

**Sustainable Management Strategies:  
Thailand's Sustainable Plastic-Management Leading the  
Thai Plastic Industry Towards Becoming a Bio-Plastic Hub**

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## **Abstract**

Plastic pollution is a major environmental problem in the world, and Thailand is one of many countries faced with increasing plastic and foam waste problems. Plastic pollution affects canals, rivers and beaches, and the health of sea creatures and wild animals who eat plastic bags. The popular solutions for this plastic problem are reducing, reusing and recycling; however, the Thai government focuses on a different solution: replacing the problematic product (plastic) with bio-plastic. This research analyses the project initiated by the Thai government which aims to facilitate relevant public and private sector agencies, working together to push the Thai plastic industry towards becoming a bio-plastic hub. The government has chosen replacing because the development of bio-plastic contributes not just to environmental objectives, but also to economic, technological and social goals. The research undertakes a thorough review of critical literature in order to assess the challenges and barriers likely to face this project. The research also aims to find out how the strategies of the project in all three phases can address the challenges and barriers encountered.

**Keywords:** Plastic pollution, Bio-plastic, Thai plastic industry and Sustainable management

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## List of abbreviations

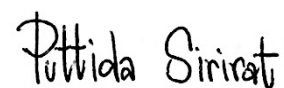
<b>AIBN</b>	: The Australian Institute for Bioengineering and Nanotechnology
<b>ASEAN</b>	: Association of Southeast Asian Nations
<b>BE</b>	: Buddhist calendar
<b>BSA</b>	: Bio Succinic Acid
<b>CAGR</b>	: Compound Annual Growth Rate
<b>DOE</b>	: Department of Energy
<b>DSD</b>	: Duales System Deutschland
<b>EBA</b>	: European Bio-plastics Association
<b>ESCD</b>	: Environmental supply dynamics
<b>EOL</b>	: End-Of-Life
<b>GPO</b>	: German Packaging Ordinance
<b>GHG</b>	: Greenhouse Gas
<b>HDPE</b>	: High Density Poly Ethylene
<b>ISO</b>	: International Organization for Standardization
<b>MCC</b>	: Mitsubishi Chemical Corporation
<b>MSW</b>	: Municipal Solid Waste
<b>NSTDA</b>	: National Science and Technology Develop Agency
<b>NIA</b>	: National Innovation Agency
<b>NZD</b>	: New Zealand Dollar
<b>PBS</b>	: Polybutylene Succinate
<b>PE</b>	: Polyethylene
<b>PHA</b>	: Polyhydroxyalkanoate
<b>PLA</b>	: Polylactide

<b>PP</b>	: Polypropylene
<b>PTIT</b>	: Petroleum Institute of Thailand
<b>PTT</b>	: Petroleum Authority of Thailand
<b>PTTGC</b>	: PTT Global Chemical Public Company Limited
<b>PVC</b>	: Polyvinyl Chloride
<b>RoHS</b>	: Restricted use of some hazardous substances
<b>SOE</b>	: Special Operations Executive
<b>TBIA</b>	: Bioplastics Industry Association Thailand
<b>Three Rs</b>	: Reduction, Re-use, and Recycling
<b>UK</b>	: United Kingdom
<b>UQ</b>	: University of Queensland
<b>USD</b>	: United States, Dollar
<b>U.S</b>	: United States
<b>WEEE</b>	: waste electronics and electrical equipment



## **Attestation of Authorship**

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

A handwritten signature in black ink, reading "Puttida Sirirat". The script is cursive and fluid, with the first name "Puttida" and last name "Sirirat" clearly distinguishable.

(Puttida Sirirat)

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- The next supervisor I would like to thank is **Professor Marjolein Lips-Wiersma** because she is behind any success of mine. She has suggested and taught the basic concepts of plastic waste solution which has led to this study and pointed me to analyse the reasons towards the Thai government has chosen to develop bio-plastic. Furthermore, she also suggests the method of collecting and the presentation of data that have been helpful for this writer in

understanding the causes and effects of this research and a final focusing on plastic solution action.

# **Chapter 1**

## **Introduction**

The research will investigate plastic pollution, especially the solution for it, through researching the Thai government's project that is supporting the Thai plastic industry so that it can become a bio-plastic hub. The research will focus on the method/strategy and challenges/barriers. However, before the research deals with these issues, it will explain and elucidate the factors (involved in this research).

Overall, the amount of single-use plastic waste has increased by around 50 percent worldwide each year, and just five percent of it can be recovered (Alessandro, 2014). Plastic is an environmental hazard because plastic is made from fossil fuel resources which causes it to be difficult for biodegrading (Özkan & et al., 2015). In Thailand, the amount of plastic waste seems to have risen as well. For example, the amount of foam waste increased to 2.7 million tonnes in 2015, and by 80 percent for plastic bags (Yangtheen, 2015). The rest is rubbish which is comprised of approximately 700,000 tonnes of non-biodegradable foam that will take up to 450 years to degrade (Kaplan, 2013; Yangtheen, 2015).

Moreover, both plastic and foam waste cause issues such as clogging in city sewers. The clogging occurs when debris is trapped by heavy rain. In addition, it has been established that sea animals can be killed by the plastic bags since it harms their digestive systems (Pollution Control Department, 2005). The secretariat of the Convention on Biological Diversity in Montreal, Canada reported, in 2012, that plastic waste can harm all sea turtle species, 45 percent of marine mammal species and 21 percent of seabird species (Rochman & et al., 2013). According to Greenpeace the

plastic is not only dangerous for animals but humans as well (Member of the National Assembly, 2014; Suriwong, 2015).

Bio-plastic has become a popular choice for reducing plastic pollution (Srinivasan and Lu, 2014), in many countries whose governments and plastic industries have started to develop bioplastic technology and markets (Moore, 2008). The Thai government's project is called "A National Roadmap for the Bioplastic Plastics Industry Development" or, simply, the National Roadmap. It focuses on designing plastic which can be easily-degradable by developing bio-plastic both in marketing production, and by helping Thailand to become a bio-plastic hub (Weerathaworn, 2013a). While some people believe that Thailand can be a bio-plastic hub, Thailand is still likely to face many challenges and barriers in this development (Panyapiwan Institute of management, 2015)

There are three significant root causes of plastic pollution: the design system, the consumers, and management of waste following consumption (Pollution Control Department, 2005). This research will discuss the normal solutions such as 'reduce, re-use and recycle' that Thailand chooses to find a way of replacing the conventional plastic waste with bio-plastic as a natural alternative which has been found to be more environmentally friendly. The design solution is in terms of new products to replace the traditional plastic.

However, recognizing the environmental benefits of using bio-plastic and forming a product market for bioplastics is still unrealized (Borisutanagul, 2013; National Innovation Agency, 2010b; Phuengchaichangul, 2013). These challenges and barriers have led to studies about strategies in the National Roadmap in Thailand. The project has adopted strategies which can be divided into two phases occurring between 2008 and 2015 (Kihirun & Chongcome, 2010;

Organisation for Economic Co-operation and Development, 2013; Weerathaworn, 2013b). The strategies of the two phases are designed to solve the weaknesses and challenges of the National Roadmap at developing a bio-plastic industry. In October 2016, the third phase of the projected strategies was designed, with four measures which have been approved for this phase. All strategies have been designed to solve the challenges and barriers that make it difficult for Thailand to become a bio-plastic hub. Phase Three also has a new aim, namely to become the bio-plastic hub in the Association of Southeast Asian Nations (ASEAN) (Ministry of Industry, 2016b).

This research mainly focuses on the Thai government's role concerning bio-plastic in Thailand through the government's project called the National Roadmap. The first aim is to describe the strategies of the government's project for finding how the Thai government and its cooperative organisations operate in directing the Thai plastic industry towards becoming this bio-plastic hub (National Innovation Agency 2008d, National Innovation Agency 2010d, National Science and Technology Development Agency, 2008b, Plastic Intelligence Unit, 2010).

Also, this research will seek to analyse the challenges/barriers faced by the project. In the light of that situation, this research paper will focus on estimating the challenges faced by the Thai government in its strategy for a National Roadmap as well as the effects of that strategy. This research will assess how the strategies of the National Roadmap address challenges/barriers to the development of bio-plastic. The research area pays attention to discovering answers to its two research questions:

1. What is the Thai government currently doing and what has it done to establish the Thai plastic industry as a bio-plastic hub?
2. What are the challenges and barriers likely to be faced in the National Roadmap?

**The following** chapter sets out the methodologies that will be utilised in the process of answering these research questions.

## **Chapter 2**

### **Methodology/Method and Analysis**

#### **2.1 Methodology/Method**

This first research question focused on the collection of ‘**Primary Data**’ or ‘**Original data**’, **and the original data for this research is from government sources** in the form of reports, press releases, websites and journals (such as the Ministry of Science and Technology (Kihirun & Chongcome, 2010; National New Bureau of Thailand, 2015) as well as from associated organisations which have an interest in establishing the Thai plastic industry as a bio-plastic hub proposal (such as Plastic Institute of Thailand (2013a)); Technology Promotion Association (Thailand-Japan) (2010); and United Nations Conference on Trade and Development (Kihirun & Chongcome, 2010).

This research used data from government sources because they were consistent with the research questions and objectives, and there were several options for the collection of primary data; furthermore, this research needed to collect relevant, primary data dependent on the research problem and design (Ghauri, Grønhaug, 2010). In this research, the types of primary data that collected were ‘Awareness and Knowledge data’ which describe what particular business activities or products are already in existence, such as the relevant data required to discover the effects of a specific advertising campaign for the business, and the term describes particular business activities or products (Ghauri, Grønhaug, 2010). The research had to show awareness of the relevant data required to discover the management strategies for bio-plastic development outlined in the National Roadmap, and also study that data in order to analyse the strategies. In terms of Question One in this research, data was collected about the Thai government’s (and



involved organisations) awareness of their actions in establishing the Thai plastic industry as a bio-plastic hub, with a focus on strategies and activities.

For the second research question, data from both government sources and non-government sources referred to the data which had already been collected and analysed by other researchers (Blumberg, 2008; Cooper and Schindler, 2006; Ghauri & GrØnhaug, 2010; Gray, 2014; Kothari, 1990; Ticehurst & Veal, 2000; Veal, 2005). This research used the data to understand the challenges and barriers of the National Roadmap. In addition, since the focus of the research was on actions taken by the Thai government, and this data was rather difficult to access, the researcher could immediately start to analyse the data to find the answers to research questions (Blumberg, 2008). The data sources were government agencies, educational institutions and specialist centres, professional organisations, management-related fields, archival material and the Internet-based resources (Ticehurst & Veal, 2000; Veal, 2005). The data could be in the form of the academic literature which involved books, academic journals, academic articles, and published literature reviews in a field (Ridley, 2012). Almost all data in this research aimed at information from Thai government agencies, company information, professional organisations, management-related fields and Internet-based resources.

The data used to answer this research question was from relevant academic literature. The reason was that the data was used to discover the challenges and barriers of the National Roadmap which has been the pushing Thai industry to become a bio-plastic hub, and this research discussed management strategies of the Thai government (from the answers of Research Question One) which were used to address the challenges and barriers (from the answers of Research Question Two). Moreover, Eriksson and Kovalainen (2015) say that critical research in business involves many perspectives of the organizations, management and firms, and their different functions

because of financial and organisational problems or politics implemented and present in business practices and procedures. Thus, the research focused on every function (such as accounting, marketing, technology, financial and political decisions) of the Thai government and other co-operating organisations in the National Roadmap (Such as PTT and NIA (National Innovation Agency)).

## **2.2 Selection of data**

Two methods were used in the research in selecting the secondary data: key words and sub topics (Topics of interest).

**Keyword** searches were used because they could involve a search for “control preference scale or control preferences scale” as phrases in titles or abstracts (Linder & el at. 2015, p. 413), while key words focused on what was essential in a topic. They were a word (or phrase) capturing the object of the research and were recognized and accepted by a database or search engine (Bell & Waters, 2014). Keyword searches that were used for Research Question One were words (such as ‘bio-plastic hub’, ‘the strategies of bio-plastic hub’ and ‘plastic development in Thailand’). These words were used to access the primary data based on relevant studies, reports, articles, website and other relevant sources in order to develop a comprehensive record of the idea. The key words of research Question Two were ‘bio-plastic hub’, ‘the challenges/and the barriers of bio-plastic hub’ and ‘bio-plastic hub in Thailand’. All these key words were used to access the secondary data based on relevant studies, reports, articles, website and other relevant sources in order to develop a comprehensive record of the idea (See Table1).

**Table 1: Keyword for selection data**

Keywords	
Question1	Outcome
<b>The National Roadmap</b>	National Science and Technology Development Agency (2008c). Strategic plans and budgets. <i>The National Plan Bioplastics Industry Development (BE 2551-2555): The policy of economic restructuring in the industry for the future (New Wave Industries)</i> , 46-63
<b>Development bio-plastic industry</b>	National Innovation Agency (2008d). Strategy, Action Plans & Budget. <i>National Roadmap for the Development of Bioplastics Industry (2008 – 2012)</i> , 24, 25-42.
<b>bio-plastic hub</b>	Kihirun, M., & Chongcome, W. (2010). <i>Conclusion the important points. Paper presented at International symposium and exhibition about InnoBioPlast 2010: Creating Global Market Opportunities through Thailand's Bioplastics Hub, Bangkok, Thailand</i> . Retrieved from <a href="http://www.nia.or.th/bioplastics/download/events/40.pdf">http://www.nia.or.th/bioplastics/download/events/40.pdf</a>  National Innovation Agency (2010d). On urgent measures to encourage investment in the industry 18 bioplastics in Thailand (2554-2558). <i>Map navigation National Development of Turkish industrial bioplastics Phase 2 (year 2554-2558)</i> . 18-23
<b>Bio-plastic Industry</b>	Weerathaworn, P. (2013a). Trend of bioplastic Industry in Thailand. <i>Plastic foresight</i> , 8(2), 12-20
Question2	Outcome
<b>The disadvantage of bio-plastic</b>	The Institute for the Promotion of Teaching Science and Technology (2011). <i>Bio-plastic</i> . Retrieved from <a href="http://biology.ipst.ac.th/?p=927">http://biology.ipst.ac.th/?p=927</a>
<b>Degradable bio-plastic</b>	Maheshwari, R., B. R., PARIHAR, S., & SHARMA, A. (2013). Eco-friendly Bioplastic for Uncontaminated Environment. <i>Research Journal of Chemical and Environmental Sciences</i> , 1(1), 44-49.
<b>The bio-plastic challenges</b>	National Innovation Agency (2010a). <i>National Legislative Assembly co-operates with TBIA delivery bag Sprout sun-resistant bioplastic one year gag Minister of Forestry created new challenges in the field of bioplastics Thailand</i> . Retrieved from <a href="http://nia.or.th/pr/images/8/2010tree/Press%20release.pdf">http://nia.or.th/pr/images/8/2010tree/Press%20release.pdf</a>
<b>The challenges of bio-products</b>	Mohanty, A. K., Misra, M., & Drzal, L. T. (2002). Sustainable bio-composites from renewable resources: Opportunities and challenges in the green materials world. <i>Journal of Polymers and the Environment</i> , 10(1-2), 19-26. doi: <a href="http://dx.doi.org/10.1023/A:1021013921916">http://dx.doi.org/10.1023/A:1021013921916</a>

Table1: This table used examples of selection data via key words for finding out the outcome of the research questions, and it showed the key words for finding ideas to both research questions.

The sub-topics or topics of interest that were used for the first research question were: the strategy of the National Roadmap; how it was progressing other countries' strategies on bio-plastic production- improvement. Also, the selection of data was guided by three sub-topics for the second research question: the challenges and opportunities likely to be confronted in the project; sustainable enterprises generally (but I focused on the enterprises which aimed at plastic development); and other alternatives to plastic. The table below shows the example of outcomes that were found by using sub-topics and topics of interest (See Table2).

**Table 2: Sub-topics /or topics of interest**

Sub-topics or Topics of interest	
Question1	Outcome
<b>The amount of Tapioca export including prices in Thailand</b>	The Thai Tapioca Development Institute (2016). <i>Tapioca Starch (Super High-Grade) Export Price</i> . Retrieved from <a href="http://www.tapiocathai.org/Graph/starch%20export%20price.pdf">http://www.tapiocathai.org/Graph/starch%20export%20price.pdf</a>
<b>Forces driving Thailand to become a bio-plastic industry hub</b>	Ministry of Industry (2016a). <i>Plastics Industry Corp holds a strategic plan to strengthen the Thailand 4.0 accelerates strengthen entrepreneurial development through research. Leverage Products Hope is the central driving force Thailand's plastic industry in the region</i> . Retrieved from <a href="http://www.industry.go.th/center_mng/index.php/2016-04-24-18-06-24/2016-04-24-18-07-10/item/9355-4-0">http://www.industry.go.th/center_mng/index.php/2016-04-24-18-06-24/2016-04-24-18-07-10/item/9355-4-0</a>
<b>Thai government pushing Thailand to be bio-plastic hub</b>	Ministry of Industry (2016b). <i>"Atchaka" reiterated Thailand is a hub for industrial biotechnology. State will push to get the world</i> . Retrieved from <a href="http://www.industry.go.th/center_mng/index.php/2016-04-24-18-06-24/2016-04-24-18-06-46/item/8633-2016-08-03-05-34-30">http://www.industry.go.th/center_mng/index.php/2016-04-24-18-06-24/2016-04-24-18-06-46/item/8633-2016-08-03-05-34-30</a>
<b>Bio-plastic Market and technology in Thailand</b>	Rodtong, S., Deepasearchkung, J. & Phriktavisak, N. (2013). <i>The data of technology</i> . Paper presented at the result of technology and market trends including analysis of technology for linking research. conference and exhibitions. <i>Conference and Exhibition on Bioplastics Levels Kebab International InnoBioPlast 2013</i> , Bangkok, Thailand. Retrieved from <a href="http://www.nia.or.th/innobioplast2013/download/Report.pdf">http://www.nia.or.th/innobioplast2013/download/Report.pdf</a>
Question2	Outcome
<b>How companies manage/ invest/ create green products</b>	Dangelico, R., & Pujari, D. (2010). Mainstreaming Green Product Innovation: Why and How Companies Integrate Environmental Sustainability. <i>Journal of Business Ethics</i> , 95(3), 471-486. doi:10.1007/s10551-010-0434-0

<b>Case study about bio-plastic development</b>	Pattayakosal, P. (2010). Bioplastic industry. <i>The Approach to Develop Bioplastic Industry Following National Roadmap: Case Study of Bioplastic Industry</i> . 26-109
<b>Analysis of technology and marketing for bio-plastic industries</b>	Rodtong, S., Deepasearchkung, J. & Phriktavisak, N. (2013). <i>The data of technology</i> . Paper presented at the result of technology and market trends including analysis of technology for linking research. conference and exhibitions. <i>Conference and Exhibition on Bioplastics Levels Kebab International InnoBioPlast 2013</i> , Bangkok, Thailand. Retrieved from <a href="http://www.nia.or.th/innobioplast2013/download/Report.pdf">http://www.nia.or.th/innobioplast2013/download/Report.pdf</a>
<b>The barriers of bio-plastic technology development/ management</b>	Theinsathid, P., Chandrachai, A., & Keeratipibul, S. (2009). Managing bioplastics business innovation in startup phase. <i>Journal of technology management &amp; innovation</i> , 4(1), 82-93.

Table 2: This table is to show the sup-topic and its outcomes for the research questions.

## 2.3 Analysis of data

### 2.3.1. Research Question One

**Critical analysis** was used to find answers for this research question because this research made a critical summary of books, reports, research and review articles to find the concept which related to the answer of this research question, and it also “examined the methodology, accuracy, and relevance of the research” (Sweeny & Hooker, 2005). In the case of my research it addressed, “What the Thai government was currently planning to do and had done to address any challenges and barriers at establishing Thai plastic industry as a bio-plastic hub”. Moreover, this research question suggested a qualitative study. Techniques and procedures for analysing qualitative data include a close reading of a text, becoming immersed in the data, reading and re-reading a text, taking notes, reflecting on the data and writing down interpretations” (Marelli, n.d.). Then I summarised and interpreted what was being said and the authors’ interests in the data, in order to find out the big picture of the study.

The collection of this research had to be from the government sources as stated in the National Innovation Agency (2010d), the Agency (2008c), the Ministry of Industry (2016a), the National Innovation Agency (2008d), the National Innovation Agency (2010c) National Innovation Agency (n.d.b), Ministry of Industry (2016b) and National Science and Technology Development (2008c). This was because they had researched, analysed and summarised the strategies of the National Roadmap, and the research also gathered the interested and related ideas from each piece of research and bringing them together to see the big picture of strategies. The overall strategies were in the form of three phases (see in Chapter 4).

The analysis in Chapter 6 started by considering strategies in three phases that the government agencies had considered to find out the main purpose of each strategies which were the same or similar to one another. For example, in Phase One, the first strategy was the readiness of biomass raw materials, and its aim was the same as the commercial support for increasing the availability of biomass feedstock. In the last strategy in Phase Two. Next, analysis moved to building the structure of National Roadmap's strategies by identifying all the main purposes of the National Roadmap's strategies. The structure was divided into five development areas: Bio-plastic development, Technology co-operation, Economic co-operation, Knowledge/ innovation and Knowledge/ innovation. Importantly, the research informed with factual material to support that main ideas (See in Chapter 6 on the National Roadmap's strategies).

### **2.3.2. Research Question Two**

**Thematic analysis**, which was used to analyse this data, is a method of understanding the data by discovering and analysing patterns within the qualitative data (Gray, 2014; Braun & Clarke, 2006). Here crucial questions to address in the coding process were the identity and then the size of the theme: it was to build an understanding of familiarity with the data which is

collected, and then to build coding in data sets which were significant, interesting and relevant to this research.

The next step was that the coding had to be collated under the heading of possible themes while gathering all relevant data for each potential theme in order to ensure that the themes connected to the coded extracts; and to investigate, by means of refining the specifics of each theme and, if necessary, providing clear titles and definitions for every theme before a final analysis was made of extracts relevant to the research question. These had to be selected in order for a “scholarly report of the analysis” to be achieved (Braun & Clarke, 2006).

In the research, I used this method of analysis to code the thematic data which could reveal the challenges that the Thai government was likely to face in pushing the Thai industry as a bio-plastic hub. Importantly, the methodology of this research question was the critical research approach which was related to management, business and business-related questions, without, however, adopting a managerial point of view (Eriksson& Kovalainen, 2015).

The management of findings to Research Question Two. There were 23 main references which were used to create themes to answer the research question. This finding divided the ideas into two themes - the problems associated with bio-plastic; and Thai Initiative: challenges and barriers. This was because the research needed to consider together the general issue as well as Thai challenges and barriers by separating them into two themes (See Tables5 and 6 on chapter 4). Then, this research used all the ideas again find out the possible challenges and barriers which the government would be likely to face to when it operanted the National Roadmap. Thus, in Chapter 6 (Discussion and Analysis), the research question was summed up in the form of two

themes. However, those themes differed from the themes in Table 7 on Chapter 6.3. The next table below represents a process analysis of Research Question Two.

After the research designed the themes of strategies and listed the challenges/and barriers involved, it moved to the next step which was analysing exactly how possible strategies could cope with the challenges and barriers of both infrastructure management and the environmental performance themes. The research checked if the strategies were compatible with the challenges and barriers. Then, the research summarised the main ideas in order to design a theme that incorporated challenges and barriers into the strategies. All results are discussed at length in Chapter 6.5 (See Table 8). For example: Accelerating both co-operation and the development of technology is addressing infrastructure management. The first strategy in Phase Two, that is, the part of technology co-operation in development, aims to develop the quality of bio-plastic. Bio-PBS also can produce a large quality of its biodegradable bio-plastic which can be sealed with heat (Rodtong., Deepasearchkung, & Phriktavisak, 2013; Iles & Martin, 2013; Lagaron & Lopez-Rubio, 2011).

### **2.3.3. Sustainable Strategies Management**

The research analysed how the strategies of the National Roadmap are ‘Sustainable Strategies Management’ by using Theoretical Propositions Analysis. It provided an explanation of the National Roadmap’s operation and its strategies, including how the strategies relate to sustainable management by comparing with a theory (Graue, 2015). Firstly, this research analysed the targeted developments of the National Roadmap, including the areas (the environment, economy/technology and society) which National Roadmap’s operation will impact (Plastic Institute of Thailand, 2013a). Then, the research compared the result of the first step to a possible



theory namely the 'Triple Bottom Line'. This is because the Triple Bottom Line is a sustainable management system which aims at the entire society, economy and the environment (Hitchcock & Willard, 2015).

This research, to summarise, chose to collect data from government and non-government sources, and key words and sub-topics were used as main choices for searching related researches and articles with the research questions. Moreover, the analysis of this research is divided into two methods. Firstly, 'Critical Analysis' was used to find the answers for the first question while 'Thematic Analysis' was used for the Second research-question. However, before this research moves to find answers to these research questions'. It presents a literature review which is necessary for a better understanding of this research for readers because it is a comprehensive collection of related research.

## **Chapter 3**

### **Literature Review**

Brayman and Bell (2007) mention that the majority of business research-questions start with an individual interested in the same area as the research for this dissertation. These research questions are based on an existing knowledge of worldwide plastic problems (especially in Thailand) and on initiatives to develop alternatives to plastics. The study seeks to fill gaps in existing knowledge and to investigate initiatives that represent “new developments in society” (Brayman & Bell, 2007, p.85). Thus, this chapter involves a deep probe of supporting information, which can lead the reader to clearly understand the background and factors of this research and of the answers to the research questions’ answers in Chapters 4 and 5, via related researches and articles. This Chapter has six information topics: Problem, Potential Solution, The properties of Bio-plastic, Bio-plastic Market, Worldwide bio-plastic solution, Thai Initiative: a description of design and strategy.

### **3.1 Problem**

#### **3.1.1 Worldwide Plastic Pollution**

“Plastics are lightweight, strong, durable and cheap”, and these features make them very convenient choices for a wide range of manufactured products (Derraik, 2002). These same properties, however, are the reason that plastics are an environmental hazard. Plastics biodegrade very slowly because contemporary plastics are synthesised using non-renewable fossil fuel resources (Özkan & et al., 2015). In addition, the amount of plastic waste is continually increasing because 50 percent of the plastic is used just once

and then thrown away, and only five percent of the plastic that is produced can be recovered (Alessandro, 2014).

Plastic has been shown to cause five major environmental problems: plastic wastes block gutters and drains, creating serious storm water problems (Butu, Ageda & Bichi, 2013; Mangizvo, 2012; Njeru, 2006); it chokes and starves wildlife and marine species, plastic debris poses a great threat to the survival of these species (Barnes & et al., 2009; Derraik, 2002; Gregory, 2009; Njeru, 2006); plastic bags are non-biodegradable, and, if burned, plastic bags release toxins like furan and dioxin gases, as well as leaving unhealthy residues among which are lead and cadmium (Njeru, 2006). According to Gregory (2009), non-biodegradable materials have become a recent phenomenon (known as “marine debris”) plastic bags improperly disposed of have been linked to the spread of malaria because they become breeding sites for mosquitoes (Mangizvo, 2012; Mudzengerere & Chigwenya, 2012; Njeru, 2006).

### **3.1.2 Plastic pollution in Thailand**

Thailand also faces plastic pollution in its environment. In Thailand, fourteen percent of municipal solid waste (MSW) generated derives from plastics (Nkwachukwu & el at., 2013). Yangtheen (2015) refers to a recent comment by DownPong Ratanasuwan (the Minister of Natural Resources and Environment in Thailand) that recently (until 2015), the amount of waste plastic and foam increased by about 2.7 million tonnes per year, (or an average of 7,000 tonnes per day), 80 percent of which was comprised of plastic bags. The rest is rubbish, which is comprised of approximately 700,000 tonnes of non-biodegradable foam that will take up to 450 years to degrade.

Styrofoam is non-biodegradable and requires 400-500 years to degrade (Kaplan, 2013; Yangtheen, 2015).

Moreover, plastic and its foam waste cause problems in city sewers. Clogging occurs because of bad drainage, and flooding is always expected when debris is trapped by heavy rain. The dumping of solid wastes into canals and rivers is causing waste plastic to float everywhere. Marine waste plastic and foam affect beaches first and are also destroying the environment. Fish in the sea have also been found eating plastic bags which harm their digestive systems, and they may eventually die (Pollution Control Department, 2005). Plastic also affects people's health if it is processed into packaging because, when the polystyrene foam is applied to food packaging, a heat reaction causes a hazardous breakout of foam containers, as well as the substances styrene and benzene, which, in turn, causes the destruction of bone-marrow, liver, and kidney and also affects nerves (Member of the National Assembly, 2014; Suriwong, 2015).

### **3.1.3 The causes of plastic pollution in Thailand**

The root causes for plastic-pollution becoming a major social problem according to the Pollution Control Department (2005) are threefold: the design system, the consumers, and management of waste following consumption.

The design system of plastic production is one cause of plastic-pollution because manufacturers do not identify the types of plastics (such as Polyvinyl Chlor (PVC), Polylactide (PLA) and Polypropylene (PP)) which are used for producing their products or packaging; nor do they show a recycle symbol on the products' tickets; moreover, the

materials of plastic are non-degradable and non-recyclable. For example, on the one hand, the materials prefer plastic products that are produced from Thermosetting which cannot be recycled (Pollution Control Department, 2005); on the other hand, Thermoplastics (such as Polyethylene Terephthalate, Polypropylene and Polystyrene) can be recycled many times (Ryedale District Council, n.d). This is because there is not any law that forces manufacturers to act with the environment in mind (Niummani, 2011; Pintong & et al., 2004; Pollution Control Department, 2005; Siraphatthada, 2015). Also, the manufacturers lack research and development (R&D) into renewable materials (Pollution Control Department, 2005), and the costs of degradable plastic product and research and development are still high (Dangelico & Pujari, 2010).

Consumers are unaware of the importance of pollution on the environment, so they are uninterested in plastic waste solutions; in addition, consumers lack education about a plastic solution (Pattayakosal, 2010). Moreover, there is the consumers' lack of knowledge about recycling and separating waste types. For example, the majority of them do not know foam can be recycled (Pollution Control Department, 2005; Tanasittisawat & Duangchinda, 2016); moreover, most consumers use plastic products that are only single use, such as food packaging, so they do not re-use plastic even if it can be used again (Pollution Control Department, 2005). Thailand does not have a law that controls people so that they separate waste types, and they also do not realize they are able to separate waste types (Control Department, 2005; Pintong & et al., 2004; Pollution). Thus, it leads to difficult collection waste for recycling.

Lastly, it is not just a consumer lack of knowledge about recycling but the existing recycle system in Thailand is not seriously used. This is because in Thailand, there are few places of garbage collection where garbage can be recycled in the community (Pollution Control Department, 2005). Moreover, plastic and foam can be disposed of in special incinerators (that do not cause dioxins which in turn lead to air pollution and affect the health of all living things) (Pollution Control Department, 2005). However, the cost is expensive. Thus, landfill is an attractive choice for authorities because the cost of landfill is cheaper. However, damaging dioxins are often formed that are a health hazard to communities if the waste from plastics is burned incorrectly; the major environmental effect occurs in the soil and the water since the residue remains in the environment because plastic bags are made from petroleum resins (Pollution Control Department, 2005). The contaminated soil and water are sometimes environmentally problematic and sometimes cause greenhouse gases and our current global warming (Maruean & et al, 2013; National News Bureau of Thailand, 2015; Office of Natural Resources and Environmental Policy and Planning, 2012; Pollution Control Department, 2005).

## **3.2 Potential Solution**

### **3.2.1 Plastic solution**

A method of responding to environmental problems associated with the sustainability of resources has been presented by Barr, Gilg and Ford (2001). They discuss the three Rs 'Reduction, Re-use, and Recycling which as key behaviours in understanding how to solve problems connected to municipal waste. The 3Rs are presented as a hierarchy of options in descending order. Particular local circumstances and different political strategies mean that different countries face different constraints

in implementing the three Rs (Sakai, et al., 2011). Consequently, this research will show examples of strategies that governments around the world use for the reduction, re-use and recycling of plastic waste.

Reduction involves decreased use, and also a decrease in the amount of material used in products or goods. It is the first option and best solution for the plastic problem. This is because no investment is needed for this solution, and it leads to minimizing resources and energy use, along with necessitating a change in consumers' attitudes and behaviours. However, reduction behaviour is the least used of the hierarchy of options and by the smallest number of people, compared to re-use and recycling (Barr, Gilg & Ford, 2001). Thus, people need to know how helpful reduction can be and be aware of its importance for the protection of the environment; moreover, manufacturers too have to avoid packing products or goods in plastic. Many countries (such as Germany, United Kingdom (UK) and New Zealand) have begun to reduce the amount of plastic utilised.

Germany has the support of significant influential organisations like Duales System Deutschland (DSD) which monitors the 'Green Dot' system, part of which involves payment by companies which release packaging products onto the market (Barker & Safford, 2009). It is the pioneer and market leader in take-back recycling systems, and it is a public-private organisation (United Nations Environment Programme. Division of Technology, Industry and Economics, 2005). Since 2005, significantly, the German Packaging Ordinance (GPO) has made fee-free 'Green Dot', for those companies which contribute to the German waste disposal infrastructure (Barker & Safford, 2009). In New Zealand, a charge on plastic bags was suggested by the successful Auckland mayoral candidate, Phil Goff. He gained by the suggestion since

many voters like using supermarket bags as bin liners. Even so, at ten cents a bag, the bin liners would be cheaper than the conventional ones. Goff was not opposed to lining bins but believed the plastic liners should not be free (Calder, 2016).

If reduction cannot be done well and receives scant attention from people, re-use is the next option in the plastic solution because it also can help to reduce the amount of plastic use because it uses less energy and fewer resources. It is the second method for handling products with a plastic composition (Ngoc & Schnitzer, 2009). However, people still use plastic, and they do not avoid using it. An important document, entitled 'Packaging Essential Requirements' has been produced in the UK, which is one of many states aware of the importance of re-use in plastic reduction. The document supports people's education in re-use as a solution to the plastic problem (Barker & Safford, 2009).

Nevertheless, different social groups and different locations mean that the outcome of the regulation also varies (He, 2010). Japan, with its measures like waste avoidance and enhancement of production life in the chain from product of service, also promotes the sustainable management of production and consumption systems. Its final aim is, by promoting the re-use of products, to secure an integrated management of End-of-life (EOL) resources (Yabar & et al., 2009). The obvious environmental benefit of re-use is in four products: Book, Car, Auto-parts and LC panel. All will be discarded and new products made to meet the demands of the market. In Japan, Bookoff (a second-hand book market), is the publishing market has been estimated to make up seven percent of the entire publishing market in 2001, and in 2007, the market was as high as 30 percent (Matsumoto, 2009).



It is not only reducing and reusing strategies in a plastics-based packaging system that substantially reduce the quantity of waste to landfill, but also recycling which can reduce the overall burden on the environment (Ross & Evans, 2003). However, recycling is the last option of the three Rs because, if we reduce the amount of plastic used, there will be less plastic needing to be recycled and also, it can reduce the additional cost of collecting the used packaging. Moreover, investing in recycling technology can be offset if the packaging is re-used several times before recycling (Ross & Evans, 2003). However, not all plastic products can be recycled since some of them have to be landfilled. The behaviour of recycling differs from the other methods because the majority of people are divided into two groups: those who 'always' or those who 'never' recycle; moreover, in comparison to reduction and re-use, recycling activity produces essentially logistical predictors. Key components are: the existence of a structured kerbside facility for recycling; widespread knowledge of that facility and understanding in the community that recycling is easy and convenient (Barr, Gilg & Ford, 2001).

Nevertheless, recycling grows the economy and labour opportunities of Thailand because it possesses at a good system of waste logistics. The research of Klaus Bellmann and Anshuman Khare (1999) points to regulations by the European Commission which establish percentage targets on the re-use and recycling of cars before 2015. The German car industry agreed to recycle or re-use (at cost) end-of-life vehicles more than twelve years old, provided that the vehicle was intended for the German market or was used in Germany for at least six months. The vehicle also had to meet certain technical requirements stipulated by the car industry.

### **3.2.2 Plastic solution in Thailand**

Replacement is another solution for plastic pollution which involves changing to the use of new products, such as bio-plastic, to replace the use of traditional plastic. According to Clara Rosalía Álvarez-Chávez, Sally Edwards, Rafael Moure-Eraso and Kenneth Geiser (2012), bio-plastic is any biodegradable plastic which can improve health and environmental outcomes because fewer fossil fuels will be used. On the other hand, even bio-plastics impact on the environment and on the health of the population at some stage of their cycle. There is still a need for more research into precisely these shadowy areas if the issue of sustainability of bio-plastics is to be addressed. At present, however, it seems that bio-plastic are more environmentally friendly than those plastics derived from petroleum both in their source and their biodegradability.

The Thai government is focusing on the design system to replace the traditional solution. Thailand focuses on new products like bio-plastic that can replace traditional plastic because bio-plastic is one of the environmentally-friendly products that constitutes a novelty. This focus is partly to solve the growing environmental threat, but also is seen as the answer to the problem posed by an uncertain petroleum supply. However, there is a caveat since the biodegradable quality of resource-based bioplastic depends on the specific demands of a given application (Mohanty, Misra & Drzal, 2002).

At present, it is the focus of worldwide attention because green products have been developed that, employing innovative product design, appear to be a novel and sustainable tool for solving current environmental problems since they have had significant attention from consumers, industries and governments around the world (Chen, 2001). Moreover, using bio-materials seems to be a popular solution but not the

most sustainable for plastic pollution because replacement does not change people's behaviour in reducing their use of plastic products, and the method also makes more resources and increases energy use. Nevertheless, a focus on a new product leave aside any problems based on consumer behaviour (such as unnecessary consumption, and inappropriate disposal) and any issues with the processes in place for post-consumer waste management.

This research finds that sustainable management for plastic waste has many methods such as reduction, re-use, recycling and replacing. The Thai government does not choose reduction, re-use and recycling; it chooses instead to focus on plastic being replaced by bio-plastic—though not to the extent of reducing plastic use. This is because, all reduction, reuse, recycle and replacing need to invest in legislation, regulation and education for supporting people to know 1) how to separate the types of waste for recycling; and 2) to become aware of plastic pollution as well as 3) to change the overall behaviour of plastic use for reduction, reuse and replacing. Moreover, the government has to provide an infrastructure which will manage waste collection and sorting for renewable recourses and/or recycling.

However, the effects of reduction, re-use and recycling are in the environmental and economic areas by using fewer resources and reducing payment and waste management, while replacing can impact the environment through environmentally friendly-products which can also improve the economy by increasing the value of exported agricultural products, as well as improving lives, by a social goal of reducing income inequality (National Science and Technology Development Agency, 2008a).

This is because bio-plastic is by agricultural material produced from products such as rice, sugar cane, cassava, cellulose, wheat and oil palm (National Innovation Agency, 2008a; National Science and Technology Development Agency, 2008b; Suwanna, 2014; Weerathaworn, 2013a), and Thailand is a country that has always exported those agricultural products without processing or producing a value product higher. Thus, if those agricultural products can be processed to bio-plastic, Thailand will have a new market line in agricultural products, and the value of agricultural products will increase as well. Furthermore, bio-degradable polymers are a step in the right direction but are certainly not a one stop solution to all environmental problems. Current views in society on environmental responsibility make it the perfect moment to promote polymers (Reddy, Reddy & Gupta, 2013).

It is not only the Thai government which has been aiming at bio-plastic development, but in the past 30 years, environmental standards imposed by governments around the world have also acted as a stimulus to 'green' product development (Chen, 2001). In Thailand, the government has completed a project called the National Roadmap in Phases One and Two whose main purpose is to solve the problem of plastic pollution and to support the establishment of Thailand as a bio-plastic industry hub (Weerathaworn, 2013a). To better understand the choices the Thai government has made to address the barriers and obstacles facing the bio-plastic project, this research will explain the three phases of management of this project through using the main four strategies: readiness of biomass raw materials; accelerating technological development and technological co-operation strategy; the creation of industry and innovation; and the establishment of a supportive infrastructure (Kihirun & Chongcome, 2010; Organisation

for Economic Co-operation and Development, 2013; Pattayakosal, 2010; Weerathaworn, 2013a).

### **3.2.3 The expected effect of the National Roadmap**

According to the Plastic Institute of Thailand (2013a), the main object of the National Roadmap is to reduce the amount of plastic waste because the ever-increasing population causes the amount of waste to grow annually. Every year plastic garbage collection will increase by two million tonnes. Moreover, numerous studies have found that carbon dioxide emissions, caused by plastic production and waste (as well as the lifetime of the product) is less than for petroleum-based plastics. Therefore, the Thai government hopes that bio-plastic will meet the government promise to reduce global warming, and the Thai government also wants to modify consumption behaviour by turning its attention to more environmentally friendly products and to lessen Thai dependence on oil. Importantly, the Thai government project will be the main impetus of adding value to Thai agricultural products. The Thai government chooses to develop bio-plastic because its project also affects three areas; namely the environment, economy/technology and society (Plastic Institute of Thailand, 2013a).

The Thai government and its corporations expect to reduce harm to the environment by transformation to a bio-plastic industry. This is because the government claims that bioplastic is a new environmentally-friendly product and it wants to ensure the effective management of waste solutions (National Innovation Agency, 2015a; National Innovation Agency & Thai Bioplastic Industry Association, 2011). Monnata Kihirun (2010) analyses bioplastics as an innovative material made from renewable plant

materials, and the biological properties of the break up. (Biodegradable) into organic matter which will not be toxic to plants. All solutions need to ensure the development of these and also their impact on the environment.

Proponents of bio-plastic claim 100 percent biodegradability and its capacity to be recycled and re-used (even burned) without any apparent toxic by-products. Moreover, it is sourced from natural and renewable resources. All these qualities indicate bio-plastics are an excellent alternative to the traditional plastics of the last 50 years (Reddy, Reddy & Gupta, 2013). However, several factors operate to determine the speed of biodegradability of the biocompatible plastics. Some of the external factors are temperature, humidity, or the amounts of soil and water. An important factor also, in affecting the rate of degradation of bioplastic is the bio-molecular weight of the polyethylene which varies according to the different polymers. All the same, bioplastic always degrades much faster than synthetic plastic which may take as long as hundreds of years (Bunme, n.d.).

In addition, bio-plastic can improve the economy because this government's project will lead to bio-plastic-monomer development and the development of a prototype for the production of resins, plastics, and poly lactic acid (PLA). The latter is obtained as the result of polymerization of lactic acids which have been derived from fermenting the microbes in corn starch or cane sugar (Chávez & et al., 2012). The development will be on an increasingly commercial scale as plastic production rose to 100,000 tonnes in 2013, and it will continue to grow in Thailand. Consequently, in 2015, investment in the plastic industry was 10,000 million baht (\$ 400 million NZD).

Thus, it has had an effect on the rising number of bioplastic manufacturing plants which have appeared in the bioplastics industry and related businesses, leading to about 200,000 million baht (\$ 8 billion NZD) of revenue and 6,260 million baht (\$ 250 million NZD) in tax revenue to the Thai government (National Innovation Agency, n.d.a; National Innovation Agency & Thai Bioplastic Industry Association, 2011). However, an increased demand for food and resources will occur. The production of raw materials for biofuels will also require a large agricultural area which will be divided between the production of food and of raw materials used in the production of biofuels. (Sanglimsuwon, 2011). The Thai government has designed a strategy such as “the readiness of biomass raw materials which is designed to support and increase crop yield”, in order to protect people from increasing food prices and demands in the future (National Innovation Agency, 2008d).

Overall, the National Roadmap focuses more on economic than on environmental development by means of increasing technology’s ability to improve the eventual amount of bio-plastic although it is a new environmentally-friendly product. From the expectations arising from the National Roadmap, the Thai government aims at increasing the value of agricultural products which are the main export-products in Thailand. It will raise the price of agricultural products from Thailand for exporting to other countries.

Furthermore, since bio-plastic will give Thai farmers more valuable end-markets in which to sell their products, it will achieve a social goal of reducing income inequality (Permanent Mission of Thailand, 2015). This is because In Thailand, there are 2.879 million poor agricultural households, and research in 2006 found that 69 per cent of agricultural households have an average debt of 42,314 baht per household or 10,003 baht per person (Office of Agricultural Economics & Ministry of Agriculture and Co-

operatives, 2006). If there is an increase in the price of agricultural products, people may face higher costs for living food. Therefore, the Thai government should ensure that improved incomes will be sufficient for coping with the costs of food which may increase, and further increasing inequality in incomes.

Nevertheless, the Thai government expects that there are four population groups which will benefit both directly and indirectly. These include cane and cassava growers, the producers of sugar and cassava starch, the plastic industry and student groups and researchers. The development of technology in Thailand is another expectation in these projects. Specifically, these will include the development of new knowledge, research and growth in the number of development researchers. Importantly, the project can build a bioplastic technology that will create progress for Thailand in the same class as international competitors. Intellectual property in the form of patents will result from the development of the technologies following the pilot plant (National Innovation Agency, n.d.a.; National Innovation Agency & Thai Bioplastic Industry Association, 2011).

### **3.2.4 Thailand's readiness to become a bio-plastic hub**

Thailand's readiness to become a bio-plastic hub lies in two areas; namely, internal readiness and external readiness. There are four main internal-strengths contributing to Thailand's becoming a bio-plastic hub. Firstly, abundant raw materials constitute a major comparative advantage in the production of bulk commodities such as rice, sugar cane, cassava, cellulose, wheat and oil palm, because Thailand is an agricultural country (National Innovation Agency, 2008a; National Science and Technology Development Agency, 2008b; Suwanna, 2014; Weerathaworn, 2013a), and it is the biggest cassava and



second biggest sugar exporter in the world (Thailand Board of Investment, 2014). In addition, there are many organisations such as National Innovation Agency and the National Science and Technology Development Agency who claim that Thailand, with its full-cycle mature plant plastic industry already possesses the potential to be a world leader. The Thai government's policy and its support measures directly cause an impetus in the bioplastics industry (National Innovation Agency, 2008b; National Science and Technology Development Agency, 2008b, Suwanna, 2014; Weerathaworn, 2013a).

However, Thailand still needs improvement in its agricultural-efficiency compared with bio-plastic production because Thai efficiency as a producer of rice, sugar cane, cassava, cellulose, wheat and oil palm, is still lower than its other competitors, and Thailand worries that, if plastic manufacturers move to use bio-material, the material will be insufficient in the future. For example, in terms of rice plants, Indonesia has the biggest area for harvesting rice among Asian countries - 85 million hectares, followed by Thailand, with 80 million hectares (Asian New Centre & Public Relations Department, 2015). Moreover, Indonesia was able to produce 33.4 million tonnes of palm oil in 2015 (which is the best result in the world), but Thailand produced only 1.8 million tonnes of palm oil in that year (Green Palm, 2016). Furthermore, Brazil tops the list of sugarcane producers, with an annual production of 739,300 thousand metric tonnes per year, while Thailand is second among sugarcane producers with 100,100 thousand per year. Also, China is the third in this area (Worldatlas, 2016), and it is expanding as it cooperates in agriculture with Vietnam to boost its sugarcane production (Songsakskul, 2010) because of the price of sugar on world markets (Phechhlaysi, 2010).

### **3.3 The properties of Bio-plastic**

During the last ten years, there has been a growing call for solutions that will move the country towards becoming a society whose production is based on environmentally responsible materials (Karana, 2012). Natural materials, mainly plant-based such as cellulose, collagen, casein, polyester, starch and beans (soy protein), are used in the production of bio-plastic (Institute for the Promotion of Teaching Science and Technology, 2014). Elvin Karana (2012) (Associate Professor of Emerging Materials, Design Engineering at Delft University of Technology) mentions all these sources are plentiful and cheap; moreover, this concept has initial appeal because of increased attention on and demand for bio-plastic.

However, the prices of the source materials will also increase because powder can be produced from plant likes corn, cassava, wheat, potatoes and sweet potatoes. She also says that bioplastics are considered among the most promising renewable source materials of all to replace commodity plastics (e.g. PLA). The reason this powder is commonly used in the production of bio-plastics is that it is natural, readily available, cheap and plentiful, since it is produced from plants which grow easily in Thailand. The most popular plants in Thailand used to produce bio-plastic are corn and cassava because of their abundance and their low cost (Institute for the Promotion of Teaching Science and Technology, 2014). Based on the material, bioplastics can take different lengths of time and higher composting temperatures can be reached within sixty-per cent of 90-180 days. Biodegradation should occur within 180 days as required by most international standards (Dituro & et al., 2010).

Table 3 (which provides an overview of bioplastics), highlights several differences of bio-plastic in the current classification (National Innovation Agency, 2008c). Apart from Poly Trimethylene Terephthalate, all plastics in the table are derived from renewable materials. Some of these, like starch plastic, cellulose polymer and PLA, have a commercial application (Chiarakorn, Permpoonwiwat, & Nanthachatchavankul, 2014). Furthermore, the future production of bio-based polymers will have a close link with agriculture and the production of renewable resources. In processes, such as steam and electricity production from bagasse, co-generation of bioenergy will still play an important part. In Thailand, it has been noted that popular plants used as raw materials in the production of bioplastics are corn and cassava because the crops are abundant and cheap (Institute for the Promotion of Teaching Science and Technology, 2014).

In addition, Srinivasan and Lu (2014) mention that numerous research initiatives in the area of bio-plastics have been triggered by the high degree of pollution caused by conventional plastics such as the introduction of Bio-based High-Density Poly Ethylene (HDPE). The latter are the most popular bio-plastics used in today's Fast-Moving Consumer Goods industry (FMCG) which, in turn, are a significant part of personal budgets in all countries. Both consumers and policy-makers have been strongly attracted to retail trade in these products since, if these essential products, are to be produced at high quality and low cost, a well-functioning retail sector is essential if they are to be provided daily to households (Erdoğan & Taymaz, 2005).

Moreover, synthetic polymers are another material for plastic design as bio-plastic to help the environment. According to Moore (2008); they are a solution to the problem of synthetic polymers and the plastic debris which resides in them as the others can occur

in nature and are biodegradable. Many of them are not sourced from petroleum and include products cellulose-based on cellophane and rayon, in addition to acid the more recent modern polylactic acid (PLA) and polyhydroxyalkanoate (PHA). Both of the latter are the result of fermentation processes (Moore, 2008). Worldwide, governments now pay attention to the design system of plastic production which leads to many projects in all continents and countries. In the following section, this research will discuss the National Roadmap on bio-plastic as well as the overall bio-plastic projects in other countries and continents.

**Table 3: The group of bio-plastic**

Bio-based plastic	Type of polymer	Types/ structure/ production method
<b>Starch plastic</b>	Polysaccharides	Partially fermented starch; Thermoplastic starch (TPS); Chemically modified starch; Starch blends; Starch composites
<b>Cellulose polymers</b>	Polysaccharides	Organic cellulose esters; Regenerated cellulose
<b>Poly lactide (PLA)</b>	Polyester	Bio-based monomer (lactide) by fermentation followed by polymerisation
<b>Polytrimethylene terephthalate (PTT)</b>	Polyester	Bio-based 1,3-propanediol (1,3-PDO) by fermentation plus petrochemical terephthalic acid (or DMT)
<b>Polymides (PA)</b>	Polymide	
<b>1. PA11</b>		Bio-based monomer 11-aminoundecanoic acid from castor oil
<b>2. PA610</b>		Monomer sebacic acid from castor oil
<b>3. PA6</b>		Bio-based monomer caprolactam by fermentation of sugar
<b>4. PA66</b>		Bio-based adipic acid by fermentation
<b>5. PA69</b>		Bio-based monomer obtained from oleic acid via azelaic (di)acid

<b>Polyhydroxyalkanoates (PHAs)</b>	Polyester	Direct production of PHA by fermentation
<b>Polyethylene (PE)</b>	Polyolefin	Bio-based monomer ethylene obtained from ethanol; ethanol is produced by fermentation of sugar
<b>Polyvinylchloride (PVC)</b>	Polyvinyls	Monomer vinyl chloride can be obtained from a bio-base
<b>Other thermoplastics</b>		
<b>a. Other polyesters (PBT, PBS, PBSL, PBSA, PBST, PBAT, PET, PEIT PVAc, Polyacrylates, PTN, PTI, thermoplastic elastomers)</b>	Polyester	Various carboxylic acids, various alcohols
<b>b. Other ethylene-based compounds (e.g polystyrene and EPDM rubber)</b>	Various	Ethylene by dehydration of bio-ethanol reacted with other compounds

Source: National Science and Technology Development Agency (2008a). The importance of bioplastics on the economy and the global environment. *Also, the National Plan Bioplastics Industry Development (BE 2551-2555): The policy of economic restructuring in the industry for the future (New Wave Industries)*, 10-11

Rodtong, S., Deepasearchkung, J. & Phriktavisak, N. (2013). *The data of technology. Paper presented at the result of technology and market trends including analysis of technology for linking research. conference and exhibitions. Conference and Exhibition on Bioplastics Levels Kebab International InnoBioPlast 2013*, Bangkok, Thailand. Retrieved from <http://www.nia.or.th/innobioplast2013/download/Report.pdf>

Nevertheless, according to Davis and Song (2006), “Biodegradable packaging materials may be broadly classified into biodegradable polymers and biopolymers based on whether the dominating ingredient is synthetic oil-based polymer or a biologically derived polymer” (p.150). In terms of plastic waste management, because of the negative environmental effects associated with leachate and methane production, biodegradable packaging materials are potentially suitable for including in the composting process or the waste system and also enable the development of a new way of treating waste.

### **3.4 Bio-plastic Market**

#### **3.4.1 Worldwide Bio-Plastic Market**

The forecast amount of global bio-plastic production seems to have continually increased from 2009 to 2016 according to the Central Europe Cooperating for Success and Europe Union Europe Regional Development Fund (2013). In 2009, the global amount of bioplastic-production capability (Figure 1) was just about 0.47 million tonnes. The amount grew to 1.1 million tonnes in 2011. It is forecast that bioplastics production can achieve almost 5.7 million tonnes by 2016. Furthermore, in 2012, the global amount of bioplastic-production capability estimated by Professors Peter Halley and Michelle Coote (n.d.) increased to 1.5 million tonnes (Figure 2).

The number is approximate to the result of growth of the Central Europe Cooperating for Success and Europe Union Europe Regional Development Fund in year 2011. However, Professors Peter Halley and Michelle Coote find a different result from the Central Europe Cooperating for Success and Europe Union Europe Regional Development Fund in that Halley and Coote forecast that the production-capacity of biodegradable plastic in the world will be around 2.03 million tonnes by 2016. The figures produced by Halley and Coote differ from those produced by the Central Europe Cooperating for Success group by over 3.0 million tonnes in 2016.

Moreover, it was estimated that the global demand for plastic packaging was \$270 billion. There is an expectation that, at a CAGR (Compound Annual Growth Rate) of 4.8 percent between 2015 and 2020, the demand will reach \$375 billion dollars by 2020. In 2014, the volume of sales of plastic packaging was 81,750 kilo tonnes (Kmbree, 2016). According to The European Bio-plastics Association (EBA), the global forecast for bio-

plastic production by 2020 is a fourfold increase from 2013. Importantly, when produced on a small scale, prices of any biopolymer are likely to be high since the costs of the raw material and of the chemistry involved are likely to be less influential than the scale of production. By 2018, according to EBA, consumption of bioplastics is likely to reach two million tons (Reddy, Reddy and Gupta, 2013). Even if there are varied forecasts of bio-plastic production-capability, the overall result indicates that it is going to increase in the future. This may be because it has been predicted that, by 2020 the global market for bio-plastics will reach \$ 30.8 billion (registering a CAGR of 14.8% during 2015-2020). Pivotal factors in the increased adoption of bio-plastic for rigid packaging are: the growing awareness by consumers of environmental issues and curiosity about biodegradability by the packaging industries (Australasian Bioplastic Association, 2016).

**Figure1: Global bioplastics production ability and forecast (A)**

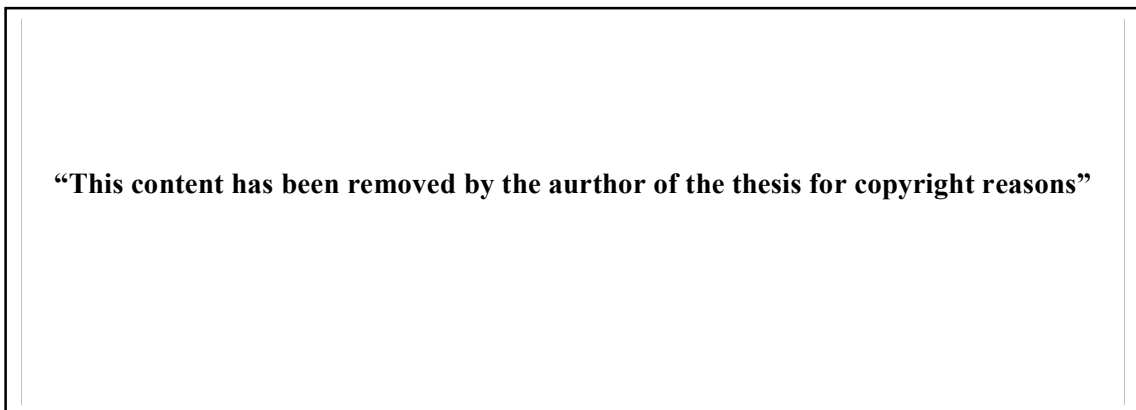


Figure1: The amount in 2009-2011 is the real amount that is used to forecast that bioplastic production- capability in 2016.

Source: Central Europe Cooperating for Success and Europe Union Europe Regional Development Fun (2013). Plastic. *Bio-plastic opportunity for the future*. 24

**Figure 2: Global bioplastics production ability and forecast (B)**

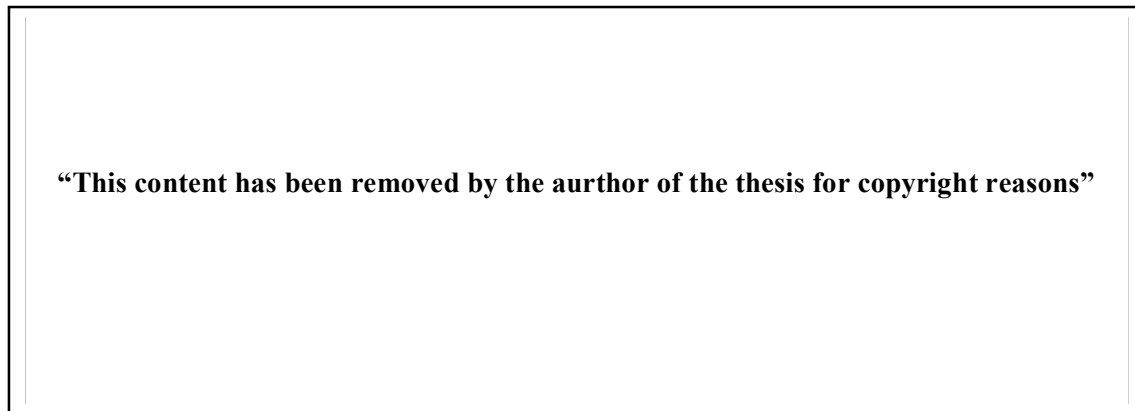


Figure 2: The amount of bio-plastic production in 2012-2013, while, from 2014 to 2018 is the forecast amount is shown.

Source: Halley, P. & Coote, M. (n.d.). *Over the last ten years, we have produced more plastic than during the whole of the last century*. Retrieved from <http://www.nova.org.au/earth-environment/future-plastics>

### **3.4.2 Bio-plastic Market in Thailand**

In terms of market growth and value, bio-plastic production in Thailand rose by 38 percent between 2003 and 2007; and it is estimated that it grew by up to 41 percent between 2010 and 2015 (Weerathaworn, 2013a). The result of Preechanaruechitkul's research in 2010 shows that 33 percent of the target group (those of working age) are willing to use bio-plastic because they would like to preserve the environment. Moreover, 21 percent of them now already use bio-plastic in everyday life. Overall, Markets and Markets expect that, after 2016, the worldwide growth of biopolymer and bioplastic will increase by 12 percent per annum so that, by 2021, the market will be valued at up to 5.08 billion USD (7.05 billion NZD) (Plastic Institute of Thailand, 2016). Mr. Hiroaki Numata (VP Marketing at PTT MCC Biochem Company Limited in Thailand) says that



nowadays, Thai consumers pay more attention to green products than in the past because of the general trend towards waste management worldwide (Rodtong & et al., 2013).

In conclusion, this section has discussed worldwide problems as well as solutions of plastic pollution, with a greater focus on Thailand than on other countries. In terms of the problems, the research finds that Thailand faces similar problems to other countries. For example, many animals die because of eating plastic wastes that people discard in the sea, rivers, forests and soil. There are three main root causes for the plastic-pollution which are: the design system, the consumers, and management of waste following consumption. Moreover, using bio-plastic is a solution for plastic pollution that this research will study because of the properties of bio-plastic and a possible market. Bio-plastic which is produced from natural materials is degradable and, consequently, it is on friendly-environment product. There has been a continuous worldwide growth of bioplastic since 2009, and a prediction that the amount of bio-plastic capability in production will increase about fourfold by 2020 (from a base in 2013). In Thailand, the market growth and value of bio-plastic increased by 38 percent between 2003 and 2007.

### **3.5 Worldwide bio-plastic solution**

There are many countries which are trying to develop and produce bio-plastic. According to Uyen Nguyen Ngoc and Hans Schnitzer (2009), many other countries in the Association of Southeast Asian Nations (ASEAN) (such as Malaysia, Indonesia, Thai and the Philippines) have been developing the production of bio-products like bio-plastic in all their countries and, for at least three years, have successfully used degradable plastics. For example, in Thailand, Coffee café' called Amazon, used bio-plastic which

is produced from Coated Paper Polybutylene Succinate (PBS) which is used to coat paper packaging in glass, paper cups and paper boxes. This coated paper can contain both hot and cold liquids because plastic is heat resistant to 100 degrees Celsius.

PBS is suitable to Thailand's climate for degradation because Thailand has a tropical climate, so the paper-coated PBS is degradable in normal conditions without the need for landfills, disposal through composting, or waste plants. Paper-coated PBS can be left under normal conditions in Thailand which often reaches a heat of 40-50 degrees Celsius and has a relative humidity of about 50 percent. Moreover, microbes that naturally exist in Thailand can cause PBS to decompose into water gas for photosynthesis and the biomass of plants that are beneficial to the soil over a period of about four months (The Thai Printing Association, 2014).

Nevertheless, the Thai government faces a major challenge in transitioning from a fossil—based industry towards a low—carbon, resource- efficient and sustainable one; Conventional industrial processes and products must be transformed into bio-based ones, along with developing industrial bio-technology, integrated bio-refineries and opening new markets for bio-based products. Growth of bio-based products is dependent on their ability to replace older fossil fuels at a competitive cost, along with their ecological footprint and lower Greenhouse Gas (Ngoc and Schnitzer, 2009). On the other hand, the quality of bio-plastic cannot totally replace normal plastic; therefore, in reality, most bio-based plastics on the market today are blends of bio-based and petroleum-based materials, and a bio-based plastic is not really a sustainable plastic. Thus, every country has to ensure the quality of its products in that they are degradable. This is because of the

health and safety of workers, consumers and the environment (Álvarez-Chávez & et al., 2012).

Accordingly, all types of bio-mass should be subject to sustainability requirements with identical criteria for different uses such as food, chemicals, bioenergy and biofuels, and it is relevant since bio-plastic is produced in the bio-chemicals of the bio-based product group (Scarlat & el at., 2015). Nevertheless, bio-plastic is not just being developed in order to reduce plastic pollution. The successful production of Poly Lactic Acid (PLA) and other biomaterials ensures a significant benefit to the economy of each nation, and stimulates further technologies in a chain sequence (Theinsathid, Chandrachai & Keeratipibul, 2009).

Focusing on the United States (U.S.), there has been more innovative manufacturing than in Thailand because the U.S. has “a group of researchers at the Composite Materials and Structures Center at Michigan State University” (p.25) that is using knowledge in composite technology to fabricate sustainable bio-composites from renewable resources. In addition to using commercial green/bioplastics like cellulose acetate, starch plastics, bacterial polyesters, and PLA, researchers are busy developing bioplastic from soy protein and vegetable oils (Mohanty, Misra & Drzal, 2002). The United States also has a project termed “the Technology Road Map for Plant/Crop-based Renewable Resources in 2020” (p.19) which is sponsored by the U.S., Department of Energy (DOE), with a target of 10 percent of all basic chemical building blocks derived from renewable plant resources by 2020 (Mohanty, Misra & Drzal, 2002). It is the same as the PTT MCC Biochem Company Limited demonstrating co-operation between the PTT (Petroleum Authority of Thailand) and MCC (Mitsubishi Chemical Corporation).

Furthermore, Australia has successfully researched biodegradable plastic following Dr Richard McQualter (2013) at University of Queensland (UQ), who explains that he and his research team at the Australian Institute for Bioengineering and Nanotechnology (AIBN) from the university have achieved a major milestone in producing biodegradable plastic (polyhydroxybutyrate) from transgenic sugarcane. Important compounds like medicinal proteins, sweeteners, nutraceuticals, biopolymers, bio-pigments, precursors and various enzymes are being genetically engineered from sugarcane cultivars with the result that, in future, sugarcane can be launched as a bio-factory (Singh & et al., 2013). The quest of thirteen years is almost close to commercial reality. McQualter explains that their motivation is to reduce costs and, simultaneously, to add value to the Australian sugar industry. Finally, In the United Kingdom (UK), there are a few resin-manufacturing sites of bioplastic industries; however, the UK resembles Thailand in developing the manufacture of Polylactic Acid (PLA) which can form the basis of a bioplastic industry in the UK and also provide a new market for UK farmers (Barker & Safford, 2009).

### **3.6 Thai Initiative: description of design and strategy**

The plastic pollution problem and its causes led the Thai government to consider the environmental problem in Thailand and around the world. According to Ren (2003), new challenges and higher requirements for integrated waste management, ranging from clear labelling, source separation, to the sound operation of composting and of the application of compost, are the result of wide acceptance of bio-degradable plastics. Public procurement, which has usually followed economic principles, could be made 'greener' if all governments commit to sustainable development, thus positively

influencing the organisation and corporate purchasing. In this matter, impacts on the supply chain should aim to achieve general optimization of the environment. It is termed the environmental supply dynamics (ESCD) as it describes the way in which environmental innovations and concerns spread to supplier firms from private or public customers (Ren, 2003).

In addition, world use of bio-plastics is likely on average to grow at 50 percent per year. The Kasikorn Research Center in Thailand reports that, in the next four to five years, the demand for bioplastics in the world will increase dramatically. This is because of consumer acceptance of the use of bioplastics in order to further preserve the environment. The governments of various countries, acting in concert, have produced policies and enacted legislation to support the use of bioplastics (National Science and Technology Develop Agency, 2015). A notable example is the United Kingdom, where, by learning from European and United States examples, the government can achieve efficient production and economics of scale. The result is cost-efficient, bio-plastic products that benefit both producers and consumers (Center of Economic and Business Research, 2015).

As part of a similar effort, the Thai government (beginning in 2006), has driven strategies for developing and supporting the bioplastics industry to ensure sustainable management in Thailand (Philp, 2014). On the one hand, Thailand has no law directly related to the reduction in production volumes, and the management of plastic bags in accordance with international law. On the other hand, it possesses a law supporting the production and use of bio-plastic instead of normal plastic. In addition, it has a relevant, indirect law contained in an act involving exports to and imports from outside the

Kingdom. B.E. (Buddhist calendar) 2522 requires that plastic bags and plastic as a raw material used in the production of plastic bags, are formed into a product group which incurs a special charge on imports. It requires an extra fee on the import of these which will possibly reduce the number of imported plastic bags, and also of plastic as a raw material used in the manufacture of plastic bags (Leelakriangsak, 2012).

According to Dr Piphat Weerathaworn (2013a) (President, Thai Bioplastic Industry Association), the Thai government has offered support in developing a bio-plastic industry by coordinating strategies in the public and private sectors, and providing a budget of approximately 1,800 million bath (\$72 million NZD) to implement it. In this way the government has ensured the National Innovation Committee's role in monitoring strategies planning for 'a National Roadmap for the Bioplastic Plastics Industry Development'. The aim of the project again is to move the Thai plastic industry towards becoming a bio-plastic hub. The government selected the National Innovation Committee to co-operate with the Ministry of Science and Technology, and together they have created and presented the project known as the National Roadmap for the Bioplastic Plastics Industry Development for the Thai government (Weerathaworn, 2013a).

In addition, the Thai government has reduced taxes to those businesses which support the government's measures and which also support the development and upgrading of technologies that are clean and environmentally friendly. Moreover, the government has ordered its departments (which deal with plastic-pollution management) to have environmental conservation campaigns that made people aware of the importance of using bioplastic containers or bags to address plastic-pollution (Office of Natural Resources and Environmental Policy and Planning, 2013).

The PTT and PTIT (Petroleum Institute of Thailand) were enthusiastic about bio-plastic. PTT was the form of Special Operations Executive (SOE) sector through mergers and acquisitions, energy enterprises of the two organizations that organized the fuel industry (Department of Energy Office of the Secretary of Defense, military) and the organization of natural gas (Ministry of Industry) in Thailand (PTT Public Company Limited, 2012). The PTIT was established in the form of a non-profit organisation of PTT that has taken responsibility for emphasising the development of human resources, information services, technical services, public policy and regulatory support, in order to secure the continued-sustainable development of the industry and the economy of Thailand (Petroleum Institute of Thailand, n.d).

Importantly, this institute's mission received constant support from the government, as well as from the private and academic sectors. Recently, Siri Jirapongsphan, the director of the Petroleum Institute of Thailand (PTIT), stressed that the drive of Thailand is to become the industry leader in a fully integrated global biotechnology (Bio Hub) within 20 years (2015-2035) (ASTV online management, 2015). The Petroleum Institute of Thailand has been involved in pushing Thailand as a bio-plastic hub because PTIT is a company in the PTT (Petroleum Authority of Thailand) Group, and Chavalit TipPowerNiche (the Executive Vice President of PTT) says that PTT is an important 'cog' in supporting the development of industries in Thailand, which have served as a mainstay for the development of the petrochemical industry for Thailand (Plastic Institute of Thailand, 2013b).

Bio-plastic will appear to threaten PTT's core business because the National Roadmap diminishes the demand for petroleum because bio-plastic products have long been designed to replace petroleum plastic. Thus, PTT needs a new opportunity to create

a new product which relates to its business area; therefore, PTIT (it is just one of the parts of PTT) has to provide information services about a new product such as bio-plastic, focusing on bio-chemicals which, in turn, involve the development of bio-plastic technology and quality for the production in the Petroleum Institute of Thailand (n.d.). The National Roadmap is a good opportunity for PTT to expand a new line product in the market which both responds to the environment and helps the firm in creating a successful image, along with demonstrating corporate social responsibility (CSR).

Also, bio-plastic can increase PTT's income in the future because the bio-plastic market has developed very fast (Petroleum Institute of Thailand, 2011). A large project that it has achieved is 'the PTT and the company, Mitsubishi Chemical Corporation (MCC). This project aims to develop a plant to produce precursor Bio Succinic Acid (BSA) and bio-plastic plant species Polybutylene Succinate (PBS), using sugar as 'the raw material', Consequently, they established a new company called the PTT MCC Biochem Company Limited (PTT Public Company Limited, 2011; Technology Promotion Association (Thailand-Japan), 2010).

Nevertheless, in an interview, Janice Li from JinHui group (BRIGIT, 2014; PackWebasia.com, 2014; SHANXI JINHUI GROUP, 2014), says that, within three to five years, China will become the largest bioplastic producer and converter in the world. Li also mentions that, "Thailand is doing well, and we can learn a lot from them". Li believes that, because of China's greater overall production capacity and its potential market, Thailand will be unable to compete with China which she predicts will be the Asian and global hub for bioplastic production (Rigit, 2014; PackWebasia.com, 2014; SHANXI JINHUI GROUP, 2014). China already possesses a business model, namely the biodegradable plastic leap of B & G, which is a joint venture between China and



Belgium. Currently, its lactic acid production capacity is ranked second in the world, producing 30,000 tonnes per year. The company, namely Tianan, is capable of producing Polyhydroxyalkanoates (PHA) commercial 1,000 tonnes per year (Department of Industrial Promotion, 2009).

Furthermore, Somchana Kangvarajit (The packaging designer and owner of the Prompt Design Company that focuses on a portfolio of green packaging in Thailand) says that Thai manufacturers seem to take care of environmentally-friendly production by speech, but in fact, no company is interested in taking the matter very seriously owing to the increased burden on their own costs. However, in Thailand, the company has not been interested in replacing the old system because the production of environmentally-friendly packaging will need an entirely new production system. New tools will be required for bio-plastic production, and it will have to be blended onto the plant. This writer believes that it is still impossible for Thailand to develop as a bio-plastic hub because no company is interested enough to invest in the purchase of machinery for packaging production like bio-plastic ((Panyapiwan Institute of management, 2015), 2015).

Nevertheless, it is just Kangvarajit's belief, and the Thai government also realizes the co-operation between the government and the plastic industry must occur to develop bio-plastic technology for production because government co-ordination is necessary. Thus, the Thai government has identified a strategy for 'Accelerating technological development and a technological co-operation strategy' in the National Roadmap (National Innovation Agency, 2008d; National Science and Technology Development Agency, 2008c).

**Table 4: The conclusion-table how other countries' plastic solution are similar to the solution of Thailand**

Worldwide Plastic Solutions		How are other countries' solutions similar to Thailand
<b>ASEAN</b>	Development bio-plastic production	Thailand also does develop bio-plastic production the same as Malaysia, Indonesia, and the Philippines Uyen Nguyen Ngoc and Hans Schnitzer (2009).
<b>United States</b>	<p>1. Having its own group of researchers at the Composite Materials and Structures Center</p> <p>2. Having the Technology Road Map for Plant/Crop-based Renewable Resources in 2020</p>	<p>1. Thailand has a group like that, <b>but</b> it is not enough, so Thailand receives support at it from other countries (Ministry of Industry, 2016a). (See more on Chapter 4)</p> <p>2. PTT MCC Biochem Company Limited demonstrating co-operation between the PTT (Petroleum Authority of Thailand) and MCC (Mitsubishi Chemical Corporation) to focus on renewable resources (PTT Public Company Limited, 2011; Technology Promotion Association (Thailand-Japan), 2010).</p>
<b>Australia</b>	It has achieved a major milestone in producing biodegradable plastic (polyhydroxybutyrate) from transgenic sugarcane.	In Phase Two from the National Roadmap's strategies Thailand has supported investors who can use bioplastics, sugar cane and cassava and also develop the raw material (National Innovation Agency, 2010d).
<b>United Kingdom</b>	Development of manufacture of Polylactic Acid (PLA) which can form the basis of a bioplastic industry	Thailand also aims at the development of a prototype for the production of resins, plastics, and poly lactic acid (PLA) (Chávez & et al., 2012).

This chapter summed up the overall of plastic problems overall because the amount of plastic has continually increased and it has been hard to degrade. This problem has led to serious storm water problems, the survival of animals, toxins gases and the spread of malaria Thailand has faced to the problem. The causes of plastic pollution in Thailand have been the design system, consumers, and management of waste following consumption. In addition, the three popular plastic solutions have been to reduce, re-use and recycle, but Thailand has chosen a different solution because Thailand has aimed at re-new able products. It has been the development bio-plastic via the government's project called the National Roadmap. This project readiness in an agricultural country, having many full-cycle mature plant plastic industry, and also having policy and support measures, directly caused an impetus in the bioplastics industry. In the worldwide market, the amount bio-plastic seems to have continually increased since 2009, and the global market for bio-plastics may reach \$ 30.8 billion by 2020. Lastly, many countries (such as United States, United Kingdom and Australia) are now in the process of developing bio-plastic the same as Thailand. The next chapter will make a close analysis of the strategies and outcomes of the National Roadmap of Thailand in three phases.

## **Chapter 4**

### **The Thai government's strategies of the National Roadmap**

The National Roadmap of the Thai government is focused on improving bio-fuels/bio-chemicals and the agriculture/biotechnology industries because they are involved in the development of the bio-plastic industry. In addition, the Ministry of Finance has grouped bio-plastic into ten target industries engineered for future economic (Ministry of Finance, 2015; Sangsupran, 2015). This, research investigated the strategies which are used for the projects of National Roadmap. The overall strategy of the National Roadmap already established was divided into three phases: 2551-2555BE, 2554-2558BE and 2559-2563BE (In Thailand, people always use the Buddhist calendar (BE), so this research used both the Buddhist calendar and Anno Domini (AD) to discuss the year of each phase and strategy).

#### **4.1 Phase One**

The first phase aims at four areas of overall strategies (2551-2555BE or 2008-2012AD): readiness of biomass raw materials; accelerating technological development and technological co-operation; the creation of industry and innovation; and the establishment of a supportive infrastructure (Kihirun & Chongcome, 2010; Organisation for Economic Co-operation and Development, 2013; Weerathaworn, 2013a). The research of Pattayakosal (2010) and the report of National Innovation Agency (2010c) explains the main objectives of the strategy which are:

**1. The first strategy** of the National Roadmap is the readiness of biomass raw materials and is designed to support as well as increase crop yields and to manage plantations efficiently. This is because the demand of biomass raw materials for bio-plastic production can have an effect on food demand. Bio-mass is from fruit and vegetables which people need to eat in their normal lives; therefore, it can be in short supply, and this situation leads to the high cost of both raw material and of food for humans. The budget of this strategy is 100 million baht (4 million NZD).

This figure will ensure that bio-plastic production will reach the ‘break even’ point, along with avoidance of various problems relating to crop cultivation. These will include the destruction of the balance in the ecosystem (National Innovation Agency, 2008d). This strategy’s budget was spent on research into plant breeding technologies, including mechanical cultivation as substitute labour for planting and harvesting (The National Science and Technology Development Agency, 2008c) because the operators of plastic in Thailand also have a weakness, in their lack of research and in the development of sufficient plastic products and in the bioplastics industry itself. Operators (including agriculturists) also lack a proper understanding of bio-plastic (Ministry of Industry, 2016a).

One area of operation for this strategy is the office of Permanent Secretary for the Ministry of Agriculture and Cooperative performances about the revolving fund for loans to farmers and the poor in 2010. At that time, the numbers of cases in loan approvals rose by 107 people or to 18.51 percent and amounted to approval of an increase of 21.23 million baht. This represented 12.51 percent of approval results in the fiscal year of 2009 because of amendment regulations which provide extra aid to poor farmers and more

widely in the population (Pintong, 2010). In addition, 250 million baht for this strategy's budget was spent for research on plant breeding technologies, including mechanical cultivation as substitute labour for planting and harvesting (The National Science and Technology Development Agency, 2008c) because the operators of plastic in Thailand also have a weakness, in their lack of research and the development of sufficient plastic products and the bioplastics industry (Ministry of Industry, 2016a). Operators (including agriculturists) also lack a proper understanding of bio-plastic (Ministry of Industry, 2016a). Consequently, another 20 million baht was used to provide insights for farmers linking agricultural crops as feedstock to the production of bioplastics and the choice of species distribution and seeding technology to enhance productivity (The National Science and Technology Development Agency, 2008c).

**2. The second strategy** is 'Accelerating technological development and a technological co-operation strategy' which aims at preparing technology and budget investment. Its budget is 1,000 million baht (40 million NZD). This is because advanced technology is necessary to research and develop performances in bio-plastic production. Also, it leads to the adjustment of price of bio-plastic and the quality of bio-plastic in competition with normal plastic. The goal is to provide a technology that is available immediately, that is to seek and evaluate technologies suited to imports; or to invest in technology. All of them are aimed at possible investing. Moreover, co-ordination between groups, such as industrial enterprises and companies owned by foreign technology, aim at directing and supporting research grants and conducting research (The National Science and Technology Development Agency, 2008c; National Innovation Agency, 2008d). In addition, lecturers from industrial sectors and research sectors (comprising 38 people

from around the world), support Thailand in the development technology and marketing of bio-plastic (Kihirun & Chongcome, 2010).

An example of this strategy is a large project of the PTT and MCC that aims at the development of a plant to produce precursor Bio Succinic Acid (BSA) and bio-plastic plant species Polybutylene Succinate (PBS), using sugar as ‘the raw material’ by setting up a new company called the PTT MCC Biochem Company Limited (PTT Public Company Limited, 2011; Technology Promotion Association (Thailand-Japan), 2010). This corporation can build the sustainability of Bio-based polybutylene succinate (Bio-PBS) in Thailand, and in 2015, the PTT MCC Biochem Company Limited was able to produce Bio-based polybutylene succinate (Bio-PBS) of around 20,000 tonnes (Rodtong, Deepasearchkung, & Phriktavisak, 2013). The company has created many bio-products. For example, Bio-PBS; whose outstanding properties are that it is biodegradable, and it also can be sealed with heat as well as operating at high temperatures (Rodtong, Deepasearchkung, & Phriktavisak, 2013).

Thus, Bio-PBS can prove the outstanding properties of bio-plastic in terms of melting strength and thermal instability (Iles & Martin, 2013; Lagaron & Lopez-Rubio, 2011). Lecturers from industrial sectors and research sectors (comprising 38 people from around the world), support Thailand in the development technology and marketing of bio-plastic (Kihirun & Chongcome, 2010). The development of technology and marketing in this strategy can increase the quality and efficiency of bio-plastic which may help contribute to a competitive price in the market because the bio-plastic price is still higher than for normal plastic (The Siam Commercial Bank, 2014).

3. **The next strategy was considered by** the National Science and Technology Development Agency (2008c) in that the budget of this strategy is 500 million baht (20 million NZD) in order to focus on the development of knowledge, innovation and industry to produce bio-plastic. In turn, the creation of industry and innovation has two main focuses. Firstly, this strategy supports joint investment between the industrial enterprises and companies owned by foreign technology which are creating industrial pilot plants for the production of the Mercury Monterey and polymers suitable for Thailand, as well as supporting activities to strengthen the bioplastics industry in Thai technology. Moreover, this strategy will also support internal and external marketing in Thailand, and it emphasises 'Expos' by encouraging producers to join fairs abroad and to participate in promotions with companies in Thailand and abroad (National Innovation Agency, n.d.b). This strategy will help prepare the bio-plastic products by building or finding industrial pilot plants, since bio-plastic is a new 'green' product. Consequently, opening a new market for bio-plastic is very important for supporting consumers to buy and use it and also for supporting entrepreneurs to invest in the bio-plastic industry.

In this strategy, the National Legislative Assembly has supported the private sector for investment in innovative projects on bioplastics numbering 48 projects with a budget of 42 million baht to support the establishment and the operation of activities of Thai Bioplastics Industry Association (TBIA) continue. TBIA is the organisation that cooperated with NIA to set up the Roadmap for the National Development of Bioplastics Industry since 2008. Moreover, it has made many promotions and presented bio-plastic via international exhibitions and conferences on bioplastics such as EcoInnovAsia 2008: Bioplastics, InnoBioplast 2010 and Pilot projects using bioplastic products with NIA uses bio plastic in a Puff & Pie (Thai Bioplastics Industry Association, n.d.). Furthermore, the



responsibility for the project of the National Innovation Agency can be managed by the Thai government which will provide a capital loan without interest to expand or build plants, as well as to import bioplastic for experimental development technology. This is because the government aims at establishing industrial pilot production of monomer/and industrial pilot production of polymer by the year 2555BE (or 2012AD) as well as Industrial Building Company of the Year and industrial products within a year up to 2554BE (or 2011AD) (The National Science and Technology Development Agency, 2008c).

4. The establishment of a supportive infrastructure is **the last strategy**. This strategy is supported by budgets of the Thai government- at around 200 million baht (8 million NZD), and it has four managed areas for the National Roadmap. The creation of industry standards for the degradation test is the driver of the first Board of Education for understanding bio-plastic because the majority of Thai people do not know it, and it is the preparation of biodegradable plastic (including certified logos), clearly defined (and officially adopted) standards to ensure that people can decide which products are good for the environment and which are not. It also establishes testing centres for the degradation of bioplastic products because there are many methods for breaking down bio-plastic and some of them people cannot access.

Consequently, the government must ensure that bio-plastic can degrade and break down after use (The National. Science and Technology Development Agency, 2008c; National Innovation Agency, 2008d). Furthermore, this strategy pays attention to environmental conservation. Consequently, it has other projects that propose measures to support the bioplastics industry and consumer bio-plastic products, such as the

proposed law and policy incentives for the production / and use of environmentally friendly plastic (The National Science and Technology Development Agency, 2008c). It drafts standards which insist that biological; Industrial plastics must be produced biologically in accordance with the international standards of ISO (International Organisation for Standardization) 17088: 2008 to ensure properties degrade biologically (The National Science and Technology Development Agency, 2008c).

An example of this strategy can be found in the Ministry of Education adding the subject of bioplastics as part of the environmental program to educate and distribute a government-produced documentary about bio-plastic. The government funds these products to educational institutions (The National Science and Technology Development Agency, 2008c). This strategy also set bioplastics standards and has established a certification system. For example, in this phase, the Thai Industrial Standards Institute has drafted standards insisting that biological Industrial plastics biologically must be produced in accordance with the international standards of ISO 17088: 2008 (Specification for Compostable Plastics) to ensure properties degrade biologically. (Compostable) of degraded biologically (The National Science and Technology Development Agency, 2008c). Lastly, NIA has established guidelines for the development of systems certified products. The bioplastics-industry in Thailand has received the recognition of a certification system comparable to international standards by coordinating with the European Bioplastics Association (European. Bioplastics) metrology and accreditation system and the products of Germany's DIN CERTCO (National Innovation Agency, 2010d).

## 4.2 Phase Two:

According to the National Innovation Agency (2010d), the second phase consists of stimulating commercial investment over five years (2554-2558BE or 2011-2015AD), and this phase is to operate continually using four strategies of the first phase. However, the Thai government suggests the committee consider three measures to support the four strategies.

1. The first measure was created to improve the efficiency of **the first strategy** by means of setting up the pilot plant to produce a bio-plastic capacity of 1000-10000 tonnes per year (to the operation within three years (2554-2556BE or 2011-2013AD)) by incorporation of the then National Innovation Agency and the Bioplastics Industry Association Thailand (TBIA). It supports the polymers to TBIA, in that the polymers which are derived from Pilot Plants, will be sold to members of TBIA at a price close to the plastic from petroleum PE (Polyethylene), or PP (Polypropylene) totalling not less than 500 tonnes since 2011 when production started for a period of three years. (National Innovation Agency, 2010d).

In 2011, Laurel BioComposite opened a pilot plant and resin composite, Bio-Res, which was the first product to a major customer. The company will test the adhesion of the mixed bio-plastics, which are used as a component of this type of household product, in a trial production of bioplastics. This type is formed by the injection of moulding with plastic. It reveals toughness and resistance to deformation of the stretch to pull up about 10% of the property which has increased owing to the low specific gravity. The use of fillers includes calcium carbonate and talc, along with plastic, mixed with elements of alternative materials or materials that are

environmentally friendly. Approximately 40% will be used instead of the polymer from petroleum for industrial production plastic (Petroleum Institute of Thailand, 2011). This operation will develop the quality of bio-plastic because bio-plastic has had a problem in terms of melting strength, thermal instability, and sheer sensitivity. Consequently, it is difficult forming as a product (Iles & Martin, 2013; Lagaron & Lopez-Rubio, 2011).

2. The next measure was the implementation of the action plan to promote the investment in bioplastics. It was designed to support the second **strategies** from Phase One, namely, accelerating technological development and the technological co-operation strategy' along with the creation of industry and innovation. NIA collaborates with the National Research Council of Thailand, PTT Research and Development Center, Petroleum Authority of Thailand and Chiang Mai University to develop catalysts which are effective; to process manufacturing and to expand the production capacity and to support the building of a "Bioplastics pilot plant in order to produce high-quality medical supplies". A system certified ISO 13485 (quality management system for medical devices) is also being developed (Kihirun, 2014).

NIA collaborates with the National Research Council of Thailand, PTT Research and Development Center, Petroleum Authority of Thailand and Chiang Mai University to develop catalysts which are effective; to process manufacturing and to expand the production capacity of synthetic resin plastics. Moreover, they support the building of a "Bioplastics pilot plant to produce high-quality medical supplies" along with the development of a system certified ISO 13485 (quality management system for medical devices) in order to produce bio-plastic resin of a medical grade for use as a feedstock;

the production of various medical supplies, such as, sutures that dissolve duct nerves; a controlled release material; a medication designed to control drug release slowly in the body over a long period of time (Kihirun, 2014). This development has involved the incorporation of four organisations which will support Thailand in confronting earlier bio-plastic initiatives, while satisfying the increased need for innovative products in the Thai plastic industry so that it is better able to compete with other countries (The Siam Commercial Bank, 2014).

3. The last measure has been concluded by National Innovation Agency (2010d) with the overall aim of measuring the commercial stimulus of Danu in these five years (2554-2558BE or 2011-2015AD), and to solve the allocated expenditure by dividing commercial measures into five small measures. Nevertheless, there are four measures, each of which is to address the four strategies from Phase One. They support (1) the availability of biomass feedstock, whereby investors can use bioplastics, sugar cane and cassava in also developing the raw material for export as well as developing a plan to promote productivity; (2) supporting research and development as bio-plastic; (3) preparing standards for bioplastics internationally to ensure an environmentally friendly standard by the comptroller; and 4) benefiting investment and entrepreneurship to support the third strategy as industrial development for investment. The last small-measure is a new aim of the National Roadmap's strategies. This is because it focuses on supporting people's knowledge about bio-plastic via the process of preparation of the pilot project, along with the campaign to disseminate knowledge which that is very important for the development of bio-plastic and for expanding the bio-plastic market. Therefore, the last measure focuses on the promotion and expansion of the market for environmentally friendly bio-plastic products (National Innovation Agency, 2010d).

Cassava or tapioca is the main, raw material of bio-plastic, and has been continually developing its quality and amount since 2552BE (or 2009AD) by Strategy One from Phase One. According to the research of the Thai Tapioca Development Institute (2015), the production of cassava continually decreased from 8,292,146/ 1.6 hectare (2551BE or 2008AD) to 7,911,323 / 1.6 hectare (2554BE or 2010AD) before it increased to 8,697,948/ 1.6 hectare in 255BE (or 2014AD). The price of cassava seems to have been successful at achieving price parity with other competing countries because, since 2012, its price has sharply reduced, despite the fact that it was well over 500 USD per ton in 2013. However, the price fell to around 315 USD per ton in Oct 2016 (the Thai Tapioca Development Institute, 2016) (figure 3).

**Figure 3: Tapioca Starch (Super High-Grade) Export Price**

**“This content has been removed by the author of the thesis for copyright reasons”**

Source: The Thai Tapioca Development Institute (2016). *Tapioca Starch (Super High-Grade) Export Price*.

Retrieved from <http://www.tapiocathai.org/Graph/starch%20export%20price.pdf>

### **4.3 Phase Three:**

This phase is happening at the time of writing (late 2016). Consequently, it can be asserted that the bio-plastic hub has not yet been established. As the project continues for five years (2559-2563BE or 2016-2020AD), under nine-million-baht (\$360,000 NZD) budget has been assigned by the Office of Industrial Economics. Nevertheless, the aims of this phase are considered in three ways according to the Ministry of Industry (2016b). They are: to research and develop the ability to market competitively; research and create in order to design plastic products of a higher value; to support environmental awareness in the global market, including investment, with a focus on products that help the environment. Overall, this phase has dual aims—to conduct research/and development and to improve competitiveness in marketing by increasing the value of the bio-plastic product. Moreover, it supports environmental awareness for marketing and investment. All these aims seem to be new strategies which have been created for existing challenges and barriers even if the National Roadmap has been in place for Phase One and Two.

These strategies were designed through studies by the Office of Industrial Economics which discovered that Thailand still has some limitations that needed to be defined, and there are measures requiring the development of bioplastics for the industry to meet these suggestions. The Thai government proposes pushing Thailand to become a bio-plastic hub in ASEAN: the Office of Industrial Economics has designed five measures for promoting bioplastics: (1) Technology/ The Company Quaid's bioplastics industry to develop the properties of bioplastics products so as to support various applications; (2) promoting the domestic market for processing bioplastic products; (3) improving its ability to reduce the unit cost of production in enterprises in Thailand; (4) the determination and certification of bioplastic products to build confidence in and

acceptance of bioplastic products for export and domestic use; and (5) orientation to manage bio-waste effectively; to encourage the use of bioplastics by causing maximum environmental benefits (National News Bureau of Thailand, 2016).

Overall, the main aspects and objectives of the National Roadmap focus on replacing for industrial-economic reasons which include a better environment. The development of a bio-plastic industry in the project can improve technological performance and impose a better technology to increase the capability of bio-plastic production which is friendlier to the environment than normal plastic is. In addition, improving the economy is another factor because, becoming a bio-plastic hub, will cause Thailand to have a new product to export, and it means that Thailand will have more income, and agricultural products will have a higher value.

The National Roadmap's strategies are operating in three phases. In addition, all of them are designed to overcome all challenges and to address any barriers that remains a worldwide problem and is also happening in The National Roadmap of Thailand, for developing bio-plastic production and for leading the Thai plastic industry towards becoming a bio-plastic hub. In the first phase, the strategies aim at developing bio-plastic product in four areas such as biomass raw materials, technological development/ and co-operation strategy, support joint investment/marketing and creating, a supportive infrastructure. While, the strategies in Phase Two and Three aim to improve the efficiency of strategies in Phase One and to cope with other new challenges and barriers that will follow as well as the income of Phase One and any world changes that are occurring. All challenges and barriers to bio-plastic production are presented in the next



section (Chapter 5), and there are both worldwide and internal Thai challenges and barriers.

## Chapter 5

### Likely challenges and barriers

The study is driven by two research questions. (1) What has the Thai government done to establish the Thai plastic industry as a bio-plastic hub? and (2) what are the challenges and barriers likely to face the National Roadmap? Addressing the plastic solution in Thailand via using bio-plastic is likely to face some challenges and barriers that will make it difficult for Thailand to be a bio-plastic hub. This literature review will contribute to these overall questions by dividing these challenges and barriers into three main themes: the problems associated with bio-plastic; challenges which have confronted previous bio-plastic initiatives; and challenges which confront green initiatives more generally.

**Table 5: the process of designing themes for the finding of Research Question**

**Two (A)**

References	Quotes	Codes	Theme
<b>The Institute for the Promotion of Teaching Science and Technology, 2011</b>	1. Bio-plastic cannot be used for agriculture.	1. Quality of bio-plastic	The plastic associated with bio-plastic
<b>National Innovation Agency, 2010a</b>	2. The development needs of bio-plastic that lasts more than one year.		
<b>Iles &amp; Martin, 2013</b>	3. Bio-plastic which is produced by blending biopolymers with petroleum is harder to recycle or re-use		

<b>Barker&amp; Safford, 2009</b>	4. Bioplastics are highly vulnerable to risk from the additives, cross-linking agents and preservatives.		
<b>Perviaz &amp; Sain, 2006</b>	6. High prices and costs of basic raw materials, material development for bio-plastic.	2. Cost of bio-plastic	
<b>Waramit, 2012</b>	7. Bio-plastics' prices are non-competitive, and fossil resources will increase in price.		
<b>Lagaron &amp; Lopez-Rubio, 2011; Waramit, 2012</b>	8. Higher cost of bio-material		
<b>Dietrich &amp; et al., 2016</b>	9. The price for Polyhydroxyalkanoates is "15-17 times higher than the major petroleum-based polymers and 4-6 times higher than commercial polylactic acid.		
<b>Barker&amp; Safford, 2009</b>	10. Bio-plastic production, such as Polymer plant, has the high cost of both construction and small-scale, while research and development costs are high.		
<b>Dangelico &amp;Pujari, 2010</b>	11. Companies need their own concept of a sustainable strategy for the environment.	3. Challenges which confront green initiatives more generally	
<b>Dangelico and Pujari, 2010</b>	12. The physical life-cycle perspective of the new product is important, so companies need to		

	have product managers and environmental specialists		
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**Table 6: the process of designing themes for the finding of Research Question Two**

**(B)**

References	Quotes	Codes	Theme
<b>Iles &amp; Martin, 2013</b>	13. Many organisations face the problem of balancing between making a profit with reducing the environmental impact.	4. Challenges which have confronted previous bio-plastic initiatives	Thai Initiative: Challenges and barriers
<b>Barker&amp; Safford, 2009</b>	14. A current gap in the efficient harvesting of bio-mass and an inadequate supply chain network.		
	15. Significant challenges with respect to social inclusion for using of sugarcane ethanol in bio-plastic.		
<b>Eric Koester, 2016</b>	16. Rules and regulations governing the imparting of technology, medicines, biotechnology and agricultural products when exporting those products to other countries.		
<b>Gaskell &amp; et al., 2006</b>	17. People in Europe think supporting bio-plastic research is the government's responsibility, and the majority of them do not and	5. Several social-cultural	

	may not pay more money to support bio-plastic.		
<b>Kurka &amp; Menrad, 2009</b>	18. People in Europe will buy bio-plastic if bio-plastic makes them more eco-friendly for the environment.		
<b>The Siam Commercial Bank, 2014</b>	19. Thailand needs to increase innovative products in its plastic industry to improve its ability to compete with other countries.		
<b>National Innovation Agency, 2010b; Phuengchaichangul, 2013</b>	20. The operators and end-users in Thailand do not know how to distinguish between conventional plastics and bioplastics, and they cannot recognize the environmental benefits from using bio-plastic.		
<b>Ministry of Industry, 2016a</b>	21. Thailand lacks research and has an insufficient development of plastic products.		
<b>ASTV online management, 2015</b>	22. The consolidated research and development of Thailand is also relatively low.		
<b>Theinsathid, Chandrachai, &amp; Keeratipibul, 2009</b>	23. Thailand needs to improve the education of the prospective market and technology about bioplastic.		

Tables 5 and 6 show the overall consideration of challenges and barriers to divide them into groups.

Mainly, there are two big groups of challenges and barriers that are plastic-associated with bio-plastic (Table 5) and Thai Initiative: Challenges and barriers (Table 6).

## **5.1 The problems associated with bio-plastic**

### **5.1.1 Quality of bio-plastic**

One of the problems associated with bio-plastic is its age for use because, generally, bio-plastic undergoes easier degradation than normal plastic (Lagaron & Lopez-Rubio, 2011; The Institute for the Promotion of Teaching Science and Technology, 2011). Consequently, bio-plastic cannot be used for every business such as agriculture. In Thai agriculture, there are many plastic products that are commonly used, such as a film for mulching this (film, aims to prevent the growth of weeds and retain soil moisture), as well as materials for agriculture, including bags or pots for seedlings. (The Institute for the Promotion of Teaching Science and Technology, 2011). However, the nursery seedlings will become large forest trees. It takes time to cultivate seedlings at least one to two years, where the roots can grow sufficiently. Therefore, planting bags must be able to withstand the conditions inside a greenhouse nursery without spoiling the seedlings. Climate and soils can hold the key to reforestation, and, when transplanting seedlings into the soil, it must be biologically degraded so that the roots can spread and grow out (Kihirun, 2010). There is a need for the development of bio-plastic that lasts more than one year if it is to be used in the planting of saplings because the immature plants need more than a year's protection. Consequently, a new bio-chemical mix has been evolved (National Innovation Agency, 2010a).

Bio-based polymers must meet at least the same processing and performance indications as those required by conventional polymers, according to the producers' argument. Consequently, the focus of the industry has increasingly been on duplicating the most frequently used thermoplastics so that customers will continue to find biopolymers a more attractive option. The problem of the poorer performance in meeting

strength, thermal instability and shear sensitivity of polymers has been overcome by blending biopolymers with petroleum— based monomers or polymers. However, it is harder to recycle or re-use such materials (Iles & Martin, 2013). The lower material performance of some biopolymers has been noted by Lagaron and Lopez-Rubio (2011). Research noted in the area of food packaging will be one of the most important themes in future. Bioplastics also are highly vulnerable to risk because of the additives, cross-linking agents and preservatives, not present in traditional plastic packaging (Barker& Safford, 2009).

Raaz Maheshwari, Bina Rani, Sangeeta Parihar and Anju Sharma (2013) mention the fallacy, since bio-plastic is degradable, that degradation will occur spontaneously in about 90 days. But, in fact, it does not break down in natural conditions, since it requires perfect conditions for degradation to occur. A large composting facility is required but few individuals can access one. A single secondary settlement process occurs as a result of combined creep and bio-plastic— induced settlement. It is a function suitable for areas that inhibit biodegradation but is not suited to landfills after closure because of the difficulty in dealing with the speeded-up settlement that have been often observed. The cause of the problem is that the process of biodegradation is dependent on factors like “the amount and nature of organic matter”, and the moisture content (essential as a vector and reactant for the spread of microbes) (McDougall,2007). Significantly, most bioplastics will remain permanently in landfills since most landfills fail to provide perfect conditions for degradation (Maheshwari & et al., 2013).

### **5.1.2 Cost of bio-plastic**

In comparison to conventional plastics, the prices of basic raw materials for bio-plastic are high, owing to the high cost of material development because a key factor is that Thailand has a limited capacity to produce bio-plastic. Therefore, both challenges have impacted the price. Pro-active buying behaviour has only been the result of consumer awareness of environmental issues (Perviaz & Sain, 2006). Several industries have been slow to introduce green products, not because of a lack of adequate green technologies but because their prices are non-competitive, owing to high manufacturing and development costs.

Naroon Waramit (2012) has researched the development of a bio-economy, and has discovered that, within a decade, fossil resources will increase in price. Moreover, an increased demand for energy and chemicals, occurring at the same time that greenhouse gas emission will be restricted, could transform the situation (Waramit, 2012). In this future scenario, bio-based products (including biofuels, chemicals and plastics) could find many new markets. This expansion will include both food and non-food crops (bio-materials), namely cosmetics, food additives and vaccines (Imre & Pukánszky, 2013; Waramit, 2012). But a snag will be the consequently higher cost of bio-material (Lagaron & Lopez-Rubio, 2011; Waramit, 2012) — a problem that will need to be addressed through increasing the amount of biomass material production or controlling the price.

At present, conventional plastics are two to four times cheaper than the ‘green’ bio-plastics, according to Barker & Safford, 2009. Other researchers place the price for commercial PHAs (Polyhydroxyalkanoates) at “15-17 times higher than the major petroleum-based polymers and 4-6 times higher than commercial polylactic acid from



Cargill (Dietrich & et al., 2016). Moreover, there are many factors concerning the price which will affect both the production costs and an increase in the cost of goods (National Innovation Agency, 2010b; Phuengchaichangul, 2013; Weerathaworn, 2013b). Some of these include: the high cost of both construction of the polymer plant and of the raw materials; the fact that production is small-scale while research and development costs are high. However, some options already exist that will aid the penetration of bio-plastics into a petro-plastic-dominated market (Barker& Safford, 2009).

### **5.1.3 Challenges which confront green initiatives more generally**

The research of Rosa Maria Dangelico and Devashish Pujari (2010) concludes that the challenges faced by companies manufacturing green products will be multiple. This research will show two themes of these challenges: cost/and market pressure and the environment performance.

#### **1. Individual companies will have varied motives for developing green products.**

Companies need their own concept of a sustainable strategy for the environment, and the developing environmental strategies should be continually growing under any policy of regulation. This is exemplified in the case of the European Community's directives since 2006 which relate to the restricted use of some hazardous substances (RoHS) as well as waste electronics and electrical equipment (WEEE). There is an ongoing impact on various industries from these products and their processes (Dangelico &Pujari, 2010). Thus, companies are compelled to create sustainable strategies in line with the regulations.

2. There is the question of the environmental performance of the product which will involve ensuring the reduction of an adverse environmental impact through the entire process of production. However, companies normally face their evaluation of the environmental effects of their product in a systematic and scientific fashion. An important aspect of green product innovation is the physical life cycle perspective of the new product which compels companies to find product managers and environmental specialists able to measure and assess the impact on the environment at each stage of the process and production (Dangelico and Pujari, 2010).

#### **5.1.4 Challenges which have confronted previous bio-plastic initiatives**

There is an urgent need for government initiatives in developing a bio-plastic industry sustainably. Success in the scheme is dependent on a firm commitment at the highest levels of government. An important factor will involve improved understanding between institutions involved in the process (National Innovation Agency, 2010b; Phuengchaichangul, 2013). Thus, the connection and co-operation between governments and other organisations is a challenge which the Thai government must find a way of addressing. Many organisations face the problem of balancing the need to make a profit with the need to reduce the environmental impact by developing products with a superior environmental outcome. What is more, new green products usually are more expensive than ‘normal’ products. Bio-plastic is a new choice for this challenge. However, producers worry about how the organisation’s activity systems can deliver value to their customers and suppliers (Iles & Martin, 2013). In addition, there is a current gap in the efficient harvesting of bio-mass and an inadequate supply chain network incorporating adequate crop storage and separating systems (Barker& Safford, 2009). Thus, the

organisations need to develop technologies and their business models to relate to customers and suppliers.

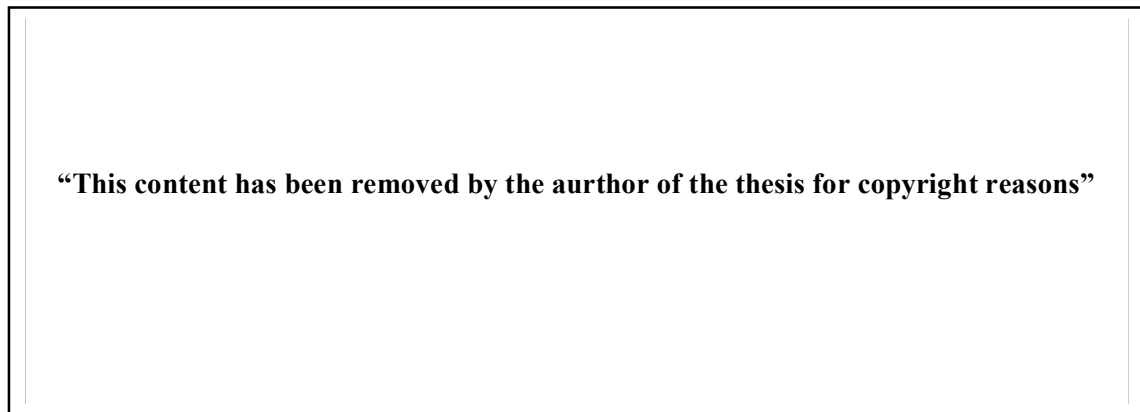
It is the hydrophilic characteristics of starch and protein-based bioplastics that constitute the main obstacle to mass production of these products which are, for the most part, environmentally friendly (Lagaron & Lopez-Rubio, 2011; Pervz & Sain; 2006). On its own, starch makes a poor material for packaging because of its brittleness and its hydrophilic nature. Polymer hydrogels are insoluble and prone to excessive swelling of the polymer when used as “selective membranes scaffolds and drug-delivery systems” (Imre & Pukánszky, 2013). In the Netherlands and France, some research and development efforts in this area of research are making progress, but the problem really requires a coherent approach (Barker& Safford, 2009). The country arguably the most well-developed sugarcane ethanol business is Brazil, but it is also a country that faces significant challenges with respect to social inclusion. The Brazilian case study is exploratory in nature, notably because the commercial use of sugarcane ethanol in bioplastic is a relatively new phenomenon (Wells & Zapata, 2011). Eric Koester (2016) demonstrates that “Packaging and labelling” is also a challenge faced by label packages for distribution abroad. Even within English-speaking countries (like England and the United States) certain phrases, marks or graphics are interpreted differently. “Legal issues” are a further obstacle many countries face when exporting products abroad. These can include rules and regulations governing the imparting of technology, medicines, biotechnology and agricultural products because they often face strict rules restricting international transactions.

### **5.1.5 Several social-cultural issues**

Social Cultural factors are important in choosing plastic use. According to George Gaskell and other researchers (2006) there are the several social philosophies in Europe about supporting bio-plastic. More than 70 percent of their research's respondent (who are Europeans) have incentives to develop bio-fuels and plastics; nevertheless, 47 percent of the respondents think that supporting bio-plastic researches is a definite responsibility of the government while the number is not very different from the number of people who are unsure or disagree with the idea. Moreover, these European respondents seem to have less desire to support bio-plastic because there only 21 percent of them are willing to pay a little extra for bio- plastics, and the other 79 percent disagree and would not be willing to pay for it. This is because people have different reasons for supporting the purchase bio-plastic.

In addition, the research of Stefan Kurka and Klaus Menrad (2009) focuses on the reasons that would motivate people to buy bio-plastics. They have surveyed the attitudes of consumers in Europe (Sweden, UK, Poland, Netherlands, Greece and Germany) towards bio-based products (See Figure 4). Important reasons include: the strengthening regional economy; getting bio-plastic at a low price; trying a new product, satisfying one's curiosity for a new product and being progressive and modern. Thus, a different strategy must be adopted in marketing bio-plastic in different markets.

**Figure 4: If I were to buy a bioplastic product it would be important for me...**



Source: Inquiry of University of Applied Sciences of Weihenstephan 2009 (Kurka and Klaus, 2016)

## **5.2 Thai Initiative: Challenges and barriers**

Thailand started to develop bio-plastic more slowly than many other countries such as United States, Europe and Japan. Thus, Thailand faces challenges that have confronted earlier bio-plastic initiatives, while Thailand has an increased need for innovative products in its plastic industry to improve its ability to compete with other countries. The United States, Europe and Japan are pioneers in the development of bioplastics (The Siam Commercial Bank, 2014). In Europe, Germany has continued to develop this business— both small and medium-sized business. They have already developed a technology of mixing additives with bio-plastics and other bio-plastic products.

(Compounding), to ensure granular plastics can move easily, as well as other features. Dr Suchinda Chotpanich (the Permanent Secretary of Ministry of Science and Technology), says that the 'Bio-plastic market in America, Europe and Japan has become bigger, and there are various bio-plastic products. Market Resource sums up by saying that the worldwide demand for bio-plastic in 2009 was 385,000 tonnes, and the main market is Europe- with 42 percent, followed by America (31 percent) and then Asia (27 percent) (National Innovation Agency, 2010b). Over half the demand for bio-plastic is in the product-group of 'Starch Base' — (66 percent), while 27 percent make up the 'Polyester Base' product-group (Plastic Intelligence Unit, 2010).

Moreover, improvement in the quality of bio-plastic to make Thailand ready for competition with other countries, means it needs personnel who are skilled in the property and technology of bio-plastic (Pattayakosal, 2010). However, the operators and end-users do not know and cannot distinguish between conventional plastics and bioplastics. Also, they often cannot recognize the environmental benefits of using bio-plastic because all stakeholders are ignorant both of the benefits of bioplastic and often cannot distinguish between it and conventional plastic (National Innovation Agency, 2010b; Phuengchaichangul, 2013).

In addition, operators of plastic Thailand also have a weakness, in the lack of research and an insufficient development of plastic products (Ministry of Industry, 2016a) including educating the prospective market about bioplastic and its benefits, as well as the technical and technological 'Know how' on PLA production. The latter is the most promising of the bioplastics (Theinsathid, Chandrachai, & Keeratipibul, 2009). The consolidated research and development of Thailand is also relatively low (ASTV online

management, 2015). Prasobsook Homhol and Yupin Kanjanasakda (2010) are currently the assistant professors of the University of the Thai Chamber of Commerce with the goal of ensuring that Thailand has enough engineers to develop the country. Nevertheless, Thailand does have quality engineers with the brains to invent tools/equipment such as insignia of their own in order to accelerate food production engineers in the energy petrochemical, bio-medical and bio-chemistry areas.

The current position of a ‘breakeven’ in the production capacity of bioplastics is not equivalent to plastics from petrochemicals. Consequently, its price is still higher (Rodtong, Deepasearchkung & Phriktavisak, 2013). Other researchers note the product market for bioplastics is, consequently, unrealized (Rodtong, Deepasearchkung & Phriktavisak, 2013; Weerathaworn, 2013b). Despite the outlook, the bio-plastic-market for growth is rather high; however, it is also attended by a high risk because bio-plastic is a new product on the market. It is just over seven years old compared with the petroleum-based plastics industry that has been over 50 years in operation (National Innovation Agency, 2010c).

In addition, consumers lack knowledge about bio-plastic. Consequently, they do not understand the importance of bio-plastic for the environment, which leads to a very small market for bio-plastic. This is because public relations about bio-plastic, including the Roadmap (the government project), have not been advertised sufficiently for the majority of the Thai people to know about bio-plastic (Pattayakosal, 2010). The conclusion from the twelfth NSTDA (National Science and Technology Development Agency) Annual Conference by the National Science and Technology Development Agency (2016a) shows that, if the population of the world increases, and greater interest in bio-

plastic is shown by many countries around the world, then bioplastic technology is the new technology wave (Plastic Institute of Thailand, 2013b). Therefore, an increased demand for food and resources will occur. The production of raw materials for biofuels will also require a large agricultural area which will be divided between the production of food and raw materials used in the production of biofuels. The result of this situation will be higher land prices and a reduced supply of food (Sanglimsuwon, 2011).

The National Roadmap faces additional problems and barriers if the Thai plastic industry becomes a bioplastic hub: expenditure must be allocated according to need as institutions apply for and receive expenditure (National Innovation Agency, 2010b). Development will have to face continual competition which increases the risks to investors (Rodtong, Deepasearchkung & Phriktavisak, 2013). The bio-plastic industry in Thailand needs around 1,000 million baht (25 million NZD) for the investment of the production of bio-plastic products from upstream to downstream; moreover, the government has no clear measures to encourage investment in bioplastics as well as lacking a proper understanding of the bioplastics industry operators and downstream users. Consequently, the use of bio-plastic is not widespread in the country (National Innovation Agency, 2010c).

It leads to development of knowledge and innovation in the national Roadmap such as the third strategy in Phase One. Thailand also finds that the quality of the bio-plastic remains lower than for plastics from petrochemicals in that it does not withstand high shear, and its rheology properties mean improper difficult moulding along with the smells still naturally attached to the product (Riebleishilrunj & Phusiemuang, 2014). In the beginning, bioplastic produced directly from starch proved limited in use because it



swells and loses its shape when exposed to moisture (National Innovation Agency & Thai Bioplastic Industry Association, 2011). Thus, bioplastics are a new material and cannot be used to create new commodities in line with the needs of the market (Borisutanagul, 2013).

In conclusion, the development of bio-plastic production in Thailand still faces many challenges and barriers such as quality, price, investment, technology, academic personnel, researches/ers as bio-plastic production. Thus, the Thai government needs to create strategies (according to Chapter 4) which can develop the bio-plastic production and address the challenges and barriers. Since 2008, the Thai government has completed about three phases of strategies, and some strategies in each phase are connected to the preceding phase and/or are created to cope with new challenges and barriers. Thus, in a next chapter, this research will analyse the relation between the National Road map's strategies and challenges/and barriers. Moreover, this research will prove how the government project can become sustainable management.

# **Chapter 6**

## **Discussion and Analysis**

This section discusses and analyses the findings from Chapters 4 and 5 by referring to the principles of sustainable management. In addition, this section explores how the strategies in Chapter 4 connect to the main challenges and barriers in Chapter 5. The discussion and analysis are presented in five topic areas: sustainable management, National Roadmap strategies, challenges and barriers, sustainable strategies management and strategies for the challenges and barriers.

### **6.1 Sustainable Management**

The National Roadmap in Thailand has stated its ambitions about sustainability in management. Consequently, it has designed strategies to pay attention to plastic waste pollution, to limit natural resources, along with the country's income and, finally, the quality of people's lives. The National Roadmap involves sustainable management for plastic pollution by moving away from traditional plastic to bio-plastic. Bio-plastic is a useful solution for environmental problems, including plastic waste pollution and the over-use of petroleum, which is a limited resource. Bio-plastic has the advantage that it is also produced from natural materials (such as sugar cane, corn, wheat, potato, sweet potato and cassava), and is designed to be degradable. Thus, bio-plastic is friendly to the environment (Hitchcock & Willard, 2015).

In addition, it is sustainable and meets people's needs through its limited nature while not compromising the capability of meeting the needs of future generations. In general, sustainable management is concerned with three areas: economy, the society

and the environment (Hitchcock & Willard, 2015; Young & Dhande, 2013). However, sustainable management in the National Roadmap means combining these different goals together. Instead of trading these realms off against one another— (“Jobs or the environment; economic growth or environment and health; development or habitat”)—the aim of sustainability is to optimise all three of what businesses have long referred to as the triple bottom line’ to optimize all three (Hitchcock & Willard, 2015, p 8). The National Roadmap uses materials which are natural, able to be replaced, and degradable. Therefore people (including current and future generations) can have their needs met without negative effects, and the National Roadmap provides sustainable management in the three areas: of environmental growth, economic growth and development of the habitat/community.

## **6.2 National Roadmap’s strategies**

The strategies of the National Roadmap are designed to support the bio-plastic industry in Thailand, and they can be divided into five development areas:

- **Bio-plastic development** which needs to increase the amount of bio-mass raw materials to dampen the increased-demand of agricultural products in future. Thus, the Thai government has invested in 100 million baht in the first strategy of Phase One for increasing crop yields and management plantations efficiency. In Phase two, the first measures as well as commercial measures, such as the availability of biomass feedstock, conform to this development area.

- **Technology co-operation** mainly aims at research and development (about bio-plastic) with other core-organisations both inside and outside Thailand. According to the second strategy in Phase One, it promotes and supports the importing or purchase of technology among industrial enterprises and companies owned by foreign technology; moreover, its direction and support research grants and research are aimed at integration in order to further develop and improve the technology.

- **Economic co-operation** is investment in bio-plastic involving internal and external organisations such as outlined in the second strategy in Phase One. It co-ordinates groups of Industrial enterprises and companies which are foreign-owned, technological industries and also directs and supports research grants, as well as conducting research.

- **Knowledge/ innovation** is part of the third strategy in Phase One, and it helps to develop knowledge, innovation and industry for possible bio-plastic products. The Thai Industrial Standards Institute and National Innovation Agency draft ensures that standard plastics decompose biologically, based on international standards of ISO 13485 and ISO 17088: 2008.

- **Public Education/ marketing development** is designed for Phases Two and Three. In Phase Two, the last of these measures of the commercial stimulus involve the preparation of policies, plans and budgets in the process of preparation of the pilot project, along with the campaign to disseminate knowledge. In the last Phase, one strategy supports environmental awareness in the global market and investment in bio-plastic. Moreover, another strategy aims at improving people's knowledge of orientation to manage bio-waste effectively. The third strategy in Phase One supports

internal and external marketing in Thailand, and emphasises 'Expos' in promotions with companies in Thailand and other countries in order to attract investors and consumers.

### **6.3 Challenges and Barriers**

The National Roadmap must design for an increasingly enhanced green-product by developing bio-plastic, and it is able to draw on a wide variety of techniques to cost-effectively design a green product. However, the research has found two themes of challenges/and barriers to the National Roadmap which are the project's infrastructure management and environmental performance (See Table7).

#### **6.3.1 Themes One: infrastructure management**

The technological infrastructure of Thailand still needs improvement and development to improve bio-plastic's quality, production costs and continued research. This is because bio-plastic has a short life of only about 90-180 days (Dituro & et al., 2010). The Bio-plastic has to replace the identical processing and performance specifications of conventional polymers (Iles & Martin, 2013). Thailand has only a limited capacity to produce bio-plastic because of the high costs of material development there (Perviaz & Sain, 2006). In addition, other factors are operative, such as insufficient research and development of plastic products, a lack of education of the prospective market and limited technical production of bio-plastic (Ministry of Industry, 2016a). In the industry/marketing area, apart from users, the Thai government has passed no clear measures to encourage investment in bio-plastic. The outcome is that bio-plastic use is not widespread in Thailand (National Innovation Agency, 2010c). For successful development and marketing of green products, there must be a way of ensuring they are green, and a way must be found to sell the products competitively in spite of the high

cost of developing new processes (Dangelico and Pujari, 2010). Finally, neither the end-users nor the operators are able to distinguish between bio-plastics and their conventional rivals. The stake—holders are unable to perceive the benefits to the environment of using and making bio-plastic as a preferred option (National Innovation Agency, 2010b; Phuengchaichangul, 2013). In addition, most Thai people are ignorant of the existence of bio-plastic because of inadequate publicity about it or about the Roadmap itself (Pattayakosal, 2010).

### **6.3.2 Themes Two: environmental performance.**

To ensure that bio-plastic will not have a negative adverse environmental impact through the entire process of production is yet another challenge to be faced. Consequently, it is important that product managers and environmental specialists are found, capable of assessing and measuring environmental effects at each stage of the process and production (Dangelico and Pujari, 2010). A second problem arises because environmental factors impinge on biodegradation, especially in landfills after closure (McDougall, 2007). Finally, although these plastics cannot break down in natural conditions, people often expect a compost pile of bio-plastic in their backyard to break down in 90 days, but this is possible only in a large composting facility not available to most people. The implication is that most bio-plastics will end up in landfills which rarely meet the perfect condition required for degradation (Maheshwari, Rain, Parihar & Sharma, 2013).

**Table 7: the process of designing themes for discussion and analysis of Research Question**

Two			
References	Quotes	Codes	Themes
<b>Dituro &amp; et al., 2010</b>	1	Need improvement and development bio-plastic's quality, production costs and continued research.	1. Infrastructure management
	2	Bio-plastic has a short life, but is able to meet agriculturists' needs.	
<b>Perviaz &amp; Sain, 2006</b>	3	The high costs of material development	
<b>Ministry of Industry, 2016a</b>	4	A lack of education of the prospective market and limited technical production of bio-plastic	
<b>Dangelico and Pujari, 2010</b>	5.	Selling the products competitively in spite of the high cost of developing new processes	
<b>National Innovation Agency, 2010b; Phuengchaichanul, 2013</b>	6	End-users not the operators are able to distinguish between bio-plastics and their conventional rivals.	
<b>Pattayakosal, 2010</b>	7	Most Thai people do not know about the existence of bio-plastic	2. The environment performant
<b>Dangelico and Pujari, 2010</b>	8	Having product managers and environmental specialists for checking the impact to the environment of each process in bio-plastic production.	
<b>McDougall, 2007</b>	9	Unsure biodegradation, especially in landfills after closure	
<b>Maheshwari, Rain, Parihar &amp; Sharma, 2013</b>	10	Bio-plastic cannot always break down in landfill, but has to use large composting for break it down.	

Table 7 shows show the research analysis of the themes of challenges and barriers to bio-plastic management

## 6.4 Sustainable Strategy Management

The overall strategy of the National Roadmap is to move the green debate in the right direction through the application of business principles which emphasise the contingent nature of environmental investments (Orsato, 2009). The reason that the government of Thailand has invested in developing the bio-plastic industry is both to improve the quality of plastic production and to use bio-plastic which will not be environmentally destructive. Its management view differs from the traditional one of the industrial-age in that the traditional one focused on the economy more than society and environment (Young & Dhande, 2013). On the other hand, the strategies of the National Roadmap aim at three lines— the economic, the social and the environmental which, collectively, are called the ‘**Triple Bottom Line (TBL)**’ (Figure 5).

Triple Bottom Line is a form of reporting that states that the businesses’ (including every investment) responsibility extends to all of its stakeholders not merely to its shareholders (Young & Dhande, 2013). It means society, the environment and the economy must all be included. Although the National Roadmap is a government project without shareholders, it operates alongside many private companies, the university and farmers, Thus, the Thai government remains aware of its triple focus on the economy, society and the environment. This is because the strategy is designed to connect the operations and outcomes for the economy, society and the environment. Consequently, the National Roadmap’s strategies are used for developing all the 3P terms such as the planet, profit and people (Young & Dhande, 2013). This research will compare the 3Ps with expectations arising from the National Roadmap.



1. In the first place, environmental growth involves **the protection of the planet**. For Thailand, importantly, the National Roadmap aims to develop the environment because bioplastic is a good method for developing and creating new environmentally-friendly products such as bio-plastic, in order to manage plastic waste pollution (National Innovation Agency, 2015a; National Innovation Agency & Thai Bioplastic. Industry Association, 2011). One writer believes that replacing petroleum-based plastics, in part, with bio-plastics is a realistic strategy towards sustainability (Piemonte, 2011). By reducing the dependence on petroleum products and saving energy, bio-plastic is beneficial to the environment and reduces environmental pollution from petroleum products because bio-plastic is also mainly produced from fruit and vegetables like corn, cassava and soy protein (Mohanty & et al., 2005; Institute for the Promotion of Teaching Science and Technology, 2014). Considerable energy can be generated by replacing conventional plastic with bio-plastics since the latter is produced from renewable sources. Moreover, bio-plastic can make savings in greenhouse gases (GHGs) emissions (Piemonte, 2011).
2. Profit derives from **economic growth** because bio-plastic production in Thailand is responsible for increasing the quality and value of agricultural products which the country has always exported overseas by transformation from agricultural products to bio-plastic, and also supporting marketing, which increases people's awareness of bioplastic use, both inside and outside Thailand. Thus, if Thailand can become a bio-plastic hub of production, it can also export bio-plastic to other countries, further leading to increased national income (Plastic Institute of Thailand, 2013a). The profit motive has had an effect on the rising number of bioplastic manufacturing plants which have appeared in the bioplastics industry and related businesses, providing

about 200,000 million baht (\$ 8,000 million NZD) of revenue and 6,260 million baht (\$ 250.4 million NZD) in tax revenue to the Thai government (National Innovation Agency, n.d.a; National Innovation Agency & Thai Bioplastic Industry Association, 2011).

3. When environmental economic growth is successful, it will increase **the social developmental habitat**, including the quality of people's lives. Thailand is a society of income inequality, especially in agriculture. There are 2.879 million poor agricultural households. This is because the National Roadmap focuses on creativity in order to design plastic products of a higher value; moreover, it increases the value of agricultural products and demand (National News Bureau of Thailand, 2016). However, the Thai government will face high cost food costs because of the greater demand for agricultural products demand. Consequently, the first strategy in Phase One is designed to meet the high demand for agricultural products/or food in the future. Finally, the National Roadmap supports people's knowledge about using plastic, aiming at increased use and development of bio-plastic (National Innovation Agency, 2010d). The Roadmap is able to protect the environment and people's habitat from social problems. A practical situation is when bad drainage causes clogging, resulting in the flooding caused by debris trapped by heavy rain (Pollution Control Department, 2005).

**Figure 5: Triple Bottom Line**

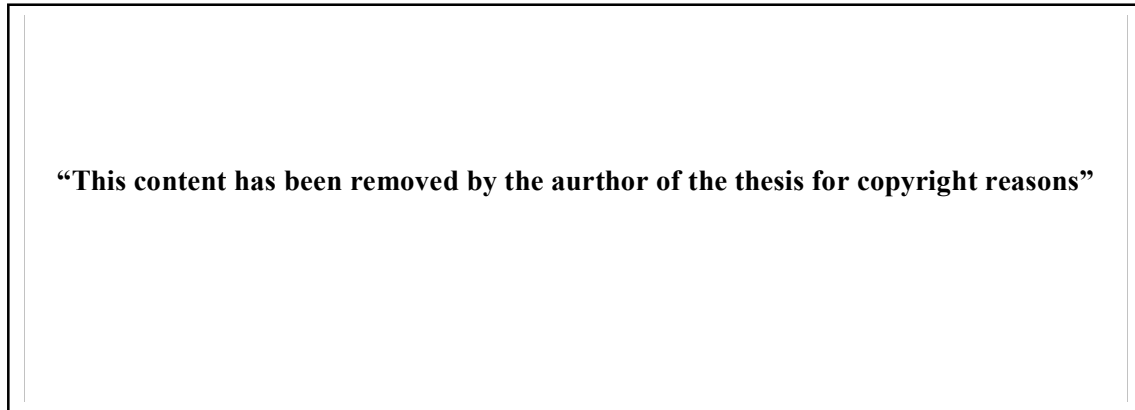


Figure5: It is a picture of 'Triple Bottom Line' that show the relative of society environment and economic.

## **6.5 Strategies for the Challenges and Barriers**

Many strategies are being used in the implementation of the Roadmap for National Development of the Bioplastics Industry Phase One and Two (2551-2558BE or 2008-2015AD) by the National Legislative Assembly (Thailand) and government agencies (National Innovation Agency, 2015b). However, because of present and possible future challenges, the Thai government has recently established a project to help the Thai plastic industry towards becoming a bio-plastic hub. Thus, this research has discussed and analysed the data from these strategies to show how the Thai government addresses the challenges and barriers in the project by comparing strategies which are being used to address the challenges and barriers according to three main themes: accelerating the

development of technology and technological co-operation; building an innovative industry and businesses throughout; and building infrastructure (National Innovation Agency, 2015b) (See Table 8).

**Table 8: The theme of coping challenges and barriers by the strategies**

Strategies themes	Challenges and barriers theme	Strategies adopted to cope with barrier and challenges
<b>1. Bio-plastic development</b> <b>2. Technology co-operation</b> <b>3. Economic co-operation</b>	1. Infrastructure management	1. Accelerating both co-operation and the development of technology 2. Building innovative industry and businesses
<b>4. Knowledge/ innovation</b> <b>5. Public Education/ marketing development</b>	2. The environment performants	3. Building infrastructure

Table 8 shows how to match strategy themes along with the challenges and barriers theme, and indicated how to create classifications for addressing challenges and barriers.

### **6.5.1 Accelerating both co-operation and the development of technology**

According to Jan-Olaf Willums (1998), there is a widely recognized and critical need in transition economies and developing countries demonstrated by the multitude of government— sponsored technology transfer initiatives. He also indicates the importance of technology transfers for business so that the technology can be put into practice immediately, with immediate results.

- **Acceleration —technological cooperation:** The Thai government focuses on technology as a means to develop bio-plastic because of problems concerning the lack of research and development of a bio-plastic technology. These problems can be addressed by cooperating with other countries, which will bring an improved bio-plastic technology for the development of bio-plastic in Thailand, as well as personnel who are skilled in the properties and technology of bio-plastic (Pattayakosal, 2010). Thus, in the second strategy in Phase One, the Thai government (like PTT) has co-operated with MCC to set up a new company using the bio-plastic plant species Polybutylene Succinate (PBS), where sugar is the raw material (PTT Public Company Limited, 2011; Technology Promotion Association (Thailand-Japan), 2010). At present the cooperation just involves researchers but it is leading to bio-plastic production from sugar. Moreover, 38 lecturers from industrial sectors and research sectors are also helping Thailand in the development of a technology that will increase the quality and efficiency of bio-plastic (The Siam Commercial Bank, 2014).

- **The further development of new technologies and the creation of bioplastics:** Bio-plastic quality still has problems since bio-plastic cannot be used for every business such as agriculture because it has a short age-use, and because some biopolymers have a lower material performance in respect to shear sensitivity, thermal instability and melting strength (Iles & Martin, 2013; Lagaron & Lopez-Rubio, 2011). New technologies and the creation of bioplastics in Thailand are important (National Innovation Agency, 2015b), and the first strategy in Phase Two aims to develop the quality of bio-plastic. Bio-PBS also can produce a large quantity of its biodegradable bio-plastic which can be sealed with heat, including the ability to operate at high temperatures (Rodtong., Deepasearchkung, & Phriktavisak, 2013; Iles & Martin, 2013; Lagaron & Lopez-Rubio,

2011). The measures in Phase Three continually aim at evolving strategies to increase the value of units of plastic product and at focusing on the promotion of knowledge via research and creativity, in order to design plastic products of a higher value. The last Phase aims to focus on the quality of bioplastic. Consequently, the Quaid Company's bioplastic industry uses technology to support various applications of the properties of bioplastics products (National News Bureau of Thailand, 2016).

### **6.5.2 Building innovative industry and businesses:**

The Thai government has to encourage innovation for bio-plastic products since, successfully introducing a new product, process or business model, will act as a powerful engine in the competitive arena. Also, essential in the innovation process is investment by entrepreneurs since they will be the agents of change in the competitive system by figuring out how to use inventions, as well as introducing-new formats, processes, products and services (Rothaermel, 2015).

- **Grants to support the development of innovative projects:** Expenditure is a further barrier because the government must ensure that all strategies can receive a sufficient budget. In this matter, institutions must receive aid according to need (National Innovation Agency, 2010b). The Thai government provides the budget for each strategy to its co-operatives and agents. To accelerate technological development and technological co-operation strategies (the second strategy in Phase One), there is a budget of about 1,000 million baht (40 million NZD) (The National Science and Technology Development Agency, 2008c; National Innovation Agency, 2008d). The next phases (Two and Three) will assess which strategies need more development and expenditure allocated. The last strategy of Phase One pushes for an infrastructure to

support and strengthen the Bioplastic industry in the test laboratories (The Siam Commercial Bank, 2014).

- **Supporting investment in the bioplastics industry:** As well as lacking a proper understanding of the operations in the bioplastic industry and of the downstream users, the government has no clear measures to encourage investment in bio-plastics. For these reasons use of bioplastics is not widespread in Thailand (National Innovation Agency, 2010c). In the second phase, the implementation of the action plan to promote investment in bioplastics is designed to involve the incorporation between private and government organisations /industries which will support Thailand in confronting earlier bio-plastic initiatives, while satisfying the increased need for innovative products in the Thai plastic industry so that it is better able to compete with other countries (The Siam Commercial Bank, 2014).

- **Creating a network of cooperation with industries:** While Thailand has an increased need for innovative products in its plastic industry in order to improve its ability to compete with other countries, it faces challenges that have confronted earlier bio-plastic initiatives. ‘The United States, Europe and Japan are pioneers in the development of bioplastics’ (The Siam Commercial Bank, 2014). Thus, Thailand needs help and cooperation from these other countries in order to develop bio-plastic technology. Consequently, the third strategy in Phase One also supports foreign-owned industrial enterprises and companies who have already created industrial pilot plants to produce Mercury Monterey and polymers suited to Thailand (The National Science and Technology Development Agency, 2008c).

- **An initiative to create markets for bioplastic products both at home and abroad:** The Thai government needs to solve the challenges and overcomes barriers in that it aims to initiate the market for bio-products and to promote bio-plastic as a significant product in the plastic market. Also, Thailand must simultaneously confront earlier bio-plastic initiatives, while satisfying the increased need for innovative products in the Thai plastic industry, so that it is more competitive internationally (The Siam Commercial Bank, 2014). Significantly, Thailand's limited capacity to produce bio-plastic is a key factor (along with the high cost of material development) in the high prices for the basic raw material of bio-plastic. Therefore, both challenges have impacted the price (Perviaz & Sain, 2016). The development of marketing in the second strategy in Phase One can help contribute to a competitive price in the market because the bio-plastic price is still higher than for normal plastic (The Siam Commercial Bank, 2014). Moreover, the third strategy of Phase One will help to support internal and external (Thailand) marketing in the form of 'Expos' by encouraging producers to join fairs abroad and to participate in promotions with companies in Thailand and abroad (National Innovation Agency, n.d.b).

### **6.5.3 Building infrastructure:**

This part involves designing measures to support the bio-plastic hub project and increasing social awareness of bio-plastic and bio-materials. The measures of this project are measuring capability performance by identifying possible strategies and capabilities, accompanied by a certainty that their product is really competitive (Hubbard, 2004). Furthermore, infrastructural knowledge for a new product in the market and in industry



needs expansion, to make people understand the importance of the product for the environment, society and the economy.

- **Creating policies and measures to support the use of bioplastics:** The general challenge in the green industry is that each company will have different motives for developing green products, and consequently must develop their own sustainable strategies for the environment. These, in turn, must continue to grow “under any policy of regulation” (Dangelico &Pujari, 2010). Thus, the last strategy of Phase One proposes, by means of new legal policy incentives to support the bio-plastics industry and to encourage consumption of bio-plastics because they are environmentally—friendly products (The National Science and Technology Development Agency, 2008c). The third strategy of Phase Two is to solve the allocated expenditure by dividing commercial measures into five small measures: enacting measures to ensure the availability of biomass feedstock; passing measures to support research and development; measures to prepare standards for bioplastics; measures to benefit investment and entrepreneurship; measures to promote a market environment (National Innovation Agency, 2010d).

- **To raise awareness and understanding of bioplastics and biomaterials:** The distinction between conventional and bioplastic is not discernible to producers and end-users. Nor can they always recognize the benefits to the environment of using bioplastics since all stakeholders frequently fail to distinguish between the two types of plastic and are ignorant of the benefits of bio-plastic (National Innovation Agency, 2010b; Phuengchaichangul, 2013). The Thai government uses the first strategies in Phase One to: provide insights linking farmers to agricultural crops for raw materials

in the production of bioplastics; to select interbreeding species, along with the transfer of technology to increase crop yields; to recommend that farmers use inputs and appropriately include knowledge and understanding for the farmers of the importance of bioplastics (Pintong, 2010). Moreover, Phase Three prepares to meet needs for the availability of raw materials in the production of bioplastics which can be used in various industries in the future (Ministry of Industry, 2016b). The third strategy of Phase Two also has a measure providing a budget to involve the preparation of policies, plans and budgets in the process of preparation of the pilot project, along with the campaign to disseminate knowledge. It also raises awareness by encouraging people to use more biodegradable plastic products (National Innovation Agency, 2010d).

## **Chapter 7**

### **Conclusion**

Nowadays, plastic waste pollution in the world causes people to face environmental problems. The popular solutions are reducing, reusing and recycling. Nevertheless, Thailand has chosen a different, but valuable solution to the problem of plastic waste. The solution is to replace conventional plastic with bio-plastic by making the National Roadmap project.

The National Roadmap creates strategies which are operationally divided into Phases One, Two and Three of the project. All three phases focus on the development of five areas of the bio-plastic industry; namely bio-plastic development, technology co-operation, economic co-operation, knowledge/and innovation, and public education/and marketing development. Furthermore, the National Roadmap's strategies focus on sustainability and it aims at enabling Thailand to become a bio-plastic hub. Importantly, it includes strategies designed for meeting challenges and barriers which the National Roadmap is likely to face according to three main themes: accelerating the development of technology and technological co-operation; building an innovative industry and businesses throughout; and building.

In addition, the challenges and barriers of the National Road map have two main themes: infrastructure management and environmental performance. The challenges and barriers of infrastructure management involve the problems of the high cost of bio-plastic material and technology as production, leading to the high price of bio-plastic. Moreover, Thailand lacks bio-plastic technology including research and development into bio-

plastic, Consequently, co-operation with other countries is another challenge. Lack of knowledge by both consumers and manufacturers of the merits of bio-plastic and of the pollution caused by conventional plastic must also be overcome if the necessary development is to occur. Another theme focuses on the environment because even bio-plastic still faces problems of an adverse environmental impact and finding a suitable way for degradation to happen.

However, the strategies in the three phases of the National roadmap still have risks in operation. The reason is that Thailand has a smaller number of bio-plastic products when competition with other developed countries such as the United States, Europe and Japan. Also, the strategies in Phase Three will face the risk of addressing the quality of bio-plastic because it is still lower than normal plastic such as petrochemicals in that it does not withstand high shear. Thus, it will also be necessary to improve personal skills in technology and to improve the properties of bio-plastic as Thailand has to continually cope with property's skill problems from Phase One to Phase Three. Another risk to solve is the barrier from people including investment because they lack knowledge about bio-plastic and do not understand the importance of protecting the environment. Furthermore, bio-plastic development may lead to higher land prices and a reduced supply of food.

Moreover, the National Roadmap is a sustainable management programme because this project is not only an environmental solution, but it also focuses on development of the economy and the social fabric. Thus, the National Roadmap involves sustainable management which lessens the negative effects on all stakeholders. The programme brings together social, economic and environmental sustainability, and it is often referred

to as Triple Bottom line sustainable management because the outcomes and expectations arising from it can be understood as an attempt to balance concerns for the economy, society and the environment.

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