National Roadmap for the Development of

Bioplastics Industry

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NATIONAL INNOVATION AGENCY

MINISTRY OF SCIENCE AND TECHNOLOGY

National Roadmap for the Development of

Bioplastics Industry

(2008 – 2012)

In accordance with the policy towards

"New Wave Industries"

สำนักงานนวัตกรรมแห่งชาติ

NATIONAL INNOVATION AGECY

MINISTRY OF SCIENCE AND TECHNOLOGY

Innovation: as new things derived from the exploitation of knowledge and creativity, leading to enhancement of social and economic value.

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Executive Summary

1. Rationale

Bioplastics, as the biodegradable plastics, are plastics which could be derived from plant-based materials or other renewable resources through fermentation process. This process requires low energy input and produces the plastics with the ability to degrade when being composted, yielding carbon dioxide and water as end products. In fact, bioplastics have become one of the most innovative materials which answer to the ever-increasing demand for more environmentally friendly solutions. Around the world, especially in the leading industrialized nations, there is a great awareness in searching for new raw materials or polymers to improve the quality and functionality of bioplastics so that they can replace the conventional plastics that produced by petrochemical industries.

An awareness in using bioplastics can be witnessed in many developed countries where a wide range of favorable initiatives are put into action, including government policies, a research and development, and the industrial promotion. These resulted in a rapid growth of bioplastics business in a clearly defined direction. The United States, for example, has stepped forward to become the pioneer in bioplastics industry as a result of the success in the industrial-scale bioplastics resin production. NatureWork LLC (USA) has successfully produced lactic acids and polylactic acids (PLAs) from corn feedstock; whereas, Metabolix Inc. has developed the technology to produce PHAs (Polyhydroxyalkanoates) and is constructing its first production facility in the USA.

This development has been encouraged by the state policies to increase the production of biomass-based products from 5% in 2002 to 12% and 20% in 2010 and 2030 respectively. Furthermore, 11 states have declared the policies to promote the environmentally friendly packaging market. Green Report I and II have also been issued to serve as the guidelines for advertising eco-friendly products. With regard to the plastic waste management, MARPOL convention prohibits the dumping of plastic waste to the sea. These movements arose from the questioning of the conventional plastics' inability to degrade naturally and resulted in the initiation of 17 cent per piece charged for each plastic bag.

On the other continent, the European Union also announced a mandate for automobile industry that, from 1 January 2006 onward, more than 85% (by weight) of the vehicle parts must be made of reusable or recoverable materials. Bioplastics, consequently, stand out as one of most sought-after answers for those regulations. For example, Germany has exempted the tax for the compostable packaging, while France requires that by 2010 all trash bags must be compostable. In Florence, Italy, all food packaging must be made from degradable materials. As another example, Denmark bans the use of water containers which cannot be recovered. In Norway, the UK and Ireland, there is a plan to program to lower the consumption of petrochemical-based plastic shopping bags as these conventional bags must be bought by consumers instead of be given freely.

Many more countries in Asia-Pacific also join in enforcing laws and measures with an aim to reduce environmental loads from the growing demands for packaging. In Japan, Green Procurement policies were imposed along with the Revised Recycling Laws and the Pollutant Release and Transfer Register to counter this problem. In Ladakh, India, it is announced that 1 May of every year is the Plastic Ban Day; while, in Bombay and Himachal Pradesh, there is a strict regulation of plastic bags and Styrofoam production. On the other hand, Bangladesh has issued a more strict regulation of countrywide prohibition of plastic bags since 2002. In Taiwan, R.O.C., the conventional LDPE plastic bag control scheme called "Plastic Shopping Bag Use Restriction Policy" bans all shops from distribute plastic bags and Styrofoam containers to their customers without pay.

In some regions, bioplastics have been used as a tool for waste management. Taking Australia for example, during the Sydney Olympics Games, bioplastics containers and packaging were used and 75% of these bioplastics was gathered for compost. This greatly eased the burden of having to separate conventional plastics before compost and proved to be very effective in the management of plastic waste.

The growth of bioplastics market has been evident in many developed countries, e.g. USA, European Union and Japan. In Germany, the advances in the bioplastics compounding technology, the blending process of bioplastics resin and other additives to attend the desired mechanical and physical properties, has resulted in the rapid growth of small and medium enterprises (SMEs). Also, the governmental agencies both at the national and local levels issue tax deterrent for non-degradable plastics making their price higher and in turns helping the bioplastics to stay competitive.

In Japan, the development of bioplastics product has been substantial and rapid. Many large companies, e.g. Sony, Panasonic and Toshiba, have turned to bioplastics for their product packaging, computer devices and compact discs.

Considering the business rationalization of bioplastics in the abovementioned examples, it is apparent that the market share for bioplastics is on the rise and bioplastics is rapidly replacing the conventional petroleum-based plastics. The production capacity for bioplastics worldwide was 360,000 ton in 2005 or approximately 1% of the total plastics production of 200 million ton per year. The demand for bioplastics in the EU is estimated at 40,000-50,000 ton per year with the projected growth of 20% each year; whereas the bioplastics consumption in Japan is at 15,000 ton per year and this number is anticipated to double each year. On the other hand, the demand for bioplastics in USA is estimated at 70,000 – 80,000 ton per year with the projected growth of 16% each year. All these figures amount to the global projected expansion for bioplastics demand of 30% per year.

2. Opportunity for Thailand to Create Well-Established Bioplastics Industries

Thailand is an agricultural country which is endowed with biomass materials and agricultural products including rice, sugarcane, cassava, corn, cellulose, palm, etc. These products contain abundant composition of either starch (carbohydrates), sugar (glucose), or fibers (cellulose). All of which can be used as feedstock for the production of bioplastics. Favored with the price competitiveness and strength in the cultivation techniques, Thailand is clearly standing at the prime spot.

Cassava starch, one of the most promising potential feedstock for bioplastics, is priced relatively lower than other kinds of starch in the global market. In fact, Thailand has long been the largest exporter of cassava starch. In 2005, the country produced 16.94 million ton of cassava roots and exported approximately 4.6 million ton of cassava-based products amounting to 85.5% of the market share which worth more than 40,000 million baht.

The value chain of the production of bioplastics from these agricultural products is another major propelling factor for the development of bioplastics from cassava feedstock. At present, the processed products from cassava, in the form of chips, pellets or starch, are still low in price and subject to unreliable global market both in the sense of price and demand. These processed products can raise the value by 2 folds or about 40,000 million baht. However, if cassava is to be used as the feedstock for bioplastics, its value will increase 10 folds, valued as high as 200,000 million baht.

Thailand's readiness in the downstream industries is yet another important supporting factor. Downstream plastics industries are very well-established with capability to produce wide-ranging products. Therefore, a full cycle of bioplastics product development can be achieved in the country once the upstream production is in place. Majority of plastics producers in Thailand is categorized as SMEs (almost 4,000 factories). The largest proportion is the packaging products at 41.9%, followed by household products at 16.9%. The rest includes the compounding enterprises making up 5.1% of the industry.

Thailand is regarded as ASEAN's number one plastics exporter and ranks number eight in the global market. Notable exported products are films, foil straps, synthetic fibers, sacks, etc. The key markets for Thailand's plastics export are Japan, USA, Hong Kong, UK, Australia and ASEAN countries. During 2000 to 2003, the export value expanded by more than 40% with the total value as high as 51,000 million baht in 2003. Considering the whole export sector for the country, the plastics resin and plastics products actually came fourth with the total value of 140,000 million baht.

Furthermore, Thailand is equipped with researchers and experts covering the entire cycle of bioplastics production process ranging from the upstream, midstream to downstream industries. About 100 of these personnel are ready and willing to work actively on the R&D with the industrial sector.

3. Thailand's Environmental Issues

Thailand is currently producing 40,000 ton of waste daily (or about 14 million ton per year). Among this is the plastics waste, making up 20% of the mix, and only 22% of this plastics waste can be recycled or transformed into fuel. As a result, the remaining 2.2 million ton of plastics waste needs to be disposed each year (Pollution Control Dept., 2005). However, bioplastics will not create such a problem as they can be degraded naturally in the suitable condition, leaving no other residues but carbon dioxide and water. Therefore, bioplastics can be a potential solution to tackle the problem of the overwhelming plastics waste.

Not only bioplastics can be an effective tool for waste managements, but they also help combating with various environmental issues including the air pollution (caused by the global warming from the rising carbon dioxide emission, ozone depletion and haze from fuel combustion), water pollution (e.g. acidification or eutrophication of natural bodies of water), and soil and water problems (e.g. the deposition of non-degradable plastics). The fact that bioplastics can be degraded by the activity of naturally occurring microbes means that this type of plastics will not cause the overwhelming load of waste and needs no other waste management such as burning. As the end products from biodegradation are non-toxic, bioplastics can be used effectively in the separation of organic waste for compost.

4. Development of Thailand's Bioplastics Industry

Bioplastics industry can be regarded as the country's New Wave Industry due to the fact that there has not yet been the complete value chain of the bioplastics industry and the products have not been distributed widely in the local market. However, the initiations from both government and private sectors have been carried out continuously. Some of the prominent organizations, which have been involved with the development of bioplastics in Thailand, are National Innovation Agency (supporting financially and technically to the companies which are eager to invest in bioplastics), Thai Industrial Standards Institute-TISI (developing bioplastics standard for biodegradability, National Research Council of Thailand-NRCT and National Metal and Materials Technology Center-MTEC (supporting and conduct R&D in bioplastics), and Thai Bioplastics Industry Association-TBIA (established from the cooperation of plastics companies which have great interest in creating infrastructure to support the bioplastics industry in the country), Board of Investment- BOI (providing tax privileges for bioplastics investment). By working together as a cluster, TBIA can gain more negotiating power with other trading counterparts and also successfully kick off various supporting initiatives, e.g. the drafting of standards for biodegradability of bioplastics products and cooperation with NIA, NRC, MTEC and some universities to introduce the R&D direction.

National Innovation Agency (NIA), being the initiator of this project in Thailand, has its major roles to encourage, support and gather information associated with bioplastics continuously. The key activities carried out with regard to the development of Thailand's bioplastics project are summarized chronologically as follows:

- In 2003, NIA and cassava starch producers carried out a feasibility study for Thailand to establish bioplastics industry and assess the business opportunity.
- During 2004 to present, NIA has facilitated Thai companies to negotiate with the world's leading bioplastics companies, e.g. NatureWorks LLC (USA), Metabolix Inc. (USA), Unitika (Japan), Mitsui Chemicals (Japan) BASF (Germany), Uhde Inventa-Fischer (Germany) and PURAC(Netherlands) to seek cooperation on investment, creation of market opportunities, technology licensing technology transfer and research and development.
- In 2006, NIA initiated the founding of the Thai Bioplastics Industry Association (TBIA) by inviting plastics leading companies (both large and medium sized) in the country to join as a business association. The pioneers included Thantawan Industries Plc., Thai Plastics Bag Industry Co., Ltd, Unity Thai Co., Ltd. and Quality Minerals Plc. This initiative was also supported by National Metal and Materials Technology Center (MTEC) and Petroleum and Petrochemical College (PPC), Chulalongkorn University.
- In 2006, the industry standards for bioplastics were firstly drafted by the cooperation of NIA, TBIA, PPC and MTEC for further developed by the Thai Industrial Standards Institute (TISI)
- In 2005, bioplastics testing facility was developed by MTEC.
- In 2006, brainstorming sessions, meetings and workshops were conducted by NIA to assemble all opinions from all stakeholders (business executives from private sectors, researchers, academia and related governmental agencies) in order to conclude the operating direction for the bioplastics roadmap.
- NIA organized 2 international conference-and-exhibitions on bioplastics, i.e. InnoBioPlast 2006 (September 21-24, 2006) and EcoInnovaAsia 2008 (October3-5, 2008). These events aimed at disseminating knowledge and create understanding related to Thailand's bioplastics development, catching up on the latest technology trend delivered by the world experts, providing the platform for co-investment and cooperation on bioplastics businesses and, most importantly, demonstrating Thailand's potential to step forward as a bioplastics hub in the region.
- In 2006, NIA was assigned as the responsible agency to coordinate drafting of a Thailand's National Roadmap for the development of Bioplastics Industry, according to the national economic restructuring policies to prioritize 'New Wave Industries'.

At the same time, the private sector could develop some bioplastics products from with the support from NIA through technology transfer and joint research with universities and research institutes. This technology cooperation between private and government sectors has resulted in the import of bioplastics compounds for products processing and of bioplastic resin to blend with starch to produce cost-effective compounds. These products, in fact, have made it to the international markets.

On the research and development collaboration, NRCT, NIA and TBIA have initiated a targeted research to develop innovative bioplastics products. This has been NRCT under the project, "Research and Innovation Helix Program on Bioplastics". Numerous universities and research institutions were the research counterparts in this project; among these include Chulalongkorn University, King Mongkut's Institute of Technology Ladkrabang, Suranaree University of Technology, Chiengmai University and Kasetsart University.

Up to present, there are 3 strategic areas for bioplastics R&D in Thailand namely: (1) Agricultural Raw Materials, (2) Biotechnology, and (3) Chemical and Compounding Technology. Approximately 100 researchers have been actively conducting studies on these 3 areas ranging from the improvement of plant breeding, the enhancement of crop productivity for industry feedstock, selection of natural strains of microbes, improvement of microbe strains, fermentation technology, starch technology and polymerization technology.

In summary, the development of bioplastics industry in Thailand is still in the early stage. Therefore, there is a need for a national roadmap in order to propel this initiative into the streamlined manner to facilitate all stakeholders (both government and private) to work together to induce a favorable environment for investment, establishment of business partnership, establishment of supporting policy, market development and development of technology and innovation. This roadmap can, in turn, enable Thailand to secure a competitive edge to position herself on the global bioplastics market.

5. Preparation of National Roadmap for the Development of Bioplastics Industry

Realizing the challenges and opportunities in the development of bioplastics industry in Thailand, the National Subcommittee on Economic Restructuring endorsed the plan to include the development of bioplastics industry along with the development of biomass-based renewable energy in the action plans for the economic restructuring under "New Wave Industries" on 12 January 2006. The subcommittee appointed the Ministry of Science and Technology as a core organization and asked the Ministry of Industry and Board of Investment (BOI) to take part in this project. After the meeting on 14 February 2006, the working committee appointed NIA as a key focal point in this project and a responsible agency to draft the "Bioplastics" New Wave Industries Action Plan as the National Roadmap for the Development of Bioplastics Industry.

6. National Strategies and Targets in the National Bioplastics Roadmap

To ensure the most efficient execution of the Roadmap, 4 key strategies were pinpointed and the implementation is planned to last for 5 years. Brief outlines of the 4 strategies are as follows:

Strategy One: Sufficient Supply of Biomass Feedstock

(Budget: 100 million baht)

This strategy targets at preparing sufficient quality and quantity of raw materials for the industry without having to interfere with the food supply. Also the acceleration of technology development to enhance the productivity of starch-producing crops must be carried out to ensure that the bioplastics production can reach the break-even point and to prevent various problems on the crop cultivation including the destruction of an ecosystem balance.

Strategy Two: Accelerating Technology Development and Technology Cooperation

(Budget: 1,000 million baht)

This strategy not only focuses on the adoption of overseas technologies, but also aims at having local researchers and scientists to develop technological advances and innovation further from those adopted technologies. The goal to create the country's own technologies is at the heart of this strategy.

Strategy Three: Building Industry and Innovative Businesses

(Budget: 475 million baht)

Under this strategy, an investment in bioplastics industries and businesses must be encouraged from the upstream, midstream right to the downstream stages both at the international business and local business levels.

Strategy Four: Establishment of Supportive

(Budget: 225 million baht)

Many supportive infrastructures must be established to facilitate the development of bioplastics industry in Thailand. These include establishment of industrial standards, setting up the laboratory for testing and certifying bioplastics products, raising public awareness for the use of bioplastics products for an environmental protection, implementation of pilot project for bioplastics utilization in small municipals or community and various activities of public relation.

7. Expected Outcomes

At the end of this 5-year Roadmap, the cooperation and initiative from both governmental and private sectors under this action plan should create significant impact on the following 4 areas:

7.1 Economic, Industrial and Agricultural Aspects

Thailand, through the new wave industries and innovative business on bioplastics, can anchor herself on the international bioplastics market and manage to take a considerable proportion of the global market share. Also, this can provide value creation and value-added to the agricultural raw materials are anticipated to result in the value totaling up to 4,500 million baht.

7.2 Technological Aspect

The development of new technology can lead to the creation of intellectual properties, technology transfer and integration of technology from abroad resulting in the growing number of research specialists on bioplastics. This consequently gears the

country toward the integrated and directed R&D process which could produce an economic value of 500 million baht.

7.3 Environmental Aspect

Awareness in using bioplastics as a solution for environmental problems can help lower the burden caused by the plastics waste. Thus, less money will be allocated to the management of plastics waste and air pollution created from the burning of these non-degradable plastics will be eliminated. This equates with an economic impact of 500 million baht.

7.4 Policy Aspect

The execution of the National Bioplastics Roadmap can induce the establishment of policy, framework and measure to promote and incentives favoring the investment in the bioplastics industry including the establishment of various testing and certification standards on bioplastics products.

Chapter 1: Current Situation of Bioplastics in Thailand*

1.1 Introduction

The amount of garbage produced in Thailand is constantly increasing, with over 14.4 million tons created in 2003. The main elimination process is landfill- only 11% is recycled. With the situation driving research into developing environmentally friendly new products, there is an increasing interest in biodegradable plastics as one of the potential solutions. This chapter focuses on government and private sector activities in the area of bioplastics, the potential for Thailand's materials and plastic industry, and the current government policy.

1.2 Status of bioplastics in Thailand

With increasing concern over the amount of garbage produced, both government and private organizations are beginning to support the development of Thailand's bioplastics sector. The National Innovation Agency (NIA) supports the investment, technology acquisition and assessment in bioplastics, The Pollution Control Department has enacted laws to alleviate the garbage problem; The National Metal and Materials Technology (MTEC) supports testing laboratory for biodegradable plastics; and the Thai Bioplastics Industry Association (TBIA) - which was recently initiated to stimulate development of the sector- serves as a national focal point for negotiations with other industrial countries on issues such as collaboration on drafting standards for biodegradable plastics.

In particular, since 2003 NIA has been active in promoting bioplstics, compiling technology and business information on bioplastics from leading countries as well as coordinating with all stakeholder organizations to drive the support infrastructure and policy for the establishment bioplastics industry in Thailand.

The production of bioplastics products from biomass is shown schematically in Figure 1.1. Cassava roots are first transformed into cassava starch, which is then put through a scarification process using enzymes to produce liquid glucose. The liquid glucose can then be fermented by specialized bacteria or fungi to produce lactic acid monomer, which is then polymerized to produce polylactic acid (PLA), a biodegradable polymer. These polymers undergo a compounding process in which its basic properties are modified and enhanced as needed by addition of plasticizers and other ingredients. In the final part of the production process, the material is moulded or blown into various types of finished product as needed. Thailand currently has two technologies at industrial levels - saccharification by using enzymes to produce glucose from starch, and molding into finished products. Other technologies are still at the research and development stage.

* Parts of this material have been translated by GTZ, Thailand, based on the original Thai version of the National Roadmap for the Development of Bioplastics Industry.

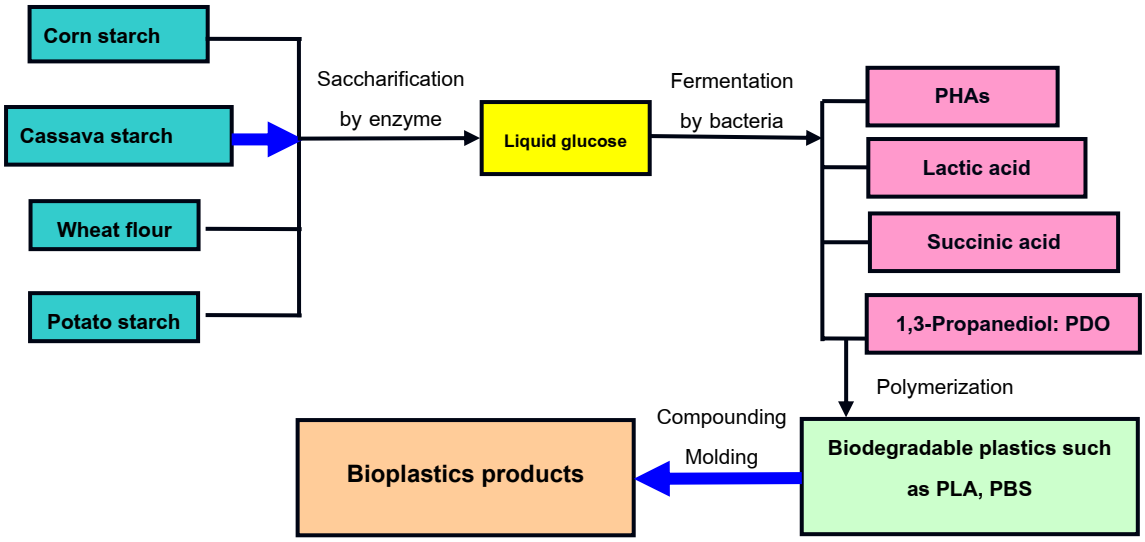

Figure 1.1 Production process of bioplastics products from biomass
(The bold arrows shows industrial level in Thailand)

Production of liquid glucose from starch or saccharification by enzymes

Syrup glucose or liquid glucose is the starting point in producing monomers for biodegradable plastics production. It can be prepared from cassava starch by digestion with amylase and amyloglucosidase enzymes, as shown in Figure 4.2.

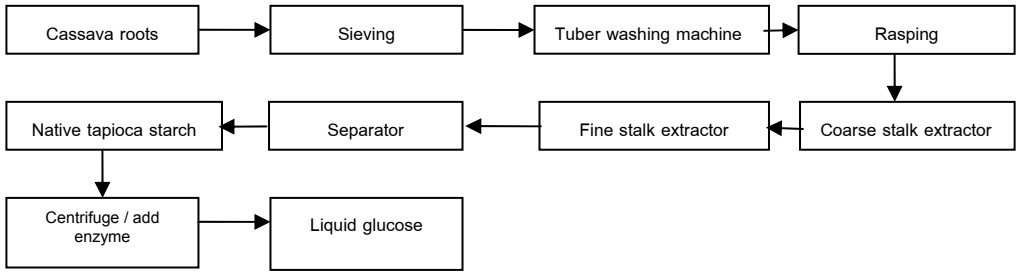

Figure 1.2 Liquid glucose production process

Sources: adapted from liquid glucose production process by PSC Starch Products Co, Ltd.
http://www.pscstarch.com/th/process.asp

Liquid glucose can be produced from cassava starch and molasses. However, the process is still under development to optimize the use of specific enzymes necessary for the digestion process. Production of glucose from corn starch is possible but different equipment must be used. Since there is only one corn starch factory in Thailand and a 60% import tax is levied on, its use as a feedstock is not currently cost-effective.

In Thailand glucose is produced from cassava starch, most of it destined for the food industry. The liquid glucose price is approximately 14 baht/kg (August 2006). Glucose, as a feedstock for bioplastics, does not need to be purified as for the food industry. Liquid glucose used for making ethanol is produced directly from cassava chip, which will generate 20% glucose and can be used directly in the monomer production process without purification. There are many such glucose factories in Thailand, producing both liquid and powdered glucose, as shown in Table 1.1. These factories have the potential to expand their facilities to produce monomers such as lactic acid.

Table 1.1 Glucose factories in Thailand

Factory	Location
Mr. Kamol Tangkamornsiri	Bangkhuntian, Bangkok
Hangya Thai 1942	Ratburana, Bangkok
Prasertchai Co., Ltd.	Muang, Samut Prakarn
Thai Sugar Products Co., Ltd.	Bangplee, Samut Prakarn
Pure Chem Co., Ltd.	Bangplee, Samut Prakarn
Chaokhun Kaset Pheud Phon Co., Ltd.	Gaengkhoi, Saraburi
PSC Starch Products Ltd.	Nongyai, Chonburi
Thai Wattana Pharmaceuticals Dextrose Ltd.	Banglamung, Chonburi
Thai Cassava Industry Co., Ltd.	Bankai, Rayong
Rong Paeng Sin Sahasin Wattana Ltd. Part.	Pongnamron, Chantaburi
Sima Inter Products Co Ltd (Branch2)	Panom, Sarakam, Chachoengsao
Corn Products Amadas (Thailand) Co., Ltd.	Muang, Nakhon Ratchasima
Siam Sorbitol Co., Ltd.	Muang, Nakhon Ratchasima
Mr Kamol Pichitsingh	Sikeo, Nakhon Ratchasima
Asia Fructose Co., Ltd.	Tamoung, Kanchanaburi
Sin Udom Flour and Foods Co., Ltd.	Muang. Nakhon Phatom
Heng Uy Nguan	Dontoom, Nakhon Phatom
Nakorn Luang Glucose Co., Ltd.	Sampran, Nakhon Phatom
Thai Glucose Co., Ltd.	Sampran, Nakhon Phatom

Sources: http://www2.diw.go.th/cluster/Fac_EIA1.asp

Production of monomer and bioplastics products in Thailand

Since there are currently no bioplastics factories in Thailand, many companies have started importing bioplastics compounds to use the existing plastics processing machinaery to produce finished bioplastics products as pilot production for both domestic and export markets. Moreover, some companies have started developing their business to produce relating bioplastics products as shown in Table 1.2.

Table 1.2 Companies carrying on business relating to bioplastics

Company	Location	Product	Technology
1. Advance Packing Co., Ltd. (Special Tech Group)	Phranakorn Sri-Ayutthaya	Plastic bags for plants	- produced from corn starch - import raw plastic from USA and process in Thailand
2. M.S.V. Trading Ltd., Part	Bangkok	Food container such as plate, bowl, spoon and fork	
3. Bio Green World Co., Ltd. (BGW)	Samut Prakarn	Food container such as Plates, bowls, spoons and cups	- produced from PLA or PLA / starch blend - PLA pellets imported from Taiwan
4. BIOFOAM Jazzy Creation Co., Ltd.	Bangkok	Heat-resistant food packaging (single-use) such as disposable plates, bowls and food trays	- Produced from cassava starch, hot-molded into finished products - Own proprietary technology
5. Biodegradable Packaging for Environment Co., Ltd. (BPE)	Bangkok	Single use food packaging such as disposable plates, bowls and spoons	- Produced from bagasse
6. KU-GREEN: Biodegradable Package	Bangkok	Single use food packaging such as disposable plates, bowls, trays and glasses	- Produced from cassava starch, hot-moulded into finished products - Own proprietary technology
7. Thantawan Industry Public Co., Ltd.	Bangkok	Bag, film	- Import raw plastic from USA and process in Thailand - Development compounding
8. PURAC Thailand	Rayong	Lactic acid	- Produced from molasses or cassava

1.3 Thailand's readiness for a bioplastics industry

1.3.1 Raw materials

As an agricultural country, Thailand has major comparative advantages in producing bulk commodities such as rice, sugar cane, cassava, cellulose, wheat and oil palm. Such products contain carbohydrates, glucose or cellulose that are suitable as feedstock for producing bioplastics. Considering its competitive prices and abundant growing capacity in Thailand, cassava is the most feasible and appropriate crop for bioplastics industrial production. Comparing starch prices on the world market, cassava starch has the lowest price, as shown in Figure 1.3. Moreover, Thailand is now the world's largest cassava exporter.

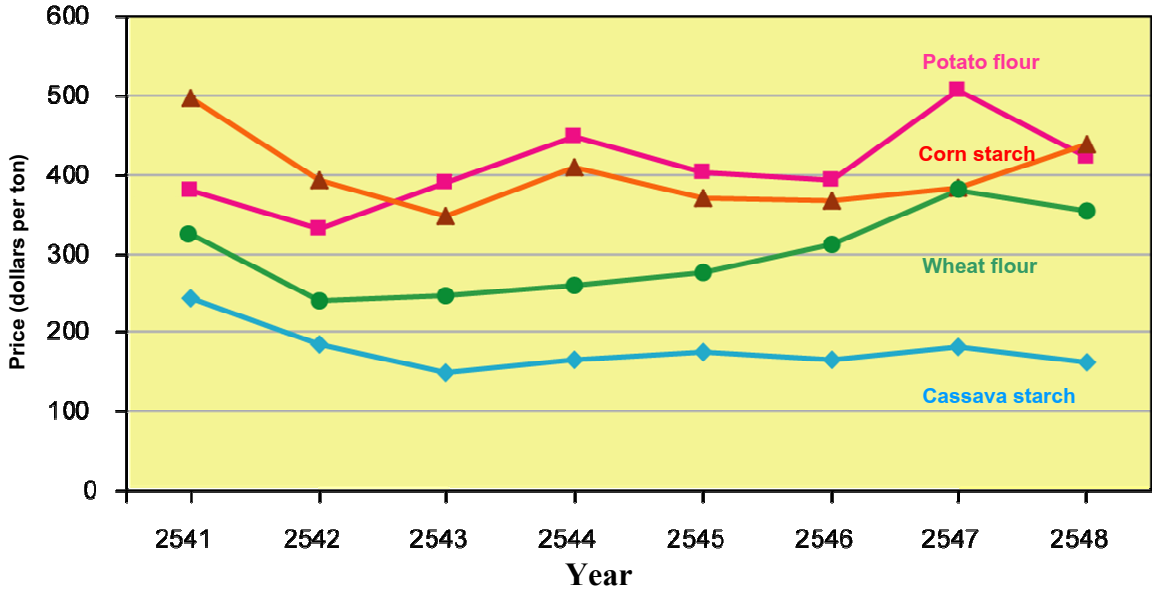

Figure 1.3 Prices of cassava starch, potato flour, corn starch and wheat flour in the world market

In 2005, Thailand produced 16.94 million tons of fresh cassava roots, equal to 8% of world production and ranked No. 4 among fresh cassava producers, behind Nigeria, Brazil and Indonesia. 73.5% of fresh cassava roots are exported as pellets, chips or flour, as shown in Figure 1.4. As mentioned, Thailand is ranked as the world's top exporter of cassava products, with 4.6 million tons p.a., or 85.5% of market share, valued at more than 30 billion baht. Its exports to China, Taiwan and other emerging markets mean that cassava has now become one of Thailand's most important industrial crops. The non-exported production (26.5%) is mostly used as fresh starch in various agro-industrial processes such as the monosodium glutamate production, as well as the lysine, sweeteners, papers, and weaving industries. However, the export demand for cassava remains the main market driver.

Figure 1.4 Cassava utilization ratios between domestic industry and exportation (2005)

Source: adapted information from The Thai Tapioca Trade Association Book B.E. 2547 (the detail based on the Ministry of Agriculture and Cooperatives and Customs Department) From draft report 'Evaluation and Identification for Raw Intervention Ideas for Thailand's Tapioca Subsector' by AgriSource Co. Ltd. Figure 3.3, page 28.

Notes:

Conversion ratio for fresh cassava roots:

1 kg cassava chip : 2.2-2.4 kg fresh cassava roots
1 kg pellets cassava : 2.5-3.0 kg fresh cassava roots
1 kg fresh starch : 3.5-4.0 kg fresh cassava roots

Cassava is cultivated over 6.5 million rai (1 rai: 1,600 square meters), amounting to 14.22% of the total cultivated areas in Thailand. (Source: Ministry of Agriculture and Cooperatives). Around 52% of the cassava production area is in the northeastern provinces of Nakorn Ratchasima, Chaiyaphum, Kalasin, Khon Kaen, Buriram, and Sa kaew, and 25% in the eastern provinces of Chacheongsao, Chonburi, Chantaburi and Trat. The northern and central regions have 15% and 8%, respectively. Table 1.3 to 4.6 show statistics on the cultivated area, annual productivity, productivity per rai, farm gate prices of fresh roots, wholesale prices of cassava product, and volumes and value of cassava exports.

Table 1.3 Primary information on commercial cassava cultivation

Average product	3.5 tons/rai
Production cost	2,100 baht/rai
Cost of product	4,000 baht/rai

Source: Agricultural Development Plan, Tambon Kornswan, Chaiyaphum

Table 1.4 Cultivated area, product, product per rai, cassava selling price by farmers B.E. 2539-2005

Year	**Cultivated area**	**Harvested area**	**Production**	**Production per rai**	**Selling price by farmers**
	(1,000 rai)	**(1,000 rai)**	**(1,000 ton)**	**(kg)**	**(baht/kg)**
1996	7,885	7,676	17,388	2,265	0.98
1997	7,907	7,690	18,084	2,352	0.71
1998	6,694	6,527	15,591	2,388	1.26
1999	7,200	6,659	16,507	2,479	0.91
2000	7,406	7,068	19,064	2,697	0.63
2001	6,918	6,558	18,396	2,805	0.69
2002	6,224	6,176	16,868	2,731	1.05
2003	6,435	6,386	19,718	3,087	0.93
2004	6,757	6,608	21,440	3,244	0.80
2005	6,524	6,162	16,938	2,749	1.31

Source: Department of Agriculture http://www.doa.go.th/fieldcrops/cas/eco/index.HTM

Table 1.5 Cassava product price B.E. 1990-2005

Year	Cassava product				
	Wholesale price in Bangkok (baht/kg)			FOB price (baht/ton)	
	Pellets	Chip	Flour	Pellets	Flour
1990	2.36	2.03	5.16	3,700	5,740
1991	2.62	2.40	5.70	3,860	6,070
1992	2.57	2.40	5.59	3,850	5,893
1993	2.16	1.94	4.31	2,736	5,056
1994	2.43	2.22	4.31	2,736	6,184
1995	3.10	3.08	8.48	3,495	8,869
1996	2.96	2.70	6.47	3,160	7,343
1997	2.21	2.05	6.46	2,479	7,566
1998	3.20	3.01	10.64	3,301	11,306
1999	2.65	2.43	5.85	2,865	6,826
2000	2.00	1.81	5.27	2,210	6,308
2001	2.22	2.27	7.29	2,574	7,648
2002	2.22	2.69	7.62	2,807	7,898
2003	2.57	2.56	6.39	2,911	7,052
2004	2.72	2.85	7.60	3,097	7,473
2005	3.20	3.99	9.28	3,207	9,495

Sources: Office of Agricultural Economics, Ministry of Agriculture and Cooperatives. From draft report 'Evaluation and Identification for Raw Intervention - Ideas for Thailand's Tapioca Subsector' by AgriSource Co. Ltd. Table 4.3

Table 1.6 Exports of cassava products 2003-2004 (volumes and value)

Products	2003		2004	
	Amount (ton)	Cost (million baht)	Amount (ton)	Cost (million baht)
Fresh tubers	127	4.2	75	1.8
Cassava chips	1,812,374	5,352.9	2,805,988	8,640.7
Cassava starch	1,084,068	7,439.6	1,113,633	8,196.5
Cassava pellets	1,859,939	5,096.0	2,212,948	6,391.6
Sago	21,684	251.9	26,742	315.5
Dextrin and other modified starch	525,515	8,780.0	492,638	7,500.7
Glue	5,091	161.2	10,231	289.5
Cassava stalks	61,594	138.7	194,267	479.2
Total of cassava products	5,370,392	27,224.7	6,856,522	31,815.5

Sources: Office of Agricultural Economics http://www.doa.go.th/fieldcrops/cas/eco/stat_1.HTM

Thailand's cassava exports consist mostly of chips, pellets and starch, which have low prices and depend on the foreign commodity market factors leading to unstable prices and demanding conditions. Therefore, in order to increase its value, cassava needs to be adopted as an industrial raw material. Cassava starch in particular can be used for a number of industrial processes. As shown in Figure 1.5, when raw cassava roots are transformed into secondary products such as pellets, chip or flour, the value added will be only 50%, equal to 30 billion baht. But when further transformed into its tertiary products such as bioplastics, modified starch, cellulose products or liquid glucose, the added value will be 150% of its original, equal to 76 billion baht. For bioplastics alone, the added value would be 44 billion baht.

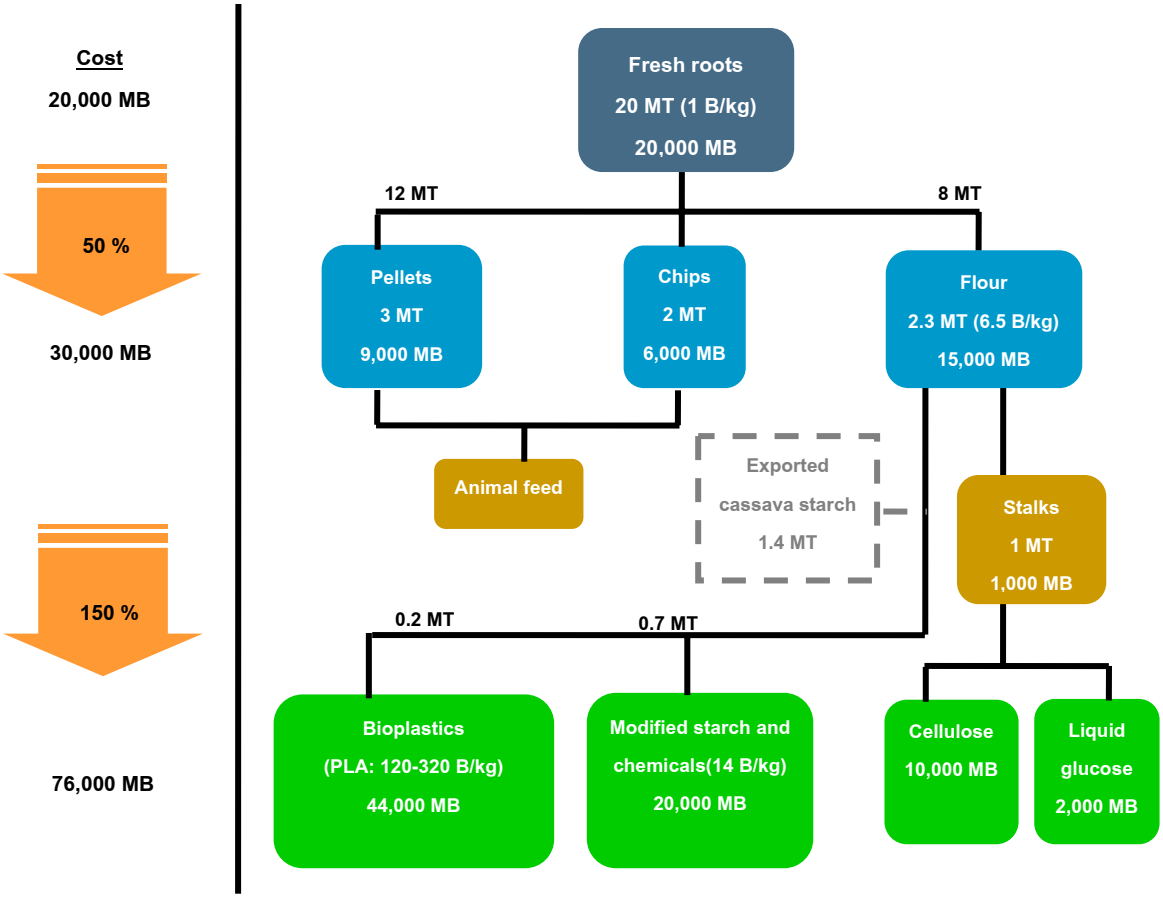

Figure 1.5 Cassava value chain

Source: adapted from strategic plan for agriculture and ago- industrial research, according to national research period in crisis for national revival by Prof. Dr. Theera Sutabutra, Kasetsart University. Diagram 2, page 17

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1.3.2 The plastics industry and market growth in Thailand

Plastics production and markets

Thailand's plastic industry is a full-cycle mature industry sector with a world-class potential. Figure 1.6 shows the industry structure. Plastic granules or resin from the tertiary petrochemical industry may either directly enter the plastic industry or may undergo compounding or polymer blending or poly-alloy production in order to increase its value and utility. There are various plastic molding processes such as an injection molding, extrusion, blow molding and extrusion blow film/sheet. Plastic products are also extremely diverse, including packaging for household appliances, plastic parts for use in consumer goods, electrical appliances and the electronics industry, vehicles, shoes, construction materials etc. Thailand also has an active molding machinery production sub-sector, including die and mould machinery manufacture.

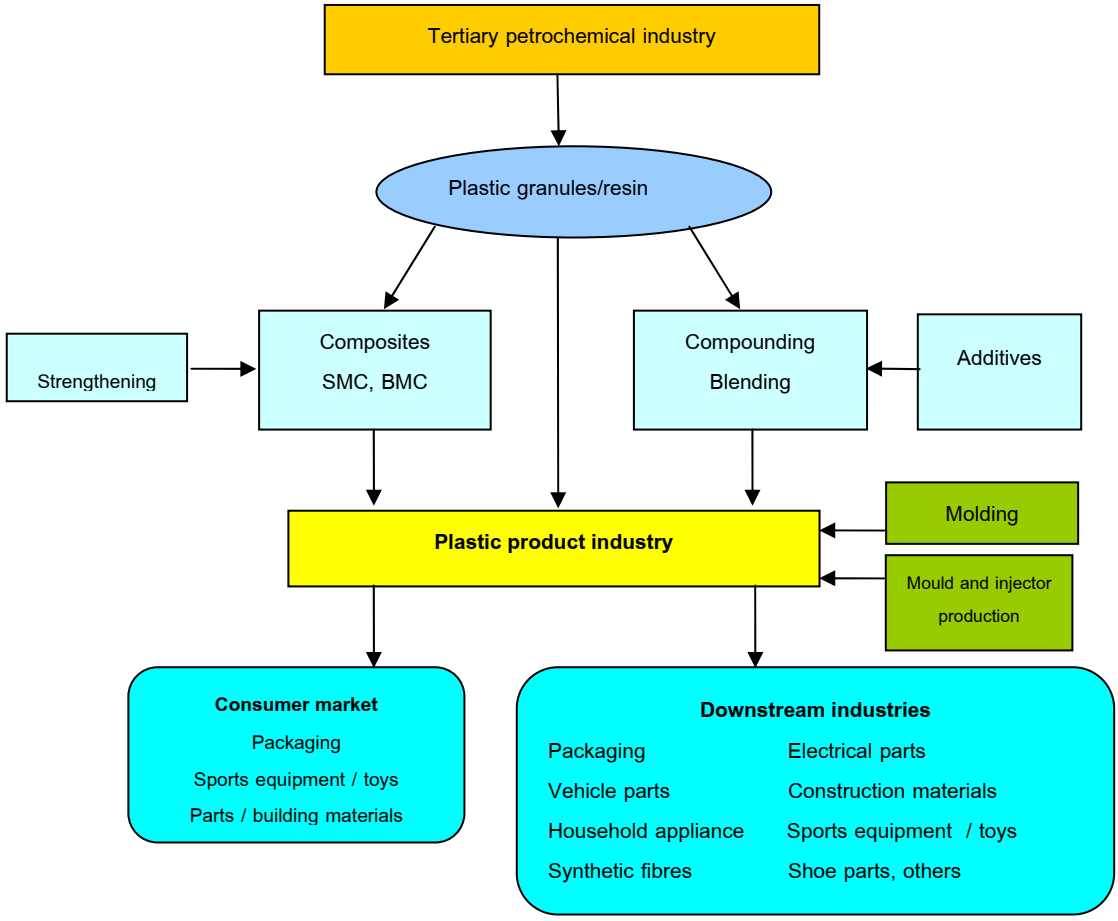

Figure 1.6 Structure of Thailand's plastic products industry

Thailand's plastic granule and resin production accounts for 4% of worldwide production, as shown in Figure 1.7. Annual production amounts to 6.38 million tons/year, which is 38.7% more than domestic demand. Thus, Thailand has become an exporter of both basic pellets and engineering plastics. Thailand has fewer primary

sources (natural gas from the Gulf of Thailand) than others such as the Middle Eastern countries, Indonesia and Malaysia. Nevertheless, Mabtapud Petrochemical Industrial Estate is ranked 8th in the world, and No.1 in the ASEAN region, as the producer of plastic granules. Thailand produces a diverse range of high quality plastic granules, including thermoplastics and thermoset. Both types are made in both basic and engineering forms. Thailand's plastic granule exports are destined mainly for Japan, Singapore, USA, South Korea and Taiwan (See Figure 1.7).

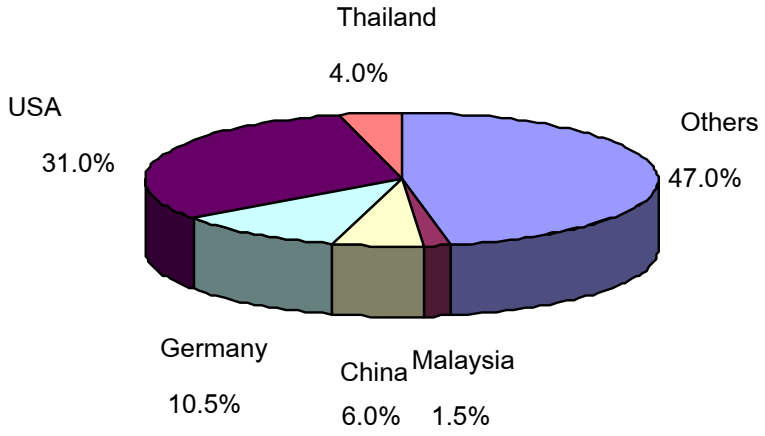

Figure 1.7 Major producers of plastic granules and resins, 2003

Plastic production facilities in Thailand are mainly medium and small-sized. 80% of them are located in Bangkok and its surroundings, with a concentration in the southwestern part of Bangkok- Bangkhuntian, Bangbon, Chomthong, Ratburana and Toongkru districts.

Table 1.7 The plastics industry in Thailand, 2003

Detail	Thailand
No of factories	4,296
SME ratio (%)	88
Congested factory area	Bangkok and surroundings
No of domestic consumer (millions)	62
Domestic consumers / factory (people/factory)	14,432
Ranking (in terms of production quantity)	No.1 in ASEAN

Sources: Department of Industrial Works, Ministry of Industry and Department of Trade Negotiation, Ministry of Foreign Affairs

There are 4,296 factories producing plastic products for molding registered with Department of Industrial Works, Ministry of Industry (data from the DIW, December 2002). However, it was estimated that the real number of factories could be over 5,000, including 30 plastic granule factories. From 2002 data there are 4,229 registered factories categorized into packaging manufacturers (41.9%, the largest market), followed by household products (16.9%) and finally, compounding plastic granules (5.1%). Figure 1.8 below shows the breakdown of plastic product factories in Thailand.

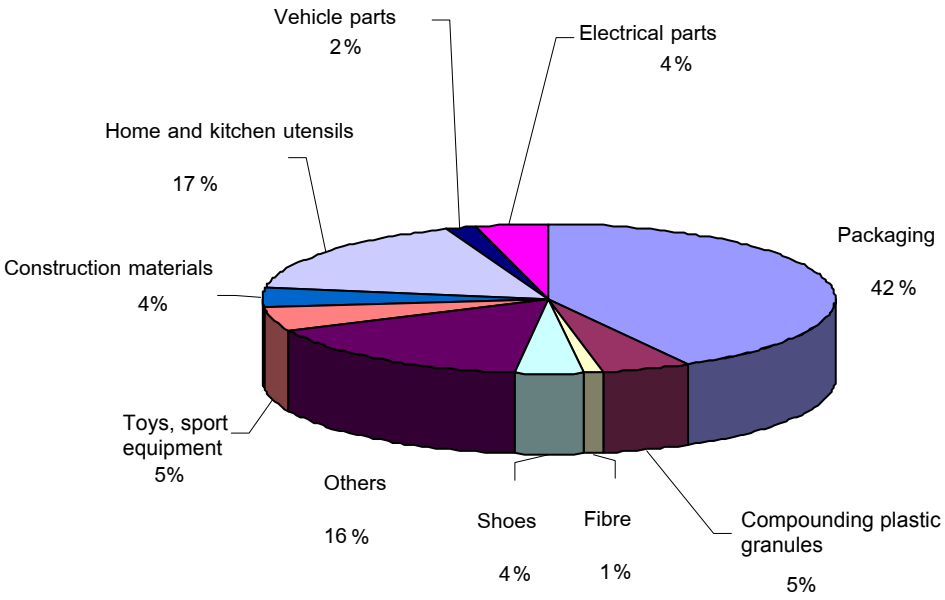

Figure 1.8 Categories of plastic product factories in Thailand

Source: Department of Industrial Works (2002) and the Federation of Thai Industries.

Economic Importance

Although Thailand has always been considered primarily as an agricultural country, over 75 percent of its exports are industrial products, including plastic granules, which indeed form one of the country's most important exports. Even during the economic downturn in 1997, the export value of plastic granules is listed in the top 10 in Thailand. Thailand's export volume and value of plastic granules between the years 1996 – 2003 are shown in Figure 1.9 below.

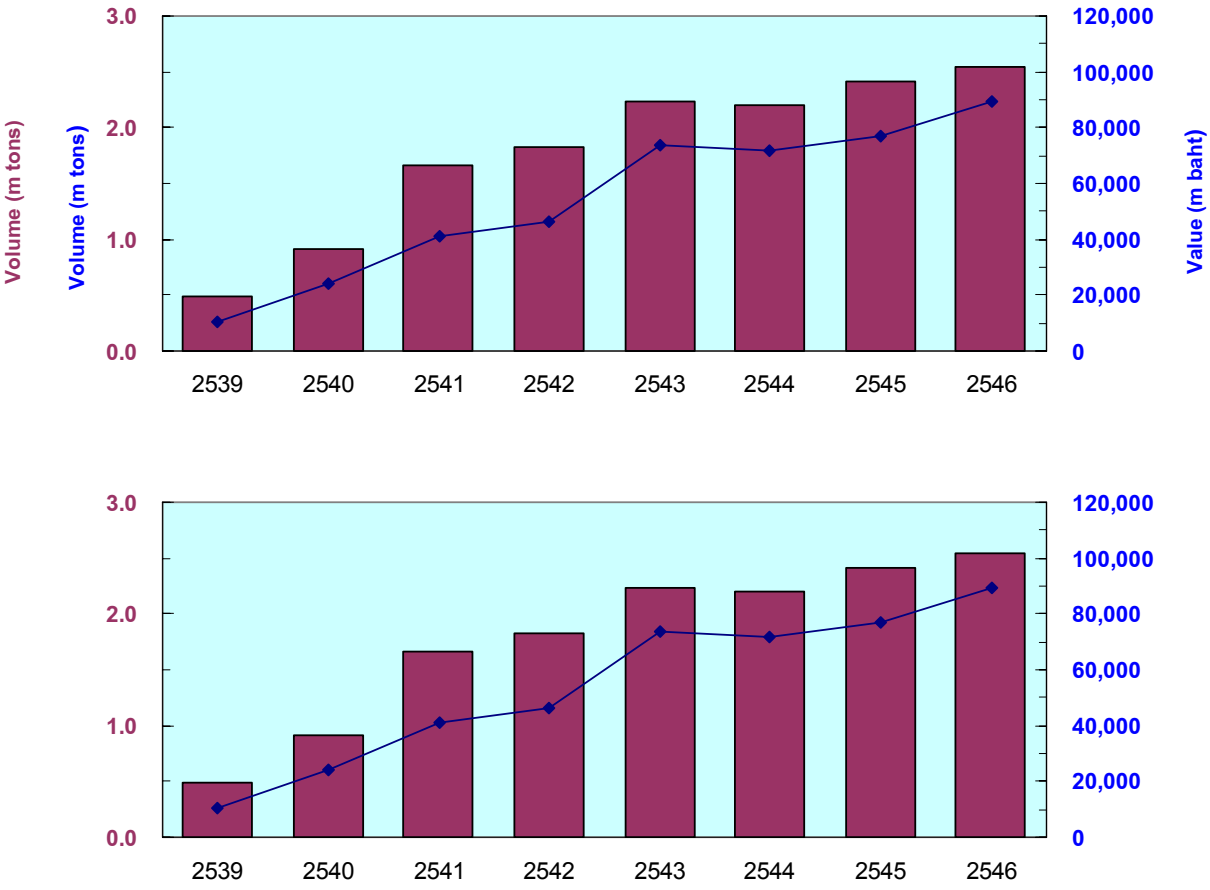

Figure 1.9 Export volumes and value of plastic granules (1996 – 2003)

Source: IT Centre for Economy and Trade, and the Customs Department

Thailand is now ASEAN's leading exporter of plastic products and is ranked 8th in the world. The most important exports are films, foil/tape, synthesized fibers and sack bags. As we can see from Figure 1.10, the growth in export value from 1996 to 2003 is as high as 25.3 percent. The most important markets are Japan, USA, Hong Kong, UK, Australia and other ASEAN countries. From 2000, the value of plastic exports grew by more than 40 percent to 51 billion baht in 2003. Moreover, the export value of plastic granules and plastic products comprises 4 percent of the country's total export value (140 billion baht).

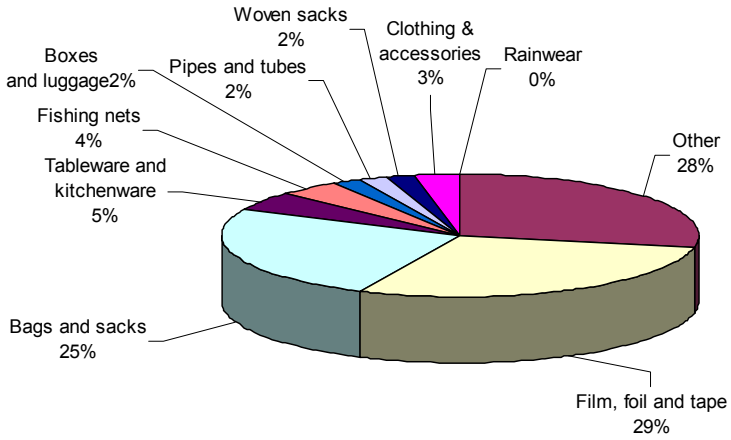

Figure 1.10 Key plastic exports, by value (2003)

Source: Department of Trade Negotiations, Trade Information Centre, and Thai Customs Department.

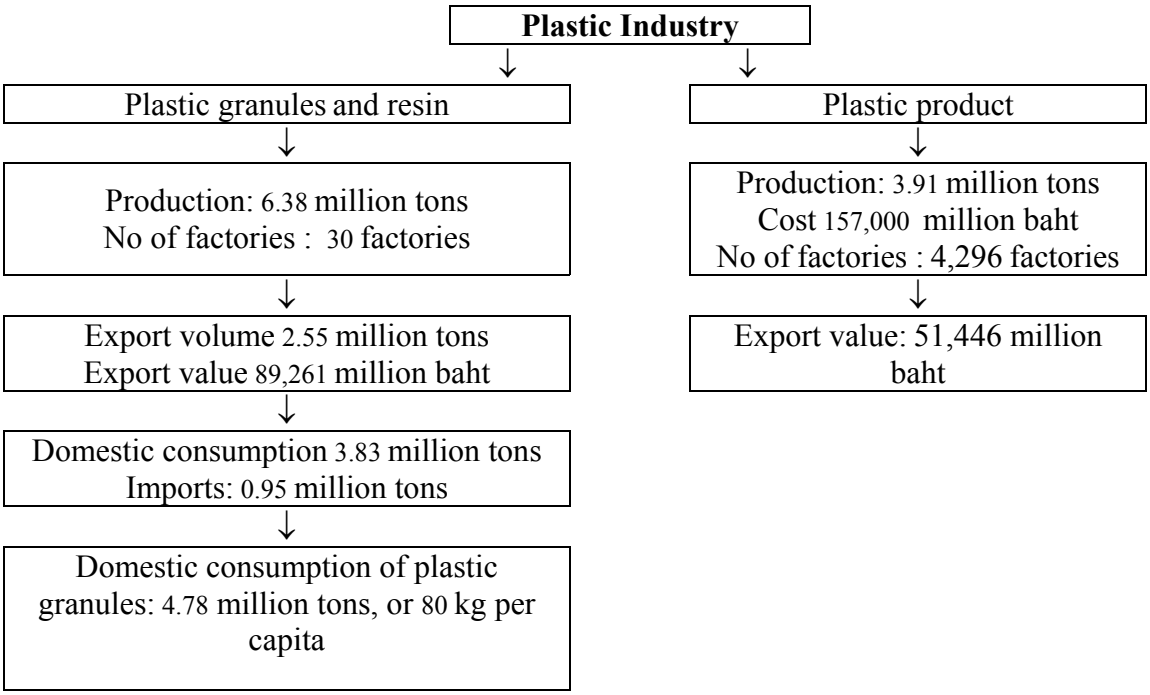

Figure 1.11 Potential of Thai plastics industry (2003) by volume and value.

Figure 1.11 indicates the potential for Thailand's plastic industry, from the production of basic intermediates (plastic granules) from the petroleum industry at Maptaphut to midstream technologies (compounding) and downstream (molding) and the presence of strong market demand both within Thailand and overseas.

The potential and competitiveness of the petrochemical-based plastics industry brings both advantages and possibilities for the production of bioplastics, especially downstream technologies that employ similar production processes and machinery.

As shown in Table 1.8, Thailand has many advantages and strengths. With the government policy supports in various areas such as an environment, trades and investment as well as an encouragement to build technology, Thailand has the potential to play a leading role in bioplastics industry development in the region.

Table 1.8 Strengths and potential of Thailand's bioplastic industry

Industry	Strength and opportunity	Constraints	Possibility
Polymer Industry	- Ample supplies of low-priced cassava feedstocks	Lack of technology and expertise	Moderate
Compounding granule industry	- Readiness for machines, technology, staff, domestic and foreign market - Ability to import bioplastics in order to blend with abundant cassava starch to reduce costs	High price of bioplastics	High
Plastic products industry	- Readiness for machines, technology, staff, domestic and foreign markets	High price of bioplastics	Highest

1.3.3 Government policy and support measures

The government policy and support measures have a direct and major effect in driving the bioplastics industry. Implementing existing policies and establishing new ones to create an appropriate enabling regulatory framework to promote the bioplastics sector will be crucial to achieve national objectives. Since there is currently no law dealing specifically with bioplastics, laws concerning plastics and foams packaging are currently applied. New Royal Decrees are needed to amend existing legislation and ensure an effective enforcement in order to provide an effective and enabling regulatory framework for a viable bioplastics industry sector in Thailand. Some suggestions related to current legislation are offered below.

1. **Customs Tariff Decree, B.E. 2530 (1987)**

Increases in import tariffs (collection of special tariffs) for non-biodegradable raw materials, would help reducing import volumes and encouraging manufacturers to turn to biodegradable materials or to recycle products domestically.

2. **The Excise Tax Act, B.E. 2527 (1984)**

This is an important statute which could be amended to incorporate tax rate reductions, exemptions and other rules and conditions to reduce the use of foams and plastics. Under this Act imports and exports could be controlled by establishing tax-free policies for importing bioplastics, foam compounds, raw materials and biodegradable products which can substitute for conventional plastic bags and foam trays.

3. Industrial Product Standards Act, B.E. 2511 (1968)

This Act could be amended to specify standards for biodegradable plastics, including imprinting of the standard assurance logo and use of environmentally friendly printing inks.

4. Consumer Protection Act (No.1), B.E. 2522 (1979) and Consumer Protection Act (No.2), B.E. 2541 (1998)

The Consumer Protection Acts specify product label requirements. The Act might be amended to specify that the label for plastic and foam products and packages must indicate whether the products are made from biodegradable materials, are environment-friendly, and rank their suitability for re-use or recycling. This would provide consumers with alternatives and would influence distributors to take this into consideration when choosing products to distribute.

5. Public Health Act, B.E. 2535 (1992)

This Act authorizes a local government and public health officials to control any business that have the potential to cause damage to public health. Therefore, the Act might be applied to the business relating to plastics and foams, and include new measures for collecting, transporting and disposing of plastics and foams solid wastes. It could also introduce new measures for plastics and foams garbage separation for households and enterprises in Bangkok and surrounding areas. The Act could establish different fee rates for collection of separated and non-separated garbage categories. Separation of the plastics and foams garbage could be used as a mean to reduce costs of municipal garbage separation services.

Identifying suitable channels for a waste separation and biodegradable plastic packaging will provide an impetus for the efficient implementation of the green plastic pilot project. Under this Act, the authority is given to a local government to prescribe rules, procedures, fees and conditions for collecting, transporting, and disposing of sewage or solid wastes and the issuance of operating licenses for collection and disposal of garbage or wastes (pursuant to Articles 20(3), (4) and (5)), could be extended to include provisions for operations which separate plastics and foams from other categories.

Moreover, there are some more Acts which are relevant to the sector, as follows:

- Hazardous Substance Act (2nd Issue), B.E. 2544 (2001)
- Enhancement and Conservation of National Environmental Quality Act, B.E. 2535 (1992)
- Industrial Estate Authority of Thailand Act, B.E. 2522 (1979)
- National Metrological System Development Act, B.E. 2540 (1997)
- Investment Promotion Act, B.E 2520 (1977) and Amendment
- Factory Act, B.E. 2535 (1992)
- Price of Goods and Services Act, B.E. 2542 (1999)

Chapter 2: Strategy, Action Plan and Budget

Updated information about the industry, technologies, methods and strategies employed by leading countries in the field of bioplastics will be crucial to accelerate the development of bioplastics industry in Thailand and also to attend the status of a regional hub for bioplastics production.

There is an urgent need to establish alliances at national and international levels to support technology transfer and accelerate the development of bioplastics innovations and technologies. This will facilitate investment in bioplastics industry and further enhance the international competitiveness for Thailand. Apart from technology transfer, the enhancement of the national technology capacity will be required in order to make best use of its comparative advantages in terms of natural resources and existing supporting industry, proximity to markets etc., and also to aggressively develop Thailand's R&D capacity and ownership of intellectual property rights on bioplastics related technologies.

Furthermore, at the policy level, it will be necessary to impose a range of measures to support production and encourage the use of bioplastics, including procurement policies, taxation, and public relations, and pilot schemes and compliance with international standards. Intermediary organizations which have the power to negotiate on behalf of the industry at regional and international levels will also be needed.

The Road Map recognizes the need to ensure stable and adequate supplies of raw feedstock materials, and therefore contains outline plans for utilizing raw materials which are readily utilizable by industry as feedstock, and which support growth and stability in the agricultural sector, as well as creating new cultivation and harvesting technologies.

To support the development of bioplastics as the New Wave Industry, a five-year Road Map (2008-2012) for bioplastics development in Thailand was proposed. The Road Map consists of 4 key strategies, and is supported by a budget proposal. These strategies with relating budget are summarized in the Table 2.1.

Table 2.1 Strategy and budget allocation for the Road Map for the Development of Bioplastics Industry

Strategies	Budget (million baht)
Strategy 1 Sufficient Supply of Biomass Feedstock	**100**
Strategy 2 Accelerating Technology Development and Technology Cooperation	**1,000**
2.1 Immediate adoption of available technologies	(100)
2.2 Further developing / generating indigenous new technologies	(900)
Strategy 3 Building Industry and Innovative Businesses	**475**
3.1 Industry innovative business	(445)
3.2 Domestic and overseas markets	(30)
Strategy 4 Establishment of Supportive Infrastructure	
4.1 Establishing industry standards for biodegradability and testing	**225**
4.2 Environment	(55)
4.2.1 Environmental conservation	(50)
4.2.2 Public relations and building awareness	(120)
4.3 Policies (Technology, Industry, Environment)	
Total Budget	**1,800**

Each strategy consists of 6 components: target identification, indicators, action plans, responsible agency, functions of each agency and a budget for implementation. The rest of this chapter provides specific details for each of the 4 strategies.

Action Plans

Strategy 1: Sufficient Supply of Biomass Feedstock (100 million baht)

Targets	Key Indicators
1. To obtain sufficient cassava as raw materials for production feedstock	- To have approximately 10,000 tons of cassava annually - To increase the cassava productivity to more than 8 ton per *rai*[#]

[#]1 Hectare = 6.25 Rai or 10,000 sq. m.

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
1.Introduce policies and regulations on supporting cultivation and productivity enhancement **(20 million baht)**	- Found contingent loans and a lending system for farmers to increase cassava cultivation and its productivity **(20 million baht)**	- Ministry of Agriculture and Cooperatives*	The total of 10,000 ton increase in cassava production (~20 million baht) with the aid of 20 percent of the capital for five years; total budget 20 million baht.	4	4	4	4	4
	- Study and formulate policies for the use of genetic engineering in the field of GMO development to improve cassava variety to be used as feedstock for bioplastic production							

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
2. Educate farmers to understand the use of agricultural products as feedstocks for bioplastic production **(22 million baht)** - Select high-yield variety and distribute them to farmers together with the transfer of good cultivation techniques and other necessary knowledge to ensure high productivity	- Advise and educate farmers on the importance of using cassava as feedstock for bioplastic production and its impact on the economics and environment **(2 million baht)**	- Ministry of Agriculture and Cooperatives*	A 2.5-year project for giving farmers the understanding; 4 times a year and 0.2 million baht a time, worth 2 million baht.	0.8	0.8	0.4		
	- Gather and establish the collection of crop variety **(2 million baht)**		Implementation budget worth 2 million baht	1	1			
	- Transfer technology and distribute newly improved variety to farmers **(5 million baht)**		A 5-year project for outreach program and cultivation techniques transfer; twice a year and 0.5 million baht each time; worth a total 5 million baht	1	1	1	1	1
	- Advise cultivation techniques and secure all necessary supports e.g. good variety of crop, fertilizers and farming equipments **(13 million baht)**		Fund for procuring all supports for farmers lasting 5 years with 2.6 allotted each year; worth a total 13 million baht	2.6	2.6	2.6	2.6	2.6
3. Encourage improved management of cultivated areas **(5 million baht)**	Map the cultivation areas and managing those areas for agricultural crops especially cassava **(5 million baht)**	- Ministry of Agriculture and Cooperatives* - Ministry of Industry	A pilot cultivation project covering the area of 2,000 *rai*, worth 5 million baht.	1	1	1	1	1

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
4. Support the research and development, enhancement of crop variety, cultivation technology, and machinery to replace manual labor in cultivation and harvest process **(50 million baht)**	- Prepare the direction for research on crop variety enhancement, and development of cultivation and harvesting technology - Allocate fund to support the research and development activities **(50 million baht)**	- National Research Council of Thailand* [Working in a form of committee consisting of representatives from Ministry of Education, Ministry of Industry, Thai Bioplastics Industry Association, etc.]	Research fund for crop improvement and development of cultivation technique lasting for 5 years. The fund is allocated to 7 projects (worth 3 million baht each) and 29 project (worth 1 million baht each)	22 →	20 →	8 →		
6. Promote proper management to ensure stable supplies to meet demand e.g. channeling the low-value cassava products for bioplastic production **(3 million baht)**	- Analyze the demand for bioplastic production feedstock **(3 million baht)**	- Ministry of Agriculture and Cooperatives* - Thai Tapioca Development Institute	Hosting inter-ministry meeting to formulate plans to manage the crop supplies for 5 years with the budget of 0.2 million baht each time (to be conducted 3 times a year)	0.6 →	0.6 →	0.6 →	0.6 →	0.6 →
	- Gather information and acting as source of information on the status of raw material supply							
	- Allocate the crop for the production of bioplastics							
	- Analyze all economic factors concerned with using cassava for bioplastic production	- Ministry of Commerce*						
Total Budget for STRATEGY 1: Sufficient Supply of Biomass Feedstock 100 million baht				**33**	**31**	**17.6**	**9.2**	**9.2**

Strategy 2: Accelerating Technology Development and Technology Cooperation (1,000 million baht)

2.1 Immediate adoption of available technologies (100 million baht)

Targets	Key Indicators
1. To gain an access to at least 1 modern technology for fermenting sugar for monomer production and/or PHAs by 2012	- To have an access to 2 types of technologies in transforming sugar into monomer and/or PHAs, such as production of lactic acid, PDO, succinic acid and/or PHAs
2. To gain an access to at least 1 modern polymerization technology for polylactic acids (PLAs) by 2012	- To have an access to 2 types of polymerization technologies such as PLA and PBS production
3. To gain an access to modern compounding technologies for the preparation of PLA resin for molding products at least 1 technology by 2010	- To have an access to at least 5 compounding formulae, with an emphasis on the formulae for use in packaging applications, thermoforming film and injection

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
1. Assess and acquire suitable technologies to adopt or co-invest (including the execution of feasibility study) **(10 million baht)**	- Conduct all necessary activities to acquire suitable technologies from upstream to downstream industry **(7.5 million baht)**	- National Innovation Agency*	Supporting representatives from private sector and member of academia to attend seminars and factory visits in countries of advanced bioplastics technology; 5 areas of technology (upstream, midstream and downstream); 1.5 million baht for each technology making up the total of 7.5 million baht	3	3	1.5		
	- Hire expert(s) to conduct the technology assessment (from upstream to downstream) in order to recommend the technology with feasibility to invest in **(2.5 million baht)**		Budget for hiring expert(s) to assess the technologies worth 2.5 million baht	1	1	0.5		

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
2. Promote and support the import or investment of technology between groups of industry entrepreneurs and enterprises which own overseas technologies **(60 million baht)**	- Identify groups of industry executives/ entrepreneurs who have the potentials and are interested in bioplastics investment (from upstream, midstream and downstream) **(5 million baht)**	- National Innovation Agency*	- Conducting various activities to identify and persuade investors lasting 2 years; 2 events per year with 2 million baht allocated annually, making up 4 million baht in total - Partial grant support for business executives to attend conference/seminar or have a factory visit to the country of leading bioplastics technology; 2-year project, 0.5 million baht allocated annually making a total of 1 million baht	2.5 →	2.5 →			
	- Undertake activities to introduce proven technologies to groups of industry executives/entrepreneurs **(5 million baht)**		Seminars to introduce suitable technologies; 10 times with 0.5 million baht allotted to each, worth a total of 5 million baht	1.5 →	1.5 →	1.5 →	0.5 →	
	- Allocate partial subsidy funds for buying licenses of intellectual property for groups of industry entrepreneurs **(50 million baht)**		Support fund for procuring intellectual properties for 10 technologies worth 50 million baht	20 →	20 →	10 →		
	- Issue investment incentives	- Board of Investment (BOI)*		→	→	→		

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
3. Coordinate groups of industry entrepreneurs with enterprises which own overseas technologies **(5 million baht)**	- Undertake activities to provide groups of local executives/entrepreneurs with an opportunity to associate with overseas enterprises which own technology **(5 million baht)**	- National Innovation Agency* - Ministry of Industry	Organizing meetings between the local and overseas counterparts (2-year project, 1 meeting per year, 2.5 million baht for each meeting, totaling to 5 million baht)	2.5	2.5			
	- Create a stimulating environment for investment, coordinating and facilitating groups of local executive/entrepreneurs and overseas technology owners in order to encourage co-investment between them			→	→	→		
	- Issue incentives to facilitate the co-investment of local executives/entrepreneurs and oversea technology owners	- Board of Investment (BOI)*		→	→	→		
4. Develop human capacity to transfer knowledge of technology **(25 million baht)**	- Conduct seminars and training for personnel from private sector to broaden knowledge of technology **(20 million baht)** - Support the training of personnel overseas for both government and private sectors; in case of the private sector, the trainees must share the cost incurred during the training **(5 million baht)**	- National Innovation Agency*	- 5-year project of training and personnel development; 4 times a year, 1 million baht set for each seminar/training, making up the total of 20 million baht - 5-year project of sending personnel overseas for technology training; 2 times a year, 0.5 million baht set for each training	4 1	4 1	4 1	4 1	4 1
				→	→	→	→	→
Total Budget for STRATEGY 2.1: Immediate adoption of available technologies 100 million baht				**35.5**	**35.5**	**18.5**	**5.5**	**5**

2.2 Further developing / generating indigenous new technologies (900 million baht)

Targets	Key Indicators
1. Further development and generation of new technologies for fermenting sugar for monomer production and/or PHAs (by 2012), in polymerization (by 2011) and in compounding (by 2010)	- To have at least 2 types of technologies for fermenting sugars for monomer production and PHAs, e.g. production of lactic acids, PDO, succinic acids and/or PHAs - To have at least 2 types of technologies in polymer production - To have at least 5 compounding formulae per year for commercial use - To have at least 20 research papers per year published in national academic journals and at least 5 papers per year in international academic journals - To have at least 20 research papers presented in national academic conferences and at least 10 in international academic conferences - To register at least 10 national patents per year and at least 1 international patent per year (starting from 2011)

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
1. Define research directions and offer research funds for integrative research in further development and/or generation of technologies for industrial application **(395 million baht)**	- Collect and evaluate a status of global research and state of the art technologies which can be applied to the production of bioplastics at industrial level **(20 million baht)**	- National Research Council* - National Innovation Agency	5-year research program; 5 projects with 4 million baht allocated for each	4	4	4	4	4
	- Collect data on finished/processing research projects and research personnel of countries in connection with technology of bioplastics production							
	- Define research directions for further development and/or generation of technologies for industrial applications							

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
(cont.)	- Allocate research funds for research projects in the following areas: - Upstream research **(100 million baht)** - Midstream research **(90 million baht)** - Downstream research **(60 million baht)**	- National Research Council* [Working in a form of committee consisting of representatives from National Innovation Agency, Bereau of the Budget, Ministry of Education, Ministry of Industry, Thai Bioplastics Industry Association, etc.]	5-year research funds for target research; 1)45 one-year small projects, 1 million baht per project, worth 45 million baht in total 2)23 three-year medium projects, 5 million baht per project, worth 115 million baht in total 3)9 five-year large projects, 10 million baht per project, worth 90 million baht in total	15 40 30	15 40 30	15 35 30		
	- Support the instruments and durable goods to research institutes or research teams along with research fund in order to facilitate the development of further research or improvement of existing technology **(125 million baht)**		Instruments and durable goods to support: 1)Upstream research, 60 million baht 2)Midstream research, 30 million baht 3)Downstream research, 35 million baht	 60 30 35				

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
2. Define research directions and allocate research funds for target and integrative research in the generation of the country's own technologies that must be both crucial and feasible **(305 million baht)**	- Gather local information on research projects and existing technology concerned with bioplastics and prioritize available technologies in order to determine direction for research which aims at producing country's own technology **(5 million baht)**	- National Innovation Agency*	Conducting meetings to gather project information	1	1	1	1	1
	- Allocate research funds for research projects in the development of crucial and feasible technologies in the following areas: - Upstream research **(90 million baht)** - Midstream research **(80 million baht)** - Downstream research **(30 million baht)**	- National Research Council* [Working in a form of committee consisting of representatives from National Innovation Agency, Bureau of the Budget, Ministry of Education, Ministry of Industry, Thai Bioplastics Industry Association, etc.]	5-year research funds for target research; 1) 50 one-year small projects, 1 million baht per project, worth 50 million baht in total 2) 12 three-year medium projects, 5 million baht per project, worth 60 million baht in total 3) 9 five-year large projects, 10 million baht per project, worth 90 million baht in total	10 20 50	10 20 40	10 20	10	10
	- Support the durable goods for research to institutes or research teams to ensure the readiness of the pilot plant **(100 million baht)**		Instruments and durable goods to support: 1) Upstream research, 50 million baht 2) Midstream research, 25 million baht 3) Downstream research, 25 million baht	50 25 25				

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
3. Encourage and support the industrial engineering and production process at model or pilot level for building fully-equipped industrial factories **(150 million baht)**	- Establish a database on research projects and researchers who work on industrial engineering and production process at the model or pilot level	- National Innovation Agency* - National Research Council		→	→	→	→	→
	- Allocate funds for relevant research projects which co-develop with private sector **(100 million baht)**	- National Research Council* [Working in a form of committee consisting of representatives from National Innovation Agency, Bureau of the Budget, Ministry of Education, Ministry of Industry, Thai Bioplastics Industry Association, etc.]	5-year research funds for target research; 1) 10 three-year medium projects, 5 million baht per project, worth 50 million baht in total 2) 5 five-year large projects, 10 million baht per project, worth 50 million baht in total	20 → 20	15 → 20	15 → 10		
	- Allocate funds for relevant research projects to university with research excellence on various areas concerned with bioplastics in order to develop to the industrial scale **(20 million baht)**		5-year research funds for target research; 4 three-year medium projects, 5 million baht per project, worth 20 million baht in total	10 →	10 →			
	- Support the durable goods for research to institutes or research teams to ensure the readiness of the pilot plant **(30 million baht)**		- Upstream instruments, 10 million baht - Midstream instruments, 10 million baht - Downstream instruments, 10 million baht	10 10 10 →	→	→	→	→
	- Initiate the cooperation among industry sectors to support the industrial research on the pilot scale and invest with own fund to carry out R&D activities with lecturers and researchers	- Thai Bioplastics Industry Association*		→	→	→	→	→

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
4. Encourage and support researchers in conducting collaborative research, and to exchange research data within and between groups **(25 million baht)**	- Conduct meetings, seminars and workshop training for researchers in relevant fields **(25 million baht)**	- National Innovation Agency*	5-year project to host meetings and academic seminars; 2 meetings and seminars a year, 1 million baht per one event; total budget 10 million baht.	5	5	5	5	5
5. Encourage and support registration of patents, selecting from research with potential for development at industry level **(20 million baht)**	- Provide advise and consultation for the intellectual properties registration procedures	- Ministry of Commerce* (Department of Intellectual Properties)						
	- Allocate subsidies for registering patents **(20 million baht)**		5-year subsidy funds for protecting intellectual property of the country's technologies: - 50 national intellectual property, 0.3 million baht per case, budget 15 million baht, and - 5 international intellectual property cases, 1 million baht per property; total budget 5 million baht	3 1	3 1	3 1	3 1	3 1
7. Establish database of research in technology and bioplastics industry **(5 million baht)**	- Establish database of research, technology and companies engaged in bioplastics - Allocate subsidy funds for establishing a database **(5 million baht)**	- National Innovation Agency*	- 5-year subsidy funds for establishing database (5 million baht)	1	1	1	1	1
Total Budget for STRATEGY 2.2: Further developing / generating indigenous new technologies 900 million baht				**485**	**215**	**150**	**25**	**25**

Strategy 3: Building industry and innovative businesses (total budget Baht 475 million)

3.1 Industry innovative business (445 million baht)

Targets	Key Indicators
1. Establish a pilot industrial factory for monomer production (by 2012)	- To have 2 starch, sugar or new factories to produce monomer (such as lactic acid, succinic acid, PDO) from sugars, with capacity of at least 1,500 tons per year and approximate investment value of 1.0 billion baht
2. Set up a pilot industrial factory for monomer production (by 2012)	- To have 2 factories for monomer production (such as PLA and PHAs), with capacity of at least 1,000 tons per year and approximate investment value of 1.5 billion baht
3. Set up an industrial factory for compounding (by 2011)	- To have 5 compounding factories which expand their existing businesses to bioplastics, or set up new factories, with capacity of at least 300 tons per year in productivity and approximate investment value of 200 million baht
4. Set up an industrial factory for molding products (by 2011)	- To have 30 molding factories expanding their businesses lines to bioplastics, with capacity of at least 100 tons per year and with approximate investment value of 300 million baht

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
1. Encourage co-investment between groups of entrepreneurs and enterprises which own foreign technologies in order to build pilot industrial factories for monomer and polymer production **(350 million baht)**	- Allocate zero-interest contingency loans for building factories **(100 million baht)**	- National Innovation Agency*	Zero-interest contingency loans worth 100 million baht	30	30	40 →		
	- Establish co-investment with groups of entrepreneurs **(250 million baht)**		Funds for co-investment worth 100 million baht	100	150 →			
	- Suggest, advise, facilitate and coordinate relevant sectors for building factories			→	→	→	→	→
	- Issue support incentives	- Board of Investment (BOI)*		→	→	→	→	→

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
2. Encourage compounding industry and product molding by having manufacturers expand their business lines to include bioplastics, or building new factory facilities to fully support bioplastic production **(70 million baht)**	- Subsidize loans to expand or construct new factories without interest **(15 million baht)**	- National Innovation Agency*	Subsidized loan without interest of 15 million baht	3	3	3	3	3
	- Initiate joint ventures with prospective investors **(50 million baht)**		Joint venture subsidy fund of 50 million baht	25	25			
	- Support via subsidy fund for importing bioplastics granules for compounding trial run in the pilot project **(5 million baht)**		5-year subsidy for importing a total of 25 tons of granules worth 5 million baht	1	1	1	1	1
	- Issue support incentives/measures	- Board of Investment (BOI)*						
3. Support establishment of full-cycle industrial estates specifically for bioplastics **(10 million baht)**	- Determine the area of the industrial estate including provision of public utilities and services and infrastructure **(10 million baht)**	- Ministry of Industry* - National Innovation Agency - Ministry of Commerce - Board of Investment (BOI)	Budget for conducting study on the zoning for bioplastics industrial estate lasting for 2 years; worth 5 million baht per year	5	5			
4. Support various activities to help strengthening Thailand's bioplastics industries **(15 million baht)**	- Support activities and initiatives conductive to the strengthening of bioplastics industries **(15 million baht)**	- National Innovation Agency*	Support funding of 3 million baht annually	3	3	3	3	3
Total Budget for STRATEGY 3.1: Industry innovative business 445 million baht				**167**	**217**	**47**	**7**	**7**

3.2 Building domestic and overseas markets (30 million baht)

Targets	Key Indicators
1. Establish a domestic business on bioplastics compounding and bioplastics products	- To sell 4,500 tons per year of compounding granules, valued at 300 million baht per year - To sell 800 million baht of bioplastic products per year
2. Establish overseas markets for bioplastics compounding and bioplastics products	- To export 1,500 ton per year of compound granules and bioplastic products worth 400 million baht per year.

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
1. Encourage manufacturers to participate in domestic product exhibition shows **(10 million baht)**	- Subsidize participation in exhibitions for manufacturers **(10 million baht)**	- National Innovation Agency* - Ministry of Commerce	Subsidy on exhibition participation for 100 manufacturers during the 5-year period, 0.1 million baht per company - a total of 10 million baht	2	2	2	2	2
	- Collect data of annual product exhibitions and disseminate news to manufacturers and consumers							

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
2. Encourage manufacturers to participate in product exhibitions and major trade events abroad **(20 million baht)**	- Subsidize participation of manufacturers at exhibitions and trade shows **(20 million baht)**	- National Innovation Agency* - Ministry of Commerce	Subsidy on participation in product exhibitions and trade promotion events for the period of 5 years; granted to 100 companies, 0.2 million baht each – a total of 20 million baht	4	4	4	4	4
	- Collect data and publicize product exhibition event abroad to manufacturers.							
	- Coordinate cooperation between Thai companies and foreign counterparts							
	- Coordinate cooperation with foreign companies	- National Innovation Agency* - German Technical Cooperation (GTZ)						
Total Budget for STRATEGY 3.2: Building domestic and overseas markets 30 million baht				**6**	**6**	**6**	**6**	**6**

Strategy 4: Establishment of Supportive Infrastructure (225 million baht)

4.1 Building industry standards for biodegradability and testing (55 million baht)

Targets	Key Indicators
1. Set national biodegradability standards for bioplastics	- To set up certification standards for biodegradation for domestic products, including assurance logo for certification
2. Establish a Degradability Testing Center for bioplastics	- To establish at least 2 functioning centers

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
1. Establish a committee to set national standards for bioplastics, including assurance logo and render these standards effective through public announcement **(5 million baht)**	- Conduct preliminary study, define national standards, and submit for approval **(5 million baht)**	- National Innovation Agency*	- Standards establishment – 4 million baht.	2 →	2 →			
	- Execute these national standards	- Ministry of Industry* (Thai Industrial Standards Institute)		→				
	- Conduct public hearing on biodegradability standards	- Ministry of Industry* (Thai Industrial Standards Institute) - National Innovation Agency	- 2 public hearings over 2-year period – 1 million baht	0.5 →	0.5 →			

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
2. Establish a Degradability Testing Center for bioplastics **(50 million baht)**	- Support via subsidy fund for establishing Degradability Testing Center of bioplastics **(40 million baht)**	- National Science and Technology Development Agency (NSTDA) * - Thailand Institute of Scientific and Technological Research (TISTR)* - Department of Science Service - Thai Bioplastics Industry Association (TBIA) - German Technical Cooperation (GTZ)	Purchase of equipments for 5 tests (40 million baht): (1) Measureing carbon content before testing (2) Weighing (3) Measuring CO_2 by the DIC method (dissolved in organic solution) or titration with $Ba(OH)_2$ (4) Measuring O_2 through BOD test (5) Measuring CH_4 by using GC	40 →				
	- Personnel development **(10 million baht)** - Provide information on testing techniques and equipment. - Participate in development of the Testing Center - Support information and advise on the model of Testing Center		Staff training (10 million baht): - 5 million baht for domestic training - 5 million baht for on-the-job training abroad	10 →				
Total Budget for STRATEGY 4.1: Building industry standards for biodegradability and testing 55 million baht				**52.5**	**2.5**	**-**	**-**	**-**

4.2 Environnent

4.2.1 Environnemental conservation (50 million baht)

Target	Indicators
1. Implement government measures or policies to encourage and facilitate the production and utilization of bioplastics	- To establish at least 2 government measures/policies to encourage manufacturing and use of bioplastics
2. Establish pilot bioplastic project for environmental protection	- To launch at least 2 projects/campaigns such as the *Green Airline* and *Compost Bag for Organic Waste*
3. Reduce the volume of waste in Bangkok	- To reduce waste in Bangkok by at least 12 percent (equivalent to 1,000 tons per day)

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
1. Study the available measures and policies addressing the environmental issues in order to support the development of bioplastics industry and the utilization of bioplastic product **(10 million baht)**	- Analyze the regulations, policies and measures concerned with environmental issues in order to support the development of bioplastics industry and the utilization of bioplastic product **(10 million baht)**	- National Innovation Agency*	The analysis and research study on regulations, policies and standards on environment for the bioplastics development worth 10 million	5 →	5 →			
2. Propose measures or policies to reduce greenhouse gases, reducing use of energy and chemicals from industrial sources.	- Propose regulatory control and policies or environmental standards, e.g. control of aerial discharge from factories and gaseous ejection from biohazard incinerator	- Ministry of Natural Resource and Environment* (Department of Pollution Control) - Ministry of Science and Technology		→	→	→	→	→

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
3. Propose measures or policies for local waste management	- Propose waste management measures with emphasis on household waste separation	- Ministry of Natural Resource and Environment* (Department of Pollution Control)		→	→	→	→	→
	- Participate in initiatives for practical waste separation (e.g. supporting the *Livable City*, *Livable Community* Project)	- Ministry of Interior* (District Administration)		→	→	→	→	→
	- Participate in generating regulations for hospital waste management	- Ministry of Public Health* (Department of Health)		→	→	→	→	→
4. Propose measures to promote the use of bioplastics as means to protect the environment	- Propose incentives for manufacturers and consumers	- Ministry of Natural Resource and Environment* (Department of Environmental Quality Promotion)		→	→	→	→	→
	- Propose incentives for manufacturers and consumers	- Ministry of Commerce*		→	→	→	→	→
5. Establish an efficient biodegradable waste management model **(20 million baht)**	- Support measures for efficient waste management.	- Ministry of Natural Resource and Environment* (Department of Pollution Control)		→	→	→	→	→
	- Support measures for efficient waste management. **(10 million baht)**	- Ministry of Interior* (District Administration)		2 →	2 →	2 →	2 →	2 →
	- Encourage the waste separation (dry and wet) to enable the waste recovery **(10 million baht)**	- National Innovation Agency*	Project funding of 10 million baht for 5-year implementation period	2 →	2 →	2 →	2 →	2 →

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
6. Conduct Life Cycle Assessment (LCA) for bioplastics and compare with result from conventional plastics **(10 million baht)**	- Support the LCA analysis of bioplastics	- Ministry of Natural Resource and Environment* (Department of Pollution Control)		→	→			
	- Appoint researcher(s) to study, gather information, analyze and conduct LCA for bioplastics **(10 million baht)**	- National Science and Technology Development Agency (NSTDA)*	Funding for the LCA study worth 10 million baht	5 →	5 →			
7. *Green Airport Project* for Suvarnbhumi International Airport	- Promote the use of bioplastics in the airport compound	- Ministry of Transport*		→	→	→	→	→
8. Pilot community project for bioplastic bags and organic waste for biogas production; to be implemented in 2 selected districts **(10 million baht)**	- Create understanding about waste separation to people in the community - Distribute garbage bags within the target community **(10 million baht)**	- Ministry of Interior* (District Administration)	Funding for the provision of bioplastic garbage bags for the duration of 5 years; 1 year for 1 locality with estimated 5,000 bag/day, worth 10 million baht in total	2 →	2 →	2 →	2 →	2 →
	- Coordinate and create understanding with community in the pilot areas.	- Thailand Environmental Institute (TEI)*		→	→	→	→	→
Total Budget for STRATEGY 4.2.1: Environnemental conservation 50 million baht				**16**	**16**	**6**	**6**	**6**

4.2.2 Public relations and building awareness (120 million baht)

Target	Index
1. Arrange campaigns to introduce bioplastics to consumers	- To hold regional exhibition on bioplastics once a year during the 5-year period
2. Create positive attitudes towards using bioplastics, including social and environmental consciousness	- To create advertising media including, but not limited to, radio and television spots

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
1. Hold the exhibition introducing bioplastics. **(5 million baht)**	- Enhance public understanding on bioplastics, from manufacturing processes, degradation and environmental impacts **(5 million baht)**	- National Innovation Agency*	5 exhibitions over the 5-year period; total budget of 5 million baht	1	1	1	1	1
2. Integrate the content on bioplastics into Environment Studies in the education curricula.	- Submit the content to be added to the curricula	- Ministry of Education* (Schools, colleges and universities)						
3. Establish and/or purchase documentary on bioplastics, and distribute to school and institutions of higher education **(30 million baht)**	- Produce or purchase documentaries **(30 million baht)**	- National Science and Technology Development Agency (NSTDA)*	Subsidy fund of 5 million baht to purchase a documentary from overseas (e.g. BBC or NHK from Japan, or to produce locally	6	6	6	6	6
	- Distribute documentary to education institutes	- Ministry of Education* (Schools, colleges and universities)						
4. *Environment Innovation Award* **(5 million baht)**	- Determine conditions and award prizes **(5 million baht)**	- National Innovation Agency*	Prize money and event support of 1 million baht per year	1	1	1	1	1
5. Produce television and radio promotional media **(30 million baht)**	- Produce advertising media to create positive attitudes towards bioplastics **(30 million baht)**	- National Innovation Agency*	Subsidy fund of 30 million baht for the duration of 5 years – 1 event per year, max 6 million baht per promotional event	6	6	6	6	6

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
6. Convene an international exhibition in Thailand **(50 million baht)**	- Organize exhibitions and publicize the events **(50 million baht)**	- National Innovation Agency*	Hosting 1 exhibition per year; 10 million baht set for each event	10	10	10	10	10
Total Budget for STRATEGY 4.2.2: Public relations and building awareness 120 million baht				**24**	**24**	**24**	**24**	**24**

4.3 Policies (Technology, Industry, Environment)

Target	Key Indicators
1. Establish supportive technology policies	- Technology policies created and implemented
2. Establish supportive policies for bioplastics industry business	- Industry business policies created and implemented
3. Establish supportive policies to stimulate domestic and export markets	- Market stimulation policies created and implemented

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget Figures	Period/Budget				
				2008	2009	2010	2011	2012
1. Propose policies and measures to accelerate growth and technology transfer	- Issue policies and measures for tax, inducement, privileges and exemptions (such as the privilege for tax exemptions for investment in technology R&D)	- Ministry of Finance* (Thai Customs Department, Revenue Department)		→	→	→	→	→
	- Issue policies and measures to accelerate technology R&D	- National Innovation Agency* - National Research Council - Ministry of Education (education institutes, Commission on Higher Education, Institute for the Promotion of Teaching Science and Technology) - Thailand Research Fund		→	→	→	→	→

Action Plans (Total Budget)	Functions (Budget)	Responsible Agency (* Key Agency)	Sources of Budget	Period/Budget				
				2008	2009	2010	2011	2012
2. Propose policies and measures supporting bioplastic industry development	- Issue policies to support establishment of bioplastics production facilities (e.g. tax privileges for investment)	- Ministry of Industry* (Dept. of Industrial Promotion, Board of Investment, Office of Industrial Economics, Office of SME Promotion, Industrial Estate Authority) - Ministry of Finance		→	→	→	→	→
	- Issue policies to enforce some locally produced plastic parts, e.g. electrical parts, to be replaced by bioplastics	- Ministry of Natural Resource and Environment* - Ministry of Industry (Board of Investment) - National Innovation Agency		→	→	→	→	→
3. Propose policies and measures facilitating import and export of compounding granules and bioplastic products	- Issue policies, measures, tax privileges, trade privileges and international measures facilitating imports and exports of bioplastics	- Ministry of Finance* (Thai Customs Department, Revenue Department) - Ministry of Commerce (Dept. of Foreign Trade, Dept. of Interior Trade, Dept. of Trade Promotion, Dept. of Export Promotion) - National Innovation Agency		→	→	→	→	→
	- Issue biodegradation standards	- Ministry of Industry* (Office of SME Promotion, Industrial Standards Institute) - National Innovation Agency		→	→	→	→	→

Table 2.2 Summary of Annual Budget Allocation

Organization	Year/Budget (million baht)					Total
	2008	2009	2010	2011	2012	
1. Ministry of Agriculture and Cooperatives	11.0	11.0	9.6	9.2	9.2	50.0
2. Ministry of Industry	5.0	5.0	-	-	-	10.0
3. National Research Council of Thailand	496.0	224.0	147.0	14.0	14.0	895.0
4. National Science and Technology Development Agency	36.0	11.0	6.0	6.0	6.0	65.0
5. Thailand Institute of Scientific and Technological Research	25.0	-	-	-	-	25.0
6. National Innovation Agency	238.0	288.0	98.5	45.5	45.0	715.0
7. Ministry of Commerce	4.0	4.0	4.0	4.0	4.0	20.0
8. Ministry of Interior (District Administration Organizations and Bangkok Metropolitan Administration)	4.0	4.0	4.0	4.0	4.0	20.0
Total	819.0	547.0	269.1	82.7	82.2	1,800.0

Table 2.3 Annual budget allocation for Strategy 1

Organization	Year/Budget (million baht)					Total
	2008	2009	2010	2011	2012	
1. Ministry of Agriculture and Cooperatives	11.0	11.0	9.6	9.2	9.2	50.0
2. Ministry of Industry	-	-	-	-	-	-
3. National Research Council of Thailand	22.0	20.0	8.0	-	-	50.0
4. National Science and Technology Development Agency	-	-	-	-	-	-
5. Thailand Institute of Scientific and Technological Research	-	-	-	-	-	-
6. National Innovation Agency	-	-	-	-	-	-
7. Ministry of Commerce	-	-	-	-	-	-
8. Ministry of Interior	-	-	-	-	-	-
Total	33.0	31.0	17.6	9.2	9.2	100.0

Table 2.4 Annual budget allocation for Strategy 2

Organization	Year/Budget (million baht)					Total
	2008	2009	2010	2011	2012	
1. Ministry of Agriculture and Cooperatives	-	-	-	-	-	-
2. Ministry of Industry	-	-	-	-	-	-
3. National Research Council of Thailand	474.0	204.0	139.0	14.0	14.0	845.0
4. National Science and Technology Development Agency	-	-	-	-	-	-
5. Thailand Institute of Scientific and Technological Research	-	-	-	-	-	-
6. National Innovation Agency	42.5	42.5	25.5	12.5	12.0	135.0
7. Ministry of Commerce	4.0	4.0	4.0	4.0	4.0	20.0
8. Ministry of Interior	-	-	-	-	-	-
Total	520.5	250.5	168.5	30.5	30.0	1,000.0

Table 2.5 Annual budget allocation for Strategy 3

Organization	Year/Budget (million baht)					Total
	2008	2009	2010	2011	2012	
1. Ministry of Agriculture and Cooperatives	-	-	-	-	-	-
2. Ministry of Industry	5.0	5.0	-	-	-	10.0
3. National Research Council of Thailand	-	-	-	-	-	-
4. National Science and Technology Development Agency	-	-	-	-	-	-
5. Thailand Institute of Scientific and Technological Research	-	-	-	-	-	-
6. National Innovation Agency	168.0	218.0	53.0	13.0	13.0	465.0
7. Ministry of Commerce	-	-	-	-	-	-
8. Ministry of Interior	-	-	-	-	-	-
Total	173.0	223.0	53.0	13.0	13.0	475.0

Table 2.6 Annual budget allocation for Strategy 4

Organization	Year/Budget (million baht)					Total
	2008	2009	2010	2011	2012	
1. Ministry of Agriculture and Cooperatives	-	-	-	-	-	-
2. Ministry of Industry	-	-	-	-	-	-
3. National Research Council of Thailand	-	-	-	-	-	-
4. National Science and Technology Development Agency	36.0	11.0	6.0	6.0	6.0	65.0
5. Thailand Institute of Scientific and Technological Research	25.0	-	-	-	-	25.0
6. National Innovation Agency	27.5	27.5	20.0	20.0	20.0	115.0
7. Ministry of Commerce	-	-	-	-	-	-
8. Ministry of Interior	4.0	4.0	4.0	4.0	4.0	20.0
Total	92.5	42.5	30.0	30.0	30.0	225.0

Expected Outputs from the Implementation of the National Road Map for the Development of Bioplastics Industry

Economic, industrial and agricultural aspect (valued 4.5 billion baht)

- Establishment of new wave industry and a complete range of innovative bioplastics business (from the upstream to downstream) with an investment value of 3,000 million baht.
- An ability to reach 1 percent of the market share (by value) of plastic products produced, worth 1.5 billion baht.
- New value creation and value-added which will increase a price stability for agricultural crops used as feedstock

Technological aspect (valued 500 million baht)

- New technology for the country, leading to at least 50 items of the intellectual property, worth 300 million baht.
- Technology transfer and business integration between foreign technology owners and local partners, making use of Thailand's supplies of biomass. The economic value of this contribution to the country's technology base is valued at 100 million baht.
- Creation of national core expertise in specialized fields, leading to integrated and targeted R&D which will create the industrial innovation research work valued at 100 million baht.

Environmental aspect (valued 500 million baht)

- Budget reduction of 400 million baht (currently allocated to dispose of the conventional plastic wastes).
- Awareness and consciousness of the environment preservation throughout Thailand's population.
- Use of biodegradable plastic products to help enhance quality of life and contribute to environmental protection.
- Pilot demonstration areas with the complete range of system of biodegradable plastic use, with an environment value of 100 million baht.

Policy aspect

- Establishment of effective policies and measures which will promote and facilitate investment in the bioplastics industry.
- Establishment of effective policies and measures to accelerate, R&D and technology transfer for manufacturing of bioplastics.
- Measures and environmental regulations supporting the use of biodegradable plastics.
- Bioplastics industry measures.

Abbreviations

Organization

ASEAN	Association of South East Asian Nation
MTEC	National Metal and Materials Technology Center
NIA	National Innovation Agency
NRCT	National Research Council of Thailand
PPC	Petroleum and Petrochemical College
R&D	Research and Development
SME	Small and Medium Enterprise
TBIA	Thai Bioplastics Industry Association

Chemical reagents

AAC	aliphatic-aromatic polyester
BDO	1,4-butane diol
BOD	biological oxygen demand
COD	chemical oxygen demand
DMT	dimethyl terephthalate
DOA	dioctyl adipate
DOP	dioctyl phthalate
HDPE	high density polyethylene
HDT	heat distortion temperature
LDPE	low density polyethylene
PBA	poly(butylene adipate)
PBAT	poly(butylene adipate terephthalate)
PBS	poly(butylene succinate)
PBSA	poly(butylenes succinate adipate)
PBT	poly(butylene terephthalate)
PCL	poly(carprolactone)
PDLA	poly(d-lactic acid) or poly(d-lactide)
PDO	1,3-propane diol
PE	polyethylene
PEG	poly(ethylene glycol)
PES	poly(ethylene succinate)
PET	poly(ethylene terephthalate)
PGA	poly(glycolic acid)
PGLA	poly(glycolic-co-lactic acid)
PHAs	poly(hydroxyalkanoate)s
PHB	poly(hydroxybutyrate)
PHBV	poly(hydroxybutyrate-hydroxyvalerate)
PLA	poly(lactic acid) or polylactide
PLLA	poly(l-lactic acid) or poly(l-lactide)

PP	polypropylene
PS	polystyrene
PTT	poly(trimethylene terephthalate)
PVA	poly(vinyl alcohol)
PVAc	poly(vinyl acetate)
PVC	poly(vinyl chloride)
Tg	glass transition temperature
Tm	melting temperature
TPA	terephthalic acid
TPS	thermoplastic starch