Formulation of Temburong Eco Town Master Plan in Brunei Darussalam

NIKKEN SEKKEI CIVIL ENGINEERING LTD

ERIA

Economic Research Institute
for ASEAN and East Asia

NIKKEN

Preface

One of the most important policy issues in Brunei Darussalam, in which more than 60% of the gross domestic product comes from oil and natural gas, is how to become a non-oil economy.

Temburong district, which will be connected with the capital Bandar Seri Begawan by a new bridge in 2020, is expected to develop new industries (e.g. tourism). Most of the Temburong district is still covered by primeval forests such as morass and tropical rainforest jungle, so it is essential to achieve sustainable growth of the region through a balance of development and preservation.

This master plan proposes a next-generation eco-city model which balances development and preservation by focusing on issues such as energy, life/work style, and tourism. We believe that this plan could contribute to the vision of making Brunei a non-oil economy.

I hope this study can bring valuable insights to those involved in the Temburong district development.

Tetsushi Fujita

Director of NIKKEN SEKKEI CIVIL ENGINEERING LTD

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List of Abbreviations

ASEAN	Association of Southeast Asian Nations
APEC	Asia-Pacific Economic Cooperation
AEMS	area energy management system
Bt.	*bukit* (hill or mount)
BSB	Bandar Seri Begawan
CBD	central business district
EIA	environmental impact assessment
EMS	energy management system
ERIA	Economic Research Institute for ASEAN and East Asia
EV	electric vehicle
FCV	fuel cell vehicle
FDI	foreign direct investment
GDP	gross domestic product
HEMS	home energy management system
HEP	hydroelectric power
HOB	Heart of Borneo
IoT	Internet of Things
Jl.	*jalan* (road)
Kg.	*kampong* (village or village area)
LNG	liquefied natural gas
MIPR	Ministry for Industry and Primary Resources
MW	megawatt
NER	net enrolment ratio
P.	*pulau* (island)
PE	person equivalent
PV	photovoltaic
P2G	power to gas
Sg.	*sungai* (river)
SWOT	strengths, weaknesses, opportunities, and threats
TCP	Department of Town and Country Planning, Ministry of Development

TDP	Temburong district plan
WHO	World Health Organization
ZEB	net zero energy building
ZEH	net zero energy house

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Executive Summary

Brunei Darussalam's 'Wawasan Brunei 2035' vision assumes a sustainable society for the future and advocates a departure from oil dependence, development of human resources, creation of new industry, and development of small and medium-sized enterprises.

In Temburong district, tourism will increase with the opening of the new bridge from Bandar Seri Begawan district in 2020.

To ensure compatibility between development and nature conservation, this project sets the vision of a carbon-neutral society for wildlife preservation in Borneo. It proposes strategic development through the following approaches or key words:

- Living lab: diverse community, creative work and life style
- Carbon-neutral: renewable energy, sustainable mobility system, sustainable architecture/agroforestry, small economy
- Learning tourism: feature of Temburong and Borneo, Showcase of Smart Tech

Based on the above vision, Bangar and Labu Estate was positioned as growth centres. Bangar will have district office, hospital, market, and residential functions, as the centre of administrative services in Temburong. This study proposes to improve the internal road and new bridge connecting the two areas divided by the Temburong River, and to make the road in front of the current commercial area along the river a pedestrian priority area to make it a bustling riverfront.

Labu Estate will have university, research and development (R&D), hotel, convention, tourism centre, and residential functions as the centre of education, R&D, and tourism. By clustering universities, R&D, and houses in close proximity, we propose the formation of a diverse community that fosters interaction and innovation.

The energy supply system's medium-term target (by 2023) considers effective use of photovoltaic and pilot renewable energy-based hydrogen as existing technologies and use of Electric vehicle (EV) and Fuel cell vehicle (FCV). This study hopes that the above plan will be

publicised at the Asia-Pacific Economic Cooperation (APEC) meeting as an eco town showcase. The long-term aim (by 2030) is for the whole town to convert to low carbonisation.

Towards the APEC Economic Leaders' Meeting, which may be held in Brunei Darussalam in 2024, the development of the construction yard for the Bandar Seri Begawan–Temburong Bridge was positioned as a priority project named 'Gate Zone project'. This carbon-neutral site will be home to a mobility hub and tourism base, and will be one of the venues for the APEC meeting.

Chapter 1

Introduction

1.1 Background and Objective

Temburong district is the easternmost part (*daerah*[1]) of Brunei Darussalam. It is an exclave–detached land located in Malaysia, separate from the Brunei mainland. Most of the area is covered by tropical forest and morass.

In Temburong district, development needs such as tourism will increase with the opening of a new bridge from Bandar Seri Begawan (BSB) district in 2020. Most of Temburong district's land is included in the Heart of Borneo (HOB) advocated by the World Wildlife Fund (WWF), so it is important to achieve economic development that coexists with extensive wetland, jungles, or ecosystems with abundant nature.

Demand for smart city and eco town development has been increasing, since these concepts make a huge contribution to energy conservation in the business and commercial sector. Brunei Darussalam's 'Wawasan Brunei 2035' vision[2] assumes a sustainable society for the future and advocates a departure from oil dependence, development of human resources, creation of new green industry, and development of small and medium-sized enterprises.

This project formulates a nature-friendly eco town master plan for Temburong district. The master plan considers the country's development vision and ecological protection.

1.2 Rationale

The rationale of this study is based on the Temburong Eco Town Project Phase 1 and 2 studies, which were discussed by the Economic Research Institute for ASEAN and East Asia (ERIA) and the Ministry of Energy and Industry.

The phase 1 study in 2015–2016 investigated the idea of turning Temburong district into an eco town, with energy-saving technologies (e.g. buildings, automobiles, and smart-grids). the Phase 2 study in 2016–2017 estimated the electrical power that Temburong eco town would need; and simulated the power generation, including a combination of diesel power, solar power, and storage batteries. Although solar power and storage batteries could generate enough uninterrupted power for Temburong eco town, without a diesel power source, the cost would

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[1] *daerah* is the principal administrative divisions of Brunei. The country is divided into four districts, consisting of Brunei-Muara, Belait, Tutong, and Temburong.

[2] Wawasan Brunei 2035 is the vision of the nation toward 2035 announced by the Government of Brunei Darussalam in January 2008. It aims to raise the quality of life of its citizens, and transform Brunei from an economy relying heavily on oil and natural gas into a more economically diversified and dynamic social nation. Section 2.1 discusses Brunei Vision 2035.

be quite high. Therefore, this study suggests continuing to use diesel power and slowly shifting the balance toward solar power and storage batteries, with the expectation that the cost will decrease in the future.

This phase 3 study (2017–2018) of the Temburong Eco Town Project continues the master plan, based on the recommendations for eco-friendly solar power and storage battery use described in phases 1 and 2.

1.3 Study Method

This project comprised the formulation of (i) the basic concept plan and (ii) the master plan for the development hub.

(1) Formulation of Basic Concept Plan

(i) Collection, analysis, and evaluation of current conditions

    - Collect material and data

    - Analyse current natural, social, infrastructure and environmental conditions

    - Evaluate site location, relationship with the surrounding district, potential for land use, traffic, infrastructure, environment, potential for sightseeing, research and development (R&D), convention, etc.

(ii) Vision and goals

    - Define the vision and goals

    - Define the concept

(iii) Setting the planning framework for urban planning

    - Set up the following planning framework based on the evaluation of current conditions and the vision/goals/target:

        + Population–residential, working, and tourist

        + Urban function to introduce–convention area, R&D, commercial, sightseeing, education, medical, residence

        + Land use frame

        + Size/Scale of the facilities to be introduced

(iv) Selection of development hub (growth centre) location

    - Select two areas for the development hub

    - Set the scale and function for each area.

(v) Prepare the zoning map

Figure 1.1: Study Area for the Basic Concept Plan

Source: Study team.

(2) Formulation of Master Plan for Development Hub

This task is based on the preliminary development hubs selected in task 1.

(i) Detailed analysis and evaluation of current conditions

(ii) Detailed development concept and frame

(iii) Formulation of land use plan

(iv) Study of smart cities policy in this masterplan

   - Study the way to create an 'eco friendly city' based on city development style and lifestyles.

   - Examine the introduction of smart energy such as solar energy and hydrogen gas for urban infrastructure, e.g. electricity (energy), water, and transportation.

(v) Proposal of priority project

Chapter 2

Analysis and Assessment of Current Conditions

2.1 Brunei Vision 2035 (Wawasan Brunei 35)

Wawasan Brunei 2035 is the vision of the nation towards 2035 announced by the Government of Brunei Darussalam in January 2008. It aims to turn Brunei into a nation widely recognised for its quality of life amongst the top 10 nations in the world, its well-educated and highly-skilled people, and a dynamic and sustainable economy–without relying heavily on oil and natural gas.

To realise this vision, the long-term development strategy and outline for policies served as the guideline for the next 10 years' development. Projects are identified based on the five-year national development plan.

Figure 2.1: Sites of Main Development Project
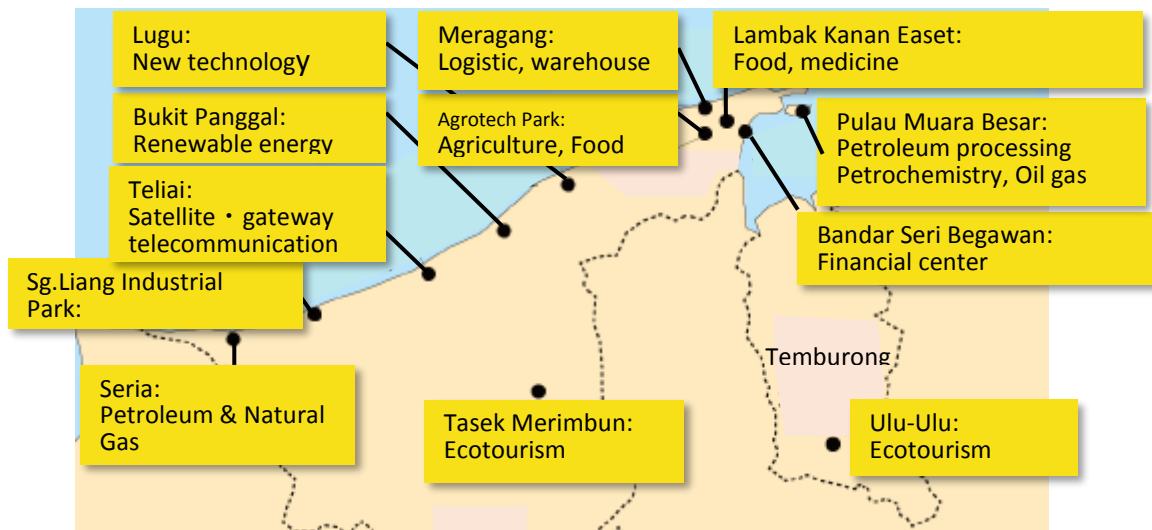
Source: Study team.

In February 2017, the government announced the next phase of economic policies, reflecting progress towards Wawasan Brunei 2035. These policies will (i) stimulate other industries to overcome the dependence on oil and natural gas, (ii) implement measures to support domestic entrepreneurs, (iii) implement incentives for small and medium-sized enterprises, and (iv) make effective use of them when ASEAN Economic Community is established.

2.2 Heart of Borneo

2.2.1 Natural Environment of Borneo Island

The island of Borneo has one of the world's most biologically diverse tropical rainforests, lying just below the equator. It is thought to be home to about 5% of the species on earth, spanning Indonesia, Malaysia, and Brunei. It is also one of the few living habitats of several endangered large mammals as well as many unique species that cannot be seen elsewhere. The WWF announced the discovery of 123 new species on this island since 2007 in its 2010 report. However, Borneo is estimated to have lost about 50% of its forests in the second half of the 20th century (Figure 2.2). Development activities such as plantation and lumber export have been involved in the destruction of lowland in the tropical forests, which is flat terrain suitable for development. Nevertheless, Brunei still has many untouched forests and the preservation of these forests is not only significantly important for Brunei but also for the biodiversity of Borneo.

Figure 2.2: Deforestation in Borneo Island
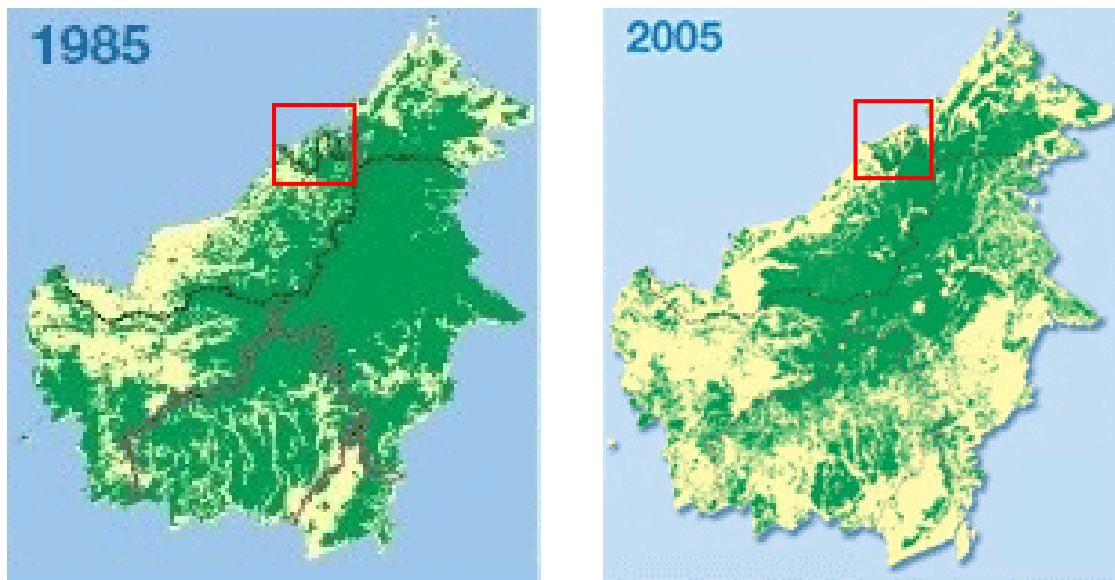
Note: The red box denotes Brunei Darussalam.
Source: WWF Germany.

2.2.2 Sustainable Forest Preservation with Heart of Borneo

In coordination with the WWF, Indonesia, Malaysia, and Brunei announced the HOB program in 2007, in which they promised to protect the island's central area of about 220,000 square kilometres (km^2).

The mission of the HOB programme until 2020 is to (i) establish a protection area of 24 million hectares (ha), (ii) prevent damage to all the valuable forests, (iii) promote alternative sustainable long-term financial programmes that provide support for replacing deforestation activities to local people and governments, and (iv) strengthen the ecosystem's products and services.

The HOB contains about 58% of Brunei's territory, including the mountainous region south of Temburong district. According to the HOB plan, ecotourism promotion is leveraging the untouched forests in Temburong district. The national park in Temburong district covers 50,000 square metres (m^2), but tourists are only allowed on about 100 m^2 (tower canopy area and waterfall area), while the remainder is restricted to government officials.

Figure 2.3: Map of Proposed Heart of Borneo Area

Source: http://wwf.panda.org/knowledge_hub/where_we_work/borneo_forests/

© WWF-Indonesia/GIS Team.

2.3 Surrounding Context in Temburong District

2.3.1 Natural and Social Environment of Temburong District

Temburong is one of four districts in Brunei Darussalam. Situated in the easternmost district in Brunei Darussalam, Temburong is the Sultanate's second largest district, covering 1,304 km². It has a 1,000 m class mountain range in the south, hilly terrain in the centre that is 30–200 m above sea level, and wetland in the north.

Figure 2.4: Map of Temburong District
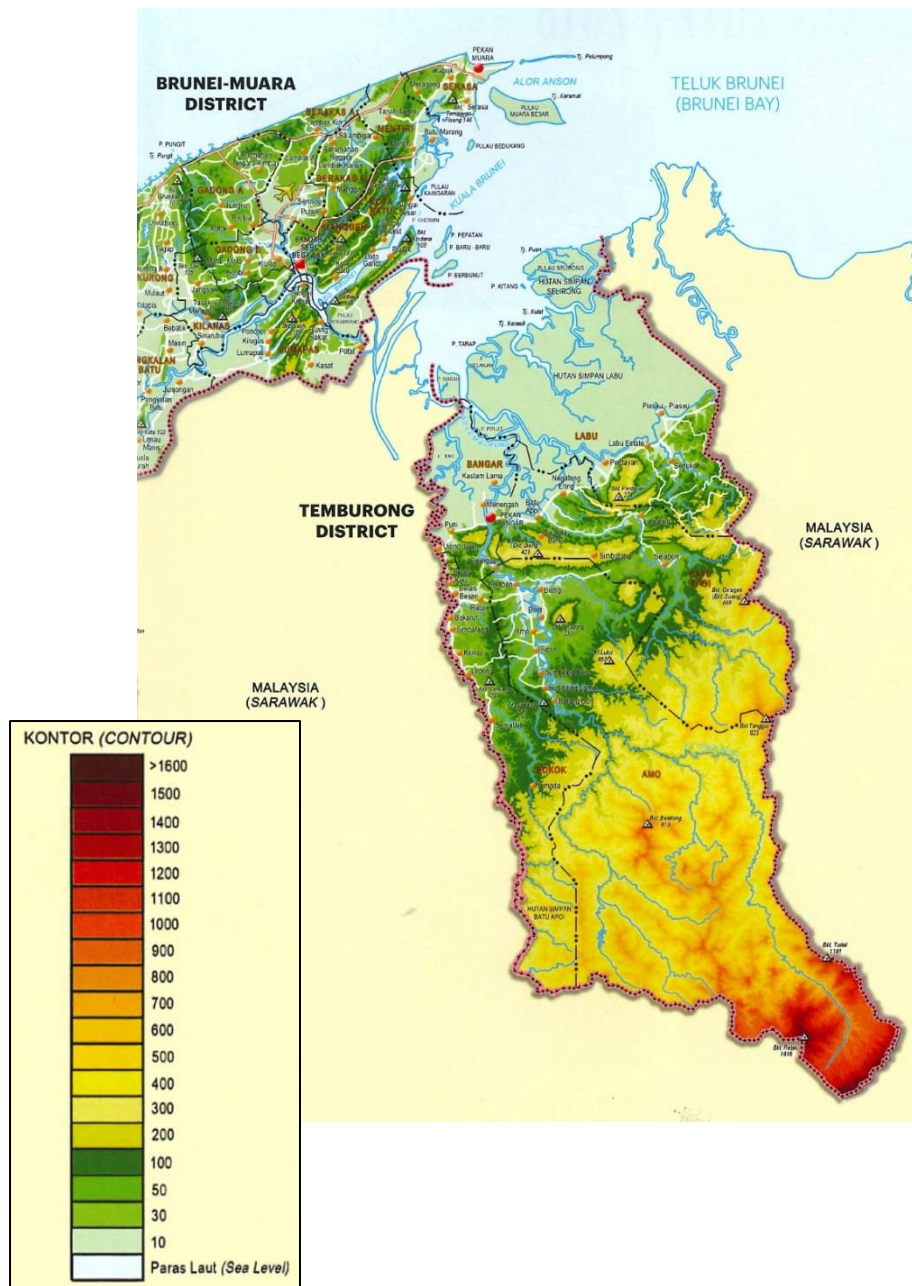
Source: Borneo Bulletin Yearbook (2017).

Temburong district has a population of about 8,900 (2014), or about 2% of Brunei's population. It is divided into five sub-district (*Mukim*): Mukim Amo, Mukim Bangar, Mukim Batu Apoi, Mukim Bokok, and Mukim Labu. Temburong District Office in Bangar Town is the administrative centre and is administered by a district officer. Certain government departments have branches in the district to accommodate citizens and residents in the area. Temburong District can be accessed via the river or by land through Limbang District of Sarawak, Malaysia. This east–west main road, Jalan Labu, also marks the edge of the northern swale land and the central hilly area (Figure 2.5).

Figure 2.5: Map of along Jalan Labu area
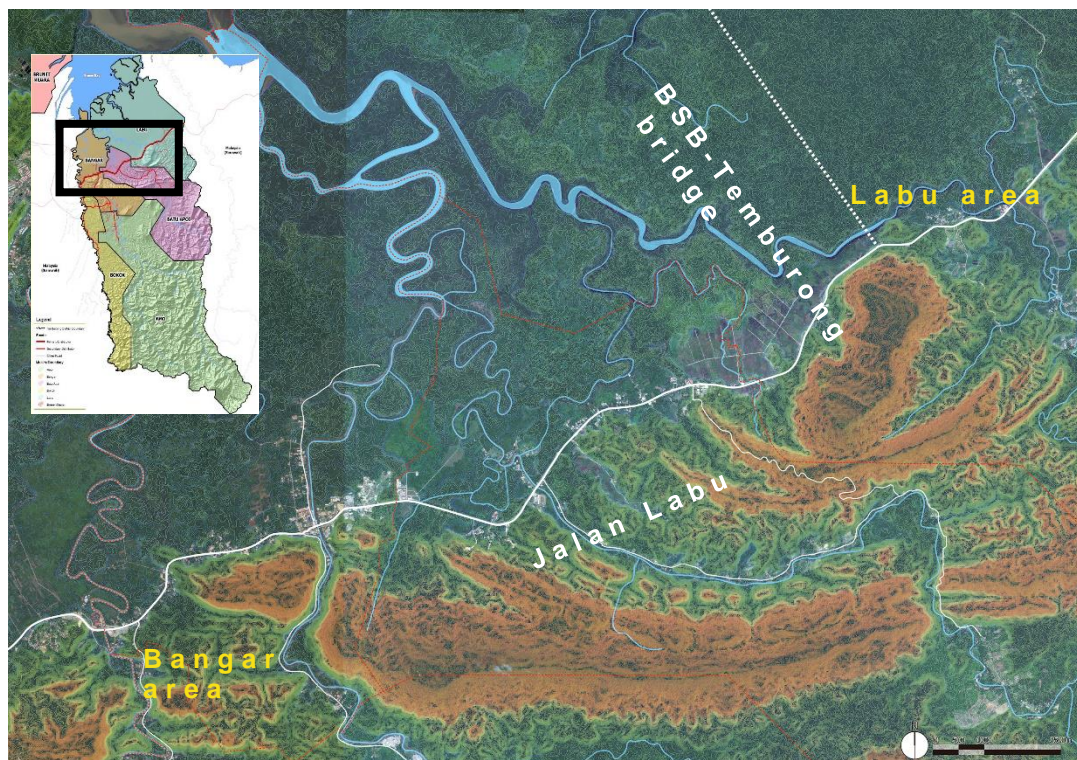
Source: Study team.

2.3.2 Opening of Bandar Seri Begawan–Temburong Bridge

The Temburong Bridge Project is a 30-km dual two-lane highway crossing Brunei Bay that will connect the relatively isolated district of Temburong to Brunei's other three districts (Figures 2.6 and 2.7). The main objective of the project is to stimulate economic growth in Temburong district by connecting it to the country's airport and ports. The alignment crosses two navigation channels, requiring two cable-stayed bridges–the Brunei Channel Bridge (145 m main span) and the Eastern Channel Bridge (260 m main span).

https://www.ernst-und-sohn.de/en/news/temburong-bridge-design-of-two-cable-stayed-bridges

The Temburong Bridge construction is expected to be completed by the end 2019.

Figure 2.6: Route of Bandar Seri Begawan–Temburong Bridge
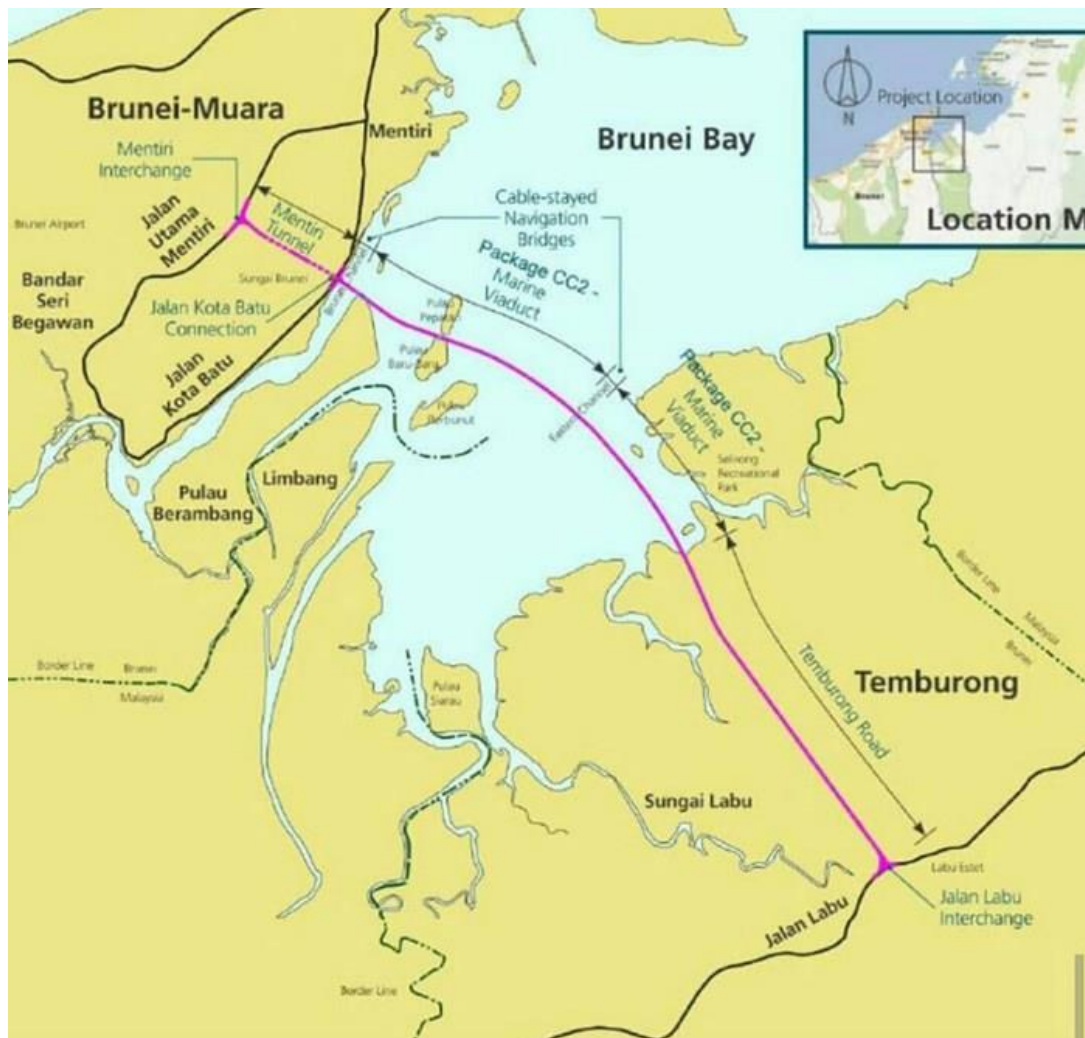
Source: Latest photos of Borneo's longest bridge project in Brunei Darussalam.
http://www.bintulu.org/2017/04/10/brunei-temburong-bridge.php.

Figure 2.7: Perspective Image of Bandar Seri Begawan–Temburong Bridge

Source: Borneo Bulletin Yearbook 2017.

Source: Temburong–Tranquility in Diversity, 2015.

2.4 Summary of Temburong District Plan, 2006–2025

2.4.1 Potential of Land Use in Temburong District

According to land use analysis by the Department of Town and Country Planning, Ministry of Development (TCP), about 9% of Temburong district (about 12,000 ha) is unconstrained land for new development (Figure 2.8).

Unconstrained lands are mainly located along Jalan Labu and the north–south Temburong River. They are mainly occupied by old-growth forests.

Figure 2.8: Unconstrained Land in Temburong District

Legend

■	URBAN FOOTPRINT
■	FUTURE INVESTIGATION AREA
■	UNCONSTRAINED LAND
■	EXISTING PROTECTION AREAS
⬚	HEART OF BORNEO BOUNDARY
▬	TEMBURONG BRIDGE

Constraint	Area (ha)	% of Temburong Land Area
Slope >20°	67,300	53%
Protected Areas	63,800	50%
Water collection	42,600	33%
Flooding (tidal)	27,800	22%
Forest Reserve	25,700	20%
Flooding (rivers)	15,300	12%
Gravel Resource	7,000	6%
Recreation Forest Reserve	1,500	1.1%
Proposed Protection Areas	1,200	0.9%
Sanctuary	400	0.3%

Source: Department of Town and Country Planning, Ministry of Department, 2017, Proposed Developments in Temburong district.

2.4.2 Temburong District Plan, 2006–2025

The Temburong District Plan, 2006–2025 projects the district population to reach 13,270 (low), 14,568 (medium), or 17,535 (high) by 2025. The proposed growth strategy identifies the northwest area (including most of Mukim Bangar and part of Mukim Batu Apoi) and Labu area (including part of Mukim Labu) as development areas.

Figure 2.9: Development Areas Proposed in Temburong District Plan, 2006–2025
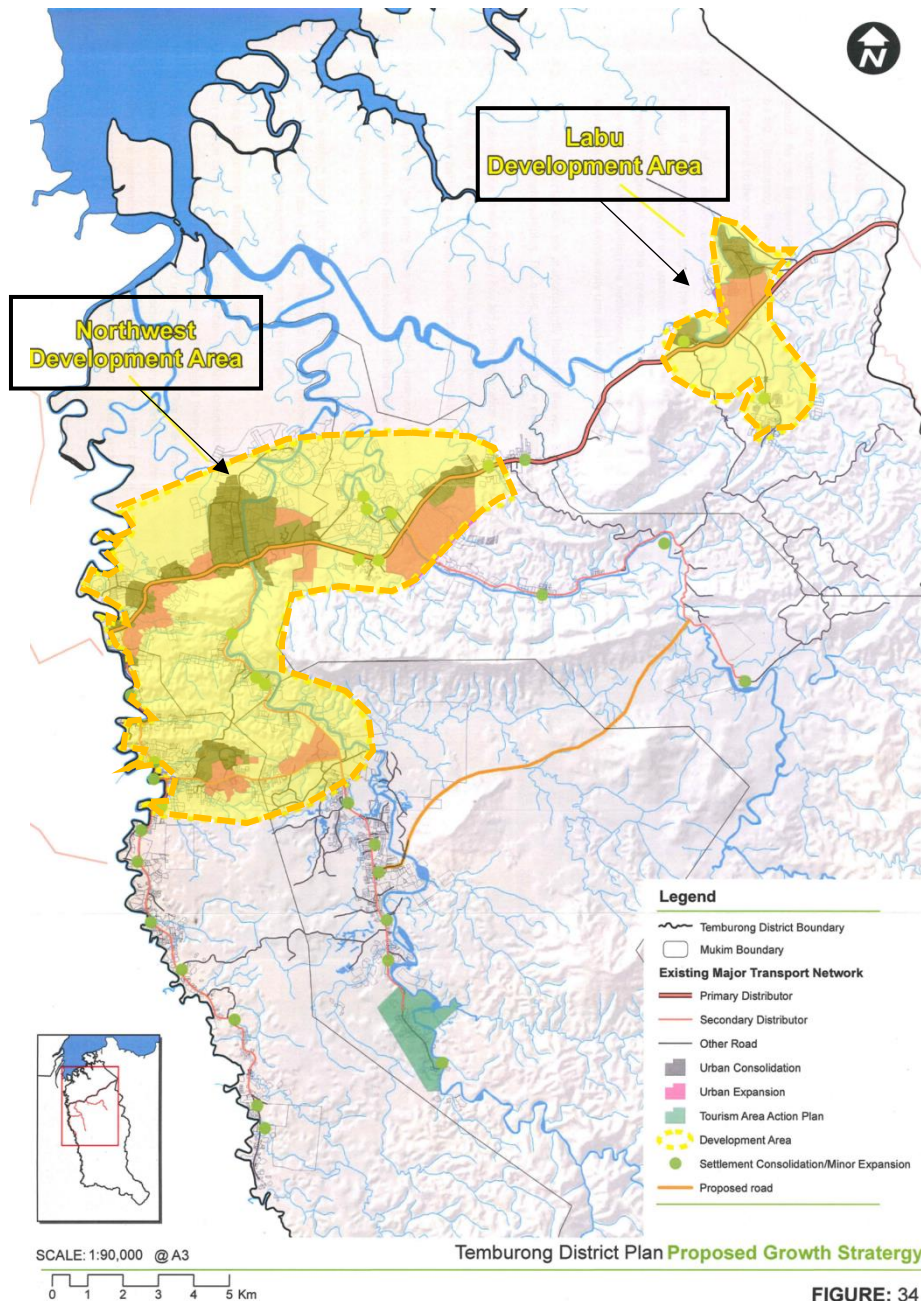
Source: Temburong District Plan, 2006–2025.

2.5 Assessment of Current Conditions

The study conducted a strengths, weaknesses, opportunities, and threats (SWOT) analysis considering Temburong district's surrounding environment (Table 2.1).

Table 2.1: SWOT Analysis of Temburong District Development

	Helpful	Harmful
Internal origin	【Strength】 +Most of the area is in natural condition, without human intervention +Almost no serious destruction of nature +A lot of the land is unused and suitable for development +Tourism, such as ecotourism, is already established +Administrative centre in Bangar is controlled by central government +Connected with larger market of Malaysia by land	【Weakness】 +Small population, with very few roads or other infrastructure +Accessibility is still very limitedf, with only Jalan Labu accessible by land or sea. +No major industry
External origin	【Opportunity】 +Temburong Bridge, connecting with Bandar Seri Begawan, will be opened in 2020 +Wawasan Brunei 2035 aims to reduce oil dependence, create new businesses, and assist small and medium-sized enterprises +Hydrogen manufacturing in Brunei has already started* +Closely related region to Heart of Borneo.	【Threat】 +Uncontrolled development, caused by the increasing population, could affect the environment. +Climate change may have a significant impact +District might receive impact from Bandar Seri Begawan and Malaysia's cities in the flow of resident population, market, employment +Development may threaten local people's lifestyle

* Chapter 5, section 5.3.1.

Source: Study team.

Based on the SWOT analysis, this study proposes development policies that focus on maximising strengths and potential as well as compensating for weaknesses.

Chapter 3

Basic Concept and Assumptions for Preparation of Master Plan

3.1 Vision and Approach Method

3.1.1 Vision

Temburong district will be a model next-generation eco city. As part of the rich ecosystem of Borneo island, Temburong should represent an urban system where nature and human life co-exist in harmony. Planning should include tourism, nature preservation, and other local elements.

Urban development to date has destroyed nature, local communities, and other historical elements, but this project will seek to preserve these elements and create a harmonious balance between them. To build such a sustainable ecosystem, this eco master plan focuses on the relationship between urban development, preservation of local elements, and Borneo's natural environment. The vision is a 'showcase of a carbon-neutral society for Borneo wildlife preservation' (Figure 3.1).

Figure 3.1: Eco Master Plan Vision of Temburong

Source: Study team.

3.1.2 Approach Method

How should we approach building a sustainable ecosystem?

We used three methods to design Temburong district.

(1) Living Lab

(2) Carbon-neutral

(3) Learning Tourism

(1) Living Lab

Temburong district will be a 'living lab' of a carbon-neutral city. A living lab is a user-centered, open-innovation ecosystem, often operating in a region, integrating concurrent research and innovation processes within a public–private–people partnership.[1]

The concept is based on a systematic user co-creation approach, integrating research and innovation processes through the co-creation, exploration, experimentation, and evaluation of innovative ideas and technologies in real-life cases. Temburong district will apply cutting-edge eco-technologies to people's lives and evaluate their contribution to an eco-lifestyle.

The style of Temburong district development itself will be a showcase of innovation, such as future technology of energy and human lifestyles in the abundant forest, especially for the urban development on Borneo Island.

Figure 3.2: Temburong's Eco-Friendly Innovation Informs Borneo Island
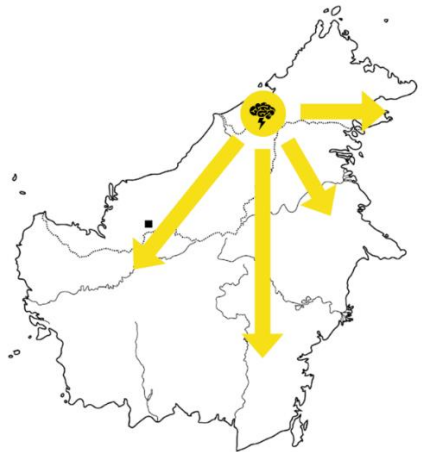
Source: Study team.

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[1] LIVING LABs http://s3platform.jrc.ec.europa.eu/documents/20182/117542/S2E_Fiche_Living_Labs.pdf/994eafb3-4393-415b-a36d-d8cf6f33d44c

i) Diverse Community

Temburong will be the R&D flagship for Borneo's wildlife preservation. Creating innovation via a living lab will require interacting with various people to share regional issues and create solutions. Collaboration will include researchers, entrepreneurs, local residents, and government staff, as well as other sources of innovation.

Urban planning considers how to create diverse communities in terms of function and land use plan as follows:

- ・Housing

- ・University

- ・Company office (R&D center)

- ・Office for start-up company

- ・Government office

- ・Public service

Figure 3.3: Diverse Communities in Temburong
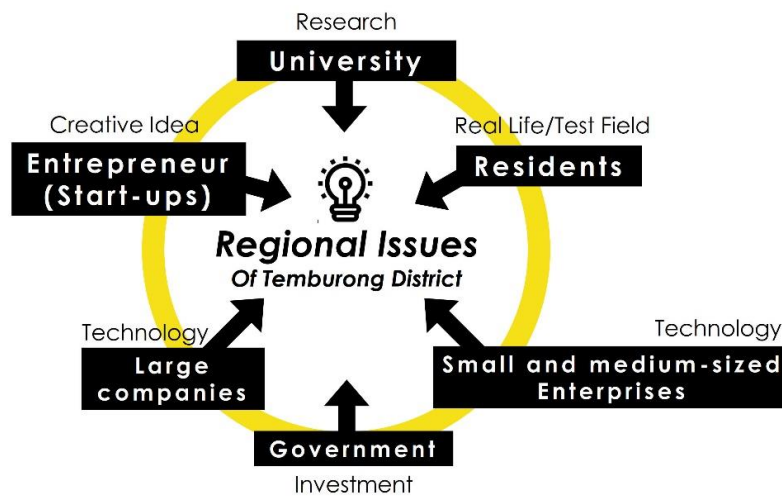
Source: Study team.

ii) Creative Work/Life Style

To achieve innovation, workers in Temburong district must be creative. To make people creative, it is important to have the opportunity to get various and cutting-edge information.

This study considers how to create these connections in daily life and aims to build a future society in which different people live together, share values, and seek solutions to regional issues.

In urban planning, we propose (i) creating a place where research and local life meet; (ii) R&D

and educational facilities with public spaces; and (iii) a forest creative village, satellite R&D office or unexplored region resort.

● **Creating a place where research and local life meet**

Instead of separating new elements from established local components in urban development, this study advocates embedding new elements within local life to lead to new discoveries and encounters. This will encourage innovation and foster a plan–do–check–act (PDCA) cycle for the resolution of regional issues, which will enable long-term giving back to the local community.

Figure 3.4: Connection between Research and Local life
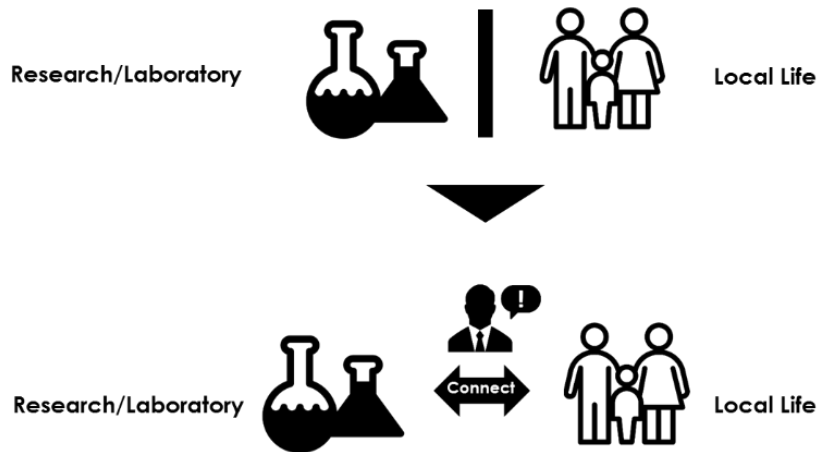
Source: Study team.

● **R&D and educational facilities with public spaces**

This study recommends developing facilities and spaces, mixed with research functions and public services, as regional cores. One proposal of this public space is shown for Public Space between R&D and University in Urban Design Image Labu Estate Growth Centre in Figure 4.18

- Create a gallery space, open to the community, for research activities in the laboratory.

- Establish contact points between R&D and local life, to establish a co-creative relationship

Figure 3.5: R&D and Educational Facility with Public Space
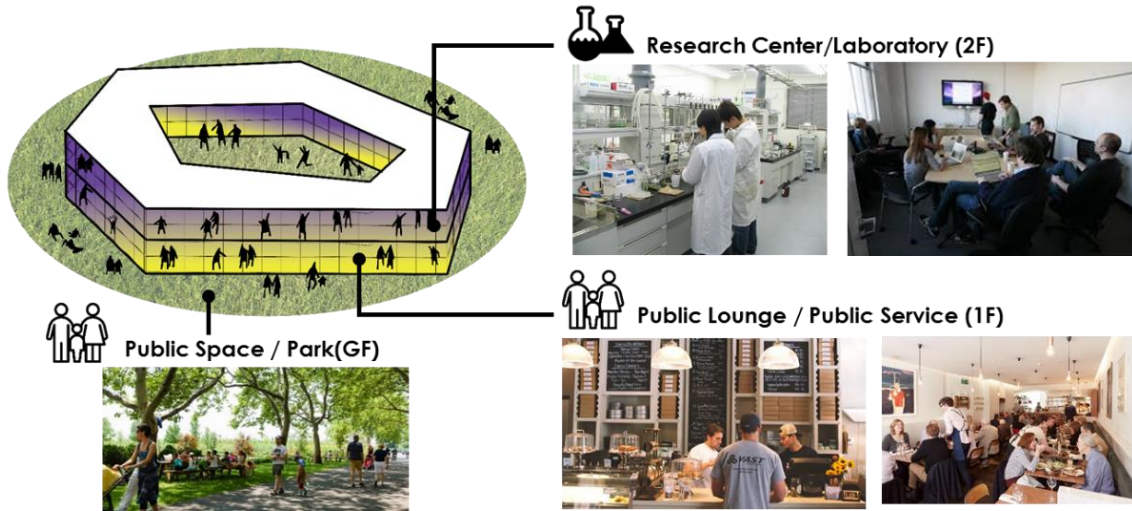
Source: Study team.

● **Forest creative village**

A working environment surrounded by nature is stimulating for researchers and workers.

The forest creative village such as satellite R&D office or unexplored region resort, aims to leverage the power of nature to foster innovation, discovery, and creativity.

Figure 3.6: Forest Creative Village
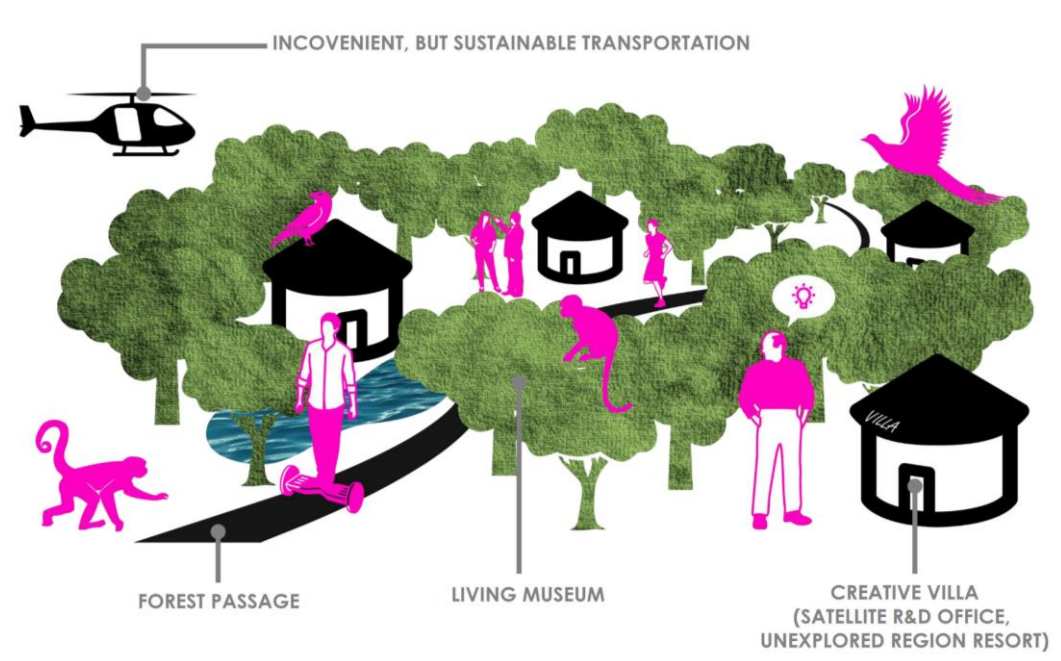
Source: Study team.

(2) Carbon-neutral

Temburong district will be the most advanced eco city in the world, aiming at zero carbon dioxide (CO_2) emissions. This study proposes the following policies to balance circulation energy supply and demand; (i) renewable energy, (ii) a sustainable mobility system, (iii) sustainable architecture/agroforestry, and (iv) a small economy. The Dialogue of Carbon Neutral Development is shown in Figure 3.7.

Figure 3.7: Dialogue of Carbon Neutral Development
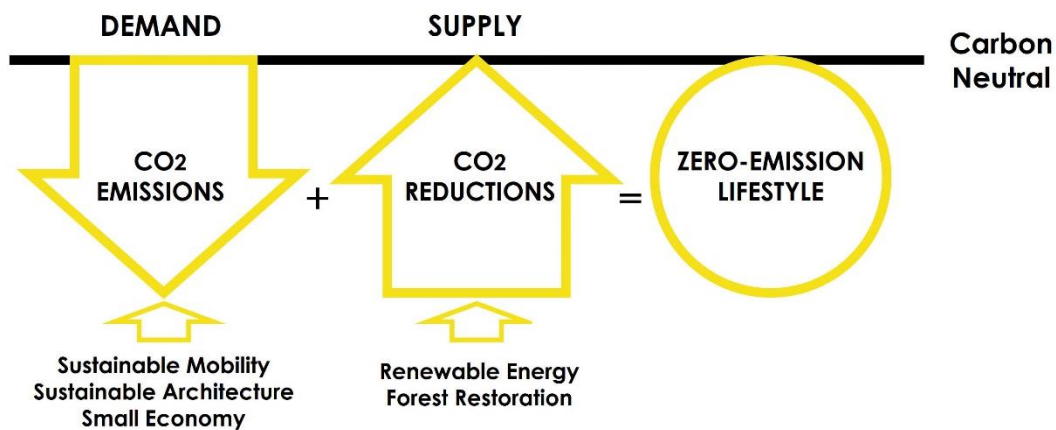
Source: Study team.

i) Renewable energy

Temburong district will be entirely powered by renewable energy. It will pioneer innovative technology such as solar, wind, biomass, and hydrogen energy.

ii) Sustainable mobility system

People usually require a significant amount of energy to move around urban areas. We need to consider a sustainable mobility system to minimise the energy consumption caused by movement. For example, hydrogen-powered buses (CO_2 zero) could bring tourists from BSB to Temburong district and tourists could travel around in Temburong in hydrogen-powered autonomous cars.

iii) Sustainable architecture and agroforestry

● **Sustainable architecture**

To achieve zero CO_2 emissions, the energy impact of housing and other facilities must be minimised with a sustainable architecture system. Renewable energy, such as solar and hydrogen power, are very effective for CO_2 reduction. This study recommends introducing net zero emissions houses or a house energy management system. Advanced technologies adapted to Brunei's climate will be introduced to the architectural system.

● **Agroforestry**

Food production is one of the most important issues. A self-sufficient food production and consumption system is crucial in the region. This study proposes agroforestry, a land use management system in which trees or shrubs are grown around or amongst crops or pastureland (Figure 3.8). This helps balance food production and nature preservation.

Figure 3.8: Agroforestry
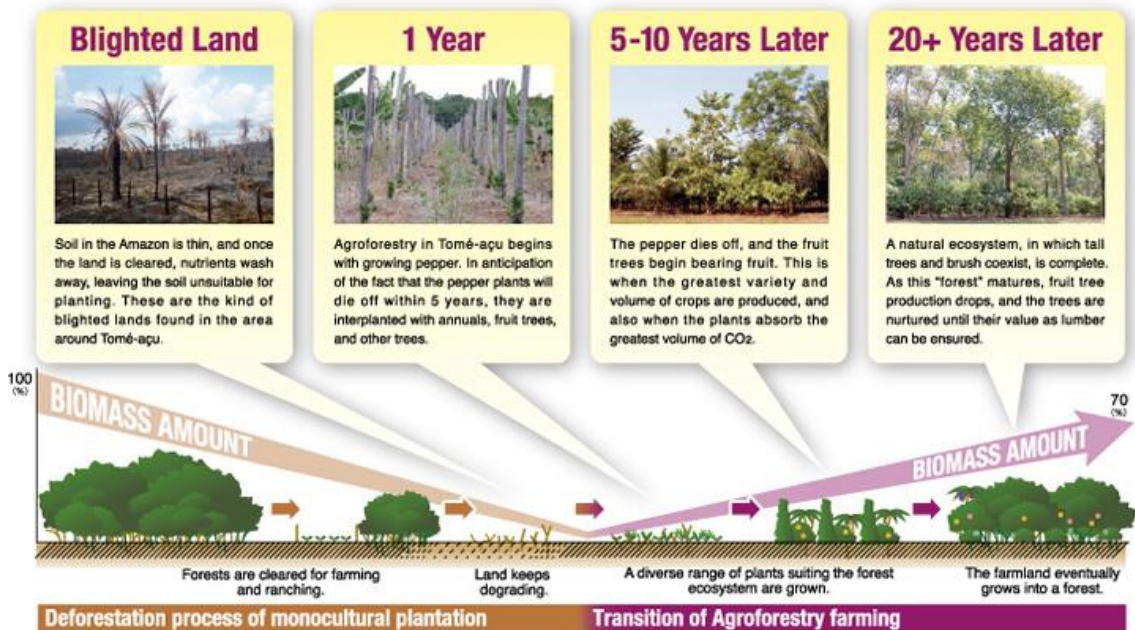
Source: Fruta Fruta. https://www.frutafruta.com/global/agroforestry/agroforestry.html,
"Agroforestry is a method of farming on lands devastated by logging and other activitiy that builds on the example of natural ecosystems to enable a wide range of agricultural products to co-exist."

iv) Small economy

In an era of unpredictable social change, a small regional flexible city which grows gradually through self-sufficiency is in demand rather than a mega city built on a large amount of investment (Figure 3.9).

Figure 3.9: Self-Sufficient Circulation
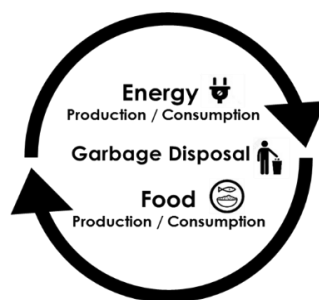
Source: Study team.

Various uses–housing and offices, shopping malls, and a university–can co-exist in one unit of a small district. This creates a compact city and neighborhood community (Figure 3.10).

Figure 3.10: Compact City
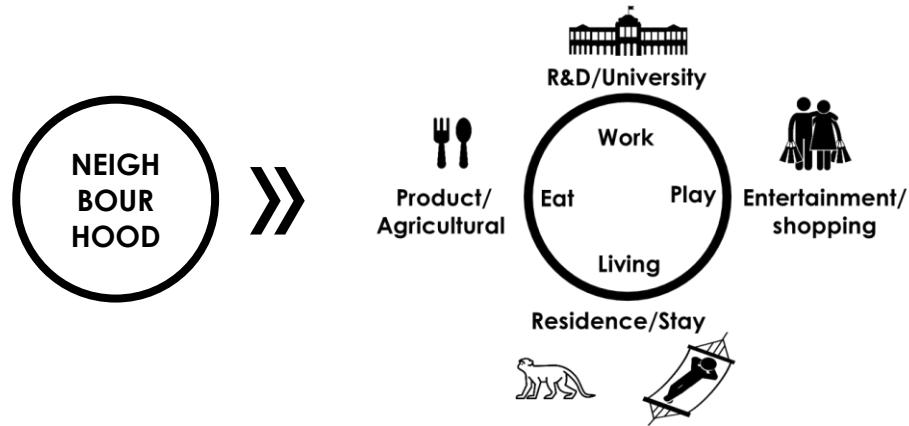
Source: Study team.

Establish a new eco-friendly lifestyle for Temburong district, this study proposes a self-sufficient city model with many elements of small unit circulation (e.g. circulation of industry, market, energy or food).

With an advanced eco-friendly lifestyle, which does not exist in western countries or Japan, Temburong district will establish itself as a brand name in advanced city environments in Brunei and all of Southeast Asia.

Figure 3.11: Eco-Friendly Lifestyle in Temburong

ZEH

Solar energy

Drone logistics

HEMS/AEMS

Natural light

Electrical storage

EV/FCV

Permaculture
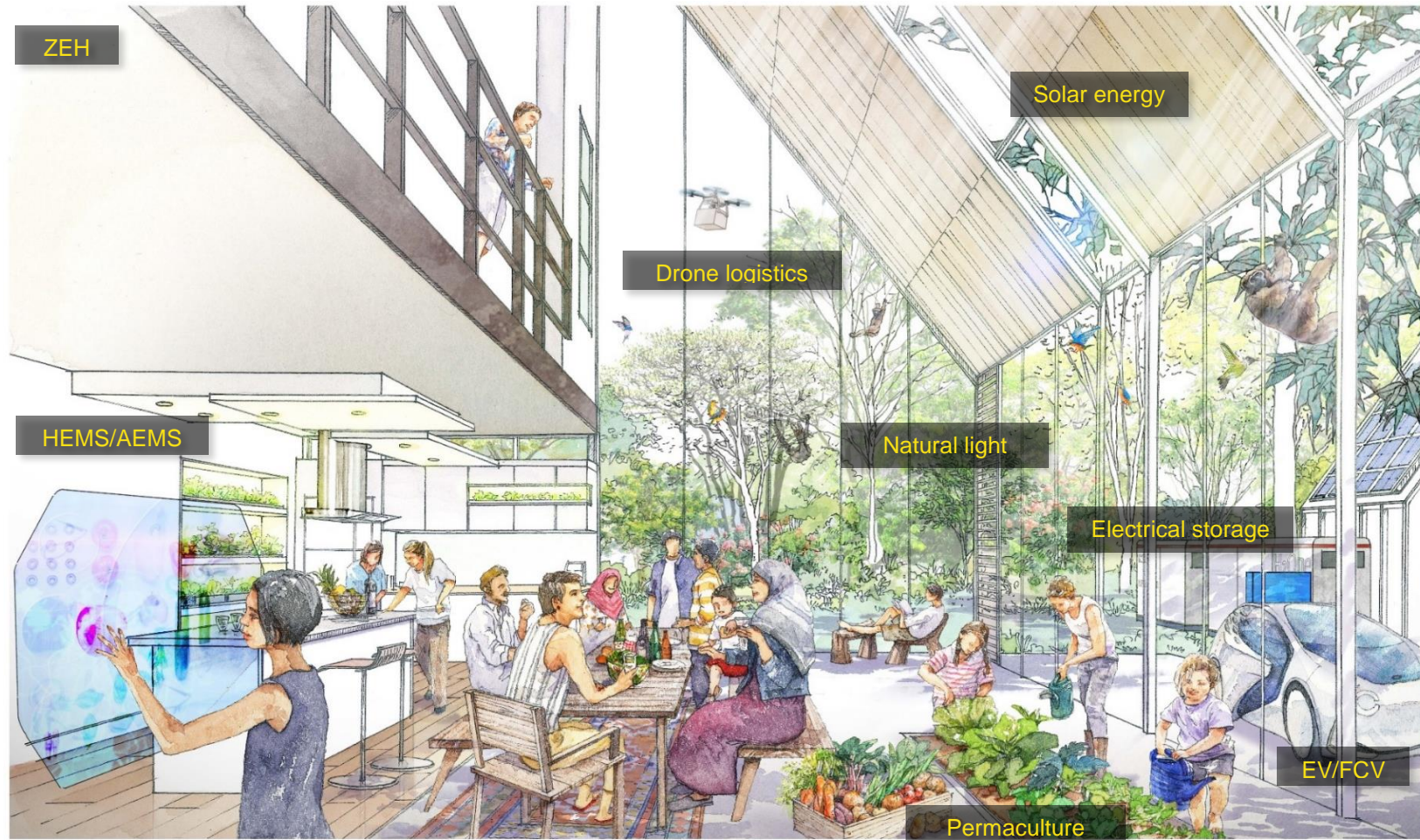
AEMS = area energy management system, EV = electric vehicle, FCV = fuel cell vehicle, HEMS = home energy management system.
Source: Study team.

(3) Learning Tourism

In Brunei, it is the immediate goal to create a new industry ahead of natural resources, especially development of the tourism industry is important. In Temburong, we propose not only sightseeing just to visit but also incorporating learning and education as tourism resources with the characteristics of the area. In other words, tourism here means learning about Borneo's nature and the future.

i) Feature of Temburong and Borneo

Temburong has a rich natural environment, with mangroves and sea. Living in Temburong permits access to the natural ecology and environmental problems, offering an abundant learning environment. Both tourists and residents can improve their environmental awareness. By changing the awareness and mindset of people living here, Temburong will become a truly environmental city.

This study promotes the idea that humans are part of the species in the ecosystem. We want to create a new eco-friendly lifestyle in Temburong which emphasises the co-living of humans and other species, leading to a society that co-exists with Borneo's great nature.

Figure 3.12: Learning Activities in Forest Area

Source: #GoTemburong Holiday Packages http://www.geekinwhite.com/travels/2016/11/16/gotemburong-holiday-packages

Source: Borneo Insider's Guide http://borneoinsidersguide.com/education-fun-come-together-sumbiling-eco-village-school-camp-brunei/

ii) Smart technology showcase

Temburong will symbolise smart technology, and tourists and locals will be able to discover ecology through daily experience with advanced smart technologies.

As the base for ecological learning, we will build a resort high in the forest which will allow people to immerse themselves in nature, away from hustle and bustle of daily life. The resort will offer the rare experience to live in very close proximity with the forest and the creatures who live there. This will attract many visitors with high awareness of the environment.

We will build many small individual structures to minimise destruction of the forest. This will allow everyone to enjoy their stay while experiencing the true delights of the forest.

Figure 3.13: Learning Tourism Elements and Smart Technology Showcase
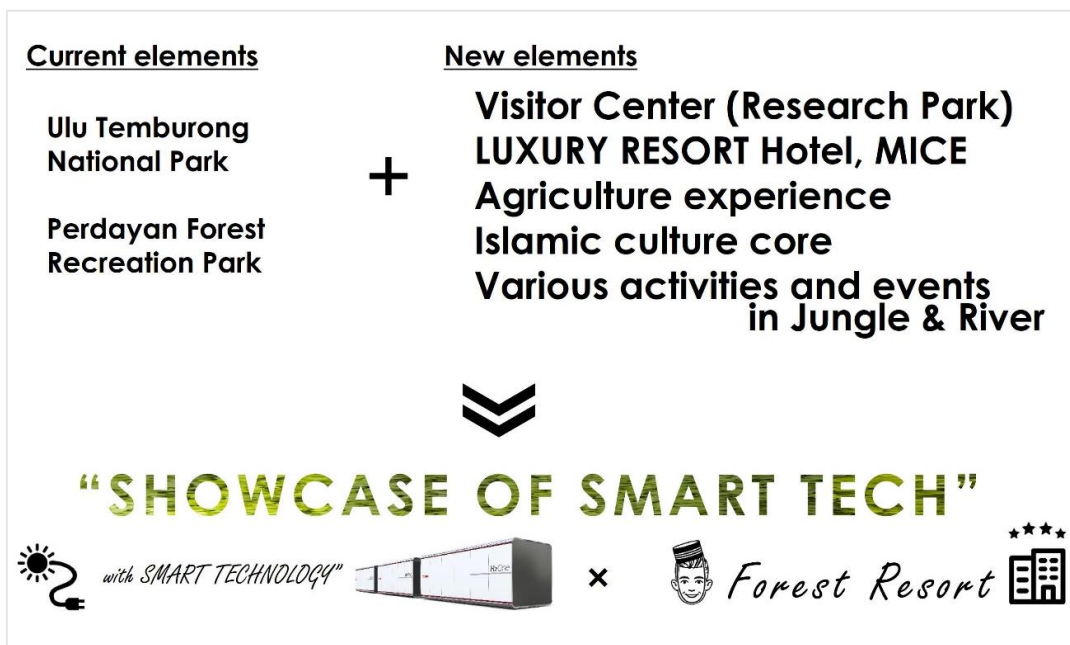
MICE = meeting, incentive, conference, and exhibition.
Source: Study team.

Figure 3.14: Future of Temburong
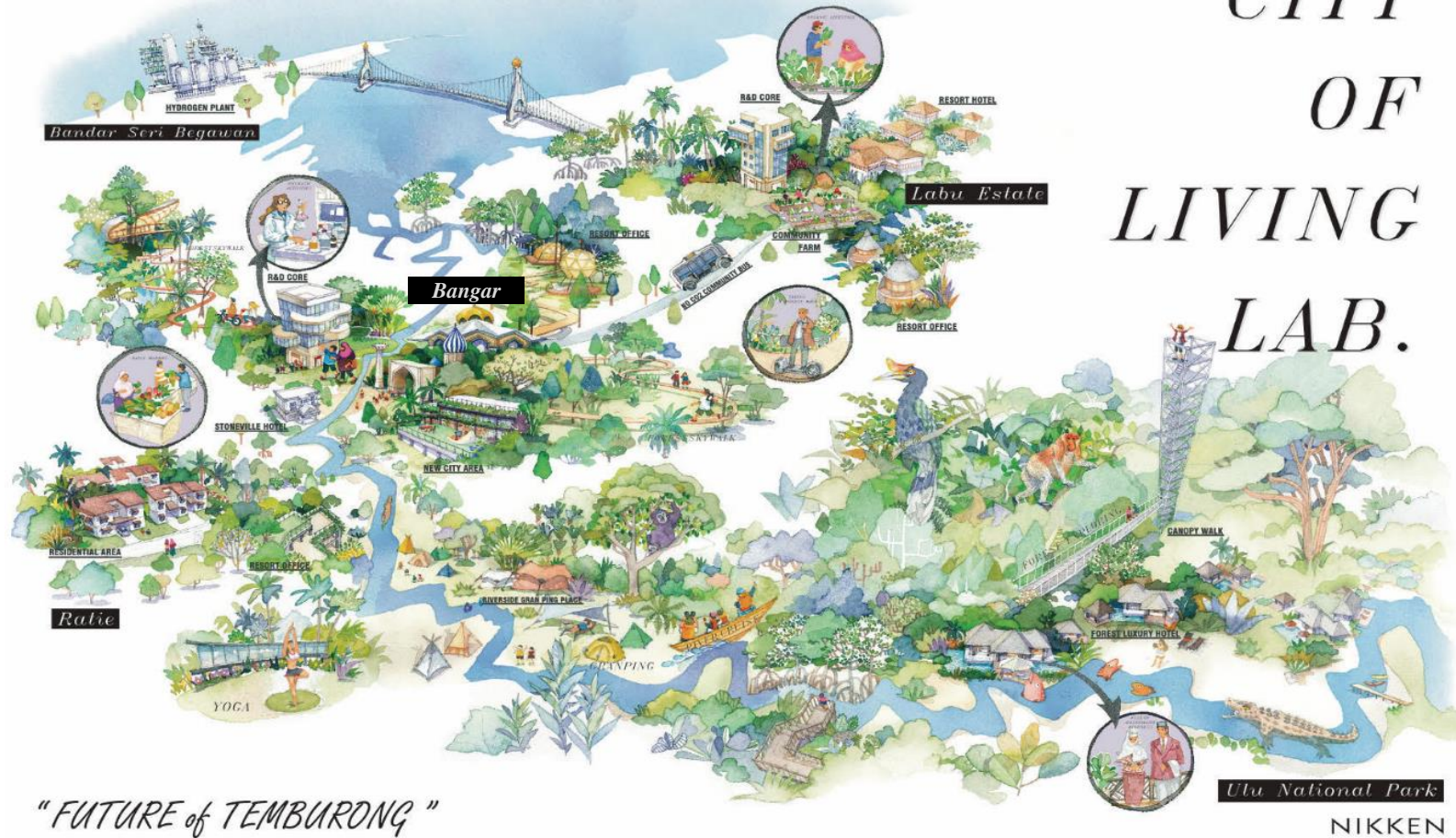
Source: Study team.

3.2 Target of Master Plan in Temburong District

To realise the vision and to avoid uncontrolled development by the private sector, this study formulates a land use plan and urban design image in the master plan (Chapter 4).

The target year of the master plan is 2030, 10 years after 2020, when the world's first international hydrogen supply will begin between Brunei and Japan, and the bridge connecting BSB and Temburong will open. The short-term target will be 2024, when the Asia-Pacific Economic Cooperation (APEC) Economic Leaders' Meeting will be held in Brunei.

3.3 Facilities to be Introduced

Based on the vision, goal and approach method and the Temburong District Plan, 2006–2025, the main facilities to be introduced to the planning site are as follows:

- University, R&D
- Hotel, convention centre zone
- Hospital zone
- School zone
- Residential zone
- Commercial zone
- Public services zone
- Tourism zone

3.4 Selection of Suitable Location for Development Hub

Bangar and Labu Estate are positioned as growth centres, considering the new bridge that will open between BSB and Temburong.

As shown in Figure 3.15, Bangar will have functions such as district office, hospital, market, and residential, as the centre of public services. Labu Estate will have functions such as the university, R&D, hotel, convention, tourism facilities, and residential, as the centre of education, R&D, and tourism.

3.5 Framework of Residential Population and Tourist Population

3.5.1 Framework of Residential Population

Considering the new bridge connecting BSB and Temburong, the development of Sultan Sharif Ali Islamic University (UNISSA) and R&D, the annual population growth rate is projected at 5%.

Figure 3.15: Suitable Location for Development Hub
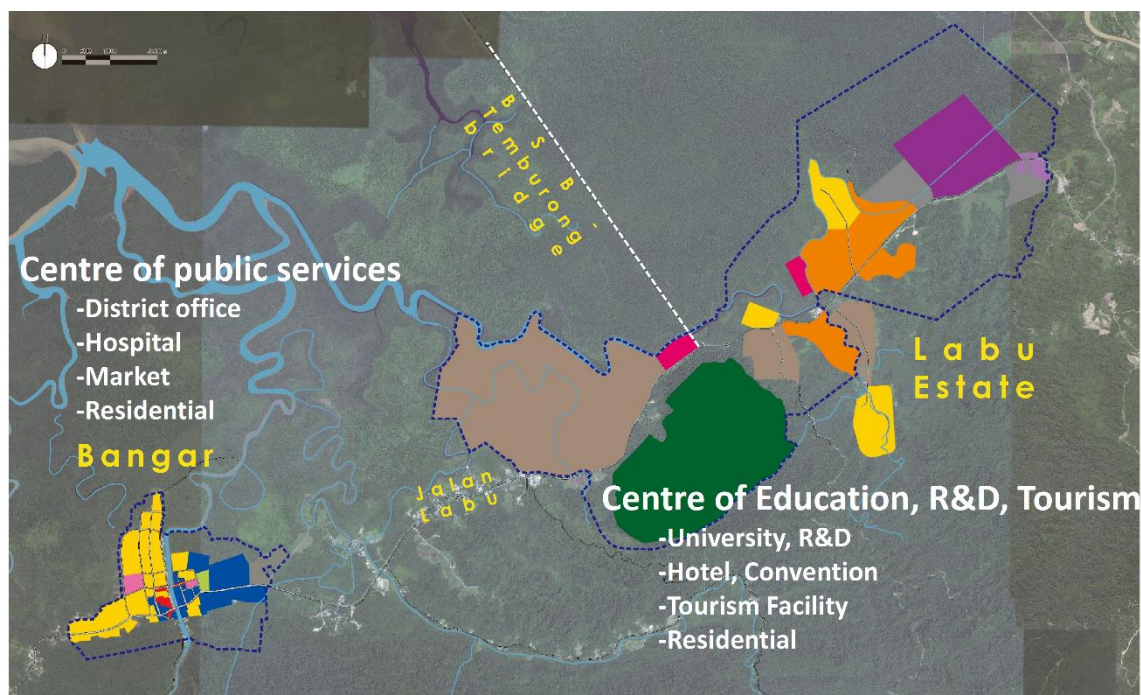
Source: Study team.

Table 3.1: Temburong Population

Item	Amount
Population in 2016 (number of persons)	9,000
Growth rate (%)	5
Population in 2030 (number of persons)	17,819
Population growth (number of persons)	8,819

Source: Study team.

Table 3.2: Bangar Population

(number of persons)

Item	Amount
Population in 2017	2,395
Population in 2030	6,395

Source: Study team.

Table 3.3: Labu Estate Population

(number of persons)

Item	Amount
Population in 2017	582
Population in 2030	4,582

Source: Study team.

3.5.2 Framework of Tourist Population

The tourism area should be expanded not only to Ulu Temburong National Park but also to Perdayan Forest Recreation Park and Labu Estate. The target number of tourists is 400,000 per year.

Table 3.4: Labu Estate Tourist Population

Area	Activity	Number of tourists (people/day)
Ulu Temburong National Park	Canopy walk, camping, trekking, fishing, kayaking	500
Perdayan Forest Recreation Park	Boat tour	300
Labu Estate	Nature amusement park, agro park, learning tourism	300
Total		**1,100**
		= 400,000 people/year

Source: Study team.

Chapter 4

Formulation of Master Plan for Development Hub

This chapter proposes a framework, land use, and urban design image for the Bangar and Labu Estate areas, which are identified as suitable locations for the development hub, based on the vision, development policy, and framework for Temburong district in Chapter 3.

4.1 Master Plan of Bangar

4.1.1 Framework of Bangar

(1) Residential

Based on the predicted population of 6,395 in 2030, the assumed residential area is 213 ha (Table 4.1). The average density of the residential area is 30 persons/ha, which is the same as the residential density in Rataie, which is a standard suburban residential area in Brunei Darussalam (Figure 4.1).

Figure 4.1: Rataie Residential Density
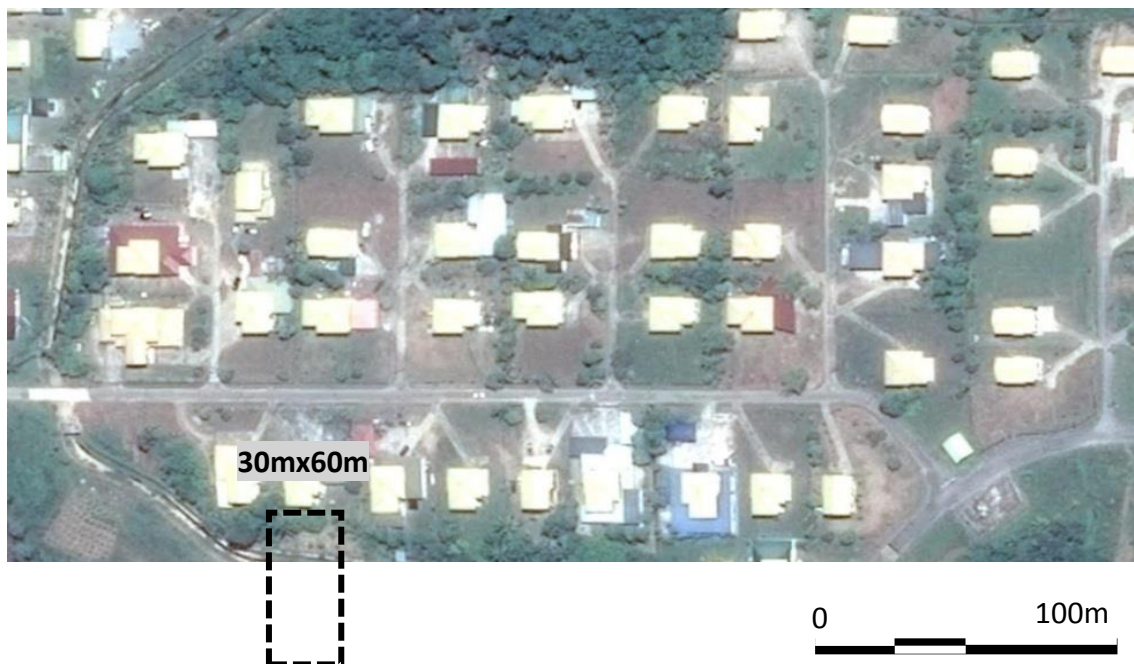
Note: About 30 persons per hectare.
Source: Study team.

Table 4.1: Bangar District Housing Land Demand Forecasts to 2030

Item	Amount
Population (number of persons)	6,395
Population density (persons per hectare)	30
Housing area demand (hectare)	213

Source: Study team.

(2) Education

Based on the predicted population of 6,395 in 2030, the assumed primary and junior high school area in Bangar district is 2.5ha for Primary School land and 2.1ha for Secondary School Land as shown in Tables 4.2 and 4.3.

Table 4.2: Bangar Growth Centre Primary School Land Forecasts to 2030

Item	Amount
Population (number of persons)	6,395
Students (number of persons)	491*
Area per person (m^2)	50
Area (hectare)	2.5

m^2 = square metre.

* United Nations Population Division.

Source: Study team.

Table 4.3: Bangar District Secondary School Land Forecasts to 2030

Item	Amount
Population (number of persons)	6,395
Students (number of persons)	428*
Area per person (m^2)	50
Area (hectare)	2.1

m2 = square metre.

* United Nations Population Division.

Source: Study team.

Table 4.4: Bangar Growth Centre Hospital Land Forecasts to 2030

Item	Amount
Population in 2030 (Temburong)	17,819
Demand for hospital beds (beds)*	71
Floor area per bed (m^2)	200
Floor area (m^2)	14,256
Gross FAR (%)	50
Area (m^2)	28,511

m^2 = square metre, FAR = Floor area ratio.

* 4 beds/1,000.

Source: Study team.

(3) Hospital

The hospital targets all Temburong district. Based on the predicted population of 17,819 in 2030, the assumed hospital area is about 3 ha (Table 4.4).

4.1.2 Assessment of Land Use of Current Condition and Current Land Use Plan by Department of Town and Country Planning (TCP)

(1) Current condition

The central town of Bangar area is located along the Jalan Labu Bridge, which runs across the Temburong River. Administrative and public facilities as well as residences are concentrated in this area of about 1 km^2. The town is surrounded by abundant forested areas. The south of the town has mainly steep hills, so residences and public facilities are mainly located in the flat land in the north as well as along the Jalan Labu road, and expand slowly from there. Access to the Bangar area is mainly by land via the Jalan Labu road or by water via the fast ferry port in the south of the town.

The current condition of Bangar area is shown in Figure 4.2 and 4.3.

Figure 4.2: Condition of Bangar Growth Centre
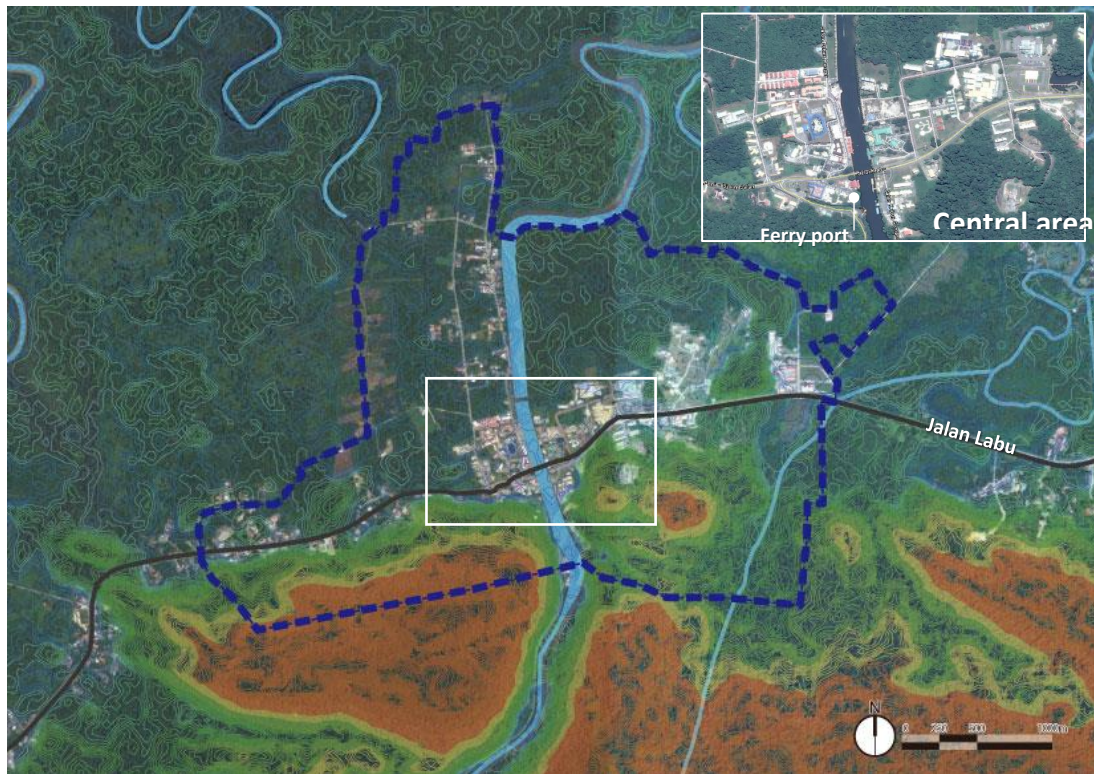
Source: Study team.

Figure 4.3: Central Area of Bangar Town

Source: Temburong – Tranquility In Diversity, 2015.

Jalan Labu Bridge   Inner road and buildings   Residence
Source: Study team.

(2) Current land use plan by Department of Town and Country Planning (TCP)

The TCP developed the land use plan for Bangar growth centre is shown in Figure 4.4 and it was proposed with the following key elements:

- Principal tourist node
- Provision of enhanced commercial area building in the current shopping and services area at the centre of Bangar (3.2 ha of additional land)
- Retention of the east bank of Bangar as the administrative zone for the district
- Allowance for future expansion of the hospital at its existing site or relocation in a new complex
- Identification of land suitable for tertiary education campus
- Amenity improvement, such as riverside park, in Bangar

- Modern port facility in north-east Bangar
- Provision of green space within the settlement and environmental protection of the ridge
- Improvement in road circulation along Jalan Temburong and Jalan Labu

Figure 4.4: Land Use Plan of Bangar Growth Centre
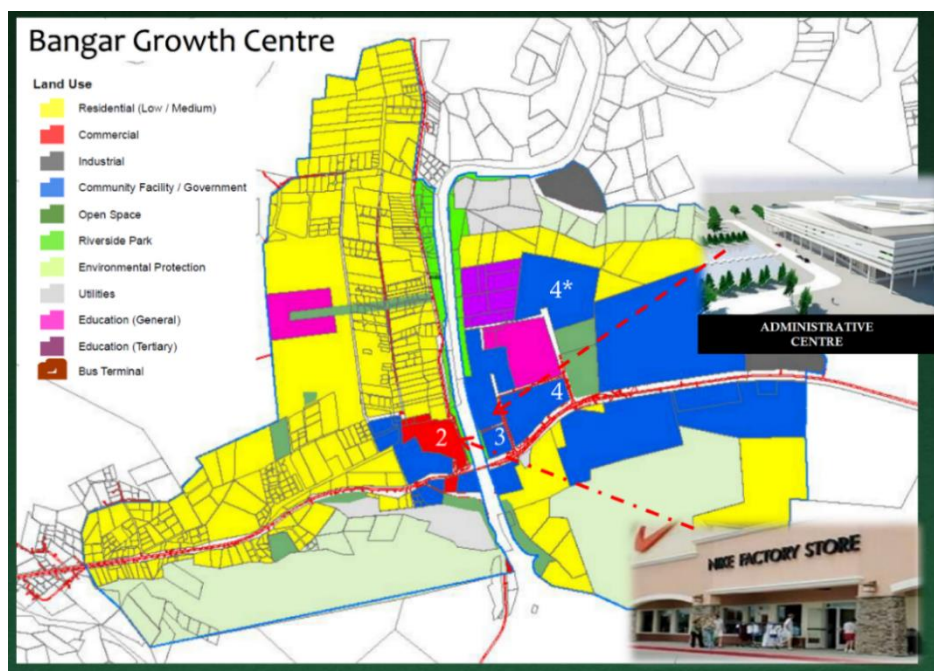
Source: TCP (2017), Proposed Developments in Temburong District.

4.1.3 Proposed Master Plan in Bangar District

(1) Land use plan in Bangar

This study agrees with the key elements proposed in 2.1.2 (2) by the TCP regarding the development of Temburong district. In addition, based on the vision and other elements proposed in Chapter 3 for the entire Temburong area (e.g. dealing with the increasing traffic volume in the future and the need for tourism facilities) from the perspective of eco-friendly development as well as effective land use, this study proposes the following improvement and enhancement of functionality (Figure 4.5, Figure 4.6, and Table 4.5).

1) Construct internal roads and bridges connecting both sides of the river

The Temburong River divides Bangar district and the Jalan Labu road is the only connection between the two areas. Considering the increase in population and expansion in the logistics sector, through traffic should be separated from inner-city traffic by constructing more inner roads and bridges.

2) Arrange housing area based on demand

Despite the demand estimation of about 213 ha for housing, the TCP's land use plan allocates too much land for housing. This study believes that the current natural environment should be

preserved as much as possible. Housing areas in the lowlands in the north and the hills in the south of the east side area of the Temburong River should be considered a reserve area to deal with the long-term expansion of the urban area. This area should not be developed in the short term.

3) Locate schools in densely populated area in the west

Schools are located east of the Temburong River in the TCP's land use plan. For convenient commuting to school and traffic safety, this study proposes that schools be positioned in the housing area west of the river.

The TCP plan sites the new university on the east of the river. However, because of the decision from the Brunei authorities to establish the university in Labu Estate district, this study does not include tertiary education facilities in the Bangar district land use plan.

4) Pedestrianise the roads along the Temburong River to create a bustling area

By pedestrianising part of the roads between the current commercial area and the Temburong River, this study aims to make a bustling area with uninterrupted shopping space. This will create an urban space for local residents and tourists to enjoy.

Figure 4.5: TCP Land Use Plan Proposal for Improvement

1) Construct internal roads and bridges connecting both sides of the river

2) Arrange housing area based on demand.
(In the short term, these areas should not be developed as residential and treated as reserved areas in the future.)

3) Locate schools in densely populated area in the west

4) Pedestrianise the roads along the Temburong River to create a bustling area
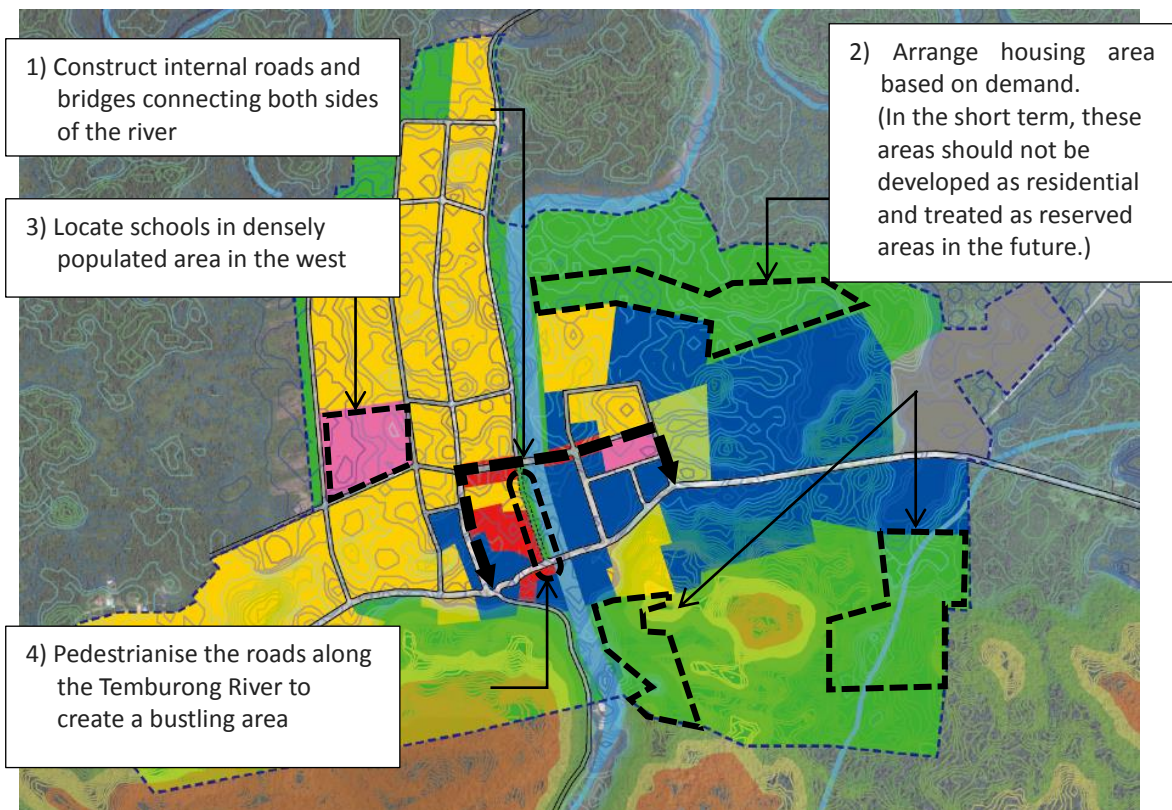
Source: Study team.

Figure 4.6: Land Use Plan in Bangar Growth Centre
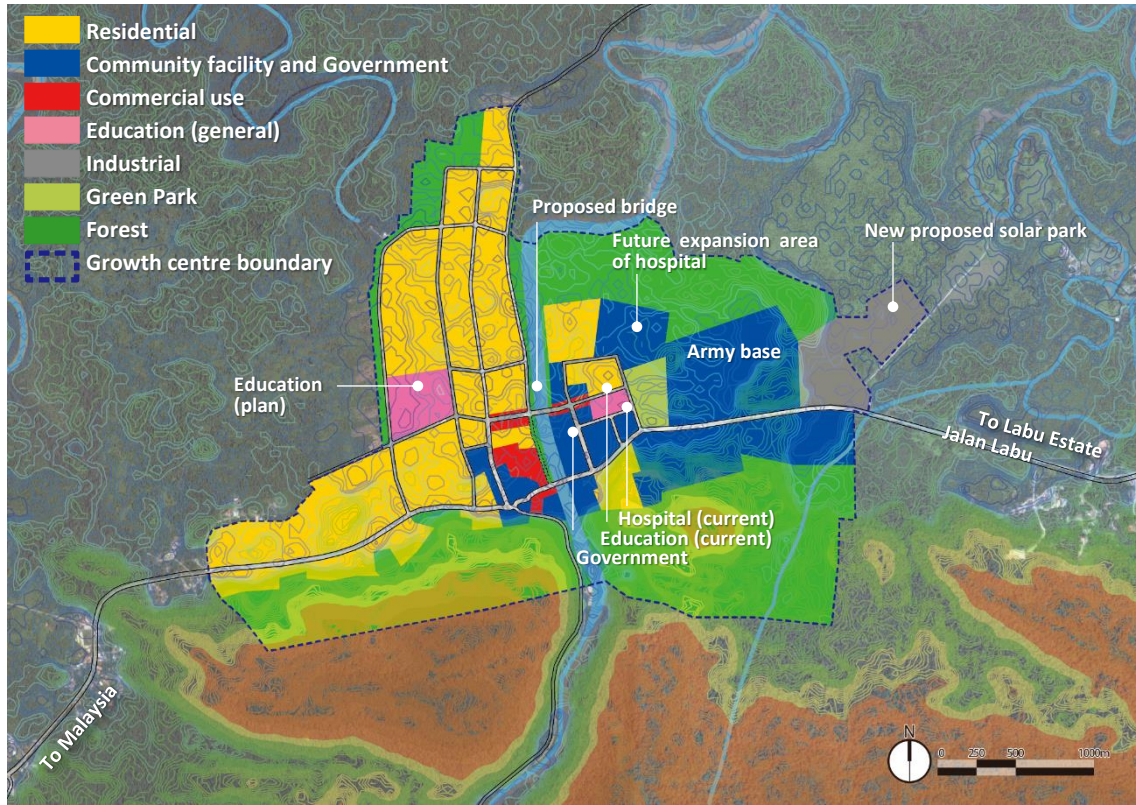
Source: Study team.

Table 4.5: Bangar Growth Centre Land Use Area

Land Use	Area (hectare)
Residential	228
Community facility and Government	145
Commercial use	10
Education (general)	18
Industrial	34
Green park	9
Forest	345
Road	44
Water	22
Total	**855**

Source: Study team.

(2) Urban Design Image

The centre of Bangar district is mainly located in the downstream area near the Jalan Labu Bridge. The left bank of the river is the commercial district and the right side has stately administrative buildings. The current small population, with very few pedestrians or cars, results in a peaceful neighbourhood. However, an increase in population and growing demand from tourism are expected. Therefore, Bangar area will need to be prepared. The current condition of central area along the Temburong river are shown in Figure 4.7.

Figure 4.7: Condition of Central Area

View from the Jalan Labu Bridge (downstream)

Administrative area with Islamic building

Commercial district I

Road in the commercial district along the Bangar River (Jalan Pekan Bangar road)

Note: These images show the downstream area of Jalan Labu Bridge.
Source: Study team.

This central area across the Temburong River has significant potential to become a bustling riverside space. This study proposes a space design that focuses on creating an area of about 500 m along the river, between the ferry port and the new bridge, to become the bustling centre of Bangar district. This design will take into account the future expansion of the urban area as well as the proposed new bridge construction plan.

Primary policies in space creation of the bustling central area

The primary policies of bustling central area are followings. (Figure 4.8 and 4.9)

- Revitalise the Bangar River and its riverside.
- Construct space for social exchange
- Improve accessibility
- Ensure safety and security

1) Construction of transit mall[1] in front of the commercial centre on the left bank (part of Jalan Pekan Bangar)

The Jalan Pekan Bangar road on the left bank is one of the main roads on the north–south axis of the town's inner city transportation. However, the road separates the commercial area and the space along the river.

To avoid this separation when pedestrian and traffic volumes increase, and to create a continuous bustling space from commercial facilities to the open space near the river, part of the Jalan Pekan Bangar road will be converted to a transit mall. This will prioritise pedestrians and public transportation (e.g. buses).

2) Preservation of the landscape of the administrative area on the right bank

The administrative area at the foot of the bridge on the right bank has beautiful architecture surrounded by nature. This landscape should be preserved as much as possible by avoiding constructing with too much decoration.

3) Construction of river walk and recreation area

The study plans to build new boardwalks and open spaces on the walkway, along with resting zones, for walking or using small mobility devices (e.g. wheelchairs and Segways) on both sides of the river.

4) Introduction of river-related activities and sightseeing dock

The main ferry port, downstream from Jalan Labu road, is the terminal for high-speed, large vessels used to travel to BSB and neighbouring countries. The study plans to introduce new river-related activities in Bangar and Labu, along with a sightseeing dock in the transit mall area in front of the commercial district on the left bank as well as the administrative area on the right bank. These new docks will avoid the complication with the high-speed, large vessel ferries and create a lively river space.

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[1] A transit mall is a street that restricts private cars and prioritises public transportation (e.g. buses, trams, light rail transport, and taxis) and pedestrians. It is frequently introduced to revitalise town centres.

Figure 4.8: Location of Bustling Central Area

Riverside park

Internal road & proposed 2ⁿᵈ bridge

Busty axis

Jalan Labu

To Labu

Commercial & Hotel zone

Pedestrian priority zone (Transit mall)

Government zone (current)

Sightseeing boat stand (proposed)

Ferry port (current)

Market (current)

To Malaysia

N 0 250 500m
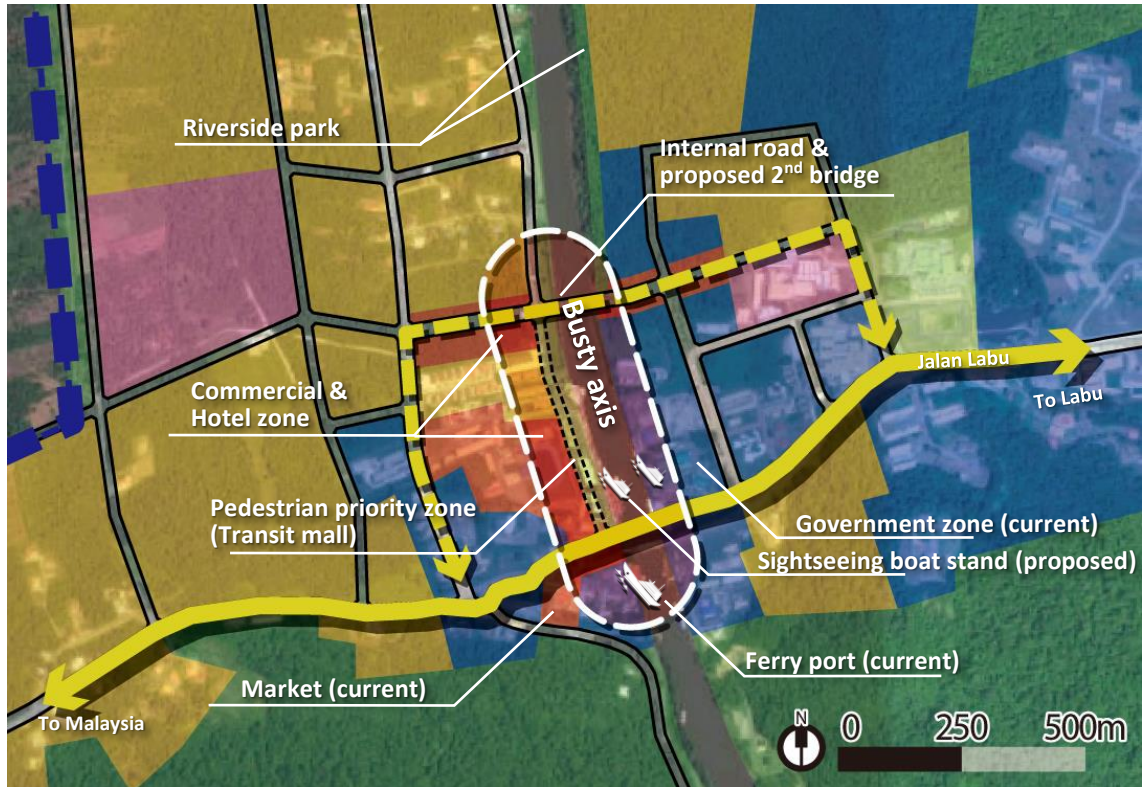
Source: Study team.

Figure 4.9: Creation of Bustling Central Area

Pedestrian Promenade

Riverside walkway

Internal road bridge

Cruising activities

Public service (Current)

Source: Study team.

Figure 4.10: Bustling Central Area

Source: Study team.

4.2 Master Plan of Labu Estate

4.2.1 Framework of Labu Estate

(1) Residential

Based on the predicted population of 4,582 in 2030, the assumed residential area is 229 ha and the average density is 20 persons/ha (Table 4.6). In low-density residential areas like Cairns in Australia (Figure 4.11 approx. 3,600m^2 for one housing area), it will be possible to develop residential areas with minimal impact on forest.

Table 4.6: Labu Estate Growth Centre Housing Land Forecasts to 2030

Item	Amount
Population (number of persons)	4,582
Population density (persons per hectare)	20
Area (hectare)	229

Source: Study team.

Figure 4.11: Residential Density in Cairns, Australia
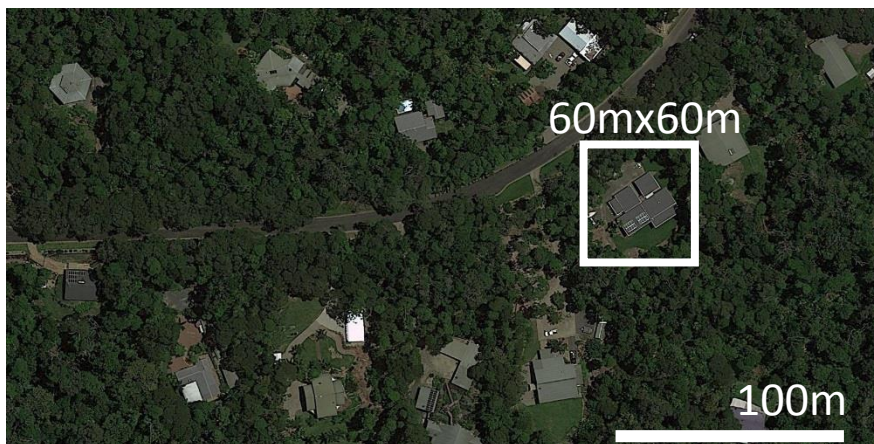
m = metre.
Source: Study team.

(2) Education

From the predicted population of 4,582 in 2030, the assumed area is 1.8ha for Primary School land and 1.5ha for Secondary School, as shown in Tables 4.7 and 4.8. And landuse are for the university is 310ha (Table 4.9).

Table 4.7: Labu Estate Growth Centre Primary School Land Forecasts to 2030

Item	Amount
Population (number of persons)	4,582
Students (number of persons)*	352
Population density (number of persons per hectare)	50
Area (hectare)	1.8

* United Nations Population Division.
Source: Study team.

Table 4.8: Labu Estate Growth Centre Secondary School Land Forecasts to 2030

Item	Amount
Population (number of persons)	4,582
Students (number of persons)*	307
Population density (number of persons per hectare)	50
Area (hectare)	1.5

* United Nations Population Division.
Source: Study team.

Table 4.9: Labu Estate Growth Centre University Land Forecasts to 2030

Sultan Sharif Ali Islamic University (UNISSA) is planned to be located at Labu Estate.

Item	Amount
Area (hectare)	310
Students (number of people)	3,000

Source: Study team.

(3) Hotel, Convention Centre

The hotel targets tourists to Perdayan Forest Recreation Park and Labu Estate (Table 4.10).

Table 4.10: Labu Estate Growth Centre, Hotel, and Convention Centre Land Forecasts to 2030

Item	Amount
Area (hectare)	20
Floor area (square metre)	20,000
Rooms (number)	200

Source: Study team.

(4) R&D

Based on Table 4.11, the study proposes a target of 3,000 R&D workers on 50 ha (Table 4.12).

Table 4.11 shows a case study of global R&D facilities. Many successful R&D facilities have more than 3,000 workers.

In this master plan, the R&D area is proposed approx. 50ha. (Table 4.12)

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Table 4.11: Case Study of R&D Facilities

Location	Area (ha)	Floor area (m^2)	Gross FAR (%)	Working population (persons)	Floor area (m^2/person)	Category
Stanford Research Park (US)	283	991,515	35	23,000	43.1	ICT, biotechnology
Cambridge Science Park (UK)	62	145,540	23	5,000	29.1	
Singapore Science Park I+II	50	400,000	80	10,000	40.0	High-tech R&D, ICT, biomedical
Hong Kong Science Park	28.2	320,000	113	13,800	23.2	Biotechnology, electronics, green technology, ICT, precision engineering
Thailand Science Park	32	264,000	82	3,000	88.0	Biotechnology, materials, electronics, software nanotechnology
One-North (Singapore)	200	5,000,000	250	138,000	36.2	Biomedical sciences, ICT, media, physical sciences & engineering

ICT = information and communication technology, FAR = floor area ratio, ha = hectare, m^2 = square metre, R&D = research and development, UK = United Kingdom, US = United States.
Source: Study team.

Table 4.12: Labu Estate Growth Centre R&D Land Forecasts to 2030

| Item	Amount
Area (hectare)	50
Gross FAR (%)	50
Floor area (m^2)	250,000
Floor area per person (m^2 per person)	80
Working population (number of persons)	3,000

FAR = floor area ratio, m^2 = square metre.
Source: Study team.

4.2.2 Assessment of Land Use of Current Condition and Current Plan

TCP is studying the following Labu district land use plan.(Figure 4.12):

- UNISSA (about 300 ha=766 acre), an industrial zone, and a golf course are planned near the border with Malaysia
- Housing is proposed to expand near the south of the growth centre boundary
- Dam and reservoir are planned to be constructed in the south of the housing area
- Water park is proposed, but the location is still unknown
- Agricultural land and forest reserve areas are also specified based on the current land conditions.

Figure 4.12: Labu Growth Centre Land Use Plan
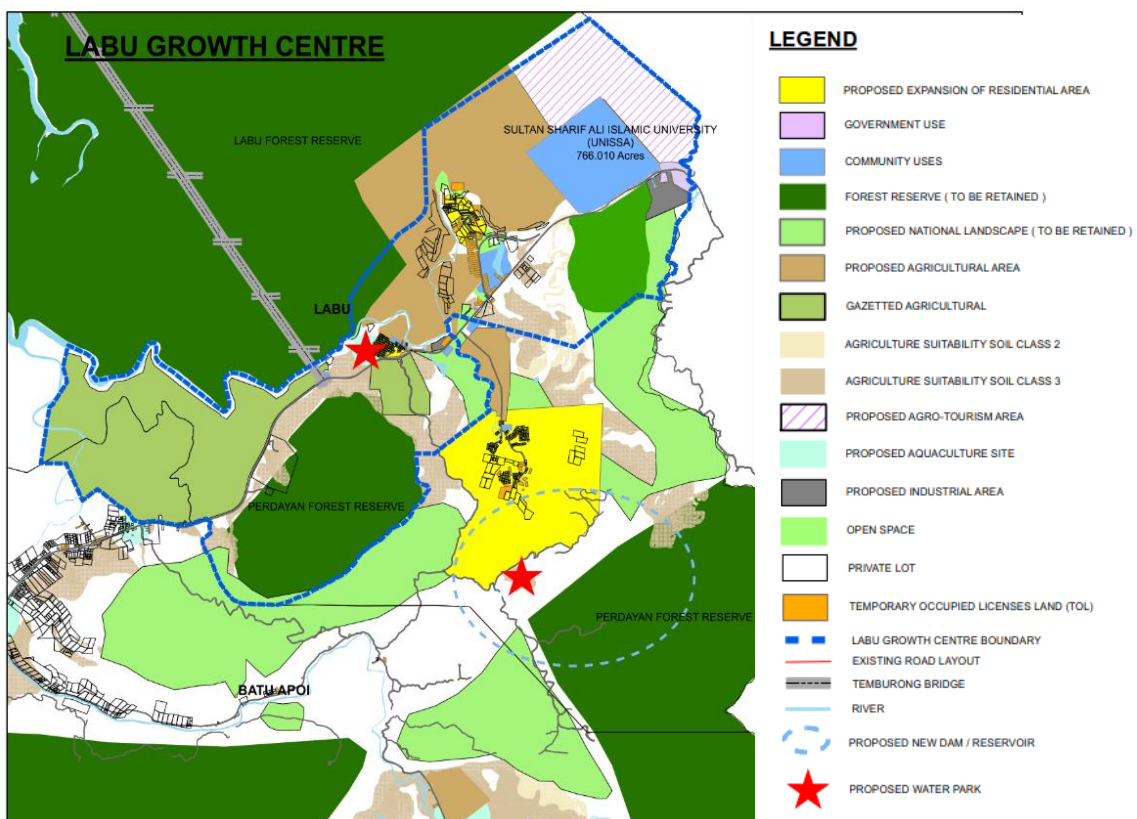
Source: Proposed Developments in Temburong District (TCP).

4.2.3 Proposed Master Plan

(1) Zoning plan

Base on the TCP plan, we propose the following revised zoning plan（Figure 4.13）from viewpoints: 'creating a diverse community with interaction across the university, R&D, residential', and 'building resorts to use Perdayan Forest Recreation Park'.

1) Form a community in which the university, R&D, and residential areas collaborate

In the current plan, land for the university is far from the town, so it is hard to form a symbiotic

relationship. By rearranging the university, R&D, and residential areas to be close to each other, we can build a diverse creative community.

2) Form residential areas with excellent transport links

The current plan divides the housing area into three villages. By developing housing in between the three villages to connect them, we can provide better service based on the optimisation of public services and the effect of scale.

3) Set up priority projects

To advance the plan for Labu district, we need to set up priority projects which can become a driving force for the development. This study proposes (i) a tourism hub, (ii) a convention facility for the 2024 APEC meeting, and (iii) a facility for research in agriculture and tourism using the construction yard for the bridge.

Figure 4.13: Labu Estate Growth Centre Zoning Plan
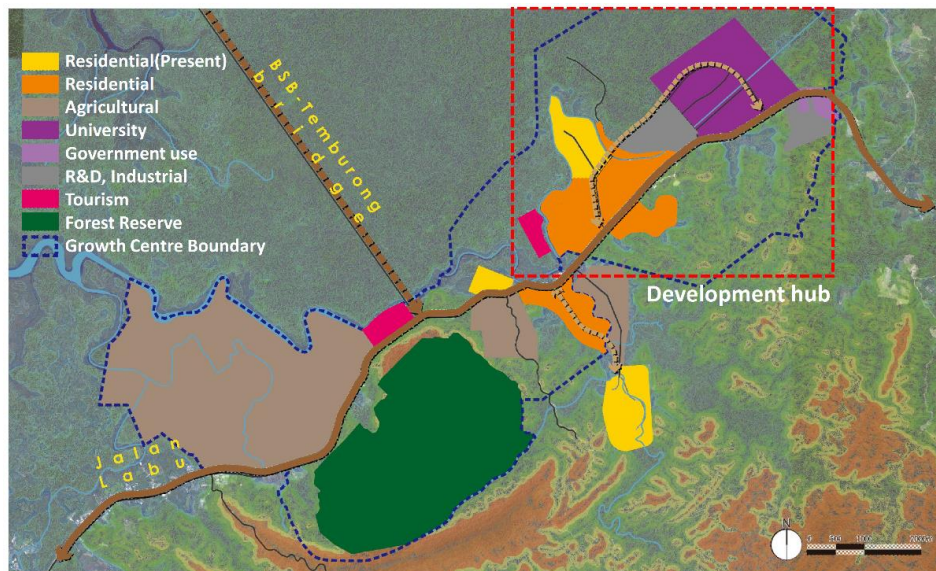
R&D=Research and development.
Source: Study team.

(2) Land Use Plan

This study proposes a land use plan for the university, R&D, and housing area based on the zoning plan (Figure 4.14) (Table4.13).


1) Commercial area and public service area

A commercial area and a public service area, serving as a collaborating hub, will be located between the R&D and housing area facing the river.

2) Inner city roads

We plan to build three inner city roads connecting the university, R&D, and housing area in the southwest taking advantage of the geographical features.

Figure 4.14: Labu Estate Growth Centre Land Use Plan
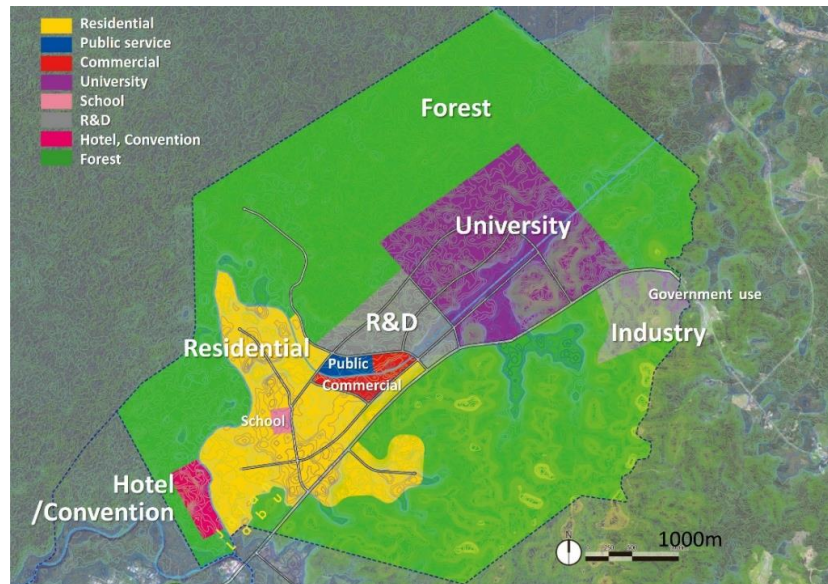
R&D=Research and development.
Source: Study team.

Table 4.13: Labu Estate Growth Centre Housing Land Forecasts to 2030

Land Use	Area (hectares)
Residential	297
Hotel/Convention centre	24
University	296
R&D/Industry	122
School	6
Commercial	21
Public service	10
Government use	19
Forest	1,664
Total	**2,459**

Source: Study team.

(3) Urban Design Image

The project site is covered by forests with small and mid-sized trees. The existing housing area is also a low-density area surrounded by forests. A river passes through the forest and local people use docks scattered along it (Figure 4.15).

Figure 4.15: Labu Estate Growth Centre Conditions

Existing housing area   River and dock
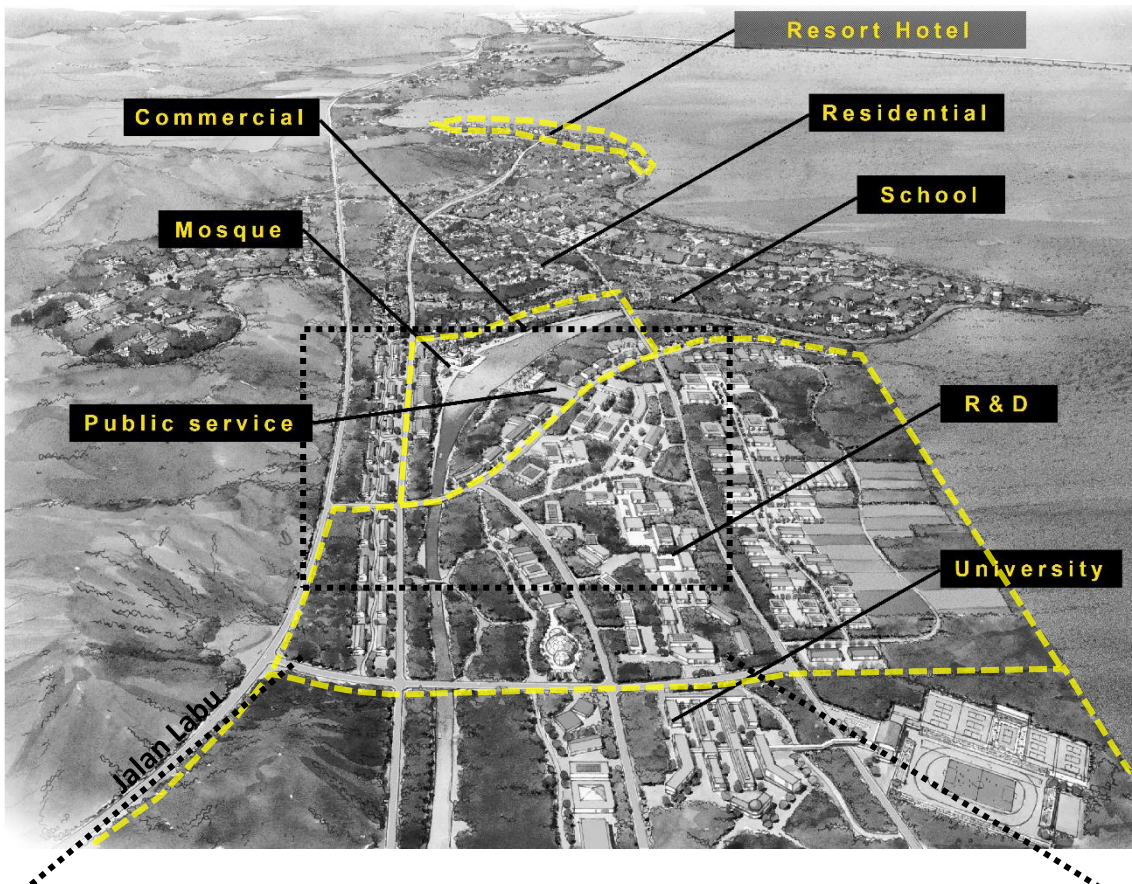
Source: Study team.

Primary policy for space design

Based on the current conditions, the primary policy for space design is as follows.

- Preserve the current forests as much as possible, and restore and value forests during development
- Integrate the river into daily life by locating riverside facilities facing the river or using the river.
- Prepare public spaces, such as parks and open spaces, to create exchange hubs
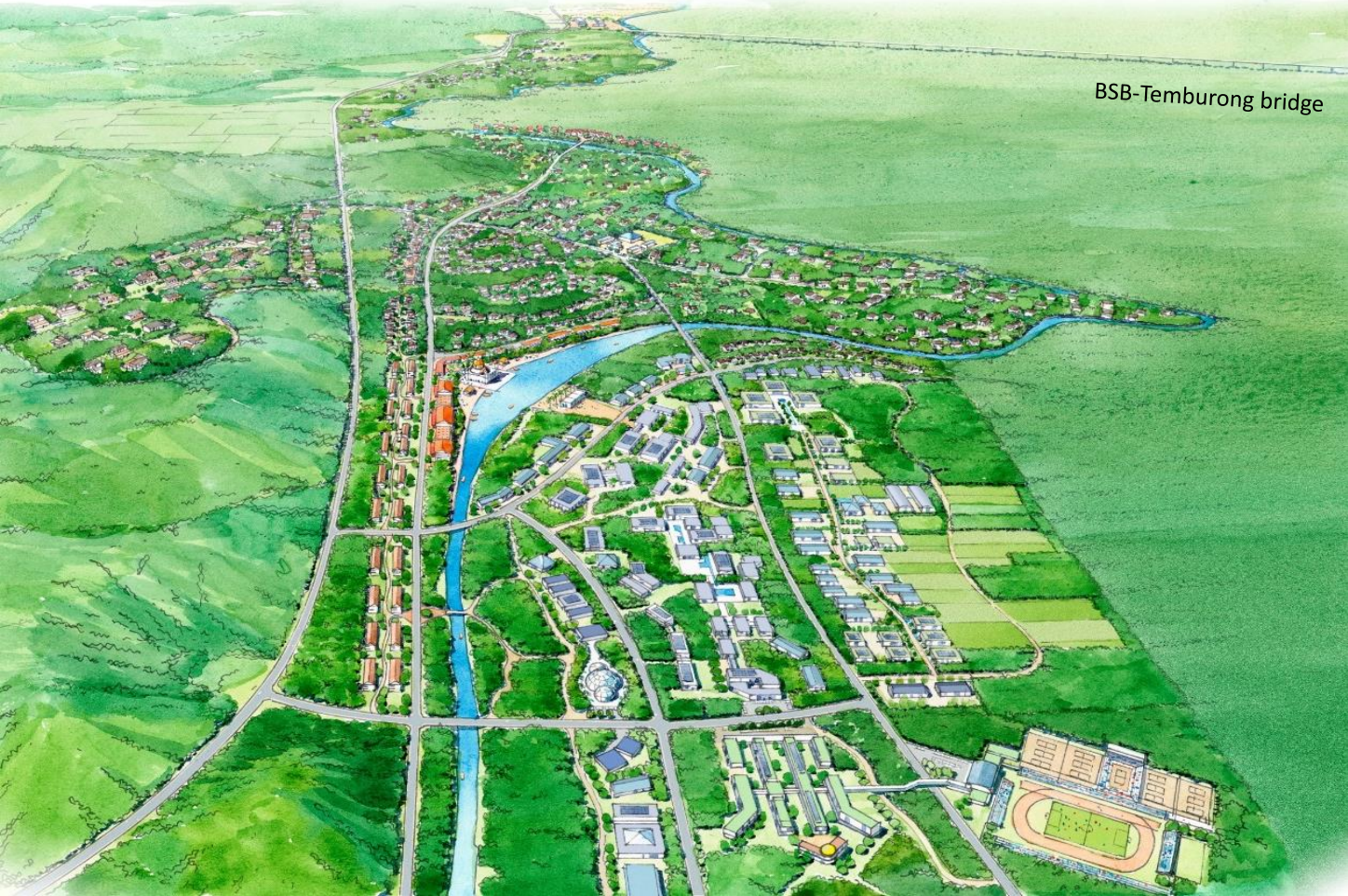
Urban design images are shown in Figure 4.16, 4.17, and 4.18.

Figure 4.16: Centre of Labu Estate Growth Centre

R&D = Research and development.
Source: Study team.

Figure 4.17: Labu Estate Growth Centre

BSB-Temburong bridge

BSB= Bandar Seri Begawan.
Source: Study team.

Figure 4.18: Public Space between R&D and University

Source: Study team.

Chapter 5

Concept of Energy Supply Management

5.1. Research Background and Objective

Brunei Darussalam has abundant reserves of natural resources such as oil and natural gas, but its economy is excessively dependent on them. It plans to move away from a resource-dependent economic structure to avoid a substantial effect on the domestic economy from fluctuations in crude oil prices or a change in the intent of the countries to which the resources are exported, and to prevent an increase in CO_2 emissions.

To prevent global warming, the Intergovernmental Panel on Climate Change (hereafter IPCC) is leading the approach to decarbonising. As a global trend, the use of hydrogen energy has received a lot of attention recently, in addition to the introduction of renewable energy sources.

Since Brunei has many potential renewable energy sources and a great amount of hydrogen is generated when oil and natural gas are refined, effective use of those energy resources is required.

This chapter will review the utilisation policy for renewable energy and hydrogen energy resources, the introduction effect, roadmap, and so forth, considering the economy and energy conditions in Brunei.

5.2. Economic and Energy Conditions in Brunei Darussalam

### 5.2.1. Economic Conditions in Brunei Darussalam

In Brunei's economy, resource prices fell broadly because of the worldwide financial crisis in 2008 and 2009, so economic growth was negative. In 2010, oil prices recovered and the economic growth was positive in 2011. However, production of oil and natural gas did not increase as much as expected in 2012 and 2013, so economic growth was negative. These are shown in the Figure 5.1.

Oil prices declined steeply worldwide in 2015, and the fall continued in 2016, forcing Brunei's government to reduce the budget.

5.2.2. Energy Conditions

The latest values for reserves, production volume, and export volume of oil and natural gas are in Tables 5.1. The relationship between production and export volume shows that most of the production volume is exported.

Figure 5.1: Economic Conditions in Brunei Darussalam
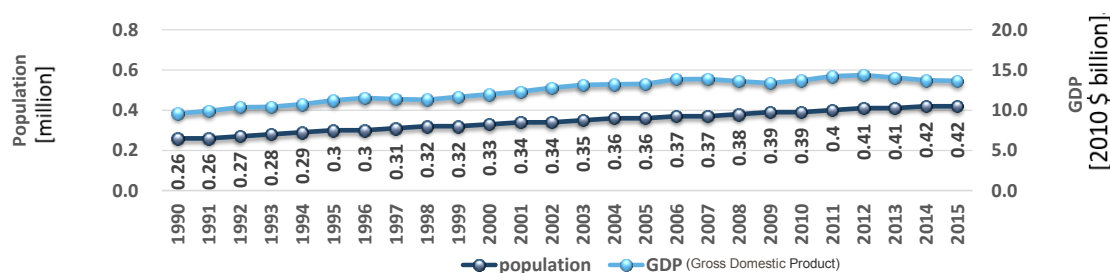
Table 5.1: Oil and Natural Gas Reserves, Production, and Exports

Type	Item	Details
Oil	Reserves	1.1 billion barrels (2016)
	Production volume	121,000 barrels/day (2016)
	Export volume	130,000 barrels/day (2015)
Natural gas	Reserves	300 billion cubic meters (2016)
	Production volume	11.2 billion cubic meters (2016)
	Export volume	8.3 billion cubic meters (2016)

Note: All amounts are approximate.

Table 5.2: Brunei Darussalam Exports, 2016

Type	Details
Item	Oil, liquefied natural gas. (approx. 88%); machinery and transport equipment, etc. (approx. 5%); others (approx. 7%)
Export counterpart	Japan (35.5%), Republic of Korea (13.8%), India (9.3%), Thailand (8.9%), Singapore (6.6%)

Figure 5.2: Change in Energy Production Volume and Export Volume in Brunei Darussalam
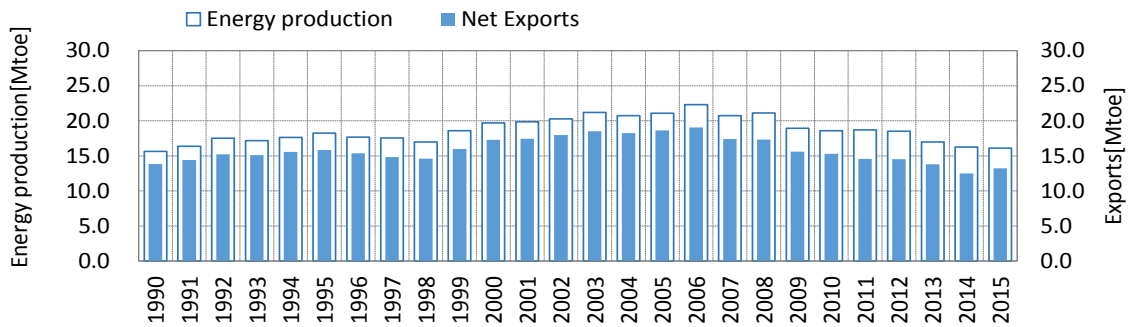

Mtoe = million tons of oil equivalent.

Source: IEA, *World Energy Statistics, 2018* : International Energy Agency

https://webstore.iea.org/world-energy-statistics-2018

On the other hand, energy consumption increases year after year. Figure 5.3 shows that the energy consumption volume for industrial use remained flat while the energy consumption volume for residential use increased. Brunei has seen a remarkable increase in losses and other items since 2000, exceeding 10%, which indicates poor efficiency. However, this ratio exceeds 10% in all Southeast Asia countries.

Figure 5.3: Change in Energy Consumption
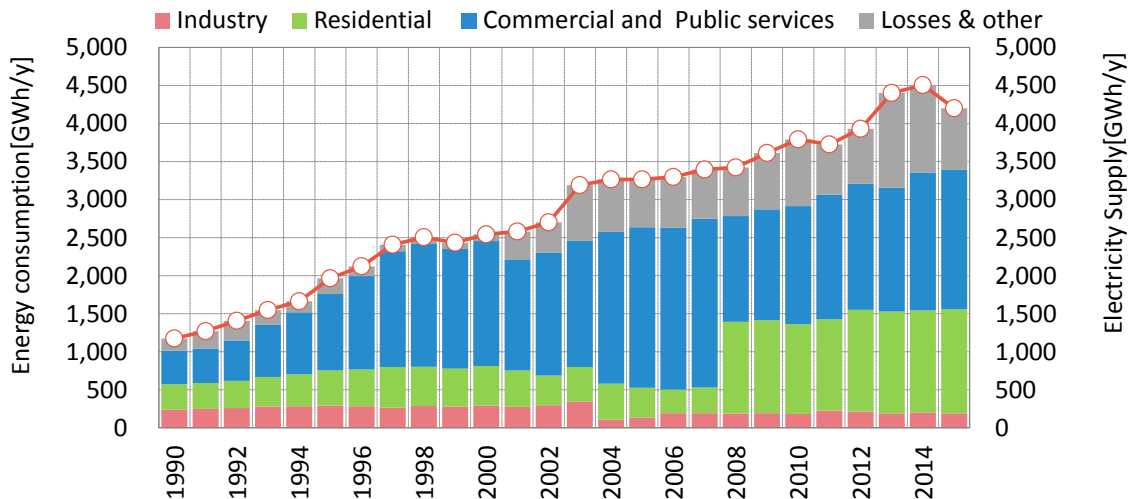
GWh = Gigawatt hours.

Source: IEA, *World Energy Statistics, 2018*: International Energy Agency

https://webstore.iea.org/world-energy-statistics-2018

5.2.3. Target in the Future of Use in Energy

Brunei aims to reduce the amount of energy used in 2035 by 63% in comparison with the business-as-usual scenario (BAU) of 2005. The Energy white Paper in Brunei by Energy Department, updated in 2014, shows that the electricity-generating capacity of renewable energy sources will account for 10% of total power generation by 2035.

With high levels of solar radiation, Brunei plans to promote the introduction of photovoltaic power generation and replace diesel power generation in Temburong with photovoltaic power generation by 2019. In parallel, the introduction of waste power generation will be promoted as industrial waste has adverse effects because of the small size of the country.

Brunei encourages renewable energy sources, such as a photovoltaic power generation demonstration project, and a feed-in tariff scheme (0.25BND/kWh) for renewable energy is in place. As this scheme enables the government to buy electric power from local solar power generation firms and ordinary households with solar panels, the promotion of introduction of renewable energy is expected.

5.3. Latest Hydrogen Technical Trends

5.3.1. International Hydrogen Supply Chain Experimental Project

Brunei is an oil and gas producing country, and its economy is heavily dependent on the export income of oil and Liquefied Natural Gas (LNG). However, a project has started that is to extract hydrogen from by-product gas generated when gas is liquefied and to export all its hydrogen to Japan. Use of this hydrogen is carbon-free.

In an attempt toward building an international hydrogen supply chain by 2020, which is expected to be the next generation power source, the New Energy and Industrial Technology Development Organization is conducting the experimental business of exporting hydrogen from Brunei to Japan. Construction on the hydrogenation plant began on 21 April 2018 (Figure 5.4).

The cost of transporting hydrogen is an issue in building a hydrogen supply chain. To store and transport hydrogen, it needs to be compressed at about 700 atm (standard atmosphere: 1 standard pressure (1 atm = 101.325 kPa)) or cooled to –252.9 degrees Celsius to become liquid. Since these processes are expensive, more affordable technology and techniques for transporting hydrogen in normal conditions need to be developed.

**Figure 5.4: Hydrogenation Plant in Brunei Darussalam
and Dehydrogenation Plant in Kawasaki**

Hydrogenation plant in Brunei Darussalam

Dehydrogenation plant in
the coastal area of Kawasaki

Source: New Energy and Industrial Technology Development Organization.
http://www.nedo.go.jp/english/

5.3.2. Hydrogen Production Technology

The latest technical trends of hydrogen technology to date are summarised based on the assumption that the hydrogen technology will be introduced to Brunei in the future. Hydrogen production technologies are roughly divided into hydrocarbon-based hydrogen (by-product hydrogen, natural gas reforming) and CO_2-free hydrogen (utilisation of renewable energy). Table 5.3 lists further-segmented categories.

In Brunei, hydrogen is produced by steam reforming, based on the gas generated by Brunei LNG (Liquefied Natural Gas)'s plant. Hydrogen could also be produced using renewable energy or biomass.

5.3.3. Hydrogen Energy Introduction Case

Advanced cases for hydrogen energy introduction are collected and summarised. The main cases are shown below.

(1) Nagasaki Huis Ten Bosch in Japan

As a popular model for an area without sufficient energy infrastructure, a hotel in Huis Ten Bosch produces and stores hydrogen using surplus photovoltaic power in summer when the days are long and generates power through fuel cells in winter. It uses the stored hydrogen to supply electric power to the hotel building throughout the year.

Table 5.3: Hydrogen Production Technologies Outline

Item	Practical viability stage	Stability	Environment	Economy
Hydrogen as by-product	Many types have already been introduced.	Depends on production volume of original target products.	CO_2 is emitted but there is no additional environmental load.	Economic because secondarily produced products are used.
Fossil fuel reforming	These have already been introduced and are now in the practical stage.	Stable and large-scale production is possible.	CO_2 is emitted unless CCS is used.	Technically established, and production is possible at comparatively low price.
Water electrolysis (Thermal plant)			CO_2 is emitted during power generation unless CCS is used.	More expensive than natural gas reforming, but comparatively inexpensive.
Water electrolysis (renewable energy)	Technically established, but costs for power generation using renewable energy must be reduced.	Output may fluctuate depending on the type of renewable energy.	CO_2 is not emitted.	Generally expensive because renewable energy is used.
Biomass	Technically established but the problem is low-cost operation.	Supply places are dispersed.	CO_2 emission amount can be regarded as zero.	Costs are high at present.
Heat decomposition	R&D stage (partially demonstrated).	Stable supply is possible.	Varies, depending on sources of heat to be used.	
Photo catalyst	Basic research stage (current conversion efficiency is about 0.5%.)	Depends on weather conditions.	CO_2 is not emitted.	

CCS = Carbon dioxide Capture and Storage, CO_2 = carbon dioxide, R&D = research and development.
Source: Study team.

Figure 5.5: System Configuration
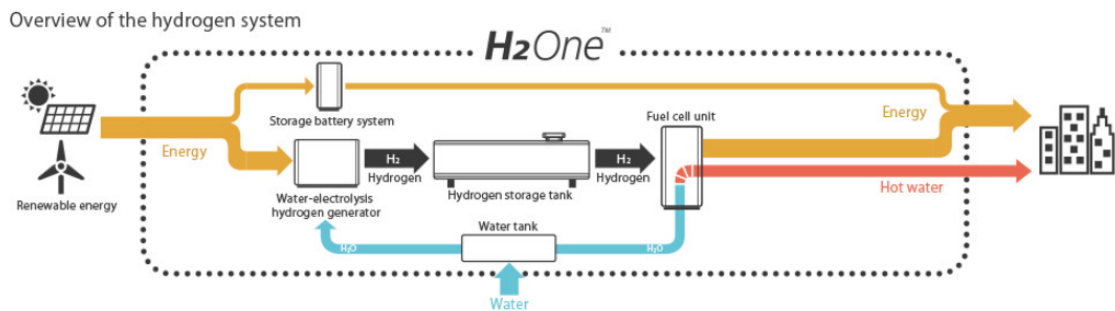
Source: Toshiba. Toshiba Energy Systems and Solutions Corporation.
https://www.toshiba-newenergy.com/en/products/

(2) Port Island in Kobe in Japan

Electric power and exhaust heat obtained from the hydrogen mixed-combustion gas turbine are supplied to the main facilities of manufacturing industry in Kobe City. The hydrogen mixed-combustion gas turbine supplies electricity (about one-quarter of the total electric power of 4,500 kilowatts [kW] for four facilities and 15% of the annual electric power) and heat (35% of the total heat demand and 55% of the annual heat demand).

Although the gas turbine outputs 1,800 kW (Maximum) using 100% utility gas, the output in the case of hydrogen mixed combustion is reduced to 1,100 kW. Further, countermeasures against NOx (Nitrogen Oxide) must be taken (spraying steam) during hydrogen mixed combustion. The spraying spot should be adjusted to prevent a decrease in efficiency.

Figure 5.6: Hydrogen Production and Supply Facility

Source: New Energy and Industrial Technology Development Organization.

5.4. Proposal for Use and Application of Renewable Energy and Hydrogen Energy in Brunei Darussalam

**5.4.1. Use and Application of Renewable Energy**

Brunei is naturally rich in sunlight, rain, and forests, and this study assumes effective use of those resources. The creation of new industries (domestic industries) instead of oil and natural gas based business, and the diversification of energy sources (a combination of renewable and hydrogen energy), are required in the future. Therefore, this study proposes a local energy production model for local consumption, in combination with natural energy and the latest low-carbon technology. The proposal is as follows:

- If it takes long to introduce the latest technology, the people should promote to change daily life to eco lifestyle.
- Use of fossil fuel based energy will be reduced by using renewable energy (photovoltaic generation) and promoting ZEH.
- Electric power obtained by photovoltaic generation will be stored and used for households and electric vehicles.
- Residential waste, coconuts will be used for power generation and fuel for vehicles as biomass energy.

**5.4.2. Roadmap Showing Achievement of Eco Town**

This study created feasible medium- and long-term goals for an eco town in Brunei and future achievement targets. In the medium term (by 2023), the main purpose is to use existing resources aggressively and reform consciousness (eco lifestyle). Effective use of photovoltaic and renewable energy-based hydrogen as existing technologies and the use of EV can be considered. It is hoped that this plan will be publicised at the APEC meeting as a showcase eco town. In the long term (by 2030), the aim is for the whole town to convert to low carbonisation instead of only the facility, in combination with biomass energy and EMS. It is aimed to build towns that do not emit CO_2 by introducing the latest technologies in the future.

Figure 5.7: Proposed Renewable Energy Use in Brunei Darussalam
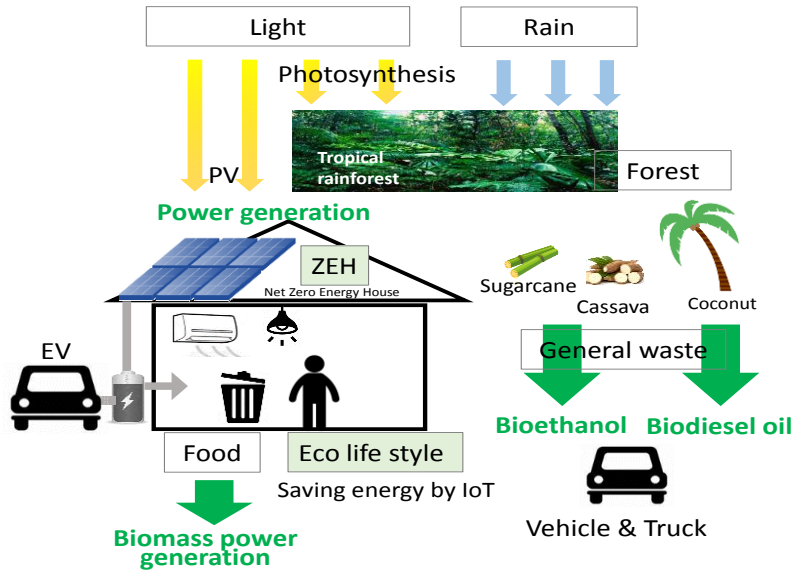
Source: Study team.

**Figure 5.8: The Roadmap of the Realisation of Eco Town**
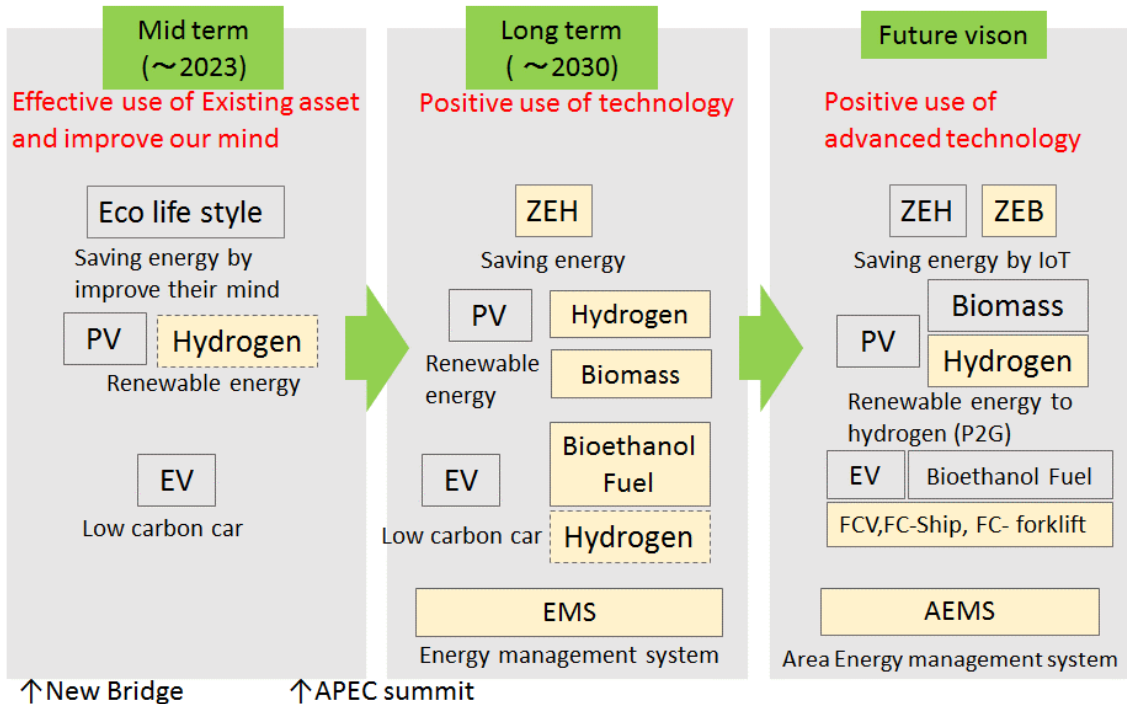
Source: Study team.

5.4.3. Proposal of Energy Model Zone in Temburong District

In consideration of the study results until now, the area will be developed based on renewable and hydrogen energy in Temburong district.

Figure 5.9: Renewable Energy and Hydrogen Energy Showcase in Gate Zone

**(The entrance of Temburong district)**
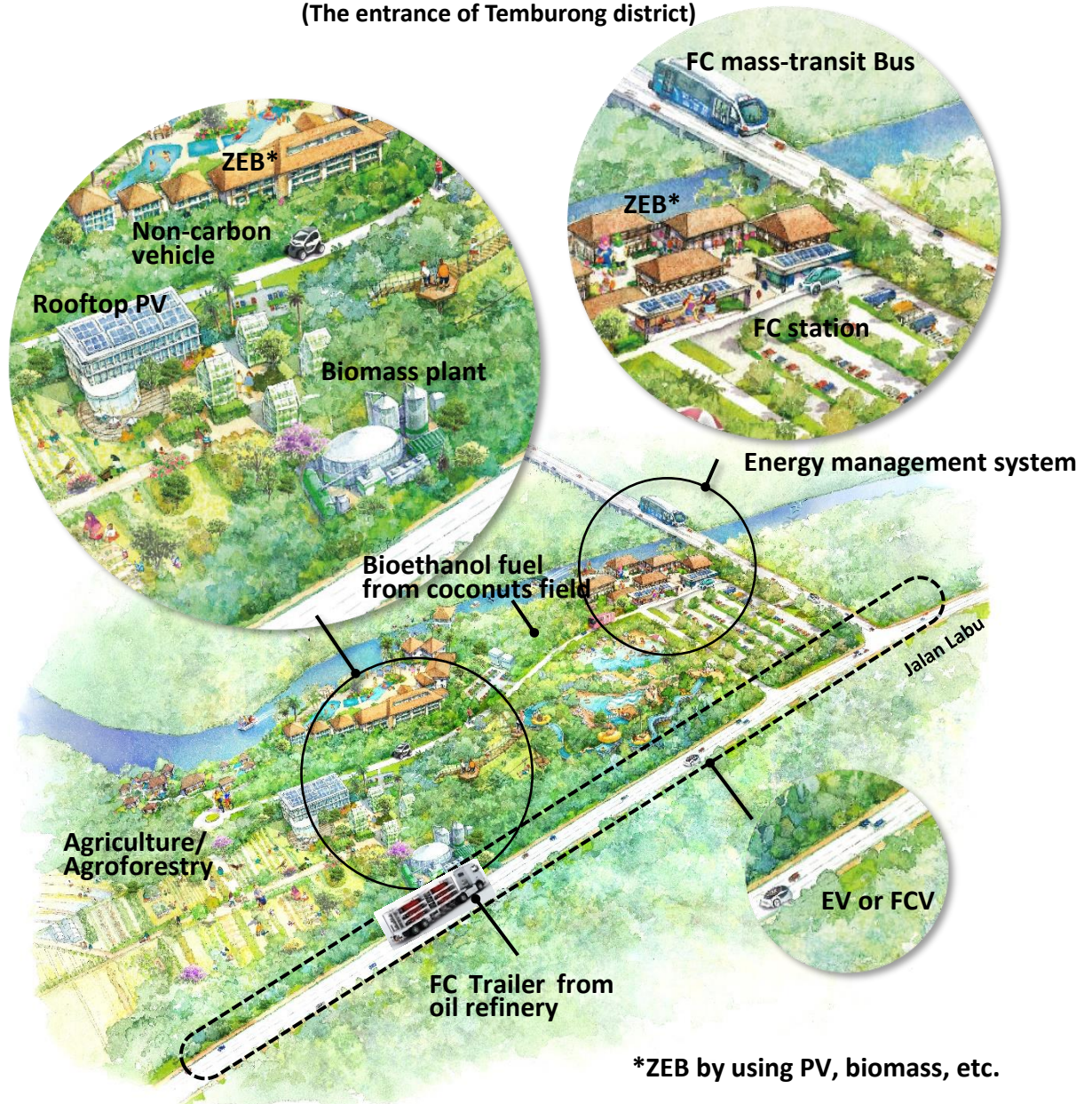
Source: Study team.

5.5. Effects Expected by Introduction of Renewable Energy and Hydrogen Energy

The effects of using oil and natural gas continuously or introducing renewable energy and hydrogen energy are summarised in Figure 5.10. Renewable energy and hydrogen energy are expected to create effects such as a reduction in CO_2, job creation, and an economic ripple effect.

Hydrogen energy will be expanded throughout Brunei to full scale in the short term, and an increase in exports of hydrogen to the main export countries for oil and natural gas in Southeast Asia as well as Japan can be expected in the medium and long term. The Summer Olympics and Paralympics will be held in Tokyo in 2020 and Tokyo plans to showcase itself as a hydrogen-based town. Therefore, it is desirable to make the best use of this opportunity.

Figure 5.10: Effects of Introduction of Renewable Energy and Hydrogen Energy
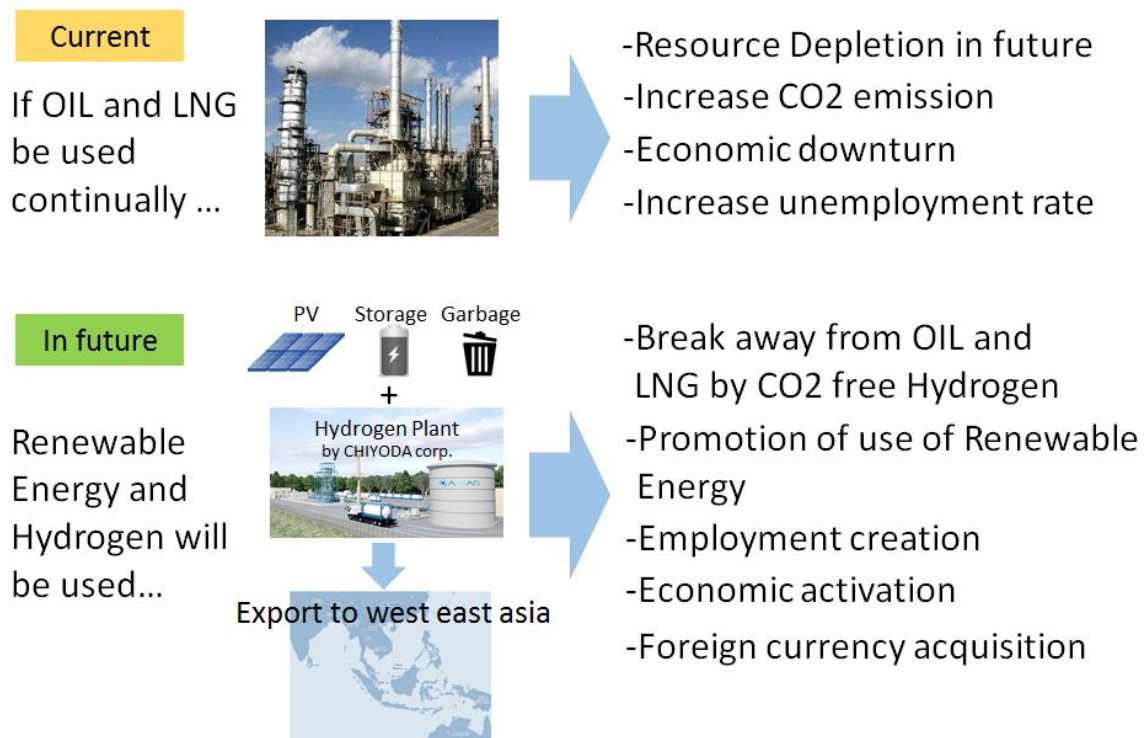
Source: Study team.

Figure 5.11: Domestic and International Development of Hydrogen
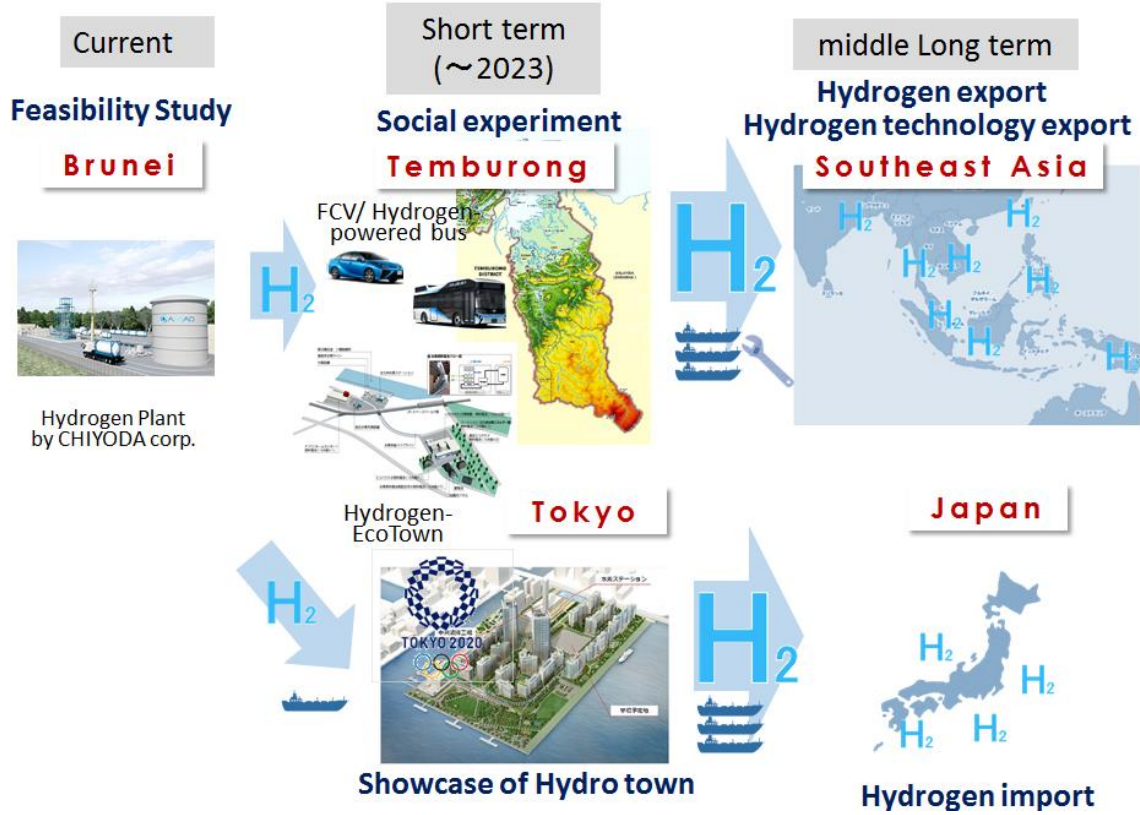
Source: Study team.

Chapter 6

Sustainable Mobility System in Temburong District

6.1 Mobility Network in Temburong District

6.1.1 Basic Concept

As a model of a carbon-neutral society, Temburong district aims to build an eco-friendly as follows:

- Suppression of traffic volume:

    - Control entry of vehicles from Temburong Bridge

    - Promote carpooling system

    - Introduce public transportation

    - Encourage a new logistics system, such as drones, that does not depend on vehicles

- Prioritisation of transport devices with small environmental loads:

    - Develop traffic regulation that gives priority to Electric vehicle (EV) or Fuel cell vehicle (FCV)

    - Introduce transportation device that does not depend on automobiles, such as electric motorcycles

- Introduction of various transport devices to activate ecotourism:

    - Introduce various transportation devices such as autonomous vehicles, boats, buses, taxis, electric motorcycles, and bicycles.

6.1.2 Mobility Network in Temburong district

- Tourists from BSB, such as the Empire Hotel, BSB airport, or the central business district (CBD) visit Temburong via hydrogen-powered mass-transit bus through Temburong bridge.
- Tourists travel around Temburong district in non-carbon vehicles such as community buses, boats, and taxis.
- In future, only non-carbon cars will be permitted to drive in Temburong district. This also aims to control the traffic volume (internal-combustion engine cars, buses, and trucks) passing through Temburong from Sabah to Sarawak State in Malaysia.

Figure 6.1: Mobility Network of Temburong District
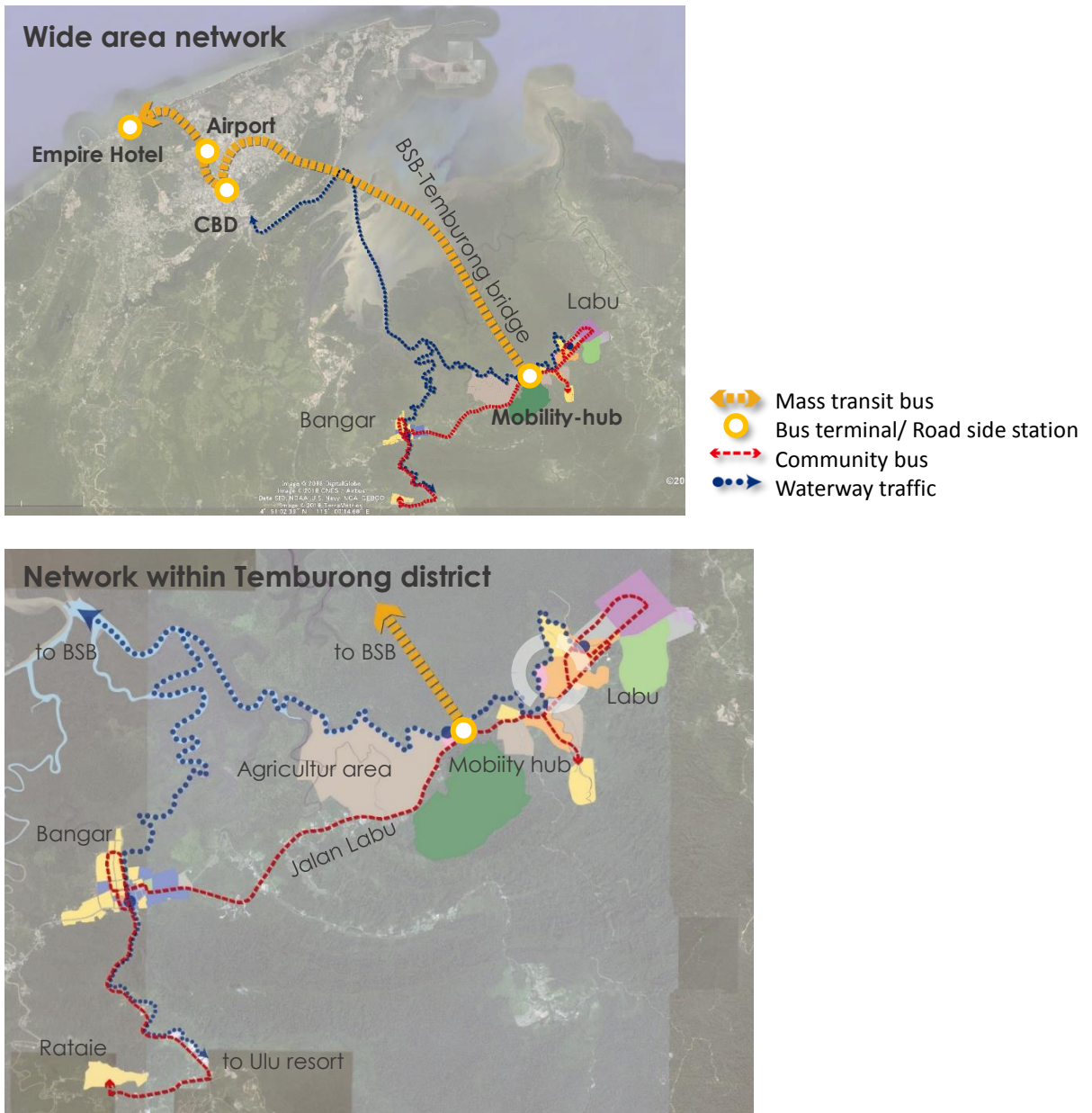
Source: Study team.

6.2 Proposal of Gate Zone

The bridge construction yard (50 ha) at the end of Temburong bridge in Labu district has high development potential. It is supposed to be covered with tropical rainforest or agroforestry when construction in finished.

**Figure 6.2: Condition of Gate Zone**

Note: The construction yard covers about 50 hectares.
Source: Study team.

We propose developing this area as the gate zone of Temburong district, comprising five zones: (i) mobility hub zone, (ii) nature amusement park zone, (iii) agro park zone, (iv) resort and convention zone, and (v) eco residential zone.

This land will become a tourist hub and showcase of new energy and mobility.

Figure 6.3: Gate Zone
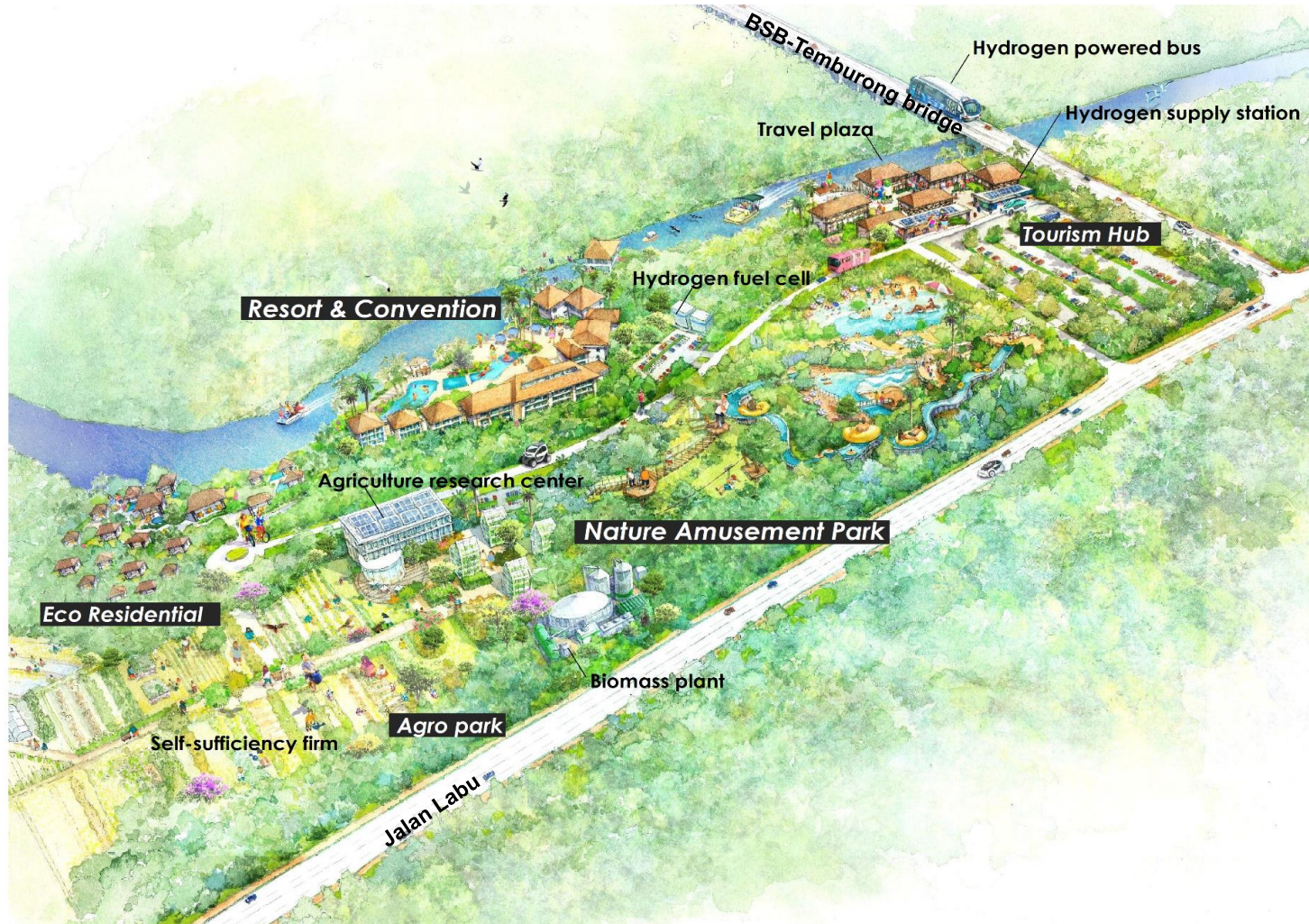
Source: Study team.

6.2.1 Mobility Hub Zone

A mobility hub is a place where hydrogen-powered buses, electric cars, autonomous cars, electric boats, and bicycles are connected. Tourists arriving in Temburong from BSB via hydrogen-powered bus can transfer here to other means of transportation such as electric cars, autonomous cars, electric boats, and bicycles to go to other tourist spots.
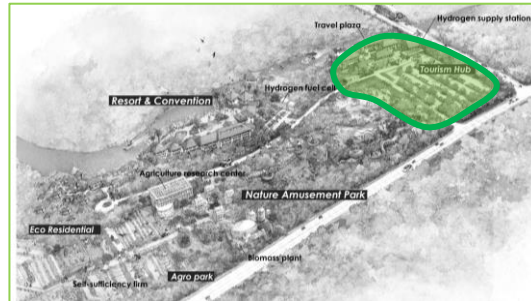
With the travel plaza here, tourists can enjoy many services such as accessing tourism information, booking tours and accommodation, and using the hydrogen supply station (Figures 6.4 and 6.5).

Figure 6.4: Mobility Hub Zone Design
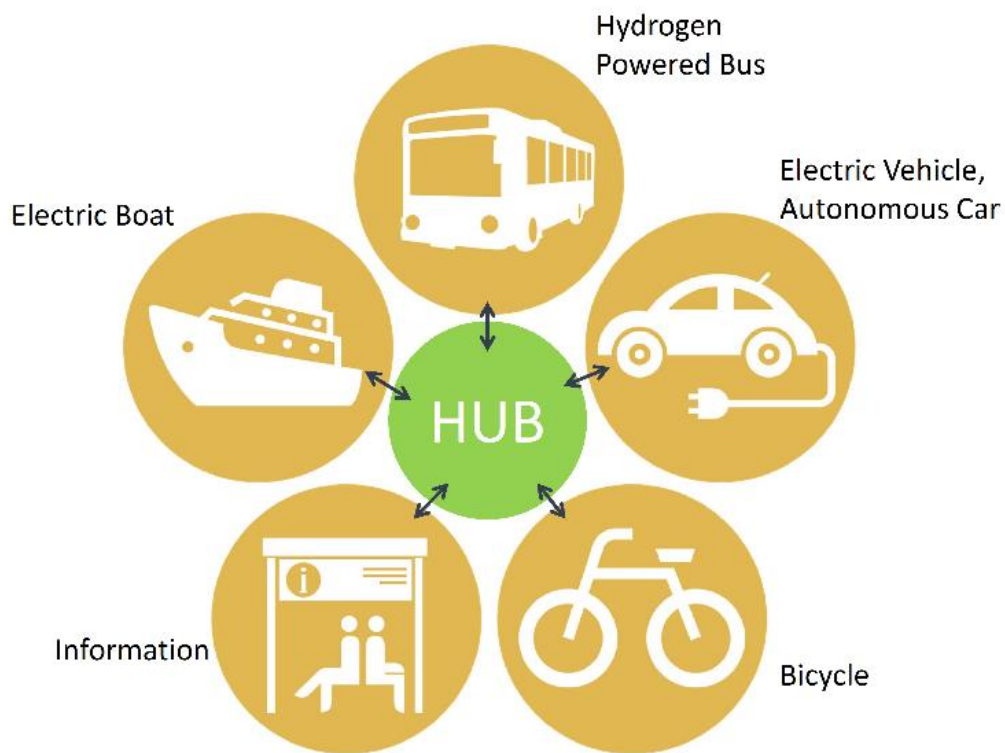
Source: Study team.

Figure 6.5: Mobility Hub Zone

Source: Study team.
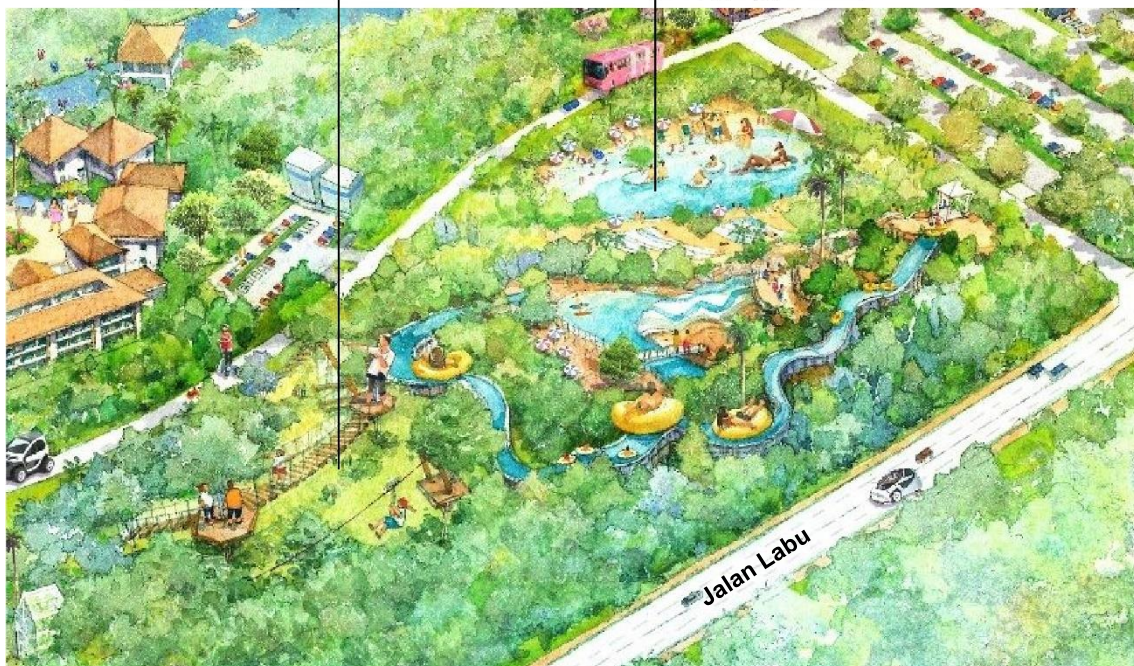
6.2.2 Nature Amusement Park Zone

The restored forest will become the Nature Amusement Park. An adventure land and water park will be planned here. The construction of the Nature Amusement Park aims to create a new tourist destination in Temburong to encourage longer visit such as staying more than two nights (Figure 6.6).

Figure 6.6: Nature Amusement Park Zone

Source: Study team.

6.2.3 Agro Park Zone

The Agro Park will be constructed to promote food self-sufficiency. We plan to construct an agricultural research institute, plant factory, and agricultural test site as well as introduce photovoltaic and biomass plants as energy facilities. We aim to improve production in agriculture by linking surrounding agricultural lands like the existing one in the west (Fig.6.1). We also plan to attract tourists by building a tourist firm and organic restaurant as part of the learning tourism ecosystem (Figure 6.7).

Figure 6.7: Agro Park Zone
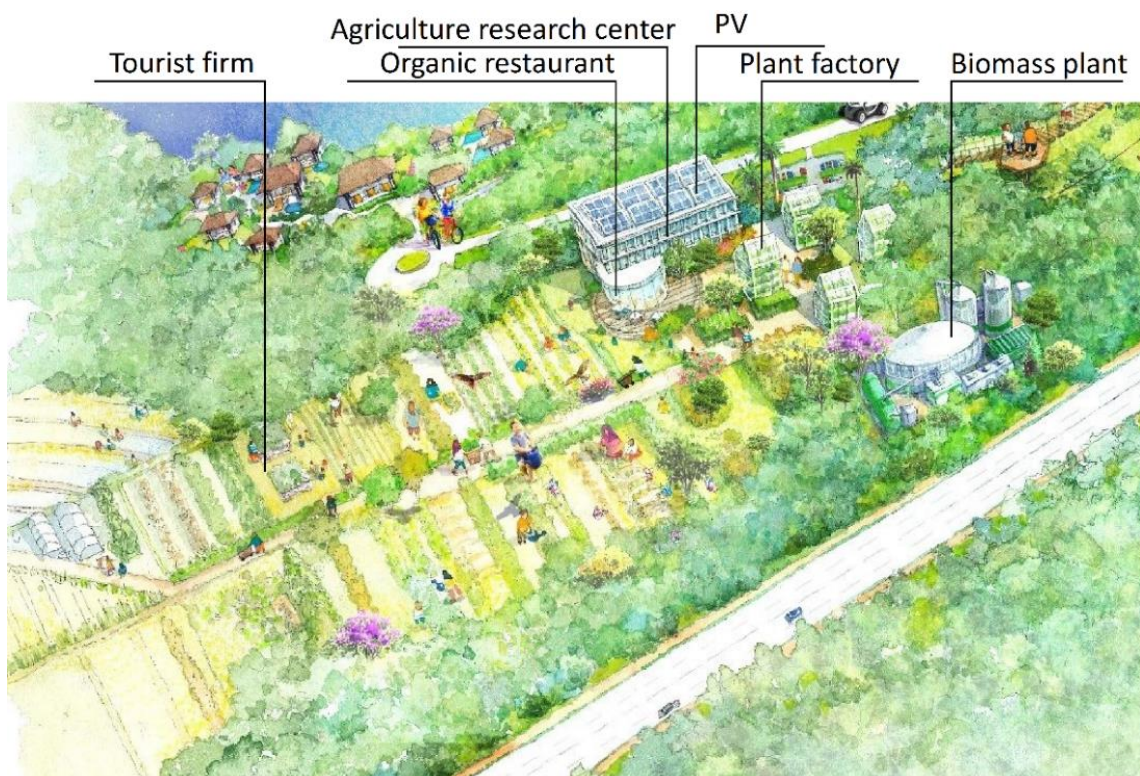
Source: Study team.

6.2.4 Resort and Convention Zone

The zone facing the river is the Resort and Convention Zone. We expect this to become a tourist hub for Labu district sightseeing and Perdayan Forest Recreation Park. This resort consists of hotel and convention facilities. The convention centre should be one of APEC's venues at the meeting to be held in Brunei in 2024. As the venue of APEC, the power source of this hotel will be hydrogen fuel cells to help promote the potential of hydrogen to each APEC country (Figure 6.8).

Figure 6.8: Resort and Convention Zone
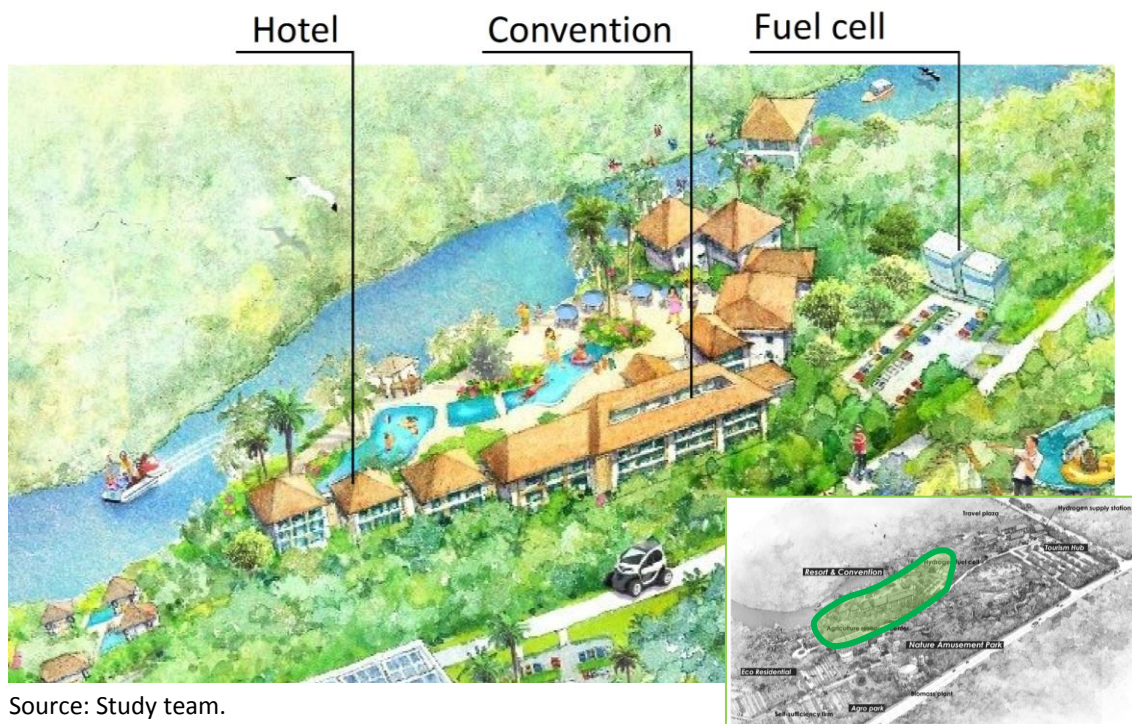
Source: Study team.

**Figure 6.9: APEC Economic Leaders' Meeting, Da Nang, 2017**

Source: Asia-Pacific Economic Cooperation.

6.2.5 Eco Residential Zone

The Eco Residential zone is planned next to the Resort and Convention zone. Eco Residential is a diverse community that is home to people working at the gate zone, energy and transportation workers, agricultural researchers, and employees in the service industry. With the introduction of smart technology, such as renewable energy and sustainable architecture, Eco Residential will become a living lab (Figure 6.10).

Figure 6.10: Eco Residential Zone
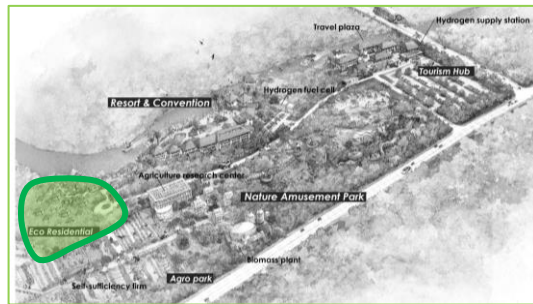
Source: Study team.

Chapter 7

Conclusion and Policy Recommendations

7.1. Conclusion

This study set the vision of a 'showcase of a carbon-neutral society for Borneo wildlife preservation', introducing the latest technology for a carbon-neutral and new work and life style that can also encourage the local community.

In the master plan, Bangar will have the function of district office, hospital, market, and residential area, as the centre of administrative services; and Labu Estate will have the university, R&D, hotel, convention centre zone, tourism centre, and residential area, as the centre of education, R&D, and tourism. This study proposed a land use plan and perspective image for these two development hubs.

For energy supply and demand, to realize the Brunei eco town, we have formulated feasible mid- to long-term targets, assuming the introduction of high-end energy-efficiency architecture and hydrogen energy.

For the APEC Economic Leaders' Meeting to be held in Brunei in 2024, we proposed the development of the site of the construction yard of the BSB-Temburong Bridge (50 ha) as the priority project, and proposed a specific development image as the gate zone.

7.2. Policy Recommendations

In this study, we proposed the following policy-related recommendations:

- The master plan will be based on the policy of the Temburong district plan, 2006–2025, drawn up by the Ministry of Development (MOD), and will be revised to respond to changes in the social situation or surrounding environment.

- Concepts such as smart technology, development of tourism, or convention centre zone will be adapted in setting the vision; and the urban functions and technologies which may be necessary for them will be introduced in the master plan. This master plan will contribute to the promotion of the Wawasan Brunei 2035 national vision.

- In the eco city in particular, eco friendly technology such as renewable energy or hydrogen gas will be introduced aggressively, so that this project can be a showcase of new energy technology in Brunei Darussalam–pioneering the advent of a hydrogen society, which is expected in the future.

- By promoting energy conservation of buildings built in Temburong district, it will contribute considerably to a reduction in electricity demand.

- This report was prepared by the working group on the Study of the Formulation of

Temburong Eco Town Master Plan Project in FY2017 in Brunei Darussalam under the Economic Research Institute for ASEAN and East Asia Energy Project. Therefore, the data used for this report and the consultations made are limited compared with the normal master plan. In the process of application, further coordination is needed with each relevant organisation, such as the TCP, as well as detailed examination and adjustment, as necessary.