L		>20000L/h
Foodvalley	Concept Validation TRL 3-4	Prototyping TRL 5	Pilot Production TRL 6-7	Market introduction TRL 8	Market Expansion TRL 9

Figure 4.1 Illustration of Pilot Plant Capacity Landscape for Alternative Protein Production (Concluded from interviews conducted by FoodvalleyNL,2023)

4.1 Inventory of Pilot Plant Capacity for Alternative Proteins

We evaluated the pilot plant's capabilities for alternative protein production. This involved an examination of key process technologies and the requisite volume scales across different protein categories. Figure 4.1 provides a visual representation of this capacity landscape, elucidating the diverse requirements within each category.

Differences in Unit Operations

The main differences between the categories are related to the first step in the process. In this step the protein is produced or extracted and, in each category, different techniques are used to realize that.

- Extraction of proteins from plant material is mostly done with extraction vessels.
- Fermentation is done in a fermenter optimized for mixing and providing the right components for organism growth.
- Cell cultures on a larger scale need a different bio reactor than used in precision fermentation as the cells are much more shear-sensitive.

For all three categories, the downstream processing is different and requires different techniques.

Overlap in Unit Operations

Overlap in processing steps and equipment can be found towards the end of the process:

- In the purification and isolation steps of plant protein and fermented protein. The unit operations needed for purification and isolation can be used in both categories.
- Most proteins need to be concentrated and dried, which can be performed in the same installation. The most used drying technique is spray drying and there are several options in the Netherlands.

Hygiene

Apart from the unit operations, a significant difference between the protein categories is the hygienic standard needed to execute the pilot runs.

- Plant-based proteins can be produced under normal food-grade operations.
- For precision fermentation where GMOs are used advanced standards are needed: pilot runs need to be executed under ML I & II conditions.
- Cultured meat needs to be produced under higher hygienic standards used in pharma as these cell growths last a long time and are highly vulnerable to infections.

4.2 Pilot Plant Availabilities for Startups

CURRENT AVAILABILITY

Available capacity on different technologies for ventures to develop, process scale-up and demonstration

Available
In Pipeline
Not Available
Only at closed corporate facilities

Capabilities	Pilot Volumes			Pre-Commercial Volumes	
Extraction	0-50kg/h	0-150kg/h	1000-2000 kg/h	>2000kg/h	
Spray Drying	0-25L/h Evaporation	80L/h Evaporation	250L/h Evaporation	>250L/h Evaporation	
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Figure 4.2 Current Availability of Pilot Plant Capabilities for Alternative Proteins (Concluded from interviews conducted by FoodvalleyNL, 2023)

Next, we engaged in interviews with companies to ascertain the accessibility of pilot capabilities across different technological innovations and processes within the alternative protein sector. Companies engaged in this study included DSM-Firmenich (marked as a closed corporate facility), Cosun, Nizo, Bodec, Biorefinery Solutions (BRS), Vreugdenhil, and WUR FBR. Figure 4.2 subsequently illustrates the availability of these capabilities, offering a comprehensive visualization of the industry's capacity to facilitate the scaling of alternative protein production through technological innovation. These discussions yielded critical insights into the current landscape of pilot plant capacities and their correspondence with various technological advancements.

Plant-based

For startups in plant-based ingredients, there are several piloting options available for extraction and drying. At the pre-commercial capacity, there is currently no shared location available.

Precision Fermentation

Startups specializing in fermentation-based ingredients currently face limited options for scaling their operations due to the lack of available pilot-scale fermentation capacity. There are currently capacities up to 1000L, which is insufficient for larger scale-up needs. However, the situation is expected to improve significantly with the implementation of a project funded by the National Growth Fund (NGF)[6], which plans to invest €25 million in a pilot plant facility. This facility will specialize in precision fermentation and cultured meat, offering capacities of up to 10,000L.

Despite these advancements, the gap in the ecosystem highlights the ongoing challenge for startups to access the necessary infrastructure for scaling to commercial production levels.

Cell Culture

For startups in cell culture, there are currently no shared facilities available for scaling in the Netherlands. After the NGF project, there will be capacity available up to 1000L.
Options for further scale-up above 1000L will not be available in the Netherlands even after the NGF project. Larger volumes above 1000L will be essential for the evaluation of the technology at a larger scale.

Addressing the Flexibility Challenge

To strategically address the limitations in flexibility and scale faced by many Dutch pilot facilities, startups can leverage partnerships with larger, more versatile entities. For example, the Bio Base Europe Pilot Plant (BBEPP) in Gent, Belgium, and Wageningen Food & Biobased Research exemplify this approach. BBEPP, the world's largest and most advanced precision fermentation pilot plant, offers shared-use facilities and a non-profit model, providing a cost-effective and accessible pathway for Dutch companies to scale their innovations. Secondly, Wageningen Food & Biobased Research, with its scalable facilities and extensive research network, presents another strategic option for startups seeking collaborative environments and expert guidance. Both entities offer the flexibility to integrate custom equipment, further tailoring their capabilities to specific needs. By strategically collaborating with such established players, startups can overcome resource limitations, accelerate their commercialization timelines, and drive the growth of a competitive and sustainable alternative protein sector in The Netherlands.

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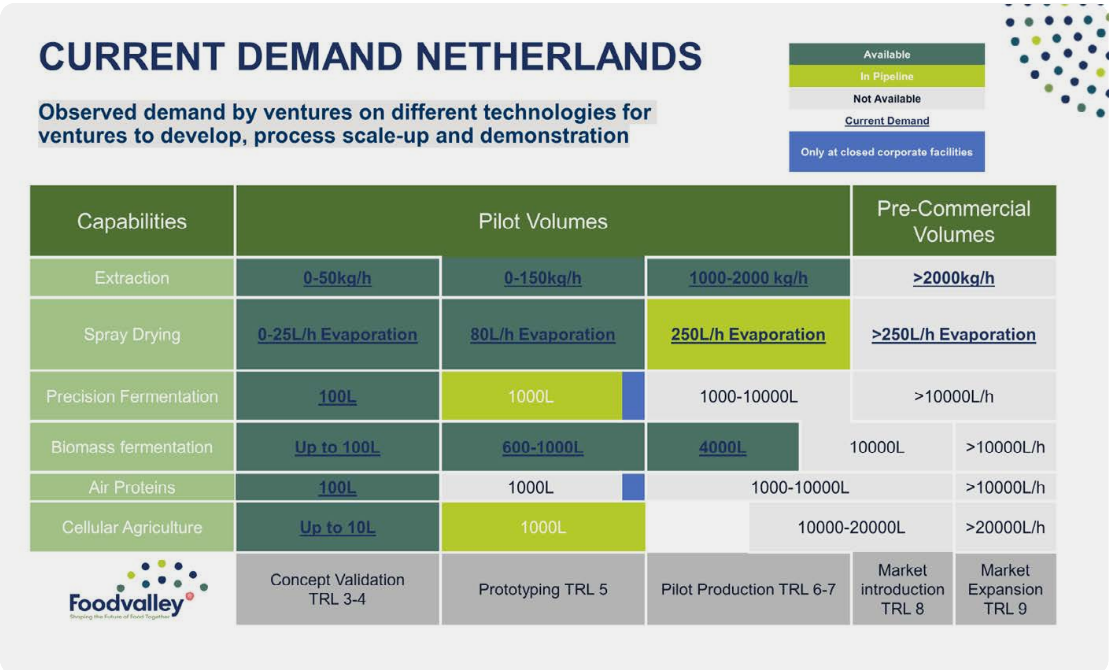
6 The growthplan | Cellulaire Agricultuur Nederland

4.3 Scaling Up: Current and Future Demand for Alternative Protein Production Capabilities in The Netherlands

This section aims to chart the trajectory of demand from today to 2030, examining the immediate requirements for innovative technologies to scale up production (Fig 4.3). Furthermore, it anticipates the expansion needs and technological advancements that will become essential as the sector matures, driven by increasing consumer demand, environmental considerations and the strategic positioning of The Netherlands as a leader in sustainable food innovation (Fig 4.4). Based on the current number of 55 Dutch startups in 2024 that focus on the protein transition, we estimate this number will grow to approximately 70 start- and scale-ups working with alternative protein (See Appendix 8)



Capabilities	Pilot Volumes			Pre-Commercial Volumes	
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Figure 4.3 Current Demand for Scale-up and Demonstration Facilities for Alternative Protein (Concluded from Interviews Conducted by FoodvalleyNL, 2023)

The current demand for scaling up capabilities and technologies in The Netherlands' alternative protein sector is driven by a growing number of small and medium-sized enterprises (SMEs) focusing on plant-based, fermentation-derived, cell-cultured proteins. These companies are at various stages of development, from initial research and development to small-scale production. Their immediate needs include access to pilot and demonstration facilities capable of bridging the gap between lab-scale experiments and commercial-scale production at higher volumes.

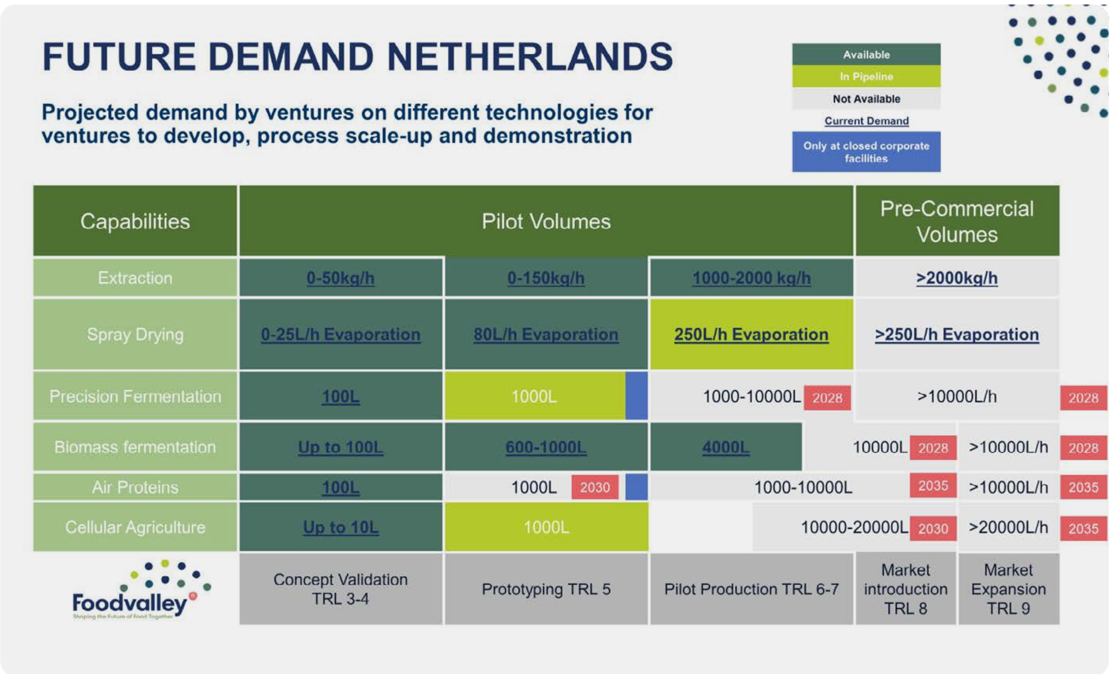

Figure 4.4 Projected Demand for Scale-up and Demonstration Facilities in Alternative Protein (Concluded from Interviews Conducted by FoodvalleyNL, 2023)

Looking towards 2030, the demand for alternative protein production capacity is projected to surge significantly. Several key factors underpin this projection, including the maturation of existing SMEs in the sector, the influx of innovative startups fueled by ongoing investment, and the escalating consumer demand for sustainable protein sources. This growth trajectory necessitates a corresponding expansion in processing capacity. As the industry scales, there will be a growing need for larger, more technologically advanced production facilities capable of efficient mass production while upholding the quality and integrity of alternative proteins. In this dynamic market landscape, sector growth becomes a crucial safeguard against resource underutilization, revitalizing existing assets and stimulating innovation to meet evolving consumer needs.

Startups in this sector often favor partnerships with Contract Manufacturing Organizations (CMOs) over building their own pilot plants. CMOs offer significant advantages in cost-effectiveness, specialized expertise and accelerated time-to-market. Building and operating an in-house pilot plant requires substantial capital investment, a challenge for many startups[7]. CMOs eliminate this upfront cost while providing access to established infrastructure and personnel with deep knowledge of food-grade bioprocessing and regulatory compliance[8].

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7 https://www.foodbusinessnews.net/articles/24015-startup-connecting-food-brands-to-contract-manufacturers

8 https://www.businesswire.com/news/home/20231113548569/en/Global-Plant-Based-Food-Market-Set-to-Exceed-75-Billion-by-2028-Fueled-by-Health-and-Sustainability-Trends---ResearchAndMarkets.com

This allows startups to conserve resources and focus on product innovation and market penetration[9]. Furthermore, CMOs often boast streamlined processes and the ability to scale quickly, enabling startups to rapidly bring their alternative protein products to market – a crucial factor in this competitive industry[10].

The strategic focus for The Netherlands will involve fostering an ecosystem that supports these scaling needs. This includes investments in infrastructure, research into novel production technologies, and policies that encourage innovation and sustainability in food production. By addressing these current and future demands, The Netherlands can strengthen its position as a global leader in the alternative protein industry, contributing to food security and environmental sustainability on a global scale.

In Summary

- The availability of pilot capacity depends on which protein category is considered. For plant-based proteins, there are more options available than for precision fermentation and cultured meat.
- There are currently limited options for shared facilities using fermentation technology whereas for cultured meat, there are none. After the NGF project, this situation will be significantly improved. For fermentation and cultured meat, options will be created.
- Still, limited options remain available in The Netherlands for the demo phase during the development. This work must be done by the startups by:
    - installing a demo line by themselves
    - teaming up with a corporate company that has a suitable pilot plant
    - going abroad.

4.4 Valley of Death

The further the technology's development progresses, the more limited the shared piloting options are, while the costs of every subsequent phase increase. These piloting phases are known as the ‘Valley of Death’.

The Valley of Death for startup companies in the alternative protein sector can be described as the most challenging phase in their development. It typically occurs between the initial research and development stage and the point of achieving commercial viability. It goes hand in hand with the phases where the companies do pilot work. During this period, startups often face significant additional hurdles to bring the cost down to traditional levels:

1. Technical Challenges: Perfecting the technology to produce alternative proteins at scale, maintaining quality and ensuring consistency can be complex and resource-intensive. Typically, if issues arise during the scale-up phase it will require a lot of resources, time and capital to solve them.
2. Regulatory Hurdles: Navigating the intricate landscape of food safety regulations and obtaining necessary approvals is time-consuming and costly. If process changes are made during the scale-up sometimes the regulatory dossier needs to be re-filed, which restarts the clock and takes more time and capital.
3. Market Competition and Consumer Acceptance: Establishing a market share dominated by traditional protein sources and winning over consumer trust and acceptance for alternative protein products.

The result of these hurdles often means that the development takes much more time than anticipated and the funding runs short. As the funding becomes depleted, startups often struggle to secure additional investments necessary for solving the issues and realization of the commercial plant.

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9 https://gfi.org/wp-content/uploads/2023/01/2022-Plant-Based-State-of-the-Industry-Report.pdf

10 https://www.forbes.com/sites/chloesorvino/2023/01/20/fresh-take-what-2023-has-in-store-for-the-food-industry/

This Valley of Death represents a critical transition period where many startups fail due to these compounded challenges, but overcoming it is key to becoming a sustainable and successful player in the alternative protein industry. As can be seen in Figure 4.5, the curve of the Valley of Death goes deeper and deeper when the development progresses further in the scale-up. This is logical because the pilot work on a larger scale is a lot more expensive than earlier phases and additional unexpected problems during these expensive phases rapidly deplete the funding.

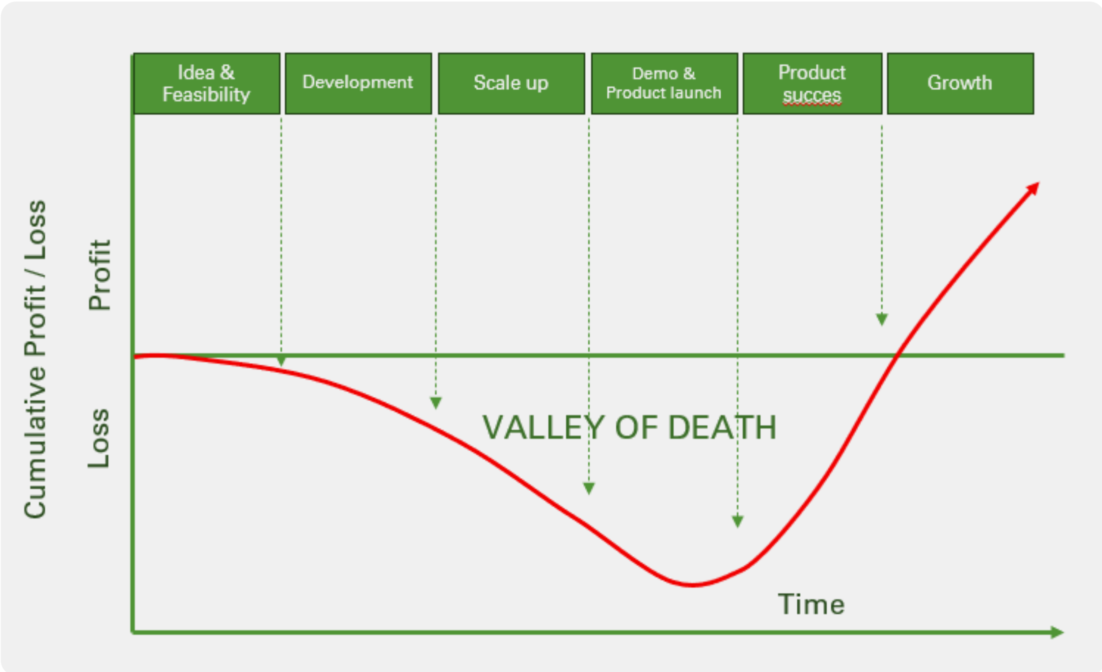

Figure 4.5 Overview of the Valley of Death, (Ritter & Pedersen, 2022)

Helping companies to bridge the Valley of Death will improve the chance of success in getting to the commercialization phase; shortening or flattening this curve is typically the most effective approach to overcome this. Making the curve shallower can be done by lowering the costs of the pilot runs by giving support to pilot plants and making the runs as efficient as possible as well as by providing sufficient support to the start-ups. Making the curve shorter can be realized by having pilot facilities available. If one considers the most promising segments in alternative proteins, precision fermentation and cultured meat, this has not sufficiently been the case in The Netherlands. A shallower and shorter Valley of Death will significantly improve the ability of startups to finance this phase. The lower amount of funding required makes an investment more attractive and significantly broadens the pool of potential investors.

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9 https://gfi.org/wp-content/uploads/2023/01/2022-Plant-Based-State-of-the-Industry-Report.pdf

10 https://www.forbes.com/sites/chloesorvino/2023/01/20/fresh-take-what-2023-has-in-store-for-the-food-industry/

5.
Challenges and Considerations for Scale-Up in Shared Pilot Facilities

Scaling up innovative food technologies, such as plant-based products, precision fermentation, and cultured meat, presents a unique set of challenges. This section builds on insights from interviews with startups navigating these challenges within shared pilot facilities and presents them in thematic areas: flexibility and planning, specialized equipment and process optimization, participation and location constraints, and cost implications and capacity limitations.

5.1 User Experiences and Needs

Startups in alternative proteins shared their varied experiences with existing shared pilot facilities. Their feedback sheds light on the critical services they require, their assessment of the current landscape of shared facilities, and what they envision as the ideal support structure to foster their growth. This feedback underscores the importance of understanding startup needs from a holistic perspective, encompassing technical, operational and financial support.

5.2 Operational Challenges in Shared Facilities

Flexibility and Planning

Startups voiced concerns over the rigidity of shared facilities, noting that the inability to modify protocols mid-run severely restricts the iterative learning process essential for product development. Additionally, the extended lead times required for scheduling runs—often six weeks or more—significantly delay the overall development cycle, impacting time-to-market and agility.

Specialized Equipment and Process Optimization

The reluctance of shared facilities to accommodate specialized equipment is a significant bottleneck. This limitation not only constrains startups' ability to differentiate and innovate but also forces them into costly in-house optimizations or equipment purchases. The lack of flexibility in equipment usage highlights a gap between the facilities' offerings and the startups' technological needs.

Participation and Location Constraints

The limited opportunity for startup teams to engage directly in the operational runs diminishes the learning experience and team cohesion. Furthermore, the geographic location of pilot facilities plays a crucial role in the decision-making process, with a preference for proximity to facilitate better collaboration and supervision by the R&D teams. If the technology is available, users don't mind traveling but prefer something closer.

Cost Implications and Capacity Limitations

Financial constraints emerge as a critical hurdle, with the high costs associated with using pilot facilities posing a challenge for startups, especially in the capital-intensive pilot phase. Additionally, the transition from pilot to demo stages often requires larger volumes not available within The Netherlands, pointing to a need for strategic planning around capacity and scalability.

5.3 Preferences for Ownership and Hybrid Models

Despite the benefits of shared facilities for cost-sharing and collaborative opportunities, the feedback indicates a strong preference among startups for owning their pilot plants. This preference stems from the desire for control over specialized equipment, reduced development times and enhanced learning opportunities. However, the significant investment required prompts some startups to consider hybrid models that balance in-house processing with external services for specific needs, such as drying.

5.4 Service Providers and Collaborative Ventures

Emerging models of service providers offering shared utilities and spaces for startups to install their process lines present a promising avenue. These collaborative ventures can provide efficiency, flexibility and cost benefits essential for startups, enabling them to focus on innovation while leveraging shared resources for operational needs.

5.5 Broader Ecosystem Services and Support

Beyond the operational challenges within pilot facilities, startups also face broader ecosystem challenges. These include the need for integrated services like labs and analytics, the difficulty in finding skilled personnel, complexities in navigating the novel food registration process, and the bureaucratic hurdles of accessing financial support through vouchers. Addressing these ecosystem challenges is crucial for creating a conducive environment for innovation and scale-up.

The interconnected nature of these challenges necessitates a comprehensive approach to developing recommendations, aimed at addressing the identified barriers and fostering a conducive environment for the growth of innovative food technologies. By providing detailed context in each thematic area, we pave the way for actionable, impactful recommendations that can catalyze the transition from innovative concepts to market-ready solutions.

Moving Forward: From Challenges to Recommendations

This comprehensive exploration of the scale-up challenges faced by startups within shared pilot facilities highlights the critical need for a supportive, collaborative and flexible ecosystem.

6.
Challenges for Shared Facilities

As the alternative protein sector grows, driven by consumer demand for sustainable and ethical food sources, the role of pilot facilities becomes increasingly critical. These facilities are the proving grounds for innovations in plant-based products, precision fermentation and cultured meat, transitioning them from concept to commercial viability. However, operating these facilities involves navigating a complex array of challenges that can hinder progress and innovation. This section delves deeper into the unique hurdles faced by pilot plants and the essential support mechanisms that could facilitate their success, drawing on comprehensive interviews with a variety of pilot facilities actively engaged in the alternative protein space.

6.1 Detailed Examination of Challenges

Financial Burdens of Startup and Operation

The substantial initial capital required to establish pilot facilities, encompassing land acquisition, construction and the purchase of specialized equipment, poses a significant barrier to entry. Additionally, ongoing operational costs, including utilities, maintenance, staff wages and raw materials, create a continuous financial strain. These expenses necessitate a multifaceted funding approach, combining equity, grants, loans and, increasingly, venture capital, particularly focused on the burgeoning field of sustainable food technology.

The November 2022 bankruptcy of the Bioprocess Facility (BPF) in Delft, despite its advanced capabilities, size and significant backing by larger corporates, serves as a critical case study for strategic decision-making in the alternative protein sector. It underscores the complex challenges faced by pilot plants in achieving long-term financial sustainability within a competitive landscape. Factors like scale, ownership structure, competitive pressures from established facilities and the limitations of public funding models without long-term private commitments all contributed to the BPF's downfall. This case study provides valuable insights for policymakers and investors, emphasizing the need for a nuanced approach that carefully considers these factors to ensure future investments in pilot-scale shared infrastructure not only foster innovation and accelerate commercialization but also contribute to a financially sustainable and resilient alternative protein ecosystem.

Navigating Irregular Customer Demand

Pilot facilities must deal with the erratic nature of customer demand (start-ups in protein transition), which directly affects their economic viability. Achieving even a 50% uptime is an accomplishment in this fluctuating market. The requirement to customize processes for different customers introduces further complexity, necessitating frequent shutdowns for cleaning and reconfiguration, which escalates costs and operational downtime.

Workforce and Technological Adaptation

The specialized nature of alternative protein production demands a skilled workforce capable of managing non-standardized processes and potentially operating around the clock. The challenge of recruiting and retaining such talent, coupled with the necessity for continuous technological upgrades to maintain competitive and operational efficiency, underscores the need for sustained capital investment in both human and physical resources.

Operational Vulnerabilities

Specifically, for facilities engaged in fermentation processes, operational failures such as contamination can have drastic consequences, leading to significant financial losses and the wastage of resources. The difficulty in swiftly identifying and addressing the causes of such failures adds to the operational challenges, emphasizing the need for robust troubleshooting and quality control measures.

6.2 Enhancing Support Mechanisms

Targeted Financial Aid

The call for financial support encompasses assistance with both operational expenses and the procurement of new equipment. International examples illustrate varying levels of governmental aid, from substantial subsidies for research activities to public projects underwriting a major portion of operational costs. However, disparities in support levels across regions highlight the need for more uniform and accessible financial assistance programs.

Equipment and Innovation Subsidies

The reluctance of equipment manufacturers to engage in supportive partnerships or offer price reductions hampers innovation and technological advancement. Pilot plants advocate for subsidies or financial incentives to facilitate the acquisition of innovative equipment, which could drive forward the sector's development.

Voucher Systems and Subsidy Projects

The potential of voucher systems to alleviate financial pressures on pilot facilities and their users is evident, yet the current regional restrictions limit their effectiveness. A broader, more inclusive voucher system, alongside more strategically directed European or national subsidy projects, could significantly impact fostering innovation and operational sustainability.

6.3 Role of Governments in Accelerating the Protein Transition

Governments must play a central role in driving the protein transition. Their support is essential for building shared facilities, which are often not commercially viable at the early stages, yet vital for scaling alternative protein startups. Government participation is logical as these facilities serve multiple stakeholders within the industry. The €60 million growth fund grant is a positive start, but more comprehensive and structural funding is required. The alternative protein sector should work closely with governments to identify specific infrastructural needs, map out long-term funding strategies, and select industry leaders to champion these initiatives.

A coordinated national initiative, integrating existing regional projects, is essential for streamlining the protein transition. This will prevent a fragmented approach which ensures optimal allocation of resources and overall acceleration of progress. Close collaboration between government and industry will maximize the impact of investments and achieve the transformative potential of alternative proteins.

6.4 Conclusion and Future Directions

The challenges faced by pilot facilities in the alternative protein sector are multifaceted, spanning financial, operational and technological realms. Addressing these challenges requires a concerted effort from all stakeholders, including governments, industry players and the facilities themselves. By expanding and enhancing support mechanisms, such as financial aid, equipment subsidies and flexible voucher systems, the sector can overcome these hurdles, paving the way for the successful scale-up of innovative food technologies and contributing to a more sustainable and ethical food system.

7.
International Best Practices

This chapter explores international best practices in the development and operation of pilot and demonstration scale facilities within the alternative protein industry. Drawing from a comprehensive analysis of successful ecosystems across the United States, Israel, Belgium, Germany and Singapore, alongside insights from private sector initiatives, we compare the models that have propelled the industry forward. Through interviews with industry leaders and an examination of capital expenditures, operating expenses and key drivers of success, we aim to distil valuable lessons and identify the factors that contribute to a thriving alternative protein ecosystem. This analysis not only highlights the diverse approaches adopted by different countries and companies but also underscores the critical role of flexibility, cost consciousness, leadership, network support and government backing in fostering innovation and scaling up alternative protein production.

7.1 Comparing Models

In our analysis, we sought to identify the key success factors of alternative protein ecosystems globally. Through interviews with leading production facilities and companies in the United States, Israel, Belgium, Germany, Singapore and Spain, we gained insights into diverse approaches to creating, financing and operating pilot and demonstration scale facilities. These conversations revealed distinct models, each with their unique strengths and challenges. Our interviews led to the development of models which were informed by the Key Observations in each of the Case Studies. From these analyses, six models emerged (Fig 7.1) and are summarized below:

- United States: Characterized by a synergistic triangle of government support, research universities and private enterprise, this model has catalyzed the growth of numerous industries, including alternative proteins. Its success is evident in the emergence of multiple companies achieving valuations over $1 billion, demonstrating a robust ecosystem for innovation and scale.
- Israel: Operates on a scale similar to the U.S. model, focusing on a tight-knit collaboration between government, academia and industry. However, its success in creating leading companies on a global scale is still evolving, with capital and scale often sought in the U.S. market.
- Singapore: Distinguished by its heavy reliance on central government strategy and funding, Singapore's model is a testament to the strategic importance placed on alternative proteins. While promising, its impact on a global scale remains to be fully realized.
- Belgium: The approach used in Belgium combines governmental funding with private investment to create a dynamic environment for bringing alternative proteins from the lab to the market. This strategy is an example of an innovative public-private partnership that is driving the bio-based industry forward.
- Spain: a non-profit private model (started with government subsidy). Its members are the main companies and entities within the agro-food sector, which enjoy a series of services and exclusive advantages.
- Fraunhofer: Germany's approach through the Fraunhofer-Gesellschaft combines government backing with a strong emphasis on applied commercial research and corporate contracts. While its application to alternative proteins is in the early stages, its potential is significant. Likely the most difficult to copy.
- Private: Illustrates a scenario where private entities, both large and small, independently invest in production capabilities. This model highlights the diverse strategies companies employ to navigate the alternative protein sector, from leveraging corporate investments to navigating the challenges faced by startups.

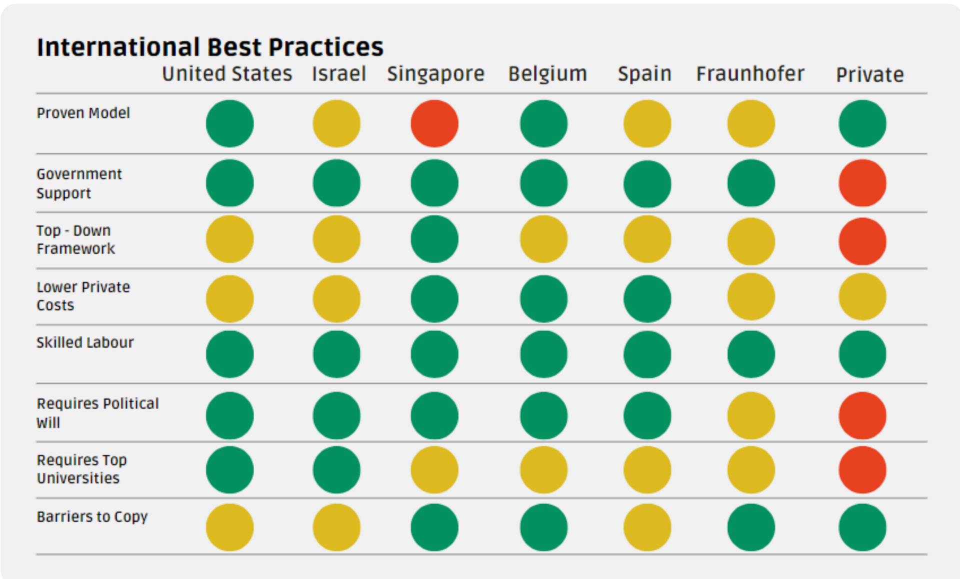


Figure 7.1 Key Models and Observations in Scaling Alternative Proteins

7.2 Capital Expenditure and Operating Expenses

In all of the United States, Israel, Singapore and Fraunhofer models, the capital expenditure for the facilities and capital equipment were financed via government funding. In the U.S., this came from the federal level (e.g. Department of Energy, Department of Education, National Science Foundation, etc.) as well as state /regional level (as most US states have innovation and business development funds such as Empire State Development, a New York State run investment arm supporting the facilities at Cornell). In both Israel and Singapore, the funding was at the central government level (e.g. Israel Innovation Fund and A*STAR in Singapore). For Fraunhofer, over one-third of their annual budget comes from German tax revenues. The only exception to this is the Private model, where large companies like Buhler and many smaller companies have funded their production capacity with their own funds. For a large company such as Buhler, this is a savvy and strategic business decision, and they have easy access to sufficient capital for these types of projects. For smaller companies such as EVERY and WildType, this expenditure is extremely costly, and a substantial burden given where they are in their corporate lifecycle. Government funding for the capital needed to build these types of facilities is a strong accelerator for companies and is clearly a global best practice.

The operating expenses for these facilities are typically paid for by contract production work done for companies of all sizes. Except for the Singapore model (and also the Private model, where the finances are more opaque), the goal of these facilities is to operate on at least a breakeven basis annually via revenue from companies renting some combination of time, space and technical expertise. For the Singapore model, as this area is a strategic focus of the government, the state is willing to also significantly underwrite the operating expenses of the facilities as well. In this case, the metric for judging return on investment is how successful, over a longer period, the companies who use these facilities become.

7.3 Drivers of Impact and Success

Our analysis identified five key drivers critical to the success of these facilities:

- Flexibility / Adaptability: Facilities emphasizing modular equipment and adaptable production processes are well-equipped to accommodate the dynamic requirements of both startups and established companies. This emphasis on flexibility emerged as a recurring theme in our interviews. For example, Cornell highlighted its use of equipment on rollers, enabling swift and easy modifications to production setups. Similarly, institutions like Fraunhofer CMI and ABPDU underlined the significance of responding to clients' evolving needs. The Food Tech Innovation Centre (FTIC) in Singapore also underscored the importance of rapidly adjusting production techniques. Given that neither technological demands nor company needs are fixed, the capacity to adapt is fundamental to a facility's success.

- Cost Consciousness: Adopting a strategic approach to investment, particularly in acquiring versatile equipment, can mitigate financial risks and enhance resource efficiency. The concept of cost consciousness balances the need for flexibility; facilities with unlimited budgets might afford any configuration of equipment, but practical wisdom advises against excessive early investments. As highlighted previously, the allure of innovative technology poses a risk of overspending. The preferred strategy is cost mitigation and leveraging existing equipment creatively. For instance, investing in a 500L bioreactor for cultivated meat, which, for an added cost under 20% of the total, can simulate the capabilities of a 5,000L bioreactor, demonstrating judicious spending. Effective cost management is essential, especially for startups without the luxury of unlimited funding.

- Leadership: The pivotal role of visionary leaders in the success of facilities is undeniable, with their passion and expertise laying the foundation for achievement. Interviewees consistently praised the talent and dedication within their teams, emphasizing the importance of strong leadership. Leaders such as Pam Ismael (PPIC), Brian Jacobson (IBRL), Christine McBeth (Fraunhofer CMI), and Bruno Xavier (Cornell) were highlighted for their profound commitment and positive influence on their facilities. The selection of the right leader is crucial, as our analysis confirms that an exceptional facility head is key to its success.

- Network / Ecosystem: Being located near a dynamic network of industry leaders, academic entities and tech hubs markedly boosts a facility's influence. The strategic positioning of facilities like ABPDU at the heart of the U.S. technology and biotech sectors, PPIC within the core of American food production alongside companies like Cargill and General Mills, and IBRL in proximity to ADM and key cities reflects the advantage of such connections. Similarly, facilities in Israel and Singapore benefit from their location within specialized zones and near leading universities. The significance of proximity to these ecosystems cannot be overstated, underscoring the advantage of integrating closely with a thriving network.

- Government Support: Except for Buhler and the startups forced by necessity to use pilot facilities, government support and investment were constant. Pilot and demo scale production facilities are poorly suited for private CapEx and have been ignored by those sources. Government funding is a critical element.

7.4 Strategic Implications for The Netherlands: Adopting International Best Practices

A strategic analysis of international best practices reveals a roadmap for The Netherlands to accelerate the growth and global competitiveness of its alternative protein sector. By aligning with these successful models, The Netherlands can optimize its approach to pilot plant development and operation:

- Foster Public-Private Synergies: Emulating the U.S., Belgian and German models, The Netherlands should prioritize public-private partnerships, leveraging government resources and industry expertise to establish and operate pilot facilities. This collaborative approach can streamline funding, knowledge sharing and market access.

- Prioritize Agility and Adaptability: To remain competitive in a rapidly evolving landscape, Dutch pilot facilities should embrace the flexibility showcased in leading international examples. Investing in modular equipment and adaptable processes will allow them to respond swiftly to technological advancements and shifting market demands.

- Cultivate Financial Prudence: While government funding is crucial, The Netherlands should learn from international examples and instill a culture of cost-consciousness. Strategic investments in versatile equipment, resource optimization and innovative financial models will ensure long-term sustainability and reduce reliance on public funding.

- Develop Specialized Expertise: To attract international clients and differentiate itself in the global market, The Netherlands should identify and cultivate niche expertise in specific protein sources or production technologies. This specialization will enhance the country's value proposition and attract targeted investments.

- Leverage Regional Synergies: The Netherlands' strategic location and strong agricultural base provide a natural advantage. By strengthening collaborations with neighboring countries, such as exploring synergies with the Bio Base Europe Pilot Plant (BBEPP) in Gent, Belgium, and engaging with research institutions and industry leaders, The Netherlands can tap into a vast network of expertise and resources, fostering a vibrant regional ecosystem for alternative protein innovation.

By adopting these strategic recommendations, The Netherlands can not only create a thriving domestic alternative protein sector but also position itself as a global leader in sustainable food production. The integration of international best practices will pave the way for accelerated innovation, economic growth and a more resilient food system.

8. Stakeholder Perspectives on Infrastructure and Investment

A roundtable discussion was held following the initial findings of this report to gather in-depth perspectives from a diverse group of stakeholders, including researchers, industry representatives, government officials and investors. This discussion centered on the challenges and opportunities related to infrastructure development and investment priorities in the Dutch bio-based economy.

Infrastructure Needs and Challenges

Participants emphasized the need for flexible and adaptable infrastructure that can cater to the diverse requirements of startups and scale-ups throughout their development cycle, from initial concept and lab-scale testing to pilot production and eventual commercialization. This includes access to specialized equipment, shared facilities and technical expertise. While existing facilities like BBEPP in Gent offer potential solutions, concerns were raised regarding geographical constraints, particularly for early-stage startups that may benefit from localized support. There was also discussion about the potential impact of shared resources on the learning curve for startups, as it may limit their ability to experiment independently and develop proprietary knowledge.

Financial challenges associated with developing and maintaining such infrastructure were also highlighted. Despite existing unused capacity in some facilities, stakeholders like NIZO stressed the need for more structural funding to create flexible spaces and support innovative models such as the 'hotel model'. This model envisions facilities offering customizable lab and production spaces, along with shared services and expertise, to startups and scale-ups on a flexible basis. However, regional funding was identified as a significant hurdle due to the current political climate, with concerns about 'funding fear' and short-term budget cycles hindering long-term investments in infrastructure.

Investment Priorities and Investor Perspectives
Investors expressed a clear preference for investing in startups or new facilities rather than providing structural funding for existing infrastructure. This preference is driven by the potential for higher returns and greater impact associated with early-stage ventures and innovative technologies. Investors are seeking opportunities that align with the growing demand for sustainable solutions and the transition to a circular economy.
The perceived risk-reward balance of investing in structural infrastructure was identified as a key factor influencing investor decisions. Building and maintaining specialized facilities requires significant upfront investment and carries the risk of technological obsolescence or underutilization. Participants suggested that de-risking mechanisms, such as public-private partnerships, could incentivize greater private investment in infrastructure development by sharing risks and ensuring long-term sustainability.

Roundtable Recommendations

Based on the roundtable discussions, the following recommendations emerged:

1. Explore Innovative Funding Mechanisms: Investigate alternative funding mechanisms, such as public-private partnerships, co-investment models and grant schemes that can leverage private capital and de-risk investments in infrastructure. Explore the potential of creating dedicated funds or financial instruments specifically for bio-based economy infrastructure development.

2. Develop Flexible Infrastructure Models: Prioritize the development of flexible infrastructure models, such as the hotel model, that can adapt to the evolving needs of startups and scale-ups. This includes offering modular spaces, shared equipment, and customizable services that can be tailored to specific project requirements and growth stages.

3. Foster Collaboration: Encourage greater collaboration between users, facilities and funding partners to optimize resource utilization, share knowledge and address funding gaps through coordinated efforts. This could involve establishing networks or platforms for information exchange, facilitating partnerships between research institutions and industry players, and creating incentives for collaboration on infrastructure development projects.

4. Engage Investors: Actively engage with investors to understand their preferences and risk-reward expectations, and develop investment propositions that demonstrate the long-term value and potential returns of supporting infrastructure development in the bio-based economy. This could involve showcasing successful case studies, highlighting the market potential of bio-based products and technologies, and developing financial models that demonstrate the viability and scalability of infrastructure investments.

By addressing these challenges and implementing these recommendations, the Dutch bio-based economy can create a more supportive and attractive environment for innovation, fostering the growth of startups and scale-ups while maximizing the impact of investments in infrastructure. This will contribute to the development of a thriving bio-based ecosystem that can drive sustainable economic growth and environmental sustainability in The Netherlands.

9.
Conclusions

Globally, food systems are responsible for about 30 percent of the current anthropogenic greenhouse gas emissions driving climate change. Impacts of the growing demand for animal-source foods takes place in the context of unsustainable farming methods and overconsumption, especially in middle- and high-income countries. Overall, production and consumption significantly contribute to climate change, air and water pollution, biodiversity loss and soil degradation. Novel plant-based meat, cultivated meat and fermentation-derived foods show potential to reduce environmental impact compared to many conventional methods. They also show promise for reduced risk of zoonoses and antimicrobial resistance, and can significantly alleviate animal welfare concerns associated with conventional animal agriculture.

Scaling up new alternative protein products in The Netherlands faces unique challenges, especially when transitioning from laboratory-scale operations to pilot plants and larger-scale demonstration units. Limited access to advanced, affordable testing facilities is a major barrier for a relatively small but crucial group of 68 companies that are currently classified as mature startups and early-stage scale-ups. These ventures are in the process of bringing interesting innovations to the market and are thus a driving force within the innovation ecosystem. Investing in pre-commercial pilot plants and equipment is very expensive and, at this stage, these ventures cannot prove to investors that they can scale up their products to commercial scale and thus make a profit. As a result, raising the necessary capital is very difficult and time-consuming, significantly delaying the scale-up process. The tightening of the capital markets over the last few years is exacerbating the problem.

Even when the right equipment is found, it is often too expensive and takes time to fit into the plant owner's schedule. If special equipment is needed for the process, it is often not easy to integrate it with existing equipment, except in unique modular systems. Participation during the process may be limited or restricted to some shared facilities. These factors slow down the learning curve for startups, which is undesirable. On the other hand, the SME voucher experiment of the Foodvalley region deal has shown that these shared facilities can be helpful for some companies at a certain stage if the price is reduced.

Many ventures expressed the need to have their own process line and demonstration unit that they can operate and modify as required. This becomes increasingly important in the later stages of the development cycle to fine-tune the technology, test its durability and produce the product needed for market development. In short, the existing network of shared facilities provides support for ventures when they are in earlier stages but, at some point, there is still quite a gap between having their own facility and being able to produce higher volumes on pilot and demonstration scale.

Shared Pilot facility owners in the alternative protein production industry face significant challenges, including high initial investments, irregular customer demand, downtime when switching processes and the need for a skilled workforce. Ongoing equipment upgrades are essential to stay competitive, and operational failures can be costly. These facilities mainly seek financial support through subsidies, voucher systems and increased funding for innovation through public-private partnerships.

Based on the findings, we conclude that if The Netherlands were able to address the bottlenecks described, there would be a significant difference in accelerating the scale-up process and helping companies cross the Valley of Death.

10. Recommendations

The infrastructure to support such scaling — especially in the form of accessible, affordable and appropriately equipped pilot facilities — is crucial yet often insufficient. Recognizing these hurdles, this section proposes a multifaceted approach to bolster the ecosystem supporting these ventures. Through targeted interventions aimed at enhancing the accessibility, affordability and efficiency of pilot plants, we aim to foster a more vibrant and sustainable innovation landscape. These proposals are designed to bridge critical gaps in the current infrastructure, enabling startups to navigate the complex transition from laboratory to market with greater ease and success.

The Dutch government has a wealth of policy options at its disposal to explore and bolster the potential of innovative alternatives in the agricultural sector. This includes robust support for (open-access) research and commercialization, as well as the implementation of fair transition policies to ensure a smooth shift in practices. However, while these measures are crucial, they are just the beginning of a larger vision for a sustainable and resilient food system.

To truly realize this vision, it is imperative to develop a comprehensive national strategy that unites stakeholders across the entire ecosystem. This strategy should not only focus on immediate policy interventions but also lay out a long-term roadmap for transformative change. By fostering collaboration among government agencies, research institutions, industry players, civil society organizations and consumers, we can harness the collective expertise and resources needed to drive the innovation and adoption of novel alternatives. At the heart of this strategy lies a commitment to sustainability, health and animal welfare. By prioritizing these values, we can pave the way for a food system that not only meets our nutritional needs but also safeguards the environment and promotes the well-being of all living beings. This requires reimagining our approach to food production and consumption, embracing new technologies and practices that minimize the ecological footprint and maximize resource efficiency.

Moreover, it is essential to recognize the regional nuances and challenges inherent in this transition. What works in one part of the country may not be feasible or effective elsewhere. Therefore, our strategy must be flexible and adaptive, allowing for tailored solutions that take into account local contexts and realities. By empowering communities to take ownership of their food systems, we can foster resilience and diversity while ensuring equitable access to nutritious and sustainably produced food for all.

In essence, the pursuit of innovative alternatives in agriculture is not just a matter of policy but a shared endeavour that requires collective action and vision. By coming together as a nation, we can chart a course towards a future where food is not only abundant but also ethical, equitable and environmentally sound. Let us seize this opportunity to build a better food system for generations to come.

Terms & Abbreviations

CMO (Contract Manufacturing Organisation)

A company that provides manufacturing services to other firms on a contract basis. CMOs offer a range of services including production, packaging and quality assurance, allowing their clients to outsource parts of their manufacturing process and focus on other aspects of their business

Demo phase

The 'demo phase' for a startup company typically refers to a stage where the company is focused on developing a demonstration or prototype of its product or service in a quality that is similar to the full-scale production plant. This phase is crucial for showcasing the viability and potential of the startup's concept to potential investors, partners or customers.

NGF

National Growth Fund, a Dutch Government initiative to foster economic development, supporting innovation, and investing in key sectors to promote overall growth.

Scale-up (company)

'Scale-up' refers to the process of increasing the size or capacity of a business, project or operation. It is often used in the context of startups or businesses that have successfully proven their concept and are now looking to expand their operations to reach a larger market, increase production or enhance their overall impact.

Scale-up (technology)

The term 'technology scale-up' refers to the process of increasing the size, capability or efficiency of a technological system. This implies testing the technology in larger volumes or at higher rates. The goal of scaling up technology is to make it more robust, capable of handling larger workloads and suitable for commercial applications.

Startup (company)

A startup is a newly established business, typically in the early stages of its development. These companies are characterized by their innovative ideas, high growth potential and a certain level of uncertainty about their future success.

Startup (process)

A process startup refers to the initial phase of starting and bringing a particular industrial or manufacturing process into operation. This term is commonly used in the context of agro-industries when complex processes are involved.

Valley of Death

In the context of technology development, the Valley of Death can describe the gap between the research and development phase and the commercialization or widespread adoption of a new technology. It often involves challenges such as funding constraints, regulatory hurdles and the need for additional resources to bring a technology from the lab to the market.

Appendix

Appendix 1 Hypotheses

The study operated under the following hypotheses:

- H1: The lack of advanced, affordable testing capacity is a major barrier to scaling up new plant-based protein businesses in The Netherlands.
- H2: Implementing shared production facilities can mitigate financial risks and increase the likelihood of success for plant-based protein companies, provided intellectual property rights are adequately protected.
- H3: Companies that use shared locations struggle to find sufficient market connectivity due to insufficient opportunities to test products.
- H4: By removing the identified bottlenecks, it is possible to accelerate the protein transition, make an impact and increase the competitiveness of The Netherlands as a business location.

Sub-question #1

- What is the specific facility requirement and technological capabilities needed for the successful scaling of alternative protein ventures in The Netherlands over the next five years?
- What specific types of testing facilities do ventures expect to need to facilitate growth and innovation in the alternative protein market?
- What technological capabilities are needed to maintain and improve these facilities? What skills do staff need to have?
- How can the necessary facilities be made available in a timely and cost-effective manner?
- How can we ensure that these facilities comply with regulations and support intellectual property protection?

Sub-question #2

- How can we address the identified bottlenecks in infrastructure, technology and financing to improve the scale-up process for plant-based protein companies in The Netherlands?
- How can shared production facilities be funded and made accessible to startups in the alternative protein market?
- How can we better match the supply and demand of alternative protein production?
- What infrastructural improvements are needed to facilitate the scale-up process?
- How can we better connect these ventures to the market and attract more funding?

Sub-question #3

- What are the best practices in terms of facility availability, technology use and funding from successful international case studies that can be applied in scaling up plant-based protein companies in The Netherlands?
- What successful models for shared production facilities, infrastructure and financing are being used in other countries, particularly in thriving ecosystems such as Israel, Belgium, Singapore, the U.S. and Germany
- How do these countries facilitate faster access to testing capacity for ventures?
- What types of technologies and facilities are dominant in their successful case studies?
- How is the protection of intellectual property ensured in these shared spaces?

Sub-question #4

- Based on international benchmarking, which interventions could be applied in the Dutch ecosystem to facilitate the scaling up of plant-based protein ventures?
- Based on the best practices in other countries, how can the Dutch ecosystem be restructured or improved to better support upscaling?
- How can these interventions improve access to testing capacity, the availability of shared facilities and the protection of intellectual property?
- How can we promote a better connection of these ventures to the market and attract more funding based on successful international models?

Appendix 2 What are Alternative Proteins?

In discussions surrounding the protein transition, the term ‘alternative proteins’ is frequently employed. Before delving into the intricacies of their development, it is essential to establish a clear understanding of what this term means in this report's context. Figure A2.1 illustrates the various categories within alternative proteins, encompassing plant-based, fermentation-derived and cultivated proteins.

Figure A2.1 Different Categories of Alternative Proteins (Boston Consultancy Group, 2023)

Alternative proteins refer to a range of protein sources not derived from traditional animal agriculture. They are innovative alternatives designed to meet the nutritional needs of consumers while addressing concerns related to sustainability, environmental impact, animal welfare and food security. Advancements in alternative protein technologies are poised to revolutionize the food industry. As they become more cost-effective and consumer-accepted, they can significantly alter global food production and consumption patterns. In this report the following categories of alternative proteins were considered:

Plant-based Proteins

Plant-based proteins are sourced from plants such as legumes (like peas, lentils and chickpeas), soy, grains, nuts and seeds. Plant-based proteins are used to create meat substitutes, dairy alternatives and various other products. They offer a sustainable alternative to animal-based proteins, often with lower environmental footprints.

Biomass Fermentation

Biomass fermentation is a classic method of fermentation where microorganisms are grown as the product itself. In the case of proteins, the fermentation aims to achieve a high biomass protein content. The whole biomass is used as the product, with no further isolation or purification process done to isolate the pure protein. Examples are mycoproteins, which are used for meat alternatives.

Precision Fermentation

Precision fermentation involves using microorganisms like yeast, fungi or bacteria to produce specific proteins, nutrients or other compounds without the need for agricultural production. It's a process where these microorganisms are genetically modified or engineered to ferment and create proteins or substances that can be used in food products. The proteins are produced intracellular or extracellular and after the fermentation need further isolation, purification and concentration after the protein is obtained.

Air Protein

Air Protein is a relatively new concept in alternative protein production. It involves using gases (such as carbon dioxide) and combining them with microorganisms in a fermentation process to create protein. This innovative approach aims to produce protein without sugars and thus not rely on traditional agriculture or land use, potentially offering a highly sustainable and resource-efficient method for generating protein sources.

Cell-based or Cultured Protein

Cultivated protein refers to the production of meat or fish proteins through cell culture techniques, bypassing traditional animal farming by cultivating animal cells in a bioreactor. This approach aims to provide a more ethical and sustainable method of meat production, reducing environmental impact and addressing animal welfare concerns.
Each of these alternative protein sectors represents innovative approaches to providing sustainable proteins, addressing concerns related to environmental sustainability, animal welfare and increasing global demand for protein-rich foods.

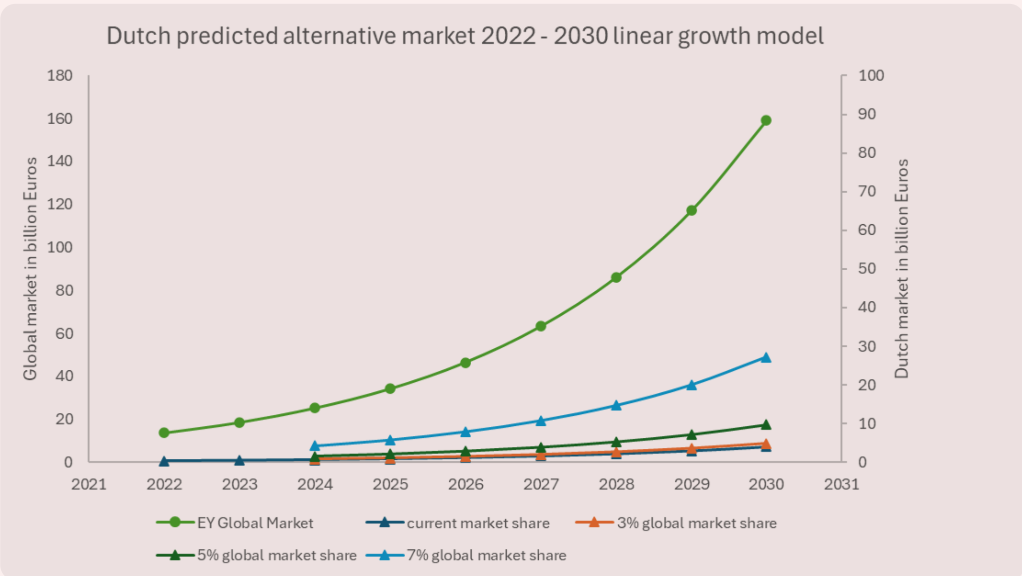
Appendix 3 Prediction Model for Market Growth of Dutch Alternative Proteins

Linear and Logistic Growth Models

The evolution of modeling approaches for forecasting the Dutch alternative protein market's growth transitioned from a linear to a logistic growth model to capture the sector's dynamics more accurately. Initially, a linear model was utilized for its simplicity and effectiveness in projecting growth trends based on historical and global market data, offering valuable early insights despite its assumption of constant growth rates. However, recognizing the limitations of the linear model in addressing the complexities of a rapidly evolving market like alternative proteins, a shift was made towards the logistic growth model. This non-linear approach, acknowledging variable growth rates and saturation effects, offers an understanding of market development, particularly as it matures. It incorporates the concept of carrying capacity to reflect the market's growth limit more accurately and adapts to various market engagement levels.

Both the linear and logistic growth models start with an identical baseline, establishing the Dutch market's added value at €346 million in 2022 for the alternative proteins sector. This common starting point ensures a coherent foundation for comparing the projections derived from each model. In alignment with EY's optimistic outlook on the sector's growth, we adopt a uniform annual growth rate of 36%, mirroring EY's prediction for the global alternative protein market. For the logistic model, a distinctive parameter is introduced: the carrying capacity, which represents the maximum potential market size that the Dutch alternative proteins sector can achieve by 2030. This capacity is inferred from the linear model's projection, considering a scenario where the Dutch market maintains a static global market share of 2.5% from 2022 to 2030. This assumption allows us to estimate the saturation point of the Dutch market within the given timeframe, providing a realistic limit to the growth envisaged by the logistic model. The results of both modeling approaches are shown in Fig 2.1 for the linear model and Fig 2.2 for the logistic model.

Figure A3.1: Dutch market projections using linear growth model compared to EY global market projections.



The analysis of the Dutch market's growth potential in the alternative proteins sector, when compared with EY's global market forecasts, highlights a trajectory of significant expansion aligned with increasing global demand. EY predicts growth from $13.6 billion in 2022 to $159.2 billion by 2030 in the global alternative protein market, reflecting a compound annual growth rate (CAGR) of 36%. This rapid growth underscores the sector's rising economic significance on a global scale, driven by increasing consumer preference for sustainable and health-conscious dietary options, as well as technological innovations in food production.

The Dutch market's projected growth, from a baseline of €0.346 billion in 2022 to €4.05 billion by maintaining its current market share, signifies a substantial upward trend, mirroring the global momentum but magnified within the Dutch context. Furthermore, the scenarios exploring the Dutch market capturing increased shares of the global market (3%, 5%, and 7%) reveal more growth potentials. Achieving a 3% share by 2030 would elevate the market to approximately €5 billion by simply sustaining the current market share. This increases with the extrapolated targets of 5% and 7% global market shares by 2030 at €9.7 billion euros and €27.2 billion respectively.

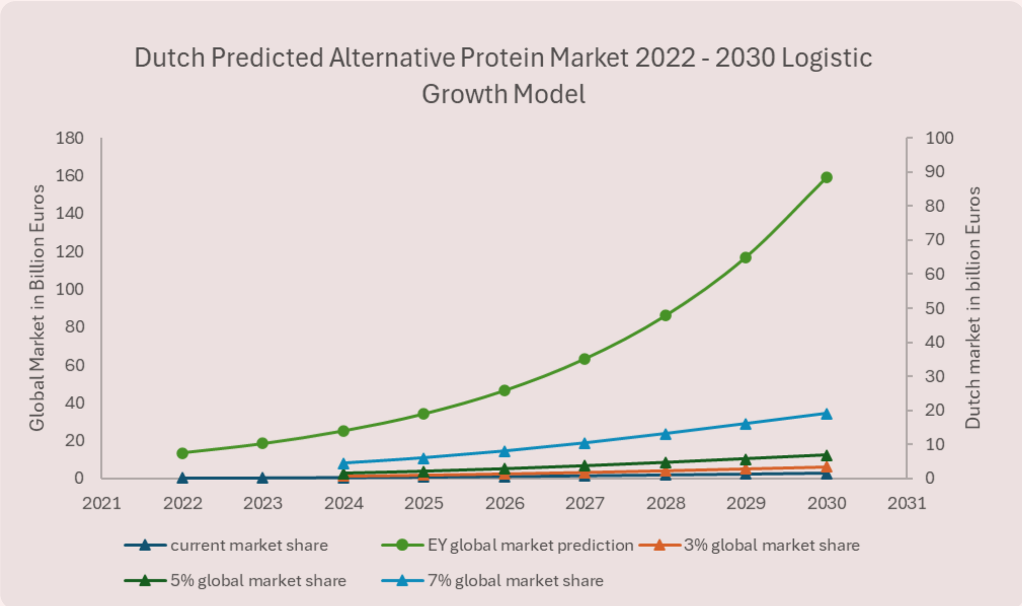


Figure A3.2: Dutch market projections using logistic growth model compared to EY global market projections.

While EY projects an increase in the global market from $13.6 billion to $159.2 billion, indicating a compound annual growth rate (CAGR) of 36%, the logistic model's forecasts, which begin with a 2022 baseline of €0.346 billion, demonstrate moderate growth to €2.8 billion by 2030 at the current market share. This model underscores the Dutch market's significant growth potential, albeit in a manner that acknowledges the inherent limitations posed by market saturation. The projections for capturing increased shares of the global market, resulting in market sizes of €3.4 billion for a 3% share, €6.8 billion for a 5% share, and €19.1 billion for a 7% share.

Applying the Linear Growth Model

The forecasting model can be described using a simplified linear growth formula, where the future market value is projected based on current market values and growth rates. For the Dutch market, the projection formula under each focus scenario is given by:

$$V_t = V_o \times (1+r)^t$$

Where:
- V_t is the market value in year t
- V_o is the base year market value (for 2022),
- r is the compounded annual growth rate (CAGR), calculated based on the global market growth projections, and
- ^{t} is the time in years from the base year (2022) to the target year (2030).

For global market projections by EY, a similar formula is applied to their respective CAGRs:

$$G_t = G_o \times (1 \times r_{EY})^t$$

Where:
- G_t represents the global market value in year ^{t} according to $_{EY}$,
- G_o is the global market's base year value for 2022,
- r_{EY} is the CAGR specific to EY projections.

Table A3.1. Dutch Market Projections compared to global market projections linear growth model

Year	Current market share	3% Global market share	5% Global market share	7% Global market share	EY Global Market
2022	0.346				13.6
2023	0.471				18.5
2024	0.640	0.768	1.536	4.301	25.2
2025	0.870	1.044	2.089	5.849	34.2
2026	1.184	1.420	2.841	7.954	46.5
2027	1.610	1.932	3.864	10.818	63.3
2028	2.189	2.627	5.254	14.712	86.1
2029	2.977	3.573	7.146	20.009	117.1
2030	4.049	4.859	9.718	27.212	159.2

Conceptual Application of the Non-linear Logistic Growth Model

The Logistic Growth Model is optimally suited for analyzing markets nearing saturation, accurately reflecting phases of rapid initial growth that stabilize over time. This characteristic makes it especially pertinent for burgeoning sectors like alternative proteins. Utilizing the formula:

$$P(t) = \frac{K}{(1+ \left(\frac{K-Po}{Po}\right) .e^{-rt}}$$

we project the growth of the Dutch alternative protein market up to 2030. To simplify, we adopt a growth rate r of 20% (or 0.20) and a carrying capacity K of €5 billion.

Table A3.2 Dutch Market Projections compared to global market projections logistic growth model.

Year	Current market share	3% Global market share	5% Global market share	7% Global market share	EY Global market prediction
2022	0.346				13.6
2023	0.481				18.5
2024	0.662	0.795	1.590	4.452	25.2
2025	0.898	1.078	2.155	6.035	34.2
2026	1.194	1.433	2.866	8.025	46.5
2027	1.551	1.861	3.723	10.424	63.3
2028	1.960	2.352	4.704	13.170	86.1
2029	2.401	2.881	5.763	16.136	117.1
2030	2.849	3.419	6.837	19.145	159.2

Appendix 4 Evaluation of the Interviews

Feedback from Users

The startup companies that were interviewed had a lot of critical remarks on the performance and experiences at pilot plants. Although it might give the impression that pilot plants are not working according to the expectations of startups, it should be realized that the interviews specifically asked about the challenges for the startups to learn from their experiences. However, a lot of successful runs and scale-up work are done at pilot plants in The Netherlands that enable startup companies to grow. But from the comments made there is room for improvement.

Planning, Costs & Flexibility

The main remarks made were on planning, costs and flexibility. For a startup that wants to go fast, a planning time of 6 weeks before a run and having to freeze the pilot protocol is often not easy in a dynamic development phase. It is logical that almost all startups mention that they would prefer to have their own pilot line which they could start and run whenever they want.

It is important to realize that part of the issues mentioned is not only the responsibility of the pilot plants but also refers to the planning of the startups themselves. Planning multiple runs over the year in advance can be a way to get enough testing capacity. The remark that pilot plants are expensive is true but also a fact for the scaleup phase. The point is that piloting always takes longer and costs more than expected because unexpected issues arise during the piloting as discussed earlier.

Pilot Plant Availability

From the feedback and earlier evaluation, it can be concluded that for precision fermentation and cultured meat, there is currently a lack of pilot capacity for every development phase. This leads to the fact that every startup developing its own pilot installation. For plant-based ingredients the problem is less severe sinceoptions are available. With the realization of the NGF project, the capacity problem will be largely solved. However, this situation with restricted capacity will continue for at least 18 months as it is expected that somewhere in late 2025 the pilot plant will become operational.

After the realization of the NGF project solutions, the demo phase for startups remains limited for all three categories.

Feedback from Pilot Plants

From the feedback from pilot plants, running a pilot plant is a difficult business. It is risky to operate a pilot plant, costly and with low uptimes due to the many changes in the plant the costs of a pilot run are high: and it needs to make up for these risks and costs.

It is also understandable that pilot plants want to standardize their performance and runs as much as possible to get a high success rate of the runs. This leads to insufficient planning time ahead of the run, which is perceived as inflexibility by the startups. Also, the involvement of the startups during the run is limited for the same reason, to maximize the success rate, but this is also not welcomed by the startups.

The statement from pilot plants that they have difficulty finding a good connection with the market is, in that respect, not surprising: there are conflicting interests between doing good pilot runs for the startups and running an economically viable pilot plant.

As proposed, pilot plants can be best assisted by providing them with financial support through a financial base. In Europe, most successful pilot plants are supported one way or the other via the government. Financial support is also very welcome to install new equipment. The lack of pilot facilities in The Netherlands in precision fermentation and cultured meat is related to the high investment costs in realizing these installations.

Appendix 5 Models

Category	1 Plant based	2 Fermentation	3 Cell culture
Unit operations	**Protein extraction** Separation of raw material Protein isolation & purification Concentrating Drying	**Fermentation** Biomass separation Protein isolation & purification Concentrating Drying	**Cell culture** Cell differentiating Concentrating Dewatering
Available in NL 2023	5 m3	100 liter	Not available
Gap after NGF	>10 m3	>10 m3	>1 m3
Quality	Food grade	GMO ML I & II	Pharma hygiene standards

Fig A5.1. Overview of unit operations available in The Netherlands

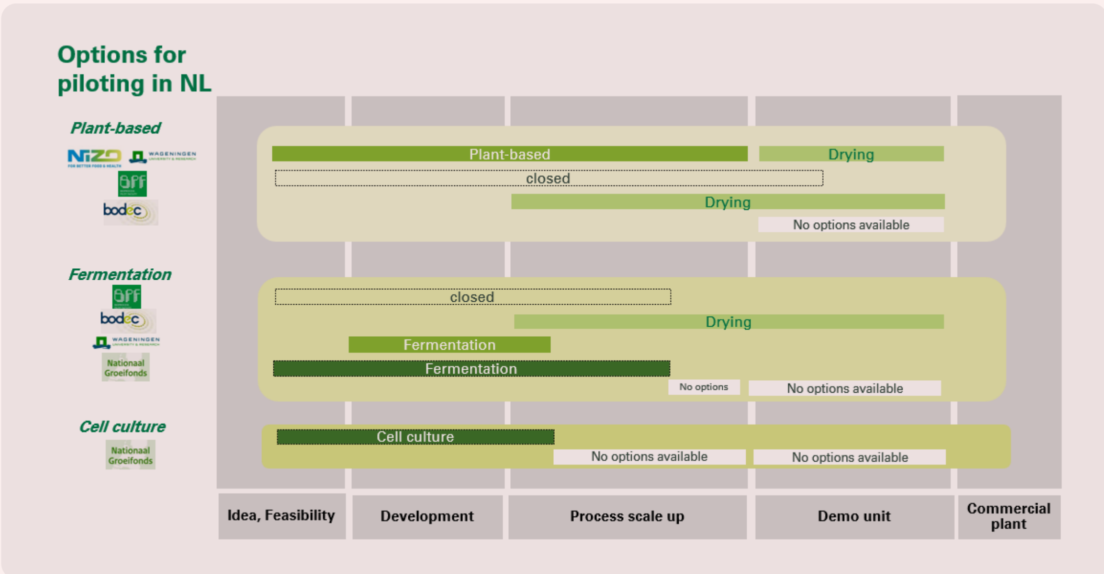


Fig A5.2. Options for startups during the development, scale-up and demo phase.

Appendix 6 Details on International Models

1 United States Model

The economic development model involving a triangular partnership between government funding, research universities and private companies is a fundamental strategy in the United States to drive innovation, technological advancement and economic growth. This model is structured as follows:

1. Government Funding: The U.S. government plays a crucial role in this model by providing funding for research and development (R&D). This funding is often channeled through various federal agencies like the National Science Foundation (NSF), the National Institutes of Health (NIH), the Department of Energy (DOE) and the Defense Advanced Research Projects Agency (DARPA). These funds are typically allocated for basic research, which is the foundation upon which applied research and development are built.

2. Research Universities: These institutions are the primary beneficiaries of government R&D funding. Universities conduct a significant portion of the nation's basic research, often leading to groundbreaking discoveries. They provide the human capital in the form of highly educated researchers, scientists and students. In addition to conducting research, universities play a key role in knowledge transfer and in training the next generation of scientists, engineers and entrepreneurs.

3. Private Companies: Private sector companies leverage the discoveries and innovations that emerge from university research to develop new products, services and technologies. These companies often collaborate with universities either directly through partnerships or indirectly by licensing technologies developed at universities. In some cases, companies also invest in university research, complementing government funding.

The synergy in this model works as follows:

- From Basic to Applied Research: Government-funded basic research at universities often leads to new scientific knowledge and technological breakthroughs. These breakthroughs are then translated into practical applications through applied research, often conducted in collaboration with or by private companies.

- Commercialization and Innovation: Private companies take the knowledge and discoveries from university research and invest in developing them into marketable products, services or processes. This process of commercialization turns scientific discoveries into tangible innovations that drive economic growth.

- Feedback Loop for Further Research: The interaction between universities and private companies often leads to the identification of new research questions and challenges, feeding back into the cycle of research and development.

- Economic Growth and Job Creation: This model contributes to economic growth by fostering new industries, creating high-tech jobs, and maintaining the United States' competitive edge in global innovation.

- Spillover Effects: The partnerships and research activities often lead to spillover effects, benefiting other sectors and industries and contributing to overall economic progress.

In the U.S., the coalition of groups that have most commonly coalesced to create and sustain pilot production facilities are governmental entities, universities, startups, suppliers and large corporations.

- Government: Support comes from federal agencies such as the Department of Agriculture (USDA) a§nd the Department of Energy (DOE) as well as state agencies such as Empire State Development in New York.

- Universities: The United States has a system of Land-Grant Universities that were established by state governments in conjunction with federal support. Many of these have strong food and agriculture programs, and of the cases analyzed in this study they are a part of this system, including Cornell University, the University of Minnesota, the University of Illinois and North Carolina State University.

- Suppliers: Equipment manufacturers like Buhler, JBT and others frequently give, or provide at heavily discounted rates, equipment to these facilities. This is generally treated as a marketing expense, and one that they are happy to fund as their equipment will then be familiar to the next generation of food technology leaders.

- Smaller Startups: There is near universal demand for pilot facilities from every startup that has developed a technology and process that works at lab / bench scale.

- Large Corporations: These are often regionally dependent. For example, Cargill is headquartered in the Minneapolis, MN suburbs, and works closely with the facility at the University of Minnesota. Similarly, ADM's headquarters in Decatur, IL, are a relatively short distance from the University of Illinois. Virtually all of the major food companies in the United States have one or more affiliations with these types of pilot facilities.

In summary, the triangular model in the United States is especially prominent in technology-intensive sectors such as biotechnology, information technology and advanced manufacturing, and has been instrumental in maintaining the United States' position as a global leader in innovation and technology.

2 Israel Model

The Israeli model is similar to the United States model of engaging the triangle of government funding, university research facilities and private corporations from small startups to multinational conglomerates. However, the overall funding levels in Israel are considerably smaller due to both its relatively smaller size and the deeply held cultural pride in the ability to do more with less. Israel's strategy with respect to alternative proteins reflects its commitment to innovation, sustainability and technological advancement. Israel has also focused on this area from the perspective of national food security. Key elements include:

- Government Funding and Incentives: The Israeli government provides funding and various incentives to support research and development in biomanufacturing and alternative proteins. This includes grants, tax incentives and other financial support mechanisms targeted at startups and research institutions.

- Public-Private Partnerships: Israel encourages collaboration between the public sector, private companies and academic institutions. These partnerships often focus on developing new technologies and bringing them to market.

- Innovation and Research Hubs: Israel has established several innovation hubs and research centers that focus on biotechnology, sustainable agriculture and food technology. These centers serve as a nexus for academic research, industrial R&D and startup innovation.

This triangle is further supported and enhanced by the following:

- Startup Ecosystem Support: Israel's robust startup ecosystem is a key component of its strategy. The government supports startups through incubators, accelerators and venture funding, particularly those in high-tech sectors like biomanufacturing and alternative proteins.

- International Collaborations: The Israeli government and private sector actively seek international partnerships to advance research and development in these fields. Collaborations with global entities help in technology transfer, research and market expansion.

- Regulatory Framework Development: Recognizing the importance of a supportive regulatory environment, the Israeli government works on developing regulations that encourage innovation in biomanufacturing and alternative proteins while ensuring safety and quality standards.

- Focus on Sustainable Agriculture: Given its arid climate and water scarcity, Israel places a strong emphasis on sustainable agriculture technologies, which extends to the development of alternative protein sources that are less resource-intensive than traditional animal agriculture.

- Education and Talent Development: Investment in education and skill development ensures that there is a pool of talented professionals to support the biomanufacturing and alternative protein sectors.

- Focus on Cutting-edge Technologies: Israel's strategy often involves leveraging its strengths in technology and innovation to develop cutting-edge solutions in biomanufacturing and alternative protein production, such as advanced fermentation technologies, cellular agriculture and plant-based protein innovations.

- Alignment with National Goals: The investment in these sectors aligns with Israel's national goals of environmental sustainability, technological leadership and economic development.

In Israel, the coalition of groups that have worked closely in this area are governmental entities, universities, startups and large corporations.

- Government: Support has come largely from the Israel Innovation Authority (IIA) and the Prime Minister's Office (PMO).

- Universities: Technion and the Hebrew University are the two leading universities for food science in Israel.

- Smaller Startups: Similar to the US, pilot facilities are in heavy demand from food technology startups.

- Large Corporations: The Strauss Group, Tnuva and Osem (owned by Nestlé) are all very active in the startup ecosystem, with Strauss using its Kitchen Hub incubation and innovation facility to bring in promising startups, and Tnuva doing most of its development in-house. Osem is the least innovative of these three major companies.

Israel's investment strategy highlights its approach to leveraging technological and innovative capabilities to address global challenges in sustainability and food security. By fostering a supportive ecosystem for research, development and commercialization, Israel aims to be at the forefront of advancements in biomanufacturing and alternative proteins.

3 Singapore Model

The Singapore model relies mainly on government support of strategic goals for applied research, economic development and private industry. It is a top-down, government-led approach that is long-term, strategic and heavily planned. Key aspects of this model include:

- Government-Led Strategy: The Singapore government plays a central role in shaping the country's R&D and economic development strategies. It identifies key sectors for growth and channels resources into these areas. The government's involvement is not just in funding but also in setting policy directions and creating a conducive environment for research and innovation.

- Research and Innovation Hubs: Singapore's government has established several research and innovation hubs, such as Biopolis for biomedical sciences and Fusionopolis for engineering and physical sciences. These hubs bring together researchers from public institutes, universities and private companies, fostering collaboration and innovation.

- Substantial Investment in R&D: The government invests heavily in R&D through its Research, Innovation and Enterprise (RIE) plans, which are multi-year investment plans. These plans focus on areas like advanced manufacturing, health and biomedical sciences, urban solutions and sustainability.

Other aspects of the Singapore model include:

- Public-Private Partnerships (PPPs): Singapore actively encourages collaboration between public research institutions and private industry. These partnerships often involve co-funding arrangements, where both the government and private companies contribute resources towards research and development projects.

- Support for Startups and Entrepreneurship: The government offers various forms of support for startups, including funding, mentorship, and providing a favorable regulatory environment. Initiatives like Startup SG provide entrepreneurs with access to capital, mentorship and space.

- Attracting Foreign Investment and Talent: Singapore has positioned itself as a global business hub, attracting multinational corporations to set up regional headquarters and R&D centers. The country's pro-business policies, skilled workforce and strong intellectual property protection are key attractions.

- Education and Workforce Development: The government invests in education and workforce development to ensure a steady supply of skilled professionals in various fields. This includes specialized programs in universities and polytechnics, as well as continuous education and training for the existing workforce.

- Focus on Future Technologies: Singapore places a strong emphasis on future technologies such as artificial intelligence, data science and biotechnology, aligning its R&D efforts with these emerging areas.

- Global Collaboration: The country actively seeks international research collaborations and partnerships, both to bring in global expertise and to provide Singaporean researchers with international exposure.

- Regulatory Environment: Singapore's regulatory framework is designed to be supportive of innovation, with clear and efficient processes. This aspect is particularly important for sectors like biotechnology and fintech, where regulation plays a significant role.

In Singapore, coalitions mainly include government-affiliated entities, universities, startups and large corporations. One key difference though is that Singapore more actively courts an international group of both startups and large companies to participate in the food technology ecosystem.

- Government: Support has come largely from the Agency for Science Technology and Research (A*STAR), Enterprise Singapore and the Economic Development Board (EDB). Temasek, which is one of the two primary Sovereign Wealth Funds (SWF) in Singapore, has a large global team focused on innovation in food and agriculture, and has made significant investments in alternative proteins globally. Also noteworthy is the Singaporean Government '30 by 30 Initiative'. This strategy is aimed at enhancing the country's food security. The goal is for Singapore to produce 30% of its nutritional needs locally by 2030. The initiative encourages the adoption of technology and innovation in food production, such as vertical farming and cultivated meat, to overcome land and resource constraints in Singapore.

- Universities: Nanyang Technical University (NTU) is the primary university in Singapore that excels at food science and technology.

- Smaller Startups: Singaporean facilities actively work to attract startups from around the world to develop their technologies and products in Singapore as there is not enough home grown talent.

- Large Corporations: ADM backed ScaleUp Bio with Nurasa, which is owned by Temasek.

In summary, Singapore's model is a comprehensive, government-led approach that strategically integrates R&D investment, public-private partnerships, entrepreneurship support and has a focus on future technologies to drive economic development and position the country as a global innovation hub.

4 Spanish Model

The Spanish model was initiated with foundational support from the government in the form of subsidies. These initial subsidies were instrumental in establishing the framework for a non-profit private model that aims to foster innovation in the alternative protein sector, with the government's role primarily focused on catalyzing the initial setup and ensuring that a robust structure was in place to facilitate research and development through public funding.

- Non-Profit Private Partnerships: At the core of the Spanish model is a non-profit organisation that operates through partnerships with key players in the agri-food sector. This unique structure allows for collaborative efforts between diverse entities ranging from large corporations to small enterprises, all dedicated to advancing alternative protein technologies. The non-profit status of this model ensures that the primary focus remains on innovation and sustainability.

- Membership and Involvement of Agri-Food Entities: Members of this non-profit organisation include a wide array of companies and entities within the agri-food sector. These members benefit from a variety of services and exclusive advantages such as access to specialized research, shared technology platforms and collaborative project opportunities. This inclusive membership model helps in pooling resources and expertise, significantly boosting collective research and development efforts.

Within the Spanish model, the services that are offered to members are designed to accelerate innovation and efficiency within the alternative protein landscape. These services might include access to research and development facilities, pilot production capabilities, regulatory guidance and market analysis insights. Exclusive advantages may also involve networking events, partnership opportunities and co-branding initiatives, which enhance visibility and market reach for member companies.

- Public-Private Collaborations: Although primarily a non-profit private initiative, the Spanish model encourages ongoing collaboration with public entities and academic institutions. These collaborations are crucial for integrating new scientific discoveries into practical applications and ensuring that the research is aligned with national priorities such as sustainability and health.

- Regulatory Support and Framework: The Spanish model operates within a regulatory framework that promotes the development of safe and sustainable alternative proteins. The non-profit organisations often play a role in advocating for favourable policies and regulations that support industry growth while ensuring consumer safety and environmental protection.

- Sustainability and National Impact: Aligned with Spain's broader goals of sustainability and economic diversification, this model contributes significantly to the national agenda. By focusing on alternative proteins, the model supports Spain's commitment to reducing its environmental footprint, enhancing food security and positioning itself as a leader in innovative food technologies.

Overall, the Spanish model exemplifies a strategic approach to fostering innovation in alternative proteins through a non-profit structure supported by both private initiatives and initial government subsidies. This model encourages widespread collaboration across the agri-food sector, leveraging collective strengths to drive forward advancements in sustainable food technologies.

5 Fraunhofer Model

The Fraunhofer model, originating in Germany and now also employed in the United States, is a unique approach to research and industrial development that bridges the gap between basic research and industrial application. This model is exemplified by the Fraunhofer-Gesellschaft, Europe's largest application-oriented research organization. Key features of this model include:

- Focus on Applied Research: Unlike academic institutions that primarily focus on basic research, the Fraunhofer model emphasizes applied research. The goal is to develop practical technologies, processes and products that meet specific industry needs.

- Public and Private Funding: The Fraunhofer-Gesellschaft receives its funding from both public (government) and private (industry) sources. Public funding is often used for more fundamental research, while private funding is typically directed towards specific projects with direct commercial applications. This dual funding model ensures a balance between exploratory research and market-driven development.

- Collaboration with Industry: A hallmark of the Fraunhofer model is its close collaboration with private companies. Businesses commission the Fraunhofer institutes to solve specific problems or develop new technologies. This direct involvement of industry ensures that the research is relevant and can be quickly adapted to commercial ends.

- Contract Research: Fraunhofer institutes engage in contract research for industry clients. This means they work on specific projects funded by these clients, which allows for targeted research and development that aligns closely with market needs.

Additional aspects of the Fraunhofer model include:

- Intellectual Property Rights: The Fraunhofer model places a strong emphasis on protecting and licensing intellectual property (IP). This approach not only provides a revenue stream back to the institutes but also encourages companies to invest in research, knowing they can secure IP rights for the developments.

- Network of Institutes: The Fraunhofer-Gesellschaft consists of a network of institutes, each specializing in different fields of applied science. This allows for a broad spectrum of research areas, ranging from energy technology and materials science to biomedical research and digital communication.

- Talent Development: These institutes are also involved in educating and training scientists and engineers. Many researchers at Fraunhofer institutes also have positions at universities, fostering an exchange of knowledge and talent between academia and industry.

- International Collaboration: While primarily based in Germany, the Fraunhofer model has expanded internationally, with research centers and offices in Europe, the Americas, Asia and the Middle East. This global presence facilitates international research collaboration and technology transfer.

- Market-Oriented Approach: Research activities are typically market-oriented, aiming to create products and solutions that are commercially viable and meet the demands of the market.

- Social and Economic Impact: The model aims not only at technological advancements but also considers the social and economic impacts of the research, aligning with broader societal and environmental goals.

The Fraunhofer model successfully combines scientific excellence with a strong orientation towards practical application and commercialization, making it a highly effective model for technology-driven economic development.

6 Private Model

In this study, the Private model has been employed by Buhler, the Swiss equipment manufacturer, and all three startups: EVERY, Nature’s Fynd and Wildtype. The model, very simply, uses private company funds to finance the development of pilot scale facilities.

For Buhler, a large and well established private company with significant cash flows and profits globally, this is a strategic decision since they want to be deeply integrated into the alternative protein ecosystem. It can be assumed that the strategy to use company resources to build and own pilot scale production facilities positions them well to succeed as an equipment provider to this growing space.

For the alternative protein startups, the situation is different. They made the decision to finance and build their own pilot production capabilities out of necessity rather than choice. Venture capital dollars are an extremely costly method to use for the capital expenditures needed for these types of facilities. The capacity that they needed being either extremely difficult to access or entirely unavailable led to the decision to build a facility. However, with shared facility capacity being available, the decision might have been different.

Appendix 7 Potential Interventions

Non-regional Pilot Vouchers for Ventures:

- Objective: To facilitate access to pilot facilities for startups, particularly in the early stages of development, by subsidizing the cost of utilizing these facilities.

- Rationale: Early-stage startups often face significant financial constraints. By providing vouchers that cover part or all the costs associated with using pilot facilities, we can lower the barriers to entry, enabling more startups to test, refine and scale their innovations.

- Expected Outcome: Increased innovation and a higher success rate among startups, as they can afford to iterate their products and processes without the burden of high pilot plant fees. Additionally, as startups are not restricted to facilities in their immediate region, this could lead to a more geographically diverse innovation landscape.

Additional Base Funding for Pilot Plants:

- Objective: To lower the financial barriers for startups seeking to scale their operations by subsidizing the operational costs of pilot plants.

- Implementation: Secure commitments from government bodies, industry associations and private investors to provide ongoing funding support. This could involve grants, tax incentives or direct investments in pilot facilities.

- Impact: By reducing the cost of access to pilot facilities, more startups and innovators can test, validate and scale their technologies, encouraging a richer ecosystem of sustainable food innovations.

Expanding the Network of Shared Facilities:

- Objective: To create a more flexible and accommodating infrastructure for startups at various stages of development, particularly those nearing market entry. For many startups, access to a robust ecosystem of experts in various fields is crucial for both process and product development. Smaller facilities often lack this comprehensive expertise. Furthermore, for projects in the demonstration phase, the ease of material transportation to the site and the subsequent transfer of processed products to other facilities for further refinement or distribution is of utmost importance.

- Implementation: Develop partnerships with research institutions, corporate entities and existing pilot plants to offer space and utilities for rent. This model should include support services for integrating and operating specialized equipment brought in by the startups.

- Impact: Startups gain the ability to conduct extended testing and scaling in a controlled, cost-effective manner, bridging the gap between small-scale experimentation and full-scale commercial production.

Lowering Access Thresholds by Corporates:

- Objective: To foster a collaborative innovation ecosystem where corporate-owned pilot facilities are more accessible to startups.

- Implementation: Encourage corporations to adopt more open innovation models, including making pilot facilities available to external startups, through partnership programs, incubators or open innovation challenges.

- Impact: Startups benefit from access to high-quality resources and expertise, while corporations can tap into fresh ideas and potential partnerships, driving mutual growth in the sector.

Enhanced Communication about Pilot Facility Capabilities:

- Objective: To ensure startups have a clear understanding of what pilot facilities can offer at different development stages, preventing mismatches in expectations.

- Implementation: Create a centralized, regularly updated database or platform that provides detailed information on each facility's capabilities, specialisms and access conditions. This platform could also feature case studies and testimonials.

- Impact: Improved clarity and transparency can streamline the process of matching startups with the most suitable facilities, optimizing resource use and accelerating development timelines.

Collaboration with VC and Public Investment Agencies:

- Objective: To develop innovative funding models that reduce the financial risk of investing in pilot-scale and pre-commercial technologies.

- Implementation: Facilitate roundtable discussions and workshops with VCs, public agencies and startups to identify and develop new investment mechanisms. These could include co-investment funds, guarantees or performance-based funding models.

- Impact: By providing more secure investment pathways, startups can secure the funding they need to scale, and investors can mitigate their risks, encouraging more capital flow into the sector.

Coordinated Investment in Specialized Capabilities:

- Objective: To optimize the development of new and necessary pilot capabilities through strategic planning and investment.

- Implementation: Establish a consortium or working group of shared facility owners to discuss, plan and execute investment strategies. This group would assess market needs, technological gaps and opportunities for collaboration.

- Impact: Coordinated efforts can lead to more rationalized investments, reducing redundancy and ensuring that the sector is better equipped to support the next generation of food technologies.

- These measures not only facilitate the practical aspects of scaling up but also contribute to a culture of collaboration and innovation. The success of these interventions will depend on the collective effort of stakeholders across the industry to adopt, implement and champion these changes, driving towards a future where sustainable food solutions can flourish and reach their market potential with unprecedented speed and efficiency.

Appendix 7 Interview list

Name	Type	Country
Advanced Biofuels and Bioproducts Process Development Unit (ABPDU)	Shared facility	United States
Buhler Food Application Center (FAC)	Shared facility	United States
Cornell Food Venture Center (CFVC) Pilot Plant	Shared facility	United States
Cornell AgriTech's Fermentation Farming Lab (FFL)	Shared facility	United States
EVERY	Shared facility	United States
Fraunhofer USA (Michigan)	Shared facility	United States
Fraunhofer USA Center for Manufacturing Innovation (CMI)	Shared facility	United States
Integrated Bioprocessing Research Laboratory (IBRL)	Shared facility	United States
Nature's Fynd	Shared facility	United States
North Carolina Food Innovation Lab (NCFIL)	Shared facility	United States
Plant Protein Innovation Center (PPIC)	Shared facility	United States
Wildtype	Shared facility	United States
Israel Carasso Food Technology Innovation Center	Shared facility	Israel
Innovation Food Tech Center	Shared facility	Israel
Kitchen Hub	Shared facility	Israel
Sustainable Protein Research Center	Shared facility	Israel
A*STAR	Shared facility	Singapore
Esco Aster	Shared facility	Singapore
Food Technology Innovation Centre	Shared facility	Singapore
Bio Base Europe Pilot Plant	Shared facility	Belgium
Those Vegan Cowboys	Venture	The Netherlands
GOA Ventures	Venture	The Netherlands
NoPalm	Venture	The Netherlands
Cano-ela	Venture	The Netherlands
Farmless	Venture	The Netherlands
Time Traveling Milkman	Venture	The Netherlands
Bioscienz	Venture	The Netherlands
Mosa Meat	Venture	The Netherlands
BPF	Shared facility	The Netherlands
Bodec	Shared facility	The Netherlands
NIZO	Shared facility	The Netherlands

Appendix 8 Viable Alternative Protein Startups by 2030

Startups in NL in 2024 (Source- Invest in Holland)	55
Alt protein CAGR in EU and NL until 2030	12 - 22%
Startups who make it (Techleap 2021)	16%
Starups founded every year (Source: Mc Kinsey- building a world class dutch start up ecosystem)	1000
Average # of protein startups by 2030	64
Number of protein startups by 2030	429
Number of viable startups by 2030	68

Colophon

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