DEVELOPING A BIOECONOMY IN THAILAND

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ABSTRACT

With a growing world population, we face a range of challenges including environmental and socio-economic problems, and energy instability over the next decades. The worldwide demands for increased healthcare and more agricultural products such as food and animal feed, bioindustry and bioenergy are increasing in many countries, including Thailand. The increasing demands are the major economic driving force behind developing a large and rapidly growing segment of the world bioeconomy. The bio-based or bio-economy is based on the economic activities fueled by sustainable production and conversion of renewable biomass for a range of food, health, industrial and energy products. The research and innovation in the biological sciences are powerful tools playing an important role in overcoming those challenges to create public benefits and well-being. Investment and bioeconomic policy emphasize increasing food and energy security, reducing greenhouse gas emission, and growing new jobs and industries.

Currently, the bioeconomy growth faces various challenges. The increasing demands for food, fuels and biomaterials in the context of an expanding human population result in the food versus non-food debates and the biomass feedstock competition between energy and materials that still needs to be fixed. GMOs technologies applied in economic crops worldwide have met strong opposition from national policy and consumers. The development of innovation bio-based products is the research and development intensive, resulting in increasing production cost. If Thailand has still a very low spending on research and development (≤0.24% of GDP), this would be a big challenge for developing novel bio-based products and the initial construction of biorefinery pilot plants. Strategic objectives for a bioeconomy with the potential to facilitate economic growth and meet societal needs includes 1) support R&D investment providing the foundation for the future bioeconomy development, 2) develop and improve regulatory processes and regulations, 3) improve incentive measures for investment, 4) develop infrastructure systems and support instruments, 5) develop a Qualified Human Resource System in fields related to biotechnology.

With its new strategy for 2021, the Royal Thai Government has created a framework through which to accomplish the purposeful series of goals including economic, social and environmental by the end of this decade. Thailand has made positive progress over the past few years in the different domains of the bioeconomy, both in terms of research and supportive policy development. Over the next 10 years, we can expect to see a shift in practice from a sectoral approach towards a more integrated approach to the bioeconomy growth with large public benefits. Therefore, there must be consistency across policies and product sectors, combined with the political momentum to ensure that this goal is placed in the top priority of the national development plan. The potential benefits for the economy, the environment and society as a whole will be achieved through collaboration of all stakeholders to make the Thai bioeconomy a reality.

Keywords: bioeconomy, sustainable development, bioenergy, biobased products
INTRODUCTION OF BIOECONOMY DEVELOPMENT

With an increasing global population moving towards 9 billion by 2050 (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2009), the world is facing a number of social, economy, and environmental crises. More natural resources were consumed and rapidly depleted, especially depleting fossil resources. As a result, this has accelerated the increasing environmental pressures and climate change caused by high greenhouse gas (GHG) emissions. In 1970-2004, greenhouse gas emission increased about 70% (Langeveld et al., 2010). In addition, the needs for increased health services and more resources currently have occurred worldwide including food and animal feed, fibers for clothing, and housing, sources of energy, and chemical for manufacturing. With a dependence on biorenewable resources, the bio-based or bio-economy has been accepted that could offer a unique opportunity to address those complicated crises and to meet the basic needs of life (i.e. food, clothing, shelter, and medical care etc.). So far, mechanisms and processes at the genetic and molecular levels and its application to industrial process have considerably understood and made major socioeconomic contributions in countries. The set of economic activities derived from a number of biological sciences and biotechnological research refer to as bioeconomy. A number of advanced biotechnology (i.e. systems biology, genomics, proteomics, DNA technology, synthetic biology, cell factory, and DNA chip) are playing a key role in developing agriculture, health, chemical, and bioenergy industries. These advanced technologies add value to a host of biobased products and services, boosting the productivity of agricultural products and then agribusiness, and enhancing environmental sustainability (OECD, 2012). Therefore, IEA (2004) reported that the bioeconomy would be able to considerably contribute to reduce greenhouse gas emissions, raise energy supply and reduce dependence on foreign petroleum source, enhance rural development, and protect of ecosystem services and improve environmental concerns. The bioeconomy growth can provide diverse pathways towards the achievement of these goals. The advancement of research and development in biological technologies offers the potential to accelerate its transition to a more sustainable growth model while making Thailand competitive in the future bioeconomy capable of creating new jobs, in rural as well as urban environments.

KEY AGRICULTURAL PRODUCTS FOR A BIOECONOMY IN THAILAND

Thailand is one of the world’s major agricultural countries with 24.4 million hectares of farm land (Office of Agricultural Economics [OAE], 2012). Agricultural products were accounted for 11.7% of exports and generated nearly US$4.5 billion of Thailand’s agricultural trade surplus (OAE, 2011). The major crops (the top export commodity) of Thailand include rice, para rubber, cassava, oil palm, sugarcane and corn. The value of exports are 6.53, 22.631, 2.1, 0.54, 3.6, and 0.1 billion US dollars respectively (OAE, 2010). In addition to conventional agricultural products as food and feed, biobased products derived from biomass have played an important role in the emerging bioeconomy in the near future (Van Haveren et al., 2007). The biobased product is made from biological materials in whole or in some important part derived from living organisms. They include high-value added fine chemicals (e.g. pharmaceuticals, cosmetics, food additives, and vaccines etc.) to high volume materials (e.g. enzymes, biopolymers, biofuels, fibers etc.) (Langeveld et al., 2010).

Of biobased products, biomaterials and biofuels are significant products that are receiving more attention and agree with Thailand’s National Biotechnology Policy (National Center for Genetic Engineering and Biotechnology [BIOTEC], 2005).

A. Biomaterials in Thailand

The potential biomaterials receiving more attention include pharmaceuticals, chemicals, biopolymers and fibers (Thoen and Bush, 2006). A bioplastic, a prospective biomaterial made from cassava could be used for a number of industrial processes in Thailand. As industrial raw materials,
converting cassava roots into secondary products in particular biobased materials (polylactic acid, PLA) has been estimated that it can add about 150% of the value (USD 2,533 million) (Fig. 1). In addition to PLA, other biomaterials including polyhydroxyalkanoate (PHA) and starch plastic (KU-Green) made from cassava starch (Sudarat et al., 2006) will compete with fossil polymer (PET) in the future.

![Cassava value chain in Thailand.](image)

**Fig. 1.** Cassava value chain in Thailand.


### B. Bioenergy in Thailand

In Thailand, the potential of cereal biorefinery for bioenergy production is restricted by the government perceptions of cereals as food and feed. Sugarcane and cassava are major crops used for bioethanol production. As the largest producer in South-East Asia, Thailand allocated around 1.28 million hectares of farm land for sugarcane with about 98 million tons of yield in 2012 (OAE, 2012). The production of sugarcane was 28% higher than that in 2010. This is likely due to a sugarcane development plan for ethanol production devised by government. With the low costs and energy used for producing the crop, cassava is accepted as one of the highest potential raw materials for bioethanol production (Silalertruksa and Shabbir, 2009). Thailand, the world’s third largest grower of cassava, allocated around 1.2 million hectares for cassava cultivation with around 22 million tons of yield in 2011 (OAE, 2011). Whereas sugarcane and cassava are grown as main raw materials for bioethanol production in Thailand, many types of lignocellulosic biomass is currently receiving more attention. Lignocellulosic biomass available and used potentially include rice husk, straw, bagasse, cassava pulp, corncob and corn leaf, oil-palm fruit brunch, shell and fiber, as well as wood chip. The surplus biomass can potentially be produced to 11,938.67 ktoe of energy annually (Table 1).
Oil palm is the major crop used for biodiesel production due to low cost and energy requirements. Ministry of Agriculture has formulated a development plan to increase the production of palm oil to meet increasing demands by 2011. The plan called for the adoption of strategies including genetic improvement, better practice management, and also allocating more lands for oil palm plantation (Pleanjai and Gheewala, 2009). As a result, the palm oil production was increased from 8.2 million tons in 2009 to 10.7 million tons in 2011. Moreover, other raw materials (such as used cooking oil; and oils extracted from castor, sunflower, and jatropha) have accepted as potential candidates for biodiesel production in Thailand (Surin et al., 2007).

Table 1 The potential of biomass feedstock in Thailand in 2009.

<table>
<thead>
<tr>
<th>Species</th>
<th>Yield (MT)</th>
<th>Biomass</th>
<th>Biomass availability (MT)</th>
<th>Heat value (MJ/kg)</th>
<th>Energy potential (TJ)</th>
<th>Energy potential (ktoe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane</td>
<td>66,816,446</td>
<td>Bagasse</td>
<td>4,190,794</td>
<td>14.40</td>
<td>60,347.44</td>
<td>1,428.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shoot and leaves</td>
<td>13,439,727</td>
<td>17.39</td>
<td>233,716.86</td>
<td>5,532.52</td>
</tr>
<tr>
<td>Rice</td>
<td>31,508,364</td>
<td>Husk</td>
<td>3,510,598</td>
<td>14.27</td>
<td>50,096</td>
<td>1,185</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Straw</td>
<td>25,646,547</td>
<td>10.24</td>
<td>262,620</td>
<td>6,216</td>
</tr>
<tr>
<td>Corn</td>
<td>4,616,119</td>
<td>Cob</td>
<td>584,539</td>
<td>18.04</td>
<td>10,545</td>
<td>249</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stem and leaves</td>
<td>2,758,777</td>
<td>18.04</td>
<td>49,768</td>
<td>1,178</td>
</tr>
<tr>
<td>Oil palm</td>
<td>8,162,379</td>
<td>Empty bunch</td>
<td>1,024,868</td>
<td>17.86</td>
<td>18,304</td>
<td>433</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fiber</td>
<td>162,970</td>
<td>17.62</td>
<td>2,871</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shell</td>
<td>38,959</td>
<td>18.46</td>
<td>719</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leaf stalk</td>
<td>2,203,740</td>
<td>9.83</td>
<td>21,824</td>
<td>516</td>
</tr>
<tr>
<td>Cassava</td>
<td>30,088,025</td>
<td>Stem</td>
<td>2,439,236</td>
<td>18.42</td>
<td>44,930</td>
<td>1,063</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rhizome</td>
<td>1,834,466</td>
<td>18.42</td>
<td>33,790</td>
<td>799</td>
</tr>
<tr>
<td>Coconut</td>
<td>1,380,980</td>
<td>Leaf stalk</td>
<td>628,990</td>
<td>15.40</td>
<td>9686</td>
<td>229</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fiber</td>
<td>464250</td>
<td>16.23</td>
<td>7534</td>
<td>178</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shell</td>
<td>128936</td>
<td>17.93</td>
<td>2311</td>
<td>54</td>
</tr>
<tr>
<td>Para rubber</td>
<td>3,090,280</td>
<td>Branch/stem</td>
<td>312,118</td>
<td>14.98</td>
<td>4,675</td>
<td>110</td>
</tr>
<tr>
<td>Total</td>
<td>145,853,073</td>
<td></td>
<td>59,539,905</td>
<td></td>
<td>504,339</td>
<td>11,938.67</td>
</tr>
</tbody>
</table>

Source: modified from Department of Alternative Energy Development and Efficiency (2009)

**PERSPECTIVES ON BIOECONOMY DEVELOPMENT**

For the bioeconomy’s success, various challenges must be addressed through coordinated policy action by governments. Recently, The White House in the U.S. has released a National Bioeconomy Blueprint called as a comprehensive approach to harnessing innovations in biological research. The goals are to address national challenges in health care, food, energy, and the environment (The White House, 2012). In Europe, the EU commission has proposed strategies to shift the EU economy towards a bioeconomy for sustainable growth with a more innovative and low CO2 emission (Clever Consult BVBA, 2010).

For Thailand, it is the fact that there is a biodiversity, an abundance of biomass feedstocks accounting for 145,853,073 MT/yr, approximately. Most biomass are crop residues derived from starch crops (such as sugarcane, rice, cassava and corn), oil crops (such as mainly oil palm and coconut) and trees (such as para rubber) (Table 1). In addition, Thailand has the capacity to develop significantly a new innovative technology relating to biological science supported by the National
Economic and Social Development Board (NESDB), the National Science and Technology Development Agency (NSTDA) and other relevant agencies. Yearly, the major export commodities of Thailand are produced from farm households. As a result, the Royal Thai government has foreseen the potential of bioeconomy towards the development of country.

GOALS OF BIOECONOMY DEVELOPMENT IN THAILAND

For bioeconomy development, Thailand’s National Biotechnology Policy Framework (Phase I: between 2004 and 2011 and Phase II: between 2012 and 2021) has set up by the National Economic and Social Development Board (NESDB), in collaboration with the National Center for Genetic Engineering and Biotechnology (BIOTEC), and the National Science and Technology Development Agency (NSTDA) (National Center for Genetic Engineering and Biotechnology, 2005). The frameworks are to encourage in developing biobusiness and investment in biotechnology research.

There are key six goals of the framework as following:
1. “Emergence and Development of New Bio-Business”
2. “Biotechnology Promotes Thailand as Kitchen of the World”
3. “Thailand Represents Healthy Community and Healthcare Center of Asia”
4. “Utilization of Biotechnology to Conserve the Environment and to Produce Clean Energy”
5. “Biotechnology as the Key Factor for Self-Sufficient Economy”

NATIONAL STRATEGIES FOR BIOECONOMY DEVELOPMENT

To generate economic growth and meet the goals, summarized below are the strategic objectives and the next steps helping realize the full potential of the Thai bioeconomy. In 2007, Thai government granted USD 120 million for investing in biotechnology research and development (Fig. 2). The research funding was allocated to public research centers (46%), academic institution (39%), and private sectors (15%). National Research Centers of Thailand primarily encouraged the research in fields of genetic engineering and biotechnology, medical development, science and technology development, agro-industrial products improvement, rice science, etc.

Fig. 2. The distribution of research and development (R&D) funding in biotechnology in Thailand by sectors.

Source: modified from BIOTEC (2005)
A. Develop and improve regulatory processes and regulations

The regulatory processes and regulations were improved to create an environment and incentives for venture capital to be invested in bio-business. For example, agencies prepared and utilized scientific data from research in decision-making, laying down key measures, and negotiating or solving trade barrier problems. Developing a clear policy on genetic engineering, genetically modified organisms and transgenics in Thailand is essential.

B. Improve incentive measures for investment

Measures that have been carried out include taxation privileges, in particular import duties, such as instruments and research investment; supporting the listing of biotechnology companies on the Stock Exchange of Thailand (SET), and making use of ASEAN Economic Community (AEC) and Asia Cooperation Dialogue (ACD) to attack investment and expand Thailand’s markets.

C. Develop infrastructure systems and support instruments

Government developed infrastructures such as a biotechnology and science parks to persuade investment, and using services in research and development. Biotechnology laboratories were set up to certify quality and standard for export products, and inspection of imported products. Establishing Science Park (TSP) in academic institutions across Thailand provided both government and the private sector with facilities such as a laboratory, pilot plant, conference center, and human resources. Agencies established for technology support and management include Industrial technology assistance program (iTAP), Technology Licensing Office (TLO), and National Innovation Agency (NIA). Financial support has been provided by Company Directed Technology Development Program (CD) and National Science and Technology Development Agency (NSTDA) and National Investment Center (NIC).

For example, Chem-Creation Co., Ltd. with laminate-digested enzyme production supported by TSP won the Gold medal award in Environmental session in ITEX 2009, Malaysia (Janwarasuth and Meerod, 2012).

D. Develop a Qualified Human Resource System in fields related to biotechnology

Ministry of Science and NSTDA provided the financial support for students and researchers from both public and private sectors including grants for research project, attending academic conferences, and co-investment etc.

Government formulated the human resource development program to achieve the entire goal mentioned above. Key strategies included the following:
- at least 5,000 personnel to engage as professional biotechnology researchers in the public and private sector,
- at least 500 personnel engaged in biotechnology management
- at least 10,000 students with bachelor’s, master’s, and doctoral degrees in the fields of modern biological science
- persuade foreign experts in biotech to conduct research and development in Thailand in areas where the country lacks
- create on-the-job training to provide a skilled workforce for the private sectors via cooperation among research institutes, and universities

For example: (Janwarasuth and Meerod, 2012):
- NSTDA provided 8 months of training programs for new biotech companies on entrepreneurship, management, law, technology, and negotiations.
- King Mongkut's university in Thailand offered the workshop on “Problem-Based Learning in Biogas Plant Operation” supported financially by National Center for Genetic Engineering and Biotechnology and NSTDA.
- NSTDA’s Investor Day was a fast track for the private sector to access and adopt the innovation and technology of NSTDA.


1. Investment in biological and biotechnology research and development were increased through emergence of new bio-business at different levels, both locally and from abroad. New companies in agribusiness increased from 60 companies in 2002 to 180 companies in 2009 (Fig. 3), approximately. In 2009, agribusiness generated a total revenue of more than USD 1.3 billion including agricultural and food sector (USD 261 million), healthcare and medical sector (USD 834 million), and biotech service (USD 227 million) (Table 2).

2. The value of biomedical products and healthcare in 2009 increased at about USD 520 million higher than that in 2002 (such as diagnostic kits, medical supplies, cosmetics and pharmaceuticals etc.).

3. The economic loss from the major diseases severely affecting Thai people was reduced about 1.1 billion USD.

4. The USD 733 million of energy worth per year was saved using bioenergy from biomass and farm waste.

5. The revenue of local communities at least USD 166 million was increased from selling of their agricultural products.

6. The increased economic competitiveness resulted from developing new advanced biotechnology led to selected products in a sustainable manner.
Fig. 3. The emergence of new companies in agribusiness across years in Thailand
Source: modified from Meerod and Janwarasuth (2012)

Table 2. The total revenue of agribusiness in Thailand in 2009.

<table>
<thead>
<tr>
<th>Sector</th>
<th>In 2009</th>
<th>Million US dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Agricultural and food sector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Seed production</td>
<td></td>
<td>117</td>
</tr>
<tr>
<td>- Vaccines for animals</td>
<td></td>
<td>77</td>
</tr>
<tr>
<td>- Animal feed supplements</td>
<td></td>
<td>67</td>
</tr>
<tr>
<td>2. Health care and medical sector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- New medicines</td>
<td></td>
<td>667</td>
</tr>
<tr>
<td>- Food supplements</td>
<td></td>
<td>167</td>
</tr>
<tr>
<td>3. Biotech service business</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Medical diagnostic kits</td>
<td></td>
<td>110</td>
</tr>
<tr>
<td>- Molecular-level detection/analysis for medical care</td>
<td></td>
<td>117</td>
</tr>
</tbody>
</table>

Source: modified from Meerod and Janwarasuth (2012)

MAIN CHALLENGES AND NEEDS FOR BIOECONOMY DEVELOPMENT IN THAILAND TOWARDS 2021

Over the next 10 years, a decrease in the low-cost supply of petroleum resulting in an increase in the cost of fossil resources, as well as higher demand for energy, and chemicals coupled with restriction on greenhouse gas emission could offer a growing market for biobased products including biofuels, chemicals and plastics. In addition, with higher advanced biotechnology, both food and non-food crops would be significantly used to produce valuable biomaterials such as cosmetics, food additives, and vaccines etc. However, in order to meet these future goals, there would be many key challenges to address as following:

A. Competitive Cost of Materials

The question of food versus non-food crops for industry must be answered. The needs for food and feed will be raised with an increasing world population in the next 10 years. The abandoned or degraded lands on where food crops can not be grown would be more used for biomass crops without any impact on the food supply. Additionally, incentives and high subsidies for energy crops would increase land prices making other biomaterials unattractive. With growing new biobusiness, the feedstock shortages might occur. Therefore, the National’s Development Framework is needed to improve the financial support and other incentives for both energy and biomaterial use to balance the feedstock production for the growing bioeconomy.

B. Clear Protocol Required

Advanced biotechnologies are key factors for the optimization of biomass feedstock to supply the future demands in bioeconomy. Some advanced biotechnologies are, however, controversial, especially GM crops, for example. Although many countries have adopted this technology, the public acceptability of this technique in crops and livestocks has not been clarified in Thailand. GM products still await authorization and approval for bio-industry.

C. More Public Funding for R&D
Investments in research and development in the area of industrial biotechnology for innovative biobased products is a key challenge. For Thailand, gross domestic expenditure on R&D as a percentage of GDP was low (not exceed 0.24% of GDP). In 2009, Thailand GDP was about USD 253.45 billion devoting to R&D activities only USD 716 million, approximately (UNESCO Institute for Statistics, 2010). Therefore, such a serious mismatch between the investments in industrial biotechnology R&D and the potential biobusiness opportunities for growing bioeconomy in the future is still a key challenge.

D. Preservation and Restoration of Ecosystem

To overcome the challenges in the increased living needs with growing global population, the total amount of agricultural output will have inevitably to double over the next 10 years. This can negatively affect ecosystem stability. Agricultural activities contribute to GHG emissions, including CO₂ and other green house gases (such as methane and nitrous oxide etc.). A wide range of technologies including improved farming practices (agricultural input uses, carbon sequestration, soil and water conservation, farm waste management etc.) should be developed and provided enough financial support for R&D programs. For sustainable development, the advanced technologies need to be integrated with socio-economic aspects on how to introduce new technologies to help local farming communities without negative impact on ecosystem services. Moreover, the revision of the Policies is needed to stimulate innovation in bio-industries, and at the same time, address the environmental concerns.

E. Reform and Update Training Programs to Improve Workforce Skills Needed

Updating training programs and improving academic institution incentives with student training for bioeconomy is still required for the next 10 years. The success of bioeconomy development relies on the education and skills of workforces in term of an interdisciplinary program. A gap in education, biological sciences, biotechnology, and chemistry currently exists among bioeconomy workforces. Additionally, there is a lack of awareness of bioeconomy potential both among policy makers, consumers and even the manufacturing industry. Communication and stakeholder involvement remains a big challenge of the long-term development.

Therefore, over the next 10 years we can expect to see a shift in practice from a sectoral approach towards a more integrated approach to the bioeconomy growth with big public benefits. There must be consistency across policies and product sectors, combined with the political momentum to ensure that this goal is placed in the top priority of the national development plan. The potential benefits for the economy, the environment and society as a whole will be achieved through collaboration of all stakeholders to make the Thai bioeconomy a reality.

REFERENCES


Clever Consult BVBA. 2010. The Knowledge Based Bioeconomy (KBBE) in Europe: Achievements and Challenges, Brussels.


