Green and Smart Industrial Estate Model:

Case Study of AMATA City Chonburi, Thailand

November 2019

Acknowledgements

This report was executed through the collaboration between Amata Corporation PCL and the Global Green Growth Institute (GGGI) with the goal of guiding planning and design fora Green and Smart Industrial Estate Model and having Amata City Chonburi transitioning into a green and smart industrial estate.

The more details on potential works of Amata City Chonburi, the case study in this report, has been deliberately complemented by estudioOCA, a landscape architecture and urban design studio dedicated to the creation of social and sustainable landscapes, and Anthony Paul Fullelove, a senior professional and leader in the energy industry, with a focus on renewable energy, microgrids and net zero precincts.

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Contents

Executive Summary

A wide array of challenges increasingly threatens the health and quality of urban and industrial areas. Causing concern at range of scales, the most critical challenges are posed by changing climatic conditions, environmental risks, as well as rapid urban and industrial growth and mixed industrial and residential zoning. Risks most pertinent to industrial lands and surrounding communities range from deterioration of natural resources, natural disasters (e.g. flood and stormwater), and industrial emissions (e.g. air, water and land pollution as well as noise and odor).

To overcome challenges and take advantage of opportunities, decision-makers, and industrial developers in particular, must rethink the way their developments are planned, infrastructures are built, services are offered, systems are linked, and communities are engaged. Given current risks and global conditions, future international industrial competitiveness will increasingly be linked to sustainability performance. The **"Green and Smart Industrial Estate Model"** focuses on using sustainable landscape and master planning, namely through green infrastructures, as well as smart management of energy and waste with the assistance of information technologies, to identify, recommend, and outline green projects to implement to overcome relevant risks.

In this report, the emerging trends which can be considered and even incorporated into the estate development masterplan, to enhance the greener and smarter status of an industrial estate are also introduced. These trends include the "Circular Economy" which is a new way of creating value through extending product lifespan and relocating waste from the end of the supply chain to the beginning of another. This could also lead to the "Zero Waste" management concept. The transformation of energy scheme is another trend where the estate could become a "Net Zero Carbon" precinct by generating and consuming energy entirely from clean and/or renewable resources.

Roles of industrial land developers and attempts towards greener and smarter practices have arisen in many different sites around the world. Reasons and some examples are discussed and presented. The Kalundborg Industrial Estate in Denmark is a role model for industrial symbiosis, i.e. the opportunity for companies to utilize wastes and exchange by-products in an effort to reduce both economic costs and environmental impacts. Qingdao Sino-German Eco Park in China is an excellent example of smart cooperation between governments, businesses and research institutions to achieve a world leading environmentally-friendly and innovative industrial park.

In order to transform or develop a **"Green and Smart Industrial Estate Model"**, it is important to understand the concept and establish smooth relationship internally and among external stakeholders. The vision of the landowner alone proves hard to achieve this ideal position. There are key attributable aspects, or supporting pillars, to become green and smart including green and smart improvement projects, community Enhancement and support mechanisms. The report has divided actual implementations into ten key green and smart categories: Green Spaces, Green Buildings and Renewable Energy, Smart Manufacturing and Data Infrastructure, Green & Smart Transportation, Smart Water Management, Smart Waste Management, Industrial Symbiosis, Community Enhancement, Regional Infrastructure Extended, and Economic Value Added.

In order to demonstrate the potential path in transition to smarter and greener industrial park, Amata City Chonburi, one of the biggest industrial estates situated in the middle of the Eastern Economic Corridor (EEC), was selected for the purpose. Amata Corporation PCL, the estate developer, has a vision of not only providing a location with state-of-the-art facilities for businesses, but also creating integrated cities with a range of services and long-term design to support businesses and communities in and around the estate.

Ultimately, this report aims to guide the development of a sustainable industrial area that simultaneously improves economic, social, and environmental conditions. Introducing the conceptual idea, researching best practices, identifying categories of actions/activities, showcasing the process towards greener and smarter Amata Chonburi (the case study), and suggesting challenges and lessons learned, the products and methodology of this report can be used and replicated by any industrial areas to transform into a sustainable development. The methodology and analyses were formulated generally and therefore are replicable for other industrial areas around the world.

1. Introduction

The objective of the **Green and Smart Industrial Estate Model** is to develop guidelines not only to introduce innovative, smart, environmentally industrial estate model but also to transform existing large industrial parks into a sustainable and innovative development. Through a design approach that integrates landscape and industrial ecology planning, the industrial lands will be transformed into a Green and Smart City which will serve as a model of best practices.
It is essential to develop an inclusive framework of green growth development pathway that enables both businesses and communities to grow in a healthy and sustainable manner. A holistic approach to green infrastructure and practices should look at impacts and improvements to the natural environment, urbanization, transportation networks, climate, housing, and community. With proper vision and planning, green infrastructure can help or mitigate environmental hazards while simultaneously improving safety and quality of life, all while reducing costs and disruptions. Ultimately, comprehensive planning can enhance the business environment and the livability of the community in and around the industrial land areas.

This report presents a development model for industrial areas to follow in order to transition into green and smart estates, with an emphasis on simultaneous economic, social, and environmental improvement. Given current global issues—e.g. human wellbeing, unemployment, pollution, climate change—and development patterns, sustainability performance will play a significant role in the competitiveness of industrial areas in the future. Existing industrial areas are most often designed with a singular purpose, to promote economic advancement, overlooking opportunities to improve environmental and social conditions. Accordingly, existing and new industrial areas should investigate methods to create and transition their properties to be sustainable estates that exemplify green growth and circular economies. This report is intended to be used as tools to assist the sustainable development of industrial areas by providing best practice models, recommending green improvement projects, and evaluating the impacts of projects.

The **Green and Smart Industrial Estate Model** has been developed during 2018 and 2019 based on the collaboration with Amata Corporation PCL, being key contributor to the case study, and one of its most developed industrial estate in Thailand. This work has been conducted under GGGI Thailand project *'Transitioning to Green and Smart City: Case Study of Amata'*. It was aimed to enhance future green growth projects in the industrial estates in Thailand and internationally, utilizing environmentally conscientious, climate-resilient industrial development.

The objectives of the abovementioned project *'Transitioning to Green and Smart City: Case Study of Amata'* were to develop green and smart industrial estate as a best practice for Thailand, and to share the experiences obtained from this assessment to interested parties across public and private stakeholders nationally and internationally. This report is considered the result of the initial phase which was aimed to convene best practice model and to identify potential smart and green projects to Amata's pilot site. Based on the accomplishment of this phase, the follow-on phase will be further discussed with Amata, as well as GGGI internally. However, it is expected to advance some of recommended green projects into bankability and experience and knowledge will be shared.

It is expected that the transitioning of industrial estates into green and smart cities will provide reliable functions and facilitating facilities (e.g. waste treatment, electricity generation, etc.) for both businesses and communities in and around the areas. Any transition will not only benefit the estate developer and the country's economy but also contribute to other socio-economic improvements

including creation of green jobs; increased access to clean energy, sanitation and sustainable waste management; improved air quality; and GHG emission reductions.

GGGI Country Approach on Green and Smart Cities

GGGI's interventions emphasize change in four priority areas in which we consider to be essential to transforming countries' economies. While not limited to these themes, GGGI is maximizing the impact of its products and services in the following areas: Sustainable Energy, Water and Sanitation, Sustainable Landscapes and Green Cities.

GGGI and Green Cities Activities

Over two-thirds of global population are forecast to live in urban areas by 2050. The implications of this phenomenon are significant. Many of the world's cities are urbanizing in a largely unplanned manner, which has high negative externalities including poor air quality, infrastructure that is not climate resilient, inadequate provisioning of basic services and a lack of social inclusion and opportunity. Cities have a vital role to play in transitioning from resource inefficient patterns of growth and increasing access to services, and in so doing, supporting the transition to green growth.

Greening cities provides opportunities to create sustainable livelihoods through providing green jobs, reducing GHG emissions, and increasing access to sustainable infrastructure and services.

GGGI's thematic approach to green cities supports an integrated and cross-sectoral approach and responds to local, national, and global needs and commitments, through its five priority areas, namely:

(a) Mainstreaming green growth into urban planning and management;
(b) Resource efficient and low carbon cities;
(c) Solid waste management: managing waste as resource;
(d) Decentralized sanitation and wastewater solutions;
(e) Sustainable transportation and mobility: connected and healthy cities.

GGGI aims to address these gaps through responding to demand in policy development at the national and municipal level, with a focus on supporting secondary and emerging cities. To support the change that is needed for urban transformation, we link project ideation to finance and build capacity which both enhances understanding of green growth in relation to cities, but also acts as a platform for identifying innovative projects for implementation. In doing so, GGGI strives to realize pro-poor, smart and inclusive cities in which sustainable urban services and green jobs are created to address the unmet needs of under-serviced and urban poor communities.

Several of GGGI member countries have identified its green urbanization as one of the country's key elements of economic growth. Taken Rwanda as an example, in order to better distribute economic growth across the country and accomplish the national urbanization target of 35% by 2024, the Government of Rwanda has identified six secondary cities to serve as growth poles.

However, this project is rather more specific to greening the industrial parks, but undoubtedly adaptive to the 'Green Cities' scheme. The Green Cities activities of GGGI's have been the basis to the project in Thailand and extended to cover the development of industrial land areas. Below show some experiences on the green / smart industrial zones development in GGGI member states.

Green Industrial Zone Development (Ethiopia)

In Ethiopia, there is currently a big push for the rollout of industrial parks across the country (16 parks by 2025, with 5 already completed and operational). Accordingly, GGGI has been asked to work on greening strategies for the parks. Our industrial parks program for 2019 has three main workstreams:

- Design a road map for greening industrial parks (to be applied to all parks) – policy
- Design a business case for the use of industrial sludge and salt (in two industrial parks) – bankable project
- Design a business case for the use of solar PV (in one industrial park) – bankable project
- For projects #2 and #3, we are in the relatively early stages of project development, confirming the technical aspects to determine the viability and scope of the business cases.

Mapping of Public Spaces to Inform Master Plan Review for Secondary Cities in Rwanda

GGGI is supporting the government of Rwanda to develop secondary cities as competitive economic centers pursuing climate resilience, sustainable & inclusive growth. GGGI, in close collaboration with Rwanda's Ministry of Infrastructure and other stakeholders, has recently accomplished a study on the improvement of public spaces in Rwanda's secondary cities. The report was developed after the mapping and assessment of 36 public spaces in six secondary cities in Rwanda, through citywide surveys and revision on the master plans for Rwanda's secondary cities with technical analysis of public spaces.

Amata Corporation and Its Green and Smart Transition

Established in 1989, Amata Corporation PCL is one of the biggest industrial estate developers in Southeast Asia. The selected case study estate, namely Amata City Chonburi[1], is located in Chonburi province, in the nation's Eastern Seaboard region. With a former vision to become World's Leading Industrial City Developer, Amata has pivoted their business paradigm as an industrial estate developer to focus more on the importance of social responsibility and the impacts created by the estate.

Amata now focuses on developing, managing, and marketing integrated industrial estates. The estate highlights a vision of not only providing a location with state-of-the-art facilities for businesses, but also creating integrated cities with a range of services and long-term design to support businesses and communities in and around the estate. Currently, high-quality facilities are provided on site including: an international standard road system, a private security system that incorporates support from local police, reliable utilities and waste disposal facilities, and well-maintained green areas.

This collaborative project presents innovative but practical development activities to transition this project's case study, Amata City Chonburi, into an industrial estate that complements the needs of industries, communities, and the environment.

To achieve Amata's vision of creating 'a perfect city where possibilities happen', the Corporate is working on developing the Chonburi estate into a green and smart city that integrates industrial facilities with the landscape and community, to minimize environmental impacts and enhance social wellbeing. Amata envisions the future Chonburi development as a catalyst of industrialization that ultimately positions the estate as a leading sustainable economic force in the Chonburi region, Thailand, and beyond. Further, given the goals of the estate, Amata has the opportunity to play a leading role in the growth of the Eastern Economic Corridor (EEC) of Thailand from an early stage in its development.

The mission of Amata is to promote sustainable socio-economic and environmental development while accelerating Thailand's national and regional growth in targeted green industries. To achieve comprehensive green growth, Amata should strive to fulfill economic,

[1] More information of Amata City Chonburi can be found in *Section 4*.

social, and environmental improvement goals to achieve a variety of benefits for the Chonburi estate.

- ***Economic:*** Reduce the negative externalities and impacts for the public and environment by abandoning pure commercial development for a new green growth model. A more sustainable development approach strives to provide economic benefits such as increased property values, reduced infrastructure and operating costs, attraction of new investment sources, and creation of a more competitive and resilient business community.
- ***Social:*** Enhance public wellbeing and share improvements with the community by shifting to a sustainable development paradigm. Application of green growth principles in the industrial estate will offer social benefits including improved health, better work conditions and education opportunities, and enhanced livability by creating excellent work, recreation, and education environments.
- ***Environmental:*** Improve ecological performance and health in order to foster environmental benefits including ecosystem services and environmental resilience. This can be achieved through wise management of resources, application of green growth principles for planning, and investment in nature-based infrastructure solutions.

Figure 1: Bird-eyed View of Amata City Chonburi (Photo credit: www.amata.com

Collectively, a new sustainable development model will help Amata achieve its vision to be a self-reliant, energy-efficient, and climate resilient city by providing strategies and identifying potential green projects for improvement. By turning its green and smart vision into implementable green projects is believed to create shared prosperity for the estate, its stakeholders and businesses, the general public, and the environment. In September 2018, Amata further showed commitments to its green and smart vision with these key performance indicators illustrated in *Table 1*.

From Vision to Implementation

The structure of this report aims to gradually leading the readers from the concept to the actual implementation.

Section 2: Green and Smart Cities introduces the key conceptual ideas of what Green and Smart City could be meant, why the industrial land developers are moving towards it and what the global development trends are, then coupled with some world-classed case studies.

Table 1: Amata Key Performance Indicators

KPI		Endline 2040	
Item	**Indicator**	**Area A (Brownfield)**	**Area B (Greenfield)**
1. Achieving Sustainability through "Zero" Emission	Waste to energy electricity generation	40MW	
	Energy self-reliance with smart grid management	100%	100%
	Renewable energy utilization rate	20%	20%
	Wastewater utilization rate	100%	100%
2. Providing Easy Access and Effective Mobility	Public transportation utilization rate for commuters	50%	50%
	Green vehicle (Hybrid, electric) utilization rate	20%	20%
3. Enhancing Quality of Life and Sustainable Environment	Tenant occupancy rate	100%	100%
	Create walkable city, increase recreational walk way length	30%	
	Increase per capita public green space	20%	
4. Linking Top Level Education with Innovation	No. of educational facility	10	15
	No. of R&D facility	10	10
	% of skilled labor	30%	
5. Fostering Innovative Technology-based Industry	Companies on 10 target industries	30%	50%
	Services network coverage (4G+FTTX)	100%	100%
	Use of smart factory application	50%	50%
6. Exhibiting Healthy Living Style for All Ages	Employees having a periodical medical-check up	100%	100%
	People working after 60 years old (% of senior executive levels)	10%	10%

Source: Amata (2018)

Section 3: Roles of Industry and the Green and Smart Industrial Estates discusses the roles of industries and key attributable aspects to become Green and Smart, then which categories of, within and around the industrial parks should be enhanced.

Last but not least, *Section 4: Amata City Chonburi: A Case Study in Thailand* presents a specific case study. Amata City Chonburi is an existing and active industrial estate in the eastern part of Thailand. Here the report looks into its existing conditions, site assessment, challenges and opportunities, gaps and site potential analyses, and how Amata Chonburi can upgrade itself towards Green(er) and Smart(er) status. The lessons learned of this specific case are also be deliberated at the end of this report.

2. Green and Smart Cities

To the dawn of Green and Smart Industrial Estate, we shall define what would be considered "Green" and what is the relevance of "Smart" in the context of a city, especially drilling down to industrial estate. This section will first define the meaning of "Green" and "Smart", explore the global interest towards greening industrial zones and end with some apparent examples of green and smart industrial parks worldwide.

What is Green and Smart City?

Beginning with the concern of rapid urbanization process, leading to adverse environmental impacts which in turns deteriorating humans' quality of life, **"Green"** city has come into the development pathway to ensure and increase the sustainability and wellbeing in urbanized areas. It is somewhat similar to a common urban planning concept of harmonizing city with nature, restoring the values of urban ecosystem, minimizing resource and energy consumption, and wisely taking advantage of ecosystem services. GGGI defines a Green City as "A city/town/city-region which pursues resource efficient, low-carbon, climate resilient and socially inclusive urban development, generating green job opportunities".

Being **"Smart"** can be considered as a set of tools to successfully achieve a city's goals of sustainable growth, livability and being green. In order to do so, strong understanding and a solid foundation have to be installed to ease and ensure systematic organization and management of the city, with the aim of increasing citizens' welfare and sustainable growth of the city. This digitalized system includes infrastructure, datahubs for data sharing and standards for data security and privacy. Most importantly, being smart is intellectual property attached to human resources; thus, maintaining and enhancing it are vital to the long-term success of the smart city. As such, GGGI views that, both "smart" and "green" concepts ought to go and embed alongside. Thus, a smart, green city is well governed, inclusive, manages its eco-resources sustainably and through ICT is able to provide efficient, affordable and effective services to all through smart approaches and systems. It is able to efficiently use finances & generate investment to support its plans.

The "Smart" and "Green" fashion is not an emerging trend. It has been visualized, and even materialized, for a few decades. The concept has prevailed in many different labels, such as smart cities, intelligent cities, creative cities, green cities, sustainable cities, cities of the future, etc. In this report, **"Green and Smart Industrial Estate" is a community where balance among ecological and social needs are established and harmonized with the economic and industrial development, through appropriate applications of ICT technologies, to ensure a clean, healthy and safe environment for all members of society.**

Transitioning Conventional Industrial Estate into Green and Smart City

Aimed to amplify one country's economic growth, industrial estates development is seen to be a powerful approach, while being in control and having an advantage over others. However, concerns on environmental and social impacts have strongly emerged. Public resistance towards industrial development may be grueling. Land clearing and transformation of land use are feared to change the natural structure of the ecosystem, as well as social and cultural ways of life of surrounding communities. Over the course of its operations, communities fear of environmental impacts on quality of air, land and water, as well as wastes and pollutants from the manufacturing processes.

Environmental damages resulted from conventional industrial land operations have created pressure to industries and relevant players from both public and private sectors to implement the principles of sustainable businesses. As such, the concept of a "green [and smart] industrial estate" has been picturized in hopes of enhancing environmental and economic performance in and around industrial areas.

As industrial land development market is becoming more and more competitive, being greener is another feature to attract more investors, especially those large corporates with green vision. It can also be viewed as an economic strategy that seeks to transform the nation's economy from one reliant on conventional manufacturing to a value-based economy focused on innovation, higher technologies and green industries. Besides, the demonstration of social responsibilities can also lessen public resistance. Therefore, the creation of more sustainable industrial parks is an enhancement to the bottom-line, while green investment will help people on the ground, including the owners and investors to save costs through energy efficiency and higher productivity from the workforce because they are able to enjoy a better quality of living.

Emerging Trends: A Friendlier Industrial Estate

Reducing risks of environmental damages and human livability is only the foundation of all attempts to shift the industrial parks across the line, these are other initiatives promoting the greener and smarter estates in more sustainable manner.

Net Zero Carbon Initiative

Net Zero Carbon, commonly known as carbon neutrality, refers to the concept where one particular system achieves net zero carbon dioxide emissions (equivalent) by balancing carbon emissions with carbon removal or simply reducing carbon released altogether. Similar initiative on Net Zero Carbon can be applied in various activities such as energy production, transportation, industrial processes, or even agricultural practices. The concept may be extended to cover other types of GHGs measured in terms of their carbon dioxide equivalence (CO2e).

In the context of Green Industrial Estate, several aspects and activities can contribute to the net zero carbon. Activities ranging from the most valiant GHG emitter to the least may include energy production/consumption to green spaces have different levels of contributions towards the Initiative.

Since energy part is generally the key source of GHGs in each country especially from the consumption in industrial sector, the focus of this Initiative in greening the industrial estate is to focus on energy transformation. The pathway to low carbon emissions at industrial parks require a systematic decarbonization of all aspects of the energy cycle. Best practice addresses onsite energy use and only using offsets as a last resort.

Box 1 illustrates facts and lessons learned from Monash University, Australia's largest university, has committed to reach net zero emissions.

Zero Waste

The definition of zero waste varies widely, with various organizations defining zero waste differently, each with their own interpretation. The Zero Waste International Alliance (ZWIA) has recently had an updated definition of "Zero Waste" which was adopted by the ZWIA board in December 2018. It is defined as, ""Zero Waste: The conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning and with no discharges to land, water, or air that threaten the environment or human health."[2]

Generally, Zero Waste concept focuses on waste prevention, eliminating the generation of waste materials to be sent to landfills, incinerators, or release to nature. Zero waste encompasses more than eliminating waste through recycling and reuse, it focuses on restructuring production and distribution systems to reduce waste in a long-term, sustainable manner.

[2] Source: http://zwia.org/zero-waste-definition/ [Accessed on 26 August 2019]

Circular Economy

The UN Industrial Development Organization has given an explanation of "Circular Economy" as "a new way of creating value, and ultimately prosperity, through extending product lifespan and relocating waste from the end of the supply chain to the beginning [of another chain]—in effect, using resources more efficiently by using them more than once. In a circular economy, however, materials for new products come from old products. As much as possible, everything is reused, re-manufactured or, as a last resort, recycled back into a raw material or used as a source of energy."[3] According to the UN Conference on Trade and Development (UNCTAD), large social gains can be realized from improving resource circularity in multiple sectors, such as in recycling and reutilization of materials, energy efficiency, value-chain optimization, and in collaborative economy models such as in fast-growing space and vehicle sharing.[4]

The concept of a circular economy has been strengthened by Ellen MacArthur Foundation Transitioning to a circular economy does not only amount to adjustments aimed at reducing the negative impacts of the linear economy. Rather, it represents a systemic shift that builds long-term resilience, generates business and economic opportunities, and provides environmental and societal benefits.[5]

The circular economy concept can be applied into various context, ranging from village to national level. An example of circular economy showcased in *Box 2*, so-called "Industrial Symbiosis", is an implementation fit well within the boundary of industrial lands.

[3] Source: https://www.unido.org/our-focus-cross-cutting-services/circular-economy [Accessed on 26 August 2019]
[4] Source: https://unctad.org/en/Pages/DITC/Trade-and-Environment/Circular-Economy.aspx [Accessed on 26 August 2019]
[5] Source: https://www.ellenmacarthurfoundation.org/circular-economy/concept [Accessed on 26 August 2019]

Box 1: Monash University and its Net Zero Carbon Initiative

Monash University, the winner of the 2018 UNFCCC Momentum for Change – Lighthouse award at COP24, has committed to a Net Zero target by 2030 with costed implementation strategy. Monash was the first Australian university to commit to an energy reduction target and proud to be a leader in taking action on climate change. It has been decarbonizing its campuses since 2005 when it became the first Australian university to commit to an energy reduction target.

Monash is Australia's largest university, also a large energy user. The Net Zero Initiative is based on the ClimateWorks Australia approach which pursues 'four pillars of decarbonization': ambitious energy efficiency, renewable energy, electrification/fuel switching, and offsetting residual emissions. To meet increased demand for energy and resources, while reducing emissions, Monash will make considerable improvements to energy efficiency and lead the way to a 100% renewable future. Monash is transforming its campus infrastructure to demonstrate how the transition to the low carbon economy makes not only environmental but also business sense.

Helping the planet: Monash is pursuing and achieving the goal of net-zero emissions by ending its dependence on natural gas and completely electrifying its Australian campuses. The University has signed a long-term Power Purchase Agreement with a local wind farm to help meet their 100% renewable power target. To unlock solutions to today's energy challenges through simulating a "smart energy city", Monash is setting up a market-leading microgrid, that will control how and when energy is used across campus to maximize value for customers.

Helping people: The Net Zero Initiative is dedicated to raising awareness of the benefits of working towards net zero emissions and smart cities. This is undertaken through engagement activities (lectures, events, media presence), and also to efforts to embed sustainability into the university culture and work practices, and to create change champions within the university and beyond.

Spillover effect: Monash and ClimateWorks Australia are working with industry and government to communicate the lessons learned from the Net Zero Initiative, and to encourage other entities to undertake similar initiatives. A strong emphasis is placed on transforming Monash's campuses into smart cities and creating models that can be replicated well beyond campus boundaries.

Source: https://unfccc.int/climate-action/momentum-for-change/climate-neutral-now/monash-s-net-zero-initiative [Accessed on 23 August 2019]

Box 2: Industrial Symbiosis

Industrial Symbiosis presents the opportunity for companies to utilize wastes and exchange by-products in an effort to reduce both economic costs and environmental impacts. Industrial Symbiosis projects have been implemented at various scales (local, regional, national) around the world as a method for a network of organizations to create shared benefits through exchanges of materials. For industrial estate operator, industrial symbiosis is a potential method to materialize the vision and goal of creating a truly sustainable industrial estate.

Industrial symbiosis is defined as the utilization of surplus resources as a new input into another process. Akin to a circular economy and green supply chain, industrial symbiosis practices focus on reducing waste and utilizing recycled materials over virgin ones. The concept was originally developed for economic purposes but has continually demonstrated the environmental and social benefits it can provide. The co-location of complementary industries has been documented to increase efficiencies and decrease costs and has been applied in industrial parks around the world. Kalundborg Industrial Estate is the pioneer of the industrial symbiosis concept and delivers significant cost savings to firms involved in exchanges.

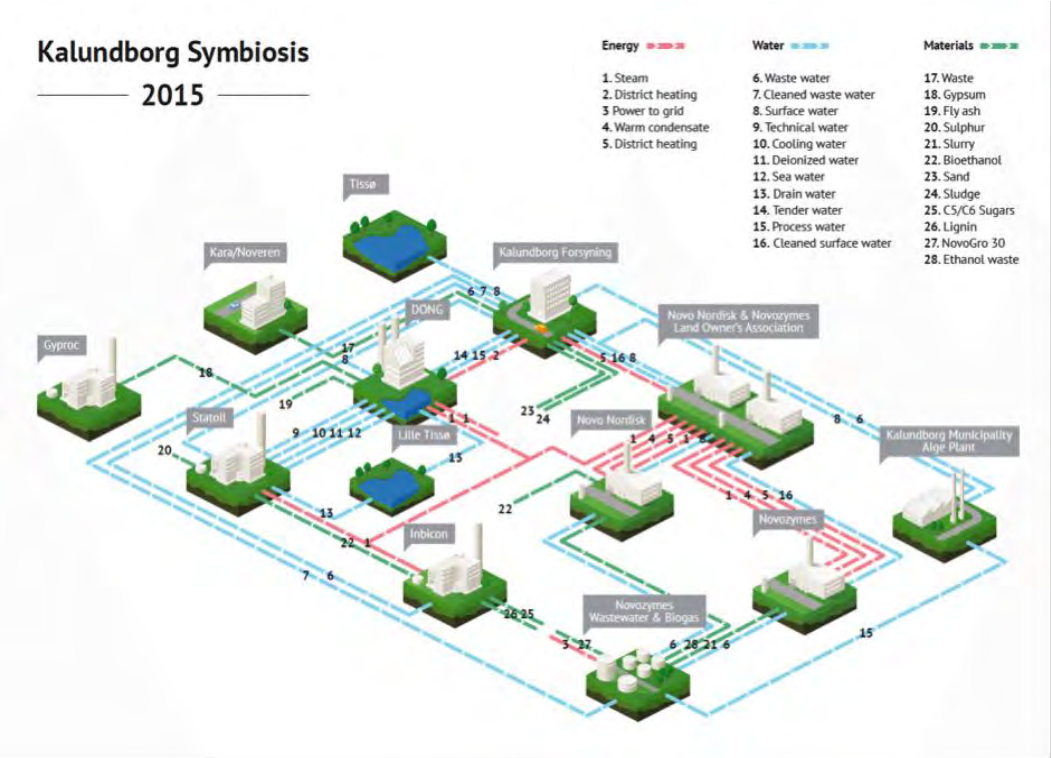


Figure credit: http://projects.mcrit.com/esponfutures/index.php/home/85-kalundborg-symbiosis-in-denmark-the-world-s-first-working-industrial-symbiosis

Attempts towards Greener and Smarter Estates: Worldwide Examples

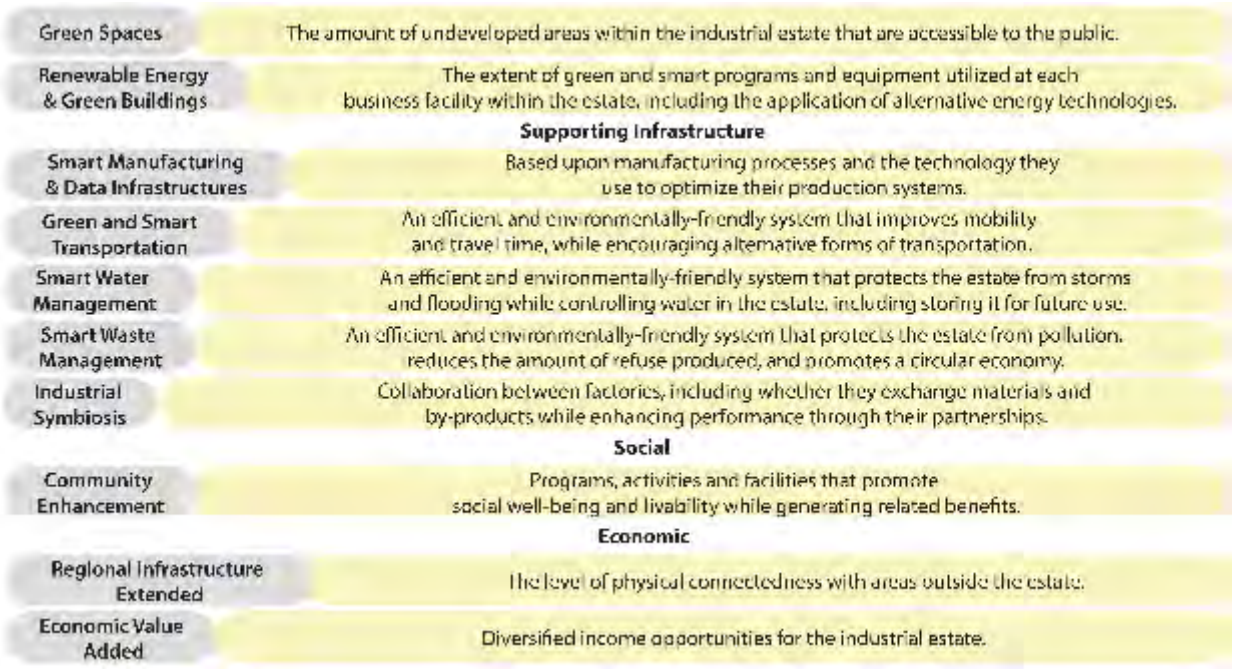
The following case studies were selected based on a number of criteria, including awards, international perception and sustainable development aspects. The model industrial parks *Case 1: Kalundborg Industrial Estate, Denmark* and *Case 2: Qingdao Sino-German Eco Park, China* have been constructed, *whereas Case 3: Oakajee Industrial Estate, Australia* is still undergoing development yet nonetheless illustrate optimal green and smart development.

The green and smart practices of these case studies were evaluated based on a selection of the most critical practices. These were designed from green

industrial estate standards and evaluations[6] used around the world and are redefined as illustrated in *Figure 2*.

the highest to meet global best practice of the same category.

Figure 2: Ten Categories of Green and S mart Industrial Estates



Below, the reviews of selected international case studies and scoring of their performances are defined and briefly discussed. Each case was scored to determine their effectiveness in each of the ten categories (referred to *Figure 2*). It should be noted that the scoring is on comparative basis among these selected world's best standard. This aims to show opportunities to strengthen their green and smart vision practice. Finally, an evaluation system for the eco-parks is illustrated: classifying their performance in rating scales from 1 to 4, where 1 is the lowest and 4

Case 1: Kalundborg Industrial Estate, Denmark

Kalundborg is the most famous example of a circular economy and by-product exchange in an industrial estate, as it is credited with being the pioneer of industrial symbiosis. The estate did not develop through a large-scale planning process, but rather is the result of a gradual evolution of cooperation and exchanges to create a complex web of symbiotic interactions between eight neighboring businesses and the Kalundborg municipality. Initially for solely cost-saving purposes, the exchange network has evolved, and the estate now demonstrates how green practices can provide social and environmental advantages as

[6] Referred to:
- World Bank Group, United Nations Industrial Development Organization (UNIDO), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), "An International Framework for Eco-Industrial Parks," 2017. https://openknowledge.worldbank.org/handle/10986/29110
- United Nations Industrial Development Organization (UNIDO), "Implementation Handbook for Eco-Industrial Parks," 2017. https://www.unido.org/sites/default/files/files/2018-05/UNIDO%20Eco-Industrial%20Park%20Handbook_English.pdf
- UN Environment, "Green Industrial Policy: Concept, Policies, Country Experiences," 2017. http://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/22277/Green_industrial_policy.pdf?sequence=1&isAllowed=y

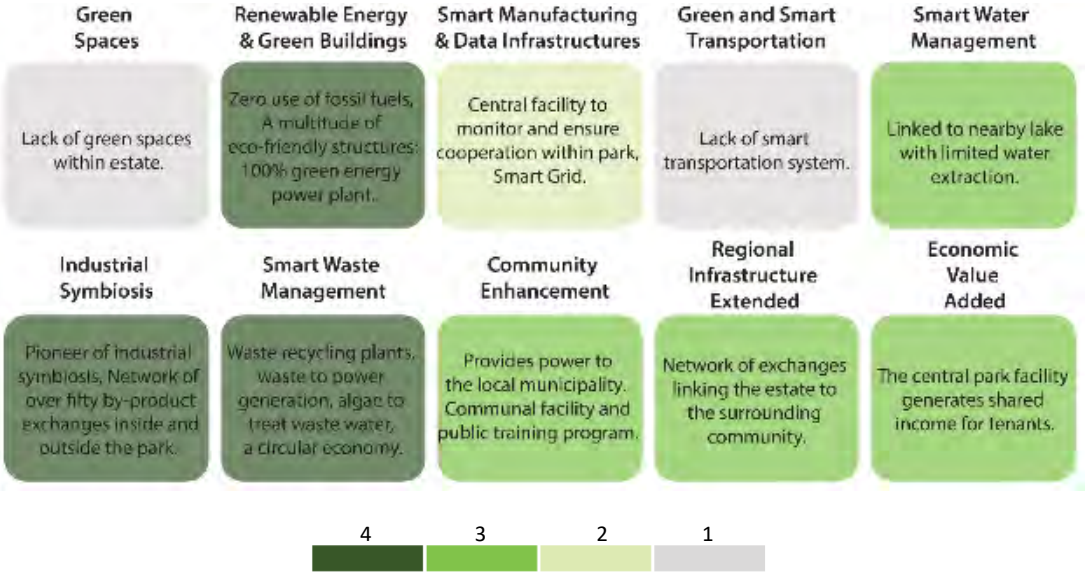
well. The estate is independent of fossil fuel energy and achieves sustainable growth through its framework focused on innovation, new green technology and resource efficiency. The estate is home to businesses in a variety of industries including energy, pharmaceuticals and biotechnology, clean technology and waste management. This network of recycling and reuse has generated cost savings for companies of roughly USD15 million per year while reducing pollution and waste outputs in the area.

The development of this park was led by private industries, through commercial agreements between business partners, adding the local municipality as a partner at a later stage. Currently, the park is managed and supervised by a committee consisting of a representative from each business and the municipality. The role of the local government is to help monitor exchanges and ensure cooperation between industries. Additionally, it has created local policies and incentives to encourage waste reduction by park tenants.

Apart from its pioneering scheme in industrial symbiosis, Kalundborg Industrial Estate has shown its strengths in renewable and green buildings; and waste

Figure 3: Kalundborg Industrial Estate, Denmark

Figure 4: Performance of Kalundborg Industrial Estate



management. The lacking is in the areas of green spaces; and smart transportation (see *Figure 4*).

Case 2: Qingdao Sino-German Eco Park, China

The Sino-German Eco Park, a 4,060 Hectares industrial park located in Qingdao, China, is an excellent example of a green and smart industrial estate. The project demonstrates cooperation between governments, businesses and research institutions to achieve a world leading environmentally-friendly and innovative industrial park. The vision of this project, which was designated as a Smart China pilot city, was to create an industrial park that would be a laboratory for sustainable industrialization and urbanization. The industrial park was initiated through a bi-lateral national partnership between the Chinese Ministry of Commerce (MOC) and the German Ministry of Economic Affairs and Energy (BWMI). The partnership was created to capitalize on the strengths of each nation, pairing China's rapidly growing economy and lack of green industrial processes with Germany's advanced technologies and management expertise.

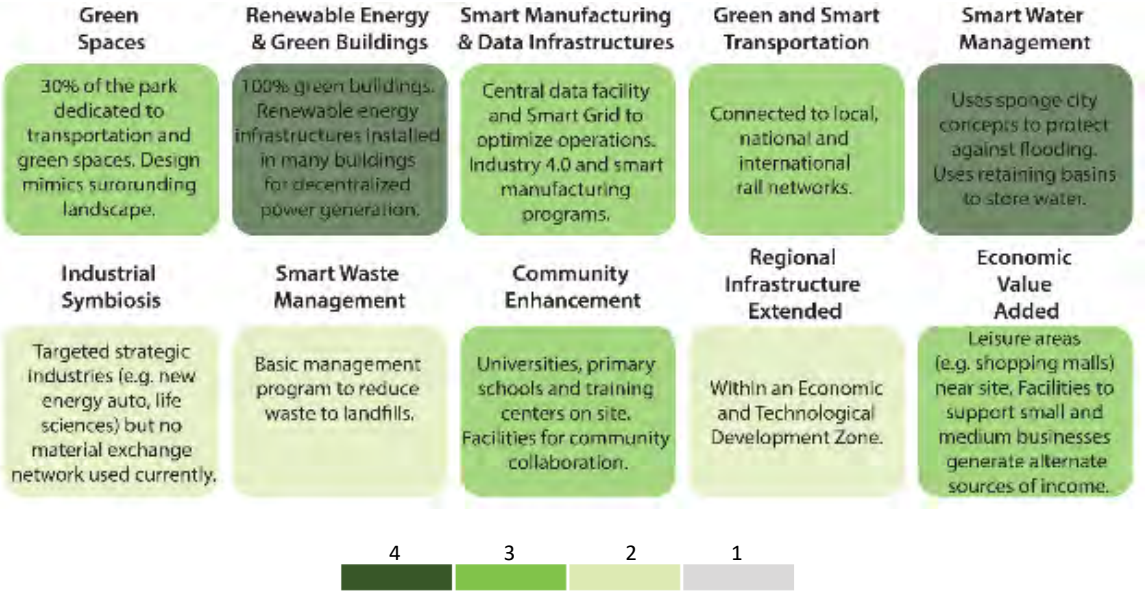
The park is financed through a mixed model PPP (Public-Private Partnership). Investments for the project from China come from the government, while investments from the German side come from private companies and stockholders as the park is listed on the German stock exchange. The park is managed by a joint venture, the Sino-German Eco Park Development Co., which oversees park operations. The aspects where the Sino-German Eco Park are considered strong including the renewable energy and green buildings; and its smart water management (see *Figure 6*).

Figure 5: Qingdao Sino-German Eco Park, China

Case 3: Oakajee Industrial Estate, Australia

The Oakajee estate illustrates exemplary integration of an industrial estate with the surrounding environment under an ecological framework. The project is a result of long-term planning and in-depth site analyses for a strategic greenfield industrial development. The site is still in the construction and implementation phase; however, it will be home to heavy and light industries that are linked to nearby transportation hubs, including a deep-sea port. The development strategy has three goals: protect and incorporate natural values, enhance cultural benefits, and stimulate regional economic growth. One key practice used to achieve these goals is dividing the estate into four areas: Strategic Industry, Coastal, General Industry and a Buffer. The site aims to be a model of local and regional industrial

Figure 6: Performance of Qingdao Sino-German Eco Park



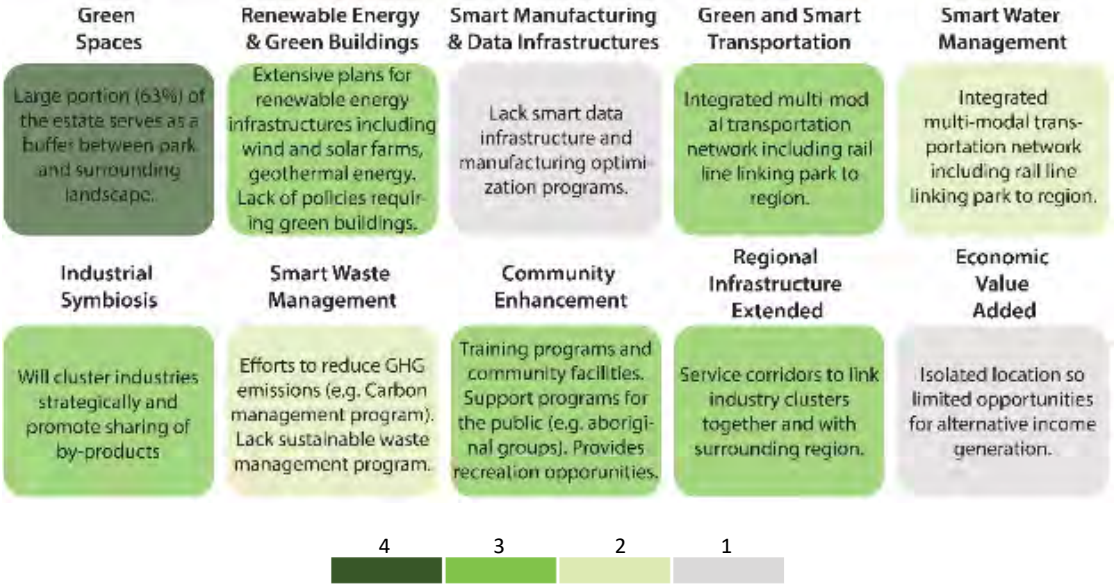
development that provides social and environmental benefits.

The project was initiated by the government in an effort to enhance economic development in the region, therefore several government entities are participating. This includes the Department of State Development, Western Australia Planning Commission, Western Australia Environmental Protection Authority and the local municipality. However, the estate is managed, and a majority of the land is owned, by a private development company, LandCorp.

Oakajee estate has undoubtedly had a precious plan for its landscape. However, its data infrastructure is still lacking, while the economic value added is limited due to its isolated location.

Figure 7: Oakajee Industrial Estate, Australia

Figure 8: Expected Performance of Oakajee Industrial Estate



Key Takeaways from Kalundborg, Qingdao Sino-German and Oakajee

From the above three examples, **planning and development processes** are deemed equally important steps towards success. The case of Kalundborg Industrial Estate (Denmark) has proved successful through gradually development, not through a large-scale planning at the early stage. The initial planning at Oakajee Industrial Estate (Australia), through zoning to ensure social and environmental benefits, can advantageously illustrate different scenarios for considerations, leading to foreseeing risks and potential advancements from the very beginning.

Deep-Green and Smart model of industrial area development highly requires different levels of **cooperation**. Qingdao Sino-German Eco Park in China is a good example of intergovernmental partnership matching strengths of China's rapidly growing economy and of Germany's advanced technologies and management expertise together, through an innovative PPP model. Oakajee has planned to involve three-levelled inter-ministerial cooperation: central, regional and local. Kalundborg has actively involved the local government who plays role to ensure smooth cooperation among businesses and municipality in the area.

All in all, the attempts towards greener and smarter status of all three examples are to ensure environmental sustainability, economic growth, as well as social wellbeing. The industrial symbiosis model at Kalundborg has proved beneficial not only to the businesses (cost saving of USD15 million yearly), but also to the local municipality in terms of both social and environmental advantages. The Qingdao Sino-German Eco Park model aims to provide sustainably harmonization between urban and industries. Oakajee's plan has also involved ecological and cultural benefits into its scheme.

3. Roles of Industries in Green and Smart Industrial Estates

Role of Industry in Green City

Presently, each major city around the globe tends to be highly vibrant while facing varieties of political, economic and social challenges in one limited boundary. To distinct some economic activities especially heavy industries away from the cities, the idea of industrial estate development has come into actions.

The government has played an important role in arranging separate areas of land to be developed as sites for factories and other industrial businesses. In doing so, communities will perceive generic benefits from risks of noise, odors, lights and pollutions. While the estate operator shall ensure that the required facilities and factory accommodation are provided to the entrepreneurs to establish their industries there. Apart from necessary facilities for industrial operation such as water, transport, electricity, steam, wastewater and waste management services, others might also be included such as bank, post office, canteen, hospital and first-aid, or even other special arrangements for technical guidance and common service facilities.

Provided that there are huge working opportunities and necessary provision in and around the industrial zone, while the housing prices in city centers rising, this migration of industry has pushed the working class out to the peri-urban areas. Large numbers of not only workers but also people looking for cheap land, often near these estates, tend to roam and settle in the adjacent area, or even within the estate boundary where space available, leading to emergences of communities, eventually, end up creating conflicts when they start complaining about noise, odor, etc. Therefore, it is crucial and unavoidable to find harmonized way to urge industrial development to go hand-in-hand with living societies.

What Attribute to Green and Smart Industrial Estates?

The subsequent section will provide an overview of concerning aspects to pursue green and smart development: Green and Smart Improvement Projects, Community Enhancement, and Support Mechanisms. These development categories coupled with specific case studies and global trends (*Section 2*) will formulate the criteria used for the recommendations for the green and smart Best Practices for the case study Amata City Chonburi (*Section 4*).

Green and Smart Improvement Projects

For an industrial estate, implementing projects that are environmentally friendly, climate-resilient and innovative will allow the estate to model sustainable industrial development nationally and worldwide. Improvement should first focus on adhering to strategic initiatives and implementing varied types of green infrastructure improvement projects.

At international level, the adhering **strategic initiatives** may be tied to the *UN Sustainable Development Goals*, which outline of goals to achieve by 2030 for the creation of the sustainable world. These goals address the most pressing global challenges, and the *UNIDO Green Industry Initiative*, where the estate can work with governments to support industrial institutions that provide assistance to enterprises for greening of industry. Attempt to green industries by promoting sustainable economic growth and improving production processes.

Urbanization and changes in land use surrounding the industrial estate may be some of the problems causing concern for the surrounding community. Incorporation of **green infrastructures**—e.g. permeable pavements, green streets and alleys, green parking space, urban tree canopy, etc.—into the estate can help reduce the negative environmental impacts of development while improving economic opportunities, social conditions and environmental health. Green infrastructures are

Figure 9: Aspects in Pursuit of Green and Smart Development

defined as networks of natural and semi-natural features and green spaces that intersperse and connect communities. The green infrastructure projects will ultimately create an enhanced industrial area that harmoniously promotes human welfare, ecological sustainability, and economic prosperity.

The following concept "Sponge City" illustrate an example of a potential green infrastructure project.

Community Enhancement

There is always an opportunity to improve social conditions of the surrounding community and minimize adverse public impacts from activities within an industrial estate. Social improvement outcomes can be achieved by engaging stakeholders, facilitating community outreach programs, and constructing social infrastructures.

First of all, **relevant stakeholders** are to be identified. In general circumstance, stakeholders that should be involved with programs and engagement strategies include industrial estate planners, developers, operators, and management; firms within the estate; industrial associations and chambers of commerce; national, regional, local governments; financial sector, funding agencies, and donors; international development agencies and NGOs; scientific research institutions/universities; and local community.

Box 3: Sponge City

One acclaimed application of green infrastructure to promote climate resilience and environmentally-friendly communities is the sponge city concept.

Urbanization and land use changes have caused an increase in the incidence of flooding globally. Sponge Cities are an alternative stormwater management method to grey infrastructures. A sponge city is an urban area designed to manage water and mitigate flood damages. This is achieved by increasing infiltration, as well as better managing (delay, store, resist), and purifying stormwater runoff. Common stormwater management plans are made of networks of expensive grey infrastructures, including storm drains and canals. Increased urbanization has causes stress on stormwater infrastructure, since increases in paved areas cause larger amounts of water to accumulate than ever would naturally because this water cannot infiltrate into the ground. This leads to recurrent flooding, surface water pollution, and water shortages.

Sponge Cities are a way to combat these issues with a nature-based solution. A Sponge City is a development that absorbs, cleans, and uses rainfall to reduce flooding and polluted runoff by employing environmentally conscious and nature-based water management solutions. The goals of a sponge city are to absorb, store, infiltrate, and clean excess stormwater, in addition to helping mitigate impacts of too little and too dirty water. These concepts are particularly relevant and useful for areas subject to flooding, since these green infrastructures reduce and slow water during periods of persistent rainfall. Therefore, sponge cities provide economic, social, and environmental benefits when implemented.

Sponge cities are created by constructing a network of green infrastructures and permeable surfaces that control water sheet flow. Accordingly, green infrastructures and sponge cities in particular provide a wide array of benefits for developments where they are implemented. The utilization of green infrastructures in developments yield ecosystem services such as improvements to: air, soil and water quality; energy, nutrient and water cycles; noise and GHG pollution; public health; biodiversity and environmental health; and climate resilience and regulation.

China is a leader of sponge city development and has created a pilot program to implement these projects in several communities. One successful Chinese project is Minghu Wetland Park in Liupanshui City. This project in a deteriorated peri-urban area restored a formerly channelized river to a meandering river and wetland, in an effort to control flooding and purify water. The project inundates flooding and promotes climatic resilience by storing flood water during periods of high rainfall; however, when flooded areas are empty during the dry season those lands are used as park space. The site is characterized by a network of bridges that connect to several areas of land and permit use during both the wet and dry season, creating public space and enhancing the site's ecological integrity.

Community outreach helps create a productive link between an industrial estate and the local community. Therefore, it is important for an estate to establish mechanisms for collaboration and dialogue with stakeholder groups to provide benefits and facilitate connections between all parties. An essential component of the community outreach program will be public participation and collaboration events. These programs could manifest as using community-based planning tools, facilitating stakeholder engagement workshops and programs, hosting community events, and developing public enhancement strategies. Building relationships and implementing outreach programs with stakeholders will provide an improved understanding of perspectives, ultimately helping to prioritize development projects and cultivate public support.

Social infrastructures are a mix of facilities, spaces and projects that provide social services and improve the standard of living and quality of life in a community. Including assets such as school, medical and utility facilities, these areas support the public by providing shared community spaces. These infrastructures represent an opportunity to improve community health, function, and quality of life by creating structures based on ecologically-friendly and smart designs, which will ultimately make a community a more pleasant and productive place to work, live and learn.

The implementation of social infrastructures promotes numerous benefits for communities. A particular estate should craft an approach that targets specific benefits they would like their social infrastructures to generate. Potential social benefits include quality employment opportunities; improved working conditions and spaces; training and education opportunities; social inclusion; local and small business assistance; public health and wellbeing; safety; environmental improvement (air, soil and water quality); recreation and leisure opportunities; diverse transportation options; and flood and disaster resilience.

Support Mechanisms

For industrial estates to effectively transition from a production-based industrial site to an environmentally-friendly estate with high technology and innovation, there are several partnerships and support mechanisms they could use. This section illustrates the potential partnerships and support mechanisms, including governmental support, public-private partnerships and other strategic partnerships.

Government supports in the form of policies and funding is critical for the creation of a successful and sustainable eco-industrial park (EIP). The following roles, responsibilities, and policies to embrace or enact offer insight into how various levels and agencies of the government can help create a green and smart industrial estate that serves the mutual interests of the estate and communities simultaneously.

Eco-Industrial Parks are especially valuable in developing and emerging countries since they promote environmental, economic and social benefits; therefore, it is in the interest of the government to promote their development. Governmental support for eco-industrial park projects can be applied through a variety of methods and activities, including the following roles and responsibilities from EIP projects around the world:

- Participation of national agencies (including in PPP's) to support EIP development
- Creation of funds, environmental investments, and community programs
- Streamlining of permit processes
- Support of R&D for studies, projects and ongoing programs in the estate
- Facilitate financing from international sources
- Technical support, training and education
- Incentives for recruitment
- Awards for environmental performance
- Creation or amendment of policies and regulations to support EIP development

Apart from the variety of government's supporting mechanisms for green and smart improvement projects, these supports may be provided at various levels: national, regional and local. Some examples of different supports are provided below.

- *National*: National Industrial Symbiosis Program (NISP, UK) – Program developed in 2005 to facilitate exchanges of wastes and unused by-products from businesses in a variety of industries by delivering cost savings while reducing reliance on raw materials and waste discharged in landfills. In the first four years of the program, it delivered cost savings of USD166 million to its members as well as prevented the use of 9.4 million tons of industrial water and 7.9 million tons of raw materials.
- *Regional*: Tertre Eco-zoning (Belgium) – The Walloon regional government designates zones for specific industries to locate.
- *Local*: Kalundborg Industrial Park (Denmark) – Prompted by water shortages, industrial exchanges have been funded, planned, and supervised by the Kalundborg municipality in partnership with private businesses to save money and promote environmentally-friendly development within the industrial park in support of industrial symbiosis initiatives. The exchange of by-products and resources is done with a primary emphasis on promoting economic benefits, delivering total estimated savings of USD 91 million per year, while reducing yearly emissions by about 240,000 tons.

Public-Private Partnerships (PPP) are an innovative method for private industries to work with governments and other institutions. They are utilized when governments want to compensate the private sector for public improvement projects and are most viable when their shared investments create mutual benefits. In PPP's, public and private sector partners share resources, risks, responsibilities and rewards, and work together to develop, operate and maintain infrastructures. Typically, PPP's are used for long-term contracts such as community infrastructures. Specific to industrial parks, PPP's are an effective method to secure government support for projects that extend or provide benefits outside of the estate, such as green corridors and transportation networks. The Asian Development Bank outlines the basic steps to form a PPP as:

- Discuss financing strategy, development plan, and timing for creating each partnership
- Establish roles for members and channels of communication for coordination of activities
- Create allied nonprofit organization (if applicable to access certain funding)
- Execute established plans and programs with continued monitoring

Forming **strategic partnerships** is considered another beneficial approach. Key types of strategic partnerships are:

- *Educational Institutions*: Eco-Industrial Parks can increase their productivity and improve the likelihood of their success by partnering with educational institutions, particularly universities. EIP's around the world have formed various types of partnerships with universities for research and development, planning, satellite campus locations, and training courses.
- *Other National Governments*: Partnerships between two national governments have been a successful mechanism to create sustainable industrial park projects that serve mutual interests. The most productive national partnerships couple the expertise of one country with the weaknesses of the other to create mutually prosperous collaborations. Nations considering these types of partnerships must objectively evaluate their strengths and weaknesses, then search for a complementary country.

- *International Organizations*: Collaboration with international institutions is a valuable method to create a green and smart industrial park. These types of institutions can offer support to industrial estates through studies and technical training, planning and policy development, and funding. Non-Governmental Organizations (NGO), development banks and aid organizations are suitable partners for industrial estates while transitioning into a green and smart development.
- *Businesses within the Estate*: To ensure a successful and lasting green and smart industrial estate, it is vital to attract and house businesses that buy into the development plan. Park management should educate companies already established within the park as well as potential recruits on the benefits of being located within a green and smart industrial estate. Securing commitments to green production practices from businesses in the estate will result in a community of tenants that is more resilient, cooperative and economically prosperous.

Key Categories of Green and Smart Industrial Estates

The ten key green and smart improvement categories for industrial parks have been identified to gauge performance and guide development of industrial estates, based on the standards, guidelines, and criteria dictated by UNIDO, World Bank, and GIZ, as well as the standards for Eco-Industrial Parks (EIP) in China. Additionally, critical concepts and strategies from international best practice case studies were researched to further ascertain key categories for sustainable industrial development (Refer to *Section 2*, subsection *Attempts towards Greener and Smarter Estates: Worldwide Examples*). The ten key Green and Smart Categories are reappeared in *Figure 10*, with description that followed.

Figure 10: Ten Categories of Green and S mart Industrial Estates

Green Spaces	The amount of undeveloped areas within the industrial estate that are accessible to the public.
Renewable Energy & Green Buildings	The extent of green and smart programs and equipment utilized at each business facility within the estate, including the application of alternative energy technologies.
Supporting Infrastructure	
Smart Manufacturing & Data Infrastructures	Based upon manufacturing processes and the technology they use to optimize their production systems.
Green and Smart Transportation	An efficient and environmentally-friendly system that improves mobility and travel time, while encouraging alternative forms of transportation.
Smart Water Management	An efficient and environmentally-friendly system that protects the estate from storms and flooding while controlling water in the estate, including storing it for future use.
Smart Waste Management	An efficient and environmentally-friendly system that protects the estate from pollution, reduces the amount of refuse produced, and promotes a circular economy.
Industrial Symbiosis	Collaboration between factories, including whether they exchange materials and by-products while enhancing performance through their partnerships.
Social	
Community Enhancement	Programs, activities and facilities that promote social well-being and livability while generating related benefits.
Economic	
Regional Infrastructure Extended	The level of physical connectedness with areas outside the estate.
Economic Value Added	Diversified income opportunities for the industrial estate.

1. **Green Spaces** are defined as areas of vegetation dedicated for conservation, recreation, and aesthetic purposes. These can contribute environmental, economic and social

benefits when created, particularly if they are near built environments. Examples of green spaces are parks and conservation areas as well as green corridors and streets.

2. **Renewable Energy & Green Buildings** investigate applicability of green and smart programs and equipment utilized at each business facility within the estate, including the application of alternative energy technologies. Buildings can achieve these outcomes through a variety of methods, including efficient use of resources (e.g. water, energy) and renewable energy, reduction of waste, and integration of green infrastructure components.
3. **Smart Manufacturing & Data Infrastructures** employ computer-integrated manufacturing combining with digital infrastructure in order to promote high levels of adaptability and rapid design changes, digital information technology, more flexible technical workforce training, as well as data sharing and consumption.
4. **Green & Smart Transportation** networks would include a combination of light rail, local transit routes, high capacity transit lines, feeder buses, shared mobility options, bikeable/walkable streets. Mobility hubs are locations where transitions between these modes can occur.
5. **Smart Water Management** is with an objective to create man-made spaces and enhance ecosystems that play an important role in the water cycle by helping to regulate storms and flooding; to store water for future use; as well as to filter water pollutants.
6. **Smart Waste Management**, with an ultimate aim to apply zero-waste management systems, is an effective method to improve resource efficiency and demonstrate a commitment to sustainability to the public.
7. **Industrial Symbiosis** is defined as the utilization of surplus resources as a new input into another process. Industrial Symbiosis presents the opportunity for companies to utilize wastes and exchange by-products in an effort to reduce both economic costs and environmental impacts. Industrial Symbiosis projects have been implemented at various scales (local, regional, national) around the world as a method for a network of organizations to create shared benefits through exchanges of materials.
8. **Community Enhancement** programs, activities and facilities provide the public with space for various outdoor and recreational activities, which in turn promote social wellbeing and livability while generating related benefits.
9. **Regional Infrastructure Extended** in order to increase the level of physical connectedness with areas outside the estate. The infrastructure should be linked with sustainable transportation networks to serve as nodes in the system (e.g. stops along bike and pedestrian routes) that allow users to take breaks and change routes during their journeys.
10. **Economic Value Added** is an aspect which aims to diversify and extend economic opportunities for not only the industrial estate itself, but also workers and other inhabitants in the surrounding communities.

4. Amata City Chonburi: A Case Study in Thailand

Having focused on "Green Cities" as one of the emerging areas in green and sustainable advancement, GGGI Thailand has discussed with relevant government and private agencies seeking for promising players in the field. Amata Corporation is one of the most advanced estate companies in Thailand and was recommended by the Industrial Estate Authority of Thailand (IEAT). While its Chonburi site was chosen as it was the pilot site of the Corporate itself at the time of project commencement.

Given GGGI and Amata's mutual vision on economic and social development, the two bodies clearly share similar objectives to pioneer a green city-industry development model. It is believed that the impacts of this project will lead to a simultaneous growth of both Thailand's economy and living standard of the communities in, and surrounding areas, as well supporting a more climate resilient and environmentally sustainable industrial transformation.

The objectives of the project *'Transitioning to Green and Smart City: Case Study of Amata'* carried out in Thailand are to work with Amata Corporation PCL (i) to develop green and smart industrial estate as a best practice for Thailand, and (ii) to share the experiences obtained from this assessment to interested parties across public and private stakeholders nationally and internationally. The initial phase of this project covered 2 outputs as followed:

- **Output 1. Transitioning to Green and Smart City** – by assessing Amata's Smart vision against other green industrial estate development initiatives, and making recommendations on necessary supports from relevant governmental bodies in order to formulate a 'Green and Smart City' best practice which is adaptable to other industrial lands and to provide recommendations to further enhance the Amata's green initiatives
- **Output 2. Green Projects Identification** – from the reviews under the scope of Output 1, turning the results into realization by working closely with Amata in identifying potential green projects with specific focuses on Community and Environmental aspects of the Smart vision. Among the identified green projects, the spin-offs are focusing on those relevant to environment, green area or others enhancing livability of the community in Amata City Chonburi.

It is planned that the spatial scope of the proposed project is to cover Amata City Chonburi, including communities within the industrial estate. The greater details of the selected estate are discussed in the following section. It should also be noted that, with the purpose of this phase to identify gaps and potential green projects, in-depth analyses were not determined at this stage. The project was conducted mainly based on secondary data, site surveys and various discussions with different stakeholders. Additional information on the project *'Transitioning to Green and Smart City: Case Study of Amata'* that carried out in Thailand can be found in other project reports.

Project Methodological Frameworks: Integrating Urban Planning to Industrial Planning

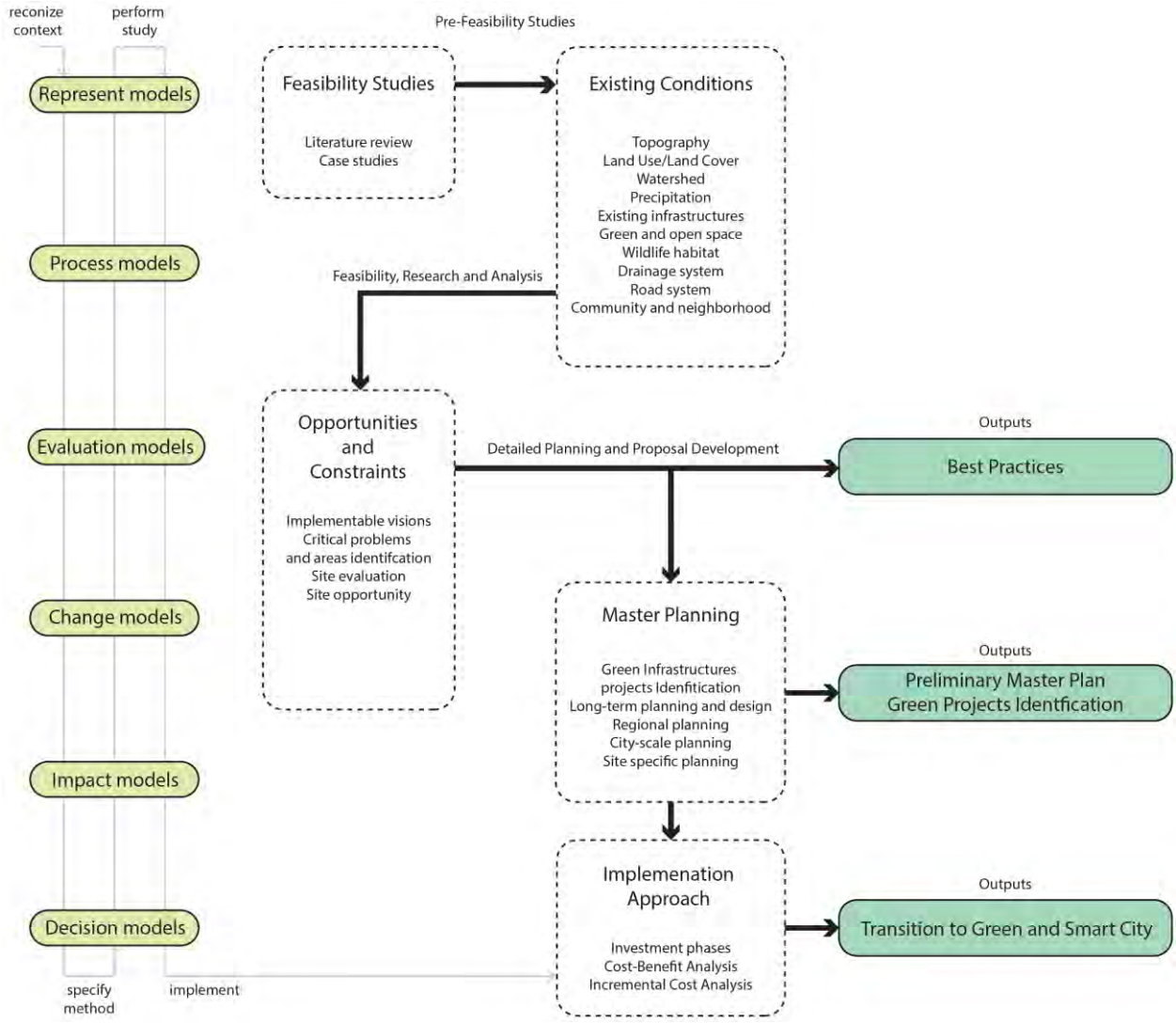
The concept of project methodological framework has been based on Carl Stenitz's "Framework for Geodesign" process structure (Foster, 2016), as depicted in *Figure 11*.

1. Representation: Feasibility study is included in this process to understand and be able to describe the study areas. Also, the analysis of existing conditions and means to examine the characteristics of the study areas.
2. Process: How do the study areas operate? Functional and structural relationships between

the industrial estates and landscape elements are studied.

3. Evaluation: Are the current study areas working well? Identifying constraints and opportunities of the study site.
4. Change: How might the study area be altered? There are two types of change that should be concerned—change by current conditions and change by implementable design.
5. Impact: What differences might the changes cause? Estimate outputs and outcomes of the proposed projects and compare with its cost-benefit.
6. Decision: How should the study be changed? This phase focuses on how a comparative evaluation of the impacts of alternative changes ought to be made.

Figure 11: Carl Stenitz's "Framework for Geodesign" process structure



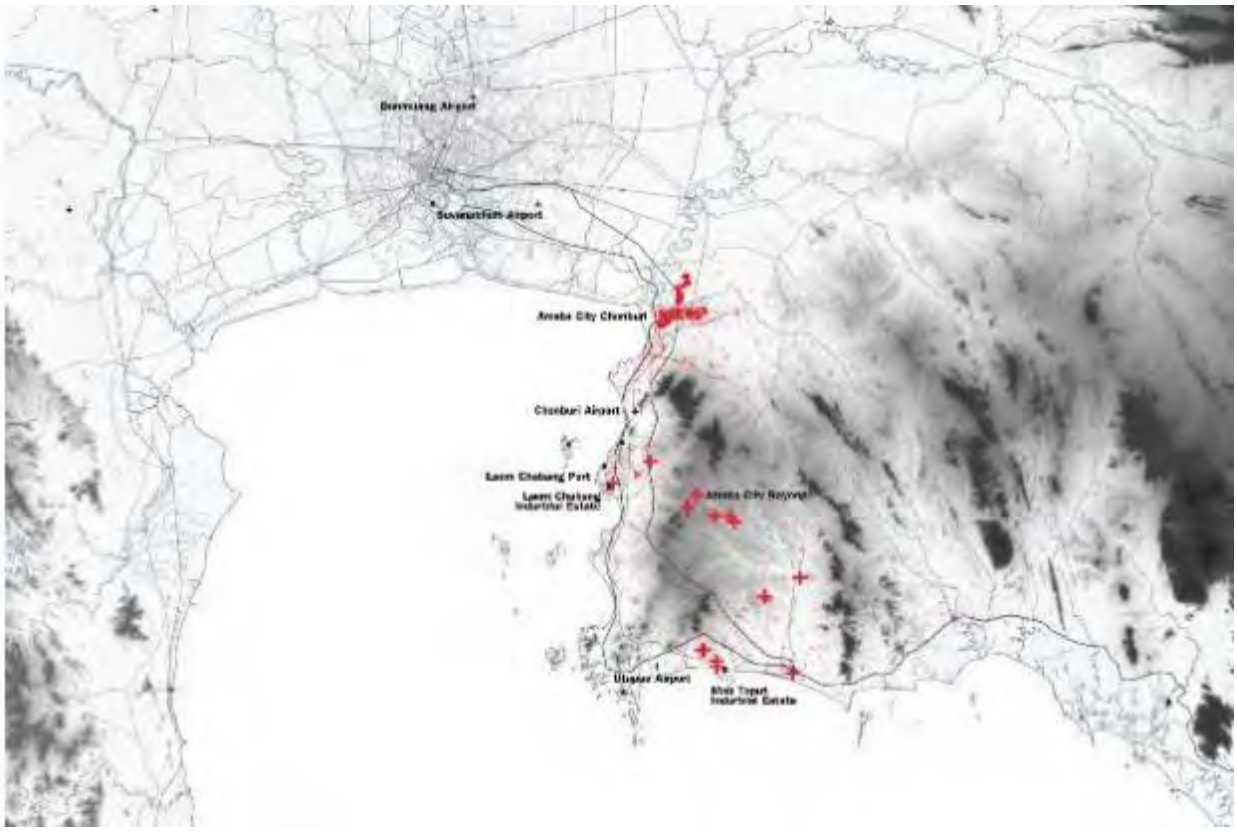
Site Assessment

Amata City Chonburi is a globally competitive industrial estate, aided by its close proximity to local, national, and international transportation links which will be improved upon as the EEC is developed further. Located about 70 kilometers from Bangkok, the site has access to large domestic markets (see *Figure 12*). In this section, existing and general physical conditions

are presented along with challenges and opportunities for Amata Chonburi development.

The existing area of Amata City Chonburi covers approximately 3,020 hectares and includes ten phases in total. The estate is zoned into two main areas,

Figure 12: Thailand Eastern Economic Corridor



Remark: Red color represents industrial estates

Chonburi Estate Existing Conditions

Located north of Chonburi city in the eastern seaboard region of the country, Amata City Chonburi is one of the most economically important industrial areas in Thailand. This industrial estate can be accessed through two main roads, Burapavithi tollway and Bangkok-Chonburi motorway. These main roads and the close proximity to other industrial parks make Amata a gateway and invaluable hub for the EEC of Thailand.

commercial and industrial. The former includes the Amata office, school, Amata golf course, hotel (in development), hospital, a financial center, and a shopping mall. The latter area includes around 700 factories, factory facilities, and a home of around 200,000 workforces. The estate is situated right in the heart of government's EEC development area. This estate alone covers the area of 27,067 Rai or 4,330 hectares.[7]

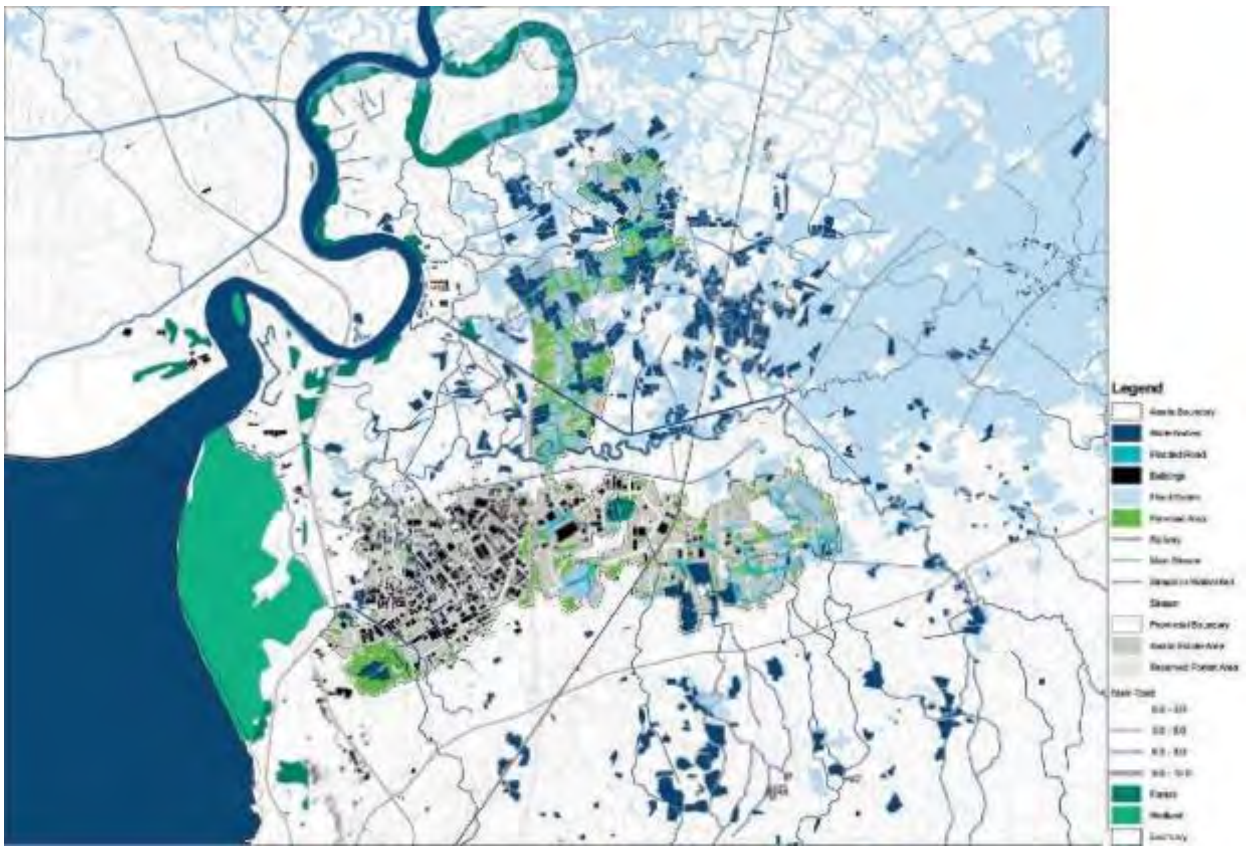
A new development area in Amata Chonburi, Zone B, is located north of the existing estate along the

[7] Source: https://www.amata.com/en/industrial-cities/amata-thailand/industrial-cities/amata-city-chonburi/

motorway and proposed to cover around 976 hectares (see *Figure 13*). This new extension is currently being prepared for development to create an innovative international business and education area. Several countries will have clusters of companies comprising 'Smart Cities' in this new area, including China, Japan, and Taiwan. One section of Zone B will be dedicated to an education campus, which will serve as a collaborative site for multiple universities.

In terms of hydrology, Amata is located in the lowest floodplain of the Bang Pakong River near its outlet into the Gulf of Thailand. Consequently, the site is affected by flood problems mainly caused by water from the Bang Pakong watershed and the dynamics of ocean tides. Moreover, the site is indirectly affected by water diverted from Bangkok through the government's flood protection plan. The catchment area that directly effects Amata is approximately 402 square kilometers. This area receives 1,300 mm of rainfall per year

Figure 13: Amata Industrial Estate Chonburi Conditions



General Physical Conditions

The Amata estate is located in a lowland area of the Chonburi province, where the highest elevation is around 750 meters and the land slopes from the higher southeast towards the Bang Pakong River basin in the northwest. The estate is slightly above sea level, with areas ranging between 0 and 3 meters in elevation.

according to the forty-year average; however, rainfall trends for the area have become unpredictable and more severe due to global climate change.

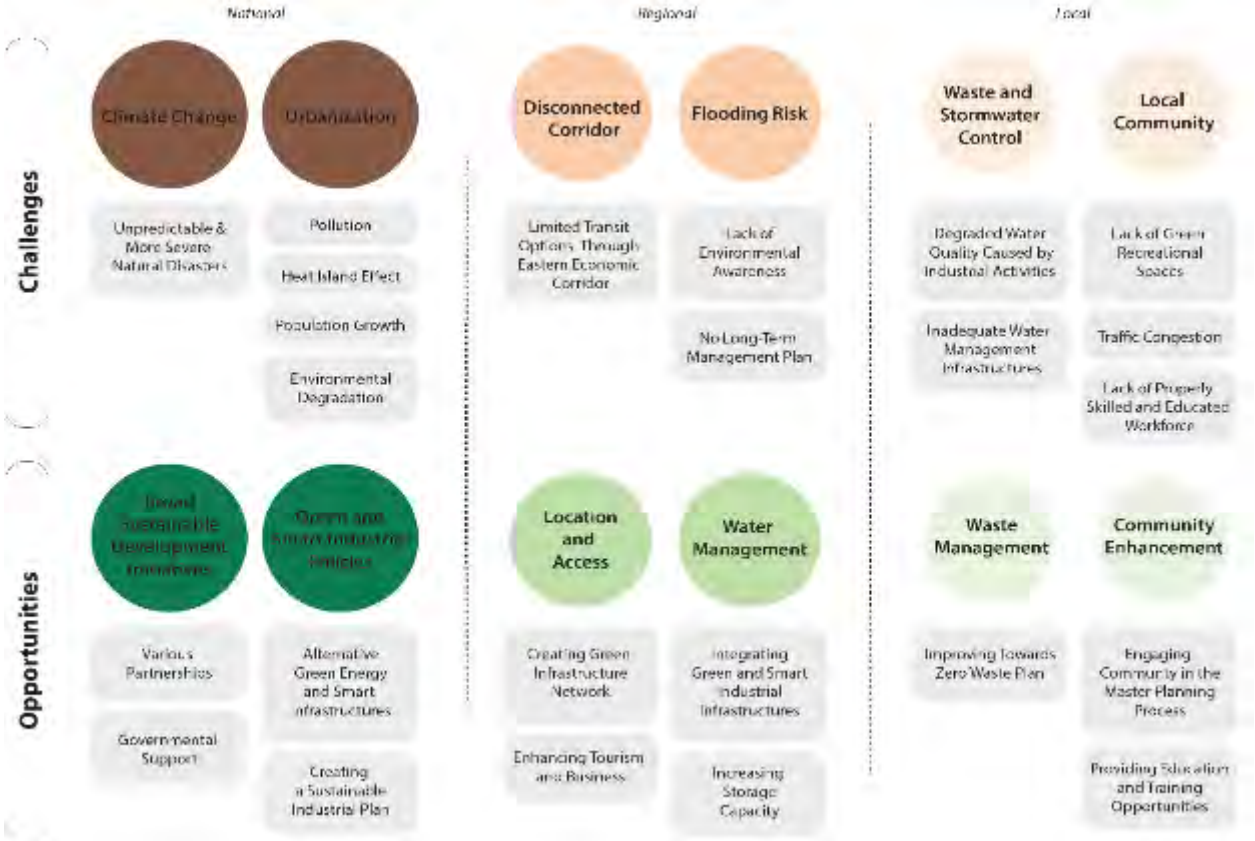
The existing drainage system of Amata is based solely on a conventional engineering approach utilizing grey

infrastructures[8] including canals, pumps, and water gates. Twenty-six pumps are installed in seven different areas inside Amata to drain water to the closest canal. Water gates at the site play an important role in protection against rises in sea level, while concrete canals and dredging are used to accelerate water drainage. However, given future development plans and changing environmental conditions in the EEC region, a sustainable water management plan that takes ecological systems and low-impact development into consideration should be explored further for the Amata estate.

Challenges and Opportunities

Amata City Chonburi is a regionally competitive industrial estate, aided by its close proximity to local, national, and international transportation links which will be improved upon as the EEC is developed further. Although its business has been successfully accepted in neighbor countries, Amata would still need to maintain its position in the country. Given the fact that the labor cost in Thailand has been ascending in the past decade, while other business-oriented functionalities are deemed all-inclusive, Amata has to find new outstanding position in the business to attract foreign investors. Sustainability, conserving natural

Figure 14: Challenges and Opportunities for Amata Chonburi Development



[8] The International Institute for Sustainable Development (IISD) provides a general explanation of Grey Infrastructure as "engineered assets that provide one or multiple services required by society, such as transportation or wastewater treatment". [Sources accessed on 23 August 2019: https://iisd.org/savi/faq/what-is-grey-infrastructure/] In the concept of water management and engineering, while green infrastructure refers to projects that draw from nature to achieve desired results, the so-called Grey Infrastructure usually refers to the traditional methods of managing water, using man-made, constructed assets including the pipes, pumps, ditches, and detention ponds. Such systems are engineered by people to manage stormwater and require technical engineering, continual maintenance, and often need to be upgraded. [Sources accessed on 23 August 2019: http://nwrm.eu/node/3837, https://www.soils.org/discover-soils/soils-in-the-city/green-infrastructure/important-terms/grey-infrastructure]

resources and fighting global warming have become the Corporate's agenda. Taken into account existing and general physical conditions, challenges and opportunities for Amata Chonburi development are illustrated in *Figure 14* and further discussed below.

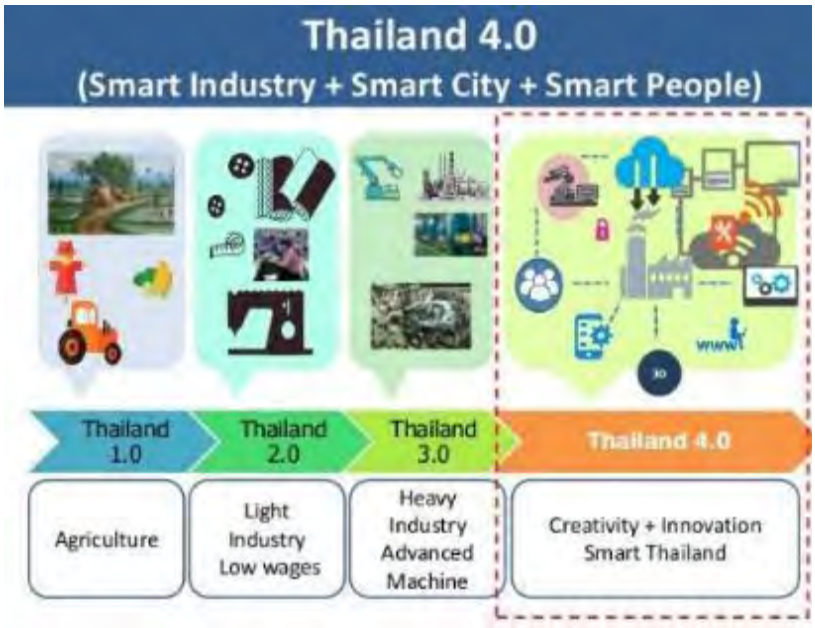
National

Challenges: Global ecosystems and the services they provide are in decline, non-renewable natural resources are becoming increasingly scarce, and the demand for these services and resources is growing. This trend is true in Thailand, where emerging risks of climate change, such as flood, drought, and greenhouse gas emissions, have caused a plethora of deleterious effects for the public and the environment. Thailand's key challenge is industrial pollution causing environmental degradation and the associated negative effects on public health (e.g. PM 2.5, greenhouse gases).

Opportunities: The government of Thailand is encouraging a transition to a newly industrialized country through the Thailand 4.0 initiative (*Box 4*). With its strategic geopolitical position and significant influence, it has the second-largest economy in ASEAN. Industrial areas have the opportunity to reduce pollution by using green and smart infrastructures. Effective planning and design of industrial areas and their sustainability performance heavily influences their success. Further, because natural areas like wetlands and forests filter large amounts of harmful pollutants and emissions (e.g. PM 2.5, carbon dioxide), nature-based and sustainable development solutions could mitigate negative effects of climate change and public health issues throughout the country.

Box 4: What is Thailand 4.0?

Thailand 4.0 is an economic model that aims to unlock the country from several economic challenges resulting from past economic development models. Thailand 4.0 focuses on a "value-based economy," as the country needs to deal effectively with disparities and the imbalance between the environment and society. The ultimate goals of this new initiative are to drive Thai economy and production towards significant changes: becoming a high-income nation, moving towards inclusive society and focusing on a sustainable growth and development.



Regional

Challenges: The Eastern Economic Corridor currently has incomplete connectivity between hubs, while Amata is in a position to perform the bridging role in this region. Additionally, the region surrounding Amata is frequently plagued by flooding, in large part due to periods of heavy rainfall and long droughts. Three sources of water affect Amata flood and drainage problems, including water from Royal Irrigation Department's flood protection plan for Bangkok, sheet flow from the Bang Pakong watershed, and water management issues within the estate itself.

Opportunities: Developing a green infrastructure network is a sustainable method to improve

connectivity of the estate with the region, ultimately increasing the influence and importance of Amata as a vital hub of the Eastern Economic Corridor. This would also increase the water storage capacity and flood resilience of the region.

Local

Challenges: Being located in a floodplain has led to complications with stormwater management in the estate. Although the estate has survived several floods in the area, these floods were manageable under an unsustainable solution. Further, Amata Chonburi has significant traffic problems in both the morning and evening, which contributes to low mobility and high reliance on auto transit. The existing plans for development of current green areas will displace local populations and disrupt their methods of subsistence (e.g. fish farms).

Opportunities: Amata can generate income for local communities and the estate by providing new business opportunities, through tourism for example. Thus, creating green spaces and corridors that serve as attractions will bring tourists and residents to the area and provide diversified income opportunities. Additionally, to improve the working conditions and livability of the estate, Amata can support community improvement initiatives by providing facilities for recreation, education, and engagement.

Methodology and Selection Criteria

The methodology applied is based on the steps shown in *Figure 15*, while the criteria is based on the following components:

1) Location of green projects identified by Site Potential Analysis (see below)
2) Gap assessment against Ten Categories for Green and Smart Improvement of Industrial Estates (see below)
3) Outcomes and impacts, which elaborated upon in each project[9]

Site Potential Analysis

Site potential analyses assess development suitability to determine green development strategies to aid the identification of the most effective green projects. These strategies were ascertained based on principles of sustainable development, industrial ecology, green growth, and landscape urbanism, along with best practice case studies. The site potential analysis took the following into consideration:

a) ***High-risk and critical areas***: Critical areas were identified through the Geographic Information System (GIS), site survey data collection, and stakeholder engagement; accordingly, these are areas in which green projects could be the most vital to implement in order to overcome the challenges of the site.
b) ***Industrial and natural clusters***: One goal is to link or group complimentary industries together to create a closed loop management system to reduce waste outputs, improve logistics and transportation, as well as efficiently use energy and materials. This ultimately contributes to the development of a more circular economy and minimization of negative environmental impacts. Clustering concepts can be applied to improve performance of other land uses as well, such as natural areas for water retention, ecological restoration, and preservation. This concept is particularly applicable for new development areas.
c) ***Corridor networks***: Industrial ecology advocates for the creation of corridors that link complimentary industries to improve logistical and transportation efficiency, thereby reducing energy consumption, traffic, and pollution, while improving connectivity and mobility. In

[9] More details of each project are illustrated in the Thailand' project report, *"Transitioning to Green and Smart City: Case Study of Amata – Recommended Green Projects Report"*.

Figure 15: Methodology

this way, corridors act as a pathway, in addition to providing significant benefits, serving as a green belt or buffer that improves the area by supporting the health of employees, the surrounding community, and environment. Thus, these corridors need to be classified and prioritized for different uses, for example, car, pedestrians and bikes, truck pathways, and tree and hedge rows. Further, linking green spaces with one another, as well as creating green buffers between community, natural, and industrial areas provide improvements to public health, livability, recreation networks, and ecological conditions.

Figure 16: Site Analysis at Regional Scale

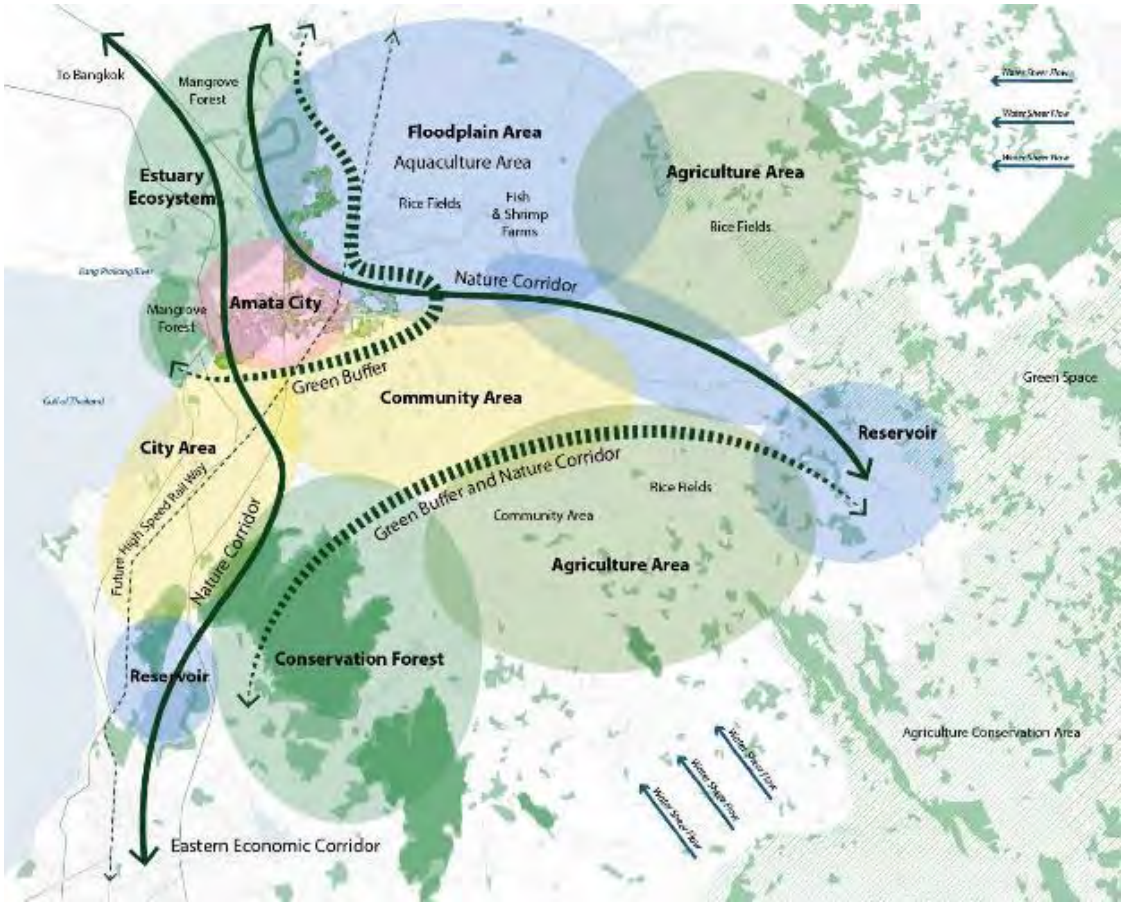


Figure 16 and *Figure 17* demonstrate site potential analyses in regional and Amata's estate scale, respectively.

Ten Categories for Green and Smart Improvement of Industrial Estates

The ten key green and smart improvement categories identified can help evaluate potential green projects by analyzing them based on environmental, supporting infrastructure, social, and economic criteria. They were used to perform a gap analysis that compared the variance between the existing performance of Amata City Chonburi and the performance of an ideal green and smart industrial estate. The outcomes of the gap analysis were used to identify targeted areas for green and smart improvement in Amata, which can be used to help prioritize green projects.

Building upon the results of the gap analysis, the performance of Amata Chonburi in each key category was described in detail to identify targeted areas for improvement (See *Figure 18*). It is important to reiterate that the performance rating scale is "comparative" to the best practice of each particular category, based on selected case studies, not an absolute scale. The evaluation system classifies the performance in rating scales from 1 to 4, where 1 is the lowest and 4 the highest to meet global best practice of the same category. With this basis, it is perfectly normal that the results may show low scores in certain areas.

The current rating of each category was used to help prioritize green projects and can help inform Amata's decision making by identifying potential categories upon which Amata can focus the development of green(er) opportunities. To summarize the targeted areas for green and smart improvement, at this time Amata lacks projects that address three categories:

Figure 17: Site Analysis at Amata Estate Scale

Figure 18: Opportunities for Amata to Strengthen Green and Smart Vision

Green Spaces	Renewable Energy & Green Buildings	Smart Manufacturing & Data Infrastructures	Green and Smart Transportation	Smart Water Management
Existing green spaces should be retrofitted, expanded, and connected to serve multiple functions as well as improve performance.	Should be integrated throughout the park, including, employing green building instruments, to create a self-sustaining industrial estate.	Amata should apply to optimize production processes and create a circular manufacturing model.	Amata should concentrate around a central transportation hub linking areas inside the park to strategic EEC areas, and facilitate use of diverse transit options.	Amata should focus on mitigating floods and droughts by integrating green infrastructures to generate environmental, economic and social resilience.
Industrial Symbiosis	**Smart Waste Management**	**Community Enhancement**	**Regional Infrastructure Extended**	**Economic Value Added**
The new development area could strategically cluster and plan a network of material and by-product exchanges.	The existing waste management facility could be expanded to collect waste from surrounding communities.	Amata should focus on Improvement of social well-being and livability as well as education programs.	Amata could link to the surrounding region through green infrastructures and corridors, transportation networks and community-based policies.	Implementing green projects will add economic value to Amata by creating new sources for revenue and incentives for investment.

4 3 2 1

Green and Smart Transportation, Industrial Symbiosis, and Regional Infrastructure Extended. Amata has preliminary improvement projects in place that satisfy: Green Spaces, Renewable Energy & Green Buildings,

Smart Manufacturing & Data Infrastructures, Smart Water Management, Community Enhancement, and Economic Value Added. Amata currently has projects that are effective in satisfying Smart Waste Management in place.

Recommended Green Projects

For Amata City Chonburi, the case study conducted in Thailand, the project utilized site assessments and analyses to recommend green projects at different scales, including green infrastructures, social enhancement programs, and other related industrial projects. Ultimately, the outcomes will aid the preparation of in-depth studies required to implement green projects as well as support the transition of Amata Corporation into a sustainable industrial developer.

The project presents a diverse selection of projects that aim to create a model for sustainable industrial parks, with an emphasis on recommending projects that satisfy the ten key criteria for green and smart industrial estates. Potential green projects are suggested at various scales, within the industrial estate, along its perimeter, and in the surrounding region.

A project the size and scale of Amata City Chonburi cannot be studied by solely examining the estate, it requires research from a much larger scope and scale. There are issues and natural conditions beyond the spatial extent of Amata City Chonburi that have implications for the region, which has informed the various scales of project recommendations. As a leader of industrial development in Thailand and because of its physical presence in Chonburi, the Amata Corporation has a special responsibility to take environmental, social and economic issues into consideration at all scales, and implement projects that improve these conditions in both the estate itself and surrounding areas.

The preliminary locations identified for green projects were based on site analyses and Amata feedback. If a green project is selected for development and implementation, the preliminary locations of the project should be explored further through in-depth research and site assessments to determine optimal locations and characteristics.

Overview of Green Projects

The recommended green projects for Amata City Chonburi are those that would address key green and smart improvement categories identified in the Section 3 as well as address the challenges Amata faces within its Chonburi estate and in the surrounding region. Green projects were formulated by coupling the sustainable growth knowledge and experiences of the project team with examples extracted from case studies of other eco-industrial parks worldwide. *Table 2* presents the list of potential green projects for Amata City Chonburi, together with its preliminary cost estimates. *Figure 19* displays the relation between impact and costs of recommended projects, based on the study in Thailand.

In order to implement these recommended green projects, they should be prioritized based on the multi-criteria evaluations, along with Amata's visions and goals for development. Below some green projects, based on cost-impact relation as shown in *Figure 19*, are selected, plus emerging, innovative practices—the industrial symbiosis and net zero carbon—are selected for further elaboration

Table 2: List of Potential Green Projects for Amata City Chonburi

Area	Potential Green Project	Description	Cost Estimate (USD)*	Specification used for Cost Estimate**
Inside Amata	Green Streets	Creation of streets that provide flood mitigation and more desirable spaces, including supporting multi-modal transportation.	8,287,950	10-m width. Includes: permeable pavement, bioswales, street trees.
	Canal Restoration & Linear Parks	Improve the ecological quality of water inside canals and in surrounding areas, as well as provide green public spaces.	21,092,451	7-m width. Includes: dredging, canal reconstruction, trails, vegetation.
	Green Bridges	Sustainably connect areas of varied uses across main roads by utlizing green infrastructure and green and smart transportation concepts. Example: Bridge at Amata Office.	4,206,750	200m x 15m. Average from green bridge case studies across Europe and in Thailand. Costs significantly vary depending on space for vegetation and design specifications.
	Green Spaces	Develop community spaces throughout the estate that provide recreation and public interaction opportunities by utilizing green infrastructure and landscape designs.	1,264,406	70% of the (under construction) hotel lot (55,390 sq.m.) dedicated to green space.
	Green and Smart Transportation Network	High-quality and highly-accessible transit system that connects areas of the estate with one another and with the surrounding region with a diverse range of transportation options.	172,693,364	Estimate for a gold standard Bus Rapid Transit (BRT) system, including exclusive lane alignment on existing roadways, stations, operation system, vehicles. Does not include significant improvements to roadway, station area access, utilities, and stormwater infrastructure. A fully developed sustainable transportation network should also utilize mobility hubs, complete streets, and bike and pedestrian trails.
	Complete Streets	Reprioritize streets within the estate to support a variety of different transportation modes and users.	8,287,950	20-m width including: bike and pedestrian lane, bus lane,and street reconstruction cost. Costs can vary widely based on local context and conditions. Low end costs assume reallocation of existing roadway with restriping, pedestrian crossing markings, signage, and signals. High end costs assume complte reconstruction of roadway to safely accomodate additional modes as appropriate for context. depending on improvements, from low end of restriping existing street to reallocate cross sectional space to high end of reconstructing the street.

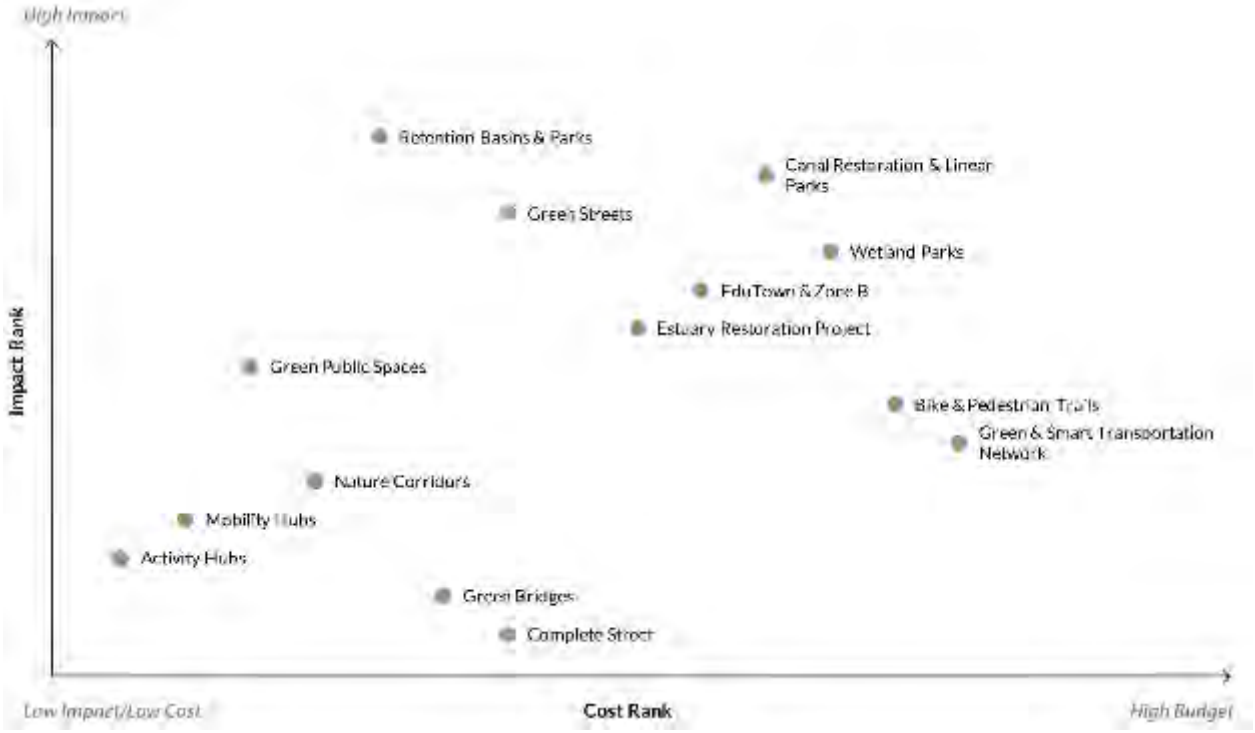
Area	Potential Green Project	Description	Cost Estimate (USD)*	Specification used for Cost Estimate**
	Mobility Hubs	Transfer points between various forms of transit, which serve as important nodes in a green and smart transportation network, to improve mobility and diverse transportation option.	516,550	Mobility hubs vary depending on context. Costs assume inclusion of the following amenities: transit stop enhancements (shelter, platform, real-time digital information system), active mobility access improvements (pathways, sidewalks, covered walkways, bike lanes, safety enhancements), shared mobility options (car and bike share), pick-up/ drop-off areas, wayfinding, secure bike parking, and encouragement of approriate adjacent land uses (e.g. food concession, convenience retail store). Does not include stormwater infrastructure, utility relocations, or land acquisition.
	Bike & Pedestrian Trails	A well connected network of trails to provide recreation opportunities and interactions with nature, as well as encourage non-auto transit.	27,436,817	4-m wide permeable paved pathway, wayfinding, enhanced street crossings (signs, markings, signals), earthwork, and rest areas and trail heads (bench, shade structure, water source, trail system map, specialty paving). Does not include stormwater infrastructure, utility relocations, land acquisition.
	Green Buildings	Creation of policies and installation of equipment that generates renewable energy or reduces energy consumption of buildings.	68,938,529	Green Roof implemented for 10% of total existing estate area (30,200,000 sq.m.).
	Renewable Energy Projects	Projects that support the use of renewable energy, microgrids and reduced emissions to support a net zero carbon vision.	N/A	N/A
	Zero Waste Management	Expansion of existing program to reduce wastes in surrounding communities through capacity building and enlargment of facilities.	N/A	Note: Project activities under this category can be largely varied in activities, scale, design, area, etc. thus, cost estimation is subject to various factors.
	Industrial Symbiosis	Utilization of wastes and by-products between facilities to reduce costs and environmental impacts. Primarily focused on New Development Area.	N/A	Note: Project activities under this category can be largely varied in type of by-products, scale, coundary, flow design, area, etc. thus, cost estimation is subject to various factors.
Along Amata	Wetland Parks	Green infrastructure component that provides flood mitigation, water filtration and public recreation opportunities.	26,062,286	10% of total estate area, excluding park features.

Area	Potential Green Project	Description	Cost Estimate (USD)*	Specification used for Cost Estimate**
	Retension Basins & Parks	Green infrastructure component that provides flood mitigation, water supply management and public recreation opportunities.	2,185,064	Landscaping on the 4-m wide dike (excluding park features) and connecting basins to Green Infrastructure system.
	EduTown & New Development Areas	World class educational and work campuses that encourages knowledge sharing and skill improvement through sustainable design.	19,096,690	Estimate for only green infrastructure components, covering 30% of the total new development area.
Outside Amata	Estuary Restoration Project	Restoration of the estuary areas north and west of Amata Chonburi to provide opportunities for sustainable tourism and food production, protect valuable ecosystems and mitiagate flood damages to the estate.	14,150,171	Estimate for restoration of 30% of estuary area (total area covers 14,463,833.3 sq.m.), excluding recreation trails.
	Nature Corridors	Creation of natural corridors to support a sustainable transportation network and flood mitigation.	1,862,090	10-m width, excluding park features/land acquisition/trails.
	Activity Hubs	Multi-use hubs that supply space for various recreation and outdoor activities to surrounding communities.	226,186	Depending on detail design. Hubs could cover average 4,000 sq.m. (Unit cost 1,734 Baht per sq.m.) including green space and park amenities.

*Note: Notes: *Exchange rate = THB30.6650/USD, as of 28 August 2019, based on https://www.bloomberg.com/quote/USDTHB:CUR*

***The information presented in this estimate is intended to provide helpful information regarding potential costs of green projects. This information is not intended to be used as a standard for financing projects, but rather to inform stakeholders on the costs of similar projects. Costs for green projects were estimated based on case studies of similar projects internationally and in Thailand. These represent rough estimates for costs of construction, excluding costs associated with research, planning, land acquisition or maintenance. Costs will become more accurate through future research studies and stakeholder input.*

Figure 19: Relation between Impact and Costs of Recommended Projects in Amata Chonburi



Green Streets (low cost, high impact)

Green streets are roads that provide nature-based solutions to stormwater management and they create more desirable spaces by integrating vegetation, supporting alternative transportation options to cars, and mimicking local hydrology prior to development. Managing stormwater on site, green streets can help mitigate flooding by increasing infiltration and storage space for run off with vegetation. Streets can be designed to address and mitigate floods that have low property damage but high recurrence affecting the business community, which are increasing due to changing climatic conditions. More desirable spaces can be created with green streets since they provide aesthetically attractive streetscapes with high environmental quality, providing connections between businesses and public spaces by catering to the diverse transportation needs of pedestrians, bicyclists, and cars. Accommodating alternative transportation options can add economic value to an area by increasing the number of people and their access to establishments along green streets, ultimately leading to higher property values. Potential features to include in green streets are bioswales, rain gardens, permeable pavement, separated pedestrian and bike lanes, wider sections of landscape, as well as other traffic calming and pedestrian oriented features. Green streets also improve water quality and livability, in addition to the plethora of other benefits they provide.

A green street here could also function as a transportation and recreation route that provides an attractive linkage to many areas of the estate. Several streets in Amata are subject to recurrent flooding due to overflow from canals or current water diversion practices. Green streets in these nuisance flood areas would help mitigate flooding by storing and infiltrating water in these areas.

Green & Smart Transportation Network (high cost, low impact)

Mobility Vision

Amata strives to be a dynamic destination for residents, employees, and visitors. The ability of people to move freely and travel to their daily destinations safely and conveniently is a key element of Amata's continued success and future growth. The mobility vision provides the lens through which future

Figure 20: Green Street for Runoff Control and Flood Mitigation

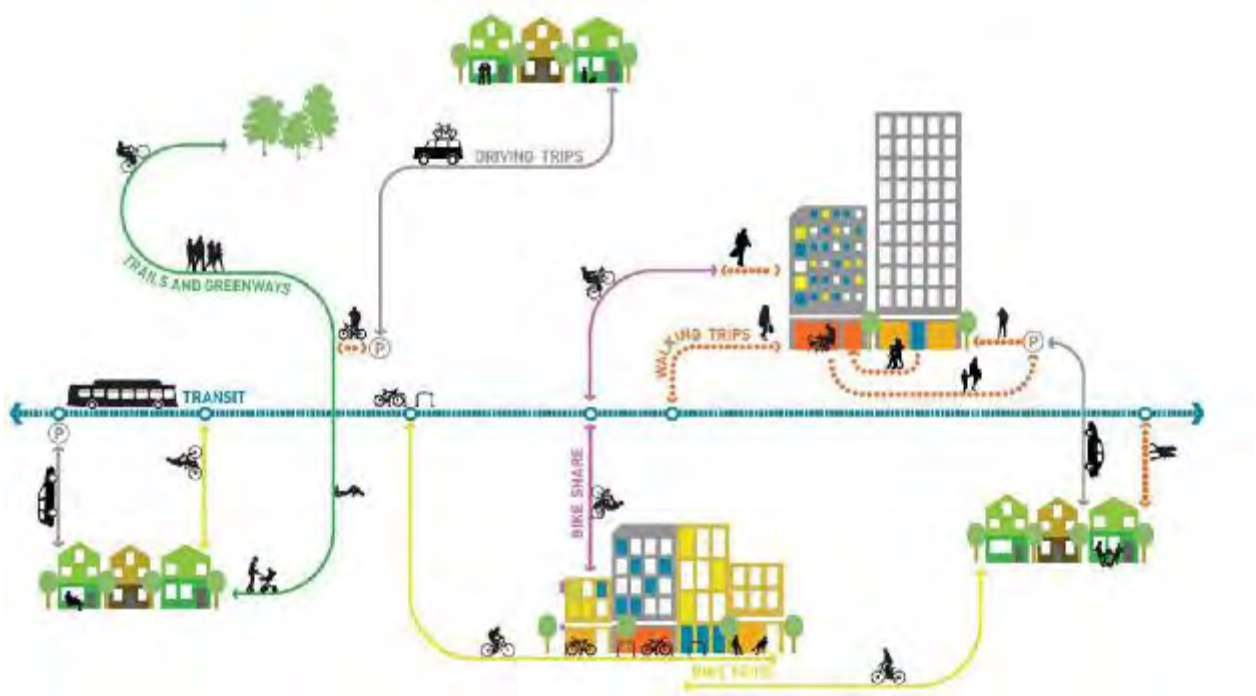
transportation projects should be developed and prioritized. Going forward, does the transportation network—including physical infrastructure and transportation services—meet the needs of those that live, work, and visit here. Additionally, do they support the anticipated growth, both regionally and locally, while also preserving the quality of life and human dimension of the City that make it unique, accessible, and diverse? This vision for mobility outlines a way forward and attainable goals to improve overall mobility for estate residents, workers, and visitors.

Green & Smart Transportation Network Needs

The efficient movement of goods and people are essential for the long-term economic success of an industrial estate. Investing in transit services and amenities allows an estate to grow without compounding vehicular traffic congestion by serving more people in less space. It also provides an affordable transportation option that is accessible to a wide range of ages and abilities. To succeed, a transit service must provide frequent, reliable, accessible, and convenient service. This type of high-quality, highly-accessible transit system connects regional areas to activity centers, and is paired with a local mobility services that connect to key destinations. Transit should work in tandem with users who walk and bike to create a seamless, convenient trip. Transit corridors should be designed with these users in mind, ensuring stops are located in close proximity to grocery stores, parks, services, and job centers.

Near-term Improvements: Establishing a transportation demand management (TDM) program is an immediate action that can relieve current traffic congestion. A TDM program promotes walking, bicycling, carpooling, ridesharing, telecommuting, and other transit options to increase accessibility and reduce dependence on single-occupancy vehicle travel. TDM efforts will reduce congestion, parking demand, reliance on private cars, and travel costs for employees. Successful TDM programs expand mobility for

Figure 21: Complete Mobility Networks for Freight, Transit and People of All Ages and Abilities



residents, commuters, and visitors so that they have the freedom to choose between multiple options to meet their travel needs.

Long-term Improvements: Identify priority routes for the movement of freight, transit, and emerging mobility options, such as electric shared vehicles or bike share. Technology is transforming almost every aspect of transportation. It is important to take advantage of available technology while proactively planning for emerging technology to expand travel choices, improve safety, improve predictability of service, and collect data to improve service options.

A green and smart transportation network will service the entire park and link it to key surrounding areas. The network could integrate several green and smart projects (e.g. green streets, complete streets, mobility hubs) which would intersperse the estate to effectively service the transportation needs of stakeholders in Amata Chonburi. These green projects could be complemented by a central transportation station, that links local estate transportation to regional and national infrastructures (e.g. highspeed rail).

EduTown & New Development Areas (high cost, high impact)

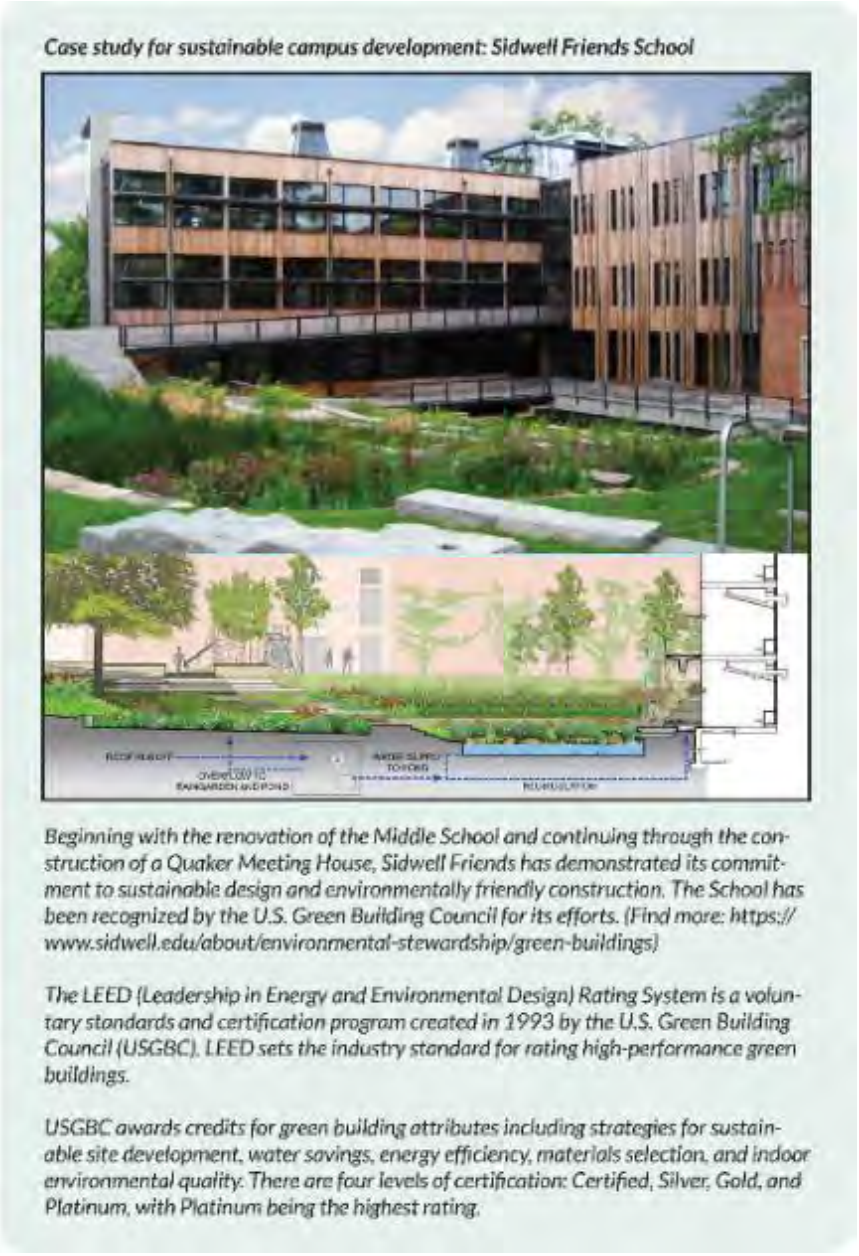
Amata has begun planning and constructing Zone B, a 976-hectare extension north of Amata City Chonburi. The concept is to develop a site for targeted innovative industries based on knowledge sharing and new technologies, such as Aerospace and Digital as described in Thailand 4.0 initiatives. Zone B will include areas for strategic purposes, including 'Smart Cities' for companies from China, Japan, and Taiwan, as well EduTown. A 64-hectare educational campus shared by several universities, EduTown strives to provide world-class facilities for universities from China, Japan, and Taiwan. One aim of the area is to provide education and technical training for specific fields, particularly targeting worker development for businesses within Amata industrial parks. EduTown can serve as a pilot project and model for holistic sustainable development for Zone B.

EduTown and other new development areas in Zone B should incorporate the aforementioned green infrastructures (e.g. wetland, retention parks) as well as other green and smart projects (e.g. industrial

symbiosis, renewable energy projects) to yield environmental, social, and economic benefits. Currently, the land in Zone B is used for agriculture (e.g. rice farms) and aquaculture (e.g. fish and shrimp farms). These low-impact land uses function as green infrastructures, storing water during times of flood and high rainfall. Development of these lands necessitates a carefully planned stormwater management strategy for the area, which can be achieved cost-effectively by integrating green infrastructures throughout. Further, the implementation of green and smart initiatives will advance the economic performance of Zone B, providing improvements to the public and contributing to the creation of an innovative area that demonstrates green growth and a circular economy. These can also provide cost-savings to companies, which in addition to the increased property values from green infrastructures, will attract new investors and industries that contribute to the creation of a sustainable industrial development.

Green projects should be integrated throughout Zone B, however one potential strategy is to create a green infrastructure buffer along the eastern edge of the area to mitigate flooding. In-depth research studies and hydrological modeling should be performed to determine specifications for the locations and sizes of green projects.

Box 5: Case Study for Sustainable Campus Development



Nature Corridor (low cost, low impact)

The concept of nature corridors which originates from landscape ecology is used to join two or more green patches, typically having widespread ecological implications for productivity, biodiversity, soil, and water. Landscape urbanism uses ecological design elements, such as nature corridors, in order to improve connectivity for nature and people as well as provide flood mitigation for urban areas.

Nature corridors are a key element in an effective sustainable local and regional transportation network. They are a crucial element of the green projects, since they help merge and connect green spaces together, linking different areas at various scales from local to regional. Often times, these corridors maximize movement efficiency by serving as transportation

routes for eco-friendly modes of transit (e.g. biking, walking) for commuters and recreationists alike.

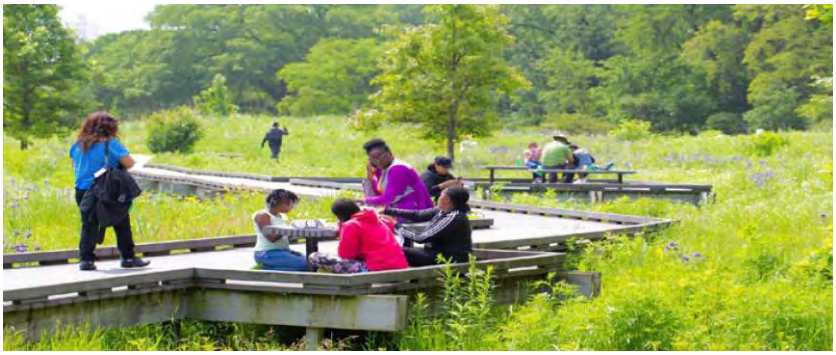
Another important function of nature corridor's is mitigation of flood damages through nature-based engineering approaches. These corridors serve as spaces to transport, store, and infiltrate runoff water, and are more effective than conventional grey engineering solutions at a lower cost. Corridors improve the resiliency of landscapes to climate change and related disasters, and also help reduce greenhouse gas emissions by storing carbon in native vegetation. Depending on their size and level of connectedness, nature corridors can have a significant impact mitigating flood and reducing subsequent economic damages. The creation of a network of nature corridors helps to restore previous environmental conditions and connections that have been separated by human activity, such as urbanization and agriculture. Nature corridors permit sustainable dissemination of flood waters, serving as valuable conduits for water, energy, wildlife, and people, ultimately providing a myriad of environmental, social, and economic benefits.

Links to natural areas in the south, west, and east are potential locations for Amata to implement nature corridors around the Chonburi estate. These would contribute to a smart water management plan to mitigate flooding from the three sources that threaten the estate.

Box 6: Nature Corridor and its Foreseen Benefits

Nature corridor between agricultural areas, providing water storage

Bike and pedestrian trails integrated with a nature corridor



Environmental and public education programs can make use of nature trails

Industrial Symbiosis

Industrial symbiosis presents an opportunity for companies to utilize wastes and exchange by-products in order to reduce economic costs and environmental impacts. Industrial symbiosis is defined as the utilization of surplus resources as a new input into another process. Akin to a circular economy and green supply chain, these practices focus on reducing waste and utilizing recycled materials over virgin ones. The concept was originally developed for economic purposes, but has continually demonstrated the environmental and social benefits it can provide. The co-location of complementary industries has been documented to increase efficiencies and decrease costs and has been applied in industrial parks around the world.

These systems help promote a circular economy through strategic clustering of industries and exchanging materials between facilities. These

practices reduce transportation costs, enhance collaboration and knowledge sharing, as well as create an efficient network for by-product exchanges between complementary industries and businesses. Examples of materials that can be exchanged between facilities include water, energy and heat, as well as by-products and wastes. The ultimate goal of industrial symbiosis projects is to promote coordination between facilities to enhance environmental, social, and economic performance.

To identify potential industrial symbiosis networks, in-depth studies and analyses should be performed to understand outputs from companies and the most effective areas to implement cluster planning and platforms for exchange. However, retrofitting an existing industrial estate to add an industrial symbiosis network can be challenging due to difficulties planning and constructing clustered industries and exchange network infrastructures; therefore, Amata should focus industrial symbiosis projects in the new development area, Zone B.

Industrial symbiosis projects represent a planning and development strategy, rather than a specific infrastructure that can be constructed. For this reason, coupled with the large variety in the characteristics of industrial symbiosis projects, the outcomes, impacts, and preliminary costs were not assessed as part of this project.

Towards Net Zero Carbon Precinct: Amata Energy Transformation

Amata's stated aim is that "the company would convert from being an industrial estate developer supporting traditional industrial production to become Smart City developer and would develop new projects to support the Smart City such as Science City project, EduTown project and MediTown project with intention to raise the bar of research and development of Thailand science and technology."

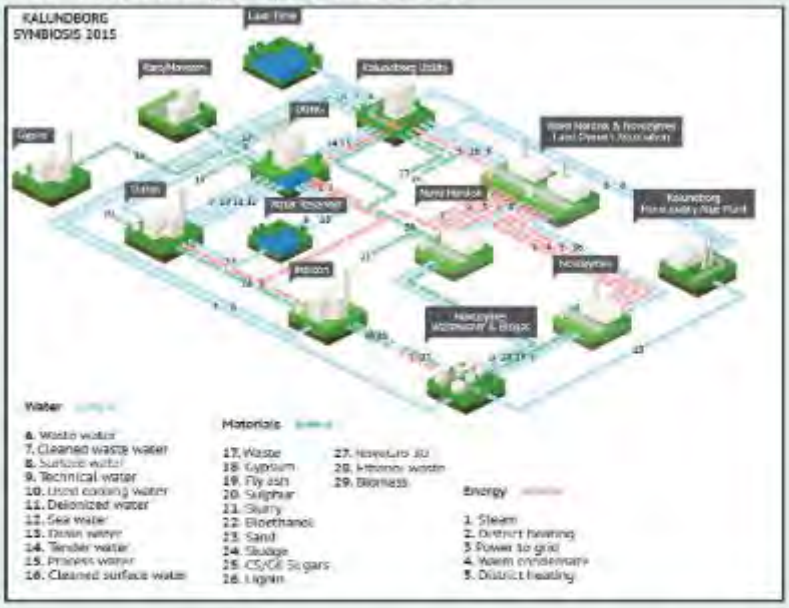
The company, therefore, initiated several projects such as Eco-Industrial Estate development with environmental-friendly infrastructure and utility design, environmental management and energy management and green area expansion in Amata's industrial estates. The development of a unifying energy strategy was commissioned through GGGI to tie this effort together.

This phase identified the recommended pathway to low carbon emissions at Amata City Chonburi, requiring a systematic decarbonization of all aspects of the energy cycle. Best practice addresses onsite energy use and only using offsets as a last resort.

Amata is already committed to encouraging energy efficiency programs,

Box 7: Case Study of Industrial Symbiosis

Case Study: Kalundborg Industrial Estate, Denmark



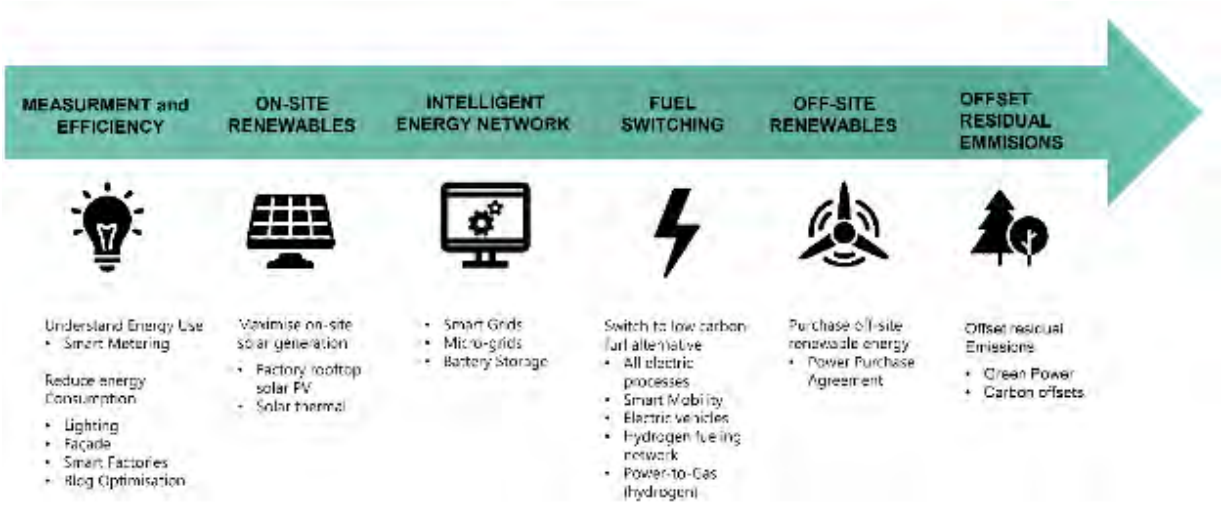
Kalundborg, the pioneer of industrial symbiosis, has a renowned reputation for exhibiting a circular economy and by-product exchange network. Through cooperation between private industries for cost savings, this network of exchanges has developed into an industrial area that focuses on utilizing new green technology and resource efficiency, and is independent of fossil fuel energy. The network of recycling and reuse in Kalundborg results in total costs savings for companies of roughly $15 million USD per year while reducing pollution and waste outputs of the area.

that should include its own facilities and should provide tools for customers to achieve low energy use in factories across the precinct. Of course, to control and reduce energy, Amata and its customers must be able to measure it, and smart metering is recommended to be integrated throughout the estate.

- Link to the long-term goals of Amata Smart City at Chonburi

The energy transformation is a central plank of the Amata goal to "enhance all levels of education in the industrial estate area ..... to increase the quality of human resource available to serve future demands by establishing educational institutions with international standard curriculum" and research.

Figure 22: Amata Energy Transformation Pathway



The energy transformation must take advantage of the huge investment in Internet of Things (IoT) infrastructure by Amata, which has been considered when assessing energy related projects.

Finally, onsite generation is required to reduce carbon emissions at Chonburi. Rooftop solar alone will not achieve net zero emissions for Amata, but at this time, aggressive fuel switching (with the exception of electric vehicles) and an offsite solar PPA are not considered further due to cost and Thailand's regulatory environment.

Thus, it is recommended that the Amata smart energy transformation is designed to:

- Identify trial projects that can get immediate effect
- Be able to scale quickly across site with existing customers and be applied to greenfield sites
- Adopt global best practice in energy efficiency, management

Explored Opportunity towards Net Zero Carbon: Rooftop Solar PV

The Chonburi industrial park has a large amount of unobstructed rooftop available for solar PV Installation. It is recommended that all new development in the greenfield Amata expansion site include a provision for solar, and the following information is required: plan of proposed buildings and load profiles (if known).

Besides, it is also recommended that existing customers could engage collectively to explore an estate wide solar solution. This will require Amata to consider below actions:

- Build a partnership of existing customers
- Update profile data with timeframes and units
- Form partnerships with large solar developer, able to carry project on their balance sheet

- Give permission for partners to engage with existing and new industry partners
- From a collaboration with Provincial Electricity Authority (PEA)

- Due to the lack of a feed in tariff, it is most economical efficient to self-consume all energy produce by PV on site. Hence options favor a design based on existing load profile with no export

Figure 23: Rooftop Solar PV

Amata has previously investigated solar business models as an important factor in achieving green growth of the Chonburi smart energy precinct. In order to realize these ambitions, Amata is suggested to accomplish some tasks including:

- Lessening complications regarding based customers with its current utility partner
- Partnering with tenants especially those corporates have head office sustainability and renewable energy targets
- Securing a suitable solar partner, who is flexible, but most importantly a partner who can move quickly

However, there are some key regulatory issues to be considered. Thailand is the most advanced solar market in South East Asia but there are still some regulatory frameworks to be considered:

- Existing property rights cannot be found on public databases and will need to be clarified.
- Rights of access must be given by each building owner.
- There is not restriction for a lender to take a security interest over a rooftop.
- Electrical certification is required, which is not appointed by the EPC contractor and is the

responsibility of the asset owner, i.e. customer or Amata.

All in all, establishing an emission inventory is first recommended step. This can help greatly in strategizing how to arrive at net zero. Without measuring and demonstrating change, it is difficult to convince how the facility becomes or aims to become net zero.

Key Success Factors

This subsection provides perspectives regarding key elements and additional supports in order to achieve the 'Green and Smart' Industrial Estate. Although a strong corporate vision is the key element paving the way towards "green and smart" development, advancing the green and smart initiative would require collaborative efforts from various angles.

Estate Developers

- **Management commitment** is always one of the most important success factors in driving any initiative. In the absence of corporate management support, the new vision, outside of the day-to-day business, would be hardly materialized. Supports are concerning not only clear vision, but also in the forms of time and budgets which are necessary fuels for the success.
- **Clear understanding, learning opportunities and knowledge sharing** are required from the very beginning and throughout the implementation process. The Corporate should define its strategy and clear roadmap towards its green and smart vision, future trends, opportunities, risks and challenges.
- **Clear responsibilities, collaboration and integration of all employees** are among critical factors of success. To achieve the green and smart vision, it is highly needed the smooth involvement of many functional areas and employees. It is therefore necessary to clearly define roles and responsibilities, and what is expected of the employees. The vision should be seen, actively initiated and supported by all level of employees; thus, awareness-raising, inspiring, motivative measures should be introduced and continually refreshed periodically. Shaping the vision into corporate culture may be ideal.
- **Strategic land use masterplan** should be deliberately allotted from the very beginning. Alike urban planning, an industrial estate masterplan requires deliberate technical planning knowledge. The development and design of land use and the built environment, including air, water, and other necessary infrastructures—i.e. transportation, communications, and distribution networks—in the area, as well as connected to surrounding areas, have to be all inclusive.
- **Strong network of collaborative partners and tenants** can also be seen valuable to drive the initiative towards success. Wise establishment of this green and smart network can pool not only entities with mutual vision, but also with different strengths: technical, financial, legal, and even greater networks regionally and globally.
- **Strong relationship with stakeholders**, especially in the surrounding communities, is another crucial factor to realize the green and smart vision. It is found that many of potential projects with high impacts towards greener industrial land, which subsequently create positive effects to surrounding communities, are likely to involve other different stakeholders—e.g. local authorities/communities. Thus, not only establishing strong relationship with these stakeholders may suffice the completion of green and smart city, but it is also required supports, plans and systematic landscape of who involving the area to be even reconstructed.

Government Supports

In a larger scale development, it is undoubtedly required **government or even intergovernmental reinforcement**. Over the course of GGGI study in Thailand, one of the crucial challenges in smart and green industrial estate development is the unclear strategies and arrangements of **institutional and regulatory enabling environment**. To achieve a large-scaled area which is simultaneously socially inclusive, environmentally friendly, and economically sustainable is undeniably required strong support from the government. The issue has a wide range of solutions needed from the regulatory framework greening and smarting the industrial lands, role and responsibilities of central and local relevant state agencies, the holistic approach to various policies influencing this kind of development. From the case study of Amata City Chonburi, there are some challenges which can be seen as examples of the issue.

- ***Lack of attractive incentives and other favorable enabling conditions to clean energy:*** As Amata's main business is industrial land development, sufficient provision of energy is one of the mandatory facilities to be provided. To stimulate renewable energy sources in Amata compound, one of the options is the offsite PPA (Power Purchase Agreement), where the power generation is located offsite with the electricity being grid-delivered to Amata. However, further investigation regarding regulations in such case is needed. Several other possibilities can still be explored.
- ***Lack of coordination from relevant agencies:*** With unclear set of roles and responsibilities in the green and smart industrial estate theme, smooth coordination, decision making, and implementation will not be attainable. In order to accomplish the mutual benefits amongst the land developers, industries and communities, the green approach within the industrial land alone is not enough. The extended benefits beyond its fences are to ensure the communities would also be beneficiaries to the green and smart industrial estate development. Therefore, it is crucial that relevant stakeholders joining hand in this development agenda.

Lessons Learned

The lessons learned acquired from the implementation of Thailand's project report, *"Transitioning to Green and Smart City"* can be categorized into two main areas: working with private sector and GGGI's Green Cities Team.

Working with Private Sector

- **Background and vision** of the company are immediate stances which needed to be clearly understood in order to establish a clear and well-designed term of references, scope of intervention from the very beginning.
- As a development organization, **expectation management** is one of the most challenging aspect working with private sector. **GGGI's strategic positioning** must be well-defined of how the organization works with the country's government, how the private company can be linked to the country's green growth development, what the benefits the company would likely to gain from this involvement, etc.
- In order to build an impactful project, it is very important to work with the right team and personnel**. To understand the private entity's internal structure, roles and responsibilities** is seen as a key factor to bring this initiative toward success.

GGGI's Green Cities Team

In order to build up GGGI's Green Cities Team at global scale, there are some aspects which should be prepared to ensure consistency and neutralize green cities works across countries.

- Periodic updates of the list of GGGI's publications, work experiences on green cities and/or green infrastructure theme

- Organization-wide definitions of terms, e.g. “Green Cities”
- Periodic updates of texts on general background of GGGI works in the area
- Guide to establish a peer review team across countries (if in needed)