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The BCG Economic Model in Practice: A Case Study of Thai Eastern Eco-Industrial Land

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ABSTRACT

This research aims to assess the feasibility of developing the Eastern Thai Industrial Land (TEIL), Chonburi province using the bio-circular-green (BCG) economic models via small-group activities and stakeholder analysis to create suggestions for sustainable development. The data is evaluated using the Sustainable Balance Scorecard (SBSC) technique. Thailand's eco-industrial towns (EIT) implementation in accordance with the BCG economic approach, resulting in the EIT framework being more aligned with the national strategy, policy, and plan as a result of continuing EIT development in a variety of EIT areas. The TEIL is a major bio-based industry consisting of a group of agricultural products processing plants, including rubber and oil palm, with high capacity for the development of the BCG economic model. TEIL's management has a clear commitment to driving TEIL to be a leader in applying the BCG economy model. It is found that sustainable EIT development guidelines in accordance with the BCG economy are included in the 5 perspectives: eco-effectiveness focusing on value creation development, stakeholder by promoting key players in the area, social and environment focusing on improving the quality of life based on eco-thinking, learning and growth by knowledge and innovation storage and transfer, and management by continuous monitoring and assessment using socioeconomic indicators. Monitoring and assessing EIT operations in various biobased contexts in other EIT areas are further recommended in order to compare differences in results and more appropriately improve the guidelines.

1. INTRODUCTION

Throughout the 1980s, global industrialization was a major source of greenhouse gas emissions. It has a global impact on the environment [1]. As a result, the eco-industry concept was developed to improve industrial systems so that they resemble natural systems [2]. Global climate change and greenhouse gas emissions challenges are crucial in motivating eco-industrial cities and eco-cities to grow in certain ways, such as "greenest city" and "low carbon city." Leading industrial countries have begun to embrace the concept of converting the existing industrial system from linear to closed-circuit production, resulting in the establishment of eco-industrial parks and the development of eco-cities such as the Eco-Industrial Park in Kalundborg, Denmark [3] and recycle cities in Japan [4].

Since 1999, Thailand has been developing industrial ecology, beginning with a collaboration between the Industrial Estate Authority of Thailand (IEAT) and the Deutsche Gesellschaft Für Technische Zusammenarbeit (GTZ) that resulted in the creation of eco-industrial park pilot projects [5]. Later that year, the Ministry of Industry tasked the Department of Industrial Works (DIW) with developing a master plan for the implementation of EIT in five provinces for pilot project testing in 2013. Furthermore, the DIW has defined the characteristics and indicators of an EIT and expanded it to 18 EIT areas spread across 15 provinces before the Government has set a target of advancing eco-industrial towns as a key part of the 20-Year National Strategy and increased the target over 40 EIT areas in 37 provinces [6]. DIW has established a target for EIT area development objectives in accordance with Thailand's Bio-Circular-Green (BCG) economy principles, which include a plan to transform 54 regions in 40 provinces into "livable cities with industries" in eco-industrial towns by 2037 [7]. The Department of Industrial Works is pushing the EIT development in line with the green economy idea as part of the BCG strategy issued by the Ministry of Industrial [8]. Thus, the integrated EIT development vision is "livable cities with industries based on eco-thinking" aiming to establish industries that can cohabit with communities in a sustainable and tangible manner. The development of EIT regions in accordance with the BCG economic recommendations necessitates collaboration from key parties.

Thai Eastern Industrial Zone in Chonburi is expected to be the first bio-industrial zone in Thailand, with an annual economic value of more than USD 3.2 billion. As part of the Eastern Economic Corridor (EEC), it has been assisting farmers in developing quality crops to fuel the bio industry while also providing steady income and employment to 8,000 residents over a three-year period. The European Union successfully promotes businesses that are similar to BCG, such as food for the future, medical, agriculture, and biotechnology. Thus, the Thai Eastern Industrial Zone should have a great potential to build an eco-circular economy industrial zone focused on bio-agricultural product processing. The industrial zone includes agricultural palm oil processing facilities, rubber, renewable energy, and downstream industries such as palm pulp mills, as well as the upstream, midstream, and downstream parts of the bio-agriculture industry. In addition, the BCG Integrated Center for research, technology, and innovation will be established to support the Bio Medical Hub. It is an excellent area to test the feasibility of building an EIT area within the context of sustainable management ideas.

From BCG's economic perspective, the aim of this research is to assess the feasibility of developing such industrial zones using BCG economic models suited to the location via small-group activities and stakeholder analysis to create suggestions for sustainable development. The data is evaluated using the Sustainable Balance Scorecard (SBSC) technique. Following that, the audited data was then utilized to build EIT development criteria in accordance with the BCG economy.

2. LITERATURE REVIEW

2.1 The notion of eco-industry

The discussion of ecological deterioration during the 1972 United Nations Conference on Environment and Development raised environmental awareness in many countries. In particular, industrialized nations have begun to pay attention to the environment and maintain natural ecosystems, culminating in the evolution of industrial systems and the transition to eco-industries. Preston Cloud, an American geologist, defined industrial ecology in a 1977 paper presented at the annual meeting of the German Association of Geologists.

Many environmentalists have established the use of eco-industrial, for examples, the eco-industrial concept by Frosch and Gallopoulos [9], the eco-industry research by Erkman [10], and the closed-circuit production transformation by Graedel and Allenby [11]. Industrial ecology was explained [10] as a system of integrative relationships among the various components of the industrial units and their relationships with the biosphere, considering the form of material and energy flows within and outside the industrial system in the appearance of industrial symbiosis, which necessitates a similar symbiosis between producers, consumers, and decomposers to the ecosystem. The industrial symbiosis is a sort of relationship that links firms to enhance efficiency, taking into consideration all material and energy flow systems in the same cluster to provide reciprocal benefits [12]. An industrial ecosystem is a system that emerges in any industrial region when there are interwoven symbiotic links among groups of firms in an area with increasing complexity, as shown in Figure 1.

As depicted in Figure 1, industrial symbiosis has been widely established in eco-industrial operations to build links between industrial facilities through material, energy, and waste exchange processes for mutual benefit [13]. Collaboration between firms in the same region can result in industrial symbiosis, which can boost the efficiency of raw materials and energy resources while decreasing waste generation [14]. This approach may be used to build a new city or community with the purpose of developing both the city and industry. Eco-industrial systems may be effectively implemented by establishing industrial networks based on a circular economy [15]. Developing into a new industrial model that integrates environmentally friendly processes through the management of balanced resources such as matter, water, energy, and waste. This allows for closed-circuit circularity and effective resource usage while lowering emissions and waste [16].

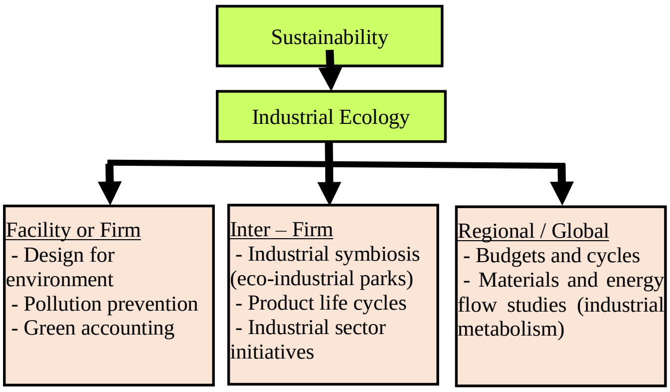

Figure 1. The level of eco-industrial operations
Source: Chertow [13]

A circular economy (CE) is a concept pioneered by the European Union and some economic powerhouses such as China, Japan, the United Kingdom, France, Canada, and the Netherlands. The circular economy encompasses more than just reusing and recycling in manufacturing; it also includes product management and cost-effective resource and energy use, such as solar, wind, biomass gas, and waste-to-energy. As shown in Figure 2, the manufacturing process focuses on reuse and recycling processing to produce environmentally friendly manufacturing processes that boost the value of the product chain and establish a new production model that considers the cradle-to-cradle life cycle [17].

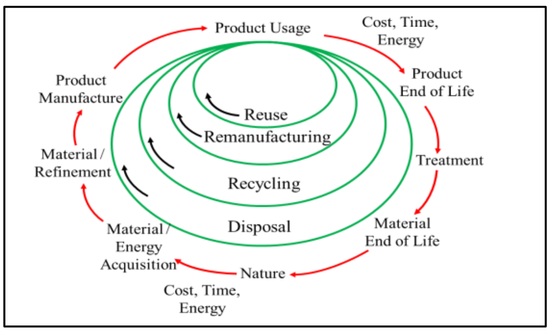

Figure 2. Circular economy system
Source: Korhonen, Honkasalo, and Seppälä [18]

The circular economy is based on the goals of sustainable development while taking economic factors into account. The circular economy has created and disseminated benefits in all three dimensions while also restricting the amount of matter and energy flow patterns to what nature can sustain [18]. The most efficient use of resources in the context of businesses, networks or internal supply chains, eco-industrial parks, local infrastructure, the government, manufacturers, utility providers, and consumers leads to cleaner production and industrial ecology [19]. Thus, the circular economy entails not only recycling in industrial processes, but also productive management in order to increase the value of the product value chain and develop a production model capable of simulating this circular economy in eco-industrial town operations.

2.2 Uplifting in several nations from eco-industrial parks to eco-industrial towns or eco-cities

According to Lowe [14], an "eco-industrial park" is a combination of industrial plants and related enterprises to promote production efficiency and strengthen the capacity of mutual economic and environmental management, which is both a combination of industrial plants located in the same location as an "eco-industrial park" and a collection of factories located in different places but with the interchange of raw materials and waste between each other, which is referred to as an "eco-industrial park".

The United Nations Conference on Environment and Development (UNCED) in 1992 resulted in the creation of eco-industrial parks in several notable nations, including the United States, the United Kingdom, Japan, South Korea, and China. The shift from eco-industrial parks to eco-cities necessitates efforts to adapt industrial systems based on natural ecosystem patterns achieving closed material cycles to decrease the use of natural resources, save energy, and reduce pollution and waste. The eco-industrial park is a collection of industrial enterprises gathered for economic and environmental advantages in order to build industrial ecosystems in that industrial region and promote efficient resource and energy. However, to achieve the goal of balancing industrial activity, the environment, and equity concerns, the development of an eco-industrial park in accordance with the industrial ecology guidelines necessitates the establishment of relationships with surrounding communities [20].

This involves shifting the paradigm of environmental protection from pipeline prevention to the construction of ecologically friendly manufacturing processes and goods. Improving manufacturing processes, developing an industrial symbiosis, integrating into concrete activities, and establishing business models are all part of the operation of an eco-industrial park or network [21].

Industrial enlarges from individual factories to eco-industrial parks, eco-industrial networks, and eco-cities through an industrial symbiosis [22]. The rise of eco-cities, particularly in Japan and China, has gotten a lot of attention since 2017 [23]. China is another outstanding example of a green plan, having developed a solid strategy for constructing low-carbon cities in a range of industries. The central government is responsible for creating goals and assigning duties to local governments so that they may modify their policies successfully. Low-carbon cities will strengthen local economies, attract investment, and make use of new technology, among other things [24]. In practice, it has been observed that the patterns and procedures for developing industrial interdependent processes vary depending on the physical and social context, with locations experiencing operating obstacles. Developing eco-industrial cities that take mutual benefits between industry and local communities into account has resulted in the development of both industrialization and urbanization, resulting in environmental and social benefits such as increasing efficiency in preventing industrial pollution, improving the quality of life for people in the area, and, most importantly, creating equity in all parties' joint development. Thus, important success and limiting features of the transition from eco-industrial parks to eco-industrial cities, such as information sharing and awareness, symbiotic connection building, organizational structure, and legislation [25].

As a result, the government should promote and assist the elimination of barriers and the broadening of the scope of activity. To create a participatory growth strategy, develop an ecological industrial network, and adopt production technology and environmental protection [26], both procedures link industrial systems with the livelihoods of surrounding communities, resulting in industrial and urban coexistence for mutual benefit [27].

2.3 The current state of Thailand's EIT development

Thailand's eco-industry development began in 1999 with a cooperation between Thailand's Industrial Estate Authority (IEAT) and Germany's Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). The Eco-Industrial Estate and Networks Project (DEE + Net Project) was created and five pilot projects in industrial estates were built under IEAT [28]. Following Thailand's adoption of the Johannesburg Declaration in 2002 and the Manila Declaration on Green Industry in 2009 [29], the Cabinet approved the establishment of eco-industrial towns (EIT) and delegated EIT development to the Ministry of Industry (MOI) [30].

In 2011, the MOI allocated many departments under its supervision to participate in the development of eco-industry in accordance with green industry principles [31], and an EIT development model, characteristics, and indicators were formed. The EIT model was divided into four categories: eco-industrial factory or green factory, eco-industrial park or estate, eco-industrial town, and eco-city. During the same year, nine industrial zones in six provinces were tested for an eco-industrial pilot project, which has since progressed steadily [30]. Thailand's EIT development has continued to improve from 2014 to 2021, led by a master plan and action plan in their EIT regions [32], as well as annually assessed the progress of operations in each area as follows:

1) 2014: EIT Development Master Plan for Existing EIT Areas in 5 Provinces: Samut Prakan, Samut Sakhon, and Rayong; and New Industrial Areas in Chachoengsao and Prachinburi Provinces.

2) 2015: Extend the EIT Development Master Plan for industrialized provincial areas, including areas with high potential for industrial development in 10 provinces: Chonburi, Nakhon Pathom, Pathum Thani, Ratchaburi, Phra Nakhon Si Ayutthaya, Saraburi, Nakhon Ratchasima, Khon Kaen, Surat Thani, and Songkhla.

3) 2016: The action plan under the EIT Development Master Plan (2018-2021) for 18 areas in 15 provinces has been completed, and the master plan and action plan for special economic zones (SEZ) in 4 provinces, including Mukdahan, Sa Kaeo, Tak, and Trat, have also been completed.

4) 2017: The EIT development of 18 areas in 15 provinces was carried out based on 5 dimensions of features; 20 areas, 41 indicators, and the degree of eco-industrial city development based on 41 were tested. Indicators 2017 was the first year, and certain indicators have to be revised to reflect the new geographical context.

5) 2018: Revised criteria and indicators were completed, and the results of eco-industrial city development were reviewed, which found that for 18 areas in 15 provinces, 1 area passed the assessment criteria level 2 (enhancement), and 16 areas passed the assessment criteria at level 1 (participation).

6) 2019: The results of the eco-industrial city development assessment showed that two target areas in Rayong province passed the assessment criteria level 4 (symbiosis), and the remaining 16 areas in the remaining 14 provinces passed the assessment criteria level 2 enhancement.

7) 2020: Four areas in Rayong and one area in Pathum Thani province passed level 4 (symbiosis), while two areas in Nakhon Pathom and Nakhon Ratchasima provinces passed level 3 (resource efficiency), and the remaining 13 areas in the remaining 13 provinces passed level 2 (enhancement).

8) 2021: There are 4 areas that meet the criteria for level 4 (symbiosis): Rayong (2 areas), Pathum Thani (1 area), and Nakhon Ratchasima (1 area). In addition, five areas in Nakhon Pathom Province, Chachoengsao Province, Ratchaburi Province, Surat Thani Province, and Songkhla Province passed level 3 resource efficiency, and the remaining nine areas in the province passed level 2 (enhancement) assessment criteria.

9) 2022: The FTI's DIW held a meeting to examine, analyze, and evaluate EIT's performance against the objectives of government agencies and state companies with the EIT mission. EIT participants from the public and commercial sectors developed and revised spatial action plans in line with the EIT Development Master Plan and national plans such as the 20-year National Strategy, the 13th National Economic and Social Development Plan, and the National Reform Plan.

The DIW has launched a project in 2022 to construct Thailand's eco-industrial development framework in collaboration with the United Nations Industrial Development Organization (UNIDO) and the Global Environment Fund to design EIT development projects that are appropriate for each area's context, resulting in many locations achieving greater degrees of EIT development. The DIW has developed guidelines with an emphasis on improving the data platform, metric criteria, and evaluation systems at various levels in accordance with international eco-industry development guidelines, as well as mechanisms and systems to support EIT development.

The new monitoring and evaluation system has been adjusted in accordance with the principles of the Quality Standards System, so that the assessment findings can demonstrate the development gap in comparison to the target. Based on the Deming cycle (PDCA) wheel, the data may be used to design concrete adjustments and development, and there is continuing progress. Internal monitoring and evaluation systems and external monitoring and evaluation systems are the two types of monitoring and evaluation systems. External monitoring and evaluation must provide uniform norms and audit criteria for the entire country. Furthermore, the DIW is considering appointing representatives from third-party organizations or the private sector. The auditor is a third party who ensures that there is a single standard that can be linked to national and international indicators or development goals.

2.4 Development of EIT in accordance with BCG guidelines

Economic expansion in the country occurs at the price of resources and biodiversity, resulting in resource degradation and biodiversity depletion, waste pollution, environmental difficulties, and health concerns. Furthermore, resource depletion and biodiversity loss have an impact on the country's economic growth, social development, and cultural preservation. The Thai government has launched the BCG economic model in order to promote the use of the resource base and biodiversity through a new economic model that may seamlessly relate to the circular and green economies [33].

As a result, the BCG economic idea has been evolved from the green economy concept to fit Thailand's contemporary economic growth setting. BCG economy is an abbreviation for "bio-circular-green economy," which is an economic model that promotes and expands Thailand's ownership of high-value goods and services that encourage long-term economic growth. Improving industry competency in science, technology, and innovation are used to create the new S-curve of rapid growth, which includes the agro-food industry, the energy industry, the materials industry, the health and medical business, and the tourist and hospitality sectors. Thus, the Ministry of Higher Education, Science, Research, and Innovation (MHESI) has created the "BCG in Action: The New Sustainable Development Engine" plan for 2021 to concretely promote the BCG economy in Thailand, which has plentiful natural resources and strong agricultural operations [34]. The BCG model focuses on four types of emerging S-curve industries: 1) agriculture and food, 2) bioenergy, biomaterials, and biochemistry, 3) medicine and health, and 4) tourism and the creative economy [35]. As indicated by the rise of the agricultural and food industries, science, technology, and innovation are critical in enhancing the skills and competitiveness of those engaging in upstream and downstream value chains. At the same time, it supports a comprehensive bioeconomy because biomass is the cornerstone of all bioeconomy firms.

Creating value from the many biological and cultural underpinnings, the following are the primary activities of the BCG economic model: 1) resource conservation, restoration, and development to increase natural resources capital, biodiversity, and culture; 2) sustainable utilization and consumption management; 3) waste reduction and utilization from the manufacturing and service sectors; 4) value creation throughout the value chain from upstream agriculture to manufacturing and service sectors; and 5) build up resilience to increase self-reliance. Thailand's well-known cultural identity may be used as a commercial element, such as Thai food, which is popular and considered as a healthy and nutritious food, providing an excellent potential to become the world's kitchen. The world's population is predicted to reach 9.8 billion people by 2050, with food consumption growing by 70%, providing Thailand the ability to provide quality, safe, and standard food in the future, according to the United Nations [36].

Furthermore, the bio-products business boosts agricultural productivity, which raises farmer incomes along the production chainwheel. As technology and innovation enhance upstream agricultural goods, the competitiveness of downstream industry improves. Healthy food ingredients are employed in the health and medical sectors as "biopharmaceuticals" and precision medical treatments that may be applied to the energy and chemical industries, as well as tourist enterprises. Medical tourism is one example of how it is closely associated with high-value agricultural goods. According to BCG, it is a great potential for Thailand's eco-industrial growth, therefore BCG's economic aims fit with five parts of eco-industrial city development: physical, economic, environmental, social, and management. The BCG Model has also encouraged the development of circular economy innovations, such as the ability to design products and manufacturing processes to reduce waste (eco-design and zero-waste), promote reuse, refurbishment, and sharing, and prioritize waste management from production and consumption via recycling and upcycling processes [37]. As a result, the BCG economic model is expected to drive Thailand's economic and social improvement in accordance with the Sustainable Development Goals. The SDGs and the concept of the Sufficiency Economy are fundamentally based on science, technology, and innovation, and they encompass both upstream and downstream development.

Thailand has been paying close attention to the circular economy during the last few years. The country is doing well, and its 20-year national strategy (2018-2037) addresses the circular economy issue [38] to solve existing problems and create new economy, as shown in Figure 3. Two techniques have been recommended to accelerate the circular economy [39]: 1) the use of circular thinking to solve current environmental problems; and 2) the use of the circular economy to establish a new economy. As a result, the government has established a new economic direction known as the BCG economy model, which is based on the Sufficiency Economy philosophy as a guideline and the integration of all sectors in all dimensions, including behavior change, thought promotion, and innovation for natural resource protection [34].

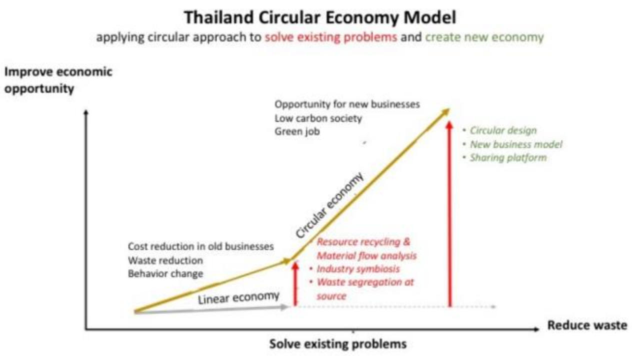

Figure 3. Thai circular economy driving approach
Source: NXPO [39]

The government has established a five-year strategy plan (2021-2026) that includes four essential parts to support the BCG economic model as a means of achieving sustainability and more equitable and resilient growth [34]. The plan's key elements include: 1) promoting bioresource sustainability by balancing conservation and utilization; 2) strengthening communities and grassroots economies by leveraging resource capital, creativity, technology, biodiversity, and cultural diversity to create value for products and services, allowing communities to drive the value chain; 3) enhancing and promoting the industry's long-term competitiveness through information, technology, and innovation, with an emphasis on environmentally responsible production and innovation; and 4) Increasing adaptability to global change. Furthermore, the BCG economy is predicted to propel Thailand into Thailand 4.0 strategy. Although environmental and economic benefits are important motivators, the present shift to a circular economy does not appear to be efficient. A very effective policy approach, promotion of a circular economy in accordance with the SDGs, and implementation of a circular economy strategy in a geographical context [40] will all contribute to making the circular economy a driving force in the economy. For examples, the BCG economy's sustainability requires technology and innovation for bioeconomy development, resource efficiency and waste management (3Rs to Zero Waste) for a circular economy, and greenhouse gas emission reduction for a green economy [41]. Such elements must be incorporated into the overall strategy. EIT has already been adapted to fit within the BCG economy. Various key institutions also assist the BCG economy in a mutually advantageous manner, assuring that such integration will benefit local communities and positively promote the long-term development of eco-industrial towns.

2.5 The example of high potential area promoting to BCG economy: Thai Eastern Industrial Land (TEIL)

Thai Eastern Industrial Land (TEIL) conducts an industrial enterprise in Nong Yai, Chonburi, processing biological agricultural products in the form of an eco-circular economy on an area of 725 Rai (287 Acres). TEIL is a big processor of natural rubber and crude palm oil in the eastern area, as shown in Figure 4. By 2025, TEIL aims to be Asia's premier bio-circular green complex (BCG complex) [42].

Figure 4. TEIL Landscape
Source: Brochure_TEIL_2023 [42]

TEIL is composed of agricultural product processing plants such as rubber stick plants, biodiesel plants, palm oil extraction plants, and palm pulp mills, as shown in Figure 5. Using the 5R concept, the factories in TEIL are designed to recycle trash into raw materials for other manufacturers. Furthermore, there are power plants that create renewable energy by turning biowaste into biogas, which is then used to generate electricity for usage in various industrial operations in the vicinity.

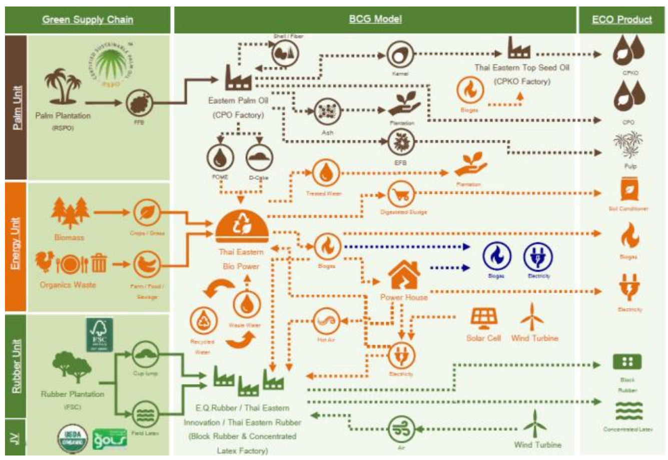

Figure 5. TEIL material exchange flow diagram
Source: TEIL [43]

TEIL has a robust bio-industry basis, and its management is dedicated to propelling TEIL to the top of Asia's BCG economy by 2025. In compliance with the criteria, TEIL leaders have issued policies, formed working groups, and developed action plans in accordance with the DIW's EIT development and the BCG economy pattern, as shown in Figure 6.

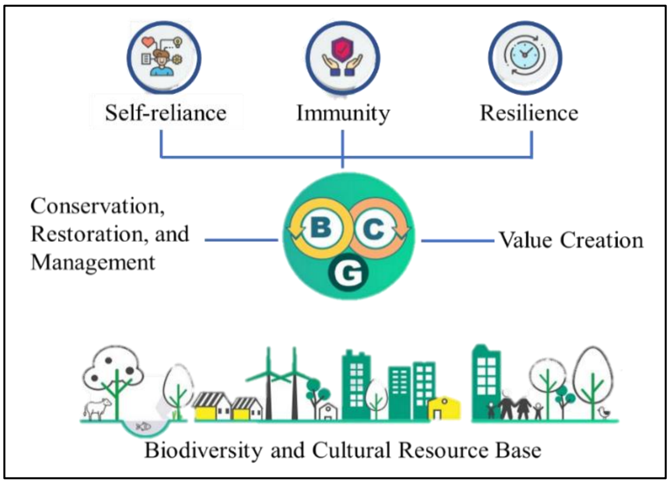

Figure 6. TEIL BCG economy pattern
Source: TEIL [43]

3. METHODOLOGY

The research methodology comprised their application to the industrial sector and the available data based on literature reviews on eco-industrial concepts, international development of eco-industrial cities and eco-cities, Thailand's EIT development strategy, and the BCG economic approach.

The purpose of this research is to evaluate an eco-industrial park that is evolving into an eco-industrial town in order to determine development guidelines in accordance with the BCG economy. The research perform was based on five different perspectives, as indicated in Figure 7: 1) effectiveness; 2) stakeholder; 3) social and environmental; 4) learning and development; and 5) management. The authors have chosen an integrated Scorecard approach called the Sustainable Balance Score Card (SBSC). This evaluation methodology is more suited than others since it is critical in eco-industrial operations to balance administrative and managerial components with environmental and social sustainability.

In relation to the COVID-19 pandemic, key informants, including the government and private sector, were interviewed and joined the group activity by phone and VDO call. The primary data is gathered from a representative sample of stakeholders involved in the development of EIT in the target region. The following key informants are involved in the EIT development: 1) the administrator who responds to the Thai Eastern Industrial Zone's EIT development; 2) the corporate social responsibility representative of companies located in the Thai Eastern Industrial Zone; 3) the head of Chonburi provincial industry; and 4) the community leader or expert in the EIT development. Questions for key informant interviews include challenges, barriers, and considerations for establishing EIT from an individual's perspective, as well as further ideas for building EIT in accordance with national strategies. To examine this data, content analysis principles are employed, analyzing similarities and differences in the interview data received from each target group.

The secondary data is collected and investigated by reviewing information from two primary sources: 1) the international and national growth of eco-industrial cities and eco-cities, Thailand's EIT development, and BCG economics; and 2) the Action Plan and Guidelines for EIT Development of the DIW. A variety of related data was gathered from academic papers, books, articles, research, and other reliable sources, including a synthesis of EIT development in Thailand based on BCG economics, the characteristics and situation of community enterprises in Thailand, and concepts and theories of sustainability management.

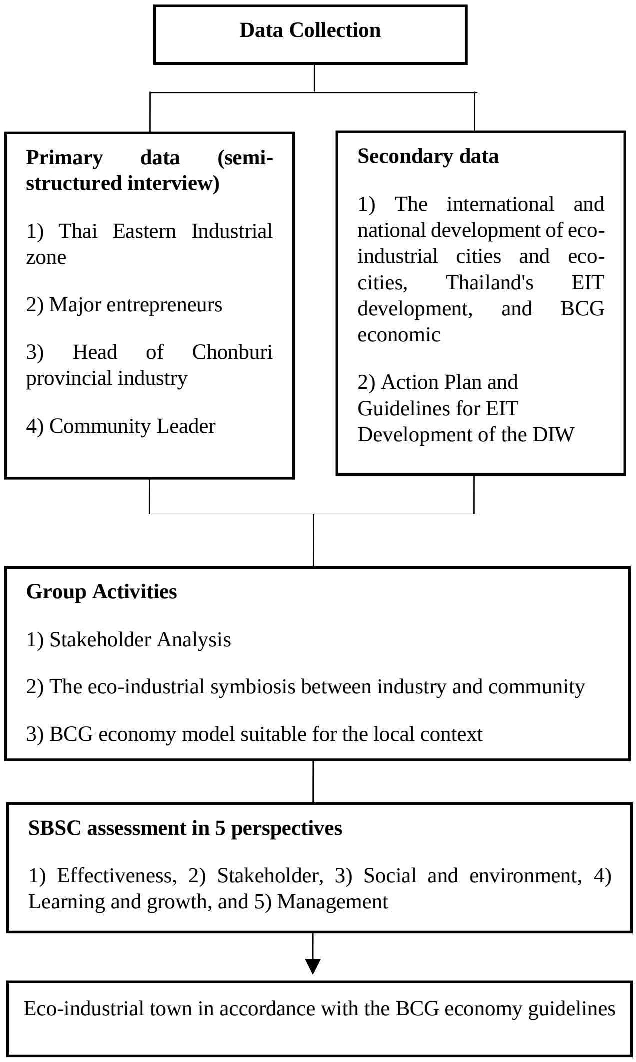

Figure 7. Research process

The assessment form and semi-structured interview form were flexibly generated, which can compare information from numerous key informants. TEIL's eco-industrial head, TEIL's industrial plant representative, the Federation of Thai Industries' (FTI) EIT development working group, and a Chonburi industry representative were interviewed without missing the key issue in order to gain insights and a deep and correct understanding of key informants' views, experiences, ideas, and attitudes. To design the BCG economic model fit for the local context, focus group activities, stakeholder analysis, and eco-industrial symbiosis between industry and community were carried out.

The prototype of the EIT development according to the

BCG economic approach was considered through the Sustainability Balanced Scorecard (SBSC) from five perspectives as previously mentioned: 1) effectiveness, 2) stakeholder, 3) social and environmental, 4) learning and growth, and 5) management. SBSC analysis and improvement will be utilized in focus group activities to generate draft recommendations for the development of EIT in accordance with the BCG economic approach.

4. RESULTS AND DISCUSSION

4.1 Development of eco-industrial cities in accordance with Thailand's BCG economic approach

The authors examined Thailand's EIT development gap by DIW and associated agencies in 2021 [32], as well as further research works. A partnership between the DIW and United Analyst and Engineering Consultants Company in 2021 [44] assessed the current difficulties and impediments to the growth of the EIT in Thailand in six issues as 1) separate EIT zones; 2) significant mobility and explicit separation of tasks among agencies 3) award advantages and priority 4) an enough budget or goals that are linked to indicators set by the province or governor 6) Focus on the BCG economy and EIT development at Level 3.

To ensure the continuity and appropriateness of EIT development in various dimensions, DIW has established guidelines for the preparation of an action plan for the development of eco-industrial cities at the area level, so that the plans are linked and coordinated in a consistent manner. As a result, the development of EIT in diverse areas may be carried out concurrently and in collaboration with appropriate authorities, with a priority given to the interests of the people in the region. The Eco-Industrial Town development action plan for each area must be congruent and linked to with DIW's ministry-level plan as well as the National Economic and Social Development plan. The key informants examined for this study were divided into three groups: 1) central authorities, 2) operating agencies, and 3) communities. As illustrated in Figure 8, each group assigns a different weight to the problem.

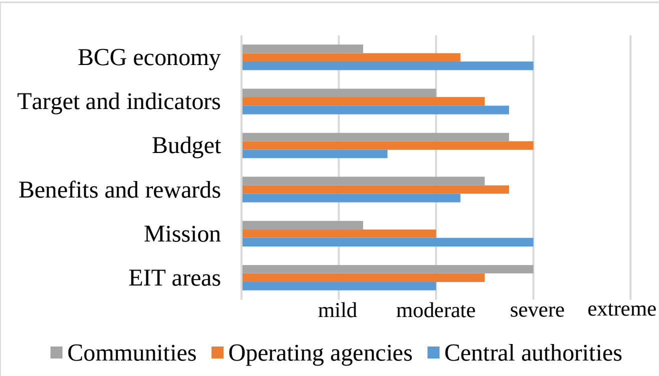

Figure 8. The prioritization of problems and obstacles of eco-industrial town development

The key informant in each group has a different perspective on the issues and impediments to eco-industrial city development. The top three concerns in the development of eco-industrial towns that were discussed the most in each group vary. Executives in Regulatory Agencies Central Authorities have prioritized the problem of eco-industrial city development toward the BCG economy, the implementation of missions to achieve targets, the enhancement of EIT indicators to fit the context of the area, and the clear separation of EIT areas. Local action groups prioritize finances, benefits and rewards, and achieve goals based on indicators. Both groups, however, have quite different perspectives from local community leaders who, on the other hand, believe that the problem of splitting EIT regions into distinct budgets and advantages for the community will be addressed. From the standpoint of advancing EIT toward the BCG economy, it was discovered that communities and local practitioners still do not grasp the path of action and do not perceive practical advantages.

4.2 BCG economic model analysis for TEIL area

The SBSC tool arose from the Balance Score Card (BSC), a multi-dimensional performance assessment technique that incorporates environmental and social sustainability management dimensions to analyze performance and identify drivers in an organization's operations. Under the BCG economy method, the BCG economic model analysis technique may be achieved by identifying important stakeholders, outstanding economic costs, and mutually beneficial interests to link symbiosis activities between industry and surrounding community groups.

Representatives of major stakeholders were invited to voice their comments on the data on the functioning of the EIT in order to cooperatively analyze the BCG economic model that is suited for the local environment. The authors employed the SBSC approach to examine the BCG economic model in order to enhance and sustain it.

4.2.1 Stakeholder analysis

It is found that TEIL has been involved in CSR efforts. According to the BCG strategy, group activity includes studies of stakeholders who have a significant effect on EIT development. TEIL's commitments to growing and improving the operations of stakeholders have been planned in seven business partner groups: 1) agricultural processing; 2) supporting industry; 3) metal product group; 4) infrastructure; 5) light industry; 6) electronics and electrical appliances industry; and 7) agriculture [42] as shown in Figure 9.

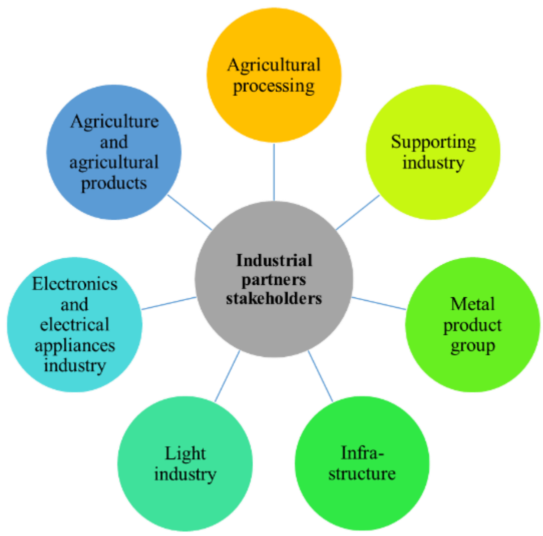

Figure 9. The TEIL's industrial partners stakeholders

TEIL factories include agriculture plantations, and agricultural processing plants to process two types of agricultural products: 1) natural rubber products such as block rubber and concentrated latex, which are exported as the world's leading rubber producers; and 2) crude palm oil (CPO), crude palm kernel oil (CPKO), kernel, kernel cake, and by product. Customers include the biodiesel industry and the food sector. TEIL recycles organic waste from the manufacturing process to provide sustainable energy such as biogas and electricity generated from biogas to support the industry. In accordance with the area's new S-curve industrial development policy, TEIL intends to establish factories in the metal product group, light industry, and electronics and electrical appliances industries, as well as an eco-industrial town by expanding the relationship to the surrounding communities and bringing the current robust bioeconomy to the circular and green economy for sustainability.

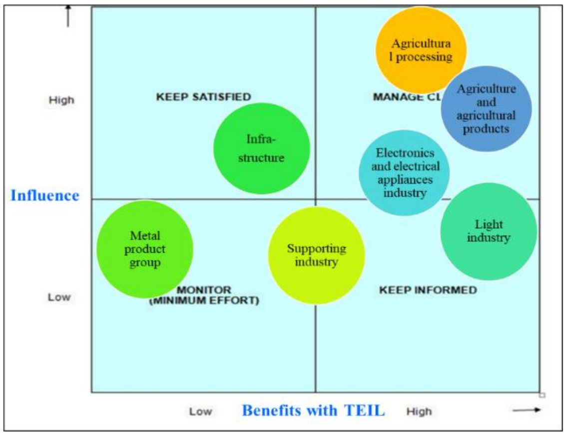

Figure 10. TEIL Stakeholder assessment

Meanwhile, Figure 10 illustrated stakeholder assessment using the factors for measuring influence and benefit with TEIL in EIT development, as seen in the diagram. As seen in the diagram, agriculture and agricultural processing are all important to 'manage closely' factor since they help drive EIT activities at the operational level, as shown in the diagram. Agriculture and agricultural processing groups are inextricably linked to many of the local communities surrounding the TEIL area. Local community activities can be linked to the processing of waste materials and waste from the bio-industry inside the TEIL, resulting in value-added goods in accordance with the BCG economic model and EIT development in accordance with the BCG economy.

4.2.2 The eco-industrial symbiosis between industry and community

The manufacturing processes of various factories within TEIL are unique in the way that they can be linked according to the industrial symbiosis principle by being able to recycle waste back into renewable energy. In order to enhance and link its operations to community activities, TEIL has established projects and activities in partnership with the community. The project plan and activities according to TEIL's EIT Development Strategy for 2023 are divided into 5 dimensions as 1) smart environment, 2) smart governance, 3) smart living, 4) smart economy, and 5) smart people. These projects can be classified into three bottom line dimensions as follow:

1) Smart environment: Waste Bank Project / Organic Waste to Energy Project, and Community Forest Project

2) Smart economy: TEIL Marketplace Project, Direct Purchase of Raw Materials from Farmers Group, and Local Community Enterprise Promotion Project (Organic Fertilizer Production and Bio-Agriculture Group)

3) Smart People: The establishment of learning centres for Local Community Enterprises in organic fertilizer production and bio-agriculture groups.

Six projects in three dimensions can be synthesized into a diagram of the connection of industrial symbiosis with industrial groups within the TEIL area as in Table 1:

Table 1. TEIL-Communities industrial symbiosis

Dimension	Project	Input	Process	Output
Smart Environment	1) Waste Bank / Organic Waste to Energy	Industries - Not applicable Communities - municipal solid waste	Industries - RDF - Biogas Communities - Not applicable	Industries - Heat and electric energy Communities - Households energy
	2) Community Forest	Industries - Budget - Manpower Communities - Manpower	Industries - Reforestation activities - Carbon credit accounting and claims Communities Reforestation activities - Caring for community forests	Industries - Carbon credit Communities - Benefit from the forest - Natural learning center
Smart Economy	3) TEG Market Place	Industries - Utilities (Electrical) Communities - Agriculture goods - Household goods	Industries - Market management Communities - Not applicable	Industries - Employee brough organic goods Communities - Income
	4) Direct Purchase of Raw Materials from Farmers Group	Industries - Raw materials purchase Communities - Raw materials buying	Industries - production Communities - Not applicable	Industries - Industrial goods Communities - Income
	5) Local Community Enterprise Promotion	Industries - Budget	Industries - Not applicable	Industries - CSR awards

		- Technical, promotion and marketing assistance Communities - Local Community Enterprise's goods	Communities - Production	Communities - Income
Smart People	6) The establishment of learning centers for Local Community Enterprises	Industries - Budget - Technical and promotion assistance Communities - Local Community Enterprise's operation and training program	Industries - Management Communities - Operation and training	Industries - CSR awards Communities - Capability building - Income

Table 1 shows that TEIL collaborates with communities on a variety of initiatives, and the authors discovered six programs that address economic, social, and environmental elements of sustainable development. TEIL may enhance such initiatives by connecting the aims to the BCG economy; thus, industrial businesses in the TEIL sector could collaborate to develop current projects to raise the intensity of minor operations that benefit stakeholders concretely. TEIL should broaden the scope of operations, particularly for projects and activities in the smart economy dimension, in order to achieve project results in accordance with the standards in BCG economy as measured by bioeconomy, circular economy, and green economy indices.

4.3 BCG economic model for sustainability

The authors examined and identified sustainable practices for the BCG economic model using the Sustainable Balanced Score Cards (SBSC) approach. The analysis will include five perspectives: 1) effectiveness, 2) stakeholder, 3) social and environmental, 4) learning and growth, and 5) management.

4.3.1 Effectiveness perspective from eco-industrial development according to BCG economic guidelines

The effectiveness of the EIT encompasses operational success in five dimensions, which can be assessed using the most recent revision of the EIT development indicators. Beyond the assessment results are the creation of value added in physical, economic, social, environmental, and management that generates mutual benefits for stakeholders in the area, as well as outstanding and sustainable tangible results such as increased resource efficiency, reduced waste volume, and increased contribution of the BCG economy in the area among other outcomes.

From the standpoint of effectiveness analysis, it was discovered that the TEIL sector has taken care of and developed activities in eco-industrial cities with the goals of 1) growing knowledge, 2) contributing value to the economy, and 3) improving inhabitants' quality of life. This comprises establishing linkages in economic promotion and environmental protection in tandem in order to advance toward sustainable development by utilizing resources or raw materials in manufacturing and services to achieve a balance between the economy and the environment.

The agricultural process industry in a bioeconomy is the primary business of enterprises headquartered in the TEIL region. Each firm exchanges material waste, and some industries can improve their operations by expanding the reach of material-waste exchange activities to adjacent communities. This type of operation is consistent with the notion that according to the BCG economy, eco-effectiveness which improves on previous business-centred approaches to sustainability by establishing supporting interconnections between economic and environmental systems, and connections with neighbouring communities [45]. Eco-effectiveness may be assessed using ecological performance evaluation, life cycle analysis, and waste circularity to decrease environmental negative effects while improving business economic performance.

4.3.2 Stakeholder perspective

Before beginning a project or activity in ecological industrial development, according to the BCG economic strategy, stakeholder analysis should be done to identify community requirements. Industrial sectors may need to provide subsidies and utilizes businesses and services from local enterprises. Local material use and revenue generation can be used to develop the local community or local enterprise. The Waste Bank / Organic Waste to Energy (Household Biowaste Purchase Project), for example, has been improved to create energy utilized in communities that gain cash from bio-waste and bio-mass sales as well as profit from the ensuing electrical energy. This business model is consistent with the hybrid renewable energy system (HRES) initiative, which has been established successfully in England and Bulgaria and has used biomass to meet local energy demands [46].

Furthermore, TEIL's Smart Economy Strategy has broadened its scope to establish marketplaces for products and services trading in industrial estates by fostering proper trade in communal commodities. These are beneficial to local communities: small groups with high home output can participate in and profit from initiatives and activities. EIT development that fulfils bio-economy and green economy features is based on the value of important stakeholders and has no bearing on stakeholder group size. The goal is to truly care about the stakeholders and share the available resources in order to generate long-term benefits and positive connections.

4.3.3 Social and environmental perspective

Environmental concerns including resource efficiency, waste management, and lowering greenhouse gas emissions are topics that global organizations have interested from a social and environmental standpoint connected to EIT. The EIT's operations must be improved or upgraded in order to develop initiatives or activities that address such environmental concerns. In practice, for a project to be sustainable, it must include the local community engagement and support. The Global Chemical (GC) company, for example, developed the "You Turn" campaign to collect PET bottle plastic rubbish at drop points at department shops and PTT gas stations. Plastic waste collected will be segregated and supplied to the plastic recycling process [47].

When the industrial sector joins forces to establish strength for local firms and communities, it has the ability to produce initiatives that can integrate social and environmental challenges in the region in a harmonious manner. The outcomes will support GHG emission reduction and control, enhanced public health, and environmental preservation. Furthermore, converting solid municipal waste from local communities and developing wastewater technology to store and recycle biogas into electricity would contribute significantly to the creation of considerable co-benefits for sustainable development [48]. In this case, it is similar to TEIL's "Waste Bank/Organic Waste to Energy" project, which gathers organic waste from local communities as a sustainable raw material for biogas production.

The following additional issues should be concerned regarding the operation of EIT development in line with the BCG economy as:

1) Health and safety concerns are another high-level EIT indicator relating to the quality of life for everyone living in the EIT region. EIT areas will provide safe places for both the physical and emotional health of both personnel working in industrial areas and local populations living in the surrounding region if green spaces in eco-industrial zones and public spaces in community areas are managed well. Indicators include sufficient public park areas and public green spaces for the populace. Important EIT will have a good influence on local public health. Public space management can be accomplished through collaboration between industrial estates and community sub-units known as "temples, homes, and schools" to conserve the environment, ensure safety, and aid in the creation of an eco-community in which residents demonstrate a concern for social, economic, and environmental needs through their collaboration [49].

2) TEIL's community forest initiatives in community conservation zones hosted by government agencies, which will have a good influence on biodiversity in the region, are examples of environmental concerns that have remarkable positive benefits. The indirect advantages include TEIL's reputation enhancement as an environmental conservation leader. Communities can also utilize the promoted community forests in defined areas as environmental education and eco-tourism destinations. It is clear that community forests may be extended further to provide advantages other than environmental protection by creating sustainable revenue for the community. Furthermore, low-end factories can encourage communities together to plant perennial trees in their areas to support the upcoming carbon credit business, generate income for surrounding communities, and contribute to Thailand's greenhouse gas emission goals.

4.3.4 Learning and Growth perspective

Transfer of knowledge and mutual innovation in project and activity execution are required to develop the ability of industrial workers and communities, particularly children and youth. Mutual learning results in long-term development and progress. Part of the process of information transfer and innovation is the Smart People strategy, which aims to build learning centers for local community enterprises in organic fertilizer production and bio-agriculture groups. It also fosters a sense of belonging, understanding, acceptance, and engagement among local residents, all of which contribute to long-term growth.

Knowledge management, like knowledge transmission and innovation, is critical. A systematic data storage procedure should be defined from the beginning of a project and should be included in the success indicators for each project. Because unrecorded interpersonal knowledge transfer may be lost over time, knowledge management should be held explicitly accountable. Furthermore, knowledge on relevant topics is a sort of intellectual property that can be used for commercial purposes. As a result, effective knowledge management and transfer systems will be critical in the development of technologies as part of knowledge-sharing initiatives that support EIT development. At the same time, collaborative learning innovation can build on the success of the sustainable BCG economy model [50].

4.3.5 Management perspective

Continuous monitoring and assessment of projects in the eco-industrial zone is based on effective management that improves sustainability. Good monitoring and assessment are required for assessing results that include both economic and social benefits, referred to as the social return on investment (SROI), an evaluation considered both monetary and non-monetary social values as well as both positive and negative outcomes. If the qualitative variable measurement that an industrial plant should have by establishing monetized value measurement of the social value that an industrial plant has generated in comparison to the monetary value of the costs spent on the industrial plant's activities and the surrounding communities.

However, SROI analysis is insufficient to ensure the success of environmental and social project management. The integral effective management approach in the four aforementioned dimensions is necessary. SROI makes an essential addition to determining non-profit value creation and recalculating the rate of return on investment by taking into account both direct and indirect benefits [51]. Good environmental and social projects should be evaluated as well. A high SROI indicates that the investment provides a significant social return for future development and enhancement of efficiency, transparency, and accountability.

5. CONCLUSIONS

According to this research analysis, TEIL's EIT implementation still has gaps in development to link activities between industry and communities in line with the BCG economy approach. Typically, the industrial sector prioritizes corporate social responsibility (CSR) operations. As a result, it is possible to make a transition from donation to collaboration by sharing the potential of existing industries, such as knowledge, resources, byproducts, and capabilities, in order to develop initiatives and create links between industries and communities for the achievement of sustainable development and mutual benefit.

The initiatives outlined in the economic, social, and environmental plans have found that some have the potential to enhance operations by using technology and innovation to achieve higher goals, such as waste to fertilization, carbon credits, etc. However, stakeholder prioritization is essential and must be implemented from the very beginning of project design so that the benefits derived from projects are reflected comprehensively to stakeholders and in line with the EIT development strategy. The "Flora Exhibition Hall" project by PTT LNG Company is a notable illustration of the large influence of mega-projects in Rayong. PTT LNG has used waste cooling energy from the LNG transformation process to create a new tourist destination, and it has the potential to encourage the Thai flower export [52] and develop an ecotourism program in the EIT region in the future.

The sustainability of EIT development according to the BCG economy guidelines consists of five perspectives: 1) Eco-effectiveness: focus on value creation development with driving forces to create a BCG economic model based on bio-complex industry, 2) Stakeholder perspective: promote large organizations in the area as key players to create mega-change and impact information communication in EIT, 3) Social and environmental perspective: focus on improving the quality of life of local communities and effective environmental management services to create a quality of life based on eco-thinking, 4) Learning and growth: create a process to store and transfer knowledge, innovation, and local wisdom through local learning centers to learn and grow together, and 5) Management perspective: manage EIT operations efficiently by monitoring and evaluating results with appropriate frequency as well as increasing socio-economic indicators to achieve sustainable development.

Because each region of Thailand has unique agricultural and biodiversity context, the key to EIT development based on the BCG economy is to adopt a wide range of economic activities to guarantee that the BCG economy strategy actually creates mutual benefits for the people in the area. The authors suggest that the BCG economic guidelines for EIT development include five perspectives that could be applied to these various biobased contexts in other EIT areas. However, more research should be conducted to refine the guidelines by monitoring and assessing operational sustainability or experimenting by applying these sustainable perspectives of EIT development according to the BCG economy guidelines to compare differences in results and improve the guidelines more appropriately.

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