Roadmap and Key Steps for Non-Animal Protein (Plant and Alternative) Towards Israel's Food Security 2050

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Neaman Institute
FOR NATIONAL POLICY RESEARCH

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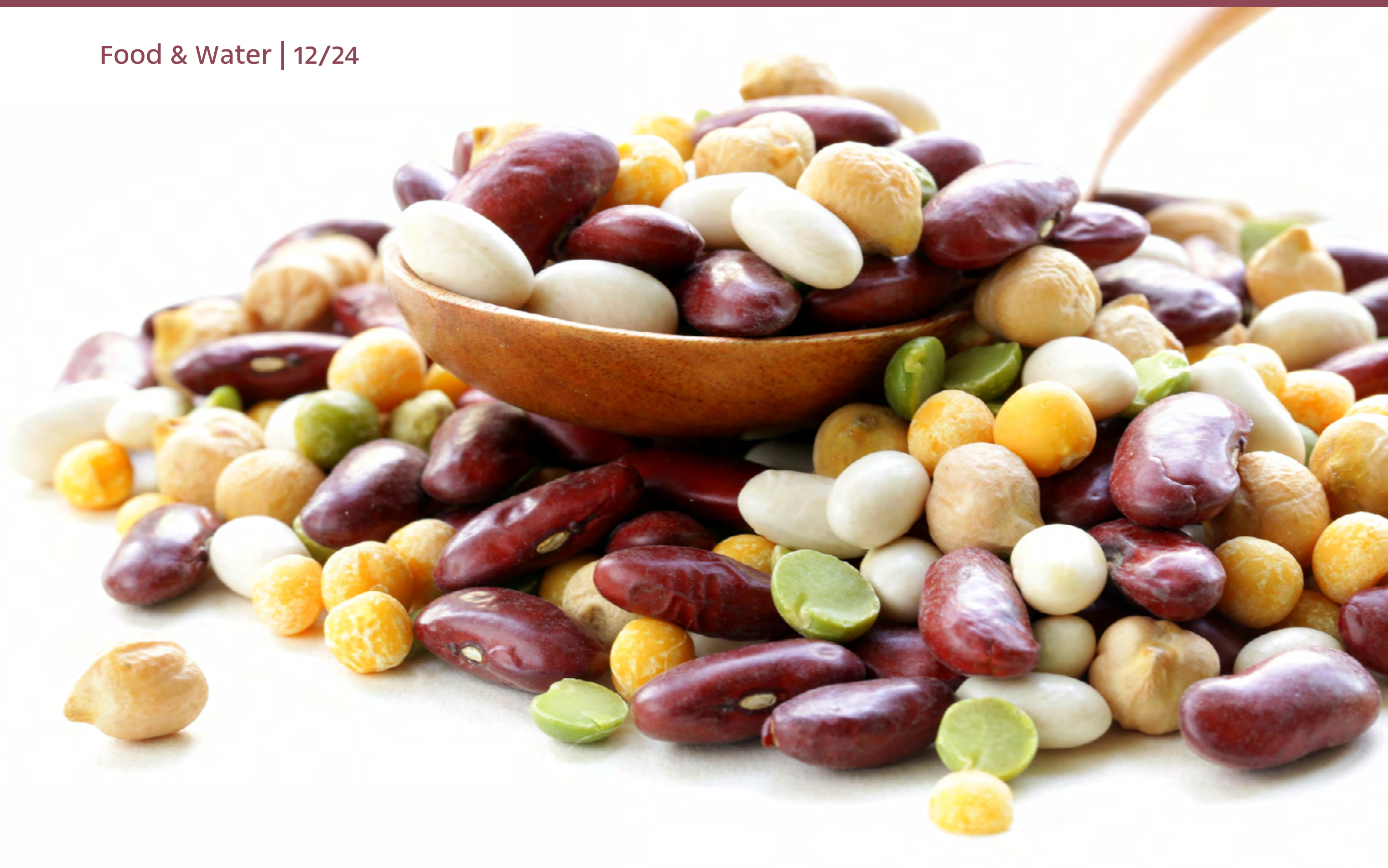

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List of Terms and Abbreviations

Animal-Based Products (raw materials)	Red meat and Animal fats, Poultry, Eggs, Fish, Dairy and Dairy Products in Nutritional Plate (Mediterranean diet).
Available Supply in Food Balance Sheet	A parameter in CBS-Food Balance Sheet; Includes local production plus changes in stocks and imports, minus exports, of the surveyed year.
First-of-a-kind (FOAK)	Product, technology, or project being developed or implemented for the first time. It represents an innovation without prior examples, involving high levels of uncertainty. FOAK projects are crucial for proving feasibility and pioneering advancements but often face challenges in development, investment, and market adoption.
Food Balance Sheet	Comprehensive record of food items available to the public during the surveyed year, detailing their sources and nutritional value, including energy (calories), protein, fat, minerals, and vitamins, averaged per capita per day. It provides policymakers with insights into Israel's food self-sufficiency and its dependence on imported food products[1].
Plant-Based Products (raw materials)	Cereals and products, nuts and seeds, legumes in nutritional plate (Mediterranean diet).
Net Protein (raw materials)	Net protein in raw materials.
Non-animal protein (plant and alternative)	Non-animal proteins such as cultivated meat and fish, molecular farming, processed plant-based proteins, insects, mycelium and fungi, precision fermentation, and algae.
Required Supply	Future Available Supply
Self Sufficiency Ratio (SSR)	Production / Available supply

[1] For further reading about Food balanced sheet: CBS. Food Balance Sheet.

1. Summary

Overview

This report explores the critical role of non-animal proteins (plant and alternative) in achieving Israel's food security by 2050. The demand for protein is set to rise substantially, alongside significant population growth and environmental challenges. Non-animal proteins provide sustainable solutions to address these challenges. Examining the need for non-animal protein includes investigating various issues:

Food security through increased domestic production: Israel's low self-sufficiency ratio in key food groups like cereals, legumes, and nuts, increases its reliance on imports and its vulnerability to global supply chain disruptions. Strengthening domestic production of non-animal protein will reduce these risks, enhance resilience to geopolitical and economic uncertainties, and support sustainability goals by lowering the environmental impact of importing and producing animal-based proteins.

Environmental Impact: Non-animal proteins significantly reduce greenhouse gas emissions, land use, as well as water consumption compared to conventional animal protein.

Dietary characteristics: When evaluating the food quantities required for 2050, aligning the Israeli diet with the Mediterranean diet recommendations, substantially reduces the gap between current production and future demand across most food groups. By 2050, we suggest that 50% of the population is anticipated to consume the recommended dietary plate. This adjustment includes a decrease in the consumption of red meat, poultry, and dairy products, alongside an increase in the consumption of legumes.

Economic and Policy Challenges: Scaling up new non-animal protein production requires significant investments in production facilities, emphasizing the need for supportive policies, including subsidies, R&D investments, and consumer education.

Global Context and Israel's Leadership: Israel is positioned as a global leader in non-animal protein innovation. However, further government and private sector investment and collaboration is crucial to overcome FOAK production challenges.

Chapters 2-5 introduce non-animal proteins, their definitions, and global policies promoting their adoption. They emphasize environmental benefits, such as reduced resource use, and explore dietary guidelines that advocate for plant-based and alternative protein inclusion. The focus is on global trends and their relevance to Israel's food system.

Chapters 6-10 analyze Israel's current and future protein needs, emphasizing self-sufficiency and sustainability. They detail available non-animal protein solutions, evaluate their environmental and economic impacts, and outline a roadmap with key actions for transitioning to a resilient, partly non-animal protein-based food system by 2050.

The aim of the study

Analyzing the role of non-animal protein in the context of food security in Israel 2050 and laying out key steps for the country & private sector to follow to attain this goal.

Methodology

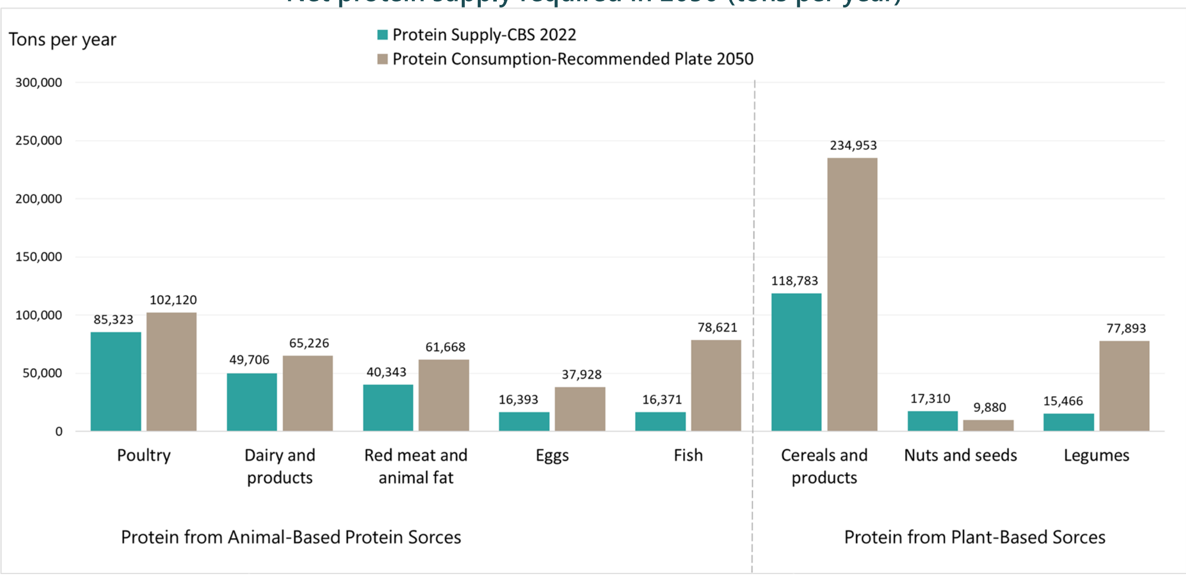
- Obtain a data driven protein demand for Israel 2050.
- Identify potential protein sources, alternatives, and possible roles for non-animal protein.
- Setting a roadmap for non-animal protein in Israel's food security 2050.

Protein requirements

Israel's current protein sources demonstrate low self-sufficiency ratio in key food groups like cereals, legumes, and nuts and seeds.

The substantial contribution of plant-based proteins (especially cereals and legumes) in the Mediterranean diet, highlights the importance of plant-based foods in meeting protein demands. Plant-based proteins may become increasingly critical due to population growth and environmental challenges.

Net protein supply required in 2050 (tons per year)



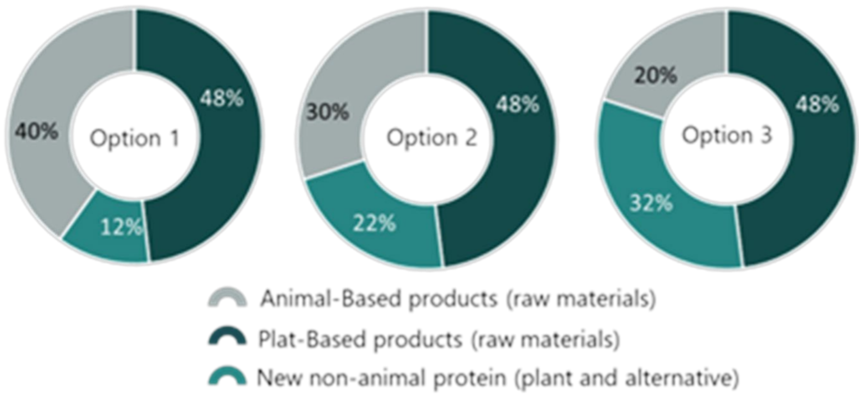
Protein needs

New non-animal protein sources, including cultivated meat and fish, molecular farming, processed plant-based proteins, insects, mycelium and fungi, precision fermentation, and algae, will be vital to supplement traditional and plant-based proteins.

Based on future protein demands, it is recommended to shift to products of plant-based and new non-animal proteins (plant and alternative) to meet dietary needs while reducing animal-based protein consumption down to 20-40% of the total protein.

Reducing animal-based protein consumption is reflects a 23-61% reduction in animal derived protein, a demand of 79K to 212K tons of new non-animal protein source, respectively.

Future distribution of non-animal protein (plant and alternative) sources by type of product (2050)



Possible scenario for New non-animal protein (plant and alternative)
(Available Supply 2050 of protein-based products in Mediterranean Diet, tons per year)

% of Animal-Based Products (2050)	52%	40%	30%	20%
Animal-Based Protein Products (raw materials)	3,862 K	2,981 K	2,236 K	1,490 K
Plat-Based Protein Products (raw materials)	3,589 K	3,589 K	3,589 K	3,589 K
Animal-Based Net Protein (raw materials)	345 K	267 K	200 K	133 K
New non-animal protein (plant and alternative)	0	79 K	146 K	212 K

Given the uncertainty regarding the contribution of each non-animal protein technology (plant-based and alternative), the proposed distribution is as follows: cultivated meat and fish are projected to replace 25% of conventional meat and fish, processed plant-based proteins are expected to capture 30% of the market, precision fermentation is anticipated to contribute 25%, molecular farming 5%, mycelium and fungi 8%, insects 2%, and algae 5%.

Key actions and recommendations for non-animal protein supply by 2050

Mitigating risks for animal protein supply chain

Israel's animal-based protein supply chain faces significant vulnerabilities, including reliance on imports, geographic exposure to conflict zones, and climate change. Beef and fish are at the top risk, followed by eggs, poultry, and dairy. Diversification, non-animal proteins are crucial to mitigate risks. Non-animal protein supply is critical to secure Israel's food security by 2050. **Reducing animal protein consumption to 20-40% of total protein and promoting local protein production (legume and alternative)** are key strategies for ensuring Israel's food security by 2050.

Maintain Israel as non-animal protein powerhouse

Israel's leadership in innovation of non-animal proteins is vital for local and global food security and sustainability. **It must be sustained through continued investment in research, infrastructure, and public-private partnerships.** Strengthening its role in global markets can attract investments and position the country as a hub for sustainable food technologies.

Overcoming the FOAK challenge

Government and private sector support is crucial for startups overcoming challenges in scaling and building a first-of-a-kind (FOAK) manufacturing facility. **FOAK facilities are critical for the mass adoption of new non-animal proteins**. This involves addressing barriers like high initial production costs, limited infrastructure, and regulatory hurdles, which can be mitigated through government support and industry collaboration. Government interventions can help startups transition from prototypes to scalable solutions.

Boosting mass production capabilities

Achieving large-scale production of new non-animal proteins requires investments over 2 billion USD for production facilities of red meat, poultry, and fish alternatives, and over 600 million USD for dairy alternatives. Annual investments of 100-200 million USD in R&D infrastructure, pilot production facilities, public-private partnerships, and market development are crucial. These efforts are key to making non-animal proteins affordable and widely accessible, with success relying on a supportive regulatory and financial framework.

Fostering plant protein self-sufficiency

Expanding the local cultivation of plant-based proteins, particularly legumes, is essential for reducing reliance on imports and promoting sustainability by decreasing dependence on animal-based proteins. Supporting advanced agricultural techniques, fostering research, and providing incentives can enhance production and strengthen food security. **Integrating cultivation and breeding strategies can increase legume production, advancing plant-based protein self-sufficiency, food security, and sustainable agriculture in Israel.**

Conclusions and Recommendations

Conclusion

To ensure Israel's food security by 2050, reducing reliance on animal-based proteins is crucial. This requires diversifying into alternative and plant-based proteins to lower meat consumption among heavy meat consumers. Advancements in technology and growing consumer acceptance present opportunities for integrating these proteins into the national strategy.

Key actions include investing in alternative and plant-based protein production, promoting local legume cultivation, supporting innovative startups, and fostering a favorable regulatory and financial framework. Israel's leadership in non-animal protein technologies is vital for addressing global food security, climate change, and resource scarcity, positioning the country as a global leader in sustainable protein solutions.

Recommendations

Develop a national strategy for protein diversification

- Allocate budget for programs to integrate non-animal proteins into Israel's food system, targeting a reduction in animal protein consumption to 20-40% of total protein by 2050.
- Promote plant-based diets aligned with the Mediterranean diet and sustainability goals by public awareness campaigns.

Foster local legume cultivation

- Develop financial incentives such as subsidies and guaranteed procurement schemes to encourage farmers to grow legumes.
- Invest in breeding programs to enhance the yield, drought-resistance, and nutritional properties of legume crops suited to Israel's semi-arid climate.

Enhance research and development (R&D)

- Fund R&D of climate-resilient and pest-resistant crops, as well as advanced processing technologies to optimize plant-based protein production.
- Continue the development of non-animal protein technologies, with a focus on enhancing texture, taste, and nutritional value.

Support startups and innovation

- Increase funding for new non-animal protein startups, focusing on technologies such as precision fermentation, Mycelium and Fungi, Algae, cultivated meat and fish, processed plant-based and insect-based substitutes solutions.
- Provide access to shared infrastructure, testing facilities, and R&D hubs to reduce operational costs for startups.

Invest in scaling production facilities and R&D

- Allocate 2 billion USD or more to develop manufacturing facilities for cultivated meat, eggs, poultry, and fish protein alternatives; And over 600 million USD for dairy protein alternatives
- Prioritize funding for First-of-a-Kind (FOAK) production facilities to address scalability challenges through grants, low-interest loans, tax incentives, and subsidies.
- Allocate 100–200 million USD annually in R&D infrastructure, pilot production facilities, public-private partnerships, and market development.

Regulatory and market support

- Allocate resources for streamlining regulatory processes for non-animal protein products to facilitate market entry.
- Use public procurement and offtake agreements to provide revenue certainty for producers and stimulate early adoption.

Encourage foreign investment and collaboration

- Allocate budget for initiatives that attract foreign investment by showcasing Israel's leadership in non-animal proteins.
- Strengthen partnerships with global suppliers of raw materials.

2. Introduction

Alternative proteins refer to novel protein sources intended to replace conventional animal-based proteins such as microbial, insect-based, cell-based, plant-based, and fungal proteins[2]. Different countries and organizations define and regulate them according to their environmental, health, and food security priorities.

World organizations support the development and adoption of alternative proteins to enhance food security, sustainability, and health while also addressing economic and regulatory considerations. According to the FAO[3], there is growing interest in developing alternative proteins to meet global food security needs. These include proteins derived from insects, algae, and plant-based sources, as well as lab-grown meats. Such alternatives can reduce reliance on traditional livestock farming, which has significant environmental impacts. New food sources and production systems are designed to enhance sustainability, reduce environmental impact (such as vertical farming, precision agriculture), and improve food security in a growing and changing world. The OECD also explores various aspects of the shift from traditional meat consumption to alternative protein sources. In a policy paper[4], which provides a comprehensive overview of the potential benefits and challenges associated with meat protein alternatives (plant-based proteins, cultivated meat, and insect proteins), the authors offered policy recommendations to facilitate their adoption, such as supporting research and innovation, investing in R&D, promoting collaboration partnerships between public research institutions, private companies, and academia, establish clear and consistent regulatory frameworks for the production and labeling of alternative proteins, facilitate market access, enhance consumer awareness and promote acceptance, and offer financial incentives such as subsidies, grants, or tax breaks to support startups and established companies involved in the production of alternative proteins.

As to September 2024[5], there were 72 startup companies in Israel developing or dealing with alternative proteins, with raised funding of $1.35B in total. Most of them (64%) were founded in the last 5 years and are in the early stages of funding (71%)[6] (Figure 1).

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[2] FAO (2024). Alternative proteins top the bill for the latest FAO–International Sustainable Bioeconomy Working Group webinar.

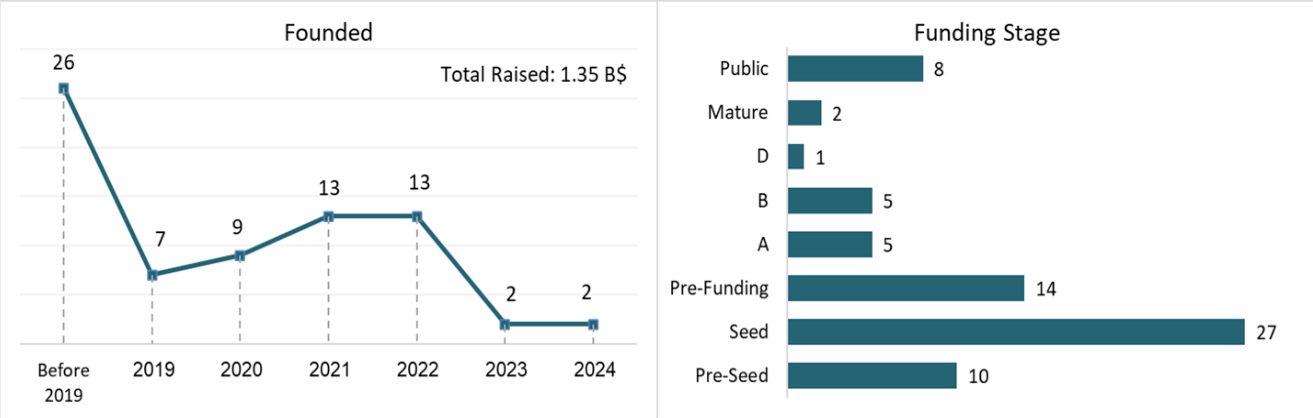
[3] FAO (2022). Preliminary Pages. Chapter 4: New food sources and food production systems.

[4] OECD (2022). Meat protein alternatives- Policy paper.

[5] Startup Nation Finder. Accessed Sep. 2024.

[6] Early funding stages: pre-seed, seed, pre-funding

Figure 1: Alternative proteins startups in Israel



Source: processing by Samuel Neaman Institute of data by Startup Nation Finder (Sep. 2024)

2.1 Environmental Impact of Alternative vs. Conventional Protein

Alternative proteins, including cultivated meat and plant-based protein substitutes, are considered innovative and have the potential to reduce the environmental impact of food production. Several comparative studies examine the environmental effects of producing these proteins in comparison with conventional animal-based proteins, such as beef, poultry, and fish. The evaluations focus on key parameters: land use, water consumption, greenhouse gas emissions, and energy consumption.

A comparison of the environmental footprint of proteins from various sources (conventional and alternative) presented in Table 1 reveals significant differences between animal-based, plant-based, and alternative proteins. Since large-scale production of cultivated meat is still almost non-existent, the LCA (Life Cycle Assessment) analysis in the literature is largely based on hypothetical data and various scenarios, ranging from the worst to the most optimistic (Tuomisto and de Mattos, 2011).

Research on the environmental impact of food in Singapore[7] has demonstrated that importing food by sea from countries utilizing cleaner energy sources could potentially reduce greenhouse gas (GHG) emissions. In Israel, over 90% of the fish consumed is imported, with the majority transported by sea. This factor should be carefully considered when evaluating the environmental impact of food imports.

[7] Deloitte. (October 2019). Environmental Impact Food in Singapore.

Table 1: Comparison of the Environmental Impact of Animal, Plant, and Alternative Protein Sources (average data)

Category	Energy (Non-renewable) MJ / kg product	Energy (renewable and non-renewable kWh per kg of food)	Water Use (m^3 / kg product)	Land Use (m^2 / 100 g protein)	Greenhouse Gas Emissions (kg CO_2 / 100 g protein)	Reference
Beef	57.5	42.6	387.5	204.75	53.17	Malilla et al. 2024, Tuomisto and de Mattos 2011, Santo PE. (2020)
Lamb		32.8	154	185	20	Malilla et al. 2024
Poultry	17.5	23.0	368	6.55	5.42	Malilla et al. 2024, Tuomisto and de Mattos 2011
Fish		30.3	267	2.18	5.82	Malilla et al. 2024, Santo PE. 2020
Plant Protein (Legumes, Grains, Nuts)			3.73	4	1.05	Heusala et al. a (2020), Heusala et al. b (2020), Fresán et al., 2019
Plant-based Protein Substitutes (Plant-based burgers, nuggets, tofu)			0.15	1.85	1.58	Santo PE. 2020, Goldstein et al., 2017, Seves et al. (2017), Santo PE. 2020
Insect-based Substitutes (Mealworm larvae, locusts, bee larvae)	17.57		2.89	1.4	0.32	Malilla et al. 2024, Ulmer et al., 2020, Smetana et al. 2023, Malilla et al. 2024
Fermentation (Microprotein, lignocellulosic-mycoprotein, Trichoderma reesei)	63.8		5.39	1.83	6.55	Santo PE. (2020), Upcraft et al., (2021), Järviö et al. 2021, Smetana et al. (2015, 2018)
Cultivated Meat (Cyanobacteria, Wheat, corn, soy, and glucose)	289.1-331.85		0.91	0.25-1.35	1.58-9.35	Smetana et al. (2015), Tuomisto et al. (2014) Tuomisto et al. (2014), Sinke et al., 2023, Mattick et al. (2015)

The best protein source from an environmental point of view
The worst protein source from an environmental point of view

2.1.1 Indicators for testing the environmental impact:

Greenhouse Gas Emissions (GHG)

Animal-based conventional protein sources exhibit the highest greenhouse gas emissions. For example, beef emits between 17.3 to 89.03 kg of CO_2 per 100 grams of protein, and lamb produces around 20 kg CO_2 per 100 grams of protein (Malilla et al., 2024). By contrast, plant-based protein, including legumes, grains, and nuts, generates much lower greenhouse gas emissions, ranging from 0.2 to 2.1 kg CO_2 per 100 grams of protein (Heusala et al., 2020). Plant-based substitutes like veggie burgers or tofu show slightly higher emissions, between 0.25 to 6.15 kg CO_2 per 100 grams of protein (Santo PE., 2020).

Insect-derived proteins, such as those from locusts and larvae, exhibit the lowest emissions, around 0.3 kg CO_2 per 100 grams of protein (Malilla et al., 2024). Cultivated meat shows varying values depending on the feed source. When blue-green algae (cyanobacteria) are used for cell growth, greenhouse gas emissions are the highest, at 9.2-9.5 kg CO_2 per 100 grams of protein (Smetana et al., 2015). Feed sources based on corn, wheat, and soy present much lower emissions, between 1.2 to 2.47 kg CO_2 per 100 grams of protein (Tuomisto et al., 2014).

Land Use

Land use is another parameter where alternative proteins have an advantage over animal-based proteins. Cattle farming, for example, requires a particularly large amount of land for grazing – between 41.5 to 368 square meters per 100 grams of protein, while sheep farming uses approximately 185 square meters. In contrast, poultry farming uses relatively small amounts of land, ranging from 1.9 to 9 square meters per 100 grams of protein (Malilla et al., 2024). Producing plant-based protein requires between 1.4 to 7.9 square meters of land per 100 grams of protein (Heusala et al., 2020), while plant-based protein substitutes need between 1 to 3 square meters per 100 grams of protein (Santo PE., 2020). Insect protein production requires only about 1.4 square meters of land per 100 grams of protein (Malilla et al., 2024). Cultivated meat presents the lowest land use requirements, between 0.2 to 1.5 square meters per 100 grams of protein (Tuomisto et al., 2014), except in cases where soy is used as cell feed, which can require up to 11.5 square meters in extreme scenarios (Mattick et al., 2015).

Water Use

In terms of blue water consumption, animal-based protein requires the highest investment, ranging from 136 cubic meters per kilogram of product for poultry to about 530 cubic meters per kilogram for beef. Sheep require approximately 154 cubic meters, while fish farming demands between 246 to 288 cubic meters per kilogram of product (Malilla et al., 2024). Producing plant-based protein and fermentation-based protein requires an average of between 3 to 6 cubic meters per kilogram of product (Heusala et al., 2020), while cultivated meat requires the least amount of water – less than one cubic meter per kilogram of product (Tuomisto et al., 2014).

Energy Consumption

When calculating the conventional energy required to produce cultivated meat, it is clear that this method demands more energy than any other source – 290.7-373 MJ per kilogram of product, significantly higher than the energy required to raise cattle, which ranges from 50 to 65 MJ per kilogram of product. Plant-based protein substitutes, poultry, insects, and fermentation-based protein require between 70 to 181 MJ per kilogram of product (Malilla et al., 2024). A significant portion, up to 75%, of the energy costs for cultivated meat is attributed to cooling during cell proliferation in bioreactors, as cell growth generates a substantial amount of heat. Some studies suggest that cell-based fish may be more sustainable than other forms of cultivated meat (such as minced meat or beef), since fish cell lines tend to grow more easily, have faster doubling times, more stable cell lines, and lower oxygen needs. Moreover, cell lines from aquatic species generally require less energy than those from land species because they can grow at lower temperatures (15-30°C compared to 37°C) (Vural Gursel, I., Sturme, M., Hugenholtz, J., & Bruins, M., 2022). However, this advantage diminishes when cooling becomes the primary energy cost.

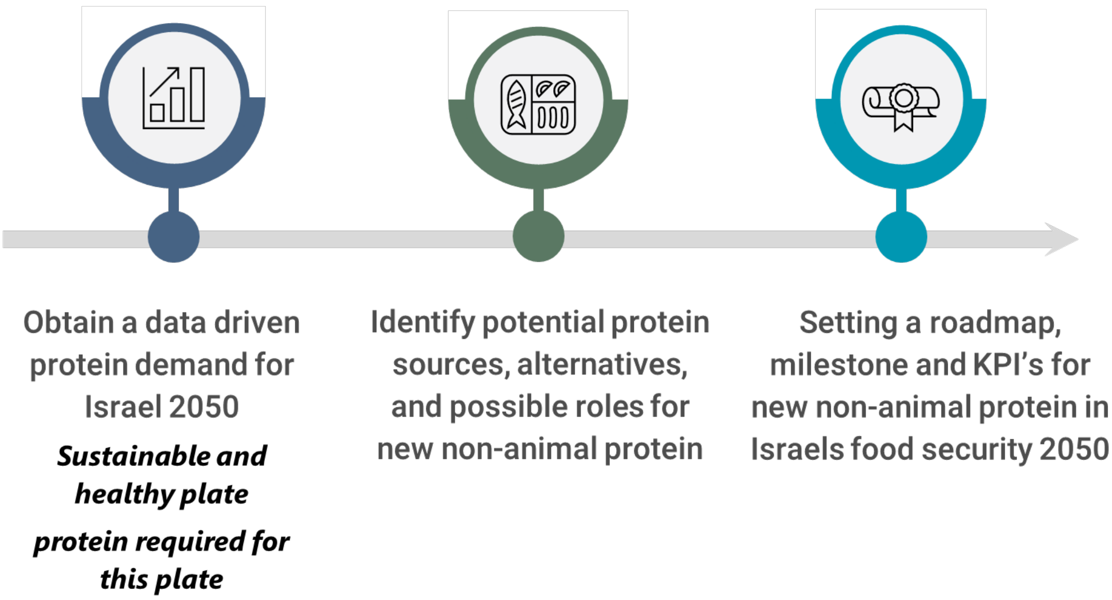
Conclusion

Plant-based proteins, along with plant-based substitutes and insect-based proteins, exhibit a much lower environmental footprint compared to conventional animal-based proteins. Although cultivated meat offers potential benefits in terms of land and water use, its high energy demand could pose challenges to its widespread commercial implementation. In general, new non-animal proteins offer significant environmental benefits despite the energy demands associated with fermentation and culture. The ongoing research and development in this field holds the potential to optimize processes both economically and environmentally. As improvements in energy efficiency are anticipated, the eventual market introduction of these products is expected to further enhance their positive environmental impact. More important, from self-sufficiency perspective, is the fact that cultivated protein technologies will contribute to reduce the feed import into Israel.

2.2 The aim of the study

Analyzing the role of non-animal protein in the context of food security in Israel 2050 and laying out a roadmap and key steps for the country & private sector to follow to attain this goal.

2.3 Methodology



The research methodology will be based on gathering and analyzing data concerning the nutritional needs and sources of the Israeli population, particularly focusing on its protein sources. The analysis will encompass aspects such as production, import, supply chains, climate, and health implications. The analytical process will be accompanied by a series of consultations in ad-hoc forums of subject matter experts on specific aspects in public health, agriculture, supply chain, industry, innovation, education, behavioral economy, food waste, and more.

This process will be utilized to develop the principles for Israel's 2050 food security policy regarding sustainable protein.

2.3.1 Workflow

Obtain a data driven protein demand for Israel 2050

- Defining the “sustainable and healthy Israeli plate 2050”. Defining a sustainable and nutritious Israeli plate for 2050 requires employing a comprehensive set of metrics drawn from recommendations provided by esteemed entities like the Ministry of Health of Israel, the EAT-Lancet Commission, NIH-National Library of Medicine, and similar institutions. This endeavor will be carefully tailored to reflect the cultural and culinary inclinations of the nation while promoting sustainable practices within local agriculture. Moreover, it judiciously considers the importance necessary to meet protein nutritional needs. **Since the Israeli Ministry of Health made significant progress, we will rely on the ministry’s recommendation as these will be very likely adopted by other local entities.**
- Draw the cumulative protein required for this plate. The total protein needed for the plate encompasses both the baseline requirement for the Israeli diet and the specific protein sources. This includes protein derived from local 'traditional' agriculture and imported items, such as chicken, beef, turkey meat, fish, dairy products, and legumes. We will focus here on areas where non-animal protein may be an alternative to animal derived protein.

Identify potential protein sources, alternatives, and possible roles for non-animal protein

- Analyze the potential sources for the protein part of this plate. An analysis is conducted to assess the contribution of protein from both local production and imports, including a breakdown of their respective sources. This examination also explores the potential for non-animal protein sources to substitute or augment protein obtained from imports or unsustainable agricultural practices that do not align with climate objectives or with nutrition recommendations.
- Draw alternatives for supply (locally grown, import, alternative and conventional). The evaluation of protein supply alternatives will entail a thorough analysis across four dimensions of protein sources: local cultivation versus imports, conventional production versus alternative methods. We will also use predictions of consumer adoption for non-animal protein to examine its potential in reducing Israel’s dependency on animal derived sources.

Setting a roadmap, milestone and KPI's for non-animal protein in Israels food security 2050

- Run a SWOT on the alternatives – focusing on non-animal protein solutions. SWOT analysis will include strengths, weaknesses, opportunities, and threats for each protein solution, for analyzing and drawing the preferred option or options: fermentation-derived, plant-based, and cultivated meat, within each dimension: local cultivation versus imports, conventional production versus alternative methods.
- Draw KPI's and milestones for Israel to follow to achieve the preferred option/s. To effectively gauge performance and progress, we will establish time-based Key Performance Indicators (KPIs) and milestones. This will be achieved through evaluation of protein supply (traditional and alternative), including a SWOT analysis. Additionally, we will consider population expectations and cultural preferences. Milestone and KPI's will be designed for the public sector, alongside opportunities and recommendations for the private sector as well.

2.3.2 Research tools

Literature review:

- Outlining the composition of the Israeli food plate for 2050 and its diverse array of protein sources.
- Existing programs related to food security and non-animal protein, both domestically in Israel and internationally.
- Literature review and data collection will be conducted using OSINT (Open-source Intelligence) methods, primarily from publicly available sources as well as unique databases accessible to Samuel Neaman Institute. Sources of information at the state level will be retrieved from relevant government websites, such as the ministries of health, welfare and environmental protection, and any other information centers such as the Central Bureau of Statistics (CBS) and The Knesset Research and Information Center (RIC). In addition, to find works and reports in the field, databases of international institutions and organizations will be used - a database of reports of the Samuel Neaman Institute, OECD, AET, FAO, UNESCO, and more.

Data analysis and estimation:

- An analysis of the protein sources of the Israeli food plate.
- Conducting a quantitative assessment of the protein requirements for the Israeli food plate in correlation with anticipated population growth in Israel, encompassing numerical, socioeconomic, cultural, and other relevant factors.
- Assessment of the present status of protein sources compared to the targeted scenario for 2050.
- Analyze the ability to address disparities across different dimensions:

  - Generate local raw materials through diverse methods including agriculture, fermentation, and cellular processes.
  - Adjust forecasts to align with projected climate change impacts in our regions.
  - Residual reliance on imports for finished materials, raw materials for products, and materials for alternative industries.

Forum of experts:

- A forum of experts will be held to discuss the problems and action strategies required to achieve nutritional security regarding sustainable protein.
- We will hold a series of consultations in ad-hoc forums of subject matter experts in specific aspects, such as public health, agriculture, supply chain, industry, innovation, education, behavioral economy, food waste, and more.

Expert questionnaire:

- Structured personal questionnaire with experts on new non-animal proteins.
  The questionnaire will include questions regarding the Israeli market on the following topics: production technologies, development time, supply chain challenges, production infrastructure challenges, raw materials for non-animal protein production, regulatory barriers and challenges, support for start-ups, economic viability, consumer perception, health concerns, global versus local trends, market potential, and cultural considerations.

Definition and recommendations:

- Developing strategic plans to guide Israel towards achieving nutritional security in the protein sector by 2050.
- Comparative analysis of current programs.
- Initial Recommendations for Closing the Identified Gaps.

By employing this methodology, the study aims to substantiate its underlying rationale, which suggests that addressing the issue of food security and analyzing the role of non-animal protein in this context involves a multi-dimensional approach and necessitates long-term strategic planning and comprehensive consideration of a range of factors.

3. Alternative protein definitions

In this chapter, we explore the various definitions of alternative proteins as outlined by different countries and organizations. These definitions highlight diverse perspectives on how alternative proteins can contribute to addressing future food security challenges and sustainability goals.

According to the British Innovation Roadmap[8], "Alternative proteins are proteins produced from sources with a low environmental impact, aiming to either supplement animal-based protein sources or offer alternatives to them in line with 13 out of 17 of the United Nations Sustainable Development Goals (SDGs), providing promising innovation opportunities."

However, in a report prepared in 2022 for the UK Food Standards Agency[9], it is noted that the full extent of the environmental impact of most alternative proteins is still not fully defined. This report suggests that although alternative proteins offer advantages compared to beef and dairy production in terms of methane emissions, land use, and eutrophication, they cannot be regarded as sustainable in terms of the SDGs.

According to Singapore's Food Safety Authority[10], alternative proteins refer to proteins not derived from animals. Some alternative proteins based on soy or wheat are part of the country's food culture. Other forms of alternative proteins, such as cultivated meat, certain types of algae, mycoprotein, and insects, represent new protein sources in the country and are developed using innovative technologies. These proteins are classified as "novel food" and are subject to stricter regulatory standards.

According to Swiss Food & Nutrition Valley (SFNV) [11], ‘Sustainable Proteins’ refers to the production of new sources of protein. This may be cell-based foods or protein-rich plants, as well as mycelium, algae and microbes. New approaches towards conventional meat and dairy farming also provide significant opportunities to reduce our environmental impact.

While alternative proteins, such as cultivated meat, plant-based substitutes, and insects, are often touted as sustainable solutions to the environmental challenges posed by traditional meat consumption, their sustainability is not guaranteed. Research indicates that many of these novel protein sources require significant transformation and processing, which can lead to inefficiencies in resource use and potentially lower sustainability gains. In contrast, established protein sources like pulses, which require minimal processing, demonstrate the highest sustainability benefits[12]. However, pulses often face a negative stigma and lack of public interest compared to their more high-tech counterparts. This highlights the need for a cultural shift in

[8] “Proteins :Identifying UK priorities - A roadmap for the future of the alternative protein sector in the UK”, June 2022, Innovate UK

[9] Alternative Proteins for Human Consumption. The Food Standard Agency June 8, 2022.

[10] Factsheet on alternative proteins, 2024, Singapore Food Agency

[11] https://swissfoodnutritionvalley.com/impact-platforms/sustainable-proteins/

[12] Niraja Chopadem, Alternative proteins: the future of sustainable consumption? 2021. Yale Environment Review

consumer preferences, encouraging awareness of the true sustainability of food choices. Ultimately, it is essential to critically evaluate the marketing narratives surrounding alternative proteins to avoid favoring resource-intensive options at the expense of genuinely sustainable sources like pulses (Van der Weele et al., 2019).

According to the Netherlands Foreign Investment Agency (NFIA)[13] (an operational unit of the Dutch Ministry of Economic Affairs), alternative proteins are defined as "protein-rich sources, ingredients, intermediates or final products that can be applied as variations on meat, dairy, fish, and eggs". They specify re are three main categories for human consumption: 1. Proteins grown on land or in the sea, including plant-based proteins (beans, pulses, nuts, grains) and seaweed; 2. Microbials, fungi (mycoprotein), algae, cellular agriculture (cultivated meat and dairy); 3. Insect-based proteins.

Since the term "alternative protein" has many different definitions, we are using in this report a "new non-animal protein" term, to simplify the differentiation.

[13] The Netherlands Foreign Investment Agency (NFIA). (2022). Future Protein NL.

4. Policies in the world

The global shift towards non-animal proteins has gained significant attention as countries seek sustainable solutions to address food security, environmental concerns, and public health. From plant-based proteins to lab-grown meat and other alternatives, nations around the world are exploring diverse strategies to reduce reliance on traditional animal agriculture. Table 2 reviews some examples of the approaches taken by various countries, highlighting action plans, regulations and investments in non-animal proteins.

Table 2: The activity of different countries relating to non-animal proteins

Country	Action Plan and Regulation	Investments	Types of non-animal Protein (plant and alternative)
Denmark[14, 15]	• Investment in Plant-based Production • Incentives for Farmers to cultivate more plant-based proteins • Dietary Guidelines- more plant-based foods • Training and Education for Chefs for plant-based meals- integration into Danish cuisine and culture • Lower greenhouse gas emissions • 70% carbon reduction by 2030 • Climate neutrality by 2045	• Public funding: 224M$ (by 2023) • Funds allocation: DKK16 675M (98M USD[17]) (2023-2030)	• Plant-based proteins • Seaweed • BioSolutions (enzymes, proteins, and bacteria development)
United Kingdom[18,19]	• Focusing on plant-based, fermentation, and novel proteins, such as plant extracts, lab-grown meat, and insect-based proteins • Achieving net-zero emissions by 2050 through dietary shifts and sustainable protein sources	• Investments: UKRI, BBSRC and Innovate UK[20] £15M ($19M USD[21]) in new National Alternative Protein Innovation Centre (NAPIC)[22] • Public funding: 59M$ • £12M for Cellular Agriculture Research Hub	• Plant proteins (pulses, legumes) • Fermentation-based proteins (fungi, algae, lab-cultivated meat) • Insect and aquaculture proteins

[14] Ministry of Food, Agriculture and Fisheries of Denmark. (October 2023). Danish Action Plan for Plant-based Foods.
[15] GFI. 2023 State of Global Policy Report
[16] Exchange rate based on the current market rates for the Danish Krone (DKK) to the US Dollar (USD): approximately 1 DKK = 0.1466 USD
[17] based on an exchange rate: 1 DKK = 0.145 USD
[18] Innovate UK (June 2022). Alternative Proteins: Identifying UK priorities. A roadmap for the future of the alternative protein sector in the UK.
[19] GFI. 2023 State of Global Policy Report
[20] UKRI -The UK Research and Innovation; BBSRC-Biotechnology and Biological Sciences Research Council
[21] Exchange rate based on the current market rates for 1 GBP = 1.30715 USD
[22] UK Research and Innovation (28 Aug. 2024). National alternative protein innovation centre launches. Retrieved in Oct. 2024.

Country	Action Plan and Regulation	Investments	Types of non-animal Protein (plant and alternative)
Canada [23,24,25]	• Market Potential Goals of approximately 10% of the global plant-based food market by 2035, equating to CAD 25B in annual sales • A global leader in alternative proteins by 2035 • Food and Drug Regulations – sales regulatory recommendations • 2030 and 2050 net-zero targets	• Public funding: 303M$ (by 2023) • Capital investments: Over $260M • The goal: generate $25 billion annually by 2035	• Plant-based proteins (a state-of-the art protein processing to produce novel canola and pea protein isolates). • Fermentation-based proteins
Singapore [26,27,28,29]	• A global leader in alternative protein research and regulation with significant government support for both plant-based and cultivated meat industries • In 2020 Singapore was the first country to allow the commercial sale of cultivated meat • Reducing reliance on imported food and contributing to climate goals by promoting sustainable proteins	• SGD $165 M ($117 M) (by 2023) • The government supports alternative proteins through R&D initiatives and has made strategic investments in infrastructure such as food innovation facilities and alternative protein labs	• Plant-based proteins • Fermentation-based proteins (fungi and microalgae) • Cultivated meat (cell-based meat
United States [30,31,32,33]	• FDA and USDA approved cultivated meat products allowing their sale in the U.S. (2023) • Lower greenhouse gas emissions, reduced land and water use, biodiversity protection	• Public funding: 129M$ (by 2023) • DARPA's $40M investment in fermentation research and USDA support for precision fermentation	• Cultivated (Cell-based) Meat • Plant-based Proteins • Fermentation-based Proteins • Insect-based Proteins

[23] Protein Industries Canada (2022). Five-year strategy. 2023-2028.
Government of Canada. (Sep. 2024). Sector Trend Analysis – Plant-based protein food and drink trends in Canada. Retrieved Oct. 2024.
Natural Products Canada (2022). Game Changers: Canadian Opportunities in Alternative Protein.
[24] GFI. 2023 State of Global Policy Report
[25] Government of Canada. (Nov. 2020). Government of Canada launches consultation on guidelines for simulated meat and poultry products. Retrieved Oct. 2024.
[26] The Singapore Economic Development Board (EDB). (Mar 2023). Where can Singapore take the lead in alternative proteins? Retrieved in Oct. 2024.
Singapore Government Singapore Food Agency.
[27] GFI. 2023 State of Global Policy Report
[28] Pay, C., & Gianoli, A. (2024). Securing the future: Analyzing the protein transition in Singapore. Cities, 150, 105072.
[29] GFI. 2023 State of Global Policy Report
[30] Congressional Research Service (Sep. 2023). Cell-Cultivated Meat: An Overview.
[31] Hunter College. (Julu 2023). Lab-Grown Chicken Approved for Sale in U. S. Accessed in Oct. 2024.
[32] Upside Foods (June 2023). UPSIDE is approved for sale in the US! Here's what you need to know. Accessed in Oct. 2024.
[33] GFI. 2023 State of Global Policy Report

Country	Action Plan and Regulation	Investments	Types of non-animal Protein (plant and alternative)
Netherlands [34,35,36]	• Increasing domestic production of alternative proteins by 50% by 2025 • Policies to guide the population towards an increasingly plant-based diet (60% plant-based proteins and 40% animal-based). • Encouraging Cellular Agriculture by awarding €1M for research • July 2023- the first EU country to enable pre-market tastings of cultivated meat and seafood • Regulatory frameworks developed for cultivated meat with the European Food Safety Authority (EFSA) • Reducing greenhouse gas emissions from livestock production	• Government investment in public-private partnerships to promote R&D in alternative proteins: €60 M allocated to develop plant-based and cultivated meat sectors. • Public funding: 79M$	• Plant-based proteins (soy, peas) • Fermentation-based proteins • Cultivated meat (pioneering lab-grown meat industry)
Australia [37,38]	• Enhancing research, innovation, and industry collaboration • Developing regulatory frameworks for cultivated meat to facilitate commercialization • Reducing greenhouse gas emissions through the promotion of alternative proteins	• The Australian government, along with industry partners investing in R&D initiatives to boost the alternative protein sector • Public funding: 54M$ (by 2023)	• Plant-based proteins (legumes, grains) • Fermentation-based proteins (fungi, algae) • Cultivated meat (developing regulatory frameworks for production)

[34] Health Council of the Netherlands (dec. 2023). A healthy protein transition.
[35] The Netherlands Foreign Investment Agency (NFIA). (2022). Future Protein NL.
[36] GFI. 2023 State of Global Policy Report
[37] Australia's National science Agency. (2022). Australia's Protein Roadmap.
[38] GFI. 2023 State of Global Policy Report

5. Dietary Recommendations

The inclusion of Types of non-animal proteins in dietary recommendations varies between countries (and organizations), reflecting regional dietary habits, cultural preferences, environmental considerations, and health guidelines.

In general, guidelines emphasize consuming protein from a variety of sources within a balanced diet that includes all macronutrients (carbohydrates, fats, proteins) to meet daily nutritional needs. Most dietary guidelines stress the importance of consuming protein from both animals (meat, poultry, fish, dairy, eggs) and plant-based sources (legumes, nuts, seeds, whole grains, and products).

The emphasis is to focus on lean proteins, like poultry and fish, low-fat dairy, and plant-based proteins and limit the intake of saturated fats, highlighting the benefits for sustainability and environmental issues as well as health factors.

Here are some specific examples:

Table 3: Dietary Guidelines

	Source	Protein Recommendations	Emphasized Protein	Nutritional Plate Division	Environmental focus
Canada	Food Guide Plate[39]	Emphasizes plant-based proteins[40]. Specific amounts of plant-based protein are not explicitly outlined	Legumes, nuts, seeds, tofu (plant-based); also includes meat and dairy.	One-quarter whole grains, one-quarter protein foods, half vegetables and fruits.	Shift towards plant-based diets. In 2015, approval of whole algal protein for use[41].
Germany	German Nutrition Society (DGE) [42]	Advocates for reducing meat consumption. Promotes plant-based proteins; more than ¾ plant-based, just under ¼ animal-based.	Legumes, nuts, seeds, whole grains (plant-based); fish, meat, sausages, eggs.	Graphic circle model divided into seven food groups	Advocates a more plant-based approach for health and sustainability.

[39] https://food-guide.canada.ca/en/tips-for-healthy-eating/make-healthy-meals-with-the-eat-well-plate/. released in January 2019. Updated in June 2023. Accessed: July 2024.

[40] https://food-guide.canada.ca/en/healthy-eating-recommendations/make-it-a-habit-to-eat-vegetables-fruit-whole-grains-and-protein-foods/eat-protein-foods/

[41] Government of Canada. Whole Algal Protein to be used as alternative protein source in unstandardized foods. Accessed Sep. 2024.

Government of Canada. Novel Food Information - Whole Algal Protein to be used as alternative protein source in unstandardized foods. Accessed Sep. 2024.

[42] DGE Nutrition Circle

	Source	Protein Recommendations	Emphasized Protein	Nutritional Plate Division	Environmental focus
United States	Dietary Guidelines for Americans (2020-2025) [43]	Encouraging more plant-based protein alongside meat and poultry, less red and processed meat. Plant-based (Nuts, Seeds, Soy Products) recommended: 5 ounces per week (~142 grams) out of 39 ounces protein per week (~1,107 grams)	Beans, peas, lentils, nuts, seeds (plant-based); lean meats, poultry, seafood.	MyPlate[44]: Half plate vegetables and fruits, half grains (whole grains); Dairy not included in the plate but recommended separately	Highlight the benefits of choosing foods that are both healthy and environmentally sustainable.
United Kingdom	The UK's Eatwell Guide[45]	Encourages reduction of red and processed meat; supports plant-based alternatives. Specific amounts of plant-based protein are not explicitly outlined	Beans, pulses, tofu, tempeh, mycoprotein; also includes fish, eggs, meat.	Graphic circle model is divided into five food groups: vegetables and fruits, whole grains, dairy, protein and fats.	Highlighting the importance of considering the environmental impact of food choices
Netherlands	The Netherlands Nutrition Centre's dietary- Wheel of Five[46]	Shifting towards more plant-based proteins encourages a reduction in meat consumption. (58% animal protein, 37% plant protein).	Legumes, nuts, seeds (plant-based); fish, eggs (minor contributions).	Graphic circle model divided into seven food groups	The Wheel takes environmental considerations into account.

[43] DGA. Dietary Guidelines for Americans, 2020-202. https://www.dietaryguidelines.gov/resources/2020-2025-dietary-guidelines-online-materials

[44] USDA. What is MyPlate.? https://www.myplate.gov/eat-healthy/what-is-myplate

[45] https://assets.publishing.service.gov.uk/media/5ba8a50540f0b605084c9501/Eatwell_Guide_booklet_2018v4.pdf

[46] https://www.voedingscentrum.nl/nl/gezond-eten-met-de-schijf-van-vijf.aspx

	Source	Protein Recommendations	Emphasized Protein	Nutritional Plate Division	Environmental focus
Australia	The Australian Dietary Guidelines[47]	Variety of protein sources recommended; emphasize plant-based options. The guidelines do not specify exact portions but recommends on standard serve size of ½ cup (75 grams) cooked dried or canned beans, peas or lentils (preferably with no added salt)	Legumes, nuts, seeds (plant-based); lean meats, poultry, fish, eggs.	A circle divided into five food groups: lean meats and poultry, fish and seafood, eggs, nuts and seeds, legumes and beans, dairy and alternatives.	Highlights environmental benefits of reducing meat; visualized as a circle divided into five food groups.
Singapore	My Healthy Plate[48]	Variety sources of protein. Specific amounts of plant-based protein are not explicitly outlined	Beans, lentils, nuts, seeds, lean meats, poultry, fish, shellfish, eggs, dairy, plant-based alternatives like tofu and tempeh.	A plate Quarter plate whole grains, quarter plate protein, half plate vegetables and fruits.	Promotes sustainability and alternative proteins; government invests in lab-grown meat and other innovative sources.
India	The dietary guidelines for Indians[49]	Emphasis on plant-based proteins due to vegetarian population; includes pulses, beans, nuts, dairy. Recommendations: Pulses and legumes 90 grams per day	Emphasis on plant-based proteins due to vegetarian population; includes pulses, beans, nuts, dairy.	divided into five food groups.	Guideline touch upon aspects of sustainability

[47] Department of Health and Age Care (Australian Government). The Australian Dietary Guidelines. https://www.health.gov.au/resources/publications/the-australian-dietary-guidelines?language=en
Department of Health and Age Care (Australian Government). Eating well. https://www.health.gov.au/topics/food-and-nutrition/about/eating-well?language=en
[48] HealthHub. Nutritious Foods for A Healthy Diet. https://www.healthhub.sg/programmes/nutrition-hub/eat-more
[49] https://main.icmr.nic.in/sites/default/files/upload_documents/DGI_07th_May_2024_fin.pdf

	Source	Protein Recommendations	Emphasized Protein	Nutritional Plate Division	Environmental focus
Denmark	Denmark's dietary guidelines[50]	Encourage more fish and plant-based foods; reduce meat intake. Recommendations: Approximately 100 g per day of legumes	Legumes, nuts, seeds (plant-based); fish; insect-based and lab-grown meat under research.	A brochure of food groups: Protein, grains, vegetables and fruits, fats, encouraging a higher intake of plant-based foods and fish.	Active researching alternative proteins promotes sustainability in food production.
Finland	Finland's dietary guidelines[51]	Emphasizes a plant-based diet and reduces red meat. Specific amounts of plant-based protein are not explicitly outlined	Legumes, nuts, seeds (plant-based); environmentally friendly fish; Exploring alternative proteins like mycoprotein and insects.	Focus on five food groups (Vegetables, fruit and berries; Whole grain products; Fish and fish products; Meat, meat products and eggs; Milk and dairy products)	Emphasizes sustainable food choices; supports reduction of red meat for health and environmental reasons.
Nordic Countries	The Nordic Diet Recommendations[52]	Variety of nutrient-rich foods; moderate amounts of animal proteins. Recommendations: Pulses and legumes 100 grams per day	Fruits, vegetables, whole grains, beans, legumes, nuts, seeds (plant-based); fish, dairy, eggs, limited meat.	Focus on a variety of nutrient-rich foods; promotes a balanced diet.	Focus on environmentally sustainable diets; combines diverse protein sources including both animal and plant-based proteins.

[50] https://en.fvm.dk/news-and-contact/focus-on/the-danish-official-dietary-guidelines
[51] https://www.ruokavirasto.fi/en/foodstuffs/healthy-diet/nutrition-and-food-recommendations/
https://www.ruokavirasto.fi/en/foodstuffs/healthy-diet/sustainable-food-choices-on-the-plate/
[52] The Nordic Nutrition Recommendations (NNR) 2023

	Source	Protein Recommendations	Emphasized Protein	Nutritional Plate Division	Environmental focus
EAT-Lancet	Planetary Health Plate [53]	Variety of protein sources (red meat, poultry, eggs, fish, Legumes and nuts), Emphasizing moderation of animal protein, increasing the consumption of plant-based proteins. Recommendations: Pulses and legumes 75 grams per day	Red meat, poultry, eggs, fish, Legumes and nuts	A plate of half vegetables and fruits; half should contain whole grains, plant protein sources, unsaturated vegetable fats and modest amounts of animal protein sources.	The guidelines aim to balance nutritional needs with environmental sustainability.
Israel	The Ministry of Health's Food Rainbow[54]	Mediterranean diet which encourages less animal food (especially red meat) and more plant protein Recommendations: Pulses and legumes 74 grams per day	Red meat, poultry, eggs, fish, Legumes, nuts and seeds	graphic rainbow visualization of five groups: vegetables, fruits, and whole grains; olive/canola oil, tahini, nuts, legumes, milk, dairy products and alternatives; poultry, fish, and eggs; red meat	Food rainbow encourages to choose sustainable and environmentally friendly protein sources

[53] EAT. Food Planet Health. Summary Report of the EAT-Lancet Commission.
[54] Ministry of Health, Nutrition Branch (2020). Healthy is Possible. Israel's New Food Rainbow

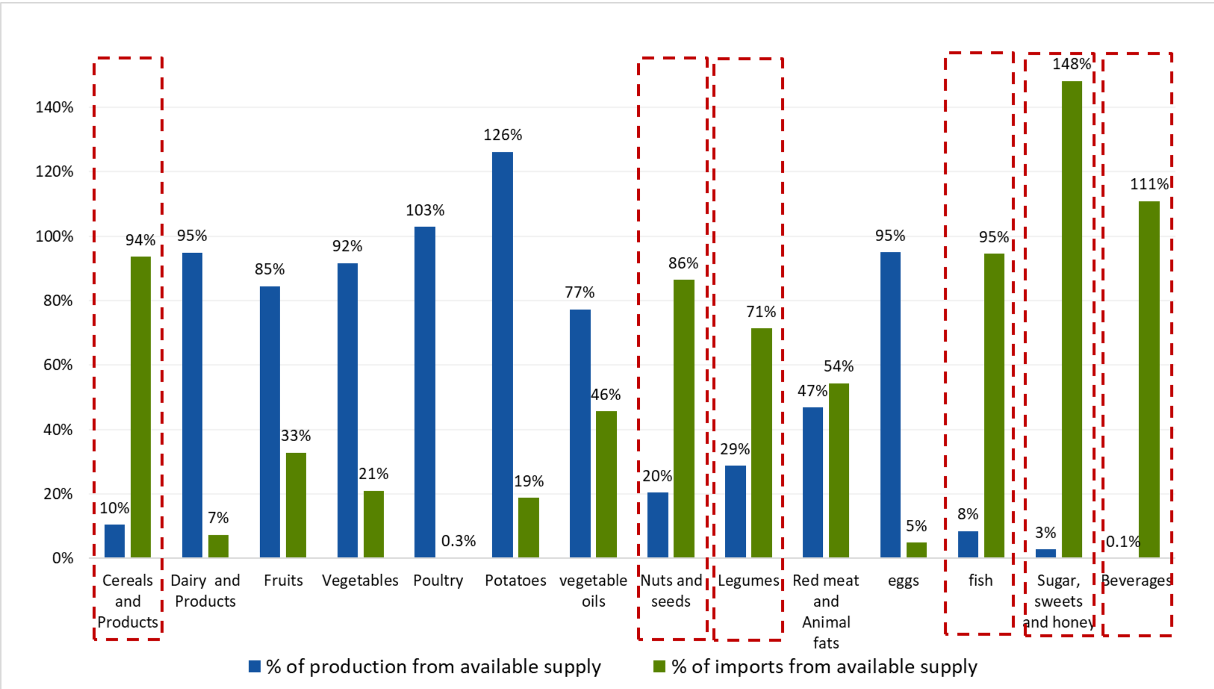
6. The protein required for Israel

The chapter provides an overview of various food groups focusing on the protein they provide.

6.1 Protein food sources in Israel

The 2022 data indicates that Israel's Self Sufficiency Ratio (SSR)[55] is low in food groups such as fish, cereals, legumes, nuts and seeds (Figure 2). Therefore, there are immediate risks to the future available supply[56] of these food groups in Israel. On the other hand, Israel's SSR is high in the production of poultry, including eggs, and in the production of dairy and dairy products.

Figure 2: Ratio of Production and Import out of available food groups for protein supply (2022)



* Processing by Samuel Neaman Institute of CBS data: Table 4 Food Balance Sheet 2022, published: September 29, 2024.

* Food groups were calculated according to the food groups in the "Israeli Food Plate 2050" report, updated to the 2022 balance report[57]

* **Self-Sufficiency Ratio (SSR) = production / available supply**

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[55] Self Sufficiency Ratio (SSR) – pertains to the percentage of domestic production out of available supply. From: Israeli Ministry of Environmental Protection (2023). Summary report: committee for implementing preparation of food systems to climate change for 2030. Publication date 09/21/2023; Updated on 09/24/2023. Retrieved 03/04/2024.

[56] Available Supply in Food Balance Sheet - Includes local production plus changes in stocks and imports, minus exports, of the surveyed year. Available supply includes other uses and depreciation, meaning use to produce another consumer good item that is included in the balance (animal feed, seeds for planting, and industry uses)

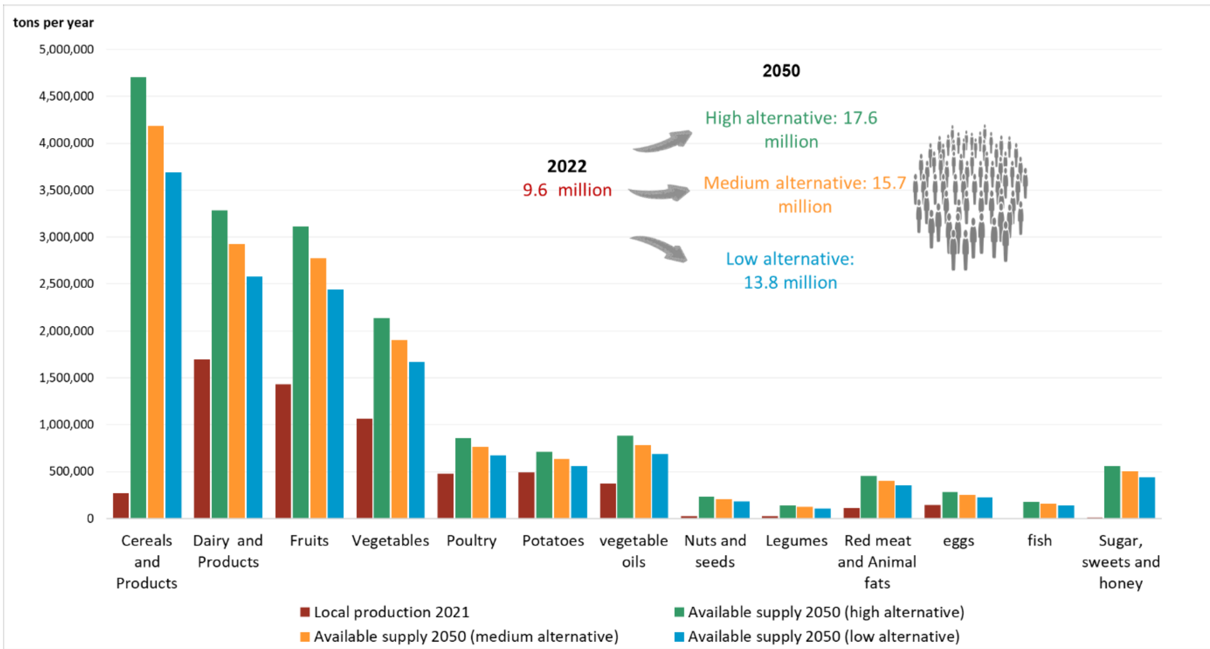
[57] Shimoni, E., Tziperfal, S., Shapira, N., Ayalon, O., Ben-Haim, Y., Dayan, T., Tal, T., Fortuna, G., Flugelman, A., Raviv, O., & Shoham, A. (2024). "Scenarios and National Goals for Food Security in 2050" a Second Interim Report Within the Israel 2050 Food Security Project. Samuel Neaman Institute.

6.2 Demographic consideration

In 2022 about 9.5 million tons per year of available food supply[58] were required per year, of which 2.9 million tons per year for protein sources[59]. One should consider that the overall available protein is much higher, however, from sources such as cereals that are not considered as high-quality protein.

In 2050, according to the expected population growth, food supply will range from about 14-18 million tons per year, of which approximately 4.2-5.4 million tons per year will be required for protein sources (animal-based, legumes, nuts and seeds)[60]. Looking at the high alternative of demographic growth, the need for protein sources will grow from 2022 to 2050 by 84%, from 2.7-5.05 million tons per year for animal-based products respectively, and from 0.2-0.37 million tons per year for plant-based products (legumes, nuts and seeds) respectively. Whether the low or high growth forecast is realized, Israel must prepare for a much higher supply than the current one to meet needed protein supply.

Figure 3: Production 2022 and Available Supply 2050 (entire Israeli population, tons per year)



* Processing of CBS data by Samuel Neaman Institute: Chart 2.10 Israel population forecast (1) for 2025-2065, by population group, sex and age, published 12/09/2023; Chart 2.3 Population, by population group, religion, sex, and age. Published 12/09/2023; Table 4 Food Balance Sheet 2022, published: September 29, 2024. * Food groups were calculated according to the food groups in the "Israeli Food Plate 2050" report, updated to the 2022 balance report[61]

[58] Available Supply in Food Balance Sheet - Includes local production plus changes in stocks and imports, minus exports, of the surveyed year. Available supply includes other uses and depreciation, meaning use to produce another consumer good item that is included in the balance (animal feed, seeds for planting, and industry uses).

[59] approximately 2.7 million tons for animal sources, including dairy and eggs, and the rest for plant protein sources, i.e. legumes, nuts and seeds

[60] Plat-Based Protein Products (raw materials): nuts and seeds, legumes; Animal-Based Protein Products (raw materials): red meat and animal fats, poultry, eggs, fish, dairy and dairy products

[61] Shimoni, E., Tziperfal, S., Shapira, N., Ayalon, O., Ben-Haim, Y., Dayan, T., Tal, T., Fortuna, G., Flugelman, A., Raviv, O., & Shoham, A. (2024). "Scenarios and National Goals for Food Security in 2050" a Second Interim Report Within the Israel 2050 Food Security Project. Samuel Neaman Institute.

6.3 Recommended Nutrition Plate

6.3.1 The Nutritional Rainbow - Ministry of Health's

מתוך אתר משרד הבריאות – אגף התזונה

In June 2020, the Ministry of Health published its new nutrition recommendations[62] for the Israeli public, the main recommendation being adhering to a mediterranean diet recommending on more plant-based proteins and less protein from red meat. Beyond the health aspect, a mediterranean diet has environmental, economic, and socio-cultural advantages, as well as advantages in coping with epidemics and climate crises[63]. The new recommendations are visualized as a "nutritional rainbow". Unlike the food pyramid, the new nutritional rainbow considers foods according to their level of processing (and not according to ingredients)[64] and is built as a graphic visualization of the nutrition recommendations. The different rainbows (in different colors) reflect the recommended consumption frequency according to the following principles:

- Green rainbow – vegetables, fruits, and whole grains: diversify daily
- Yellow rainbow – olive/canola oil, tahini, nuts, legumes, milk, dairy products and alternatives: at least once a day
- Orange rainbow – chicken, turkey, fish, and eggs: diversify weekly
- Pink rainbow – beef: up to 300 grams a week
- Red rainbow – foods that are best avoided

6.3.2 Choosing the Nutrition Plate Composition

To propose the recommended nutrition plate, we compared the daily nutritional composition (quantity in grams per day, calories per day, in each food group) from several sources (Israel, EAT Lancet, Germany, Nordic Nutrition, and Singapore). These specific sources were chosen for several reasons, including having sufficient information from which to extrapolate about the food groups, and diversification in food and dietary culture.

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[62] Ministry of Health, Nutrition Branch (2020). Healthy is Possible. Israel's New Food Rainbow.

[63] FAO (2017). Mediterranean food consumption patterns. White Paper.

The Knesset's Research and Information Center (2023), Health recommendations about meat consumption in Israel and in various countries

Adler Dorit (2021), Food Security and the Climate Crisis – the Mutual Influence of Food on the Environment and the Obesity Epidemic, Food Insecurity and Climate Emergency. Israeli Forum for Sustainable Nutrition, Change Direction.

[64] Ministry of Health. The new food spectrum

The food groups were established based on several sources: CBS[65], the Ministry of Health's Nutritional Rainbow[66], and EAT Lancet's nutritional table[67]. These sources were chosen for the following reasons:

- The Israeli Ministry of Health and the World Health Organization[68] recommend the mediterranean diet as it promotes longevity and is connected to a lower risk of developing chronic illnesses such as cardiovascular diseases, diabetes, and certain types of cancer. The mediterranean diet also helps manage and maintain a healthy weight. The mediterranean diet is based on the traditional nutrition of the countries along the Mediterranean Basin, and includes a high consumption of fruit, vegetables, whole grains, nuts, legumes, olive oil, fish; moderate consumption of chicken, eggs and dairy products (especially yogurt and cheese), and sparse consumption of red meat.
- The Ministry of Health's Nutrition Branch has provided detailed recommendations about plate composition with reference to the various food groups.
- EAT Lancet is a global science-based platform for changing food systems. Recommendations in the EAT Lancet report were established by leading scientists from 16 countries and various disciplines (human health, agriculture, nutrition, political science, and environmental sustainability) to define global scientific goals for a healthy diet and sustainable food production[69].

We also sought to adapt our food groups as much as possible to the food groups specified in the CBS's Food Supply Balance, to allow future conclusions about the required levels of domestic production and import based on the nutritional plate. In all chosen sources, quantities were calculated in daily grams per capita for each food group. The caloric calculation in each food group was conducted based on EAT Lancet's nutritional table.

Examining the nature of the recommended plate, we have found that the World Health Organization also recommends a mediterranean diet[70,71]. The mediterranean diet is at the center of the Ministry of Health's recommendations and can be suitable for the geography and overall culinary character of the Israeli residents' diet. Therefore, the nutrition plate based on the Ministry of Health's Food Rainbow is the plate recommended **by us[72]**.

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65 CBS. Chart 21.20 Food Supply Balance 2021. Published 08/29/2023.
66 Ministry of Health, Nutrition Branch (2020). Healthy is Possible. Israel's New Food Rainbow.
67. Food Planet Health. Summary Report of the EAT-Lancet Commission.
68 WHO. (2023), Director-General's remarks at Food Systems Summit – 24 July 2023.
69 The EAT-Lancet Commission on Food, Planet, Health
70 https://www.who.int/news-room/fact-sheets/detail/healthy-diet.
71 The WHO recommends other dietary compositions, such as Nordic and Japanese nutrition, but emphasizes the importance of adapting the diet to local culture and local food systems.
72 Shimoni, E., Tziperfal, S., Ayalon, O., Blekhman, A., Ben-Haim, Y., Dayan, T., Tal, T., Fortuna, G., Flugelman, A., Raviv, O., Klein, R., Shoham, A., & Shapira, N. (2024). "The Israeli nutrition plate in 2050" an interim report within the Israel 2050 food security project. Samuel Neaman Institute.

6.3.3 Protein Sources in the Israeli Plate

Recommended protein sources merit a dedicated discussion, as various nutrition recommendations assert that red meat consumption should be minimized and replaced with non-animal protein sources (such as legumes, nuts and seeds) as well as modern food tech proteins from precision fermentation, cultivated meat, algae, and mycelium). This recommendation is supported by the following reasons[73]:

- Health: consumption of red meat and processed meat has been connected to chronic illnesses such as cardiovascular diseases, cancer, and diabetes. Reducing consumption can help reduce the risk of these diseases.
- Environment and sustainability: the meat industry contributes to greenhouse gas emissions, water and soil pollution, and waste of natural resources (including animal feeding). Reducing consumption can reduce the adverse environmental impact.
- Animal welfare: the meat industry often entails harsh conditions for animals. Reducing consumption can contribute to improving animal welfare.

6.3.4 Production and Demand 2050 - Israeli Plate

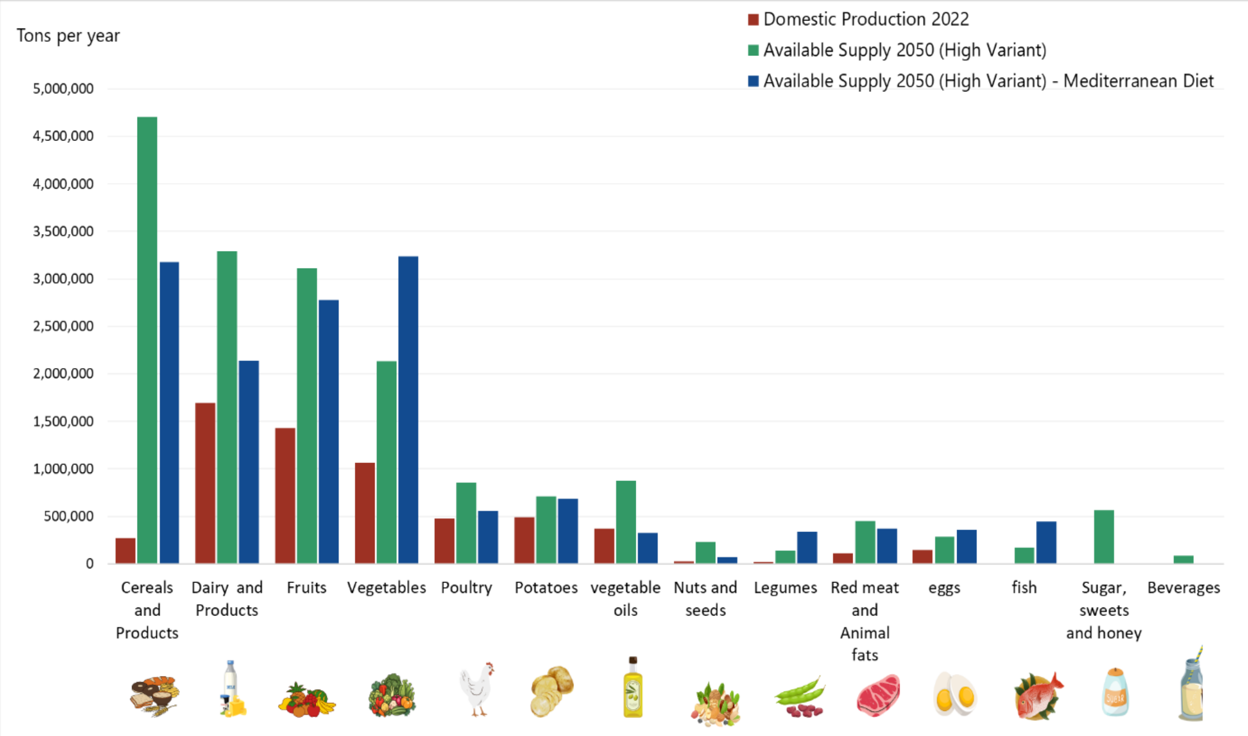
When examining the food quantities required for 2050, we should also consider the impact of the population's dietary habits. As aforementioned (Figure 3), given production and consumption characteristics like the current ones, the required available supply[74] will be higher (in million tons). However, if we change the Israeli diet according to the nutrition plate recommendations, the gaps between current production and future demand will be reduced across most food groups (Figure 4).

It is important to note that alongside a decrease in most categories, there will be an increase in legumes, which are considered a healthy non-animal protein and vital to a sustainable diet. Additionally, there will be a growing need for eggs and fish to meet dietary recommendations and population preferences. Addressing these increases will require focused efforts to enhance production for these food groups. Furthermore, non-animal protein sources, such as plant-based proteins, cultivated meat, and insect-based products, must be incorporated into long-term planning to ensure a resilient and sustainable food system capable of meeting future nutritional demands.

[73] The Knesset's Research and Information Center (February 2023). Health recommendations about meat consumption in Israel and in various countries.

[74] Available Supply in Food Balance Sheet - Includes local production plus changes in stocks and imports, minus exports, of the surveyed year. Available supply includes other uses and depreciation, meaning use to produce another consumer good item that is included in the balance (animal feed, seeds for planting, and industry uses)

Figure 4: Production 2022 and Available Supply 2050 as Required for Nutrition Plate (tons per year)



* Processing of CBS data by Samuel Neaman Institute: Chart 2.10 Israel population forecast (1) for 2025-2065, by population group, sex and age, published 12/09/2023; Chart 2.3 Population, by population group, religion, sex, and age. Published 12/09/2023; Table 4 Food Balance Sheet 2022, published: September 29, 2024. Ministry of Health – Israel's New Nutritional Rainbow
* Food groups were calculated according to the food groups in the "Israeli Food Plate 2050" report, updated to the 2022 balance report[75]
* Categories: Sugar, sweeteners, and honey; and Beverages (including stimulants), are not included in the dietary recommendations.

The recommended total protein intake, including proteins from fruits and vegetables, as outlined by the recommended nutritional plate, is approximately 91 grams per capita per day (of which, 13% legumes). This is lower than the actual protein supply reported by the Central Bureau of Statistics (CBS), which is approximately 110 grams per capita per day (of which, 4% legumes), as depicted. The discrepancies are observed in various protein sources derived from animals (including poultry, dairy and dairy products, red meat and animal fats) as well as from grains and their derivatives. According to the nutritional plate guidelines, the consumption of these protein sources should be reduced, while the intake of alternative sources, such as fish and legumes, should be increased.

Gaps analysis between current consumption and the projected appropriate consumption levels for 2050 reveals a series of challenges. Foremost among these is the need for a significant increase in per capita consumption of legumes, alongside a marked decrease in poultry, meat, and dairy products. These consumer-level adjustments will rely on a range of product

[75] Shimoni, E., Tziperfal, S., Shapira, N., Ayalon, O., Ben-Haim, Y., Dayan, T., Tal, T., Fortuna, G., Flugelman, A., Raviv, O., & Shoham, A. (2024). "Scenarios and National Goals for Food Security in 2050" a Second Interim Report Within the Israel 2050 Food Security Project. Samuel Neaman Institute.

categories, such as raw dried legumes, plant-based dairy substitutes, plant-based meat alternatives, poultry and fish substitutes, as well as cultivated meat, fish, and poultry products. In terms of raw materials, the focus will be on plant-based proteins, fermentation-derived proteins, algae and microalgae proteins, mycelium/mushrooms, as well as insects and insect-derived proteins. The next chapter will discuss these protein sources and their potential impact on self-sufficiency rates.

7. Available solutions

Traditional protein intake

According to Samuel Neaman Institute interim report "The Israeli nutrition plate in 2050" [76], animal-based products account to 52% from the total products contributing to protein intake in 2050, while plant-based protein account to 48% of these products (by product weight). This means that we will need approximately 3.9 million tons of animal-based products (red meat and animal fats, poultry, eggs, and dairy products), and 3.6 million tons of plant-based products (cereals and products, legumes, nuts and seeds), as detailed in Figure 5.

Reducing animal protein contributes to food security in Israel and to Israel's self-reliance rate (SSR). In addition, reducing animal protein consumption is important for Israel's nutritional security and for the health of Israelis. Since most grains are imported (Figure 2) and since grains are required for animal feed, reducing the consumption of animal protein will reduce the need for grain imports and contribute to increasing Israel's self-sufficiency ratio (SSR). Also, replacing consumption of conventional animal protein, will contribute to decrease of imports, increasing Israel's SSR.

In Samuel Neaman interim report discussing scenarios and national goals for Israel's food security in 2050[77], it was suggested that a target of 60% Percentage of non-animal protein in the total protein intake will help to increase Israel's self-sufficiency ratio. We believe that the appropriate target for the State of Israel for 2050 is a reliance of **no more than** 40% animal protein.

According to the net protein supply required in 2050 (Figure 6), the largest plant-based protein supply will come from cereals and products, with a substantial volume of 230K tons per year. Among plant-based sources, legumes (more than 77K tons, 5 times more than in 2022) are also a significant contributor. Animal-based protein will contribute to protein supply more than 340K tons, with a substantial volume of more than 102K from poultry, followed by fish (more than 78K tons) and dairy and products (more than 65K tons). The substantial contribution of plant-based proteins (especially cereals and legumes) to the Mediterranean diet highlights the importance of plant-based food in meeting protein demands. Plant-based proteins may become increasingly critical as populations grow (17.6 million projected for 2050) and environmental sustainability becomes a priority.

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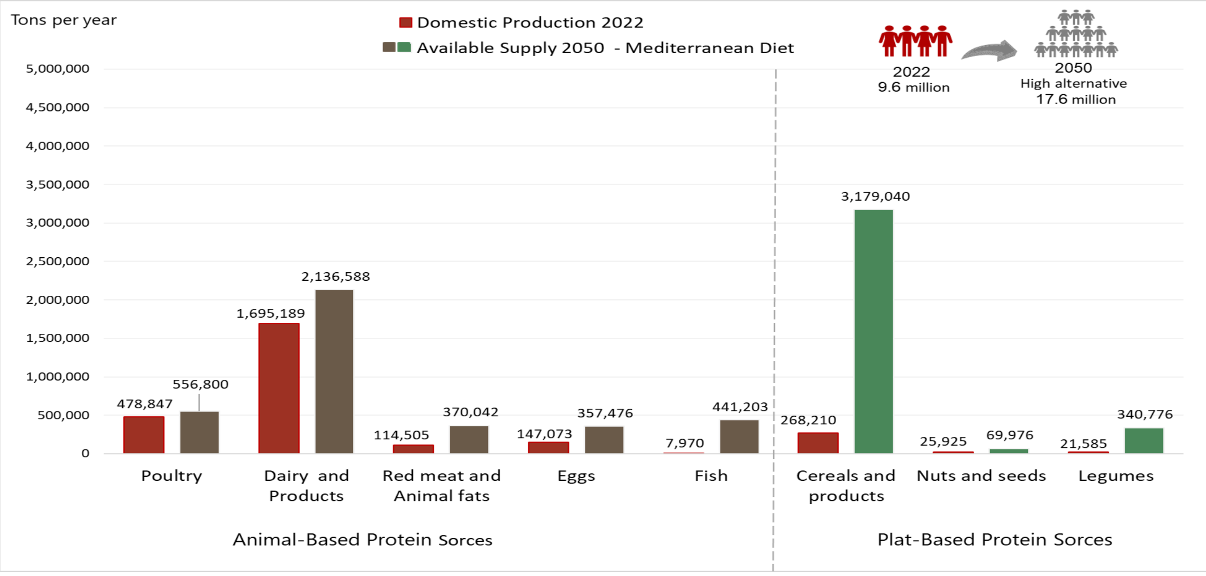
[76] Shimoni, E., Tziperfal, S., Ayalon, O., Blekhman, A., Ben-Haim, Y., Dayan, T., Tal, T., Fortuna, G., Flugelman, A., Raviv, O., Klein, R., Shoham, A., & Shapira, N. (2024). "The Israeli nutrition plate in 2050" an interim report within the Israel 2050 food security project. Samuel Neaman Institute.

[77] Shimoni, E., Tziperfal, S., Shapira, N., Ayalon, O., Ben-Haim, Y., Dayan, T., Tal, T., Fortuna, G., Flugelman, A., Raviv, O., & Shoham, A. (2024). "Scenarios and National Goals for Food Security in 2050" a Second Interim Report Within the Israel 2050 Food Security Project. Samuel Neaman Institute. (HEB). https://www.neaman.org.il/en/scenarios-and-national-goals-for-food-security-in-2050/

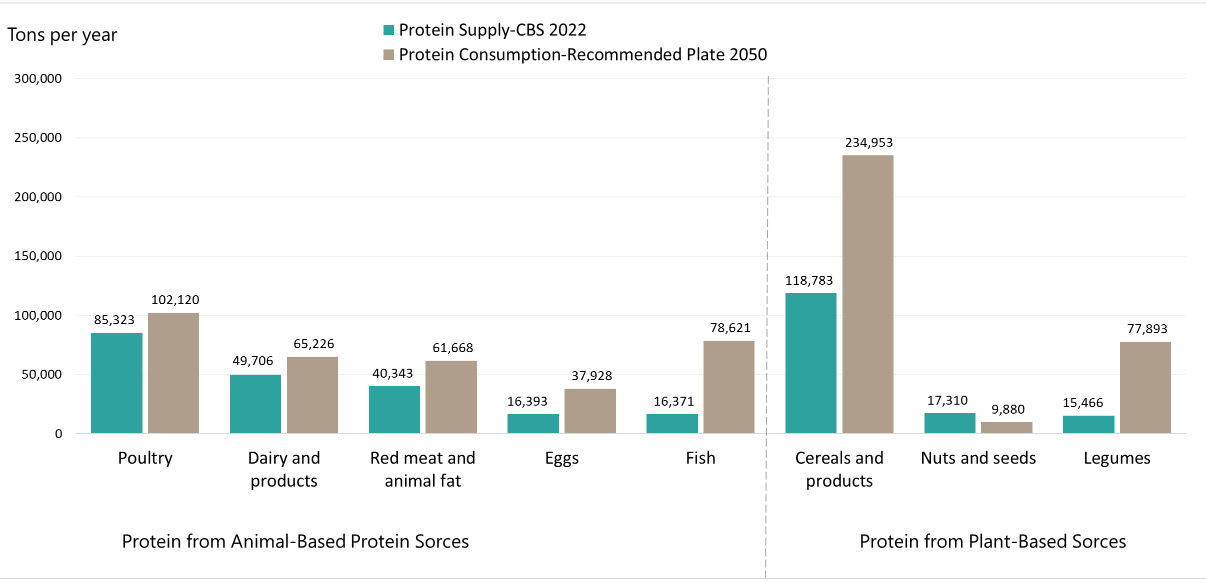
Figure 5: Required supply of raw materials for protein in 2050 vs domestic supply in 2022 (tons per year)



* Domestic production: Processing of CBS data by Samuel Neaman Institute: Table 4 Food Balance Sheet 2022, published: September 29, 2024. Population: Processing of CBS data by Samuel Neaman Institute: Processing of CBS data by Samuel Neaman Institute: 2.10 Israel population forecast (1) for 2025-2065, by population group, sex and age, published 12/09/2023

* Mediterranean Diet based on Based on the nutrition plate, Samuel Neaman Institute publication (2024)78.

Figure 6: Net protein supply in 2022 (CBS) and in 2050 Mediterranean Diet, Tons per year



* Domestic production: Processing of CBS data by Samuel Neaman Institute: Table 4 Food Balance Sheet 2022, published: September 29, 2024. Population: Processing of CBS data by Samuel Neaman Institute: Processing of CBS data by Samuel Neaman Institute: 2.10 Israel population forecast (1) for 2025-2065, by population group, sex and age, published 12/09/2023

* Mediterranean Diet based on Based on the nutrition plate, Samuel Neaman Institute publication (2024)[79].

[78] Shimoni, E., Tziperfal, S., Ayalon, O., Blekhman, A., Ben-Haim, Y., Dayan, T., Tal, T., Fortuna, G., Flugelman, A., Raviv, O., Klein, R., Shoham, A., & Shapira, N. (2024). "The Israeli nutrition plate in 2050" an interim report within the Israel 2050 food security project. Samuel Neaman Institute.

[79] Shimoni, E., Tziperfal, S., Ayalon, O., Blekhman, A., Ben-Haim, Y., Dayan, T., Tal, T., Fortuna, G., Flugelman, A., Raviv, O., Klein, R., Shoham, A., & Shapira, N. (2024). "The Israeli nutrition plate in 2050" an interim report within the Israel 2050 food security project. Samuel Neaman Institute.

Non-animal protein sources (plant-based and alternative)

The term “alternative protein” is often misinterpreted. Since the main goal is to reduce animal sourced protein due to self-sufficiency, health and sustainability goals – we use an interchangeable term: “**non-animal protein**”. As mentioned, non-animal protein can come from various alternative sources: plant protein, precision fermentation protein, algae and microalgae protein, mycelium / fungi, as well as insects and insect protein. In appendix A we try to describe the main foreseen sources of non-animal protein that can help reduce animal protein sourcing.

8. Alternatives Analysis

In the pursuit of enhancing Israel's food security, an analysis of alternative strategies is essential. This analysis aims to evaluate how each proposed solution influences key food security indicators, notably self-reliance. Self-reliance can empower communities and regions to achieve greater autonomy in food production and distribution. Furthermore, it is crucial to consider the time frames within which these strategies can be effectively implemented. Understanding the practical timelines will allow prioritize and allocate resources efficiently. Finally, the examination of risks and prospects associated with the significant and impactful implementation of each solution is imperative. Identifying potential obstacles and opportunities will enable a more informed decision-making process, ensuring that the chosen alternatives not only address current challenges but also contribute to sustainable food security in the long term.

8.1 How can each protein source affect Israel's self-sufficiency?

Environmental impacts

During the preparation of the comparison between various protein sources, diverse information sources were reviewed, providing current and scientifically grounded data regarding their environmental impacts. These sources include studies addressing greenhouse gas emissions, resource utilization such as land and water, and the energy consumption required for the cultivation and production of different protein sources.

Climate Studies and Greenhouse Gas Emissions: The document "Climate Impacts of Alternative Proteins" (Collett et al., 2021) is one of the key sources on this topic, presenting an in-depth analysis of greenhouse gas emissions from various protein sources, such as beef, poultry, and fish, in comparison to cultivated protein and precision fermentation. The study emphasizes the significant environmental impact of cattle farming concerning greenhouse gas emissions and land use, while protein sources like plant-based protein, cultivated protein, and precision fermentation demonstrate potential for reducing environmental impact.

Water and Land Resources: Other studies focus on the utilization of water and land in various protein sources. For instance, fish farming in pond systems shows relative efficiency in land use, while plant-based protein sources require less water and land compared to beef and poultry. Algae and microalgae, despite needing unique cultivation systems, are characterized by minimal land use.

Energy and Raw Materials: When examining energy consumption, studies indicate that cultivated protein and precision fermentation are energy-intensive processes but still offer advantages in terms of emissions and pollution. As previously noted, from a food security perspective – these protein sources are of importance in reducing the volumes of animal-feed imports. In addition, we can expect more use of renewable energy and improving their efficiency.

The integration of research data from these sources allows for a comprehensive comparison between different protein sources, focusing on the efficiency and sustainability of each source in terms of resource use and environmental impact.

Undoubtedly, the low conversion ratio of raw materials to each kilogram of protein when the source is animal-based increases the quantity of raw materials required for production (Herrero, et al., 2013). Therefore, the central question before us is how to increase the proportion of non-animal protein within the overall protein consumption in Israel.

Table 4: Needed resources Estimation to create a kilogram of protein from different protein sources[80]

Product	Land (m^2/kg)	Water (liters/kg)	Energy (MJ/kg)	Raw Materials (kg)	Group
Cattle	18-37	5,000-20,000	40-50	25	Fodder and grains
Poultry	7-12	2,000-5,000	20-30	9	Food mixture
Fish	2-6	4,000-8,000	15-25	1.5-2	Fish food mix
Plant-based Protein	1-5	500-2,000	10-20	2-4	
Cultivated Meat	<1	1,000-3,000	60-70	1-2	Cell culture media and biological supplements
Precision Fermentation Protein	<0.5	500-1,500	30-40	1-1.5	Fermentation medium (such as sugars and minerals)
Algae	<1	1,000-4,000	20-30	0.5-1	Aquatic growing medium rich in nutrients
Mushrooms	1-2	1,500-2,500	20-30	0.5-1	A growth medium based on carbohydrates and sugars
Insects	<1	500-1,000	10-20	1-2	Organic waste or recycled food mixes

8.2 What is the time frame in which it can be practical

8.2.1 Global predictions

According to our expert questionnaire respondents, **market potential** for new non-animal proteins depends on the customer audience. Different audiences show high potential for adopting non-animal protein proteins, including vegans, vegetarians and flexitarians, but also traditional religious people and athletes. Meat consumers may find value in new non-animal proteins to upgrade traditional dishes, offering a new and innovative approach to the market.

80 Collett K, O'Callaghan B, Mason M, Godfray C, Hepburn C. 2021. The climate impact of alternative proteins Rep. Smith Sch. Enterp. Environ., Univ. Oxford Oxford, UK

Environmental and health awareness can raise the potential for consuming non-animal protein proteins, especially among young people.

The global trend supports consuming non-animal protein proteins, and Israel aligns closely, even leading in areas like veganism. However, higher costs of plant-based alternatives in Israel remain a barrier. Some companies succeed by offering unique products rather than competing directly with meat. "In Israel, there is an excellent example that we can learn from – Tivall, which offered a plant-based alternative decades ago that is similar to meat alternatives but does not pretend to compete directly with them but rather offers a different product". Hybrid products combining animal and non-animal proteins offer a practical path to reduce meat consumption. Regulatory support, catering industry commitments, and dedicated shelf space for alternatives are crucial for market growth. Despite challenges, Israel has the potential to thrive in the non-animal protein sector by leveraging innovation and global developments.

Realistic predictions for the extent of non-animal protein compared to animal protein for the years 2030, 2040, and 2050 vary depending on technological advancements, consumer adoption, and regulatory support. Here are some key estimates based on available industry analyses:

1. **By 2030**:
   - Non-animal proteins are expected to make up around **10-20%** of total protein consumption globally, driven by increasing consumer demand, improvements in production, and sustainability concerns. Products such as plant-based meats and cultivated meats will likely become more accessible and cost-competitive (BCG Global) (Future Insights).
   - Plant-based proteins (e.g., pea, soy) will lead, with cultivated meat gradually entering the mainstream. Precision fermentation and microbial proteins will also play a significant role (McKinsey & Company).
2. **By 2040**:
   - Non-animal proteins could account for up to **30-40%** of total global protein consumption. This growth will be bolstered by regulatory frameworks, technological advancements, and more supportive policies like carbon taxation and agricultural subsidy reallocations (World Economic Forum).
   - Cultivated meat and microbial proteins will likely see increased consumer acceptance as costs decrease and production scales up (McKinsey & Company).
3. **By 2050**:
   - Predictions suggest that non-animal proteins could make up more than **50%** of total protein consumption. This shift would be essential to meet growing global food demands sustainably, especially considering environmental constraints like water and land use (World Economic Forum)(Future Insights).

- Technological breakthroughs, such as efficient production methods for cultivated meats and microbial proteins, will be key drivers of this transformation (McKinsey & Company).

These predictions vary depending on consumer acceptance, policy support, and the pace of technological improvements, but the trend towards non-animal proteins is clear and accelerating across these timeframes. Examining these predictions against reality already points to significant gaps. Some reports suggested that by 2025, there would be massive sales of cultivated meat in various countries – but the reality is vastly different. Therefore, these forecasts should be approached with the appropriate level of skepticism.

Predictions also depend on various factors such as the regulatory environment, consumer demand, and technological breakthroughs in the production of non-animal proteins. The regulatory status of non-animal proteins varies globally. The United States has approved cultivated meat for sale through both FDA and USDA, setting a regulatory precedent. In the European Union, cultivated meat is regulated under the Novel Foods Regulation, with some countries like the Netherlands allowing pre-market tastings. Singapore remains a leader, being the first to approve cultivated meat in 2020. Other regions like Brazil and China are developing frameworks, focusing on safety assessments and regulatory pathways (The State of Global Policy on Alternative Proteins).

While the consumption of plant-based alternatives is wide, Israel has a high dependency on raw materials spread and largely depends on taste and price, consumer willingness to adopt products based on precision fermentation or cultivated proteins remains unclear and has not yet faced the test of reality. As such, these forecasts should be approached with caution. Policymaking that supports the transition to non-animal proteins is essential, but it should not overlook the challenges these products face in achieving substantial market entry. Above all, the key question is the time frame for the technological feasibility of mass production at a price comparable to that of animal-based products.

8.2.2 Timelines for mass production

In order to become an effective part of our toolbox for reducing animal protein consumption, non-animal protein sources need to be mature enough in terms of science, safety, cost effectiveness, and taste. Once these are resolved, the biggest issue is how fast we can scale them so they can replace a significant part of the animal protein currently consumed. To understand the magnitude of the challenge we should keep in mind some key figures: the global meat production is over 350 million tons per year (140 poultry, 120 pig, 80 bovine, 15 ovine)[81] and for milk proteins it is over 980 million tons[82]. In Israel, reducing animal derived protein by 23% (from 52% to 40%) of the protein in 2050 represents over 37,000 tons of "Red meat" alternatives and

[81] FAO. Meat Market Review. Overview of market and policy developments in 2022.
[82] FAO. Dairy Market Review. Overview of global market developments in 2024.

over 210,000 tons of alternative milk and dairy products. These figures represent a significant national challenge. In the following paragraph we will review some challenges and opportunities in the scale up journey.

Scaling plant protein sources can happen relatively quickly compared to other alternative proteins, but it depends on several factors including investment, infrastructure, and consumer demand. Many plant-based protein sources, like pea and soy, already have established supply chains, making it easier to scale production rapidly. Companies are increasingly investing in the development of efficient crop varieties and processing methods to meet growing demand.

However, bottlenecks in scaling include the need for more sustainable agricultural practices that will secure long term capacity, advanced processing technologies, and resolving challenges related to taste and texture to ensure consumer acceptance. The timeline for scaling plant-based proteins could be significantly accelerated with increased public and private sector investment, as well as supportive government policies (BCG Global) (World Economic Forum).

The scaling of dairy proteins produced by precision fermentation can occur at a moderate pace and is influenced by a few key factors such as technology, infrastructure, regulatory approval, and consumer demand. Precision fermentation has already advanced significantly, and some companies have demonstrated the ability to produce dairy proteins at a commercial scale. However, expanding production further will require investment in large-scale bioreactors, optimizing microbial strains, and improving fermentation yields. These advancements could enable substantial scaling over the next 5 to 10 years (BCG Global) (Future Insights). Precision fermentation-derived dairy proteins are subject to stringent regulatory reviews in different regions. Companies need to navigate approval processes, which can slow down scaling efforts. For example, in the U.S. and Israel, precision fermentation-derived dairy proteins like whey have received approval, but global acceptance will depend on diverse regulatory landscapes (Future Insights). Once the production and regulatory hurdles are cleared, consumer demand will drive market scaling. Products with dairy proteins from precision fermentation are already appearing in markets like the U.S. and Singapore, but broader acceptance is needed to reach full-scale production.

Still, the most significant challenge is that the current fermentation infrastructure needs significant expansion to meet future demands. New production facilities will be required, and the building of these facilities could take several years. Additionally, the supply chain for fermentation feedstocks (like sugars) must be secured and scaled up (World Economic Forum). Overall, the scaling of precision fermentation for dairy proteins could reach significant levels in 5 to 10 years, particularly if investment in infrastructure and regulatory approvals is fast-tracked.

Scaling cultivated meat and fish to mass production is expected to be slower than other alternative proteins due to several key challenges, but advancements are being made. ***Technological Barriers***: Cultivated meat and fish require complex technology to replicate the texture, flavor, and structure of conventional animal meat. Achieving cost-effective and large-scale production involves improving bioreactor capacity, cell culture media, and scaffolding technologies. Currently, these technologies are still in the early stages of commercial readiness. Experts predict that scaling to mass production could take 5 to 10 years under optimistic conditions (World Economic Forum)(Future Insights). ***Cost Efficiency***: At present, the production cost of cultivated meat is significantly higher than conventional meat. Reducing costs will depend on innovations in cell culture media and optimizing production processes. Many companies are working to bring down the cost from hundreds of dollars per kilogram to competitive pricing, which is necessary for scaling (McKinsey & Company). ***Infrastructure***: Large-scale production will require the construction of specialized biomanufacturing plants, which is capital intensive. Building this infrastructure could take several years, depending on investment and technological improvements (Future Insights). ***Regulatory Approvals***: Regulatory hurdles vary across regions. While countries like Singapore, Israel and the U.S. have approved the sale of cultivated meat, widespread adoption across other countries is still pending. Regulatory clarity will be crucial to scaling cultivated meat globally (McKinsey & Company). ***Consumer Acceptance***: Even once the technology and regulatory issues are solved, scaling will also depend on consumer demand and acceptance of cultivated meat products, which remains uncertain at this stage.

Given these factors, achieving large-scale, affordable production of cultivated meat and fish could take between 5 to 15 years, depending on how quickly the challenges in technology, cost, and regulation are addressed (McKinsey & Company).

Scaling algae and microalgae protein sources could happen relatively quickly, though there are several hurdles to overcome. ***Technology and Production***: Algae and microalgae are already being produced at small-to-medium scales for various applications, including food and supplements. The technologies for growing and harvesting are relatively well-established, especially for species like spirulina and chlorella. However, scaling these to mass production for protein applications will require improvements in bioreactor technology, light management, and nutrient optimization. This could take 5 to 10 years with the right investments (Future Insights). ***Infrastructure***: Cultivation of microalgae requires controlled environments, whether in open ponds or closed photobioreactors, both of which need significant infrastructure investment. Photobioreactors, though more efficient, are costly and require specific expertise to operate. Scaling up will depend on increasing the number of such facilities globally (BCG Global). ***Cost Competitiveness***: Currently, algae protein is more expensive than traditional plant-based proteins, mainly due to production costs. Advances in cultivation methods, along with economies of scale, could reduce prices within the next 5-7 years, making it more viable for large-scale protein production (McKinsey & Company). ***Regulatory and Consumer Acceptance***: While algae-based supplements are widely accepted, using algae and microalgae proteins as a mainstream food source will require further regulatory approvals in some markets and increased consumer familiarity. However, given the sustainability benefits of algae, consumer adoption could accelerate once costs decrease, and products become more accessible.

In summary, with increased investment and technological advances, algae and microalgae protein sources could scale significantly in the next 5-10 years.

Scaling insect protein production can happen relatively quickly, as insect farming is highly efficient compared to traditional livestock. Insects require less feed, water, and land, and have rapid reproduction cycles, making them ideal for scalable protein production. Insect protein is already being used for animal feed, and human consumption is growing in various regions.

Consumer acceptance of insect protein, particularly for human consumption, presents several challenges. Cultural and Psychological Barriers: Many consumers, especially in Western countries, have a natural aversion to eating insects due to cultural taboos and the "yuck factor." Insects are often associated with pests or uncleanliness, making it difficult to normalize them as a mainstream protein source. This perception will need to be shifted through education and marketing, which emphasize the sustainability and nutritional benefits of insect protein (World Economic Forum) (Future Insights). ***Product Formulation and Taste***: While insects can provide high-quality protein, the way they are presented matters. Consumers are more likely to accept insect protein when it's processed into familiar forms, such as powders used in protein bars or snacks, rather than whole insects. Additionally, the taste and texture need to be neutral or appealing to ensure consumer satisfaction (Future Insights). ***Environmental and Health Messaging***: Successful adoption of insect protein will depend on framing it as a solution to environmental issues such as climate change, as insect farming requires fewer resources compared to traditional livestock. Highlighting the nutritional benefits, such as high protein content and essential nutrients, can also help build acceptance (BCG Global). ***Kosher and Religious Considerations***: As mentioned earlier, kosher laws only permit specific species of insects, such as certain locusts, and even then, the kosher status can be difficult to confirm. Without clear guidance from religious authorities, many consumers who observe kosher dietary rules may be hesitant to adopt insect protein, even if it is deemed sustainable.

In summary, scaling and consumer acceptance of insect protein will require addressing cultural biases, clarifying kosher regulations, offering familiar product formats, and promoting the sustainability and health benefits of insect-based foods. The timeline for scaling kosher insect protein depends on resolving these religious considerations and gaining regulatory approval in key markets. Given the efficiencies of insect farming, it is feasible that insect protein, including kosher-certified options, could scale within 5-10 years, but progress will depend on religious authorities clarifying the status of kosher species and approving their use in large-scale food production (McKinsey & Company)(Future Insights).

8.3 Strengths, challenges and Barriers

Non-animal protein production offers several notable strengths for Israel’s food security. It is also facing significant challenges and barriers for a significant and influential implementation of each of the solutions in Israel. Literature and conducted expert's questionnaire explain various issues for non-animal proteins.

Israel has a **high dependency on raw materials**, and its heavy reliance on imported ingredients and materials poses risks to supply stability and costs. As noted, non-animal sources such as alternative protein can play significant part in addressing this challenge: be reducing feedstock and animal protein import and increasing Israel's SSR.

The advantages of alternative protein production are reflected in its reduced **environmental impact**, as it requires fewer resources, such as land and water, compared to traditional animal farming. [83]Additionally, land previously used for animal feed cultivation can be repurposed to grow crops directly for human consumption, potentially improving food security [84].

However, cultivation faces challenges due to climate conditions and land availability, which hinder the growth of water-intensive crops and necessitate the development of resilient plant varieties. Furthermore, the environmental impact of some extraction methods, such as plant-protein extraction, is significant; these methods often consume substantial energy and water and may involve chemicals that pose environmental and safety concerns[85] [86]. Lastly, climate challenges affecting the yields of legumes and other plant-based protein crops highlight the need for innovative crop breeding to ensure resilience.

Other considerations are **health benefits** resulting from a plant-based diet[87], but also health concerns related to the consumption of alternative proteins. Unlike conventional livestock farming, alternative protein production does not rely on antibiotics, thereby reducing the risk of contributing to antibiotic-resistant microorganisms, which is a significant public health concern[88]. Some respondents in the expert questionnaire see no consumer concerns regarding health risks, while others noted potential risks associated with ultra-processed products. Grasshoppers, on the other hand, are viewed as a healthier, minimally processed option. However, the fact that alternative proteins are considered processed foods does not necessarily reflect their health attributes, which may surpass those of meat in several parameters, such as fiber content, absence of antibiotics, lower fat levels, and more.

There are also **ethical and cultural considerations**, such as animal welfare[89] and kosher dietary laws. These factors may positively influence the adoption of alternative proteins, especially among religious audiences, with grasshoppers seen as a revival of traditional practices. Broader cultural factors, including innovation, sustainability, health, and veganism, can also support the acceptance of alternative proteins.

Economic growth and viability must also be considered. Economic growth can be enhanced by creating new markets and job opportunities[90]. In the past year, the Israeli Ministry of Health has

[83] Bright Green Partners. Accessed December 2024.
[84] BIS Research. Accessed December 2024.
[85] Icos Capital. Accessed December 2024.
[86] Earthshot Prize. Accessed December 2024.
[87] VitalAbo. Accessed December 2024.
[88] Gfi. Alternative proteins can help prevent the next pandemic. Accessed December 2024.
[89] Frontiers. Accessed December 2024.
[90] CSIS. Accessed December 2024.

approved beef-based "***cultivated meat***"[91]. However, there are still challenges that need to be addressed. Producing cultivated meat remains difficult from a cost perspective, with current production costs ranging from $37–$50 per kilogram and retail prices around $90 per kilogram, compared to $5 per kilogram for ground meat. Additionally, there are issues related to scaling up production. Replacing just 1% of the protein market requires 220–440 million liters of fermentation capacity, which far exceeds the current capacity of the biopharmaceutical industry. One of the experts who responded to the questionnaire explained that achieving price parity for cell-cultivated meat necessitates industry growth and the development of cost-reducing technologies, "reducing production costs to achieve competitiveness with traditional meat and managing significant investments in infrastructure research and development".

Having said that, traditional meat is heavily subsidized globally. Shifting these subsidies to investments in the alternative protein sector can boost that change[92]. Rising traditional protein costs and improved raw materials will influence prices. Innovations in feed and automation may make grasshopper protein more affordable within five years. However, biological constraints related to achieving economic viability must be addressed due to production challenges and waste removal issues[93].

Capital investment in adapted facilities and large-scale infrastructure is essential. However, there is a challenge in attracting investors from outside Israel for startup support due to perceived risks. For example, fermentation is a young industry that lacks sufficient understanding among investors and experts. "High capital expenditure requirements cannot be met by venture capital investors alone, necessitating more developed financial tools such as infrastructure funds and state guarantees". Beyond that, ***operating and personnel costs*** must also be considered. While Israel has a professional, expert, and skilled workforce, financing their salaries can be difficult. "The Innovation Authority and the government offer funding for … new technological developments or investment in infrastructure. However, during a time when preserving existing operations and survival are critical, there are currently no significant tools supporting these efforts".

Significant investment is needed in advanced ***processing equipment*** to improve efficiency and product quality. Minimal production capacity affects competitiveness; large-scale infrastructure is needed. "Currently, there is no approved facility for industrial-scale food production, and the maximum scale that can be achieved is limited due to limited electricity and water resources[94]". When developing cell-cultivated meat there

[91] Ministry of Health. First in the World: the Ministry of Health Has Approved Cattle-Based Cultivated Meat. Updated date: 24.01.2024. Accessed: December 2024.

[92] GFI. (October 2021). National Plan: Israel as a world leader in research, innovation and production of alternative protein – Executive Summary.

[93] Israel Innovation Authority.

[94] From an expert questionnaire

is the need for "developing efficient refrigeration systems to ensure product freshness and overcoming transportation challenges in hot climates".

Respondents of expert survey noted several **production strengths**, for example, experts and highly skilled workforce and government support in microalgae, strong hi-tech in fermentation production, production processes, and consumers eager to try new products. "Production costs in Israel, from seeds to animal feed to labor costs, are high and challenging compared to various alternatives in the world. However, the integration of dry feed mixtures, which reduce the cost of feed by 97% … and enable the integration of full automation for all production processes, make it possible to significantly reduce the cost gaps between Israel and the world and make the source of protein from grasshoppers highly competitive compared to existing protein alternatives".

Logistics management needs to be addressed when managing perishable raw materials with limited shelf life, as it requires careful logistics and temperature-controlled storage.

Quality Control: Ensuring product consistency and managing contamination risks necessitates strict quality control measures.

To address these challenges, we must tackle the complexity of **regulatory issues**. Navigating intricate approval processes for innovative products presents significant obstacles to market entry. "Openness and education of professionals in the Ministry of Health to the next generation of food ingredients and products. We must work together and closely with them to find a way to continue to advance".

Regulatory considerations must be taken into account when producing new protein sources, especially those derived from novel microorganisms or insects[95]. These regulatory challenges can include labeling restrictions (for example, can alternative meat be labeled as "meat"?), which may hinder market entry and consumer acceptance[96]. Therefore, when considering cultivated meat, it is essential to address "the evolving regulatory framework for the approval of cultivated meat and establishing clear standards for the safety and quality of cultivated meat products".

Of course, when considering **consumer perception**, it is essential to educate "Israeli consumers about the safety and benefits of cultivated meat while addressing kosher and ethical considerations". And remembering that "Taste is King and texture is Queen". Raising awareness about the benefits and safety of alternative proteins is crucial for consumer acceptance. Kosher considerations can also be critical. "The main obstacle to the grasshopper is the perception of insects as food.... The main way we identified to change the perception in Israel is through the aspect of kashrut and the renewal of the biblical tradition of eating grasshoppers. From survey we conducted, about 50% of consumers changed their

[95] AZTI. Accessed December 2024.
[96] Vox. Accessed December 2024.

perception of the product… when they learned that it was a kosher product". Consumer acceptance, taste, and healthiness of alternative proteins always pose another obstacle[97].

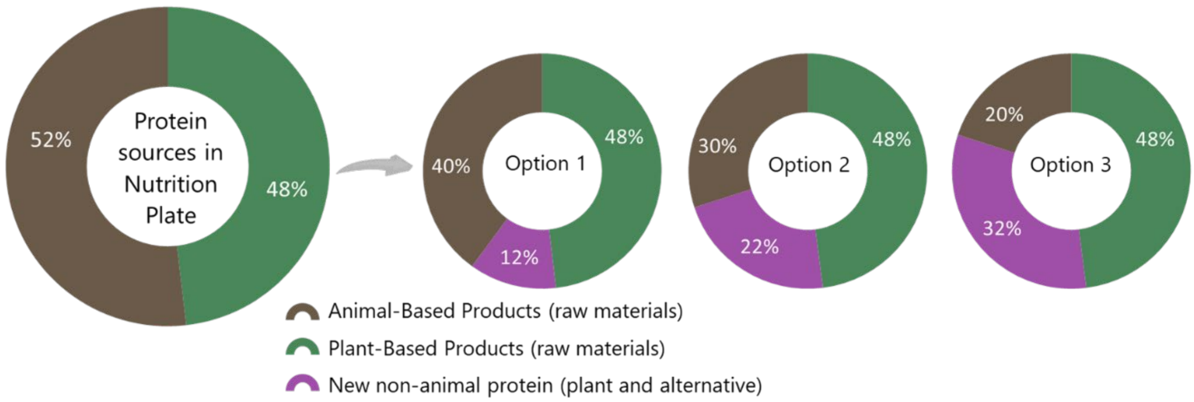
Despite the challenges and barriers, all respondents to the expert questionnaire believe that **producing alternative protein in Israel is possible**. "On an optimistic note – despite all the challenges outlined above, Israel has an advantage in technological innovation and the ability to find practical solutions".

[97] PubMed Central. Accessed December 2024.
Green Arc Capital. Accessed December 2024.

9. How much non-animal protein Israel needs

Based on the recommended dietary plate, towards 2050 Israel will need supply of 3,589K tons of plant-based products (raw materials) vs 316K tons of domestic production today, and 3,862K animal-based products (raw materials) vs 2,443K tons domestic production (raw materials) today. Using non-animal protein sources derived from plant, cultivated protein, precision fermentation, algae, molecular farming etc., Israel can reduce its dependence on animal-based products for protein intake. In this context our interim report suggests reducing it to 40% or even 20% of the total protein intake, representing a reduction of 23-61% of the animal protein consumed. Therefore, we are looking at three options for non-animal protein: reducing animal protein consumption in the Israeli plate to 40%, 30% and 20% (no change in plant-based products raw materials) (Figure 7). This poses a significant challenge for production to meet these goals. As shown in Table 5, new non-animal protein sources demand can range from 79K to 212K tons of net protein per year, in the case of reducing animal-based products to 40% or 20% respectively.

Figure 7: Protein sources distribution by type of product, 2050



* Based on the nutrition plate, Samuel Neaman Institute publication (2024)[98].
* Animal-Based Protein Products (raw materials): Red meat and Animal fats, Poultry, Eggs, Fish, Dairy and dairy Products
* Plat-Based Protein Products (raw materials): Cereals and products, Nuts and seeds, Legumes
* New non-animal protein: Cultivated meat and Fish, Processed Plant-Based Proteins, Precision Fermentation, Insects, Mycelium & Fungi, Molecular Farming

[98] Shimoni, E., Tziperfal, S., Ayalon, O., Blekhman, A., Ben-Haim, Y., Dayan, T., Tal, T., Fortuna, G., Flugelman, A., Raviv, O., Klein, R., Shoham, A., & Shapira, N. (2024). "The Israeli nutrition plate in 2050" an interim report within the Israel 2050 food security project. Samuel Neaman Institute.

Table 5: Possible scenario for New non-animal protein (plant and alternative)

(Available Supply 2050 of protein-based products in Mediterranean Diet, tons per year)

% of Animal-Based Products (2050)	52%	40%	30%	20%
Animal-Based Protein Products (raw materials)	3,862 K	2,981 K	2,236 K	1,490 K
Plat-Based Protein Products (raw materials)	3,589 K	3,589 K	3,589 K	3,589 K
Animal-Based Net Protein (raw materials)	345 K	267 K	200 K	133 K
New non-animal protein (plant and alternative)	0	79 K	146 K	212 K

* Based on the nutrition plate, Samuel Neaman Institute publication (2024)[99].
* Animal-Based Protein Products (raw materials): red meat and animal fats, poultry, eggs, fish, dairy and dairy products
* Plat-Based Protein Products (raw materials): cereals and products, nuts and seeds, legumes
* Animal-Based Net Protein (raw materials): Net protein in raw materials of red meat and animal fats, poultry, eggs, fish, dairy and dairy products
* New non-animal protein: cultivated meat and fish, processed plant-based proteins, precision fermentation, insects, mycelium & fungi, molecular farming

While the need for non-animal protein to reduce the animal derived protein use is clear, as well as the volumes that will be required, it is challenging to predict what will be the contribution of each technological source. These predictions can be challenged by technological barriers, scale up gaps, regulatory compliance and adaptation, consumer acceptance, as well as unforeseen technological leaps.

While trying to predict the volumes actually consumed in the future, the allocations are hypothetical and based on current industry trends and projections. For instance, the global alternative protein market is expected to grow significantly, with estimates suggesting it could reach USD 290 billion by 2035, accounting for about 11% of annual global protein consumption[100]. Another example suggests that the alternative protein market size is poised to reach USD 74.67 billion by the end of 2037, growing at around 11.2% CAGR during the forecast period. The industry size of alternative protein in 2025 is assessed at USD 20.26 billion[101]. The main commonality of all projections is that the alternative protein market will grow significantly, and that it will become a significant portion of the annual protein consumption.

The next question is what portion of the new non-animal protein market will be taken by each of the technologies? Some analysts suggest that the total meat market is expected to grow by 2040, with cultivated meat projected to account for 35%, novel vegan meat replacements for 25%, and conventional meat for 40%[102]. Since there are no precise estimates of the production

[99] Shimoni, E., Tziperfal, S., Ayalon, O., Blekhman, A., Ben-Haim, Y., Dayan, T., Tal, T., Fortuna, G., Flugelman, A., Raviv, O., Klein, R., Shoham, A., & Shapira, N. (2024). "The Israeli nutrition plate in 2050" an interim report within the Israel 2050 food security project. Samuel Neaman Institute.
[100] The Center for Strategic and International Studies (CSIS). (May 11, 2023). Mitigating Risk and Capturing Opportunity: The Future of Alternative Proteins.
[101] Research Nester. Global Market Size, Forecast, and Trend Highlights Trends Over 2025-2037. Published: 11 October 2024. Accessed December 2024.
[102] Kearney. (2020). When consumers go vegan, how much meat will be left on the table for agribusiness?.

share of each alternative production technology, we estimated the percentage distribution of the various alternative options. One assessment indicates that cultivated meat and fish will replace 25% of conventional meat and fish, while processed plant-based proteins are expected to capture 30% of the market. Additionally, other novel new non-animal protein alternatives will account for 45% of the alternative proteins, with precision fermentation contributing 25%, molecular farming 5%, mycelium and fungi 8%, insects 2%, and Algae 5%.

Due to the uncertainty as for the portion each technology will take, we propose to follow this line of thinking: the new non-animal protein volume will be split very similar to the animal derived protein sources. Table 6 demonstrates possible scenarios and its implications on the protein demand from each sector.

Table 6: An example of scenarios for the new non-animal protein (plant and alternative) required for Israel in 2050 by source and by use

***The percent distribution between the various sources is only once possible scenario estimate – used for purpose of demonstration rather than accurate prediction**[103]

Tons per Year		Cultivated Meat & Fish	Processed Plant-Based Proteins	Molecular Farming	Insects	Mycelium & Fungi	Precision Fermentation	Algae	To reduce animal protein to 40%	To reduce animal protein to 30%	To reduce animal protein to 20%
		25% of the total new non-animal protein	30% of the total new non-animal protein	5% of the total new non-animal protein	2% of the total new non-animal protein	8% of the total new non-animal protein	25% of the total new non-animal protein	5% of the total new non-animal protein	Total Tons of **final product reduced**		
Poultry									127 K	234 K	342 K
Dairy and dairy Products									488 K	900 K	1,312 K
Red meat and Animal fats									84 K	156 K	227 K
Eggs									82 K	151 K	220 K
Fish									101 K	186 K	271 K
To reduce animal protein to 40%	Tons of new non-animal **net protein**	14 K	23 K	1.9 K	2.9 K	4 K	6 K	3 K			
To reduce animal protein to 30%		25 K	44 K	2.3 K	3.4 K	8 K	11 K	6 K			
To reduce animal protein to 20%		37 K	64 K	2.6 K	3.9 K	12 K	16 K	9 K			

[103] Based on the nutrition plate, Samuel Neaman Institute publication (2024).

10. Key actions to achieve the required non-animal protein supply by 2050

Mitigating risks for animal protein supply chain by non-animal protein sources

Israel's animal-based protein supply faces significant risks across all stages of the supply chain. These risks stem primarily from a heavy reliance on imports for feed and products, limited domestic production, and the geographic concentration of facilities near border areas, which are highly vulnerable during conflicts. Climate change exacerbates these challenges by increasing the frequency of extreme weather events, reducing livestock productivity, and elevating production costs. Furthermore, the perishability of animal-based protein products, combined with limited and costly storage options, limits flexibility in crisis scenarios. The centralized nature of supply chains, along with dependencies on foreign labor, further exposes the system to potential disruptions. These vulnerabilities emphasize the critical need for strategic diversification, enhanced local production, and increased resilience in Israel's protein supply systems[104]. Beef and fish are clearly at the highest risk, followed by eggs, poultry and dairy.

Therefore, non-animal protein supply is critical to secure Isreal's food security by 2050. Specifically, new non-animal protein sources are important tools for reducing animal protein consumption down to 20-40% of the total protein. Alongside that, country level planning of local legume cultivation is needed.

Maintain Israel's position as non-animal protein powerhouse

Israel is a powerhouse of technological innovation in non-animal protein across all fields – from plant-based solutions through precision fermentation, cultivated meat, chicken and fish, algae, mycelium and fungi, as well as Agro-innovation to enhance yield and quality of plant-based protein crops. This position is a critical bed for growing long term viable solutions. It is also a national asset for bringing foreign investment and developing national relations with potential suppliers of critical raw materials.

Israel must enhance support for startups in Agro-food and new non-animal proteins to solidify its leadership in addressing global food security challenges and advancing sustainable food systems. New non-animal protein ventures, including cultivated meat, plant-based products, and precision fermentation, are at the forefront of tackling resource scarcity, climate change, and the growing global demand for protein. Fostering non-animal protein startups aligns with Israel's goals of reducing agricultural emissions, conserving water, and enhancing self-reliance

[104] ביטחון מזון לאומי – אתגרי מערכות מזון מהחי בישראל, GFI2024. ישראל

in food production. By prioritizing these ventures, Israel can contribute to a more resilient, sustainable global food system while reaping economic and environmental benefits.

Overcoming the FOAK challenge

In the innovative technologies developed to produce non-animal protein sources, startups often face a major hurdle as they approach building their first-of-a-kind (FOAK) production operation (be it a factory of agriculture at scale). Governments can address key challenges startups face, such as high costs, technical risks, and market uncertainty, enabling them to transition from prototypes to scalable, impactful solutions. The Israeli government can play a pivotal role in helping startups establish first-of-a-kind (FOAK) production operations by providing financial support, infrastructure access, regulatory assistance, and market facilitation. Financial backing can include grants, subsidies, low-interest loans, loan guarantees, and tax incentives, helping to reduce the significant costs and risks of scaling up innovative technologies.
Access to shared facilities, testing sites, and government-owned infrastructure allows startups to validate their products without prohibitive expenses. Regulatory support, such as streamlining permits and assisting with compliance and certifications, minimizing delays and facilitating market entry. Support can also be provided through public procurement and offtake agreements, providing revenue certainty and a crucial initial market.

Boosting mass production capabilities

Boosting alternative-protein production requires significant investments. For example, reducing animal-based products to 40% of the total protein required for Israel in 2050 represents about 63.5K tons net protein of red meat, chicken, eggs and fish alternatives and about 14.7K tons net protein of dairy alternatives. In terms of final products, this reduction will require an additional 127k tons of non-animal poultry, 488k tons of non-animal dairy products, 84K tons of non-animal red meat products, 82k tons of non-animal eggs, as well as 101k tons of non-animal fish products (Table 6).

These figures represent a significant national challenge. In the following paragraph we will review some challenges and opportunities in the scale up journey. To achieve these volumes of new non-animal protein in Israel, some major investments are required. A broadly agreed estimate of the cost of a factory that produces 10,000 tons of cultivated meat or alternative dairy protein at the range of 100-200 million USD. For example, Believer Meat invests 123 million USD in a cultivated meat plant to produce 10,000 tons per year[105]. Similarly, in 2022, after raising another 120 M$, Remilk announced building its first manufacturing factory for precision fermentation dairy proteins[106]. These publicly available numbers reaffirm the estimates by industry experts in these fields.

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[105] PR Newswire. (Dec 07, 2022). BELIEVER Meats Breaks Ground on Largest Cultivated Meat Production Facility in The World. Accessed December 2024.

[106] Remilk. (Apr 26, 2022). Remilk to Build the World's Largest Precision Fermentation Facility. Accessed December 2024.

Therefore, the manufacturing facilities that can support the production of these alternatives require some serious attention. By rough estimates, the cumulative investments in production facilities that will reduce animal derived protein use in Israel to 20% towards 2050 can be well over 2,000 million USD for red meat, poultry, and fish protein alternatives, and over 600 million USD for dairy protein alternatives. This level of investment requires a supportive regulatory and financial environment.

The required investment to advance new non-animal proteins in Israel over the coming decades will need to align with global trends and the national strategic importance of this field. According to the WEF[107], achieving the full potential of new non-animal protein technologies globally requires an annual public investment of $10 billion in research and development, commercialization, and marketing. Given Israel's leadership position in this sector, a proportional investment of $100–200 million annually is estimated to be necessary to support R&D infrastructure, pilot production facilities, public-private partnerships, and market development. This strategic funding would ensure Israel's long-term competitiveness and sustainability in the rapidly growing global new non-animal protein ecosystem.

Fostering plant protein self-sufficiency

Plant proteins both in their natural form and as processed products will also play their traditional role in reducing the consumption of animal proteins. Therefore, alongside promoting the use of new tech solutions, we should ensure sufficient supply of plant proteins.

The main source for plant-based protein alternatives are legumes. To increase legume production, Israel can adopt a multifaceted approach that leverages advanced agricultural practices, research, and policy support. Developing high-yield, drought-resistant seed varieties suited to the semi-arid climate, coupled with precision agriculture technologies like drip irrigation and remote sensing, can optimize yields while conserving resources. Rehabilitating marginal lands with salt-tolerant crops and soil amendments can expand cultivable areas. Additionally, crop rotation and intercropping improve soil fertility, benefiting the long-term sustainability of agricultural systems. Financial incentives, such as subsidies and guaranteed procurement schemes, can encourage farmers to prioritize legume cultivation.

Research into pest-resistant and climate-resilient legume varieties, along with improved pest and disease management, is crucial to reducing losses and boosting productivity. In addition, promoting legumes as a staple of the Mediterranean diet can drive local demand. This integrated strategy can enhance legume production, contributing to the growth of the plant-based food sector.

In addition, there is a clear need to integrate breeding efforts to meet the growing demand for plant-based products. Breeding programs should prioritize enhancing the functional and nutritional

[107] World Economic Forum. (May 2024). מובילות טכנולוגית האופן שבו מקדמת ישראל :יצירת אקוסיסטם פודטק חדשני בתחום החלבון האלטרנטיבי עולמית. נייר עמדה. בשיתוף רשות החדשנות, IR4C ישראל ו– Israel) GFI (Institute Food Good The.

properties of legume proteins, while also considering how these crops can be optimized for downstream processing. These efforts are crucial not only to ensure that legumes meet dietary requirements, but also to align with consumer preferences and behaviors, while providing sustainable and high-quality products.

By integrating breeding and cultivation strategies, Israel can enhance its legume production, thereby contributing to both food security and the sustainability of agricultural systems.

11. Appendix A

11.1.1 Plant-based proteins

Plant-based proteins, primarily derived from legumes such as soybeans, peas, and chickpeas, along with cereals, and oil seeds, are becoming increasingly popular for their nutritional benefits and lower environmental impact. Soybeans stand out as one of the most critical sources of plant protein, containing around 35–40% protein along with other beneficial nutrients such as fats, fibers, and vitamins. Soy is used in various food products, including milk substitutes, meat analogs, and fermented products. Pea protein, another key legume, is known for its rich amino acid profile, especially lysine, and is hypoallergenic, making it an alternative for consumers sensitive to soy. However, both soy and pea proteins face challenges regarding solubility and gelling capabilities, which impact their functionality in food production (Collett et al., 2021).

Cereals like wheat and rice also play an essential role in plant-based protein production. Gluten, a wheat protein, is particularly valuable for its water retention capacity, which enhances the juiciness and tenderness of products like plant-based meat substitutes. Additionally, pseudo-cereals like quinoa and amaranth provide a more balanced amino acid profile, although quinoa's superior emulsifying properties make it more favorable for applications in plant-based foods (Benković et al., 2023).

Oilseed proteins from hemp, sunflower, and rapeseed are emerging as sustainable protein sources, offering high digestibility and health-promoting properties. For example, chia seeds are recognized for their anti-inflammatory and cardioprotective effects. These proteins are also used for their functional properties, such as emulsification, to create desired textures in plant-based food products (Smetana et al., 2023).

11.1.2 Meat and Dairy Substitutes Based on Plant Protein

Plant-based meat analogs (PBMAs) are designed to replicate the sensory and nutritional qualities of meat, with proteins from legumes, cereals, and pseudocereals forming the bulk of ingredients. Soy and pea proteins dominate this space, offering fibrous textures that mimic meat, although their limited gelling properties can complicate texturization. Various technological methods, such as wet spinning, electrospinning, and extrusion, are employed to process raw plant proteins into meat analogs. Wet spinning, commonly used for soy and pea proteins, is effective in creating fibrous textures, while electrospinning is being explored for incorporating additional components like polyphenols or probiotics. Low- and high-moisture extrusion techniques are especially promising for industrial-scale production due to their scalability and potential for creating meat-like textures (Smetana et al., 2023)**Error! Bookmark not defined.**.

In particular, high-moisture extrusion stands out as the most efficient method for producing fibrous, meat-like textures in PBMAs. This technique is favored for its ability to maintain product quality while being environmentally friendly. Additionally, wheat gluten is often blended with legume proteins to improve the fibrous structure and increase the overall protein content (Jang, 2024).

Innovations in plant-based meat substitutes also extend to the use of pulse proteins from sources like mung beans, fava beans, and lentils. These proteins, combined with cereal proteins, create a more complete amino acid profile, offering better nutrition and functionality. For instance, the combination of pea, chickpea, and wheat gluten proteins enhances the quality of plant-based meat, making it suitable for products like burgers and sausages (Benković et al., 2023)**Error! Bookmark not defined.**.

In the realm of plant-based dairy, soy remains the most popular and nutritionally comparable alternative to cow's milk, offering high protein content. Other emerging milk alternatives include beverages made from peas, chickpeas, and oats. These products often use ultrasonic treatments and enzyme modifications to improve the texture and nutritional profile of plant-based dairy substitutes (Karabulut, Goksen, and Khaneghah, 2024).

The production of plant-based protein substitutes typically involves processing raw grains to enhance nutrient availability. Techniques such as wet spinning, electrospinning, and extrusion methods are employed to create food-grade fibers and textures that mimic meat. Wet spinning, a widely used technology, processes proteins from sources like soy, pea, and faba beans. Meanwhile, electrospinning is explored for specialized applications, including the incorporation of polyphenols or probiotics, though its industrial use is limited. More scalable methods include low and high-moisture extrusion and shear cell technology, which are still largely in the pilot stage but show promise for industrial application. These methods differ in terms of resource demands and environmental footprints (Karabulut, Goksen, and Khaneghah, 2024)**Error! Bookmark not defined.**.

11.1.3 Molecular farming[108]

Molecular farming represents a significant advancement in this field, involving the use of genetic engineering to insert genes that code for useful proteins into host plants, creating genetically modified organisms (GMOs). This method allows plants to produce high-value proteins and chemicals, which are typically difficult or expensive to manufacture by conventional means.

Molecular farming not only complements existing plant-based, fermented, and cultivated technologies but also proposes a scalable solution to meet the increasing demands for sustainable protein sources. As such, it is emerging as a significant investment opportunity in the pursuit of innovative and sustainable agricultural solutions.

[108] Bright Green Partners (May 27th, 2024). Revolutionizing food production: The rise of molecular farming.

11.1.4 Fermentation-produced protein

Single-cell proteins

Single-cell protein (SCP) typically refers to consumable microbial biomass derived from single-cell microorganisms, including bacteria, archaea, fungi (such as yeasts), and certain types of algae (Molfetta et al., 2022).

Mycoprotein

Mycoprotein is a fungal-based protein, primarily produced through fermentation. Quorn, a leading producer in Western markets, has a mycoprotein content of 92%. The fermentation process typically uses wheat or sugar beet as feedstock, though gases can also be utilized (Collett et al., 2021). While fungi biomass production forms the basis of mycoprotein products, the environmental impact is greatly influenced by the processing stages.

Biomass fermentation method is key to mycoprotein production. It involves growing microorganisms in controlled environments like bioreactors. Quorn uses specialized mycelium fermenters, which minimize processing and produce highly nutritious products (Jang, 2024). The production of mycoprotein through fermentation has high resource demands. Despite the environmental benefits compared to animal proteins, mycoprotein production requires substantial energy and high-quality raw materials such as sugar (Collett et al., 2021).

Precision Fermentation

Precision fermentation harnesses the natural capacity of microorganisms to ferment organic matter, utilizing biotechnological tools to produce highly specific ingredients with exceptional purity. This process involves either splicing genes for desired components into the microorganism's genome or inducing the microbes to produce larger quantities of the required product through techniques like UV radiation. Additionally, precision fermentation contributes to a lower carbon footprint, as it requires less land and water to produce specific ingredients such as casein, whey proteins, and vitamins. Microbes can also utilize agricultural waste as a substrate for their growth, thereby promoting a circular economy.

The precision fermentation process consists of several stages. It starts with the selection of an appropriate host platform for gene expression, followed by expression of the target gene in the chosen strain, optimization, and scale-up. In industrial applications, microorganisms that are classified as generally recognized as safe (GRAS) are typically preferred. In this context, bacteria, yeast, and filamentous fungi serve as the primary vehicles for microbial engineering (Knychala et al., 2024).

11.1.5 Microalgae

Microalgae, such as chlorella, are rich in protein and widely used in human nutrition, with other forms like kelp and water lentils (e.g., duckweed) gaining attention as potential sources. The cultivation of microalgae, however, is often energy-intensive and capital-intensive. Photobioreactors, commonly used to grow microalgae, require substantial energy for maintaining optimal growth conditions like light and temperature, which can limit the environmental benefits. Furthermore, cultivation is highly sensitive to variables such as the system, location, and scale, as well as the species of algae being used. Despite these challenges, alternative cultivation methods, such as open raceway ponds or heterotrophic systems that use organic carbon sources like glucose, show promise. These methods can significantly reduce energy use and environmental impact compared to traditional phototrophic systems (Smetana et al., 2023).

11.1.6 Insect-based meat substitutes

The development of insect-based meat substitutes involves various innovative methods that enhance sustainability and nutritional value. Insects can be farmed for consumption in their entirety or processed into powder for use as flour (Collett et al., 2021). A wide range of plant-based feed stocks can be utilized, including materials unsuitable for human consumption, which supports environmental goals. Cultures practicing entomophagy have existed for centuries, and the global market for insect products is expanding (Smetana et al., 2023).

While few studies focus on the life cycle assessment (LCA) of insect-based meat substitutes, they typically differentiate between “fresh” insect biomass and advanced processed products imitating meat texture (Kim et al., 2019b). Insect species like mealworms (Tenebrio molitor) and crickets (Acheta domesticus) can significantly replace traditional animal proteins in various formulations, with potential replacement rates reaching up to 40% (Kim et al., 2022). Techniques such as fat extraction and protein purification allow to produce insect protein concentrates, with greenhouse gas emissions for these products ranging from 3.05 to 10.87 kg CO_2 equivalent per kg of protein extract (Laroche et al., 2022).

Hybrid meat products that combine insect protein with plant-based ingredients have shown high acceptability and can bridge the gap between meat and meatless options, potentially overcoming food neophobia. Furthermore, insects contribute to environmental sustainability by requiring less land and water compared to traditional livestock and utilizing organic waste as feed (Lange & Nakamura, 2021).

While the integration of insects into the food supply chain shows great promise, concerns about potential allergenic reactions pose a challenge. Insects have been linked to cross-allergenic responses, particularly in relation to crustacean and house dust mite proteins (Pan et al., 2022). Although cultural barriers hinder wider consumption in Europe, insects are increasingly recognized in animal nutrition, particularly in aquaculture. The regulatory landscape is evolving, with several insect species authorized for food and feed use in the EU, reflecting a growing acknowledgment of their potential in enhancing food security (Services et al., 2024).

11.1.7 Cultivated Meat and Seafood

Cultivated meat, also referred to as cell-based meat, represents a groundbreaking approach to protein production that utilizes in vitro cell culture techniques, enabling the creation of meat products without the need for animal slaughter. This innovative process begins with the non-lethal extraction of muscle or stem cells from living animals, which serves as the foundation for cell cultivation. The production of cultivated meat encompasses several key phases, including cell sourcing, where muscle cells are harvested; cell cultivation, which involves proliferating these cells in controlled environments; and tissue formation, where the cells differentiate to develop into muscle tissues that closely resemble traditional meat (Collett et al., 2021; Services et al., 2024).

The choice of growth media is particularly significant, as it must be free of animal products and contain essential nutrients such as amino acids, sugars, and growth factors to facilitate optimal cell growth and maturation (Smetana et al., 2023). Achieving a product with the desired taste and texture requires a combination of different cell types, including muscle precursor cells, fat cells, and connective tissue. Advanced cultivation techniques must be employed to create complex structures, such as chicken breasts or steaks, which necessitate the use of scaffolding. These scaffolds are designed to provide a supportive environment for the cells, allowing for proper attachment and nutrient flow.

Methods such as electrospinning, 3D extrusion printing, and the use of biocompatible materials are utilized to achieve the necessary structural complexity (Bhat et al., 2017; Seah et al., 2022). As the cultivated meat industry continues to evolve, addressing challenges related to scalability, cost-efficiency, and regulatory approval remains critical for its future success in the marketplace.

Similarly, cell-based seafood production leverages cellular agriculture techniques to create sustainable seafood alternatives. By utilizing vitro cell culture methods, this system allows for the cultivation of muscle, fat, or fibroblast cells from aquatic animals without the need for animal slaughter (Potter et al., 2020; Chandimali et al., 2024). This process begins with the extraction of cells through a non-lethal biopsy, followed by their proliferation in a controlled environment. The use of serum-free growth media—composed of essential nutrients such as carbohydrates, amino acids, and lipids—facilitates optimal cell growth and differentiation (Chan et al., 2024; Stephens et al., 2018).

The scalability of cell-cultivated seafood production hinges on several technical aspects, including the development of robust and diverse seafood cell lines. As few fish cell lines are currently established, isolating and immortalizing these cells presents a significant challenge (Potter et al., 2020). Furthermore, creating three-dimensional structures that closely mimic the texture and flavor of traditional seafood often require advanced tissue engineering techniques, such as the use of biomaterial scaffolds (Chandimali et al., 2024). These scaffolds support cell attachment and nutrient flow, enabling the production of structured products like fish fillets or other seafood items.

Research in the field is also addressing the lack of understanding regarding seafood cell differentiation and maturation. Advances in omics technologies—encompassing genomics, proteomics, and metabolomics—are shedding light on the growth factors and conditions essential for successful cell development (Chan et al., 2024). This comprehensive approach not only aims to enhance the efficiency of production but also seeks to improve the overall quality of cell-based seafood products. As the demand for seafood continues to rise amidst growing environmental concerns, cell-based seafood may play a crucial role in developing sustainable food systems and addressing the challenges posed by traditional fishing and aquaculture practices.

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