DEVELOPMENT OPPORTUNITIES FOR THAILAND'S ALTERNATIVE PROTEIN INDUSTRY

BY

OFFICE OF NATIONAL HIGHER EDUCATION, SCIENCE, RESEARCH, AND INNOVATION POLICY COUNCIL

Development Opportunities For Thailand's Alternative Protein Industry

1. Research & Development

Opportunities to Develop the Alternative Protein R&D Ecosystem in Thailand

1. Research & Development: Opportunities to Develop the Alt-Protein R&D Ecosystem in Thailand

1.1 Current state of Research and development for Alternative protein in Thailand

	R&D Strengths	R&D Gaps
Plant based meat (PBM)	- High biodiversity of local crops for ingredient development (e.g., mung beans, rice, mushroom and wolffia). - Strong lab-scale expertise in optimizing plant protein extraction and food tech.	- Lack of focus on developing scalable processes and technologies (e.g., HME for plant-based meat). - Research not aligned closely with market demands, especially for export markets.
Fermentation-derived protein (FD)	- Significant expertise in microbial fermentation at the lab scale. - Access to national biobanks of microorganisms.	- Limited R&D on scaling industrial fermentation. - Lack of strain development for industrial use and issues with Freedom to Operate (FTO) agreements.
Cultivated meat (CM)	- Strong cell biology research capabilities and available cell lines. - Expertise in tissue engineering at the lab scale.	- Lack of bioreactors/tools to scale R&D. - Research focuses primarily on academic publications, with limited prototype development. - No clear national strategy for cultivating meat R&D.

1.2 Opportunities to develops the Alternative protein R&D Ecosystem

Cluster A National R&D focus : **Develop a national R&D theme focused on AP research areas where Thailand has a competitive edge in its ability to create breakthrough R&D with industry relevance.**

- Opportunity 1: Develop a national R&D focused on creating a microbial library of characterized or developed strains for precision and biomass fermentation
- Opportunity 2: Develop a national R&D focus on creating a plant-based raw materials library characterized and developed as functional and cost-effective ingredients for alternative protein products, feedstock input, and culture media input

- Opportunity 3: Develop national R&D focus on developing cell lines for cultivated meat application

Cluster B R&D ecosystem : Create a collaborative R&D ecosystem that promotes R&D commercialization.

- Opportunity 4: Set up an industry-academia partnership platform focused on aligning benchmarks for national R&D grant calls
- Opportunity 5: Strengthen existing research consortiums to drive R&D focus and increase buy-in and funding/financing

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Cluster A: national R&D focus

Opportunity 1: Develop a national R&D focused on characterizing the national microbial biobank and developing strains for precision and biomass fermentation

Rationale: Thailand has a high biodiversity of microorganisms. Many strains of microbes with potential have not been deeply researched. This opportunity enhances microbial strain development to increase fermentation efficiency and improve precision fermentation for alternative proteins. It targets critical cost-effectiveness and scalability areas where Thailand is limited. A national focus will address Freedom to Operate (FTO) issues and promote local research and development.

Impact: Developing industrial strains locally will reduce reliance on imported strains, stimulate the economy by fostering innovation in fermentation, and position Thailand as a global leader in fermentation scale up hub in APAC. It will create high-skilled jobs in bioengineering and fermentation technologies.

Feasibility (RIsk/Effort/Buy-in): Feasible with targeted funding to deep characterization in properties of local microbes' strain, changes in FTO regulations, and collaboration with biobanks and international fermentation experts.

Potential Workstreams: Developing cutting-edge research in deep characterization for potential uses of local microbial strains and utilizing them to produce protein-rich ingredients, and exploring their application in food products. Advancing the production of specific proteins,

fats, or bioactive compounds (e.g., dairy proteins, heme) through precision fermentation technology, which can replace animal-derived components in foods.

Opportunity 2: Develop national R&D focus on characterizing existing biodiversity of plant-based raw materials as functional and cost-effective ingredients for alternative protein products, feedstock input, and culture media input

Rationale: Thailand's biodiversity of plants and microbes is largely unexplored for their potential in meat analogs, feedstock, and cell-culture media. This opportunity will characterize these species for functional ingredients, supporting local industries by developing cost-effective and sustainable alternatives.

Impact: Utilizing local biodiversity for cost-effective ingredients will reduce Thailand's import dependency, foster local innovation, and create a competitive edge in the global AP industry. This will contribute to job creation in biotechnology and stimulate economic growth.

Feasibility (RIsk/Effort/Buy-in): Feasible with dedicated research programs to research in indigenous plants , government incentives, and partnerships with universities, Funding agencies (e.g., ARDA), and private sector stakeholders.

Potential Workstreams: Research on local plant varieties that can be used as protein sources (e.g., mung beans, rice, mushroom and wolffia) and optimizing their use for texture, flavor, and nutrition in food products. Innovating in techniques such as extrusion, fermentation, and enzymatic processes to create meat-like textures and improve the overall sensory experience of plant-based products.

Opportunity 3: Develop national R&D focus on developing cell lines for cultivated meat application

Rationale: Thailand can offer cell lines derived from local breeds and species that are culturally relevant to the region, such as native chickens, shrimp, and fish (e.g., tilapia, catfish). These are widely consumed in Southeast Asia, giving Thailand an advantage in catering to the local market's preferences. Thailand has several prominent universities and research institutions focused on cell biology, biotechnology and food science, including collaborative efforts between academia and industry. With the right investment and partnerships.

Researchers can derive cell lines from native species of chicken, pork, and seafood, which are highly consumed in the country and across the region.

Impact: Thailand could establish itself as a hub for research in cellular agriculture and develop commercially viable cell lines for cultured meat production.

Feasibility (RIsk/Effort/Buy-in): International collaborations with leading companies and research institutions in the field of cultured meat could accelerate Thailand's role in supplying cell lines for global markets.

Potential workstreams: Establishing indigenous animal cell lines in supplying them for global markets suitable for the cultivated meat industry in Thailand. Research on reducing the costs of cell culture media and bioreactors to make lab-grown meat commercially viable at scale. Collaborating with government agencies to create a regulatory framework for the approval, production, and sale of cultivated meat products.

Cluster B: R&D ecosystem

Opportunity 4: Set up an industry-academia partnership platform focused on aligning benchmarks for national R&D grant calls

Rationale: Industry-academia intermediaries will bridge the gap between research institutions and market-driven R&D, ensuring research is aligned with real-world applications. This opportunity will enhance commercialization by focusing academic research on market needs.

Impact: Aligning R&D with industry benchmarks will accelerate commercialization, boosting economic value through quicker product development cycles. It will also build workforce capabilities and enhance Thailand’s competitiveness in the AP global value chain.

Feasibility (RIsk/Effort/Buy-in): Highly feasible with modest government investment to create intermediary bodies. Requires coordination among academia, private sector players, and government stakeholders.

Potential workstreams: Develop a set of standardized benchmarks and metrics for evaluating R&D proposals, ensuring consistency and transparency across grant applications. Create a

framework to facilitate collaborations between universities and companies, helping them identify common research interests, share resources, and form joint teams. Hold regular meetings with stakeholders from industry, academia, and government to refine benchmarks and ensure that grant calls remain aligned with emerging trends and technology advancements.

Opportunity 5: Strengthen existing research consortium to drive R&D focus and increase buy-in and funding/financing ***(Cluster B: R&D ecosystem)***

Rationale: A national research consortium will bring together academic institutions, the private sector, and government agencies to collaborate on large-scale R&D projects. Pooling resources and expertise will ensure strategic alignment with national and global trends.

Impact: A research consortium will coordinate R&D efforts at a national level, attracting global investment and building a collaborative environment. This will enhance the growth of high-tech jobs, strengthen Thailand's R&D ecosystem, and position Thailand as a leading exporter of AP innovations.

Feasibility (RIsk/Effort/Buy-in): With initial government policy, funding agencies and support from NSTDA and TISTR, it is feasible. Involvement from leading universities and private sector stakeholders will be critical for success.

Potential workstreams: Align industrial growth with national priorities, create supportive policies, and foster collaboration between the private sector and government agencies. Establish formal working groups, set up a regular dialogue framework, co-investment funds between FTI and government agencies.

1.3 Key stakeholders needed to make an impact

Stakeholder	Role/Impact
Government Agencies	Provide policy direction, funding, and national strategy support (e.g., NXPO, TSRI, PMU-B, PMU-C, ARDA).
The Office of National Higher Education Science Research and Innovation Policy Council (NXPO)	● Design strategies and facilitate the policy addressing higher education, science, research and innovation. (e.g., BCG economy policy, Higher Education Sandbox) ● Proposing law and regulation which involve supporting the research and innovation ecosystem such as the Tri-Up Act.
Thailand Science Research and Innovation (TSRI)	● Develop the National Science Research and Innovation (SRI) plan to provide direction, investments prioritization and guidance for the advancement of the SRI system. ● Allocate and Manage the SRI's Budget to organizations which are in the SRI system. ● Monitor and evaluate the state of national SRI to improve the development of the SRI system.
Program Management Unit for Human Resources & Institutional. Development, Research and Innovation (PMU-B)	Allocates funds for frontier research issues in fields necessary for national development according to policies and strategies for higher education, science, research and innovation and government policy.

Program Management Unit for Competitiveness (PMUC)	Allocates research funds and creates innovations to increase the competitiveness of the manufacturing and service sectors, technology transfer, innovation market. (This funding focuses on supporting plans that include cooperation or joint investment with beneficiaries such as SMEs and the industrial sector)
The Agricultural Research Development Agency (ARDA)	Promote, support, and develop agricultural research, agricultural research personnel. To be a center for providing information on agriculture obtained from studies, research, and development, as well as connect with educational institutions and other relevant agencies both at the national and international level.
Academic Institutions	Lead research in strain development, fermentation technologies, and characterizing biodiversity (e.g., Mahidol University, Kasetsart University, BIOTEC).
BIOTEC	● Provide researcher experts who will collaborate between the research network and the industrial sector. ● Deep research in plants and microbial strains characterization, strain improvement, pilot-scale optimization with GMP standard and plant factory testing.
Thailand Institute of Scientific and Technological Research (TISTR)	● To provide R&D services, analysis and testing services on biotechnology, to meet the needs of the industrial sector through Expert Centre of Innovative Health Food (InnoFood), Expert Centre of Innovative Agriculture (InnoAg) and Expert Centre of Innovative Herbal Products (InnoHerb) ● To collect bacteria, yeast, mold and seaweed which are beneficial to industrial and environmental usage. (e.g., BRC) ● Solving the problems of product quality and production processes for industrial sector and community enterprise domestically and internationally.
National Biobank (NBT)	Supports infrastructure for the conservation of the biological resources of Thailand (National Biobank) including plants, microbes and Thai population genomics, and carries out research using advanced technology

	on the value and potential for development of biological resources from the genetic to the ecosystem level.
Chulalongkorn University	Deep research in microbial strains characterization, strain improvement culture meat research and lab-scale optimization to small scale pilot plants.
Mahidol University	Deep research in microbial strains characterization, strain improvement ,culture meat research and lab-scale optimization to small scale pilot plants.
Kasetsart University	Deep research in plants and microbial strains characterization,strain improvement, pilot-scale optimization with GMP standard, culture meat research, animal cell line collection, and landfill plant testing.
Private Sectors	Align R&D with industry needs and drive commercialization, particularly in plant-based meat production and fermentation.
International Experts	Provide expertise in microbial strain development, fermentation, and cultivated meat, and help establish global partnerships.

2. Workforce

Opportunities to Develop the Alternative Protein Workforce in Thailand

2. Workforce: Opportunities to Develop the Alt-Protein Workforce in Thailand

2.1 Current state of Alternative protein workforce

	Talent & Skills Strengths	Talent & Skills Gaps	Key Job Roles Required
Plant based meat (PMB)	- Strong expertise in food tech and product development. - Local chefs and food stylists with experience in product design and flavor optimization. - Adequate number of food tech scientists.	- Lack of technicians and engineers skilled in scaling processes (e.g., extrusion technology). - Shortage of professionals in flavor science and sensory analysis. - Limited rheology scientists and system optimization experts.	- Extrusion technology specialists - Sensory scientists (flavor and texture optimization) - Food technologists with a plant protein focus - Bioprocess engineers - Product development scientists
Fermentation derived protein (FD)	- Strong base in microbiology and fermentation science at the lab scale. - Availability of skilled microbiologists. - Expertise in traditional fermentation techniques that can be adapted to AP.	- Shortage of bioprocess engineers and bioreactor design specialists to scale fermentation. - Lack of trained professionals for regulatory compliance and law. - Experts in strain development and precision fermentation are needed.	- Bioprocess engineers - Bioreactor design specialists - Regulatory compliance experts - Strain development scientists - Precision fermentation technologists
Cultivated meat (CM)	- Strong talent pool in cell biology and tissue engineering. - Available researchers with biomedicine and molecular biology skills	- Shortage of specialists in bioreactor design and large-scale production. - Limited expertise in growth media	- Cell line development experts - Growth media optimization specialists

	that can be reskilled for CM R&D.	optimization for cost-effective production. - Few professionals with regulatory expertise in CM production.	- Bioreactor design engineers - Regulatory scientists for CM production - Tissue engineering scientists

2.2 Opportunities to Develop the Alternative protein Workforce in Thailand

Cluster A: Specialized training programs for immediate needs

- Opportunity 6: Create specialized training programs on characterizing plant-based proteins and microbial strains for AP applications (R&D goals/academia workforce)
- Opportunity 7: Create specialized training programs to upskill/reskill bioprocess engineers who can operate fermentation bioreactors at the manufacturing scale (manufacturing workforce)
- Opportunity 8: Create specialized training programs to upskill/reskill on extrusion and rheological science for plant-based meat (product development workforce)
- Opportunity 9: Create specialized training programs to upskill/reskill on flavor development & sensory science for plant-based meat (product development workforce)

Cluster B: Develop an ongoing feedback loop for understanding industry talent needs

- Opportunity 10: Establish public-private partnerships and protocols to align workforce development with market needs

Cluster C: Attracting foreign-trained talent

- Opportunity 11: Attract international talent to fill gaps in advanced AP roles or send local employees/students internationally for work-study.

Cluster A: Specialized training programs for immediate needs

Opportunity 6: Create specialized training programs on characterizing plant-based proteins and microbial strains for AP applications (R&D goals/Academia workforce)

Rationale: Academic researchers must develop advanced skills in characterizing plant-based and microbial strains for alternative protein applications. This opportunity focuses on enhancing academic expertise, which will support the AP industry with functional ingredients and strain development.

Impact: Fostering skills in strain characterization will help Thailand's academic institutions to provide cutting-edge research, driving innovation in the AP industry. This will also improve collaboration between academia and industry, strengthening the R&D ecosystem.

Feasibility (RIsk/Effort/Buy-in): Feasible with funding for research programs and partnerships with biobanks and international experts to support advanced training.

Potential workstreams: Developing targeted curricula and hands-on laboratory modules, strengthening partnerships with international experts and biobanks, and upgrading laboratory infrastructure to support advanced analytics.

Opportunity 7: Create specialized training programs to upskill/reskill bioprocess engineers who can operate fermentation bioreactors at the manufacturing scale (Manufacturing workforce)

Rationale: Thailand has a shortage of bioprocess engineers capable of scaling fermentation technologies. By creating specialized training programs, Thailand can build a workforce with the skills necessary to manage bioreactors and fermentation systems at the manufacturing scale.

Impact: Building this workforce will strengthen Thailand's fermentation manufacturing capabilities, enabling the country to scale industrial production. This will also foster job creation in high-tech manufacturing sectors and improve Thailand's global fermentation supply chain position.

Feasibility (RIsk/Effort/Buy-in): Feasible with industry partnerships and government support to fund reskilling programs. Existing academic infrastructure can be leveraged to deliver specialized training.

Potential workstreams: Developing practical, industry-aligned curricula on large-scale bioprocessing and automation, establishing hands-on training facilities in collaboration with existing pilot plants, and partnering with fermentation companies for internships and on-site learning. Joint certification programs and continuous learning modules can be introduced to ensure workforce readiness, supported by government funding and industry co-investment to sustain long-term capacity building and strengthen Thailand's position in global fermentation manufacturing.

Opportunity 8: Create specialized training programs to upskill/reskill on extrusion and rheological science for plant-based meat (Product development workforce)

Rationale: Extrusion technology and sensory science are critical for developing scalable, high-quality plant-based meat products. Upskilling workers in these areas will allow Thailand to strengthen its product development capabilities and meet local and export market demands.

Impact: Strengthening skills in extrusion and sensory science will create higher-quality products that can compete globally. It will also generate new opportunities for job creation in product development and food tech industries.

Feasibility (RIsk/Effort/Buy-in): Feasible with collaboration between food tech companies and academic institutions. Industry demand for these skills will drive the need for well-designed training programs.

Potential workstreams: Designing practical courses and workshops in collaboration with food tech companies and universities, establishing demonstration and pilot-scale extrusion labs, and integrating sensory evaluation modules to enhance product quality understanding. Industry partnerships can support on-site training and internships, while certification programs and government-backed incentives can ensure a steady pipeline of skilled product developers capable of advancing Thailand's competitiveness in the global plant-based meat market.

Opportunity 9: Create specialized training programs to upskill/reskill on flavor development & sensory science for plant-based meat (product development workforce)

Rationale: Extrusion technology and sensory science are critical for developing scalable, high-quality plant-based meat products. Upskilling workers in these areas will allow Thailand to strengthen its product development capabilities and meet local and export market demands.

Impact: Strengthening skills in extrusion and sensory science will create higher-quality products that can compete globally. It will also generate new opportunities for job creation in product development and food tech industries.

Feasibility (RIsk/Effort/Buy-in): Feasible with collaboration between food tech companies and academic institutions. Industry demand for these skills will drive the need for well-designed training programs.

Potential workstreams: Developing practical curricula combining flavor chemistry, sensory evaluation, and consumer preference analysis; establishing joint training facilities or flavor innovation labs in collaboration with food tech companies and universities; and organizing industry-led workshops or internships for hands-on experience. Certification programs and co-funded initiatives between academia, government, and industry can further ensure a steady talent pipeline, enhancing Thailand's product development capacity and global competitiveness in the plant-based food sector.

Cluster B: Feedback loop with industry

Opportunity 10: Establish public-private partnerships and protocols to align workforce development with market needs

Rationale: Public-private partnerships (PPPs) will ensure workforce development programs align with real-world market demands. Industry-driven training programs will ensure that graduates have the relevant skills needed to enter the AP workforce immediately.

Impact: Aligning workforce development with market needs will accelerate Thailand's AP industry growth by ensuring a steady supply of skilled workers. This will reduce hiring bottlenecks and enhance Thailand's ability to commercialize AP products.

Feasibility (RIsk/Effort/Buy-in): Highly feasible with government incentives and industry collaboration. Existing institutions can serve as partners in creating industry-aligned curricula.

Potential workstreams: Creating an industry advisory council under agencies like FoodInopolis or National Food Institute (NFI) to guide curriculum design, skill standards, and internship frameworks; developing co-funded training programs and apprenticeships tailored to Alternative proein industry roles; and setting up regular feedback mechanisms between academia and industry to update programs based on emerging technologies. Leveraging existing university–industry partnerships and government incentives will ensure sustained collaboration and continuous workforce relevance.

Cluster C: Attracting foreign talent

Opportunity 11: Attract international talent to fill gaps in advanced Alternative protein roles or send local employees/students internationally for work-study.

Rationale: Attracting foreign experts in key areas such as bioprocess engineering, regulatory compliance, and strain development will help fill immediate skills gaps and facilitate knowledge transfer to local talent, improving the overall competency of Thailand's AP workforce.

Impact: Bringing in international talent will provide the advanced expertise to scale AP production, innovation, and regulatory compliance. It will also expedite knowledge transfer to local workers, accelerating workforce development.

Feasibility (RIsk/Effort/Buy-in): Feasible with government initiatives to attract talent and industry partnerships to offer placements for international experts.

Potential workstreams: Establishing short-term visiting expert or fellowship schemes (ex. The Reinventing Universities model) to bring foreign specialists in bioprocessing, regulatory affairs, and strain development to Thai institutions; launching bilateral exchange programs with countries such as Singapore, India, and ASEAN for hands-on training; and leveraging initiatives like the SCI-FI program to connect Thai students and professionals with global AP ecosystems.

2.3 Key Stakeholders That Can Make an Impact

Stakeholder	Role/Impact
Government Agencies	Provide funding and policy support for workforce development initiatives, including reskilling programs and international talent attraction (e.g., Ministry of Higher Education Science Research and Innovation, NXPO, PMU-B).
Ministry of Higher Education Science Research and Innovation	Preparation in curriculum which are necessary for supporting manpower including undergraduate in the university.
NXPO	Provide policy guidelines for workforce development initiatives, including reskilling programs, higher education sandbox and international talent attraction.
TISTR	To provide training services and consultancy in order to leverage standards and competitiveness of the industrial sector.
PMU-B	Providing scholarships Funds to support researchers and other post-graduate personnel Scholarships for the development of higher education institutions and research and innovation institutes
Academic Institutions	Develop training programs and short courses for high-demand roles (e.g., Chulalongkorn University, Kasetsart University, Mahidol University).
Chulalongkorn University	Developing and providing quality education and specialized training to students with knowledge and skills necessary for their careers and personal growth especially R&D skills talents.
Kasetsart University	Developing and providing quality education and specialized training to students with knowledge and skills necessary for their careers and

	personal growth especially R&D skills talents and hand-on projects with industry.
Khon Kaen University	Developing a special curriculum in alternative proteins and providing quality education and specialized training to students especially R&D skills talents and hand-on projects with industry.
Mahidol University	Developing and providing quality education and specialized training to students with knowledge and skills necessary for their careers and personal growth especially R&D skills talents.
Private Sector	Collaborate with academia and government to align training programs with market needs and provide hands-on experience through internships and job placements.
International Experts	Provide advanced expertise in bioprocess engineering, strain development, and regulatory compliance, and facilitate knowledge transfer to local talent.
Industry Associations	Coordinate public-private partnerships and represent industry needs in discussions on workforce development (e.g., AP industry groups, food and beverage associations).

3. Infrastructure

Opportunities to Develop the Alternative Protein Infrastructure in Thailand

3. Infrastructure: Opportunities to Develop the Alternative Protein Infrastructure in Thailand

3.1 Current State of Infrastructure for Alternative protein in Thailand

Pillar	Available Infrastructure (Strengths)	Infrastructure Gaps/Needs
Plant-Based Meat (PBM)	- Lab-scale infrastructure for extrusion, homogenization, and rheological analysis is well-established in research institutions (e.g., extruders, homogenizers, rheometers). - Some pilot-scale processing tools available for trials.	- Lack of large-scale High-Moisture Extrusion (HME) equipment for scaling production. - Limited access to pilot and demonstration-scale infrastructure for upscaling. - Absence of shear cell technology and 3D printing for texture development.
Fermentation derived protein (FD)	- Lab-scale fermentation equipment, including small bioreactors (1-5L), is available at Mahidol University, VISTEC, and other institutions. - National biobank for microorganisms supports strain research.	- Lack of commercial-scale fermentation facilities. - Limited downstream processing equipment such as membrane filters and centrifuges. - No GMP-certified fermentation infrastructure to support food-grade fermentation processes.

Cultivated Meat (CM)	- Small-scale bioreactors (1-5L) for cultivated meat research are available in institutions like Mahidol University. - Research facilities equipped for cell biology and tissue engineering.	- Absence of pilot and demonstration-scale bioreactors for cultivated meat production. - No large-scale production facilities for transitioning from lab to commercial scale. - No commercial-scale bioreactors for full-scale CM production.

3.2 Opportunities to Develop the AP Infrastructure in Thailand

Cluster A: Mapping infrastructure pathway

- Opportunity 12: Create a national map of existing AP infrastructure and build access pathways for academic and industry stakeholders
- Opportunity 13: Establish connections with international CDMOs (Contract Development and Manufacturing Organizations) to address infrastructure gaps

Cluster B: Optimising existing infrastructure

- Opportunity 14: Assess and optimize the operational (and workforce) needs to run pilot and demonstration-scale facilities at total capacity
- Opportunity 15: Establish GMP-certified fermentation facilities for food-grade production
- Opportunity 16: Build business cases for shared facilities and market them to international stakeholders (International investment to build CDMOs in Thailand)

Cluster A: Mapping infrastructure pathway

Opportunity 12: Create a national map of existing AP infrastructure and build access pathways for academic and industry stakeholders *(Cluster A: Mapping infrastructure pathway)*

Rationale: By mapping out all available infrastructure across institutions and industries, Thailand can showcase how academic and industry partners can access these resources. A centralized platform providing clear pathways for utilization will optimize use of infrastructure and improve R&D outcomes.

Impact: A national infrastructure map will enhance collaboration, reduce duplication of effort, and increase the utilization of existing resources. By providing easy access to state-of-the-art infrastructure, it will foster innovation and accelerate R&D.

Feasibility (Risks/Effort/Buy-in): This is feasible with collaboration between government agencies, academic institutions, and industry partners. A shared online platform can facilitate this mapping and access process.

Potential workstream: Mapping Existing Alternative Protein Infrastructure and identifying academic institutions, industry facilities, and government-backed research labs involved in AP industry. Organize infrastructure based on categories and prepare document key details such as available equipment, scale of operation, and accessibility for partners. Create clear guidelines for accessing shared AP infrastructure such as safety regulations and fees for users.

Opportunity 13: Establish connections with international CDMOs (Contract Development and Manufacturing Organizations) to address infrastructure gaps

Rationale: Connecting with global CDMOs that specialize in alternative proteins will allow Thailand to address any infrastructure gaps, particularly in areas like fermentation and cultivated meat. These partnerships will offer access to cutting-edge technologies and expertise, enabling Thailand to scale AP production more efficiently.

Impact: Partnerships with international CDMOs will enhance Thailand's capabilities in scaling AP technologies, reduce the time and cost of building new infrastructure, and position the country as a key player in the global AP supply chain.

Feasibility (Risks/Effort/Buy-in): Feasible through government-backed incentives to attract international CDMOs and industry-led partnerships. These connections will allow Thailand to leverage global expertise while building domestic capacity.

Potential workstream: Develop a targeted outreach strategy for engaging international CDMOs. Create attractive financial and regulatory incentives for international CDMOs to partner with local companies in joint ventures or public-private partnerships (PPP). Collaborate with regulatory bodies to simplify approval processes for international CDMOs looking to set up operations in Thailand.

Cluster B: Optimising existing infrastructure

Opportunity 14: Assess and optimize the operational (and workforce) needs to run pilot and demonstration-scale facilities at total capacity

Rationale: Many of Thailand's pilot and demonstration-scale facilities are underutilized due to gaps in operational capabilities. A detailed assessment of these needs (e.g., staffing, equipment maintenance, and technical support) will allow these facilities to run at maximum capacity and contribute more effectively to the AP industry.

Impact: Optimizing the operational efficiency of pilot and demonstration-scale facilities will enable greater throughput in R&D and product testing, supporting industry growth. It will also attract more research projects and investment, both locally and internationally.

Feasibility (Risks/Effort/Buy-in): Feasible with investment in workforce training, facility management, and government-backed programs to improve operational standards. Collaboration with international facility operators can provide additional insights.

Potential workstream: Conducting facility audits to identify gaps in staffing, technical capacity, and maintenance; developing targeted training programs for facility managers and technicians; and upgrading critical equipment or processes to meet industry standards. Establishing best-practice guidelines through collaboration with international operators and implementing performance monitoring systems can further enhance utilization.

Opportunity 15: Establish GMP-certified fermentation facilities for food-grade production

Rationale: GMP certification is essential for producing food-grade fermentation products that meet international regulatory standards. Establishing GMP-certified facilities will allow Thailand to enter global markets with high-value, safe, and certified fermentation-based ingredients.

Impact: GMP-certified facilities will enable Thailand to produce high-quality, food-grade fermentation products, expanding market access and creating export opportunities. This will also stimulate local industry and foster job creation in high-tech production roles.

Feasibility (Risks/Effort/Buy-in): Feasible with government support for regulatory alignment and infrastructure development. Collaborations with international experts and CDMOs can fast-track the certification process and facility setup.

Potential workstream: Collaborate with government agencies (e.g., Thailand's Food and Drug Administration) and global certifying bodies to streamline the approval and inspection processes for fermentation facilities. Partner with funding agencies to support GMP shared facilities especially in regional Thailand.

Opportunity 16: Build business cases for shared facilities and market them to international stakeholders (International investment to build CDMOs in Thailand)

Rationale: Developing detailed business cases for shared infrastructure facilities (e.g., pilot plants, bioreactors) will help attract international investment and partnerships. A clear value proposition will encourage global stakeholders to leverage Thailand's infrastructure for their AP projects.

Impact: Well-developed business cases will attract international companies and investors to use Thailand's shared facilities for R&D and production. This will boost foreign investment, create high-tech jobs, and position Thailand as a global hub for AP innovation.

Feasibility (Risks/Effort/Buy-in): Feasible with collaboration between government agencies, industry associations, and business development experts. Marketing campaigns and global partnerships can enhance Thailand's visibility in the AP industry.

Potential workstream: Conduct and analyze the competitive landscape of existing CDMOs to identify global demand and pinpoint gaps that Thailand's shared facilities can fill. Collaborate with the Thai government to design attractive financial incentives for international investors

(e.g., tax breaks, subsidies, or special economic zones). Demonstrate how Thailand's CDMOs can attract international clients seeking cost-effective, high-quality, and scalable solutions.

3.3 Key Stakeholders That Can Make an Impact

Stakeholder	Role/Impact
Government Agencies	Provide funding and policy support for infrastructure projects and certification initiatives (e.g.,BOI, NXPO, TSRI, PMU-B, NSTDA)
Thailand Board of Investment (BOI)	Create measures and attract investment in target industries such as future foods industry (e.g. alternative proteins)
NXPO	Partner with BOI to create measures and attract investment in target industries such as future foods industry (e.g. alternative proteins)
TSRI	Manage and allocate the budget for the Science and Technology plan including infrastructures.
PMU-B	Providing funds for the development of science and technology infrastructure.
PMU-C	Allocates research funds to develop laboratory infrastructure for providing quality services.
Food Innopolis	Partner and collaboration with future food labs which are in many universities throughout Thailand. (e.g., KU, NU, PSU) to support and share some equipment and instruments.
Academic Institutions	Develop R&D infrastructure and facilitate collaboration with industry (e.g., Mahidol University, Kasetsart University, BIOTEC).
NSTDA	Support pilot plant for testing and small scale production which has GMP facilities for SMEs and provides testing and is registered with FDA. especially in Precision fermentation.

TISTR	• Support pilot plant for testing and small scale production which has GMP facilities for SMEs and provides testing and is registered with FDA especially in plant based meat products. • To provide analysis, testing and calibration services with a laboratory management system certified according to the ISO/IEC 17025 and ISO/IEC 17020 • Solving the problems of product quality and production processes for industrial sector and community enterprise domestically and internationally.
Chulalongkorn University	Provide Lab scale and pilot plant production, especially in Saraburi campus has GMP food production facilities
Kasetsart University	Support pilot plant for testing and small scale production which has GMP facilities for SMEs. (e.g., Food Innopolis at KU)
Khon Kaen University	Support pilot plant for testing and small scale production which has GMP facilities for SMEs.
Mahidol University	Support pilot plant for testing and small scale production facilities for SMEs. (e.g.,SPACE-F)
Private Sector	Invest in and utilize infrastructure for pilot plant, scaling production, particularly in fermentation and plant-based meat technologies.
International Partners	Bring in expertise and technology to support GMP certification, bioreactor design, large-scale production and regulatory compliance.
Industry Associations	Coordinate infrastructure initiatives, align stakeholders, and market shared facilities to international partners (e.g., food and beverage associations).