
BIOTECH
Thailand's National
Biotechnology
Policy Framework
(2012-2021)

Thailand's National Biotechnology Policy Framework (2012-2021)

Food and Agriculture | Medicine and Health | Bioenergy | Bio-based Industry

National Science Technology and Innovation Policy Office (STI)
National Center for Genetic Engineering and Biotechnology (BIOTEC)
National Science and Technology Development Agency (NSTDA)

Ministry of Science and Technology, Thailand

Preface

Biotechnology plays a vital role in Thailand's development, driven by ongoing investments in research, development and manufacturing across multiple sectors. National biotechnology policies stimulate innovations, boost competitiveness and increase productivity, while working to improve the quality of life for Thai citizens and the conservation and rehabilitation of the country's natural resources.

As biotechnology advanced into the genomic and post-genomic eras, it created no less benefit to the world than the previous three technological revolutions. In addition to well-publicized advances in medicine, biotechnology has stimulated major shifts in the industrial sector. Where chemical-based industries once dominated, bio-based alternatives have evolved, including many environmentally friendly and energy efficient products gaining increased traction in the marketplace. Production processes have been greatly simplified and streamlined as a result of biotechnology. So it is no surprise that many countries invest in biotechnology research and development to raise competitiveness and minimize the risks of being left behind as the industry matures.

In Thailand, the implementation of the previous National Biotechnology Policy Framework (2004-2009) helped establish the country's capacity to pursue biotechnology, resulting in a significant leap forward in the sector's evolution. This is evidenced by rapid growth in: biotechnology businesses; investment targeting biotechnology research by existing and new enterprises and the development of many new products and services. At the community level,

increased biotechnology capacity enhanced people's livelihoods by improving food fermentation, facilitating organic fertilizer production and use, and stimulating demand for the preservation of rare, indigenous plant species now recognized as valuable economic assets. Combined, the Framework's results have helped increase competitiveness within the economy and brought greater efficiencies to society.

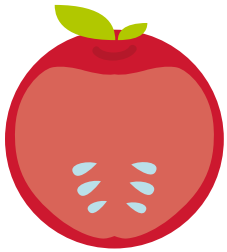
Despite Thai society's increased biotechnology capacity and knowledge, the public and private support system the industry requires is not keeping pace. Insufficient capital and financing mechanisms, along with limited IP management, standards system and regulations are all working to impede Thailand's biotechnology development. Moreover, increasing challenges facing society such as climate change, global economic integration, lost livelihoods and emerging infectious diseases further reinforce the need to ramp up biotechnology's support infrastructure.

National Science Technology and Innovation Policy Office (STI), National Center for Genetic Engineering and Biotechnology Office (BIOTEC) and National Science and Technology Development Agency (NSTDA) collectively undertook the preparation of the current National Biotechnology Policy Framework (2012-2021). This was undertaken in accordance with the 1st National Science, Technology and Innovation Policy and Plan (2012-2021). The principle objective was to initiate programs that solidify biotechnology's role as a leading force for sustainable social and economic development by bolstering Thailand's energy, food and health security.

The completion of the National Biotechnology Policy Framework (2012-2021) was possible thanks to the kind support of many committed people, especially Dr. Yongyuth Yuthavong who chairs the Policy Framework Steering Committee and Dr. Amaret Bhumiratana who chairs the Framework's Working Committee. We take this opportunity to express our sincere gratitude to them and all those who contributed.

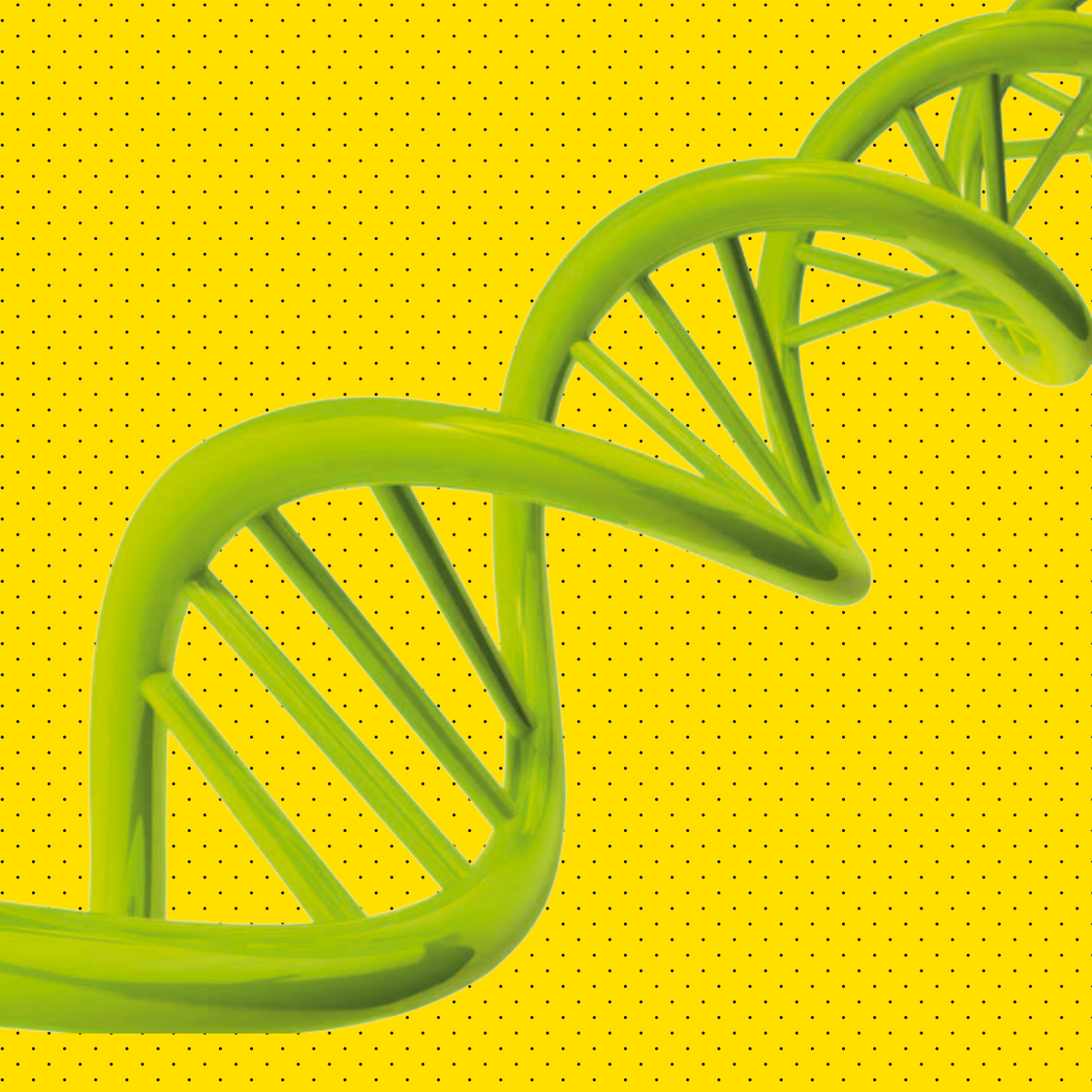
Dr. Pichet Durongkaveroj
Secretary General
National Science Technology and Innovation Policy Office

Contents



Thailand's Biotechnology Development Strategy

- Rationale
- Targets
- Strategies
- Implementation Measures
- Expected Results



Conceptual Approach

1 Work in parallel with global, regional and national development priorities

In formulating the Policy Framework, strong consideration was given to how the Policy Framework's objectives and targets could reinforce those of related plans and initiatives underway globally, regionally and nationally. Among those considered were: the Millennium Development Goals (MDGs), ASEAN Economic Community (AEC), Thailand's National Economic and Social Development Plan (2012-2016), the National Science, Technology and Innovation Policy and Plan (2012-2021), the 8th National Research Policy and Strategy (2012-2016) and the National Guideline for Capacity Building in Science, Technology and Innovation Competitiveness.

2 Strengthen Thailand's competitiveness and self-sufficiency through biotechnology

Building competiveness and self-sufficiency in the areas where Thailand either has strong potential and/or pressing needs.

3 Promote private sector investment in biotechnology R&D and the biotech industry development, and deeper community engagement in biotechnology

Increasing private sector investment in R&D as well as biotech industry development and work to mainstream biotechnology into community development plans.

Targets

1 Increase competitiveness by advancing science and technology in areas where Thailand has a comparative advantage and/or strong capacity.

2 Increase wealth and reduce inequality by creating jobs.

3 Increase quality of life by strengthening economic, social, health and environmental security and promote lifelong learning.

4 Foster sustainable development by helping to realize economic development objectives that safeguard environmental quality and conserve natural resources.

5 Strengthen national security by increasing self-reliance in strategic sectors such as energy and healthcare.

‘Science and Technology Critical to Success’

Success in biotechnology development for the Policy Framework’s Strategic Sectors rests with a deeper application of:

- Platform technologies including: systems biology, genomics, proteomics, DNA technology, synthetic biology, cell factory and DNA chips.
- Basic sciences such as biology, zoology, microbiology, physics, chemistry and mathematics.
- Multidisciplinary technologies such as nano-biotechnology, bioinformatics and biophysics.

‘Supporting Infrastructure Requirements’

1 Physical infrastructure such as biology research institutes, centers for excellence, pilot plants and regional bioparks.

2 Personnel development and capacity building for biotechnology and related fields including professional researchers, biotechnology business managers, IP managers and local researchers generated from the Royal Golden Jubilee Ph.D. Program and multidisciplinary study programs.

3 Critical investment and biotechnology development fund established through a public-private partnership to provide capital for biotechnology entrepreneurs.

4 Streamlined regulation and investment policies advance more efficient policies, regulations and standards to eliminate bottlenecks impeding progress in key areas such as GMOs, biosafety, bioethics and IP management. Seek tax deductions for R&D expenses related to the Framework’s strategic sectors. Structure government procurement processes to support markets for bio-based products.

Strategic Sectors

Food and Agriculture

Advance market competiveness and strengthen agricultural sustainability by increasing quality, productivity and innovation while reducing costs

Medicine and Health

Advance wellness, improve self-reliance and increase competiveness in medical and healthcare fields where Thailand has a comparative advantage

Bioenergy

Increase energy security by developing alternative energy sources without compromising food production or environmental sustainability

Bio-based Industry

Increase industry commitment to environmental protection through more resource efficient production and stimulating innovation in fields where Thailand holds a comparative advantage

Targets

- Improve quality of life
- Increase incomes and local employment
- Increase competiveness
- Strengthen national security
- Further sustainable development

VISION

"Green Innovations for Economic Security, Competitiveness and a Healthy Society"

Supporting Infrastructure

Physical

- Regional bioparks
- Bioscience research institutes
- Pilot plants

Human Resources

Strengthen biotechnology curricula at the undergraduate and graduate levels, especially programs emphasizing multidisciplinary fields

- Increase biotechnology manpower
- Recruit and develop research and technology professionals at local levels
- Increase the capacity of technology and IP management and grow their workforce
- Work Integrated Learning (WIL) Program
- Thailand Advanced Institute of Science and Technology (THAIST)
- The Royal Golden Jubilee (RGJ) PhD Program

Management

- Intellectual Property Management
- Access and utilize biological diversity and related technologies with a good system of Access and Benefit Sharing: ABS
- Biotech Fund for small and medium enterprises (SMEs)
- Research and production standards
- Bioethics
- Biosafety
- Targeted and full circle research management systems
- Science awareness and science communications

Science & Technology

Multidisciplinary technologies

- Nanobiotechnology
- Bioinformatics
- Biophysics

Platform technologies

- Post-genomics and Omics
- Cell factory
- Lab-on-a-chip

Basic sciences

- Biology
- Zoology
- Microbiology
- Physics
- Chemistry
- Mathematics

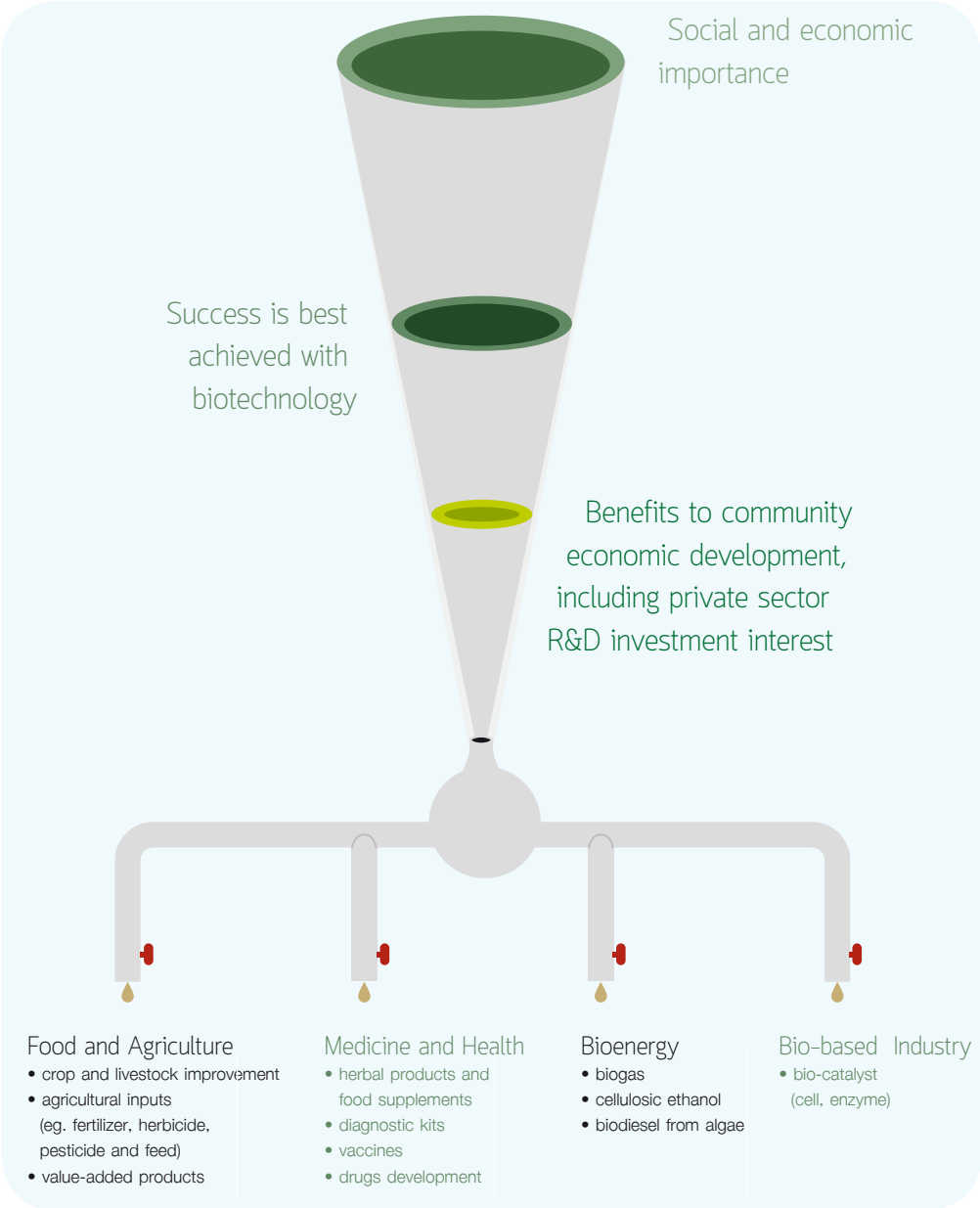
'Implementation Strategies'

The Policy Framework is designed to mobilize resources from multiple sources to achieve maximum impact within a short period of time. Innovative programs to promote development in research, human resources and capital availability for the Policy Framework's Strategic Sectors will stem from the following criteria:

1 High social and economic importance

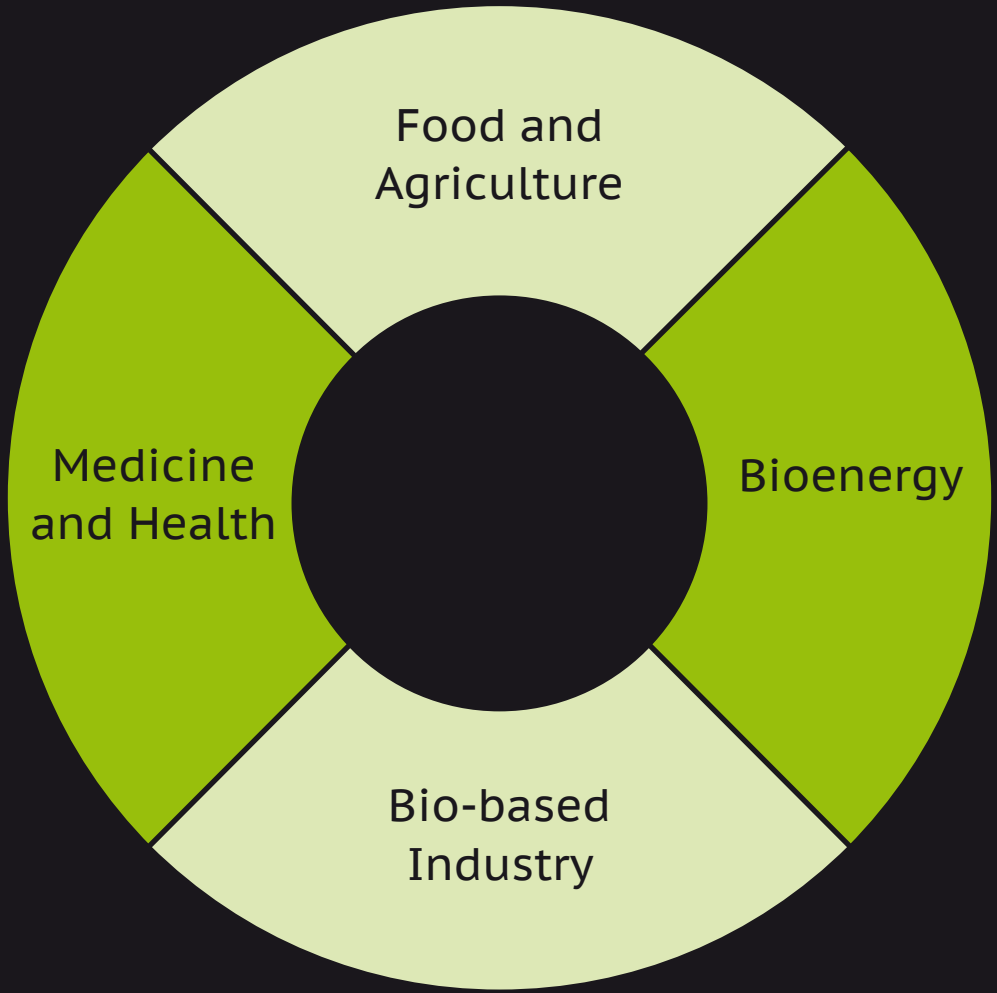
2 Biotechnology's comparative advantage to attain productivity and quality improvements relative to other methods

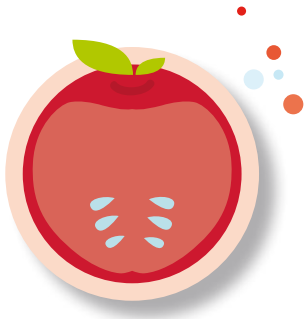
3 High tendency for private sector R&D investment to pursue products that have strong market potential, and/or enhance livelihood at the community level



Selection Criteria for Strategic Sectors


Strategic
Sectors
The Policy Framework prioritizes
four strategic sectors


Food and
Agriculture
Bioenergy
Bio-based
Industry
Medicine
and Health



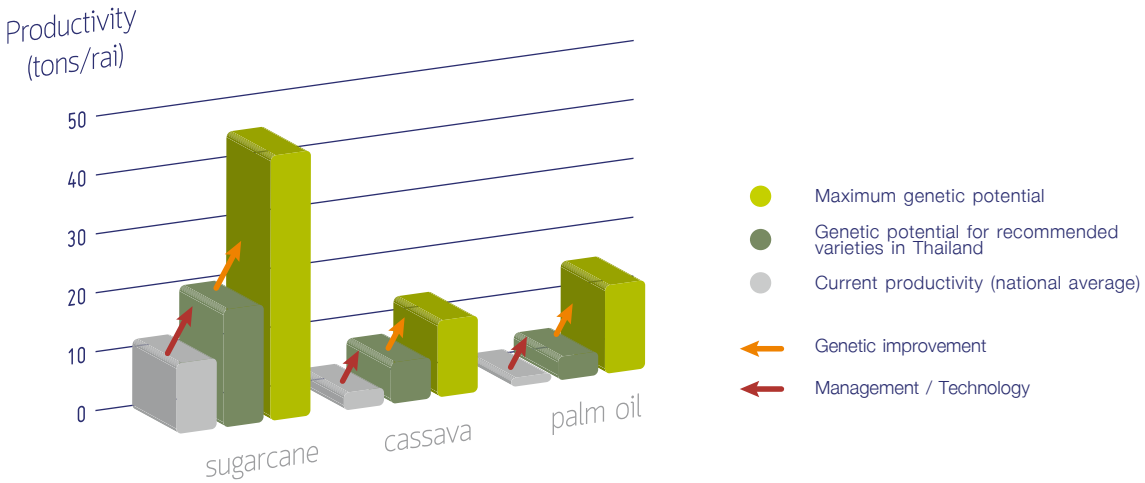
1st Strategic Sector

Food and Agriculture

Thailand is among the world's leading agriculture and food exporters. It is therefore critical for the country to adapt to global trends so as to maintain its position, especially to meet growing global food demands and the need to respond to climate change mitigation by transitioning toward more bio-based energy sources.

World agricultural demand forecasts show a strong need for increased production of crops to supply the rapidly evolving bioenergy and biotech industry: cassava, sugarcane and palm oil in particular. Thailand must increase its output of these crops two-fold over the next decade, to more than 200 million tons, in order to maintain its global market position.

Increased crop productivity can be achieved through management technology gains and the application of biotechnology to improve yields up to a crop's maximum genetic potential.



Genetic potential for cassava, sugarcane and palm oil[1]

1 Morakot Tanticharoen, M. et al 2552 (2009) Potential Yield Increase for Sugarcane, Cassava and Palm Oil for Bioenergy by Technology and Plantation Land Expansion. The study was undertaken as a part of policy research to support the development and use of renewable energy to increase energy efficiency in Thailand (Phase 2), submitted to the Department of Alternative Energy Development and Efficiency

‘Rationale: Food and Agriculture’

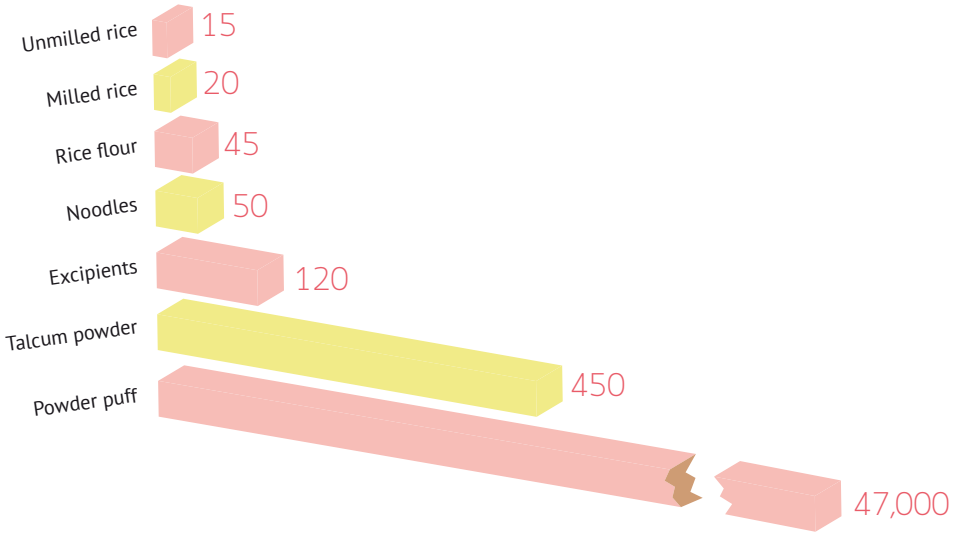
- Advance market competiveness and strengthen agricultural sustainability by increasing quality, productivity and innovation while reducing costs. Increase biotechnology’s role in crops and livestock cultivation, especially through their inputs (eg. fertilizer, herbicide, pesticide and feed) to raise food production efficiency and to contribute to environmentally responsible and sustainable agricultural production.

- Increase agricultural quality and productivity to yield a 50 percent increase in the sector’s value chain through genetic improvements, quality and safety controls, nutrient labeling and product diversification and innovation.

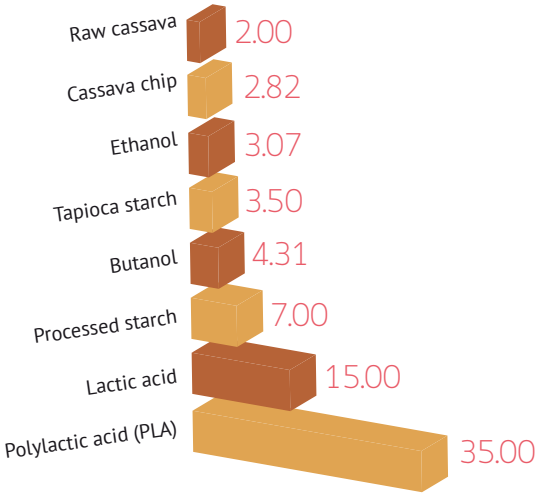
Prices for rice seeds

Products	Prices (Baht/Kg)
Common rice	23-25
Jasmine rice	29
Black jasmine rice	35
Hybrid rice	120

Complied by BIOTEC’s Policy Research and Bio Safety Division, with data from Department of Rice, Center for Community Rice and Product Support in Ubon Rachathani and Bangkok Seeds Industry Co.,Ltd.



Prices of products produced from 1 kg of rice (Baht)



Price of products produced from 1 kg of cassava (Baht)

Targets and Strategy

Target: Advance market competiveness and strengthen agricultural sustainability and farmer livelihoods by increasing quality, productivity and innovation while reducing costs and responding to climate change.

Strategy: Apply genomic technology, genetic engineering and cell factory systems in combination with other technologies along with conventional plant breeding to enable the following:

1 Crops and livestock cultivation improvement

Increase productivity, pests and disease resistance, and meet emerging industrial demands such as high-starch and fine pellet cassava or high-protein and antioxidant-rich rice.

Adapt to changing climatic conditions, such as developing drought-resistant rubber. In the case of livestock, genetic development can generate more productive and faster-growing farm animals such as high-meat content pigs, higher yields of healthy piglets per mother and dairy cows that remain productive in warmer climates.

2 Agricultural inputs' improvement

Diversify and increase productivity of microorganism for soil nourishment by modifying organic fertilizers, pesticides and livestock food supplements to reduce antibiotics , and by developing easy-to-use vaccines and test kits for accurate disease diagnosis.

3 Products value-added

Increase agricultural and food production value by utilizing farm wastes as inputs for other industries. Such waste could aid in the production of sweeteners, bioenergy, biopolymers and other biochemical products as well as food supplements such as dissolvable fibers, low-calorie food, fat substitutes and biochemical substances.

Implementation Measures

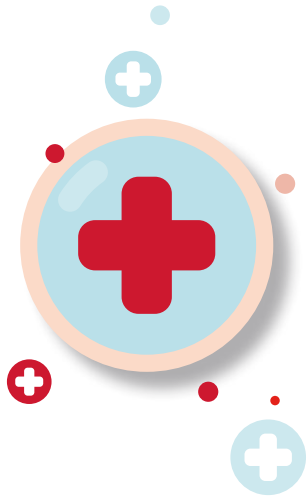
- Increase community access to biotechnology by simplifying research products and developing technologies appropriate to their localities. Establish pilot farms with community participation and local administration leadership. Support these farms through existing mechanisms such as technology assistants, local/village agricultural technology transfer centers and local universities.

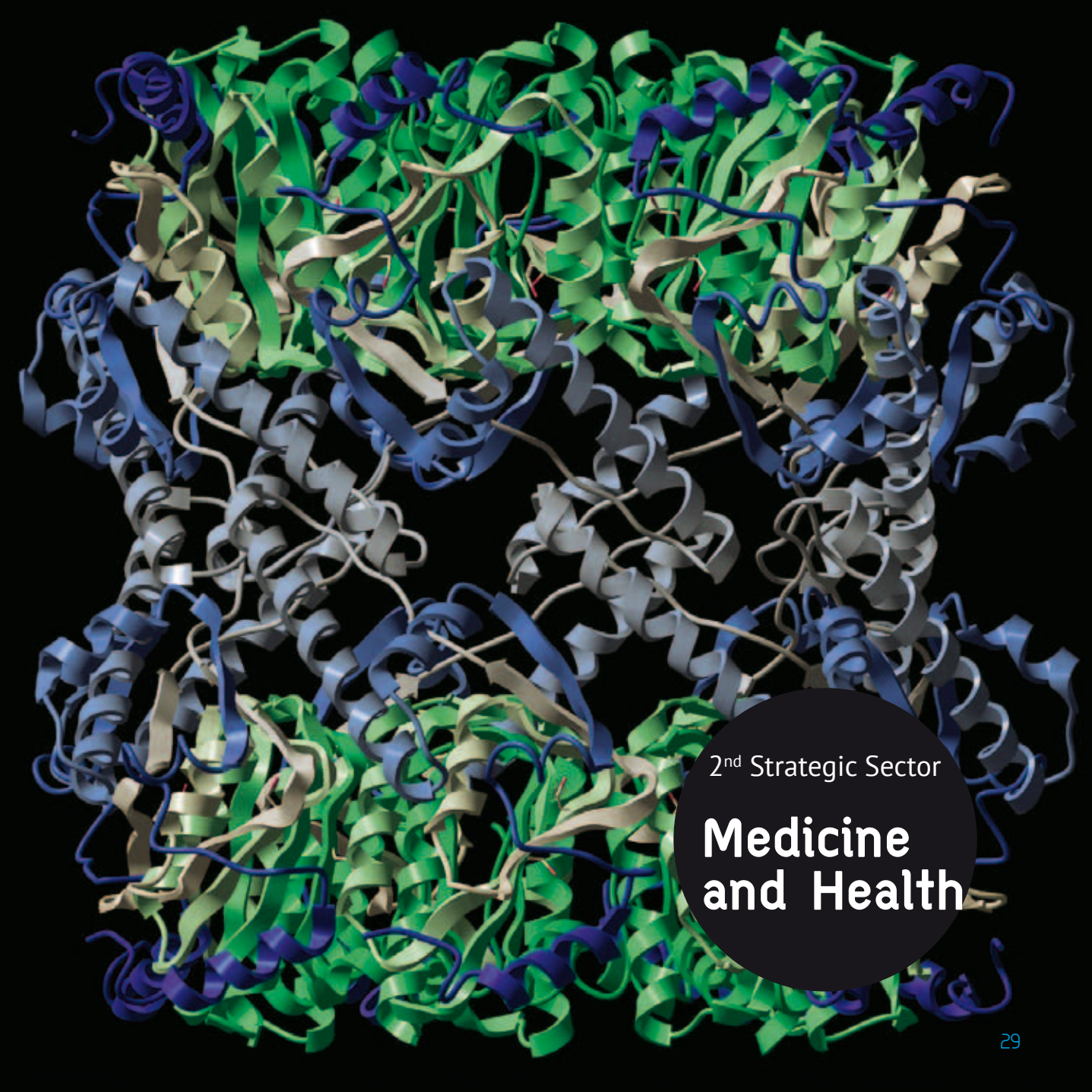
- Accelerate R&D for crop/livestock strains of desired qualities. Improve inputs such as high-performance microorganism strains for organic fertilizer and livestock feed supplements. Initiatives to stimulate funding for R&D within the food sector, both to stimulate innovation and to enhance basic science research, could be derived in part from agricultural and food export taxes.

- Increase government support for GMO research and commercial production together with strengthening biosafety policy and procedures.

Expected Outputs

The implementation of such measures will result in improved farmers' quality of life and job security, increased food productivity, and better food quality and safety that together will yield added revenue for farmers. They will also realize reduced costs through less agricultural chemical use, recycled resources and reduced losses from pest, disease and climatic variability.





2nd Strategic Sector

Medicine and Health

Thailand's public healthcare system has faced increasing challenges over the past few decades. Rapid lifestyle changes accompanying globalization and growth in the market economy has brought greater public health risks associated with unhealthy diets, accumulated stress and lack of regular exercise or physical activity. Between 2007 and 2011 cancer, diabetes, heart and vascular diseases were among the leading causes of death within the Thai population. Increasing frequencies of emerging and re-emerging infectious diseases have also added social and economic costs to the country's healthcare system. Like many nations, Thailand's population is aging. The senior sector is expected to reach 15.3 percent in 2020, more than double its 7.2 percent share in 1990. Moreover, increased longevity has brought with it a steady rise in the prevalence of diabetes, heart disease, kidney failure and neurological diseases such as Alzheimer's and Parkinson's. Growth in healthcare costs is destined to command a significant portion of the government budget.

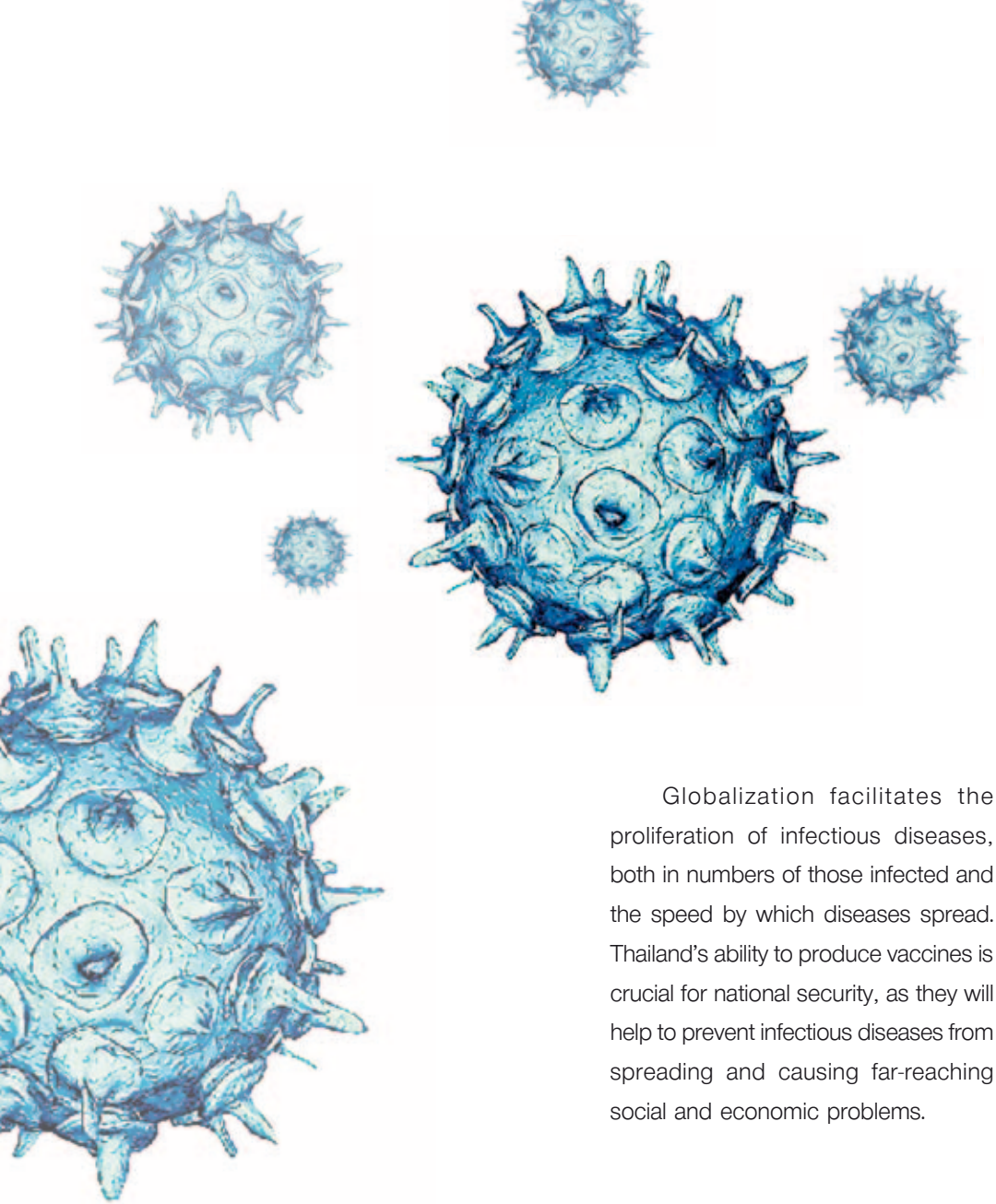
Medical technologies will continue to compliment preventive medicine and other public health management measures in helping Thailand cope with these challenges. Biotechnology in particular is increasingly being relied upon: from prevention and early diagnosis, to treatment and rehabilitation.

Thailand's biotechnology development in medicine and healthcare is at a relatively advanced level, especially in tropical diseases. Thailand has received international recognition thanks to its longstanding investments in basic sciences and clinical research. This capacity, when combined with the country's inherently rich biodiversity, provides a solid foundation for ongoing, commercially viable product development, particularly for biopharmaceuticals, herbal products, active pharmaceutical ingredients (API) and functional foods. Continuing along this trajectory will help to reduce medical products' import stresses on national public health budgets, while generating export revenues by marketing these products overseas.

Cause of Death	2007		2008		2009		2010		2011	
	Number	Rate	Number	Rate	Number	Rate	Number	Rate	Number	Rate
Malignant neoplasm, all forms	54,343	84.9	55,403	87.6	56,058	88.3	58,076	91.2	61,082	95.2
Vascular diseases	34,742	55.2	35,391	56.0	35,050	55.2	39,459	61.9	44,133	68.8
Infectious diseases and parasites	38,123	60.6	38,672	61.2	38,511	60.7	41,369	64.9	41,466	64.6
Accidents and suicide	42,884	68.1	41,786	66.1	41,946	66.1	39,926	62.7	40,682	63.4
Respiratory diseases	25,414	40.4	26,358	41.7	26,166	41.2	29,654	46.6	32,057	49.9
Reproductive system and urinary tract diseases	14,095	22.4	14,896	23.6	13,907	21.9	14,705	23.1	15,811	24.6
Gastronomic diseases	13,072	20.8	13,053	206.0	13,038	20.5	13,484	21.2	14,278	22.2
Endocrine, nutritious and metabolism diseases	8,505	13.5	8,601	13.6	7,901	12.5	7,829	12.3	8,854	13.8
Neurological diseases	5,259	8.4	5,093	8.1	4,590	7.2	4,633	7.3	5,137	8.0
Blood, blood forming organs and immune system	594	0.9	563	0.9	538	0.8	596	0.9	618	1.0
TOTAL	237,031	375	239,816	565	237,705	374	249,731	392	264,118	412

Thai mortality per 100,000 people by leading causes (2007 – 2011)[3]

3 Health Information Unit, Bureau of Health Policy and Strategy, Ministry of Public Health (http://bps.ops.moph.go.th/2.3.4-50.pdf)

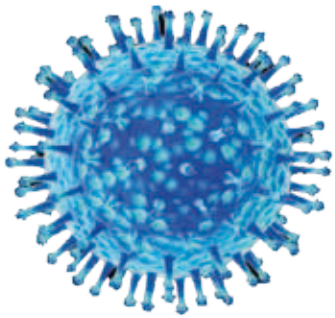


Globalization facilitates the proliferation of infectious diseases, both in numbers of those infected and the speed by which diseases spread. Thailand's ability to produce vaccines is crucial for national security, as they will help to prevent infectious diseases from spreading and causing far-reaching social and economic problems.

‘Rationale for Biotechnology Development in Medicine and Health’

- Biotechnology can play a key role in the overall wellness of Thai people by creating pharmaceutical and healthcare products that bring about inexpensive and rapid diagnosis, effective treatments and preventive care.

- The private sector is poised to invest in promising research and development in biotechnology related medicine and healthcare products.



'Targets and Implementation Strategy'

Targets: Promote public wellness, increase national self-reliance in healthcare and build competitiveness in markets where Thailand's biotechnology sector is poised to contribute.

Strategy: Expand the use of key technologies including: genomics, genetic modification and molecular biotechnology, production of Active Pharmaceutical Ingredients (API) and new industrial production techniques, all with an aim to grow the following product sectors.

1 Medical diagnostic kits

accelerate development of products that simultaneously diagnose multiple diseases, are easy to use and are affordable. Emphasize diagnostics' development of diseases of national concern including cancer, genetic diseases and tropical diseases.

2 Drug development

strengthen baseline technology for active pharmaceutical ingredients (API) and biopharmaceutical products such as therapeutic proteins for which Thailand has demonstrated capacity to pursue. Partner with international drug companies to mobilize investment resources and to enable local interests to rapidly expand their capacities to build and operate a complete drug production chain.

3 Vaccines

prioritize the development of vaccines critical for common diseases in Thailand, and construct pilot plants that pave the way for industrial-level vaccine production.

4 Food supplements

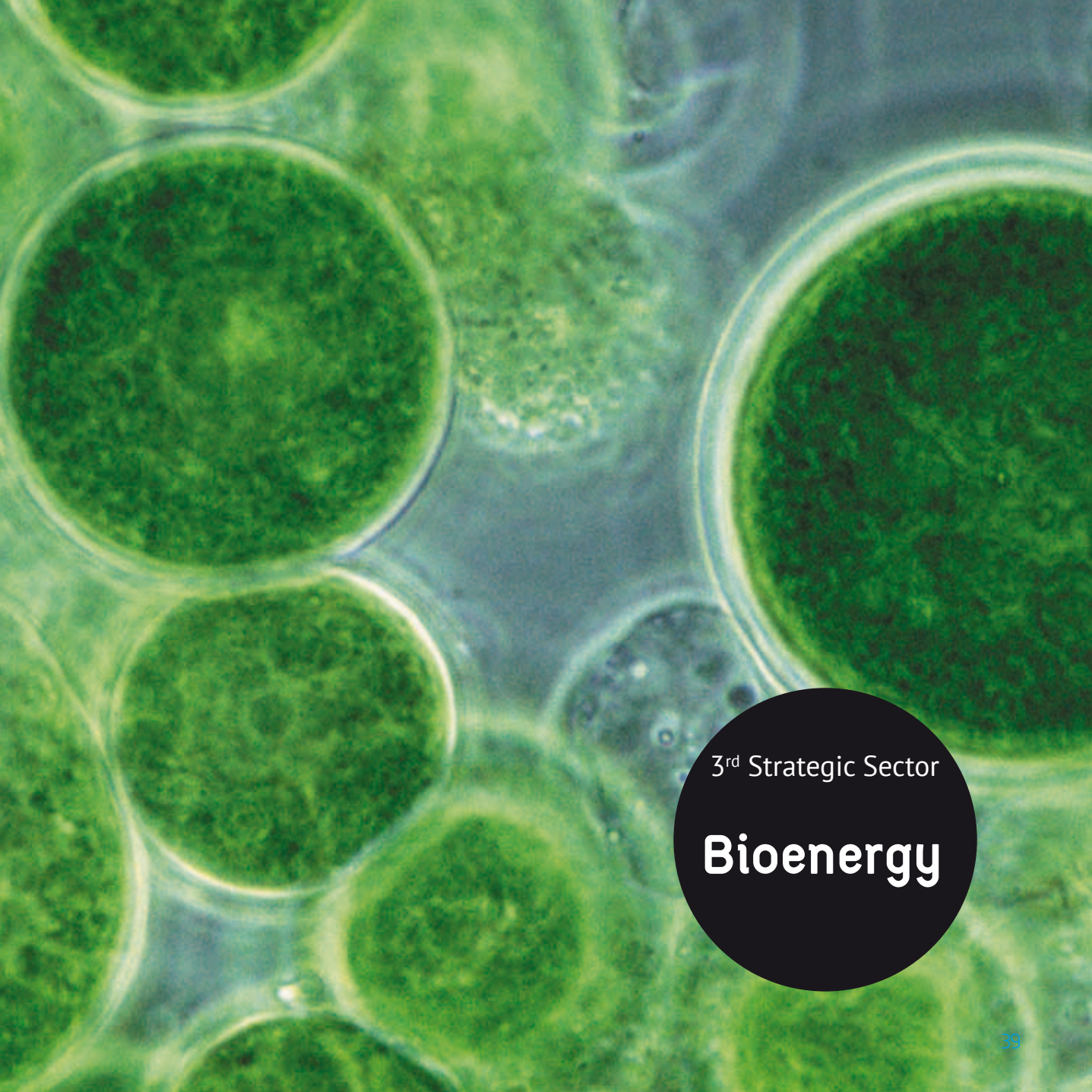
promote research to provide scientific evidence of the benefits of natural products and compounds available domestically. Establish quality control measures for the cultivation and extraction of compounds from herbal plants across different localities that realize high yields and provide a consistent supply chain throughout the year.

Implementation Measures:

- Facilitate the development of support infrastructure for the upgrade of animal testing labs to GLP standards, and establish pilot plants for the production of drugs, vaccines, food supplements and biological substances.
- Advance critical platform technologies such as genome, nutrigenomics, pharmacogenomics, proteomics and drug discovery.
- Promote research to attain scientific justification to certify natural ingredients for food supplement products, strengthen consumer confidence in these products, and support product registration.
- Develop production processes for active ingredients that ensure consistency in high quality and yields.
- Create mechanisms and incentives for foreign investment and technology transfers that enable local entrepreneurs to accelerate product research, development and production.

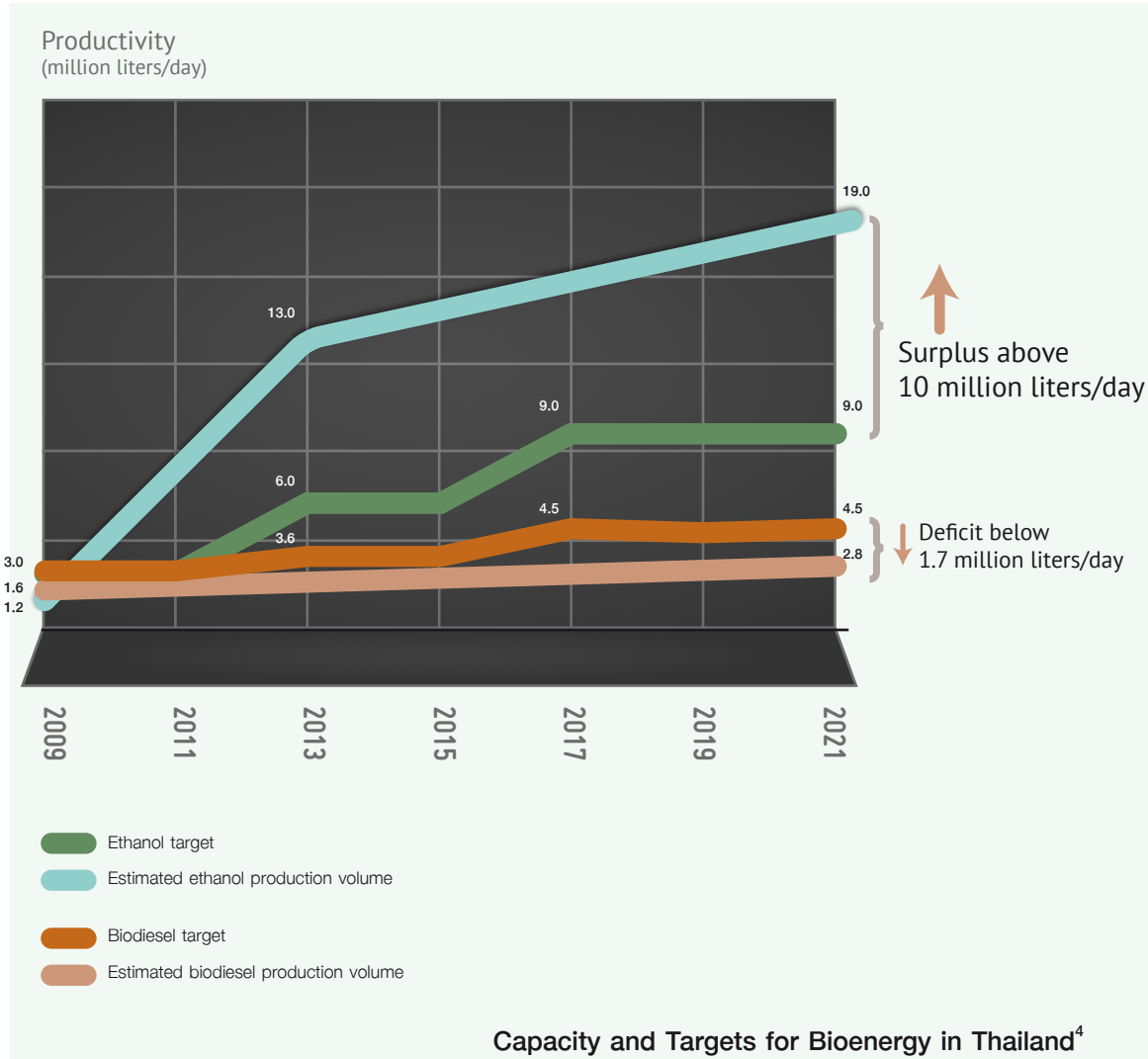
Expected Outcome:

Implementation of these measures will significantly strengthen all aspects of Thailand's medicine and healthcare sector. By supporting advances in innovation and by cultivating a stronger biotechnology support infrastructure, the industry will be able to generate high-value healthcare products. Furthermore, the sector's increased capacity will reduce imports of medicine, healthcare products and food supplements by 20-30 percent over the next decade. Conversely, these measures will help reduce by 10 percent raw material imports for therapeutic proteins and food supplements. Combined, these initiatives will set the stage for Thailand to become a healthcare production hub within ASEAN.


3rd Strategic Sector
Bioenergy

In 2021 Thailand intends to meet 25 percent of its energy needs through renewable sources. To achieve this, it is estimated that biodiesel production will need to increase to 6 million liters per day and ethanol to 9 million liters per day. This calls for securing additional and alternative raw materials. In so doing, particular attention must be paid to avoiding conflicts with food production as most bioenergy is presently generated from food crops such as sugarcane, cassava and palm oil.

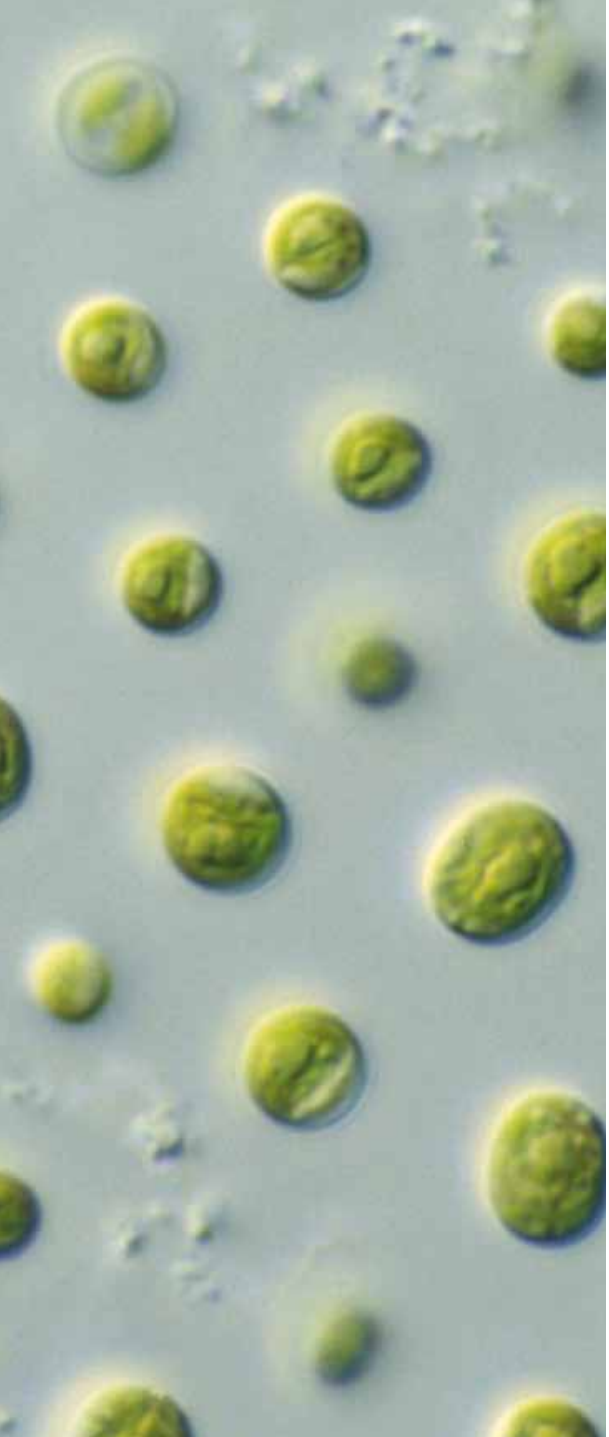
Palm oil, for example, is currently used to generate 2.8 million liters of biodiesel per day. It's unlikely, however, that much more palm oil can be directed to meet the additional 3.2 million liters of biodiesel per day forecasted. Food industry demand and limited cultivatable lands virtually assure that palm oil biodiesel production has reached its ceiling. Recognizing such constraints, the government has emphasized research and development for future biodiesel beyond third generation bioenergy.



Capacity and Targets for Bioenergy in Thailand[4]

4 Ministry of Energy targets with reference to the study on Potential Yield Increases for Sugarcane, Cassava and Palm Oil for Bioenergy through Technology and Plantation Expansion: policy research to support the development and use of renewable energy to increase energy efficiency in Thailand (Phase 2)

Biogas will play a much greater role in meeting the country's future energy needs. By 2021, the government aims to realize a three-fold increase in biogas supply above current production. Such growth is possible due to readily available raw materials such as waste generated by livestock farming, agriculture and food processing and households, combined with high-level technological R&D that stands ready to be applied to commercial biogas production.



‘Rationale: Bioenergy’

- Clean, low-carbon bioenergy must be generated from inputs not in conflict with the food production sector.
- Biotechnology offers the best path to identifying and maximizing feedstock potential.
- The private sector is highly motivated to advance R&D in bioenergy.

‘Targets and Strategy’

Targets: Increase energy security by using biotechnology to develop alternative energy sources which are not in conflict with food production. Thailand needs to invest in research and development to fuel its second generation bioenergy, namely establishing a strong base for ethanol production from agricultural waste cellulose. This will then allow advancement to the third generation of bioenergy from algae feedstock along with more widespread use of biogas from organic waste generally.

Strategy: Apply several technologies including genomics, microorganism physiology, genetic modification, high throughput screening, fermentation and industrial manufacturing technologies to increase bioenergy production efficiency in Thailand. Three specific energy sources will be targeted:

- Biogas from wastewater and solid wastes
- Cellulosic ethanol
- Biodiesel from algae

1 Biogas from waste products

Expand biogas production and usage to help transition the country away from fossil fuel energy sources within the industrial, transport and residential sectors. Emphasize community level feedstock inputs, be they from farms, livestock production or other organic waste streams.

It is necessary to develop a deeper and more multidisciplinary base in technology use at the domestic level. This is critical to the advancement of such disciplines as bioengineering, which can help propel the country's biogas technology to a much higher level. Different biogas uses require different technologies. For example, biogas production technology to service industry must assure efficiency and reliability. Community producers will focus more on locally suitable decomposition technology along with smaller-scale and lower-cost production processes.

The government has established mechanisms to provide financial support and tax benefits as incentives for the private sector to invest in biogas production system. But to more quickly deploy biogas technology at the community level, supportive mechanisms must be designed that cater to specific community needs and should include:

- Interest-free loans financed by the National Environment Fund

- Accelerate the development of appropriate technologies such as high-performance microorganisms suitable for raw materials use, and efficient, small-scale biogas production systems

Implementation of the above mechanisms will lead to expansion of biogas use by industry and local consumers. This will improve domestic energy security through energy import reductions. They will also create a more healthy society through environmentally friendly, low carbon energy supplies.

2 Ethanol from cellulosic materials

Advance development of enzymes appropriate for different raw materials, and upscale enzymes' production for effective fermentation at the industrial level. Success requires platform technology support such as fermentation technology, genomic technology and genetic modification technology. Also needed is increased manpower in bioengineering and related fields to staff demonstration plants and commercial manufacturing facilities.

Additionally, the following measures to attract private sector investment in research and development should be considered:

- Seek overseas partnerships and investment to facilitate technology acquisition at local levels, especially industrial fermentation technology and downstream processing
- Establish matching funds and/or public-private partnerships to support demonstration plants
- Secure tax incentives such as a carbon tax to stimulate the biogas market and to generate revenue for ongoing research and development within the sector
- Develop policies that promote research, development and production of commercially viable GMOs and that strengthen GMO biosafety measures

By 2021, it is anticipated that the production costs of ethanol from cellulosic materials for commercial application will be 10 Baht per liter, and that cellulosic ethanol will meet 10 percent of the country's biofuel demand.

3 Biodiesel from algae

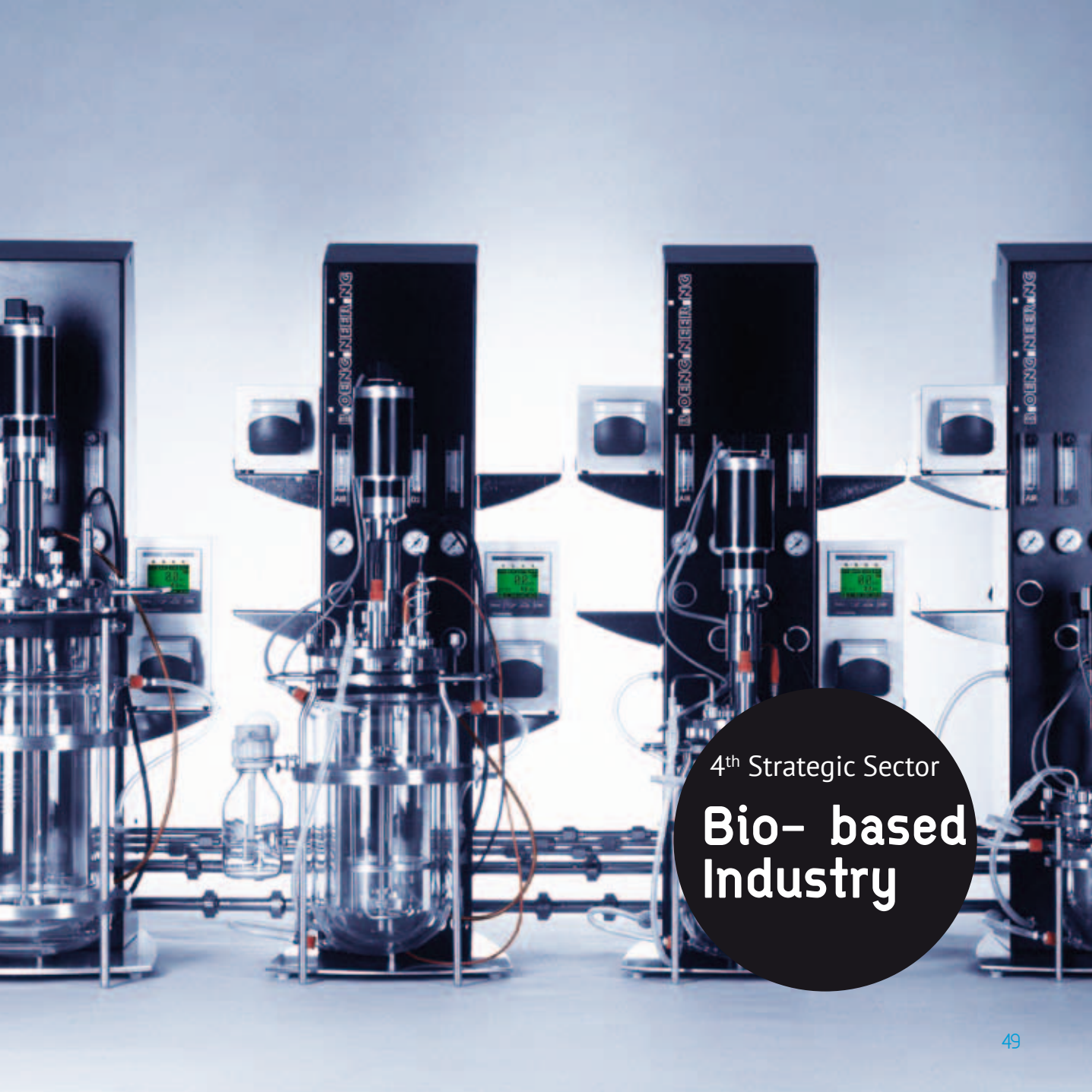
The initial step in harnessing biodiesel from algae is to accelerate biotechnology use throughout the algae-biodiesel production chain: from algae species selection, culture management systems, oil extraction to quality and qualification control. During the first five years (2012 – 2016) emphasis will be placed on technology applications from genomics, physiology and genetic modification. Additionally, a five-fold increase in manpower will be required, along with support infrastructure in the form of laboratories a demonstration plant that can be scaled-up to 100,000 liters per day. The second five-year period (2017 – 2021) will focus on the application of generated knowledge to screen and develop algae species offering high productivity, improving and expanding culture management systems toward demonstrated production viability, and assuring sufficient human resources.

Here too it is critical to promote measures that cultivate private sector investment in research and development:

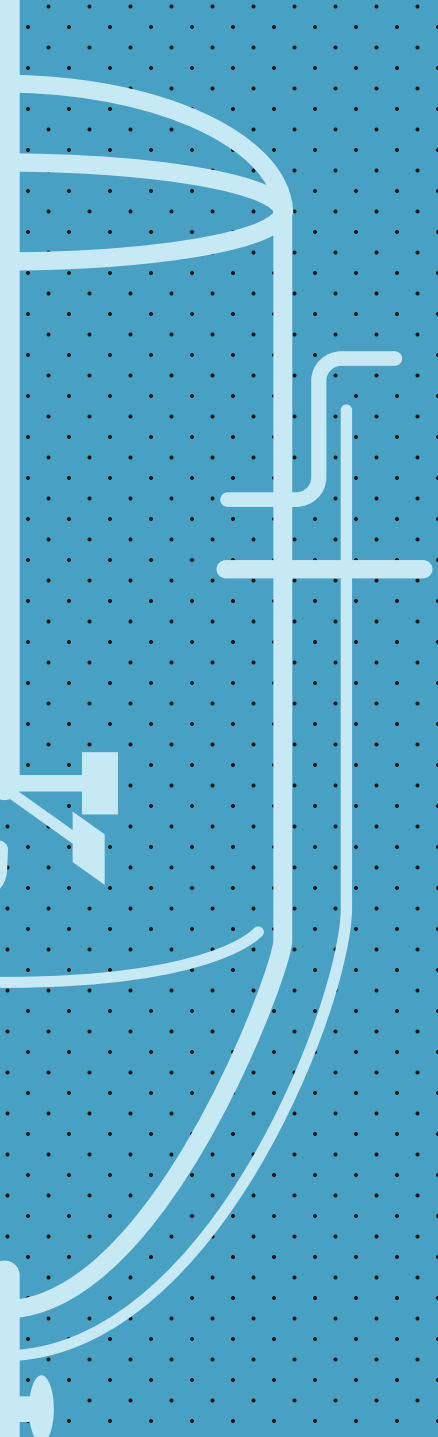
- Secure tax incentives such as carbon taxes to stimulate the biogas market and generate revenue for relevant research and development

- Promote policies for research, development and production of GMOs and strengthen biosafety assessment system to assure public confidence in GMO products

By 2021, it is anticipated that biodiesel from algae will meet 10 percent of the country's biofuel consumption target. However, at present the generation of biodiesel from algae costs $US 150 per barrel, well above the price of petroleum-based and other fuel substitutes. Efforts therefore must be made to identify and develop high-value, co-products from algae production, such as pigment, vitamins and food supplements.


4th Strategic Sector
Bio- based Industry

Thailand imports an estimated 350 billion Baht worth of industrial chemicals annually, of which 14 billion Baht is for biochemical products such as organic acids, antibiotics, alcohol, vitamins, amino acids, enzymes and yeast. Multiple forces are now shifting industrial demand toward bio-based inputs. Environmental protection, calls for reduced natural resource exploitation, water conservation and manufacturing of multiple products from a single process are among the contributing factors driving the push for more bio-based industrial inputs. Thailand is positioned to remain at the leading edge of this transition thanks to the country's rich endowment of biodiversity, its large agricultural sector and the strength of its evolving biotechnology sector. The country is ready to creatively cultivate these assets to meet demand for new industrial inputs, increase production efficiency and improve environmental stewardship through reduced greenhouse gas emissions.



‘Rationale: Bio-based Industry’

- The future calls for an increasingly robust bio-based industrial sector.
- Biotechnology will play a major role in optimizing production processes by reducing costs, waste, effluent and greenhouse gas emissions.
- The private sector is motivated to invest in promising research and development within the sector.

‘Targets and Strategy’

Targets: Strengthen industry’s commitment to prioritize environmental protection by taking advantage of biotechnology’s offerings that allow for cleaner, more efficient manufacturing processes. Promote innovation where Thailand has comparative advantages such as in bioplastics, bioenergy and livestock feed.

Strategy: Apply multiple technologies including genomics, genetic engineering, fermentation technology and manufacturing technologies to generate biological catalyst with an emphasis on discovery and genetic improvement of microorganism strains. To upscale domestic fermentation technology, it is viable to import technology from overseas for a rapid maturity of the industry at home.

Implementation Measures:

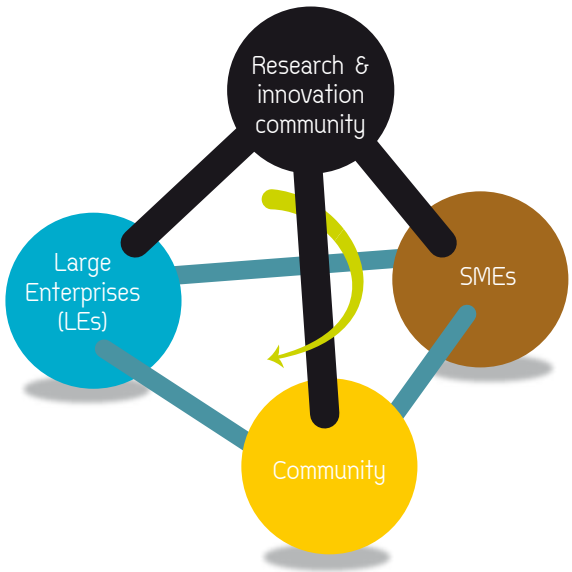
- Accelerate establishment of biosafety safeguards for the use of GM organisms in controlled conditions.
- Attract foreign investment and/or import fermentation and downstream process technologies so that local manufacturing gains a comparative advantage to cultivate bio-based industry development opportunities.
- Structure government procurement processes to support markets for bio-based products.

Additional public sector leadership in areas such as GMO policy refinements, mechanism to stimulate foreign investment and more aggressive application of the Polluter-Pays Principle (PPP) will help encourage the use of microbial leavening agents or enzyme for chemical replacement. Bio-based manufacturing will thus expand, reducing energy and water consumption and cutting greenhouse gas emissions, contributing to the country's vision for clean and green economy.

‘Key Actors in Thailand’s Biotechnology Development’

Four groups of main actors

- Community
- Small and medium enterprises (SMEs)
- Large enterprises
- Research and innovation community



Key Actors in Thailand’s Biotechnology Development

1 Community

Biotechnology is not novel to an agricultural society such as Thailand's. Preservation and fermentation of food and beverages have longtime been a part of local livelihoods. This technology has evolved over time along with increasing scientific knowledge introduced by government agencies and the business sector. Common biotechnology usage at the community level includes plant tissue cultures, inoculum for mushroom cultivation, organic fertilizers, natural pesticides, and biogas from agricultural and community organic waste.

As biotechnology advances, it is critical to ensure communities at the local level are not left behind. Increasingly, they need to become better equipped with technology to cope with changing socio-economic conditions. For example, competition in agricultural markets is becoming more intense. Emerging regional trade agreements are lowering cross-border trade barriers. Natural resources are disappearing and environmental degradation is accelerating. The labor pool is shrinking as the population ages. In recognition of these challenges, the government has designed an appropriate technology outreach strategy specifically for communities known as 4P: Public, Private, People and Partnership. Among its priorities are mainstreaming technology transfer and usage into relevant local development plans, increasing the number and skill sets of researchers, and stimulating an atmosphere for technology advocacy and communication.

2 Business Sector

To better target commercial development mechanisms for biotechnology the Framework divides the business sector into two groups – small and medium enterprises (SMEs) and large enterprises.

2.1. Small and Medium Enterprises (SMEs)

SMEs, particularly small enterprises, comprise more than 70 percent of all biotechnology business in Thailand. However, these small enterprises have limited roles in research and development as a result of poor access to: financial capital, high-level biotechnology and other supporting biotechnology infrastructure.

Support Measures:

1. Establish a private sector-led biotechnology development fund to: enhance SMEs' research and development capacity; improve their access to advanced technology domestically and abroad through patent and other IP acquisitions; and provide for low-interest bank loans for investment in industrial infrastructure and commercializational activities.

2. Provide an environment conducive to biotechnology research and development by creating a mechanism to increase SMEs' access to government services and facilities such as research databases, personnel, equipment, one-stop research and development service centers and more favorable regulations. Establish and/or further advance necessary infrastructure including animal testing labs with GLP standards, quality control monitoring facilities, standardized laboratories and regional science parks.

3. Improve investment incentives for research and development by creating tax deductions for R&D expenses related to the Policy Framework's strategic sectors. Extend the period during which such R&D deductions can be claimed from 8 to 15 years. This longer deduction period would be complimentary to R&D-related tax incentives provided by Thailand's Board of Investment (BOI) to SMEs generally.

2.2 Large Enterprises

Investment in technology research and development by large companies in Thailand remains relatively low as compared to other countries. This stems from: the lack of a clear vision or policy direction for biotechnology at the national level, lack of a sizable domestic market for biotechnology products and a shortage of research personnel with advanced expertise.

Support Measures:

1. Clearly articulate key national objectives such as Thailand becoming a clean and green nation, and a leader in research and utilization of genetically modified technologies backed by strong biosafety standards.

2. Establish marketing programs that promote the use of biotechnology products through: government procurement, market expansion to neighboring countries and opportunities within the ASEAN Economic Community.

3. Enact policies that promote knowledge-sharing and training opportunities for public sector research personnel through six-month to two-year secondments to the private sector.

4. Encourage private sector leadership to establish laboratories, research centers and research service facilities through the use of government incentives such as tax benefits and public-private partnerships in finance, research and research advisory.

3 Research and Innovation Community

Thailand's biotechnology research and development capacity will benefit from: acquiring in-depth and multidisciplinary research skills; strengthening research infrastructure such as well-equipped laboratories; growing a larger pool of qualified research personnel, increasing research funding and creating the research system that bridge knowledge to commercialization.

Support Measures:

1. Over the next decade, increase biotechnology's research and development budget from the current 0.25 percent to 2 percent of GDP through Thailand Research Organizations Network (TRON) including: the Health Systems Research Institute(HSRI), the Agricultural Research Development Agency (Public Organization)(ARDA), the National Science and Technology Development Agency (NSTDA), the Thailand Research Fund (TRF), the National Science Technology and Innovation Policy Office (STI), the National Research Council of Thailand (NRCT) and the Higher Education Commission Office (MUA).

2. Fostering Technology management especially on technology and innovation acquisition. Identify and promote advantages available through global innovation by developing alliances with overseas research institutes to fill capacity gaps in critical fields; purchasing technologies, patents and other IPRs from abroad; acquiring stocks and/or businesses to rapidly gain access to knowledge and advanced technologies and to create future market opportunities; and identifying new opportunities evolving from regional and international agreements.

3. Create, accelerate and expand the use of core technologies and cross-cutting technologies necessary for each strategic sector's development.

4. Establish management mechanisms that foster multidisciplinary research by strengthening the links between basic and applied research, connecting knowledge across interrelated sectors and training professional research managers to share knowledge from the beginning to the end of a product's value chain.

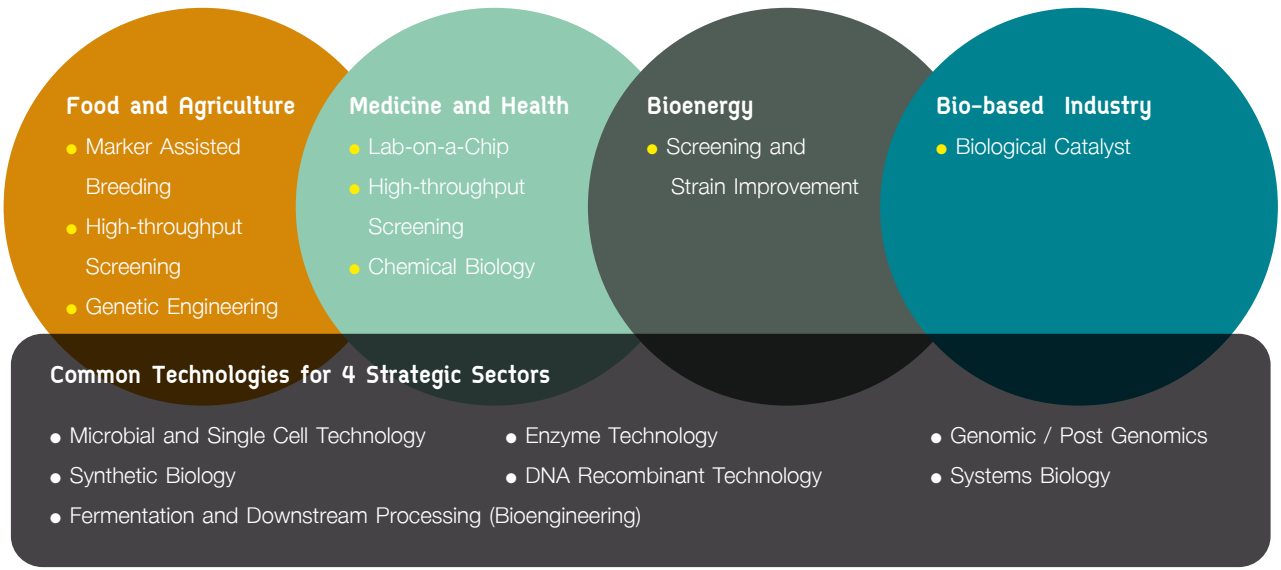
5. Establish specialized biology research institutes, advance scientific research facilities and centers of excellence to support strategic sectors such as food and food supplements, and bioenergy from algae. These institutes will simultaneously create knowledge, train professionals and generate employment opportunities.

6. Support and establish research and development that leads to commercialization infrastructure such as GMP pilot plants for industrial level fermentation and GLP animal testing labs.

7. Train and support career path development for research professionals, especially PhDs in multidisciplinary fields and university-private sector collaboration, through Thailand's Advanced Institute of Science and Technology and the Royal Golden Jubilee PhD Program.

8. Expand the public sector biotechnology job market by revising regulations of the Office of Civil Service Commission. To promote more use of biotechnology in order to create knowledge and qualified personnel in biotechnology within public sector.

CORE TECHNOLOGY



Financial Resources	Mainstream biotechnology into local development planning	Establish a biotech fund	Establish public and private joint research fund	Increase national research budgets for biotechnology through Thailand Research Organizations Network (TRON)
Human Resources	Increase biotechnology advocates, experts and leaders to promote locally viable technology	Link with universities and research institutes	Exchange research professionals between public and private sectors	Increase/ further groom research professionals, develop their career paths and train professional research managers
Management	Create mechanism for community participation through the 4-P Public-Private-People Partnerships	Set up regional bio-parks in strategic locations	Clarify national biotechnology-related policies such as GMO	Establish research institutes for basic biology and related sciences
Target Groups	**Community**	**SMEs**	**Large Businesses**	**R&D Community**

Summary of Biotechnology Development Measures by Target Groups

Key Signposts for the National Biotechnology Development Policy Framework (2012-2021)

2012

Biosafety Act

Bt1 billion Biotech Fund

2013

One-stop research services

5%
of local development plans focus on biotechnology

Multidisciplinary bio-engineering curriculum

GLP animal testing labs

2014

Public- private matching fund

Internationally recognized institutes for agriculture and food biotechnology

High yield and high quality crop breeds

2015

Green business utilizing advanced biotechnology

Scientific documentation mechanisms established for certification of food supplements

Biology research institutes

2016

Two-fold increase of biological materials utilization by farmers

30%
of community waste is used for biogas production

Thailand produces basic vaccine through modern technology

70 : 30
public-private biotechnology investment partnership

Responsible Agencies

2012

- Ministry of Natural Resources and Environment
- Ministry of Agriculture and Cooperatives
- Ministry of Public Health
- Ministry of Science and Technology
- Federation of Thai Industries

- Ministry of Finance
- Thai Association for Biotech Industries

2013

- Local science parks
- Local universities

- Local administration organizations
- Local universities
- National Research Council of Thailand
- Thailand Institution for Science and Technology Research
- BIOTEC

- Universities teaching biotechnology
- Office of the Higher Education Commission
- Association for Biotech Industries

- National Research Council of Thailand
- National Laboratory Animal Center

2014

- Thailand Research Organizations Network (TRON)
- Federation of Thai Industries
- Association for Biotech Industries

- Universities teaching biotechnology
- Office of the Higher Education Commission
- Thai Society for Biotechnology

- Ministry of Agriculture and Cooperatives
- BIOTEC
- Agricultural Research and Development Agency
- Private sector

2015

- Thai Association for Biotech Industries
- BIOTEC
- Universities
- Private sector

- Food and Drug Administration
- Universities
- Health Food and Supplements Association

- Local science parks
- Science Society of Thailand under the Patronage of His Majesty the King
- Universities

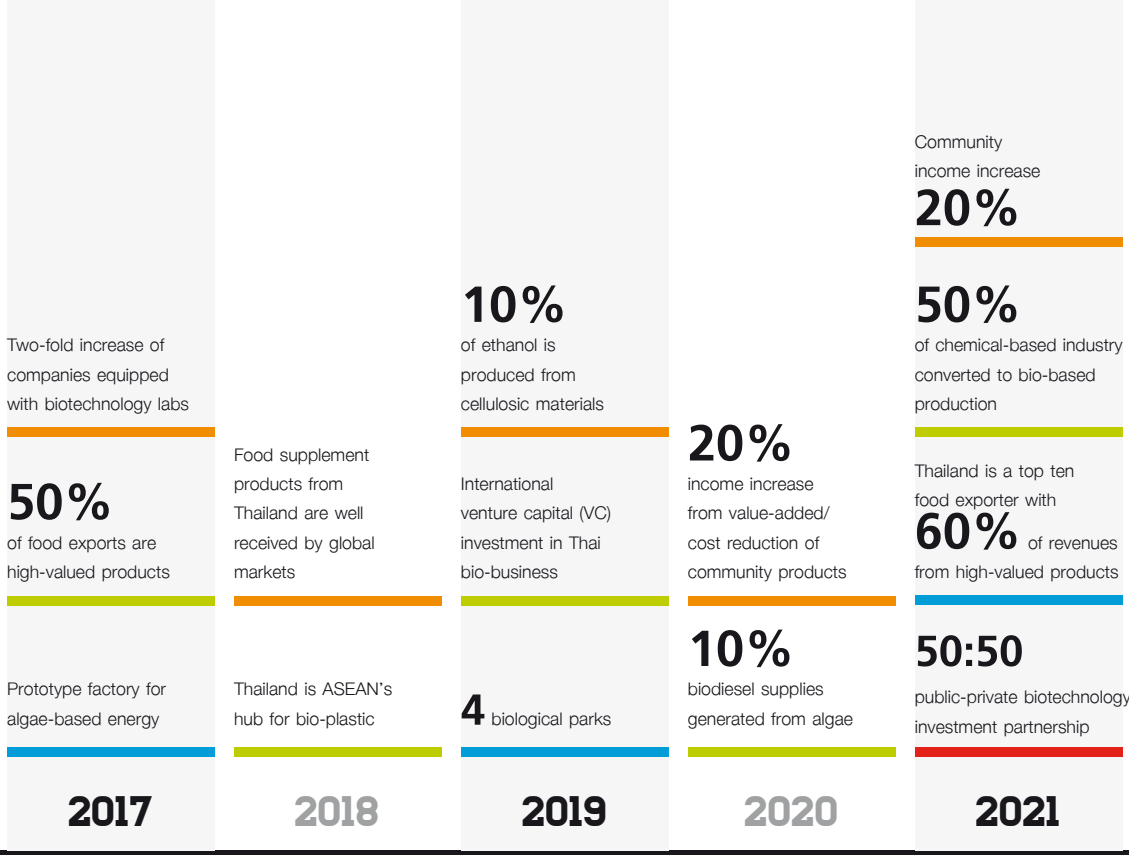
2016

- Ministry of Agriculture and Cooperatives
- Agricultural Research and Development Agency
- Local science parks
- Universities

- Ministry of Energy
- Local administration organizations
- Thailand Environment Institute
- Local science parks
- Universities

- National Vaccine Institute
- National Science and Technology Development Agency
- Food and Drug Administration
- Universities
- Private sector

- Board of Investment
- Ministry of Finance
- Thai Association for Biotech Industries
- Private sector



- Thailand Science Park and local science parks
- Thai Association for Biotech Industries

- Ministry of Industry
- Ministry of Commerce
- Thailand Science Park and local science parks
- Universities
- Private sector

- Ministry of Energy
- National Science and Technology Development Agency
- Public science research funding agencies
- Petroleum Institute of Thailand

- Ministry of Public Health
- Ministry of Science and Technology
- Universities and research institutes
- Food and Drug Administration
- Health Food and Supplements Association

- National Innovation Agency
- Plastic Institute of Thailand
- Universities
- Private sector

- Ministry of Energy National Science and Technology Research Agency
- BIOTEC
- Universities

- Ministry of Finance
- Board of Investment
- Private sector

- Local science parks
- Local universities
- Thai Business Incubators and Science Parks Association

- Local administration organizations
- Ministry of Commerce
- Ministry of Industry
- Ministry of Science and Technology

- Ministry of Finance
- Ministry of Agriculture and Cooperation
- Ministry Natural Resources and Environment
- Ministry of Science and Technology
- Ministry of Public Health
- Board of Investment
- Federation of Thai Industries
- Thailand Collaborative Research Network on Microalgae for Energy
- PTT Group

- Ministry of Agriculture and Cooperation
- Ministry Natural Resources and Environment
- Ministry of Science and Technology
- Ministry of Public Health

- Ministry of Education
- Local administration organizations
- Thai Social Enterprise Office
- Thailand Research Fund

- Ministry of Industry
- Board of Investment
- Thailand Science Park
- Federation of Thai Industries
- Thai Association for Biotech Industries

- Ministry of Commerce
- Ministry of Industry
- Universities and research institutes
- Federation of Thai Industries
- Bank of Agriculture and Agricultural Cooperative
- Foundations and networks for farmers

Measures that support the Policy Framework's key actors in the development of Thailand's biotechnology include:

- Establishment of a public–private research matching fund for demonstration plants.
- Tax benefits allowing 300 percent annual deductions for research and technology development expenses.

‘Financial and Human Resources for Biotechnology Development in Thailand’

Finance

Thailand must continuously invest in technology research and development. By year five of this Policy Framework’s implementation this should reach 26 billion Baht, of which 30 percent should come from the private sector. In year ten the total investment should reach 67 billion Baht, 50 percent of which from the private sector.

Human Resources

The National Science Technology and Innovation Policy Office estimates that by 2016 Thailand must groom at least 4,000 new PhDs for science and technology research professions, 800 specializing in biotechnology’s four strategic sectors: 270 for food and agriculture, 200 for medicine and health, 150 for bioenergy and 180 for bio-based industry.

There is also a need to strengthen biotechnology curricula at the undergraduate and graduate levels, especially programs emphasizing multidisciplinary fields including bioinformatics, bioengineering, biophysics, biomaterial, systems biology, computational biology and bioelectronics.

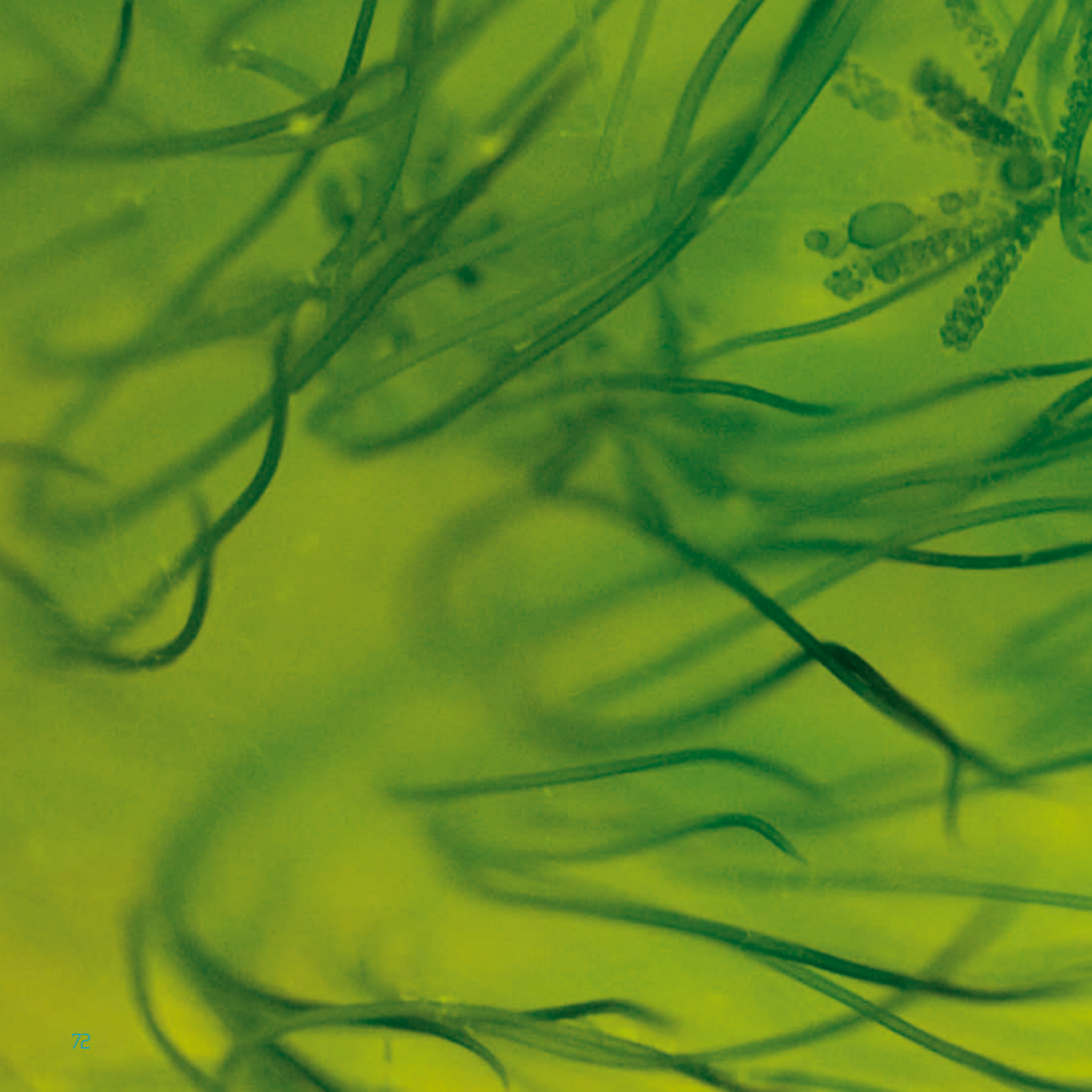
Anticipated Impacts from Biotechnology Investments Resulting from the Policy Framework

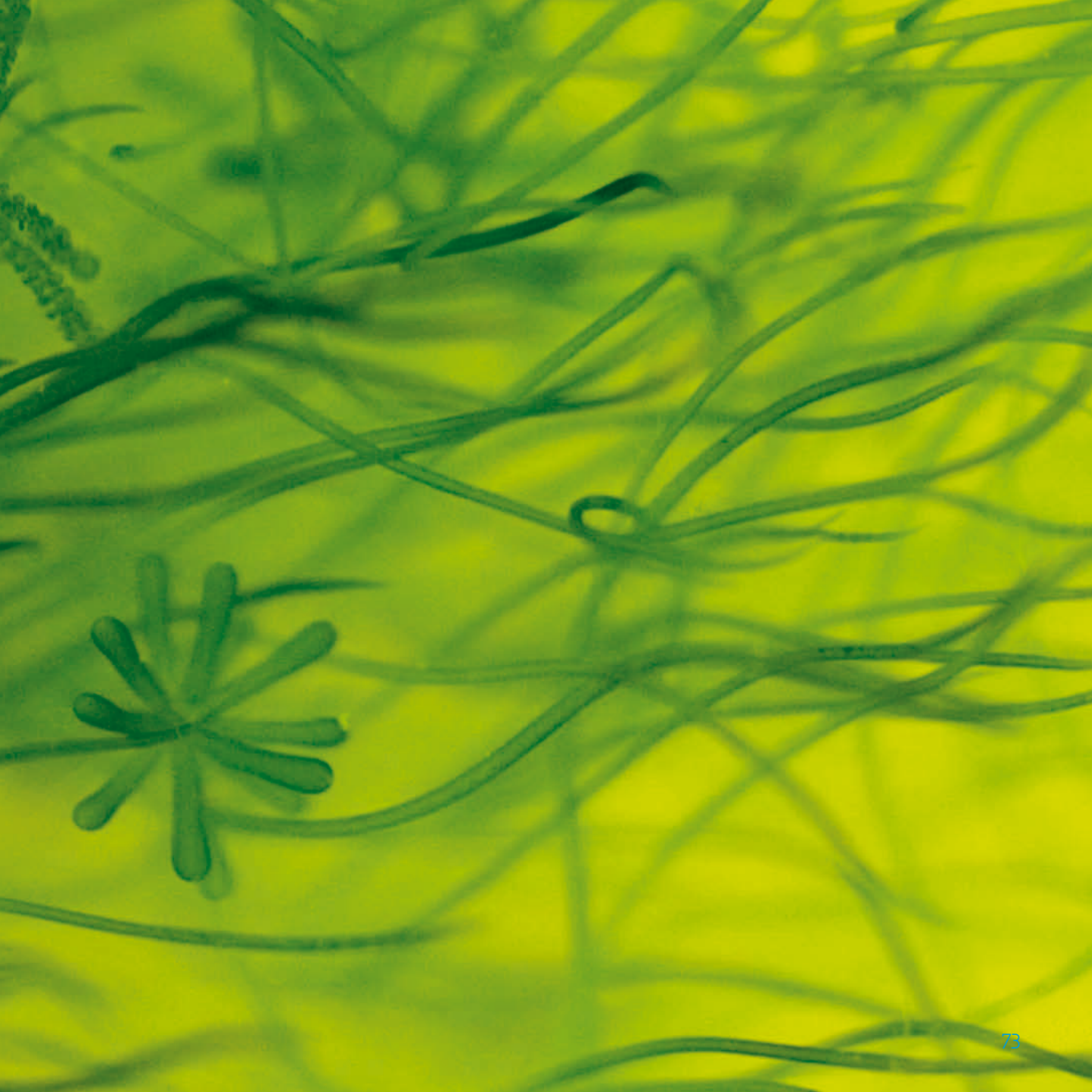
Impacts	5 Years	10 Years
Competitiveness • **Economy** • **Science and Technology**	• Thailand achieves higher competitiveness in global food and agriculture markets and the product market value increases 30 billion Baht per year due to increases in production efficiency and innovation • A 30:70 private-public investment ratio in biotechnology research and development • Thai biotech business expansion across the AEC	• Thailand is among the word's top ten exporters as a result of increases in high-valued agriculture and food products • A 50:50 private-public investment ratio in biotechnology research and development
Advance Quality of Life	• 10 percent reduction in healthcare costs for Thai citizens • All household have access to healthy and safe food	• Access to quality healthcare for all Thai citizens
Raise Income Level	• At least 0.5 million family farms increase production efficiency by 10 percent	• At least one million family farms increase production efficiency by 20 percent

Impacts	5 Years	10 Years
National Security	• Raw materials for production of 9 million liters of ethanol and 4.5 million liters of biodiesel per day • Thailand can produce a greater variety of basic vaccines such as one for Encephalitis and Hepatitis B Virus • Food security at the community level	• At least 10 percent of bio-energy comes from cellulosic and algae • At least 50 percent of biochemical produced locally
Sustainable Development	• 10 percent of degraded land rehabilitated • 30 percent of community waste is recycled	• 30 percent of degraded land rehabilitated • Demonstrated progress toward a low-carbon society

‘Mechanisms Powering the Policy Framework’s Implementation’

Effective implementation of the Policy Framework requires the National Science Technology and Innovation Policy Office to collaboratively work with relevant agencies across many technology fields to create the necessary multidisciplinary approach biotechnology development requires. This platform can then generate the required research and development results necessary to deliver tangible socio-economic benefits to the country. A roadmap for this has been devised with clear objectives, implementation pathways and key actors identified. It then must be submitted to the National Science Technology and Innovation Policy Committee for endorsement and implementation.





Biotechnology Policy Framework Steering Committee

1.	Prof. Dr. Youngyuth Yuthavong	National Science and Technology Development Agency (NSTDA) – **Chairman**
2.	Secretary General or representative	National Research Council of Thailand (NRCT)
3.	Permanent Secretary or representative	Ministry of Public Health
4.	Permanent Secretary or representative	Ministry of Finance
5.	Permanent Secretary or representative	Ministry of Agriculture and Cooperatives
6.	Secretary General or representative	Office of the National Economic and Social Development Board (NESDB)
7.	Secretary General or representative	The Board of Investment of Thailand (BOI)
8.	Secretary General or representative	Office of Higher Education Commission, Ministry of Education
9.	Director or representative	The Thailand Research Fund (TRF)
10.	Director or representative	National Science and Technology Development Agency NSTDA)
11.	Secretary General	National Science Technology and Innovation Policy Office (STI)
12.	Kan Trakulhoon	The Siam Cement Public Company Limited (SCG)
13.	Pornsil Patchrintanakul	Charoen Pokphand Group (CP Group)
14.	Dr. Pisuth Lertvilai	Health Food and Supplements Association (HFSA)
15.	Prof. Dr. Morakot Tanticharoen	National Science and Technology Development Agency (NSTDA)
16.	Mechai Viravaidya	The Population and Community Development Association (PDA)
17.	Prof. Dr. Sakarindr Bhumiratana	King Mongkut's University of Technology Thonburi
18.	Dr. Songkiat Tansamrit	PTT Public Company Limited
19.	Prof. Dr. Amaret Bhumiratana	The Royal Golden Jubilee Ph.D. Program The Thailand Research Fund (TRF)
20.	Dr. Ajva Taulananda	True Corporation Public Company Limited
21.	Dr. Kanyawim Kirtikara	National Center for Genetic Engineering and Biotechnology (BIOTEC)
22.	Dr. Nares Damrongchai	National Science Technology and Innovation Policy Office (STI)

Working Committee

1.	Prof. Dr. Amaret Bhumiratana	The Royal Golden Jubilee Ph.D. Program The Thailand Research Fund (TRF) – **Chairman**
2.	Dr. Pichet Durongkaveroj	National Science Technology and Innovation Policy Office (STI)
3.	Dr. Peeradet Tongumpai	Agricultural Research Development (Public Organization) (ARDA))
4.	Assoc. Prof. Dr. Sittiwat Lertsiri	Department of Biotechnology, Faculty of Science, Mahidol University
5.	Assoc. Prof. Dr. Suphachai Nuanualsuwan	Department of Veterinary Public Health, Faculty of Veterinary Sciences, Chulalongkorn University
6.	Dr. Kanyawim Kirtikara	National Center for Genetic Engineering and Biotechnology (BIOTEC)
7.	Dr. Lily Eurwilaichitr	Bioresources Technology Research Unit, National Center for Genetic Engineering and Biotechnology (BIOTEC)
8.	Uthaiwan Grudloyma	Policy Study and Biosafety Unit National Center for Genetic Engineering and Biotechnology (BIOTEC)
9.	Dr. Nares Damrongchai	National Science Technology and Innovation Policy Office (STI)

Expert Panel on Algae Biodiesel

1. Dr. Aparat Mahakhant	Thailand Institute of Science and Technology Research (TISTR)
2. Dr. Sorawit Powtongsook	Center of Excellence for Marine Biotechnology
	National Center for Genetic Engineering and Biotechnology (BIOTEC)
3. Assoc. Prof. Dr. Prasert Pavasant	Department of Chemical Engineering
	Faculty of Engineering, Chulalongkorn University
4. Assoc. Prof. Dr. Prayad Pokethitiyook	Department of Biology, Faculty of Science, Mahidol University
5. Dr. Metha Meetam	Department of Biology, Faculty of Science, Mahidol University
6. Dr. Kunn Kangvansaichol	PTT Research and Technology Institute, PTT Public Company Limited
7. Dr. Wipawan Siangdung	Pilot Plant Development and Training Institute
	King Mongkut's University of Technology Thonburi
8. Assoc. Prof. Boosya Bunnag	Pilot Plant Development and Training Institute
	King Mongkut's University of Technology Thonburi
9. Dr. Rutjawate Taharnklaew	Betagro Public Company Limited
10. Dr. Chaya Chandavasu	PTT Global Chemical Public Company Limited
11. Dr. Wilaiporn Chetanachan	Corporate Technology Office
	The Siam Cement Public Company Limited (SCG)
12. Dr. Anek Silapapun	Crop Intregration Business, CP Group

Expert Panel on Private Sector R&D Investment

1.	Komkrit Sajjaanantakul	i+MED Laboratories Company Ltd.
2.	Wiwan Tharahirunchote	Kasikorn Research Center Co., Ltd.
3.	Vitoon Vonghangool	BioNet-Asia Co. Ltd.
4.	Asst. Prof. Dr. Akkharawit Kanjana-Opas	Prince of Songkla University Science Park Prince of Songkla University
5.	Dr. Bhasu Bhanich-Supapol	Fiscal Policy Research Institute Foundation (FPRI)
6.	Assist. Prof. Dr. Thanaphol Virasa	College of Management, Mahidol University

Expert Panel on Biotechnology for Community Sustainable Development

1.	Sumate Tanchareon	Institute for Scientific and Technological Research and Services (ISTRS), King Mongkut's University of Technology Thonburi (KMUTT)
2.	Benjamaporn Limpisathian	Thai Health Promotion Foundation
3.	Somsak Ploypanichcharoen	National Science and Technology Development Agency (NSTDA)
4.	Nun Pakdi	Social entrepreneur
5.	Assist. Prof. Chanchai Limpiyakorn	Energy Ashram Appropriate Technology Association (ATA)
6.	Rungsima Tantalakha	Biodiversity Research and Training Program (BRT) National Science and Technology Development Agency (NSTDA)

Expert Panel on Food Supplement Technology

1.	Dr. Paiboon Thammarutwasik	Faculty of Natural Resources Prince of Songkla University Hat Yai
2.	Dr. Pisuth Lertvilai	Health Food and Supplements Association (HFSA)
3.	Asst. Prof. Dr. Anadi Nitithamyong	Institute of Nutrition, Mahidol University.
4.	Asst. Prof.Dr. Akkharawit Kanjana-Opas	Prince of Songkla University Science Park Prince of Songkla University
5.	Assoc. Prof. Parichat Hongsprabhas	Faculty of Agro-Industrial, Kasetsart University
6.	Asst. Prof. Dr. Wantanee Kriengsinyos	Institute of Nutrition, Mahidol University.
7.	Prof. Dr. Pavinee Chinachoti	Faculty of Agro- Industry, Prince of Songkla University
8.	Suphakanya Tantrabundit	Faculty of Pharmacy, Mahasarakham University
9.	Asst. Prof. Jintanaporn Wattanathorn	Faculty of Medicine, Khon Kaen University
10.	Assoc. Prof. Promchit Saralamp	Faculty of Pharmacy, Mahidol University
11.	Somnuek Suchaitanavanit	Department for Thai Traditional and Complementary Medicine. Ministry of Public Health
12.	Dr.Bhasu Bhanich-Supapol	Fiscal Policy Research Institute Foundation (FPRI)
13.	Chanwit Rattanarasri	National Innovation Agency (NIA)

The secretary of the Working Committee and the Steering Committee of the Biotechnology Policy Framework

National Center for Genetic Engineering and Biotechnology (BIOTEC)

National Science and Technology Development Agency (NSTDA)

1. Uthaiwan Grudloyma
2. Dr. Nataporn Chanvarasuth
3. Watcharin Meerod
4. Dr. Yuwanan Santitaweeroek
5. Surisa Tipphong
6. Kulwarang Suwanasri
7. Krisada Bamrungwong

National Science Technology and Innovation Policy Office (STI)

1. Dr. Nares Damrongchai
2. Dr. Suchat Udomsopagit
3. Sopida Tongsopit
4. Sirijunya Aokram

National Science Technology and Innovation Policy Office

319 Chamchuri Square Building, 14th Floor , Phayathai, Bangkok, Thailand 10330

tel 0 2160 5432 | fax 0 2160 5438-9

info@sti.or.th | www.sti.or.th

Designed by

Pen Thai Publishing co.,ltd.

tel 0 2736 9918 | fax 0 2736 8891

waymagazine@yahoo.com | waymagazine.org

As biotechnology advanced into the genomic and post-genomic eras, it created no less benefit to the world than the previous three technological revolutions. In addition to well-publicized advances in medicine, biotechnology has stimulated major shifts in the industrial sector. Where chemical-based industries once dominated, bio-based alternatives have evolved, including many environmentally friendly and energy efficient products gaining increased traction in the marketplace. Production processes have been greatly simplified and streamlined as a result of biotechnology. So it is no surprise that many countries invest in biotechnology research and development to raise competitiveness and minimize the risks of being left behind as the industry matures.

Dr. Pichet Durongkaveroj
Secretary General
National Science Technology and Innovation Policy Office

National Science Technology and Innovation Policy Office
319 Chamchuri Square BD., 14, Phayathai Rd., Patumwan, Bangkok, 10330
Telephone: 0 2160 5432 Fax: 0 2160 5438-9
Website: http://www.sti.or.th Email: info@sti.or.th